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Thames Estuary Dredging Association

Marine Aggregate Regional Environmental Assessment of the Outer Thames Estuary

October 2010

THAMES ESTUARY DREDGING ASSOCIATION

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MARINE AGGREGATE REGIONAL ENVIRONMENTAL ASSESSMENT OF THE OUTER THAMES ESTUARY

October 2010

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GLOSSARY

A

Adaptability	The ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect of dredging
Abiotic	Refers to non-living objects, substances or processes e.g. climate/
Ablated	Refers to non-living objects, substances or processes e.g. climate/
Accretion	An increase in land resulting from depositional processes.
Adaptability	The ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect of dredging
AIS	Automatic Identification System
Aggradation	Rising of a river or seabed due to the deposition of sediment.
Alluvial deposits	Sediment deposited by flowing water, as in a river bed, flood plain or delta.
Amphidrome	A point within a tidal system where the tidal range is almost zero.
Amphipods	Phylum Arthropoda, Class Malacostraca, Order Amphipoda) are small, shrimp-like crustaceans recognised by their laterally compressed bodies, lack of a carapace, and numerous, differently modified legs.
Anoxic	Without oxygen
Appendicularians	(Phylum Chordata) or larvaceans are solitary, free swimming tunicates. They are filter feeders, live in the pelagic zone. Planktonic organisms 1 cm in length.
Archaeological Exclusion Zone	A defined zone within a dredging licence where extraction is excluded to protect archaeological features- including wrecks.
Armoured Revetment	Shore protection structure made with stones/ rock laid on a sloping face.
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (United Nations).
Auditory Brainstem Responses	An electrical signal evoked from the brainstem of a mammal by presentation of a sound.
Automatic Identification System (AIS)	A system used to track a ship's location .

B

BAT	Best Available Technique
Beach Replenishment/ Nourishment	The process of placing new sediment onto beaches to replace sediment lost through erosion.
Beach toe	The distance to the first break in slope of the submerged beach.
Bedform	A depositional feature on the bed of a river or other body of flowing water that is formed by the movement of bed material due to the flow. The shape of the surface of a bed of granular sediment, produced by the flow of air or water over the sediment.
Bedload	Particles of sand, gravel, or soil carried by the natural flow of a stream on or immediately above its bed.
Bedrock	The rock underlying the Earth's surface.
Benthic	The ecological zone at the lowest level of the water column including the surface layer of sediment.
Berm	A raised barrier separating two areas used to prevent coastal erosion.
Bern Convention	The Convention of the Conservation of European Wildlife and Natural Habitats 1979. The aims of the convention were to ensure conservation and protection of wild plant and animal species and their natural habitats.
Biodiversity Action Plan	The UK Biodiversity Action Plan is the government's response to the Convention on Biodiversity 1992. It describes the UK's biological resources and commits a detailed plan on the protection of these resources.
Birds Directive	The Directive (79/409/EEC) provides a framework for the conservation and management of, and human interactions with, wild birds in Europe.
Bivalves	(Phylum Mollusca, Class Bivalvia) are organisms characterised by having two hard outer shells and they usually live in the intertidal and subtidal coastal zone. They include oysters and mussels.
Bloom	Rapid increase in the concentration of phytoplankton, often dominated by one species; may be seasonal (spring bloom); natural or anthropogenic.
BMAPA	British Marine Aggregate Producers Association
Boreal waters	Subarctic and subantarctic waters.
Bottom dwelling	Organisms that live on or close to the sea bed.
Bycatch	Part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, usually dead or dying.

C

Carapace	A dorsal section of the exoskeleton or shell in a number of animal groups, including arthropods such as crustaceans and arachnids.
Catadromous	Organisms that live in freshwater but migrate to marine waters to breed.
CEFAS	Centre for the Environment, Fisheries and Aquatic Sciences.
Cenozoic London Basin	A Tertiary marine geological formation of Cenozoic age.

Cephalopods	(Phylum Mollusca) are organisms with bilateral symmetry, a prominent head and modified feet into tentacles. The Class includes the octopus, squid and cuttlefish.
Cetaceans	(Phylum Chordata, Class Mammalia). Species include dolphins and whales.
CFP	Common Fisheries Policy. This is the fisheries policy for the European Union.
Circalittoral	The subzone of the rocky sublittoral (see below) that is below the infralittoral and is dominated by animals.
CITES	Convention on International Trade in Endangered Species.
Cladocera	(Phylum Arthropoda, Class Branchiopoda) are small free-swimming crustaceans found most commonly in freshwater habitats, with few species in marine environments.
Clupeids	Clupeids are fish of the herring and mackerel family.
Coastal retreat	The retreat of coastlines due to rising sea levels.
Coastal squeeze	When a coastal margin is 'squeezed' between a fixed landward boundary (artificial or otherwise) and rising sea level.
Cold-climate Gravel	Gravel formed during glacial periods.
Coralline algae	(Phylum Rhodophyta) is a type of red algae characterised by fronds with calcareous deposits. They are widespread in the world's oceans.
Cross-shore transport	The cumulative movement of beach and nearshore sand perpendicular to the shore by the combined action of tides, wind and waves, and the shore-perpendicular currents produced by them.
Crustacean	(Phylum Arthropoda, Sub-phylum Crustacea) are organisms characterised by having a hard outer shell and jointed appendages and usually live in the water and breathe through gills. They include lobsters, crabs, shrimps, and barnacles.
Ctenophores	(Phylum Cnidaria, Sub-phylum Ctenophora) commonly known as comb jellies, they have distinctive cilia that they use to swim.
Cumulative Impact	Impacts that arise from multiple marine aggregate extraction activities within a region.

D

Demersal	The part of the water column that is near to the seabed and the benthos. Demersal fish are those that spend the majority of their lifecycle on or near to the seabed.
Density Plume	A flow of water and sediment created by a dredger's overflow and screening returns that travels rapidly back to the seabed by virtue of its higher density compared with the surrounding seawater.
Detritus	Non-living particulate organic material, usually consisting of faecal matter and dead organisms.
Diadromous	Fish species that use both marine and freshwater habitats during their life cycle.
Diatoms	Are unicellular organisms of the Kingdom Protista characterised by a silica shell. They exist singly or can form colonies and are found in marine and freshwater environments.
Direct Impact Zone (DIZ)	The zone within which impacts resulting from the passage of the draghead over the seabed surface occur.
Draghead	Equipment on the end of a dredge pipe that is in contact with the seabed during dredging.
Dredging Lane	A sub-division of an active dredge area sometimes used by marine aggregate companies to manage dredging operations.

E

Ebb tide	The receeding or outgoing tide. Tide passing from high to low.
Ebb-delta	An accretionary deposit of sand found on the seaward side of an inlet and usually formed by tidal currents.
EC Habitats Directive	(92/43/EEC) European Directive on the conservation of natural habitats and of wild flora and fauna. The aim of the directive is to promote the maintenance of biodiversity by requiring member states to take measures to maintain natural habitats.
Echinoderms	(Phylum Echinodermata) are invertebrate marine organisms usually characterised by a five-fold symmetry. Examples include: sea urchins and starfish.
Eddy flows	The swirling movement of sections of water that move independently of the main body of water.
Elasmobranchs	(Phylum Chordata, Class Chondrichthyes) Cartilaginous fishes, including sharks, rays and skates.
Epibenthic	Living on or near the surface of the seabed.
Epibenthos	The flora and fauna living on the sea bed.
Estuaries	A partly enclosed body of water that has one or more rivers flowing into it and is connected to the open sea.
Eulittoral	The intertidal band, in-between the low and high water line.
Euphausiids	(Phylum Arthropoda, Subphylum Crustacea, Class Malacostraca) are also known as Krill and are a group of shrimp-like pelagic marine invertebrates found in cold waters. They play an important part in marine food chains for whales, seabirds, herring, and gadoid species.
Exclusion Zone	An area around a defined seabed feature within which dredging is not permitted in order to prevent disturbance.

F

Fetch	The horizontal distance over which wave-generating winds blow.
Fetch distance	The horizontal distance over which wave-generating winds blow.

Fisheries Science	A government funded initiative to get scientists and fishermen to work in partnership to develop a better understanding of fish stocks.
Flood tide	The advancing or incoming tide. Tide passing from low to high.
Fluvial	Produced by the action of a river or stream.
Fluvially Derived Marine Aggregate	Marine aggregate that was deposited by a river associated with a former land surface now submerged.

G

Gadoid	Gadoids are fish of the cod and hake family
Gastropods	(Phylum Mollusca) are a class of Mollusca. The shell is an asymmetrical spiral and is carried when crawling and feeding on the extended foot. Gastropods can be found in benthic and pelagic marine environments as well as in freshwater and on land.
Geological Stratigraphy	The study of rock successions and their interpretation in a general time scale.
Geomorphological evolution	The evolution of Earth's landforms and processes that formed them.
Glacial transgression/ regression	Glacial transgression occurs when glaciers form over areas of previously exposed land. Glacial regression takes place when glaciers retreat exposing previously covered land.
Glacially Derived Marine Aggregate	Marine aggregate that was deposited by a glacier or ice sheet.
Glacio-eustacy	Changes in sea level due to storage or release of water from glaciers.
Glacio-isostatic rebound	The rise of land masses that were previously depressed by glaciers that have since retreated.

H

HADA	Humber Aggregate Dredging Association.
Haul out sites	Hauling out is the behaviour, especially associated with pinnipeds (seals), of temporarily leaving the water between foraging activity for sites on land or ice. Haul out sites can be used for mating, giving birth, predator evasion, social activity and rest.
High Water Mark	The highest reach of the water at high tide.
Hobby fisherman	Recreational fishermen.
Hydrodynamic	Of, relating to, or operated by the force of liquid in motion.

I

ICES	International Council for the Exploration of the Sea.
ICZM	Integrated Coastal Zone Management.
IFCA	Inshore Fisheries and Conservation Authorities.
IMO	International Maritime Organisation.
Important fishing ground	A fisherman's ground that is second to prime grounds and is only used when the prime grounds are unavailable.
In-Combination Impact	The total impacts of all industrial sectors operating within the same region in the context of natural variability or trends.
Infaunal	Benthic organisms which live within the seabed.
Infralittoral	A subzone of the sublittoral (see below) in which upward-facing rocks are dominated by algae, typically kelps.
Interglacial Period	A period of geological time when the average global temperature was warmer that separates glacial periods.
Intertidal Pools	Bodies of water along the coastal zone that are exposed at low tide and flooded at high tide.
IUCN	International Union for Conservation of Nature and Natural Resources.
IUCN Red Data List Species	This list is the most comprehensive objective global approach for evaluating the conservation status of plants and animal species.

J

JNCC	Joint Nature and Conservation Council.

K

Keystone Species	A species that plays a critical role in maintaining the structure of an ecological community and whose impact on the community is greater than would be expected based on its relative abundance or biomass.

L

Lagoons	A body of shallow salt or brackish water that is separated from deeper sea water by a shallow or exposed barrier beach, sand bank or coral reef.
Littoral drift	Materials moved by waves and currents of the coastal zones. Also know as longshore drift.
Lowest Astronomical Tide	The lowest possible tide

M

Macrobenthic	Marine invertebrates measuring at least 1mm in size that live within the seabed sediments.
Marine transgression/ Regression	Marine transgression occurs when an influx of the sea covers areas of previously exposed land. Marine regression takes place when submerged seafloor is exposed above sea level by the basinward migration of the shoreline.
Mean significant	The average wave height (trough to crest) of the

wave Height	highest one-third of the waves in the wave spectrum.
Megaripples	Sub-aqueous dunes formed on a bed of sand or gravel under the action of water flow (0.5-1m high).
Merisitic characters	Features in organisms that show repetition as a consequence of segmentation such as the number of fins, scales or vertebrate.
MFA	Marine Fisheries Agency
MMO	Marine Management Organisation.
Mobile Sediment	Sediment particles on the seabed that can be mobilised and transported under prevailing hydrodynamic conditions i.e. tidal and wave driven currents.
Mollusc	(Phylum Mollusca) one of the largest phyla. The unsegmented, soft-bodied animal are characterised by a muscular foot (the surface on which they crawl), a calcareous shells secreted by the mantle.
MSC	Marine Stewardship Council
Mysids	(Phylum Arthropda, Subphylum Crustacea, Class Malacostraca) are small shrimp-like organisms and can be found in marine and freshwater environments. The carapace is not fused with the last four thoracic segments but covers them loosely.
Nationally Important Marine Feature	Through UK BAP criteria have been developed for the designation of area of sea containing marine landscapes, species and habitats.

N

Neap tide	This is when the tides are weakest and the lowest high tides occur. This occurs when the Moon and Sun are separated by 90^0 around the Earth.
Negative Impact	Impact results in an adverse change from the baseline conditions.
North Atlantic Oscillation	The North Atlantic Oscillation (NAO) is a large-scale pattern of natural climate variability caused by east-west oscillation motions of the Icelandic low and the Azores high, which controls the strength and direction of westerly winds and storm tracks across the North Atlantic, especially Europe.

O

Olfactorial feeders	Organisms that use olfactory (sense of smell) cues to find food.
OSPAR	Oslo and Paris Commission – for the protection of the marine environment of the North East Atlantic (1992).

P

Paeleovalley	Geologically ancient river valleys which no longer function as active surface water systems.
Palaeographic	The study of the earth's geographic features belonging to any part of the geologic past.
Peat	Organic rich sediment formed mainly of slightly decomposed or undecomposed plant matter that originally accumulated in a waterlogged environment.
Pelagic	The part of the water column in the open sea that is not closely associated with seabed.
Peneplain	The final stage in fluvial erosion.
Peri-glacial zone	The area influence by cold-climate processes and landforms, such as freeze-thaw activity.
Pinnipeds	(Class Mammalia, Suborder Pinnipedia) Marine carnivorous mammals including walruses and seals.
Plankton	Plankton are small micro-organisms that float or drift in great numbers in the water column.
Plume	Sediment that has been resuspended in the water column after disturbance
Polychaetes	(Phylum Annelida, Class Polychaeta) are truly segmented worms, mostly marine, and are characterized by extensions of each segment with numerous bristles projecting from them.
Positive Impact	Impact results in an improvement to the baseline conditions.
Post fledgling/ moult period	The period after a bird's first flight when they shed their first feathers and moult into their adult coats.
Prime fishing ground	A fisherman's most used and important grounds.
Profile corridors	The routes taken when carrying out geophysical surveys.
Progradation	A general term for coastline that is advancing into the sea.
Promontory	A high ridge of land or rock jutting out into a body of water; a headland.
Pulse train	A type of sound wave.

R

Ramsar sites	Wetlands of international importance designated under the Ramsar Convention 1971.
Receptor	Any ecological or other feature that is sensitive to, or has the potential to be affected by an activity.
Recoverability	A measure of a receptor's ability to return to a state close to that which existed before the effect caused a change
Regional Environmental Assessment (REA)	A process by which the potential cumulative and in-combination effects of regional marine aggregate extraction proposals are investigated.
Relict Sediment	Sediment deposited by processes, and under physical conditions, that no longer exist.
River terrace Formations	A raised bank of earth with vertical or sloping sides and a flat top formed by the erosion of rivers over thousands of years.

S

Sand ribbons Thin trails of mobile sand on the seabed are aligned in the direction of the prevailing tidal currents and which can be detected from geophysical survey images.

Sand streaks Trails of mobile sand on the seabed are aligned in the direction of the prevailing tidal currents and which can be detected from geophysical survey images.

Sandbank Sandbanks and linear sand ridges are defined as all elongate coastal to shelf sand bodies that form bathymetric highs on the seafloor and are characterised by a closed bathymetric contour.

Sandwaves Sub-aqueous dunes formed on a bed of sand or gravel under the action of water flow (+1m high).

Schedule 1 of the Wildlife and Countryside Act 1981 Schedule 1 provides a list of birds which are protected either all year round or in the close season.

Sediment sink Physical processes in the coastal zone lead to the eventual deposition of sediment in new locations, or sinks. These can be low energy zones, such as harbours, tidal lagoons and offshore deep water, or natural barriers, such as headlands, breakwaters and jetties

Sediment Starvation The prevention of sediment movement to a particular area.

Sediment transport The process, driven by hydrodynamic forces (waves and tides), that mobilises and transports sediment particles.

Sediment Transport pathway The pathway of sediment as it moves from a source to a 'sink'.

Sedimentation The settling of solid particles from fluids.

Semi-diurnal tide Two tidal cycles in one day (two high tides and two low tides).

Shear stress A measure of the collective force of waves and currents exerted on the seabed.

Shingle bar A submerged or partially exposed ridge of shingle that is built by waves offshore from a beach.

Shingle spit Accretionary deposit of sand or stones located where a shoreline changes direction, formed by wave action and joined to the shore at one end only.

Single thread Channels Channels that do not branch. Most rivers flow through single thread channels.

Siphon Tube connected to the anterior end of a bivalve or gastropod mollusc through which water is conducted into the gill cavity.

Smolts Part of the life cycle of salmon when they move from a freshwater to marine environment.

SPA Special Protected Area; sites designated under Article 4 of the EC Birds Directive to protect rare and vulnerable birds (listed in Annex I of the Directive) and for regularly occurring migratory species.

Spawning Stock Biomass The total weight of fish in a stock that are old enough to spawn.

Species Action Plan See Biodiversity Action Plan.

Species of Conservation Concern (SOCC) Lists The JNCC developed criteria for identifying species that are of conservation concern. The Red list consists of species of high conservation concern and the Amber list consists of species of medium conservation concern

Spring tide This is the strongest tide and when the highest high tides occur. This happens when the Moon and Sun are separated by 180^0 around the Earth.

Stack A residual rock pinnacle which marks coastal cliff retreat and/or the landward advance of a rock form.

Storm surge Water that is pushed to shore as a result of an offshore rise of water associated with a low pressure weather system, high winds and high waves.

Strand General description of a wide intertidal area usually composed of sand.

Stratification Development of a stable layered density structure in the water column; may be as a result of temperature gradients (thermal stratification) or salinity gradients; often seasonal.

Sublittoral Zone exposed to air only at its upper limit by the lowest spring tides.

Swell waves Waves formed by storms that have travelled away from the area in which they were formed.

T

TAC Total Allowable Catch.

Teleosts Fish with bony skeleton such as cod rather than cartilaginous fish such as skates and rays.

Terrace Deposit River sediment representing a fragment of a former river valley floor isolated by subsequent downcutting by the river.

Tertiary London Clay Formation The London Clay formation is a marine geological formation of Ypresian (Lower Eocene Epoch 56-49 Ma) age which crops out in the southeast of England.

Thermal Expansion The dimensional expansion exhibited by solid, liquid or gas as a result of heating.

Tidal amplitude The magnitude of the difference between low and high tides.

Tidal cycle The daily occurrence of two complete high tides and two low tides. The takes 24 hours and 52 minutes.

Tidal excursion The net horizontal distance over which a water particle moves during one tidal cycle of flood and ebb.

Tidal mixing fronts Are sharp horizontal gradients of density created by turbulent mixing generated by tidal currents over shallow topography.

Tidal range The vertical difference between the high tide and succeeding low tide.

Tidal surge	Water that is pushed to shore as a result of an offshore rise of water associated with a low pressure weather system, high winds and high waves.
Tolerance	The extent to which the receptor (at a regional scale) is adversely affected by a particular effect of dredging.
Tombolo	A sand or gravel bar connecting an island with another land mass.
Turbidity	The measure of the degree to which water losses transparency due to the presence of suspended particles.

U

Updrift	The direction which is opposite that of the prevailing movement of coastal material.

V

VMS	Vessel Monitoring System.

W

Weald-Artois High	A geological anticline (a fold in rock strata that is convex upward) that runs from Britain across the Dover Strait into France.
Whiteweed	(Phylum Cnidaria) A fern-like colonial hydroid species that is dried and sold for decorative purposes.
Winnowing	Loss of fine particles from the sediment over time leading to a gradual increase in average particle size over time.

Z

Zooplankton	A type of plankton found in all ocean zones, particularly the pelagic and littoral zones. They form a key component of the marine food web. They include copepods.

INDUSTRY STATEMENT

FOREWORD

Over the past three or four decades the marine aggregates dredging industry has grown to become a vital, mature and responsible business. The business has been built upon the supply of good quality aggregate resources used in all forms of construction including our homes, schools, hospitals and infrastructure and for the protection of our coasts from erosion or flooding.

This report owes its origin to the need to obtain new licences for newly discovered aggregate resources in the Outer Thames Estuary and re-licensing of existing areas where viable aggregate resource remains within the boundaries of licences that are due to expire.

In order for the competent Government authority – the Marine Management Organisation (MMO) - to decide whether dredging for aggregates in the Outer Thames Estuary can continue, an assessment of physical, biological and human environmental impacts is required. In recent years there has been a growing recognition that undertaking Environmental Impact Assessments (EIAs) as part of the permitting process at the individual licence level does not fully deliver the sustainable development objectives of the industry. A more regional appraisal is appropriate and as responsible developers the companies involved in the region formed, in 2007, the Thames Estuary Dredging Association (TEDA).

TEDA, along with The Crown Estate (whose chief contribution was to fund the regional benthic ecology study), has commissioned the preparation of this independent report entitled the Marine Aggregates Regional Environmental Assessment or MAREA. Its purpose is to brief stakeholders about the existing regional environmental conditions and potential cumulative and in-combination regional environmental impacts of the proposed developments, as well as to act as a major reference for the site specific EIAs that the companies must complete as part of their applications for new licences.

INDUSTRY STATEMENT

This Industry Statement precedes the independent MAREA prepared by the consultancy Environmental Resources Management Ltd. (ERM) and consists of two parts.

The first part comprises an introduction to marine aggregates and their importance, the Outer Thames Estuary Region, the Marine Aggregate Regional Environmental Assessment (MAREA), the companies involved and the aggregate resource.

Part two outlines the proposed activity of each individual company, and summarises the dredging plans and the production forecasts for which the MAREA has been conducted.

PART 1: INTRODUCTION TO MARINE AGGREGATES

Why we need Marine Aggregates

Government recognises that marine aggregates play a key role both in servicing the requirements of society and the built environment, and the maintenance of coast and flood protection defences. This is particularly important for London and South-East England, where 36% of demand for aggregates is supplied from marine sources, **or around 8 million tonnes every year.** If construction demand is to be met, it is vital to ensure continuity of supply to meet demand and to relieve pressure on locally constrained and declining land-based sources. Government Policy is to encourage the supply of marine sourced sand and gravel "to the extent that environmentally acceptable sources can be identified and exploited within the principles of sustainable development." (Mineral Planning Policy Statement 1: Planning and Minerals, 2004).

Marine sands and gravels are essential raw materials. They are widely used in the construction industry, notably in concrete, and help underpin the socio-economic development of the UK. The marine aggregate industry plans to continue to fulfil demand into the future (see www.bmapa.org).

Supply and Quality of Marine Aggregates in the Outer Thames Region

Marine aggregates consist of sand and gravel lying on the seabed and annual production totals about 20-25 million tonnes around England and Wales. The marine sands and gravels of the Thames Estuary were commonly deposited by rivers during glaciations when sea levels were lower. Consequently marine sands and gravels are compositionally and geologically identical to local land-based sands and gravels, but are now submerged as a result of sea level changes.

The construction industry requires a continuous supply of consistent aggregates throughout the year. For example, at the time of writing large volumes of marine sourced aggregate are being supplied by TEDA member companies for the development of the London Olympics site.

Marine aggregates are delivered in large quantities (typically 3000-9000 tonne loads) to wharves which are close to the markets and commonly integrated with existing concrete and block plants. The sands and gravels are processed (for example washed and graded) on the wharves and supplied directly to building products and construction businesses. They are used in a range of construction-related applications and products, including mortars, ready mixed and pre-cast concrete and as a drainage and fill medium. For use in construction, particularly concrete, aggregates as a mix of around 55% gravel and 45% sand are required.

The licences lying in the Outer Thames Estuary have traditionally been used to supply London for over forty years (Figure 1). Although the dependence on these licences has decreased with the new licences in the East English Channel there still remains a substantial and strategically placed reserve of sands and gravelly sands. It is important to continue to extract the reserves from the existing areas thereby reducing the requirement to licence new areas of seabed. In addition securing long-term resources will provide the Industry with confidence in aggregate supply and will help promote continued investment in ships, wharves and associated jobs.

Production from the Outer Thames Estuary in the years 2000 – 2008 has ranged from a low of 0.7 million tonnes (Mt) in 2005 to a high of 1.7 Mt in 2008 and this averages to just under 1.0Mt per annum (pa) (Figure 2). During 2007 the total production from the region was 0.98Mt, of this 0.84Mt was delivered to local ports, 0.03Mt was delivered to UK ports in other regions and 0.11Mt was exported to Europe.

Figure 1 Thames MAREA Study Area

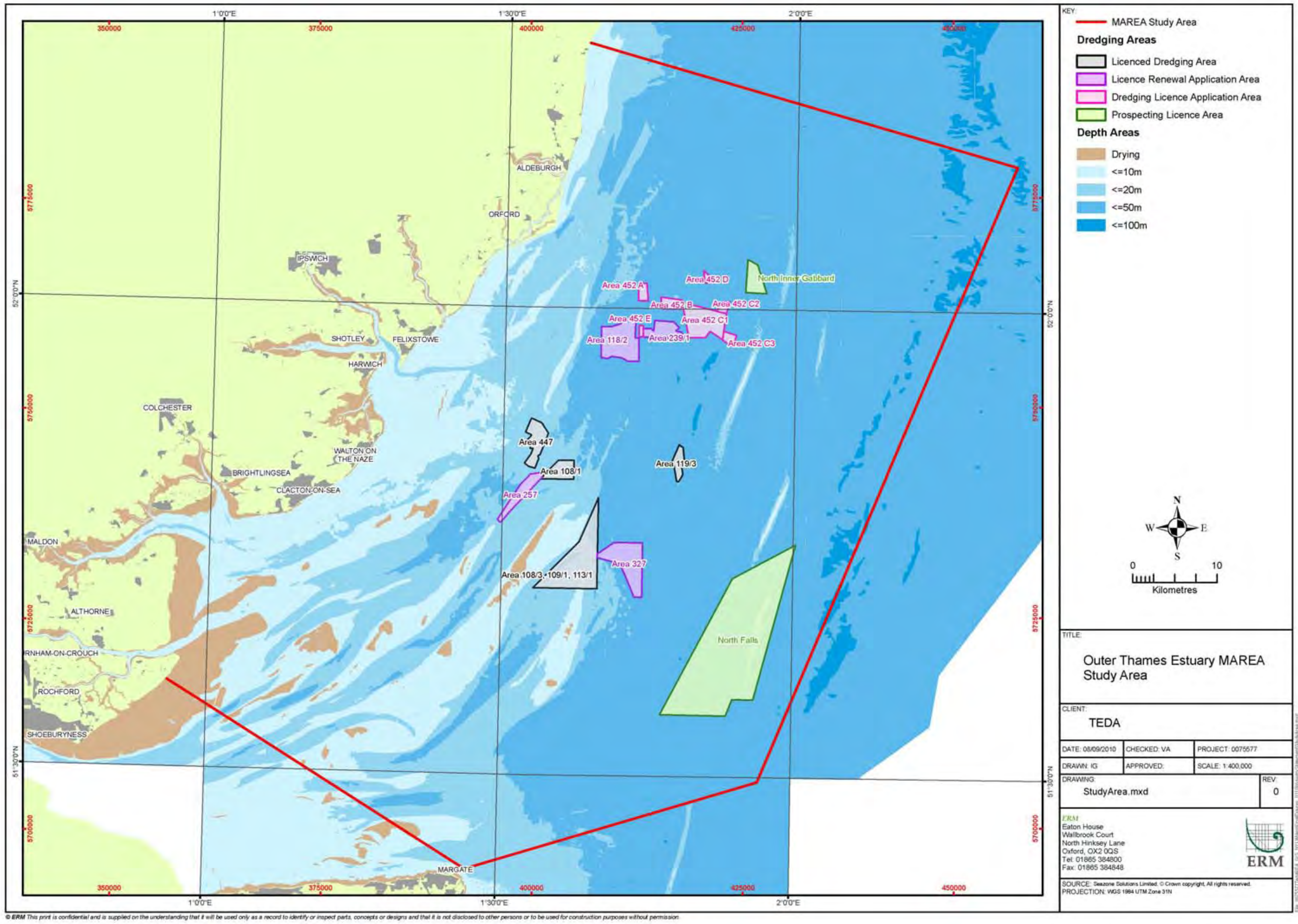
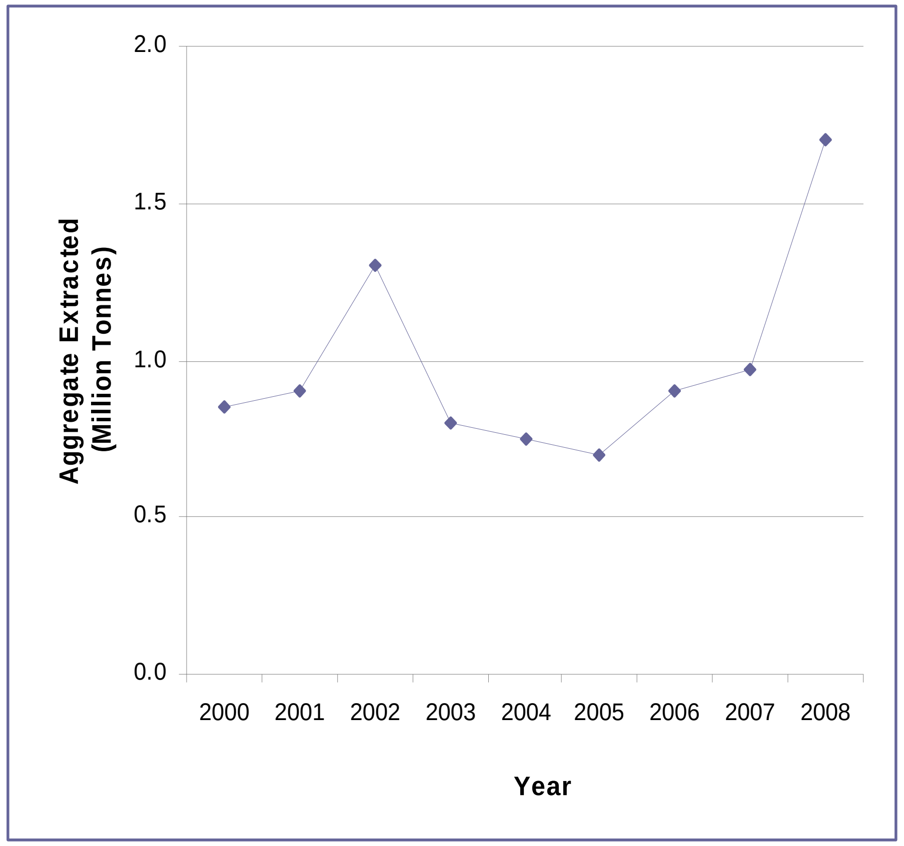


Figure 2 Graph of Regional Production 2000-2008 which excludes Beach Recharge and Contract Fill

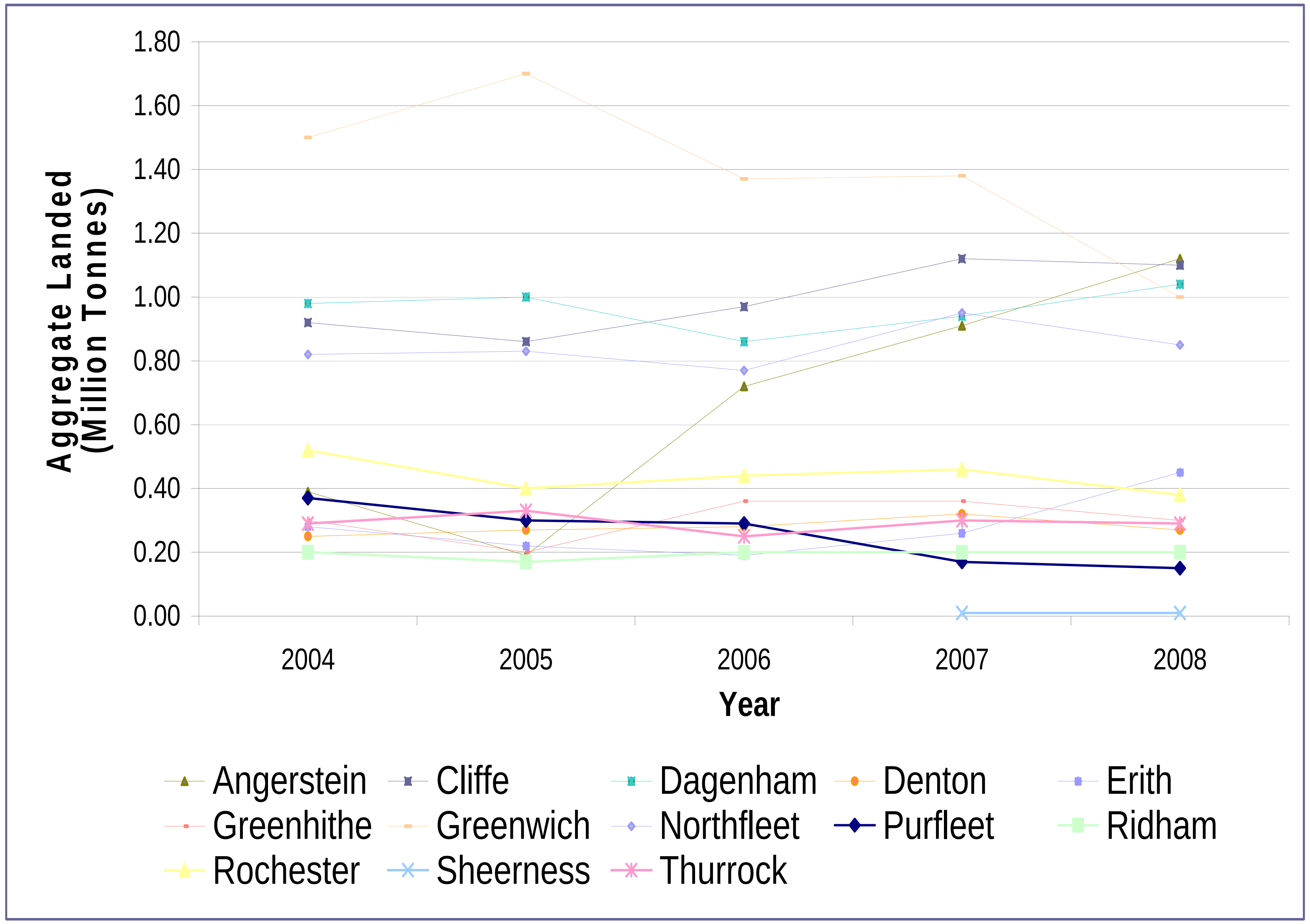


Marine aggregates are also dredged for beach recharge and contract fill (e.g. port civil engineering projects). Annual demand for both of these uses is highly variable. From 2005 to 2008 beach recharge aggregate demand has ranged from 0 to 0.65Mtpa while contract fill was required only in 2006 (0.55Mtpa). The demand for beach recharge material is expected to continue into the future with rising sea levels and increased storm events.

Between 2005 and 2008 6.5 - 7.5 Mtpa of marine sand and gravel aggregate was delivered to local ports along the Thames and Medway rivers. The majority of this (5 – 6 Mt) has originated outside the Thames region in areas that generally provide a higher gravel content more suited to market demand.

In the last few years there have been 12 or 13 ports active along the Thames and Medway that receive marine aggregates (Figure 3), with the majority of the tonnage delivered to Greenwich (1.0 – 1.4Mtpa), Cliffe (0.9 – 1.1Mtpa), Dagenham (0.9 – 1.0Mtpa) and Angerstein (0.7 – 1.1Mtpa).

Figure 3 Landings by Ports



(Note: All statistics have been drawn from Marine Aggregates, The Crown Estate Licences – Summary of Statistics 2000 - 2008. www.thecrownestate.co.uk)

Development of the Marine Aggregate Resources in the Region

At the time of writing there are 4 active dredging licences in the region along with 1 prospecting area, 1 application area and 4 further areas at various stages in the pre-application process (Figure 1). Up to the end of 2008 (the most recent date for which statistics are available) there were 9 production licences in the Outer Thames region providing 0.7-1.7million tonnes of aggregate each year, representing about 3.5-6.5 per cent of UK production. One further prospecting area is present (Area 501) which is close to the median line bordering Dutch waters. This has been excluded from the current assessment as it lies in deep water well outside the study area.

The region lies offshore stretching from southern Suffolk, through Essex and down to north Kent with the licensed areas typically in 20 to 30 metres of water. The aggregate resources of the area are critical to the marine aggregates industry and are also of key strategic importance due to the close vicinity of the London market and the fact that the Thames areas are relatively unaffected by south westerly winds which periodically interrupt dredging operations in other regions.

Whilst the importance of the Outer Thames Estuary resources to the construction and marine aggregate dredging industry is clear (an aggregate source close to the point of use has benefits to business as well as the environment by minimising the 'carbon footprint'), TEDA understands that permissions and renewals for some licence areas may not be given if environmental impacts are unacceptable whilst for others a number of mitigating conditions may be necessary. These marine environmental issues must be assessed and mitigated in accordance with Government policy (Marine Minerals Guidance 1 & 2, 2002, 2008). At the same time, the industry recognises the Government's aim for sustainable development and the importance of the prudent use of resources, maximising efficiency and minimising impacts associated with aggregate recovery. The dredging areas in the Outer Thames region can achieve these aims, should renewals and permissions be granted.

The Thames Estuary Dredging Association

The Thames Estuary Dredging Association (TEDA) was formed in 2007 and is an association of aggregate dredging companies with active licences, prospecting and application areas or a combination of these in the Outer Thames Estuary. TEDA is neither a trade association nor a commercial organisation, and was formed to research, analyse and promote aggregates dredging in the Outer Thames Estuary. TEDA members are:

- Britannia Aggregates Ltd;
- CEMEX UK Marine Ltd;
- Hanson Aggregates Marine Ltd;
- Tarmac Marine Dredging Ltd; and
- Volker Dredging Ltd.

Each member company holds production licences that are due to expire before 2014 and/or has involvement in new applications or prospecting areas. As a result the companies have decided, in consultation with Government Regulatory Advisors, to undertake a non-statutory and voluntary Marine Aggregates Regional Environmental Assessment (MAREA) to support the renewal of these licences and assist with the licensing of new areas.

Regional Assessments

Since the introduction of the environmental Impact Assessment (EIA) Directive in 1985 (85/337/EEC) marine developers and regulators have assessed the environmental acceptability of a proposed development through an Environmental Impact Assessment (EIA). Typically an individual company will independently progress an EIA as part of the process of obtaining the permits and licences required to allow its development to proceed. This process leads to a good understanding of local, site specific impacts, however there is often a less robust awareness and consideration of other existing and potential developments within the region.

More recently there has been an increasing awareness of the regional environmental context of a development. Industry regulators increasingly require the developer to assess the significance of their development on a regional scale, demanding a thorough assessment of both cumulative and in-combination impacts. As defined by the regulatory guidance (see below) [1], 'cumulative impact' means impacts from multiple aggregate dredging activities in the region and 'in-combination impact' means the total impact from all industrial sectors and human activities operating in the region. Consequently there is now a regulatory expectation that cumulative and in-combination issues will be assessed within an EIA.

The process for undertaking a MAREA is now well established. Regional assessments have been guided by a working group of regulators known as the Regulatory Advisory Group (RAG). This group is comprised of the Joint Nature Conservation Committee (JNCC), the Centre for Environment, Fisheries and Aquaculture Science (Cefas), Natural England (NE) and English Heritage (EH) and supported by The Crown Estate and the industry (TEDA). Typically, a scoping study with stakeholder consultation is followed by a full-scale assessment. RAG has developed guidelines which identify a series of overarching objectives to help steer the MAREA process. These guidelines provide an outline of the practical application of the MAREA to the marine aggregate industry and also offer a mechanism for stakeholders to take part in the consultation process. '*Regional Environmental Assessment: A Framework for Marine Minerals Sector*' (2008), is available to download from the Cefas website (http://www.cefas.co.uk/media/126642/rea%20framework%20guidelines_final.pdf).

Further regional scale information is also emerging from Regional Environmental Characterisation (REC) surveys commissioned in recent years by Defra under the Marine Aggregates Levy Sustainability Fund. REC surveys have been undertaken off the south coast, in the eastern English Channel, the outer Thames Estuary, off East Anglia and in the North Sea off the Humber Estuary. The aim of a REC is primarily to provide Defra and the MMO with an environmental reference and regional scale context against which to judge marine aggregate dredging licence applications. REC surveys and reports are providing robust scientific overviews and descriptions of sea bed sediments, shallow geology, archaeology and ecology. Aspects of the Outer Thames Estuary REC report are referenced in this TEDA MAREA. Furthermore, the REC reports will be available and of value to all stakeholders, including government, marine industries, planners and environmental interests. The RECs will assist Regulators to make informed decisions, notably with regard to marine aggregate licence applications.

[1] Regional Environmental Assessment: A Framework for the Marine Minerals Sector. CEFAS, JNCC, Natural England, English Heritage. March 2008.

PART 2: Existing and Proposed Aggregate Dredging Activities

Introduction

The TEDA companies currently have 9 licences in the region that are either currently active (3) or within the renewal process (6). There is in addition 1 application underway and 2 (**please see table and note below) prospecting areas (Figure 1 and Table 1). These prospecting and application areas are at various stages of the permitting process, which may take several years to complete. In order to reflect environmental concerns, the terms, sizes and boundaries of prospecting and application areas may change before a dredging permission is granted. Note also that a Prospecting licence may not necessarily be developed into an application.

Note that in some cases licence applications are developed by more than one company working together (e.g. Area 447) and in others a particular aggregate area may be licensed to a number of different companies working independently of each other (e.g. Area 108/109/113).

Table 1: Existing Dredging, Application and Prospecting Licences in the Thames Region

Company	Existing Dredging Licences & Renewals	Application Areas	Prospecting Areas
Britannia Aggregates Ltd	108/1, 108/3		498
CEMEX UK Marine Ltd	113/1, 118/2, 239, 327, 447	452	
Hanson Aggregates Marine Ltd	119/3, 447		504 **
Tarmac Marine Dredging Ltd	109, 257, 447		
Volker Dredging Ltd			498

** Area 504 was an active prospecting licence during the production of this MAREA and its potential impacts have been assessed throughout. However, at a late stage of this report the area has been dropped by Hanson Aggregates and it has not been possible to remove it from consideration. This has lead in some cases to a very conservative assessment of regional impacts and this should be kept in mind while reading the impact chapters and specialist reports.

A prospecting licence granted by The Crown Estate gives the applicant exclusive exploration rights to that specific area of seabed and if viable resources are found the area may then be progressed into an application area. An application area is where an application to dredge has been made to the Crown Estate and the Marine Management Organisation (MMO) and an environmental impact assessment is underway. Marine aggregate dredging is only allowed with both a statutory Dredging Permission from the MMO and a Crown Estate production licence. Extraction is limited to a tonnage, area and term and is managed by MMO through a schedule of mandatory conditions. Permissions are normally issued with a 15 year term and that is the timescale assessed in this MAREA.

It is possible for a permission to be denied if the impacts associated with the application are ultimately considered to be environmentally unacceptable by the regulator and their advisors.

EXISTING DREDGING PERMISSIONS AND ACTIVITY

Dredging does not occur evenly across each dredging licence area. Typically dredging only occurs in active dredging zones which generally comprise a smaller proportion of the licensed area (Figure 4 and Table 2). Within the active dredging zones dredging is commonly concentrated in particular areas (Figure 5). Dredging activity is recorded by an Electronic Monitoring System (EMS). The EMS records are independently assessed by government regulators and The Crown Estate to ensure extraction only takes place within permitted areas.

Table 2 Total Licensed/Renewal Area and Active Dredging Area

Company	Licensed Dredging Area or Renewal	Total Area (km2)	Indicative Active Area (km2)
Britannia Aggregates Ltd	108/1 108/3	6.9 33.1	6.9 33.1
CEMEX UK Marine Ltd	113/1 118/2 239 327 447	33.1 18.1 6.7 18.0 9.0	33.1 12.3 2.5 9.0 6.5
Hanson Marine Ltd	119/3 447	3.8 9.0	3.8 6.5
Tarmac Marine Dredging Ltd	109 257 447	33.1 7.3 9.0	33.1 6.4 6.5

Figure 4 Active Dredge Zones within the Thames Licence Areas

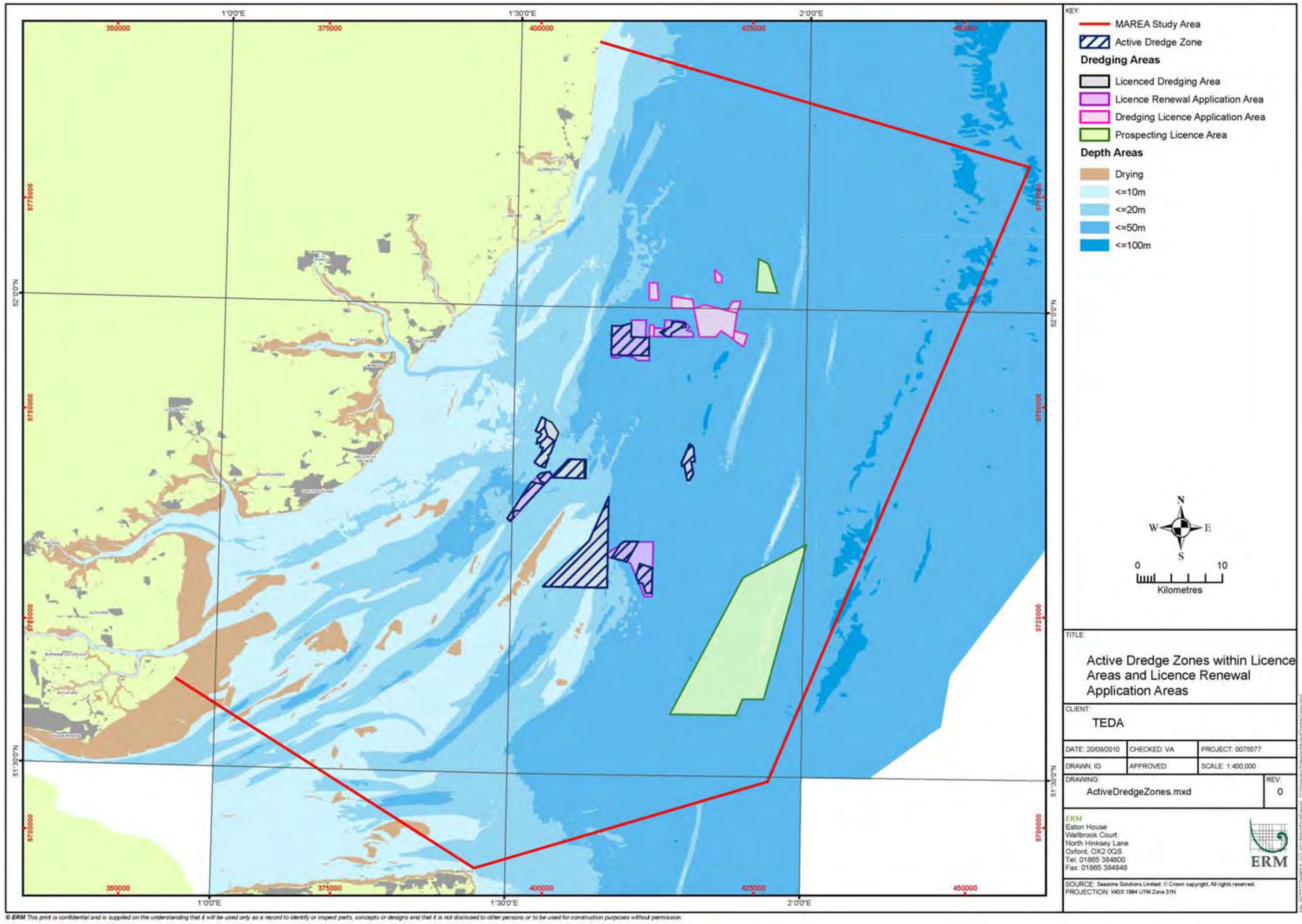
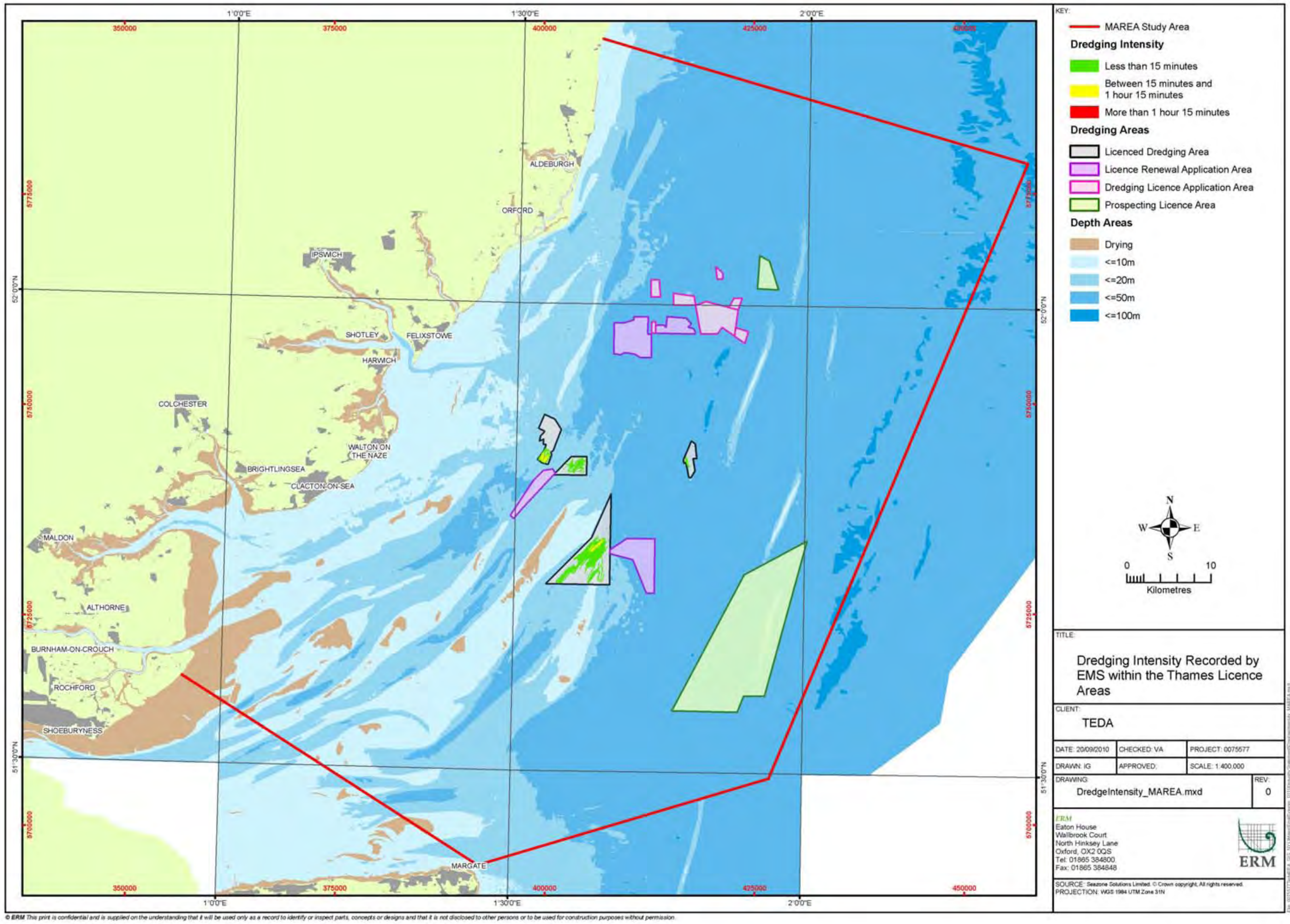


Figure 5 Dredging Intensity recorded by EMS within the Thames Licence Areas in 2009



Prospecting Licences and Applications

There is 1 application area (split into multiple zones) and 2 ** (see note above) prospecting areas in the Outer Thames Estuary study area, the areas of which are summarised in Table 3.

Table 3: Application and Prospecting Areas in the Thames Region

Company	Application Areas	Area (km2)	Prospecting Areas	Area (km2)
Britannia Aggregates Ltd			498	6.5
CEMEX UK Marine Ltd	452	7.9		
Hanson Marine Ltd			504**	145.9
Volker Dredging Ltd			498	6.5

Dredging Methods

All aggregate dredging from Crown Estate Aggregate Production Licence areas in the TEDA region is currently carried out with trailer suction hopper dredgers, a method known as trailer dredging. During this method the sand and gravel is extracted as the dredger moves slowly (typically less than 3 knots) through the water, usually parallel to the tidal direction.

While the vessel is operational a drag-head, on the end of the dredge pipe, with a width of 2-3 meters is pulled slowly over the seabed removing the aggregate on each pass to a cut depth of approximately 30cm. As the drag-head (or suction head) is trailed over the seabed a mix of sediment and water is pumped up the dredge pipe and into the hopper in the vessel hull (see Chapter 7). Over time the dredging tracks will overlap creating a shallow depression.

Once on board the coarser sediment particles settle to the bottom and excess water, which contains some suspended silt and sand, is decanted through spillways (overflows) in the side or bottom of the dredger.

During loading it is possible to influence the cargo type by screening which may be necessary where the in-situ sediment character differs from the requirement of the customer. If required the sediment mixture may be passed over screens and selected portions may be retained or returned to the sea forming a sediment plume which will gradually settle to the seabed. In order to meet the required specification it is possible to return either the sand or stone fractions via a reject chute.

Depending on whether screening is required, the size of the vessel hopper and the type of sediment being dredged it typically takes 3 – 8 hours to dredge a full load. The vessel will then return to a wharf or dock and self discharge.

Dredgers with various hopper sizes are currently utilised in the Thames region up to a maximum size of 5,000m^3 (approximately 9,000 tonnes) although the average size is closer to 2,800m^3 (5,000 tonnes). This is likely to remain the case for the foreseeable future.

Marine Aggregate Production Forecasts in the TEDA Region and Basis for the MAREA

The MAREA takes a precautionary approach to the assessment of cumulative and in combination impacts in order to clearly define sensitivities. From confidential application tonnage information provided by individual TEDA members to The Crown Estate, a 15 year marine aggregate production of 142,500,000 tonnes will be taken as the maximum extraction case to be assessed in this MAREA (equating to an average 9.5 million tones per annum). This assumes that all areas will be permitted and dredged concurrently and this leads to a maximum concurrent production from all licences, applications and prospecting licences that equates to approximately 5.5 times the highest annual production rate over the last 5 years.

This figure will inevitably include extraction tonnage "double counting" arising from competition for market shares between the TEDA companies. Each company will seek permission for tonnage to accommodate both its current market share but also might seek additional tonnage "headroom" for any potential increase in market share arising from successful competition against other operators. As a result, it is extremely unlikely that the full 9.5 million tonnes will ever be dredged in a given year, but nevertheless this MAREA now assesses the potential environmental impacts associated with this tonnage being removed each year over a 15 year period, as part of a prudent precautionary approach to assessing the regional environmental impacts of aggregate dredging.

Britannia Beaver Operated by Britannia Aggregates

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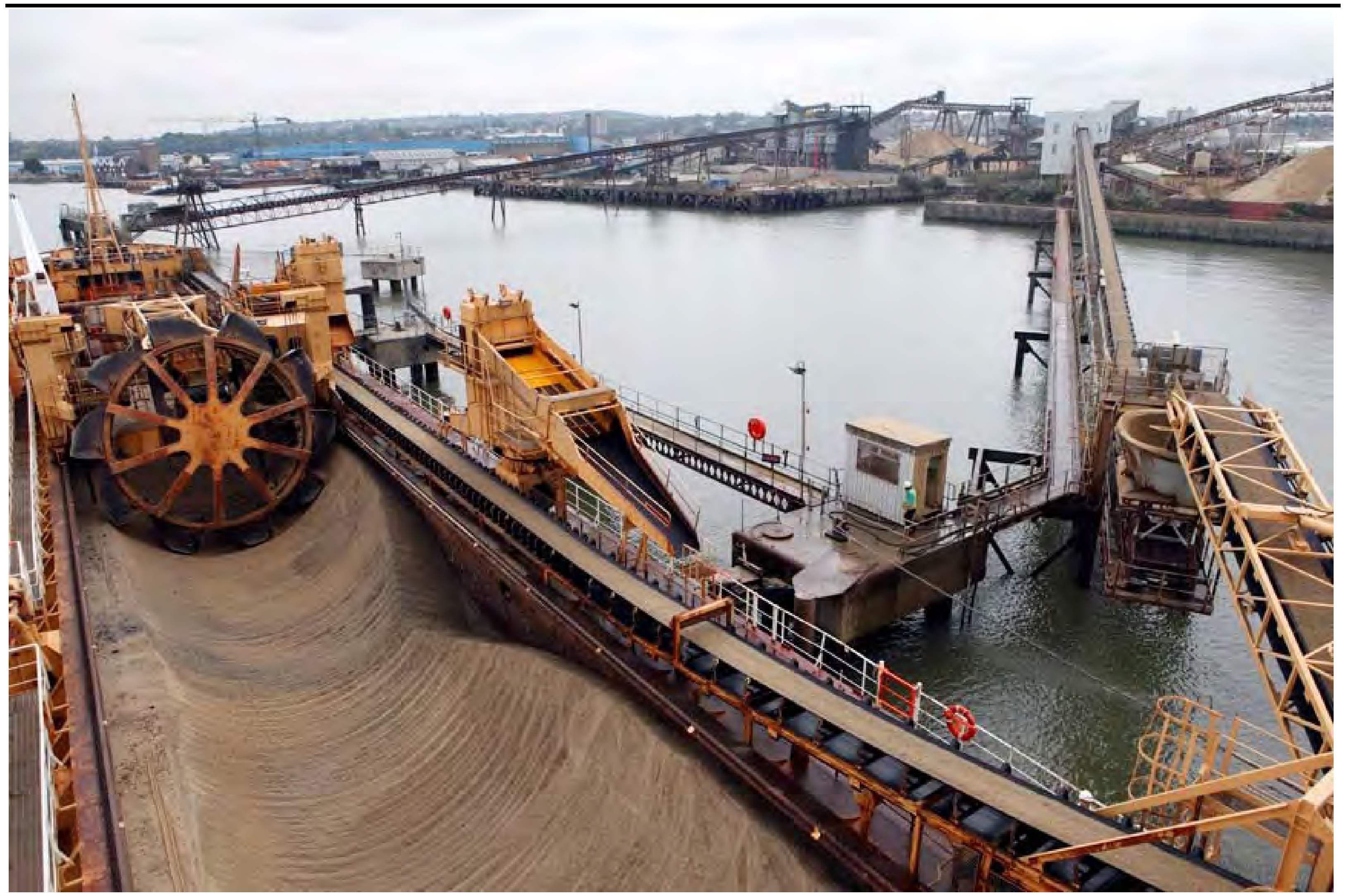
1 INTRODUCTION

1.1 INTRODUCTION

The marine aggregate extraction industry has voluntarily committed to undertake Regional Environmental Assessments for a number of strategic areas of extraction, including the Outer Thames region. Environmental Resources Management (ERM) was commissioned by the Thames Estuary Dredging Association (TEDA), a consortium of 5 dredging companies, to undertake the Marine Aggregate Regional Environmental Assessment (MAREA) for the Outer Thames region. These companies each have licence areas, application areas and/or prospecting areas within the study area. The five companies that make up TEDA are:

- Britannia Aggregates Ltd;
- CEMEX UK Marine Ltd;
- Hanson Aggregates Marine Ltd;
- Tarmac Marine Dredging Ltd; and
- Volker Dredging Ltd.

The study area for this MAREA, including the location of the licence areas, application areas and prospecting areas within it, is shown in Figure 1.1.



1.2 BACKGROUND TO MAREA

A Marine Aggregate Regional Environmental Assessment (MAREA) is a voluntary exercise, endorsed by the British Marine Aggregates Producers Association (BMAPA), The Crown Estate and the Marine Management Organisation (formerly Marine and Fisheries Agency). Even though the MAREA process is non-statutory, guidance has been provided by the Regulatory Advisors Group (RAG), which includes members of Natural England, Cefas, JNCC and English Heritage (Appendix A).

The main objectives of a MAREA are to describe the regional baseline characteristics in an area with several marine aggregate licence areas and to evaluate the potential cumulative and in-combination effects (see Chapter 3 for definitions) of all the existing and planned future dredging operations.

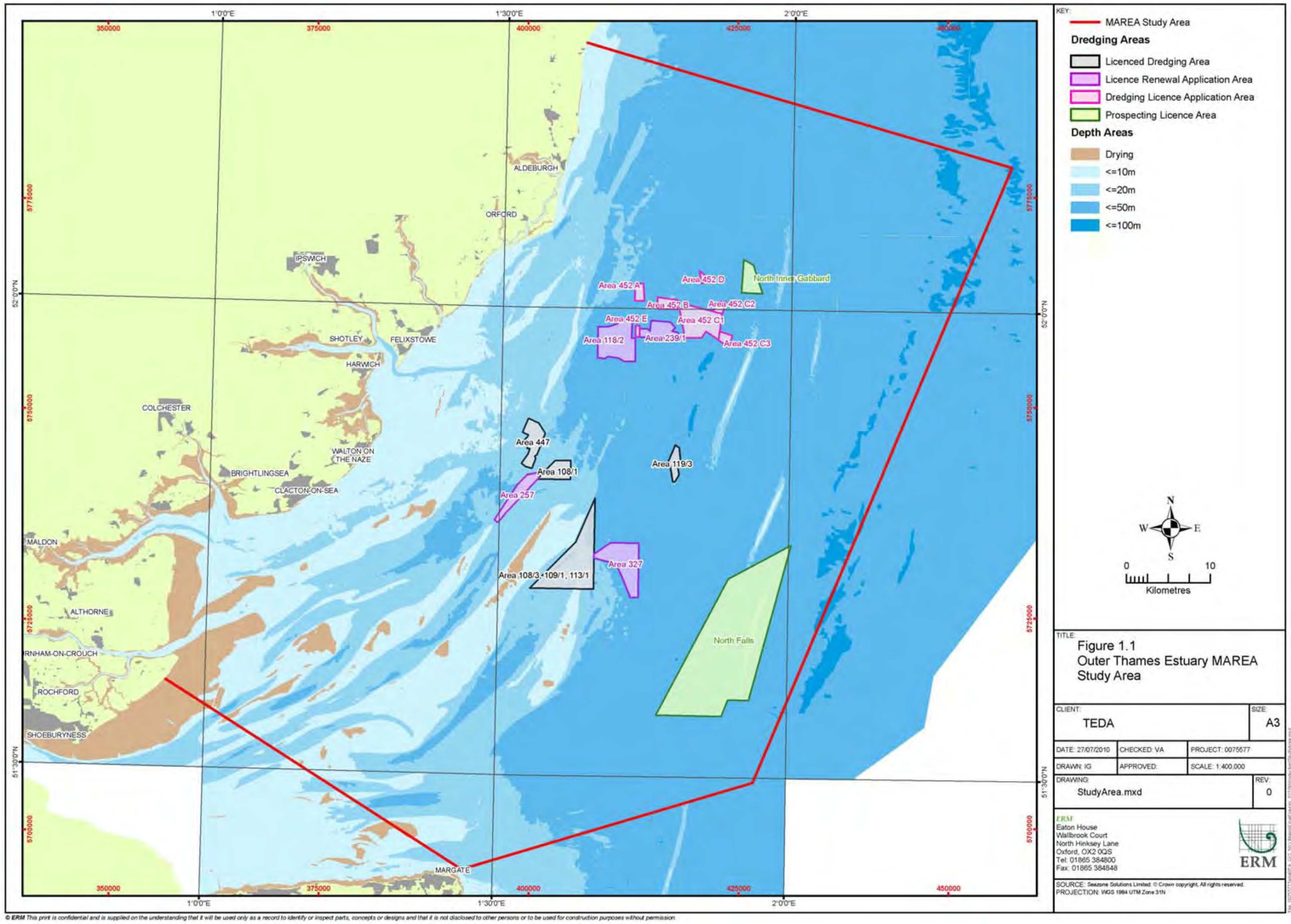
As part of the planning process and to meet regulatory requirements, Environmental Impact Assessments (EIA) will still be carried out for individual licence applications. However the MAREA will allow the EIAs to be considered in a regional context and therefore allow a better understanding of the interaction with the surrounding environment, other aggregates licences areas and other sea users.

The first MAREA was completed in 2003 for the East Channel Region. Since this early study, guidance for MAREA has been provided by the Regulatory Advisors Group (see Section 2.2). The MAREA approach has been further developed during a number of similar studies that are currently underway for other marine aggregate areas in the UK: the Humber, South Coast and Anglian regions.

1.3 STRUCTURE OF THIS REPORT

This MAREA report is split into two main parts. The first part presents the REA methodology, followed by the physical, biological and human baselines, along with a summary of the legislation and policies relevant to each. The second part presents an assessment of the potential impacts of dredging within the MAREA study area to each of the physical, biological and human receptors considered. The final impact assessment chapter assesses the potential in-combination impacts from dredging and other anthropogenic influences that are present within the region including offshore wind farms and ports.

Figure 1.1 Outer Thames Estuary MAREA Study Area



2 OVERVIEW OF THE MAREA PROCESS

2.1 AIMS AND OBJECTIVES

The aims and objectives of the Regional Environmental Assessment envisaged by the Regulatory Advisors Group (RAG) (CEFAS *et al*, 2008) (Appendix A) are outlined below, along with an explanation of how and why the Thames MAREA has deviated from the original approach where necessary:

1. The REA will concentrate on assessing key issues of risk to the marine environment.

2. The REA will provide best use of developer resources and approach to data collection, evaluation and assessment both now and into the future in the context of existing and future government policy (for example Marine Spatial Planning / Ecosystem Approach).

3. The REA will provide an objective, evidence-based assessment of potential impacts deriving from different development scenarios of the aggregate extraction industry. This can be based on industry projections and will provide realistic scenarios covering the full range (maximum and minimum) of dredging options within licence areas and summed across the REA region. The assessment will also be in relation to impacts caused by other human activities and natural variability.

   After careful deliberation, and consideration of maximum, minimum and realistic tonnages, it was decided that the Thames MAREA should assess impacts based on a maximum regional tonnage extraction scenario that is proposed to be dredged from within the MAREA area by TEDA members. This figure is the sum of all the proposed maximum extraction rates for the individual companies' licence applications and renewals. For this extraction scenario to be realised, all companies would have to dredge at their full off-take rates simultaneously, which is unlikely. However, the reasoning behind this approach is that if a potential impact is assessed as being not significant when the maximum possible tonnage is considered, then it can be concluded with confidence that there will be no significant impact in reality. Any impacts of significance might require either regional or site specific mitigation, depending on the issue in question. It was not possible to look at a 'realistic' scenario as a starting point, as present day off-take levels are not considered representative of what future levels might be, which will primarily be driven by market demand.

4. The REA will provide objective, evidence-based assessments of the distribution and importance of regional resources (living and non-living) and the potential impacts from the proposed activities on these resources at a regional level. The REA report will act as a reference source for this information, and will be based on desk-based assessments using all relevant existing information with important gaps filled by targeted cross-disciplinary desk studies and field work as necessary.

5. The REA will aim to provide a context and basis for site-specific EIAs within the relevant area and to identify site-specific issues that individual EIAs may need to focus on more specifically.

6. The REA will aim to provide a robust assessment of cumulative and in-combination impacts at the regional scale, and thus will be able to contribute towards assessments of the magnitude and scale of such impacts at specific licence areas.

7. Updated reassessments will be provided as part of the ongoing REA process where new evidence or approaches are developed with the potential to offer an improved assessment.

   During the course of compiling this assessment the baselines have been updated with new information where appropriate. However we have not become aware of any new assessment approaches that could be integrated into the MAREA. However there may be other documents published in the future as part of a regional monitoring programme that fulfil this requirement.

8. If the REA highlights issues of concern at specific licence application areas, data collected during the REA for the purpose of understanding potential regional impacts from site renewals and new applications may need to be supplemented by more targeted data collection programmes at the EIA stage.

9. The REA will make recommendations for monitoring to be addressed at the REA or individual EIA level and for R&D to address gaps in knowledge, understanding or assessment tools.

   The MAREA makes recommendations for future studies to be carried out at the individual EIA stage, and recommends that TEDA companies continue to work together to develop a regional approach to managing dredging activity, including monitoring where possible.

10. All assessments of resources, activities, and impacts need to be conducted in a standardised manner to ensure that outcomes are directly comparable within and across regions. Standardised approaches need to be developed for every aspect of the assessment process from survey design (including co-ordination of survey missions) and data collection to data analysis, presentation, and interpretation. Non-standard or ad-hoc approaches may dramatically reduce the effectiveness of the REA and have knock-on consequences to the efficiency of the advisory process.

    A standardised approach to both the Thames MAREA and South Coast MAREA was developed, with the aim of this being a blueprint for other future MAREAs in the UK (eg East Anglia and Humber).

11. All data generated from the REA will be placed in the public domain subject to the licence at the time of publication.

    All reports and metadata generated from the REA will be placed in the public domain; however the raw data will remain the property of TEDA, and in the case of the benthic data; The Crown Estate.

2.2 REGULATORY GUIDANCE

Guidance and recommendations on a framework for Regional Environmental Assessments (REA) for the Marine Minerals sector have been produced by the Regulatory Advisors Group (RAG) with input from the marine aggregate industry and its consultants engaged in undertaking REAs (Appendix A). Contributions from targeted stakeholder engagement have also been used in developing the guidance and recommendations. Members of RAG include Cefas, Natural England, the Joint Nature Conservation Committee and English Heritage. They are routinely tasked with providing scientific and technical advice to Government regulators on the matter of industry applications to extract Marine Minerals.

The guidance takes account of nature conservation, the marine and historic environment interests and provides a suggested approach for each area in turn. In terms of nature conservation, the key issue is an initial identification of the extent (or lack of), and distribution of habitats and species of conservation importance within the REA area, taking particular account of those likely to be impacted by marine mineral extraction. All aspects of the marine environment should be considered in a multidisciplinary way, including fish and fisheries resources, benthic ecology and coastal/physical processes. Consideration of the historic environment should include a comprehensive review of resources in the region including palaeo-environmental (eg prehistoric and geomorphological) features and records of wrecks, aircraft and other features.

In addition other sectors such as navigation and recreation need to be considered, and RAG recommends engagement with all relevant regulatory authorities and stakeholders, through detailed scoping and consultation.

2.3 UK LICENSING PROCEDURE FOR MARINE AGGREGATE EXTRACTION

2.3.1 Statutory Procedures

Whilst there are no statutory procedures for Regional Environmental Assessments, the procedures for marine aggregate extraction licence applications in accordance with the *Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007*, can be used to inform the process. The guidance relates to the regulation by the Secretary of State for Environment, Food and Rural Affairs, of marine minerals extraction in English and Northern Ireland waters (and some outer-marine areas around Scotland and Wales), and is administered by the MMO. The Crown Estate is the owner of most of the seabed in UK territorial waters and subject to the decision of the Secretary of State, issues licences for marine aggregate extraction.

The current regulations came into force in May 2007. They also transpose into UK law the requirements of the European Community (EC) EIA Directive (Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment, as amended by Directives 97/11/EEC and 2003/35/EEC) and the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) in relation to the assessment of the effects of marine mineral extraction by dredging.

Schedule 1 of the regulations outlines minimum and additional requirements to be included in the ES (Environmental Statement) and EIA (Environmental Impact Assessment). Part 1 outlines the minimum requirements for inclusion within an EIA which include:

- A description of the project comprising information on the site, design and size of the project.
- A description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects.
- The data required to identify and assess the main effects which the project is likely to have on the environment.
- An outline of the main alternatives studied by the applicant and an indication of the main reasons for the applicant's choice, taking into account the environmental effects.
- A non-technical summary of the information provided under the above paragraphs.

Part 2 of Schedule 1 outlines the additional requirements which should be addressed as is reasonably required to assess the environmental effects of the project and where possible with regard to current knowledge and methods of assessment. These are as follows:

1. A description of the project, including in particular—

    a) A description of the physical characteristics of the whole project and the land-use requirements during the construction and operational phases.

    b) A description of the main characteristics of the production processes, for instance nature and quantity of the materials used.

    c) An estimate, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc.) resulting from the operation of the proposed project.

2. An outline of the main alternatives studied by the applicant and an indication of the main reasons for this choice, taking into account the environmental effects.

3. A description of the aspects of the environment likely to be significantly affected by the proposed project including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the interrelationship between the above factors.

4. A description of the likely significant effects of the proposed project on the environment, which should cover the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the project, resulting from:

    a) The existence of the project.

    b) The use of natural resources.

    c) The emission of pollutants, the creation of nuisances and the elimination of waste, and a description by the applicant of the forecasting methods used to assess the effects on the environment.

5. A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment.

6. A non-technical summary of the information provided under paragraphs 1 to 5 of this Part.

7. An indication of any difficulties (technical deficiencies or lack of know-how) encountered by the applicant in compiling the required information.

Schedule 2 of the Regulations, the Selection Criteria, outlines further aspects that must be considered within the ES and EIA. These aspects generally refer to the assessment of impacts to the environment and are split into three categories:

- Characteristics of the project, including, among others, the size of the project, its cumulative effect with other projects, the production of waste and the risk of accidents.
- Location of the project including the environmental sensitivity of geographical areas likely to be affected by the project including an assessment of their existing use, relative abundance, regenerative capacity and their absorption capacity.
- Characteristics of the potential impact of the project including its extent, trans-frontier nature, magnitude and complexity, probability, duration, frequency and reversibility.

Schedule 3 outlines those natural habitats that are to be considered within the EIA and provides provision for the protection of European sites for both new and existing dredging projects.

2.3.2 Marine Mineral Guidance

The ODPM has published guidance (ODPM, 2002) on the procedural steps to be taken when preparing an Environmental Statement in accordance with the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) regulations 2007 (1). This is divided into the following four sections:

- Description of the proposed activity and environment – including a description of the nature of the seabed and the biological status of the proposed area, and a discussion of other users of the sea and the extent to which their activities may be affected by dredging.
- Assessment of the potential effects of the dredging activity – the ES should identify and quantify the consequences of the proposed project on

(1) There are separate regulations for Wales; The Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (Wales) Regulations 2007.

the physical and biological environment, fisheries, and other users of the sea, potential effects on marine archaeological sites and the cumulative impacts of dredging and other activities in the region.

- Measures to avoid, reduce or remedy significant adverse effects – the ES should include consideration of the practical steps that might be taken to mitigate the effects of the proposed mineral extraction.

- Monitoring of environmental effects – the ES should include a consideration of an appropriate monitoring programme.

These are all elements that whilst not statutory as part of the REA process, can in some instances and to some extent be used to guide it.

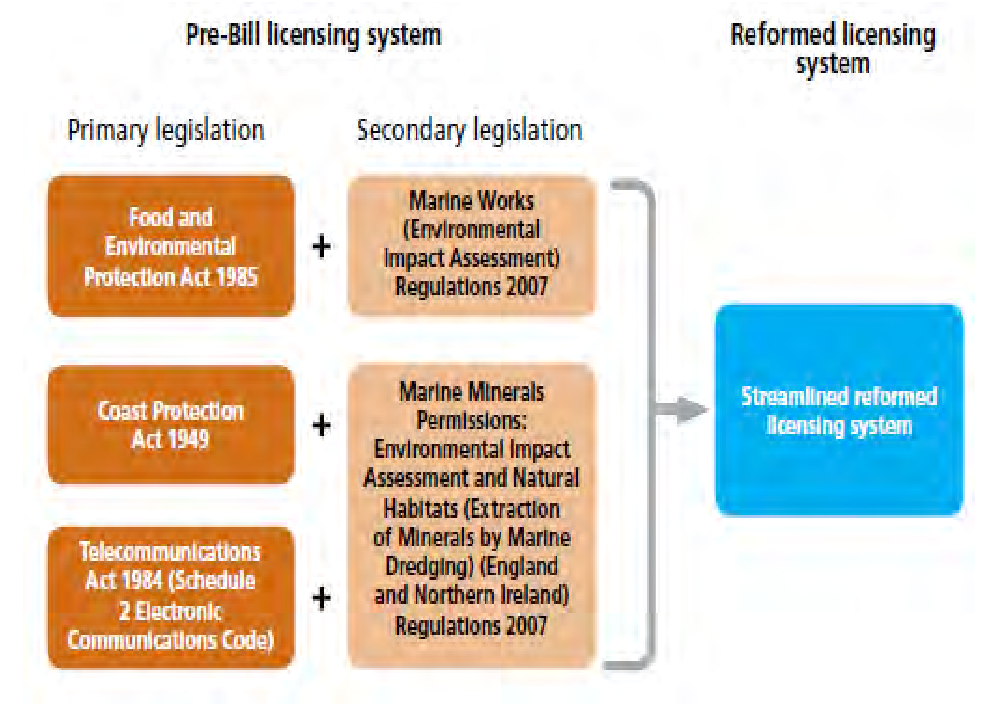
2.3.3 Marine Act

The procedure described above for marine aggregate extraction in the UK is likely to change in the foreseeable future as a result of the implementation of the new Marine and Coastal Access Act which aims to ensure clean, healthy, safe, productive and biologically diverse oceans and seas, by putting in place better systems for delivering sustainable development of the marine and coastal environment.

The changes that the Act is making to the marine licensing system will result in improved, more consistent licensing decisions delivered more efficiently by a system that is proportionate and easier to understand and to use. They will integrate delivery across a range of sectors and, through the functions of the new Marine Management Organisation (MMO), be a vital link in the chain from planning to enforcement.

The licensing and licensing enforcement provisions in the Marine and Coastal Access Act combine existing regulatory regimes from the Food and Environment Protection Act 1985, the Coast Protection Act 1949, and Telecommunications Act 1984 (Schedule 2 Electronic Communications Code). Secondary legislation under the Act will further consolidate powers by incorporating the Marine Works (Environmental Impact Assessment) Regulations 2007, and the Marine Minerals Permissions under the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007 (see Figure 2.1). The MMO will regulate these activities as the licensing authority for the new regime.

Figure 2.1 Diagram showing Licensing System before and after the Marine and Coastal Access Bill was passed.

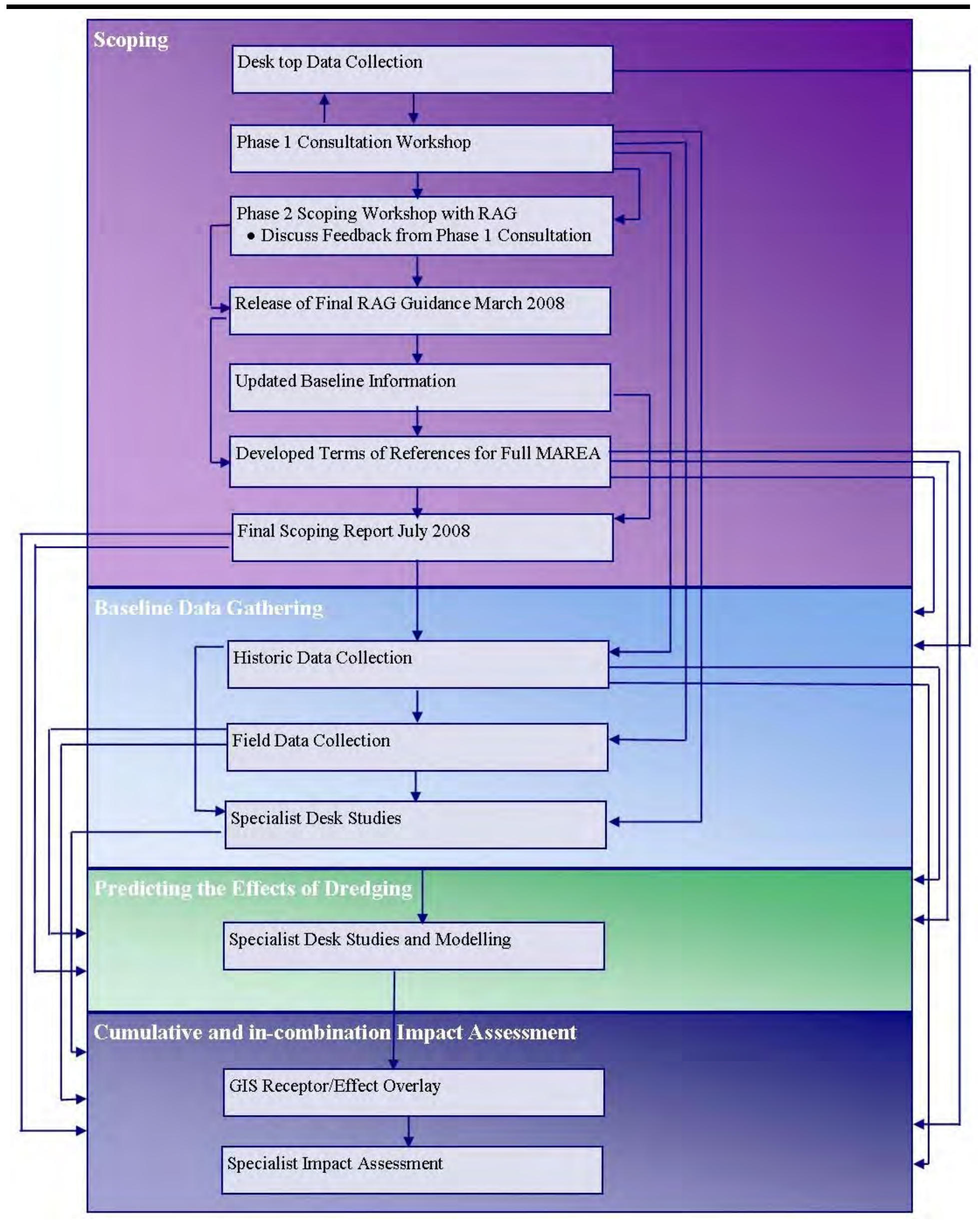


Source: Defra. 2009. Managing our marine resources: the Marine Management Organisation. Available at: http://www.defra.gov.uk/marine/pdf/legislation/mmo-brochure.pdf.

2.4 Overview of the MAREA Process

Figure 2.2 outlines the key stages of the MAREA process, described in detail in the following sections.

Figure 2.2 Key Stages of the MAREA Process



2.4.1 Scoping

The MAREA scoping process commenced in March 2007. The first stage was a desktop data collation exercise and gap analysis, identification of additional desk top data sources and consideration of the requirement for in-field baseline data collation. A copy of the draft scoping report and letter was sent to all consultees advising them of the voluntary undertaking of a MAREA by TEDA, and asking whether they have an interest in the project.

All consultees were also invited to a workshop which was held on the 12th June 2007 in Ipswich. The objective of the workshop was to provide feedback on the draft REA guidance and for consultees to have an opportunity to comment on the scoping report and provide input into the ongoing REA.

A second, phase 2 scoping workshop was held with RAG on 12th September 2007 to discuss the feedback that had been received on the RAG guidance arising from the main (phase 1) workshop and the approach to the full MAREAs that was proposed by industry and its consultants.

Following the second RAG workshop the guidance was updated and the final RAG Guidance released in March 2008. This guidance and the outputs of the scoping consultation were used to update the baseline information presented in the MAREA scoping report, and in particular to develop the terms of reference for the full MAREA. The final scoping report was published in July 2008.

2.4.2 Consultation

A list of consultees relevant to the Outer Thames Estuary study area was developed in consultation with RAG and included wide ranges of user and interest groups in the Outer Thames region (see Appendix B). Chapters 4, 5 and 6 detail the consultation process in relation to the physical, biological and human environment respectively.

2.4.3 Baseline Data Gathering

Overview

Collating existing and relevant desk top information is a key component of the MAREA process. RAG indicates that:

> *"initially the REA will provide an objective characterisation of a region based on a desk-based assessment using all relevant existing information" (RAG 2008, Regional Environmental Assessment: A Framework for the Marine Minerals Sector*).

The approach to baseline data gathering for individual topic areas is described within the relevant parts of Chapters 4 to 6. These sections identify legislation and guidance documents that influenced the scope of the baseline description, the information sources that were used and consultation that was undertaken to inform or verify the information that had been collated.

Many of the data sources used for the MAREA are unique to individual topic areas and are therefore not repeated here; however, there are a few core information sources that provided significant amounts of data to inform more that one topic area. These information sources and the role they played in the MAREA are described below:

- *Outer Thames Estuary Regional Environment Characterisation (REC).* This study was funded by the Marine Aggregate Levy Sustainability Fund (MALSF) and English Heritage and was published in July 2009. It provides information on the geological, archaeological and biological characteristics of the study area, including the results of broad scale characterisation surveys.

- *Environmental Statements (ESs) and Technical Reports for Round 1 and 2 Offshore Wind Farms.* Environmental Impact Assessments (EIAs) have been undertaken for five separate offshore wind farm projects in the Outer Thames Estuary. The resultant ESs and their annexes contain a significant amount of baseline data that can inform the MAREA baseline. Specific examples include interpreted seabed features data that was incorporated into the physical environment baseline chapter, boat and aerial bird surveys that informed the ornithology chapter and benthic species data that informed the benthic ecology chapter. In addition, the ESs provided vital information on the predicted extent of impacts from these developments that was used to inform the in-combination impact assessment.

- *Southern North Sea Sediment Transport Study II (SSNTSII).* The aim of this project was to obtain an improved understanding of the southern North Sea sediment transport system, and its impact on the eastern England coastline between Flamborough Head and the River Thames. This was achieved through numerical modelling combined with observations. The study identified sediment sources, transport pathways and volumes and areas of deposition, across the complete range of particle sizes and temporal scales. The location, size, and variability of offshore features, and their influence on and interaction with waves and tidal currents were also identified.

The quality and format of historical data were also checked as part of the data collation process and provisions made in instances where data may be out of date (for example benthic data >5 years old).
Once the data had been received, a key task was to synthesise and process it to provide a suitable description and basis for interpretation of each receptor at a regional scale. For some receptors or receptor groups this was a relatively straightforward task which involved mapping the data within a

Geographical Information System (GIS) and interpreting the results (eg ornithology). For other receptors, especially where there was an abundance of data of different quality and age (eg benthic ecology, seabed features), this was a more complex task.

GIS was used to combine databases, spatial analysis and graphics technology, to provide an efficient means of summarising, analysing and modelling spatial data and to support important assessment decisions. It also allowed the capture, storage, integration, analysis and output of spatial data, by using location as the common key between the data sets, which was an important consideration in ensuring consistency between different data sets and between topics. The distributions of physical, ecological and socioeconomic resources were mapped using ESRI software – ArcGIS 9.3.1.

A WebGIS tool has been developed to display all of the spatial data that have been generated and obtained for the MAREA. Use of the tool does not require GIS expertise or software. It provides a limited number of base layers: seabed sediments map or bathymetry map, licence areas and coastline. Any of the baseline receptor layers and/or effects layers (see Section 2.4.5) can be overlaid on the base map to allow the viewer to recreate any of the maps that they see within the MAREA report and to view any additional combinations of layers to meet their needs. The tool also has a feature to allow the user to zoom into a particular licence area, plus tools to calculate distances and areas and a basic 'print' function. The WebGIS tool is accompanied by a detailed data catalogue with references to the source of any layers (Appendix C).

Approach to Field Data Collection

In addition to the collation and interpretation of existing data relating to the environmental and socioeconomic characteristics of the Outer Thames Estuary, two new field studies were designed by ERM:

- Geophysical survey; and
- Benthic grab and epibenthic trawl survey undertaken by the University of Hull Institute of Estuarine Coastal Studies (IECS).

The geophysical survey was completed in April 2008 and the results from the survey were used to inform the design of the benthic survey which was undertaken in August 2008. At the same time the benthic survey provided an opportunity to ground truth the interpretation of seabed sedimentary characteristics that were indentified in the geophysical survey results.

The MAREA geophysical and benthic surveys sought to bridge the gap between the regional data that already exist (see above), and the site specific survey data that will be collected by the surveys of individual licence areas to inform the EIA process at the time of renewals. *The MAREA surveys are therefore regional surveys that focus on the potential footprint* [(1)] *of cumulative impacts associated with current and potential new licence areas.* The survey results were used in conjunction with the REC survey results to provide broad scale seabed features and biotope maps of the area for the MAREA. The scope of the geophysical and benthic MAREA surveys are described in more detail in the physical environment and benthic ecology baseline sections (Chapter 4 and Section 5.2 respectively).

Specialist Desk Studies

A number of specialist desk studies were undertaken to contribute to the baseline of the MAREA:

1. Anatec UK Ltd. An overview of shipping activity, densities, navigational features and other marine activities taking place in the area, and an estimation of baseline navigational risk levels.
2. Wessex Archaeology Ltd. An analysis of the known and potential archaeological resource (prehistoric, maritime and aviation archaeology).
3. HR Wallingford Ltd. A review of past reports and available data characterising the physical environment of the region.
4. Dr Brian D'Olier. Characterisation of regional geology and geomorphology and production of a regional map of seabed features and sediment characteristics.
5. HR Wallingford Ltd. A characterisation of the coastline of the region, identifying its sediment transport regime, coastal defences and management and its connection with the nearshore seabed.

2.4.4 Predicting the Effects of Dredging

There are four aspects of dredging that have been identified as having the potential to impact physical, human and biological receptors in the Outer Thames Estuary:

- The presence of the vessel.
- The removal of substrate from the seabed.
- The generation of a fine sediment plume through seabed disturbance, screening and overspill.
- Underwater noise generated by the vessel and the passage of the drag head.

These aspects of dredging lead to changes to the baseline environment that can be modelled or semi-quantitatively described to inform the assessment of potential impacts at the regional scale. A number of specialist studies were therefore undertaken as part of the MAREA to quantify these changes:

- Anatec UK Ltd. Prediction of impacts related to vessel presence and navigational risk in the MAREA area as a result of the proposed dredging scenario.
- Thames Estuary Dredging Association. Prediction of past and future changes to bathymetry as a result of aggregate dredging.
- HR Wallingford Ltd. An assessment of the potential for changes to bathymetry to alter wave heights within the MAREA region.
- HR Wallingford Ltd. An assessment of the potential for changes to bathymetry to alter tidal flows within the MAREA region.
- HR Wallingford Ltd. An assessment of the potential for changes to tidal flows to alter sediment transport within the MAREA region.
- HR Wallingford Ltd. Modelling of fine sediment plume dispersion
- HR Wallingford Ltd. Prediction of areas of sediment deposition and changes to sediment distribution.
- ERM Ltd. Prediction of the distances at which underwater noise could potentially affect marine species.

The key objectives in these studies were to quantify to the extent possible, the magnitude of aggregate extraction-induced changes, to be able to distinguish such change from natural change, and to be able to assess the significance of such change, over time. The methodology and results of each of these studies are described in Chapter 7.

2.4.5 Cumulative and In-Combination Impact Assessment

The MAREA terminology and the overall approach that are described within Chapter 3 were developed jointly by two specialist consultancies with the intention that they can be applied consistently to all present and future MAREAs within UK waters. The definitions for terms used within the impact assessment methodology were reviewed by the Regulatory Advisors Group (RAG) in November 2009 and the final definitions incorporate the comments

(1) The 'potential footprint' used to determine the spatial extent of the MAREA survey is one tidal excursion from all corners of the licence area. In the Thames Estuary this estimate is very conservative and it is likely that the footprint of cumulative impacts is actually much smaller.

and suggestions that were made. The impact assessment approach has been developed to meet the specific objectives of a Regional Environmental Assessment, but applies standard EIA practice where applicable.

The assessment can be summarised as overlaying the extent of sensitive receptors within the Outer Thames region with the extent of the key physical effects which result from dredging. The key effects that were mapped are summarised below:

- Depths of seabed lowering (ie changes in bathymetry);
- Extent of suspended sediment plume;
- Areas of suspended sediment deposition;
- Changes to wave heights;
- Changes to tidal flow rates;
- Changes to sediment transport rates;
- Underwater noise; and
- Areas of high and elevated navigational risk.

Once the effects and sensitivities had been overlaid, an assessment of the cumulative impact on each sensitive regional receptor was undertaken. This used the methodology described in Chapter 3. The effect of uncertainty on the assessment findings is described for each receptor, taking into account inherent conservatisms in elements of the assessment approach. An indication of which licence areas will need to consider a particular effect on a receptor in more detail within the individual EIAs is also provided.

GIS is integral to this stage of the MAREA process by enabling datasets to be overlain and combined to identify areas where cumulative impacts will occur. The output of this phase of assessment is a series of overlay maps highlighting cumulative impact areas.

The in-combination impact assessment focuses on identifying areas where the predicted effects of dredging could interact with effects from other developments at the regional scale. The in-combination assessment uses the data presented in the EIAs for other developments within the Outer Thames region, and the conclusions of scientific studies, to identify potential in-combination interactions. Such interactions could be region-wide (e.g. an in-combination impact on coastal processes or the spawning success of a sensitive fish species) or specific to one aggregate licence area and one other project (e.g. positive impacts to a *Sabellaria* reef from fine sediment plume at an aggregate licence area and an adjacent wind farm cable route).

These approaches to the assessment are set out in the following chapters making up the MAREA for the outer Thames region. Conclusions and recommendations for individual licence areas are drawn in Chapter 11.

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3 METHODOLOGY FOR ASSESSMENT OF CUMULATIVE AND IN-COMBINATION IMPACTS

3.1 INTRODUCTION

This chapter describes the process for identifying potential cumulative and in-combination impacts that could occur as a result of dredging in the Outer Thames Estuary and the methodology that has been used to assess the significance of these impacts. As described in Section 2.4 this methodology is a standard approach that will be applied consistently to all MAREAs.

The first stage of the impact assessment involved identifying the effects of dredging and their potential impacts. It is important to note that not all effects of dredging translate into an impact on a regional receptor. This exercise was partly informed by consultation with key stakeholders at a scoping workshop held in June 2007, and by a review of existing literature on the effects of marine aggregates extraction. The magnitude of each effect of dredging that has the potential to influence regional receptors was then predicted. The values and sensitivities were then determined for the key receptors (ie receptors important at the regional scale) in the region that could be affected by dredging operations, either directly or as a consequence of impacts to other receptor groups. The next stage used GIS to assess the extent of interaction, ie the extent to which receptors occur within the zone of influence of each effect. Finally the significance of each of the likely impacts as a result of the effects of dredging was evaluated in the context of the MAREA objectives.

It is important to note that although some of the information included within the MAREA impact assessment chapters will be directly relevant to the EIAs, the assessment of impact significance assessment applies specifically to impacts at the regional scale. An impact that has a low significance at the MAREA level may have a different level of significance for individual licence areas at the EIA stage.

The remainder of this chapter is structured as follows:

- Section 3.2: Definitions of Impacts;
- Section 3.3: Identifying Potential Impacts of Dredging;
- Section 3.1: Predicting Effect Magnitude;
- Section 3.5: Determining Receptor Value and Sensitivity;
- Section 3.6: Identifying Degrees of Regional Interactions Between Effects and Receptors;
- Section 3.7: Evaluating Impact Significance; and
- Section 3.8: Cumulative and In-combination Impact Assessment.

3.2 DEFINITIONS OF IMPACTS

For the purposes of MAREA an 'impact' is considered to be a change (which can be positive or negative) in the existing baseline for a given receptor that occurs as a consequence of an activity associated with dredging in the MAREA study area. The impact may be significant through its own unique presence or through addition to other impacts.

The MAREA considers all impacts that are directly attributable to dredging in the Outer Thames Estuary, and which are within the operating companies' ability to influence. This includes vessel movements, the act of dredging itself and screening operations. Impacts may arise as a direct consequence of a particular aspect of dredging (eg mortality of benthos due to substrate removal, or increased turbidity due to cargo screening). Equally, impacts may follow on as a consequence of another impact, sometimes as part of a chain of events (eg impacts to the livelihoods of fishermen, due to displacement of target fish species by elevated turbidity or noise). These impacts may be experienced at a point in space or time that is removed from dredging activity itself. The terminology used to describe impacts within the MAREA is presented below and a note on how this terminology differs from standard EIA terminology (Institute of Environmental Management Assessment, 2004) is provided in Box 3.1.

The following terms are used to describe different types of impact that are considered by the MAREA:

Negative Impact: Impact results in an adverse change from the baseline conditions (including natural variability).

Positive Impact: Impact results in an improvement to the baseline conditions (including natural variability).

Cumulative Impact: Impacts that arise from multiple marine aggregate extraction activities within a region.*

In-combination Impact: The total impacts of all anthropogenic activities within the same region in the context of natural variability or trends.*

* The definitions of cumulative and in-combination impacts are based on the terms that were agreed at the second RAG workshop in September 2007 (see Section 2.4.1).

It is important to note that cumulative and in-combination impacts are the primary focus of the MAREA, but potential impacts arising from individual licence areas are highlighted for consideration in site-specific impact studies.

Box 3.1 Differences between MAREA and EIA Impact Definition Terminology

It is recognised that standard impact assessment terminology for individual projects frequently uses a number of other terms, such as:

- Primary impacts;
- Secondary (and higher order) impacts;
- Direct impacts;
- Indirect impacts; and
- Induced impacts

One of the main reasons for defining these impact types is to identify the most appropriate and effective stage in an impact chain to introduce mitigation. However, there is some considerable debate about the precise definitions of these terms, and since MAREA does not include mitigation, the distinctions between these terms are not relevant to the purpose of this assessment.

3.3 IDENTIFYING POTENTIAL IMPACTS OF DREDGING

The immediate effects of the dredging process that were assessed as part of the MAREA (see Chapter 7) are as follows:

- presence of the vessel;
- removal of sediment;
- fine sediment plume/elevated turbidity;
- sand deposition; and
- underwater noise.

As a result of these effects, dredging can result in a number of secondary effects:

- changes to sediment particle size;
- changes to wave heights;
- changes to tidal currents;
- changes to sediment transport rates; and
- loss of access.

Benthic communities, fish ecology and sandbanks are examples of potential receptors that may be impacted by these effects. Any significant impacts to these receptors may then have knock-on impacts to other receptors eg marine mammals may be affected by changes to the distribution of fish. As a result the following effects are also considered as part of the impact assessment:

- changes to benthic community composition;
- changes to distribution of fish; and
- changes to sandbanks.

For each receptor group, the impact assessment identifies which of these effects of dredging has the theoretical potential to affect each of the receptors or 'receptor groups' (See Section 3.5) that have been identified in the corresponding baseline section. An interaction screening exercise was then undertaken to identify which of the physical effects of dredging have the potential to interact with each of the receptor groups. This was facilitated by GIS mapping whereby each of the potential impacts listed above was represented as a zone of effect on maps of the MAREA study area. Where no possible interaction was identified this effect was scoped out of further assessment for that receptor. The outcome of the screening exercise is presented in matrix form for each receptor group.

3.4 PREDICTING EFFECT MAGNITUDE

As outlined in Section 3.3, a number of technical studies were undertaken to establish the potential effects that each aspect of dredging could have at the regional scale, in terms of the degree and spatial extent of elevation above baseline conditions. These studies are described fully in Chapter 7 of this report. For the purpose of the cumulative and in-combination impact assessment, the predicted effects from these studies are assessed in terms of three variables: **extent**, **duration** and **frequency**; the variables are quantified to the degree practicable. These variables collectively determine an effect's **magnitude**. Awarding a value to variables can be subjective in that the extent of change is difficult to define. The results of consultation, historical analysis and a review of available literature coupled with the expert judgement and prior experience of the MAREA team, were applied to ensure a reasonable degree of consensus on the value placed on an effect variable.

The categories for each of the three variables and explanations of each value are provided in Table 3.1 to Table 3.3.

Table 3.1 Extent of Effect

Site Specific	Effects that occur within those parts of the licence area where dredging has occurred. *This category includes the effects associated with the passage of the draghead over the seabed including sediment removal. In marine aggregate EIA this area if often referred to as the ADZ (typically defined by EMS data) or PIZ (often used by regulators).*
Local	Effects that extend beyond the immediate footprint of dredging, but which do not affect the receptor at the regional scale. *This category is likely to include those effects that are usually described as being within the Secondary Impact Zone - SIZ (ie the zone where impacts resulting from the settlement of fine sediment occur) as well as other effects such as underwater noise, changes to tidal flows etc.*
Sub-regional	Effects are confined to an area associated with a group of licence areas that are distinct from any other licence areas within the MAREA study area. *This category may not be appropriate to all MAREA studies and only applies if a group of licence areas can be assessed in isolation to other licence areas within the region. Effects include sub-regional sediment transport pathways, changes to a single coastal cell or any changes to sub-regional populations of marine species.*
Regional	Effects that cover much or all of the MAREA study area but which do not extend outside it. *This category includes any effects on regional sediment transport pathways, the coastline (more than one coastal cell), or any changes to regional populations of marine species (eg changes in distribution due to noise)*

Table 3.2 Duration of Effect

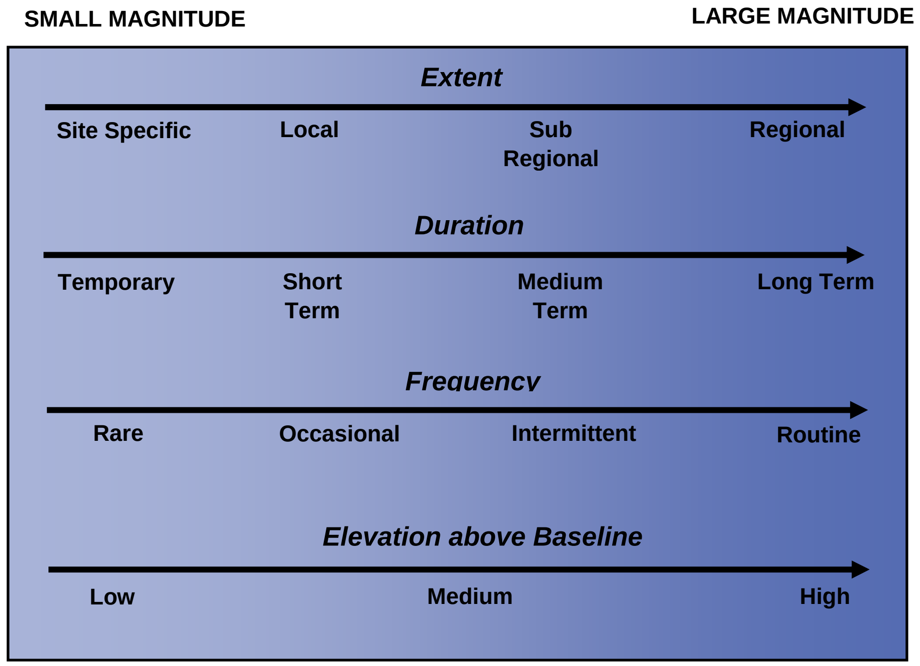
Temporary	Effects only occur during active dredging, are one off or last only a few days or hours after cessation of dredging.
Short-term	Effects are no longer observed after up to 1 year following cessation of dredging.
Medium-term	Effects that last between 1 and 10 years following cessation of dredging.
Long-term	Effects that persist for >10 years following cessation of dredging.

Table 3.3 Frequency of Effect

Routine	Effect occurs during all normal dredging operations at sea (95-100%).
Intermittent	Effect occurs regularly but not all the time during dredging operations at sea (25-95%).
Occasional	Effect only occurs during a small proportion (<25%) of routine dredging operations at sea.
Rarely	Effect only occurs very rarely as an unplanned event during dredging operations at sea (eg emergency load dumping, oil spills).

The overall magnitude of the effect was then determined by considering a combination of elevation above baseline plus extent, duration and frequency and applying professional judgment / past experience. Figure 3.1 shows how the components of magnitude were each considered along a continuum and their individual contributions used to inform the overall prediction of effect magnitude.

Figure 3.1 Components of Magnitude



3.5 DETERMINING RECEPTOR VALUE AND SENSITIVITY

The **value** and the **sensitivity** of the receptor in question were further factors considered as part of evaluating the significance of impacts at the regional scale.

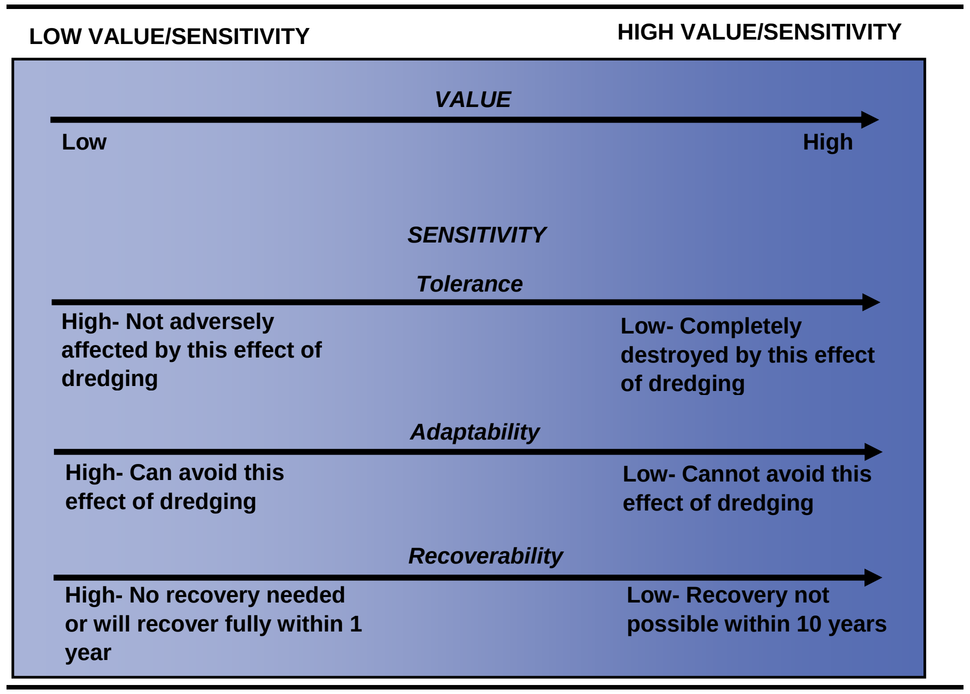
The assessment of **value** considers whether the receptor is rare, protected or threatened and in the case of biological receptors also considers whether the receptor provides an important ecosystem service (eg keystone species or important habitats). For socioeconomic receptors the consideration of value includes economic, cultural and amenity value. The value categories are receptor-specific and consequently the value of individual receptors has been considered within the physical, biological and human baseline sections of the MAREA.

The **sensitivity** of each receptor that could potentially be affected by the effects of dredging activities was also assessed. Such an assessment may, to some extent, be regarded as subjective; however, expert judgement and stakeholder consultation ensures a reasonable degree of consensus on the intrinsic sensitivity of a receptor. The sensitivity of each receptor was assessed according to three criteria (1) to the extent that they are applicable to the receptor in question:

- **Tolerance**: the extent to which the receptor (at a regional scale) is adversely affected by a particular effect of dredging:
    - **Low -** Receptor unable to tolerate effect resulting in permanent change in its abundance or quality.
    - **Medium -** Receptor has some ability to tolerate this effect but a detectable change will occur.
    - **High -** Receptor unaffected or positively affected.
- **Adaptability**: the ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect of dredging:
    - **Low -** Receptor unable to avoid effect.
    - **Medium -** Receptor has some ability to avoid the most negative consequences of this effect or can partially adapt to it (eg by moving to other suitable areas).
    - **High -** Receptor can completely avoid or adapt to this effect with no detectable changes.
- **Recoverability**: a measure of a receptor's ability to return to a state close to that which existed before the effect caused a change:
    - **Low** - Receptor unable to recover resulting in permanent or long term change (>10 years).
      NB For biological receptors this encompasses MarLIN categories 'None', 'Very Low' and 'Low'
    - **Medium** - Receptor recovers to an acceptable status over the short term to medium term (1-10 years).
      NB For biological receptors this encompasses MarLIN categories 'Medium' and 'High'
    - **High** - Receptor recovers fully within 1 year.
      NB For biological receptors this encompasses MarLIN categories 'Very High' and 'Immediate'

Overall sensitivity is then determined by considering a combination of value, adaptability, tolerance and recoverability, and applying professional judgment / past experience, and a review of available literature.

Figure 3.2 Receptor Value and Sensitivity



It is important to note that the above approach to assessing sensitivity is not appropriate in all circumstances. This is particularly the case for aspects of the human environment such as MoD activity. In such instances the REA expresses sensitivity without an attempt to break it down by the above attributes. Where this has been done the reasons for doing so are clearly stated.

The value of each receptor group together with its sensitivity has then been used to inform the impact assessment. Figure 3.2 shows how the components described above each contribute to the overall assessment of value and sensitivity.

(1) For clarity it should be noted that vulnerability (to impact) is another term often used to characterise a receptor. Vulnerability has not been specifically included as a criterion but elements of it are considered within the definitions for adaptability, tolerance and recoverability. Vulnerability is also a consideration used by statutory and other bodies in determining the need and degree of protection of habitats and individual species.

3.6 Identifying Degrees of Regional Interactions between Effects and Receptors

To establish whether a receptor may be susceptible to impacts from a particular effect of dredging, the MAREA looks at the degree to which the spatial extent of the impact and the location/distribution of the receptor overlap. In the majority of instances this was achieved by overlaying the receptor layer and the impact 'footprint' layer using GIS software. The 'degree of interaction' was then determined from the proportion of the receptor layer that was overlapped by the effect layer.

Where no predicted interaction between the effect and the receptor was found then there is no potential impact.

The second stage of the interaction quantification was only applied to those receptors and effects that were predicted to interact to any degree. The predicted degree of regional interaction (small, medium, large) was taken forward to the assessment of impact significance, the process for which is described in Section 3.7**.** This approach ensured that the assessment provided for a higher weighting to those receptors within the MAREA study area that will be exposed to a particular effect of dredging over much of their range, than to receptors that are only exposed to an impact in a small proportion of their range.

NB, it is important to note that interpretation and professional judgement was applied for some effect-receptor combinations. For example the impact will in most cases vary in terms of magnitude and elevation above baseline within the overall 'footprint' layer that is included within the GIS, with higher intensity being experienced closer to the source of the impact. In addition, while some receptor layers represent actual locations (eg ship wrecks, benthic habitats, offshore infrastructure) the exact distribution of some other receptors is less well known (eg vessel losses or marine mammals may only be recorded on the GIS by the coastal location from which they were observed).

Another key consideration throughout all stages of the MAREA impact assessment are data gaps and uncertainty; the approach to these issues is described in Box 3.2.

Box 3.2 Consideration of Data Gaps and Uncertainty

There are typically a number of uncertainties in the assessment of impacts for any project, but when undertaking a regional assessment for a number of different operators in different areas, it is a particular consideration. In the MAREA there is some degree of uncertainty in the baseline descriptions for most receptors, as even when regional surveys have been undertaken to inform the baseline, they cannot provide 100% coverage. In addition, there are some uncertainties surrounding the dredging proposals for individual companies, the predicted effect footprints and the sensitivity of receptors to a given effect.

In the absence of certainty it is necessary to adopt a precautionary approach and consequently the MAREA presents the worst case scenario in terms of effect footprints and receptor sensitivities. In this way the integrity of the MAREA is maintained. Data gaps and uncertainties have been clearly highlighted within the MAREA baseline and impact assessment chapters and their implications for the assessment of impact significance is clearly stated. These uncertainties and data gaps will, where possible, be addressed at the EIA stage.

3.7 EVALUATING IMPACT SIGNIFICANCE

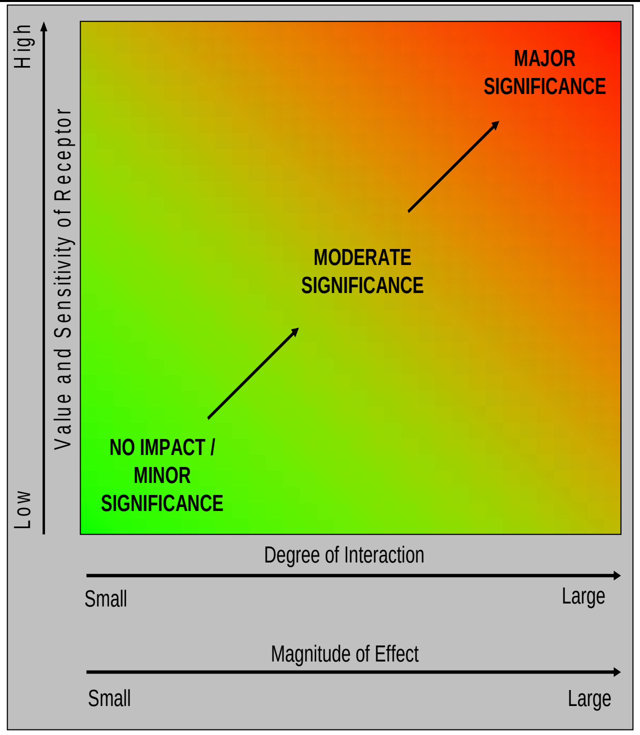
Criteria for the assessment of the significance of impacts stems from the following key elements:

- the degree of interaction between the receptor and the effect;
- the magnitude of the effect (in terms of the extent, duration and frequency); and
- the value of the receptor and its sensitivity to the effect.

An exception to the above approach is made for the Navigation Impacts Assessment. This is because the approach to this part of the MAREA requires a risk-based approach using a ship to ship collision model that quantifies the likelihood of interactions/encounters.

For the other topics covered in this assessment, impacts have been defined as either not significant, or of minor, moderate or major significance. Figure 3.3 details the general relationship between the degree of interaction, effect magnitude and receptor sensitivity based on the descriptions and definitions provided in the sections above. The individual components of magnitude and sensitivity are taken into consideration together with the degree of interaction to identify the impact significance level for each effect-receptor combination. Table 3.4 defines the impact significance criteria for each level of impact.

Figure 3.3 Impact Significance Determination Diagram



It should be noted that when determining significance, the status of compliance in terms of conformity to relevant legislation, guidelines and other pertinent environmental standards was also considered. Any impact that exceeds recognised standards or legal limits is considered significant.

Table 3.4 Significance Criteria for this REA

Impact Significance	
Not significant	Impacts that, after assessment, were found to be not significant in the context of the MAREA objectives.
Minor significance	Impacts that warrant the attention of particular stakeholders but no action is required if impacts can be controlled by adopting normal good working practice.
Moderate significance	Regional impacts that should be recognised and addressed in consultation with particular stakeholders.
Major significance	Regional impacts that are not environmentally sustainable and compromise the continuation of extraction activity in the region.

3.8 CUMULATIVE AND IN-COMBINATION IMPACT ASSESSMENT

The criteria described above are used to determine and define the significance of the impact that arises from each of the main effects of dredging (eg turbid plume, substrate removal etc) on each receptor in turn.

To complete the cumulative impact assessment all of the potential impacts to a given receptor that have the potential to arise from dredging are considered together, and an 'overall significance of dredging' is assigned to each receptor. It is important to recognise that this is not simply a case of summing the impact layers; some impacts may interact synergistically (ie the overall impact is greater than the sum of the individual impacts) while others act antagonistically where the existence of one impact reduces the significance of the second.

The final outputs from the cumulative assessment are taken forward to the in-combination assessment which considers the interaction of aggregate extraction with other human activities in the study area to potentially create in-combination impacts.

4 PHYSICAL ENVIRONMENT

4.1 INTRODUCTION

4.1.1 Overview

This section presents the baseline conditions of the physical environment within the MAREA study area to provide a sound context and basis for the REA. The Outer Thames is a large estuary, influenced by both strong tidal currents and wave action. Large-scale fluctuations in sea level during the Quaternary Period (the last 2 million years) caused by repeated marine transgressions and glacial advances are responsible for shaping the estuary and seabed. The shallow geology is predominantly comprised of the Tertiary London Clay Formation overlain by Quaternary sediments of the Pleistocene and Holocene, including sands, gravels, silts, clays and peats.

The seabed is dominated by a series of linear elongate sandbanks and their intervening channels, which curve gently southwest to northeast. The surface sediments of these banks are highly mobile, whilst the overall morphology of the seabed in the region has changed very little since the mid Holocene. Large volumes of sediment are transported through the area, predominantly in a southerly direction. However there is little evidence of any onshore transport of sediment towards the coastline. The coast is generally low-lying and the regional pattern is one of gradual foreshore steepening due to erosion and a lack of sediment supply from offshore areas towards the shore. Coastal defences are widely implemented and 'coastal squeeze' (1) is becoming an important issue in the region.

In contrast to conditions in the mid 19th to mid 20th centuries, the Thames estuary is now considered one of the cleanest metropolitan estuaries in Europe as a result of significant improvements in water quality over the past 50 years. Better sewage treatment, the diversion of some industrial effluent and the introduction of biodegradable detergents during the 1960s and 1970s have all contributed to the changes. The sediment quality in the region is typical of an environment in the vicinity of busy shipping lanes (for example higher than average concentrations of hydrocarbons are often present). Industrial land based sources are also highlighted as sources of metal contamination in marine sediments.

The following sections address each of these topics in greater detail:

- Section 4.2: Marine Geology and Geomorphology;
- Section 4.3: Nearshore Geology and Sedimentology;
- Section 4.4: Meteorology and Oceanography
- Section 4.5: Characteristics and Quality of Water and Sediment in the Study Area

(1) When a coastal margin is 'squeezed' between a fixed landward boundary (artifical or otherwise) and rising sea level.

4.2 Marine Geology and Geomorphology

4.2.1 Introduction

Sea level fluctuations in the Quaternary Period associated with and numerous cold glacial and warmer interglacial stages are responsible for shaping the seabed within the MAREA area over time. Whilst the overall morphology of the seabed has remained relatively stable throughout the mid to latter part of the present Holocene Epoch at a more local level the seabed is highly dynamic.

The following section begins by describing the shallow geology of the Outer Thames Estuary, the sediment sources in the region and the patterns of sediment movement. The section then goes on to describe the geology of the coastline, together with the management of the coastline including the use of defences, and the patterns of nearshore sediment movement.

The geological stratigraphication encountered within the study area is summarised within Table 4.1. The terminology within this table is used throughout the section.

Table 4.1 Geological Stratigraphy between the Quaternary & Cretaceous Periods for the study area

ERA	Period/sub-period		Epoch	Stage	Formation
Cenozoic (65 mya – present)	Quaternary (2 mya – present)		Holocene (10 kya – present)		
			Pleistocene (2 mya – 10 kya)	DEVENSIAN	
				Ipswichian	
				WOLSTONIAN	
				Hoxnian	
				ANGLIAN	
				Cromerian Pre-Cromerian	Red Crag
	Tertiary (2 – 65 mya)	Neogene (2 – 25 mya)	Pliocene Miocene	2-5 mya 5-25 mya	Coralline Crag
		Palaeogene (25 – 65 mya)	Oligocene (25 – 35 mya)		
			Eocene (35 – 55 mya)	Ypresian	Bagshot Sands
					Virginia Water Formation
					London Clay
			Palaeocene (55 – 65 mya)		Lambeth Group (including Woolwich & Reading Formations)
					Thanet Sand Formation
Mesozoic (65 – 250 mya)	Cretaceous (65 – 140 mya)		Upper (65 – 100 mya)		Upper Chalk Formation
			Lower (100 – 140 mya)		

Major glacial stages identified in capitals
mya – million years ago (approximate)
kya – thousand years ago (approximate)

4.2.2 Sources of Information

Thames Regional Environmental Characterisation Geophysical Survey

A survey was carried out by Gardline over a period from 7th July to 9th September 2007 on behalf of DEFRA as part of the Thames Regional Environmental Characterisation (REC) Project, and funded through the Marine Environment Protection Fund (MEPF) of the Aggregate Levy Sustainability Fund (ALSF). An element of this survey involved acquiring acoustic and geophysical data capable of describing broad scale seabed habitats and potential historic environment assets within the region, in order to develop the understanding of the physical processes that influence the regional seabed, historic environment and its faunal communities.

The survey programme consisted of a series of profile corridors parallel to the Suffolk and Essex coasts between Sizewell and Clacton with perpendicular cross corridors. The primary corridors were at 10 km intervals from the inshore limit of safe navigation to a maximum distance of approximately 50 km offshore south-east of Clacton. Each survey corridor consisted of a centre profile surveyed with a single beam echo sounder, swathe echo sounder, magnetometer and sub-bottom profiler. A wing line was run either side of the centre line with the same instrumentation, with the exception of the sub-bottom profiler.

Approximately 1,400 km of single beam bathymetry, swathe bathymetry, sonar, boomer sub-bottom profiler and magnetometry data were acquired. In addition a large volume hydraulic clamshell grab was used to collect geological samples from 70 stations for logging and particle size distribution analysis. The survey failed to achieve the full survey grid proposed due to adverse weather and tidal conditions.

The full Regional Environmental Characterisation Report is available in Appendix D.

TEDA Geophysical Survey

At the request of TEDA, ERM designed a regional geophysical survey for the Thames MAREA area. The survey was designed to focus on the areas which had not been covered in previous surveys and required the acquisition of new data, and to incorporate the maximum modelled extent of one tidal excursion around each licence area. These gave an indication of the maximum potential area that could be affected by dredging as a result of sediment plumes and their movement over a tidal cycle. In addition ERM included regional lines to complete (where possible) the proposed grid that the ALSF REC survey was unable to achieve. An industry standard full-suite of multibeam instrumentation was used, in line with that used on the REC survey.

Emu Ltd was commissioned by TEDA to conduct the geophysical survey between the 22nd April and 5th May 2008. The survey comprised the collection of multibeam bathymetry and high-resolution sidescan sonar along the total 889km length, and sub-bottom profiling data over 199km of the study area. Figure 4.1 indicates the location of the survey area and the line plan. The full report is available in Appendix E.

Archaeology Study by Wessex Archaeology

Wessex Archaeology was commissioned to undertake a regional archaeological assessment of the MAREA area. The data review identified 1,333 UKHO records for the area, and in excess of 4,000 terrestrial sites and monument records along the coastline. The TEDA geophysical survey data were used to detect any in-filled palaeo-channels, potential land surfaces of ecological significance and peat/fine-grained sediment horizons. The full report is available in Appendix F.

Sediments of the Thames Estuary Report by Brian D'Olier

Dr Brian D'Olier, a consultant geologist, was commissioned to write a review of the history of sediments in the Thames Estuary, including a discussion of sediment sources and sediment transport pathways. As part of the report he developed a seabed features map to show the interpreted sedimentary geology and bedforms in the study area, and the directions of offshore sediment transport pathways (see Section 4.2.6). The report is available in Appendix G.

Other Information Sources

There is a considerable body of information on the physical environment in the Thames estuary. In relation to the geology and sediment characteristics of the region, sources used in this study in addition to the reports listed above include relatively broad scale studies of the British Isles and Southern North Sea, principally the following:

- Bennison, G. M. and Wright, A. E. 1969. The Geological History of the British Isles. London: Edward Arnold Ltd.
- British Geological Survey. 1988. Marine Report 86/38, Marine Aggregate Survey Phase 1: Southern North Sea.
- Cameron, T. D. J., Crosby, A., Balson, P. S., Jeffery, D. H., Lott, G. K., Bulat, J. and Harrison, D. J. 1992. The geology of the Southern North Sea; British Geological Survey, United Kingdom Offshore Report, London HMSO.
- HR Wallingford, CEFAS, UEA, Posford Haskoning and D'Olier, B. 2002. Southern North Sea Sediment Transport Study, Phase 2. Sediment Transport Report. Report EX 4526. August 2002

In addition a number of sources specific to the Thames estuary were consulted:

- D'Olier, B. 1972. Subsidence and Sea-level rise in the Thames Estuary. Phil. Trans. Roy. Soc. Lond. A. 272: 121-130.
- D'Olier, B. 1975. Some aspects of Late Pleistocene-Holocene drainage of the River Thames in the eastern part of the London Basin. Phil. Trans. Roy. Soc. Lond. A. 279: 269-277.
- Bridgland, D. R. 1994. *Quaternary of the Thames*. Geological Conservation Review Services, Joint Nature Conservation Committee. London: Chapman and Hall.
- Burningham, H. and French, J. 2009. 'Seabed mobility in the greater Thames estuary'. The Crown Estate, 62 pages.

4.2.3 Shallow Geology and Sediment Sources

Shallow Geology

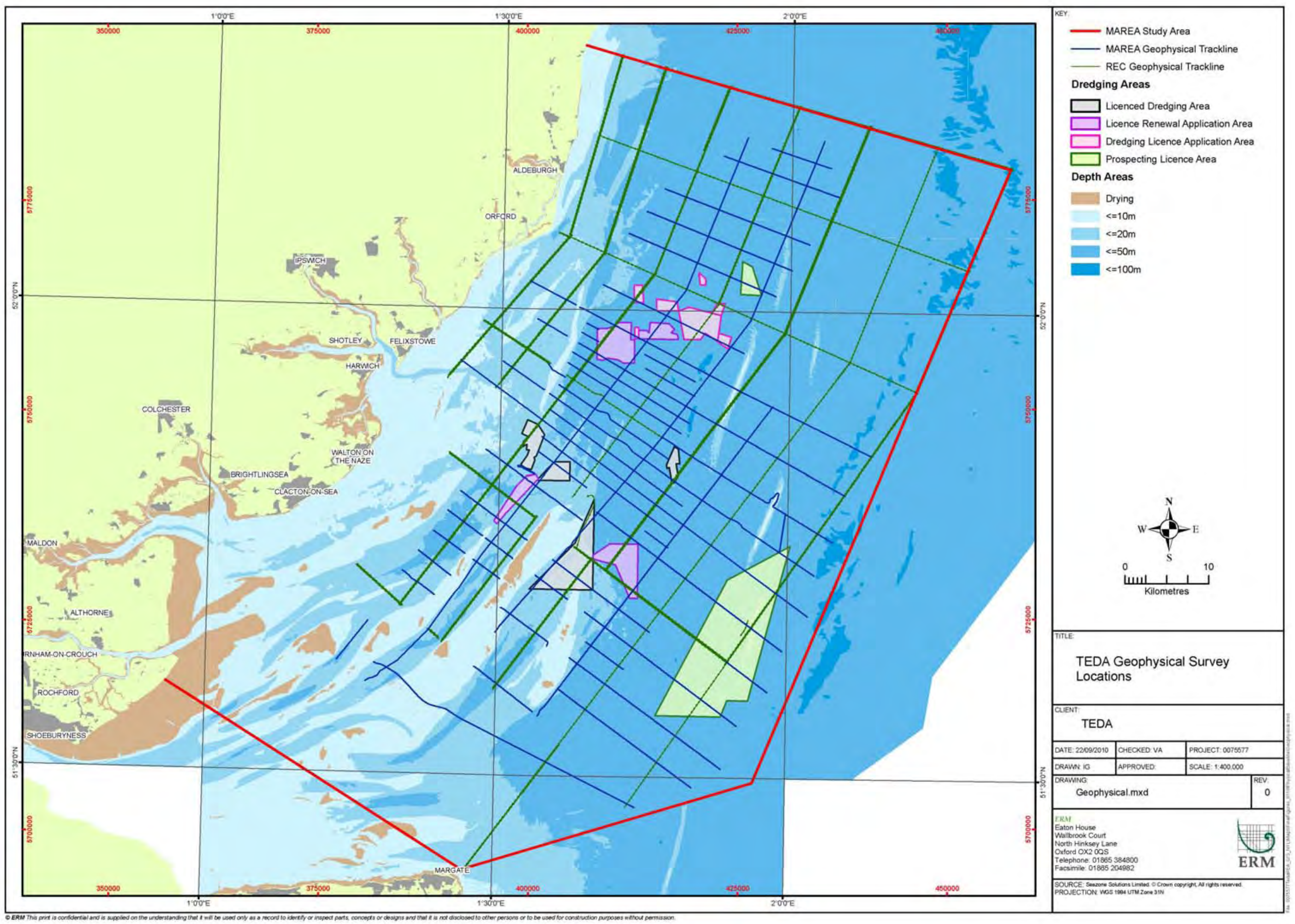
The Outer Thames lies within the Cenozoic London Basin, which stretches from the Dover Strait to East Anglia. The London Basin is a south-easterly extension of the North Sea Basin, which has existed since the early Mesozoic Era.

Although the Upper Cretaceous Chalk forms a minor component of the seabed solid geology in the area, it commonly underlies Cenozoic sediments across the region. These rocks comprise the seabed at the south east margin of the Outer Thames Estuary and are associated with the terrestrial chalk outcrop of the North Kent coast (EMU Ltd).

The London Basin sequence of Cenozoic sediments unconformably overlies the Upper Cretaceous Chalk within the study area and predominantly comprises the London Clay Formation which dominates the seabed geology across the Outer Thames Estuary.

The London Clay Formation is a 150 m thick deposit of stiff dark or bluish grey clayey silts, silty clays and silts from the Lower Eocene (Cameron *et al*, 1992 and Sherlock,1962). Towards the west and south of the study area there are areas where this deposit has been removed by erosion, revealing the underlying older Palaeocene Formations.

Figure 4.1 TEDA Geophysical Survey Location



The strata overlying the London Clay Formation are comprised of the late Ypresian Lower Bagshot Sands (Bennison *et al*,1969) and the Virginia Water Formation (King, 1981) which consist of very fine to fine-grained and well-sorted sands. These in turn are overlain by the Middle and Upper Bagshot Sands consisting of fine-grained sands, silts and pebble beds)(Cameron *et al*, 1992).

The Eocene sequence described above is overlain by Quaternary deposits made up of Pleistocene and Holocene sediments. Within the Outer Thames Estuary, Pleistocene sediments typically occur as localised submerged river terraces and channel infills constituting of mud, sand and gravel. Holocene sediments are represented by a thick coastal accumulation of sands, gravels, silts, clays and peats (Milne *et al*, 1997) together with extensive sandbanks and seabed veneers of sand and gravel.

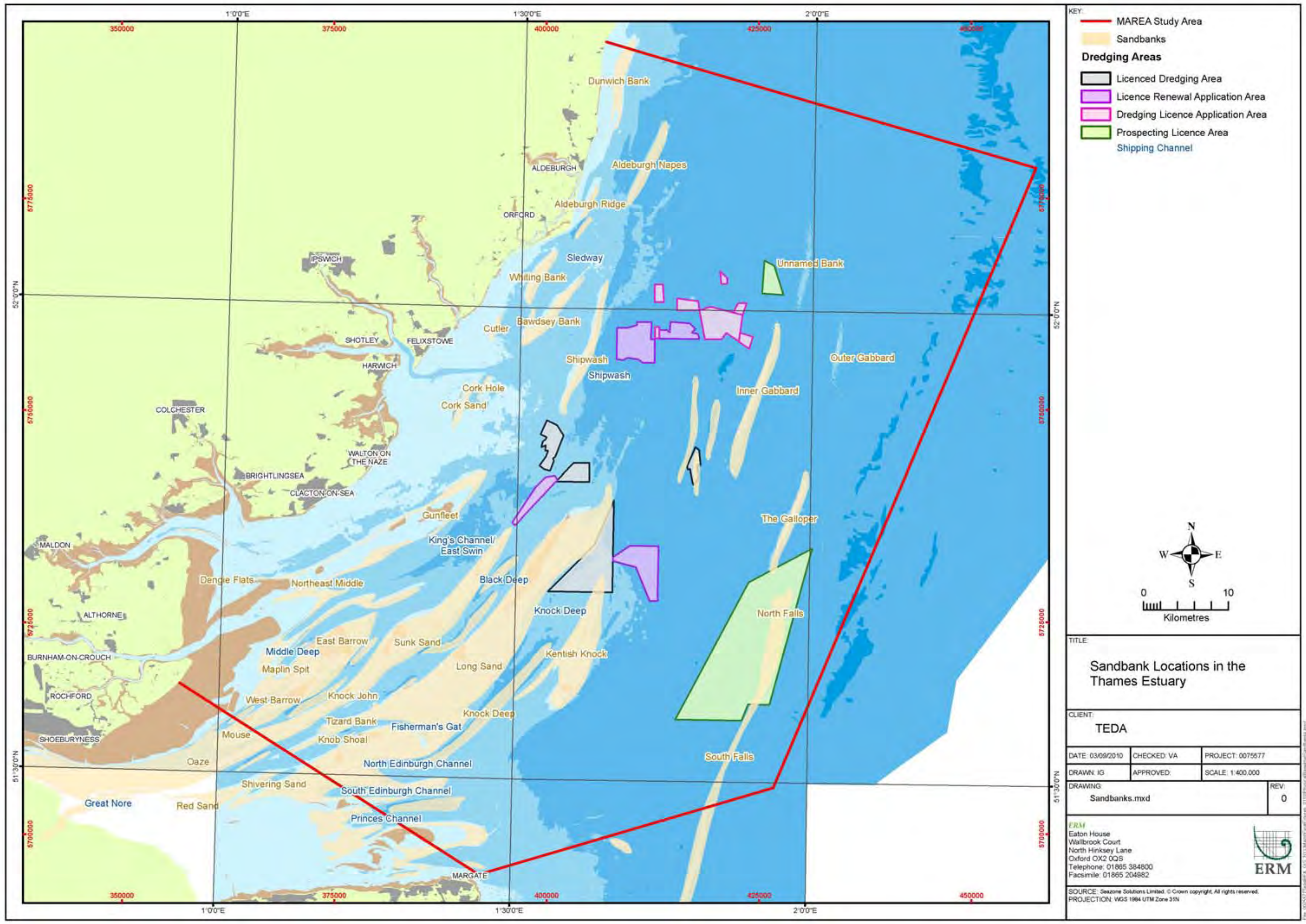
Aggregate deposits in the study area occur mainly within Pleistocene river channel infills and adjacent terraces, whose evolution has been dominated by phases of erosion and deposition during glacial and interglacial cycles.

Glacially-derived Sediments

The most extensive of the glaciations was the Anglian glacial stage (478,000-423,000 BP) which caused an ice sheet to spread across the southern North Sea and East Anglia to reach present-day north London. The study area was at the margin of the ice sheet during this phase and it has until recently been thought that only the far northern extent of the area would have been covered in ice. However, the results of the Thames REC study (EMU Ltd) tentatively suggest that the margin of this ice sheet can be extended southwards at least 50 km, which would cover the northern half of the study area. The Anglian ice sheet over-rode and diverted the course of several rivers draining into the study region at this time, including the Thames.

The extent of the subsequent Wolstonian glaciation (380,000-130,000 BP) is a point of ongoing debate and it has been suggested that the ice sheet ran across Lincolnshire and the Midlands (Wymer, 1999), therefore the study area itself would not have been covered in ice during this glacial phase. As a result post-Anglian and pre-Devensian river terrace deposits laid down by the Thames and its tributaries may occur in the study area.

Figure 4.2 Sandbank Locations in the Thames estuary



The Devensian glaciation (110,000-13,500 BP) was the last glacial stage to occur before the present climate interglacial. With the southern edge of the ice sheet extending in a line from the Severn to the Wash (Fleming, 2002), the study area would have again been outside the limits of the ice but within a periglacial zone during this phase. This period is represented by the deposition of cold-climate gravel such as that found in the East Tilbury marshes in the inner parts of the Thames estuary (Sumbler, 1996) as well as offshore within the now submerged portion of the Thames valley.

Fluvially-derived Sediments

During the Pleistocene the river courses of the south east coast of England were subject to a number of diversions, influenced in particular by the effects of glaciation and sea level fall. The sediments of these former river courses consisted of cold climate, high flow regime, fluvial sands and gravels. These were locally covered by temperate climate estuarine and marine sands, silts and clays. It is the former cold climate sediments that are usually targeted by the aggregates industry and the licence areas are commonly located over the palaeo-channels defining the courses of the rivers that deposited these sediments.

Marine-derived Sediments

Marine-derived sediments consist largely of sands, silts and clays reworked from pre-existing glacial and fluvial sediments, erosion from the shoreline and erosion of the Tertiary bedrock.

By approximately 8,000 BP practically the whole of the present Thames Estuary was submerged and a connection between the North Sea and English Channel via a deep water channel was established (EMU Ltd). A continued rise in sea level saw the gradual expansion of the estuary, so that the study area was inundated during the Late Mesolithic period between 7500-7000 BP.

4.2.4 Bathymetry

The seabed in the Thames Estuary region is dominated by the numerous sandbanks, particularly Long Sand, Sunk Sand and Kentish Knock, in the south. Smaller sandbanks are found further offshore including Inner Gabbard, Greater Gabbard, the Galloper and North Falls (Figure 4.2). These banks accumulate as a result of sediments being swept by tidal currents into ridges parallel with the shoreline. These deposits were laid down during the present Holocene interglacial and are representative of the most recent geological past of the Study Area.

Typically the sandbanks are 1-5 km across, 10-30 km long and the crests of the inshore banks locally dry at low water. Inshore, the Whiting and Bawdsey Banks are approximately 1 km across, and are associated with headlands. The banks rise relatively steeply from the adjacent seabed with slopes of around 1 in 10 (EMU Ltd, 2009). The channels lying between the banks are approximately 2-5 km across and include King's Channel, Black Deep, Knock Deep, Shipwash and Sledway, many of which are important to navigation in the area.

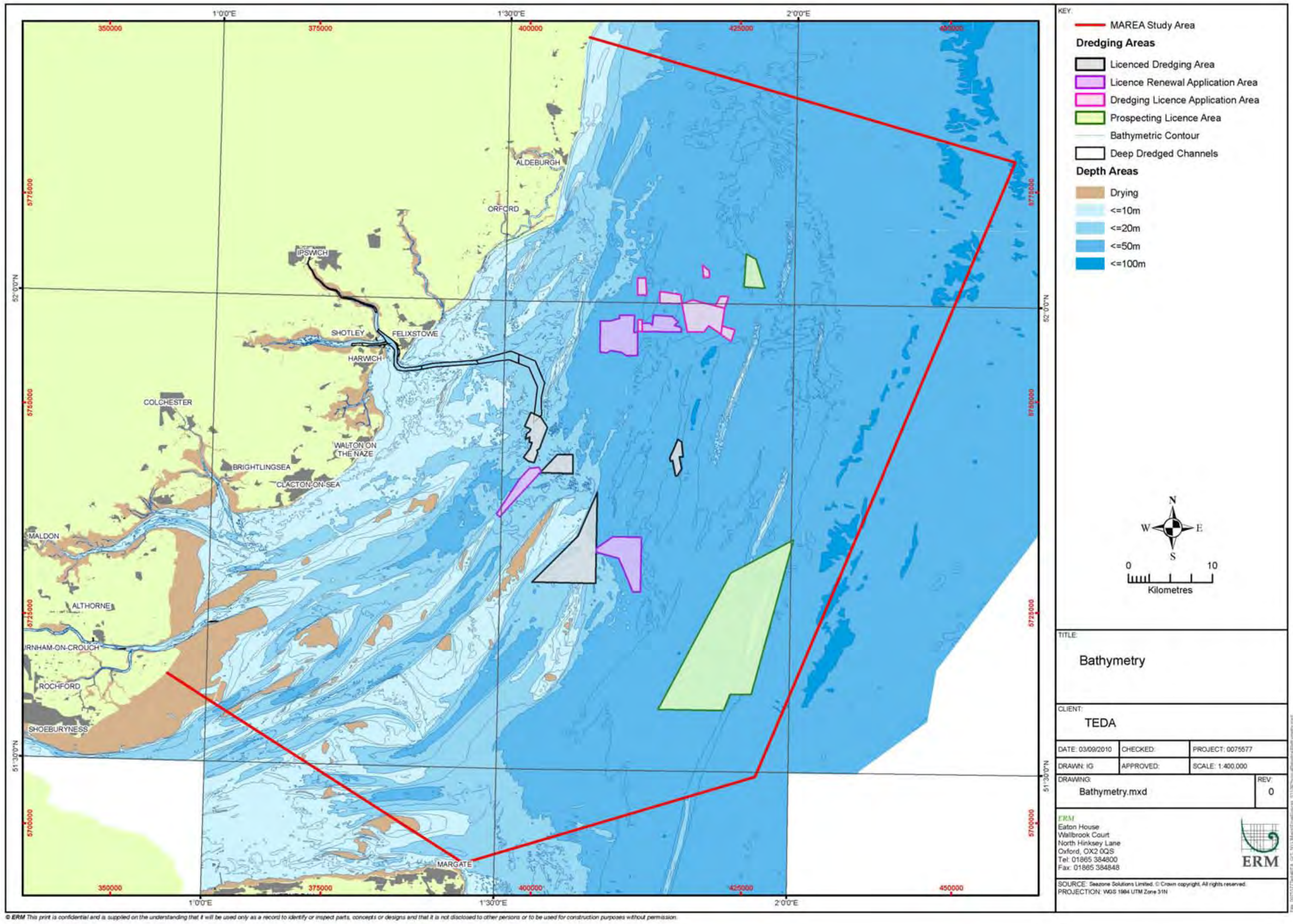
The sandbanks in the region are of particular importance due to their inclusion under the EU Habitats directive as Annex I habitat. At present the Margate and Long Sands candidate SAC (Special Area of Conservation) has been submitted to the European Commission to be included within the European 'Natura 2000' network of protected areas due to the presence of a number of Annex I sandbanks slightly covered by seawater at all times, the largest of which is Long Sand itself (see Section 5.6).

Water depths within the survey area vary from a minimum of +1.0 m LAT [1] across a series of 'drying' areas on Long Sand and a single area on the Kentish Knock, to -25.7 m LAT within Knock Deep and approximately -29.0 m LAT to the west of Fisherman's Gat, in Black Deep (Figure 4.3). A single deep water channel of approximately 14.5 m deep is dredged for the approach to Harwich and Felixstowe, and another is proposed as part of the London Gateway development (see Section 6.3).

4.2.5 Geomorphological Evolution of the Seabed

The Crown Estate – Caird Fellowship Research Project recently published a report on the geomorphological evolution of the seabed within the Outer Thames estuary, based on the analysis of bathymetric charts published over the last 180 years (Burningham and French, 2009).

Figure 4.3 Bathymetry



(1) Lowest Astronomical Tide.

The analysis showed that the broad scale arrangement of the sandbanks, channels and ridges within the Outer Thames has changed very little over 180 years, suggesting a significant long-term stability in seabed morphology. However, at a more local level the seabed is dynamic, with banks and channels displaying significant lateral shifts which account for depth changes in the order of tens of metres. This is especially true of the central, estuary mouth banks including Sunk Sand, the Barrows, Long Sand and Kentish Knock which have moved up to 2 km in some places (Figure 4.4*)*.

The outer ridges have shown some along-bank changes in depth and small-scale variations in footprint, particularly at their heads and tails. However the relative position of these ridges appears to be stable over the historical timescale. Headland associated banks near the Suffolk shore exhibit smaller subtle changes in orientation and position relative to the shoreline (Figure 4.5).

Section 4.2.6 discusses the sediment pathways that are currently operating in the offshore region of the Thames estuary

4.2.6 Offshore Sediment Transport

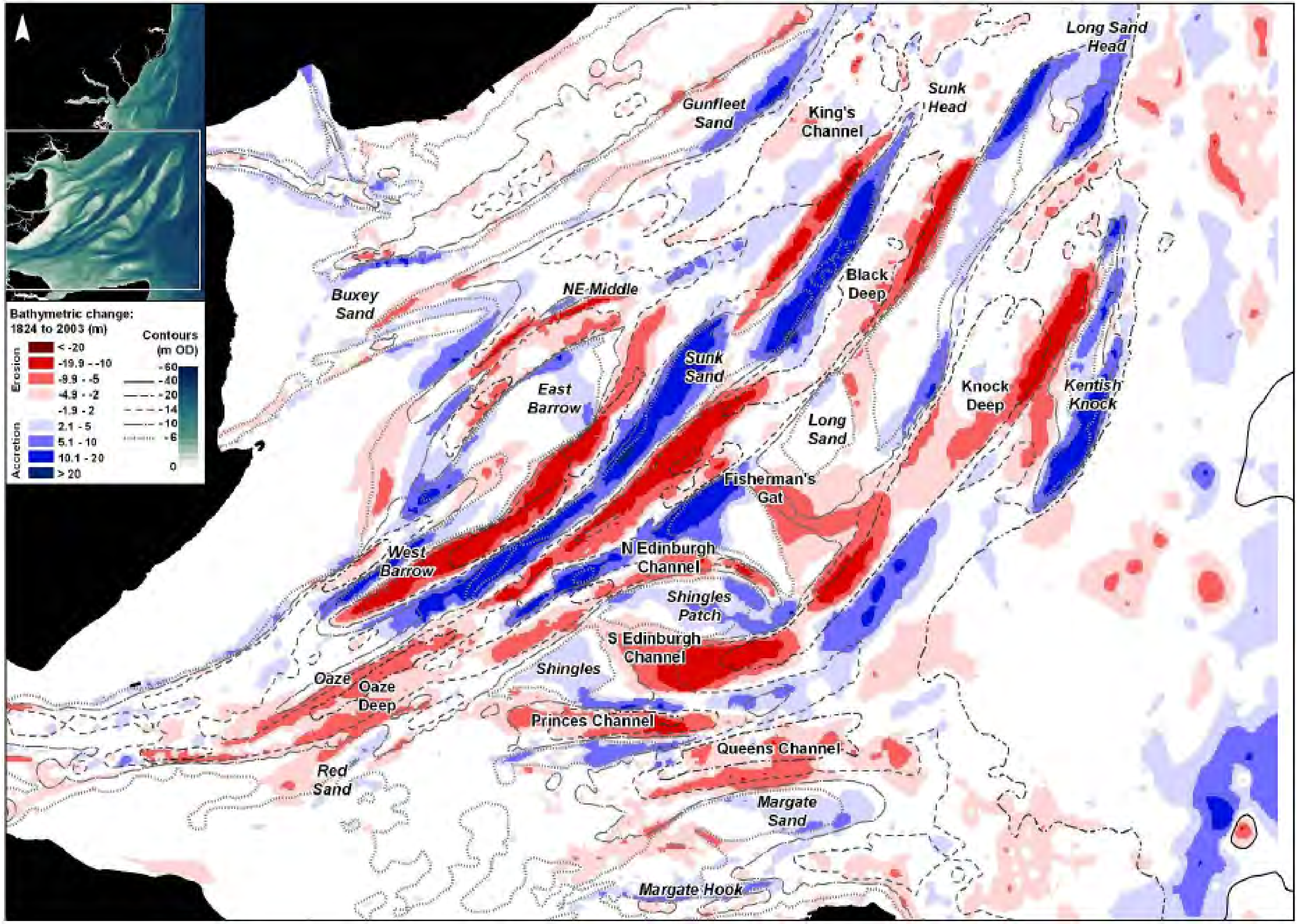
Introduction

Figure 4.6 divides the study area into zones A to E to aid in the discussion of offshore sediment transport pathways in the following section. Figure 4.7 shows the direction of the sediment transport pathways in the region and details the geology and bedforms in the study area which have been interpreted from the geophysical survey data and the grab samples (D'Olier, 2008). The information presented within the figure is used as the basis for the descriptions of sediment transport throughout this section.

Area A

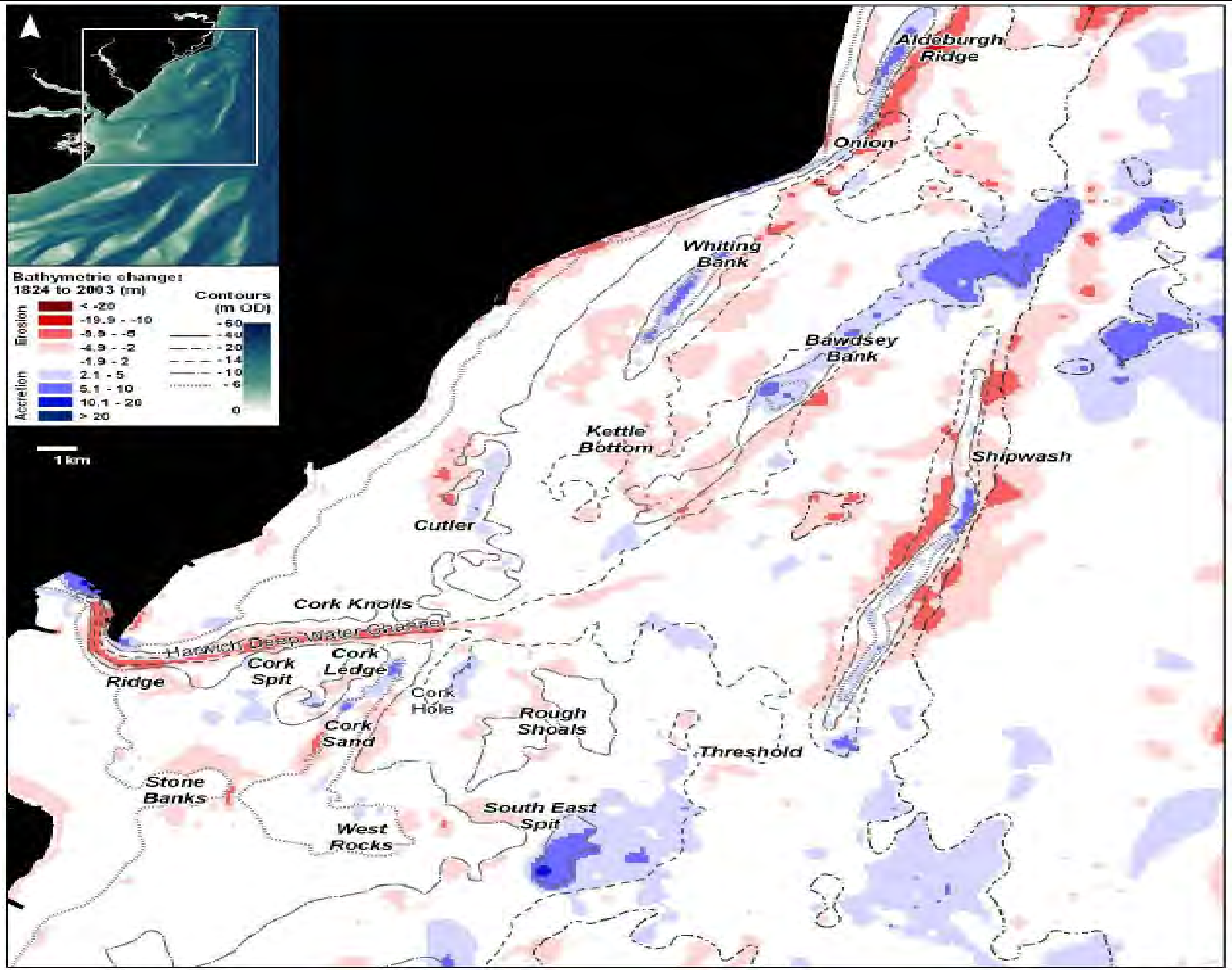
The area offshore of the East Suffolk coast, as far as approximately 2ºE (see Figure 4.6), has a number of indicators of sediment mobility including sand streaks and ribbons, megaripples and sandwaves. The orientation of these features indicates that the predominant movement of sediment is to the south, towards the Thames estuary and its approaches.

Figure 4.4 Total Change in Seabed Bathymetry between 1824 and 2003 across the Central Region of the Outer Thames Estuary



Source: Burningham, H. and French, J. 2009. 'Seabed mobility in the greater Thames estuary'. The Crown Estate, 62 pages.

Figure 4.5 Total Change in Seabed Bathymetry between 1824 and near the Suffolk Shore

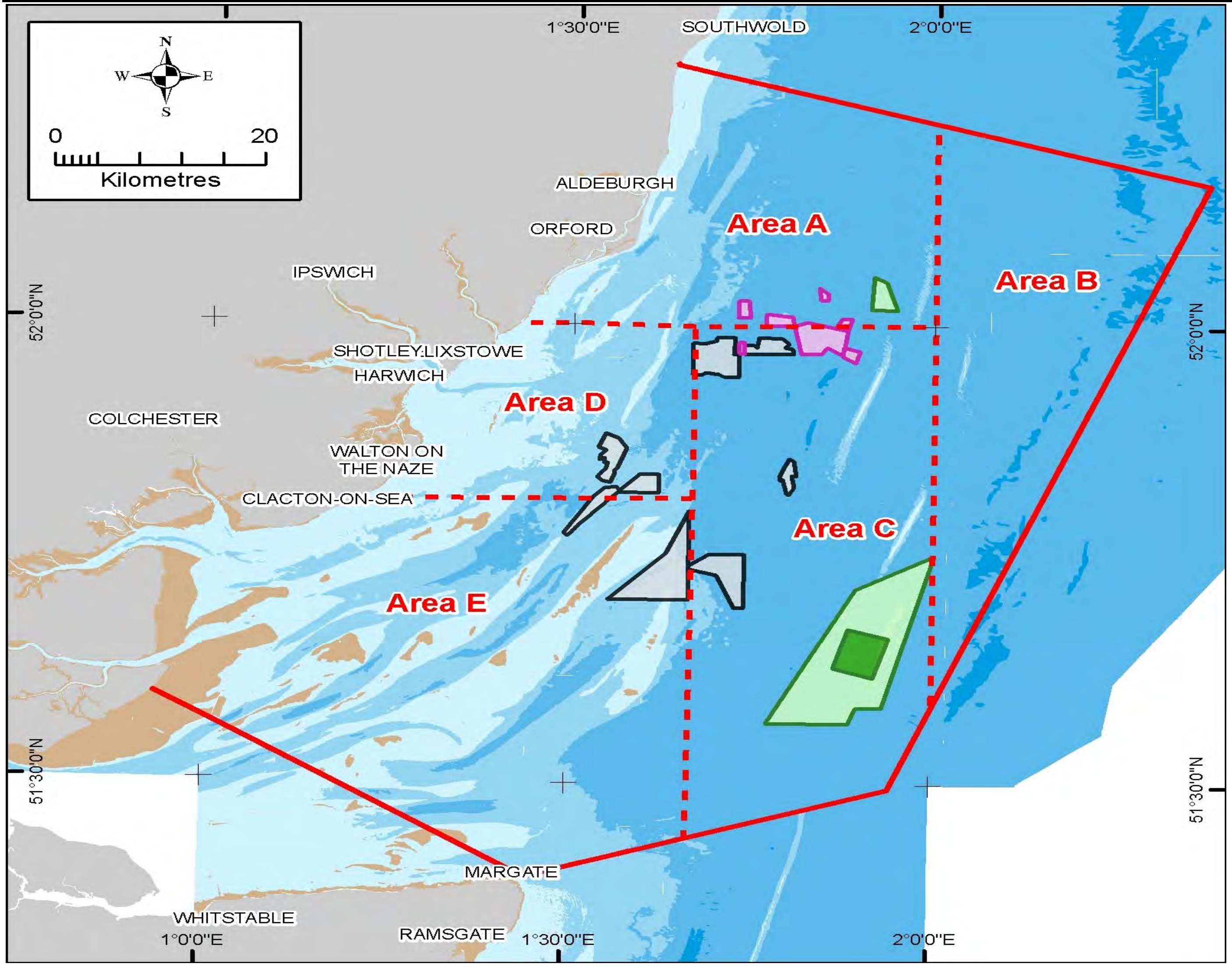


Source: Burningham, H. and French, J. 2009. 'Seabed mobility in the greater Thames estuary'. The Crown Estate, 62 pages.

Off the Suffolk coast these mobility indicators are largely parallel to the coast and are part of the Southern North Sea nearshore sediment pathway (D'Olier, 2002). Inshore there is southerly movement, although eddy flows can occasionally result in a more local change to a northward direction.

There are a number of sandbanks that are sinks for fine to medium sand, including the Sizewell and Dunwich Banks, the Aldeburgh Ridge and Aldeburgh Napes (Figure 4.2). There is a complex pattern of sediment movement around the Sizewell and Dunwich banks, although movement is essentially clockwise (Carr, 1979). The Aldeburgh Ridge is positioned as a headland bank and receives sand from the sorting of material at the head of the Orfordness shingle spit. It is possible that the Aldeburgh Napes was at one time in a similar position but coastal retreat has left it more isolated (D'Olier, 2002).

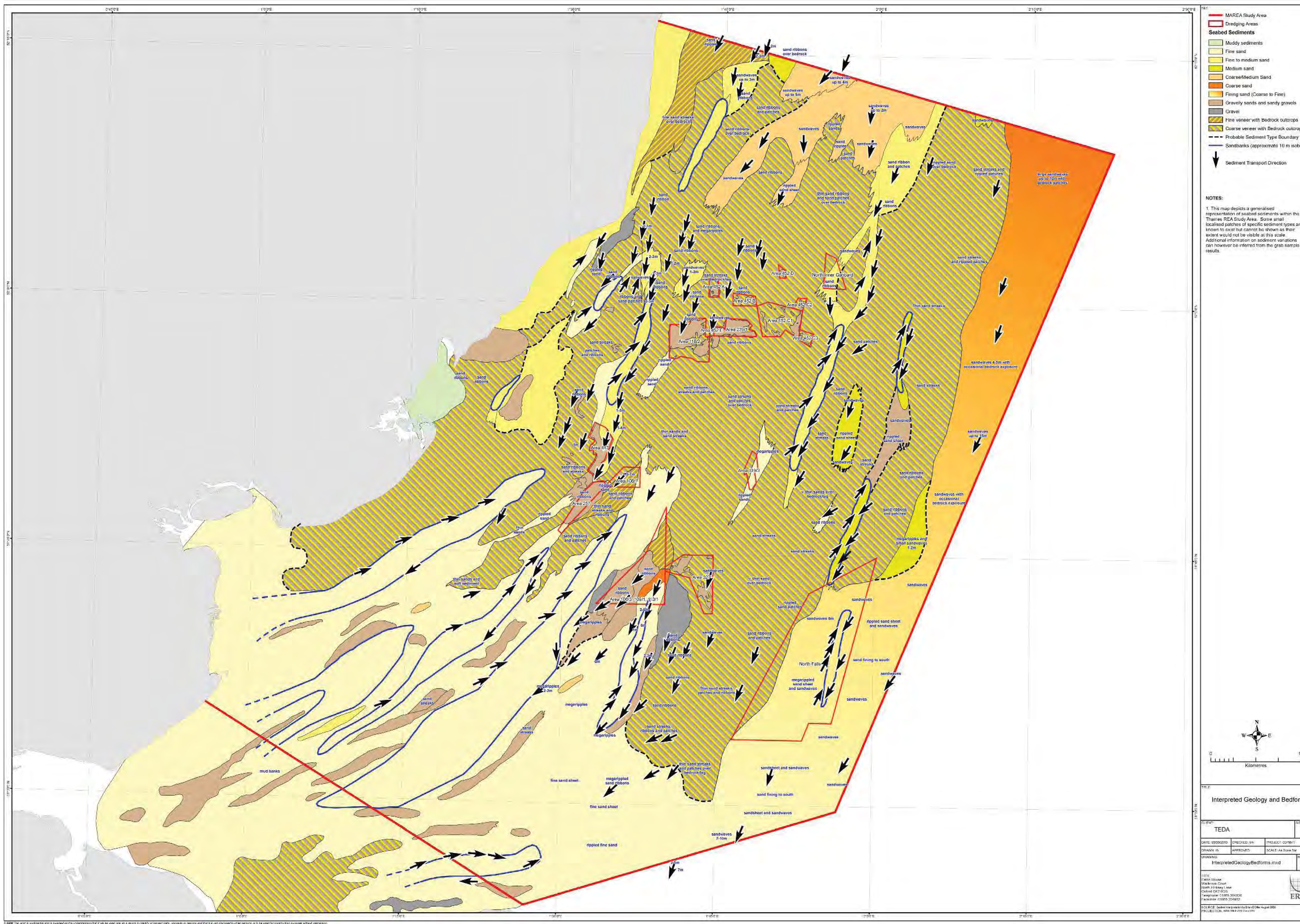
Figure 4.6 The Thames MAREA Study Area divided into Zones



Area B

In waters to the east of 2º E (Figure 4.6) at depths greater than 30 m, there is a large sand body stretching from the north to the south of the MAREA area which is composed of fine to medium sand with some shell and exhibits many megarippled sandwaves. It is believed most of this sand was deposited by the River Rhine during and shortly after the last glaciation (Houbolt, 1968) and (Veenstra, 1971). Due to the sorting action of the tides and tidal surges, the sediment grain size generally becomes finer along the sediment pathway towards the south and southwest. A large proportion of this sorted sediment is deposited in an area south of the Kentish Knock, northeast of the Margate Sands, to the west of 2º East (Figure 4.6). This depositional centre was thought to be the confluence for the Thames/Medway, the Kentish Stour/Swale and the Rhine Rivers at times of low sea level (D'Olier, 1972). The North Falls/South Falls is also a sink for this sediment.

Figure 4.7 Interpreted Geology and Bedforms



Area C

This area consists of a relatively flat surface of London Clay upon which several elongate sandbanks lie; the Inner and Outer Gabbard, the Galloper and North Falls (see Figure 4.6 and Figure 4.2). In addition there is an 'unnamed' bank to the north of the Inner Gabbard (D'Olier, 1975).

A major incision into the London Clay is cut by the palaeovalley of the Essex/Suffolk Stour River that passes from the western side of the Shipwash sandbank and under the northern ends of the Inner and Outer Gabbard banks. There may also be a series of ice marginal channels from the Anglian ice advance to the north of 52ºN. Two north/south aligned channels to the west of the Inner Gabbard may have originally been south bank tributaries of the Essex/Suffolk Stour.

The sandbanks all show an asymmetric, sandwave marked, clockwise sand circulatory system with the exception of the 'Unnamed' bank which is at present a line of discrete sandwaves. It is believed that these banks were formed as migrating beach bars some 7,500 years ago. The North Falls were formed as a southward extending 'banner' bank from the southerly projecting peninsular of the London Clay.

These banks act as elements within a broad sand pathway transporting sediment from the north to the south with the addition of some sand migrating as patches and streaks over the bedrock between.

Area D

North of and including the palaeo-watershed line from the Naze to the South Shipwash, (see Figure 4.6 and Figure 4.2*)* there are large areas where the bedrock is at or close to the seabed (Gray, 1988). This bedrock consists of basal London Clay Formation containing resistant and occasionally cemented layers of volcanic ash. The beds give rise to a number of seabed features off the north Essex and south Suffolk coast, such as the Stone Banks, Naze Ledge, West Rocks and parts of the Roughs Shoal, Threshold and South Ship Head. The Wadgate and Felixstowe Ledges, the Kettle Bottom at the Southern end of Bawdsey Bank and the Flagstone at the southern end of the Whiting Bank are all seabed expressions of this same basal unit of the London Clay.

Only the palaeovalley of the Essex/Suffolk Stour has left any appreciable aggregates on its terraced flanks. A section of this palaeovalley is Cork Hole where the current velocities are too high to allow sediment deposition. A small sink for fine muddy sand exists in the deeper water at the Southern end of the Shipway Channel.

Sand moves in a clockwise direction around the Shipwash, Whiting and Cork Sands. Asymmetric bedforms indicate southerly transport of material from the Southern Bight towards the two converging heads of the Shipwash and Bawdsey banks. However in the northern section of the Shipway Channel there is a sandwave field with asymmetric bedforms which indicates sediment movement towards the north. Bawdsey Bank also exhibits movement of sand to the north but in an anti-clockwise direction. Thus there are convergent sediment pathways supplying sediments to these two banks at their northern ends. Winnowing within this convergent sandwave field passes sediment eastwards into the Shipwash Bank which then joins a pathway southwards into the central parts of the Thames Estuary. There is also evidence in the form of sand ribbons and streaks that sediment is being transported across the seabed from the north and northeast to the western side of the Shipwash (D'Olier, 2002).

Area E

This area encompasses the major sections of the palaeovalleys of the Thames, Medway, Crouch, Kentish Stour and Swale rivers. These buried valleys are now acting as sinks largely filled with sediment. The Cant on the southern side of the estuary is a huge infilled sink overlying the most recent buried valley of the Thames and Medway. To the east this becomes the Kentish Flats comprising a London clay platform overlain with thin sands and very thin lag gravel, incised by the palaeovalley of the Swale that is itself largely infilled with soft silts and clays.

Small sections of these palaeovalleys are not completely infilled and therefore continue to be small sinks for sediment as for example at the Great Nore, the eastern part of the Cant at Red Sands, the Shivering Sands channel and the Princes Channel.

At present there is a small input of sediment from the River Thames, mostly between 364,000 tons and 700,000 tonnes per year (D.IS.R, 1964). The River Medway is also expected to contribute a similar amount (Kirby, 1990).

The cliffs of the Isle of Sheppey are a major sediment source due to the erosion of London Clay Formation, silts and clays from the cliffs, and from the seabed offshore of the Isle of Sheppey and the Kentish Flats to the east. The present erosion rate is 0.95m/year but was 12m/year between 1908 and 1965, and geophysical data suggested these cliffs extended some 28 km north-eastwards when marine erosion began approximately 8000 years ago.

The major sandbanks in this area are Margate Sand, Kentish Knock, Long Sand, Sunk Sand, East and West Barrow, Northeast Middle and the Gunfleet, all of which are sinks for fine to medium sand (see Figure 4.6 and Figure 4.2). Long Sand and Sunk Sand have extended appreciably towards the northeast during the last 150 years; in the case of Sunk Sand by approximately 5km. This bank has also extended to the South and Margate Sand has extended to the east and northeast (D'Olier, 2002).

The dominant central bank Long Sand, acts as a barrier between the English Channel tide from the south and the North Sea tide from the northeast. These tidal incursions are slightly out of time phase and as a result the water levels on each side of Long Sand may be at different levels at any particular time. In the past the Edinburgh Channel swatchways allowed water through to effect a balance between these tidal levels, however these have silted up and become increasingly narrow. In addition the elongation of Long Sand Head to the north east has forced more water on the ebb tide to leave the estuary via the Black Deep Channel on the northern side of Long Sand (D'Olier, 2002). Fishermen's Gat, is a north-northwest – south-southeast oriented shipping channel which cuts across Long Sand, and was opened as a fishing route in 2000, following the demise of the North Edinburgh Channel as a buoyed route.

The pattern of sand movement around each of the banks is generally in a clockwise direction although there are localised areas of anticlockwise circulation (Kenyon, 1981) and (Swift, 1975). The clockwise pathways bring sand into the inner reaches of the estuary and to the more mobile minor sandbanks to the south of the main MAREA study area; the Knock John, Tizard, Knob Shoal, Shivering Sands, Mouse and Oaze (see Figure 4.6 and Figure 4.2). Elements of these banks have moved northwest by up to 3 km over the past 150 years, amalgamating with the southern end of Sunk Sand and with West Barrow and transferring sand into the primary sink of the Maplin Sands and Dengie Flats.

Two channels lie immediately to the northeast of this sink; the middle deep and the western end of the East Swin. These are filling with sands and muddy sands and form part of this extending sink. This progradation is confirmed by the 3% gain in volume that has occurred since 1991 on the sand and mudflats between Dengie and Shoeburyness (Leggett, 1998).

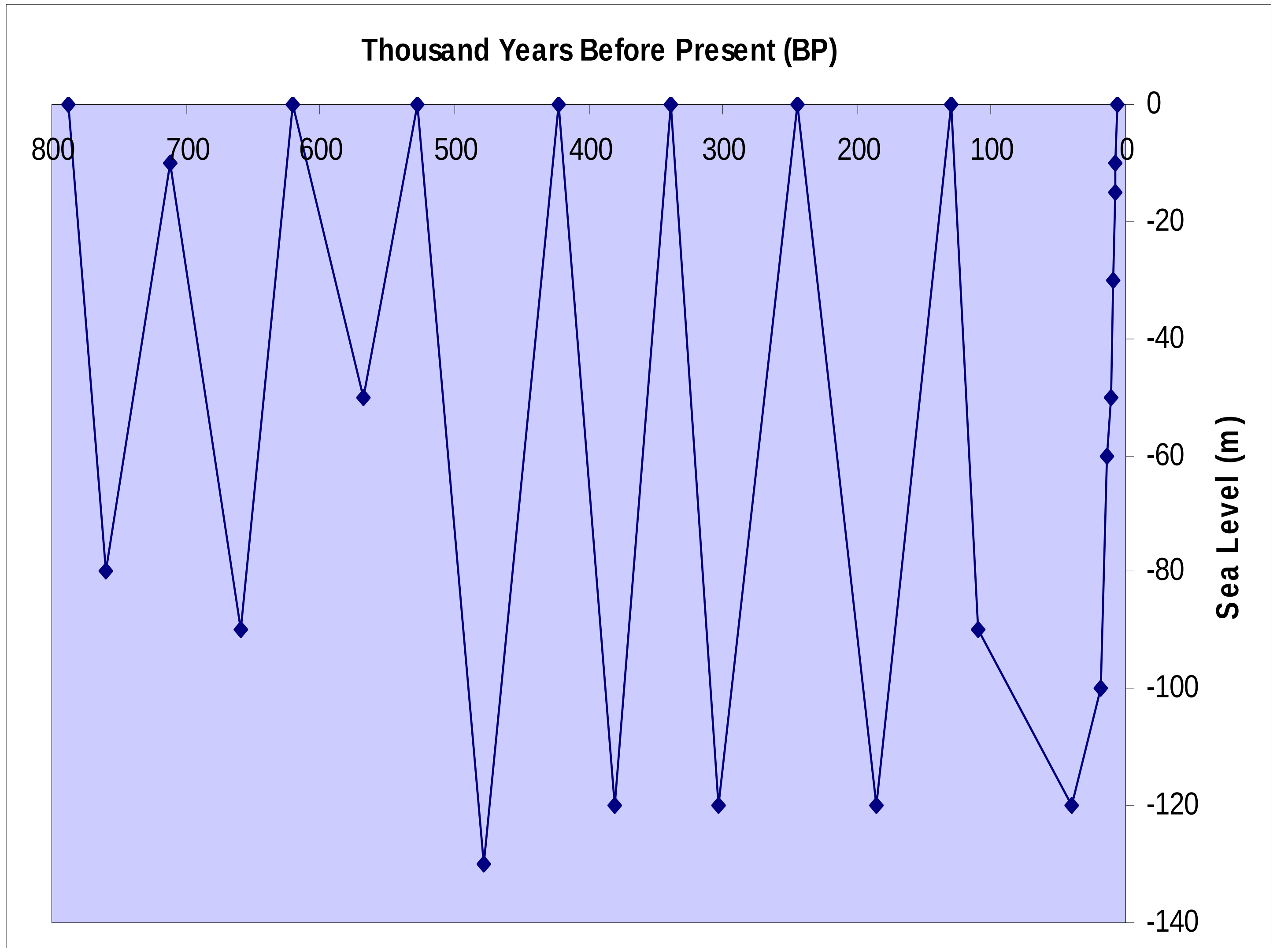
Woodhead drifters released in 7 different locations throughout the Outer Thames indicate that water movement is generally southerly and westerly but is partly compensated by a northerly drift closer to the shore leading into the Maplin Sands and Dengie Flats sediment sink (Talbot, 1982) and (Whitehouse, 1996).

4.2.7 Sea Level Change

There are large gaps in our knowledge of the relative sea level history of the North Sea, however the river terrace formations of the Thames and its tributaries form a relatively uninterrupted geological sequence which provides important evidence for the study of sea level fluctuations and environmental change during the Pleistocene (Williams, 1999).

Figure 4.8 shows an approximate indication of relative sea level change in the southern North Sea during the last c. 800,000 years (relative to the present day sea level) (see Appendix F). The lowering of sea level associated with several glaciations meant that for long periods, areas of the North Sea were exposed as dry land. The trapping of water within the extensive sheets of the Anglian glaciation resulted in a fall in sea level which is thought to be the lowest recorded sea level around the British Isles, estimated at 130 m below the present level (see Appendix F).

Figure 4.8 Sea Level Fluctuation over the past 800,000 years



Source: Adapted from Appendix F Archaeology Report.

4.3 NEARSHORE GEOLOGY AND SEDIMENTOLOGY

4.3.1 Introduction

The following section contains a description of the coastline from Orford Ness to Margate (see Figure 4.9). It should be noted that whilst the boundary of the MAREA study area is useful in defining the offshore limits of the study area the coastline is a complex feature. Therefore in this section the coastline from Orford Ness to Margate is described, excluding the inner parts of the Thames estuary itself. The descriptions, which are broken down into three stretches of coastline contain information on coastal features such as topography, sediment type, developments and coastal defences. This section also contains details on sediment transport pathways along the coast, in the offshore environment and between the two.

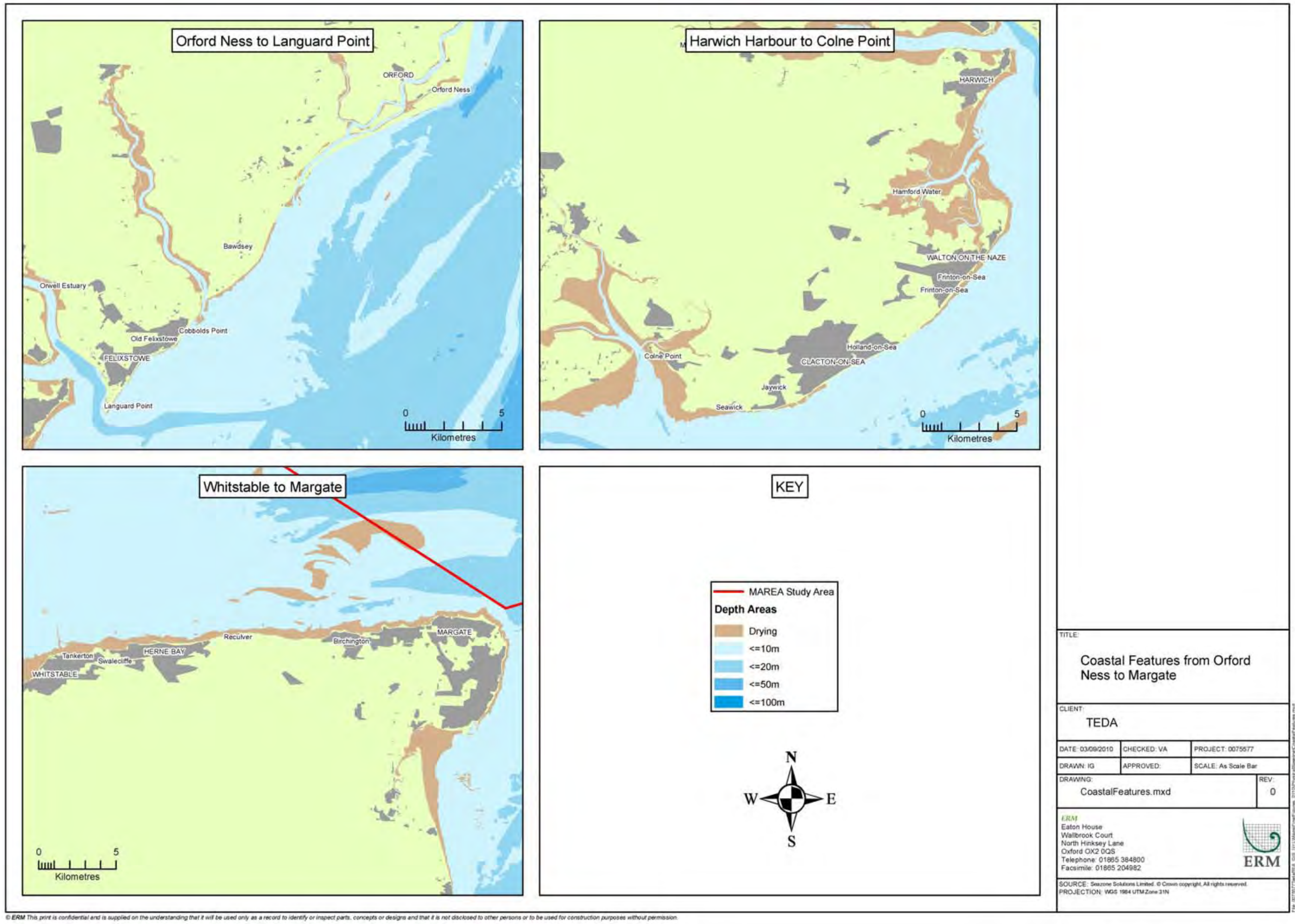
4.3.2 Sources of Information

Coastal Characterisation Study by HR Wallingford

The majority of the information in this section is derived from a study carried out by HR Wallingford on the characteristics of the coastline within the MAREA study area, describing its features, the coastal management practices employed including its defences, and the sediment pathways along the coast (see Appendix H). The following references were used to inform this report:

- British Geological Survey Marine Report 86/38 (1988). Marine Aggregate Survey Phase 1: Southern North Sea.
- HR Wallingford (2002). Southern North Sea Sediment Transport Study, Phase 2. HR Wallingford Report EX4526. Report to Great Yarmouth Borough Council, prepared by HR Wallingford, CEFAS/UEA, Posford Haskoning and Dr Brian D'Olier, 94pp and Appendices.
- Sir William Halcrow & Partners (1991). The Anglian Sea Defence Management Study, Phase II, NRA Anglian Region. Study Report (unpublished report).

Figure 4.9 Coastal Features from Orford Ness to Margate



* Sir William Halcrow & Partners (2004). Futurecoast: Research project to improve the understanding of coastal evolution over the next century for the open coastline of England and Wales. Report and CD-ROM produced by Halcrow-led consortium for DEFRA. Halcrow Group Limited, Swindon.

4.3.3 Description of the Coastline

Orford Ness to Languard Point

The coastline from Orford Ness to Languard Point is mainly low-lying and fronted by shingle beaches (Figure 4.9). Orford Ness is the apex of a massive 10 mile long shingle spit fed by the cliff erosion north of Aldeburgh. However, this cliff is now providing predominantly sandy sediments, hence the supply of shingle to the spit is decreasing. The spit has deflected the mouth of the River Alde so that it runs behind the shingle barrier and meets the River Ore further south where they share a common mouth. Shingle is transported southwards from the southern end of the spit, creating a series of shingle bars at the mouth of the Ore/Alde estuary, which provide 'temporary storage' before the shingle is transported southwards/shorewards across the mouth of the estuary. There has been a lateral shift in the position of the Ness as a result of changes in the wave climate, and breaching is a possibility towards its distal (southern) end (as occurred in 1895 and 1902). This may result in large areas of low-lying marshland as far south as Bawdsey being flooded.

Along the coast toward the River Deben, erosion of the London Clay cliffs takes place in areas where there are no coastal defences, releasing sand and shingle from the Red Crag Formation that lies unconformably over the London Clay within the area. However the volume of material released by this cliff erosion is small, as the cliff toe is generally well protected by the shingle beach. The low-lying land at the river mouth is vulnerable to flooding, particularly as the transfer of shingle from the ebb delta shoals is periodic and irregular. In addition fast currents in the river have resulted in erosion on the southern shore, where embankments and seawalls have had to be constructed. The mouth of the Deben is an important store for coarse sediments and plays a vital role in the exchange of coarse sediment from the north to the south. The beaches at the entrance to the Deben estuary are thus very dynamic.

South of the Deben the high clay cliffs that extend southwards to Cobbolds Point have a history of instability. They are protected by groynes which have reduced the southward transfer of shingle to Felixstowe. In addition they prevent coastal retreat, therefore the continued abrasion of the nearshore seabed causes the submarine slopes to steepen in front of the defences, making management of the beaches more difficult.

From Cobbolds Point southwards, land levels fall and the urban frontage of Felixstowe has extensive groyne systems to try to maintain beach levels where beach lowering has been the trend. The defences continue south on the alignment of a long shingle spit that once extended further than its present end at Landguard Point, where a terminal groyne has been constructed to safeguard what remains of the spit.

Harwich Harbour to Colne Point

The coastline from the meeting of the Stour and Orwell estuaries at Harwich Harbour and extending southwards to the Naze is a strongly indented one, and therefore is significantly less exposed than the coastline described in the previous section (Figure 4.9). Wave action is mild enough in some areas to allow saltmarsh to develop (e.g. south of Dovercourt and within Hamford Water). Hamford Water is a large tidal inlet which formed as a result of submergence of low-lying land following the last period of glaciation. It continues to act as a sink for sand and fine materials.

The convex shaped coastline between Hamford Water and the Blackwater Estuary comprises cliffs of soft London Clay. At the headland of the Naze these cliffs are unstable, and erosion of the Red Crag Formation that lies unconformably over the London Clay releases fine sediments, sand and gravel, although the volume of beach-building material that is supplied is meagre.

Urban cliff top development begins at Walton-on-the Naze and extends southwards to Clacton. This whole frontage is now protected by seawalls/rock berms and a wide variety of groynes/breakwaters including timber, rock and concrete groynes.

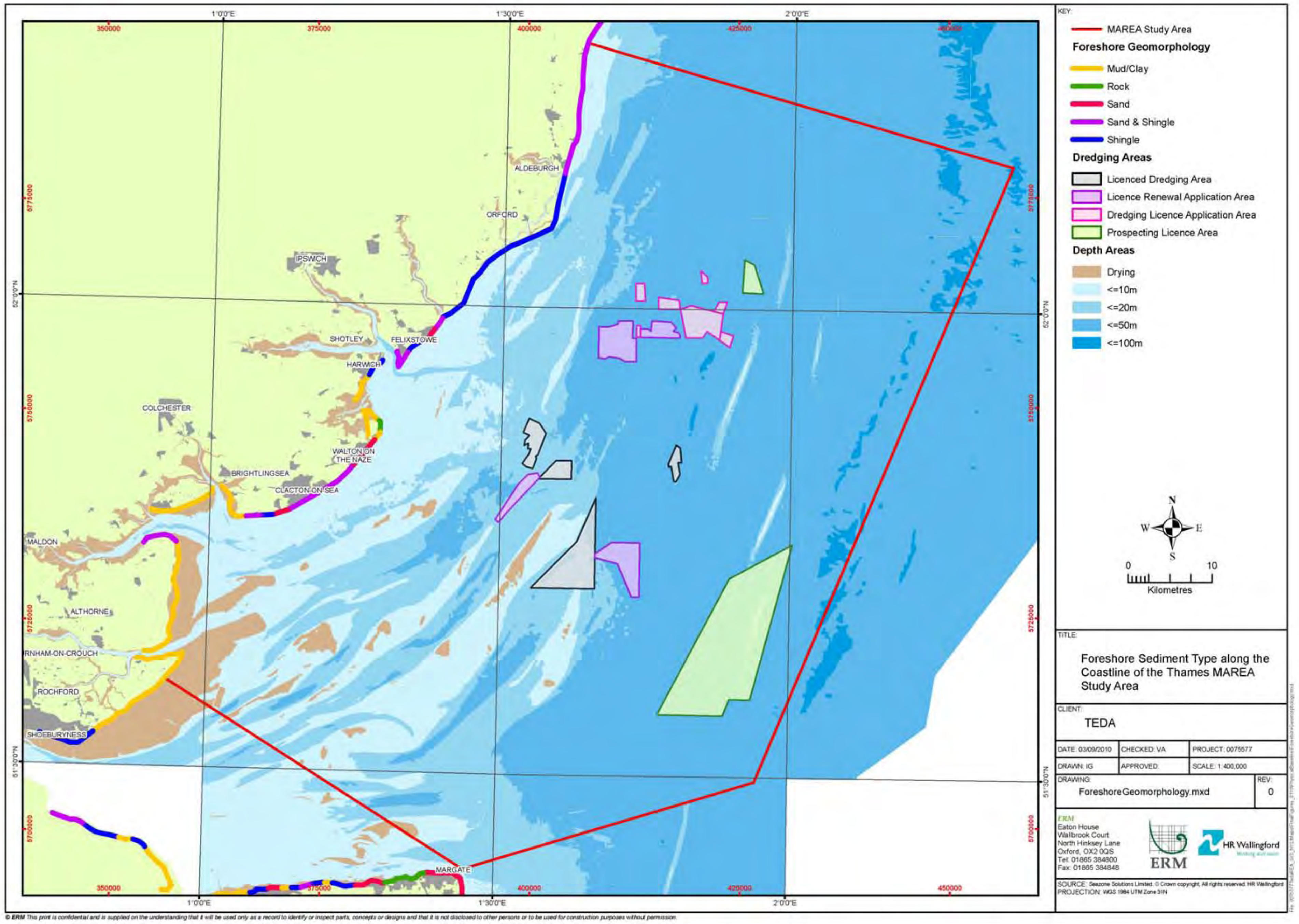
Whitstable to Margate

Like Essex, the North Kent coastline is made up of areas of low-lying land separated by cliffs of London Clay (Figure 4.9). During the postglacial period, the drowning of a number of river valleys produced several islands (Grain, Sheppey etc) around which infilling with more recent alluvial deposits has taken place. This has been aided by the reclamation and embankment activities that have taken place since Roman times.

The area between Whitstable and Herne Bay is heavily developed and much of it is protected by seawalls and groyne systems. The sand and shingle beaches in this area are narrow and require regular maintenance, and the amount of cliff erosion that can now take place produces limited quantities of beach building material. The effects of 'coastal squeeze' are thus apparent, ie as sea levels rise; the beaches cannot retreat landwards due to the presence of sea defences and therefore need recharging frequently. Littoral drift is generally from east to west, in line with the direction of dominant wave action from the open sea, however this reduces towards the western end of the coastline where there is some local reversal in longshore transport.

The nearshore seabed is very flat and contains many shingle strips such as Whitstable Street, a natural strip of shingle on clay bank which runs out to sea at right angles to the coast, for a distance of about half a mile, which has been stranded on the lower foreshore as the coastline has retreated rapidly. It stretches across the lower foreshore at right angles to the coast, but has nevertheless maintained its form despite the obliquity of wave attack that might have been expected to deflect it alongshore.

Figure 4.10 Foreshore Sediment Type along the Coastline of the Thames MAREA Study Area



Between Reculver and Birchington, the long stretch of very low-lying land is protected by a relatively lightweight embankment wall. This area forms the course of the former Wantsum Channel which was once a three mile wide waterway between Reculver and Sandwich. During the 1953 surge, this wall was almost totally destroyed and has since been rebuilt. The beaches in this area have a tendency to erode, and there is very little feed of material from the east as the chalk cliffs from Birchington to Margate are largely protected by seawalls. In comparison to the London Clay cliffs to the west, the chalk cliffs form a strongly indented coastline as a result of structural weaknesses which are vulnerable to erosion.

Figure 4.10 summarises the sediment types found along the foreshore coastline of the study area.

4.3.4 Coastal Defences and Management

Orford Ness to Languard Point

The shingle foreland of Orford Ness is largely in a natural state, with the exception of its northern end near Aldeburgh, which lies outside of the study area. South towards Bawdsey the shingle beaches form a natural flood defence, however there is a tendency for the coastline to retreat and there is a risk of flooding and of the spit breaching if the shingle beaches continue to narrow. This retreat could potentially expose large areas of low-lying land and marsh to flooding and erosion.

At Bawdsey, the seawall around the gun emplacement has become badly damaged from wave action and is now partly protected by rock armour. To the south of this wall the low, sandy cliffs have recently been retreating rapidly and rock armour has also been added here. At Bawdsey Manor the cliff toe is protected by a mixture of timber and sheet steel breastworks that reduce landward retreat and help to maintain beach levels.

The south bank of the Deben is protected by interlinked concrete block revetments from the ferry terminal eastwards, with a concrete seawall extending south round the more exposed mouth of the estuary to join up with the defences at Old Felixstowe. South of the river mouth a number of short rock groynes have been constructed in front of the seawall. Timber groynes are employed further south, however, these have not been very effective and some have been extended in length by the addition of rock armour. There is a patchwork of defences towards Cobbolds Point, due to the frequent need for repair in this area; these include seawalls, concrete block revetments and rock armour, timber and rock groynes. The clay cliffs at Old Felixstowe are unstable and particularly vulnerable to landslips. Two new fishtail groynes at Cobbolds Point separate the cliffs of Old Felixstowe from the urban frontage of the town of Felixstowe itself, and act as a partial 'drift boundary'. Immediately south of this, beach levels are extremely low and rock armour has been used to reinforce this area.

A concrete sea wall and a number of large concrete groynes span the foreshore at Felixstowe. Beach levels have fallen dramatically in recent years and new defences are currently under construction along with beach nourishment (import of sand and gravel to make good losses due to erosion), as the concrete groynes are particularly vulnerable to major damage.

Towards Landguard Point, new concrete stepped seawalls have replaced the old lightweight vertical walls in an area where severe beach erosion has recently taken place, and timber groynes replace the former concrete/sheet pile groynes. The amount of shingle that accumulates against the terminal groyne at Landguard Point is so large that material bypasses it and settles out in the approach channel to Harwich Harbour. Maintenance dredging is carried out to maintain the channel depth of about 14.5 m below Chart Datum (CD).

Harwich Harbour to Colne Point

The low-lying land at Harwich Harbour was once a sand spit that extended northwards into the Stour/Orwell estuary from the higher ground at Beacon Cliff, and is now protected by sea-walls as an anti-flood measure. However, the stony beaches in this area reduce the impact from wave activity to a low level and the coastal defences have been subject to mild wave conditions.

To the south of Beacon Cliff, levels of wave activity are higher and groynes are present on the foreshore. The weak net littoral drift is predominantly from south to north, resulting in a build up of sand immediately south of the breakwater at Beacon Cliff. This beach is prone to erosion and has been nourished in the past. A seawall extends southwards and encloses an area of low-lying land bordering Hamford Water. The setback in the line of the wall indicates that some landward retreat of the dunes has taken place; these defences are thus somewhat more exposed than those to the north.

Hamford Water is a sediment sink and contains creeks and islands fronted by a mixture of sand beaches and saltmarshes. Within the inlet there are extensive areas that have been reclaimed and are protected by flood embankments. For example the low-lying land at Foulton Hall Point, on the more exposed northern part of Hamford Water, is protected by an armoured revetment. At Horsey Island, the sandy beach and saltmarsh have been affected by erosion and as a result lighters (ie barges) have been sunk in a line across the foreshore to provide shelter and to encourage sand accretion in their lee.

The cliffs at the Naze that face north into Hamford Water are unprotected, and erosion here provides some beach-building sediment, particularly at Walton-on-the-Naze. Beach width is substantial as far south as Holland Haven where land levels fall. The outfalls that drain low-lying land at Holland Haven have been armoured and act as 'artificial headlands'. There is now very little intertidal beach in front of them. The beaches to the south are noticeably narrower than those to the north and are suffering from a lack of contemporary sediment supply, caused by the protection of the London Clay cliffs to the north. The worsening beach conditions from Holland-on-Sea to Clacton are a major challenge for future beach management.

The beaches between Clacton and Jaywick are in slightly better condition, as sand transported southward tends to collect in the lee of Clacton pier, where there is partial protection against northerly waves. However the low-lying clay cliffs at Jaywick are very exposed and were very vulnerable to wave action until the recent completion of major defences there.

From Jaywick to Colne Point the land is low-lying marshland. From Jaywick to Seawick this is protected by recently strengthened walls and the nourished beach is held in place by large 'fishtail' groynes. The former marshland to the west of Seawick, now used as a caravan park, is protected by a seawall and a system of short rock groynes. Further westwards, towards Colne Point, flood embankments have been constructed at some distance landward of the saltmarsh edge. A narrow sandspit/beach on the seaward side of the saltmarsh gives added protection and extends beyond Colne Point, protecting the marshes and tidal creeks in its lee.

Whitstable to Margate

Immediately to the west of Whitstable Harbour on the north Kent coast, there is a natural basin of low-lying land that has suffered catastrophic flooding on many occasions; the 1897, 1949 and 1953 floods being particularly severe. Following the 1953 surge the defences were reconstructed and act in combination with high beach levels. In addition the beaches require regular maintenance, usually by importing flint pebbles from inland quarries.

The stabilised clay slopes east of the harbour from Tankerton to Swalecliffe are protected by seawalls and groynes and the shingle beaches provide additional stabilisation. These are constantly monitored and periodically renourished. At Swalecliffe the shingle banks at the stream mouth are unprotected, but a flood bank set back from the shore encircles the area and protects the low-lying hinterland from flooding. East of Swalecliffe the low cliffs are protected by a seawall that extends to Hampton Pier, at the east end of Herne Bay. The pier was constructed as a large terminal groyne, and as a result the shoreline immediately west of it tends to suffer from a shortage of shingle. The root of the pier has been reinforced with rock armour and a short shore-parallel rock breakwater reduces shingle loss.

Herne Bay is protected against westerly wave action by a large, curving rock breakwater that is utilised as a marina and is open on its west side. Between Herne Bay and Bishopstone the high clay cliffs are stabilised by drainage works. Where the clay cliffs are replaced by steep, sandy cliffs below Bishopstone Manor, the coastline is defended by a short length of rock armour revetment. From here towards Reculver, the sandy cliffs are eroding rapidly, however these cliffs consist predominantly of clays and fine sands, therefore their erosion produces little in the way of coarse sediment that is suitable for building up the beaches at Herne Bay. The seawall at Reculver is prominent due to the erosion of the cliffs to the west and the landward retreat of saltmarsh to the east. Falling beach levels in front of the wall have led to the addition of rock armour.

The Northern Sea Wall to the east of Reculver and continuing to the chalk cliffs of Minnis Bay, Birchington, is of relatively lightweight construction and in recent years management has involved large-scale nourishment and the construction of rock groynes. Its low lying position makes it vulnerable to breaching and maintaining a satisfactory standard of protection against flooding is the most important coastal defence challenge along this stretch of the North Kent shoreline.

From Birchington to Margate a number of bays were formed by the differential rates of cliff retreat. The seawalls at the base of these cliffs do not seem to have interfered with the seasonal seaward migration of sand in this area.

Figure 4.11 summarises the backshore geomorphology and coastal management along the coastline of the study area.

4.3.5 Coastal Sediment Transport Pathways

Orford Ness to Languard Point

The net littoral drift along this stretch of coastline is southwards. Shingle from Orford Ness provides material for the southward extension of the spit at the northern shore of the River Deben and for the shingle banks, called the Knolls, situated on the ebb-delta of the river mouth itself. These emergent banks shelter the coastline south of the river mouth against northerly wave action, which can lead to localised drift reversal. Shingle is periodically released from the banks to reach the southern shoreline of the Deben. The drift volume from Cobbolds Point to Landguard Point is weak due to the effects of groyning and the decline in supply of fresh material. The shingle spit that now terminates at Languard Point once extended much further southward than it does today, when the supply of shingle from 'updrift' was much larger.

The beaches from Orford Ness to the River Deben are composed primarily of medium to small sized shingle, with sand tending to be found on the lower foreshore. The movement of shingle by wave action is predominantly towards the shore and the amount of material 'lost' seawards during beach draw down (for example during winter storms) is thought to be small. However the ebb currents through the Ore/Alde estuary are sufficiently strong to deflect the shingle seawards. Sand can be transported in the offshore area by severe wave action and is thought to feed into the nearshore bank systems (British Geological Survey Marine Report, 1988), however there is no evidence of any sediment transport from these banks towards the shore. There is little information on cross-shore transport (1) from the River Deben to Languard Point, but the continuing erosion of the beaches indicates that the dominant transport pathway in the area is seawards.

The Coastal Characterisation Report within Appendix H shows the beach cross-section profiles which were provided by the Environment Agency. The accumulation of shingle at Orfordness has resulted in the toe of the beach moving into deep water and is now located at approximately -9 m OD (2) which is typical for the coastline in the study area. The cross-section profiles in this area show the seabed rising and falling offshore which indicate the presence of submerged banks which are migrating offshore. At the southern end of Orford spit, the profile falls at a steeper gradient, and the shingle beach toe is estimated to be at -6mOD, and at Bawdsey, the toe is only 1m to 2m below mean tidal level. At Old Felixstowe, the beach toe is at approximately -1.5 m OD. There is then a gently-sloping 'berm' that extends 400 m to 700 m offshore, with its toe at about -5 m OD. Admiralty Chart 2693 shows a trough that runs parallel to the shoreline at Felixstowe pier and extends southwards to Landguard Point. Fine sand accumulates within this depression.

Harwich Harbour to Colne Point

The complexity of the coastline between Harwich Harbour and Hamford Water along with the changing morphology and the variations in both the strength and directions of wave approach means the net littoral drift patterns are very complex and poorly defined. Between Harwich Harbour and Dovercourt there is a weak littoral drift northward. South of Dovercourt transport is generally southward but seasonally variable. Within Hamford Water itself sediment transport processes are very complex and are affected by both wave and tidal current action. The Naze headland acts as a drift divide between transport northward to the north, and transport southward to the south.

Littoral drift along the convex coastline from the Walton-on-the-Naze to Colne Point is weak and variable in direction, but principally southward. Although supply is now fairly limited, transport increases in a southward direction at a rate faster than material drifting northward, which results in the coastline becoming increasingly more vulnerable to sediment starvation in a southward direction.

From Clacton into the Blackwater Estuary, longshore transport is westwards and material accretes around Colne Point due to the shelter against wave action.

There is little information about cross-shore transport in this area. Admiralty Chart No 1975 indicates that the flat near-shore seabed between Jaywick and Colne Point includes broken shell within the bed matrix which may well be transported shoreward. The trend is one of net erosion/seaward movement rather than transport towards the shore.

The Coastal Characterisation Report within Appendix H shows the beach cross-section profiles which were provided by the Environment Agency. At Dovercourt, the beach is very narrow, and beach toe is estimated at -1.5 m OD, very close in shore. There is very little change in profile from survey to survey. Similarly, at Hamford Water there is very little change in bed levels over time. Beach toe is estimated as -1 m OD at this location. At Walton-on-the-Naze, beach toe is approximately -3 m OD, and at Holland-on-Sea the beach is markedly steeper and narrower with beach toe at -2 m OD no more than 25 m offshore.

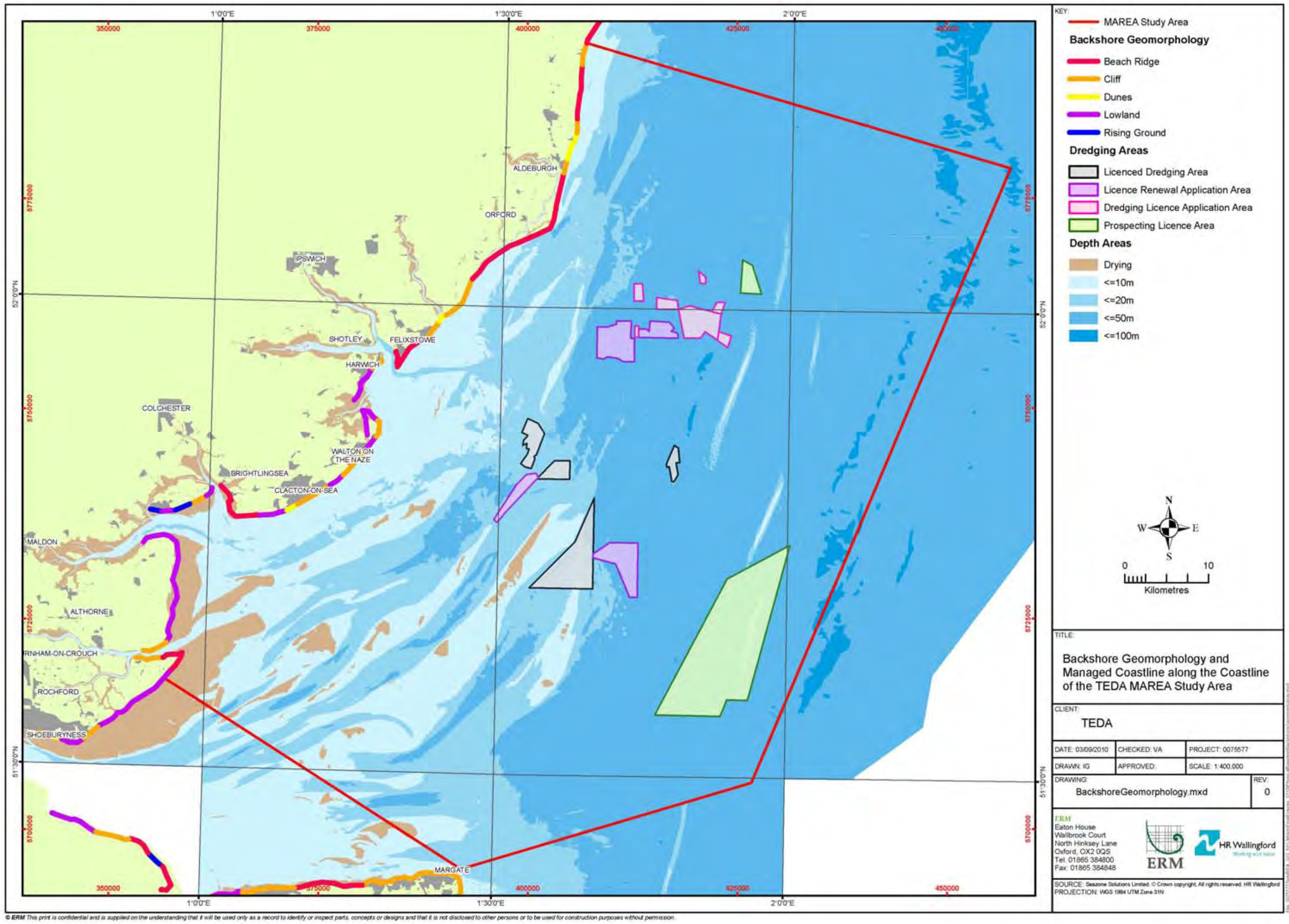
Whitstable to Margate

Longshore transport of shingle between Whitstable and Margate is predominantly from east to west, driven by the waves that penetrate the Outer Thames Estuary from the North Sea. However, net westward transport is relatively weak as the waves are reduced in size by the many linear sandbanks in the Outer Estuary and lose energy close to the shore. Drift reversals can occur, for example during periods of prolonged westerly wind and especially near Birchington where some shelter against easterly waves is provided by the chalk cliffs.

There is little information about cross-shore transport in this area. Admiralty Chart 1607 indicates that the flat near-shore seabed is predominantly covered with sand and mud, however some nearshore deposits of gravel would provide good beach-building material if

(1) The cumulative movement of beach and nearshore sand perpendicular to the shore by the combined action of tides, wind and waves, and the shore-perpendicular currents produced by them.
(2) Ordnace Datum. The zero level from which heights on Ordnance Survey maps are measured, which is mean sea level at Newlyn in Cornwall.

Figure 4.11 Backshore Geomorphology and Managed Coastline along the Coastline of the TEDA MAREA Study Area



transported towards the shore (as is the case at Whitstable). However, no such transport mechanism has been observed and the shingle beaches suffer from a deficit in supply.

The Coastal Characterisation Report within Appendix H shows the beach cross-section profiles which were provided by the Channel Coastal Observatory. At Whitstable Street, the profile has a steep gradient to a break in slope at -1.5 m OD (the beach toe), beyond which there is a nearly horizontal platform 200m offshore, which is probably part of the Street itself. At Swalecliffe the beach is very narrow and the profile has a steep gradient with a beach toe of -1 m OD, about 25m offshore. At the western end of Reculver, beach toe is estimated at being between -1 m OD and -1.5 m OD. The extremely wide intertidal foreshore in this area tends to dissipate the incoming waves, so that significant wave action tends to be restricted to a short period during the higher states of the tide. The profiles at Birchington and west of Margate display the chalky seabed sloping steeply offshore.

4.3.6 Sediment Transport towards the Shore

The Southern North Sea Sediment Transport Study (HR Wallingford,2002)) indicates that there is no major supply of sediment to the coast from offshore and that the nearshore banks off this coast do not generally provide material for the beaches. However there is a transport pathway linking Goodwin Sands with Margate Sands along the North Kent coast, and an associated intermittent transfer towards the shore of sand from the Margate Hook sandbank (part of the Margate Sands complex) to the coastline in the vicinity of Minnis Bay, Isle of Thanet. In addition, erosion of the inter-tidal Kentish Flats provides fine sediment but little beach building material.

Recent research commissioned by The Crown Estate supports this study and suggests there is very little evidence of any broad connection between offshore seabed dynamics and the regional picture of foreshore steepening (Burningham and French, 2009). Whilst the Outer Thames is a vast sink for fine sediment, there is little transport of beach-forming sediment from offshore; sediment instead is transported alongshore by tidal currents, rather than seawards by weak wave activity.

Further details can be found in the TEDA Coastal Characterisation report within Appendix H.

4.4 METEOROLOGY AND OCEANOGRAPHY

4.4.1 Introduction

This section examines the meteorological and oceanographic characteristics in the MAREA area. It describes wind characteristics including direction and speed, and provides information on wave heights and tidal currents.

4.4.2 Sources of Information

Waves Studies by HR Wallingford (Appendix H)

The cumulative effects of aggregate dredging on wave conditions within the study area were assessed by HR Wallingford. Baseline information was used to inform this discussion of the physical environment within the MAREA study area.

Tidal Flows and Sediment Transport Study by HR Wallingford (Appendix H)

A study on the effects of changes in seabed bathymetry, arising from aggregate dredging, on tidal currents and on the transport of sediment over the seabed that is caused by these currents, was carried out by HR Wallingford. The baseline information in this study was used to inform this baseline chapter.

Anatec Navigation Assessment (Appendix I)

A review of navigational activities and risks in the Outer Thames was undertaken on behalf of TEDA by Anatec UK Ltd. This review provided some of the baseline meteorological information.

Other Information Sources

In addition to the sources mentioned above, the meteorology and oceanography section was informed by:

- London Array Limited. 2005. London Array Environmental Statement, Volume 1: Offshore Works. Prepared by RPS Energy.
- Norris, S. W., 2001. Near Surface Sea Temperatures in Coastal Waters of the North Sea, English Channel and Irish Sea – Volume II. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft.
- Joyce, A. E. 2006. The coastal temperature network and ferry route programme: long-term temperature and salinity observations. Sci. Ser. Data Rep., Cefas Lowestoft, 43: 129pp.
- EMU Ltd. Outer Thames Estuary Regional Environmental Characterisation Report No 09/J/06/1305/0870. Prepared for Marine Aggregate Levy Sustainability Fund (MALSF).

4.4.3 Wind Data

Winds in the study area are predominantly from the west and southwest. The predominant wind speeds throughout the year are moderate to strong breezes (6-13 m s^{-1}), with highest speeds occurring most frequently from November to March (ARGOSS, 2008) (Figure 4.12). The occurrence of wind speeds of Beaufort Force 8 gale force and higher (17-21 m s^{-1}) is relatively low (approximately 0.4% of the year) (London Array Limited, 2005).

The wind climate is closely linked with the North Atlantic Oscillation [(1)]. This has resulted in more westerly winds in recent decades, bringing warmer air and increased mixing within the North Sea (EMU Ltd, 2009).

4.4.4 Waves and Tidal Currents

In the deeper water areas of the Thames Estuary, including those where aggregate dredging is taking place, the direction of movement of sediments over the seabed is dominated by tidal currents. Wave action can increase the degree of transport by adding to the shear stresses at the seabed.

Waves are dominated by winds from the southwest and the northeast. The south-westerly winds generate short wave periods, and the north-easterly winds generate longer period waves as a result of the greater available fetch distance and the influence of swell waves from the northern North Sea and Atlantic (EMU, 2009).

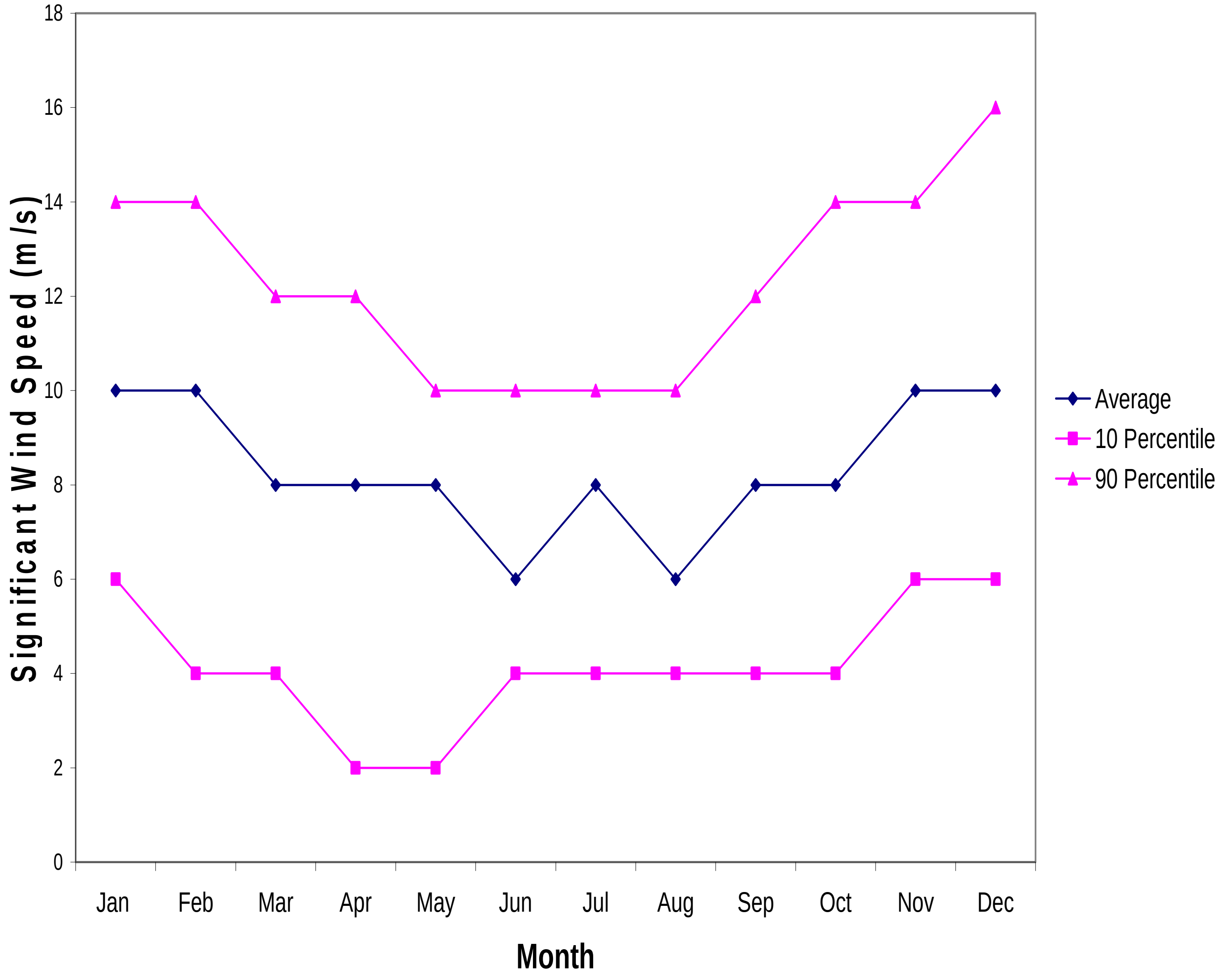
Wave height distribution from 1992 to 2007 is shown in Figure 4.123. (Argoss, 2008). Figure 4.14 shows the significant wave height exceedance curve for the MAREA area (Anatec,2009). The occurrence of wave heights greater than 4 m is low (approximately 0.4%).

The tidal amplitude in the region increases from north to south and increases as the tide travels into the narrower and shallower parts of the estuary, ie from east to west. Mean Spring tide ranges from 2.3 m at Orfordness to 4.6 m at Brightlingsea, and from 4.3 m at Margate to 5.2 m at Sheerness (HR Wallingford, 2008). This shows that the tidal range is smaller in the north than the south and increases with distance up the estuary.

Tidal flows are rectilinear (ie they travel in opposite directions on ebb and flood tides), and are affected by and in turn affect, the large sandbanks in the west of the study area (see Section 4.2.4). The currents in the region are dominated by tidal flow. They are stronger in the channels that separate these banks and are generally constrained to flow parallel to the banks. Figure 4.15 shows the main axis for tidal flows is to the southwest during the flood phase and to the north-east during the ebb phase. Surface current charts presented by the admiralty indicate that current speeds peak at 1.36 m s^{-1} on the flood and 1.41 m s^{-1} on the ebb (EMU,2009).

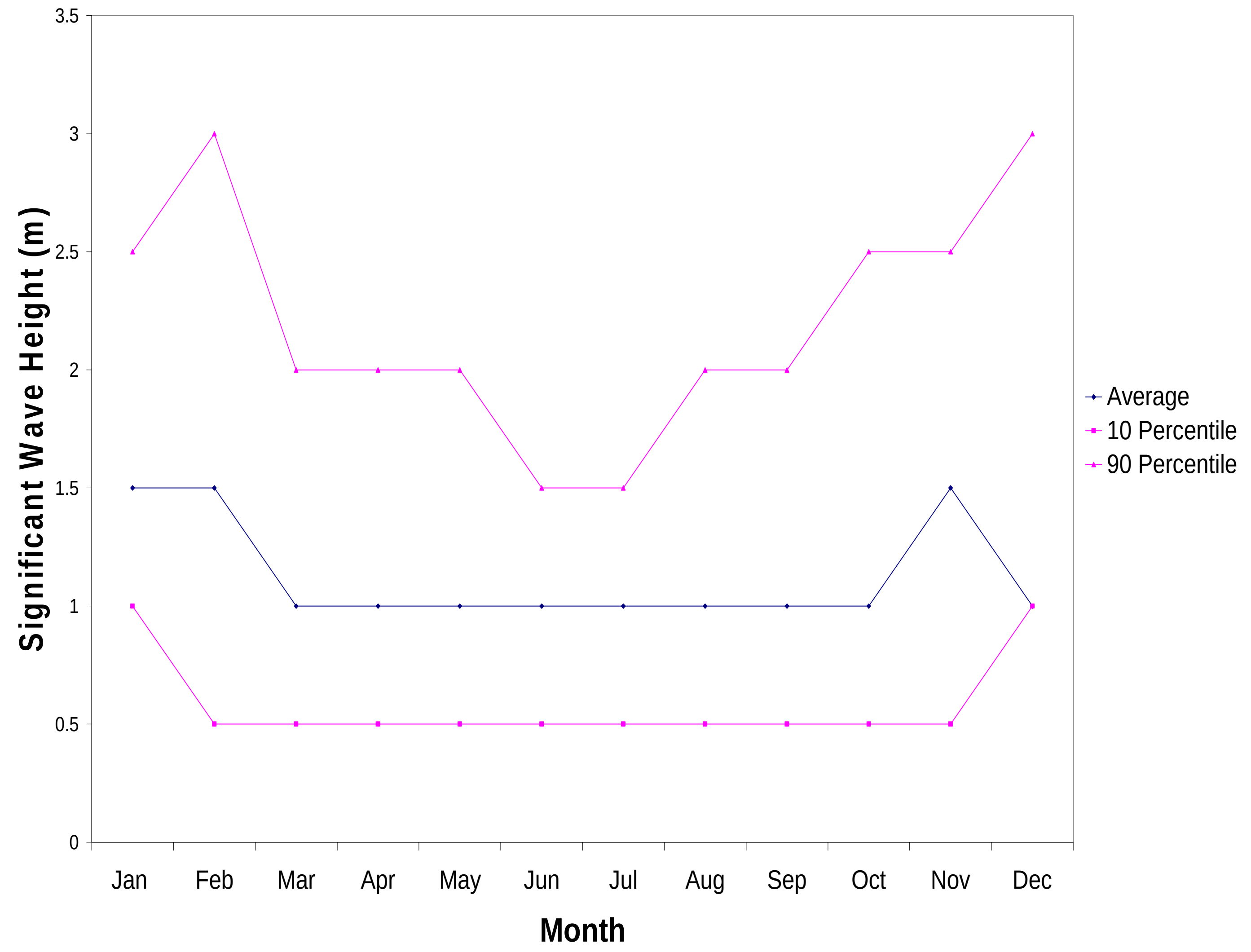
(1) The North Atlantic Oscillation (NAO) is a large-scale pattern of natural climate variability caused by east-west oscillation motions of the Icelandic low and the Azores high, which controls the strength and direction of westerly winds and storm tracks across the North Atlantic, especially Europe.

Figure 4.12 Average Monthly Wind Speed Distribution in the Outer Thames Estuary 1992-2007



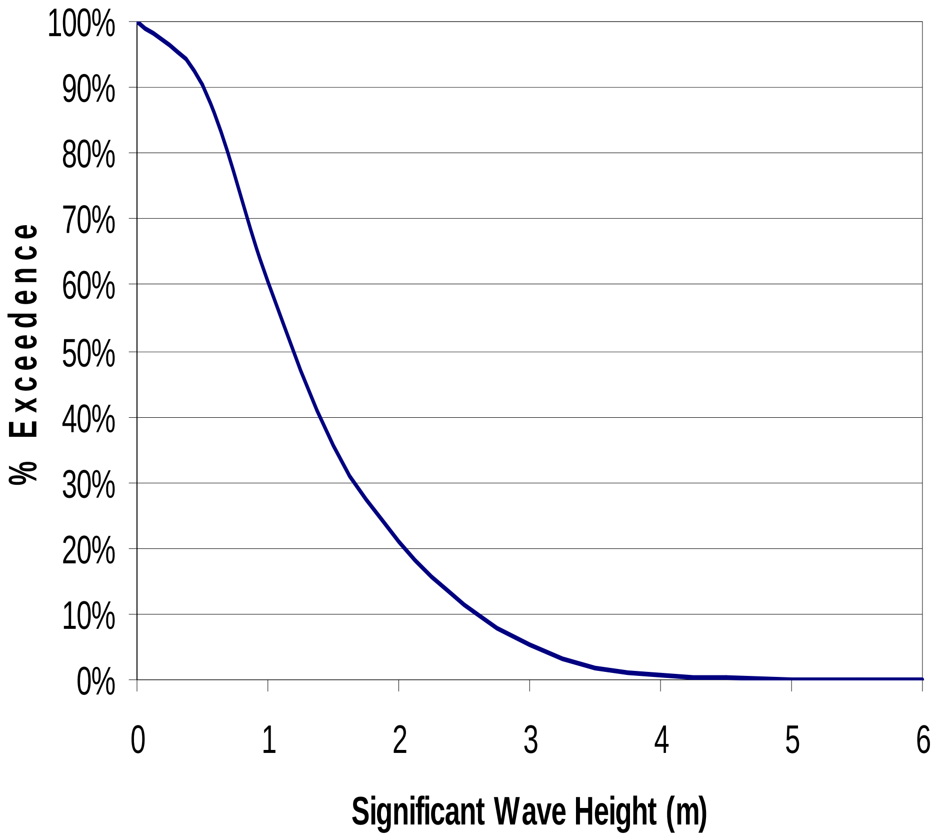
Source: www.waveclimate.com (2008).

Figure 4.13 Average Monthly Wave Height Distribution in the Outer Thames Estuary



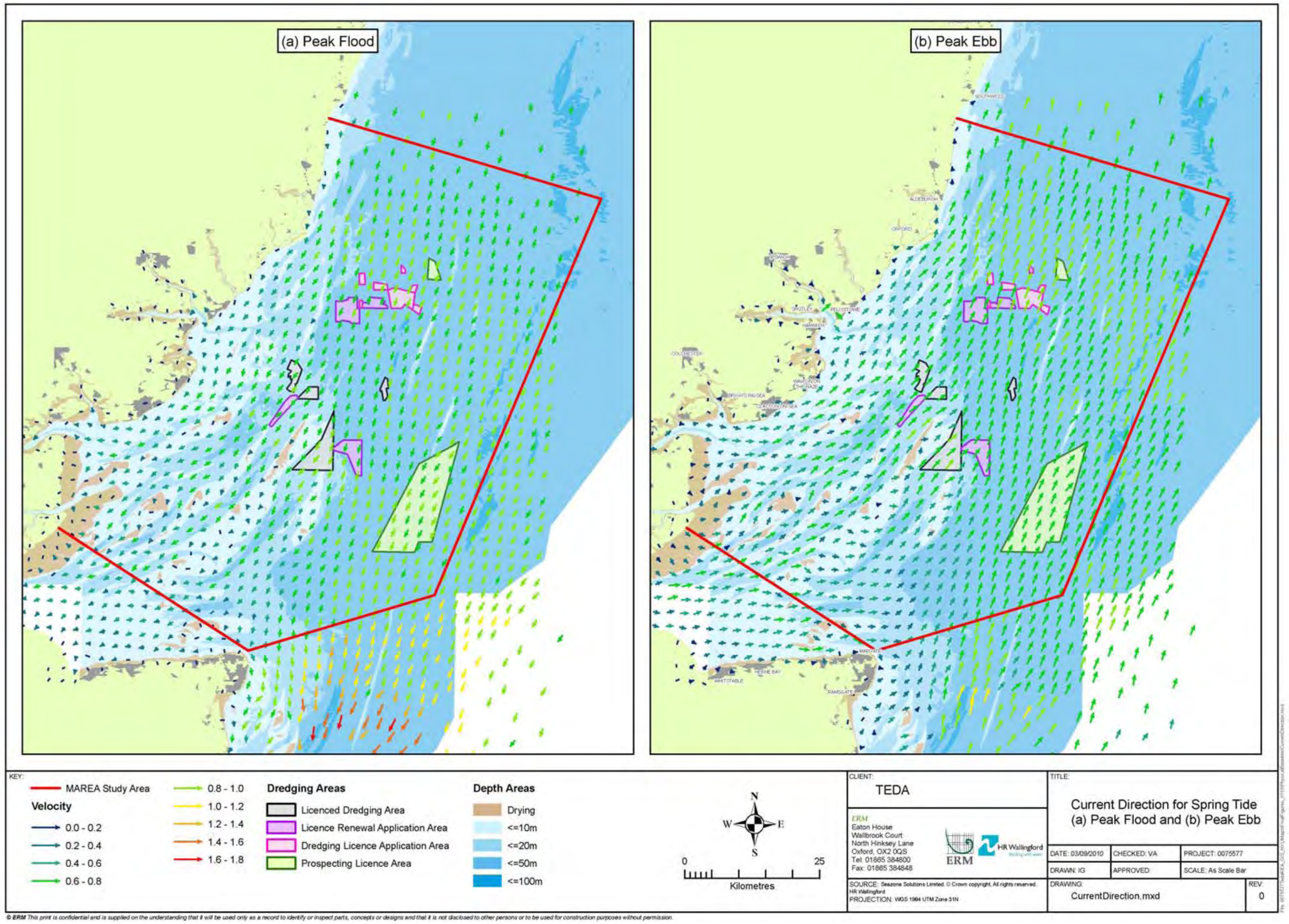
Source: www.waveclimate.com (2008).

Figure 4.14 Significant Wave Height Exceedance Curve



Source: Appendix I Navigation Assessment

Figure 4.15 Current Direction for Spring Tide (a) Peak Flood and (b) Peak Ebb



4.5 Characteristics and Quality of Water and Sediment in the Study Area

4.5.1 Introduction

This section contains information on the water and sediment characteristics and quality in the MAREA area. The water characteristics discussed are temperature and salinity, while suspended sediments, nutrients and dissolved oxygen indicate water quality. Sediment size distribution and organic matter content (both of which are often linked with high silt content tending to correspond with high organic matter content) are both examined. Concentrations of the following seven metals are compared to Canadian sediment quality standards: arsenic, cadmium, chromium, copper, lead, mercury, zinc. Hydrocarbon concentrations (particularly fluoranthene) are also included in this section.

Prior to 1800, the River Thames supported a large number of fish species indicating that water quality was good (Marine Environment Monitoring Programme, 2004). However in the nineteenth and twentieth centuries water quality drastically decreased as large volumes of sewage and industrial effluent were released into the Thames. By the 1950s, the level of pollution in the estuary had reached a level where the middle sections of the estuary were anoxic [(1)] for most of the summer and there were no established fish populations within a 70 km stretch of the river.

In the 1960s, sewage treatment works (STWs) along the Thames were improved and industrial effluents were diverted through the STWs which improved water quality, and therefore sediment quality, in the Thames Estuary and prevented anoxic conditions developing in the summer. Subsequently, the conditions in the Thames have improved to such an extent that many species of fish have returned including breeding populations of rare species such as the river lamprey and twaite shad (see Section 5.3 for details). The water and sediment quality in the Thames Estuary therefore also has knock-on effects for other species in the wider region such as birds and marine mammals. Today the Thames estuary is considered one of the cleanest metropolitan estuaries in Europe.

(1) Without oxygen.

The following beaches in Suffolk, Essex and Kent were awarded Blue Flags in 2009 for their good water quality (www.blueflag.org.uk, 2009):

- Brightlingsea;
- Clacton-on-Sea, Martello Bay;
- Dovercourt Bay;
- East Beach, Shoeburyness;
- Shoeburyness Common Beach;
- Three Shells Beach;
- Felixstowe South;
- Minnis Bay;
- St Mildred's Bay, Westgate;
- Tankerton;
- Walpole Bay, Margate; and
- West Bay, Westgate.

4.5.2 Sources of Information

The following sources were consulted to inform the water characteristics and water quality section:

- Franklin, A. & Jones, J. 1995. Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1993. Aquatic Environment Monitoring Report, MAFF Directorate of Fisheries Research, Lowestoft (44), 68 pp.
- Jones, J. and Franklin, A. 1998. Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1995-1996. Aquatic Environment Monitoring Report No. 51. Cefas, Lowestoft, 118 pp.
- Jones, J & Franklin, A. 2000. Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1997. Aquatic Environment Monitoring Report No. 52. Cefas, Lowestoft, 92 pp.
- Jones, J., and Irish, R. 2001. Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea, 1998. Aquatic Environment Monitoring Report No. 53. Cefas, Lowestoft, 92 pp.
- Irish, R. 2003. Monitoring of the quality of the marine environment, 1999- 2000. Aquatic Environment Monitoring Report No. 54. Cefas, Lowestoft, 98 pp.
- Law, R., Hustwayte, J. and Sims, D. 2003. Monitoring of the quality of the marine environment 2000-2001. Aquatic Environment Monitoring Report No 56: 38 pp.
- Joyce, A. E. 2006. The coastal temperature network and ferry route programme: long-term temperature and salinity observations. Sci. Ser. Data Rep., Cefas Lowestoft, 43: 129pp.

The following sources provided information on sediment in the region and the appropriate standards:

- Franklin, A. & Jones, J. 1995. Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1993. Aquatic Environment Monitoring Report, MAFF Directorate of Fisheries Research, Lowestoft (44), 68 pp.
- CCME. 2001. Canadian sediment quality guidelines for the protection of aquatic life: summary tables. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
- Habitats Directive Technical Advisory Group on Water Quality (HDTAGWQ). 2001. Interim guidance on Sediment Quality Guidelines for use in the assessment of the potential impact of chemicals detected in sediments at SAC/SPA sites. Prepared by Helen Wilkinson.
- Norris, S. W. 2001. Near Surface Sea Temperatures in Coastal Waters of the North Sea, English Channel and Irish Sea – Volume II. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft.
- Spencer, K.L. & MacLeod, C.L. 2002. Distribution and partitioning of heavy metals in estuarine sediment cores and implications for the use of sediment quality standards. Hydrology and Earth Systems Sciences, 6(6) 989-998.

- HR Wallingford, CEFAS, UEA, Posford Haskoning and D'Olier, B. 2002. Southern North Sea Sediment Transport Study, Phase 2. Sediment Transport Report. Report EX 4526. August 2002.

- National Marine Monitoring Programme Working Group. 2004. UK National Marine Monitoring Programme - Second Report (1999-2001). Marine Environment Monitoring Group available at http://www.jncc.gov.uk/pdf/nmmp2ndreport.pdf (accessed 25/03/09).

- ABP MER Ltd. 2005. London Array Offshore Wind Farm: Coastal Processes Investigation Appendix I: Sediment Quality. On behalf of London Array Limited.

- Emu Ltd. 2009. Outer Thames Estuary Regional Environmental Characterisation. On behalf of the Marine Aggregate Levy Sustainability Fund (MALSF).

Information from the TEDA benthic survey (Appendix J) on particle size analysis and the organic content of sediment was also included, however a more detailed discussion of these results is provided in Section 5.2.

There are currently no sediment quality guidelines for assessing the environmental quality of in situ sediments in the UK. However, the Habitats Directive Water Quality Technical Advisory Group (WQTAG) (Helen Wilkinson, 2001) determined that, in the absence of such guidelines in England and Wales, it is appropriate to use guidelines that have been developed and used elsewhere. The WQTAG's approach is to use the Canadian Council for Ministers of the Environment's (CCME) Interim Sediment Quality Guidelines (ISQGs) (CCME, 2001). The Canadian approach involves the derivation of Threshold Effect Levels (TELs), also referred to as ISQGs, affecting the most sensitive species, and Probable Effect Levels (PELs), likely to affect a range of organisms.

In addition to general information on the quality of the Thames Estuary itself, data from other estuaries in the study area, and data from surveys within the study area have been used to describe the characteristics of water and sediments within the Outer Thames Estuary region.

Data from the Marine Environment Monitoring and Assessment National Database (MERMAN) (formerly the National Marine Monitoring Programme) on metal and hydrocarbons in sediments from estuaries near the study area have been reviewed. This database has been created to support the Clean and Safe Seas Evidence Group (CSSEG) which monitors the chemistry and biology of UK waters [1]. Data on the concentration of metals within sediments from the three stations in the vicinity of the study area have been used to give an indication of the likely concentration of metals within sediments in the study area; one in the Thames Estuary, one in the Blackwater Estuary and another in the River Medway.

Information from the TEDA benthic survey (see Appendix J) on particle size analysis and the organic content of sediment has also been analysed.

4.5.3 Water Characteristics

Temperature

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) has co-ordinated the regular recording of near-surface sea temperatures since the 1960s including six stations within the inner parts of the Thames Estuary (stations 11-17) and four within the Outer Thames Estuary (stations 8-10) (Norris, 2001). Coastal sea temperatures have been recorded approximately 6 to 12 times per month, usually at a time close to high water. Figure 4.16 presents the monthly mean water temperature at each station for the years for which data were collected, showing a minimum mean winter temperature of 4.3˚C in February at Lowestoft, and a maximum mean summer temperature of 20.9˚C in August at Littlebrook Power Station.

Salinity

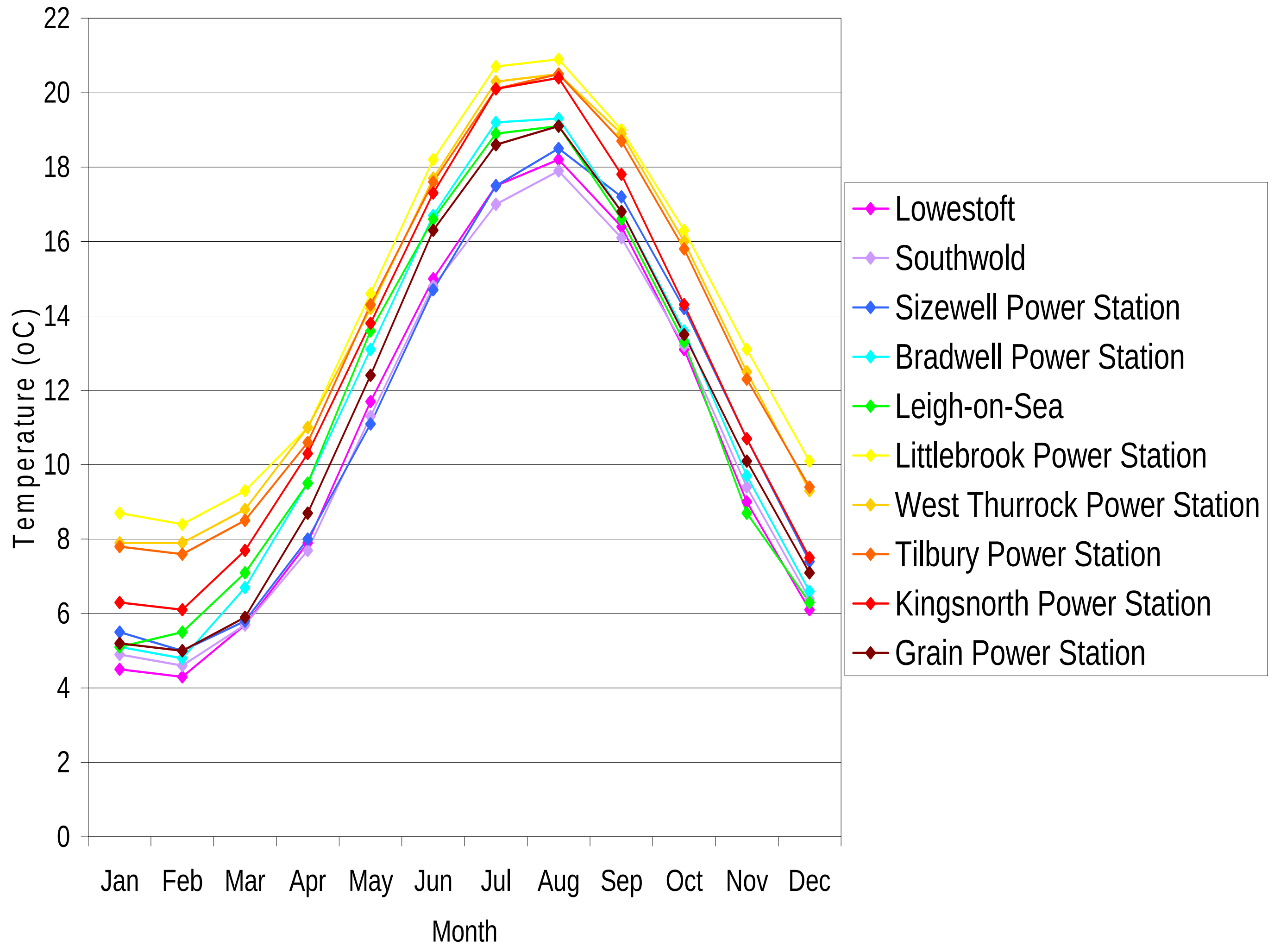
Levels of salinity in the North Sea are driven by the input of seasonal freshwater from estuaries, and by the inflow of Atlantic water. The Outer Thames remains relatively well mixed throughout the year due to the shallow water depths and the fast rate of tidal flow (EMU Ltd, 2009).

(1) The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Cefas has monitored salinity in the North Sea every month since August 1970 from samples collected by ferries, the most recent being the *Stena Partner*, along 52ºN between Harwich and Rotterdam (Joyce, 2006). The average salinity recorded in the North Sea at 52°N from 1971-2004 was approximately 34.3 ppt [2]. Figure 4.17 gives the average monthly salinity values along the transect during this period.

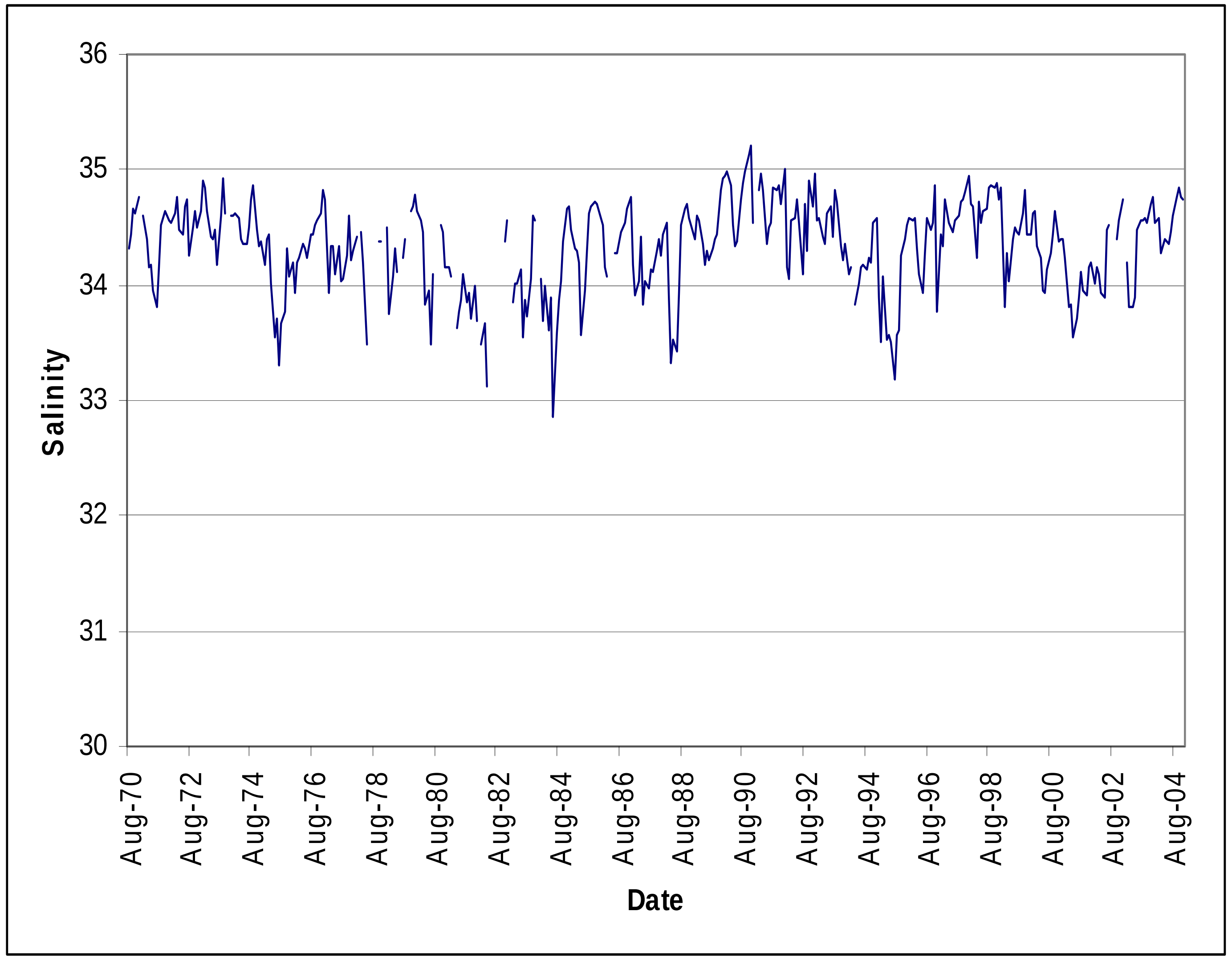
(2) The average does not include data from the position nearest Rotterdam as these values were much fresher and are not representative of the rest of the North Sea.

Figure 4.16 Monthly Mean Water Temperature at CEFAS Monitoring Stations in the Outer Thames Estuary



Source: Norris, S. W. 2001.

Figure 4.17 Average Salinity along ferry transect from Harwich-Rotterdam at 52° N, 1970-2004



Joyce, A. E. 2006. The coastal temperature network and ferry route programme: long-term temperature and salinity observations. Sci. Ser. Data Rep., Cefas Lowestoft, 43: 129pp.

Suspended Sediments

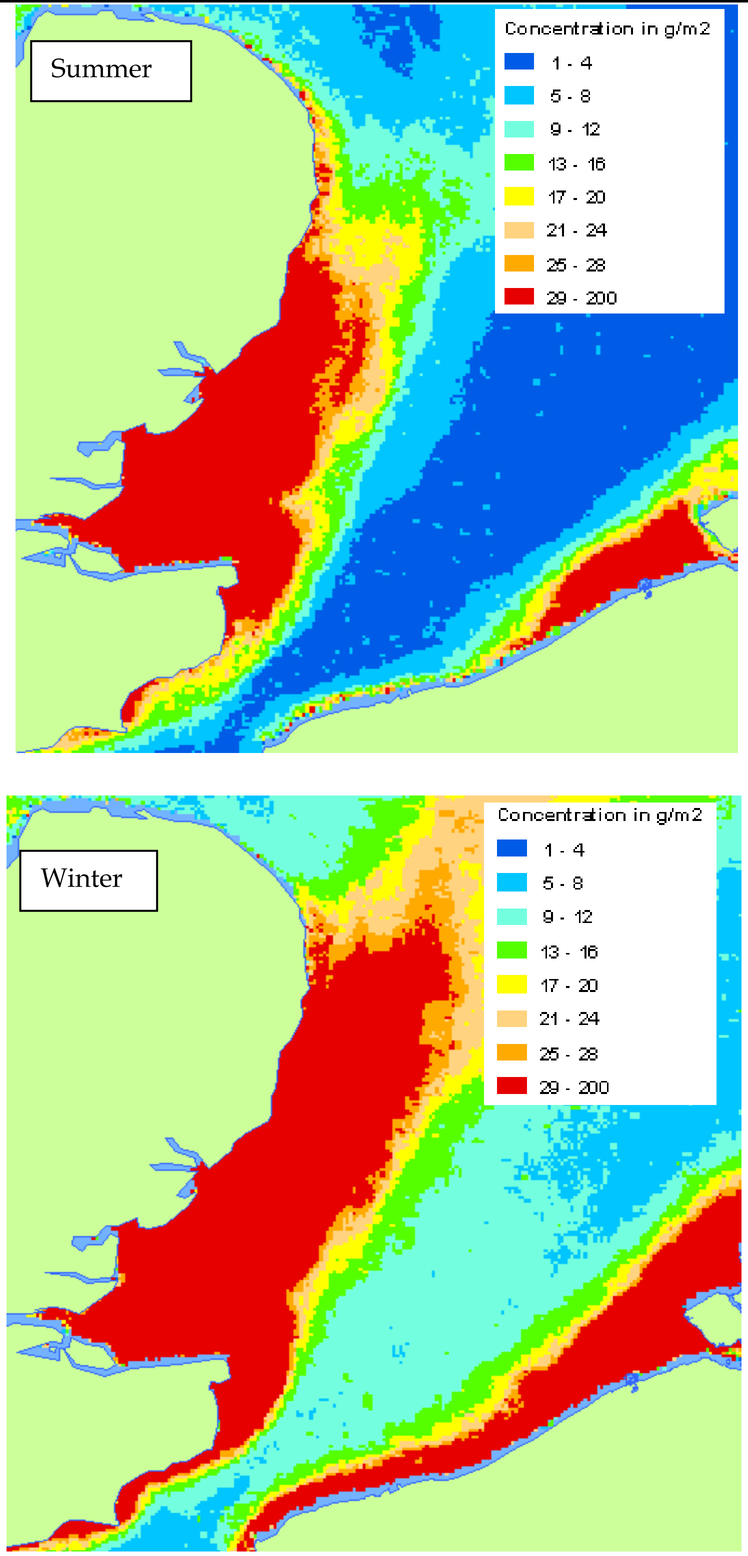
Up to 700,000 tonnes of fine sediments from the River Thames are discharged per year at the mouth of the estuary (HR Wallingford, 2002) and Orford Ness is a source of high sediment concentrations. The spring tidal currents in the Outer Thames are capable of suspending and transporting sediment of 0.5-2.0mm diameter and occasional extreme storm events can mobilise larger particles (EMU Ltd, 2009). Figure 4.18 shows that from an aerial view, the waters of the Thames Estuary take on various shades of tan, gold and green as sediments filter out from the Thames and into the North Sea (Earth snapshot, 2010).

Suspended sediment concentrations tend to be higher in estuaries than offshore; recent measurements by Emu Ltd (2008) indicate nearshore concentrations of 0.2-977 mg l^{-1} and offshore concentrations ranging from 1.7-219 mg l^{-1} to the north of the study area. Figure 4.19 from the online North Sea Atlas (North Sea Atlas, 2010) shows that suspended sediment concentrations in the Outer Thames are frequently greater than 29 g m^{-2}.

Figure 4.18 Aerial Photograph showing Suspended Sediments in the Outer Thames

Source : Earth Snapshot. Sediments near English Channel. Available at: www.eosnap.com/?p=7153 (accessed 02/02/10).

Figure 4.19 Suspended Sediment Concentrations in Summer and Winter



Nutrients

The results of monitoring by Cefas in the winters [1] of 1993, 1995-1998 and 2000-2001 [2] showed that the levels of total oxidised nitrogen (TOxN) were the second highest in the UK after the Severn Estuary compared to other UK rivers, ranging from 22.5 – 89.86 µmol l^{-1}. The surveys also found high levels of ammonium (0.78-2.5 µmol l^{-1}), phosphate (0.5-4.10 µmol l^{-1}), silicate (10.0-16.62 µmol l^{-1}) and chlorophyll (1.2-1.56 µg l^{-1}) (compared with chlorophyll concentrations in locations in the UK in winter which are low due to the lack of phytoplankton production).

Nutrients levels tend to be high in areas close to major riverine inputs, as is the case in the Thames estuary, and decrease with increasing distance offshore. It is expected that the concentration of silicate, assuming no biological uptake in the estuary, reflects the magnitude of freshwater discharge to the area. Higher chlorophyll concentrations are associated with higher ammonium concentrations; the latter is identified as a preferential nutrient for phytoplankton [3].

Dissolved Oxygen

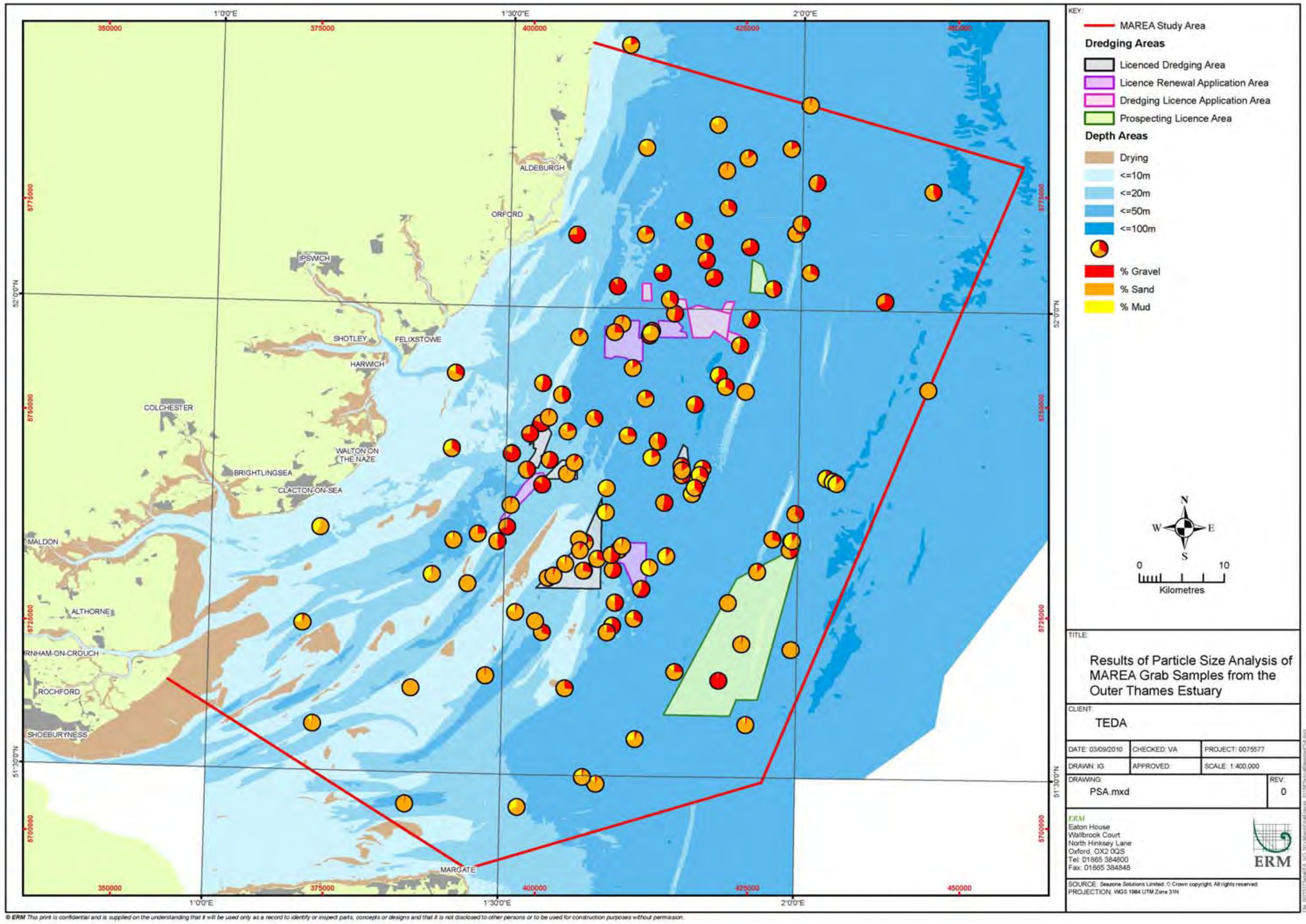
High levels of dissolved oxygen (approximately 6-7 mg l^{-1}) recorded by the Cefas monitoring programmes indicate that oxygen demand is low and that water mixing in the region is good [4].

4.5.4 Sediment Characteristics

Particle Size Distribution

Sediments from the MAREA area were collected by the Institute of Estuarine and Coastal Studies (IECS) and Particle Size Analysis (PSA) was undertaken. Sediment characteristics were found to be highly variable across the area.

Figure 4.20 Results of Particle Size Analysis of MAREA Grab Samples from the Outer Thames Estuary



(1) Nutrient concentrations were measured in the winter when, arguably, biological impact on the measured concentration is minimal.

(2) See references for Aquatic Environment Monitoring Reports 44, 51, 52, 53 and 56 listed in source of information.

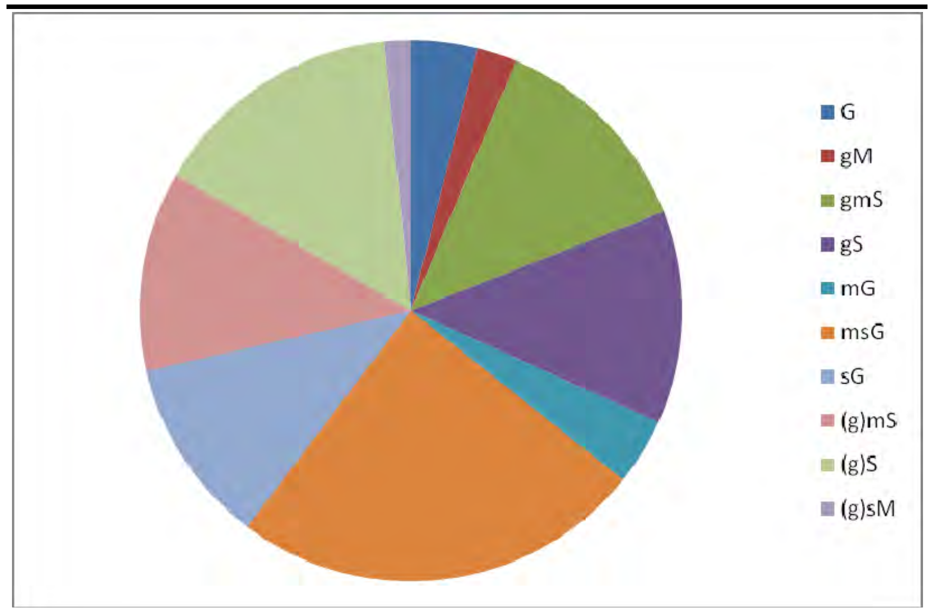
(3) See references for Aquatic Environment Monitoring Reports 44, 51, 52, 53 and 56 listed in sources of information.

(4) See references for Aquatic Environment Monitoring Reports 44, 51, 52, 53 and 56 listed in sources of information.

The results of the PSA show that in general the sediments in the south and the northernmost parts of the study area are mostly sand with a higher gravel content across the licence areas. A greater proportion of mud is present in samples to the east of the study area in the deeper offshore waters as well as in the centre of the study area (Figure 4.20). Muddy sandy gravel (msG) was the most frequently sampled sediment type and occurred at 25% of the sampling stations (Figure 4.21).

Figure 4.22 and Figure 4.23 detail the composition of the sediment grab samples according to the classification by (Folk, 1954). Figure 4.22 displays the result of the particle size analysis data and shows the majority of samples are predominantly sand and gravel. Figure 4.23 shows the results from subsamples <1 mm grain size which were analysed using laser particle size analysis (see Appendix J). The majority of this component of each sample was classified as being sand, silty sand or sandy silt.

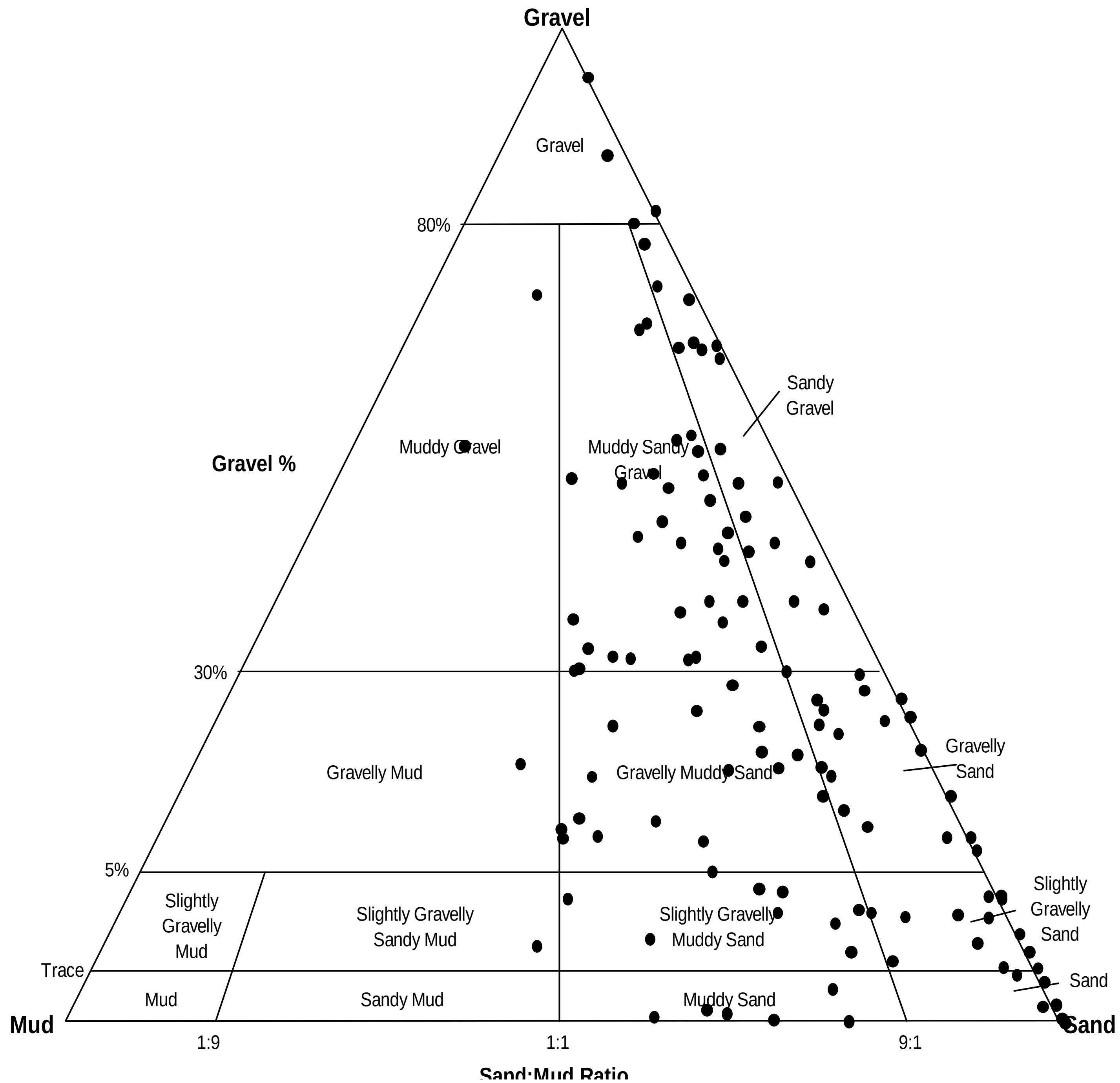
Figure 4.21 Proportional Representation of each Sediment Type in all MAREA samples



Source: Appendix J.

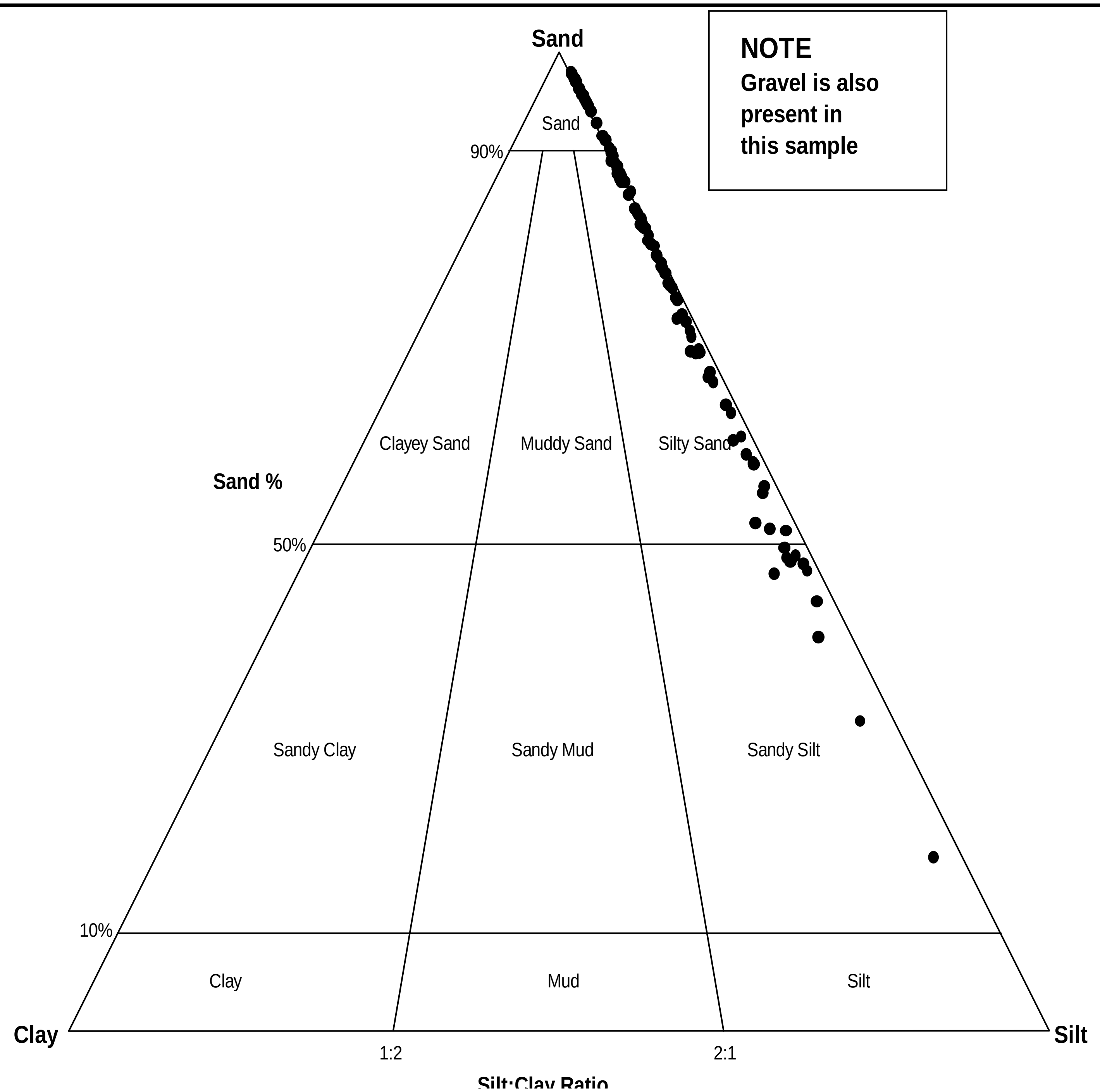
Overall, finer sediments were located to the south of the survey area and coarser sediments towards the central and northern areas. Finer-grained cohesive sediments are associated with a risk of increased chemical contamination due to the larger surface area per unit weight for contaminants to bind to the sediment.

Figure 4.22 Composition of the Outer Thames seabed in terms of Gravel, Sand and Mud



Source: Appendix J.

Figure 4.23 Composition of the <1mm Component of Samples in terms of Sand, Silt and Clay



Organic Matter

Organic content ranged from below detection to 5.81% (Figure 4.24). The sediment types were variable at the sites with the highest organic content values, whilst the sites with the lowest organic content were similar in sediment type, consisting of slightly gravelly sand, muddy sandy gravel and gravelly muddy sand.

4.5.5 Concentrations of Contaminants in Water and Sediments

Introduction

There is very little available literature on water quality in the Outer Thames Estuary. However, the Ministry of Agriculture, Fisheries and Food (MAFF), the role of which is now performed by Cefas, conducted monitoring of some non-radioactive contaminants in the aquatic environment in 1993 in order to monitor the disposal of wastes at sea. MAFF published the results in 1995 (Franklin *et al*, 1995) providing details of dissolved trace metals from two sampling stations in the River Thames: West Thurrock and Mucking (Figure 4.25). The Aquatic Environment Monitoring Report Series has not monitored concentrations of dissolved trace metals in sea water in the Thames estuary since this report was published in 1995.

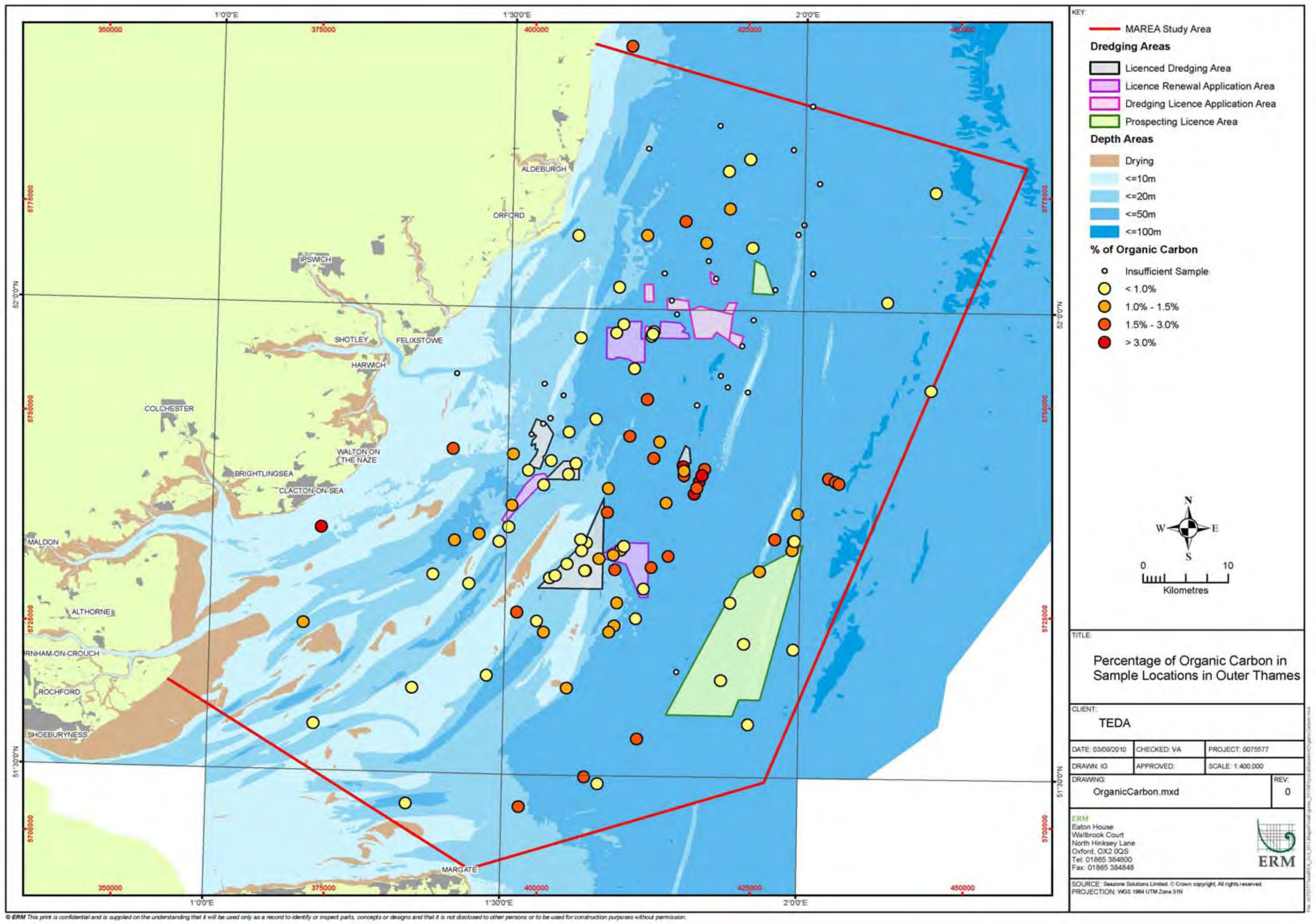
Table 4.2 below gives the concentrations of dissolved trace metals that were recorded by MAFF during this survey.

Table 4.2 Concentrations of dissolved trace metal in sea water samples from the River Thames, 9 June - 1 July 1993

Trace Metal Concentration (µg l^{-1})	Thames (West Thurrock)	Thames (Mucking)
Cadmium	0.086	0.054
Copper	4.37	2.18
Manganese	6.58	2.63
Nickel	4.59	2.01
Lead	1.143	0.328
Zinc	13.00	4.61
Cobalt	0.148	0.075

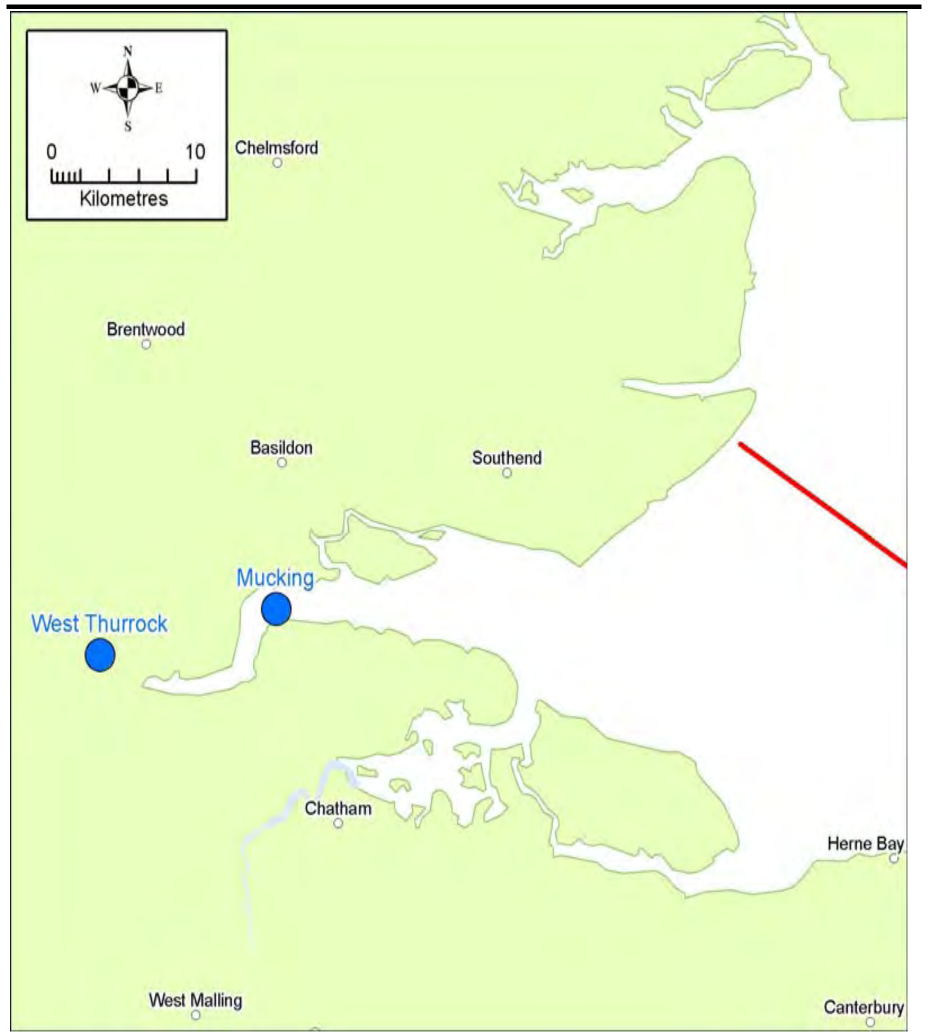
Source: Franklin, A. & Jones, J. 1995.

Figure 4.24 Percentage of Organic Carbon in Sample Locations in Outer Thames



Source: Adapted from Appendix J.

Figure 4.25 Location of West Thurrock and Mucking Sampling Stations

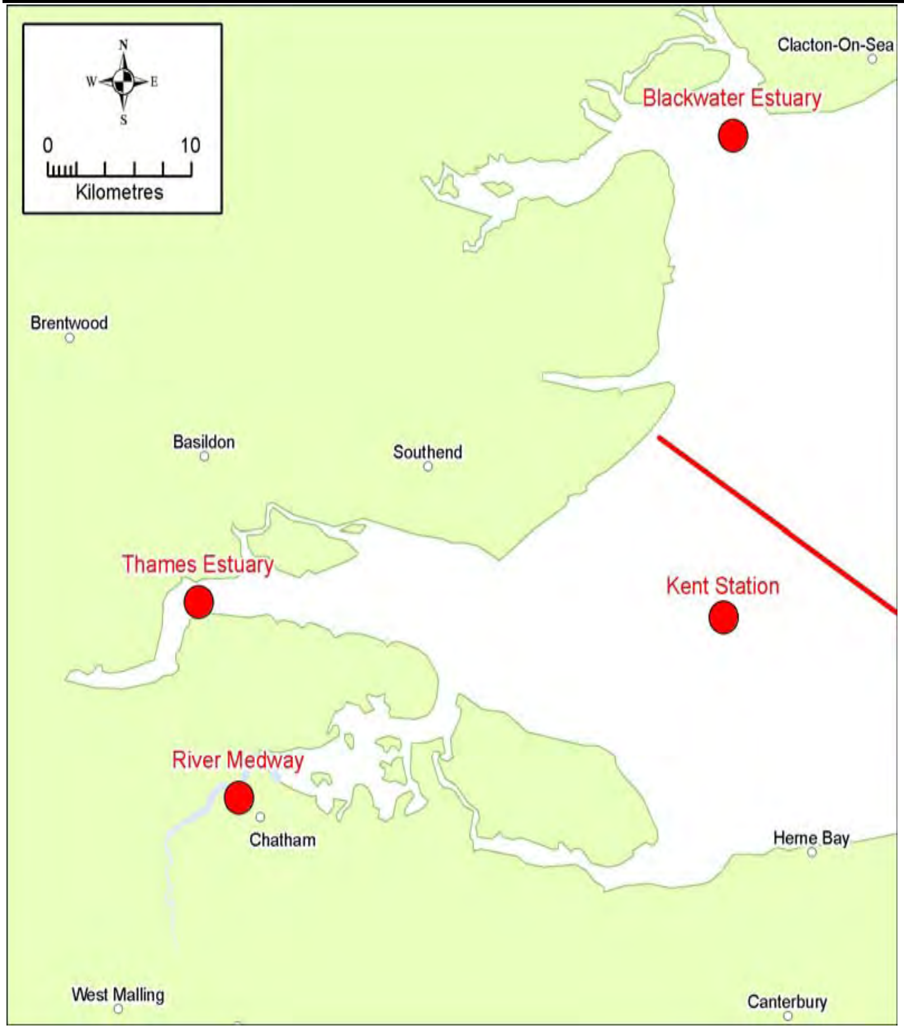


Note: the red line depicts the edge of the MAREA study area.
Source: SeaZone Solutions Ltd and The Crown Estate Projection: WGS 1984 UTM Zone 31N

Data from the Marine Environment Monitoring and Assessment National Database (MERMAN) (formerly the NMMP) on metal and hydrocarbons in sediments from three estuaries near the study area have been reviewed (Figure 4.246). In general, research suggests the concentration of metals in sediments is highest in estuaries and coastal areas (Franklin *et al*, 1995). This points to land based sources of metal contaminants as significant sources of metals in marine sediments in the study area. The Blackwater Estuary is situated in the northern part of the Outer Thames and has been subject to inputs of contaminants from urban run-off and sewage treatment works.

The River Medway enters the Thames Estuary at Sheerness in Kent. Historically it has received contamination from dockyards, a pesticide plant, paper and chemical industries, timber treatment plants and several sewage treatment works (Spencer *et al*, 2002).

Figure 4.26 MERMAN Sediment Sampling Stations for Metals and Hydrocarbons



Note: the red line depicts the edge of the MAREA study area.
Source: SeaZone Solutions Ltd and the Crown Estate
Projection: WGS 1984 UTM Zone 31N

Arsenic in Sediments

Elevated concentrations of arsenic have been reported by numerous studies on the water quality of the Outer Thames Estuary in comparison with other coastal areas (Whalley *et al*, 1999; Millward *et al*, 1997; Port of London Authority, 2004). Arsenic enters the Thames from riverine inputs, sewage effluents, and industrial sources. Certain areas are reported as having particularly high levels including the former disposal sites of Black Deep and Barrow Deep where arsenic-rich industrial waste was dumped. Black Deep received dredged material from the River Thames and its docks (capital and maintenance dredging spoil) until its closure in the late 1960s, whilst Barrow Deep was used for the disposal of sewage sludge between 1967 to the late 1990s when sea disposal was banned (Port of London Authority, 2004).

Data from MERMAN does not show any exceedance of the Canadian PEL [(1)] standard for arsenic (41.6 mg kg^{-1}) at the three estuarine sampling locations that are close to the study area (Figure 4.27). The River Medway has historically had the highest concentrations of arsenic in sediments but levels have declined in recent years. The level of arsenic at the Blackwater Estuary has increased in the last two years of data collection to a level comparable to the River Medway between 2001 and 2005. Whilst all the arsenic levels recorded exceed the Canadian ISQG levels [(2)], they are much lower than the PEL value.

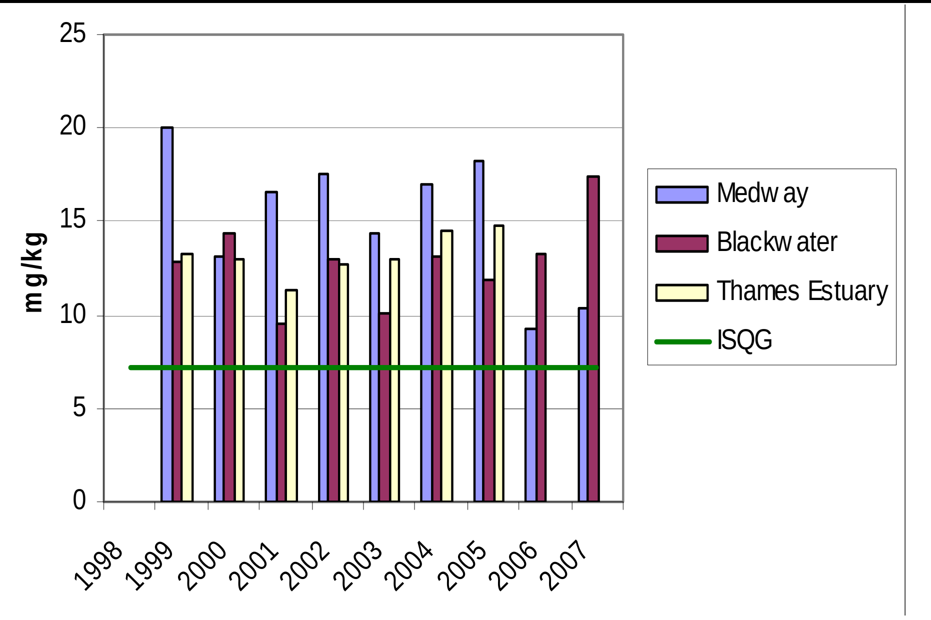
Cadmium in Sediments

Surveys conducted from 1984-1987 found elevated concentrations of cadmium in a few of the samples taken from the Outer Thames Estuary (Franklin *et al*, 1995) which were thought to be a result of sewage sludge and dredged spoil at Barrow Deep and South Falls disposal grounds.

More recently, as part of long term monitoring of contaminants in coastal waters, Cefas published a report in 2000 of monitoring work conducted in 1997 (Franklin, 2005). This report indicated that at the time there were high cadmium concentrations in the Thames but lower concentrations offshore.

(1) The upper value, referred to as the Probable effect level (PEL) is the level above which adverse effects are expected to occur frequently.
(2) Interim marine sediment quality guideleines (ISQGs) represent the concentration below which adverse biological effects are expected to occur rarely.

Figure 4.27 Arsenic Levels (1999-2007)



The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

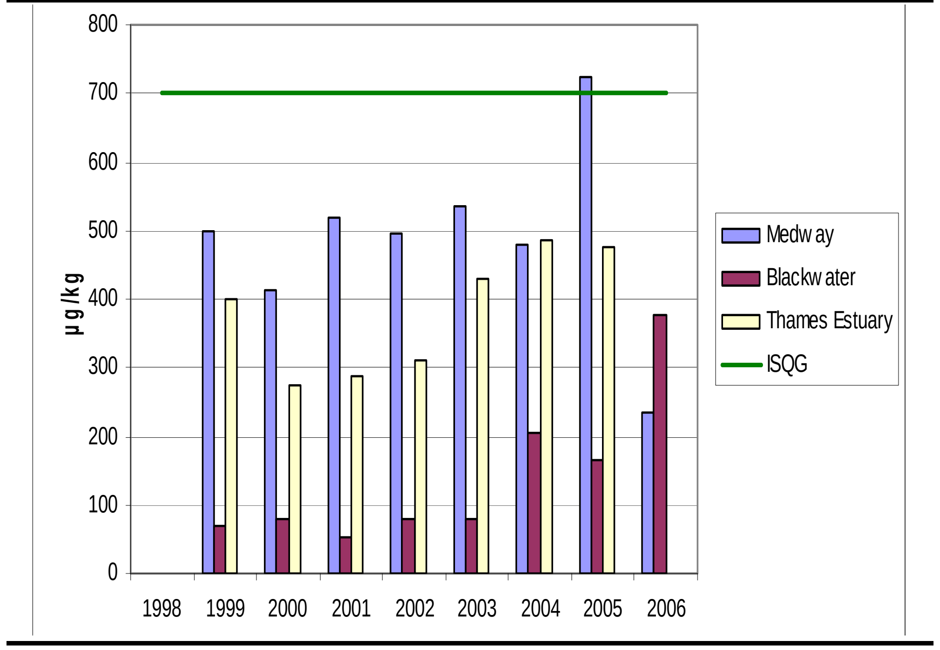
Data from MERMAN found no exceedance of the PEL for cadmium and the majority of samples were well below the ISQG of 700 µg kg^{-1} (Figure 4.28). The only exceedance of the ISQG occurred at the River Medway in 2005 when a value of 723.8 µg kg^{-1} was recorded.

Samples taken from the River Medway are much higher in cadmium concentration levels than the Blackwater Estuary. This trend appears to have been changing in recent years with an increase in cadmium levels in Blackwater and a much lower recorded level of cadmium at Medway in 2006 (Figure 4.28).

Chromium in Sediments

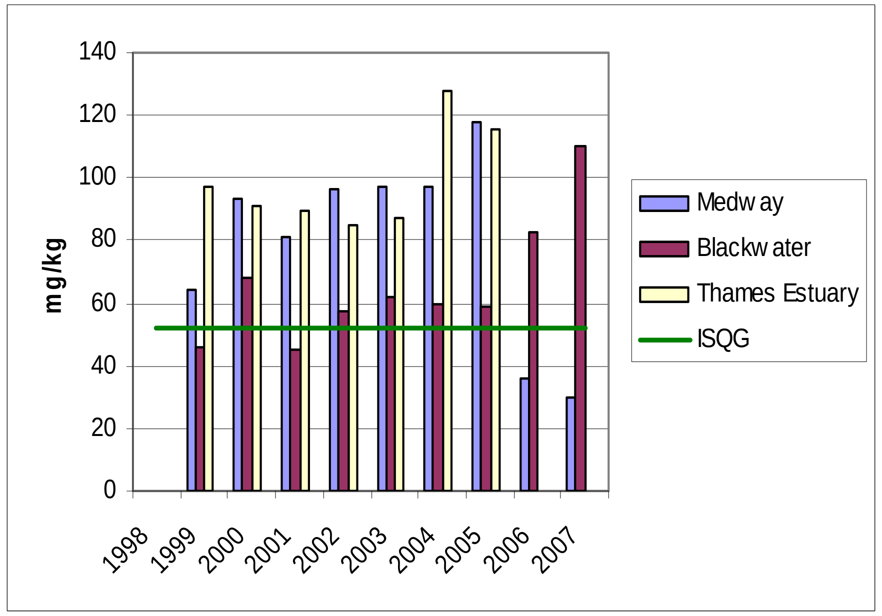
There are no recorded exceedances of the PEL for chromium in the MERMAN data (Figure 4.29) but the majority of samples for all three sites are above the ISQG. The data show a large increase in concentrations in 2006 and 2007 which is not in accordance with the relatively consistent levels seen prior to 2006. The reason for this increase is not clear. The levels of chromium in the River Medway have decreased significantly in 2006 and 2007. This comparatively large decrease in chromium level is also difficult to interpret.

Figure 4.28 Cadmium Levels (1999-2006)



The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Figure 4.29 Chromium Levels (1999-2007)

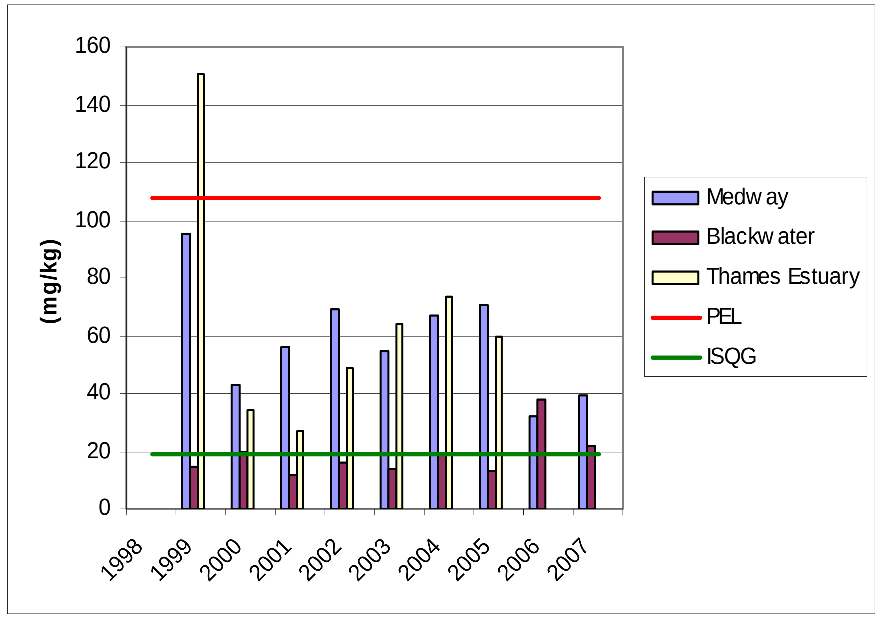


The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Copper in Sediments

The Thames Estuary is known to have elevated copper levels which are thought be the result of industrial sources (Franklin *et al*, 1995). However, the data from MERMAN suggests that these levels have reduced dramatically in recent years (Figure 4.30). The only exceedance of the PEL (108 mg kg^{-1}) for copper was in 1999 for the Thames Estuary. There have been no further exceedances since then. Copper levels in sediments at the Blackwater Estuary are generally very low and are mostly at or below the ISQG for copper (18.7 mg kg^{-1}). Samples of sediment from the Thames Estuary and Medway River are similar through the years and are greater than the ISQG but below the PEL for copper.

Figure 4.30 Copper Levels (1999-2007)



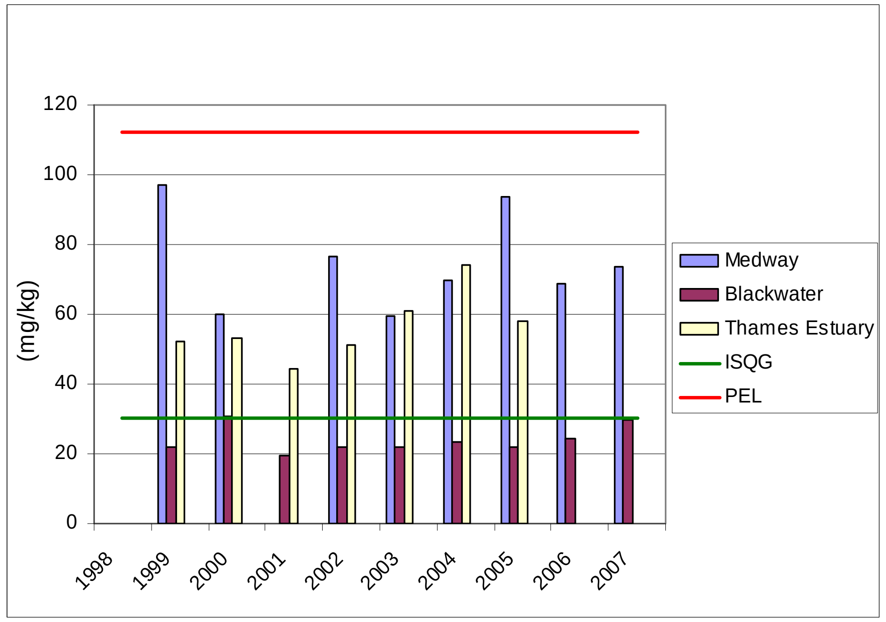
The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Lead in Sediments

No exceedances of the PEL (112 mg kg^{-1}) for lead have been recorded in the MERMAN data at any of the sediment quality sampling stations (Figure 4.26). Samples from Blackwater Estuary were consistently below the ISQG (30.2 mg kg^{-1}) for lead. Samples from the River Medway and the Thames Estuary have exceeded the ISQG between 1999 and 2007 but were generally much lower than the PEL value (Figure 4.31).

Cefas monitoring in the region (Jones *et al*, 2000) has indicated that there are high levels of lead in the vicinity of Barrow Deep.

Figure 4.31 Lead Levels (1999-2007)



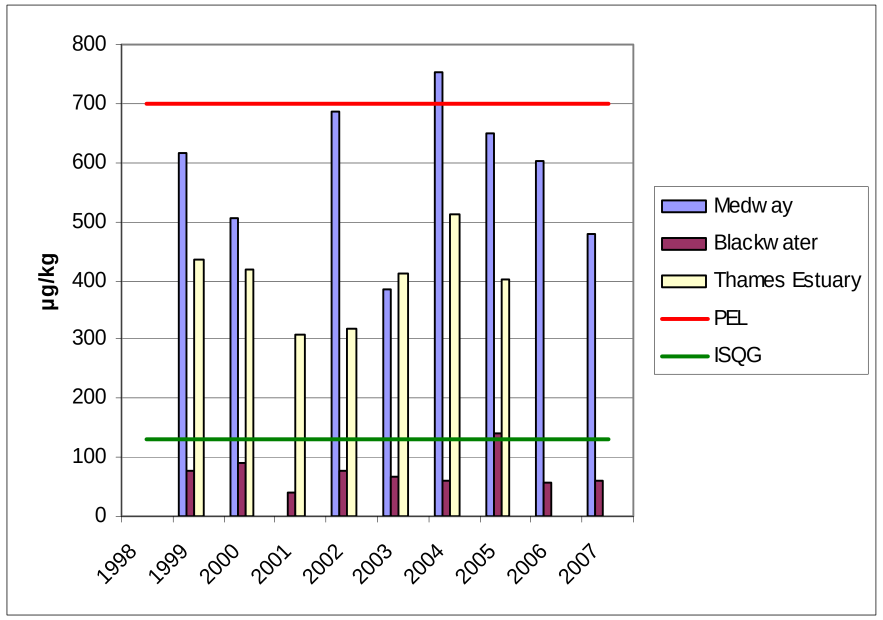
The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Mercury in Sediments

The Thames region has historically had elevated levels of mercury (Franklin *et al*, 1995). However, there has only been one exceedance of the PEL (700 µg kg^{-1}) for mercury between 1999 and 2007 according to MERMAN (Figure 4.32). This was in 2004 in the River Medway with a mercury concentration of 751.6 µg kg^{-1}. All the other samples from the River Medway and Thames Estuary between 1999 and 2007 were below the PEL but above the ISQG of 130 µg kg^{-1}. Samples from the Blackwater Estuary were generally below the ISQG and significantly lower than the PEL.

The Cefas monitoring report published in 2000 (Franklin *et al*, 2000) also indicated high mercury concentrations in the Thames which were thought to be a result of the South Falls disposal ground.

Figure 4.32 Mercury Levels (1999-2007)



The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

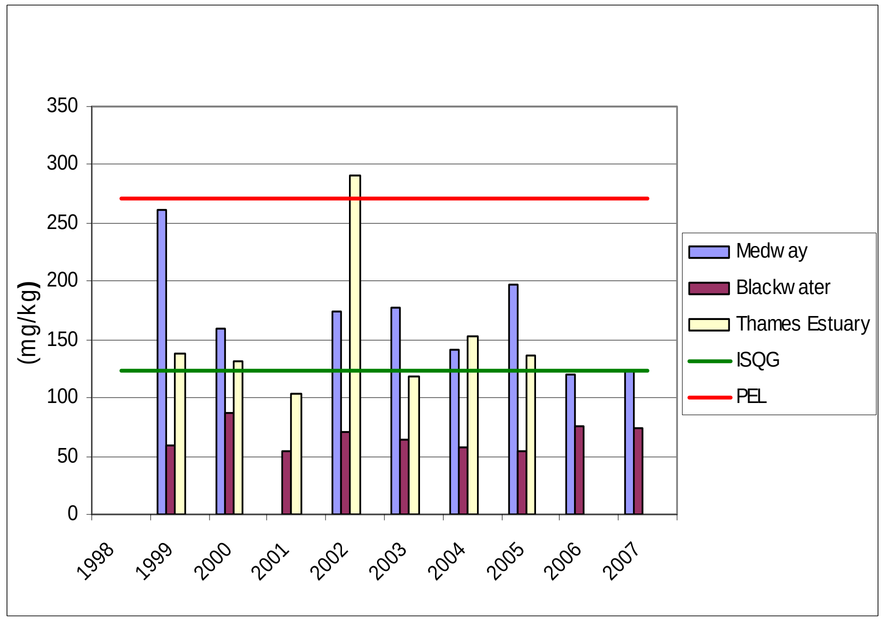
Zinc in Sediments

Data from MERMAN for zinc showed one exceedance of the PEL (271 mg kg^{-1}) in 2002 within the Thames Estuary (Figure 4.33). Samples from Blackwater Estuary were all below the ISQG of 124 mg kg^{-1}. In recent years samples from the River Medway and the Thames Estuary varied but were close to, or below, the ISQG.

Hydrocarbons in Sediments

An investigation into sediment quality in the Outer Thames carried out on behalf of the London Array wind farm (ABP MER Ltd, 2005) found that the majority of sites sampled had sediments containing levels of polyaromatic hydrocarbons (PAHs) that were within the 'rarely causing biological effect' category, with the exception of eight sites. It is likely that these exceedances are due to the location of a nearby major shipping lane.

Figure 4.33 Zinc Levels (1999-2007)



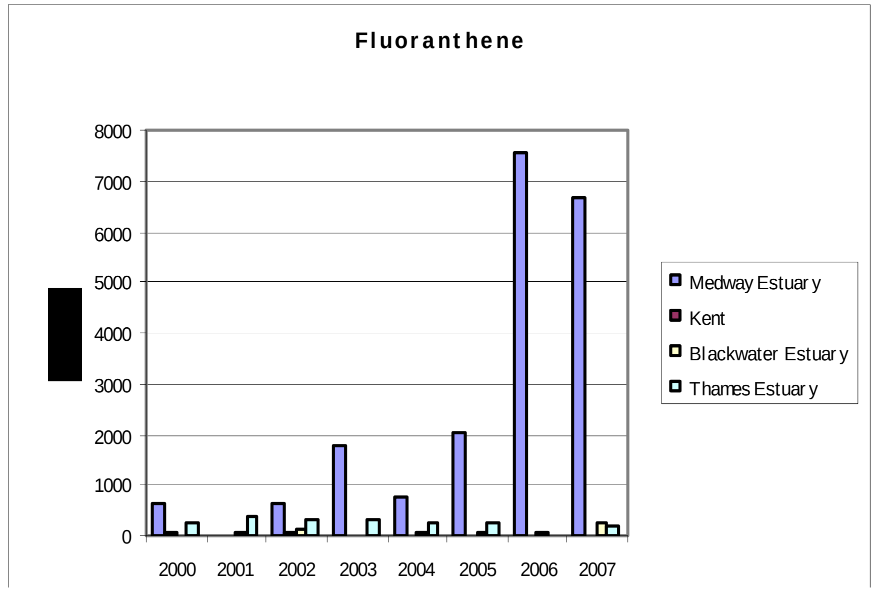
The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

Data from the MERMAN database recorded in the years 2000-2007 for the following hydrocarbons were reviewed for this report:

- anthracene;
- benzo-a-anthracene;
- benzo-a-pyrene;
- chrysene and triphenylene;
- fluoranthene;
- naphthalene;
- phenanthrene; and
- pyrene.

Data for each of the hydrocarbons showed similar changes in concentration levels between years. Data from the only offshore station, Kent, had the lowest concentrations of hydrocarbons. This is likely to be the result of the distance of this station from any major sources of hydrocarbons such as industrial effluent. The Blackwater Estuary and the Thames Estuary stations showed similar levels of hydrocarbons to one another. The Medway Estuary had the highest levels of each hydrocarbon and these levels increased significantly between 2005 and 2007. For example, fluoranthene levels in the Medway Estuary were 1763 µg kg^{-1} in 2003 and 770 µg kg^{-1} in 2004 but levels increased in 2005 to 2056 µg kg^{-1} and 7530 µg kg^{-1} in 2006 (Figure 4.34).

Figure 4.34 Fluoranthene Levels (2000-2007)



The data were supplied by the British Oceanographic Data Centre on behalf of the Clean Safe Seas Evidence Group.

4.6 UNDERWATER NOISE

4.6.1 Introduction

Noise and vibration from marine activities have the potential to adversely impact marine mammals and fish. They have been shown to produce behavioural responses and at high levels, cause temporary and permanent deafness (Turnpenny, 1994). This section presents the sources of ambient noise in the MAREA area, which is important as actual levels of impact will partially depend on the level of ambient (baseline) noise in an area. Vibration that may be produced as a result of dredging is not considered to be at a level which will significantly impact the species for which vibration sensitivity information is available and so is not discussed further.

4.6.2 Sources of Information

The majority of the information in this section is from a study carried out by ERM on underwater noise impacts from marine aggregate dredging in the Outer Thames Estuary, which was predominantly informed by interpreting the findings from the Assessment of Underwater Noise from Dredging Operations on the Hastings Shingle Bank compiled by Subacoustech. The full ERM report is contained within Appendix K.

4.6.3 Acoustic Environment of the Outer Thames Estuary

Ambient sea noise comprises a variety of individual sources, some of which are natural and some man-made. The MAREA area is heavily used by cargo and fishing vessels. Additionally, there is currently one offshore wind farm in operation and several further wind farms planned or under construction (see Section 6.3). Noise from these activities will combine with naturally occurring noise from sources such as waves breaking, wind, rain and animal calls to define the baseline environment.

No baseline underwater noise measurements were recorded within the study area as part of this MAREA, but noise levels around the Greater Gabbard wind farm sites were found to be typical of coastal noise, with a high level at low frequencies (perhaps from distant shipping) and a rapid decrease in level with frequency (Nedwell *et al*, 2005). In general the baseline noise levels range from 110 to approximately 150 dB re 1 µ Pa. The levels are centred on a mean of roughly 125 dB re 1 µ Pa at a depth of 5 metres, and a slightly higher mean of 130 dB re 1 µ Pa at a depth of 10 metres. It should be noted that these data are a 'snapshot' taken on one day and therefore levels may fluctuate with varying conditions. Baseline noise levels elsewhere in the TEDA study area are likely to vary depending on the proximity to shipping channels and other major noise sources. In particularly noisy areas, baseline noise levels may mask those produced by dredging activities.

4.6.4 Anthropogenic Noise Sources

A variety of anthropogenic activities that create underwater noise and contribute to the ambient noise in the Outer Thames Estuary are described below; further details are provided in Appendix K.

General Shipping

The study area is heavily shipped by commercial vessels (Navigational Impacts Review, 2009). A large number of vessels traverse the MAREA area heading to/from Thames Port and Harwich Haven (Navigational Impacts Review, 2009). An average of 145 ships per day during a 40 day survey period was recorded. The majority of these movements were cargo vessels (63% or 91 movements per day) and tankers (14% or 20 movements per day). The number of deeper draught and longer container ships passing through the study area is expected to increase with the construction of the London Gateway deepwater port within the river Thames (first berth intended to be fully operational by 2011) and the Felixstowe port enhancement (completion expected 2014).

Fishing Vessels

The southern North Sea and Outer Thames Estuary have been important areas for populations of a number of commercial fish species for centuries, and a wide variety of fisheries have developed to exploit them. According to VMS (Vessel Monitoring System) and overflight data, 220 beam trawlers were observed in the study area in 2007. Another 120 vessels operating in the area were made up of other trawl gears, gill nets, potters/whelkers and suction dredgers.

Recreational and Military Vessels

It has been highlighted during consultation with the Cruising Association and Royal Yachting Association that the study area is heavily used by recreational craft, mostly using the deep water channels (Navigational Impacts Review,2009). Additionally, the study area encompasses a number of military and navy submarine exercise and practice areas.

Wind Farm Construction

One 'round one' wind farm has been constructed and another is currently under construction within the TEDA study area. Two 'round two' wind farms are also being constructed and a further two are consented for development. During wind farm construction, there is likely to be an increased volume of traffic. Noise from the use of pile driving equipment has the potential to produce high levels of underwater noise, dominating the baseline noise environment over a wide area.

4.7 SUMMARY

In summary, the following key statements can be made in relation to the physical environment within the Outer Thames Estuary:

- Huge volumes of sediment derived from the reworking of Pleistocene fluvial and marine sediments have been released in the area during the previous 8000 years, and have been transported into the nearby sinks within the Thames Estuary.

- The seabed topography is dominated by the numerous sandbanks which accumulate as a result of these tidal movements. Sandbanks are important for coastal protection and as habitats in their own right.

- The broad scale arrangement of the sandbanks, channels and ridges within the Outer Thames has changed very little over 180 years, suggesting a significant long-term stability in seabed morphology. However, at a more local level the seabed is dynamic.

- Whilst the Outer Thames is a vast sink for fine sediment, there is little transport of beach-forming sediment from offshore; sediment instead is transported alongshore by tidal currents, rather than seawards by weak wave activity.

- Overall, finer sediments are located to the south of the survey area and coarser sediments towards the central and northern areas.

- Levels of contaminants are generally low within the MAREA study area. Elevated levels of copper and mercury have been recorded in areas inshore of the study area in discrete years, and levels of hydrocarbons are highest in the Medway Estuary.

- Levels of suspended sediment are high within the Outer Thames Estuary compared with further offshore.

5 OVERVIEW OF THE REGION: BIOLOGICAL BASELINE

5.1 BIOLOGICAL BASELINE ENVIRONMENT INTRODUCTION

5.1.1 Introduction

This section describes the baseline conditions with respect to the biological environment in the MAREA.

The benthic environment in the Outer Thames Estuary is dominated by polychaetes, amphipods, crustaceans and arachnids which are typical of the benthic environments of this bio-geographic region. There are commercially important benthic species in the study area including cockles, oysters and lobsters. The study area is also home to species protected under the UK Biodiversity Action Plan, and which are designated as Nationally Important Marine Features, together with habitats that are protected under European designations.

The Outer Thames Estuary is home to a large number of fish species that inhabit an area from the River Thames to the southern North Sea for spawning, nursery and as part of migration. The commercial fish species of the North Sea are protected by international and national legislation in the form of Species Action Plans.

There are many important species of other groups that are found within the Outer Thames Estuary. Marine mammal species that occur within the study area include both cetaceans (whales, dolphins, porpoises) and pinnipeds (seals) and are protected by both national and international legislation. Seabird populations of potential national and international importance can be found in the waters of the southern North Sea and south eastern England.

The Outer Thames Estuary region has a number of national and European environmental designations put in place to protect the species found there. Marine and coastal protected sites in the study area designated under European Directives include a candidate Special Area of Conservation (cSAC) under the Habitats Directive and a Special Protection Area (SPA) under the Birds Directive (see Section 5.6).

The following sections address these topics in greater detail:

- Section 5.2 Benthic Ecology;
- Section 5.3 Fish Ecology;
- Section 5.4 Marine Mammals;
- Section 5.5 Birds; and
- Section 5.6 Protected Areas.

5.1.2 Legislation and Guidance

Overview

This section provides an overview of the international, European, national and local legislation, conventions and protocols that apply to all receptors in the biological environment investigated in the MAREA. The biological receptors include benthic ecology, fish ecology, marine mammals, birds and protected areas.

International Designations

OSPAR

During the latter half of the last century the deliberate dumping of substances together with spillage disasters in the North-East Atlantic and neighbouring waters highlighted the need for international cooperation to combat marine pollution. The *Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft* (the Oslo Convention) was adopted in 1972 to address pollution at sea, while the *Convention for the Prevention of Marine Pollution from Land-Based Sources* (the Paris Convention) was adopted in 1974 to address marine pollution by discharges of dangerous substances from land-based sources, watercourses or pipelines.

The *Convention for the Protection of the Marine Environment of the North-East Atlantic* (OSPAR) was adopted in Paris, France in September 1992 and entered into force in March 1998. OSPAR replaced both the Oslo and Paris Conventions, and provided a simplified approach to addressing marine pollution and other impacts on the marine environment. In July 1998 parties agreed on a new Annex V on the protection and conservation of the ecosystems and biological diversity of the maritime area, and a new Appendix 3 with criteria for identifying human activities for the purpose of Annex V.

The UK ratified OSPAR in 1998, and Annex V and Appendix 3 in June 2000. The OSPAR Commission Secretariat is based in the UK and implementation in the UK is coordinated by the Department for Environment Food and Rural Affairs (Defra) Marine and Waterways Division.

The Biological Diversity and Ecosystems Strategy under the Convention describes Ecological Quality Objectives (EQOs) for marine species and habitats; lists species that are threatened or in decline; requires the development of a network of Marine Protected Areas (MPAs); and includes programmes and measures to combat damage to the marine environment caused by human activities. In 2003 the OSPAR Agreement on Sand and Gravel Extraction was made stating that member parties should take the ICES Guidelines for the Management of Marine Sediment Extraction into account when authorising the extraction of marine sediments including gravel.

Ramsar Sites

Ramsar sites are designated under the *Convention on Wetlands of International Importance*, agreed in Ramsar, Iran in 1971 and ratified by the UK in 1976. The Convention was initially brought about to protect sites of importance particularly as waterfowl habitat, However its scope has broadened to cover all aspects of wetland conservation and its sustainable use, recognising wetlands as ecosystems that are extremely important for biodiversity conservation and for the well-being of human communities. The criteria for assessing a site for designation as a Ramsar site include: the wetland supports 20,000 water birds; and/or supports 1% of the individuals in a population of one species or subspecies of water bird.

The Government has made it clear than Ramsar sites will, as a matter of policy, be afforded the same protection as the European designations: Special Protection Areas (SPAs) and Special Areas of Conservation) (SACs).

The UK has generally chosen to underpin the designation of its Ramsar sites through prior notification of these areas as Sites of Special Scientific Interest (SSSIs). These receive statutory protection under the Wildlife and Countryside Act (WCA) 1981. In England and Wales further protection is provided by the Countryside and Rights of Way (CRoW) Act 2000.

Originally notified under the National Parks and Access to the Countryside Act 1949, SSSIs have been re-notified under the Wildlife and Countryside Act 1981. Improved provisions for the protection and management of SSSIs were introduced by the Countryside and Rights of Way Act 2000 (in England and Wales) and the Nature Conservation (Scotland) Act 2004.

Agreement on the Conservation of Small Cetaceans of the Baltic and North Sea (ASCOBANS)

Signatory states of the Agreement on the Conservation of Small Cetaceans of the Baltic and North Sea (ASCOBANS) have agreed to work together to promote the conservation, research into and public awareness of all toothed whales in the North Eastern Atlantic except the sperm whale (*Physeter macrocephalus*).

IUCN Red Data List Species

The Red Data List is a world standard that is used to produce the IUCN Red List of Threatened Species and serves to identify plant and animal species that are in the most need of conservation and to provide a global index of changes of biodiversity.

European Designations

The Marine Strategy Framework Directive

The EU *Marine Strategy Framework Directive (2008/56/EU)* came into force in July 2008. It sets the overall goal of achieving "Good Environmental Status" for Europe's seas by 2020. Each Member State must produce a Marine Strategy for their waters, in collaboration with other Member States sharing the same marine region. Key requirements include:

- An assessment of the current state of UK seas by July 2012.
- A detailed description of what Good Environmental Status means for UK waters, and associated targets and indicators by July 2012.
- Establishment of a monitoring programme to measure progress toward Good Environmental Status by July 2014.
- Establishment of a programme of measures for achieving Good Environmental Status by July 2016.

This Directive is therefore likely to become very important to industries operating in the UK offshore area over the coming years. The UK is keen to use OSPAR as the forum to deliver all key regional elements of the Directive, and OSPAR is currently reviewing its priorities to ensure it supports the delivery of the Directive.

European Directive on the Conservation of Natural Habitats and Wild Flora and Fauna (92/43/EEC) (known as the Habitats Directive) as amended

The 'Habitats Directive' established a European ecological network known as Natura 2000. The network comprises Special Areas of Conservation (SAC) designated by Member States in accordance with the provisions of the Directive, and Special Protection Areas (SPA) classified pursuant to Directive 79/409/EEC on the conservation of wild birds. The Directive is intended to maintain biodiversity in Member States by defining a common framework for the conservation of wild plants and animals and habitats of Community interest.

Pursuant to Directive 79/709/EEC, Article 12 provides strict protection of those animals listed in Annex IV in their natural range, Article 14 states that populations of animal species listed in Annex V can only be exploited in a sustainable way and Article 15 prohibits the taking of animals listed in Annex V in certain ways.

Special Areas for Conservation (SACs) are designated under the *EC Habitats Directive*. Article 3 of the *Habitats Directive* requires the establishment of a European network of high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species (excluding birds) are those considered to be most in need of conservation at a European level. There are 76 Annex I habitat types that occur in the UK and of the Annex II species, 43 are native to the UK.

A draft SAC (dSAC) is a site that has been formally recommended to Defra by JNCC, Natural England or the Countryside Council for Wales for designation, but has not been formally approved for public consultation. It will become a European site at the point in time at which it is proposed to the Commission by the by the Secretary of State or a Devolved Administration as a site eligible for designation as a SAC. On submission, the site will become known as a candidate SAC (cSAC).

Natural England is currently progressing eight candidate SACs, including the Margate and Long Sands cSAC in the Thames Estuary. The statutory consultation process for these designations began in November 2009 and closed in February 2010, with the cSACs submitted to the EC in August 2010 (see Section 5.6).

European Directive on Conservation of Wild Birds (79/409/EEC (known as the Birds Directive)

The 'Birds Directive' aims to protect birds which are considered rare or vulnerable within the European Community and all regularly occurring migratory birds.

Special Protection Areas (SPAs) are designated under Article 4 of the Directive which came into force in April 1979. SPAs are classified for rare and vulnerable birds, listed in Annex I of the Directive, and for regularly occurring migratory species. Criteria for the selection of SPAs are described in The Birds Directive – Selection Guidelines for SPAs, published in 1999 by the JNCC.

A potential SPA (pSPA) is a site that has been formally recommended to Defra by JNCC, Natural England or Countryside Council for Wales for designation. Natural England is responsible for identifying potential SPAs and conducting public consultation on proposals for English inshore waters (0-12 nm). JNCC leads on the selection of SPAs within the UK offshore area. Sites that span inshore and offshore waters are progressed jointly by Natural England and JNCC and one such site was the Outer Thames Estuary pSPA (Natural England, 2009). The statutory consultation process for this designation began on 27th November 2009 and closed on the 26th February 2010. The site was recommended to the EC and officially designated as an SPA in August 2010.

Berne Convention on the Conservation of European Wildlife and Natural Habitats

The Berne Convention allows the exploitation of some species listed in Appendix III of the Convention providing the population is kept out of conservation danger.

Bonn Convention on the Conservation of Migratory Species of Wild Animals

The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. Migratory species that are threatened with extinction are listed in Appendix 1 of the Convention, and migratory species that need or would significantly benefit from international co-operation are listed in Appendix II.

National Designations

UK Habitats Regulations

The UK Habitats Regulations transpose the EC Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (EC Habitats Directive) into national law, and also provides for the selection of a network of Special Areas of Conservation (SAC) that are selected according to their importance for either habitats or species (listed in Annex I or Annex II of the Habitats Directive respectively).

Offshore Marine Conservation (Natural Habitats) Regulations

The Offshore Marine Conservation (Natural Habitats) Regulations were created to ensure the conservation of species in the offshore areas beyond 12 nm from the coast.

Sites of Special Scientific Interest (SSSIs)

The majority of coastal SACs are underpinned by one or more Sites of Special Scientific Interest (SSSIs), notified under the *Wildlife and Countryside Act 1981 for England, Scotland and Wales (*JNCC, 2009*)*. Many SSSIs are also National Nature Reserves (NNRs) or Local Nature Reserves (LNRs). SSSIs provide statutory protection for the best examples of the UK's flora, fauna or geological or physiogeological features. Improved provisions for the protection and management of SSSIs were introduced by the *Countryside and Rights of Way Act 2000 (England and Wales)*.

National Nature Reserves (NNRs) and Marine Nature Reserves (MNRs)

National Nature Reserves (NNRs) are selected as examples of some of the most important natural and semi-natural terrestrial and coastal ecosystems in the UK. They are managed to conserve their habitats and to provide opportunities for scientific study. NNRs are declared in England, Scotland and Wales under the *National Parks and Access to Countryside Act 1949* and the *Wildlife and Countryside Act 1981 for England, Scotland and Wales*.

Marine Nature Reserves (MNRs) are established in England, Scotland and Wales under the *Wildlife and Countryside Act 1981 for England, Scotland and Wales*.

Their purpose is to conserve marine flora and fauna and geological features of interest, and provide opportunities for research.

Wildlife and Countryside Act 1981 and Subsequent Amendments

The Wildlife and Countryside Act (WCA) consolidates and amends existing national legislation to implement the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and Council Directive 79/409/EEC on the Conservation of Wild Birds (Birds Directive) in Great Britain.

The Act makes it an offence (with exception to species listed in Schedule 2) to intentionally kill, injure, or take any animals listed on Schedule 5 and also to disturb them in a place of shelter or rest (the sea, in the case of marine mammals).

The Secretary of State may also designate Areas of Special Protection (subject to exceptions) to provide further protection to birds with special penalties in existence for offences related to birds listed on Schedule 1, for which there are additional offences of disturbing these birds at their nests, or their dependent young. While, Schedule 6 of the Wildlife and Countryside Act 1981 (as amended) makes it an offence to kill animals listed on Schedule 6 in certain ways.

Conservation of Seals Act 1970

The Conservation of Seals Act created 'closed seasons' in which seal culling is not permitted, which coincides with the pupping periods of UK resident species from the 1st June to 31st August inclusive for common seals and from the 1st September to 31st December inclusive for grey seals. The closed season has now been extended throughout the year.

Countryside and Rights of Way Act (CRoW) 2000

All cetaceans are listed under Section 74 of the CRoW Act: List of Habitats and Species of Principal Importance for the conservation of Biological Diversity in England. The Act also extends the protection to Schedule 5 animals including reckless disturbance of their places of shelter or rest. All cetaceans are listed under Section 74: List of Habitats and Species of Principal Importance for the conservation of Biological Diversity in England.

UK Biodiversity Action Plan (BAP)

The UK BAP is the Government's response to the Convention on Biological Diversity (CBD) signed in 1992. It describes the biological resources of the UK and commits a detailed plan for their protection. UK BAP priority species are transposed into UK law by inclusion under Section 74 of the CRoW Act 2000: List of Habitats and Species of Principal Importance for the conservation of Biological Diversity in England. A Species Action Plan provides detailed information on the threats facing species and the opportunities for maintaining and enhancing populations. A 'Grouped' Species Action Plan has been produced for Commercial Marine Fish as a range of common policies and actions are required for all species listed. The harbour porpoise is covered by a Species Action Plan within Essex, and harbour porpoises, bottlenose dolphins and common seals are named in the Tidal Thames Habitat Action Plan. All cetaceans are listed under the UK BAP as a group and the harbour porpoise is a priority action plan species.

Nationally Important Marine Features (NIMF)

NIMF are a part of Defra's Review of Marine Nature Conservation (RMNC). The review identifies threatened, rare or otherwise exceptional features in the marine environment, referred to as NIMFs. NIMFs will be underpinned by legislation set out in the Marine Bill and encompass marine species and habitats that do not fall within the Natura 2000 Network but are still considered to be of conservation value.

The Marine Act

The UK's Marine (and Coastal Access) Act 2009 provides for the designation of Marine Conservation Zones (MCZs) in UK offshore waters, which are currently being identified in England through the England MCZ Project and are to be recommended by October 2011.

Together with SACs and SPAs with marine components, the MCZ network will deliver England's contribution to the UK's vision of an ecologically coherent network of Marine Protected Areas (MPAs) by 2012; a key component of OSPAR's strategy.

Local Designations

Under the *National Parks and Access to the Countryside Act 1949*, Local Nature Reserves (LNRs) may be declared by local authorities after consultation with the relevant statutory nature conservation agency. LNRs are declared and managed for nature conservation, and provide opportunities for research and education.

5.1.3 Consultation

Nature Conservation, Benthic Ecology and Fisheries

Key statutory and non-statutory organisations were consulted on issues related to the biological environment throughout the REA process. The following organisations attended a Nature Conservation and Benthic Ecology and Fisheries workshop run in conjunction with the marine aggregate industry on the 11th June 2007 in Ipswich, and provided information and views on the scoping and REA stages of the regional assessment:

- Cefas (Centre for Environment, Fisheries and Aquaculture Science);
- Marine and Fisheries Agency (MFA);
- Kent and Essex Sea Fisheries Committees (SFCs);
- Zoological Society of London;
- London Gateway;
- Felixstowe Ferry Fisherman's Association;
- Fishing Industry representative;
- Natural England (NE);
- The Joint Nature Conservation Committee (JNCC);
- The Royal Society for the Protection of Birds (RSPB) Norwich office;
- Kent Wildlife Trust; and
- The Sea Mammal Research Unit.

Additionally, the following consultation sessions with fishermen took place, providing valuable ecological data such as fish ecology spawning peaks and areas:

- 26 November 2008, Wick Lodge, Clacton-on-Sea;
- 1 December 2008, St Nicholas Centre, Ipswich;
- 4 December 2008, Leigh-on-sea Town Council Offices; and

* 21 January 2009, Marlborough Hotel, Felixstowe.

A consultation meeting was held with Cefas in August 2007 to discuss the scope and timing of the geophysical and biological surveys that would be undertaken to inform the MAREA. A benthic survey protocol was developed in line with this advice and was subsequently reviewed and approved by Cefas in July 2008.

Birds

A consultation meeting was held with key statutory and non-statutory organisations to discuss issues relating to birds:

* Natural England (NE);
* The Joint Nature Conservation Committee (JNCC); and
* The Royal Society for the Protection of Birds (RSPB).

5.2 BENTHIC ECOLOGY

5.2.1 Introduction

The sand and gravel substrates in the Outer Thames Estuary provide habitat for a wide range of benthic species and communities. The species found are considered to be typical of marine habitats at this latitude. Infaunal and epibenthic invertebrate communities are commonly dominated by polychaetes, amphipods, crustaceans, and arachnids. This chapter describes the benthic environmental baseline using recent surveys (MAREA and REC benthic surveys) and information from historical surveys to provide an overview of the benthic communities within the study area. The rest of this chapter is structured as follows:

- Sources of Information (Section 5.2.2);
- Benthic Species and Communities (Section 5.2.3);
- Biotopes (Section 5.2.4);
- Commercially Important Species (Section 5.2.5); and
- Protected Species and Habitats (Section 5.2.6).

5.2.2 Sources of Information

Introduction

A desk study was conducted of published literature on benthic ecology within the Outer Thames Estuary region. The literature review is described below.

A review of the Regional Environmental Characterisation (REC) survey plan showed there was very wide spacing for the benthic samples and it was therefore decided to obtain additional 'infill' samples as part of the MAREA benthic survey. The objective of this survey work was to ensure that all the sediment types, bathymetries and different types of impact areas could be covered. For conservatism, the potential impact areas were initially based on one tidal excursion from each of the licence areas. It should be noted that sediment modelling work conducted subsequently for this MAREA allowed a more realistic possible impact area to be identified. The refined impact areas were used during the statistical analysis of benthic ecology in the MAREA survey and this is discussed in further detail below.

Site specific information from previous surveys has been used to provide detail where available. The following section describes the sources of information used for the desktop review prior to interpretation and inclusion into the baseline.

The methodology used for the MAREA field survey and laboratory work is then provided in the next section, followed by a description of the statistical analysis used to interpret the results of the field survey.

Literature Review

In order to provide a detailed understanding of the benthic baseline environment, data from recent surveys and studies in the study area have been reviewed. The reviewed surveys and reports are as follows:

- Regional Environmental Characterisation (REC) benthic survey (2007);
- Galloper Wind Farm Project scoping study report (2010);
- London Array wind farm Environmental Statement (ES) and technical reports (2005);
- Greater Gabbard wind farm ES and technical reports (2005);
- Gunfleet Sands wind farm ES and technical reports (2002);
- Thanet wind farm ES and technical reports (2005);
- Cutline Dredging Area 447 ES (1999); and
- Benthic Ecology off Suffolk (Shipwash Gabbard) Dredging Application Area 452 ES (1999).

Data gathered from Environmental Statements and related technical studies have provided an understanding of benthic ecology in some parts of the Outer Thames Estuary. Many of these surveys have been conducted as part of the process required for the Environmental Impact Assessment of new offshore developments including offshore windfarm and aggregate extraction areas. In some cases this has been in the form of environmental baseline studies for specific development sites, whilst others have been part of longer term monitoring studies or broader scale assessments of the area. The reviewed studies consist of a grab sampling regime followed by laboratory identification of the species sampled. The data gathered by these studies has in some cases been published and is available for use in the MAREA.

The areas of the outer Thames Estuary for which benthic data are available are shown in Figure 5.1. The method, scope, and survey size of the studies that have provided these data are varied as a result of differing study objectives. Figure 5.1 illustrates the various levels of sampling effort that have been given to each study site, showing a high density of samples in certain areas such as the London Array wind farm site, whilst other areas remain completely unsampled. Different sampling apparatus was also used by each study and as a result, the data from the various studies can not be directly compared. Inferences can be made however, where the benthic environment between sampled and unsampled sites is comparable, but data for these areas are only used in an indicative manner to show the species and community types that exist in the region.

A Regional Environmental Characterisation survey was undertaken in 2007 to provide context for the MAREA and covered a large area with a widely spaced grid of benthic samples. There are data gaps however, for large areas between previously studied sites and the REC sample locations. A dedicated benthic survey was conducted in 2008 to target these data deficient areas and allow broad scale maps of the distribution of species and communities across the study area to be produced.

MAREA Field Survey Methodology

The MAREA survey together with the REC and other historical data were interpreted to provide information on the following:

- How benthic communities vary spatially across the MAREA area;
- What correlation there is between benthic communities and bathymetry;and
- What correlation exists between benthic communities and sediment type.

Whether any differences can be seen between sites within licence areas that have been recently dredged, those areas where impacts due to sediment deposition and/or elevated suspended sediments could occur and those communities outside of the impact areas.

At the time that the benthic survey sampling array was developed, detailed modelling of the maximum extent of sediment transport or plume dispersal from the licence areas in the Thames had not been completed. The survey array therefore focused on the licence areas, together with areas within one tidal excursion of the licence areas. This approach was taken because tidal excursions in the Thames Estuary are large and was known to be a conservative estimate of the maximum footprint of secondary impacts that would not be exceeded by the modelling results. In practice, the modelling studies that were subsequently undertaken during the MAREA showed the predicted extent of plume dispersal, and the footprints of bedforms and changes to particle size distribution that could arise from dredging to be considerably less than the area covered by one tidal excursion.

A total of 127 sampling stations were selected (Figure 5.2) to meet a number of different objectives. The purpose of each category of station, the number of stations in that category, and the number of additional stations that were added to the survey array to meet the objectives are described in Table 5.1.

Several of the stations had more than one purpose and they are therefore only added to the total station number the first time they are mentioned.

Figure 5.1 Locations of Previous Surveys

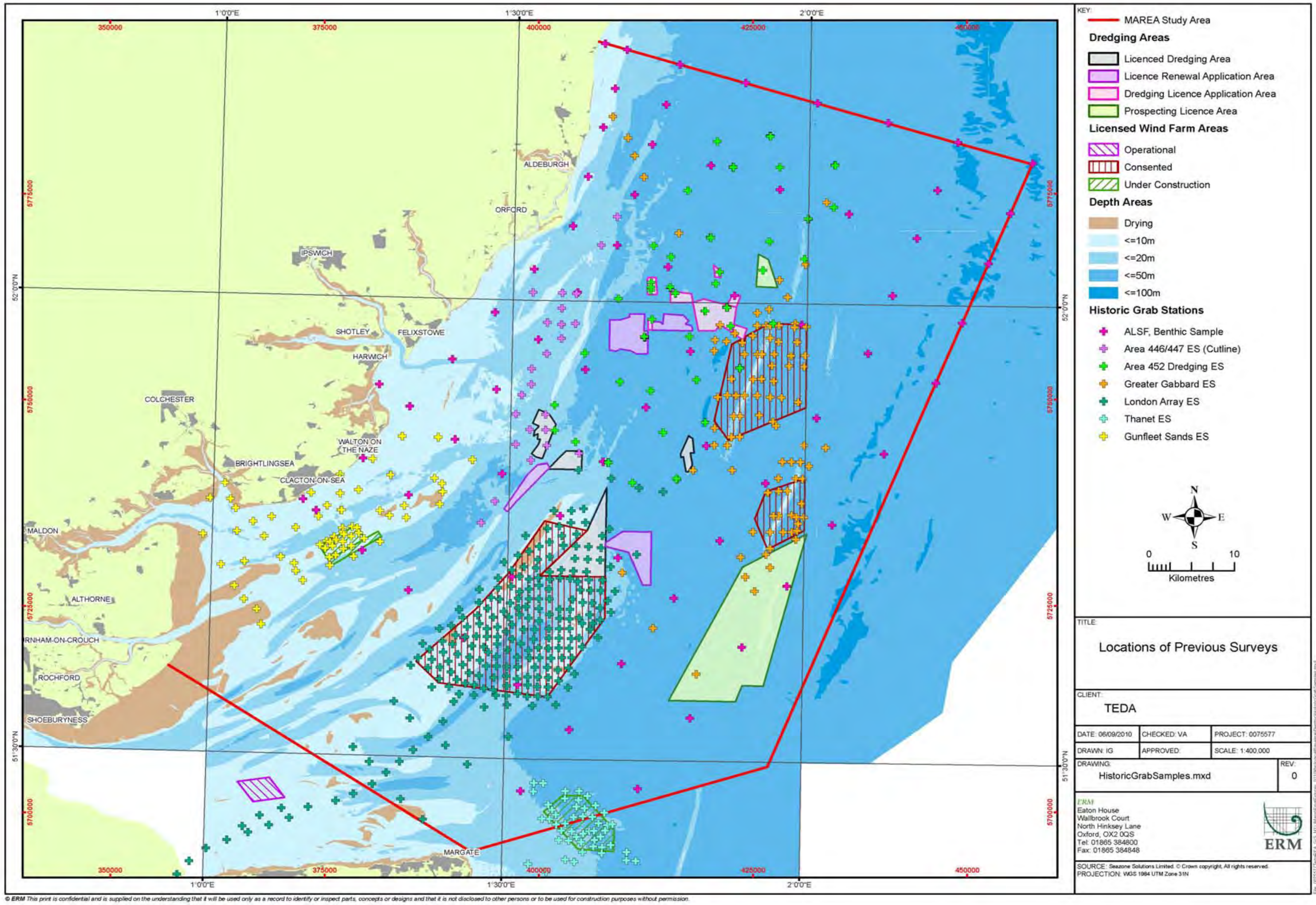


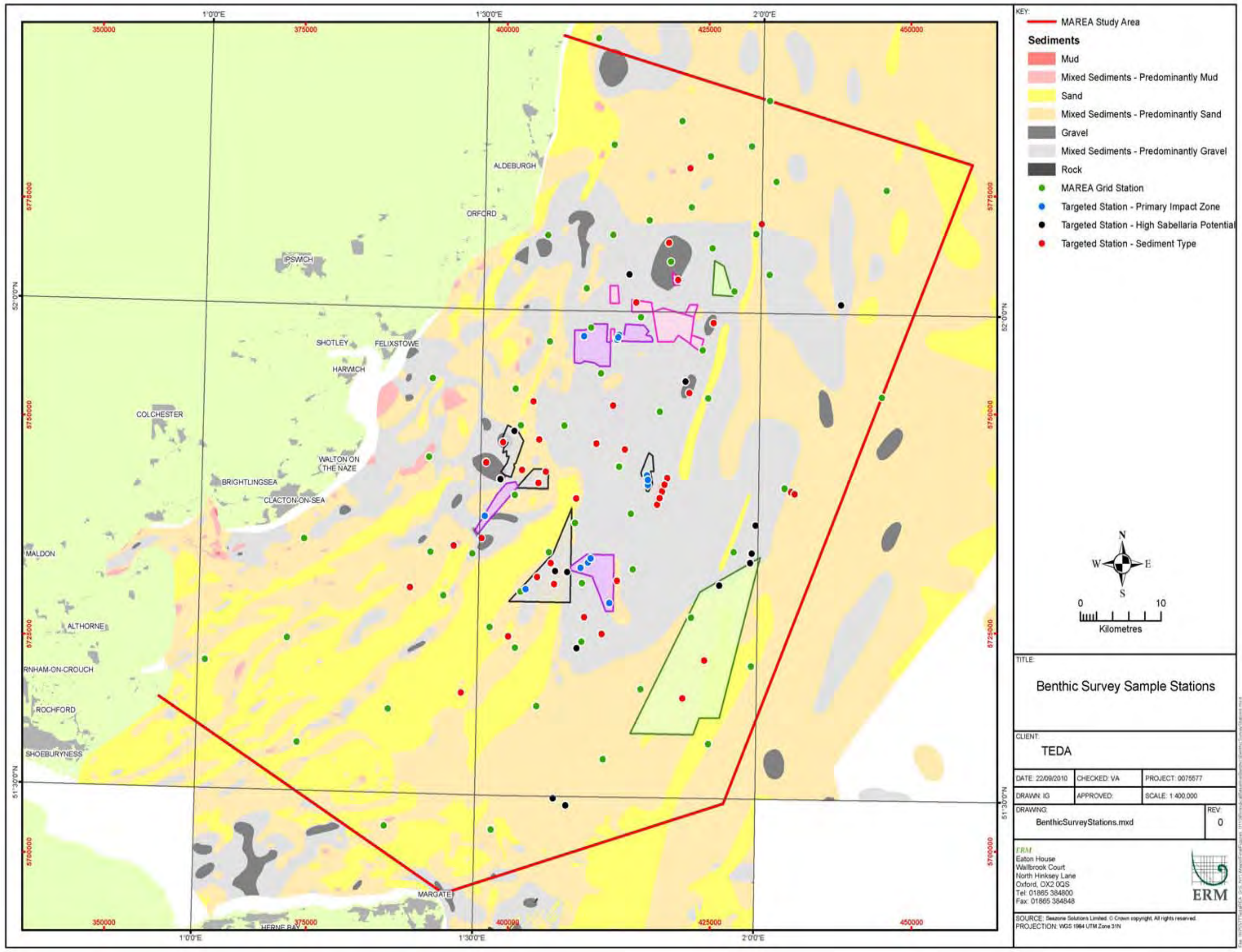
Table 5.1 Benthic Survey Stations

Total number in category	Number of new stations in array	Purpose	Comments
60	60	To ensure adequate spatial coverage and sampling density within the licence areas and one tidal excursion of licence blocks.	10 of the grid stations were in the same position as REC sampling sites to allow inter-annual variability to be analysed.
38	38	To analyse biological variability within areas of different sediment types described by BGS.	Ensure 5 samples of each sediment type were taken.
16	16	Areas of high *Sabellaria* abundance recorded in previous surveys and areas of possible *Sabellaria* reef identified from sidescan sonar survey.	Target areas with a high likelihood of supporting *Sabellaria* reef development.
16	13	Stations within licence areas of recently dredged licence areas.	Licence area stations all within areas where dredging had occurred post-2005.
N/A	**127**		

In addition to the benthic survey stations, 16 epibenthic trawl stations were selected to supplement the 20 REC trawls that were sampled in 2007. The MAREA trawl stations provided an increase in coverage in the vicinity of the licence areas and also provided additional coverage of different sediment types identified within the main survey area. Three of the trawls were located at sites that were previously sampled during the REC survey to provide information on inter-annual variability.

Drop Down Video (DDV) was deployed before grab or trawl sampling to indentify the presence of potentially sensitive features such as *Sabellaria spinulosa* reefs. As a result of technical problems during the survey, not all stations were able to be adequately videoed prior to deployment of grabs and trawls. In addition, the high turbidity of the water prevented clear analysis of the video at some locations. When possible, the DDV survey was conducted within 50 m of the target survey position. However, at some stations the water was too shallow to survey the target area and at these stations the survey was conducted up to 404.5 m from the target area. The video system (SeaViewer Seadrop) was housed within a drop down video frame and a stills camera was mounted on the frame to provide a vertical view of the seabed.

Figure 5.2 Benthic Survey Sample Stations



Samples were collected using a 0.1 m^2 Hamon grab following the Cefas Guidelines for the Conduct of Benthic Studies at Aggregate Dredging Sites (Cefas, 2002). Samples of less than approximately 5 litres were discarded and a repeat sample was taken [(1)]. At least three attempts to collect a valid sample were made. Each grab sample was sub-sampled (approximately 500 ml) for particle size analysis (PSA) and then sieved through a coarse-mesh sieving table (5 mm) and then a fine-mesh precision sieve (1 mm). Fauna were then preserved in borax buffered 4% formaldehyde solution containing Rose Bengal vital stain and returned to the laboratory for identification.

A 2 m beam trawl with 40 mm mesh liner and 5 mm (knot to knot) square mesh cod end was used to sample epibenthic fauna. Trawls were made at a speed of 1.2-1.5 knots for 5-6 minutes resulting in an approximate distance of 500 m. At the completion of each sampling run, the trawl was winched on board and the sample taken from the cod-end of the net. The catch was then sorted, photographed and analysed. All invertebrate and fish species were then identified and enumerated. When large numbers of epifaunal shrimps and prawns (Crangonidae and Pandalidae) were recorded, the enumeration was by a cross-calibrated volumetric analysis (based on the number per given volume). Encrusting species on stones and small rocks were described as present/absent. The catch was then returned to the water as soon as practicable. Any unidentified fauna was fixed with buffered formaldehyde-saline solution and returned to the laboratory for analysis.

Laboratory Analysis Methodology

Benthic samples were washed over a 212 µm sieve to remove the formaldehyde fixative. Animals were identified to species level when possible and counted. When specimens were too damaged to be identified to species level they were identified to the next higher taxonomic level. Colonial taxa were also recorded. Faunal samples were blotted dry and weighed to 0.1 mg. An estimation of dry weight biomass was made using available published conversion factors for the predominant taxonomic groups from Eleftheriou and Basford (1989). Any samples not identified on the vessel from the beam trawls were identified as described for benthic samples. Grab sub-samples were sieved and then the fine fraction was analysed by laser using a Malvern Mastersizer 2000.

Statistical Analyses

The following primary statistics were calculated for the dataset:

- Biological Analysis (univariate and multivariate);
- Number of species (S);
- Abundance (A) – number of individual per 0.1 m^2; and
- Biomass (B) - g per 0.1 m^2 .

A number of derived statistics or ecological indices were also calculated to provide information on the biological diversity of each sample:

- Shannon-Wiener diversity (H').
- Pielou's evenness (J').
- Abundance ratio (A/S).
- Biomass ratio (B/A).
- Species dominance.
- ANOVA test was carried out to test for significant differences in all primary, derived and physical parameters between stations in different depth ranges and within and outside the licence areas.

In addition, multivariate statistical analyses were undertaken to look for patterns within the faunal dataset. Exploratory analysis to identify outliers (species contributing < 1% to entire data set, low in abundance and present at very few stations), was used initially to assess the need for transformation. Multi Dimensional Scaling (MDS) and Cluster analysis with a SIMPROF test, using fourth root transformed data, was then used to investigate whether the data naturally separated into distinct groups.

Sediment Analysis

- Median grain size in phi and µm;
- Standard Deviation (sorting coefficient) of grain sizes;
- % sand/silt/gravel;
- Folks classification;
- Skewness;
- Kurtosis; and
- % organic matter.

Prior to statistical analysis, the sites were separated into groups based on their proximity to active aggregate extraction zones. A 'licence area' category included the sites within areas of the active dredge zones of current licence areas that are known to have been directly affected by aggregate extraction activity between 2005 and 2008. A 'plume footprint' group included those sites which were shown by the specialist plume dispersal studies to be within the footprint that is likely to be affected by dredging (due to the presence of bedforms resulting from sand deposition and/or changes to particle size). Sites outside the licence area and predicted plume footprint of currently dredged licence areas were named "Reference" (REF) sites for the purpose of the statistical analysis. However, it is acknowledged that other, unrelated activities may have impacted or be impacting upon these sites. As such they only represent areas that are outside the area of influence of the dredging activities themselves.

An ANOSIM test (one-way analysis) was carried out based on all species abundance data to look for significant differences between the faunal assemblages that were recorded at stations at different depths, in different impact zone categories and with different percentages of sand, gravel and mud. Finally, Similarity Percentage (SIMPER) analysis based on all species abundance data was used to determine differences between groups of stations identified within licence areas, plume footprint and reference sites.

The results of the statistical analysis are presented and discussed in Section 5.2.3.

5.2.3 Benthic Species and Communities

The number of species found during the MAREA survey varied considerably between sampling stations. At station 4, which is in the south of the study area, away from existing licence areas, no animals were found. This site has a sandy substrate (see Section 4.5.4 for discussion of sediment characteristics in the study area). The rest of the stations varied from between 1 and 96 species at each site. This is very similar to the 3-85 species found per site during the REC survey. In general a greater number of species were found in the central and northern regions of the survey area, with up to 96 species, than in the south of the survey area (Figure 5.3).

At sites where fauna were found, abundance within the study area ranged from 1 individual/ 0.1 m^2 to 10,264 individuals/ 0.1 m^2 (Figure 5.4). At these sites where fauna were detected, biomass ranged from 0.023 g/ 0.1 m^2 to 182.36 g/ 0.1 m^2. Again the highest number of species was found in the muddy, gravelly sites in the centre of the study area compared to the relatively species-poor sandy areas in the south of the study area.

(1) Some samples were borderline 5 litres and were accepted in the field, however when the sample volume was calculated from the depth measurement the result was just less than 5 litres.

Figure 5.3 Species Richness at Each Station (per 0.1 m^2)

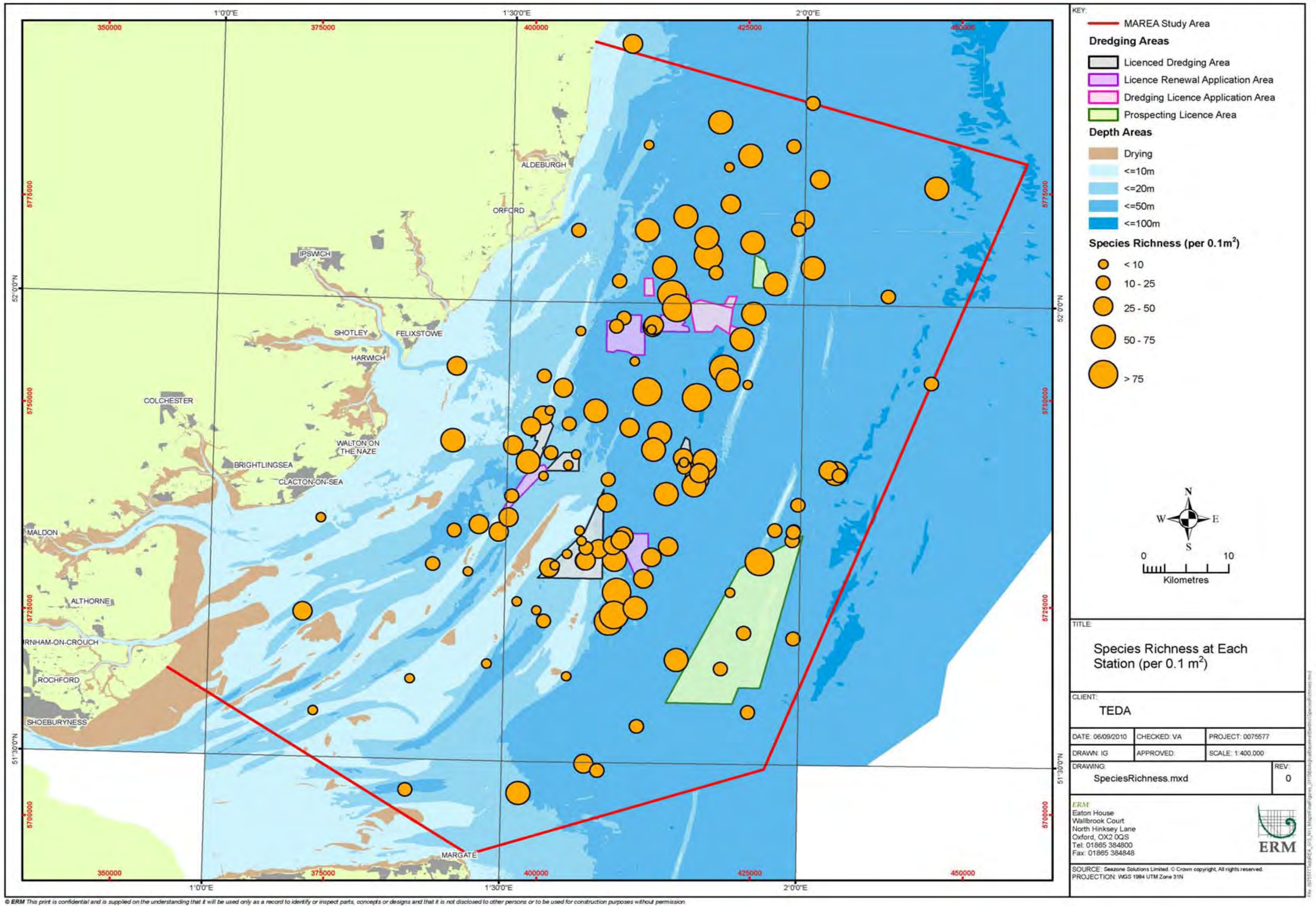
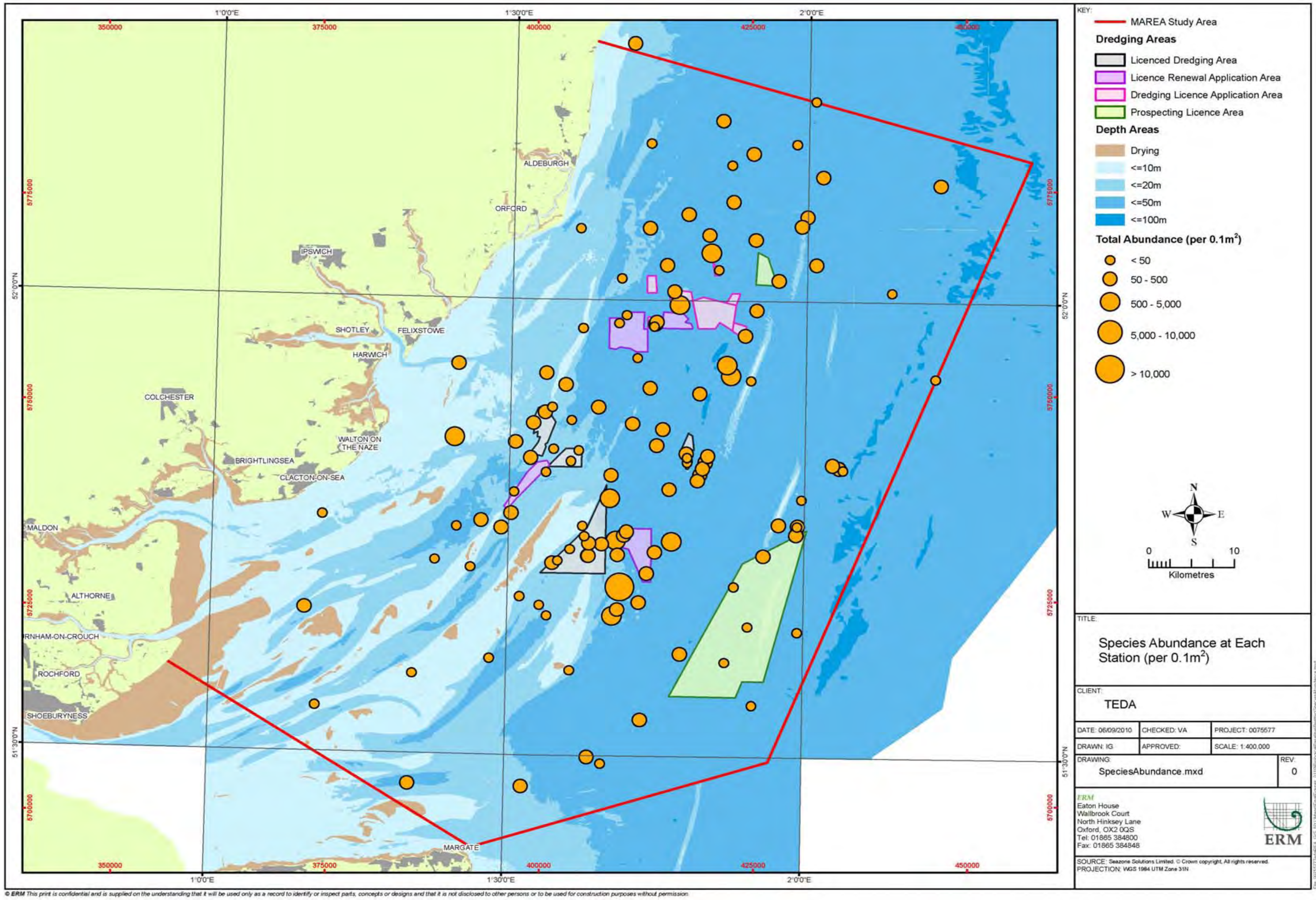


Figure 5.4 Total Abundance at Each Station (per 0.1 m2)



Analysis of the survey data using the Shannon-Weiner diversity index (H') showed the highest diversity was found at Station 99 in the east of the study area where the substrate had a high mud component. The majority of the area is considered to have high diversity (H' >4) but a number of sandy sampling stations had relatively low levels of diversity (H' <3). These sandy sites (Stations 3, 4, 29, 112, 54, and 64) were mainly in the south of the study area. Stations 3 and 4 are close together in the south west, Station 64 is found in the south east and is close to a station with higher diversity (Station 65) and Stations 112 and 54 are very close together to the south of Long Sand Head licence area (Area 108/3, 109/1, 113/1). Station 29 is a sandy site to the north of licence area 447. The results of the Outer Thames Estuary REC survey also showed higher diversity in the central and northern areas which were generally areas of mixed mud and sand and gravel sediments.

The Phyla with the largest number of species within the study area were Annelida (43%), Crustacea (30%) and Mollusca (16%) (Figure 5.5). The phylum containing the largest number of individuals was the Crustacea, which accounted for 44% of the total abundance (Figure 5.6). The most abundant species, occurring at more than 40% of the stations, were the amphipod *Ampelisca spinipes*, the decapod *Pisidia longicornis*, the bivalve *Abra alba* and polychaetes *Lagis koreni* and *Ampharete lindstroemi*, all occurring in densities >1,000/ 0.1 m^2. The most widespread fauna at over 50% of the sites were Nemertea and the polychaetes *Glycera lapidum*, *Lumbrineris gracilis*, *Notomastus* and *Caulleriella alata* as well as the decapod *Pisidia longicornis*.

The results of the Outer Thames Estuary REC survey also found that Annelida had the most numerous species (36%) followed by Crustacea (31%) and Mollusca (10%). However, the REC survey found the highest abundance was for the phylum Annelida with 40% of the total abundance.

The ANOVA test was carried out for all primary, derived and physical parameters. No significant differences were recorded between the licence areas, plume footprint and reference sites for any parameters, except mud content (p=0.001). Reference group sites contained more muddy stations, whereas sites within the impact zones recorded higher sand and gravel content.

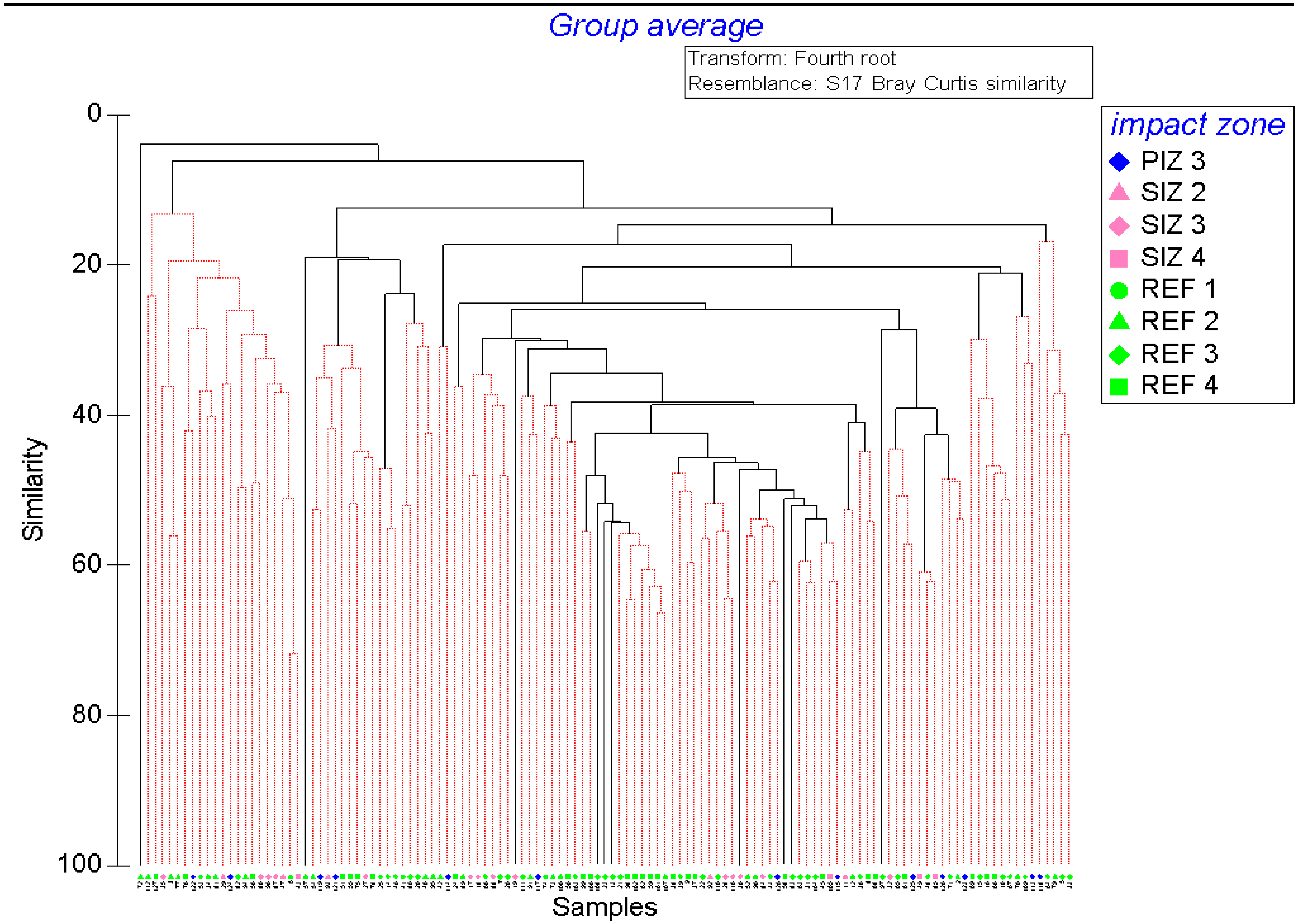
The results of Multi-Dimensional Scaling (MDS) indicated there were no visually distinguishable groups of fauna within the study area ie the stations did not group into two or more distinct assemblages. The high variability in sediment types and biological parameters as well as a large number of reference sites is the likely reason there is no separation of species into distinguishable community groups. The MDS results also showed there was no clear separation of groups between licence areas, plume footprints and surrounding areas/reference sites.

Figure 5.5 Phyla with the Largest Number of Species within the Study Area

Figure 5.6 Abundance of Species within the Study Area by Phyla

A Bray Curtis similarity test was applied to the data and a dendrogram produced (Figure 5.7). The groups of fauna in Figure 5.7 have been colour-coded by licence areas (PIZ), plume footprints (SIZ) and reference sites (REF). The symbols represent depth groups where 1= 0-10 m, 2= 10-20 m, 3= 20-30 m and 4= 30-50 m deep. The dendrogram shows there is no obvious difference between communities at different depths or between licence areas or plume footprint sites and no statistically significant differences were detected.

Figure 5.7 Dendrogram Showing the Results of Cluster Analysis by Licence Area, plume footprint and Reference Sites



Similarly, the ANOSIM test did not reveal any significant differences in the abundance of species between sites within the 'licence area', 'plume footprint' and 'reference station' groups. This indicates that at the regional scale, differences in species compositions between the groups are not apparent. This is likely to be due to the high natural variability of sediment types across the region and the fact that other sources of disturbance (natural or anthropogenic) can affect sites within any of the groups. These regional findings do not imply that it would not be possible to detect differences between the licence area, plume footprint and surrounding areas at the site-specific level, but that significant differences are not apparent at the regional scale of the MAREA survey.

BIOENV (PRIMER) was used to test the correlation between community characteristics and environmental characteristics. The results of this test indicate a weak correlation between communities and environmental variables such as the composition and organic content of the sediment or depth. The strongest correlation (r_s=0.366) was found when a combination of the sand content and the organic content of the sediment was compared to the community.

A review of historic studies has supported the results of the MAREA survey. Historical surveys have shown the benthic ecology of the outer Thames Estuary to be varied, patchy, and largely dependent on the local substrate type.

Surveys conducted in preparation of the Gunfleet Sands and Kentish Flats offshore windfarm developments reported large areas where the communities are dominated by polychaetes with key species found to be *Nephtys cirrosa* and *Magelona mirabilis*, and the sand habitat-specific amphipod crustacea *Bathyporeia pelagica*. Gunfleet Sands is located in the west of the study area, south east from Clacton-on-Sea. Kentish Flats is southwest of the study area and is further inland towards the Thames Estuary. Shallow sandy areas tended to have a low diversity of species, made up principally of polychaetes and amphipods and there was patchy abundance of the nutshells *Nucula nitidosa* and *N. nucleus*. The benthic communities in more stable and often deeper areas were found to be made up of the same ecological groups but with higher levels of diversity. This was found to be true in the regions of Barrow Deeps, Knock Deep and near Felixstowe. The Gunfleet Sands ES reported that most of the benthic communities were typical of relatively mobile sublittoral sands in the North Sea with the only notable exception being the burrowing anemone *Scolanthus callimorphus,* which is uncommon in the waters of eastern England.

The London Array offshore windfarm ES reported shallow areas (10-30 m) to be commonly dominated by the bivalve *Abra alba*, with higher numbers of bivalves from the genus *Venus* in fine grained sands. In muddier sediments and at depths of around 5-20 m, the brittle star *Amphiura filiformis* became more prevalent. Further large epifaunal species found to be common across the outer Thames Estuary include the echinoderm *Asterias rubens*, the heart urchin *Echinocardium cordatum*, and the polychaete worm commonly called the sea mouse, *Aphrodite aculeate* (Frauenheim *et al*, 1989). The London Array ES found that the richest and most diverse habitats within its survey area were those with a shelly sand and gravel substrate which were found in shallow inshore areas.

The Greater Gabbard survey found the most abundant species from the grab samples to be the polychaetes *S. spinulosa* and *Lumbrineris gracilis*, the sea urchin *Echinocyamus pusillus*, the crab *Pisidia longicornis*, and the barnacle *Verruca stroemi*. The most widely distributed species across the Greater Gabbard site however, were the bryozoans *Schizomavella spp.* and *Escharella immerse*, the polychaetes *Glycera lapidum* and *Lumbrineris gracilis*, and the previously mentioned sea urchin *E. pusillus*. Patches were also found where the abundance of certain species was particularly high. This is true of the polychaete *Scalibregma inflatum* and the barnacle *Balanus crenatus* and is indicative of the localised habitat diversity that occurs in the outer Thames Estuary.

Box 5.1 Summary of Benthic Species and Communities within the MAREA Study Area

Whilst on a North Sea-wide scale, benthic communities are influenced by environmental parameters such as bottom water temperature, bottom water salinity and tidal stress (Reiss *et al*, 2007), at a more regional scale, such as the MAREA study area, the benthic communities are largely influenced by sediment characteristics. As previously described, the sediment within the study area is patchy and the associated benthic communities are therefore varied.

It has been found that depth is not correlated closely with the distribution of benthic communities, and there is no clear separation of communities between licence areas where dredging has taken place, areas located within the footprint of dredging plumes and reference sites.

There is comparatively high benthic biomass within the North Sea with increased diversity and abundance in the north of the North Sea than in the MAREA study area and the rest of the southern North Sea (Rachor *et al*, 2007) and (Heip *et al*, 1992)

5.2.4 Biotopes

Introduction

The sediment types and epifaunal communities at each MAREA survey station within the study area were reviewed against the descriptions given by Conner *et al* (2004) in the JNCC Marine Habitat Classification. This review highlighted that some dominant species found at the stations are not recorded in the biotope listings such as the crab *Pisidia longicornis* which occurs in abundance at many sites but is not used as an indicator of biotope. In addition, as samples were not taken in areas where high numbers of *Sabellaria spinulosa* were observed from the video footage, there was potential for this species and its coverage as reefs to be under-represented based on the grab sample data. In practice, however, this only applied to the one survey station where evidence of possible *Sabellaria* reef was observed from the drop down video.

Biotope classifications were developed in parallel with the MAREA analysis for the results of the REC survey (EMU Ltd). The MAREA survey had been designed around the REC survey to give good spatial coverage across the region with a focus on the aggregate licence areas and their potential secondary impact zones. The REC and MAREA biotope classifications therefore needed to be integrated into a single biotope map.

A comparison of the initial biotope mapping for the MAREA against the biotope map provided by the ALSF REC for the area showed there were considerable differences between the biotope codes that had been assigned during the two surveys even though the survey areas overlapped considerably. These differences were discussed with Cefas at a meeting on 21st May 2009 and it was concluded that they were likely to be a result of the current methodology for determining biotope levels (using the EUNIS system) which is subjective and provides limited guidance for standardising the process. Further comparisons were undertaken to provide more information on the nature and cause of the different classifications and to develop a consistent set of biotope categories.

The biotope mapping exercise was also further complicated by the inherent patchiness of sediments types and associated biotopes in the Outer Thames Estuary Region.

The approaches adopted and the outcomes of the biotope mapping exercise are discussed in the remainder of this section.

Biotope Reconciliation and Mapping Methodology

The MAREA survey in August 2008 revisited 10 sites that had been sampled during the REC survey in August 2007. These repeat stations provided an opportunity to explore whether the apparent differences in the biotope maps were due to real differences in the community/habitat or differences in interpretation of the biotopes. Detailed comparisons between these 10 pairs of samples (one from the REC survey and one from the MAREA survey) at these repeated stations were made and at the suggestion of Cefas the biotope maps from the London Array and Greater Gabbard ESs were also examined to see if either of these maps were similar to the MAREA or REC biotope maps.

Of the ten stations (each representing a pair of samples), only two were classified as having the same or similar biotopes in both of the surveys. PRIMER was used to analyse the statistical differences between the species assemblages and sediment types that had been recorded for the REC and MAREA surveys. A square root transformation was applied to the data and then a Bray-Curtis test was used to create a similarity matrix. Cluster analysis was used with a SIMPROF test to provide a dendrogram that highlighted the statistically different groups of stations.

The dendrogram showed that nine of the ten paired sites occurred in the same group as one another, and in six out of ten cases the two sites were more similar to each other than to any of the other samples. This indicated that there was much greater similarity in the benthic communities at stations sampled from the same site in different years than between samples from different sites sampled during the same survey. The fact that the biotope categories did not reflect this pattern indicated that the difference may lie in the interpretation of the biotopes or possibly even in the original creation of the biotopes, rather than fundamental changes in the benthic community between the survey years. For example, discrepancies in the original classification regarding terms such as 'circalittoral' or 'infralittoral' is sufficient to place sites in different biotopes.

In addition to the comparison described above, the biotope maps that were constructed for the London Array and Greater Gabbard EIAs were compared with the corresponding areas of the MAREA and REC survey. A list of the biotopes within each EIA study area was compared with those recorded at MAREA and REC stations within the same area. Generally, the lists of MAREA biotopes were very similar to those found in the London Array, Inner Gabbard and Galloper areas, while many of the biotopes recorded within the EIA maps were missing from the REC interpretation. The MAREA survey also assigned a number of additional biotopes to these areas that were not recorded in either the EIA biotope maps or the REC survey. In light of the higher consistency between the MAREA biotope map and the existing detailed maps for wind farm areas, and the greater range and complexity of the MAREA biotope classifications, it was considered that the MAREA biotopes would form the basis of further mapping and that the REC species lists would be reviewed to investigate the cause of the apparent differences.

The review of the REC species lists and biotopes assigned was undertaken by Professor Mike Elliott of the University of Hull. The review highlighted that the biotopes as defined by Conner *et al.*, 2004 do not adequately cover areas of very sparse fauna, which leads to differences in the biotope code that is assigned. Professor Elliott had originally assigned biotopes to the MAREA data, and he subsequently re-assigned biotopes for the REC data. He compared the two original sets to each other and then compared the original MAREA biotope list with the re-assigned REC biotopes. In this way, a consistent list of biotopes was created by one investigator for all 200 MAREA and REC stations.

In many cases within the REC dataset, patches of seabed comprising coarse sediments with impoverished fauna were attributed the SS.SCS.CCS biotope classification. The REC report states that this was because greater definition was not possible due to the apparent paucity of species or absence of a suitable species match with the Marine Habitat Classification. However, with the benefit of the MAREA dataset for comparison, it became apparent that in many cases the numbers of molluscs and other heavier fauna in an otherwise comparable species list was much lower in the REC dataset than in the MAREA dataset. In general the species richness and total abundance were also considerably higher in the MAREA samples than the REC samples, even though the survey and laboratory methodologies (including season, grab type, sieve sizes etc) were the same. These two factors imply that a greater level of sorting effort may have been applied to the MAREA samples resulting in the difference recorded.

The REC species lists were subsequently re-interpreted with an understanding of the missing fauna and the MAREA species lists for reference to provide a consistent list of biotopes for the Outer Thames Estuary. These biotopes are listed in Table 5.2 together with an indication of whether they were recorded from the REC and/or MAREA datasets. Overall there is a fairly high degree of consistency between the MAREA biotopes and the revised REC biotopes with 20 of the 36 biotopes occurring in both surveys. These biotope categories were plotted using GIS at the 'biotope complex' level of the JNCC classification system (eg *SS.SBR.PoR*) but without further classification to the 'biotope' level (eg *SS.SBR.PoR.SspiMx*).

The process of mapping the biotopes as an overlay on the regional sediments map highlighted further difficulties with the integration of multiple benthic datasets at the regional scale. The regional seabed sediments map was based on the regional REC and MAREA geophysical survey data, plus a large number of grab samples that had been collected across the region. During the biotope mapping it was noted that while the seabed features map gives a good indication of regional trends, the local sediment characteristics, and their associated biotopes are actually very patchy. This leads to a large number of biotopes being recorded within each of the broadscale sediment categories, and meant that the sediment component of the biotope code did not always correspond to the predicted sediment category from the seabed features map.

To overcome the issue of patchiness and the biotope categories not aligning consistently with the seabed features map several different approaches were attempted with the goal of producing a robust map of 'biotope complexes' at the regional level. One of the techniques was the creation of a Voronoi output which maps areas of habitat based on the biotope category at the nearest sampling station, and draws the biotope boundary at the point that is equidistant between two boundaries. Figure 5.8 shows the output of this mapping exercise with the boundaries of the known geological and seabed features overlaid.

Figure 5.8 shows that even though this technique is statistically robust, the low density of sampling points combined with the inherent patchiness of sediment types and associated biotopes means that the areas do not correlate well at a fine scale with known features of the Thames Estuary, and spatial patterns were generally less clear than when considering the sample biotopes as spot points. At a general level, however, the map shows the expected gradation from the SW to NE of the area and thus the general progression in depth, sediment type and faunal community; the inshore area off the Suffolk coast most notably being mixed sediments with patchy distributions. The subtidal 'polychaete reef' areas, as very sparse and patchy *Sabellaria* concretions, occur randomly over the area. It was therefore concluded that the most appropriate approach was to map the biotope complexes as spot points on top of the regional seabed features map, and to consider all of the biotopes that were found to occur within geographic areas and/or sediment types that could be affected by dredging within the MAREA region. This map and the distribution of biotopes shown within it are discussed in the next section.

Biotopes of the Outer Thames Estuary

The biotopes that have been identified during this exercise have been mapped at the biotope complex level within Figure 5.9. The full list of biotopes that were identified within the study area is given below in Table 5.2. The most commonly recorded biotope was SS.SBR.PoR.SspiMx (*Sabellaria spinulosa* on stable circalittoral mixed sediment), followed by SS.SCS.CCS.MedLumVen (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) and SS.SCS.ICS.Glap (*Glycera lapidum* in impoverished infralittoral mobile gravel and sand).

Within the study area, the south-western, south-eastern and north-eastern areas are dominated by sands and sandy-muds. In contrast the central areas are dominated by gravels and sandy-gravels. As described above, the biotopes within the MAREA study area reflect a patchy and mixed sediment area. The sites are dominated by coarse sediments with most areas having a proportion of gravel even within more muddy areas. The sediments have a low proportion of sedimentary organic matter, usually less than 3%, again reflecting the coarse nature of the area.

The stability and habitat heterogeneity of the coarser mixed sediments within the study area generally cause them to be colonised by a greater number of species than the finer more homogenous substrates. The type of species able to inhabit these different environments also varies. Soft substratum communities are dominated by small infauna such as annelid and polychaete worms and other burrowing species such as bivalve molluscs, whilst harder substrates are able to sustain populations of larger epifauna such as amphipods, crustacea, and arachnids.

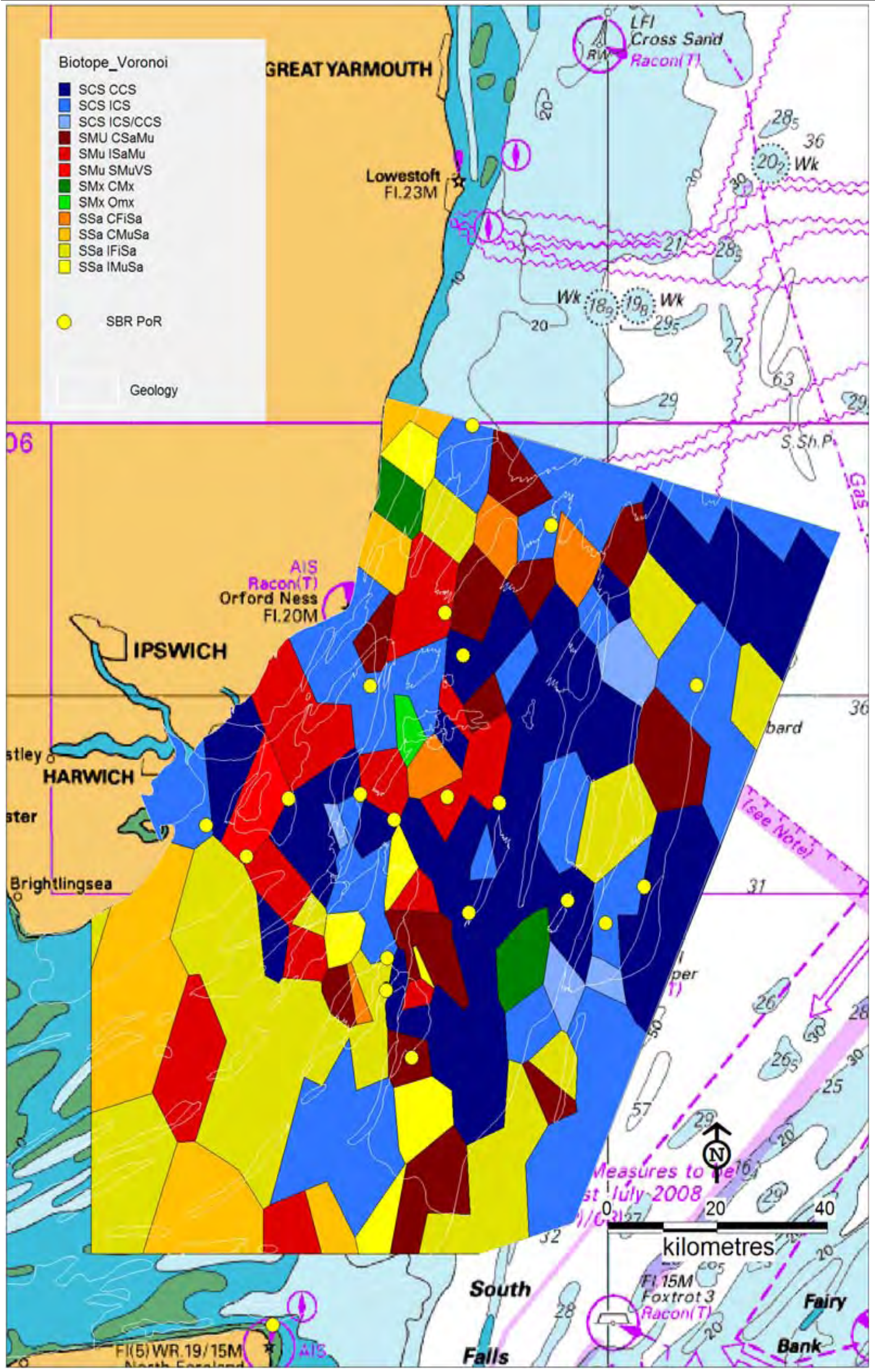
The more stable and mixed areas are characterised by small patches of the shallow reefs formed by the polychaete *Sabellaria spinulosa* and polychaetes such as glycerids, nephtyds and spionids dominate in the more mobile areas. There are small bivalves in many areas, with some sediments supporting moderate populations of *Abra* spp. It is of note that in many areas the fauna is similar to that over mixed sediments with mussel beds (*Modiolus*) although few mytilids were taken in the samples. Furthermore, while the reef-forming polychaete *Sabellaria* is present at many stations, its abundance is generally very low.

In coarse sediments where an additional amount of mud is present, the fauna contains moderate numbers of the bivalves *Abra* and *Nucula* as well as ophiuroid and echinoid echinoderms. Tube-building and burrowing amphipod crustaceans (eg *Ampelisca* spp) occur where sediment stability allows. In contrast, sites with mobile predominantly sandy sediments are colonised by cumaceans, magelonid polychaetes and bathyporeid amphipods whereas more mixed sediments have syllid polychaetes as characterising organisms. It is of note that many of these sites are impoverished both in species richness and in abundance due to the coarse and mobile nature of the sediments.

Whilst the general distribution of the biotopes shown in Figure 5.9 was found to be patchy, some broad regional patterns were discernable:

- SS.SCS (sublittoral coarse sediment) mainly correlated with the coarser sediments in the MAREA study area (medium sand through to coarse veneer / gravel).
- SS.SSa (sublittoral sands and muddy sands) occurred mainly on areas classified as fine sandy sediments (fine sand, medium sand).
- SS.SMu (sublittoral cohesive mud and sandy mud communities) occurred mainly on coarse sediments (medium sand through to coarse veneer / gravelly sands and sandy gravels).
- SS.SBR (sublittoral biogenic reefs on sediment) occurred almost exclusively on coarse sediments (medium sand through to coarse veneer / gravelly sands and sandy gravels).

Figure 5.8 Voronoi Output of Biotopes in the Outer Thames Estuary



- SS.SMx (sublittoral mixed sediment) only occurred at three stations (one each on fine veneer, coarse veneer and gravelly sands/sandy gravels).

Where there are biotope stations that do not correspond to these broad patterns they are often near to the margins of other sediment types. For example the SCS spots in the south of the region are often close to the sandbanks and similarly the only SS.SBR stations that are not on coarse sediments are at the edges of sandbank features. The pattern of SS.SSa stations corresponds the least well and it is possible that this is due to the presence of areas of mobile sand on the seabed.

Level three biotope distributions are patchy throughout the MAREA area. Some very generalised distributions can be determined, however, on a regional scale there is no particularly strong pattern. For example, the biotope SS.SSa.IFiSa is generally found in the south of the MAREA area on fine sand sediments but it is also found in other parts of the region and found on coarser sediments. The biotope SS.SCS.CCS is generally found on coarse sediments in the central and north central parts of the MAREA area, however, this biotope also occurs in medium and fine sand in the MAREA area. The biotope SS.SSa.CMuSa is generally found towards the coast but it occurs on sediments from fine sands to gravelly sands or coarse sediments.

Figure 5.9 Biotopes within the Study Area

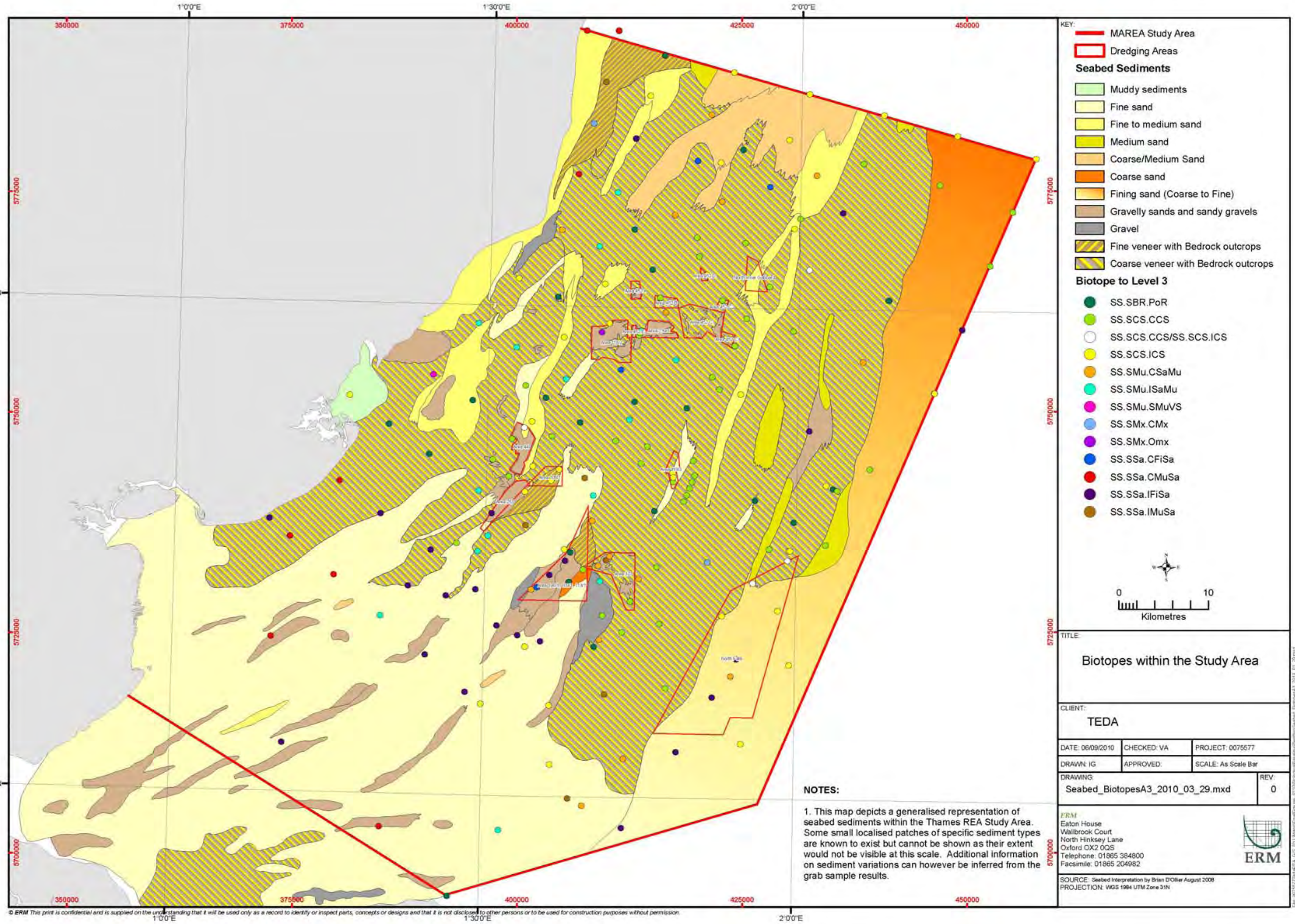


Table 5.2 Biotopes within the MAREA Study Area

Colour	Biotope	Description	REA	REC
	SS.SBR.PoR	Polychaete worm reefs (on sublittoral sediment) [but with *Lagis* and *Lanice* instead of *Sabellaria*]	✓	✓
	SS.SBR.PoR.ModMx		✗	✓
	SS.SBR.PoR.SspiMx	*Sabellaria spinulosa* on stable circalittoral mixed sediment	✓	✓
	SS.SCS.CCS	Circalittoral coarse sediment	✓	✓
	SS.SCS.CCS.Blan	*Branchiostoma lanceolatum* in circalittoral coarse sand with shell gravel	✓	✗
	SS.SCS.CCS.MedLumVen	*Mediomastus fragilis*, *Lumbrineris* spp and venerid bivalves in circalittoral coarse sand or gravel	✓	✓
	SS.SCS.CCS.Pkef	*Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand	✓	✓
	SS.SCS.ICS		✗	✓
	SS.SCS.ICS.CumCset	Cumaceans and *Chaetozone setosa* in infralittoral gravelly sand	✓	✓
	SS.SCS.ICS.Glap	*Glycera lapidum* in impoverished infralittoral mobile gravel and sand	✓	✓
	SS.SCS.ICS.HeloMsim	*Hesionura elongate* and *Microphthalmus similis* with other interstitial polychaetes in infralittoral mobile coarse sand	✓	✗
	SS.SCS.ICS.MoeVen	*Moerella* spp with venerid bivalves in infralittoral gravelly sand	✓	✗
	SS.SCS.ICS.SLan		✗	✓
	SS.SMu.ISaMu.MysAbr	*Mysella bidentata* and *Abra* spp in infralittoral sandy mud	✓	✗
	SS.SMu.ISaMu.NhomMac		✗	✓
	SS.SMu.CFiMu.MegMax	Burrowing megafauna and *Maxmuelleria lankesteri* in circalittoral mud.	✓	✗
	SS.SMu.CSaMu	Circalittoral sandy mud	✓	✓
	SS.SMu.CSaMu.LkorPpel	*Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud	✓	✓
	SS.SMu.ISaMu.AmpPlon	*Ampelisca* spp, *Photis longicaudata* and other tube-building amphipods and polychaetes in infralittoral sandy mud	✓	✓
	SS.SMx.CMx	Circalittoral mixed sediment	✓	✓
	SS.SMx.Omx	Offshore circalittoral mixed sediment	✓	✓
	SS.SMx.OMx.PoVen	Polychaete-rich deep *Venus* community in offshore mixed sediments	✓	✓
	SS.SSa.CFiSa		✗	✓
	SS.SSa.CFiSa.ApriBatPo	*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand	✓	✗
	SS.SSa.CFiSa.EpusOborApri	*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	✓	✓
	SS.SSa.CMuSa	Circalittoral muddy sand	✓	✓
	SS.SSa.CMuSa.AalbNuc	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand	✓	✓
	SS.SSa.IFiSa		✗	✓
	SS.SSa.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna	✓	✓
	SS.SSa.IFiSa.NcirBat	*Nepthys cirrosa* and *Bathyporeia* spp in infralittoral sand	✓	✓
	SS.SSa.IMuSa		✗	✓
	SS.SSa.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis* spp in shallow sublittoral slightly muddy find sand	✓	✗
	SS.SSa.IMuSa.FfabMag	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand	✓	✓
	SS.SSa.IMuSa.SsubNhom	*Spisula subtruncata* and *Nephtys hombergii* in shallow muddy sand	✓	✓
	SS.SSa.SSaVS.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp in infralittoral sand	✓	✗
	SS.SSa.SSaVS.NcirMac	*Nephtys cirrosa* and *Macoma balthica* in variable salinity infralittoral mobile sand	✓	✗

Sabellaria spinulosa

The key biotopes and their ecological importance are presented in Table 5.3. The coloured stars indicate different types of biotope as follows:

- yellow represents biotopes important for birds;
- blue represents biotopes important for fish;
- pink represents a reef development; and
- green represents a rare and diverse biotope.

Table 5.3 Biotopes Ecological Importance Summary

Survey Station Numbers	Biotope Code	Ecological Importance
Within Licence Areas		
17, 18, 19, 88, 109, 115, 116, 120, 11 (118)	SS.SBR.PoR.SspiMx	High as reef - Annex 1 habitat
16, 114, 115, 116, 32	SS.SCS.CCS.MedLumVen	The biotope is probably an important source of food for opportunistic predatory fish such as gurnards and whiting and benthic scavengers such as whelks. The bivalve, *Montacuta substriata*, is often found living commensally on the spines of the purple heart urchin, *Spatangus purpureus*.
117	SS.SMu.ISaMu.AmpPlon	Sublittoral stable cohesive sandy muds occurring over a wide depth range may support large populations of semi-permanent tube-building amphipods and polychaetes. In particular large numbers of the amphipods *Ampelisca* spp. and *Photis longicaudata* may be present along with polychaetes such as *Lagis koreni*. Other important taxa may include bivalves such as *Nucula nitidosa*, *Chamelea gallina*, *Abra alba* and *Mysella bidentata* and the echinoderms *Echinocardium cordatum* and *Amphiura brachiata*. In some areas polychaetes such as *Spiophanes bombyx* and *Polydora ciliata* may also be conspicuously numerous. This community is poorly known, appearing to occur in restricted patches. In some areas it is possible that AmpPlon may develop as a result of moderate organic enrichment. A similar community in mud has also been reported in the Baltic which is characterised by large populations of amphipods such as *Ampelisca* spp., *Corophium* spp. and *Haploops tubicola* (see Petersen 1918; Thorson 1957) and it is not known if SMU.AmpPlon is a UK variant of this biotope.
70, 86, 122, 127	SS.SSa.IFiSa.NcirBat	Apart from supporting its own biological community, the biotope supports predatory fish and bird species. In particular, the sand eel, *Ammodytes* sp., is associated with the IGS.NcirBat biotope and is an important prey species for bird populations, e.g. guillemot, razorbill, puffin and terns. The arctic tern and puffin rely on populations of sand eel as their predominant food source. The sand eel is also an important food source for wintering birds such as scoters, little terns and the red-throated diver (Batten *et al.*, 1990; Gibbons *et al.*, 1993). EC Habitats/UK BAP

Survey Station Numbers	Biotope Code	Ecological Importance
32, 125, 126	SS.SMu.CSaMu.LkorPpel	*Lagis koreni* is an important source of food for commercially important demersal fish, especially dab and plaice (Macer, 1967; Lockwood, 1980 and Basimi & Grove, 1985).
123, 126	SS.SSa.IMuSa.SsubNhom	In shallow non-cohesive muddy sands, in fully marine conditions, a community characterised by the bivalve *Spisula subtruncata* and the polychaete *Nephtys hombergii* may occur. The sediments in which this community is found may vary with regard silt content but they generally have less than 20% silt/clay and in some areas may contain a degree of shell debris. This biotope falls somewhere between SSA.FfabMag and SSA.AalbNuc with regard sediment type (i.e. somewhat muddier than SSA.FfabMag and less muddy than SSA.AalbNuc) and may have species in common with both. As a result, other important species in this community include *Abra alba*, *Fabulina fabula* spp. and *Mysella bidentata* spp. In addition, *Diastylis rathkei* typical, *Philine aperta* (in muddier sediments), *Ampelisca* spp., *Ophiura albida*, *Phaxas pellucidus* and occasionally *Bathyporeia* spp, may also be important, although this is not clear from the data available. In areas of slightly coarser, less muddy sediment *S. solida* or *S. elliptica* may appear occasionally in this biotope. Abundances of *Spisula subtruncata* in this biotope are often very high and distinguish it from other closely related biotopes.
123, 125	SS.SSa.IMuSa.AalbNuc	*Abra alba* is a common food item for *Asterias rubens* and demersal fish. Abra alba constituted ca 20% by weight (annual average) of the important food species of plaice, *Pleuronectes platessa* in Kiel Bay, Germany (Arntz, 1980; Rainer, 1985) and ca 40% by weight (seasonal average) off the North Wales coast (Basimi & Grove, 1985). Predatory fish are also likely to frequent the biotope and include the Dover sole *Solea solea* and members of the cod family. The infaunal tube-building polychaete *Lagis koreni* is a significant food-source for commercially important demersal fish, especially dab and plaice, e.g. Macer (1967), Lockwood (1980) and Basimi & Grove (1985). *Echinocardium cordatum* is also a component of the diet of a number of demersal fish, e.g. plaice (Carter *et al.*, 1991). EC Habitats/ UK BAP
Within Plume Footprint		
48, 85	SS.SMu.CFiMu.MegMax	In circalittoral stable mud distinctive populations of megafauna may be found. These typically include *Nephrops norvegicus*, *Calocaris macandreae* and *Callianassa subterranea*. Large mounds formed by the echiuran *Maxmuelleria lankesteri* are also frequent in this biotope. The seapen *Virgularia mirabilis* may occur occasionally in this biotope but not in the same abundance as SpnMeg to which MegMax is closely allied. Infaunal species may include *Nephtys hystricis*, *Chaetozone setosa*, *Amphiura chiajei* and *Abra alba*.

Box 5.2 Summary of Biotopes within the MAREA Study Area

Within the study area, the south-western, south-eastern and north-eastern areas are dominated by sands and sandy-muds, and the central areas are dominated by gravels and sandy-gravels.

The most commonly recorded biotope was SS.SBR.PoR.SspiMx (*Sabellaria spinulosa* on stable circalittoral mixed sediment), followed by SS.SCS.CCS.MedLumVen (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) and SS.SCS.ICS.Glap (*Glycera lapidum* in impoverished infralittoral mobile gravel and sand).

Level two and level three biotope distributions are patchy throughout the MAREA area. Some very generalised distributions can be determined, however, on a regional scale there is no particularly strong pattern.

The low density of sampling points combined with the inherent patchiness of sediment types and associated biotopes means that the areas do not correlate well at a fine scale with known features of the Thames Estuary. As a result it was concluded that the most appropriate approach was to map the biotope complexes as spot points on top of the regional seabed features map, and to consider all of the biotopes that were found to occur within geographic areas and/or sediment types that could be affected by dredging within the MAREA region within the impact assessment.

5.2.5 Commercially Important Species

Overview

The Outer Thames Estuary supports several benthic fisheries. This section describes eight of the commercially important benthic species found and/or reported to be present in the Outer Thames Estuary and surrounding areas. For details on fisheries landings and seasonal variation see Section 6.2.

Several fishing methods/gear types are used to catch commercially important benthic species in the Outer Thames Estuary (Walmsley *et al* , 2007). Cockles are fished by both local and visiting vessels. Local vessels use an efficient solids handling pump system that sifts the cockles from the sand and pumps the cockles into the boat. Both wild and cultivated oyster fisheries in the MAREA area exist. They are highly regulated and fished by oyster dredgers. Lobster, crab and whelk are fished by pots, while shrimp are generally caught by beam trawl.

As described in the survey methodology, information from two separate surveys has been used as part of this MAREA. The REC survey consisted of 20 beam trawl locations and 70 grab sites; the MAREA survey consisted of 16 trawls and 127 grab sites. The parts of the MAREA study area where commercially important species were recorded are discussed within the sections below.

Brown Shrimp

The brown shrimp (*Crangon crangon*) is normally found in waters up to 50 m deep on sandy or muddy ground and can be found throughout the shallow water areas of the southern North Sea. They remain buried during the day to avoid predation and feed nocturnally. They feed on most faunal material including polychaetes, fish, molluscs and small arthropods and will also feed on algae including *Ulva lactuca* and *Ulva intestinalis*.

Female brown shrimp carry fertilised eggs on their abdominal appendages for 4-13 weeks depending on the water temperature before the eggs hatch. Egg bearing females can be found throughout most of the year but there are two reproductive peaks in April- early September and October-November.

Brown shrimps are widespread throughout the MAREA area (Figure 5.10). They were more frequently present than absent at sampling stations from both surveys and numbered between 1 and 394 individuals at each site at which they were present. Brown shrimp have a low sensitivity to smothering and are not sensitive to increased turbidity.

Pink Shrimp

The pink shrimp (*Pandalus montagui*) normally lives at depths of 5-15 m but can be found down to 100 m or more. This shrimp migrates from shallower water to deeper offshore waters in October – November. They mostly feed on hydroids, small crustaceans and polychaetes. Pink shrimps lay eggs from November to February which hatch in April-May.

Pink shrimps are common and numerous in the MAREA area. They were absent from only 6 out of 36 trawl sites during surveys. At sites where pink shrimps were present, between 1 and 729 individuals were found, with the largest samples found in the north of the survey area.

Edible Crab

The edible crab (*Cancer pagurus*) is found in waters depths of 0-100 m on bedrock, mixed coarse ground and offshore in muddy sand. It is an active predator feeding on a variety of crustaceans including other crab species and the squat lobster *Galathea squamifera* and will also feed on smaller edible crabs. The edible crab also feeds on a variety of molluscs including the dog whelk, winkles, mussels, cockles and oysters.

Mating occurs in spring and summer after which the females carry fertilised eggs under the abdomen for 6-9 months, releasing the larvae in late spring to early summer in offshore waters before returning inshore to feed.

No edible crabs were found during the MAREA or REC surveys of the MAREA area, however the trawls and grabs employed by these surveys were not designed to target this species. Edible crabs have a low sensitivity to smothering and are not sensitive to increased turbidity.

European Lobster

The European lobster (*Homarus gammarus*) is found in water depths of 0-150 m on rocky sediments and is usually found to a depth of 60 m living in holes and tunnels in the rock. This lobster feeds on a variety of benthic invertebrates including crabs, molluscs, sea urchins, polychaete worms and starfish, but may also include fish and flora.

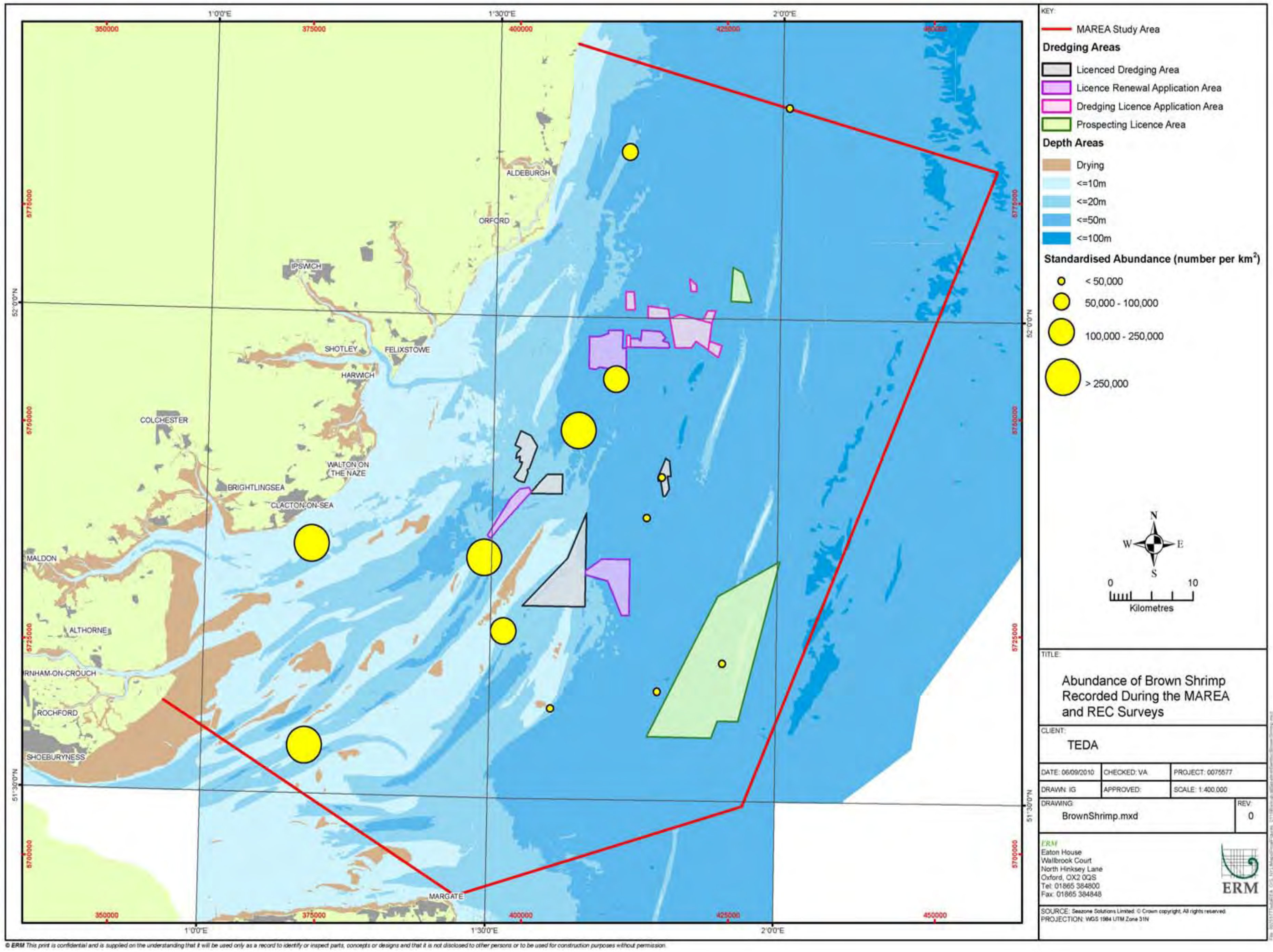
No European lobsters were found during the MAREA or REC surveys however the trawls and grabs employed by these surveys were not designed to target this species.

Cockles

Cockles (*Cerastoderma edule*) are infaunal filter-feeding bivalves that ingest plankton from the water column for nutrition. They are commonly found in shallow water along northwest European coasts and in estuaries. In the Thames region cockle fishing grounds are located predominantly in an area to the west of Felixstowe in the north to Margate in the south. No recognised cockle harvesting area overlaps with any licence area. Cockles are fished commercially from May through to November with the peak fishing period occurring during August and September. By weight cockles contribute to approximately 80% of the total landed at ports in the study area.

No cockles were found during the MAREA or REC surveys, however the trawls and grabs employed by these surveys were not designed to target this species, and there is a large cockle fishery within the Thames Estuary. Cockles have low sensitivity to smothering and are not sensitive to increased turbidity.

Figure 5.10 Abundance of Brown Shrimp Recorded During the MAREA and REC Surveys



Mussels

The common mussel *Mytilus edulis* is a filter-feeding bivalve that has a widespread distribution in intertidal areas all around the coasts of the UK. In exposed areas they form large beds on hard substrata, while in sheltered areas infaunal beds may be found on either gravel or sand. Although mussels commonly form large clumps or beds they can also be found in patches of strings. In the Thames region mussels are landed throughout the year but peak landings occur in April and December.

No mussels were found in the survey trawls in the MAREA area, however, a few individuals were found in grab samples.

Whelks

Whelks (*Buccinum undatum*) are carnivorous marine snails commonly found around the coast of the UK in the intertidal zone but they also occur in deeper water. They feed on a variety of living or dead marine organisms using a raduta on the tip of their proboscis. Whelks are fished from April through to January.

Low numbers of whelks (between 1 and 4) were found at six survey sites during the REC survey; single organisms were found at two sites during the MAREA survey. All whelks were found in the western half of the study area and in general the larger numbers were found closest to the shore.

Oysters

Oysters (*Ostrea edulis*) are filter feeders, predominantly consuming phytoplankton and protists. They are fished from October through to March. No oysters were found during site surveys trawls of the MAREA area, however, one individual was found in a grab sample. Of the commercially valuable species the most sensitive species appears to be the oyster, which has a very high sensitivity to smothering.

Box 5.3 Summary of Commercially Important Species within the MAREA Study Area

Several fishing methods/gear types are used to catch a number of commercially important benthic species in the Outer Thames Estuary (Walmsley *et al*, 2007), including brown shrimp, pink shrimp, edible crab, European lobster, cockles, mussels, whelks and oysters.

Sensitivity data on commercially important benthic species is patchy [(1)]. Of the commercially valuable species the most sensitive species appears to be the oyster (*Ostrea edulis*), which has a very high sensitivity to smothering. More mobile species, such as the brown shrimp (*Crangon crangon*), edible crab (*Cancer pagurus*) and common lobster (*Homarus gammarus*) have low sensitivity to smothering and are not sensitive to increased turbidity. Cockles (*Cerastoderma edule*), which are potentially the most important commercial species also have low sensitivity to smothering and are not sensitive to increased turbidity.

The commercial species listed above have the potential to be impacted by dredging and are therefore taken forward into the impact assessment.

5.2.6 Protected Species and Habitats

Species

UK BAP Species and Nationally Important Marine Features

The only UK BAP species found during the MAREA survey was the oyster *Ostrea edulis*. One individual specimen of this species was found at Station 20. This species is fished within the MAREA study area (see Section 6.2) but is not one of the most heavily fished shellfish species. This fishery is subject to UK shellfisheries conservation legislation but the species is not protected under any other national or international nature conservation legislation or conventions. The BAP Action Plan aims to maintain and expand the existing geographical distribution of the native oyster within UK inshore waters and to increase the existing abundance of the native oyster within UK inshore waters.

The published benthic surveys to date in the licence areas and plume footprints in the study area did not identify any of the 87 marine UK BAP priority species. A species essential to one UK BAP priority habitat was identified in both historical surveys and during the MAREA and REC field surveys. Biogenic reefs of *Sabellaria spinulosa*, JNCC Marine Nature Conservation Review (MNCR) biotope code *CMX.SspiMx*, is classified as a UK BAP priority habitat. The ecology and distribution of this species and habitat in the study area are discussed later in this section.

Six species have been identified during the MAREA and REC surveys that are Candidate Nationally Important Marine Features (cNIMF). These are:

- *Sabellaria spinulosa;*
- *Leptocheirus hirsutimanus;*
- *Modiolus modiolus;*
- *Barnea candida;*
- *Ostrea edulis* (see above section); and
- *Echinus esculentus.*

The location and abundance of *S. spinulosa* is shown on Figure 5.11. This species, as individual tubes, is considered to be commonly occurring around all British and Irish coasts but a decline has been observed as a result of fishing.

Leptocheirus hirsutimanus is an amphipod that was found at two stations during the REC survey (stations 43 and 44) that are near the centre of the study area to the northeast and the northwest of Inner Gabbard. This species is thought to be scarce but not in decline.

The horse mussel, *Modiolus modiolus*, was found at three stations during the MAREA survey (stations 13, 31 and 84). One of these locations is to the north east of Area 452A and the other two locations are to the south of Area 327. Horse mussels were also found at one site during the REC survey in the centre of the study area (at REC station 32). This species is considered to be scarce but not in decline.

White piddocks (*Barnea candida*) were found in the MAREA survey during two trawls (trawls 7 and 9) which were both near the centre of the survey area on coarse veneer with bedrock outcrops. This species was not recorded in the benthic grabs as it lives in soft rock and clays which are difficult to sample with the grabs. A total of 113 individuals were recorded at two central locations during the REC survey (REC stations 31 and 45). One of these sites is between Area 119/3 and the southern tip of Inner Gabbard and the other site is near the northeast corner of Area 452A. The abundance of white piddock recorded during the MAREA and REC surveys is shown in Figure 5.12. This species is nationally scarce. A decline has been observed in its population but studies have not been conducted to quantify this decline.

The European edible sea urchin (*Echinus esculentis*) was found in two MAREA trawls (MAREA trawls 10 and 11). One trawl site was to the north of Area 452D and the other is on the southeast corner of the prospecting area. An REC trawl (REC trawl 45) also found this sea urchin which was located to the north east of Area 452A. This species is considered to be widespread and is not in decline.

Habitats

Sandbanks

For the definition and description of sandbanks in the Outer Thames Estuary refer to the Designated Sites baseline (Section 5.6).

Typical fauna associated with the sandbanks include a high diversity of polychaetes, crustaceans and molluscs and amphipods. The bank crests are dominated by polychaete worms and amphipods, which are characteristic of a stressed, mobile sand environment, while the mobile fauna include crabs, brown shrimp, squid, sole and herring. Patchy aggregations of the reef-forming Ross worm (*Sabellaria spinulosa*) are found at Queens Channel; higher densities are typically found on the flanks of the sandbanks and towards the troughs. *Sabellaria* are able to support a diverse attached epifauna, however overall epifaunal species abundance on sandbanks is considered to be low compared to more sheltered, coastal areas (EMU Ltd, 2004).

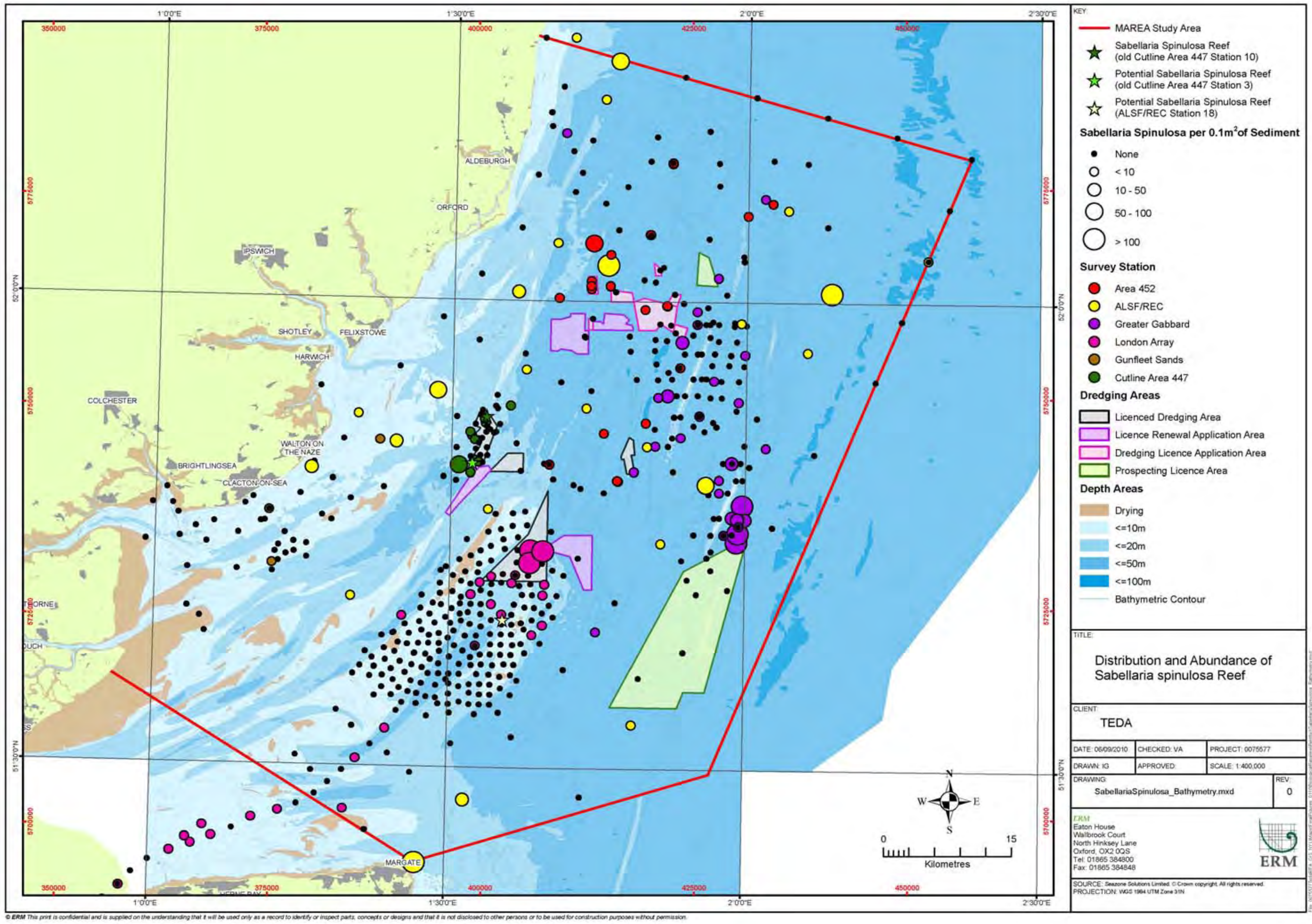
Geogenic Reef

The pre-dredge survey for Area 447 (Cutline) that was undertaken in August 2007 reported the possible presence of geogenic stony reefs at one sample station approximately 3 km northeast of Area 447. This biotope is included in the EC guidelines for the establishment of the Natura 2000 network (European Commission, 2007) and is characterised by an enhanced population abundance and biomass of epifaunal species that colonise a hard substrate of cobbles. The habitat is reported as being in patches spatially separated by areas of rippled sand.

The REC survey reported the presence of two possible geogenic reefs of exposed clay within the study area that had been heavily bored by white piddock (*Barnea candida*). The REC study concluded that the closest biotope description to this community is CR.MCR.SfR.Pid which describes piddocks with a sparse associated fauna in upward-facing circalittoral very soft chalk or clay. It should be noted, however, that during the review of the REC dataset described in Section 5.2.4 above, this biotope classification was found not to be supported by the other components of the benthic community. The CR.MCR.SfR.Pid biotope was re-classified as SS.SCS.CCS.MedLumVen in one site and SS.SBR.PoR.SspiMx in the other. While this biotope classification is considered further in the paragraphs below, it should be considered with some caution.

(1) Sensitivity data from the marLIN website available at www.marlin.ac.uk accessed 19/03/2010.

Figure 5.11 Distribution and Abundance of Sabellaria spinulosa Reef



White piddock is a Candidate Nationally Important Marine Feature. One of the sites is almost 2 km northeast of Licence Area 452A (REC site 45) and the other is located approximately 12.5 km to the east of Area 119/3 (REC site 31). Neither of these potential geogenic reefs is located within the boundaries of any licence area. The epifauna at both sites was sparse although the soft coral *Alcyonium digitatum* and the ascidian *Molgula manhatensis* were found.

There were four other areas identified during the REC survey that had exposed compacted clay but these sites were overlain with veneers of mixed muddy gravels. These were REC stations 30, 32, 38 and 44. These sites are located on predominantly gravelly mixed sediments. Station 30 is 9 km west of the Galloper sandbank, station 32 is 6 km northwest of Licence Area 119/3, station 38 is 2.5 km south of Licence Area 239/1 and station 44 is very close to the northeast corner of Licence Area 452 C2. As these sites are overlain with mud and support high diversity, biomass and species richness, they cannot be described as geogenic reef. However, they may indicate the presence of geogenic reef nearby.

MarLIN, the Marine Life Information Network, has assessed this biotope and assigned sensitivity ratings for various physical, chemical and biological factors that could cause an adverse reaction to the community. For example, some of the species that are common to this biotope are considered to have an intermediate intolerance to smothering by silt although the community has a high ability to recover resulting in a sensitivity rating of low. The community occurs in silty turbid conditions and the community is considered to have low sensitivity to increases in suspended sediment. Similarly, the community has been given a low sensitivity ranking for increases in turbidity.

Biogenic Reef

The biogenic reef that is sometimes formed by *Sabellaria spinulosa* is the only scheduled or statutorily protected habitat found within the scope of the studies reviewed here, protected under Annex I of the Habitats Directive.

Sabellaria spinulosa, or the Ross worm, is a filter feeding polychaete worm that builds tubes using sand particles found in the marine environment. These tubes protect the worm from predation and other environmental damage. They are primarily found in the shallow sublittoral zone although they have also been known to inhabit sublittoral fringe and intertidal areas (UK Biodiversity Habitat Action plan). They are normally found in mixed sediment areas as they require a good supply of sand grains with which to build their tubes. The water must be turbid enough to suspend sand grains that can be filtered out of the water by *S. spinulosa*. However, *S. spinulosa* also require a hard substrate such as shells, pebbles, kelp holdfasts, bedrock or existing mature or decaying *S spinulosa* reefs. The species is widespread in the North East Atlantic and has been recorded in all coastal waters surrounding Britain and Ireland.

Whilst *Sabellaria* are generally solitary species, they can form solid crusts or raised reef-like structures on the seabed. Dense aggregations of *S. spinulosa* tubes can reach up to several metres across and up to 60 cm in depth (English Nature, 1999) and (Northern Ireland Habitat Action Plan, 2005). This is possibly because the larvae of the species use chemical signals to detect existing colonies, showing preferential behaviour towards the colonisation of existing colonies over new areas. The reef-like structures formed by *S. spinulosa* are termed 'biogenic reefs' as the hard reef structures are formed by the tube casings rather than by living organisms themselves, as in the case of a coral reef.

Extensive aggregations of *Sabellaria* spp. can increase habitat heterogeneity and species diversity by stabilising unconsolidated sediments such as sands and by providing a hard substratum for the attachment of sessile organisms. They also create crevices and overhangs available for colonisation by a number of species that would otherwise be absent from the area. The crevices also accumulate organic debris that can serve as an important food source for scavenging species, for example the porcelain crab (*Pisidia longicornis*) and the squat lobster (*Galathea intermedia*) (Pearce *et al*, 2007).

As *Sabellaria* spp. can represent key habitat structuring species, they have been included as a sub-feature of the specific 'marine reefs' habitat defined in Annex 1 of the Habitats Directive (92/43/EEC). Biogenic reef habitats are discussed in JNCC report 325 (Johnston *et al*, 2002) and defined in the *Interpretation Manual of European Habitats (EC, 1999)* also under Annex 1 of the *Habitats Directive* as:

"*Submarine or exposed at low tide, rocky substrates and biogenic concretions, which arise from the seafloor* [(1)] *in the sublittoral zone but may extend into the littoral zone where there is an uninterrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal species including concretions, encrustations and corallogenic concretions"*.

The biogenic reef-like structures formed by *S. spinulosa* and *S. alveolata* are also classed as priority habitats under the UK Biodiversity Action Plan (UK Biodiversity, 1999).

Defining *Sabellaria* reefs has been difficult and a definitive definition has not yet been published. A recent JNCC publication based on the findings of a workshop into the definitions of *Sabellaria spinulosa* reef defined such habitats (in the context of the *Habitats Directive*) as an area of *Sabellaria spinulosa* that is elevated from the seabed and has a large spatial extent. Colonies may be patchy within an area defined as reef and show a range in elevations. The suggested criteria for 'reefiness' in the context of *Sabellaria spinulosa* are shown in Table 5.4.

Table 5.4 JNCC Recommended Criteria for Sabellaria spinulosa reefs (Gubbay, 2007)

Measure of 'Reefiness'	Not a reef	Low	Medium	High
Elevation (cm) (average tube height)	<2	2-5	5 - 10	>10
Area (m^2)	<25	25 - 10,000	10,000 - 1,000,000	>1,000,000
Patchiness (% cover)	<10	10 - 20	20 - 30	>30

During the MAREA survey, a few small aggregations of *Sabellaria* were identified at Station 62 located in the central study area, to the south of Area 452 C1. A precautionary approach was taken in line with best practice and the station was moved approximately 50 m west of the original sample location. Live video and a series of still photographs showed no *Sabellaria* reef at the relocated site. There was no other evidence of *Sabellaria* reef at any of the stations sampled for the MAREA survey in either the grab samples or from DDV.

The REC survey found encrustations of *S. spinulosa* tubes at one site that have the potential to constitute biogenic reef under the Annex 1 reef definition. Aggregations of *S. spinulosa* were observed in all five replicates of photographs taken at this site indicating a relatively consistent and extensive feature. The elevation of the tubes supports the possibility that it could be reef. This site is south of the Long Sand Head licence area (Area 108/3, 109/1, 113/1) and is very close to the high densities of *S. spinulosa* found during surveys conducted during the London Array survey (Figure 5.121).

By overlaying *S. spinulosa* distribution over the sediment types in Figure 5.124.7 it is possible to see that the majority of large abundances of *S. spinulosa* are found on predominantly gravely mixed sediments. This reflects *S. spinulosa*'s need for a hard substratum such as gravel and the high turbidity found in the Outer Thames region.

Box 5.4 Summary of Protected species and Habitats within the MAREA Study Area

There are six benthic species that were recorded during surveys within the MAREA study area that are recognised as being threatened, rare or otherwise exceptional features for priority conservation attention, and are therefore taken forward into the impact assessment. They are:

- *Sabellaria spinulosa;*
- *Leptocheirus hirsutimanus;*
- *Modiolus modiolus;*
- *Barnea candida ;*
- *Ostrea edulis; and*
- *Echinus esculentus.*

Leptocheirus hirsutimanus and *Modiolus modiolus* are both cNIMF species that were found at a small number of stations during the REC and MAREA surveys. These species are both found off most British coasts and the Outer Thames Estuary is not particularly important for either of these species. The piddock, *Barnea candida,* is a cNIMF that is found along the south coast of the UK and the Thames Estuary. Piddocks were found during trawls at two stations that were comparatively close together towards the central western section of the MAREA study area over coarse veneer with bedrock outcrops; these rocky outcrops offer a different habitat for benthic species and could potentially qualify as geogenic reef (see below).

The oyster, *Ostrea edulis*, is a UK BAP and cNIMF species that is found in shallow coastal and estuarine areas. Important stocks of this species exist in the rivers and mudflats bordering the Outer Thames Estuary but it is less common in deeper water. Only one oyster was found at a site in the north of the study area in an area of sand. The European edible sea urchin (*Echinus esculentis*) is a cNIMF species was found in two MAREA trawls and one REC trawl. One MAREA trawl site was to the north of Area 452D and the other was on the south east corner of prospecting area 498. An REC trawl also found this sea urchin which was located to the north east of Area 452A. *Sabellaria spinulosa* is a cNIMF species that is important because of its ability to form biogenic reef habitat, and is discussed below.

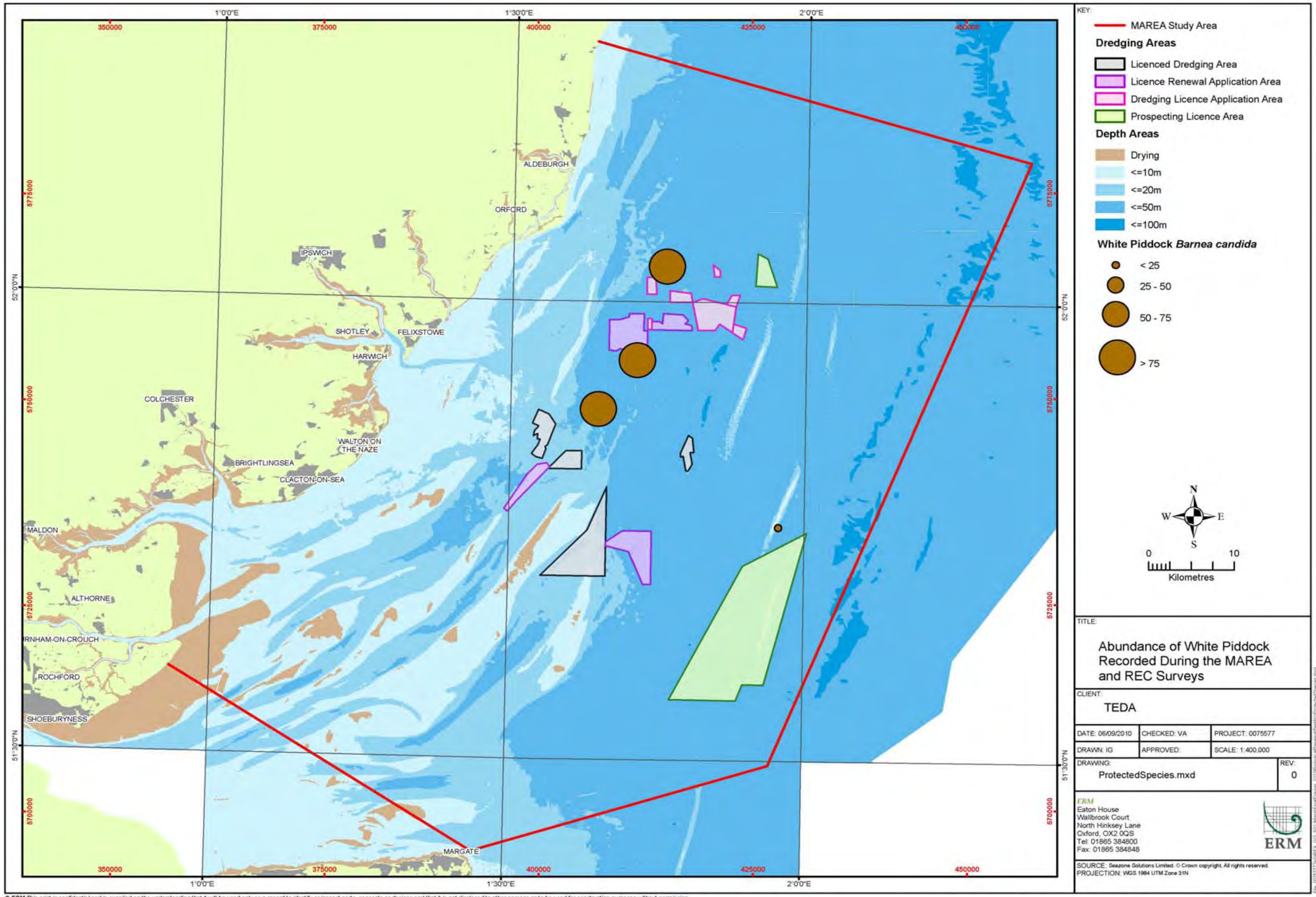
There are three sensitive habitats within the MAREA study area. They are:

- Sandbanks;
- Geogenic reefs; and
- *Sabellaria spinulosa* reefs.

There are several sandbanks in the area which may be designated as SACs in the future. Of these, Margate and Long Sands is a candidate SAC (see Section 5.6 for details). There are two potential Annex I geogenic reefs that have been identified by the REC survey within the study area that support populations of piddock. One of the sites is to the northeast of Licence Area 452A and the other is located to the east of Area 119/3. The distributions of individual specimens of *Sabellaria spinulosa* and potential reefs are shown in Figure 5.121. One site was identified during the REC survey that could be an Annex 1 *Sabellaria* reef. This site was located between Area 327 and Long Sand Head licence area (Area 108/3, 109/1, 113/1).

(1) Where 'arise from the seafloor' is interpreted as the reef being topographically distinct.

Figure 5.12 Abundance of White Piddock Recorded During the MAREA and REC Surveys



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5.3 Fish Ecology

5.3.1 Introduction

This section summarises the baseline ecology of fish resources in the Outer Thames Estuary study area, which is described in detail in Appendix L. The description is supported by information on the frequency of occurrence and distribution of fish species in the region obtained from the MAREA, REC and other surveys.

This chapter follows the following structure:

- A description of the data sources that have been used to inform the Fish Ecology section of Appendix L.
- An overview of relevant legislation.
- Summaries of the distributions of protected species, demersal species, pelagic species and elasmobranchs, and their presence within the MAREA study area.
- A summary of the information included in Appendix L including a discussion of which species will be considered in the impact assessment.

5.3.2 Sources of Information

Overview

In compiling the available information concerning the fish ecology in the study area, a desk-based review of the existing published and peer-reviewed literature was carried out and the following information sources were consulted:

- Cefas interactive Spatial Explorer and Administrator (iSEA) (http://www.cefas.co.uk/data/isea---interactive-spatial-explorer-and-administrator.aspx) (accessed 01/03/08) information on the distribution of spawning and nursery grounds based on Coull, K. A., Johnstone, R. and Rogers, S. I. 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.;
- ICES FishMap species summaries for the North Sea (http://www.ices.dk/marineworld/fishmap/ices/) (accessed 05/03/08).
- AquaMaps species distribution maps (Kaschner, K., J. S. Ready, E. Agbayani, J. Rius, K. Kesner-Reyes, P. D. Eastwood, A. B. South, S. O. Kullander, T. Rees, C. H. Close, R. Watson, D. Pauly, and R. Froese. 2008 AquaMaps: Predicted range maps for aquatic species. World Wide Web electronic publication, www.aquamaps.org, Version 05/2008.) (accessed 05/03/08).
- FishBase (www.fishbase.org), an online database containing data on fish ecology, distribution and basic biological information (accessed 05/03/08).
- NBN Gateway species distribution maps, comprising information from the following sources: Biological Records Centre, Bristol Regional Environmental Records Centre, Countryside Council for Wales, Devon Biodiversity Records Centre, Glasgow Museums BRC, Highland Biological Recording Group, JNCC, Marine Biological Association, Marine Conservation Society, Scottish Natural Heritage. Available at http://data.nbn.org.uk/ (accessed 12/01/09).
- MSC report for the Thames Herring stock (Nichols, J., Huntington, T., and Hough, A., 2005. Final Certification Report for Thames Herring Drift-Net Fishery. Marine Stewardship Council. 111 pp).
- The Norwegian Fisheries site (www.fisheries.no) (accessed 08/08/09).
- Fisheries Research Services website (www.marlab.ac.uk) (accessed 08/08/09).
- Ellis, J.R., Burt, G. & Cox, L. 2008. Programme 19: Thames Ray Tagging and Survival. Cefas, Lowestoft. Prepared for Fisheries Science Partnership: 2007/08.
- Cefas Eastern English Channel Beam Trawl Survey data from 1993-2001.
- London Array EIA survey data collected in June 2005.
- Area 477 EIA survey data collected in January 2008.
- Regional Environmental Characterisation (REC) survey data collected in August 2007.
- TEDA MAREA survey data collected in August 2008.

Cefas Eastern English Channel Beam Trawl Survey 1993-2007

Cefas (Centre for Environment, Fisheries and Aquaculture Science) conducts surveys around the coast of England and Wales using a variety of fishing gears, to collect fisheries-independent indices of stock abundance. These data are integrated into the stock assessments carried out by the ICES (International Council for Exploration of the Sea) Assessment Working Groups.

The Cefas eastern English Channel beam trawl survey samples demersal (living on or near the seabed) fish species in the eastern English Channel (ICES division VIId) and parts of the southern North Sea (IVc), including the Thames Estuary. The survey has taken place every summer since 1989. Survey results from the southern North Sea from 1993-2007 (due to minor inconsistencies in the sampling grid before 1993) were used in the following chapter as a historical reference of abundance for a number of demersal species and elasmobranchs.

The most important commercial species targeted in the Outer Thames estuary region are cod, sole and rays (50% of which were thornback ray in 2008), based on catch statistics (see Section 6.2). For these key species, a time series of the Catch Per Unit Effort (CPUE) data from 1993-2007 has been presented. For other demersal species, a summary of the abundance data in terms of percentage of total catch from 1993-2001 is given, as presented in Parker-Humphreys (2005).

AquaMaps

AquaMaps is an online tool that generates large-scale predictions of the distribution of marine fish species. The distribution maps are created in two stages. The first stage combines occurrence records with model based predictions of species habitat usage against local environmental conditions to determine the suitability of a given area for a species. At the second stage, experts review the map and revise the distribution of each species based on their knowledge and by citing suitable references.

The maps produced from this tool give an indication of the likelihood that a species will be found in that area, rather than a distribution map of where a species has been found in the past.

Historical EIA Surveys in the Thames Estuary

Recent applications for aggregate dredging licences and offshore wind farms have resulted in the completion of several surveys on fish species abundance in sections of the study area. As these surveys have largely been conducted for Environmental Impact Assessments (EIAs), the data only covers the area of interest to the developer and therefore offers patchy data for this MAREA. However, the data from these surveys provides a useful comparison to the surveys conducted for this MAREA and the REC study.

Previous survey data have been collated from the following EIAs:

- London Array Offshore Wind Farm Development (June 2005); and
- Area 447 Aggregate Dredging Licence Application (January 2008).

Data from the EIA surveys of other wind farms and dredging licences in the region were not used due to a lack of information on the survey methodology employed, which did not allow standardisation of the data to be carried out (see Box 5.5).

The historical EIA surveys used 2 m beam trawls to collect epibenthic species and smaller fish species. The survey for the London Array also used a commercial '6 fathom' otter trawl to collect larger, more mobile species of fish more effectively. The London Array project conducted beam trawls at 55 locations in April, July and December 2003 and February 2004 (ICES areas 32F1/2, 32F1/3, 32F1/4, 31F1/1 and 31F0/2). For each location, the beam trawl was towed for five minutes at a speed of approximately 2 knots. Estimates of the numbers of organisms were made using sub-samples. The otter trawls were conducted at five locations close to the London Array and were towed for approximately 25 minutes at a speed of 1.6 knots. Sub-sampling was not used for samples from the otter trawls.

The Area 447 survey was conducted at eight locations in August 2007 (ICES area 32F1/2). The 2 m beam trawl was towed for approximately five minutes at 1.5 knots.

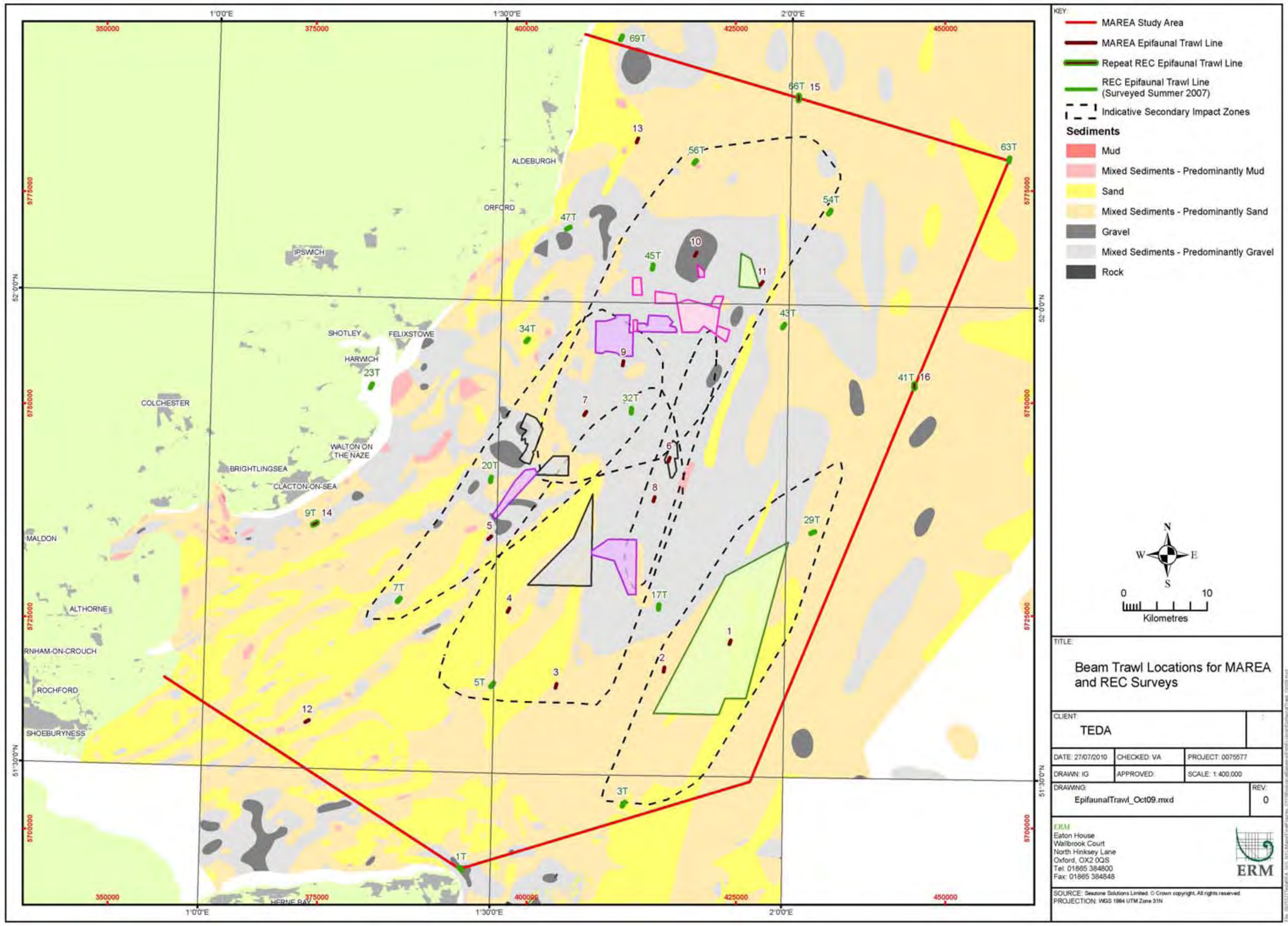
MAREA and REC Surveys

A 2m beam trawl survey similar to those carried out for the London Array and Area 477, was carried out as part of a dedicated marine ecological survey for the MAREA. The survey was conducted in August 2008 at 16 sites. At each site, the trawl was towed for 5-6 minutes at 1.2-1.5 knots covering a distance of approximately 500 m.

The Thames Regional Environmental Characterisation (REC) survey also used 2 m beam trawls to sample the epibenthos at 30 sites in August 2007. Each trawl was towed at 1.5 knots for approximately 500m.

It should be noted that these beam trawls sample benthic fish species that do not move out of the way of the approaching trawl. However this survey method does not usually catch the more mobile pelagic [(1)] species and this is reflected in the types of species caught in the MAREA and REC and other historical EIA surveys. The locations of the MAREA and REC beam trawl surveys are shown in Figure 5.13.

Figure 5.13 Beam Trawl Locations for the Regional Environmental Characterisation Survey and MAREA Survey.



(1) Species that live in the water column or 'open ocean'.

Standardisation of Survey Data

As there were differences in methodology between the historical EIA, MAREA and REC surveys and in catch effort, a direct comparison of absolute numbers is not possible. The data were therefore standardised using a 'swept area' methodology described below (Box 5.5).

Box 5.5 Swept Area Methodology

The' swept-area' methodology is commonly applied to fisheries survey data and estimates the area swept by a trawl as it moves along the seabed, based upon the width of the trawl and the distance travelled during the trawl. This allows standardisation of the results of data from both beam and otter trawls. The beam of a beam trawl keeps the mouth of the net open and so the width of the trawl is known. With an otter trawl the head rope is usually curved and so the length of the headrope does not equal the width of the trawl. Therefore, the length of the headrope is divided by 2 (Sparre *et al, 1998*) in order to estimate the actual width of the trawl.

The total number of each fish species caught in each trawl was then divided by the area swept by the trawl to provide an indication of the total number of fish per km^2.

It should be noted that applying the swept-area methodology to the survey data will result in the abundance of species appearing to be 'inflated' in some cases compared with the absolute numbers of individuals sampled. For example, 1 individual sampled in a 2m beam trawl towed for 500m would equate with 1000 individuals being found per km^2 according to the swept-area calculation. Clearly this may not be the case due to a range of factors including the mobility of the species, whether or not it tends to be solitary or found in shoals/schools etc.

5.3.3 Legislation and Guidance

Most fish stocks in the North Sea are over exploited [(1)] and a number of both commercially important and non-commercial species are now protected. Table 5.5 summarises the conservation measures in place to protect southern North Sea fish species.

In 2003 the EU Commission introduced special measures to conserve cod in the North Sea with a long-term recovery plan which was adopted in 2004. The EU Commission also implemented a long-term management plan for North Sea plaice and Dover sole in 2007 and a European recovery plan for the common eel.

The 'grouped' Species Action Plan (SAP) for commercial marine fish mentioned in the table provides detailed information on the threats facing species and the opportunities for maintaining and enhancing populations. A 'grouped' Species Action Plan was developed because a range of common policies and actions are required for a number of similar species. The overall target of the grouped SAP is to 'bring all stocks identified in the plan within precautionary reference points as defined by ICES within 5 years'. Currently this target is assessed as having achieved 'no progress'. The management advice associated with the individual species in the plan is summarised within the relevant paragraphs in Sections 5.3.6 and 5.3.7.

In 2008 the short-snouted seahorse and spiny seahorse were added to Schedule 5 of the Wildlife and Countryside Act 1981 making it an offence to kill, harm, damage or disturb them in their habitat.

For more information on the legislation and guidance summarised in Table 5.5 see Section 5.1.2.

(1) Office for National Statistics, http://www.statistics.gov.uk/cci/nugget.asp?id=367

Table 5.5 Conservation Measures in Place to Protect Southern North Sea Fish Species

Species	EC Habitats Directive (Annex number)	Wildlife and Countryside Act (Schedule 5)	IUCN Red Data List Species	Bern Convention (Appendix III)	Nationally Important Marine Feature (NIMF)	Biodiversity Action Plan
Common skate *Dipturus batis*	-	-	Critically Endangered	-	-	Common skate Species Action Plan
Allis shad *Alosa alosa*	II and V	Yes	Data Deficient	Yes	-	Allis shad Species Action Plan
Twaite shad *Alosa fallax*	II and V	Yes	Data Deficient	Yes	-	Twaite shad Species Action Plan
Atlantic salmon *Salmo salar*	II and V (only in freshwater)	-	Least Risk	Yes (only in freshwater)	-	-
Sea lamprey *Petromyzon marinus*	II and V	-	Least Risk	Yes	-	-
River lamprey *Lampetra fluviatilis*	II and V	-	Least Risk	Yes	-	
Cod *Gadus morhua*	-	-	Vulnerable	-	Yes	EU long term Cod Recovery Plan, Commercial marine fish grouped Species Action Plan
Herring *Clupea harengus*	-	-	-	-	-	Commercial marine fish grouped Species Action Plan
Whiting *Merlangius merlangus*					Yes	Commercial marine fish grouped Species Action Plan
Mackerel *Scomber scombrus*	-	-	-	-	-	Commercial marine fish grouped Species Action Plan
Horse mackerel *Trachurus trachurus*	-	-	-	-	-	Commercial marine fish grouped Species Action Plan
Lesser sandeel *Ammodytes marinus*	-	-	-	-	Yes	-
Plaice *Pleuronectes platessa*	-	-	-	-	Yes	EU North Sea Plaice and Dover sole management plan, Commercial marine fish grouped Species Action Plan
Dover Sole *Solea solea*	-	-	-	-	-	EU North Sea Plaice and Dover sole management plan, Commercial marine fish grouped Species Action Plan
Sand goby *Pomatoschistus minutus*	-	-	-	-	Yes	-
Short snouted seahorse *Hippocampus hippocampus*	-	Yes	-	-	-	-
Spiny seahorse *Hippocampus guttulatus*	-	Yes	-	-	-	-

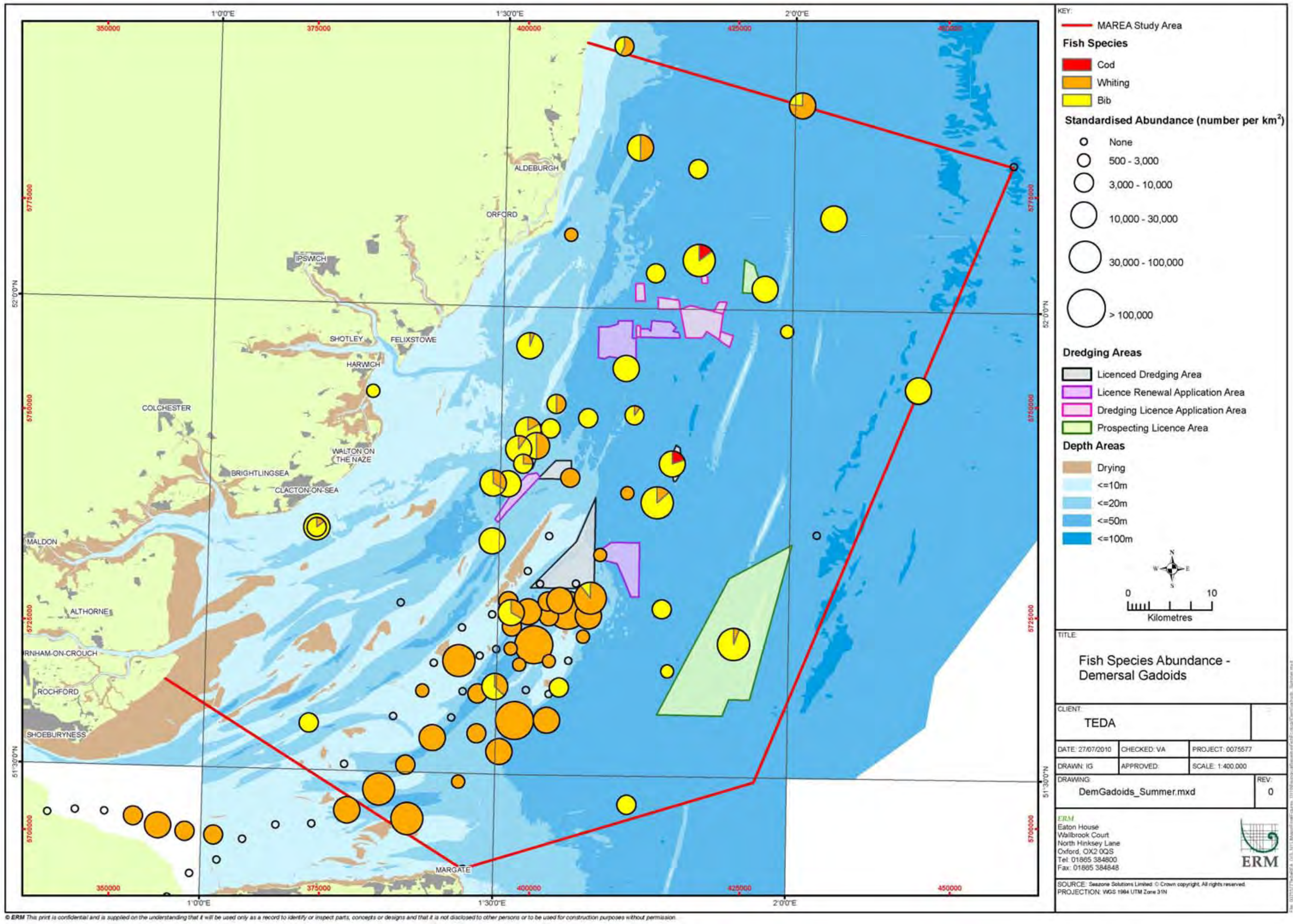
Table notes:
Annex II EC Habitats Directive – This annex includes "*Animal and plant species of community interest whose conservation requires the designation of special areas of conservation*".
Annex V EC Habitats Directive – This annex includes "*Animal and plant species of community interest whose taking in the wild and exploitation may be subject to management measures*".

Bern Convention – Conveys special protection to those species which are vulnerable or endangered. In England the Bern Convention is implemented through the *Wildlife and Countryside Act 1981*.
Nationally Important Marine Feature – Identified as part of Defra's Review of Marine Nature Conservation (RMNC). Include species for which we have a special responsibility in a national, regional or global context, and/or species that have suffered significant decline in their extent or quality, or are threatened with such decline, and can thus be defined as being in poor status.

Biodiversity Action Plan – This is the UK Government's response to Article 6 of the *Convention on Biological Diversity (1994)*. The overall goal is to conserve and enhance biodiversity in the UK. A Species Action Plan provides detailed information on the threats facing species and the opportunities for maintaining and enhancing populations. A 'Grouped' Species Action Plan has been produced for Commercial Marine Fish as a range of common policies and actions are required for all species listed.

5.3.4 Fish Abundance in the Study Area

Figure 5.14 Fish Species Abundance - Demersal Gadoids



Species Distribution

The standardised fish abundance data from the historical EIA, MAREA and REC surveys are presented together in Figure 5.154 to Figure 5.17 and Figure 5.21 to Figure 5.23. The figures show proportional pie charts of demersal gadoid species, demersal flatfish species, other demersal species, pelagic species, a diadromous [1] species, gobies and elasmobranchs [2].

The standardised survey data showed that demersal gadoids are distributed throughout the study area. There is a predominance of whiting in the south and bib in the north. Numbers of cod are low (Figure 5.154).

Demersal flatfish species were sampled throughout the study area and towards the mouth of the estuary. Sole are the most abundant species and dab and plaice are found in similar numbers. Small catches of lemon sole were recorded throughout the area (Figure 5.15)

Other demersal species (pogge, dragonet and sandeels) are widely distributed. Pogge and dragonet are found throughout, with small numbers of greater sandeel in the central and north of the study area and a larger number of lesser sandeels in the south (Figure 5.16).

Nine individuals of *Gobius niger* (black goby) were caught in the study area. Large numbers of sand goby *Pomatoschistus minutus* were sampled and are widely distributed (Figure 5.17).

There are lower numbers and a decreased distribution of pelagic species compared to demersal species, however this is likely to be a function of the type of trawl used in these surveys, which is designed to target benthic fauna. There is a concentration of herring in the south of the area and a patchy distribution of sprat throughout the area. Only one sea bass was sampled in the south of the study area (Figure 5.21).

The only diadromous species sampled in the area was the eel (*Anguilla anguilla*). Five individuals were caught inshore in the Thames Estuary mouth (Figure 5.22).

The thornback ray and lesser-spotted dogfish are distributed throughout the area, particularly along the sandbanks. Few were sampled within the estuary mouth itself. One smooth hound was caught in the northeast of the study area (Figure 5.23).

(1) Fish that migrate during their life cycle between fresh and marine waters.

(2) A group of fish with cartilaginous skeletons and external gill slits, which includes all the sharks, skates and rays.

Seasonality

The figures discussed above represent the results from the surveys conducted over the summer (July 2003 and August 2007, 2008). The surveys for the London Array EIA also sampled fish species during the spring (April 2003) and winter (December 2003 and February 2004), and therefore provide some information on the seasonality of species in the area.

Overall the demersal gadoids, which are dominated by whiting, have a patchy abundance in spring, a low abundance in the summer but with a wider distribution, and are most abundant and widely distributed in the winter. The demersal flatfish have a similar distribution and species composition throughout the year, with a slightly more northerly distribution in summer and an increase in the proportion of catch made up by dab in the winter, particularly inshore.

Other demersal species including pogge, dragonet and sandeels, gobies and elasmobranchs were most abundant during the winter, with lowest numbers in the summer. A slightly higher proportion of sandeels were caught in the spring, and there was a shift in the distribution of thornback rays inshore in winter.

Of the pelagic species, the largest catches of herring were in spring and summer, with only very small catches inshore in winter. No sprat were sampled in spring but some were sampled inshore in summer. In winter sprat is the dominant pelagic species throughout the area.

The survey results provide an indication of fish abundance and should be taken with some caution. The trawls were not targeted at fish and will not have caught representatives of all fish species in the area. In addition, trawls rarely have a 100% success rate in catching all fish within their path.

Thus, the estimates provided are only an indication of relative abundance within the survey area and not an absolute indication of abundance. In addition the majority of survey data was gathered in the summer, and thus represents only a 'snapshot' of fish communities within the season.

The results of these surveys are discussed in more detail in the relevant sections for each species.

5.3.5 Protected Species

Section 5 in Appendix L discusses the ecology of the protected species found in or around the Outer Thames Estuary region that seasonally migrate from the River Thames and nearby rivers and estuaries through the study area to either deeper offshore waters or further along the coast. These are allis shad, twaite shad, Atlantic salmon, sea lamprey, river lamprey and seahorses.

None of these species were found during the EIA surveys or the REC or MAREA surveys, however, as 2 m beam trawls were used during these surveys and would therefore only have targeted demersal species, these species would not be expected to be caught in all cases.

Table 5.6 gives a summary of the protected species that may spawn and use nursery grounds in the Outer Thames Estuary or that may migrate through the area.

Table 5.6 Summary of Protected Species

Species	Spawning	Nursery	Migratory
Allis shad	No	No	Yes – late spring and early summer presence
Twaite shad	No	No	Yes – late spring and early summer presence
Atlantic salmon	No	No	Yes – late spring and early summer presence
Sea Lamprey	No	No	Yes – late spring presence
River Lamprey	No	No	Ye s – autumn presence
Seahorses	Unknown	Unknown	Yes – migrate offshore in winter and back inshore in summer

5.3.6 Demersal Species

The ecology and abundance of the following demersal (bottom-dwelling) species within the Outer Thames Estuary is covered in detail in Section 6 of Appendix L; cod, bass, haddock, whiting, grey gurnard, red mullet, plaice, sole, lemon sole, dab, sandeel, bib, pogge, dragonet, and various species of goby. These species spend most of their life-cycle associated with the sea bed and feed and breed in benthic habitats. However, spawning may occur in the water column and eggs and larvae may be found at or close to the surface. The distribution of sensitive spawning and nursery areas is also discussed in Appendix L.

Table 5.7 and Figure 5.18 to Figure 5.19 give a summary of which demersal species use the area for spawning, nursery grounds or as part of their migratory route.

Table 5.7 Summary of Demersal Species

Species	Spawning	Nursery	Migratory Presence
Cod	October-December	Yes	Yes
Bass	March – June	No	Yes – summer feeding grounds
Haddock	No	No	Yes – summer presence
Whiting	No	Yes	Yes – summer presence
Grey gurnard	No	No	Yes – spring – late Autumn presence
Red mullet	No	No	Yes – summer feeding grounds
Skate	Spring	Unknown	No
Plaice	December – February	Yes	Yes – spawning in winter, feeding in summer
Sole	March – June	Yes	Yes – summer presence
Lemon sole	May – October	Yes	Yes – spring & early summer presence
Sandeel	December – January	Yes	No
Pomatoschistus spp	*P. minutus* December - February, *P. microps* April - August	Unknown	No
Black goby	May to August	Unknown	No

Pleuronectes platessa (plaice)

Figure 5.15 *Fish Species Abundance - Demersal Flatfish*

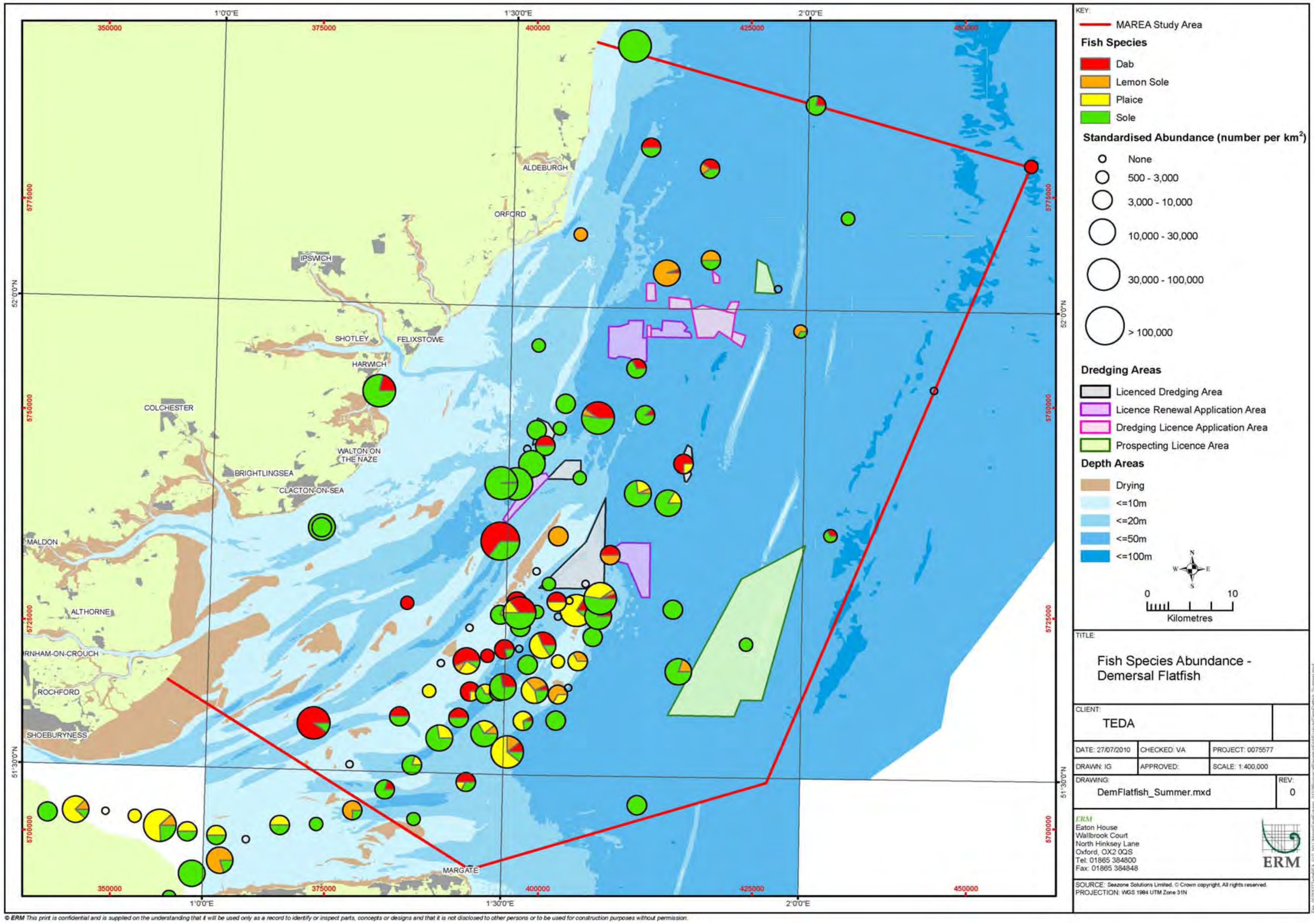


Figure 5.16 Fish Species Abundance - Demersal Other

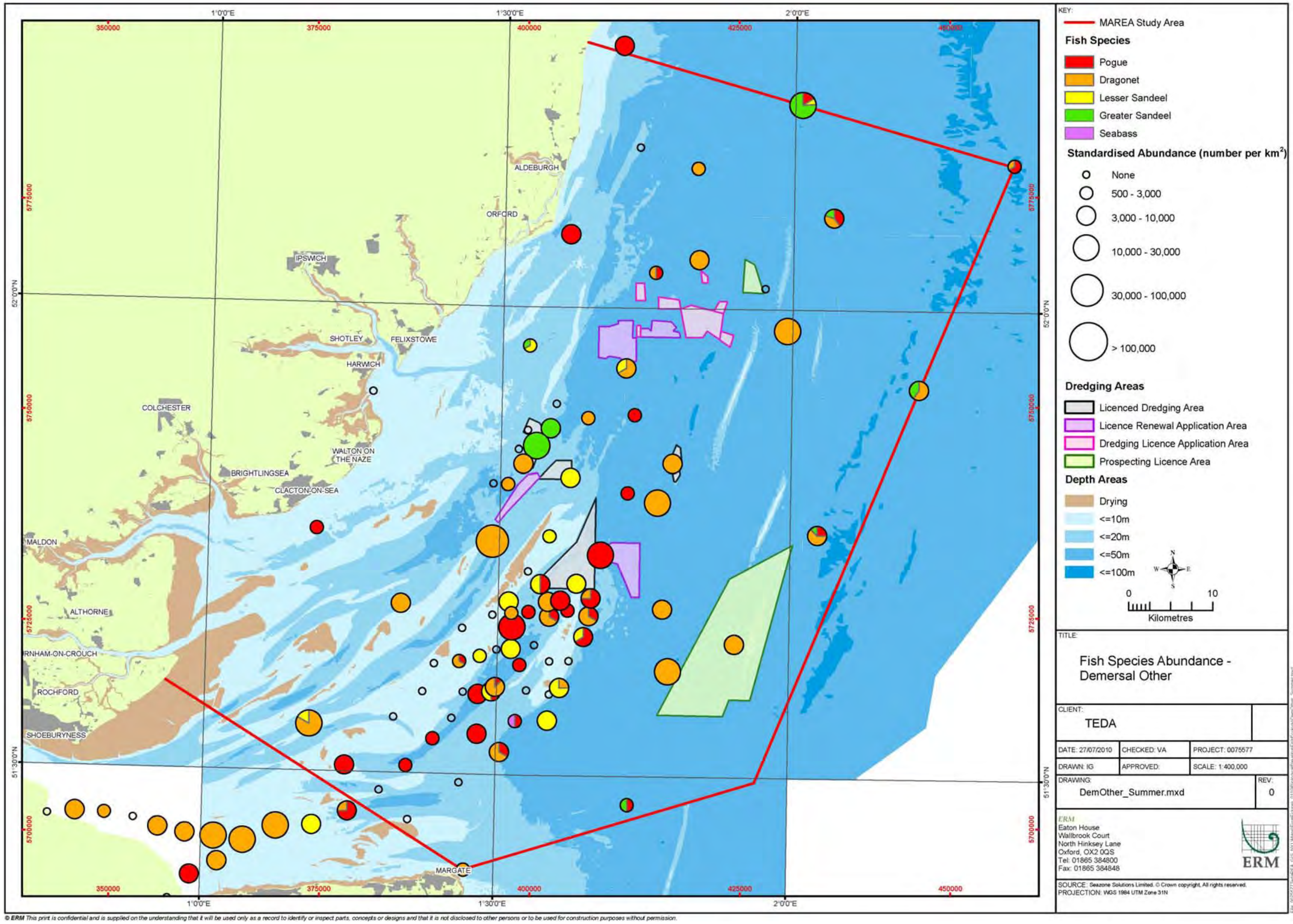


Figure 5.17 Fish Species Abundance - Gobies

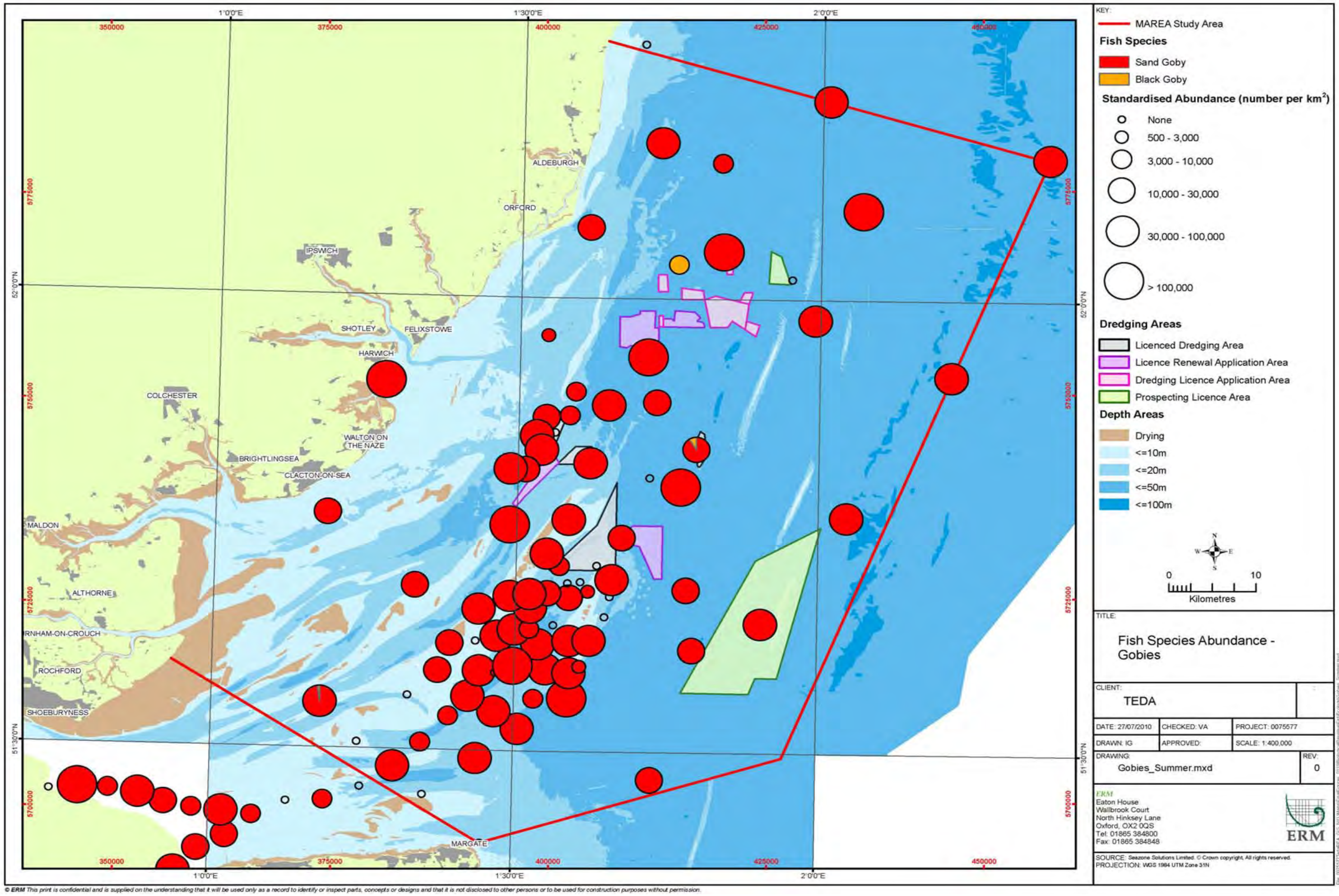


Figure 5.18 Nursing Grounds in the TEDA MAREA Study Area (1)

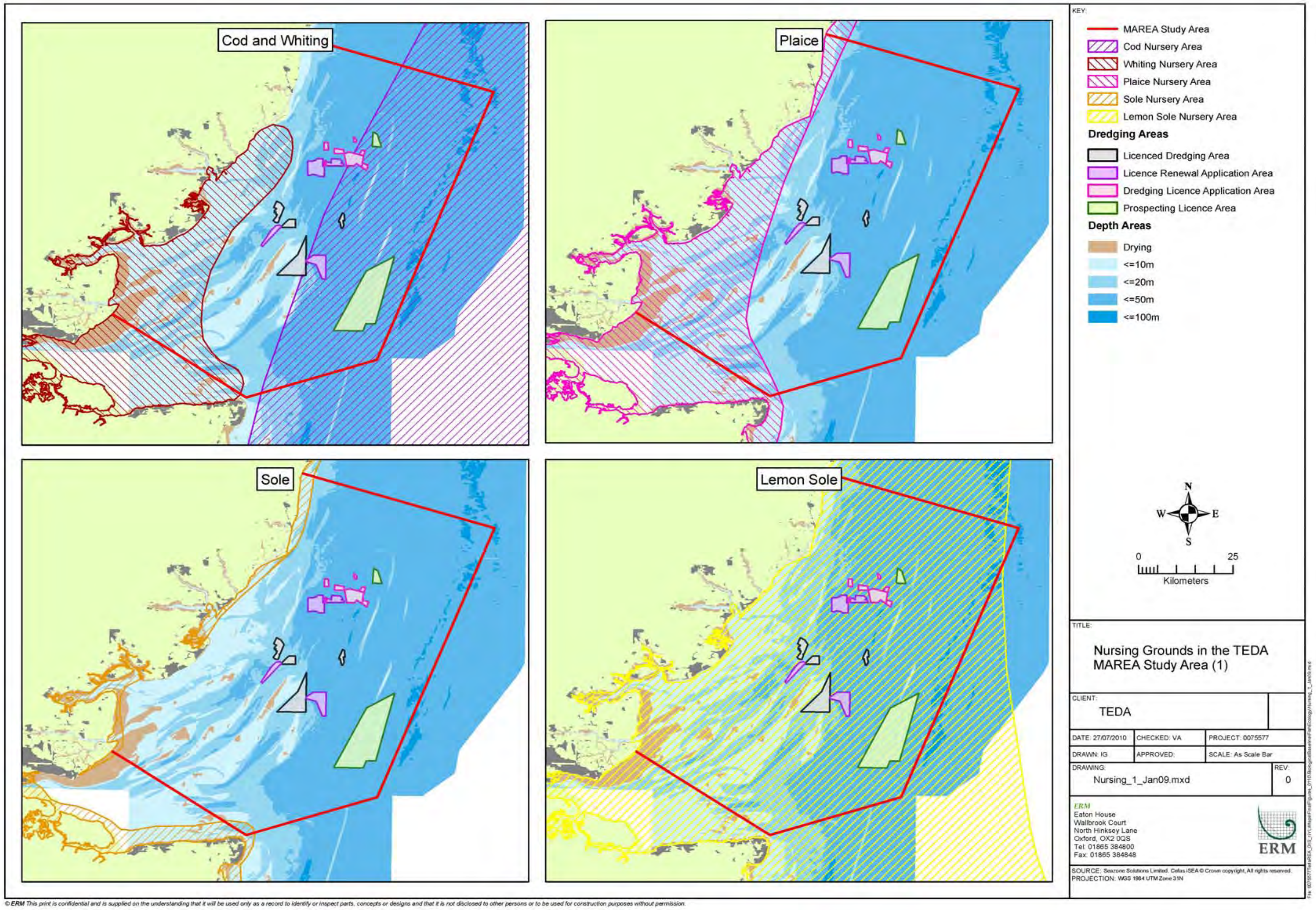


Figure 5.19 Spawning Sites in the TEDA MAREA Study Area

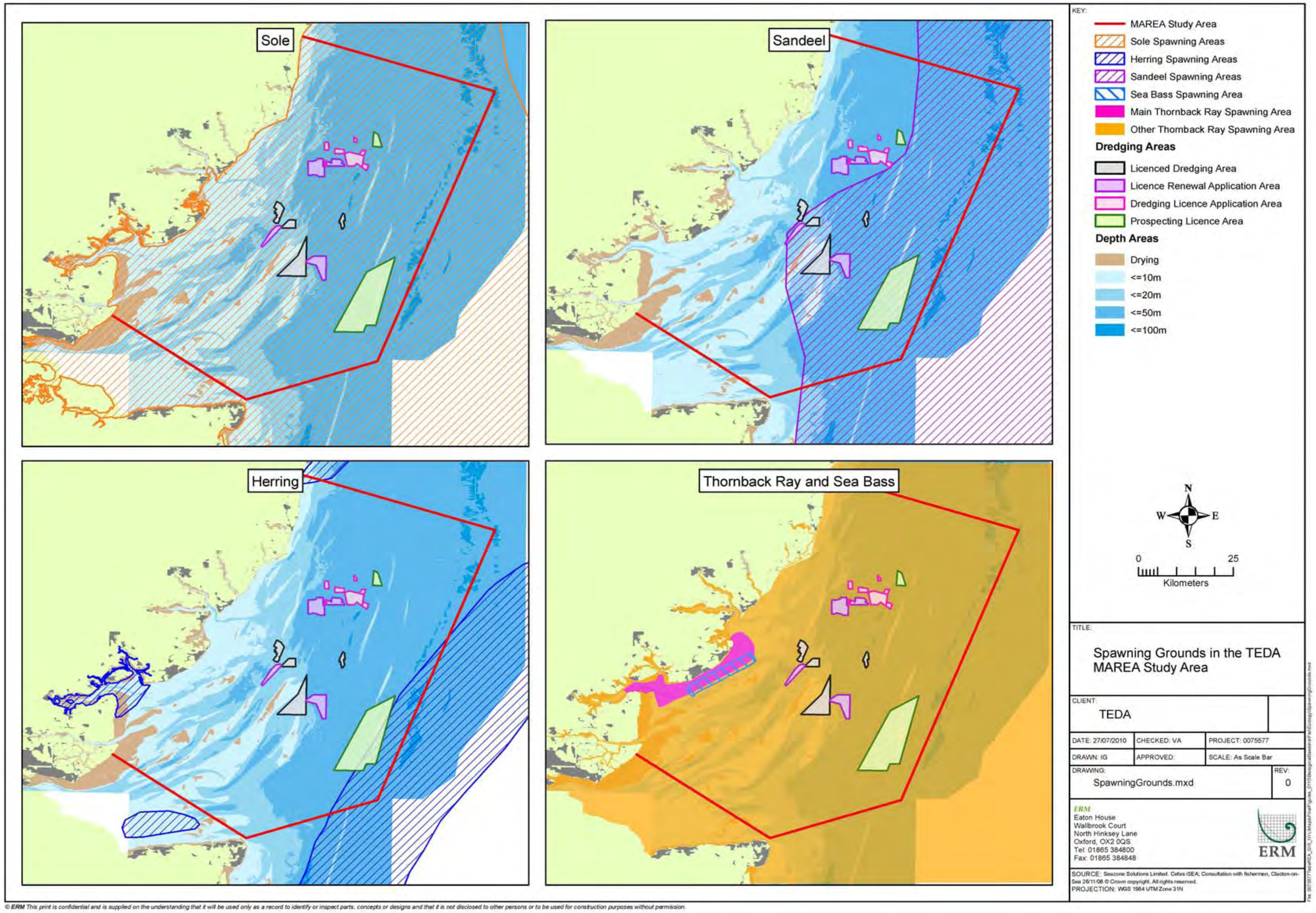
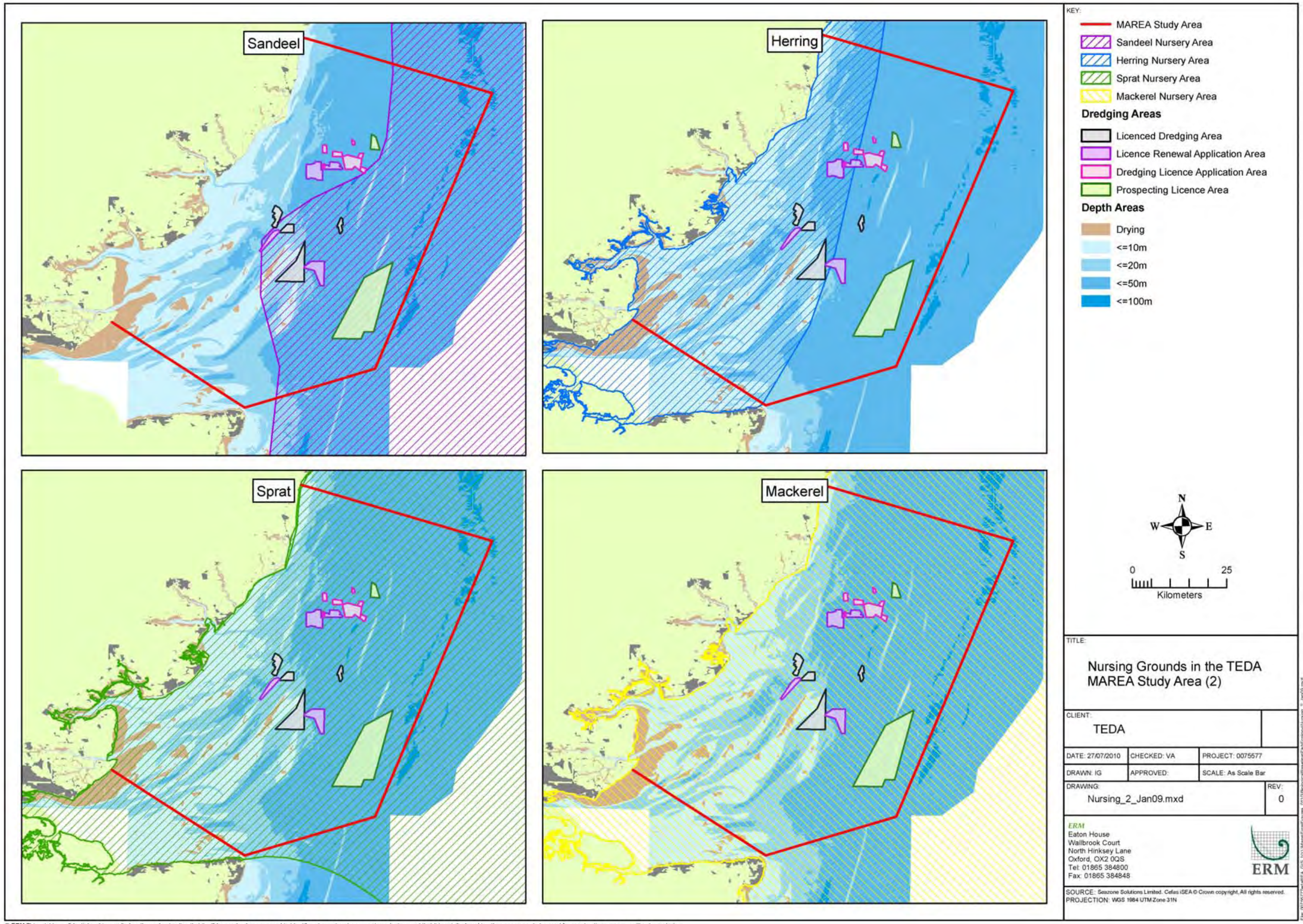


Figure 5.20 Nursing Grounds in the TEDA MAREA Study Area (2)



5.3.7 Pelagic Species

Section 7 in Appendix L discusses the ecology and the abundance of the main pelagic species which are found within the Outer Thames Estuary and the distribution of their sensitive spawning and nursery areas. Pelagic species are those that spend the majority of the life-cycle in the water column or associated with the surface and include herring, sprat, mackerel, horse mackerel, pilchard and anchovy.

Table 5.8 and Figure 5.19 to Figure 5.20 gives a summary of the pelagic species that spawn and use nursery grounds in the Outer Thames Estuary or that may migrate through the area.

Table 5.8 Summary of Pelagic Species

Species	Spawning	Nursery	Migratory
Herring – North Sea stocks	No	Yes	Yes – summer presence
Thames Estuary Herring	January – early May	Yes	Yes – move out of the area during winter
Sprat	November – January	Yes	Yes – local inshore/offshore migration
Mackerel	No	Yes	Yes – long migrations throughout the year
Horse mackerel	No	Unknown	Yes – found in study area en route between feeding and spawning grounds during spring and late autumn.
Pilchard	No	Unknown	Yes – migrate from spawning grounds in English Channel and Celtic Sea to feeding grounds in the north.
Anchovy	June- August	Unknown	Yes – move further north in summer

5.3.8 Diadromous Species

In addition to the sea lamprey, river lamprey and Atlantic salmon discussed in Section 5.3.5 on protected species, the eel (*Anguilla anguilla*) is another species that migrates between fresh and salt waters and as a result may be found in the study area. Its ecology and abundance within the Outer Thames Estuary is discussed in Section 8 in Appendix L and is summarised in Table 5.9.

Table 5.9 Summary of Diadromous Species

Species	Spawning	Nursery	Migratory
Eel	No	Unknown	Yes – migration to freshwaters in February and April.

Figure 5.21 Fish Species Abundance - Pelagics

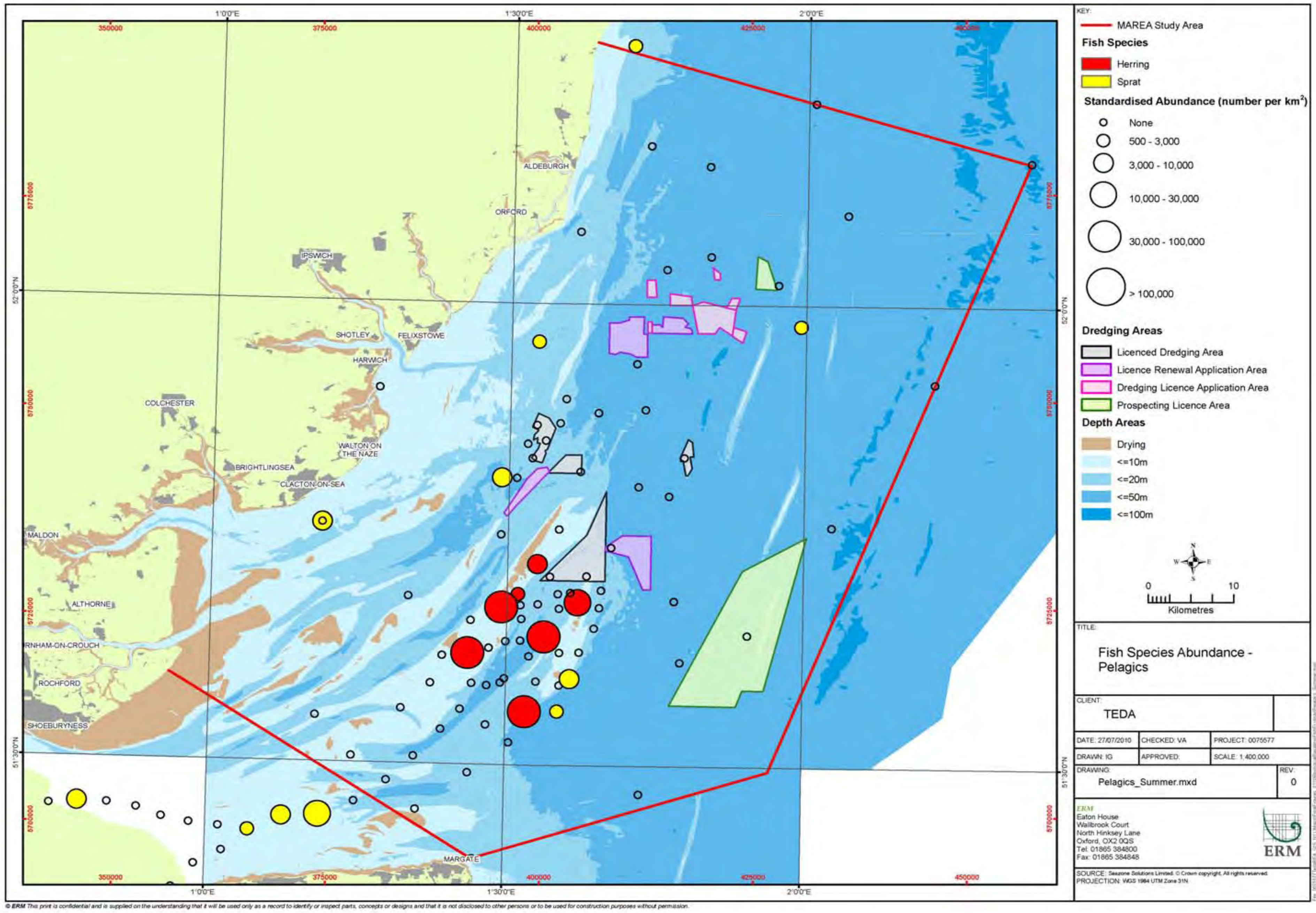
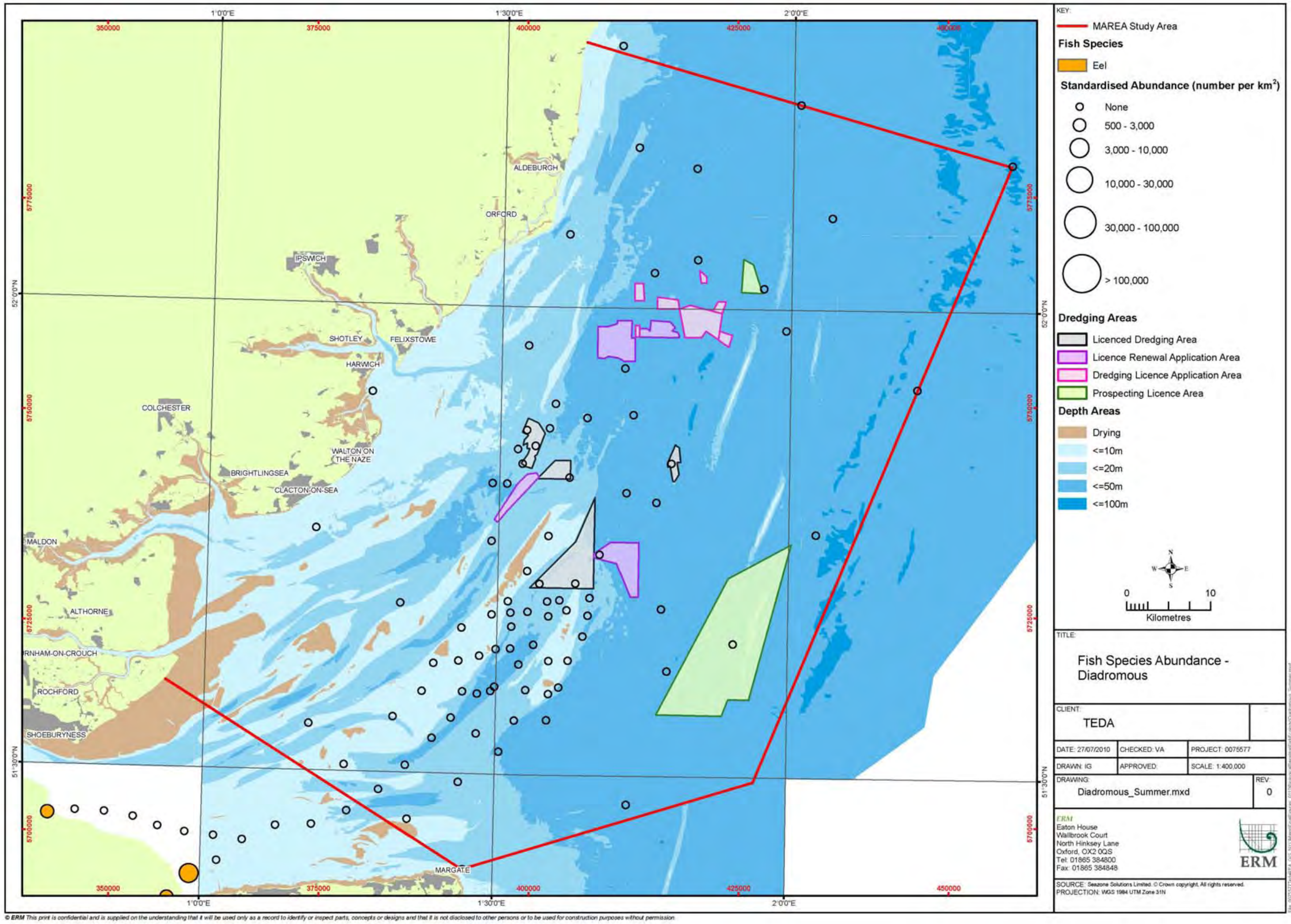


Figure 5.22 Fish Species Abundance - Diadromous



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5.3.9 Elasmobranchs

Elasmobranchs are a class of fish comprising sharks, skates and rays. They have cartilaginous skeletons, hard teeth and well developed jaws. The abundance of elasmobranch species within the Outer Thames Estuary, and their ecology, is discussed in detail in Section 9 of Appendix L. This includes a discussion of the spurdog, smooth hound, lesser spotted dogfish, and thornback ray.

Table 5.10 and Figure 5.2019 gives a summary of the elasmobranchs that may spawn/breed and use nursery grounds in the Outer Thames Estuary or that may migrate through the area.

Table 5.10 Summary of Elasmobranchs

Species	Spawning	Nursery	Migratory
Spurdog	Locations unknown. August – December	Unknown	Yes – spring and early summer presence
Thornback ray	Yes – mainly March – September	Yes	Yes – migration offshore in winter, return to shallows in summer

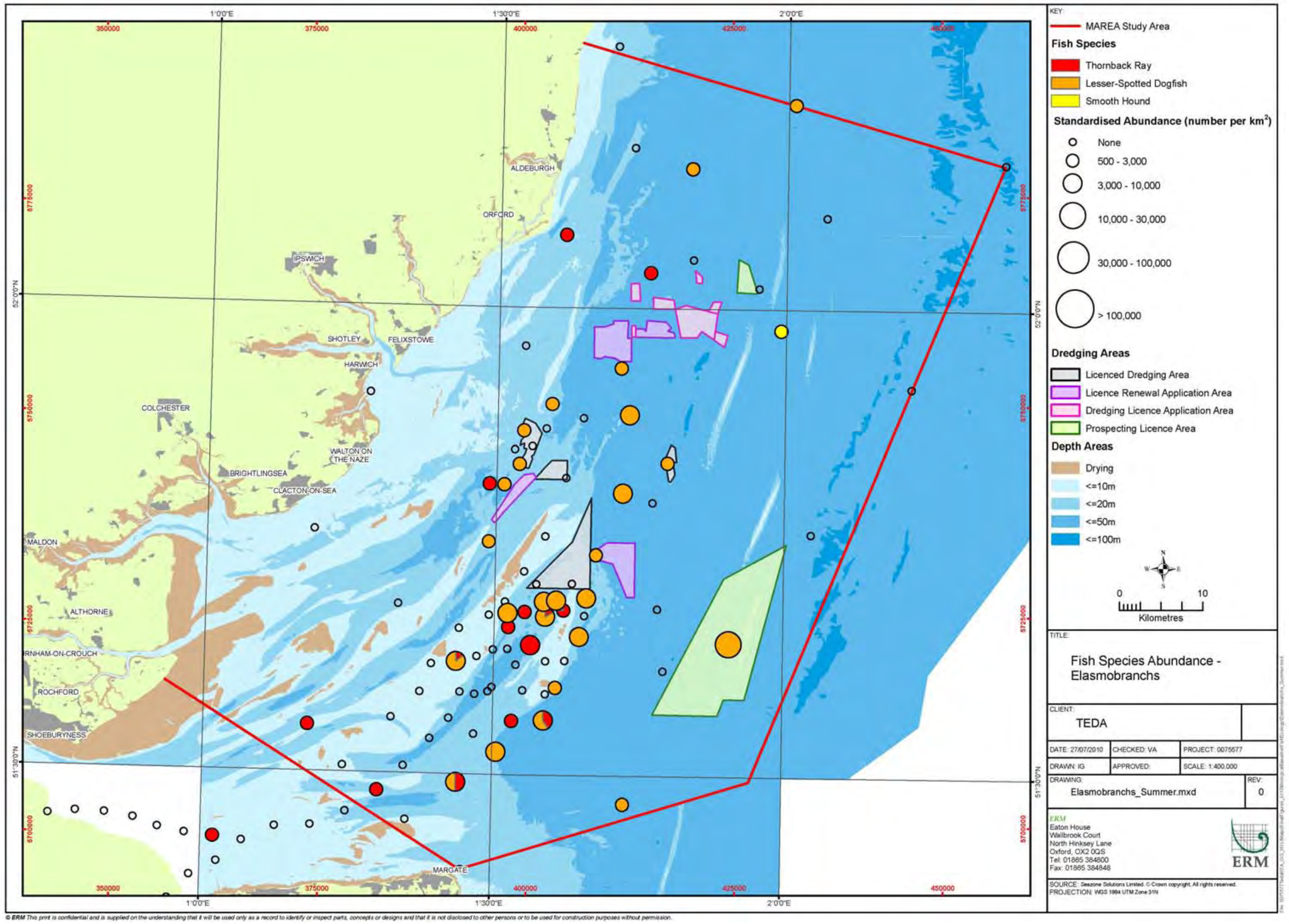
5.3.10 Summary

Species of Importance

Table 5.11 presents a summary of the fish species in the region and describes the importance of the study area to their ecology, the contribution of their population in the Thames to the overall UK population, and any specific ecological associations within the study area (eg feeding, spawning or nursery grounds or migratory corridors). This information is used to determine which species are most likely to be affected by dredging operations in the Thames and will therefore be taken forward into the impact assessment.

In terms of the protected species that seasonally migrate between rivers and estuaries to the open sea, the sea lamprey is the most likely to be present within the study area and may therefore be potentially impacted by dredging activities. In addition both the short-snouted and spiny seahorse are thought to be present in the region in shallow and coastal waters, and those in the Thames may constitute an important proportion of the UK population. High numbers of sand goby (*Pomatoschistus minutus*) are recorded in the area, which has been proposed as a Nationally Important Marine Feature (NIMF).

Figure 5.23 Fish Species Abundance - Elasmobranchs



In the Outer Thames estuary region the most important commercial species are cod, sole and thornback ray, and to a lesser extent bass, plaice and dogfish. Inshore, smaller vessels target herring, cod, whiting, sprats and plaice.

In addition, although not of high commercial importance in the region, the Outer Thames is thought to be an important nursery ground for mackerel.

Box 5.6 summarises the information in Table 5.11 and lists the species that are considered most important in the study area and will therefore be taken forward into the impact assessment.

Seasonality

In terms of the seasonal importance of the study area to fish species, the main spawning period for a number of species based on published research appears to be during the late spring and early summer months (April to June). However, a number of the most important commercial species (herring, cod and plaice particularly) spawn over the winter months (December to February).

This was confirmed during consultation with local fishermen who also noted some localised differences in spawning periods, for example cod in the study area appear to spawn between October and March, whereas this takes places between December and May in the rest of the North Sea. In general the spawning periods for most species in the area start and finish earlier in the year than the remainder of the North Sea.

In addition to spawning considerations, it should also be noted that sea lamprey and river lamprey are expected to migrate through the study area in April and October to December respectively, mackerel may migrate through the area to spawn in the southern north sea in the spring, and there is the potential for red mullet to feed in the MAREA area in the summer.

Box 5.6 Fish Species that will be considered in the Impact Assessment

The following species will be taken forward into the impact assessment process, as the study area is considered to be important to their ecology, the population in the Thames contributes a significant proportion to the national population, and/or they are an important commercial species targeted by fishermen in the area:

Protected species:

- sea lamprey;
- seahorses; and
- sand goby.

Demersal species

- cod;
- bass;
- plaice; and
- sole.

Pelagic species:

- herring (including Thames Estuary herring);
- sprat; and
- mackerel.

Elasmobranchs:

- lesser-spotted dogfish; and
- thornback Ray.

Again it is important to reiterate that applying the swept-area methodology to survey data can result in the abundance of species appearing to be 'inflated' in some cases compared with the absolute numbers of individuals sampled, therefore caution must be employed when making conclusions about the abundance of species in the Thames region based on the available survey data.

Clupea harengus (herring)

Raja clavata (thornback ray)

Table 5.11 Summary of Fish Ecology in the Study Area

Species	Lifecycle Stage	Seasonality	Specific Habitat Associations	Proportion of population in study area	Predator-prey relationships	Is this species being taken forward into the Impact Assessment?
Protected species:						
Allis shad	Migrate up rivers to spawn, surviving adults return to sea therefore both stages may be present in study area.	Possibility of movement through study area before spawning (late spring) and after spawning (late summer).	None	Numbers appear to in decline. The only recently-confirmed spawning site is in the Tamar Estuary (Plymouth Sound and Estuaries cSAC). JNCC grade this species as having a 'non-significant presence' in the Essex Estuaries SAC.	Adults may feed on planktonic crustaceans in the study area.	No – unlikely to be present in significant numbers within the Thames Estuary. Spawning unlikely to take place in the region.
Twaite shad	Seasonal migrations between freshwater spawning grounds and offshore feeding grounds – both stages may be found in study area.	Migration to rivers in late spring/early summer and back to the sea in late summer.	None	Spawning stocks of twaite shad are known to occur in only a few rivers in Wales and on the England/Wales border. JNCC grade this species as having a 'non-significant presence' in the Essex Estuaries SAC.	Juveniles feed on estuarine zooplankton. Large proportion of adult diet is juvenile sprat and herring.	No – unlikely to be present in significant numbers within the Thames Estuary. Spawning unlikely to take place in the region.
Atlantic salmon	Migrate from freshwaters rivers where they hatched to sea. Adult salmon return to freshwater to spawn – both stages may migrate through the study area.	Migration to sea from April-June. Most likely to be found in study area at this time.	None	Reintroduced into the River Thames in recent years but population only maintained by periodic stocking. Does not constitute a significant proportion of the national population – not a qualifying feature for the Essex Estuaries SAC.	Adults feed on squid, shrimps and fish, herring, smelt, small mackerel and small cod.	No – population in Thames Estuary does not constitute a significant proportion of the national population.
Sea lamprey	Adults migrate from sea to rivers to spawn.	Migration to rivers from April onwards.	None	Have begun to recolonise the catchment areas of the Thames Estuary in recent years.	Feed on dead and netted fish and also attach to large teleosts and sharks.	Yes – lampreys have recently begun to recolonise catchment areas in the region. More likely to be found in the offshore study area than the river lamprey.
River lamprey	Adults migrate from sea to rivers to spawn.	Seasonal migrations from October to December.	Does not live as far from the coastline as sea lamprey, tends to stay near estuary mouth.	Have begun to recolonise the catchment areas of the Thames in recent years.	Feed on teleosts.	No – not likely to be found in the vicinity of licence areas.
Seahorses	Larvae, juveniles and adults may be found in the study area.	Found in shallower waters during spring, summer and early autumn, migrate to deeper areas in winter. Timing of reproductive season varies with location and environmental conditions, but predominantly April to October.	Occur in shallow inshore waters amongst algae.	Recent discovery of a colony of short-snouted seahorses in the Thames. Spiny seahorse thought to be found in the region. Both species in the Thames may represent an important proportion of the UK populations.	Both species feed on small crustaceans, organic debris, fish fry and other plankton. Predators include crabs, large pelagic fish and seagulls.	Yes – the population in the Thames may represent an important proportion of the UK populations.
Demersal species:						
Cod	Larvae, juveniles and adults may be found in study area.	Anecdotal evidence from fishermen that cod spawn in Feb and March and from October to December in the study area. Adult feeding grounds in the summer.	Spawning areas thought to overlap with the study area. Cod are pelagic spawners (release eggs into the water column).	Cod are found all around the coasts of Britain, the population in the Thames does not constitute a significant proportion of the UK population.	Juveniles feed on copepod larvae and fish then from a length of 7cm onwards become demersal and feed on crustacean prey. Adults feed on other gadoids, sandeels, flatfish and clupeids.	Yes – one of the most important commercial species in the study area.

Species	Lifecycle Stage	Seasonality	Specific Habitat Associations	Proportion of population in study area	Predator-prey relationships	Is this species being taken forward into the Impact Assessment?
Bass	Larvae, juveniles and adults may be found in study area.	Most likely to be found in the study area in summer when feeding inshore. Spawning occurs from March until June.	Thought to spawn predominantly in deep water but fishermen have identified spawning areas in the study area.	Thought to be present around all coasts of Britain although not recorded in all areas. Thames population unlikely to be significant proportion of UK population.	Adults feed on small fish, prawns, crabs and molluscs.	Yes – bass are an increasingly important commercial species in the Thames region according to fishermen (1).
Haddock	Larvae, juveniles and adults may be found in study area.	Spawning from March to May.	Shoals in waters 40-300m deep.	Not found in high numbers in the Outer Thames.	Larvae feed on euphausiids, appendicularians, decapod larvae, copepods and small fish. Adults feed on sandeels, Norway pout, long rough dab, gobies, sprat and herring	No – haddock are not found in high numbers in the Outer Thames.
Whiting	Larvae, juveniles and adults may be found in study area.	Adults likely to be found in study area in summer during migration from inshore to offshore. Spawning takes place from January onwards.	Shallower inshore waters used as nursery grounds. Found near mud and gravel bottoms, also sand and rock.	Thames estuary is not particularly noted for its whiting population.	Larvae feed on nauplii and copepodite stages of copepods. Juveniles feed on euphausiids, mysids and crangonid shrimps and adult whiting feed on small fish species; Norway pout, sprat and sandeel and the juveniles of larger species including their own.	No - the Thames estuary is not particularly noted for its whiting population.
Grey gurnard	Larvae, juveniles and adults may be found in study area.	Almost completely absent in the area during winter when dense aggregations formed northwest of Dogger Bank and in central western North Sea. Spawn in southeast North Sea from April to August.	Sandy, muddy, shelly and rocky seabeds. Also found in aggregations off seabed in 50-100m.	Predominantly found along western and southern UK coasts with fewer records in eastern England. Only one individual caught during the historical EIA surveys.	Juveniles feed on variety of small crustaceans, adults feed on larger crustaceans and juveniles of cod, whiting and sole.	No - there is no notable population of grey gurnard in the Thames.
Red mullet	Migrating adults may be found in study area. Spawning unlikely to occur.	Study area may be important feeding ground for red mullet in summer months.	Sandy/muddy seabeds, occasionally rocky.	UK distribution predominantly in the south west. Outer Thames may be used as a feeding ground when migrating between English Channel and North Sea.	Adults feed on shrimps, amphipods, polychaete worms, molluscs and benthic fishes.	No - low numbers of red mullet are found in the Thames. This species is not of commercial importance in this region.
Plaice	Larvae, juveniles and migrating adults may be found in the study area.	Spawning is thought to occur within the study area between December and February. Juveniles are likely to be found in the Outer Thames in the summer months.	Live on mixed substrates. The outer Thames may be an important spawning ground and shallower areas may be used as a nursery ground.	Common all around Britain and Ireland. The population in the Thames does not constitute a significant proportion of the UK population.	Larvae feed on appendicularians, copepods, algae and bivalve post-larvae. Adults feed on polychaete worms, bivalves and small crustaceans.	Yes – plaice are an important commercial species targeted in the Outer Thames.
Sole	Larvae, juveniles and adults may be found in study area.	Likely to found spawning in study area from March to June and then as juveniles within nursery area.	Spawning and nursery areas with the Outer Thames. Burrow into sandy and muddy bottoms.	Found all around the British and Irish coast. Spawning grounds widespread along south coast but Thames Estuary is a particularly important nursery ground according to fishermen (2).	Juveniles and adults feed on polychaetes and echinoderms.	Yes – sole are one of the most important commercial species targeted in the area and the Thames is a particularly important nursery ground.
Lemon sole	Larvae, juveniles and adults may be found in study area.	Some spawning in the study area from May to October.	Hard and shell-gravel seabed from 10m to 200m.	UK distribution predominantly in the southern half of UK.	Feed on benthic invertebrates, particularly polychaetes.	No – information from fishermen suggests lemon sole do not spawn in large numbers in the area and few are caught (3) (4).

(1) Consultation with local fishermen, Leigh-on-Sea, 4th December 2008.
(2) Consultation with local fishermen, Clacton-on-Sea, 26th November 2008.
(3) Consultation with local fishermen, Clacton-on-Sea, 26th November 2008.
(4) Consultation with local fishermen, Leigh-on-Sea, 4th December 2008.

Species	Lifecycle Stage	Seasonality	Specific Habitat Associations	Proportion of population in study area	Predator-prey relationships	Is this species being taken forward into the Impact Assessment?
Dab	Larvae, juveniles and adults may be found in study area.	Spawning inshore during spring and early summer.	Sandy areas, usually 20-40m deep. High potential that the study area is used as a spawning and nursery ground.	One of Britain's most common flatfish, occurring all around the coast. The Thames population does not constitute a significant proportion of the UK population.	Adults feed on brittlestars, small sea urchins, fish, worms, crustaceans and molluscs.	No – the numbers of dab in the region are not a significant proportion of the UK population. Not important commercially.
Lesser sandeel	Larvae, juveniles and adults may be found in study area.	In winter sandeels remain buried in the sand, forage in the water column in spring and summer. Spawn in December and January.	Found on and within well-oxygenated substrates. Spawning and nursery grounds to east of study area.	Majority of sandeel spawning and nursery grounds further north towards Shetland. The population in the Thames does not constitute a significant proportion of the UK population.	Feed on planktonic prey and fish larvae. Important prey species for a number of commercial fish species and seabirds.	No - the population in the Thames does not constitute a significant proportion of the UK population. Not targeted commercially.
Bib	Juveniles and adults may be found in the study area.	Feed from July to September.	Mixed rock and sand habitats.	Widespread in UK and Irish waters. Numbers in Thames are relatively low and do not contribute substantially to the UK population.	Feed on benthic crustaceans, small fish, molluscs and polychaetes.	No - numbers in Thames are relatively low and do not contribute substantially to the UK population. Not targeted commercially.
Pogge	Larvae, juveniles and adults may be found in the study area.	Spawning from February to April.	Prefer sandy bottoms without stones.	Widespread in UK and Irish waters. Population in Thames does not constitute an important part of the national population and the area has not been highlighted as a particularly important spawning or nursery area.	Feed on benthic crustaceans and polychaetes.	No - numbers in Thames are relatively low and do not contribute substantially to the UK population. Not targeted commercially.
Dragonet	Larvae, juveniles and adults may be found in the study area.	Spawning from April to August.	Sand or shelly gravel.	Found all around the coasts of Britain and Ireland. Not thought to be a significant population in the Thames estuary.	Feed on polychaete worms, amphipod crustaceans, and molluscs, especially crustaceans.	No - numbers in Thames are relatively low and do not contribute substantially to the UK population. Not targeted commercially.
Pomatoschistus spp. (goby)	Larvae, juveniles and adults may be found in the study area.	Spawning from December to August.	Sandy or muddy bottoms, usually up to 20m.	Common all around Britain and Ireland. The population in the Thames does not constitute a significant proportion of the UK population.	Feed on small polychaetes, amphipods, cumaceans and mysids.	Sand gobies are taken forward due to their designation as Nationally Important Marine Features.
Black goby	Larvae, juveniles and adults may be found in the study area.	Spawning from May to August.	Sand, mud, seagrasses and algae.	Common all around Britain and Ireland. Low numbers recorded in the Outer Thames.	Feed on crustaceans, bivalves, gastropods, polychaetes and small fish.	No – low numbers in the Thames region. Not targeted commercially.
Pelagic species:						
Herring	Larvae, juveniles and adults may be found in study area.	Likely to be in study area in summer months	Nursery areas inshore overlapping with west of study area.	Widespread in UK and Irish waters. Thames is likely to constitute an important nursery area for Atlantic herring.	Larvae feed on copepods and other small plankton. Juveniles feed on calanoid copepods, euphausiids, amphipods, juvenile sandeels, *Oikopleura* spp and fish eggs. Adults feed on copepods, small fish, adult worms and ctenophores.	Yes – Thames is an important nursery area for herring. Targeted by the inshore fisheries.
Thames Estuary Herring	Larvae, juveniles and adults may be found in study area.	Aggregate in the study area for spawning from October to early May, although spawning does not commence until January.	Spawning on the shallow banks in the Thames Estuary. Inshore nursery areas.	Thames herring are recognised as a separate stock to North Sea herring and are found in the Thames and Blackwater Estuaries.	Larvae and adults feed on small planktonic animals. Adults also feed on sprat and sandeels	Yes – population of herring that is confined to the Thames region. Not as high a market value as Atlantic herring.
Sprat	Larvae, juveniles and adults may be found in study area.	Fishermen suggested spawning in North Sea from November to January, but it is unknown whether the outer Thames is used as a spawning ground. Most likely to be found in study area in winter.	Found in areas <50m deep. Important as a nursery area.	Thames Estuary used as a nursery area and potentially a spawning ground. However these are widespread along the UK coastline therefore the study area is unlikely to contain a significant proportion of the UK population.	Larvae feed on diatoms, copepods and crustacean larvae. Adults feed on larger planktonic organisms.	Yes – targeted by inshore fisheries in the region.

Species	Lifecycle Stage	Seasonality	Specific Habitat Associations	Proportion of population in study area	Predator-prey relationships	Is this species being taken forward into the Impact Assessment?
Mackerel	Juveniles and adults may be found in study area.	Expected to be found in study area in spring when migrating south to spawn.	Study area is used as a nursery ground.	Widely distributed around the British Isles and Ireland. Thames Estuary may constitute an important nursery ground for the UK population.	Feed on small fish including herring and Norway pout, and crustaceans such as crabs and lobsters. Stop feeding in winter.	Yes – important nursery ground for mackerel within study area.
Horse mackerel	Larvae, juveniles and adults may be found in study area.	May migrate through the study area between the English Channel and the North Sea during spring and late autumn.	Adults form large schools in coastal areas with sandy substrate.	The UK has a predominantly south-west distribution. Not thought to be a significant population in the Thames Estuary.	Feed on fish, crustaceans and cephalopods.	No – not a significant proportion in the Thames Estuary. Not commercially important.
Pilchard	Juveniles and adults may be found in study area.	After spawning (April to October) migrate north through study area to feeding grounds. In winter they migrate back to spawning grounds in the south.	None	Widely distributed around the British Isles and Ireland. Individuals present in the Outer Thames are unlikely to contribute significantly to the national population.	Feed on planktonic crustaceans and small fish.	No – not a significant proportion in the Thames Estuary. Not commercially important.
Anchovy	Larvae, juveniles and adults may be found in the study area.	Spawning from June to August. Move further north and into surface waters in summer, retreat in winter.	Can tolerate salinities of 5-41 ppt.	Wide UK and Ireland distribution, particularly on the west coast. Population in Thames is unlikely to constitute significant proportion of UK population.	Feed on plankton. Are prey for other fish and marine mammals.	No - population in Thames is unlikely to constitute significant proportion of UK population. Not commercially important.
Diadromous Species:						
Eel	Larvae, juveniles and adults may be found in the study area.	Migrate up rivers in February-April.	Inhabit deep water whilst at sea. Live on the seabed, under stones, in the mud or in crevices.	Wide UK and Ireland distribution. Not common in Outer Thames.	Larvae feed on plankton. Adults feed on vertebrates including fish.	No – not common in the study area.
Elasmobranchs:						
Spurdog	Juveniles and adults may be found in the study area.	Most likely to be found within the outer Thames in spring and summer. Females give birth in coastal bays between August and December although exact locations are not known.	Usually found near the bottom but also in mid-water and at the surface.	Widely distributed throughout UK waters but low abundance in the southern North Sea.	Feed on pelagic prey including herring, sprat, small gadoids, sandeels and mackerel. Also crustaceans, squid and ctenophores.	No – low abundance in the study area.
Smooth hound	Juveniles and adults may be found in the study area.	Breeding occurs all year round in the study area according to local fishermen (1).	Stay close to seabed. Prefer sandy, muddy, gravel substrate.	Wide UK distribution, predominantly on the west coast. Not common in Thames region.	Feed on benthic crustaceans, cephalopods and bony fish.	No – not common in the Thames region.
Lesser-spotted dogfish	Juveniles and adults may be found in the study area.	Spawning takes place throughout the year.	Prefer sandy, coralline, algal, gravel or muddy bottoms.	Wide UK distribution but not common in the southern North Sea.	Feed on molluscs, crustaceans, small cephalopods, polychaete worms and small bony fishes.	Yes – targeted commercially in the region.
Thornback ray	Juveniles and adults may be found in the study area.	Spawning though to take place between March and December, however fishermen suggest spawning takes place all year. Migration offshore in winter and inshore in summer.	Prefer mud, sand and gravel substrate, occasionally found on coarser grounds.	Outer Thames thought to have the main concentration of thornback rays in the North Sea. Spawning thought to occur throughout the area according to anecdotal information from fishermen (2).	Juveniles feed on small crustaceans. Adults feed on swimming crabs, sandeels and small gadoids.	Yes – targeted commercially and Thames thought to be an important spawning area.

(1) Consultation with local fishermen, Clacton-on-Sea, 26th November 2008.
(2) Consultation with local fishermen, Clacton-on-Sea, 26th November 2008.

5.4 MARINE MAMMALS

5.4.1 Introduction

This section describes the baseline marine mammal ecology in the vicinity of the TEDA MAREA area. Marine mammals which may use the study area include both cetaceans (whales, dolphins and porpoises) and pinnipeds (seals). Each of these groups of species is considered further below. Information has been gathered from existing sources on the distribution and abundance of marine mammals in the southern North Sea and in the outer Thames, along with information from surveys carried out within the area.

The conditions within the Thames estuary are characteristic of a relatively sheltered estuary, with fine sediments including mixed mud, sand and gravel, overlying a flat topography. Depth varies from zero at the exposed sandbanks of Long Sand and Kentish Knock on a low tide, to 30m in the Black Deep. The sandbanks are important for the local seal populations.

The tide ebbs to the north and floods to the south, with currents ranging from 1 to 3 knots and tidal range from 2m in the north and 5m in the south. Sea temperatures do not drop below 5ºC and in the summer can increase to 16.5ºC as a result of the influence of the tidal flow from the Straights of Dover; however this effect decreases with increasing distance northwards. Visibility is poor due to the high level of suspended particulate matters from riverine input, and as a result of sediment resuspension during storms.

The outer estuary is an important spawning and nursery ground for a number of species of commercially important fish including herring, sole and sprats. These are important to the marine mammal population in the area as prey resources.

5.4.2 Sources of Information

Overview

The main sources of data used to compile this baseline section include:

- Atlas of Cetacean Distribution in northwest European waters (Reid *et al*, 2003).
- Small Cetacean in the European Atlantic and North Sea (SCANS and SCANS II surveys). The SCANS survey carried out in June and July of 1994 provides quantitative information for the most abundant cetacean species in the North Sea. The SCANS II project re-evaluates the distribution of small cetaceans based on data collected in 2005 and 2006 [1].
- Seal distributions from the NBN Gateway[2], comprising information from the following sources:
  - Biological Records Centre;
  - Bristol Regional Environmental Records Centre;
  - Countryside Council for Wales;
  - Devon Biodiversity Records Centre;
  - Glasgow Museums BRC;
  - Highland Biological Recording Group;
  - JNCC;
  - Marine Biological Association;
  - Marine Conservation Society; and
  - Scottish Natural Heritage.
- Natural England's (formerly English Nature) information on The Southern North Sea Marine Natural Area (Jones *et al*, 2004);
- Information from the Sea Watch Foundation[3];
- Underwater Noise Impact Assessment on Marine Mammals and Fish during Pile Driving of Proposed Round 2 Offshore Wind Farms in the Thames Estuary (RPS Energy, 2006).
- Environmental Statement for the London Array (RPS Energy, 2005).
- Thames Marine Mammal Sightings Survey (2004-2007) data held by Zoological Society London (ZSL) (Kowalik *et al*, 2008): shore-based 'non-expert' opportunistic sightings.

Atlas of Cetacean Distribution

The Atlas of Cetacean Distribution in northwest European waters (Reid *et al*, 2003) presents an account and snapshot of the distribution of all 28 cetacean species that are known to have occurred off north-west Europe in the last 25 years, also including the narwhal and melon-headed whale for which records are only as recent as the 1940s. Maps from the Atlas have been reproduced in Figure 5.24 and Figure 5.26 in the following section to show the distribution of cetacean species in UK waters.

(1) Information available at http://biology.st-andrews.ac.uk/scans2/

(2) NBN Gateway. 2009. Available at http://data.nbn.org.uk/ (accessed 12/01/09).

(3) Sea Watch Foundation website available at http://www.seawatchfoundation.org.uk/index.php (accessed 13/01/09).

The Atlas combines data from the SCANS surveys, the JNCC's European Sea Bird At Sea Team (ESAS) [4], and data held by the Sea Watch foundation. In order to provide a standardised description of animal distribution from these different data sources, sightings rates are used to describe the perceived density of animals in a particular area, presented as the number of individuals sighted per unit time. The maps are resolved into cells equivalent to ¼ International Council for the Exploration of the Sea (ICES) rectangles (15' latitude x 30' longitude).

Each cell is shaded to indicate the level of survey effort achieved in that cell. The survey effort (in hours) was corrected for differences in sea state to account for possible biases in the estimation of sightings rates. This method was used for the following ten species; humpback whale, minke whale, sei whale, fin whale, short-beaked common dolphin, white-beaked dolphin, Atlantic white-sided dolphin, Risso's dolphin, long-finned pilot whale and harbour porpoise. For other species there were too few data to allow estimation of correction factors, therefore sightings ratings are presented as numbers of animals observed per unit search time, uncorrected, for the following species; sperm whale, northern bottlenose whale, selected beaked whales *Mesoplodon* spp. common bottlenose dolphin, striped dolphin and killer whale.

It is important to note that the minimum and maximum sightings rates on each map vary, as there are order of magnitude differences in the sightings rates between species. The maps therefore cannot be used to compare inter-specific differences in relative density. They are intended solely for comparisons to be made between areas for individual species. In addition, for each species where sea state corrections have been applied to search effort, the corrected search effort is species-specific; therefore the grey shading differs between species maps.

The data used for each map span all years of data collection, from 1979 to 1997, therefore possible inter-annual shifts in distribution are not reflected, and rather the maps present an integrated picture over the 20 year period. Similarly, these maps do not indicate any seasonal differences in distribution.

Surveys in the Thames Estuary

Incidental observations of marine mammal sightings were made during the aerial and boat-based bird surveys carried out across the Thames estuary region, on behalf of the London Array, Greater Gabbard and Thanet windfarm developments. This approach was agreed by Natural England and the JNCC as providing sufficient information to establish the marine mammal baseline in the region for these windfarm developments.

(4) Information available at http://www.jncc.gov.uk/page-1547

In total 18 aerial surveys were carried out from January 2002 to December 2005 covering 27, 096km. The bias was towards sampling in the winter as the survey was designed to record birds. These surveys collected data in a way compatible with the Cetacean Atlas (Reid *et al*, 2003) and the SCANS project (Northridge *et al*, 1995).

To account for effort intensity, indices of sightings are reported as animals per kilometre, however care must be taken when interpreting data from sightings indices maps. Where effort intensity is high the data are more reliable regardless of whether the number of animals recorded is high or low. However a low sampling intensity will include a relatively higher margin of error and the relative density of animals may not reliably reflect the relative importance of the area for that species, for example a high number of sightings within an area may indicate a single chance occurrence or a large aggregation of animals (RPS Energy, 2006).

A total of 1,167 sightings were obtained comprising an estimated 1,856 animals. There were confirmed sightings of harbour porpoise, bottlenose dolphins, common seals and grey seals, however many sightings were not confirmed to species, a common drawback of the aerial survey method.

Certain details normally recorded during marine mammals surveys such as behaviour and whether juveniles, pups or calves were present were not collected. In addition there were no details on sea state recorded which affects the efficiency of marine mammal surveys, therefore the analytical methods that can be applied to the data are limited.

The vessel-based recordings were few and were unable to provide any accurate information on the spatial distribution of species; however they were useful in providing relative information on species abundance and supporting the aerial survey data to show seasonal trends. Table 5.12 shows the seasonal differences in the sightings of harbour porpoises and seal species. Winter is taken as being from December to February, spring is from March to May, summer is from June to August and autumn is from September to November.

There is a clear increase in porpoise and seal sightings during the winter months, with harbour porpoise numbers lowest in summer, and seals lowest in autumn. However the seasonal variation in survey effort should be carefully considered.

Table 5.12 Seasonal Trends in the Sightings of Harbour Porpoise and Seals from the Round 2 Windfarm Bird Surveys

	Sightings per km	
	Harbour Porpoise	**Seals**
Winter	0.0557	0.0233
Spring	0.0273	0.0122
Summer	0.0102	0.0102
Autumn	0.0206	0.0013

Source: RPS Energy. 2006. Underwater Noise Impact Assessment on Marine Mammals and Fish during Pile Driving of Proposed Round 2 Offshore Windfarms in the Thames Estuary. For CORE Limited, on behalf of London Array Limited, Greater Gabbard Offshore Winds Limited and Thanet Offshore Winds Limited.

5.4.3 Legislation and Guidance

Table 5.13 details the legislation and conservation initiatives relevant to the marine mammals found in the southern North Sea. For further details of the legislation summarised in Table 5.13 see Section 5.1.2.

Table 5.13 International and National Legislation under which Cetaceans and Seals are afforded Protection

	Wildlife and Countryside Act 1981 (Schedule)	EC Habitats Directive (Annex)	Bonn Convention (Appendix)	Berne Convention (Appendix)	Conservation of Seals Act 1970	OSPAR (Annex)	ASCOBANS	Section 74 CRoW Act 2000	UK Biodiversity Action Plan
Minke Whale	5	IV		III				Yes	Baleen whales grouped plan
Atlantic white-sided dolphin	5	IV	II	II			Yes	Yes	Small dolphins grouped plan
Bottlenose dolphin	5 and 6	II and IV	II	II			Yes	Yes	Small dolphins grouped plan
Killer Whale	5	IV	II	II			Yes	Yes	Toothed whales grouped plan
Long-finned pilot whale	5	IV	II	II			Yes	Yes	Toothed whales grouped plan
Short-beaked common dolphin	5 and 6	IV	II	II			Yes	Yes	Small dolphins grouped plan
White-beaked dolphin	5	IV	II	II			Yes	Yes	Small dolphins grouped plan
Harbour Porpoise	5 and 6	II and IV	II	II		V	Yes	Yes	Harbour porpoise species plan, Essex LBAP
Common seal		II and V	II	II	Yes				
Grey seal		II and V	II	II	Yes				

Source: RPS Energy. 2006. Underwater Noise Impact Assessment on Marine Mammals and Fish during Pile Driving of Proposed Round 2 Offshore Windfarms in the Thames Estuary. For CORE Limited, on behalf of London Array Limited, Greater Gabbard Offshore Winds Limited and Thanet Offshore Winds Limited.

5.4.4 Cetaceans

Introduction

The cetacean fauna of the southern North Sea is considered to be relatively poor both in terms of abundance and diversity. According to Jones *et al* (2004) and the Sea Watch Foundation [(1)] there are between four and nine species of cetacean which have been sited with any regularity in the southern North Sea. Only two of these species are considered by the Sea Watch Foundation to be present throughout the year or to be present annually as seasonal visitors, harbour porpoise and bottlenose dolphin.

The SCANS II surveys (undertaken during 2004) [(2)] divided the North Sea into a number of survey blocks and used standardised survey methodology to provide abundance estimates for cetaceans for each block, with an overall aim of providing abundance estimates for commonly sited species for the whole of the North Sea. The TEDA study area lies within the SCANS II Block B which covers the whole of the English Channel and south coast of England from the coast of Norfolk to the tip of Cornwall. Within Block B the survey recorded sightings of four species: harbour porpoise, bottlenose dolphin,

(1) Sea Watch Foundation website available at http://www.seawatchfoundation.org.uk/index.php (accessed 13/01/09).
(2) Information available at http://biology.st-andrews.ac.uk/scans2/

common dolphin and minke whale. These are predicted to be the most likely cetacean species to be present within the study area and further information is provided on each below.

Harbour Porpoise

The harbour porpoise (*Phocoena phocoena*) is the most numerous cetacean found in the north-western continental shelf waters, commonly occurring in the shallow coastal seas around the UK. They are small cetaceans up to 1.9 m in length, are usually found in small groups of between one to three individuals and feed on a wide variety of small fish species including herring, sprat, mackerel, sandeel, whiting and hake as well as cephalopods including squid. Calving is most common during the late spring however calves have also been observed during January and February (RPS Energy, 2006).

The species is known to inhabit the North Sea throughout the year however historically they were thought to be relatively uncommon within the southern North Sea around the south east coast of the UK (*see* Figure 5.24) (Reid *et al*, 2003).

However the SCANS II surveys which reported their results in 2005 recorded much higher abundances in the southern North Sea, especially off the southern east coast of England. The SCANS II population estimates for Block B reflect this increase, with a predicted density of 0.331 km^2 for the block (Dr Kerry). This gives an estimated population of 1,986 harbour porpoises within the study area, representing approximately 1.8% of the estimated total North Sea population. This is compared with a modelled density of 0 harbour porpoises per km^2 from the original SCANS survey in 1994 (Hammond *et al*, 1995), therefore the results of the two SCANS surveys suggest that there was a southward shift in the distribution of harbour porpoise between 1994 and 2005 within the southern North Sea.

Local dedicated marine mammal surveys have been carried out within the study area for proposed round 2 offshore windfarms (RPS Energy, 2006). Harbour porpoises were found to be the most abundant cetacean and indeed the most common marine mammal recorded, with 952 records, representing an estimated 1,121 porpoises.

Recordings from the aerial surveys obtained unadjusted numbers of porpoises up to 0.9 animals per kilometre. Northridge *et al* (1995) suggest adjustment values of 3-4 to account for sea state during dedicated marine mammal surveys, and sightings of marine mammals during bird surveys are likely to be lower by as much as 50% compared to dedicated mammal surveys, therefore the sightings indices may be as high as 7.6 porpoises per kilometre travelled.

Harbour Porpoise, Bottlenose Dolphin, Common Dolphin and Minke Whale


Harbour porpoise


Bottlenose dolphin


Short-beaked common dolphin


Minke whale

Harbour porpoise image: Brennan Fairbairns (Sea Life Surveys). All other images: Alison Gill.

The results of the harbour porpoise sightings from the Round 2 windfarm bird surveys (Figure 5.25) suggest that harbour porpoise are distributed throughout the study area, with concentrations in the north and south east of the area and a general trend of increasing abundance away from the shore, particularly associated with the deeper water around Long Sand and Kentish Knock. The majority of the sightings (879) were made during the winter suggesting that there is a seasonal increase in use of the outer Thames estuary at this time, possibly in relation to increases in food abundance, particularly spawning herring. This is supported by historical observations which suggest that while the outer Thames estuary is home to resident populations year round it is an important feeding area for the harbour porpoise population of the southern North Sea during the winter with a peak in numbers in the first four months of the year (Reid *et al*, 2003).

The Thames Marine Mammal Sightings Survey, initiated in 2004, is network-based system of gathering information covering the tidal Thames from Teddington to Southend in the outer estuary. Sightings were recorded predominantly by non-expert sources using a formulaic report card. Harbour porpoises were found to make up 26% of sightings between July 2004 and June 2007 (Kowalik *et al*, 2008). However these shore-based 'non-expert' opportunistic sightings should not be considered as systematic or reliable as the survey data that has been collected offshore.

The toothed whales (odondocetes) including the harbour porpoise are sensitive to a very broad bandwith of sound and are responsive to underwater noise at frequencies from 100Hz to 170kHz. Peak hearing sensitivity occurs over the frequency range from 20kHz to 150kHz. At this frequency the harbour porpoise is thought to be capable of hearing sounds below 40 dB re 1 µPa (Kastelein *et al*, 2002). Harbour porpoises vocalise using clicks and other sounds with a frequency of approximately 2Hz. They echolocate with short intense pulses of 110-150kHz and with source levels of 135-177 dB re 1 µPa at 1m (Richardson *et al*, 1995).

Figure 5.24 Harbour Porpoise and Bottlenose Dolphin Distributions in the UK from 1979 to 1997

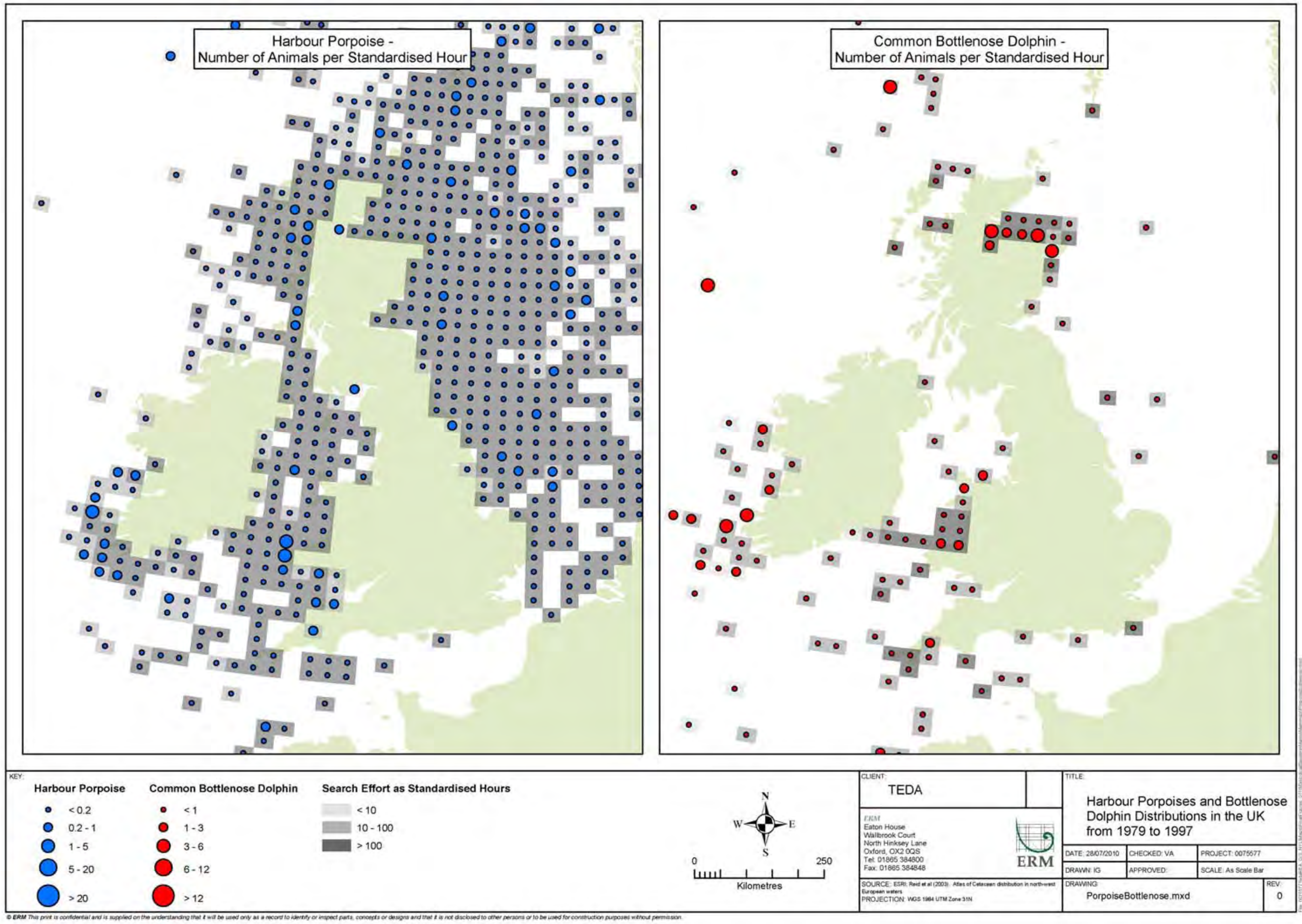
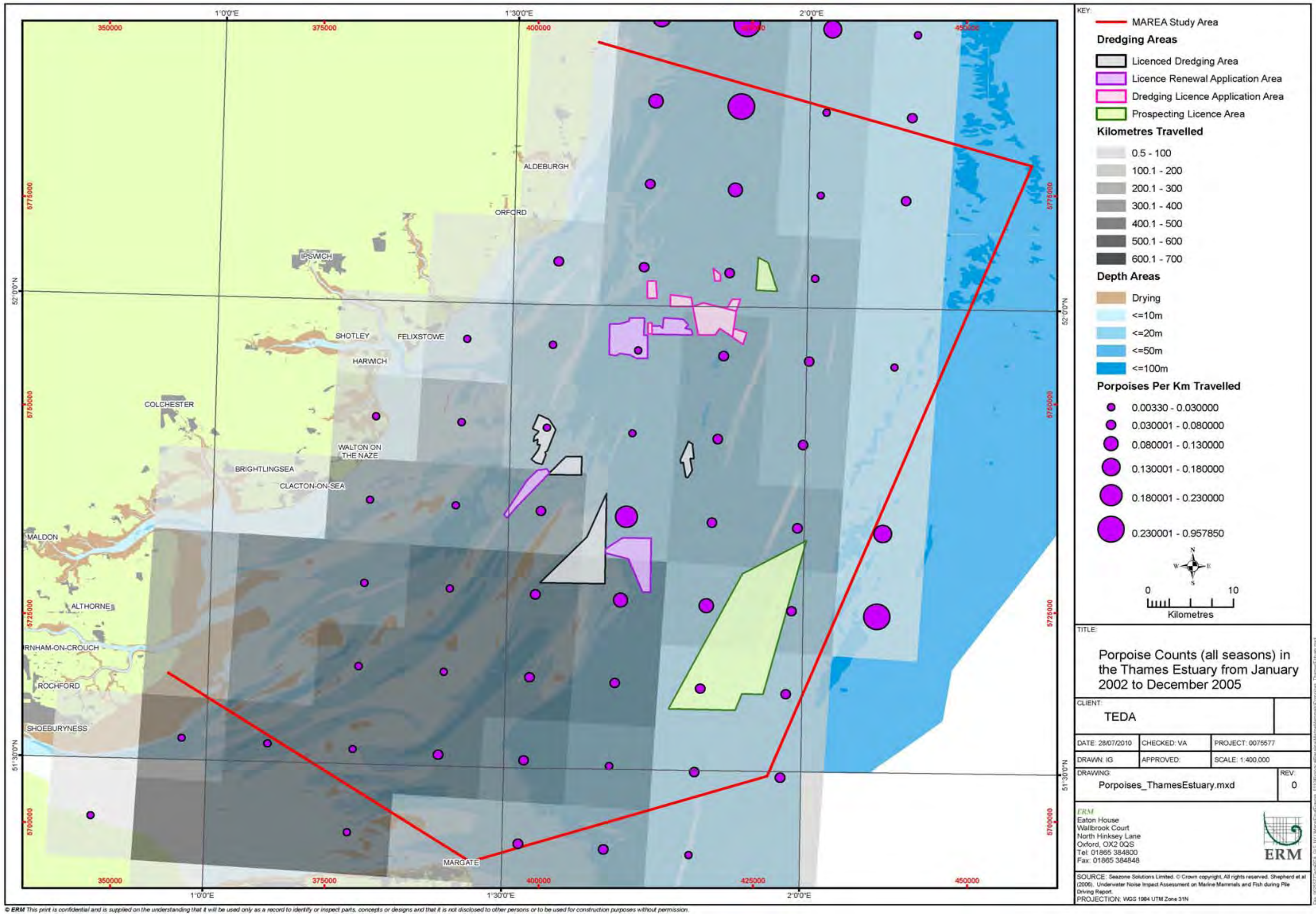


Figure 5.25 Porpoise Counts (all seasons) in the Thames estuary from January 2002 to December 2005



Bottlenose Dolphin

The common bottlenose dolphin (*Tursiops truncatus*) occurs throughout the north eastern Atlantic and is locally common around certain areas of the coast of Great Britain. They grow up to 4 m long and feed on a wide variety of fish and cephalopod species, and are very adaptable feeders with coastal populations capable of taking benthic species such as flounder, dab and sole [(1)]. The species has an extended breeding season, with a peak in births between May and October (Evans *et al*, 2003).

Bottlenose dolphins are capable of hearing frequencies between 0.08 and 1.5 kHz and are most sensitive to the range between 10.5 and 100 kHz. They are in the order of 10dB less sensitive to these frequencies than the harbour porpoise (Johnson, 1967). Bottlenose dolphins communicate with sounds and whistles with frequencies ranging between 0.8 and 24 Hz. Echolocation frequencies range between 110 and 130k Hz with source levels of 218-288 dB re 1 µPa at 1m (Richardson *et al*, 1995).

There are a number of well known groups which exist around the coast of Great Britain in the Moray Firth, Cardigan Bay, off the south west of Ireland and a smaller group which is known to inhabit the waters off Cornwall and move along the south coast of England, with sightings most common between July and October (see Figure 5.24) (Reid *et al*, 2003).

Bottlenose dolphins are uncommon visitors to the Thames estuary, and the SCANS II surveys give an abundance estimate in Block B of 0.0032 animals per km^2 [(2)]. This equates to a potential population of 21.6 bottlenose dolphins, however this number is likely to be heavily skewed by the sightings off the south coast of England and the actual number present in the Thames estuary is likely to be much less than this. During the dedicated marine mammal surveys undertaken for Round 2 offshore windfarms, there were four confirmed sightings of bottlenose dolphins within the Thames estuary, although there were also 115 sightings of unidentified cetaceans, some of which may have been bottlenose dolphins (RPS Energym 2006). The estimated population within UK inshore waters is thought to be approximately 300 [(3)].

Therefore the number of bottlenose dolphin sightings recorded during site specific surveys for the Round 2 offshore windfarms equates to approximately 1.3% of the population. During the Thames Marine Mammal Sightings Survey between July 2004 and July 2007, bottlenose dolphins comprised 8% of sightings (Kowalik *et al*, 2008). However these were shore-based, 'non-expert' opportunistic sightings and should not be considered as robust as the survey data.

Given the low number of bottlenose dolphins recorded and the distance to the closest known resident populations at the Moray Firth and Cardigan Bay, it is likely that most individuals recorded within the study area are non-resident in the area and opportunistically foraging.

Short-Beaked Common Dolphin

The short-beaked common dolphin (*Delphinus delphis*) is a small dolphin which can grow up to 2.4 m long, feeding on a range of small schooling fish species including cod, hake, mackerel, sandeel and herring [(4)]. Like most delphinids, short-beaked common dolphins produce whistles with dominant frequencies between 2kHz and 18kHz, 'chirps' between 8kHz and 14kHz and 'barks' with low dominant frequencies below 3kHz (Caldwell *et al*, 1968).

D. delphis is one of the most abundant cetaceans in the north east Atlantic however it is an irregular visitor to the southern North Sea, being a largely oceanic species with its distribution centred around the western and particularly south western coasts of Great Britain (see Figure 5.26) (Reid *et al*, 2003).

Nevertheless the SCANS II survey gave an abundance estimate of 0.1159 animals per km^2 in Block B which would equate to a population of 695.4 dolphins present within the Block[(5)]. However all of the sightings used to calculate the SCANS II abundance estimates came from the waters between the south west coast of Cornwall and Brittany, and no common dolphin were recorded within the TEDA study area during the SCANS II survey.

The studies undertaken for Round 2 windfarms did not record any common dolphins within the Thames estuary, although 115 unidentified cetaceans were recorded which may have included some common dolphin (RPS Energy, 2006). Given the known distribution of common dolphin and the lack of sightings during both the SCANS II and Round 2 windfarm surveys it is unlikely that the study area is important for common dolphin.

Minke Whale

The Minke whale (*Balaenoptera acutorostrata*) is the only baleen whale regularly recorded from the southern North Sea marine natural area (Jones *et al*, 2004). They are filter feeders which prey on schooling fish such as herring, cod, whiting and sandeel as well as free swimming crustaceans and gastropods, and they can reach up to 7-8.5 m in length. Minke whales create and are capable of detecting sound frequencies from 60 to 20000Hz, with the majority of signals having frequencies ranging between 60 and 12000Hz (Richardson *et al*, 1995).

The majority of sightings around the coast of Great Britain are made between May and September. They are uncommon within the study area, with the main concentrations off the east coast being present from Scotland to south Yorkshire (see Figure 5.26) (Reid *et al*, 2005). No minke whales were recorded during the surveys undertaken for the Round 2 windfarms.

The SCANS II surveys give an abundance estimate for minke whales in Block B of 0.0097 animals per km^2 [(6)]. This gives an estimate for the study area of 58.2 whales, approximately 0.31% of the estimated UK population of 18,600 whales (Hammond *et al*, 2006), however this estimate is heavily skewed by sightings from between the south west coast of England and Brittany in France and the real number of animals likely to frequent the TEDA study area is likely to be far less than this, with no actual sighting recorded from within the Thames estuary during the SCANS II surveys. As the usual distribution for minke whales in the North Sea only extends as far south as the Yorkshire coast, it is likely that any individuals sighted within the study area are occasional visitors exploiting locally or seasonally abundant food resources.

Other Species

The long-finned pilot whale (*Globicephalus melas*), Atlantic white-sided dolphin (*Lagenorhynchus actus*) and the white-beaked dolphin (*Lagenorhynchus albirostris*) are other cetacean species occasionally recorded in the southern north sea, however the long-finned pilot whale tends to follow the continental shelf and is rarely recorded within shallow coastal waters and the Atlantic white-sided dolphin and white beaked dolphin are largely confined to the North Sea north of the Humber estuary (Reid *et al*, 2003). These species were not recorded during the aerial surveys for the Round 2 windfarms, however it is possible that some of the sightings of unidentified dolphins were white-beaked dolphins. It is therefore considered unlikely that these species will regularly be present within the study area.

Sperm whales (*Physeter macrocephalus*) are primarily sighted in the deeper waters off the continental shelf, and have been recorded in very low numbers around the UK. Killer whales (*Orcinus orca*) are most frequently seen northwest of Scotland and the Shetland and Orkney Isles. Sightings on the east coast are limited to a few incidental records.

(1) Sea Watch Foundation website available at http://www.seawatchfoundation.org.uk/index.php (accessed 13/01/09).

(2) Personal communication with Dr Kerry McLeod of the Sea Mammal Research Unit, Gatty Marine Laboratory, University of St Andrews in October 2008.

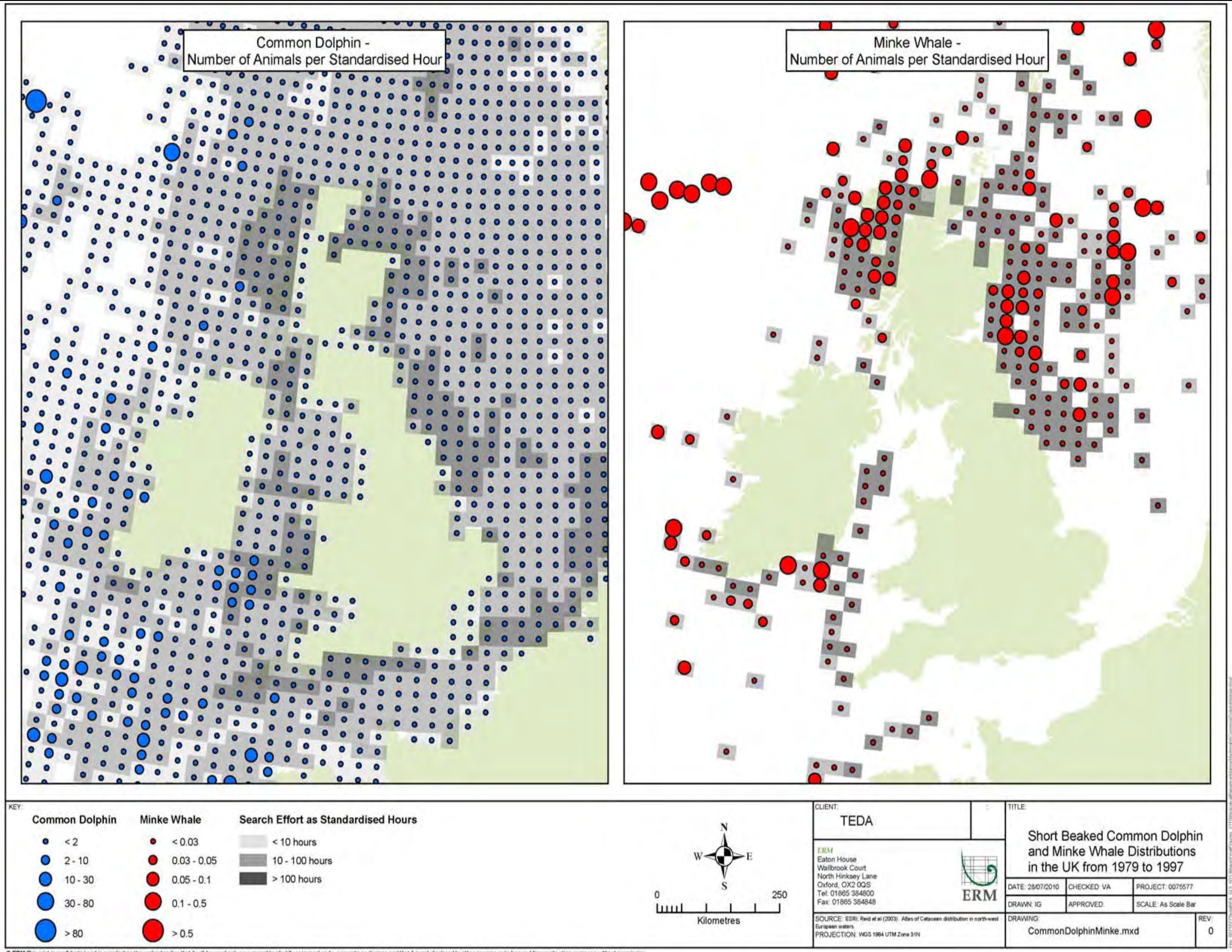
(3) JNCC, information on *Tursiops truncatus*, available at http://www.jncc.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1349 (accessed 13/01/09).

(4) Seawatch Foundation, 2008. Information sheet on the short-beaked common dolphin, available at http://www.seawatchfoundation.org.uk/docs/Common_Dolphin.pdf (accessed 13/01/09).

(5) Personal communication with Dr Kerry McLeod of the Sea Mammal Research Unit, Gatty Marine Laboratory, University of St Andrews in October 2008.

(6) Personal communication with Dr Kerry McLeod of the Sea Mammal Research Unit, Gatty Marine Laboratory, University of St Andrews in October 2008.

Figure 5.26 Short-beaked Common Dolphin and Minke Whale Distributions in the UK from 1979 to 1997



It is therefore not expected that the sperm whale and the killer whale will be encountered in the outer Thames.

A northern bottlenose whale (*Hyperoodon ampullatus*) entered the Outer Thames Estuary for three days in January 2006 before dying. There have been reports of northern bottlenose whales stranding on the east coast of the UK (Kowalik *et al*, 2008), suggesting that this species may also occur within the study area.

5.4.5 Pinnipeds

Overview

Two species of seal breed in the UK and are commonly found in UK coastal waters; the common seal and the grey seal.

Common Seal and Grey Seal

Common Seal

Grey Seal

Common Seal

The common seal (*Phoca vitulina*) is the smaller of the two UK seal species. They occur along all coasts of the UK, preferring sheltered sandy beaches to haul out on (see Figure 5.27). They are generally resident in one area, with some limited dispersal and seasonal movement between haul out sites, but do not carry out any seasonal migrations. Historical accounts suggest they are concentrated near the coast during the summer, but disperse further offshore in winter (Jones *et al*, 2004). Their diet consists of a range of species including herring, sprat, whitefish, flatfish and benthic species including crustaceans and molluscs. Pups are born between June and August on sand flats in close proximity to deep waters, and mating generally occurs a month following birth.

Common seals vocalise using clicks with frequencies of 0.5-4 kHz, however these can be as high as 150 kHz. The common seal has better low and mid-frequency hearing than the harbour porpoise and bottlenose dolphin, and can detect a frequency range from 100Hz to approximately 5kHz, however their hearing is not as sensitive at high frequencies (Kastak *et al*, 1998).

The UK supports approximately 33,800 common seals which accounts for 40% of the world population. The southern North Sea Marine Natural Area is reported to support approximately 12% of the UK population (Jones *et al*, 2004) however during the Thames Marine Mammal Sightings Survey between July 2004 and July 2007, common seals comprised 21% of sightings (and 25% of sightings were unidentified seals, some of which may have been common seals) (Kowalik *et al*, 2008). However these were shore-based, 'non-expert' opportunistic sightings and should not be considered as robust as the survey data.

Seals have been recorded on several of the ephemeral dry sand flats in the outer Thames including Long Sand, the Kentish Knock and Horse Sands in the Swale estuary. However the majority of common seals inhabit the Wash and north Norfolk coast, where there is an abundance of suitable sand bank habitat which provides haul out sites. Common seals are also known to haul out in low numbers at sites along the Essex coast at including Pyfleet Channel, Buxey Sands, Foulness Channel, Hamford Water and East Barrow sandbank [(1)] and are present within the Essex Estuaries SAC although are not one of the qualifying interest features of the site [(2)].

Almost half the population of common seals in the UK were killed during the outbreak of phocine distemper virus in 1988, and several small outbreaks have been recorded since. It has been postulated that pollution events may have resulted in immune system deficiencies in seals, which may be partially to blame for the scale of the impact.

Grey Seal

Grey seals (*Halichoerus grypus*) also occur around the coast of the UK although their distribution is centred around the northwest of Scotland and around Orkney and Shetland, and they are less numerous than common seals within the southern North Sea Marine Natural Area (Jones *et al*, 2004) (see Figure 5.27). They generally prefer more rocky coastlines however they will use sandy beaches for hauling out and pupping if the sites are suitable. During the Thames Marine Mammal Sightings Survey between July 2004 and July 2007, 15% of sightings were thought to be grey seals (and 25% of sightings were unidentified seals, some of which may have been grey seals) (Kowalik *et al*, 2008). However these were shore-based, 'non-expert' opportunistic sightings and should not be considered as robust as the survey data.

The nearest main breeding colony is at Donna Nook on the Lincolnshire coast, although small numbers of pups are born each year on Norfolk and Suffolk beaches (Jones *et al*, 2004). Scroby Sands and Blakeney Point in Norfolk are well known haul out sites. Pupping occurs around January in the southern North Sea, followed by moulting in February and March (Hammond *et al*, 2002). Their diet consists of flatfish, whitefish, sandeels, crustaceans and molluscs with most prey items taken from on or near the seabed.

The grey seal is thought to be marginally less sensitive to underwater sound than the common seal, although this difference may be within the experimental error associated with these types of measurement (Parvin *et al*, 2008). It can vocalise sounds in the region of 0.1-16 kHz, and produce clicks between 0.1 and 40 kHz (Richardson *et al*, 1995).

Seal Survey

During the dedicated marine mammal surveys for Round 2 offshore windfarms an estimated 137 common seals were identified. Grey seals were recorded on four occasions and 475 unidentified seals were recorded.

The majority of all seal sightings were made within 15 km of the shore, however several large aggregations were recorded in the vicinity of the London Array site, associated with sandbanks including Kentish Knock, Long Sands and Goodwin Sands (RPS Energy, 2006). Figure 5.28 highlights this 15km contour along the coastline and the ephemeral sand banks within the region, to show the areas within the Thames estuary which are potentially most commonly used by both seal species.

5.4.6 Summary of the Baseline and Key Sensitivities

Table 5.14 summarises the marine mammal species recorded within the Thames region as part of the Round 2 windfarm surveys, and their frequency of occurrence. The abundance and diversity of marine mammals within the study area is generally low with only two cetacean species (harbour porpoise and bottlenose dolphin) and two pinniped species (common seal and grey seal) recorded annually.

Harbour porpoise are by far the most common marine mammal species recorded within the study area with an estimated population of approximately 2,000 based on the SCANS II abundance estimates (Dr Kerry). They are present throughout the study area with a peak in activity in winter, and increasing abundance further offshore. Other cetacean species are infrequently sighted within the study area. Common and grey seals are present in the study area with common seals being more abundant, and both species tending to frequent near shore waters. This is supported by historical data which indicate that the harbour porpoise, common seal and grey seal are the species most commonly recorded across the region (RPS Energy, 2006). All three species are potentially present throughout the year and the harbour porpoise and small numbers of common seal are thought to be resident, using the area for mating, giving birth, weaning and foraging (RPS Energy, 2006).

The **harbour porpoise**, **common seal** and **grey seal** will therefore be taken forward into the impact assessment process, as they are considered to be the most common marine mammal species in the Thames estuary, and as a result are more likely to experience any potential impacts from dredging operations.

Table 5.14 Marine Mammals recorded within the outer Thames and Southern North Sea

Species	Frequency of Sightings	Conservation Status
Harbour porpoise	Common resident	National/International
Bottlenose dolphin	Occasional visitor, most years	National
Short-beaked common dolphin	Rare visitor	
Minke whale	Regular visitor, low numbers	Regional
Long-finned pilot whale	Regular visitor, low numbers	Regional
White-beaked dolphin	Occasional visitor	Regional
Sperm whale	Rare vagrant	
Killer whale	Rare visitor	
Common seal	Common resident	Regional
Grey seal	Common visitor	County

(1) South Essex Action for Mammals Report to Biodiversity and Environmental Awareness Working Party 18th November 2003. Available at http://minutes.southend.gov.uk/akssouthend/images/att3443.doc (accessed 13/01/09).

(2) JNCC, 2008. Essex Estuaries, available at www.jncc.gov.uk/ProtectedSites/SACSelection/sac.asp?EUCode=UK0013690

Figure 5.27 *Common Seal and Grey Seal Distributions in the UK – Presence in 10km Grid Squares*

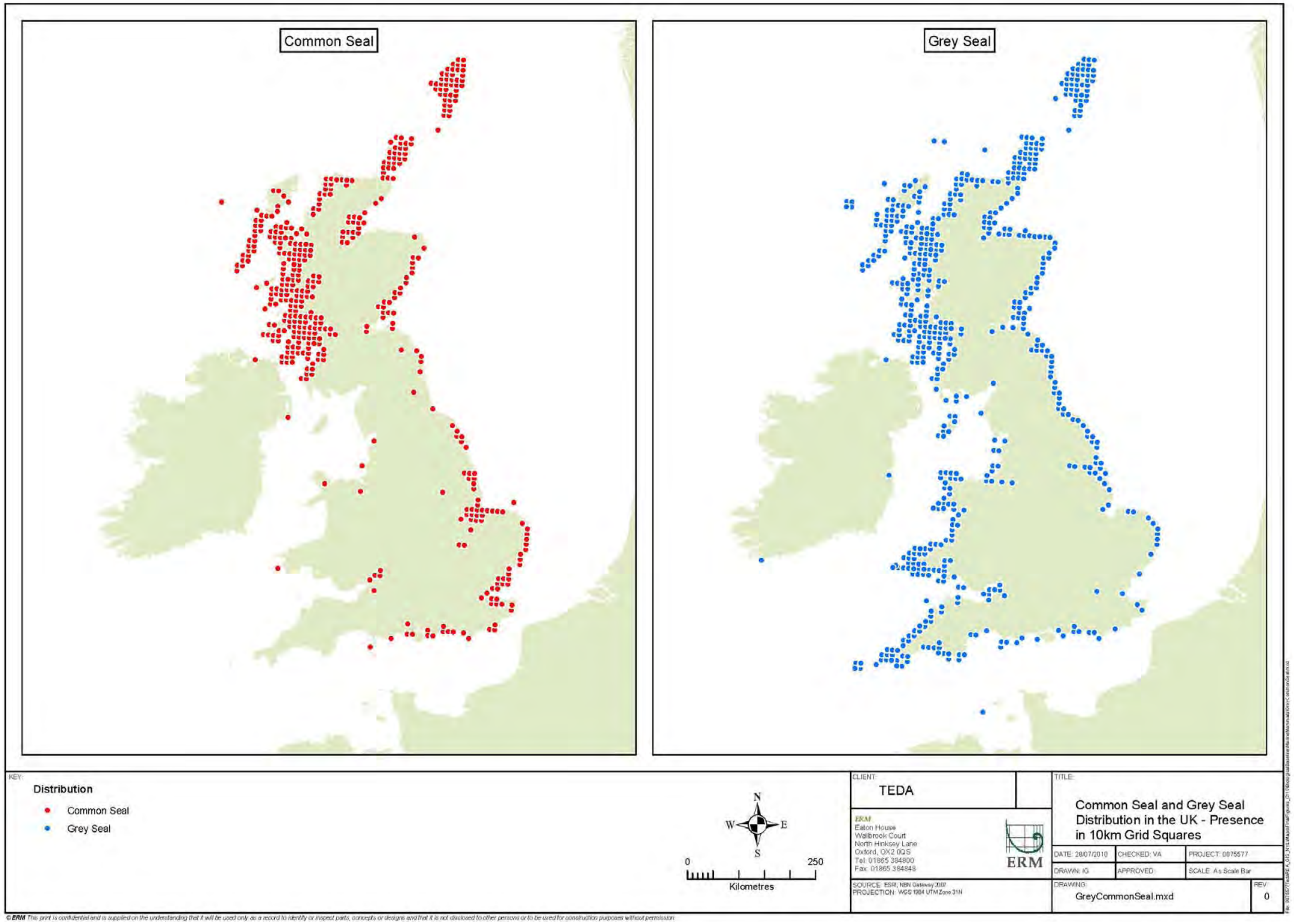
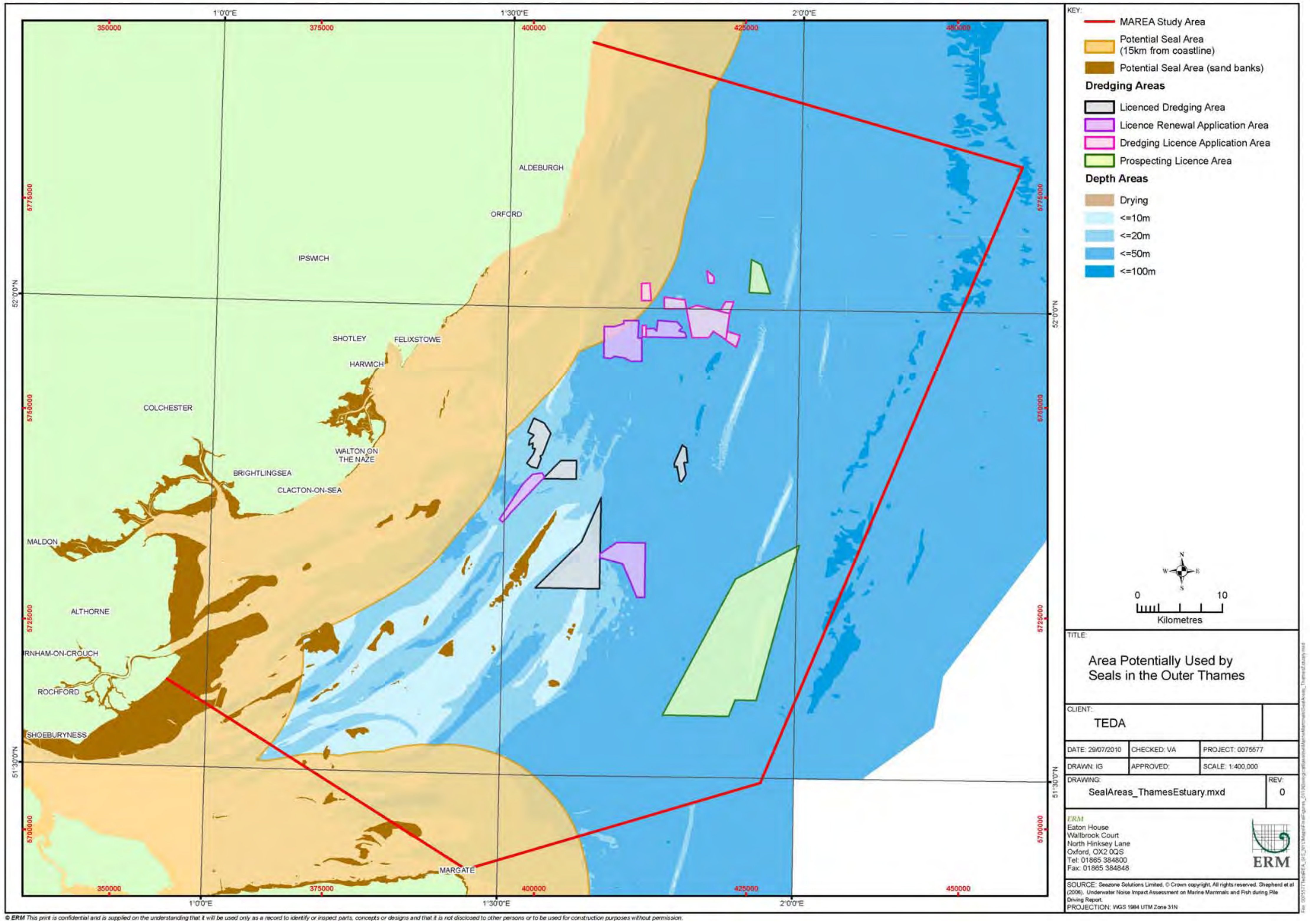


Figure 5.28 Areas potentially used by Common Seals and Grey Seals in the Thames Estuary



5.5 *BIRDS*

5.5.1 Introduction

This section sets out the baseline conditions with respect to use of the REA study area by birds.

The closest licence area to the coast is approximately 13km offshore, and although coastal designated sites have been listed, the majority of the baseline concentrates on birds using the offshore marine habitat around the licence areas as this is the habitat predicted to be most affected by the development of licence areas within the REA area.

5.5.2 Sources of Information

This baseline section has been compiled using existing sources of data. The main sources of data include:

- Natural England (formerly English Nature)'s information on The Southern North Sea Marine Natural Area (Jones *et al*, 2004)
- Survey findings from aerial surveys of the Thames Strategic Offshore Wind Farm area (Berr, 2007) and (DTI, 2006).
- Results of the most recent Wetlands Bird Survey (Musgrove *et al* 2007).
- Counts of seabird numbers and breeding success (Mitchell, 2004) (Mavor *et al* , 2008 & 2005).
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- Cork Ecology (2004). Review of red-throated diver prey species in the Thames Estuary.
- Mavor RA, Parsons M, Heubeck M and Schmitt S. (2006). Seabird Numbers and breeding success in Britain and Ireland, 2005. Peterborough, JNCC (UK Nature Conservation, No. 30.).
- RSPB. 2008. RSPB website www.rspb.org.uk.
- JNCC. 2009. JNCC website.

Annual aerial surveys have been undertaken by Business Enterprise and Regultory Reform (BERR) and previously Department of Trade and Industry (DTI) of strategic Offshore Wind Farm (OWF) areas around the coast of the UK from 2004 to 2007. The survey area for the Thames strategic OWF area encompasses almost the entire TEDA study area with the exception of the very north-east corner.

The most recent two years data from the aerial surveys (2004/05 and 2005/06) have been combined, taking into account survey effort, to produce figures of distribution for key species groups. These distributions are shown in Figure 5.3229 to Figure 5.37 and the findings from these surveys form the bulk of the baseline information.

5.5.3 General Ecological Context

The waters of the southern North Sea around the southern east coast of England support nationally and internationally important populations of seabirds. According to Jones *et al* (2004), there are 33 regularly occurring species within the Southern North Sea Natural Area which stretches from Flamborough in the East down to Dover in Kent. The coast around the TEDA study area is predominantly low lying and lacks the large sea cliffs required for many large breeding seabird colonies, and consequently supports a lower variety of breeding seabirds than areas further to the north. The main seabird species breeding in the area are gull and tern species which do not require cliff sites to breed. The use of the study area during the summer is therefore relatively low and is dominated by gull and tern species.

During winter the sheltered waters of the Thames Estuary and around the Essex and Suffolk coasts attract larger aggregations of seabirds including auks, divers and gull species, as well as seaducks.

5.5.4 Designated Sites

Introduction

The coastline which runs along the western edge of the study area supports a number of regionally, nationally and internationally designated sites. Most of these sites are covered in more detail in Section 5.6. This section concentrates on SPAs and Ramsar sites.

Special Protection Areas (SPAs)

There are a number of SPAs along the coast of the study area. All of the coastal SPAs support estuarine or reed swamp habitat, and predominantly support wintering wader and wildfowl species, as well as other wintering species such as harriers. A number of the SPAs also support internationally important breeding populations of a number of species including little tern, and also support other tern species although not in sufficient numbers to be qualifying interest features. Table 5.21 in Section 5.6 shows the coastal SPAs within the vicinity of the study area, and Figure 5.40 in Section 5.6 shows their location relative to the study area.

SPA Seaward Extensions and Marine Sites

JNCC are in the process of making amendments to the suite of UK SPAs. Initially this is being done in two ways. The first method is by recommending seaward extensions to SPAs which have been designated because they support internationally important colonies of guillemot, razorbill, puffin, gannet, fulmar and manx shearwater. The second method is selecting a number of inshore marine SPAs which support aggregations of non-breeding waterbirds.

One inshore SPA that has now been designated is the Outer Thames Estuary potential SPA which is designated based on the numbers of wintering red-throated divers (*Gavia stellata*) it supports (38% of Britain's population). See Section 5.6 for more details and Figure 5.38 for the location of this SPA.

Ramsar Sites

A number of SPAs along the coastline of the study are also designated as Ramsar sites (see Table 5.21 and Figure 5.40) due to their meeting the criteria of supporting 20,000 water birds, and/or supporting 1% of the individuals in a population of one species or subspecies of water bird.

Ramsar sites are afforded the same protection as the European designations; Special Protection Areas (SPAs) and Special Areas of Conservation) (SACs).

5.5.5 Aerial Survey Results

Introduction

The most comprehensive ornithological surveys of the study area have been undertaken by Wildfowl and Wetland Trust Consulting (WWTC) on behalf of the DTI/BERR. These surveys were undertaken over two years, 2004-05 and 2005-06 over the Greater Thames Estuary and all the way up the Suffolk and Norfolk coasts, and covered virtually the entire study area. For each year, the survey was split into seven periods, 1-4 covering the winter period, and 5-7 covering the breeding period. Additional data for divers, gulls, kittiwakes, auks and common scoters was collected in winter 2007/2008.

Due to the nature of the aerial survey, it is not always possible to distinguish individual birds down to species level and so records are often only provided down to genus or species group level. For this baseline section, most of these categories have been used, and the survey findings are grouped into the following categories:

- terns;
- gulls;
- auks;
- gannets;
- divers; and
- seaduck.

The results for each of these categories has been plotted where available. It is believed that this over fight data provides the most up to date and complete survey of the distribution of seabirds across the study area, however where it has been felt that there is not sufficient data on any particular species or species group, information from other sources has been used to supplement the survey results. Where information exists on the presence or distribution of individual species within the study area this has been included.

For further details on the methodology and coverage of the surveys please see DTI (2006) and BERR (2007).

As stated in Section 5.5.1 above, the baseline focuses on those species thought to be most likely to be affected by the development of marine aggregate dredging licences, that is seabirds and seaducks.

5.5.6 Summer Surveys

Terns

Four of the five species of tern which commonly breed in the UK have colonies present along the coast within the study area. Sandwich tern (*Sterna sandvicensis*) is known to breed at two internationally important colonies within the study area, one in the Alde/Ore Estuary SPA and one in the Foulness SPA however they also have a number of smaller colonies along the coast and are likely to be relatively common within the study area. Common terns (*Sterna hirundo*) occupy around 17 colonies along the coastline and are the most abundant tern present in the area, although only one of these colonies is of international importance. Arctic tern (*Sterna paradisaea*) generally have a much more northerly distribution than other terns in the UK and are only present at a single small colony at the Alde Ore Estuary and are consequently relatively rare within the study area. In comparison, little tern (*Sterna albifrons*) have a much more south eastern distribution in the UK and their stronghold is on the south east coast of England. They are at present approximately 20 breeding colonies along the coast of the study area, with four internationally important colonies forming a part of SPA designations.

All species of tern locate their prey by sight and feed by plunge diving. Little tern feed on small fish and invertebrates, whilst common, arctic and sandwich tern all feed on clupeids [(1)] and sandeels, with common tern taking a wider variety of prey species, including crustaceans than other terns.

Whilst rearing chicks, tern species will often forage close to their colony sites. A study undertaken into the foraging distances of breeding tern in East Anglia reported maximum foraging ranges for little tern, common tern and Sandwich tern, shown in Table 5.15.

Table 5.15 Tern Species Foraging Distances

Species	Foraging Distance from breeding colony
Little tern	Usually >3km, exceptionally >6km
Common tern	Usually 10-15km exceptionally > 30km
Sandwich tern	13-16 km exceptionally >70km

When not breeding, terns forage over a much wider area, and may travel further out to sea or along coastlines to exploit good sources of food.

(1) Clupeids are fish of the herring and mackerel family.

Figure 5.29 shows the average relative density of all tern species recorded during the aerial surveys of the Thames OWF strategic area undertaken during summer 2005 and 2006. The surveys recorded two main areas of activity.

The highest densities of terns were recorded from within the Thames Estuary, south west of a line drawn between Margate and Clacton-on-Sea. This is possibly due to the high density of common terns, and in certain areas little tern, breeding around the estuary (Mitchell *et al,* 2004). Another reason may be habitat, with common, sandwich and little tern all foraging over offshore sandbanks, which are plentiful within the Thames Estuary.

More diffuse records of terns were recorded up to 25 km offshore along the coast between Harwich and Lowestoft. Due to the distance from shore, the majority of records are likely to be common and sandwich terns, although the distribution data from the survey only identified birds down to a generic tern group rather than to species. It is also possible that these records are from post breeding birds which will forage over a wider area, although it is not possible to tell from the survey data which is not broken down into specific survey periods.

In a UK perspective, the numbers of terns recorded represent a very small proportion of the total breeding population. The UK population of common tern is estimated at 11,838 breeding pairs (RSPB, 2008) of which 806 pairs were recorded to breed in Suffolk, Kent and Essex (Mitchell *et al,* 2004). The highest count for common tern (recording all unidentified sightings of tern species as common tern) recorded during the 2004/05 surveys was 191 birds [(2)], representing 0.8% of the UK breeding population. However the total breeding population of common tern in Suffolk, Kent and Essex is approximately 806 pairs (based on 1 pair per apparently occupied nest (AON) (Mitchell *et al*, 2004). The numbers recorded in the surveys therefore represent a possible 12% of the Kent, Suffolk and Essex breeding population feeding within the area surveyed.

All species of tern are listed in *Annex I of the Birds Directive*, in *Schedule 1 of the Wildlife and Countryside Act*. Sandwich, little and arctic tern are all on the Amber list of Species of Conservation Concern (Gregory *et al*, 2002).

Gulls

Six *Larus* gull species are known to breed in the study area: black headed, common, Mediterranean, herring, lesser black-backed and greater black-backed. In addition to the *Larus* gulls, kittiwake also nest just to the north of

(2) Although this does not take into account the percentage of birds actually recorded during the survey versus the total number of birds using the area. The total number of birds using the area is therefore likely to be higher.

the area. Summer distribution of *Larus* gull species in the study area is shown in Figure 5.30, and summer kittiwake distribution is shown in Figure 5.31. Figure 5.30 shows low levels of activity across the region at the start of the breeding season during incubation, with higher activity closer to shore (<20 km) during chick rearing, especially around the centre of the study area. During the post fledging/moult period, records are spread more widely over the survey area, with fewer concentrations of birds in any particular area, suggesting a dispersion throughout the study area as birds move away from the coastal breeding sites. Use of the study area by gulls over the whole of the breeding season (periods 5-7) is relatively low during the breeding season in comparison to winter (see Section 5.5.7). Figure 5.321 shows that records of kittiwakes were largely confined to the north of the survey area, and only low numbers were recorded.

Although the results of the overflight survey do not identify gulls to species level, it is possible to use other data sources to infer the most likely species present. Black headed, lesser black-backed and herring gull are all common and widespread breeders at coastal sites in the study area and records of these species are likely to make up the majority of the records.

The highest numbers of any gull species recorded during the 2005-06 or 2004-05 survey were, 213 black headed gull recorded during 2005-06. Relatively high numbers of unidentified gulls were recorded on a number of survey periods, with 767 the highest number recorded during any one survey period. Current breeding population estimates for black headed gull are approximately 138,000, herring gull approximately 139,000 and lesser black-backed gull approximately 112,000 (RSPB, 2008). Therefore although not all of the gulls recorded during surveys have been identified to species level, it is possible to conclude that the numbers recorded during the surveys are unlikely represent nationally significant numbers of these species.

Common and greater black-backed gull are scarce in the region, both being present at only one small colony in Suffolk and records of these two species are likely to account for relatively few of the sightings. The UK population of Mediterranean gull is growing and they breed in increasing numbers in the study area, with high counts recorded on the Thames Estuary and at Berney Marshes in Norfolk in recent years (Musgrove 2007). However the UK breeding population is still at around 110 pairs (RSPB, 2008) and so records of this species are not thought to make up a large number of the records made during the aerial survey.

Figure 5.29 Distribution of Terns recorded during Aerial Surveys in Summer 2005-2006

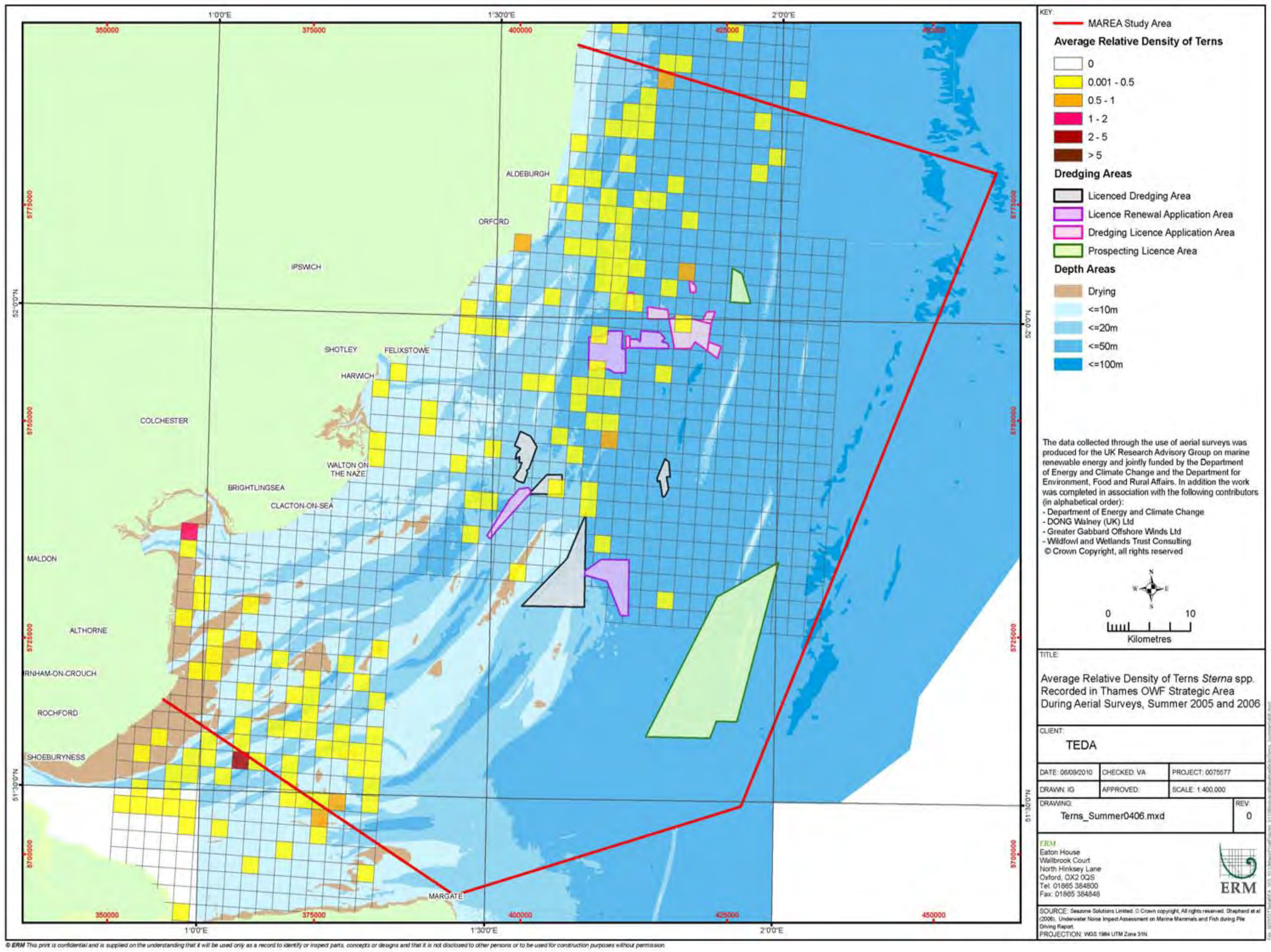


Figure 5.30 Distribution of Gulls recorded during Aerial Surveys in Summer 2005-2006

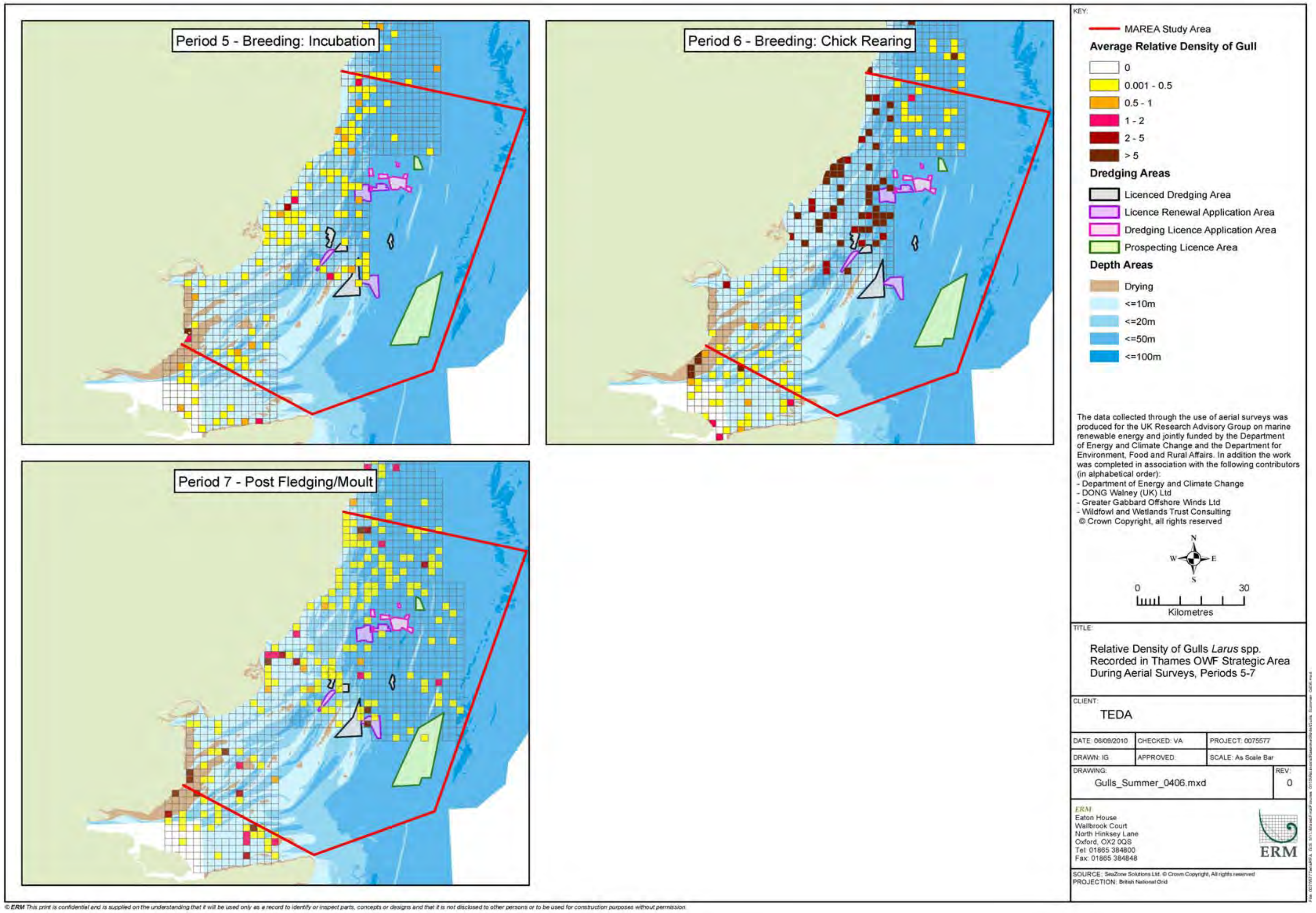
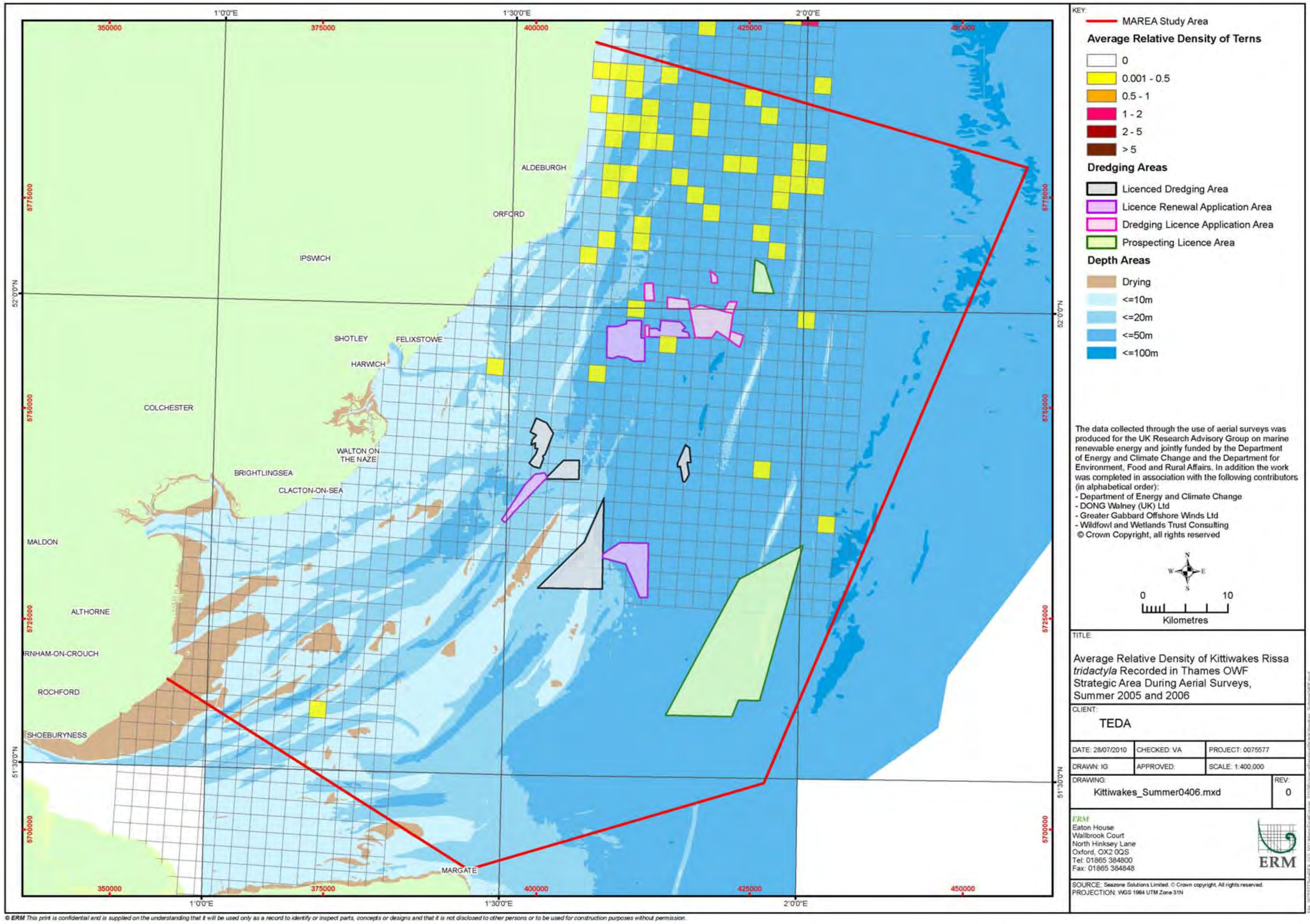


Figure 5.31 Distribution of Kittiwakes recorded during Aerial Surveys in Summer 2005 - 2006



Kittiwakes are present at two breeding colonies in the north of the study area off the coast south of Lowestoft, however aerial surveys only recorded low levels of activity in the north of the study area during the breeding season, with virtually no activity in the south (see Figure 5.31).

Herring, lesser black-backed, black headed, common and Mediterranean gull are all on the Amber List of Species of Conservation Concern.

Auks

Auks are primarily marine birds which only come to shore to breed at colonies on islands or on steep cliffs. As there are no colonies of auks in the vicinity of the study area, mainly due to the lack of sea cliffs which most auk species require for breeding, auk numbers are correspondingly low. When at sea they hunt small fish and crustaceans by diving from the surface. The aerial surveys undertaken in 2004/05 and 2005/06 recorded sightings of puffins, guillemots and razorbills. Levels of auk activity within the study area were low during the summer breeding season, possible as during the summer auks generally feed in very close proximity to their nest sites (McSorley *et al*, 2003). During Period 6 (chick rearing) there were no records of auks within the survey area, and during Period 5 (incubation) there were very low numbers recorded. Higher numbers were recorded during Period 7, mostly in the north of the study area off the coast south of Lowestoft, mostly between 15-30 km offshore (see Figure 5.32).

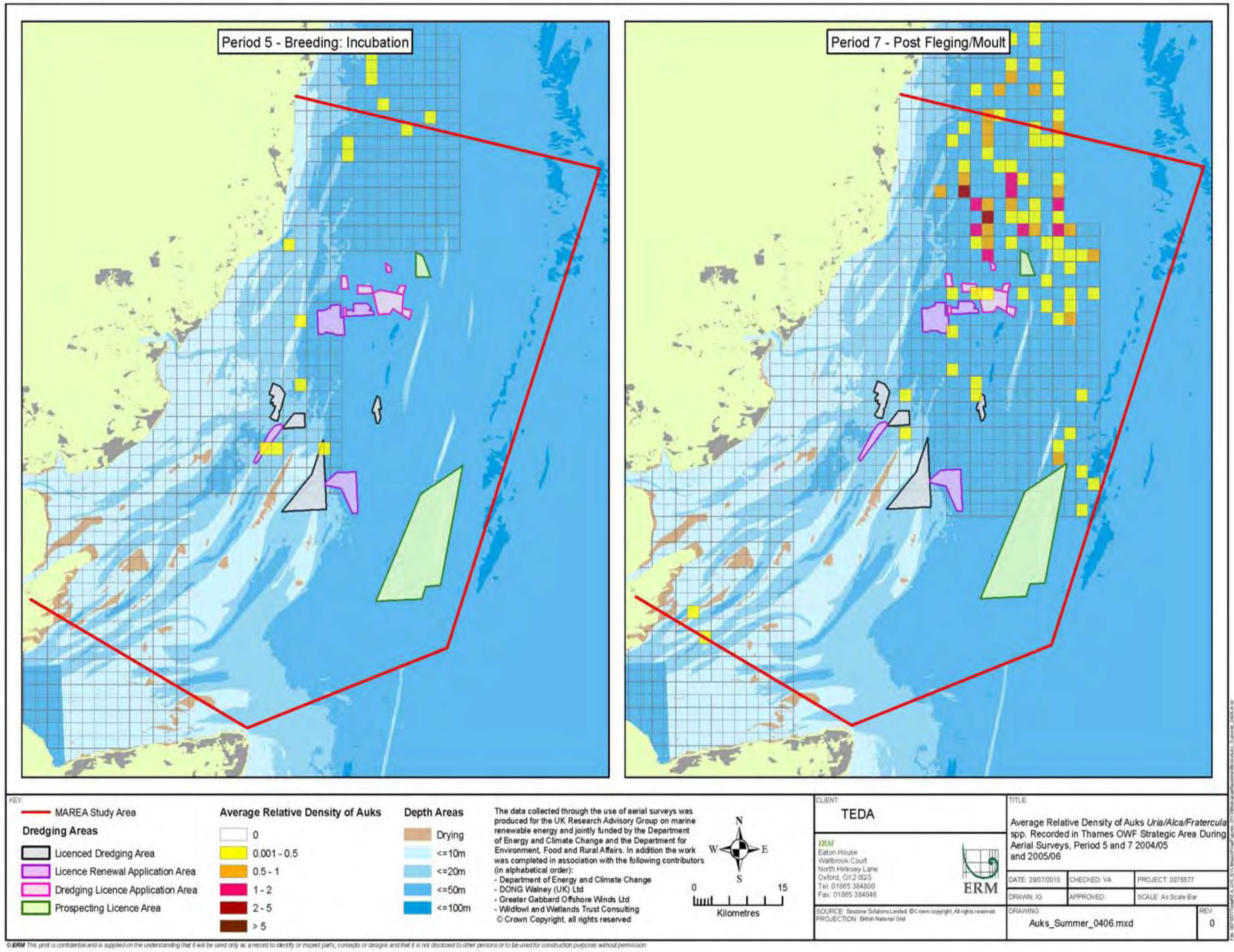
All three auk species recorded during the aerial surveys are on the Amber List of Species of Conservation Concern.

Gannets

The nearest breeding colony of gannets to the study area is at Bempton in East Yorkshire, where approximately 3,500 pairs nested in 2005 (*Mavor et al,* 2006*).* The UK breeding population of gannets is approximately 219,000 breeding pairs (RSPB, 2008). Gannets may forage over a wide range away from breeding sites and immature birds which are not breeding will forage more widely still. Gannets were recorded at low levels within the study area during summer aerial surveys, with a high count of 152 in the late summer of 2005. In a UK context therefore, the study area does not appear to be important for gannets. Although the numbers of gannets recorded during the aerial surveys was provided in the reports the spatial distribution data was not.

Gannets are listed on the Amber List of Species of Conservation Concern.

Figure 5.32 Distribution of Auks recorded during Aerial Surveys in Summer 2005-2006



5.5.7 Winter Surveys Divers

Divers are large fish eating birds which breed onshore on sheltered lochs but overwinter offshore, mostly in sheltered coastal waters. Recent aerial surveys of inshore waters have demonstrated that certain estuaries represent important areas for wintering divers, one of which is the Thames Estuary. The over wintering population of red-throated diver in the outer Thames Estuary was reported to peak at an average of 6,618 individuals between winter 2001/02 and winter 2006/07, which has led to the area being progressed as a potential SPA (Webb *et al*, 2009) (see Section 5.6).

Aerial surveys undertaken during 2005 and 2006 recorded sightings of all diver species, although the vast majority of these are red-throated diver (*Gavia stellata*), due to the more northern distribution of great northern diver (*Gavia immer*) and black throated diver (*Gavia arctica*). Figure 5.33 shows the recorded diver distribution in the study area during the winters of 2005 and 2006. The figure shows the rapid increase in numbers from early winter to mid winter as birds move to coastal areas from their breeding sites, and the distribution of birds over the whole area surveyed.

Over winter there are three main concentrations of activity, the Thames estuary, the Suffolk coast by Aldeburgh and Orford, and an area in the middle of the study area around the dredging licence Area 108/109/113. The Thames estuary supports the greatest number of wintering divers around the south and east coast of England, and the whole of the UK (44% of the national population) (Webb *et al*, 2009), with high densities as well as a wide distribution during mid and late winter. The second key area, off the coast of Suffolk at Aldeburgh and Orford, has high densities of divers recorded during mid and late winter.

The third area of high activity recorded is around Area 108/109/113. High densities of divers have been recorded here during mid and late winter.

Diver distribution during winter is largely determined by available food resources, which for red-throated diver over winter in the Thames Estuary are thought to be mainly herring and sprat, although in addition sand gobies, whiting and flatfish such as flounder and dab may also be important (Cork Ecology 2004). Red throated divers are thought to dive to between 2-9 m during pursuit dives, and in the Thames Estuary have been most often associated with relatively shallow water depths (Cork Ecology, 2004). All diver species undergo seasonal moults when they become flightless and are restricted to loafing and feeding at sea (Stone *et al* 1995). For red-throated diver this moult occurs during the autumn, although no specific moulting areas have been identified within the study area.

All diver species are on the Amber List of Species of Conservation Concern.

The red-throated diver and black-throated diver are listed in *Annex I of the Birds Directive*, in *Schedule 1 of the Wildlife and Countryside Act.*

Auks

Auks congregate offshore during winter where they feed on small fish such as sand eels and clupeids. Auks exhibited a wide distribution over the entire study area during the winter, with peak numbers recorded during the mid winter when high numbers were recorded throughout the centre and south east of the area (see Figure 5.34). The high numbers recorded may be in response to the relatively sheltered conditions near the coast, the levels of food available or to a preference for a particular water depth. The lower numbers and more easterly distribution recorded during the later part of the winter may be a result of birds moving offshore once food resources near to the coast have been exhausted.

Although relatively high numbers have been recorded during the winter in the Thames, in a UK context the numbers are low. Over the two most recent years of survey, the highest average count has been 2,844 guillemots, puffins and razorbills combined (DTI 2006, BERR 2007), with the majority likely to be guillemots as they are the most common auks species in the UK. The estimated total UK breeding population of these three species is c. 4 million birds (RSPB, 2008) with wintering numbers likely to be greater still as the breeding counts do not include juvenile birds and non-breeders, suggesting that the numbers recorded are not significant in a national context, representing approximately 0.07% of the combined UK breeding total for auks.

Gulls

Gull species recorded during the winter aerial surveys in 2004-05 and 2005/06 are shown in Figure 5.35. As well as the six gull species recorded during the summer surveys, low numbers of little gull were also recorded during the winter surveys. Records of gulls were widespread across the study area, with the highest concentrations recorded within the inner Thames. The two midwinter counts (Periods 3 and 4) recorded the most widespread distribution of gulls, but also the highest concentration of gulls, especially around the coast of Essex, and most records of gulls peaked in either Period 2 or 3. Smaller concentrations were recorded off the coast north of Felixstowe.

Table 5.16 shows averaged counts over the two winter surveys of gulls in the Thames OWF Strategic Area, compared to national population estimates.

Total numbers of most wintering gulls recorded are still relatively low compared to UK totals. For example the Thames Estuary is recognised as a nationally important site for black headed gull with a five year mean of 41,825 (Musgrove *et al*, 2007), however the wintering UK population is estimated at approximately 1,697,797 (RSPB, 2008). The highest count for black headed gull during the aerial survey was recorded during period three in 2005/06, when 1,669 black headed gulls were recorded, as well as 12,355 unidentified gulls. Even assuming that all of the unidentified gulls are black-headed gulls, the levels recorded represent 0.8% of the wintering UK population.

Table 5.16 Averaged winter gull counts from 2004/05 and 2005/06 aerial surveys of the Thames OWF Strategic Area

Species	**Period1**	**Period 2**	**Period 3**	**Period 4**	**Wintering UK Population**	**Maximum % of UK population recorded in any Period.**
little gull	37	11.5	7	0	400-800	9.3-4.6
black-headed gull	166	1248.5	256	307.5	1,697,797	0.07
common gull	24.5	155.5	108	196	430,927	0.05
lesser black-backed gull	24.5	32	39.5	29.5	60,830	0.06
herring gull	212.5	479	454	129.5	378,748	0.13
great black-backed gull	118.5	189.5	122.5	51.5	43,156	0.44
kittiwake	212.5	515	723	156.5	379,892	0.19
grey gull spp.	246.5	310.5	549.5	454.5	-	-
black-backed gull spp.	177	117	203.5	66.5	-	-
large gull sp.	83.5	243.5	149	193.5	-	-
small gull sp.	107	228.5	108.5	259	-	-
gull sp.	2785	7716	3299	2255.5	-	-

Source: DTI 2006, BERR 2007, RSPB, 2008

Using just the numbers of gulls identified to species level, most gull species are present in the study area in relatively low numbers. These figures do not take into account however those gull records which could not be identified to species level. The number of little gulls recorded represent a significant proportion of the wintering UK population, with between 4.6 and 9.3 %. However the majority of these records were made during the early part of the winter months and are likely to include passage birds passing through the area on route to wintering grounds further south.

Outside of the breeding season kittiwakes are largely oceanic, spending most of their time foraging over the North Atlantic or North Sea. During the winter surveys they were recorded over a much wider area than during the summer surveys, being recorded at low densities across the entire survey area, with the highest concentrations recorded off the east coast of Kent to the south of the study area. All of the distribution data for kittiwakes is shown for the winter as a whole in Figure 5.36, although from Table 5.16 it can be seen that there was a peak in records during the second midwinter count (Period 3).

Figure 5.33 Distribution of Divers recording during Aerial Surveys in winter 04/05 - 07/08

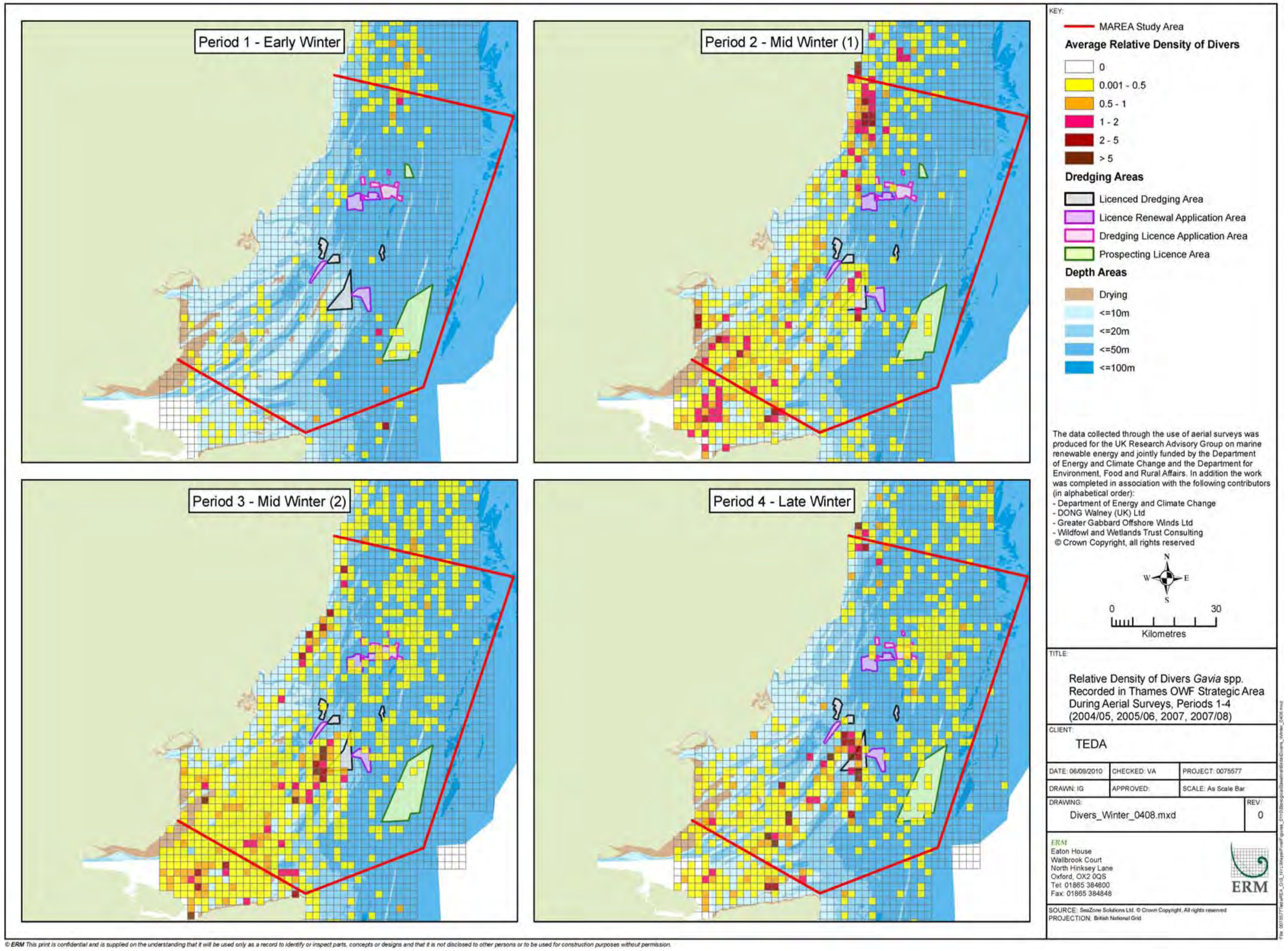


Figure 5.34 Distribution of Auks recorded during Aerial Surveys in Winter 04/05 - 07/08

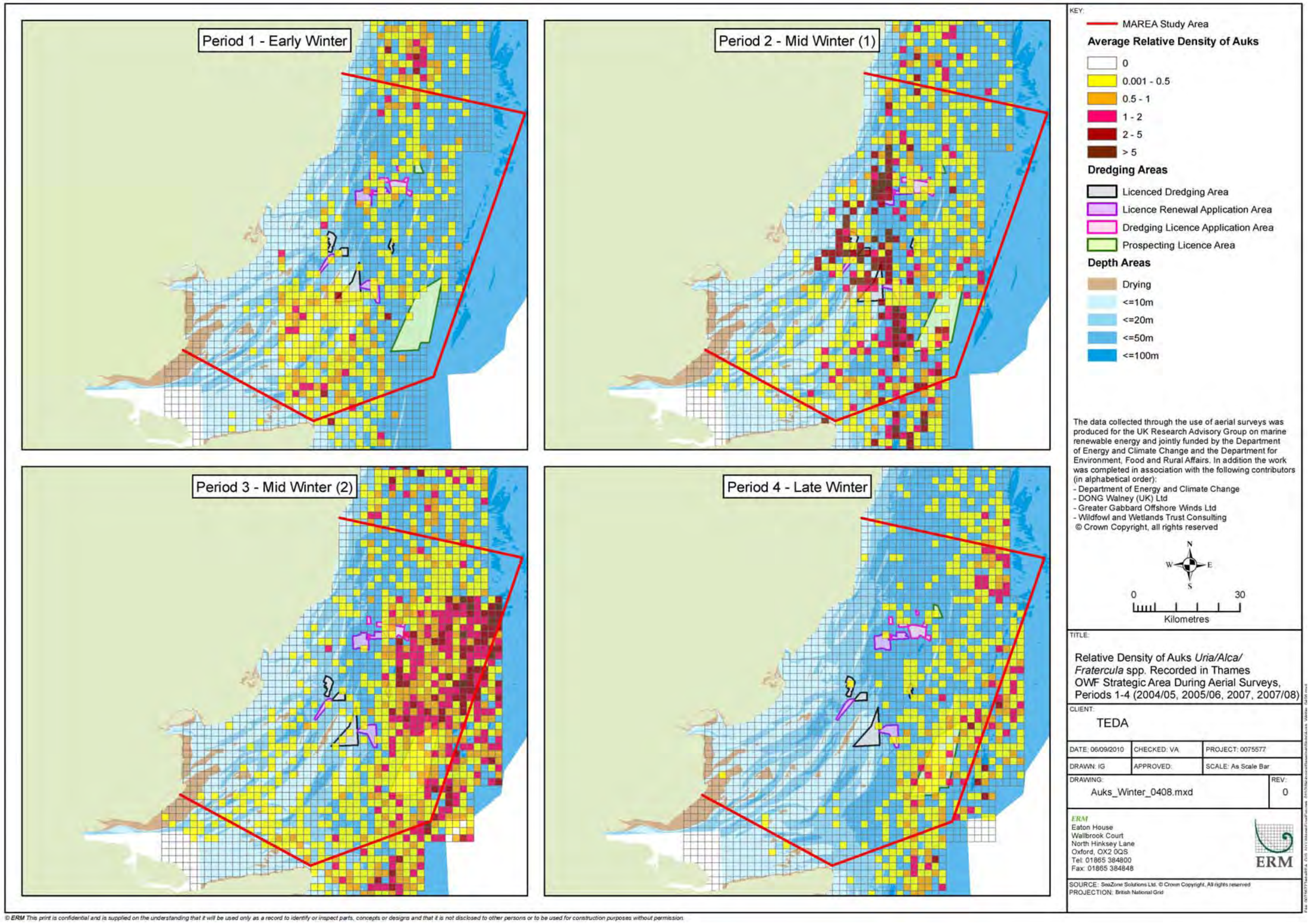


Figure 5.35 Distribution of Gulls recorded during Aerial Surveys in Winter 04/05- 07/08

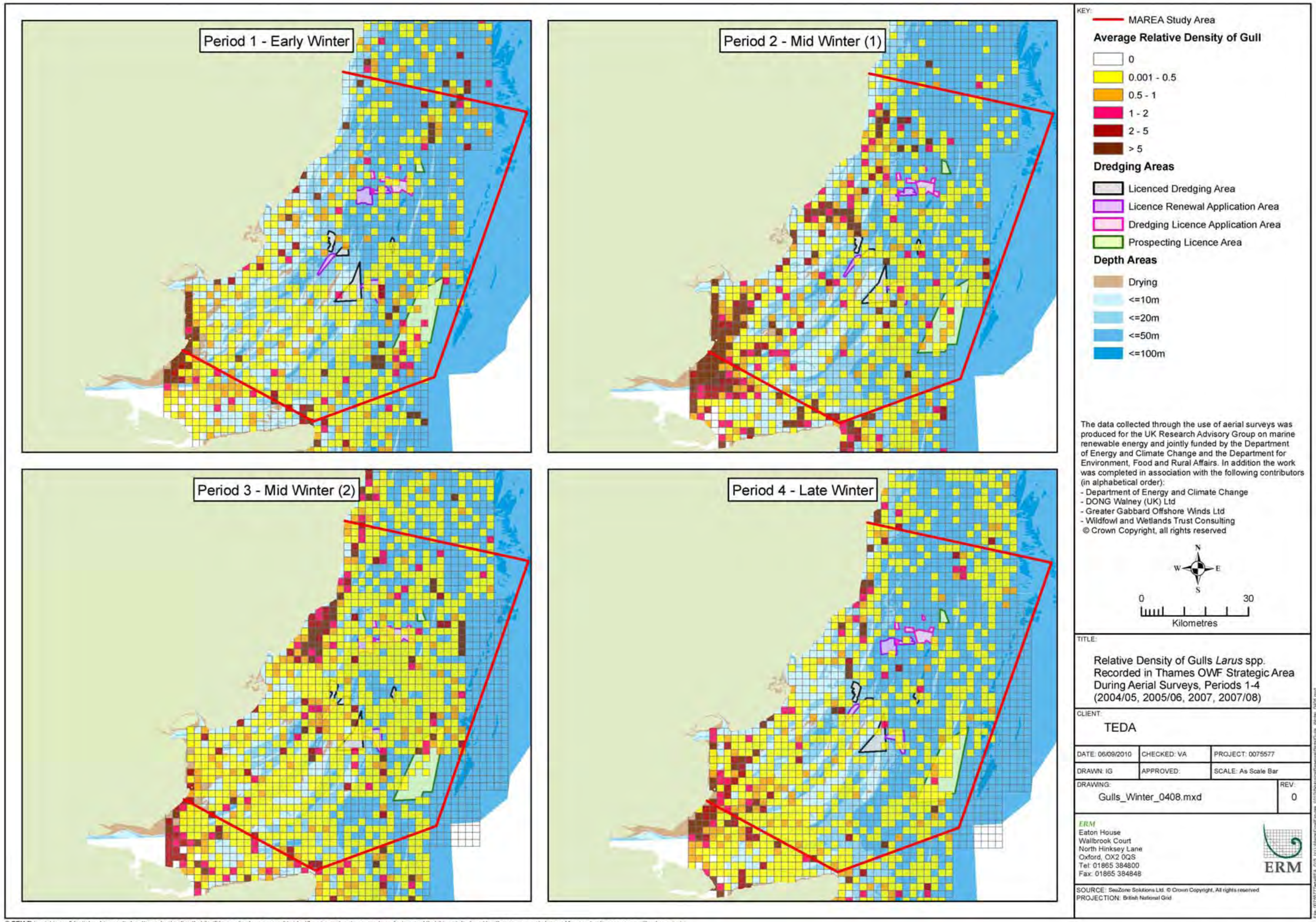
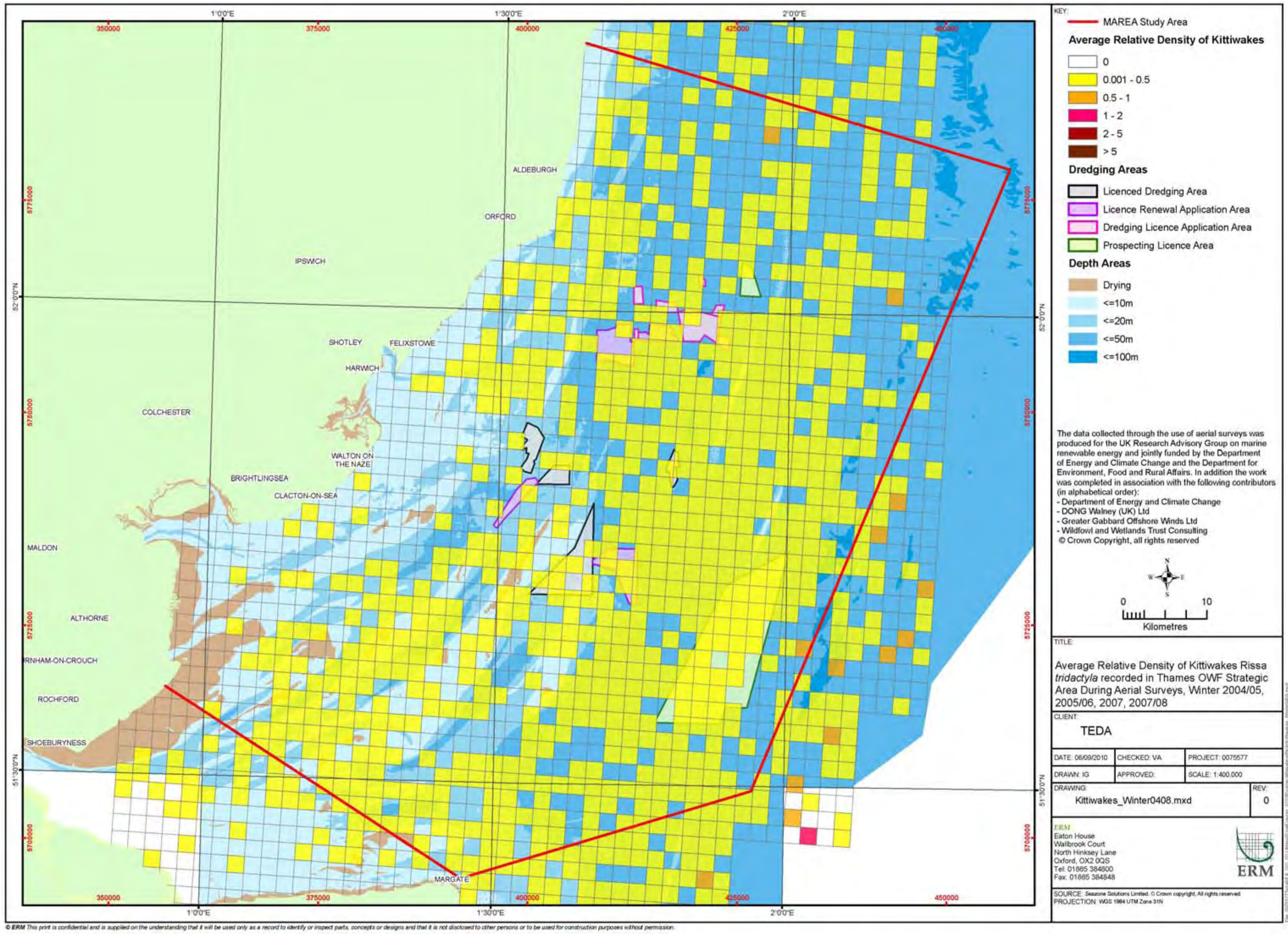


Figure 5.36 Distribution of Kittiwakes recorded during Aerial Surveys in winter 04/05 - 07/08



Gannets

The highest concentrations were recorded off the east Kent coast and north into the outer Thames Estuary, with another smaller concentration off the coast of Norfolk. The highest number of gannets recorded during the two aerial surveys was 2,404 recorded during late winter (Period 4) in 2005/06, although the vast majority of these birds were outside of the TEDA study area. This represents approximately 0.5% of the UK breeding population (as no winter population estimate is known) based on 218,546 nests (RSPB, 2008), although the actual population is larger, with gannets only reaching maturity after 5 years (BTO web 2008).

Seaduck

The Thames estuary supports low numbers of seaduck relative to other areas of the UK, such as Liverpool Bay, although the aerial surveys during 2004/05 recorded a high count of 708 common scoter during mid winter, predominantly in the outer Thames (see Figure 5.37). The wintering population of common scoter is thought to be approximately 50,000, meaning that the Thames OWF strategic area supports approximately 1.4% of the UK wintering population (RSPB, 2008). Records of other seaduck species during the aerial surveys were very low, with a high count of nine eider the only other species recorded.

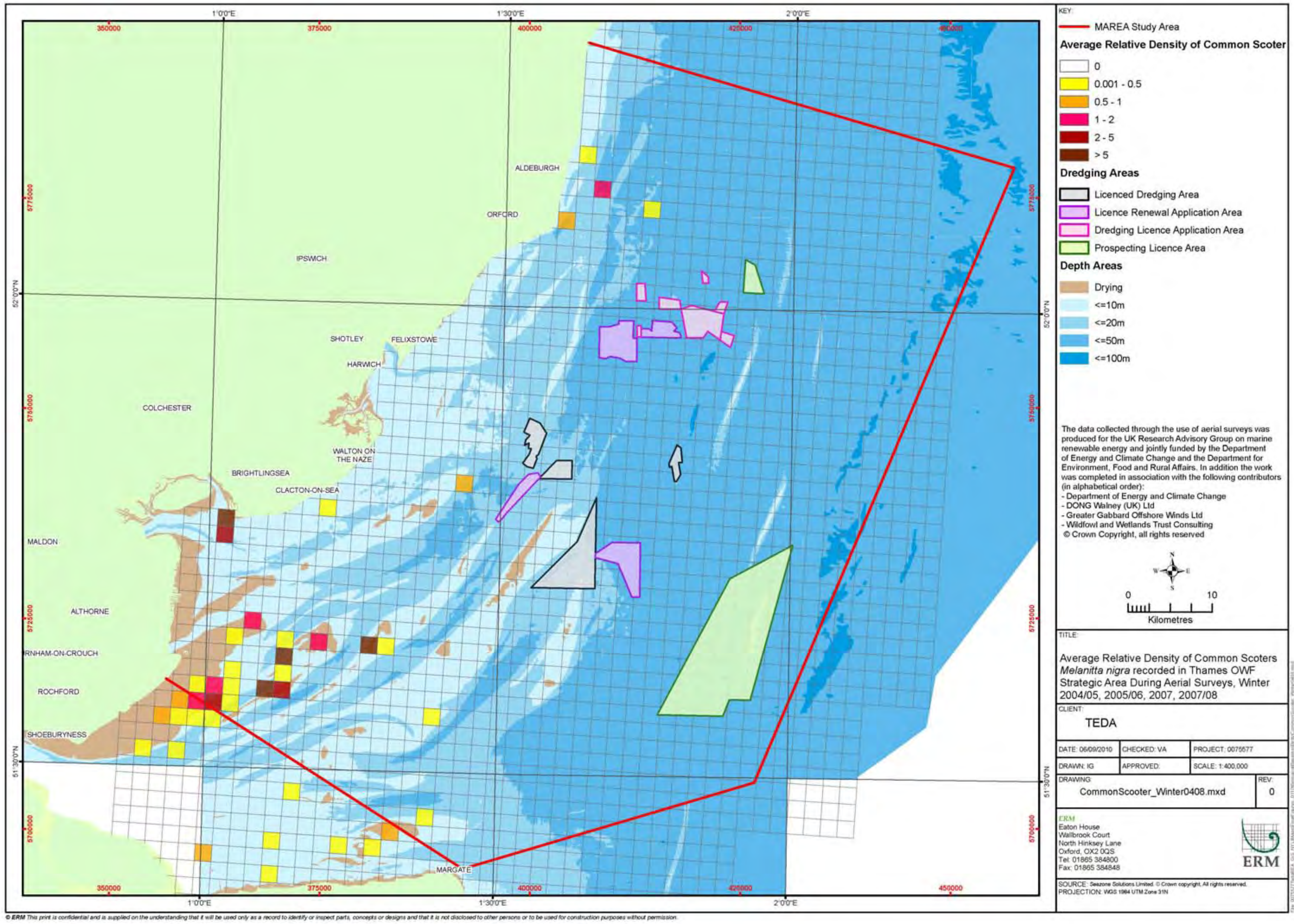
Common scoter are on the Red List of Species of Conservation Concern, although this is because of their decreasing breeding population rather than their wintering population.

Other Species

During the winter, low numbers of grebes were recorded during both surveys. Most records were not identified to species level, however some definite records of great crested grebes were collected. The highest record for any survey period was 17 grebes recorded during 2004/05.

Fulmar were regularly recorded during the year over both survey years, with much larger counts during the winter surveys. A high count of 117 birds was recorded during the late winter (Period 4) during the 2005/06 survey across the whole survey area, although the distribution is unknown. However this number of birds is not considered to be significant in the context of the UK wintering population with currently stands at approximately 1.6-1.8 million birds (RSPB, 2008).

Figure 5.37 Distribution of Common Scoters recorded during Aerial Surveys in winter 04/05 - 07/08



5.5.8 Summary of the Baseline and Key Sensitivities

The study area is characterised by relatively shallow and sheltered coastal waters which support a variety of mostly common and widespread bird species throughout the year. Key breeding species which occur in the region are tern and gull species, with several key tern breeding colonies at coastal sites in the vicinity of the study area, as well as nationally important numbers of Mediterranean gull. Wintering species of importance include nationally important populations of diver which winter offshore, as well as potentially important populations of passage little gull.

Sterna hirundo (Common Tern)

Gavia stellata (Red throated diver)

5.6 DESIGNATED SITES

5.6.1 Introduction

There is currently one site designated as a Special Protection Area (SPA) for protection under the EU Birds Directive within the offshore MAREA study area. There is also a further site which has been recommended for inclusion within the UKs Natura 2000 network as a candidate Special Area of Conservation (SAC) under the EU Habitats Directive (see Section 5.1.2). This section provides information on the offshore sites designated or proposed for protection for their nature conservation importance, and reviews the coastal sites within the study area that are already protected under international, European and national designations.

Species that are protected under national and European legislation, but which do not form part of the qualifying interest of a designated site, are covered in individual species topics for benthic communities (Section 5.2), marine fish (Section 5.3) marine mammals (Section 5.4) and birds (Section 5.5).

5.6.2 Information Sources

The following information sources were used to inform this baseline chapter:

- Birds Baseline (Section 5.5) and Benthic Ecology Baseline (Section 5.2).
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5.6.3 Marine Protected Sites

Overview

The European designations of nature conservation importance comprise Special Protection Areas (SPAs) under the Birds Directive, and Special Areas of Conservation (SACs) under the Habitats Directive (see Section 5.1.2 for a more detailed description of the relevant legislation). Within the offshore study area there is currently one SPA and one candidate SAC, as discussed in the following section.

SPA

An SPA is a site that has been formally recommended to Defra by JNCC, Natural England or Countryside Council for Wales for designation. Natural England is responsible for identifying potential SPAs and conducting public consultation on proposals for English inshore waters (0-12 nm). JNCC leads on the selection of SPAs within the UK offshore area. Sites that span inshore and offshore waters are progressed jointly by Natural England and JNCC and one such site was the Outer Thames Estuary SPA (Natural England, 2009) (Figure 5.38). The statutory consultation process for this designation began on 27th November 2009 and closed on the 26th February 2010. The site was recommended to the EC and officially designated as an SPA in August 2010.

The process of selecting SPAs in the UK involves 2 stages. The first is intended to identify areas which are likely to qualify for SPA status on the basis of population thresholds. Subsequently, these areas are then considered further using one or more of the judgements in stage 2 to select the most suitable areas in number and size for SPA classification.

An area may be considered under any one of the four components of Stage 1:

- Stage 1.1 – numbers of species listed on Annex I of the EC Birds Directive should exceed 1% of the agreed Great Britain (GB) (or if relevant the all-Ireland) population for the species on a regular basis.
- Stage 1.2 – for migratory species not listed on Annex I of the EC Birds Directive, numbers at a site should exceed 1% of the agreed biogeographical population for the species on a regular basis.
- Stage 1.3 – for waterbird species assemblages, more than 20,000 waterbirds (as defined by the Ramsar Committee), of at least two species, should occur regularly at a site.
- Stage 1.4 – where application of stages 1.1-1.3 does not identify an adequate suite of areas, sites may be selected if they satisfy one or more of various ecological criteria listed under Stage 2 (eg by contributing significantly to the species' population viability, such as by virtue of population size and density, by contributing to species range, etc).

The Outer Thames Estuary was identified as qualifying under stage 1.1 based on data collected from aerial surveys during the period from winter 1988/89 to winters of 2006/07 carried out by the Joint Nature Conservation Committee (JNCC), Wildfowl and Wetlands Trust and the Natural Environmental Research Institute, Denmark, and analysed by the JNCC Seabirds At-Sea Team. These data demonstrate that the SPA regularly supports wintering red-throated divers (*Gavia stellata*), listed on Annex I of the EC Birds Directive, in numbers of European importance.

The JNCC Marine SPA Team estimated that the Outer Thames supports an average peak of 6,618 individual red-throated divers in winter (Webb *et al*, 2009) which represents approximately 47% of the UK population (Natural England, 2009). Although not regarded as threatened within the EU, the conservation status of red-throated divers is regarded as unfavourable because of declines in the European breeding population between 1970 and 1990.

The potential area was then considered further using one or more of the judgements in stage 2. This assessment is detailed in Table 5.17 (Natural England, 2009).

Table 5.17 Assessment of the Bird Interest against Stage 2 of the SPA Selection Guidelines

Feature	Qualification	Assessment
1. Population size and density	✓	The Outer Thames Estuary pSPA is the most important wintering site in the UK for red-throated divers.
2. Species range	✓	The site is the main wintering area in Great Britain for red-throated diver which occurs off all coasts of Great Britain but there are no significant concentrations closer to this site than Liverpool Bay or western Scotland.
3. Breeding success	-	Not applicable as this site is selected only for its importance for birds in the non-breeding season.
4. History of occupancy	✓	Aerial surveys undertaken in recent years have shown that significant numbers of red-throated divers have been present in the estuary over a period of at least 15 years; also earlier records exist from shore-based observers of small numbers: most birds are in areas beyond the range of areas normally counted through wetland bird surveys (WeBS).
5. Multi-species area	-	The site supports one qualifying species listed on Annex I of the EC Birds Directive.
6. Naturalness	✓	As most of this site is beyond the mean low water mark, the habitat within the pSPA is likely to be in a relatively natural state except for the localised impacts on areas where maintenance dredging, oil and gas exploration, wind farm construction and commercial fishing take place.
7. Severe weather refuge	-	No data are available to determine whether the site functions as a severe weather refuge.

The SPA boundaries were drawn using two statistical techniques: Kernel Density Estimation and Maximum Curvature. Raw density data for red-throated diver were combined for all aerial surveys and a smoothed relative density grid of 1 km x 1 km squares was developed using Kernel Density Estimation. Maximum Curvature analysis was then applied to identify the point where the relationship between the increase in the number of birds and the increase in the size of the area changes most (ie the point where the size of the area starts to increase at a greater rate than the number of birds protected within it).

The objective of this approach is to achieve designation of the optimum area of the Outer Thames Estuary which ensures that the high density areas for red-throated divers are protected, without unduly increasing the size of the SPA. It is estimated that the entire Outer Thames Estuary supports approximately 47% of the GB population of red-throated diver and the SPA supports approximately 38% of the GB population (or over 80% of the birds in the Outer Thames Estuary).

The SPA extends from a central point mid-river just east of Southend on the Essex side and on the Kent side from a point just east of Sheerness to approximately just east of Herne Bay. To the north of the area two separate parts of the site extend southwards along the coasts of east Norfolk and Suffolk and offshore from the Lowestoft area. The seaward boundary of the SPA lies partly within the 20m depth contour and marginally within the 20-50m depth contour. Red-throated divers occur throughout the entire area of the Outer Thames Estuary, but at greatest density and with greatest frequency off the coast of Suffolk and over sandbanks in the centre of the estuary and those extending toward the coast of south Essex and part of north Kent.

Candidate SAC

In addition to proposing potential SPAs, Natural England is responsible for identifying draft SACs and conducting public consultation on proposals for English inshore waters (0-12 nm). Once a draft SAC has been identified and undergone consultation within the UK, it is submitted for approval to the EC, at which time it becomes a candidate SAC (cSAC). Natural England is currently progressing eight candidate SACs, including the Margate and Long Sands cSAC in the Thames Estuary (Figure 5.39). The statutory consultation process for these designations began in November 2009 and closed in February 2010, with the cSACs submitted to the EC in August 2010.

The Margate and Long Sands cSAC starts to the north of the Thanet coast of Kent and proceeds in a north-easterly direction to the outer reaches of the Thames Estuary. It has been put forward as a candidate SAC due to the presence of a number of Annex I Sandbanks slightly covered by seawater at all times (Box 5.7), the largest of which is Long Sand itself.

Box 5.7 Definition of habitat 1110 Sandbanks which are slightly covered by sea water all the time (EU 2007)

Sandbanks are elevated, elongated, rounded or irregular topographic features, permanently submerged and predominantly surrounded by deeper water. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Banks where sandy sediments occur in a layer over hard substrata are classed as sandbanks if the associated biota are dependent on the sand rather than on the underlying hard substrata.

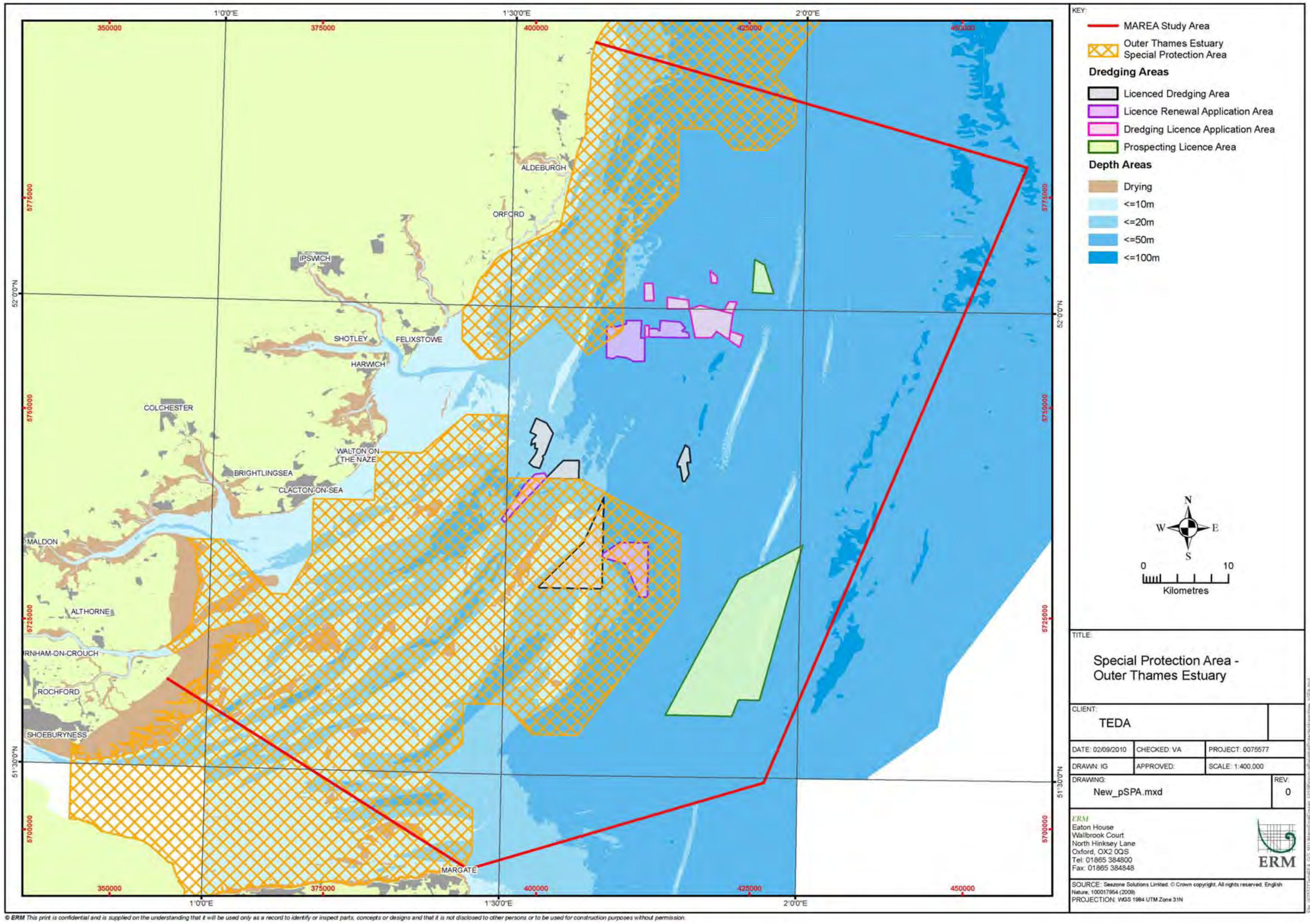
"*Slightly covered by seawater all the time*" means that above a sandbank the water depth is seldom more than 20m below chart datum. Sandbanks can, however, extend beneath 20m below chart datum. It can, therefore, be appropriate to include in designations such areas where they are part of the feature and host its biological assemblages.

The banks are tidally-influenced estuary mouth sandbanks; those in the south (Margate Sand, Margate Hook and Tongue Sand) are aligned approximately east-west in the direction of tidal currents entering the Thames Estuary from the English Channel, whilst Long Sand is aligned in a north-east, south-west orientation along the line of the tidal flows entering the estuary from the North Sea. The bank stretches approximately 45km from Long Sand at the northern end to Prince's Channel at the southern end. It is bordered by Knock Deep on the east side and by Black Deep on the west side. It is asymmetric with the western edge being much steeper than the gently-sloping eastern edge.

Allowance has been made for the perceived eastward extension of the northern end of Long Sand towards Knock Deep, and for the north-easterly progression of Long Sand at the northern tip of the bank. Natural England considers that the sandbanks are sufficiently stable to remain within the defined boundary for the foreseeable future (Natural England, 2009).

A number of channels cross the banks including Fisherman's Gat, which is a major shipping route through Long Sand (Natural England, 2009). The site is split in two by the Princes Channel, and the Queens Channel runs between Margate Sand and the Tongue and Pan Sands. These channels are two of the main approach routes into the Port of London. It has been suggested that Long Sand forms a barrier between the influences of tides from the North Sea and the English Channel. As the timing of these tides is different, the channels may play an important role in balancing out water flows across the bank.

Figure 5.38 Special Protection Area (SPA) - Outer Thames Estuary



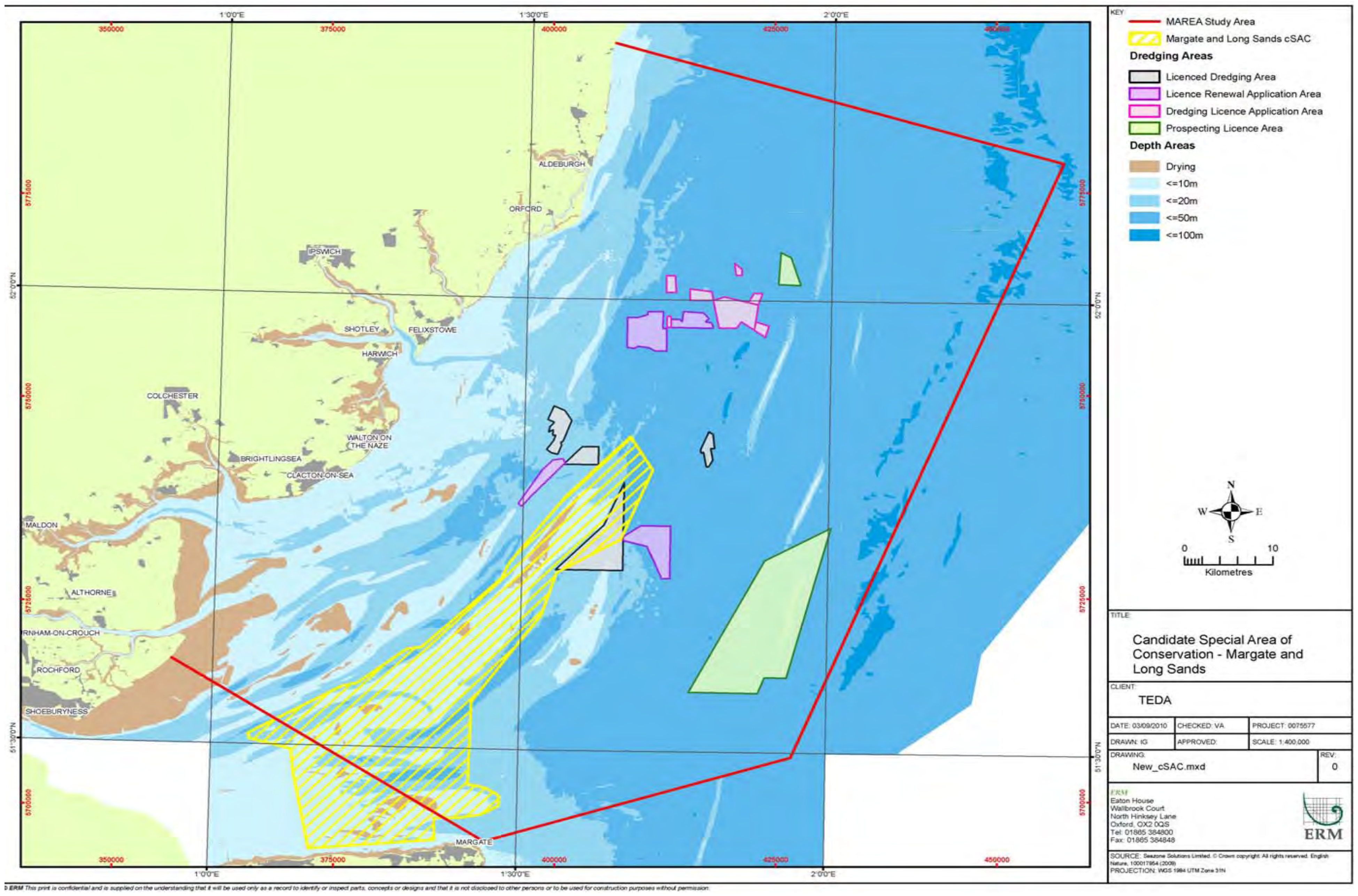
The fauna of the crests of the banks is dominated by polychaete worms and amphipods, and is characteristic of a stressed, mobile sand environment. A higher diversity of polychaetes, crustaceans and molluscs are found within the troughs and on the slopes of banks, particularly within the Queens Channel. Mobile fauna include crabs, brown shrimp, squid and commercially important fish species including sole and herring. Significant amounts of the reef-forming Ross worm (*Sabellaria spinulosa*) are found at this site, however their distribution is patchy and aggregations form crusts rather than reefs (1) Areas of high *Sabellaria* density are usually found on the flanks of the sandbanks and towards the troughs, and support a diverse attached epifauna of bryozoans, hydroids, sponges and tunicates. Overall the abundance of epifaunal species is considered to be low compared to more sheltered, coastal areas (EMU, 2004). The various different benthic sandbank communities supported by the cSAC are shown in Table 5.18.

Table 5.18 Sandbank communities supported by the Margate and Longsands cSAC.

Biotope	Description
SS.SBR.PoR.SspiMx	*Sabellaria spinulosa* on stable circalittoral mixed sediment.
SS.SCS.CCS.MedLumVen	*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel
SS.SCS.CCS.PomB	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles
SS.SCS.ICS.MoeVen	*Moerella* spp. with venerid bivalves in infralittoral gravelly sand
SS.SCS.ICS.SLan	Dense *Lanice conchilega* and other polychaetes in tide-swept infralittoral sand and mixed gravelly sand
SS.SMu.CSaMu.AfilNten	*Amphiuram filiformis* and *Nuculoma tenuis* in circalittoral and offshore sandy mud
SS.SMU.CSaMu.LkorPpel	*Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud
SS.SSA.CFiSa.EpusOborApri	*Echinocymas pusillis, Ophelia borealis* and *Abra prismatica* in circalottoral fine sand
SS.SSa.CMuSa.AalbNuc	*Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment
SS.SSA.IFiSa.IMoSa	Infralittoral mobile clean sand with sparse fauna
SS.SSA.IFiSa.NcirBat	*Nephtys cirrosa* and *Bathyporia* spp. in infralittoral sand
SS.SSA.IFiSa.ScupHyd	*Sertilaria cupressina* and *Hydrallmania falcata* on tide-swept sublittoral sand with cobbles or pebbles.
SS.SSA.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
SS.SSA.IMuSa.FfabMag	*Fabulina fibula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacts fine muddy sand
SS.SSA.IMuSa.SsubNhom	*Arenicola marina* in infralittoral fine sand or muddy sand

(1) When formed as reefs the presence of S. spinulosa qualifies as Annex I habitat (biogenic reef).

Figure 5.39 Candidate Special Area of Conservation (cSAC) - Margate and Long Sands



The Conservation Objectives and definitions of favourable condition for features on a cSAC site will inform the scope and nature of any 'Appropriate Assessment' under the Habitats Regulations (see Box 5.9) (Natural England, 2009). The draft conservation objective for sandbanks slightly covered by seawater all the time is as follows:

Box 5.8 Draft Conservation Objective for Margate and Long Sands cSAC

Subject to natural change maintain the sandbanks slightly covered by seawater all the time in favourable condition, in particular:

- dynamic sand communities; and
- muddy sand and gravel communities.

Box 5.9 Appropriate Assessment

Any proposed plan or project must be assessed in terms of its implications for any protected sites in the area. A screening process will initially identify the likely impacts of a plan or project upon a protected site, either alone or in combination with other plans or projects. Any Likely Significant Effects identified at this stage will lead to a detailed consideration of the impacts, known as the Appropriate Assessment (AA).

An Appropriate Assessment is not required at the REA stage, however individual applications for licence areas covered by this MAREA may require an AA. If the MAREA highlights any potential cumulative or in combination impacts to a protected site (or the interest features of that site) this information may form part of the AA process.

If an AA is required for licence areas covered by the MAREA and it concludes that the plan or project would have an adverse effect on the integrity of the designated site, then it can only proceed if the authority making the AA is satisfied that there are no alternative solutions and (in turn) that the project should proceed for imperative reasons of overriding public interest (IROPI).

The need for an AA extends to candidate SACs provided that such sites have been submitted for designation by the UK Government for the approval of the European Commission, and to sites which qualify, but have not yet been classified as SPAs. It is also required in the case of Ramsar sites.

Table 5.19 defines 'favourable condition' further (Natural England, 2009). Favourable condition tables will be drafted in detail on designation of the SAC and its adoption as a European marine site.

Table 5.19 Indication of attributes to be used in defining favourable condition for the Margate and Long Sands cSAC.

Attribute	**Target**	**Comments**
Extent of sandbanks	No change in extent of sublittoral sandbank sediment habitat allowing for natural fluctuation / known cyclical change.	Consideration of changes in extent will need to take account of the dynamic nature of the sandbank, but a trend of reduction in extent may indicate long-term changes in the physical conditions influencing the feature.
Topography of sandbanks	No alteration in topography of the sandbanks allowing for natural responses to hydrodynamic regime.	The depth and distribution of the sandbanks reflects the energy conditions and stability of the sediment, which are key to the structure of the feature. However it should be noted that subtidal sandbanks are naturally dynamic environments and sections of them may be subject to significant fluctuations in height over time, while other sections are more stable.
Sediment character: sediment type	No change in composition of sediment types across the sandbank, allowing for natural succession/known cyclical change.	Sediment character is key to the structure of the sandbank, and reflects the physical processes acting on it. In addition to this, the sediment character is instrumental in determining the biological communities present on the sandbank.
Distribution of biotopes	Maintain the distribution of subtidal sandbank communities, allowing for natural succession/ known cyclical change.	Changes in the distribution of communities of both sub-features may indicate long-term changes in the physical conditions at the site, and deterioration in the overall biological value of the site.
Extent of sub-feature or representative/notable biotope(s)	No change in the extent of the muddy sand and gravel communities allowing for natural succession/known cyclical change.	Muddy sand and gravel communities are of high biodiversity value to the site. Changes in the extent of muddy sand and gravel communities within this sub-feature may indicate long-term changes in the physical conditions at the site, and a deterioration in the overall biological value of the site.
Species composition of representative biotopes	No decline in biotope quality as a result of reduction in species richness or loss of species of ecological importance, allowing for natural succession/known cyclical change.	Whilst some change in community composition over time is expected (for example, as part of cyclic changes or successional trends) changes in the overall nature of communities across the key representative biotopes sandbank may indicate deterioration in the condition of the biodiversity of the sandbanks.
Species population measures: population structure of individual species	Maintain age/size class structure of individual species.	Whilst some change in community structure over time is expected (for example, as part of cyclic changes or successional trends) changes in the overall nature of communities across the sandbank, including mobile species e.g. fish, crustacean species etc, may indicate deterioration in the condition of the biodiversity of sandbanks. Species selected for monitoring should reflect the specific biological characteristics or key conservation interest of the designated site.

Table 5.20 summarises the vulnerability of the interest features and sub-features of the Margate and Long Sands cSAC to current levels of human usage (as at April 2008) according to Natural England. This is not a list of prohibitions, but rather a checklist of features which are considered to be vulnerable to the effects of some operations.

Table 5.20 Summary of Operations which may cause Deterioration or Disturbance of the Margate and Long Sands cSAC at Current Levels of use

Operations which may cause deterioration or disturbance	**Margate and Long Sands cSAC subtidal sandbanks**
Physical loss	
Removal (e.g. capital dredging, offshore development)	✓
Smothering (e.g. by aggregate dredging, disposal of dredge spoil)	✓
Physical damage	
Siltation (e.g. run-off, channel dredging, outfalls)	✓
Abrasion (e.g. boating, anchoring, demersal fishing)	✓
Selective extraction (e.g. aggregate dredging)	✓
Non-physical disturbance	
Noise (e.g. boat activity)	
Visual (e.g. recreational activity)	
Toxic contamination	
Introduction of synthetic compounds (e.g. pesticides, TBT, PCBs)	✓
Introduction of non-synthetic compounds (e.g. heavy metals, hydrocarbons)	✓
Introduction of radionuclides	
Non-toxic contamination	
Changes in nutrient loading (e.g. agricultural run-off, outfalls)	✓
Changes in organic loading (e.g. mariculture, outfalls)	✓
Changes in thermal regime (e.g. power stations)	✓
Changes in turbidity (e.g. run-off, dredging)	✓
Changes in salinity (e.g. water abstraction, outfalls)	✓
Biological disturbance	
Introduction of microbial pathogens	
Introduction of non-native species and translocation	✓
Selective extraction of species (e.g. commercial and recreational fishing)	✓

The potential for each of these types of disturbance to occur and to impact the Margate and Long Sands cSAC will be considered within the cumulative and in-combination impact assessment chapters (Sections 9.6 and 12.0).

5.6.4 Coastal Protected Sites

In addition to the designated SPA and candidate SAC offshore, a number of SACs and SPAs that are already designated are located along the coastline of the study area. The estuaries within the REA area represent the mouths of the rivers Alde, Ore, Butley, Deben, Orwell, Stour, Colne, Blackwater, Crouch and Roach, and extensive mudflats and sandflats can be found adjacent to these estuaries. A number of these are currently designated as SACs and/or SPAs. These are listed in Table 5.22 and shown in Figure 5.40.

Ramsar sites are designated under the Convention on Wetlands of International Importance, agreed in Ramsar, Iran in 1971. The criteria for assessing a site for designation as a Ramsar site include; the wetland supports 20,000 water birds, and/or supports 1% of the individuals in a population of one species or subspecies of water bird. The Government has made it clear than Ramsar sites will, as a matter of policy, be afforded the same protection as the European designations; Special Protection Areas (SPAs) and Special Areas of Conservation) (SACs) (see Planning Policy Statement 9) [(1)]. Table 5.21 and Figure 5.40 detail the Ramsar sites present along the coastline of the study area.

Twelve of the existing coastal SPAs (many of which are also Ramsar sites) have been highlighted by Stroud *et al* (2001) as being of interest to the protection of seabirds and/or inshore waterbird species. Table 5.21 lists these sites along with their associated bird species of conservation importance which have been highlighted as being recorded in the offshore parts of the Outer Thames Estuary in Section 5.5.

The table shows that species of tern (little tern *Sterna albifrons*, common tern *Sterna hirundo* and sandwich tern *Sterna sandvicensis*) are features of several SPAs and Ramsar sites along the coastline of the study area, which have also been recorded foraging within the offshore study area. Great crested grebes (*Podiceps cristatus*) also feature at a number of designated sites, however these are recorded in very low numbers within the study area in the winter. Mediterranean gulls (*Larus melanocephalus*) are increasing in numbers within the study area, and protected as part of The Swale SPA and Ramsar site. Black headed gulls (*Larus ridibundus*) are also present here and are the most abundant gull species recorded in the study area. Lesser black-backed gulls (*Larus fuscus*) and herring gulls (*Larus argentatus*) are recorded in the winter within the study area, and breed at the Alde-Ore estuary which is designated as an SPA and a Ramsar site; however, greater black-backed gulls (*Larus marinus*), also present at the site, are scarce within the study area.

The majority of coastal SACs, SPAs and Ramsar sites are underpinned by one or more Sites of Special Scientific Interest (SSSIs), notified under the Wildlife and Countryside Act 1981 for England, Scotland and Wales [(2)]. SSSIs provide statutory protection for the best examples of the UK's flora, fauna or geological features. Improved provisions for the protection and management of SSSIs were introduced by the Countryside and Rights of Way Act 2000 (England and Wales). There are a large number of SSSIs along the coastline of the MAREA study area; the closest is approximately 12 km from the nearest licence area (Figure 5.40). Any SSSIs designated for the presence of birds are generally also designated as SPAs, and therefore are captured in Table 5.21.

Many SSSIs are also National Nature Reserves (NNRs). NNRs are selected as examples of some of the most important natural and semi-natural terrestrial and coastal ecosystems in Great Britain. They are managed to conserve their habitats and to provide opportunities for scientific study. NNRs are declared under the *National Parks and Access to Countryside Act 1949* and the *Wildlife and Countryside Act 1981 for England, Scotland and Wales*. Figure 5.40 shows the location of the NNRs along the coastline of the MAREA study area.

Marine Nature Reserves (MNRs) are established under the *Wildlife and Countryside Act 1981 for England, Scotland and Wales*. Their purpose is to conserve marine flora and fauna and geological features of interest, and provide opportunities for research. There are currently no MNRs in the MAREA study area.

(1) Planning Policy Statement 9: Biodiversity and Geological Conservation. Office of the Deputy Prime Minister, 2005. Available at http://www.communities.gov.uk/documents/planningandbuilding/pdf/147408.pdf (accessed 2/12/09).

(2) JNCC. 2009. SAC Site selection criteria and principles in the UK. Available at http://www.jncc.gov.uk/page-1473 (accessed 17/09/09).

Table 5.21 SPAs and Ramsar Sites featuring Birds of Conservation Importance Present within the Offshore Parts of the Outer Thames Estuary

SPA	Status	Bird Species	Presence within the Study Area
Abberton Reservoir	Ramsar site, SPA	Great crested grebe	Low numbers of great crested grebe recorded during the winter.
Alde-Ore Estuary	Ramsar site, SPA	Little tern, sandwich tern, lesser black-backed gull, greater black-backed gull, herring gull	Low numbers of little tern are recorded in the summer, with higher abundances of sandwich tern. Both species forage over offshore sandbanks. Higher numbers of lesser black-backed and herring gulls in the area in winter. Greater black-backed gulls are scarce in the region.
Benacre to Easton Bavents	SPA	Little tern	Recorded in the summer. Forage over offshore sandbanks.
Blackwater Estuary (Mid-Essex Coast Phase 4)	Ramsar site, SPA	Great crested grebe, little tern	Low numbers of great crested grebe are recorded in the winter. Low numbers of little tern are recorded in the summer, and forage over offshore sandbanks.
Colne Estuary (Mid-Essex Coast Phase 2)	Ramsar site, SPA	Great crested grebe, little tern	Low numbers of great crested grebe are recorded in the winter. Low numbers of little tern are recorded in the summer, and forage over offshore sandbanks.
Dengie (Mid-Essex Coast Phase 1)	Ramsar site, SPA	Great crested grebe	Low numbers recorded during the winter.
Foulness (Mid-Essex Coast Phase 5)	Ramsar site, SPA	Little tern, common tern, sandwich tern	Recorded in the summer. Common terns are the most abundant tern in the area, followed by sandwich tern then little tern. However the overall numbers of terns recorded represent a very small proportion of the total UK breeding population. All species forage over offshore sandbanks.
Hamford Water	Ramsar site, SPA	Little tern	Recorded in the summer. Forage over offshore sandbanks.
Medway Estuary and Marshes	Ramsar site, SPA	Great crested grebes, little tern and common tern	Low numbers of great crested grebes are recorded during the winter. Little terns recorded in the summer. Common terns are the most abundant tern in the study area. Tern species forage over offshore sandbanks. However the overall numbers of terns recorded represent a very small proportion of the total UK breeding population.
Minsmere-Walberswick	Ramsar site, SPA	Little tern	Recorded in the summer. Forage over offshore sandbanks.
Stour and Orwell Estuary	Ramsar site, SPA	Great crested grebe	Low numbers of great crested grebes are recorded during the winter.
The Swale	Rasmar site, SPA	Mediterranean gull, black-headed gull, little terns	Numbers of breeding Mediterranean gulls are increasing in the area. Black headed gulls are the most abundant gull species recorded in the study area. Low numbers of little tern are recorded in the summer, and forage over offshore sandbanks.

Figure 5.40   ***Designated Sites along the Coastline in the Vicinity of the TEDA MAREA Area.***

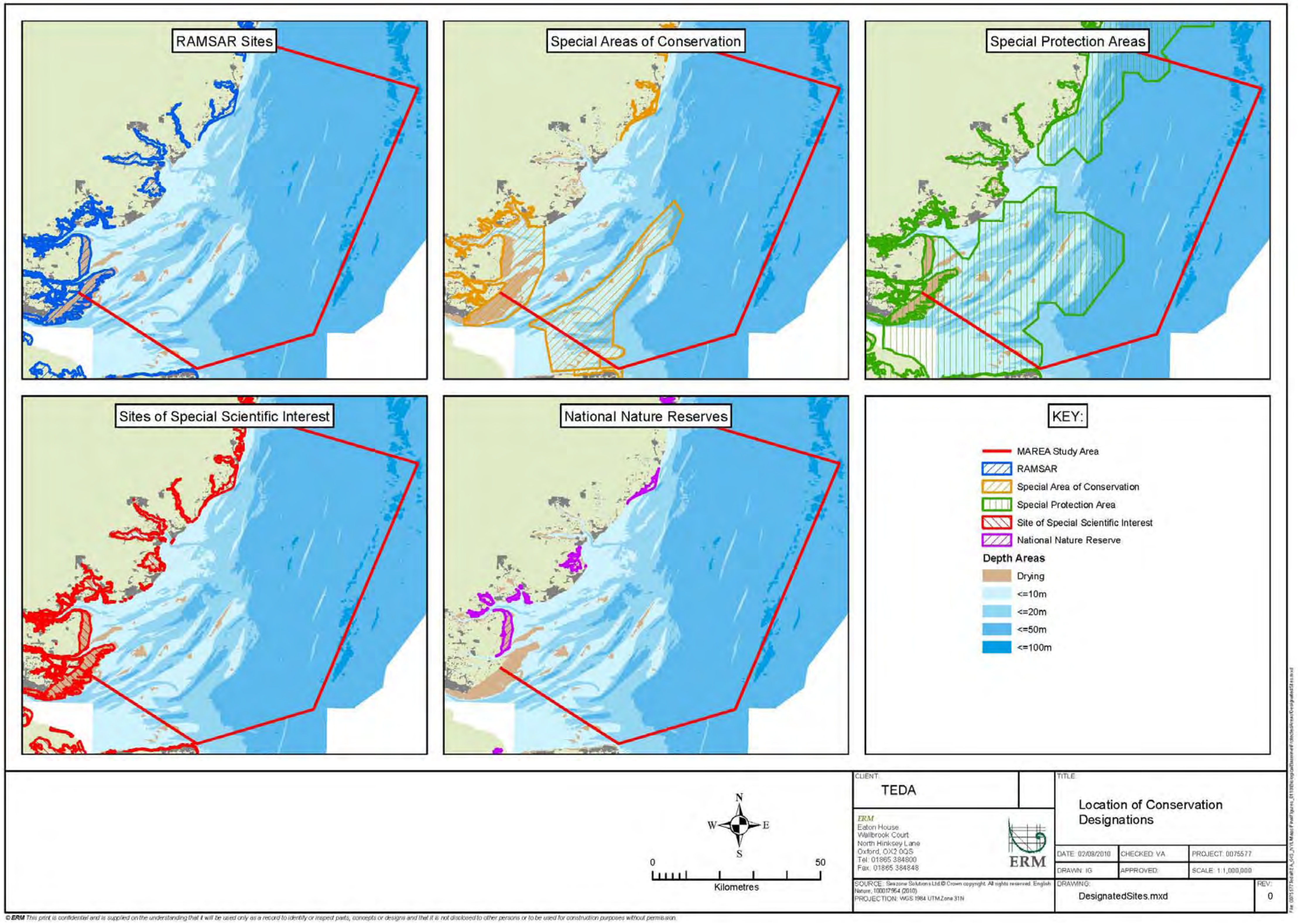


Table 5.22 Designated Sites in the Vicinity of the TEDA MAREA Area

Site	Status	Area (ha)	Qualifying Interest Features
Abberton Reservoir	Ramsar wetland, SPA	726.2 (Ramsar), 718.3 (SPA)	Abberton Reservoir is a large storage reservoir built in a long shallow valley. It is the largest freshwater body in Essex and is one of the most important reservoirs in Britain for wetland birds including breeding cormorant and wintering shoveler, teal, wigeon, gadwall, pochard, tufted duck, goldeneye, mute swan, coot, great crested grebe and 39,763 wintering waterfowl.
Alde, Ore and Butley Estuaries	Ramsar wetland (Alde and Ore only), SPA (Alde and Ore only), SAC (all)	2547 (Ramsar), 2403.5 (SPA), 1561.5 (SAC)	The site comprises the estuary complex of the rivers Alde, Butley and Ore, including Havergate Island and Orfordness shingle bar. There are a variety of habitats including, intertidal mudflats, saltmarsh, vegetated shingle (including the second-largest and best-preserved area in Britain at Orfordness), saline lagoons and grazing marsh. The Orfordness/Shingle Street landform is unique within Britain in combining a shingle spit with a cuspate foreland. The site supports nationally-scarce plants, British Red Data Book invertebrates, and notable assemblages of breeding and wintering wetland birds and seabirds including little tern, sandwich tern, lesser black-backed gull, herring gull and black-headed gull.
Benacre to Easton Bavents	SPA, SAC	470.6 (SPA), 366.9 (SAC)	Benacre to Easton Bavents Lagoons is a series of percolation lagoons (the Denes, Benacre Broad, Covehithe Broad and Easton Broad) which have formed behind shingle barriers. Sea water enters the lagoons by percolation through the barriers, or by overtopping them during storms and high spring tides. The lagoons show a wide range of salinities, resulting in a series of lagoonal vegetation types, including beds of narrow-leaved eelgrass *Zostera angustifolia*, spiral tasselweed *Ruppia cirrhosa*, and common reed *Phragmites australis*. The site supports a number of breeding bird species including bittern, marsh harrier and little tern.
Benfleet and Southend Marshes	Ramsar wetland, SPA	2251.3 (Ramsar), 2284 (SPA)	Benfleet and Southend Marshes comprise an extensive series of saltmarshes, mudflats, and grassland which support a diverse flora and fauna, including 34,789 wintering waterfowl and wetland birds including brent goose, dunlin, knot, ringed plover and grey plover.
Blackwater Estuary [17] (Mid-Essex Coast Phase 4)	Ramsar wetland, SPA	4395.2 (Ramsar), 4403.4 (SPA)	The Blackwater Estuary is the largest estuary in Essex north of the Thames and is one of the largest estuarine complexes in East Anglia. Its mudflats, fringed by saltmarsh on the upper shores, support 109,964 overwintering waterfowl and a number of wetland birds including hen harrier, brent geese, ringed plover, dunlin, black-tailed godwit and grey plover, in addition to breeding little tern, pochard, ringed plover, great crested grebe, common goldeneye and red-breasted merganser. Shingle and shell banks and offshore islands are also a feature of the tidal flats. The surrounding terrestrial habitats; the sea wall, ancient grazing marsh and its associated fleet and ditch systems, plus semi-improved grassland are also of high conservation interest. This rich mosaic of habitats supports an outstanding assemblage of nationally scarce plants and a nationally important assemblage of rare invertebrates. There are 16 British Red Data Book species and 94 notable and local species.
Colne Estuary (Mid-Essex Coast Phase 2)	Ramsar wetland, SPA	2701.4 (Ramsar), 2719.9 (SPA)	Colne Estuary is a comparatively short and branching estuary, with five tidal arms which flow into the main river channel. The estuary has a narrow intertidal zone predominantly composed of flats of fine silt with mudflat communities typical of south-eastern estuaries. The estuary is of international importance for wintering brent geese, redshank, hen harrier and black-tailed godwit and of national importance for breeding pochard, ringed plover and little tern, and also supports great crested grebes. The variety of habitats which include mudflat, saltmarsh, grazing marsh, sand and shingle spits, disused gravel pits and reedbeds, support outstanding assemblages of invertebrates and plants.
Crouch and Roach Estuaries (Mid-Essex Coast Phase 3)	Ramsar wetland, SPA	1735.6 (Ramsar), 1745.1 (SPA)	The Rivers Crouch and Roach are situated in South Essex. The intertidal zone along both rivers is 'squeezed' between the sea walls of the banks and the river channel. This leaves a relatively narrow strip of tidal mud unlike other estuaries in the county, which, nonetheless, is used by significant numbers of birds including wintering brent goose and hen harrier, as well as 18,607 wintering waterfowl. The aquatic and terrestrial invertebrates are also of interest and the area supports an outstanding assemblage of nationally scarce plants.
Deben Estuary	Ramsar wetland, SPA	978.9 (Ramsar), 981.1 (SPA)	This estuary is relatively narrow and sheltered. It has limited amounts of freshwater input and the intertidal areas are constrained by sea-walls. The site supports nationally and internationally important flora and fauna including wintering avocet and brent goose.
Dengie (Mid-Essex Coast Phase 1)	SPA	3127.2 (Ramsar), 3134 (SPA)	Dengie is a large and remote area of tidal mudflat and saltmarsh at the eastern end of the Dengie peninsula, between the Blackwater and Crouch Estuaries. The saltmarsh is the largest continuous example of its type in Essex. It hosts 31,454 internationally and nationally important wintering wildfowl, waders and waterbirds including grey plover, brent goose, hen harrier, knot and great crested grebe and in summer supports a range of breeding coastal birds including rarities. The formation of cockleshell spits and beaches is of geomorphological interest.
Essex Estuaries	SAC	46140.8	The following Annex I habitats are present at Essex Estuaries and are a primary reason for selecting this site; estuaries, mudflats and sandflats not covered by seawater at low tide, *Salicornia* spp. (glasswort) and other annuals colonising mud and sand, swards of *Spartima maritima* (native small cord grass), Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) and Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*).
Foulness (Mid-Essex Coast Phase 5)	Ramsar wetland, SPA	10933 (Ramsar), 10942.1 (SPA)	Foulness is part of an open coast estuarine system comprising grazing marsh, saltmarsh, intertidal mudflats and sandflats which support nationally rare and nationally scarce plants, and nationally and internationally important populations of breeding, migratory and wintering waterfowl and wetland birds including avocet, little tern, common tern, sandwich tern, ringed plover, hen harrier, bar-tailed godwit, brent goose, knot, oystercatcher, grey plover and redshank.

Site	Status	Area (ha)	Qualifying Interest Features
Hamford Water	Ramsar wetland, SPA	2187.2 (Ramsar), 2185.8 (SPA)	Hamford Water is a large, shallow estuarine basin comprising tidal creeks and islands, intertidal mud and sand flats, and saltmarsh supporting rare plants and internationally important species/populations of migratory waterfowl and wetland birds including breeding little tern, wintering avocet, teal, brent goose, ringed plover, black-tailed godwit, grey plover, turnstone, and redshank.
Medway Estuary and Marshes	Ramsar wetland, SPA	4696.7 (Ramsar), 4686.3 (SPA)	A complex of rain-fed, brackish, floodplain grazing marsh with ditches, and intertidal saltmarsh and mudflat. These habitats together support 65,496 wintering waterfowl and waders including bewick's swan, avocet, pintail, shoveler, teal, wigeon, turnstone, brent goose, dunlin, knot, ringed plover, oystercatcher, black tailed godwit, curlew, grey plover, shelduck, redshank and greenshank, as well as breeding avocet, little tern, common tern and great crested grebes.
Minsmere to Walberswick Heaths and Marshes	SAC	1265.5	This site is the most extensive example of 'Annual vegetation of drift lines' on the east coast of England. Species include those typical of sandy shores, such as sea sandwort *Honckenya peploides* and shingle plants such as sea beet *Beta vulgaris* spp. *martima.* Lowland European dry heaths occupy an extensive area of this site, which is at the extreme easterly range of heath development in the UK. The heathland is predominantly dominated by heather *Calluna vulgaris*, western gorse *Ulex gallii* and bell heather *Erica cinerea*.
Minsmere-Walberswick	Ramsar wetland, SPA	2018.9 (Ramsar), 2019.6 (SPA)	This Suffolk coastal site contains a complex mosaic of habitats, notably, areas of marsh with dykes, extensive reedbeds, mudflats, lagoons, shingle and driftline, woodland and areas of lowland heath. The site supports the largest continuous stand of reed in England and Wales and demonstrates the nationally rare transition in grazing marsh ditch plants from brackish to fresh water. The combination of habitats create an exceptional area of scientific interest supporting nationally scarce plants, British Red Data Book invertebrates and nationally important numbers of breeding birds including bittern, nightjar, marsh harrier, avocet, little tern, shoveler, teal and gadwall, and wintering birds such as hen harrier, shoveler, gadwall and white fronted goose.
Orfordness - Shingle Street	SAC	901.2	This site contains a number of coastal percolation lagoons and associated fauna including the nationally rare starlet sea anemone *Nematostella vectensis*, annual vegetation of drift lines including sea beet *Beta vulgaris* spp. *maritima* and orache *Atriplex* spp., and perennial vegetation of stony banks including sea pen *Lathyrus japonicus* and false oat-grass *Arrhenatherum elatius* grassland.
Sandwich Bay	SAC	1137.9	The following Annex I habitats are present at this site; embryonic shifting dunes dominated by sand couch *Elytrigia juncea*, shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes') including sea bindweed *Calystegia soldanella*, sea spurge *Euphorbia paralias* and sea holly *Eryngium martitimum*, fixed dunes with herbaceous vegetation ('grey dunes') including fragrant evening-primrose *Oenothera stricta*, bedstraw broomrape *Orobanche caryophyllacea* and sand catchfly *Silene conica*, as well as the UK's largest population of lizard orchid *Himantoglossum hircinum*.
Stour and Orwell Estuaries	Ramsar wetland, SPA	3676.9 (Ramsar), 3672.6 (SPA)	The Stour and Orwell Estuaries is a wetland of international importance, comprising extensive mudflats, low cliffs, saltmarsh and small areas of vegetated shingle on the lower reaches. It provides habitats for an important assemblage of wetland and waterbirds in the non-breeding season including great crested grebes and supports internationally important numbers of wintering and passage wildfowl and waders including avocet, pintail, Brent goose, dunlin, knott, black-tailed godwit, grey plover and redshank. The site is also home to several nationally scarce plants and British Red Data Book invertebrates.
Thanet Coast	SAC	2803.8	Thanet Coast is the longest continuous stretch of coastal chalk in the UK. It represents approximately 20% of the UK resource of this type and 12% of the EU resource. This site contains examples of reefs of soft chalk along the shore and the coastline provides the second most extensive representation of chalk caves in the UK. The subtidal chalk platforms extend offshore in a series of steps dissected by gullies. Species present include an unusually rich littoral algal flora, essentially of chalk-boring algae and the site remains the sole known location for some algal species. The caves also support very specialised algal and lichen communities containing species such as *Pseudendoclonium submarinum* and *Lyngbya* spp.
Thanet Coast and Sandwich Bay	Ramsar wetland, SPA	2169.2 (Ramsar), 1881.2 (SPA)	A coastal site, consisting of a long stretch of rocky shore, adjoining areas of estuary, sand dune, maritime grassland, saltmarsh and grazing marsh. The wetland habitats support 15 British Red Data Book invertebrates, as well as a large number of nationally scarce species. The site attracts internationally important numbers of turnstone *Arenaria interpres*, and nationally important numbers of wintering populations of four wader species: ringed plover, golden plover, grey plover and sanderling, as well as Lapland bunting and breeding little tern.
The Swale	Ramsar wetland, SPA	6514.7 (Ramsar), 6509.9 (SPA)	A complex of brackish and freshwater, floodplain grazing marsh with ditches, and intertidal saltmarsh and mudflat. These habitats together support internationally important numbers of wintering waterfowl, and rare wetland birds breed in important numbers. In summer the site is of national importance for breeding Mediterranean gull, black-headed gull and little terns. The saltmarsh and grazing marsh are of international importance for their diverse assemblages of wetland plants and invertebrates.

5.7 SUMMARY OF KEY SENSITIVITIES

5.7.1 Benthic Ecology

Benthic Species

Six benthic species recently found within the MAREA study area are recognised as being threatened, rare or otherwise exceptional features for priority conservation attention. They are presented in Table 5.23 below.

Table 5.23 Important Benthic Species

Species	Common Name	Rare or Protected Status	Details
Sabellaria spinulosa	Ross worm	cNIMF	Important because of it's ability to form biogenic reef habitat, and is discussed below
Leptocheirus hirsutimanus		cNIMF	Found at a small number of stations during the REC and MAREA surveys and is generally found off most British coasts. The Outer Thames Estuary is not particularly important for this species.
Modiolus modiolus	Horse mussel	cNIMF	Found at a small number of stations during the REC and MAREA surveys and is generally found off most British coasts. The Outer Thames Estuary is not particularly important for this species.
Barnea candida	White piddock	cNIMF	Generally found along the south coast of the UK and the Thames Estuary. Piddocks were found during trawls at two stations that were comparatively close together tow ards the central western section of the MAREA study area over coarse veneer with bedrock outcrops. These rocky outcrops offer a different habitat for benthic species and could potentially qualify as geogenic reefs.
Ostrea edulis	Oyster	UK BAP & cNIMF	Important stocks of this species exist in the rivers and mudflats bordering the Outer Thames Estuary but it is less common in deeper water. Only one oyster was found at a site in the north of the study area in an area of sand.
Echinus esculentus	European edible sea urchin	cNIMF	Found in two MAREA trawls and one REC trawl.

The most sensitive commercially valuable species appears to be the oyster (*Ostrea edulis*), which has a very high sensitivity to smothering but is not often found offshore. Cockles, which are potentially the most important commercial species have low sensitivity to smothering and are not sensitive to increased turbidity.

Benthic Habitats

There are three sensitive benthic habitats within the MAREA study area: sandbanks, geogenic reefs and *Sabellaria spinulosa* reefs. Annex 1 habitats such as reefs are also considered an important biotope, as are the following:

- SS.SSa.IFiSa.NcirBat is important for predatory birds as it supports the sand eel, which is an important prey species for several bird populations.
- SS.SCS.CCS.MedLumVen, SS.SMu.CSaMu.LkorPpel, SS.SSa.IMuSa.SsubNhom and SS.SSa.IMuSa.AalbNuc are important as they support prey species for predatory fish.
- SS.SMu.ISaMu.AmpPlon and SS.SMu.CFiMu.MegMax are both rare and particularly diverse biotopes.

5.7.2 Fish Ecology

Fish associated with the study area may be categorised as having importance for reasons including protection status, commercial value, ecological importance (spawning location and migration route) and a local (Thames) population contributing a significant proportion of the national population. The most sensitive species found in the MAREA area are listed below:

Protected Species
- sea lamprey;
- seahorses; and
- sand goby.

Demersal Species
- cod;
- bass;
- plaice; and
- sole.

Pelagic Species
- herring (including Thames Estuary herring);
- sprat; and
- mackerel.

Elasmobranchs
- lesser-spotted dogfish; and
- thornback ray.

5.7.3 Marine Mammals

The abundance and diversity of marine mammals within the study area is generally low with only two cetacean species (harbour porpoise and bottlenose dolphin) and two pinniped species (common seal and grey seal) recorded annually.

Harbour porpoise are by far the most common marine mammal species recorded within the study area; other cetacean species are infrequently sighted within the study area. Common and grey seals are present in the study area with common seals being more abundant, and both species tending to frequent near shore waters. All three species are potentially present throughout the year and the harbour porpoise and small numbers of common seal are thought to be resident, using the area for mating, giving birth, weaning and foraging (RPS Energy, 2006).

5.7.4 Birds

The study area is characterised by relatively shallow and sheltered coastal waters which support a variety of mostly common and widespread bird species throughout the year. Key breeding species which occur in the region are tern and gull species, with several key tern breeding colonies at coastal sites in the vicinity of the study area, as well as nationally important numbers of Mediterranean gull. Wintering species of importance include nationally important populations of diver which winter offshore, as well as potentially important populations of passage little gull.

5.7.5 Designated Sites

There is currently one site designated as a Special Protection Area (SPA) for protection under the EU Birds Directive within the offshore MAREA study area. There is also a further site which has been recommended for inclusion within the UKs Natura 2000 network as a candidate Special Area of Conservation (SAC) under the EU Habitats Directive. In addition the estuaries within the MAREA area represent the mouths of the rivers Alde, Ore, Butley, Deben, Orwell, Stour, Colne, Blackwater, Crouch and Roach, and extensive mudflats and sandflats can be found adjacent to these estuaries. A number of these are currently designated as SACs and/or SPAs. All of these sites represent key sensitivities within the MAREA area.

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6 HUMAN ENVIRONMENT BASELINE

6.1 HUMAN ENVIRONMENT BASELINE INTRODUCTION

6.1.1 Introduction

The section describes the baseline conditions in relation to human activities within the MAREA study area. The Outer Thames Estuary is a nationally important area for certain activities related to the human environment.

Commercial fisheries have long been important in the Outer Thames Estuary. The region provides spawning, nursery and feeding grounds for populations of a number of commercial fish species. A wide variety of fisheries have developed around the life cycles of target fish and shellfish to exploit these resources.

Within the MAREA study area, key infrastructural developments include ports and harbours, wind farms, pipelines and cables, military activity and gas exploration. The Crown Estate awarded four wind farm concessions in the area in the Round 2 designations. These include the Thanet array, the London Array (phase 1), Gunfleet Sands II and the Inner Gabbard and Galloper arrays of the Greater Gabbard development (British Wind Energy Association. 2009). No Round 3 designations are wholly within the MAREA study area, however, part of the current boundary of Zone 5 (the Norfolk Zone) is situated within the MAREA study area approximately 11.5 km from the North Inner Gabbard prospecting license area. Not all of Zone 5 will be developed but at this point it is not known which parts will be developed.

There are a number of port and harbour developments in the MAREA study area and these are the source of large amounts of shipping traffic in the region. They range from small local fishing ports such as Clacton-on-Sea, to recreational marinas in estuaries, to large international ferry and container ports such as Felixstowe. Recreational activity in the region is widespread with pleasure cruising and sailing, racing, diving and sea angling all taking place.

Archaeological and cultural heritage sites within the MAREA study area include: prehistoric archaeology such as potential peat deposits beneath the study area, maritime archaeology such as ship wrecks, and aviation archaeology including aircraft crash sites.

The following sections address these topics in greater detail:

- Section 6.2 Commercial and Recreational Fisheries
- Section 6.3 Other Infrastructure
- Section 6.4 Marine Recreation
- Section 6.5 Shipping and Navigation
- Section 6.6 Archaeology and Cultural Heritage

6.1.2 Legislation and Guidance

Overview

The following section details the European and national legislation that provide the framework for this MAREA with respect to human receptors that have important regional and national socio-economic value.

Fisheries

European Designation - Common Fisheries Policy (CFP)
The CFP provides the legal framework for the exploitation of living resources in EU waters and for those vessels registered in the EU fishing in non-EU waters. The European Commission has exclusive rights to administer up to the High Water Mark and devolves authority to the UK government through the Department for the Environment Food and Rural Affairs (Defra) to manage fisheries within 12 nm of the UK.

National Designation - Sea Fisheries Regulations
Sea Fisheries Committees (SFCs) of England and Wales are responsible for the management of fisheries within 6 nm of the mean High Water Mark, share responsibility for marine nature conservation and are able to introduce byelaws. The SFCs also enforce UK and EU fishery conservation legislation.

The Eastern Sea Fisheries Joint Committee (ESFJC) and the Kent and Essex Sea Fisheries Committee (KESFC) regulate commercial fishing within the MAREA study area. The ESFJC regulates fisheries from Donna Nook, Lincolnshire in the north well outside the MAREA study area to Dovercourt (near Harwich) in the South. The KESFC regulates commercial fisheries from Dungeness in Kent to the northern boundary of Essex on the River Stour. Both SFCs make byelaws to be observed within their Districts and enforce national and EU legislation relating to fisheries.

National Designation - Marine and Coastal Access Act (as of November 2009)
SFCs will be replaced with Inshore Fisheries and Conservation Authorities (IFCAs) on the 1st April 2011. IFCAs will enforce marine environmental legislation and will have the stronger enforcement powers, with heavier penalties for offences. IFCA districts will cover the English coast out to 6 nm and include estuaries where they will be responsible for sea fisheries management. IFCAs will retain local authority members and one member each from Natural England, the Marine Management Organisation (MMO) and the Environment Agency.

National Designation - Sea Fisheries Regulation Act 1966 and the Sea Fish (Conservation) Act 1967 (as amended)
The Sea Fisheries Regulation and the Sea Fish (Conservation) Acts include legislation for the purpose of protecting the marine environment from fisheries related activities, or taking into account conservation issues when creating byelaws.

Infrastructure

Offshore Wind Developments
The size of an offshore wind farm development determines the body awarding the consent. Wind farms between 1 and 100 MW apply to the Marine Management Organisation (MMO) for consent who will award Section 36 consents under the Electricity Act 1989. For developments over 100 MW the Infrastructure Planning Commission (IPC) is the regulatory body that awards development consents.

The Planning Act 2008 has streamlined the planning and consents process for nationally significant infrastructure projects in England and Wales, which encompasses offshore renewable development. The IPC has been set up as an independent body to make the planning decisions. The single regime includes Food and Environment Protection Act (FEPA) and Coast Protection Act (CPA) licensing in England.

Marine Disposal

Disposal at sea requires a FEPA (Food and Environment Protection Act 1985) licence issued by Defra's Marine Consents and Environment Unit (MCEU). In addition, a licence may be required under the Coastal Protection Act 1949.

The OSPAR Convention provides guidelines that have shaped the UK's licensing regime by prohibiting the majority of disposal activities at sea.

Shipping and Navigation

International Regulations for Preventing Collision at Sea 1972 (COLREGS) (as amended by the 1996 Merchant Shipping Regulations)
COLREGS requires compliance by all vessels navigating in the MAREA study area, including dredgers. It provides rules to facilitate safe navigation and to minimise collision risk and disruption during encounter situations.

International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM code)
The ISM code establishes safety management objectives and requires a Safety Management System (SMS) to be established by "the Company", which is defined as the ship owner or any person who has assumed responsibility for operating the ship.

Archaeology

Protection of Wrecks Act 1973

It is an offence under the Protection of Wrecks Act to carry out certain activities in the area surrounding a designated wreck without a license from the government. There are currently two protected wreck sites designated under the Act within the study area; the Dunwich Bank wreck and the South Edinburgh Channel wreck. If an important wreck is discovered during the dredging or survey operations, the area surrounding a wreck may become designated.

Merchant Shipping Act 1995

The Merchant Shipping act requires the reporting of recovered marine archaeological material.

Protection of Military Remains Act 1986

The Protection of Military Remains Act protects aircraft and ships that have crashed during military service and makes it an offence to tamper, damage or move such protected remains. The Act also forbids diving, salvage and excavation on the site. The Ministry of Defence (MoD) can designate named vessels as protected places or controlled sites.

Ancient Monuments and Archaeological Areas Act 1979

The Ancient Monuments and Archaeological Areas act introduces the scheduling of monuments with national importance (including buildings, structures, work, caves, excavation, vehicle, vessel, aircraft or other moveable structures).

6.1.3 Consultation

Overview

The following section details the stakeholder consultation that took place during this MAREA with respect to fisheries, shipping and navigation and archaeology.

Fisheries

Given the social and economic importance of commercial fisheries within the outer Thames Estuary, local fishermen were engaged in consultation to ensure an accurate evaluation of the fisheries was carried out. In the first instance a meeting with the KESFC and ESFJC was held on the 1 October 2008 to discuss the initial baseline findings and to identify data gaps and further data sources. Four further meetings were held with fishermen along the coast covered by the MAREA study area to gain additional understanding of the inshore fisheries in the area. Meetings were held at the following venues:

- Clacton-on-sea, 26 November 2008;
- Ipswich, 1 December 2008;
- Leigh-on-sea, 4 December 2008; and
- Felixstowe, 21 January 2008.

At each meeting the current findings of the baseline study were presented and comments were invited from those present. Notes were taken of the relevant points and commitments made to contact people holding relevant data sets. Once the presentation was completed fishermen were presented with a blank chart of the area and asked to indicate their important fishing grounds and any seasonal patterns in their fishing activity.

Shipping and Navigation

Consultation on navigational issues was carried out with key navigational stakeholders. The PLA (Port of London Authority) was identified as a key stakeholder for the Outer Thames Estuary study area given the port authority area covers a large portion of the southern part of the study area. PLA raised no concerns with regards to dredging within the outer Thames estuary. The MCA (Maritime and Coastguard Agency) stated that they agreed with the overall REA approach and that they would respond to consultation at the licence-specific EIA stage.

Trinity House and the Chamber of Shipping supported the development of marine aggregates in the area and based on their historical experience of these operations, did not foresee any significant issues in the Thames area with respect to major impacts on navigation. They would like to be consulted on individual license applications as they are being made.

The Cruising Association and Royal Yachting Association did not have any objections in principle to further dredging applications in this area. However it was highlighted that the study area is heavily used by recreational craft which mainly follow the deep water channels. Generally it was considered that dredging operations by single vessels cause no problems to craft assuming that warning is given by such measures as VTS (Vessel Traffic Service). The Cruising Association also commented that some official day marks for vessels actively dredging are poorly maintained and occasionally difficult to see. It was also noted that some dredgers on passage continue to fly their day marks after operations and this can be confusing to recreational craft users. These matters are not pertinent to the MAREA but will be noted for future licence EIAs.

Archaeology

Consultation was undertaken with the English Heritage Maritime Team. This consultation took the form of an Archaeological Methodology Meeting, held at Wessex Archaeology on the 20th August 2008 and attended by members of TEDA, project staff from ERM, project staff from Wessex Archaeology and Dr Chris Pater of English Heritage. The project and methodology were presented, and a number of key issues, including the scope of geophysical and historical data assessments were discussed and agreed.

6.2 COMMERCIAL AND RECREATIONAL FISHERIES

6.2.1 Introduction

This section describes the commercial and recreational fisheries baseline within the Thames MAREA study area. Appendix M provides a full review of the commercial and recreational fisheries in the MAREA study area and immediate vicinity. This section provides a summary of the findings in Appendix M and describes the important existing fisheries, the spatial and temporal dynamics of fishing in the area and the value of the fisheries resources within the MAREA study area.

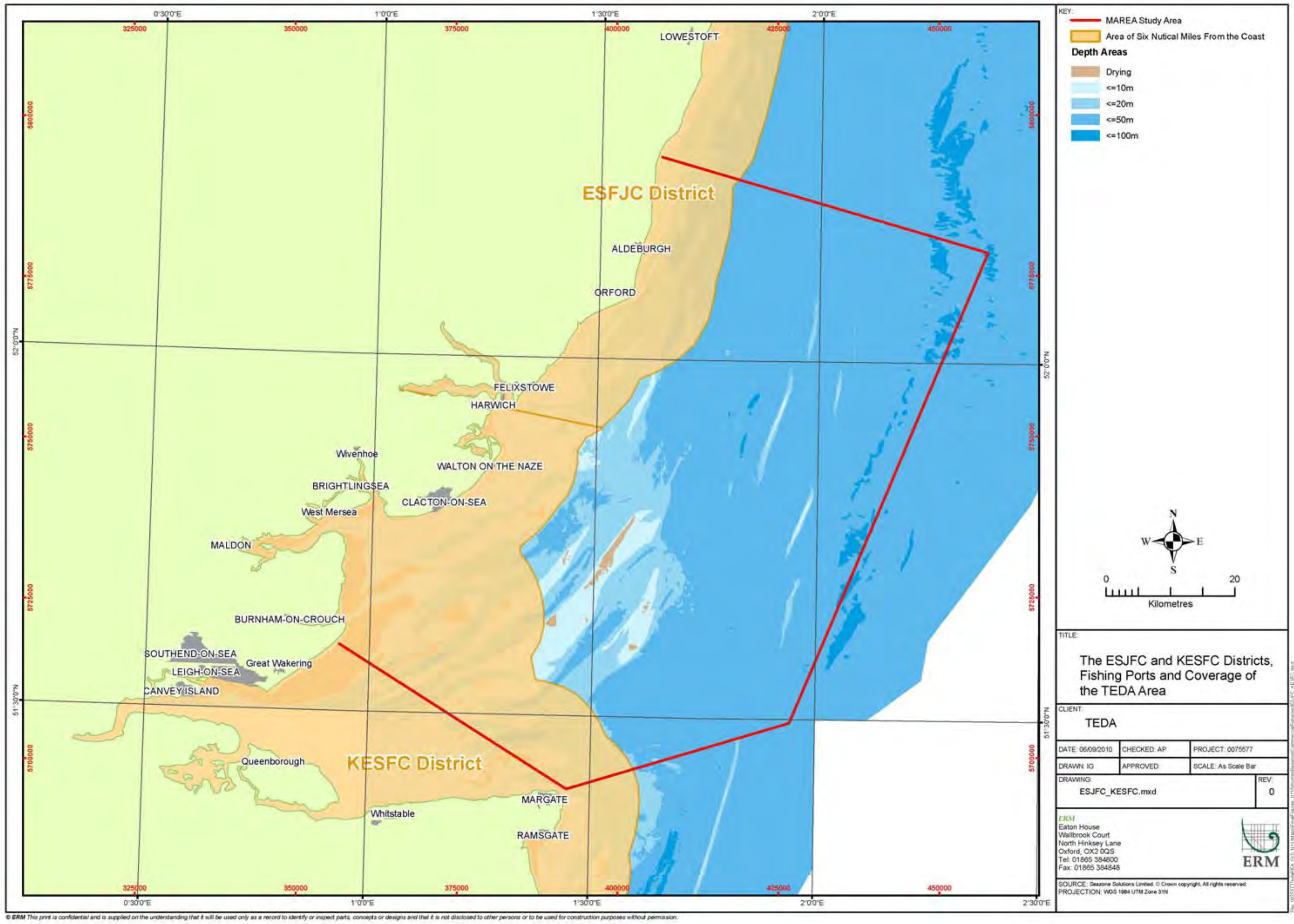
The area of the Outer Thames Estuary, within which the MAREA study area is situated, is an important fishing ground for local and international fishing fleets. The region is important fishing for many commercially exploited fish and shellfish species, providing spawning grounds, nursery and feeding areas (see Section 5.3).

The majority of fishermen who routinely work within the MAREA study area operate from launch sites along the Kent and Essex coasts within the Kent and Essex Sea Fisheries Committee (KESFC) district and the Suffolk Coast within the Eastern Sea Fisheries Joint Committee (ESFJC) district. Vessels from ports within the MAREA study area, from Burnham-on-Crouch in the south to Aldeburgh in the north were included in the study along with ports within the range of vessels from outside of the MAREA study area (eg Lowestoft, Margate) (Figure 6.1).

The MAREA study area is situated within ICES Division IVc in the North Sea and covers less then 9% of the total sea area of ICES IVc. The MAREA study area covers (or partially covers) ICES sub-rectangles 33F1, 33F2, 32F2, 32F1 and 31F1. Each rectangle is further sub-divided into four sub-rectangles (4 areas of 0.25° latitude × 0.5° longitude within each ICES rectangle) by ICES and within the dataset provided by MFA. The MAREA study area covers the sub-rectangles 31F1-1, 31F1-2, 32F0-4, 32F0-2, 32F1-1, 32F1-2, 32F1-3, 32F1-4, 32F2-3, 32F2-1, 32F1-2, 33F2-3 and 33F1-4.

There is one major fishing port (as defined by Defra) within the wider region (Lowestoft), as well as numerous other smaller ports that land fish. The region is one of the most important in the UK for mollusc landings, especially landings of cockles from the Thames Estuary cockle fishery. Landings of pelagic fish, particularly sprats and herring, are also important in the area and are among the highest in England and Wales. Other important target species include cod, Dover sole and skates and rays.

Figure 6.1 The ESJFC and KESFC Districts, Fishing Ports and Coverage of the MAREA Study Area



The commercial fishing methods currently used in the wider region can be broadly divided into two distinct categories: passive and active methods. The active fishing methods include numerous trawl methods (eg beam or otter trawls) and dredges for bivalve molluscs. The passive methods are more diverse and include nets (gillnets, trammel nets and driftnets), long-lines and pots for whelks and crustaceans. Sports fisheries are predominantly shore-based although a number of recreational angling vessels operate in the region. The range of marine species exploited is broad and reflects the diverse marine ecosystem in the shallow coastal waters of the North Sea.

6.2.2 Legislation and Guidance

Box 6.1 Relevant Legislation and Guidance for the Protection of Fisheries

European Union's Common Fisheries Policy (CFP)
- Provides the legal framework for the exploitation of living marine resources in EU waters and for those vessels registered in the EU fishing in non-EU waters.
- The European Commission has exclusive rights to administer up to the High Water Mark and devolves authority to the UK government, through Defra, to manage fisheries within 12 nm of the UK.

Sea Fisheries Regulation Act 1966
- Sea Fisheries Committees (SFCs) of England and Wales are responsible for the management of fisheries within 6 nm of mean High Water Mark and share responsibility for marine nature conservation and are able to introduce byelaws.
- The SFCs also enforce UK and EU fishery conservation legislation.

Thames MAREA Study Area Regulators
- The Eastern Sea Fisheries Joint Committee (ESFJC) and the Kent and Essex Sea Fisheries Committee (KESFC) regulate commercial fishing within the MAREA study area.
- The ESFJC regulates fisheries from Donna Nook in the north to Dovercourt in the south. The Kent and Essex Sea Fisheries Committee regulates commercial fisheries from Dungeness in Kent to the northern boundary of Essex on the River Stour (Figure 6.1).
- Both Sea Fishery Committees make byelaws to be observed within their Districts and enforce national and EU legislation relating to fisheries.

Marine and Coastal Access Act (as of November 2009)
- Sea Fisheries Committees (SFCs) will be replaced with Inshore Fisheries and Conservation Authorities (IFCAs).
- IFCAs will enforce marine environmental legislation and will have stronger enforcement powers, with heavier penalties for offences.
- IFCA districts will cover the English coast out to 6nm and include estuaries where they will be responsible for sea fisheries management.
- IFCAs will retain local authority members and one member each from Natural England, the Marine Management Organisation (MMO) and the Environment Agency.

Sea Fisheries Regulation Act 1966 and the Sea Fish (Conservation) Act 1967 (as amended)
- Include legislation for the purpose of protecting the marine environment from fisheries related activities, or taking into account conservation issues when creating byelaws.

6.2.3 Commercial Landings

Landings in ICES Division IVc

Overall catches within ICES division IVc have decreased in the last decade. Some increases have been observed in 2003 and 2006 but the general pattern is for an overall decrease. As Figure 6.2 demonstrates catches are dominated by cockles (*Cerastoderma edule*) and pelagic fish species (such as herring *Clupea harrengus* and sprat *Sprattus sprattus*). Demersal fish species are the next most important and include flatfish, cod (*Gadus morhua*) and haddock (*Melanogrammus aegelfinus*) among others.

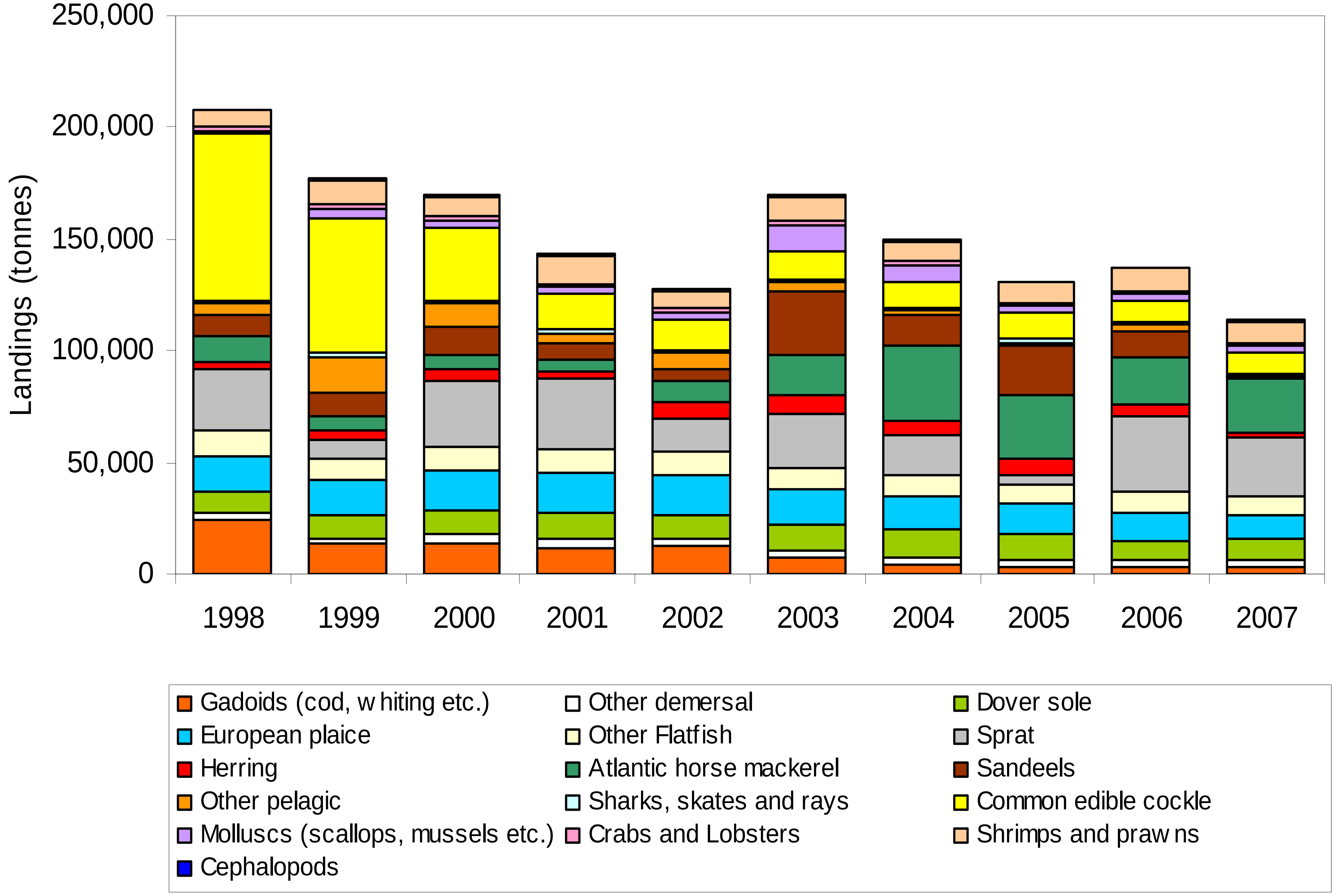
Declines in catches have been seen in most of these groups over the last decade. However, some species have shown increasing landings, particularly lobsters (*Hommarus gammarus*), sea bass (*Dicentrarchus labrax*) and Atlantic horse mackerel (*Trachurus trachurus*). Other catches have remained stable, including skates and rays and many of the flatfish species, particularly sole (*Solea solea*) and plaice (*Plueronectes platessa*).

The catches of some species show inter-annual variation with landings fluctuating from year to year rather than showing any general trend. In most instances these species populations are driven by environmental changes affecting their food source or changes in the hydrodynamic regime of the North Sea. Bivalves (eg mussels, scallops, oysters), cephalopods and shrimps and prawns are the main groups whose landings are more determined by changes in the environment than the fishing pressure exerted on their populations.

Shellfish

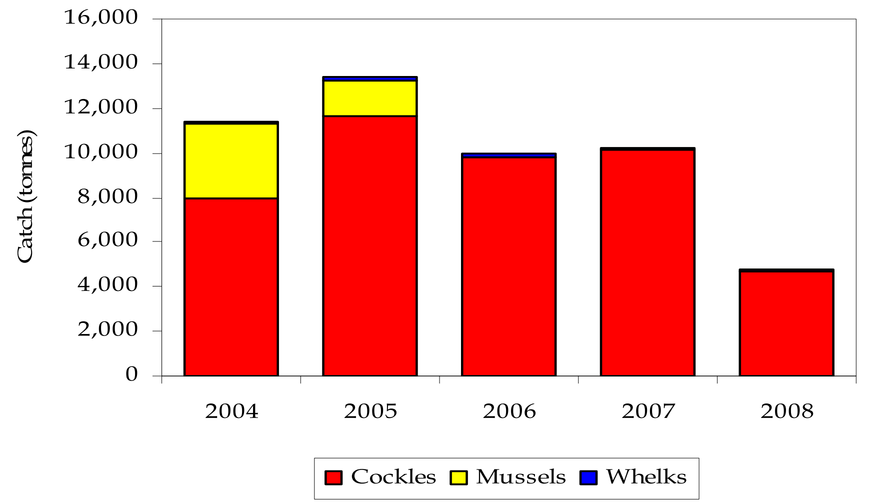
Shellfish landings are the largest recorded landings at ports in the MAREA study area and include a number of crustacean and mollusc species. The most significant landings are of cockles (*Cerastoderma edule*) which between 2004 and 2008 have been between 5,000 and 12,000 tonnes (Figure 6.3). Mussel landings during the same period reached a maximum of 3,000 tonnes in 2004 but have since declined to very low levels. Whelk catches in the same period were between 54 and 178 tonnes. Catches of crustaceans are dominated by lobsters, crabs and brown shrimp and are much lower than the catches of molluscs (Figure 6.4). Catches of crabs are the highest with a maximum of 40 tonnes in the last five years, followed by lobsters (maximum of 33 tonnes) and then brown shrimp (22 tonnes). Landings of squid, cuttlefish and octopus are low and rarely above 1 tonne.

Figure 6.2 Total Catches from ICES Statistical Area IVc 1998 – 2007



Source: Eurostat/ICES database on catch statistics - ICES 2007 Copenhagen, (formatted in FishStat Plus http://www.fao.org/fi)

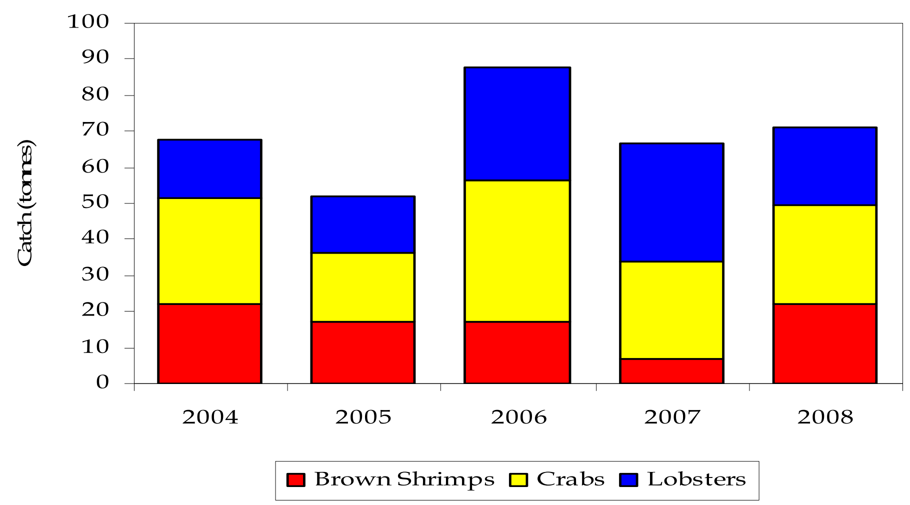
Figure 6.3 Total Landings of Molluscs in the MAREA Study Area Ports 2004 - 2008.



Source: MFA landing statistics.

Over the longer term catches of shellfish have dominated the landings at ports within the MAREA study area, with cockle catches generally stable at between 5,000 and 10,000 tonnes per year. Landings of crustaceans have continues to grow and are increasingly more important in the MAREA study area.

Figure 6.4 Total Landings of Crustaceans at Ports within the MAREA Study Area 2003-2007.



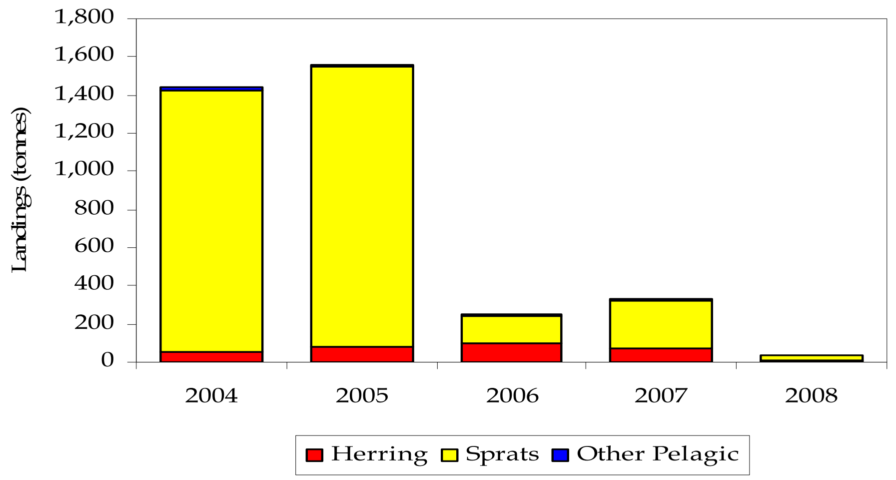
Source: MFA landing statistics.

Finfish

The most important pelagic species are herring and sprat but other species including horse mackerel, mackerel, pilchards, shads, sardines and sardinellas may also be landed. Historically demersal finfish species form the smallest group landed in the MAREA study area. However, pelagic catches have been in decline recently as fishermen, driven by a decrease in market value, have switched to target species other than herring and sprat. Therefore, demersal catches are increasingly important.

Landings of pelagic species are generally dominated by sprat at between 27 and 1,500 metric tonnes in the period between 2004 and 2008, followed by herring at between 11 and 98 tonnes (Figure 6.5). Catches of both species have declined recently due to a decrease in market value and diversification of fishermen into targeting other species. Downs herring in particular is considered a sensitive stock

Figure 6.5 Total Landings of Pelagic Fish in Ports 2003-2008 within the MAREA Study Area.

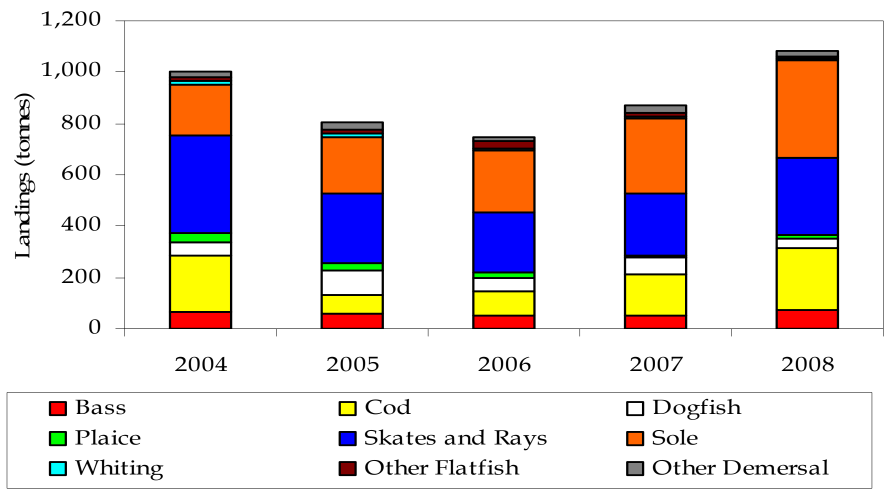


Source: MFA landing statistics.

Demersal species are dominated by cod (average annual landings of 159 tonnes), skates and rays (287 tonnes) and sole (267 tonnes). Other significant catches include sea bass, plaice, dogfish (*Scyliorhinus* spp.) and a number of flatfish species. Some species such as haddock, whiting, anglerfish (*Lophius* sp.) ling (*Molva molva*) and pollack (*Pollachius pollachius*) may also feature in landings but not on a regular basis. Most demersal fish landings in the MAREA study area have shown a decline. However, in recent years (between 2006 and 2008) cod landings have shown some increases (Figure 6.6). Sole have doubled from 200 to 400 tonnes in the last ten years.

Landings of skates and rays and bass are generally stable although bass is increasingly becoming a more important fish for the vessels operating in the area.

Figure 6.6 Total Landings of Demersal Fish in Ports 2003-2007 within the MAREA Study Area.

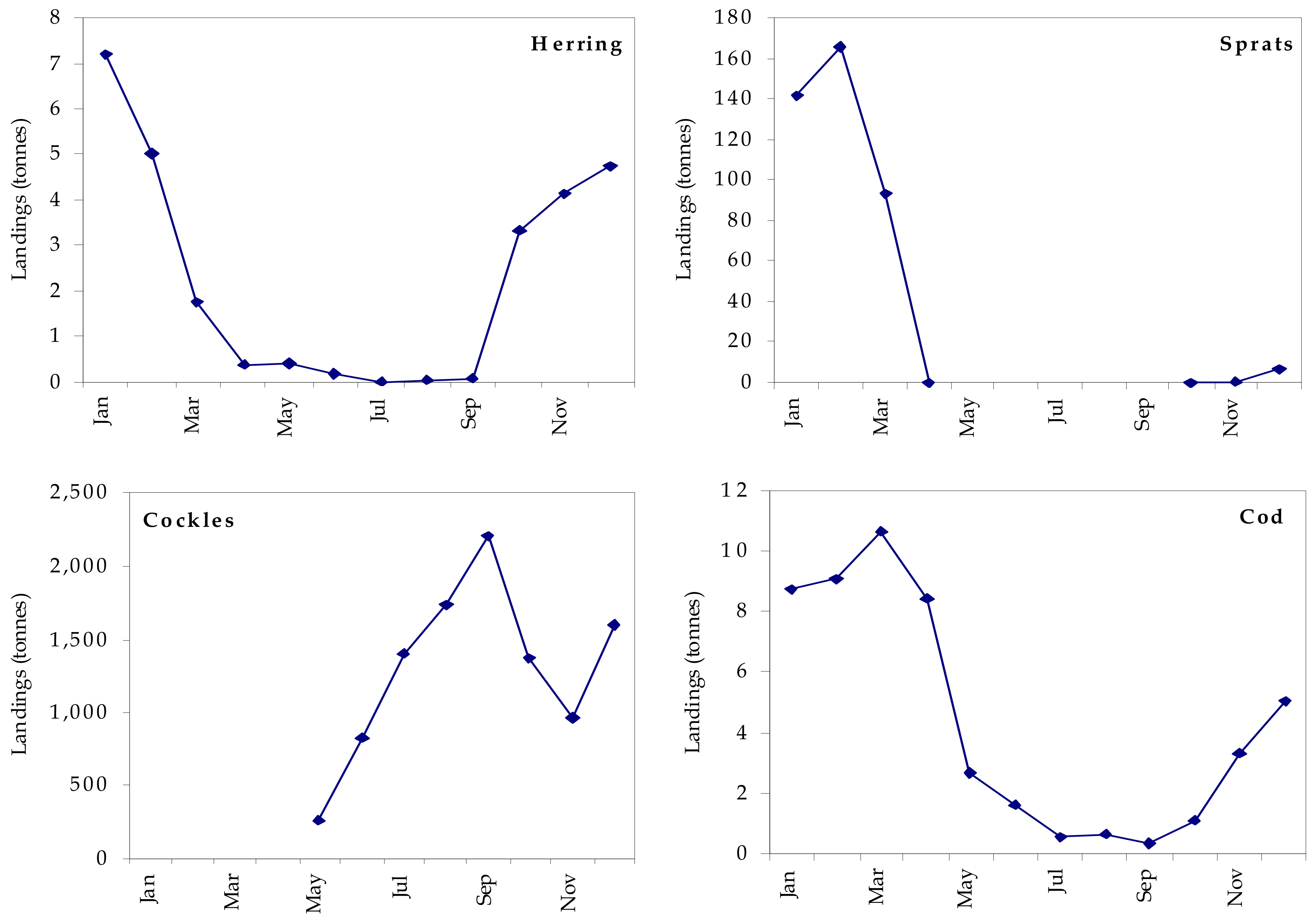


Source: MFA landing statistics.

Seasonal Variation in Landings

The fisheries in the MAREA study area are inherently seasonal as many of the species they target are only available in the area when they come inshore to spawn. This is clearly shown in the landings for herring. The Thames and Blackwater herring population spawn in the spring and become available to the fishery in October when they begin to migrate inshore (Figure 6.7). They continue to be available to the fishery until April, after completion of the spawning season (see Section 5.3). Sprat show a similar pattern, whereby the largest catches are taken in January to March before declining as the fish population disperses and moves further offshore after breeding (Figure 6.7). Cod catches (Figure 6.7) are determined by their life cycle to some degree, catches increase in the winter months when these species move inshore to breed. However, the seasonality of catches for these species is also determined by the quota restrictions placed upon them through the CFP (see Appendix M for more details).

Figure 6.7 Seasonal Variations in Average Landings of Herring, Sprats, Cod and Cockles



The seasonality of catches in some species is determined more by quota restrictions than the seasonality of the life cycle of the target species. Restrictions on cockle landings determine the levels of landings recorded during the year. The fishery opens in May and is restricted to 2 landings per week by each vessel. Landings gradually increase as more vessels enter the fishery and yields of meat within each cockle become higher. During August the landings restriction is relaxed to allow 4 landings per week and landings peak during this time as meat yields are also at their highest. Catches then decline and the fishery closes towards the end of the year (Figure 6.7).

6.2.4 Fishing Fleets

A number of vessels operate within the MAREA study area and form a number of different fleets. For the purpose of this baseline the fleets are separated into three categories:

- UK vessels under 10 m in length;
- UK vessels over 10 m in length; and
- foreign fishing vessels.

UK vessels from ports outside the MAREA study area also fish the grounds within the study area. These ports include Lowestoft and Southwold to the North and Whitstable, Margate and Ramsgate to the south (see Figure 6.1). Some UK vessels may originate from further afield but for the purposes of this report the ports in the MAREA study area and those whose vessels regularly fish the grounds have been included. Foreign fishing vessels may originate from ports in Belgium, Holland, France and Germany.

The majority of vessels operating in the study area are below 10 m in length and operate within the 6 and 12 mile nautical limits. The larger vessels (greater than 10 m in length) are fitted with VMS capabilities and are recorded during overflight surveys. As a result, the spatial and temporal variations of the larger vessels can be readily plotted. The spatial and temporal variation of the less than 10 m vessels is less well understood but through consultation it was possible to map their fishing grounds.

Table 6.1 displays the number of vessels, fishermen and major gears at the ports considered during this study. It is highly likely that potting and netting vessels are in fact the same. Some potting vessels have a category A licence with a shellfish entitlement which allows them to fish for practically all finfish and shellfish. Others may have a category C shellfish licence, entitling them to catch non pressure stock species of finfish (for example sea bass and mullet). Vessels under 10 m with a category A licence are currently restricted as to what they can catch as cod and sole quotas have been fully taken up.

The Inshore (<10 m) Fishing Fleet

There is a high degree of multiple gears being utilised by fishermen in the under 10 m fleet (Table 6.1). Due to the number of species targeted, the seasonality of the fishery and the CFP quota system fishermen need to be flexible in the methods they use. Most vessels are trawlers, netters, or dredgers and about one vessel in 4 is a multi-gear vessel, combining trawls and/or nets with longlines, pots and/or dredges. Multi-gear vessels are relatively more important in the central area where tides and currents have less effect on fishing grounds. Trawlers are dominant in the Thames estuary itself, where the grounds are softer and the tides and currents can be too strong for nets and pots.

There is strong spatial partitioning of fishing activity despite most vessels being able to move between areas within a single day. The spatial separation of vessels depends strongly on a number of factors:

- the home port of the vessel;
- the grounds used by other fishers;
- cost of fuel and steaming time if equivalent grounds are closer;
- market price of the day; and
- the necessary knowledge to work a particular ground or gear to target a particular species.

Through consultation the most important fishing grounds for the inshore vessels were identified. This was firstly carried out by des Clers *et al* (2001) for fishermen on the Essex and North Kent Coasts and provides partial coverage of the MAREA study area. To capture the Suffolk coast and update the information collected in 2001 the mapping exercise carried out by des Clers *et al* (2001) was repeated to provide an indication of the most important fishing grounds

In Figure 6.8 the results of the work by des Clers *et al* (2001) show that the fishermen's most used and important grounds (prime grounds) are extensive and cover a large area across the sandbanks at the mouth of the Thames Estuary. The grounds fished less often or when prime grounds are unavailable (very or fairly important grounds) are at the edges of the more important grounds and mostly in deeper water. Fishermen from different ports have very different fishing grounds but they often overlap or are adjacent to each other.

Table 6.1 Characteristics of the UK Fishing Fleets from Ports in the MAREA Study Area

	Vessels					Fishermen	
Home port	**<10 m FT**	**>10 m FT**	**<10 m PT**	**>10 m PT**	**Main gear types**	**FT**	**PT**
Aldeburgh	4		2		Pots, driftnets, long-line, stern trawl	8	2
Barling	1	1	3		Trawl, driftnets, gill nets, trammel nets, dredge	2	3
Brightlingsea & Colchester	2		4		Trawl, driftnets, gill nets, trammel nets, long-line, pots, dredge	3	4
Burnham-on-crouch		1	4		Trawl, driftnets, gill nets, trammel nets, dredge	2	3
Clacton & Jaywick	2		2		Trawl, driftnets, gill nets, trammel nets, long-line, pots	2	2
*Faversham	2				Trawling, driftnets, gill nets, trammel nets	4	
Felixstowe	3		7		Stern trawl, gillnets	5	12
Harwich	6	1	11	1	Trawl, driftnets, gill nets, trammel nets, long-line, pots	7	14
*Herne Bay	6				Driftnets, gill nets, trammel nets, pots	10	
Holehaven	4	1	6		Trawl, driftnets, gill nets, trammel nets,	8	7
Leigh-on-sea	10	11	3	2	Trawl, driftnets, gill nets, trammel nets, cockle dredge	40	7
Lowestoft	3	4	4		Stern trawl, beam trawl, gillnets, long--line , driftnets, pots	15	6
Maldon & Bradwell			4		Trawl, driftnets, gill nets, trammel nets		4
Mersea Island	7	3	19		Trawl, driftnets, gill nets, trammel nets, long-line, pots, dredge	21	22
Orford	2				Driftnets, gillnets, pots	4	
*Queenborough	4	2			Trawling, driftnets, gill nets, trammel nets, long-line, dredging	11	
Rochford & Paglesham	2		1		Trawl, driftnets, gill nets, trammel nets, dredge	3	1
Southend-on-sea & Thorpe Bay	3		4		Trawl, driftnets, gill nets, trammel nets	5	5
Southwold			5		Driftnets, stern trawl		5
*Thanet: Margate Ramsgate Broadstairs	32				Trawling, driftnets, gill nets, trammel nets, pots	56	
Walton-on-Naze	2	1		1	Trawl, driftnets, gill nets, trammel nets, long-line, pots, dredge	5	3
*Whitstable	9	3			Trawling, drift/gill/trammel nets, potting, dredging	20	
Wivenhoe	3		2		Trawl, driftnets, gill nets, trammel nets	4	4

Source: ESFJC Business Plan 2008 2009, KESFC Vessel Statistics (received 14 January 2009), MFA Vessel Statistics
*No breakdown of full-time and part-time fishermen available

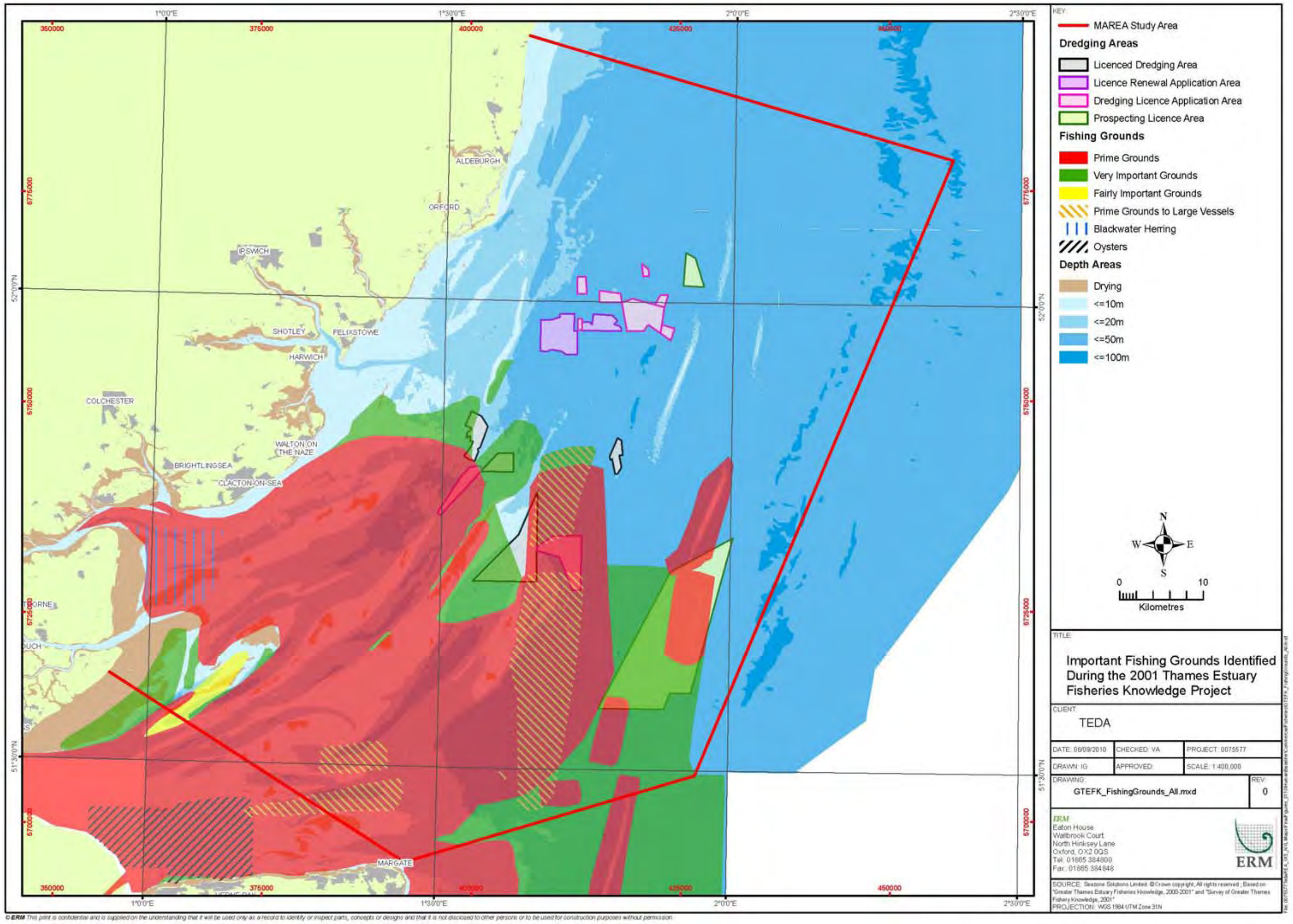
Figure 6.9 and Figure 6.10 show the results of the consultation carried out for the TEDA project and demonstrate that the sand banks are still the most important fishing grounds closer to the Thames Estuary. Further north the main fishing grounds are a similar distance offshore and cover similar depths, although there is less reliance on the sandbanks. Figure 6.10 demonstrates the fishery is highly seasonal and certain areas are fished more during particular months. In addition the area over which fishing activity takes place may expand seasonally, with the area fished for cod and sole in the Essex part of the fishery expanding between September and May and March and November respectively. In the northern area (Suffolk coast) it appears that fishing occurs closer to shore for cod, skate and sole during different periods between late autumn and spring (or late summer in the case of skate) and expands in the winter and summer. For cod two additional areas are identified where targeted fishing occurs in the central and northern areas in late spring. A similar area in late spring for skate is also identified in the central part of the study area.

Other important species fished in the area include bass, crustaceans (crabs and lobsters) and pelagic fish species (herring and sprats). Bass are mostly targeted on the sand banks in the MAREA study area between late summer and late autumn in both Essex and Suffolk fisheries. Crustacean potting effort is concentrated in the Suffolk portion of the study area and close to shore throughout the entire year. Sheltered waters within local estuaries are fished for eels and shrimps using eel fyke nets and trawling. These areas are also used for oyster cultivation (EMU Limited). Outside of the Thames and Blackwater herring fishery, (see Box 6.2) fishing for herring and sprat occurs close to the Suffolk coast near the ports of Orford and Aldeburgh between winter and spring.

The most commonly used gear in Essex are nets (fixed and drifting gill or trammel nets). Drifting and anchored tangle and trammel nets are set close inshore, and across offshore sand banks to target sole. These nets also catch bass, rays and a variety of flatfish. Thornback rays are targeted using anchored tangle nets. In the autumn gill and trammel nets are also used to target cod. A number of vessels also use trawls and target sole as well as plaice and thornback ray.

Herring and sprat are targeted during late autumn, winter and early spring. Two herring stocks are found within the MAREA study area. The first is a discrete inshore stock that spawns in spring in the northern part of the Thames Estuary, including the Blackwater Estuary (Box 6.2). A small number of boats exploit this herring stock from October to February. The North Sea herring mixes seasonally with the inshore stock, and is mainly taken by trawling. Sprats are caught in pair trawls from November to February when they appear inshore. Demand for herring and sprat is generally low resulting in many fishermen leaving the fishery. As a result catches have been considerably reduced in recent years.

Figure 6.8 Important Fishing Grounds Identified During the 2001 Thames Estuary Fisheries Knowledge Project



Source: des Clers, S., Dat, C., and Carrier, S., 2001. Survey of Greater Thames Estuary Fisheries Knowledge. Final Report to the Essex Estuaries Initiative, June 2001. 28 pp.
Note: The map is an aggregation of three maps produced for southern, central and northern Kent and Essex fishing ports.

Figure 6.9 Important Fishing Grounds Identified During Consultation

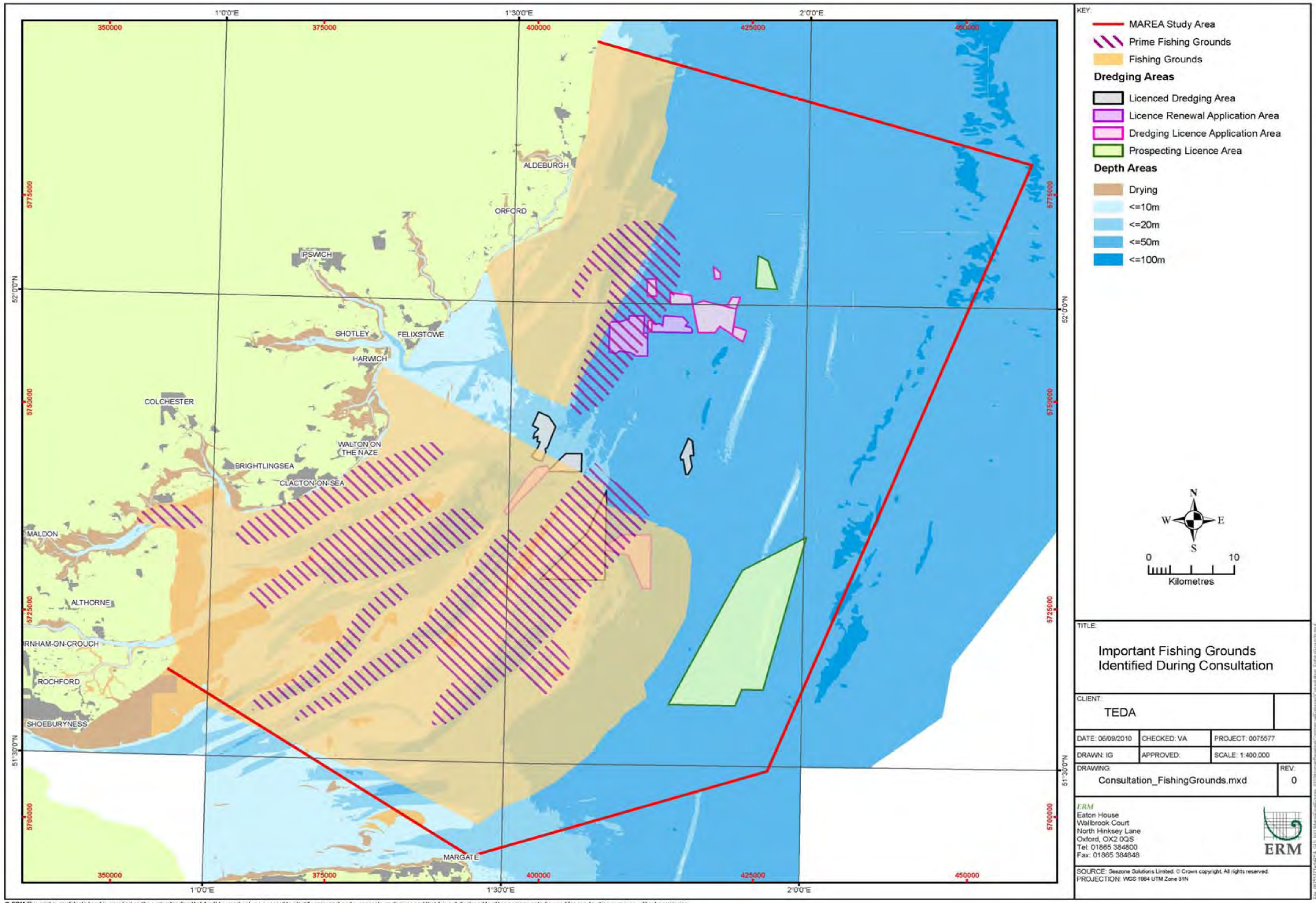
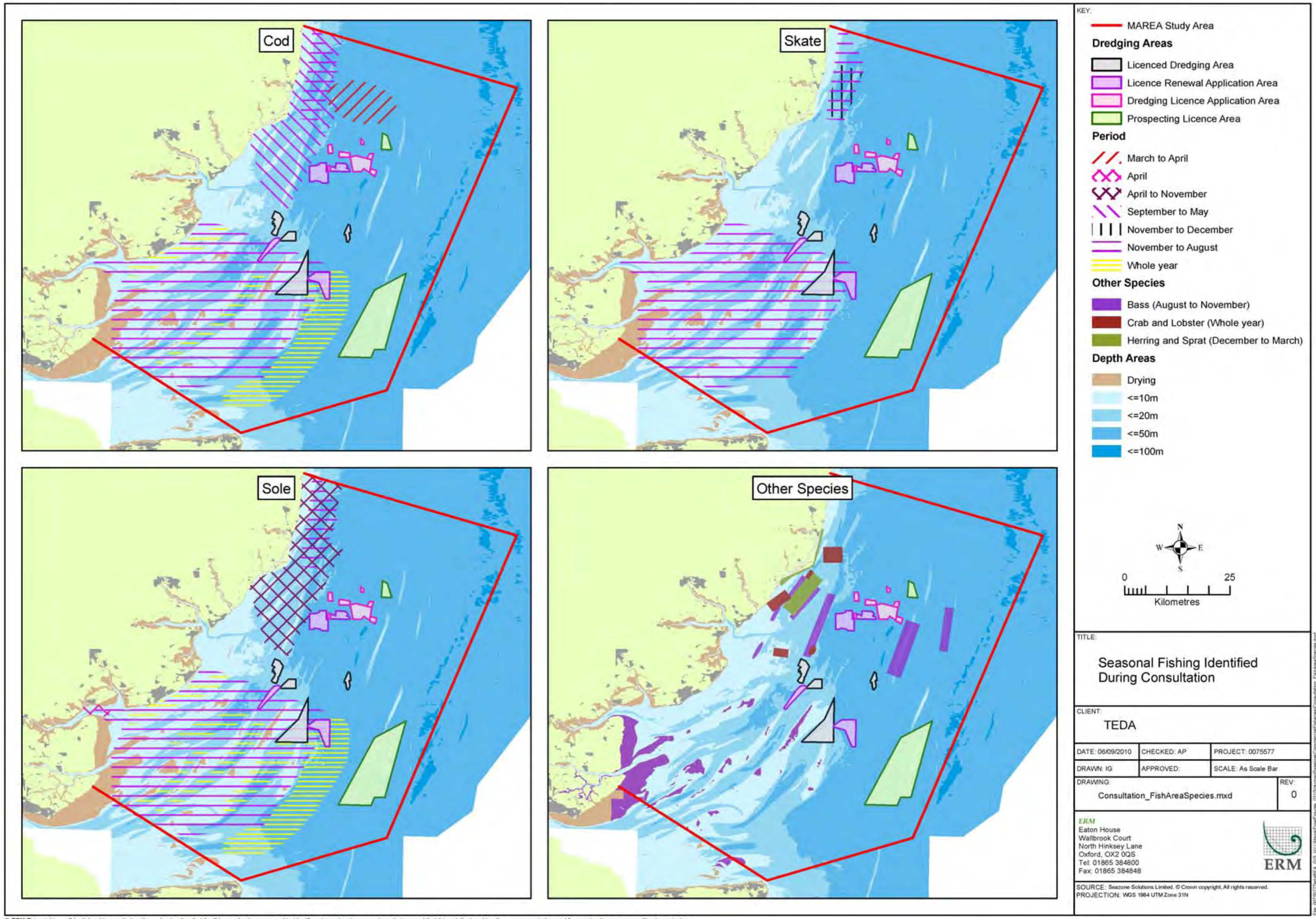


Figure 6.10 Seasonal Fishing Areas Identified During Consultation



Box 6.2 The Thames Estuary and Blackwater Herring Fishery

The Thames Estuary and Blackwater herring (Clupea harrengus) fishery was certified as sustainable by the MSC in March 2000 and re-certified in December 2005. The MSC is an independent, global, non-profit organisation that certifies sustainable fisheries. The Thames Estuary and Blackwater herring fishery is one of 7 currently certified fisheries in the UK.

The fishery is regulated by DEFRA, which sets and monitors the total allowable catch limit (TAC), set at just over 100 tonnes in the 2001/02 season. The Kent and Essex Sea Fisheries Committee makes bylaws to protect the fish stock which include regulation of mesh size, and the prohibition of trawling over spawning grounds.

With the increase in demand for Thames herring following the failure of the East Anglian fishery during the 1960s, the effort expended in targeting herring in the Thames increased in what was initially a recreational fishery. At the start of the 1988/1989 season MAFF introduced a regulation defining a drift net only area on the north side of the Thames estuary (Eagle bank) and forbidding the use of trawls.

In recent years the numbers of fishermen participating in the fishery has declined due to low demand. Total catches have also seen a decline, from 56 tonnes in the 2000/01 season to just 14 tonnes in the 2003/04 season. In 2004 a new licensing procedure was introduced. As a result in the 2004/2005 season only thirteen vessels were licensed to fish in the drift net area and only five of those were active. More recently evidence from the KESFC suggests that no vessels are taking part in the fishery due to the low market value of Thames Herring, which are generally smaller than the main North Sea population.

It is also known that native oyster grounds are present within the area fished by the Thames and Blackwater herring fishery, particularly in the mouth of the Blackwater estuary.

Along the Suffolk coast there is little in the way of safe berths or anchorages other than at Lowestoft, Southwold, Felixstowe and Ipswich. Thus, many small beach launched boats (of around 6 m length) are used to trawl, and longline up to 12 miles offshore or use drift nets within a mile or two of the shore. Gill and trammel nets are set for cod and whiting during the colder months and, in spring, tangle and trammel nets are set for sole although plaice, turbot and rays may also be caught. Longlines are used to target cod, rays, dogfish, ling, pollack and turbot. Drift nets are used for herring mainly in late autumn when they become more abundant. During late summer and autumn, sprats and mackerel are caught and the sprat fishery extends into the winter when these fish are particularly abundant. Bass are caught in fixed and drift nets during the summer together with grey mullet. There has also been a recent expansion of a brown crab fishery on inshore grounds at Aldeburgh using traditional wooden creels. Fishermen that usually pot for lobster and crab may switch to fishing for bass if catches are poor.

The UK Offshore (> 10 m) Fishing Fleet

In general there are few UK vessels greater than 10 m fishing within the MAREA study area in comparison to the number of foreign vessels. The UK vessels that do fish carry a number of gears, including gill, drift and trammel nets and twin, triple or multi-rigged otter trawls. Target species during the spring and summer are sole, rays, bass and mullet. Herring, cod and whiting are targeted during the autumn and winter. However, some vessels will fish for sole, rays and mixed flatfish for most of the year. Dredging also takes place for whiteweed [1] when restrictions prevent fishing for other species and cockles.

A large number of vessels, mainly from Southend-on-Sea and Leigh-on-Sea, fish under the Thames Estuary Cockle Fishery Order using a sieve-like mechanism that separate the cockles from the sand as they are pumped onboard. The fleet concentrates its efforts on the Shoebury, Maplin and Foulness Sands (Figure 6.11).

The Thames cockle fishery rapidly expanded following declines in other cockle stocks throughout the UK and Europe and is now the most productive in the UK. The KESFC manages the fishery through the Thames Cockle Fishery Order which limits the number of vessels that fish the major beds and restricts fishing effort. Licence holders are permitted to make between 2 and 4 landings per week, peaking during August and September, when meat yields are at their best. All cockle beds are closed during weekends and between mid November and the end of May. During the closed season and when yields are low some vessels target mussels or sole.

Cockle landings into ports covering the study area are the highest for any targeted species in the area. Over the last five years the landings of cockles into ports in and around the study area have had an average value of just under £4.5 million, more than 50% of the total value of landings (Table 6.2) and on average, approximately 80% of the total landed at ports in the study area. Cockles are also targeted in areas outside the Thames Estuary Cockle fishery and these landings contribute to the overall total.

The patterns of fishing over the last five years have been fairly stable in the UK offshore fleet. Analysis of VMS and overflight data between 2004 and 2008 demonstrates UK vessels longer than 10 m in length fished throughout the entire study area, with few annual variations. Between 2006 and 2008 increased numbers of vessels were seen fishing close to the Thames Estuary probably targeting sole. Overall the VMS and overflight data suggests fishing takes place across the MAREA study area with the most intense fishing by UK vessels seen through the central part of the area and towards the Thames Estuary

(1) A fern-like hydroid (a colonial animal related to coral) that is dried and sold for decorative purposes.

Table 6.2 Landings and Value of Cockles Recorded at Ports within the MAREA Study Area

Year	Total Landings (tonnes)	Percentage of Total Landings	Total Value (£)	Percentage of Total Value
2004	7,985	57%	£3,181,856	48%
2005	11,658	74%	£6,157,050	63%
2006	9,819	89%	£4,284,172	56%
2007	10,146	88%	£6,587,558	65%
2008	4,716	79%	£2,217,968	36%

The number of observed UK vessels is generally low across the entire study area within each season (Figure 6.12 and Figure 6.13). The number of vessels is highest in the north of the study area (33F1-4) as well as close to the Thames estuary. In the summer, autumn and winter, vessel numbers were highest close to the Thames estuary, probably due to vessels targeting sole and cockles or fishing close to shore in bad weather. From VMS data (Figure 6.13) UK vessels show a similar pattern to that of the foreign fishing fleet (see next section). In winter vessels numbers are highest outside the MAREA study area, in spring more vessels are found within the MAREA study area as vessels move inshore and during summer fishing activity remains inshore but at a lower level. Vessels are seen fishing close to the Thames estuary and Gunfleet and East Barrow sands probably fishing for sole. In the autumn fishing activity decreases, possibly as vessels move further offshore or complete their quota.

The Foreign Fishing Fleet

Until recently the majority of larger than 10 m vessels fishing in the MAREA study area are from nations other than the UK. Vessels from Belgium were the most often observed, followed by Dutch and vessels from the UK. Other nations that fish in the area include vessels flagged in Germany and Norway and the Faroe Islands (Table 6.3). In 2007 and 2008, UK flagged vessels were the most commonly observed nation fishing in the MAREA study area, although the total number of foreign vessels observed was still greater in 2007. In 2008 the total number of vessels observed in the outer Thames Estuary that were not UK flagged was considerably lower. This may be for a number of reasons, including rises in fuel bills forcing foreign vessels to fish closer to home and vessels re-flagging as UK based vessels.

Figure 6.11 Cockle Harvest Areas in the Kent and Essex Sea Fisheries Committee District

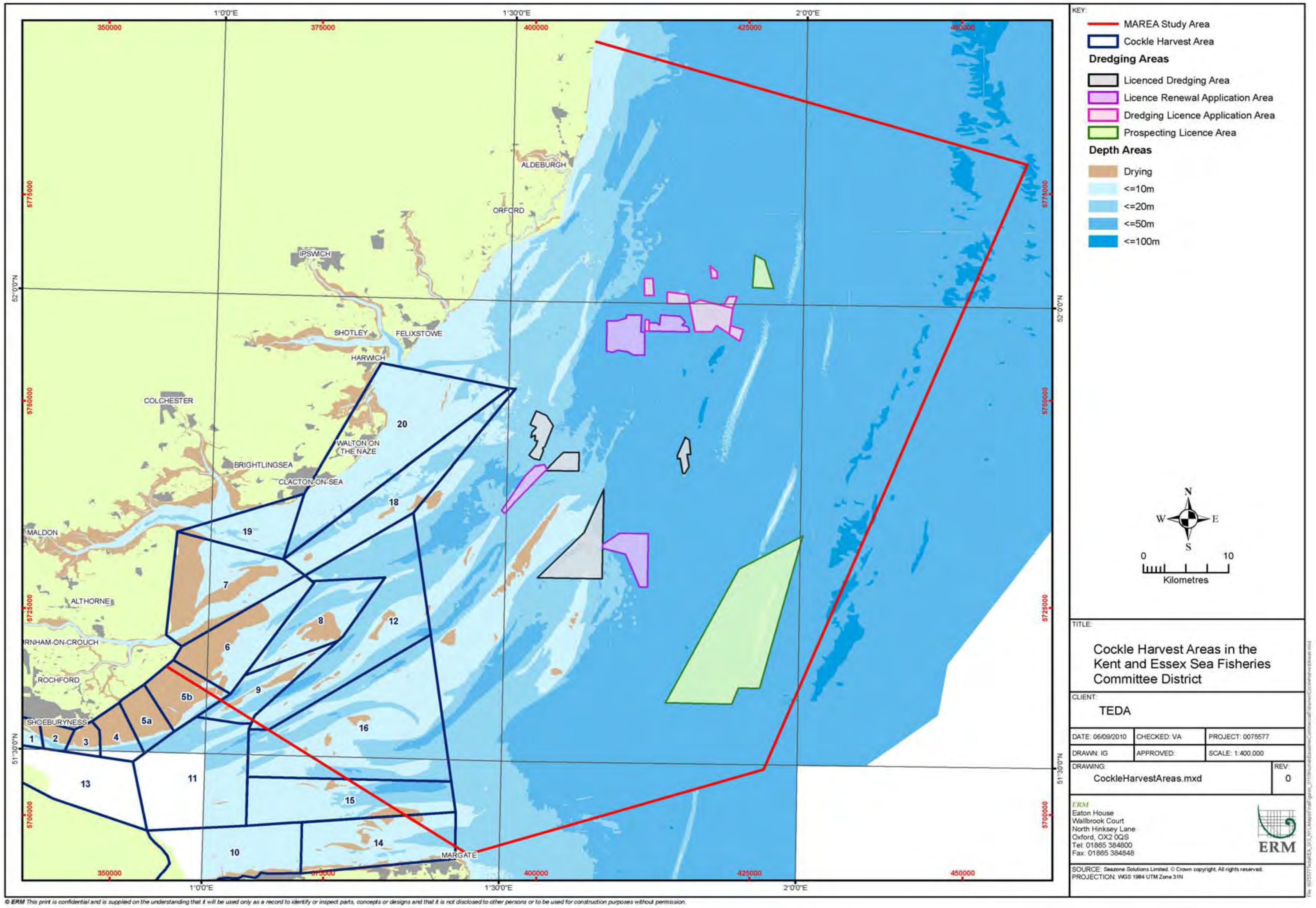


Figure 6.12 ***Seasonal Standard Observations of UK Fishing Vessels in the MAREA Study Area***

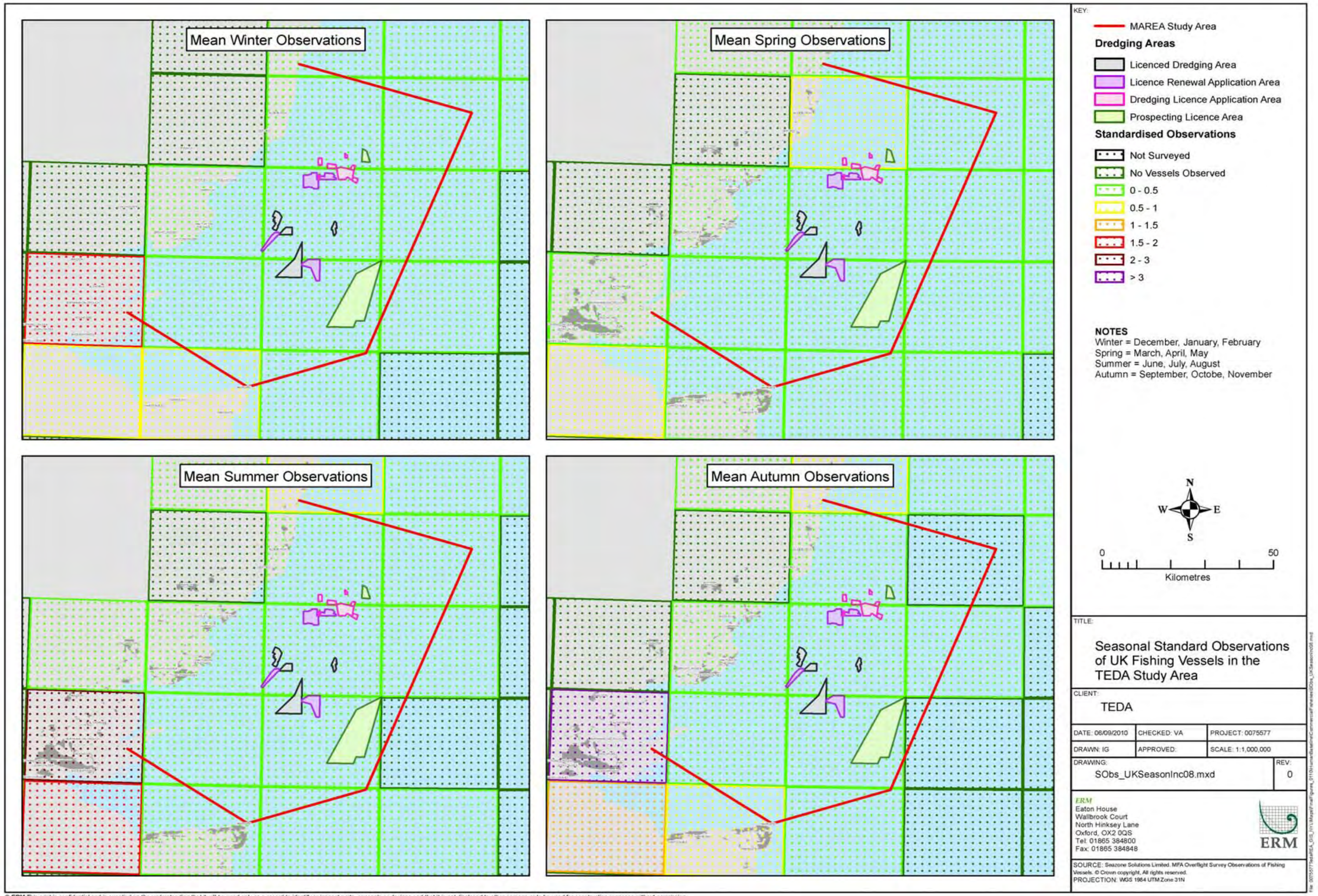


Figure 6.13 *Seasonal Distribution of Active UK Fishing Vessels from VMS Data in the MAREA Study Area, 2005 to 2008*

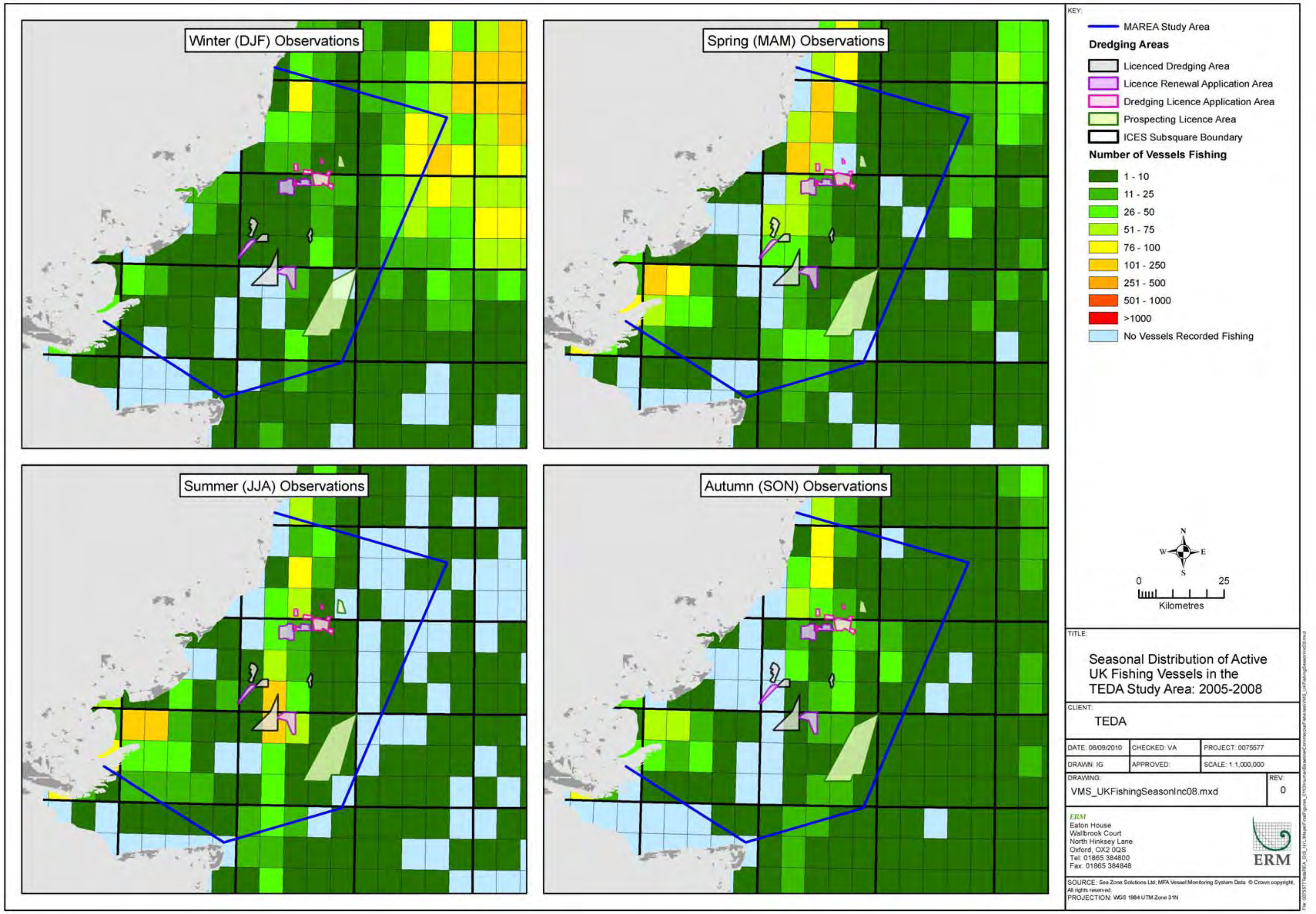


Table 6.3 Total Observations of Foreign and UK Vessels Fishing within the MAREA Study Area, 2004-2008.

Flag	2004	2005	2006	2007	2008
Belgium	194	158	219	186	203
Germany	2	10	2		2
France	49	43	28	20	36
Faroe Islands			1		
Netherlands	87	70	23	126	40
Norway		1			
UK	55	44	90	203	308

Foreign vessels are observed fishing in all areas of the study area. Over the last 5 years fishing has been evenly spread across the entire area, the number of vessels observed within each sub-rectangle being relatively moderate. The highest numbers have been observed in sub-rectangles 32F1-2 and 32F1-4, although in 2006, 33F2-3 was also higher than the remainder of the study area.

A general seasonal pattern can be seen in fishing activity by the foreign fishing fleet (Figure 6.14):

- During the winter most fishing vessels are concentrated further offshore, outside the study area.
- During spring fishing moves inshore, the number of vessels fishing increases and is highest within ICES sub-rectangle 32F1-4.
- In summer, while still mostly inshore, fishing vessels begin to move further offshore and are more evenly spread across the region.
- Fishing again moves further offshore in the autumn, the highest number of vessels is found in 32F1-4 and the sub-rectangles to the northeast and north.

6.2.5 Fishing Methods in the Study Area

A number of different fishing methods are by fishing vessels operating within the MAREA study area. While the gear types used by the smaller inshore fleet were examined using available data above the spatial and temporal trends of the offshore fleet is examined in this section (both UK and foreign fishing fleets). The number of observations from overflight surveys, carried out by Defra, of vessels within the MAREA study area using various gear types is shown in Table 6.4

Figure 6.14 Seasonal Standard Observations of Foreign Fishing Vessels in the MAREA Study Area

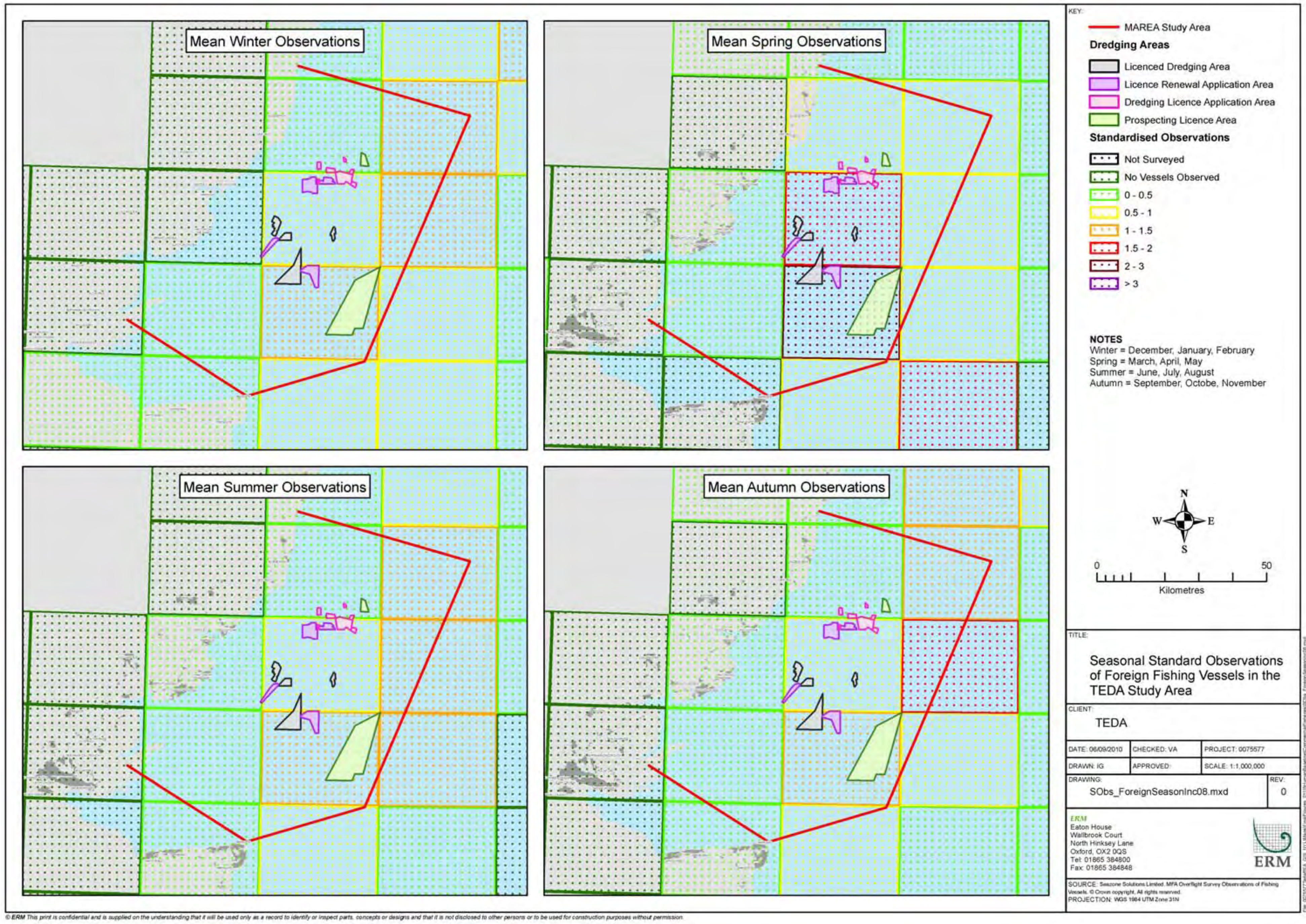


Table 6.4 Number of Vessel (>10 m) Observations from Defra Overflight Surveys for Each Gear Type within the MAREA Study Area, 2004 - 2008.

Gear type	2004	2005	2006	2007	2008
Side trawler (pelagic/demersal)	1		3		
Stern trawler (pelagic/demersal)	13	16	39	52	42
Beam trawler	272	229	234	285	222
Long liner	2		2		1
Gill netter	8	9	14	35	45
Potter/whelker	15	17	17	38	44
Drift netter	3			1	6
Rod and line		1			6
Trawler	73	52	50	83	149
Pair trawler		1	4	4	2
Suction dredger				12	42
Unknown				22	30
Scallop Dredger		1		3	

Source: Defra overflight data provided by MFA.

Trawling

Beam trawlers are largely used to target flatfish such as sole and plaice. The mouth of the net is kept open by the beam mounted at each end on guides or skids that travel along the seabed. The trawls are made more effective by tickler chains that drag along the seabed, causing fish to rise into the mouth. Otter trawls are large cone-shaped nets, towed across the seabed and are used to catch species such as cod and whiting. The mouth of the net is kept open by otterboards. This method is used by pair, side and stern trawlers. Pelagic trawls are otter trawls that are towed through mid-water or close to the surface to catch pelagic species such as sprat and herring.
Overflight data suggests that in 2004 trawl vessels were evenly distributed across the study area but in 2005, the highest numbers were found in sub-rectangle 32F1-4. A similar pattern is seen in 2006 and 2007, with the highest vessel numbers in 32F1-4 and 32F1-2. In 2008, the number of vessels is generally lower than in previous years, although 32F1-4 has the highest concentration of vessels.

The same seasonal pattern is generally observed across the study area each year (Figure 6.15). During the winter months vessel numbers are generally low with a higher concentration seen in sub-rectangle 32F1-4, although lower than for the rest of the year. During the spring and summer the number of vessels through the centre of the MAREA study area increases and the remaining area fished to a lesser degree. In the autumn the number of vessels observed decreases with vessel numbers again highest in ICES sub-rectangle 32F1-4.

VMS data for beam trawlers shows a similar pattern to that of the overflight data (Figure 6.16). In winter, most activity is further offshore and outside the MAREA study area. In spring activity moves closer in shore and during summer and autumn vessels move outside the MAREA study area. The VMS data does not include foreign vessels or vessels less then 15 m in length and as a result small differences are observed in the fishing patterns observed in the overflight and VMS datasets. The number of other trawlers and shrimp trawlers observed in the VMS dataset is much lower. Generally, for other trawl vessels fishing is spread throughout the area with only a few vessels recorded in any one area. However, during summer higher concentrations of vessels, possibly targeting cod, sole and skate, are seen close to the Blackwater estuary. Few shrimp trawlers appear in the MAREA study area and only during winter and spring. Generally shrimp fishing is further north towards the Wash and these vessels are probably fishing at the extremities of the fishery.

Nets

Gill nets can be set at or below the surface, on the seabed, or at any depth in between and are generally anchored to the seabed. Drift netting (a type of gill net), will often be used by vessels for targeting small inshore pelagic fish such as herring and sprats. Drift nets are not attached to the vessel but are allowed to drift in the water column. Generally, few vessels (maximum of 51 vessels in 2008) using this gear type are recorded during the overflight survey and fewer still are recorded by VMS data. The majority of vessels that use nets (gill, drift and trammel) are less than 10 m in length and are discussed in Section 6.2.4. Gillnet and driftnet fishing by vessels greater than 10 m in length does not show any seasonality and is at a very low level across the entire study area throughout the year. However in autumn a handful of vessels are seen in the VMS dataset fishing through the central part of the study area possibly targeting cod, bass and pelagic species such as herring or sprat.

Pots

Potting vessels are generally smaller (less then 10 m) inshore vessels rather than the larger offshore vessels. A maximum of 44 vessels in one year were seen using this gear between 2004 and 2008 in the overflight dataset. Potting for shellfish by the inshore fleet occurs throughout the year, but effort generally increases inshore from late March through to late September or early October. The species most commonly caught by potting vessels are crabs, lobsters and whelks.

The majority of pots used are of a plastic parlour pot design and are strung together in a line which is then anchored to the seabed. Pots are baited and left anchored to the seabed until the owner returns to check them. Commercial potting is concentrated around suitable hard ground, wrecks, pipelines and other areas where target species gather.

Nationally there is an increasing trend in shellfish potting effort, although this trend is less distinct within individual fisheries. Increased effort is more pronounced during the summer period and effort generally declines in autumn and winter. However, there is little seasonality in the number of larger vessels fishing in the MAREA study area. The majority of fishing using pots is carried out by small (<10 m) vessels that are not recorded in overflight surveys. Thus, total effort is likely to be much higher. Factors such as weather, the distance of target species from shore and the number of 'hobby fishermen' will determine local seasonal trends in effort. Potting is generally seasonal for the smaller vessels but larger vessels may fish all year round.

Figure 6.15 Seasonal Standard Observations for Trawl Vessels Fishing in the MAREA Study Area

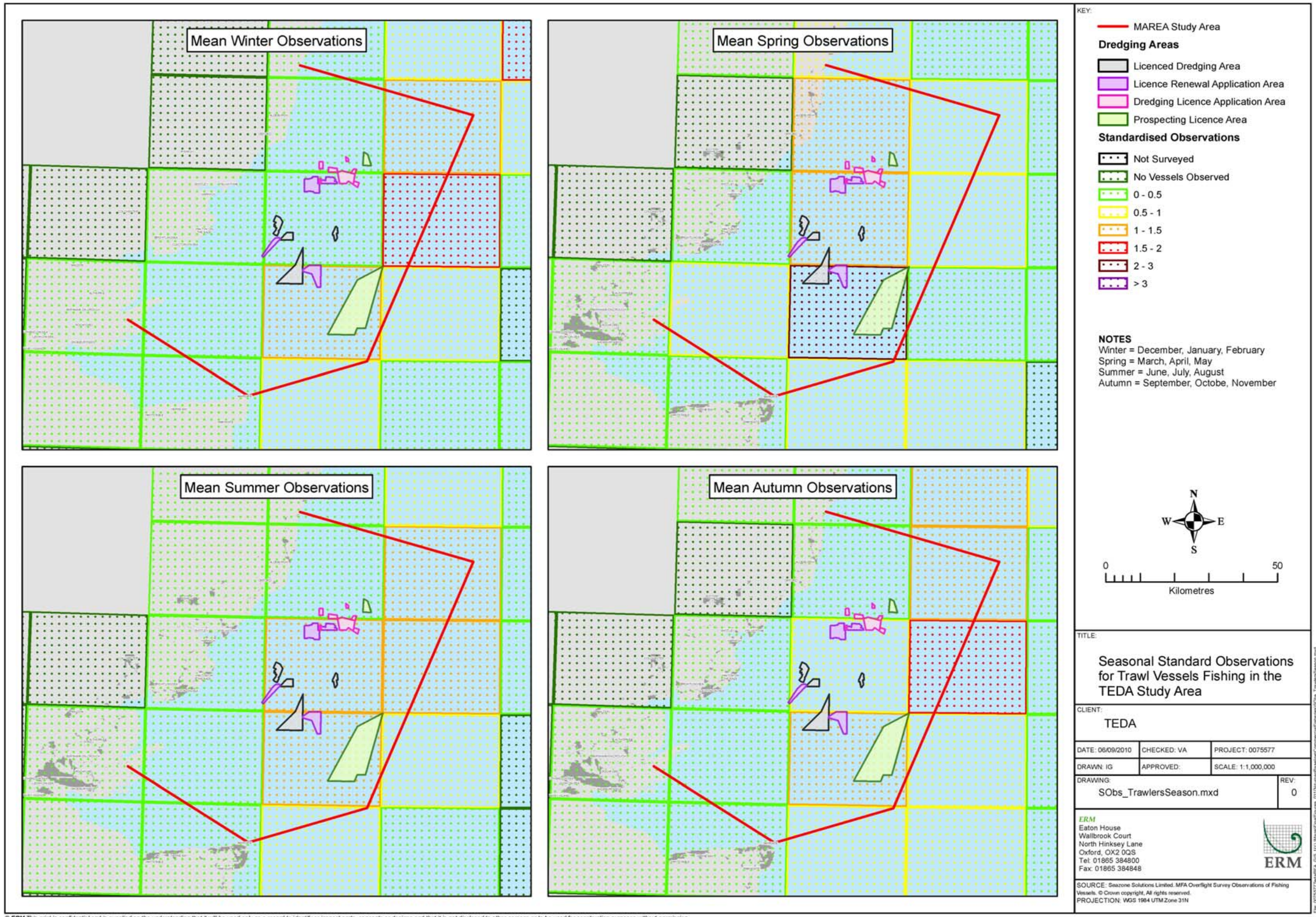
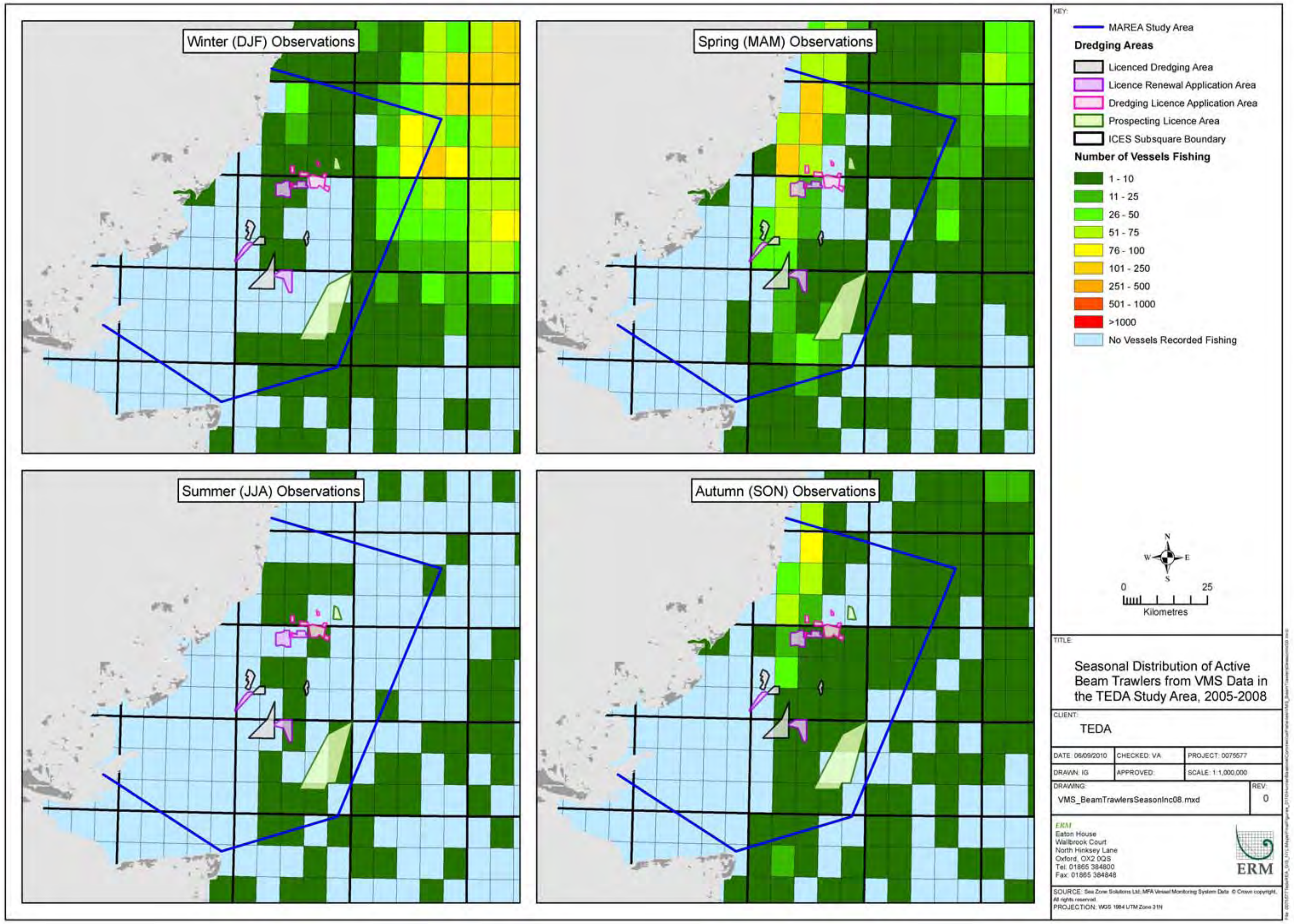


Figure 6.16 Seasonal Distribution of Active Beam Trawlers from VMS Data in the MAREA Study Area, 2005 – 2008.



Long-lines

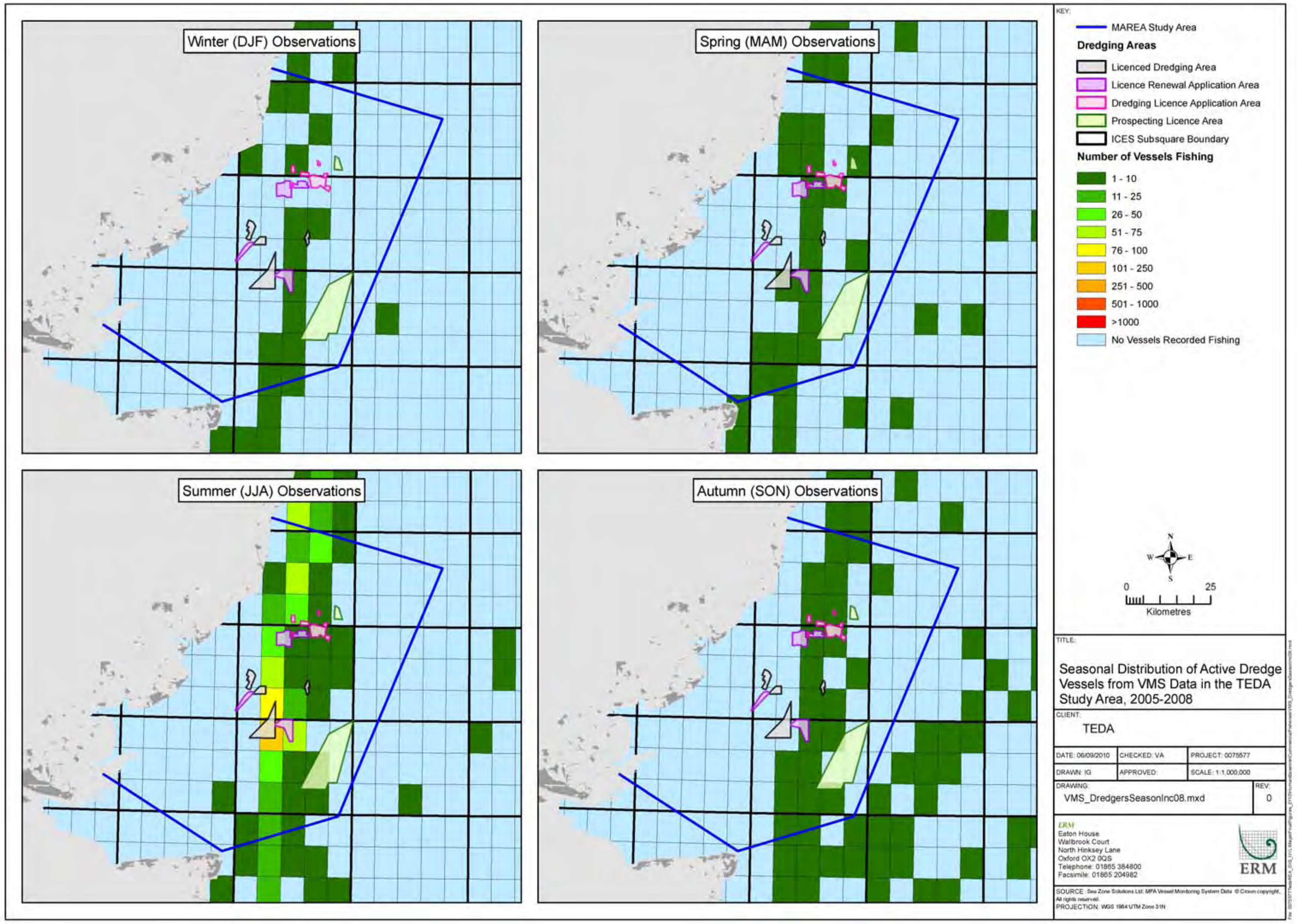
Long-line fishing takes place in the southern North Sea for cod, skates and rays, bass and whiting. A line of baited hooks is anchored at each end and left for approximately one tide before being brought ashore, any catch removed and the hooks rebaited. Long-lining is generally restricted to a small number of vessels, both above and below 10 m in length (only 3 over 10 m vessels seen between 2004 and 2008). Fishing takes place year round but different species are caught depending on the season. In years in which vessels have been observed by overflight surveys most vessels are concentrated to the north. No long-line vessels have been recorded by VMS data between 2005 and 2008 suggesting vessels less than 15 m length carry out the majority of long-line fishing in the study area.

Dredging

Surface dredges are generally utilised in waters around the UK to target a variety of bottom dwelling animals, like mussels, oysters, scallops and cockles. The number of scallop dredge vessels operating in the study area is very low (only 4 vessels in total observed between 2004 and 2008). Within the Thames Estuary, cockle suction dredging is the most common method. Suction dredging takes place between May and December with peak intensity occurring in September.

While the overflight data shows no patterns in dredge vessel fishing activity, VMS data shows dredge vessels operating throughout the MAREA study area. Generally numbers are low (less then 10 per square in winter, spring and autumn) but during the summer there is a small increase across the central part of the MAREA study area (Figure 6.17). This is most prominent close to the Longsand and Kentish knock sand banks and outside the Thames Estuary cockle fishery. During August and September activity in the cockle fishery is at its highest as meat yields are at their best.

Figure 6.17 Seasonal Distribution of Active Dredge Vessels from VMS Data in the MAREA Study Area, 2005 – 2008



6.2.6 Recreational Fisheries

Sports fisheries are relatively widespread throughout the region and carried out from boats (fishing close to wrecks) or from the shore, both methods using rod and line. Boat angling within the ESFJC regulatory area is carried out by a number of vessels operating from several ports in the region (e.g. Lowestoft, Southwold and Orford). In the KESFC area vessels operate from the majority of ports. The boat-based activity is restricted to the late spring and summer months, with no discernible activity within the area during autumn and winter. There are a number of angling clubs within the area, many organising shore-based competitions. The area also attracts many privately owned angling boats due to the large areas of sheltered water and plentiful marinas and slipways. Recreational sea fisheries attract visitors that support a number of businesses and livelihoods, including angling charter boats, bait-diggers, tackle shops, and angling guides.

During the late autumn, winter and early spring, sea anglers concentrate their effort on catching cod and whiting. Cod is historically an extremely important target species for the recreational sector and it is during this period that effort from the shore is at its highest. Much of the boat orientated angling effort is focused close to shore. During late spring, summer and early autumn bass are targeted, while species such as mackerel, red mullet, grey mullet, sea trout, thornback ray and tope tend to be targeted from late summer through autumn. Pollack, pouting, sole and smoothounds become important in the autumn, whereas dogfish are caught throughout the year.

All boats work between a mile and up to sixty miles from their home ports depending on the season and where fish are expected to be. On a good weekend there will be up to sixty privately owned fishing boats fishing in these same grounds with anything from one to six anglers on each boat.

6.2.7 Fisheries Value

Fish that are landed by vessels within the study area are sold at fish markets both locally and further afield. Some are transported to ports in continental Europe and others are landed locally. The prices received at market are determined by the supply, the time of year, the quality and source of the species being sold.

In order to estimate the value of the fisheries in the MAREA study area a number of steps were required. It was essential to estimate the value of all landings within ICES IVc and landings from UK vessels from within this area of the North Sea. The next process was to use these values and re-distribute the catches within the ICES rectangles in IVc. This allowed the landings within those rectangles covering the study area to be estimated. The proportion of effort expended in the MAREA study area from the overflight data was then used to determine the landings within the MAREA study area itself. The final piece was then to estimate the landings for the different fleets:

- The landings from the inshore (<10 m) vessels was estimated from the MFA database of landings with some adjustments for ports outside the actual MAREA study area as not all landings reported were necessarily from the MAREA study area.

- The UK offshore fleet (>10 m) was estimated from the UK landings for IVc from the MFA.

- The foreign fleet from the ICES landings minus the UK offshore fleet.

For a full methodology and the data used in calculating the fisheries value in the MAREA area see Appendix M.

In Table 6.5 it can be seen that the whole fishery in the study area is estimated to be worth just over £23 million in a single year of which £10.3 million is taken by the UK fleet (£4.1 million for the over 10 m UK fleet and £6.2 million to the inshore fleet). The catch and value of the fishery is much higher for the foreign fleet in comparison to that of the UK due to the much larger number of vessels fishing in 2006 and the larger size of vessels (see Table 6.3) fishing from other countries.

Table 6.5 Estimated Total Catch and Annual Value of Fisheries for ICES IVc and MAREA Study Area, 2006

Area	Fleet	Total Catch (tonnes)	Total Value (£)
ICES IVc	All	137,088	£224,810,483
	UK	17,763	£29,129,527
	Non UK	119,325	£195,680,956
Study Area	All	23,373	£38,328,576
	Offshore (>10 m) UK	2,527	£4,144,450
	Inshore (<10 m) UK	3,762	£6,169,156
	Non UK	17,083	£28,014,969

While these figures are estimates and may in reality be higher or lower, they provide an indication of the value of the fishery to the local economy, the fishing industry and to the economies of several ports in other European nations. However, the estimated value must be taken with some caution as the landings may have been taken from outside the MAREA study area. The method used also only provides an estimate of the total value of the fishery in ICES Division IVc as the actual value of the catch was not available. In addition there is inherent variability in market prices, generally driven by seasonal and interannual variation in availability of target species.

6.2.8 Summary

The North Sea and the Outer Thames Estuary have been important areas for fishing activity for centuries. The region is important for populations of a number of commercial fish species (eg cod, sole, thornback ray, plaice and herring), providing spawning, nursery and feeding grounds (see Section 5.3). A wide variety of fisheries (eg drift net and tangle net finfish fisheries, Thames Estuary cockle fishery) have developed in order to exploit these resources and the dynamics of the fisheries have become linked to the life cycles of the fish and shellfish they target.

The most widely used commercial fishing methods utilised in the region can be broadly divided into four distinct categories: trawling, netting, potting and others (including long-ling, seining and dredging). The range of marine species exploited reflects the diverse marine ecosystem in the area. The most important species landed at local ports are shellfish, particularly cockles. Pelagic finfish landings are dominated by sprats followed by herring. Landings of demersal species are mainly cod, skates and rays and sole. Other significant catches include bass, plaice, other species of flatfish and dogfish and a vast array of other demersal species.

The fisheries of the Essex and Suffolk coasts covered by the MAREA study area are typical of those around the UK. Close inshore small vessels target a wide variety of species using multiple gears. The main target species are sole, thornback ray and cod for most of the year with a number of other species (e.g. bass, dogfish and plaice) featuring seasonally. The area was once an important fishing ground for sprat and herring but in recent years low market prices have caused many fishermen to cease fishing for these species. Further offshore larger vessels, mainly from other European nations (Belgium, France, Holland and Germany) but also the UK, use mainly trawl gear to target a number of species including cod, whiting, plaice, sole and other flatfish. Some vessels target the large populations of herring and sprat on a seasonal basis.

There are more foreign vessels fishing in the study area, although in 2007 and 2008 UK vessels are more dominant in the offshore (larger than 10 m) sector. However, most UK vessels are below 10 m in length and fish close to shore. Fishing within the study area follows a seasonal pattern, generally due to the seasonal migrations of targeted species and their availability to the fishery. In winter fishing by larger vessels is further offshore and generally on the edges of or outside the study area. In the spring the larger vessels move closer inshore and across the entire study area, with greatest fishing effort through the central area. In summer most vessels fish inshore but some of the fleet moves further offshore. By autumn the majority of larger vessel effort is further offshore and on the edges of the study area once more.

In winter smaller vessels fishing inshore are targeting herring, cod, whiting, sprats and plaice as these species migrate towards the coast and Thames estuary to breed. In spring target species include bass, sole, cod and skate. Summer species include cod, sole, bass and skate with some squid and mullet also featuring in catches. By autumn the smaller inshore fleet continues to fish sole, skate and cod with whiting, herring and sprat again becoming important.

The observed fishing activity pattern for all fleets is driven by the biology of the targeted fish species, which move to shallower water during their breeding periods. Once the adult population migrates further offshore the fishing fleets follow them in order to continue exploiting them as a resource. The important fisheries in the area can generally be separated into three distinct types; the Thames Estuary cockle fishery, the inshore fleet (generally small less then 10 m vessels) and the offshore fleet (vessels greater than 10 m in length from the UK and overseas). Of these the Thames Estuary cockle fishery, operating across the Shoebury, Maplin and Foulness Sands, stands out as the most productive in terms of both income (54%) and volume (77%). The Thames Estuary Cockle fishery is now the most productive and most important cockle fishery in the UK and one of the largest in Europe.

6.3 OTHER INFRASTRUCTURE

6.3.1 Introduction

This section describes the other infrastructure and human activities that take place in the vicinity of the MAREA study area. This includes ports and harbours, marine disposal sites, offshore wind farms, pipelines and cables, military activity and oil and gas exploration. The infrastructure associated with commercial fisheries and navigation activities is discussed in Sections 6.2 and Sections 6.5.

6.3.2 Sources of Information

The principal sources of information used to inform this baseline section include:

Ports and Harbours

- Information from the Port of Felixstowe on the Felixstowe South Configuration (Port of Felixstowe) (1).
- Information from Harwich International Port on the Harwich International Container Terminal (Harwich International Port)(2).
- Information on the London Gateway from DP World (3), and from the Building London Gateway Seminar held by the Central Dredging Association, Port of London Authority and London Gateway Port Limited.
- SeaZone data.

Marine Disposal Sites

- Marine and Fisheries Agency, information on disposal of wastes at sea (Marine Management Organisation)(4).

Offshore Wind Farms

- British Wind Energy Association (BWEA) (5).
- Information from DONG Energy on the Gunfleet Sands Project (6).

(1) http://www.portoffelixstowe.co.uk/fsr/application/documents.htm (accessed 26/03/09).
(2) http://www.hict.co.uk/content/theapplication/intro.asp (accessed 26/03/09).
(3) http://www.londongateway.com (accessed 26/03/09).
(4) http://www.mfa.gov.uk/environment/works/consents-disposal.htm (accessed 26/03/09).
(5) http://www.bwea.com/ (accessed 27/03/09).

- Greater Gabbard Offshore Winds Limited (7).
- London Array Limited (8).
- Information from The Crown Estate on the Round 3 of offshore wind farm leasing (9).
- SeaZone Data.

Pipelines and Cables

- Kingfisher Cable Awareness Charts: South North Sea. Issue 11 – January 2009 (10).
- DECC. Information on human activities in the SEA 3 area (11).
- SeaZone Data.

Military Activity

- UK Hydrographic Office Practice and Exercise Areas (PEXA) Charts as part of SeaZone data.

Oil and Gas Exploration

- DECC. Information on human activities in the SEA 3 area (12).
- SeaZone data

6.3.3 Ports and Harbours

Shipping and maritime trade are important elements of the UK economy, with approximately 95% of the UK's international trade by volume being transported at sea.

(6) http://www.dongenergy.com/Gunfleetsands/Project/The_Gunfleet_Sands_project/The_Gunfleet_Sands_project (accessed 26/01/09).
(7) http://www.greatergabbard.com/ (accessed 29/01/09).
(8) http://www.londonarray.com/ (accessed 29/01/09).
(9) http://www.thecrownestate.co.uk/round3 (accessed 26/01/09).
(10) Available at http://www.kisca.org.uk/charts.htm (accessed 28/01/09).
(11) Available at http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).
(12) http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).

There are a large number of ports, harbours and berths along the coastline of the MAREA study area. These vary in size and purpose from large international ferry and container ports such as that at Harwich and Felixstowe, to small fishing ports such as Clacton-on-Sea and West Mersea, and the small local recreational harbours and marinas located within the estuaries (see Figure 6.18).

Harwich and Felixstowe

The approach channel serving the ports of Harwich and Felixstowe was deepened to 14.5 m below Chart Datum (CD) in 1999. This was to provide better access for deep-drafted vessels visiting the two container ports. The channel is marked by lights and buoys indicated in current Admiralty charts as shown in Figure 6.18.

This channel receives regular maintenance dredging and the extracted material is dumped at sea at licensed dumping grounds (see Section 6.3.4). The port of Harwich holds a FEPA licence to deposit 3 million wet tonnes of maintenance dredged silt and sand at designated offshore locations. Some of the dredged material however, is used for sediment recharge projects elsewhere along the coast.

Both Felixstowe and Harwich Ports currently have plans to expand their capacity. Box 6.3 and Box 6.4 summarise the proposals. The change to shipping movements in the MAREA study area as a result of these developments needs to be carefully considered and forms part of the navigation assessment in Appendix I.

Box 6.3 The Port of Felixstowe

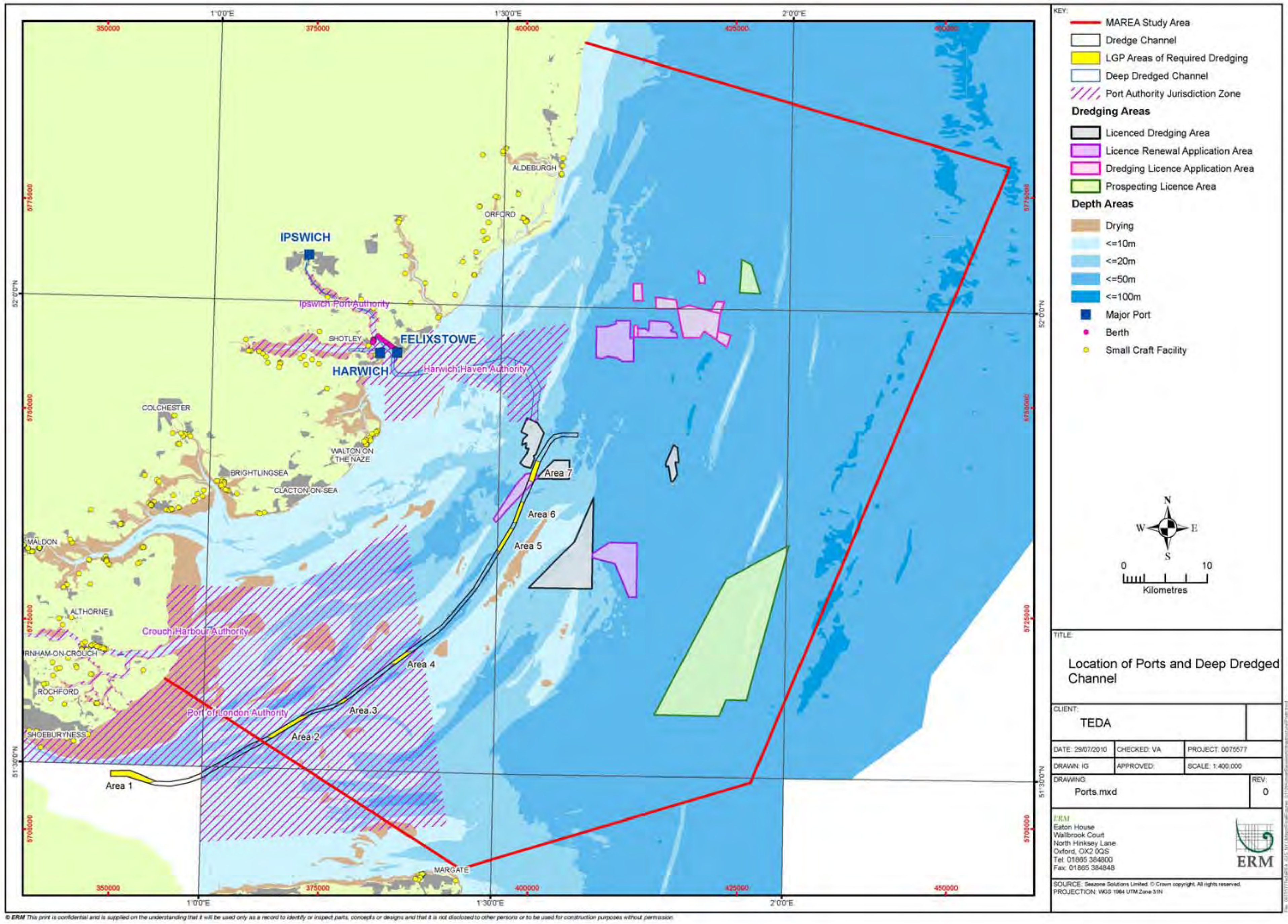
The Port of Felixstowe is currently undergoing a process of expansion and modernisation known as the 'Felixstowe South Reconfiguration', after it was granted planning permission in early 2006. The container port will be redeveloped with increased handling capacity and additional deep water berths. Phase 1 of the construction programme commenced in July 2008 and the port is predicted to achieve operational status by 2010, with all 4 berths being fully operational by 2015.

Features of the project include;

- 1350 metres of quay—dredged to 16 metres below Chart Datum (CD) – able to accommodate the latest generation of large container vessels;
- approach channel of 14.5 metres below CD;
- 13 ship-to-shore gantry cranes;
- 50 rubber tyred gantry cranes;
- storage yard capacity of 46800 Twenty Foot Equivalent Units (TEUs); and
- a new North Rail terminal.

Source: http://www.portoffelixstowe.co.uk/fsr/application/documents.htm

Figure 6.18 Location of Major Ports and Deep Dredged Channels in the Outer Thames Estuary



Box 6.4 Bathside Bay

The new Harwich International Container Terminal at Bathside Bay in Harwich, also received planning permission in 2006, which will use the same deep-water approach channel as the Port of Felixstowe. Permission is still needed for the required upgrade to the A120. The consultation process was put on hold in August 2009; until this is completed the project will not progress.

The new container port has the following principal components;

- engineering and reclamation works including construction of a cofferdam and quay wall with 11 rail-mounted quayside cranes;
- construction of a concrete block-paved container handling and stacking facility with 44 rubber Tyre Gantry cranes;
- a new rail terminal to link existing rail facilities with the cranes;
- site works including hardstanding, landscaping and mounding; and
- approach channel of 14.5 metres below CD shared with the Port of Felixstowe.

Source: http://www.hict.co.uk/content/theapplication/intro.asp

London Gateway

On the 30th May 2007, the government gave the go-ahead for a £1.5bn container port in Thurrock. The London Gateway container port is the UK's first new deep sea container port for over 25 years and will change the way millions of consumer goods are transported around the country (Central Dredging Association, 2008). Box 6.5 summarises the proposals.

Despite the proposed port being located outside the MAREA study area, shipping movements may take place within the within the vicinity of marine aggregate extraction areas, and a large scale dredging project is planned in order to lower the channel and enable access to the terminal by larger container ships. The majority of dredging will take place within the inner 30km stretch, but some areas of seabed over a distance of 100km will be lowered by 0-2m (Central Dredging Association, 2008). The location of the proposed channel is shown in Figure 6.18. The yellow boxes indicate areas of the channel where dredging will be employed to achieve the required depth. According to the plans, the full extent of each yellow area will not be dredged (DP World London Gateway, 2009). Table 6.6 gives an approximation of the proportion of each area in which dredging will occur:

Table 6.6 Proportion of Dredging in each Area according to London Gateway Plans

Area	Approximate Proportion to be Dredged
Area 1	95%
Area 2	70%
Area 3	10%
Area 4	75%
Area 5	50%
Area 6	60%
Area 7	5%

Box 6.5 London Gateway

The London Gateway Port and Logistics Park is a £1.5 billion major infrastructure project located on a 1500-acre brownfield site at the former Shell Haven oil refinery in Thurrock. The Government granted consent for the schemes in May 2007. The Harbour Empowerment Order (HEO) was received in May 2008, and the main construction contract was awarded in August 2008. Work on the dredging and reclamation phase of the project began in early 2010; however, there is uncertainty about when building work will begin and when the port will be fully operational..

The proposals include;

- a 2.3km container quay with a fully developed capacity of 3.5 million TEU (standard container units) a year;
- 580 acres of logistics park which will save 2,000 trucks from the UK's roads everyday;
- a dredging project to enable access to the terminal; the current channel will have to be lowered and re-routed in some places to avoid wrecks designated under the Protection of Wrecks Act; and
- major improvements to the road and rail network in Essex, including enhancing the A13 and M25.

Source: http://www.londongateway.com, http://www.dredgingtoday.com/2010/05/28/london-gateway-port-fishermen-concerned-over-river-thames-dredging (accessed 2nd August 2010)

6.3.4 Marine Disposal Sites

Disposal at sea is granted under a FEPA licence issued by the Marine Management Organisation.. The OSPAR convention in 1992 prohibited disposal at sea subject to certain exemptions. In addition the offshore disposal of sewage sludge ceased in 1998 when it was banned in compliance the Urban Waste Water Treatment Directive. Since then, offshore disposal has significantly decreased and the bulk of material eligible for sea disposal now comes from dredging operations, particularly those associated with developing and maintaining ports and navigation channels, and coastal engineering projects.

There are a number of active and historic disposal sites in the Thames estuary, including four active and two redundant offshore sites located within the MAREA study area (see Figure 6.19) (1). Prior to 1998, sewage sludge disposal and dredge spoil disposal occurred at the Roughs Tower dumping ground located less than 20 km offshore from Harwich. More recently Roughs Tower has been used for the dumping of considerable quantities of fine sediment and clay from dredged channels such as the Harwich Harbour deepening. There is also a former dumping ground for munitions adjacent to the Roughs Tower site in the Kings Channel, and another disused site located approximately 20 km north of the Inner Gabbard sand bank. The latter is being used during the redevelopment of the Port of Felixstowe, with a predicted 140,000 m^3 of mud and 2.96 million m^3 of stiff clay, sand, gravel and rock to be deposited between 2008 and 2014 (Royal Haskoning, 2003) and (Port of Felixstowe) (2).

A license for disposal of waste at sea is only issued by DEFRA where it can be shown that the material is not seriously contaminated and will not harm the marine environment, and sites are subject to periodic monitoring by CEFAS.

6.3.5 Offshore Wind Farms

The UK has one of the largest wind resources in Europe (40% of Europe's total potential) (BWEA, 2007) and therefore the development of wind power in the UK is recognised as being one of the key means of meeting the Governments emissions targets.

A number of wind farm schemes have been proposed in the MAREA study area. The Kentish Flats Round 1 wind farm is situated to the south of the MAREA study area and has been operational since September 2005. The Gunfleet Sands I wind farm received approval in August 2008 and became operational in spring 2010 (3).

There are four approved Round 2 wind farms within the MAREA study area; the Thanet array, the London Array (phase 1), Gunfleet Sands II and the Inner Gabbard and Galloper arrays of the Greater Gabbard development (4). The Greater Gabbard development will be the first UK project located in international waters (beyond the 12 nautical mile limit) (5) and at 1000MW (megawatts), the London Array will be the largest offshore wind farm in the world (6). Table 6.7 lists the details of these developments, and Figure 6.20 shows the wind farm locations in relation to existing dredging licence areas.

In December 2007, John Hutton, Secretary of State for Business Enterprise and Regulatory Reform announced the commencement of a Strategic Environmental Assessment (SEA) to examine 25GW (gigawatts) of additional UK offshore and wind energy generation by 2020, following on from the 8GW planned for Rounds 1 and 2. The Crown Estate subsequently announced the proposal for a third round of offshore wind farm leasing in June 2008.

The key principle underlying Rounds 1 and 2 was the robust selection of parties to develop, construct, finance and operate designated offshore wind projects. This is being carried forward into Round 3 with the addition of the concept of zonal development. The Crown Estate has awarded 9 zones (7) for Round 3 offshore wind sites with a total targeted capacity of 25GW.

Although there is the potential for more than one offshore wind site per zone, the approach for the Round 3 offshore wind sites was to award a single Partner Company for each Development Zone through a competitive tender process. The Partner Company will be able to exclusively develop each Development Zone with The Crown Estate, who will co-invest with the contracted Partner up to the point of achieving consents for wind farms. Part of the current boundary of Zone number 5; the 'Norfolk Zone' is situated within the MAREA study area, approximately 11.5km from the North Inner Gabbard prospecting licence area (see Figure 6.21) (8). Scottish Power Renewables were awarded the contract to develop the Norfolk Zone in January 2010.

(1) This figure does not show the numerous inshore disposal sites along the coast and associated with rivers which can be viewed at http://www.mfa.gov.uk/environment/works/documents/dsite_s.pdf (accessed 26/03/09).
(2) Port of Felixstowe. 2008. News Release 'Port of Felixstowe Expansion Commences' May 2008. Available at: http://www.portoffelixstowe.co.uk/portdevelopment/FSR/
(3) DONG Energy. About Gunfleet Sands http://www.dongenergy.com/Gunfleetsands/GunfleetSands/AboutGFS/Pages/default.aspx (accessed 2nd August 2010)
(4) The British Wind Energy Association (BWEA). 2009. Website available at http://www.bwea.com/ (accessed 26/01/09).
(5) Greater Gabbard Offshore Winds Limited. 2009. Available at http://www.greatergabbard.com/ (accessed 29/01/09).
(6) London Array Limited. 2009. Available at http://www.londonarray.com/ (accessed 29/01/09).
(7) The Crown Estate http://www.thecrownestate.co.uk/70-interactive-maps-r3
(8) The Crown Estate. 2009. http://www.thecrownestate.co.uk/round3_map-3.pdf (accessed 26/01/09).

Figure 6.19 Known Dumping Grounds in the Outer Thames Estuary

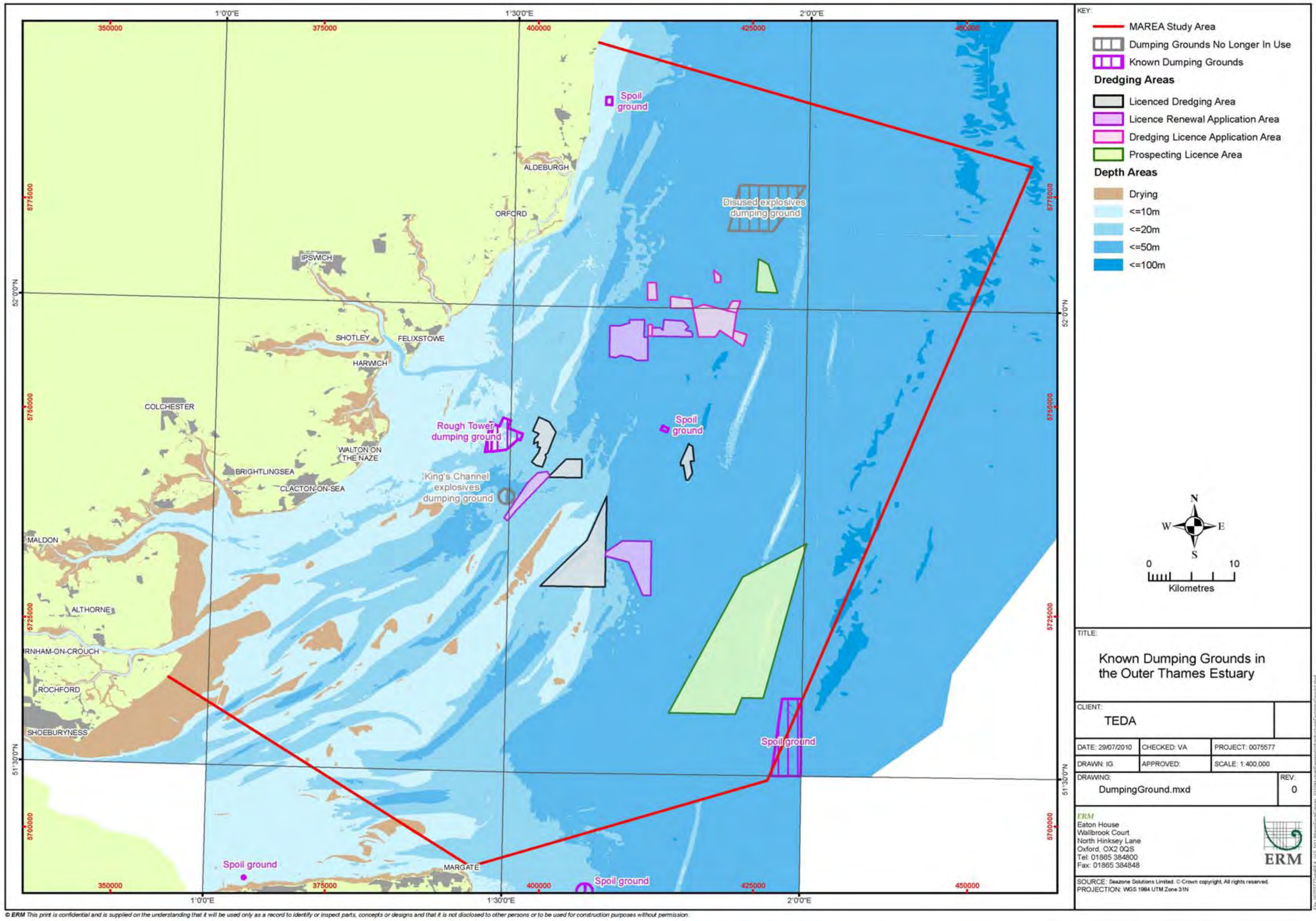


Figure 6.20 Licensed Wind Farm Sites in the Thames Estuary

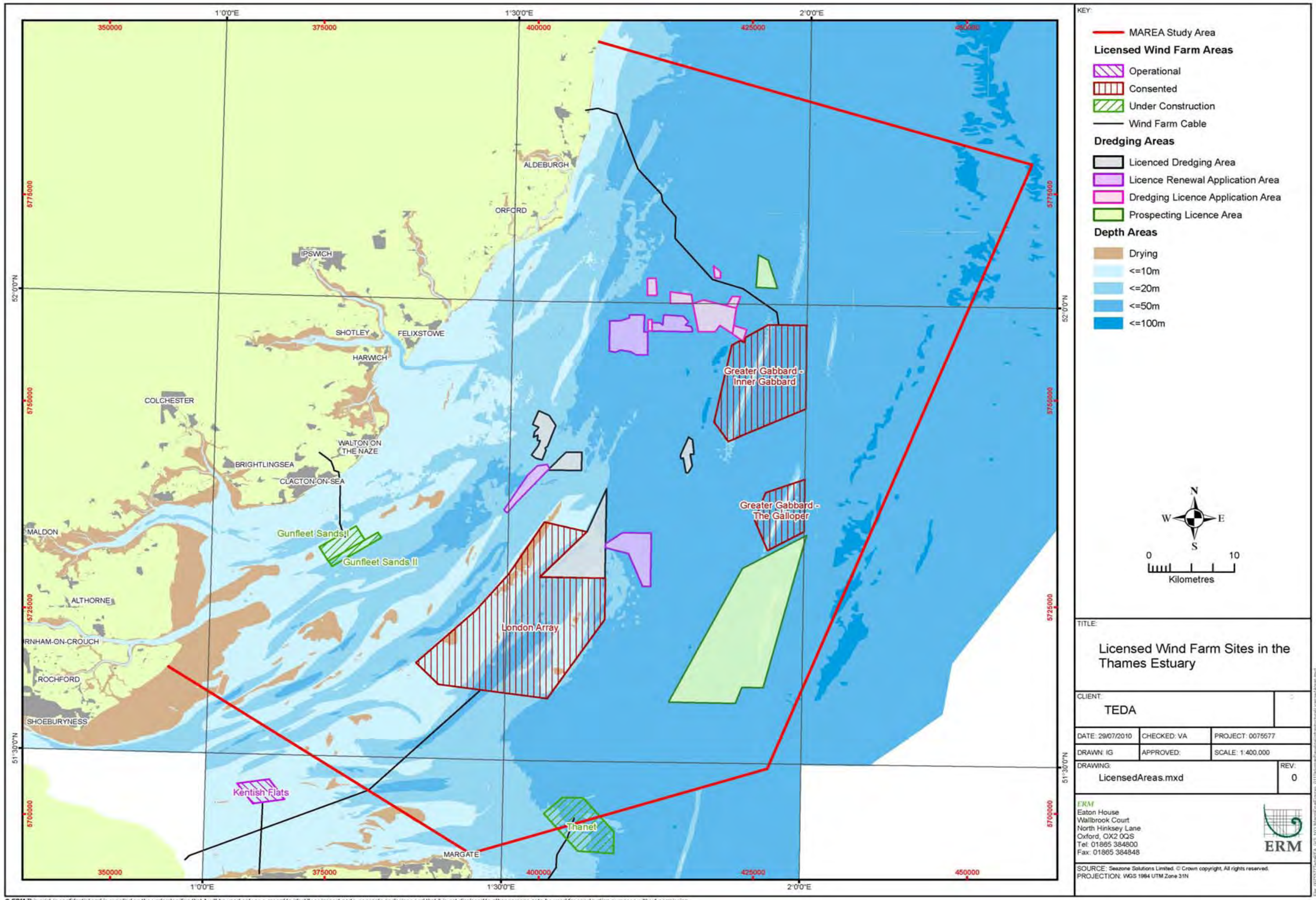


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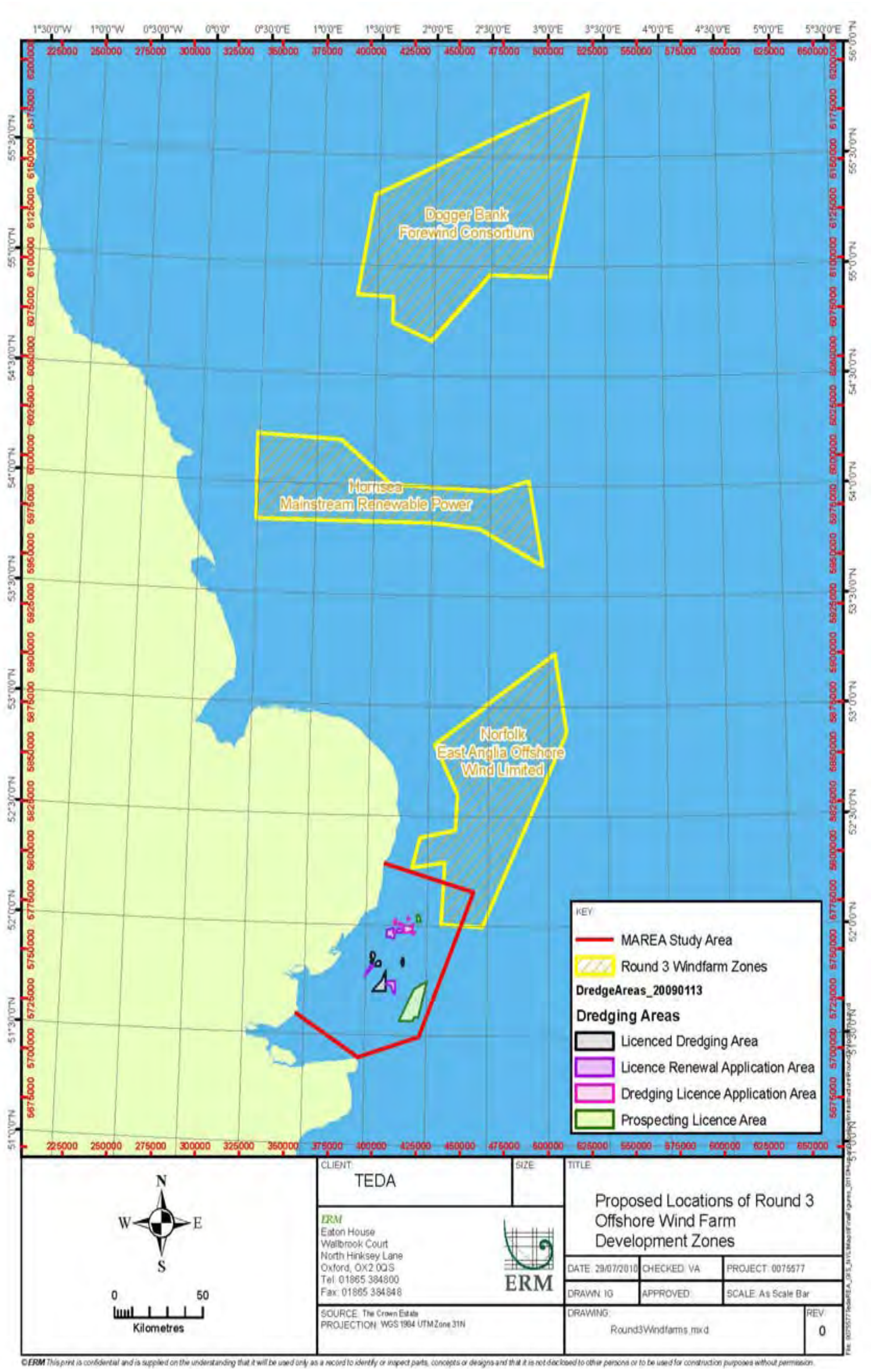
Table 6.7 Round 1 and Round 2 Offshore Wind Farms in the MAREA Area

Round	Status	Date	Wind Farm	Location	Power (MV)	Turbines	MW Capacity	Annual Homes Equivalent	Developer	Operator	Owner
1	Operational	Online July 2005	Kentish Flats	Kent	3	30	90	50323	Elsam	Vattenfall	Vattenfall
1	Operational	Approved April 2008	Gunfleet Sands I	Essex	3.6	30	108	60388	DONG Energy	-	DONG Energy
2	Operational	Approved April 2008	Gunfleet Sands II	Essex	3.6	18	64	35786	DONG Energy	-	DONG Energy
2	Under construction	Approved September 2008	Thanet	Kent-	3	100	300	240000	Warwick Energy	-	Vattenfall
2	Under Construction	Approved February 2007	Greater Gabbard	Suffolk	3.6	140	504	530000	Scottish and Southern Energy/npower (UK)	-	Scottish and Southern Energy/npower (UK)
2	Consented	Approved December 2006	London Array	Kent & Essex	Phase 1: 3.6 Phase 2: -	Up to 341 Phase 1: 175 Phase 2: -	1000	750000	DONG Energy/E.ON/Masdar.	-	DONG Energy/E.ON/Masdar.

Figure 6.21 Proposed Locations of Round 3 Offshore Wind Development Zones



6.3.6 Pipelines and Cables

There are a number of pipeline outfalls along the coastline within the MAREA study area; however no submarine pipelines traverse the estuary.

A number of subsea cables dissect the region, which are listed in Table 6.8. The growth in internet use and e-commerce has resulted in a dramatic increase in data transmission over the last decade, and cable numbers have increased with many now traversing the North Sea to link the UK with mainland Europe.

Table 6.8 Submarine Cables in the MAREA Area

Operator	Cable	Type	UK landfall
Interoute	Concerto 1N	Telecom	Sizewell
Interoute	Concerto 1S	Telecom	Thorpenss
Global Telesystems	Hermes North	Telecom	Aldeburgh
BT	Farland	Telecom	Aldeburgh
KPN Telecom BV	Rembrandt 2	Telecom	Margate
Global Telesystems	Hermes South	Telecom	Broadstairs
Global Crossing	Pan European Crossing (PEC)	Telecom	Broadstairs
Level 3 Global Submarine	Tangerine	Telecom	Broadstairs

One cable at Sizewell, two at Aldeburgh and one at Margate connect the UK with the Netherlands, and a further three at Broadstairs, and one at Thorpeness connect the UK with Belgium. In addition, a trans-Atlantic cable originating in the Netherlands, traverses the region south of Lowestoft, and runs along the Kent coast in a south westerly direction into the English Channel (1) (see Figure 6.22). The BritNed power cable – the first electricity interconnector between the UK and the Netherlands, is expected to be operational by 2011 and will landfall on the Isle of Grain in Kent and Maasvlakte in the Netherlands (2).

In general, the majority of cables in the southern North Sea are trenched to a depth of 40-90cm, with rock-dumping being used to anchor cables in some instances. The older, redundant cables are more likely not to be trenched (3).

(1) Kingfisher Cable Awareness Charts: South North Sea. Issue 11 – January 2009. Available at http://www.kisca.org.uk/charts.htm (accessed 28/01/09).
(2) BritNed 2008. http://www.britned.com (accessed 22/10/09).
(3) DECC (formerly DTI). 2002. Human Activities in the SEA 3 Area. Available at: http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).

6.3.7 Military Activity

Information relating to military activity in the region comes from Practice and Exercise Areas (PEXA) charts produced by the UK Hydrographic Office. These charts show the sea areas around the UK coast which are in use or available for use by the Ministry of Defence for practice and exercises, with or without the use of live ammunition.

The study area encompasses a range of Military and Navy submarine exercise and practice areas (see Figure 6.23). There are also a number of small land-based firing ranges.

It is also important to consider the military activity that has taken place historically in the region (4). During World War II German aircraft regularly attacked shipping areas, particularly in the Thames estuary. Many of the devices that were dropped failed to explode. In addition, defensive minefields situated at the Galloper sand bank and Dover strait, and the East coast barrier minefield, would have contained hundreds of buoyant mines, many of which may have become separated and drifted away with the current, in some cases flooding and settling to the seabed.

For safety reasons all allied aircraft returning from raids on Germany dropped their remaining bombs into the sea before landing at the airfields along the East coast. Three offshore designated dropping zones are situated seaward of Felixstowe, Sales Point and Leysdown-on-Sea.

There are also six wartime offshore artillery ranges at Felixstowe, Harwich, Sales Point, Foulness Island, Isle of Grain and Leysdown-on-Sea, which may have resulted in metal contamination within the range of firing (up to approximately 155 mm).

6.3.8 Oil and Gas Exploration

Within the Thames estuary there is significant oil and gas infrastructure including oil terminals, storage facilities and a tanker terminal. However within offshore areas there are no producing oil and gas fields and no oil or gas pipelines (5).

(4) London Array Limited. 2005. London Array Environmental Statement, Volume 1: Offshore Works. Prepared by RPS Energy.
(5) DECC (formerly DTI). 2002. Human Activities in the SEA 3 Area. Available at: http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).

Figure 6.22 Pipelines and Cables in the Vicinity of the MAREA Study Area

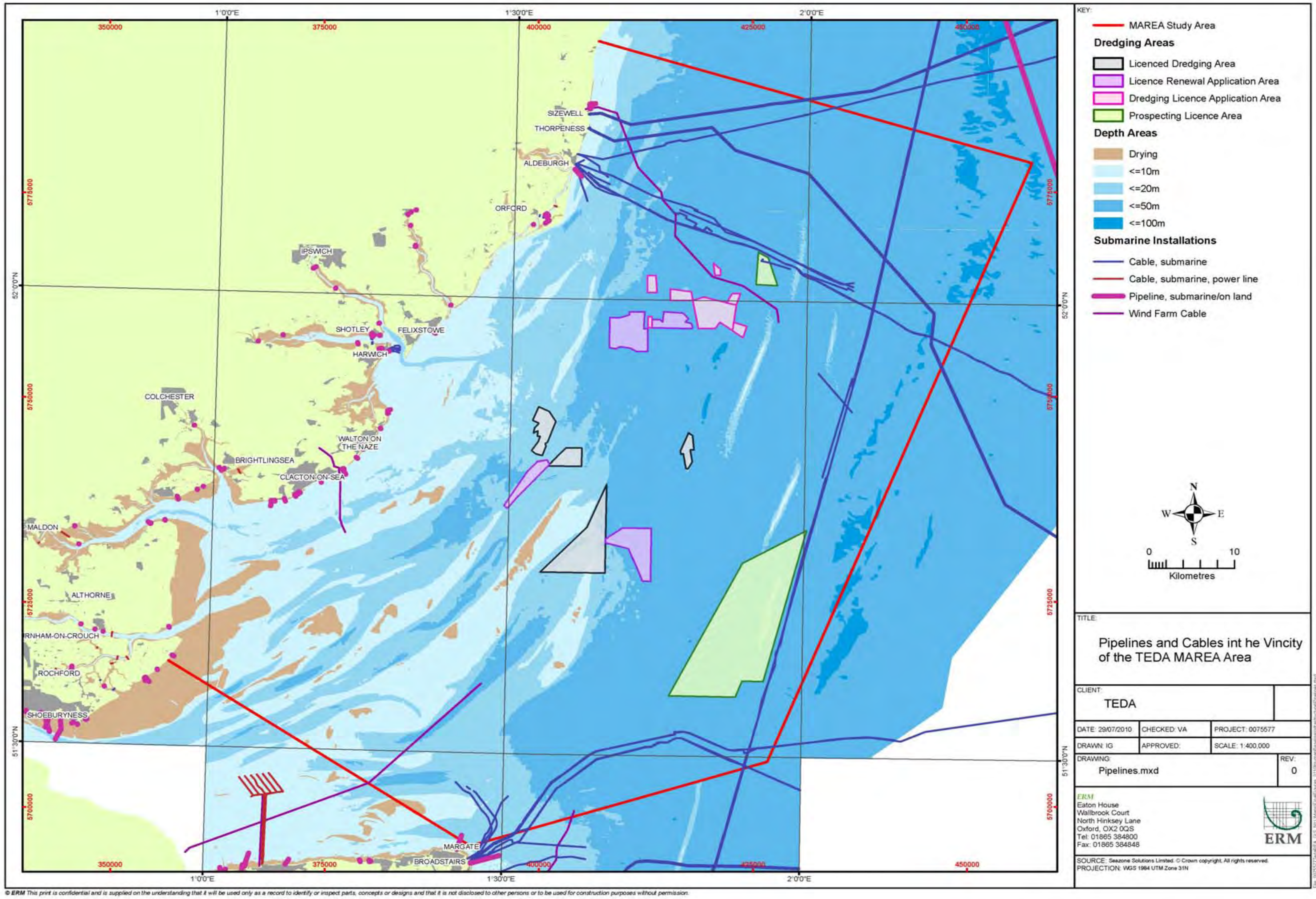
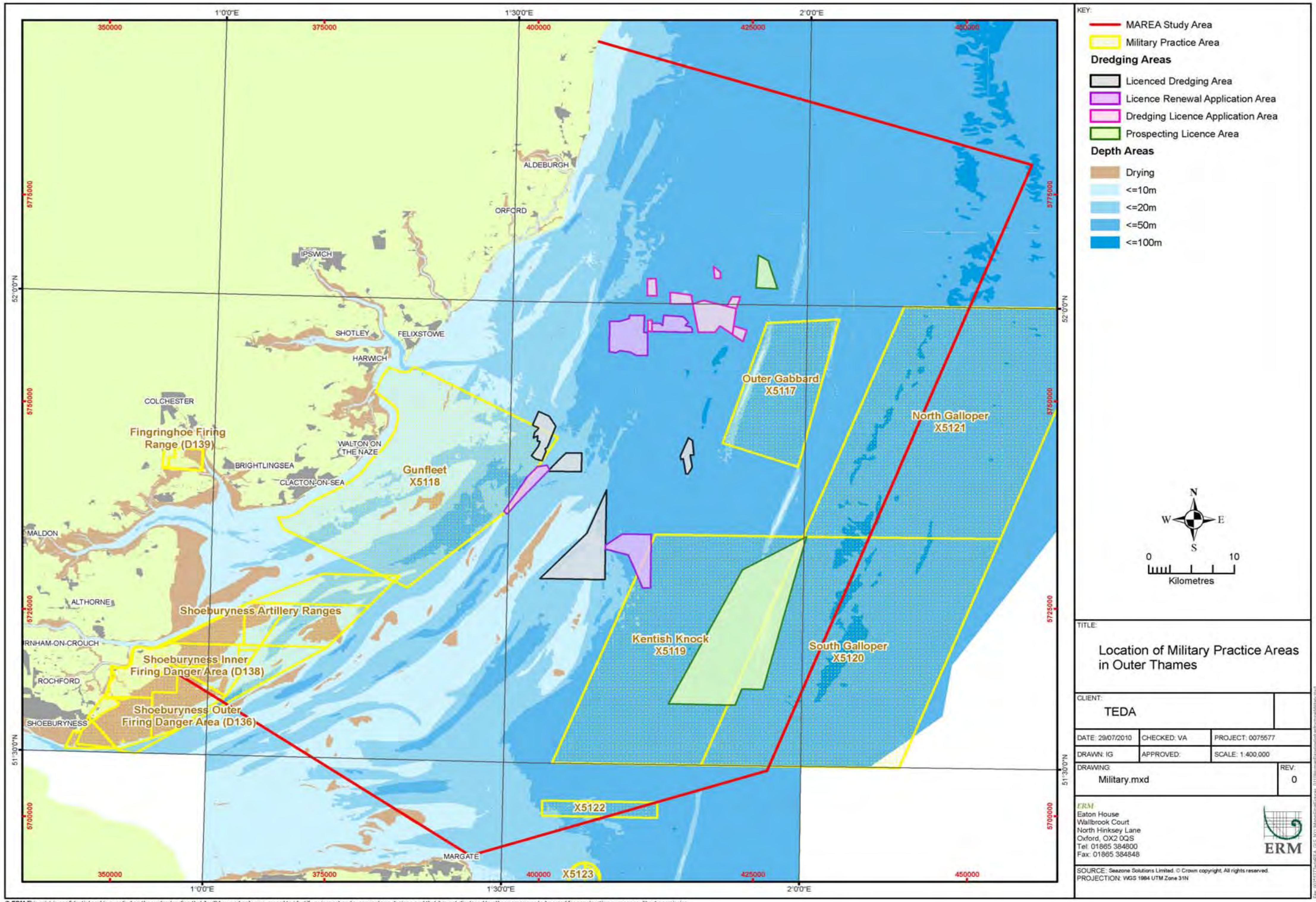


Figure 6.23 Location of Military Practice Areas in Outer Thames



6.4 MARINE RECREATION

6.4.1 Introduction

The Thames Estuary is used by considerable numbers of recreational sailing and motorised vessels, and is one of the most intensively used areas in the UK for training, pleasure cruising and racing. In comparison to sailing and cruising, other recreational activities such as sea angling from boats and diving are limited. Sea angling is known to occur, and support a small industry that exists mainly as a secondary source of income for small fishing vessels. Recreational sea angling is considered further within Section 6.2.

Although there are a number of wrecks in the Thames Estuary, recreational diving is limited due to the poor underwater visibility in estuarine waters and the high levels of shipping traffic. Popular dive sites offshore, such as wrecks, are largely either to the north of the REA study area, off the North Norfolk coast, or to the south, off the East Kent coast (1). Therefore, recreational diving is excluded from the scope of this REA and is not considered further.

There are also a number of sites of importance for recreation along the coastline within the MAREA study area, particularly along the north Kent coast and within the inner Thames estuary; however all the aggregate areas are greater than 12km away from the coastline and these recreational areas will only be affected by dredging if there are any impacts to the coastline itself. Coastal features are described in Section 4.3, and any potential impacts to the coast from dredging operations are assessed in Section 8.3.

Therefore, the areas covered in this chapter are key sailing and racing areas (Section 6.4.3), long distance offshore cruising routes (Section 6.4.4) and recreational clubs and marinas (locations are linked to the locations of sailing and cruising areas) (Section 6.4.5).

6.4.2 Sources of Information

Information relevant to this chapter was obtained primarily from the following organisations:

- Royal Yachting Association (RYA);
- Cruising Association;
- Royal Ocean Racing Club; and
- East Anglian Offshore Racing Association.

As much of the recreational use of the REA study area is informal in nature, it follows there is little quantitative data available to inform the baseline, and consequently much of the interpretation that follows is qualitative in nature, involving the examination of maps and reports of sailing and yachting activity, and consultation with the RYA and Cruising Association.

A primary source of information was the RYA's UK Coastal Atlas of Recreational Boating, which provided maps of RYA clubs, training centres and marinas, sailing and racing areas, and inshore and offshore cruising routes.

As much of the REA study area is also an Offshore Wind Farm Strategic Area, the RYA's report Sharing the Wind: Recreational Boating in the Offshore Wind Farm Strategic Areas was also reviewed for relevant information.

Research on offshore racing was based upon publically available information from organisations such as RORC (Royal Ocean Racing Club) and EAORA (East Anglian Offshore Racing Association), which co-ordinate much of the racing activity in the REA study area.

6.4.3 Key Sailing and Racing Areas

Introduction

The Thames Estuary is an important area for recreational boating on both a regional and national scale. Regionally, the Thames Estuary is located in the densely populated south east of England and is one of the primary areas of recreational water available other than inland lakes and rivers. As discussed in Section 6.4.5, there are many boating clubs and marinas located along the coast of the REA study area, and use of the estuary can be considered to be spatially widespread and varied in terms of the type of usage.

On a national scale, for recreation, the Thames Estuary is the most densely used area on the east coast of the UK and the second most significant area in the country exceeded only by the Solent on the South Coast (2).

In this section, 'recreational boating' is considered to include training and recreational cruising close to shore, whilst 'racing' considers both local inshore racing within the Thames Estuary, and longer distance offshore races to destinations on the Continent and elsewhere within the UK. Recreational cruising over longer distances is considered separately in Section 6.4.4.

Recreational Boating

Recreational boating in the Thames Estuary is widespread and consists of a range of activities including:

- canoeing and sail-boarding in the creeks and minor rivers;
- dinghies and other small boats in all rivers and offshore all coasts to about 25 kilometres;
- cruiser passage-making, both power and sail, between all combinations of shore facilities;
- cruiser day-sailing, both power and sail, in all coastal areas;
- personal watercraft (popular but limited to certain areas inshore only);
- practical sail training (extensive and based out of most large marinas); and
- visitors from Scandinavia, The Netherlands and the south coast of England

Recreational boating in the REA study area has been assessed by using maps provided by the RYA showing 'key sailing areas', defined as '*areas in extensive use for general day-sailing by all types of recreational craft but particularly smaller craft such as small cruisers, day-boats, dinghies, sailboards and personal watercraft. Such craft will not normally be undertaking point-to-point passages but will be on out and return activities*'.

Within the REA study area, key sailing areas have been identified as extending from Orford to Felixstowe, Harwich to Brightlingsea and the River Colne, over Gunfleet Sands and Buxley Sands to Burnham-on-Crouch (Figure 6.24). All of the key areas are close inshore, and do not intersect any of the existing dredging licence areas. They also avoid the busy commercial shipping lanes on the approach to the ports of Harwich and Felixstowe.

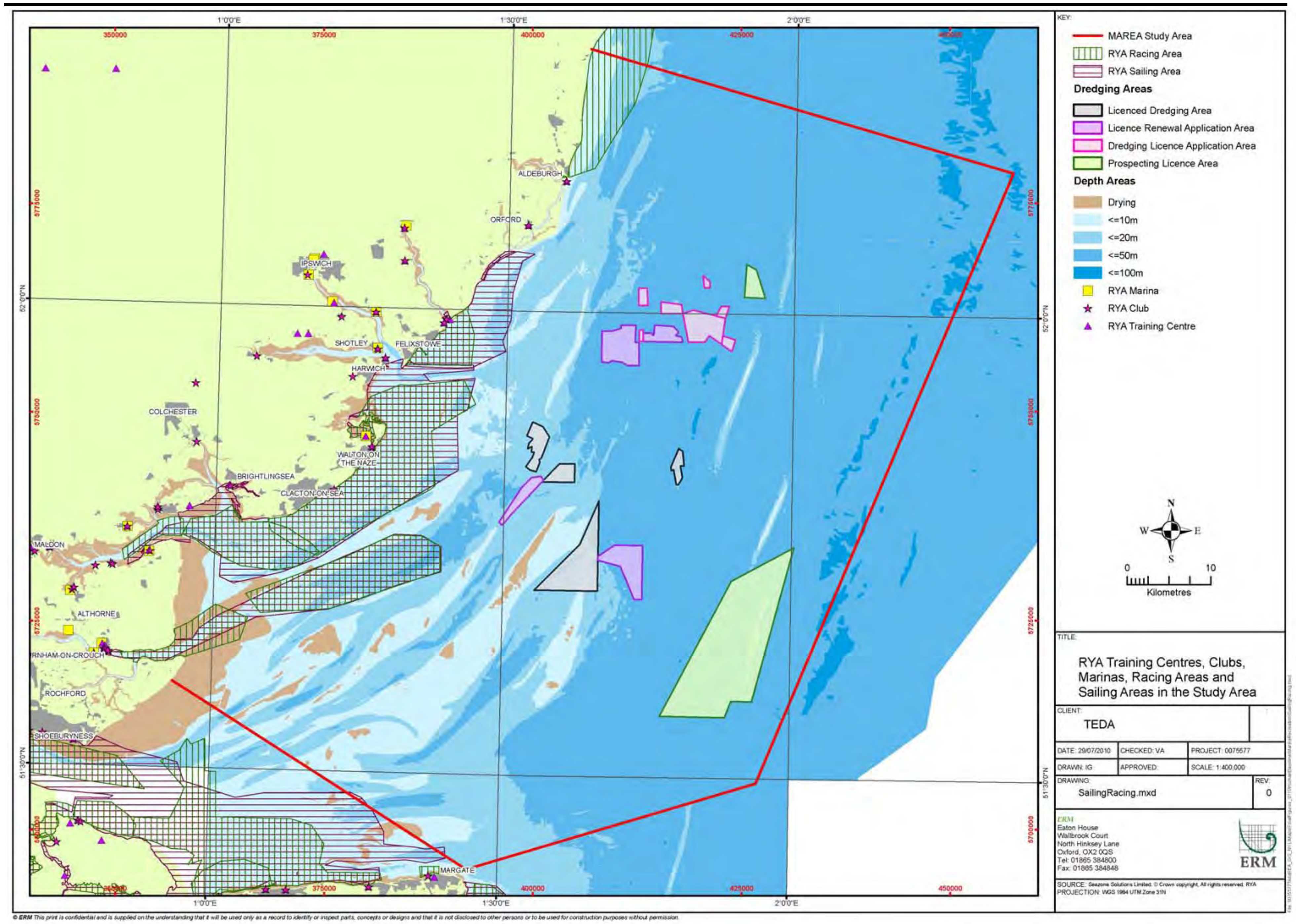
Inshore Racing

Maps provided by the RYA show that 'key racing areas' are defined as '*areas in frequent use, particularly at weekends and holiday periods, by large numbers of racing craft normally under sail but also power. Such areas are generally under the control of nearby Sailing Clubs and may contain temporary or permanent race course marking buoys*'. Key racing areas are largely constrained to those areas described above as 'key sailing areas' for recreational boating (Figure 6.24). The majority of small sailing club races or regattas are conducted close inshore, in small river estuaries or along beaches, and do not venture far enough from the coast to enter areas used for dredging.

(1) British Sub Aqua Club, http://www.bsac.com/divelocations.asp?section=1251&sectionTitle=UK Accessed 11/12/09.

(2) Royal Yachting Association and Cruising Association, 2004, *Sharing the Wind: Recreational Boating in the Offshore Wind Farm Strategic Areas*, http://www.rya.org.uk/NR/rdonlyres/9177A238-B7FC-44F6-AA4A-B4614B0B8625/0/SharingtheWindcompressed.pdf Accessed June 2008

Figure 6.24 RYA Training Centres, Clubs, Marinas, Racing Areas and Sailing Areas in the Study Area



Therefore, only races that take place out into the main estuary are considered. EAORA organises races off the East Anglian coast between April and September each year. For the 2010 season, a total of seven races are planned, of which five start and finish within the Thames Estuary, and a further two start or finish in the estuary. Common start/finish locations include Burnham-on-Crouch and West Mersea, with Medway and Harwich also occasionally being used. Races within the estuary are typically one-day events held at weekends, using navigation aids such as buoys and light ships as turning points around the course.

Offshore (Long Distance) Racing

EAORA have planned three long distance races for the 2010 season, and as most races are repeated on an annual basis it is assumed that this provides a representative picture of offshore racing in a typical year.

Long distance races are typically from West Mersea, Burnham-on-Crouch or Harwich to destinations in Belgium and The Netherlands such as Scheveningen and Ostend, lasting one to two days. Therefore, the majority of the racing routes are outside the REA study area and associated dredging areas, and pass through busy commercial shipping channels. Further information on commercial shipping and navigation is provided in Section 6.5

6.4.4 Cruising Routes

Introduction

Cruising is a popular recreational activity in the REA study area, with the continent a relatively short distance away. The RYA has defined cruising routes as falling into three categories:

- **Heavy usage** – very popular routes on which at least six or more recreational vessels will probably be seen at all times during summer daylight hours. These also include the entrances to harbours, anchorages and other places of refuge.
- **Medium usage** – popular routes on which some recreational vessels will be seen at most times during summer daylight hours.
- **Light usage** – routes known to be in common use but which do not qualify for medium or heavy usage status.

Cruising routes can further be described as either passing through the REA study area, originating/terminating in the study area, or being contained entirely within the study area. Further information on commercial shipping and navigation is provided in Section 6.5.

Routes Passing through the Study Area

Vessels passing through the area are inevitably on long passages. To the south, the nearest all-weather havens are Ramsgate, Dover and Calais. To the north, there is no reliable refuge nearer than Lowestoft or Yarmouth. Yachts on these passages will generally wish to follow a straight line outside all sandbanks to or from Orford to a position either inshore at North Foreland or outside of the Goodwin Sands or to the Sandettie area. It is therefore unlikely that many of these routes would intersect dredging licence areas.

Routes Originating/Terminating in the Study Area

Information provided by the RYA show routes of 'medium' usage extending from the REA study area to Vlissingen in The Netherlands, the French/Belgian border and small towns on the French coast between Calais and Dunkerque, as shown in Figure 6.25. Routes of 'light' usage also extend to Rotterdam, whilst all of the 'heavy' usage routes are within UK waters, mainly between harbours in the Thames Estuary, and also around the Kent coast and along the English Channel. Some caution should be applied to the interpretation of routes shown on maps, since sailing vessels behave differently to powered vessels as their actual line of travel may zig-zag across the mapped line of travel due to their dependence on wind direction. Yachts entering the Thames Estuary from the east also have to pass through the Sunk TSS in conjunction with commercial vessels on approach to the major ports in the area, so any encounters with dredging vessels will be insignificant in comparison.

Routes Entirely within the Study Area

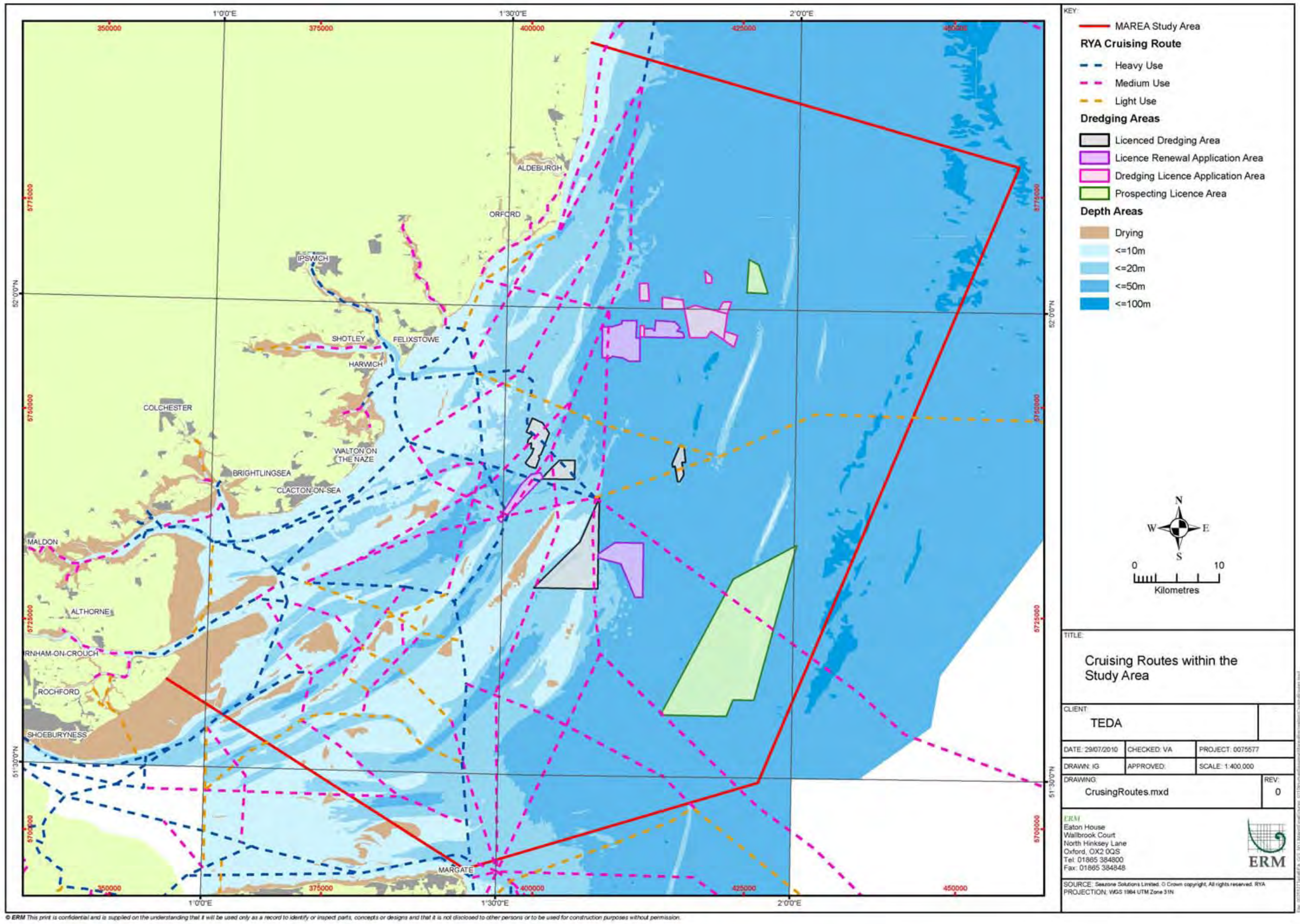
During a normal summer sailing season there is considerable yacht traffic between every combination of origin and destination in the rivers and estuaries of the REA study area, although no statistics of usage are available. Amongst important passages in the area are:

- Ore and Deben to Thames, Medway, Swale and Ramsgate;
- Harwich and Walton to Thames, Medway, Swale and Ramsgate;
- Colne, Blackwater and Crouch to Ramsgate;
- Thames and Medway to Harwich;
- Swale to Walton and Harwich; and
- Ramsgate to all except Thames, Medway and Swale.

Each passage presents a wide variety of routing options and it is not possible to generalise the optimum routes most likely to be followed.

On a national scale, it can be considered that the Thames Estuary is one of the most heavily used areas for recreational cruising, although some other areas of water, such as the Solent, are still more popular.

Figure 6.25 Cruising Routes within the Study Area



6.4.5 Marine Recreational Clubs and Marinas

Clubs

Clubs are defined by the RYA as '*membership organisations affiliated to the RYA. Each tends to specialise in certain types of activity – for example dinghy racing, sail cruising, power-boating, but all are normally open to passing visitors. The facilities provided usually include both alongside berths and swinging moorings but shore facilities are not normally to expected commercial standards*'.

It is estimated that there are approximately 92 clubs in the Thames Estuary area, of which approximately 25 are coastal RYA clubs within the REA study area. Membership of the RYA in the Thames Estuary and adjacent regions (which could reasonably be expected to use the area) is approximately 55,000, and some 30% of Cruising Association members live within 65 kilometres of the area. Individual clubs will vary in the precise nature of recreational activity that they offer, with information on the main types of activities at each club available from the RYA.

Training Centres

The RYA has defined marine training centres as '*teaching institutions providing practical and theoretical training in sailing and power boating to recognised RYA standards. Those located on the coast will normally have marina-type boat berths attached which are in use throughout the year*'.

There are believed to be approximately 73 RYA training centres in the Thames Estuary area, of which approximately 10 are coastal and located in the REA study area.

Marinas

Marinas are defined by the RYA as '*commercial marinas, where most berth-holders will be permanently based at that marina but most also have a high proportion of visitor berths available for passing craft. Most have a full range of yachting facilities such as chandlers and repair shops and should be regarded as primary ports of origin and destination for all recreational crafts routes*'.

Of the 14 formal marinas in the Thames Estuary area, two are coastal RYA marinas in the REA study area, and the remainder are assumed to be private or commercial marinas. It is estimated that there are a total of approximately 6,900 marina berths, and a further 22,500 less formal moorings.

It is considered that the RYA data do not represent all recreational clubs, training centres and marinas, since there will be a considerable number that are not registered with the RYA and hence do not appear in its data. It should therefore be noted that the numbers presented are likely to be an underestimate. This will be highlighted in the assessment of impacts to marine recreation.

6.5 SHIPPING AND NAVIGATION

6.5.1 Introduction

This section presents a baseline review of shipping and navigation activities in the Outer Thames, and identifies the navigational risks throughout the region. Baseline vessel movements are principally related to shipping, fishing and recreational activities. The potential for ship-to-ship encounters and collisions is discussed, based on modelling carried out by Anatec UK Limited.

6.5.2 Sources of Information

The main sources of information used to compile this review include:

- RYA and Cruising Association report *'Sharing the Wind: Recreational Boating in the Offshore Wind Farm Strategic Areas'*.
- Environmental Statement for the London Array (2005) (RPS Energy, 2005).
- UKHO Admiralty Charts.
- Automatic Identification System (AIS) data – 40 days (10th April – 22nd April 2008).
- CEFAS (Centre for Environment, Fisheries and Aquaculture Science) fishing vessel sightings.
- CEFAS fishing vessel satellite tracking data January 2004 to December 2007.
- MAIB (Marine Accident Investigation Branch) incident data 1994-2008.
- RNLI lifeboat response data 1998-2007.
- Anatec ShipRoutes database.
- Anatec COLLRISK model.

6.5.3 Navigational Features

The main navigational features in the vicinity of the MAREA study area are the Sunk Traffic Separation Scheme (TSS) and various anchorage areas (Figure 6.26 and Figure 6.27). Traffic Separation Schemes are the only internationally agreed compulsory routing measures, agreed through the International Maritime Organisation (IMO), and notified to and observed by the ships of all nations.

Within the MAREA study area, the Sunk Traffic Separation Scheme (TSS) is centred approximately 18 nm to the east of Landguard Point near Felixstowe. The IMO has also recommended the use of certain routes in particular areas for example for ferries heading in/out of the Sunk TSS.

Precautionary Areas including Sunk Inner/Outer and Fisherman's Gat are areas where care should be exercised due to manoeuvring traffic entering or leaving from opposing shipping routes. For the Sunk Precautionary Areas caution is advised as vessels may be embarking or disembarking pilots and shipping can also be constrained by draught. Advice on shipping movements in the Fisherman's Gat Precautionary Area can be gained from London Vessel Traffic Service (VTS) on Very High Frequency (VHF) Radio, while VHF channel 14 should be monitored for the Sunk Precautionary Areas.

To the northwest of the Sunk TSS there is the Sunk Deep Water (DW) Anchorage which is used by large vessels bound for Felixstowe. There are also several small anchorage areas to the south at Barrow Deep, Shivering Sands, and a DW Anchorage approximately 7 nautical miles to the north of Margate.

Figure 6.26 Navigational Features in the Thames Study Area

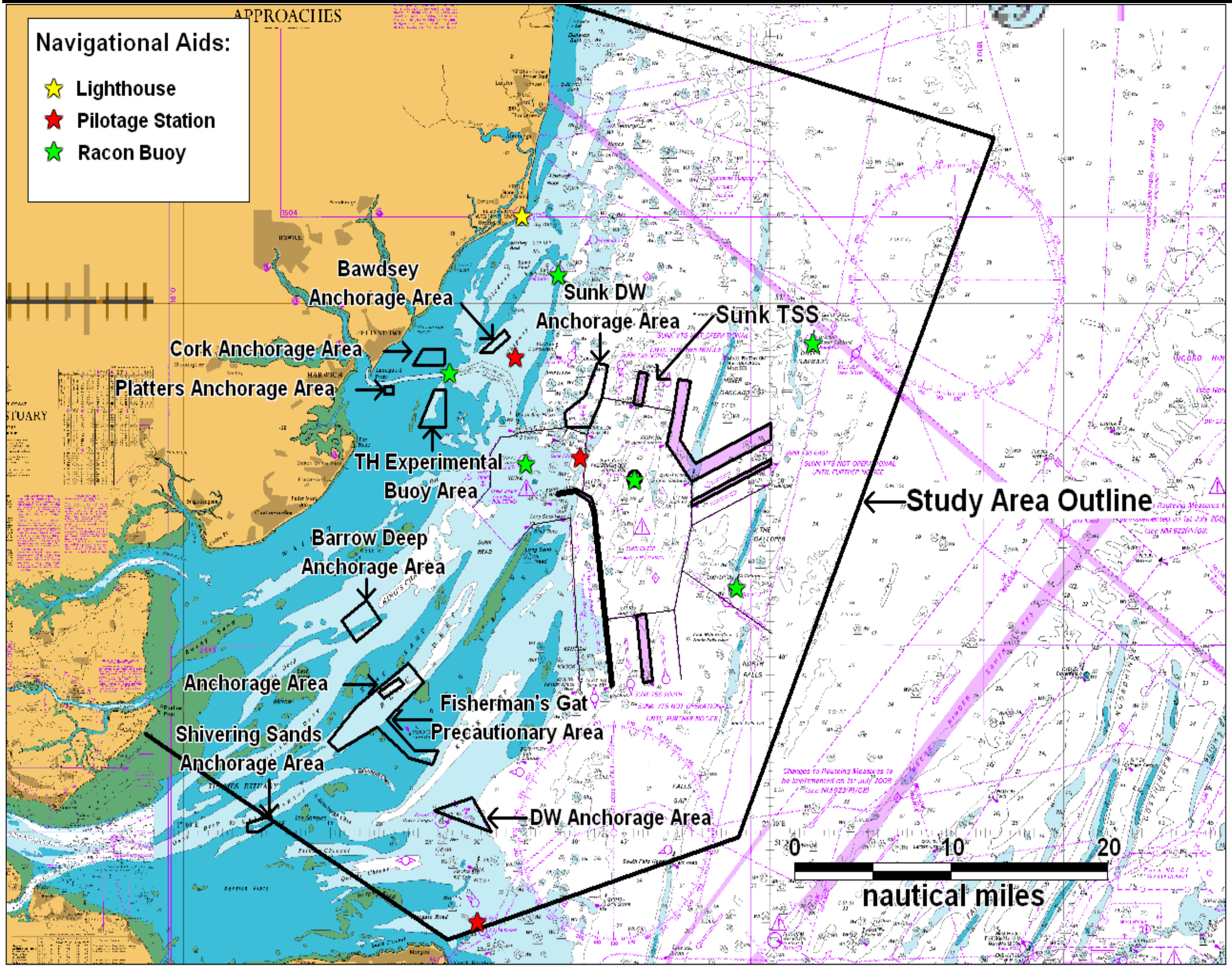


Figure 6.27 Detailed Navigational Features relative to Sunk TSS

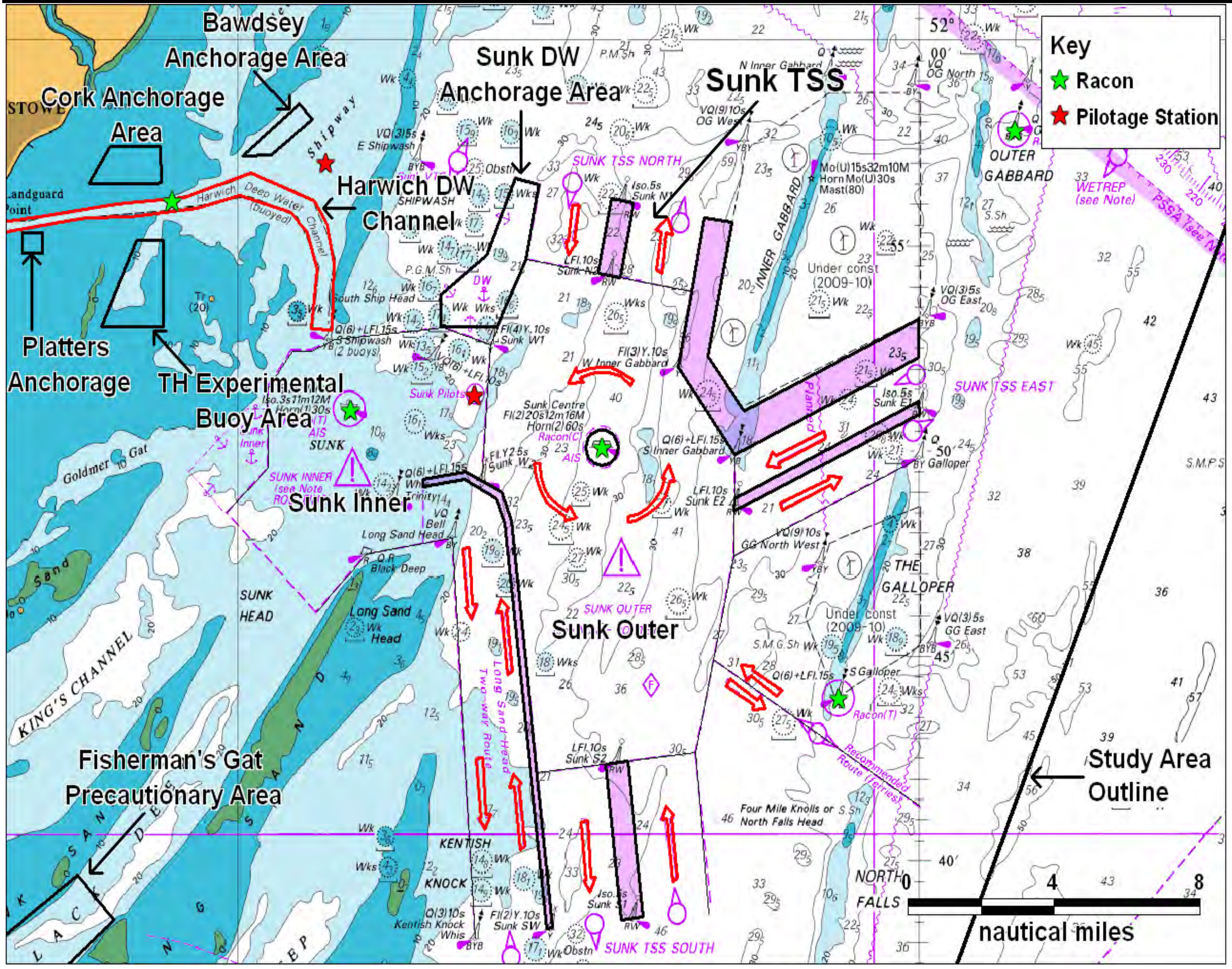


Figure 6.27 shows the ports and Port Authority limits within the study area; Port of London, Crouch Harbour and Harwich Haven. The Harwich Haven Port Authority limit is located to the west of the Sunk TSS and covers the ports of Harwich, Felixstowe, Manningtree and Ipswich. The smaller Crouch Harbour Authority encompasses the port at Creeksea and the large marinas at Burnham-on-Crouch and Wallasea.

The PLA VTS limit covers a large area of the study region, with Harwich Haven VTS Area covering the port limits. The Sunk VTS, covering Sunk Inner Precautionary Area (to the west of the TSS) and Sunk Outer Precautionary Area (within the centre of the TSS) and the Sunk TSS, is operated by the Dover Maritime Rescue Co-ordination Centre (MRCC) (1).

The northern boundary of the Western European PSSA (Particularly Sensitive Sea Area) crosses the study area. Tankers of more than 600 Dead Weight Tonnage (DWT) carrying heavy crude oil, heavy fuel oil or bitumen and tar and their emulsions, are required to participate in the Western European Tanker Reporting System (WETREP) when first entering the PSSA, when departing from a port, terminal or anchorage within the Area, when deviating from a planned route within the Area or when finally exiting the Area. The system is a mandatory reporting system under Safety of Life at Sea (SOLAS) regulations (V/11).

In addition to the navigational features and routeing measures discussed, there are a number of wind farms, areas of military activity and dumping grounds (both active and disused) in the region that the shipping traffic must avoid (see Section 6.3).

(1) Some charts indicate "Sunk VTS not operational until further notice". This is because the TSS was not operational for two years until it recommenced on 1 July 2009.

Figure 6.28 Ports and Port Authority Limits in the Study Area

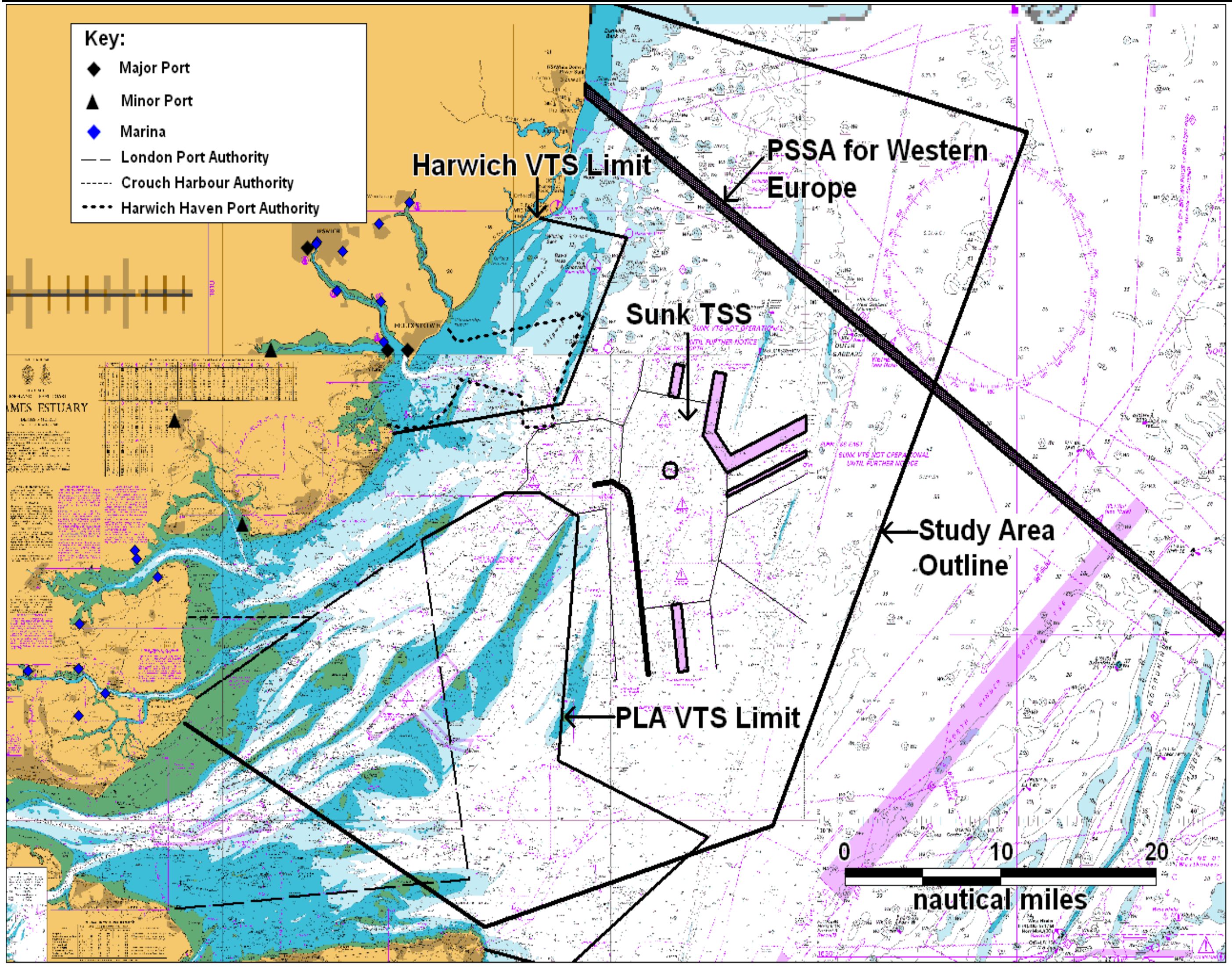
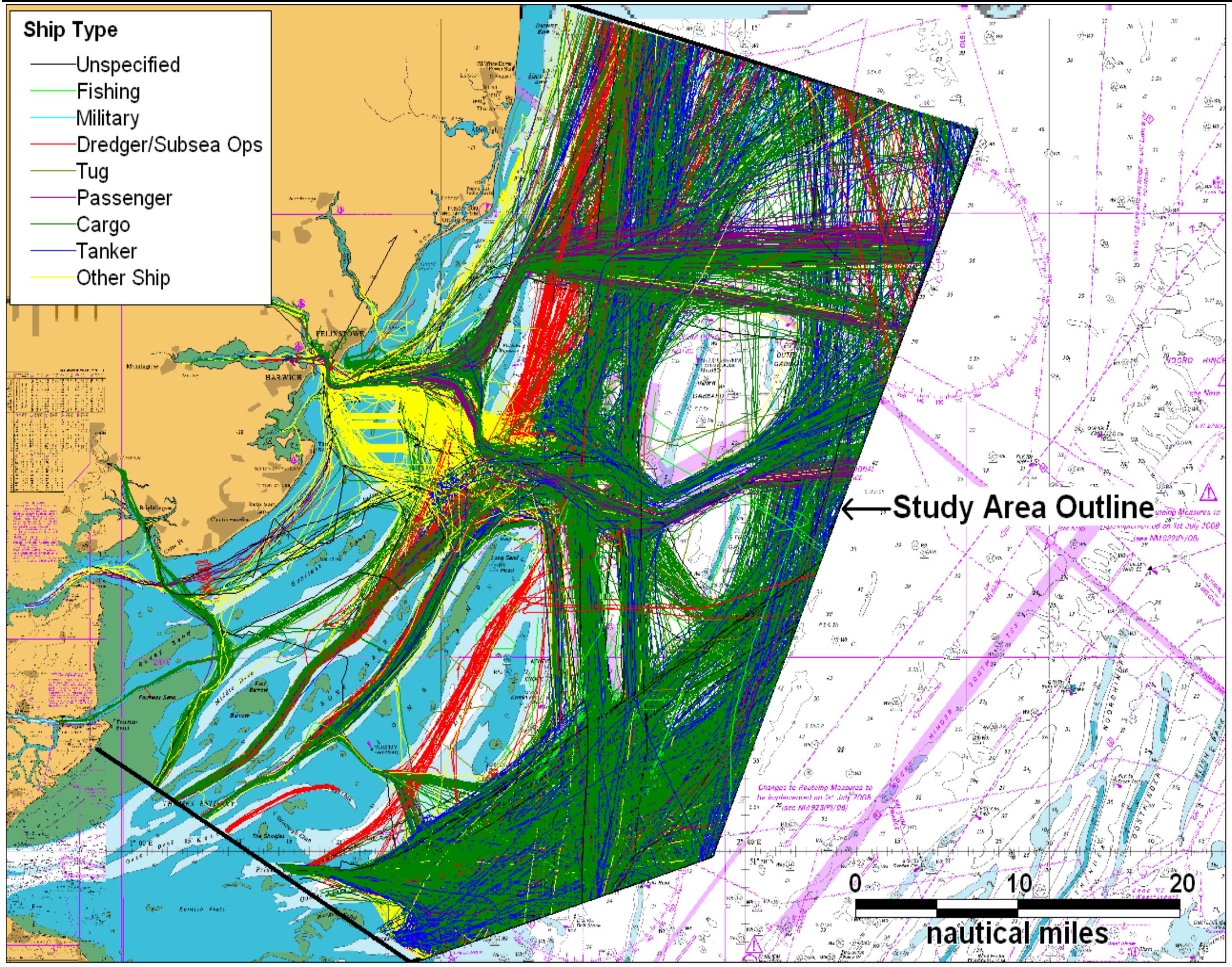


Figure 6.29 AIS Ship Tracks recorded from 10 April to 22 May 2008



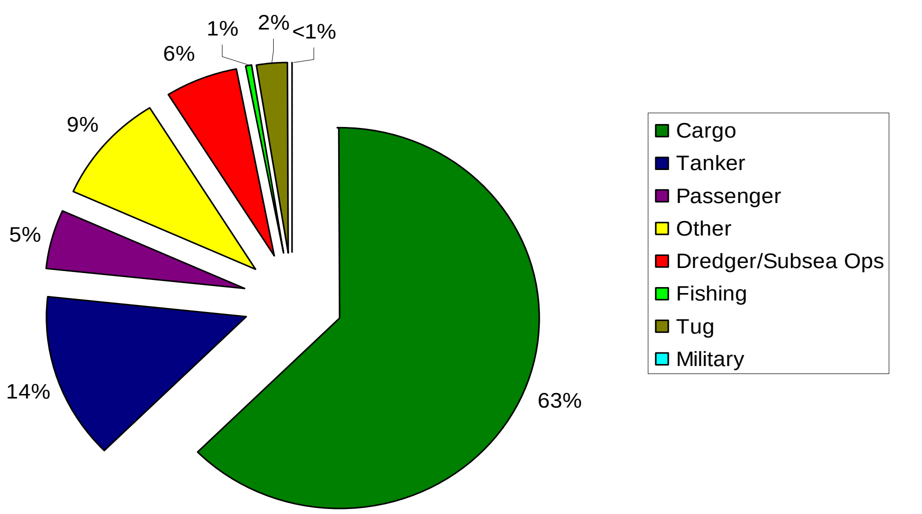
6.5.4 Commercial Shipping Activity

Automatic Identification System (AIS) data were analysed for the MAREA study area covering a 40 day period (10 April – 22 May 2008). Figure 6.29 presents a plot of all the tracks recorded in the area during this time, colour-coded by vessel type. On average 145 ships per day pass through the study area encompassing a variety of different ship types and sizes (the vast majority above 300 GRT).

As Figure 6.29 shows, a large amount of shipping heads to and from the Thames Port and Harwich Haven. In the outer (eastern) part of the area, a large number of ships move in and out of the area to/from the Dover Strait and the North Hinder South Traffic Separation Scheme. In the inshore (western) part of the study area, ships head into the Thames and a number of minor ports, including Brightlingsea and Burnham-on-Crouch, via the well-established shipping channels between the sand banks, including Barrow Deep, Black Deep and Fisherman's Gat, which is used as a Precautionary Area due to the confluence of traffic.

Figure 6.30 shows the break down of shipping recorded in the Thames region by ship type (excluding 4% unspecified). The majority of vessels in the region are cargo vessels. Dredgers and other subsea operation vessels such as survey ships and ROV/dive support vessels operating in the region accounted for 6% of all the tracks during the survey period (10 April – 22 May 2008). The majority of these were dredgers (ie aggregates and maintenance) as opposed to other types of subsea operations vessels.

Figure 6.30 AIS Ship Breakdown by Type in Study Area (April/May 2008)

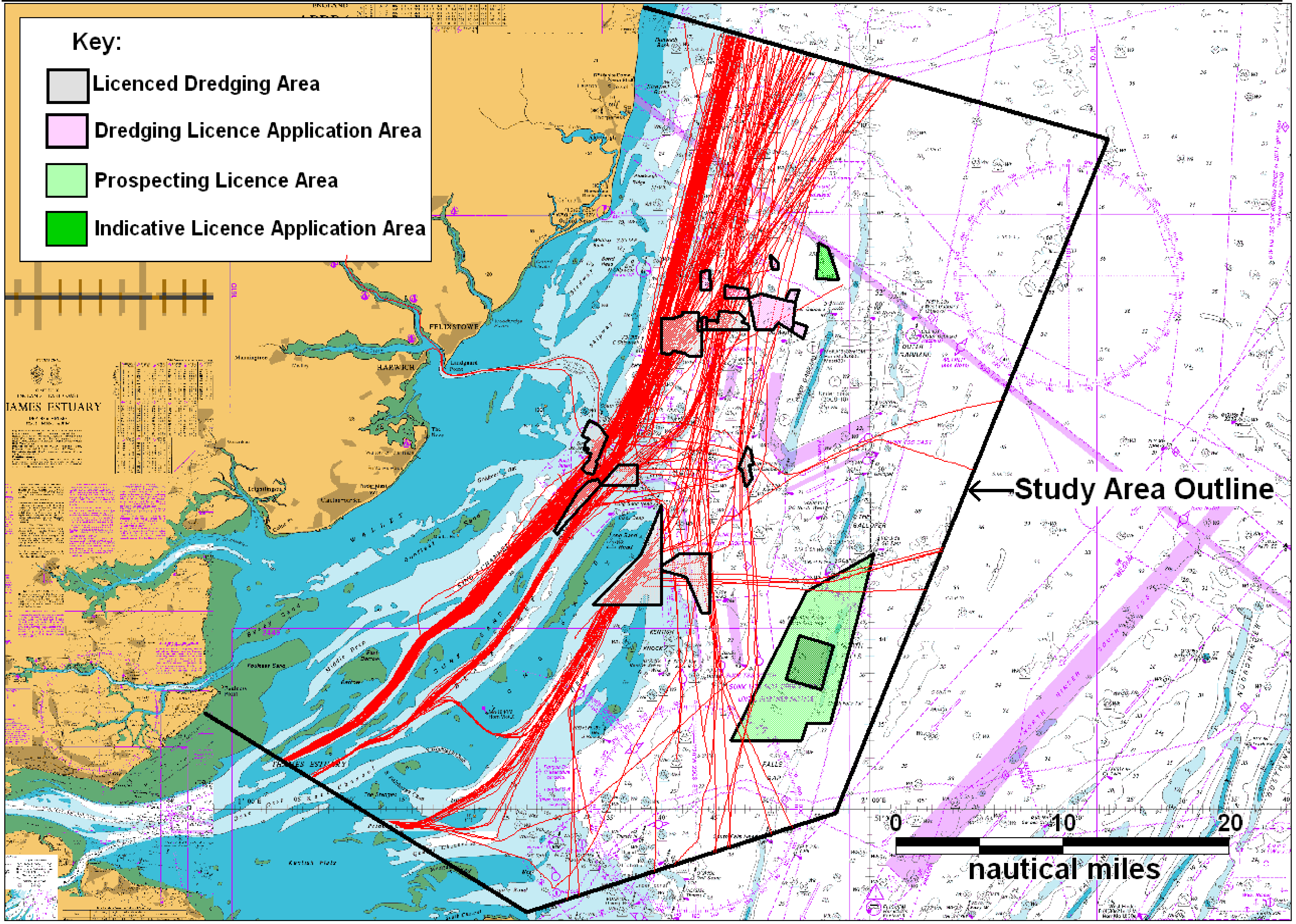


The majority of ships were inbound to ports in the outer Thames estuary, including Felixstowe and Harwich and the Inner Thames (Tilbury, Coryton) or outbound from the Thames Estuary and European ports (e.g. Rotterdam, Antwerp, Zeebruge, Ostende and Hamburg).

6.5.5 Existing and Proposed Dredging Activity

Figure 6.31 shows that the majority of dredging activity is located adjacent to the license areas within the centre of the study area. Overall, dredger tracks accounted for approximately 5% of ship movements and the number of dredgers within the study area averaged 8 per day. The majority of activity is in the centre of the study area, adjacent to the Sunk TSS where there are a number of active dredging areas, particularly Areas 447, 119/3 and Long Sand Head licence area (Area 108/3, 109/1, 113/1). A large number of tracks are also found in the Princes Channel and Black Deep heading north to and from aggregate areas in the Humber and Anglia regions. A proportion of the tracks (approximately 7%) can be attributed to maintenance dredging to deepen navigation channels and port approaches.

Figure 6.31 Steaming and Active Dredger Tracks relative to Dredging Areas (10 April – 22 May, 40 Days AIS)



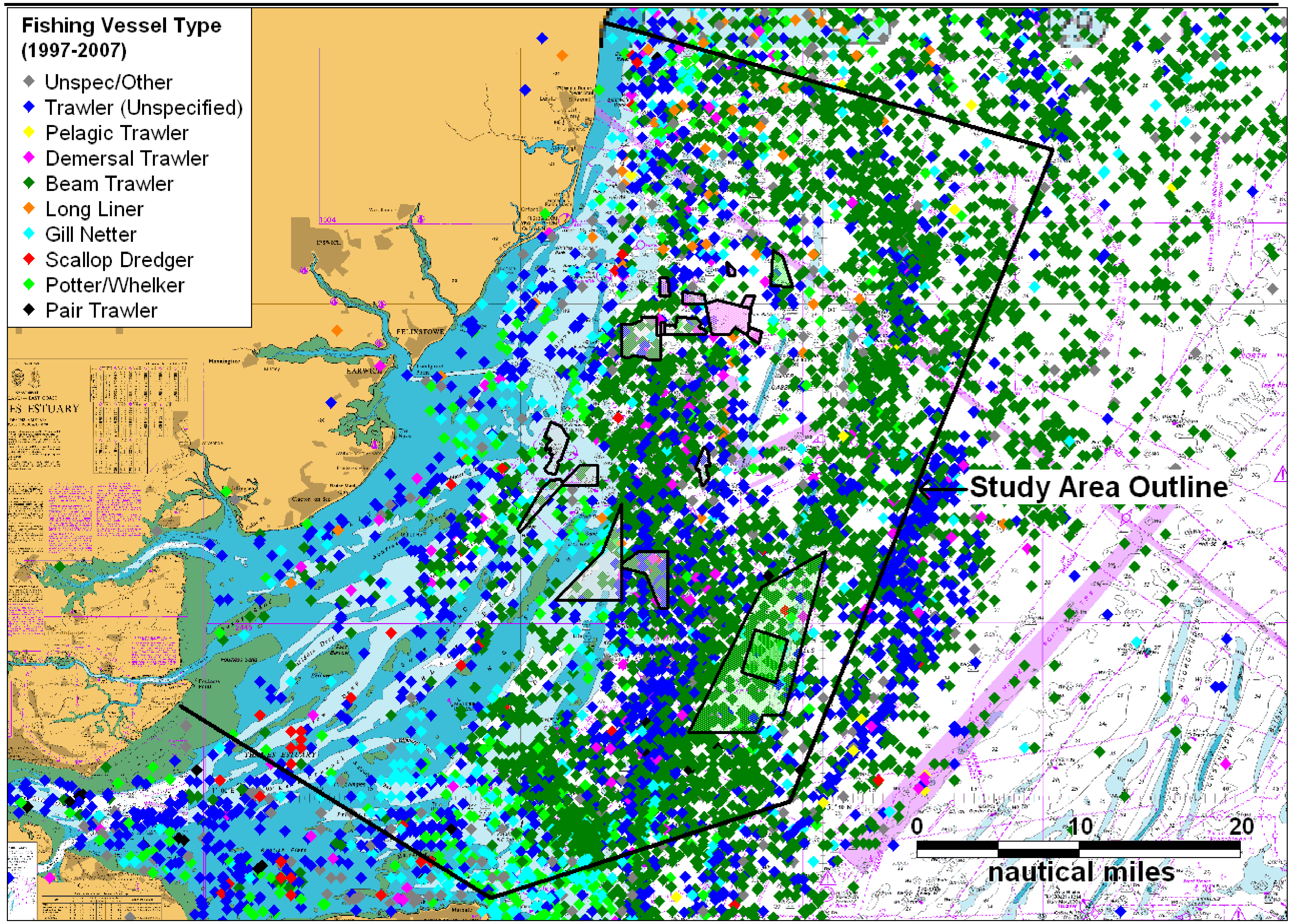
6.5.6 Fishing Activity

Fisheries statistics in the UK are reported by ICES [(1)] statistical Rectangles (sea area of 30 minutes latitude by one-degree (60 minutes) longitude) and Subsquares (one quarter of an ICES rectangle). The MAREA study area encompasses and intersects 13 ICES rectangles. Data from CEFAS [(2)] on fishing vessel sightings within the study area between 1997 and 2007 was obtained.

The following figures present vessel sightings recorded during this period, colour coded by gear type (Figure 6.32) and nationality (Figure 6.33).

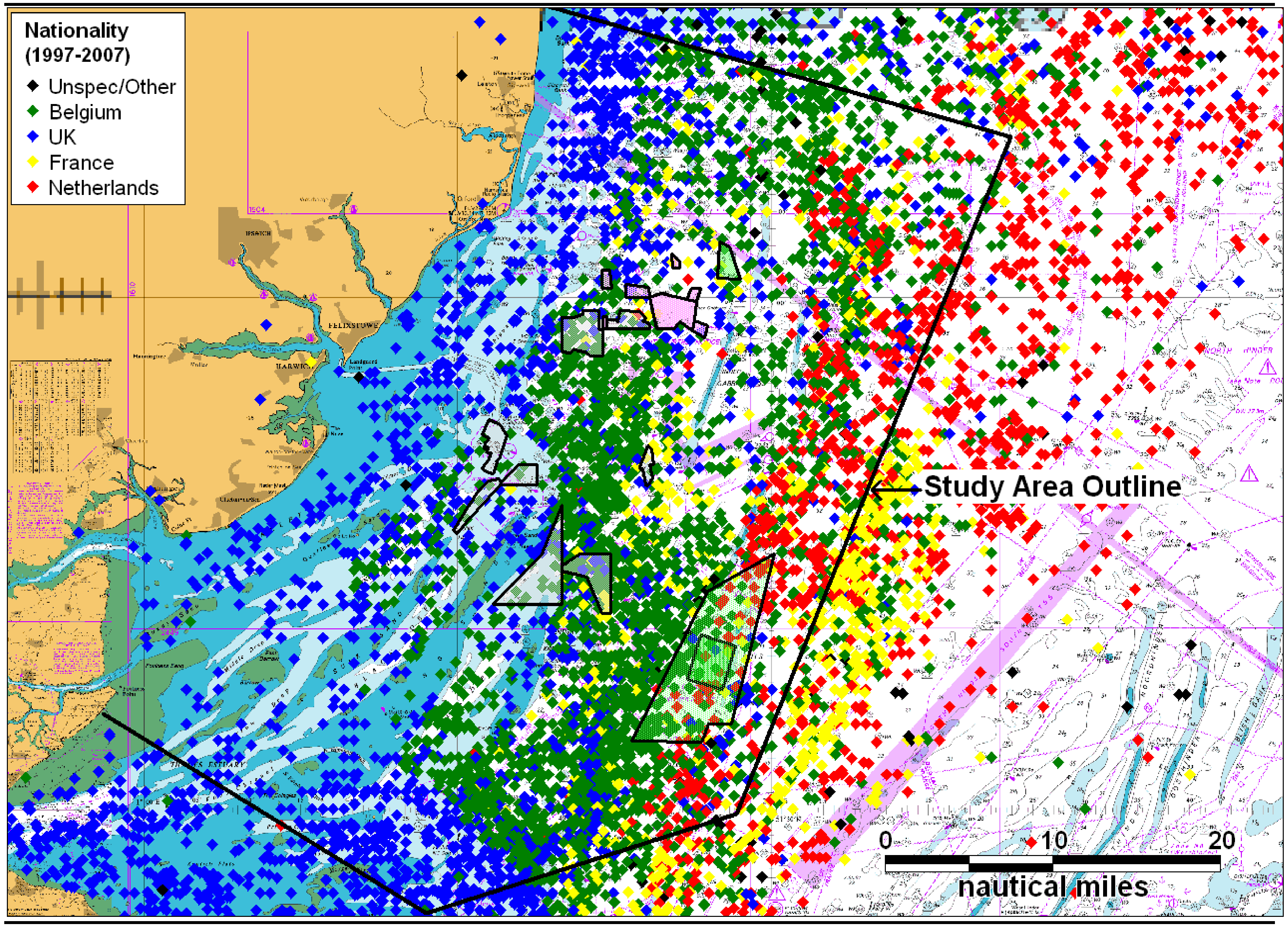
From the overflight data it can be seen that it is predominantly trawled gear, particularly beam trawls, being used in the vicinity of the dredge areas. The majority are Belgian and UK registered, with UK vessels tending to operate in more coastal areas.

Figure 6.32 Fishing Vessel Sightings by Gear Type



(1) International Council for the Exploration of the Sea.
(2) Centre for Environment, Fisheries and Aquaculture Science.

Figure 6.33 Fishing Vessel Nationality Distribution



Fishing vessel satellite tracking data was also obtained from January 2004 to December 2007 for vessels greater than 24m in length. Vessels between 15 and 24m were fitted with VMS between December 2004 and 31 March 2005 and are therefore partially covered in the data. A plot of the positions recorded in the vicinity of the study area, colour-coded by gear types, is presented in Figure 6.34. Again the main gear type used by larger fishing vessels in the vicinity of dredge areas is beam trawling.

It should be noted that qualitative information on the inshore fishing fleet (which comprises smaller vessels and is therefore poorly represented by the overflight and VMS satellite data) was obtained through consultation as part of the MAREA, and could not be quantitatively included in the navigational sensitivity ranking exercise.

6.5.7 Recreational Activity

An overview of the recreational facilities and activities in the vicinity of the MAREA study area relative to the dredge areas, is presented in Figure 6.35. The coastal areas within the MAREA study area overlap with the general sailing and racing areas off Felixstowe, Harwich, Kings Channel and The Wallet sea area (see Figure 6.35). Many sailing routes follow coastal channels such as Middle Deep, Black Deep and Wallet off Clacton-on-Sea. The most intensively used recreational areas are situated around Harwich Haven, Crouch and within the River Blackwater.

6.5.8 Marine Accident Data

All UK commercial vessels are required to report accidents to the Marine Accident Investigation Branch (MAIB). Non-UK vessels do not have to report unless they are in a UK port or are inside the UK 12 nautical mile territorial waters and carrying passengers to a UK port. There are no requirements for non-commercial recreational craft to report accidents.

The locations of accidents, injuries and hazardous incidents reported to MAIB [1] in and around the Thames Estuary from 1994 to 2008 are presented in Figure 6.36. Within the study area 15 reported incidents involved dredgers (seven hazardous incidents, four accidents to persons, two contacts in port, one grounding and one machinery failure). The average number of incidents recorded inside the study area was approximately 29 per year. Just over 10% of all incidents over the 14 year period were collisions which took place mostly in coastal waters. It should be noted that the Sunk TSS, which was established to help reduce incidents of this kind, only came into force from 1 July 2007.

(1) MAIB aim for 97% accuracy in reporting the locations of incidents.

Figure 6.34 Overview of Fishing Vessel Satellite Positions by Gear Type

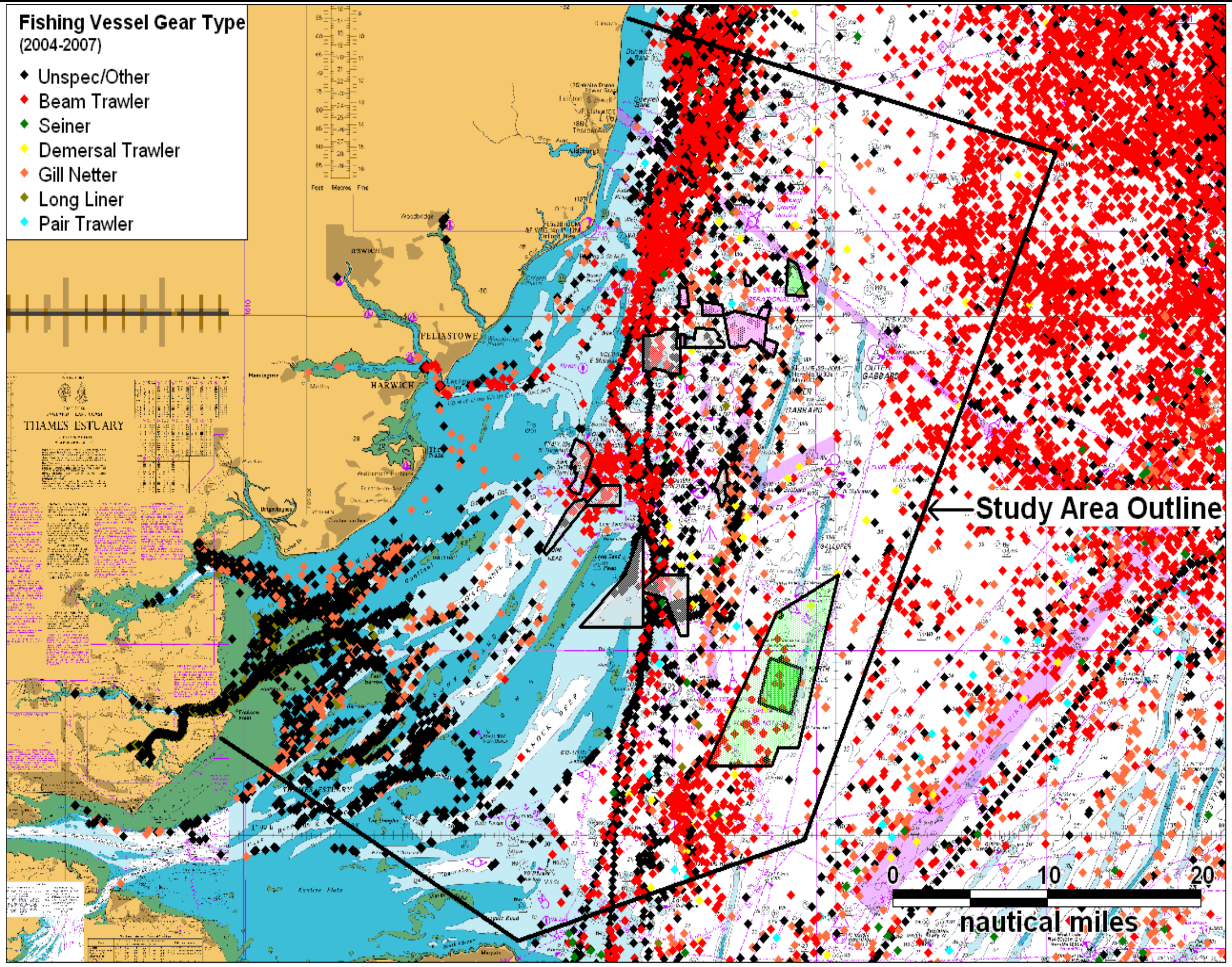


Figure 6.35 Recreational Vessel Activity in the vicinity of the Study Area

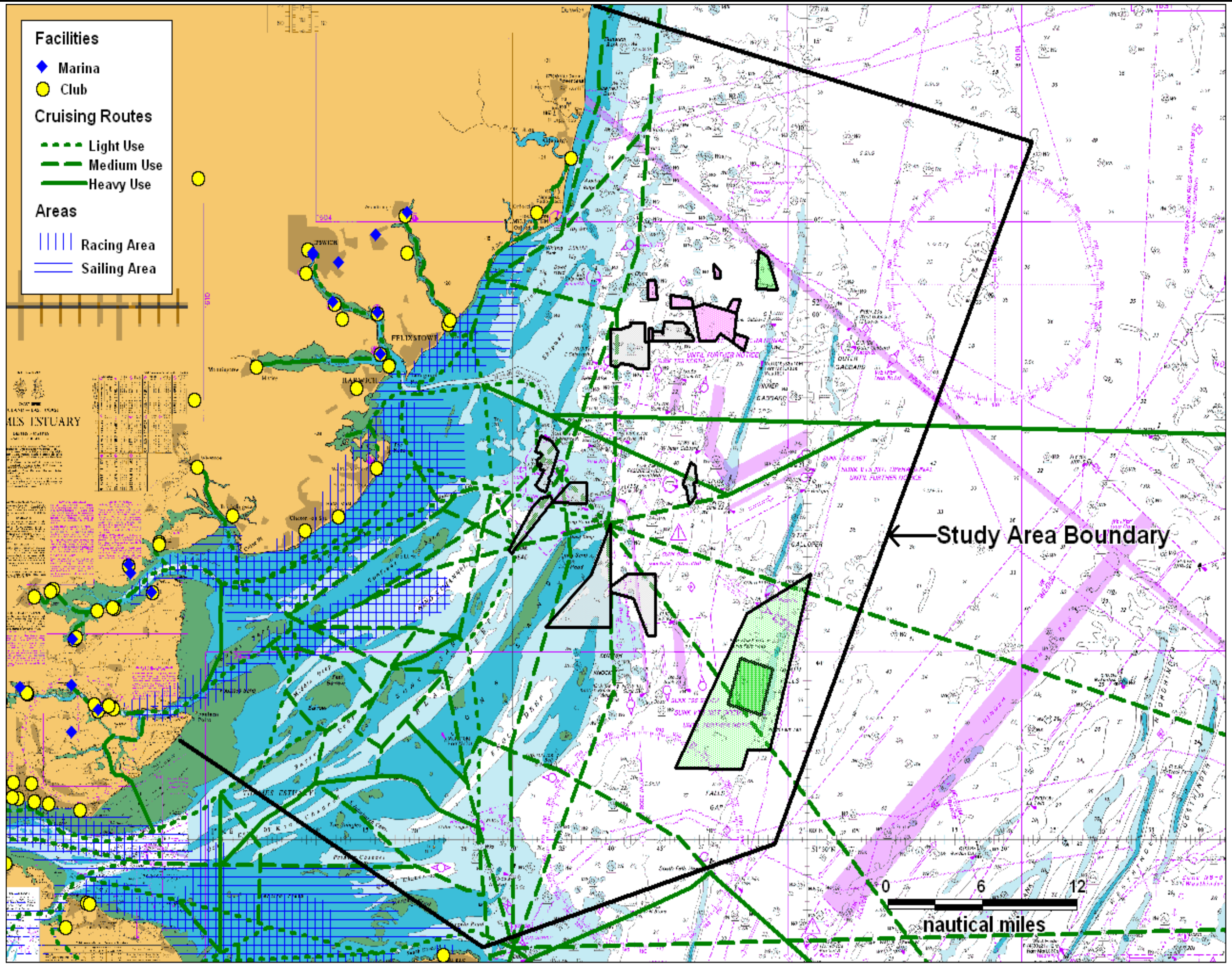
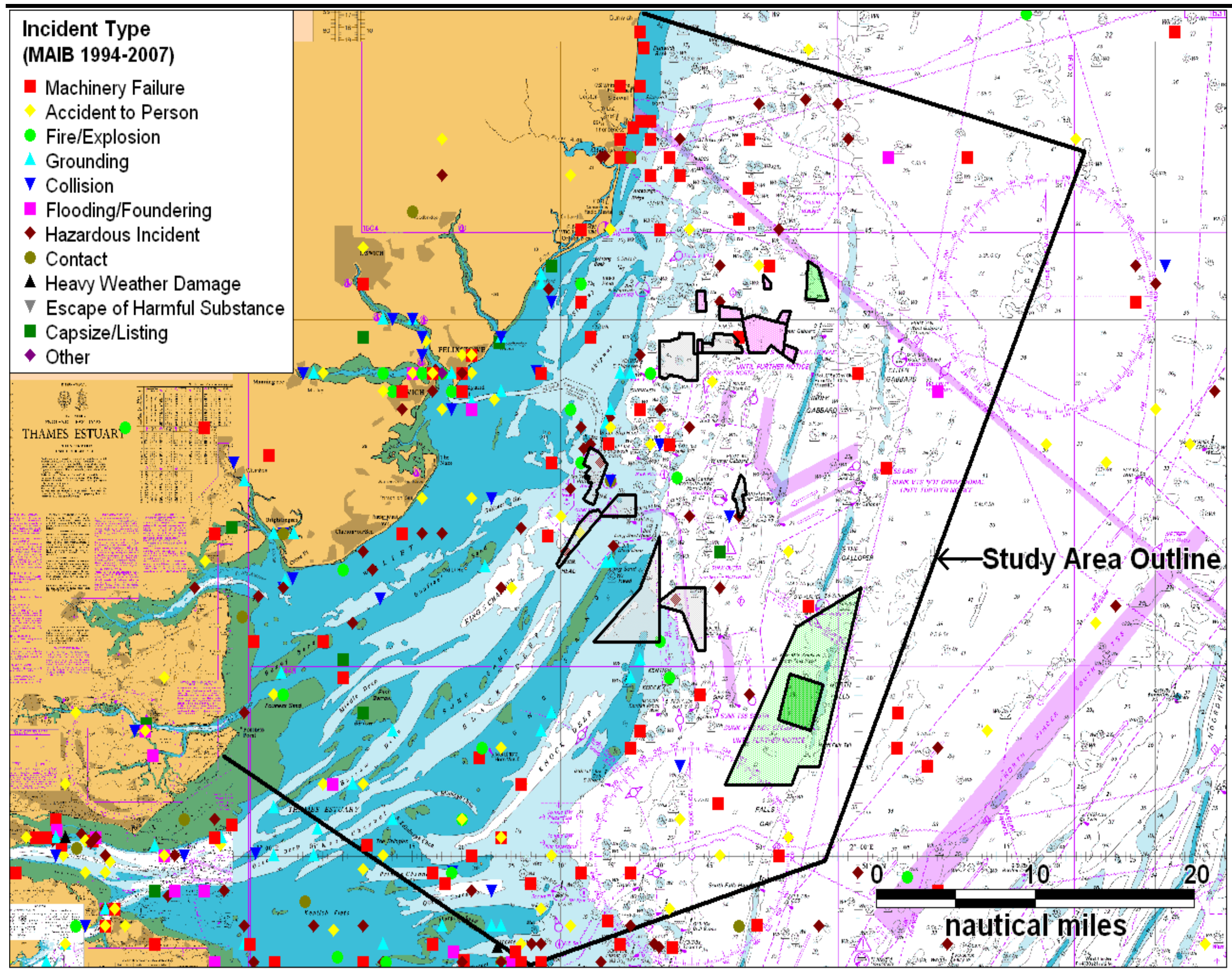
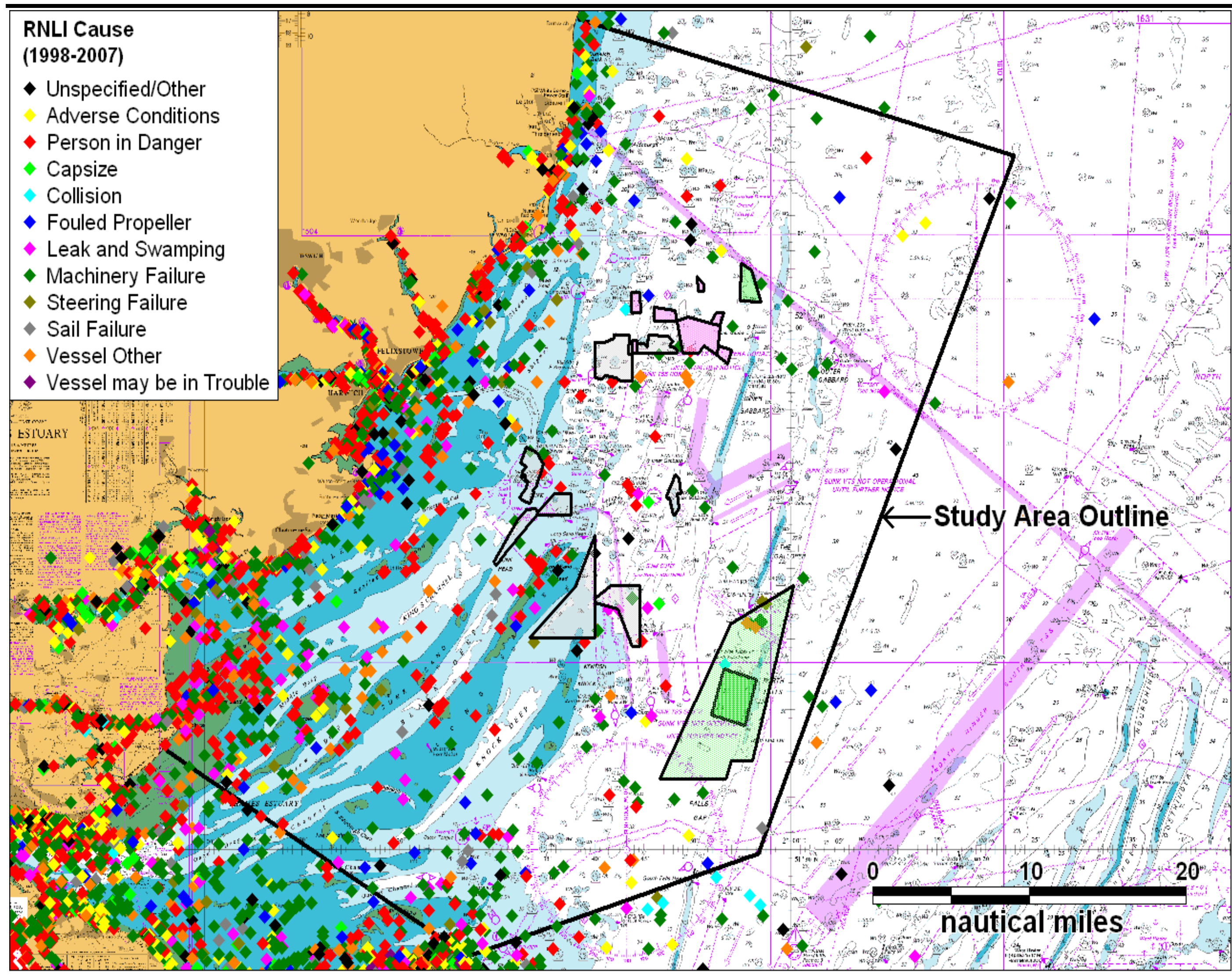


Figure 6.36 MAIB Incidents from 1994 to 2008 in the outer Thames



Data from RNLI lifeboat responses with regard to incidents in the area from 1998 to 2007 inclusive, excluding false alarms, are presented in Figure 6.37. Approximately 35% of incidents were responded to by Harwich station which may reflect the high density of recreational and merchant shipping in its vicinity. The majority of incidents involved a 'person in danger', followed by 'machinery failure'.

Figure 6.37 RNLI Incidents relative to the Study Area (1998 to 2007)



6.5.9 Ship Density

Ship density in the study area was modelled using Anatec's ShipRoutes database (see Appendix I Section 6.2 for details) which was calibrated against the AIS shipping survey data (40 days). Variation in shipping density in the region was estimated using a grid of 6,733 cells with an average cell size of 0.5 nautical miles (North/South) x 0.5 nautical miles (East/West). Anatec's ship density model was used to estimate the number of ships per year passing through each cell. The results were ranked and colour-coded according to relative shipping density as follows:

1. 0 to 100 ships per year;
2. 100 to 300 ships per year;
3. 300 to 700 ships per year;

4. 700 to 1600 ships per year; and
5. ≥ 1600 ships per year.

It is stressed that these are relative rankings for the regional study area and are not representative of the UK as a whole. By way of comparison, an average cell (rank 3) of similar size in UK territorial waters would have shipping density in the approximate range 20 to 50 ships per year, with top-ranked cells (rank 5) exceeding 200 ships per year, i.e., the Thames study area has higher than average ship density compared to the UK as a whole.

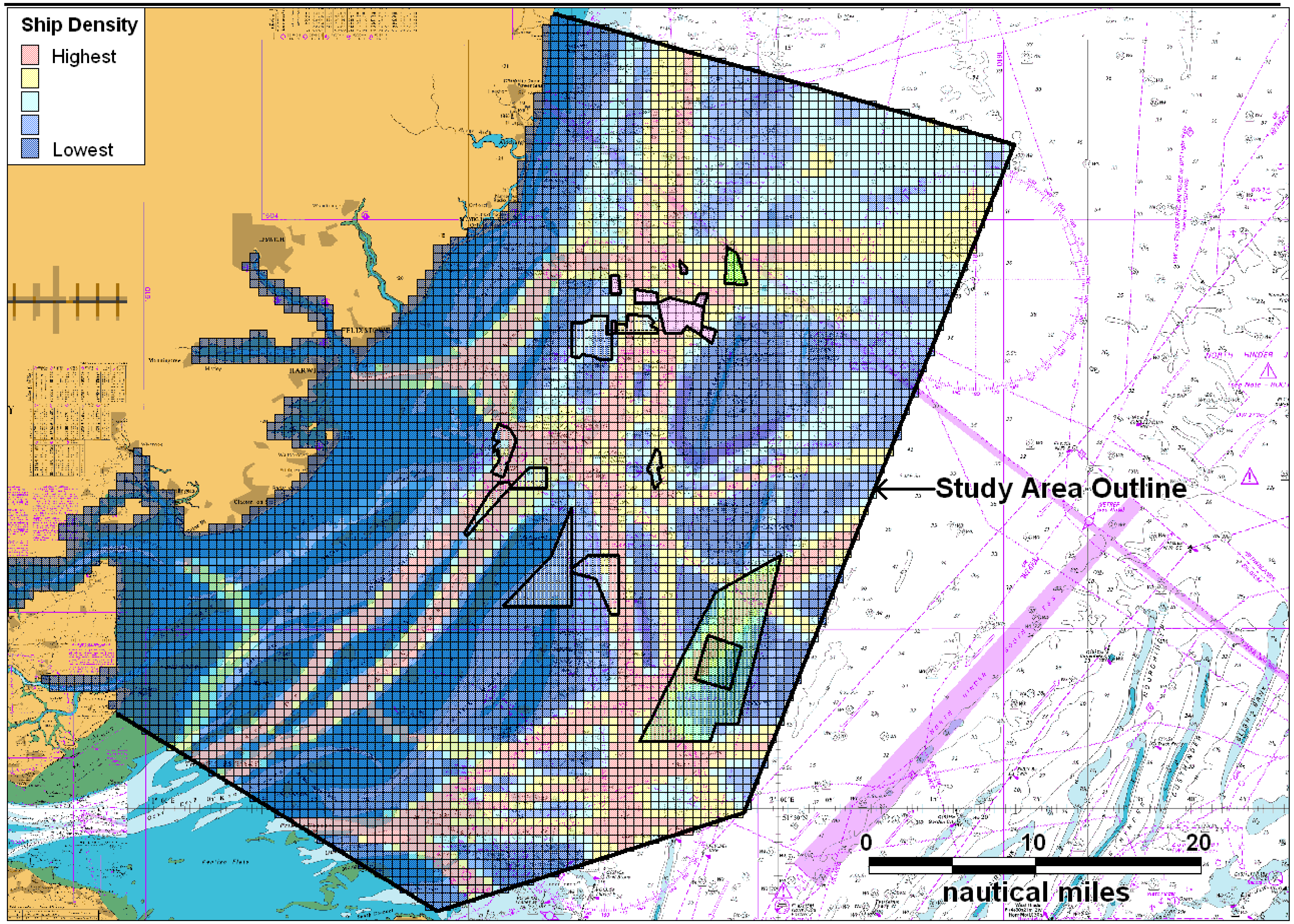
The highest shipping densities were calculated in and around approaches to the Sunk TSS, Harwich Deep Water Channel and approaches to the Inner Thames to the south of the MAREA study area, including Barrow Deep, Black Deep and the Princes Channel, which ships use to head to/from the Dover Strait TSS in the English Channel (Figure 6.38).

The dredging areas to the north of the Sunk TSS North are located within high shipping densities as these wide channels avoid the shallower water present at Inner and Outer Gabbard. In addition vessels cross the area eastbound headed towards the DW Routes and North Hinder Junction, approximately 31nm east of the Application Area 452 C3.

Within the Sunk Outer Precautionary Area which intersects Licence Area 327 and the Sunk Inner Precautionary Area which intersects Areas 108/1, 257 and 447, there are high shipping densities associated with Kings Channel and Black Deep, as these channels are used by deep-draughted vessels headed to the inner Thames.

It is noted the North Falls prospecting licence area intersects the Galloper Recommend Route which joins the Sunk TSS and is adjacent to the northbound lane of the Sunk TSS South. A large portion of shipping intersecting the North Falls area is likely to be headed to / from the North Hinder Junction approximately 30nm to the northeast.

Figure 6.38 Overview of the Ship Density for the Thames Study Area



6.5.10 Existing Ship-to-Ship Encounters and Modelled Collision Risk

Existing Ship-to-Ship Encounters

A week's worth of AIS data was analysed to calculate where real-time vessel encounters have occurred within the study area. Encounters were conservatively defined as vessels passing within 1nm of each other (including 'overtaking' encounters where vessels were heading in the same direction. It should therefore be noted that a TSS may have a high encounter rate due to traffic levels and the fact ships pass in close proximity. The benefits of a TSS in terms of separating opposing traffic flows and reducing head-on encounters are, however, taken into account with the collision risk modelling. Presenting ship-to-ship encounters helps to illustrate where existing shipping congestion is highest and where dredging applications could potentially exacerbate congestion and hence increase the risk of encounters/collisions.

The results show that the main 'hotspots' with respect to encounters were within the Sunk TSS, Harwich DW Channel and Margate Road/Princes Channel (Figure 6.39). These areas indicate where there is already congestion of shipping due to high traffic levels and/or reduced sea room. Hence these areas are more sensitive to future increases in aggregate dredging activity.

Modelled Ship-to-ship Collisions

Ship-to-ship collision frequency was calculated using Anatec's COLLRISK model with the ship density results as input. The main factors that influence the risk of collision are: ship densities, speeds, courses, vessel types and sizes, and visibility conditions in the area. The results were ranked and colour-coded as follows:

1. 0.1 to 1 ship-to-ship collisions per million years;
2. 1 to 10 ship-to-ship collisions per million years;
3. 10 to 100 ship-to-ship collisions per million years;
4. 100 to 500 ship-to-ship collisions per million years; and
5. > 500 ship-to-ship collisions per million years.

The model results show that the baseline vessel-to-vessel collision risk level is in the order of one major collision within the study area in 1.4 years (1). It should be noted that the model is calibrated based on major incident data at sea which allows for benchmarking with incidents in other parts of the world, but does not cover all incidents, such as minor impacts, or incidents occurring within port. These types of incidents are covered by the data from the MAIB and RNLI discussed in Section 6.5.8.

Figure 6.40 presents an overview of the predicted ship-to-ship collision frequencies based on the ranges listed above. The areas of highest ship-to-ship collision frequency are concentrated in and around the approaches to the Sunk TSS, Harwich Deep Water Channel and in the approaches to the Inner Thames. There was generally good correlation between the modelled annual ship-to-ship collision frequencies and the assessment of one-week of actual encounters. Whilst traffic in the Sunk TSS benefits from the mitigating effect of being separated from opposing flows of traffic, it is still an area of high collision risk due to the high density of shipping within the confined area.

The dredge areas where collision frequencies were identified as high were Area 447, which has a large number of ships intersecting its northern edge bound for Harwich, and Area 108/1 where vessels pass towards the Inner Thames. Area 327 intersects Long Sand Head two-way route, Sunk Outer and part of the southbound lane of the Sunk TSS South which is also identified as a high ship-to-ship collision risk given the high density of shipping.

(1) Note that the models have been calibrated against 'serious' casualty data at sea. This excludes incidents in port, e.g., minor bumps during berthing. It also requires the incident to be of a defined degree of seriousness in terms of loss of life, environmental damage and/or financial impact. Non-serious casualties are estimated to be in the order of 4 times more frequent than serious casualties. Anatec's models are calibrated against serious casualties as this minimises the probability of under-reporting and provides a benchmark level when comparing the frequency of accident in different parts of the World.

Figure 6.39 Density Distribution of Encounters based on one week of AIS Data

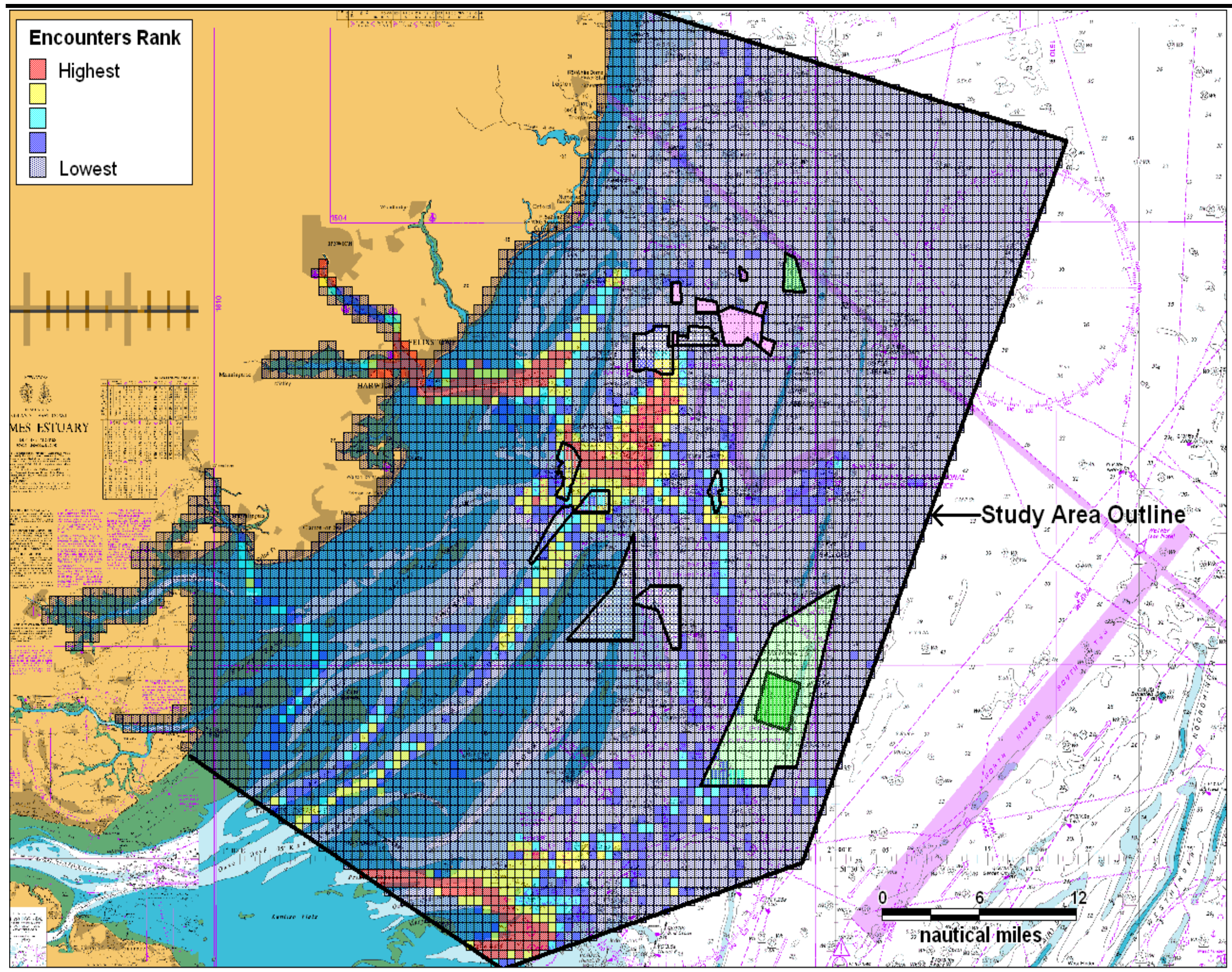
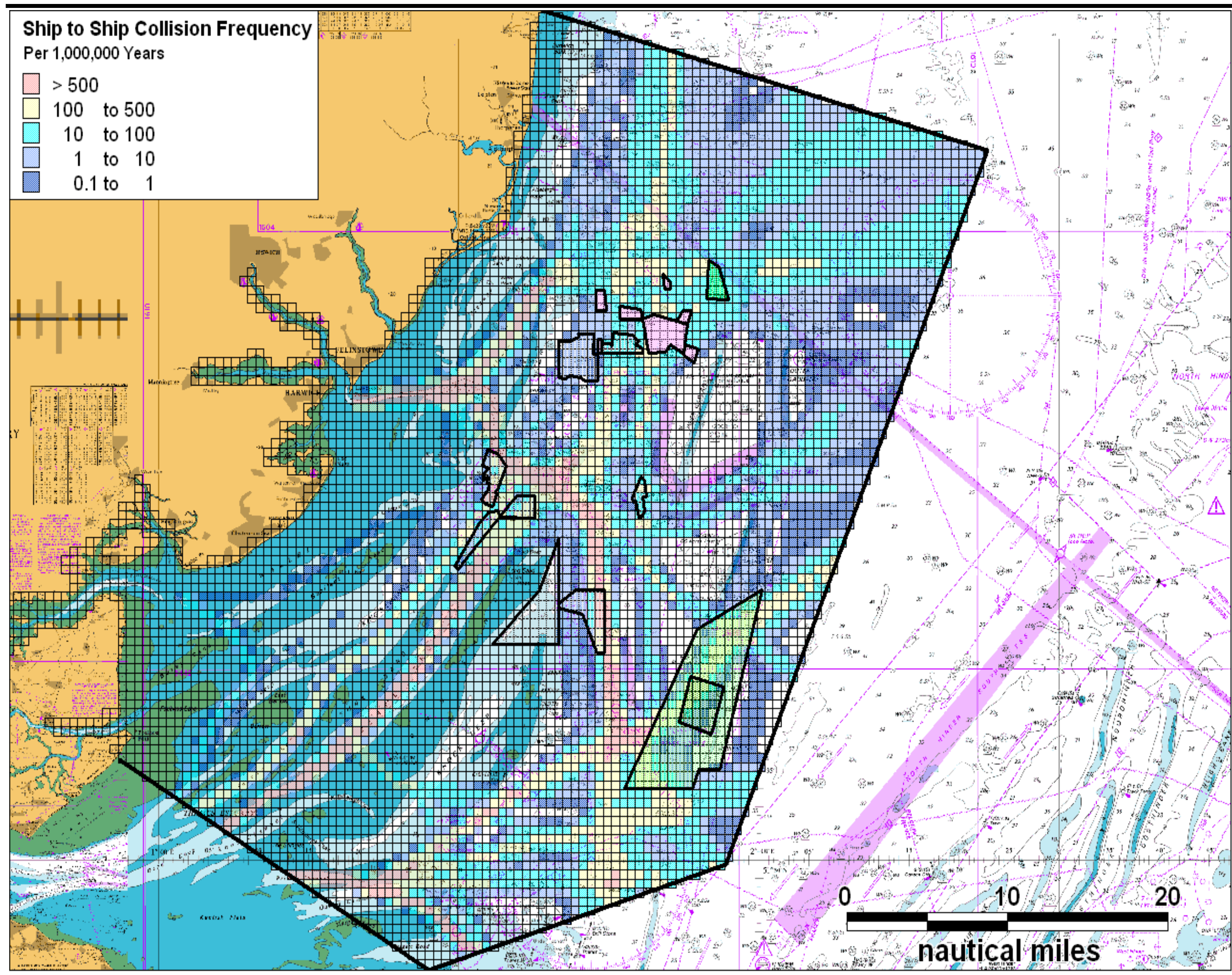


Figure 6.40 Overview of the Ship-to-Ship Collision Frequency for the MAREA Area



6.6 ARCHAEOLOGICAL BASELINE

6.6.1 Introduction

This section describes the baseline of the known and potential archaeological features in the vicinity of the MAREA study area. The baseline covers known and potential prehistoric, maritime and aviation archaeology. Details of relevant legislation and guidance can be found in Section 6.1.2.

6.6.2 Sources of Information

The main sources of data used to compile this baseline section were:

- SeaZone records of wrecks and obstructions.
- Records of Named Losses and terrestrial sites from the National Monuments Record (NMR).
- Secondary sources relating to the palaeo-environment and to the Palaeolithic and Mesolithic archaeology of Northern Europe with specific reference to the ALSF *Seascapes Project* (Southwold to Clacton) (Oxford Archaeology 2007)
- Secondary sources relating to historic shipping patterns and known and potential wreck sites and causalities, with specific reference to ALSF *England's Shipping* (Wessex Archaeology 2003a) and ALSF *Navigational Hazards* (Bournemouth University 2007).
- ALSF *Air Crash Sites at Sea* (Wessex Archaeology 2008) and various secondary sources relating to historic aviation patterns.
- Geophysical data provided by the Marine Aggregate Regional Environmental Assessment (MAREA) and the Thames Regional Environmental Characterisation (REC).

Due to the large scale of the study area, local sources of information such as the Historic Environment Records of Essex (EHER) and Suffolk (SHER) were not consulted at this stage. Many of the records held by the HERs are duplicates of those held by the NMR therefore it was not felt necessary to look at datasets from both sources. This approach was discussed and agreed with English Heritage at the Archaeological Methodology Meeting held at Wessex Archaeology on the 20th August 2008. The importance of local sources such as the HERs is recognised nonetheless and these will be used for future EIAs for specific aggregate dredging licences within the MAREA study area.

In terms of palaeo-archaeological baseline in particular there are significant problems of data quality and recording biases relating to national inventories such as the UKHO and NMR. The records within these datasets relating to the known archaeological resource are limited and often poor. Conversely, information relating to the potential archaeological resource within the Study Area is extensive.

6.6.3 Prehistoric Land Surfaces and Deposits

Overview

To understand the sedimentary sequence within the MAREA study area and evaluate the geoarchaeological and palaeoenvironmental potential of the region, 333 vibrocore logs that had been gathered by the aggregate industry were reviewed.

Geotechnical and geophysical data were also reviewed to identify features such as:

- in-filled palaeochannels;
- evidence of cutting into bedrock which has then been infilled;
- potential land surfaces of archaeological significance; and
- peat or fine-grained sediment horizons.

The geotechnical assessment identified the following sedimentary units, of which Units 2 and 3 have the potential to contain in situ prehistoric archaeological material:

- Unit 1 - Tertiary bedrock;
- Unit 2 - Pleistocene fluvial gravels;
- Unit 3 - Estuarine alluvium and peat; and
- Unit 4 - Seabed sediments.

For the purpose of the geophysical assessment the Study Area was divided into three zones based on the shallow geology and associated potential archaeology. The boundaries to the zones are indicative only and do not represent absolute boundaries of geological formations or features. Due to the resolution of the line spacings (see Figure 6.41), the boundaries appear blocky as the vertices of the zone boundaries are associated with the data lines.

Figure 6.42 shows Zone 1 is situated to the north of the Study Area, Zone 2 in the central region and Zone 3 to the south. Each f the three zones contains features of archaeological interest.

The shallow geology interpreted in Zone 1 comprises Red Crag Formation, identified as a generally seismically transparent unit with occasional layers overlying London Clay Formation sediments. In places Westkappelle Ground Formation is identified characterised by a series of weak parallel reflectors. Over the majority of the area Holocene seabed sediments are observed directly overlying these formations. There are no aggregate licence areas within Zone 1.

The main difference between Zone 1 and 2 is the Tertiary sediment type in the area. In Zone 2 there is no Red Crag or Westkapelle Ground Formation. The geotechnical data assessed within this zone highlights areas where Pleistocene gravels (classed as Unit 2) have been identified. However, in the majority of the vibrocores there is no evidence of Pleistocene gravels indicating areas where marine Holocene sediments directly overlie the London Clay Formation. The geotechnical data also indicated the presence of peaty clay and silty clay (classed as Unit 3) within this zone (0.03 – 1.76 m thick).

Prehistoric Archaeological Potential

Known prehistoric sites have been looked at to gain an understanding of the potential archaeological material that may be present within the offshore extent of the Study Area.

Pre-Devensian (700,000 – 110,000 BP): The pre-Anglian landscape of the Study Area has been extensively reworked following the retreat of the Anglian ice sheet which covered the northernmost extent of the Study Area. Palaeoliths thought to be from the Lower Palaeolithic period (380,000 BP) have been found within the Ingham Formation, notably at Warren Hill at Mildenhall. Three early human skull fragments have been found at Swanscombe in north-west Kent which are evidence that the Study Area was habitable during the Hoxnian interglacial (c.423,000-380,000 BP). In addition Lower Palaeolithic artefacts have been discovered at Hoxne in Suffolk and Clacton in Essex. A number of hand axes have been discovered in the Orsett Heath Gravel and Corbets Tay Gravel deposits in the Lower Thames region, suggesting hominid activity within the Study Area from c.380,000-245,000 BP. A large number of Lower Palaeolithic hand axes have also been found in Kent, the majority of which are thought to have been deposited on the edges of river valleys.

Devensian (110,000 – 13,500 BP): The UK's terrestrial archaeological records suggest that Britain was uninhabited from c.180,000-60,000 BP. The Late Middle Palaeolithic period (c 300,000 to 30,000 BP) is marked by the onset of the Devensian glacial and it is unlikely that the initial cooling stages of the glaciation would rule out a human presence within the Study Area at this time. The majority of Upper Palaeolithic material in the region consists of stray artefacts and a number of stratified sites which are evidence of occasional hunting forays as the peri-glacial landscape would not have been favourable for human occupation.

Figure 6.41 Survey Area showing REC and MAREA Survey Lines

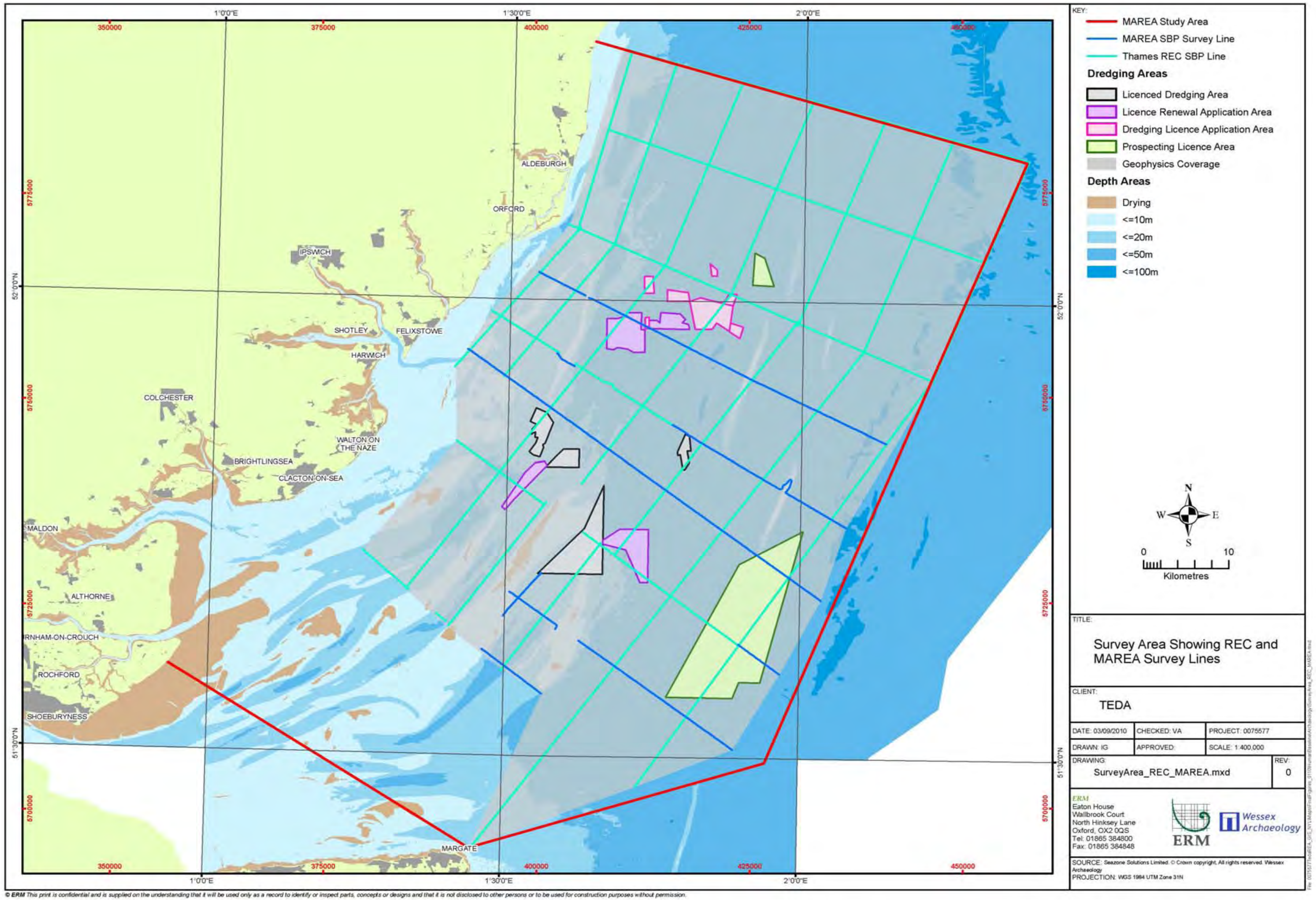
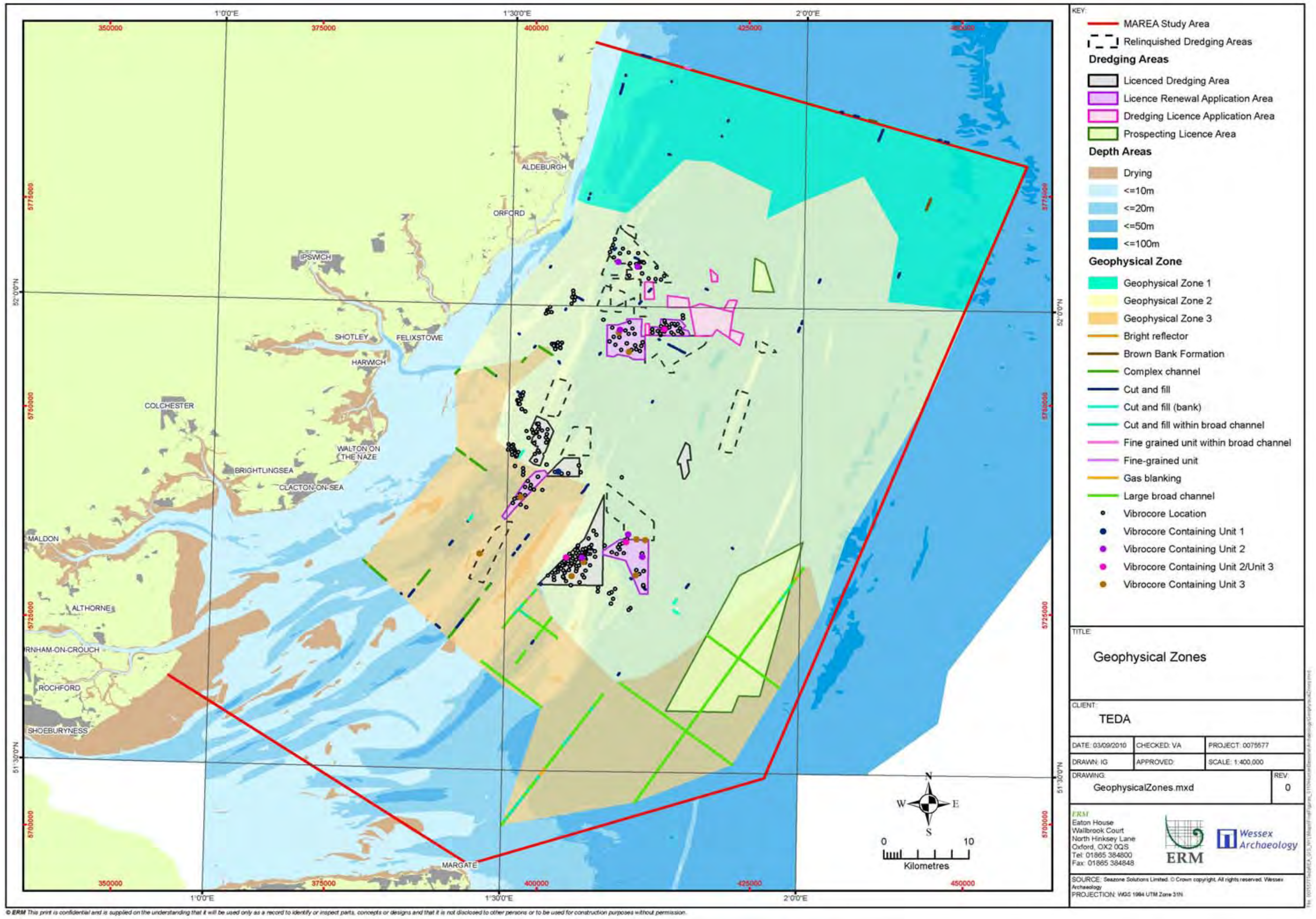


Figure 6.42 Geophysical Zones



Late Devensian and Early Holocene (13,500-6,000 BP): The discovery of a flint leaf point in gravels at Broxbourne in the Lea valley, and a number of shouldered flint points from Oare, Kent, is evidence of the presence of humans in the wider Thames Estuary region during the warming stages of the Windermere Interstadial (13,500-11,000 BP) of the Late Upper Palaeolithic. There have also been a number of Mesolithic sites discovered within the broader region of the Study Area. East Anglia is rich in Mesolithic sites, however, these predominantly comprise of surface finds of which few contain material in primary contexts.

Known Prehistoric Sites

A total of 6,069 NMR Monuments were recorded within the Study Area, of which 3,304 represent terrestrial sites which are not considered in this report. Of the remaining non terrestrial sites 1,735 were post-prehistoric in date, 87 contained no references to the prehistoric period and a further 831 records were of an unspecified period and therefore disregarded.

Lastly, 136 Neolithic sites, 137 Bronze Age sites and 65 Iron Age sites have omitted from the assessment of prehistoric sites because these periods all post-date the last marine transgression of the Study Area during the Mesolithic. As a result, no non-maritime sites (i.e. terrestrial or living sites) from these periods can be expected on the seabed of the Study Area.

As a result the remaining 313 NMR records (shown in Table 6.9) contain references to the prehistoric period.

Table 6.9 Period Classification of Prehistoric Sites

Period	Number of Records
Palaeolithic (700,000-10,500 BP)	69
Mesolithic (10,500-5,500 BP / 8,500-4,000 BC)	48
Multi-Period referring to Prehistoric sites	196
Total	313

Of the 69 Palaeolithic records shown above in Table 6.9, 50 of the sites did not contain sufficient information to be assigned a specific date. Five records assigned as multi-period sites were also seen to contain references to the Palaeolithic, although these too lacked sufficient information to enable them to be more specifically dated.

16 of the Palaeolithic NMR sites can be assigned to the Pre-Devensian period of which nine are located within 2km of the rivers Stour and Orwell. In addition a further two sites assigned as multi-period records also contained references to the Lower or Middle Palaeolithic period. A total of 51 NMR records were assigned as Late Devensian and early Holocene. Of this total, three records were assigned to the Upper Palaeolithic period (located within

the vicinity of the rivers Stour and Orwell) and the remaining 48 sites to the Mesolithic period. A further four sites assigned as multi-period records also contain references to the Mesolithic period.

It is not a surprise that some of these sites are located close to the rivers Stour and Orwell, as coastal and estuarine zones were favourable for hominid/human exploitation and activity during the prehistoric period. The presence of channel features in Zone 3 of the Study Area, identified as remnants of the Palaeo-Stour, highlights the potential for archaeological material to be present in the submerged area which is surrounds these channel features.

The NMR records confirm a certain level of human activity within the Study Area region throughout prehistory. However the figures displayed in Table 6.9 should not be viewed as directly representative of the volume of human activity within a given period. The survival of archaeological sites and artefacts is variable and depends on a complex array of interrelating factors. Moreover, there are significant problems with the quality of data provided by national inventories such as the NMR, which provide often limited datasets dependent on recording biases.

Prehistoric Archaeology Site Survival

There are a number of locations within the Study Area that are considered to have favourable conditions for site survival and visibility of prehistoric archaeological material. The depressions and gulleys between the banks and ridges north east of the Essex coast provide an environment favourable for prehistoric site survival and visibility.

Prehistoric site survival is also expected within the relict estuaries and river valleys of the Study Area. The gravel terraces laid down by the proto-Thames and its tributaries provide favourable preservation for prehistoric artefacts, which although likely to be concealed within marine alluvium, may be exposed during dredging operations.

The coastal areas adjacent to the Study Area have a high potential for the survival and visibility of the prehistoric archaeological resource. There is the potential for artefacts to erode out of modern coastlines, such as that in Suffolk, which is composed of relatively unconsolidated material and is subject to extensive erosion. Coastal sediments adjacent to the Study Area, comprising mudflats, marshes and wetlands, also have a high potential for prehistoric site survival and visibility.

Significance of Potential Prehistoric Archaeology

In broad terms, archaeological sites can be found in either primary contexts (*in situ*), where the spatial relationship of finds has not altered since they were deposited, or secondary contexts, where artefacts have been derived or moved from their original positions. Archaeological material discovered in secondary contexts may be associated with fluvial re-depositing, glacial processes and marine regressions and transgressions. Although discoveries from secondary contexts are by their very nature, derived artefacts, recent work has shown that they have the potential to provide information on patterns of human land use and demography. *In situ* finds are typically considered the most valuable to archaeologists as they can provide more information regarding environmental, spatial and temporal contexts and the nature of their deposition.

The lowering of sea level that occurred during the glaciations discussed above meant that for long periods during the last *c.*700,000 years, areas of the southern North Sea have been exposed as dry land. As such, it is probable that at various times in the past the Study Area was suitable for human/hominid exploitation. It is likely that portions of the Study Area were inhabitable for at least parts of OIS 19-6 (*c.*787,000-186,000 BP). This is important because hominid archaeological contexts are rare in the UK, and by virtue of the age of the associated assemblages and remains, all and any finds are significant to researchers in this field and could further our limited understanding of the occupation of the British Isles by hominids.

Neanderthals (*Homo sapiens neanderthalensis*) are found in the European archaeological record c 600,000 - 30,000 BP which overlaps with the period that portions of the Study Area were inhabitable. Furthermore, there is evidence that another early hominid species (*Homo heidelbergensis*) occupied the region during the period 600,000 – 400,000 BP. This is suggested by the discovery in 1994 of a lower hominin tibia bone (believed to be *H. heidelbergensis*) just a few kilometres away from the English Channel, along with hundreds of ancient hand axes, at the Boxgrove Quarry site, which overlaps the time period when parts of the Study Area were potentially inhabitable.

It is also probable that portions of the Study Area were inhabitable for substantial periods of OIS 3-5d (*c.*110,000-40,000 BP) and it should be noted that this time period within the European record includes evidence of Cro-magnon (early anatomically modern humans) in some contexts (although no Cro-magnon remains have yet been found for such an early date in the UK), any such finds would be considered very important to our understanding of the first colonisation of the British Isles by modern humans.

Because the global archaeological record of hominid evolution and colonisation is so sparse due to the great age of finds and the physical depth of most geological contexts likely to contain hominid remains, all and any finds are considered archaeologically valuable both in the UK and internationally.

Only by 7,500 to 7,000 BP did the Study Area become inundated and hence uninhabitable, it is likely that prior to this, there was significant movement of species along the land-bridge between south eastern England and the European Continent, as the ice retreated and the climate became more hospitable, and as such there is the potential for archaeologically important finds until this date. With the exception of a relatively small number of sites and finds, the known submerged prehistoric archaeology of the Study Area is sparse. In archaeology, however, absence of evidence, is not evidence of absence; the poor archaeological record is more likely to do with the difficulty in finding and identifying contexts in a submerged environment, and in turn this increases the academic 'value' of any finds from the area during prehistoric times.

6.6.4 Maritime Archaeology

Introduction

Maritime sites are defined as comprising of either vessels or debris which has been accidentally or deliberately lost overboard from a vessel. There is the potential for archaeological evidence of maritime sites of all periods dating from the Mesolithic period to the present within the Study Area.

In the past the Study Area would have provided access directly to the capital, large ports and harbours along the coasts of Suffolk and Essex and further afield to Europe and beyond. Due to this density of marine traffic passing through the Study Area since the Mesolithic, there are many remains of these vessels. Maritime archaeology that has been recorded within the Study Area dating from the Mesolithic Era onwards is summarised in Table 6.10.

Table 6.10 Maritime Archaeology within the Study Area since the Mesolithic Era

Period	Maritime Archaeology
• Neolithic and Bronze Age (4,000 – 700 BC)	• Discovery of a number of Neolithic vessels within the general vicinity of the Study Area, such as the Neolithic dug out canoe at Jaywick near Clacton [1]. • Bronze Age vessel found at Dover • Discovery of 363 Middle Bronze Age objects of Continental origin offshore at Langdon Bay, Dover, from a suspected shipwreck.
• Iron Age and Roman (700 BC – 500 AD)	• A number of Iron Age logboats have been recorded from the Thames and its tributaries. • Pottery concentrations discovered in Pan Sand in the Thames suggest the potential for the survival of lost cargoes and shipwrecks from the Roman period. • Discovery of three plank-built vessels within the Thames Estuary; the Blackfriars ship I, the New Guy's House boat and the County Hall ship.
• Early Medieval and Medieval (AD 500 – 1508)	• The remains of a fish-trap in Holbrook Bay, Suffolk have also been found, dating to the Anglo-Saxon period (Hegarty *et al*, 2004). • Discovery of a timber fishtraps within the mudflats of the intertidal zone of the Stour in Holbrook Bay, Suffolk. • A number of ship timbers dating to the 10th and 11th centuries were discovered at wharves in Southwark and the city of London. • The remains of three ships include the late 12th century Custom House Boat, and the Blackfriars ships 3 and 4.
• Coastal and seafaring activity in the study area vicinity: 1508 - 1815	• In an area north-east of Crane's Creek in Suffolk the remains of a probable post-medieval oyster dredger have been discovered.

The seabed topography within the Study Area is characterised by numerous long narrow sandbanks which run parallel to one another along the coasts of Suffolk, Essex and within the greater Thames Estuary. The crests of the sand banks are shallow and often exposed at low tides posing a navigational hazard to vessels using the area. The Study Area is also exposed to prevailing winds from the north east during the winter which again increases the risk of vessels being blown onto shallow sandbanks [2]. Therefore it can be concluded that many of the vessels which passed through the Study Area sank, as a result of natural causes, as well as casualties due to collision or war.

(1) Warren, S.H, Piggott, S, Clarke, J.G.D, Burkitt, M.C, Godwin, H. and M.E. 1936. Archaeology of the Submerged Land-Surface of the Essex Coast. Proceedings of the Prehistoric Society 2.2:178-210.

The survival of a shipwrecks or maritime structures depends largely on whether they come to lie on or within the seabed sediments (Gregory, 2006). This environment is one which has a high potential for the loss of ships [2] and with the seabed being characterised by fine grained sediments there is a high potential for preserving archaeological material.

Results of the Navigational Hazards project carried out by Bournemouth University in 2007 also highlighted there is a higher potential for the loss and preservation of vessels on approaches to estuaries inshore and shallow fine-grained sandbanks offshore, with the approaches to the Thames Estuary providing one of the largest Areas of Maritime Archaeological Potential (AMAPs) in which these trends coincided.

Recorded Wrecks

A total of 1537 charted sites were listed in SeaZone data within the Study Area. These records were subdivided into those classified as wrecks and obstructions. An obstruction is defined by SeaZone as *'an object on the seabed of known or unknown source that is neither a wreck nor infrastructure and which may hinder safe passage or other activity'*

Table 6.11 below shows the date range for the charted vessels and unspecified recorded sites. Unspecified sites may either be wrecks which have limited data, or sites which may or may not be wrecks (i.e. obstructions) and whose nature and origin cannot be defined on the basis of available survey data.

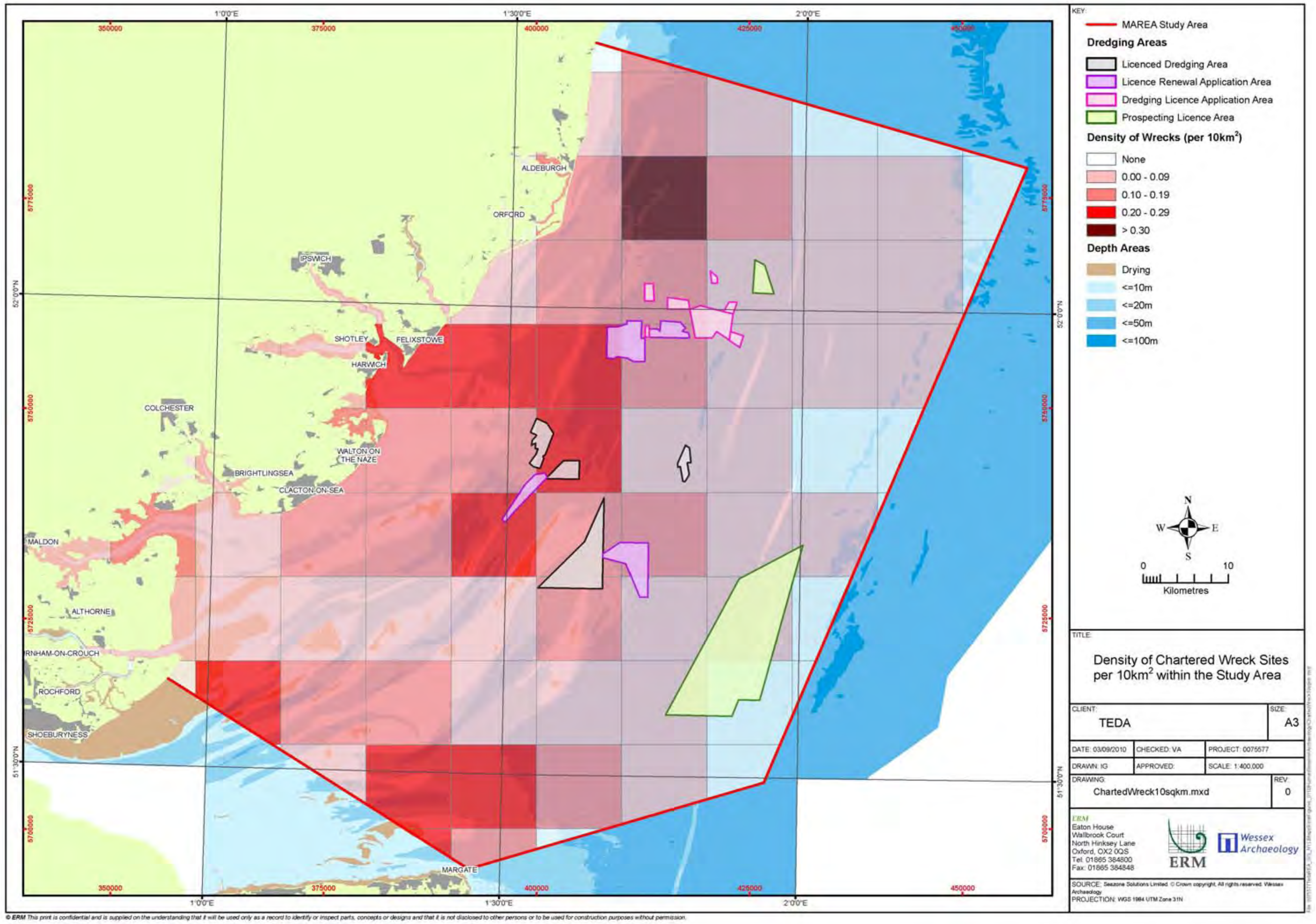
Table 6.11 SeaZone Wrecks and Unspecified Sites by Date Range

Date	Wrecks (561 wrecks/ 83 Obstructions)	Unspecified (452 Wrecks/ 441 Obstructions)	Total
<1508	0	0	*0*
1509-1815	1	0	*1*
1816-1913	5	0	*5*
1914-1945	429	18	*447*
>1946	106	17	*123*
Unknown	103	858	*961*

Figure 6.43 shows the distribution patterns of vessel wrecking incidents within the Study Area.

(2) Bournemouth University. 2007. Enhancing our understanding of the marine historic environment: Navigational Hazards Project, unpublished report.

Figure 6.43 Density of Charted Wreck Sites per 10km2 within the Study Area



The highest density of wreck sites occur in the north of the Study Area off the coast of Suffolk, some 10km east of Aldeburgh. Another concentration of wreck sites occur in the centre of the Study Area, encompassing the approach to the Stour and Orwell estuaries, possibly reflecting a relatively high density of shipping activity within this vicinity. To the south of the Study Area, concentrations of wreck sites appear to correlate with the Margate Sands to the north of Margate, Kent, and the Maplin Sands east of Foulness Island. Wreck sites here are not a surprise as it is expected that a great number of vessels were lost after foundering on the extensive shallow sand banks which characterise the surface geology of the Study Area.

Shipping Casualties

A total of 2017 recorded losses were listed in the NMR within the Study Area, of which 1891 were categorised as wrecks. The date range for these shipping casualties is shown below in Table 6.12. It is important to note that the positions of recorded losses are often vague and inaccurate and also only represent those loses which were actually recorded.

Table 6.12 NMR shipping casualties by date range

Date	Shipping Casualties
<1508	7
1509-1815	575
1816-1913	1087
1914-1945	213
>1946	8
Unknown	1

Charted sites and shipping casualties should not be regarded as directly representative of wreck sites that lie on the seabed within the Study Area. Prior to the advent of the Lloyds of London list of shipping casualties in 1741, there were no official records of ship losses and as such records of shipping casualties are biased towards wrecking incidents which occurred from the mid 18th century onwards. In addition shipping casualties which refer to wrecking incidents for which there are no known positions may lie outside the Study Area.

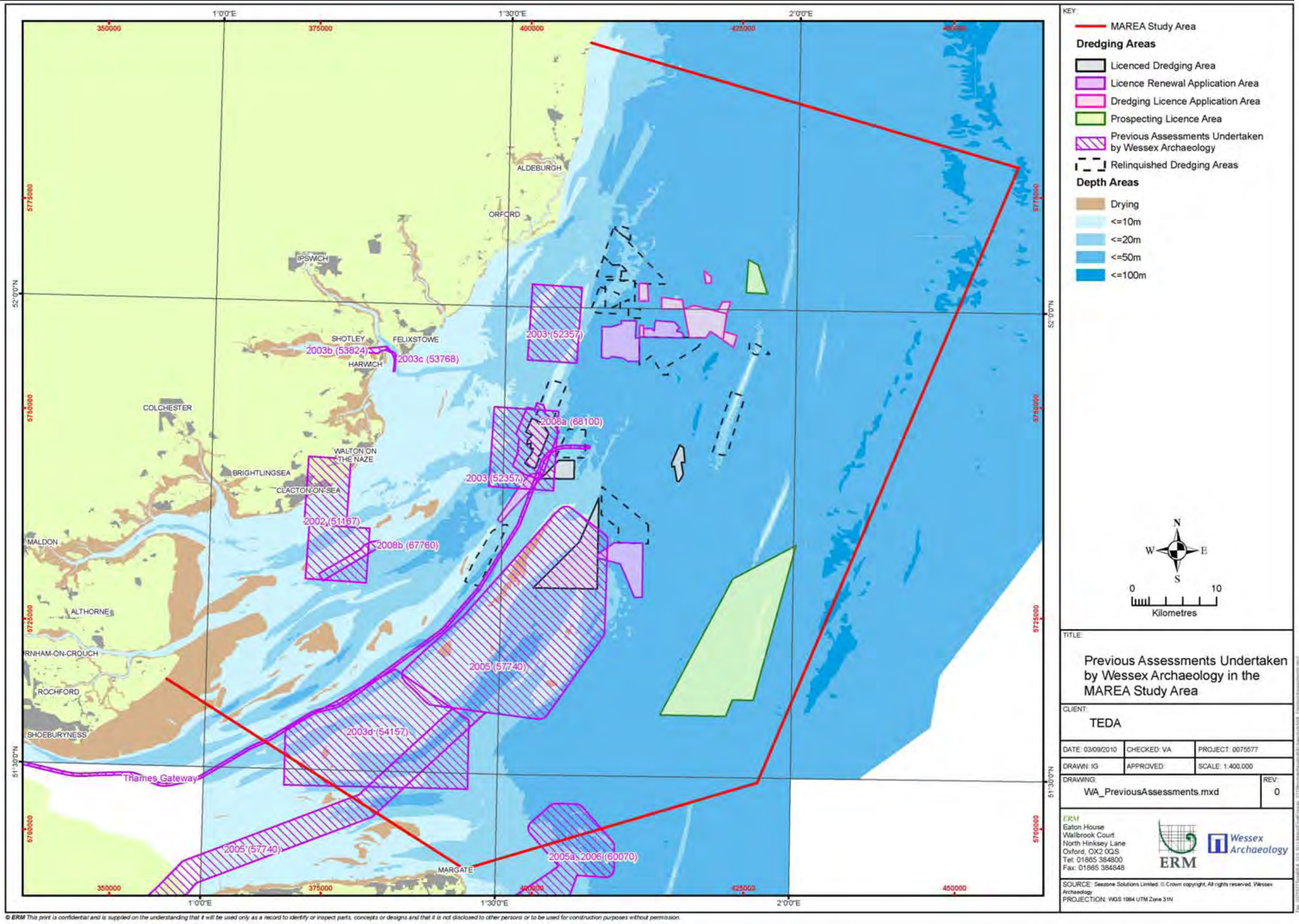
Previous Archaeological Assessments Undertaken in the Study Area

Previous archaeological studies undertaken by Wessex Archaeology have found there is the potential for uncharted and unknown wreck sites within the Study Area. The locations of these previous archaeological assessments are shown in Figure 6.44 and a summary of their findings below in Table 6.13.

Table 6.13 Previous Archaeological Assessment findings in the Study Area

Assessment	Findings
Gunfleet Sands (Wessex Archaeology 2002)	• 48 charted sites and 32 geophysical anomalies were identified. Of the geophysical anomalies, a total of five represent possible uncharted wreck sites.
Cutline Areas 446 and 447 (Wessex Archaeology 2003)	• 21 geophysical anomalies were identified. • 13 anomalies represent charted sites and six which were not thought to represent wreck sites.
Bathside Bay (Wessex Archaeology 2003b)	• 13 anomalies were identified. • One anomaly is thought to represent a wreck. Four irregular anomalies have been described as being human in origin. Six sites have been identified as probable mooring blocks and two sites are thought to represent debris or rocks.
Felixstowe South Reconfiguration (Wessex Archaeology 2003c)	• 37 anomalies were identified. • One charted wreck was identified and two further anomalies represent wreckage from this site. • Five sites were considered as having high archaeological potential, five as having medium archaeological potential and 24 sites of low or very low archaeological potential.
Thames Estuary Offshore Wind Farm (Wessex Archaeology 2003d)	• 59 known wrecks and obstructions were noted within the Study Area, but no geophysical data was assessed to supplement this data.
London Array Offshore Wind Farm (Wessex Archaeology 2005)	• 277 geophysical anomalies were identified. • 31 represent charted wrecks/obstructions and 12 represent uncharted wreck sites.
Thanet Offshore Wind Farm (Wessex Archaeology 2005a, 2006)	• 71 known wrecks were noted. • 130 anomalies were identified. 14 represent charted wrecks/obstructions and five represented charted wrecks situated outside the Study Area. Three geophysical anomalies were identified which represent uncharted wreck sites.
Area 447 Cutline (Wessex Archaeology 2008a)	• 81 geophysical anomalies were identified. 13 are thought to correlate with charted sites, 30 are described as having archaeological potential.
Gunfleet Sands 1 and 2 (Wessex Archaeology 2008b)	• 34 geophysical anomalies were identified, three of which are likely to represent wrecks.

Figure 6.44 Previous Assessments Undertaken by Wessex Archaeology in the MAREA Study Area Region



Significance of Potential Maritime Archaeology

Of the vessels which passed through the Study Area, it can be assumed that many are likely to have foundered, as a result of natural causes (sea and weather), collision or war. The seabed topography within the Study Area is characterised by numerous long narrow sandbanks which run parallel to one another along the coasts of Suffolk, Essex and within the greater Thames Estuary. The crests of the sand banks are very shallow and some are exposed at low tides (Cameron *et al.* 1992) posing a navigational hazard to vessels using the area. This risk is increased by the nature of the shore, which is exposed to prevailing winds from the north-east, increasing the risk to vessels being blown on to the shallow mobile banks (Bournemouth University 2007:34).

The significance of any potential maritime archaeology within the Study Area is discussed below in chronological order.

There is no evidence for Palaeolithic watercraft pre-dating the Devensian glacial maximum in the UK. This lack of evidence should not be taken to indicate a lack of maritime activity during this period around the UK, as the resources and technology required to construct small craft would certainly have been available to these early communities. However, due to the series of glacial events, marine transgressions and fluvial processes throughout the Palaeolithic, the potential for the survival of any archaeology associated with the maritime environment is unlikely.

It has been suggested by human settlement patterns around the North Sea that sea voyages were conducted as early as 7,000 BC, during the Mesolithic period. The type of craft used for these voyages and how extensively they were used is unknown. Vessels for which there is archaeological evidence from the Mesolithic are log boats. The oldest log boat in Europe dates to 7,920-6,470 BC and was found in Pesse in the Netherlands (McGrail 2004). Other simple craft seen in later contexts, such as the hide boat, may also have been used, although their light construction would make them much less likely to survive in the archaeological record. The Mesolithic period saw the fairly rapid inundation of the lowland areas of the southern North Sea and the deposition of Holocene alluvial muds over the former land surfaces on which Mesolithic activity may have taken place. As such there is the potential for the survival of remains of such early craft beneath the alluvial deposits which are currently well offshore. Thus there should be considered the potential for archaeological evidence of very early sea-faring vessels within the Study Area, and any such finds would be considered very important by the archaeological community both in the UK and internationally. It is important to remember that many of the finds from this era are considered archaeologically invisible due to their organic nature, and are unlikely to have survived.

The available archaeological evidence for the later Neolithic period suggests a fairly low-density human occupation within coastal and estuarine areas of the Study Area. This could be due to the poor survival of Neolithic sites and maritime vessels, rather than representative of a *de facto* low level of human activity and seafaring in particular. During the Neolithic, the sea level did not rise to the extent that would have enabled the preservation of organic material such as wood within the intertidal zone. Log boats provide the only archaeological evidence in the UK directly relating to watercraft during the Neolithic period. Evidence relating to seafaring is provided by the discovery of a number of Neolithic vessels within the general vicinity of the Study Area, and thus it is possible that the Study Area has the potential to yield more such finds.

The scale of seafaring activities continued to grow through the Bronze and Iron Ages. Some of the earliest examples of Bronze Age watercraft in Northern Europe have been found on the east coast of Britain. Of the 22 log boats recorded from the Thames and its tributaries, a number have been firmly dated to the Iron Age (Marsden 1996:222) attesting to seafaring activity within the vicinity of the Study Area. The Study Area could potentially yield important clues to both Bronze and Iron Age sea-faring, of which finds are rare, however it is likely that finds could be archaeologically invisible.

The Thames Estuary has a rich archaeological record for the remains of ships, boats and waterfronts dating to the medieval period. Broadly speaking this suggests that individual finds from this period from within the Study Area, could be considered to have 'lower' archaeological value than maritime artefacts or contexts from less well understood periods, such as the Iron Age, where the record is much more sparse. However all medieval archaeological maritime contexts should be considered as valuable due to the relatively sparse archaeological record of the sea when compared to terrestrial investigations.

The recording of ship losses was better centralised in the late post-medieval period, and as such, the available record of shipping casualties is both more complete and accurate. The potential for discovering such vessels is further enhanced by the incorporation of metal elements within the vessel design which means that wrecks on the seabed dating to this period often more evident on the seabed than their predecessors and may be discovered through non-intrusive techniques such as magnetometer surveys.

The Study Area was a focus for military activity during both World Wars. The southern North Sea provided an obvious arena for naval action between Britain and its Continental adversaries (Till 1985:227) and the sheer number of vessels lost during this period was immense. During the Second World War, the British Royal Navy alone lost a total of 75 submarines, over 350 major warships and more than 1000 smaller vessels. Wrecks from this period are relatively common, however they are more sensitive because many of them are classified as war graves and some mitigation will be required to minimise any impacts on these.

From the above it is thus clear that there is the potential for the remains of vessels which date from at least the Mesolithic period to the present day within the Study Area. The density of marine traffic which has passed through the Study Area since the Mesolithic is immense. Furthermore, by its close proximity to the Continent and its position on the approach to the River Thames, the Study Area would have not only provided access directly to the capital, and other large ports and harbours along the coasts of Suffolk and Essex, but also further afield to Europe and beyond. With this quantity of shipping activity within the region, the potential for the remains of vessels within the Study Area is clearly very high. This potential is further enhanced by the nature of the seabed topography within the Study Area. The highly mobile and numerous sandbanks which characterise the shallow geology of the region have the ability to swallow shipwrecks of considerable size. These sandbanks also often provide favourable preservation for shipwrecks. Although in some cases the remains of vessels would not survive due to post-depositional processes, the debris field of a wrecking incident may also be sealed within the sandbanks.

In spatial rather than temporal terms, overall, the wreck sites are dispersed fairly randomly throughout the Study Area, although distinct areas of concentration have been noted. The highest density of wreck sites occurs at the north of the Study Area off the Suffolk coast, some 10km east of Aldeburgh. A further concentration of wreck sites has been noted within the centre of the Study Area extending from the Harwich Haven region. This is an area of shallow reefs and shoals and a large number of vessels are likely to have foundered in this vicinity. The density of wrecks within this region may also reflect a relatively high density of shipping activity in this area.

To the south of the Study Area, concentrations of wreck sites appear to correlate with the Margate Sands to the north of Margate, Kent, and the Maplin Sands east of Foulness Island. This is not surprising, as it is expected that a great number of vessels were lost after foundering on the extensive shallow sand banks such as these which characterise the surface geology of the Study Area. Spatially it should also be remembered that the later charted wreck sites and shipping casualties should not be regarded as directly representative of the wreck sites that lie on the seabed within the Study Area and there is potential inaccuracy of the actual positions cited for wrecks, which needs to be remembered when considering mitigation options.

Consideration must also be given to the potential for isolated finds that may have come to be on the seabed having been lost or discarded overboard. Such finds may not only be useful in defining the preferred sea routes within the Study Area throughout the centuries, but may also provide evidence for other maritime activities, such as overseas commerce and naval warfare.

6.6.5 Aviation Archaeology

Introduction

Aircraft losses at sea span the entire period of aviation history, from the introduction of flight to the post-WWII period. Although records of aircraft losses at sea are extensive, data regarding their location is often limited. A guidance note published by English Heritage entitled *Military Aircraft Crash Sites* [1] outlined a case for recognising the importance of aircraft crash sites, specifically with regards to existing and planned development proposals which may have an impact on such sites.

There is the potential for the presence of a large number of unknown crash sites on the seabed within the Study Area. Due to the often minimal nature of their remains, aircraft crash sites are often not easily distinguishable. Further to this, the remains of military aircraft which are found receive blanket protection under the Protection of Military Remains Act 1986. Consequently, the potential for military remains to be present within the Study Area must be kept in mind during the assessment.

A number of aircraft dating to WWI have been recorded lost around the UK. A total of 28 fixed wing aircraft and 15 airships were lost by the German Imperial Air Service and Navy, during raids on the UK mainland throughout WWI, with the possibility of being lost at sea.

Published aviation researcher Ross McNeill identified 123 aircraft crash sites to be located off the coast of Essex, 73 off the coast of Suffolk and 380 located off the coast of Kent from WWII. In addition other studies have found that WWII losses tended to be clustered along the southern and eastern margins of England, with some 1,000 losses of British aircraft noted off the coast of Suffolk [2].

There have been few aviation losses across the UK since 1945. The Department of Transport's Air Accident Investigation Branch (AAIB) lists 120 civil aircraft losses at sea around the UK between 1946 and 1994, most of which comprised of light aircraft or in more recent years helicopters. However the discovery of the remains of a Supermaine Attacker WP275 which crashed into the sea on the 6th July 1956 off the coast of Worthing, Sussex suggests the potential for aircraft wreckage within the Study Area [3] .

(1) English Heritage. 2002. Military Aircraft Crash Sites: Archaeological guidance on their significance and future management, English Heritage (www.english-heritage.org.uk/upload/pdf/Mil_Air_C_Sites.pdf).
(2) English Heritage. 2002. Military Aircraft Crash Sites: Archaeological guidance on their significnace and future management, English Heritage (www.english-heritage.org.uk/upload/pdf/Mil_Air_C_Sites.pdf).
(3) Wessex Archaeology. 2006a. Protocol for reporting finds of archaeological interest, BMAPA annual report 2005-2006, unpublished report.

Known Aircraft Crash Sites in SeaZone and NMR databases

Of the 1551 charted sites listed in the SeaZone data, only 14 contained references to aircraft crash sites within the Study Area. Of the 14 records, four were post 1946 in date while the remaining 10 were of unknown dates. These crash sites are shown in Figure 6.45.

Of the 2017 recorded losses listed in the NMR within the Study Area, a total of 126 contained references to aircraft crash sites. Of these aircraft, six pre-dated WWII (spanning from 1921 to 1937), 119 dated between 1939 and 1945 and the remaining aircraft crash site was post 1946 in date.

Preservation of Aviation Archaeology in the Study Area

Site survival and visibility of aircraft crashes is determined largely by the cause of loss of the aircraft. With a few exceptions, aircraft come to be on the seabed as a result of an in-flight accident or enemy action. Aircraft which are on the seabed due to controlled ditching are likely to be better preserved than those which exploded in mid-air or hit the water at speed.

The factors which determine the survival of an aircraft crash site are not yet fully understood. It is, however, recognised that marine environments generally offer favourable conditions for the preservation of artefacts, enhancing the potential for the survival of aircraft crash sites on the seabed and the seabed sediments within the study area would promote the survival of aircraft crash sites.

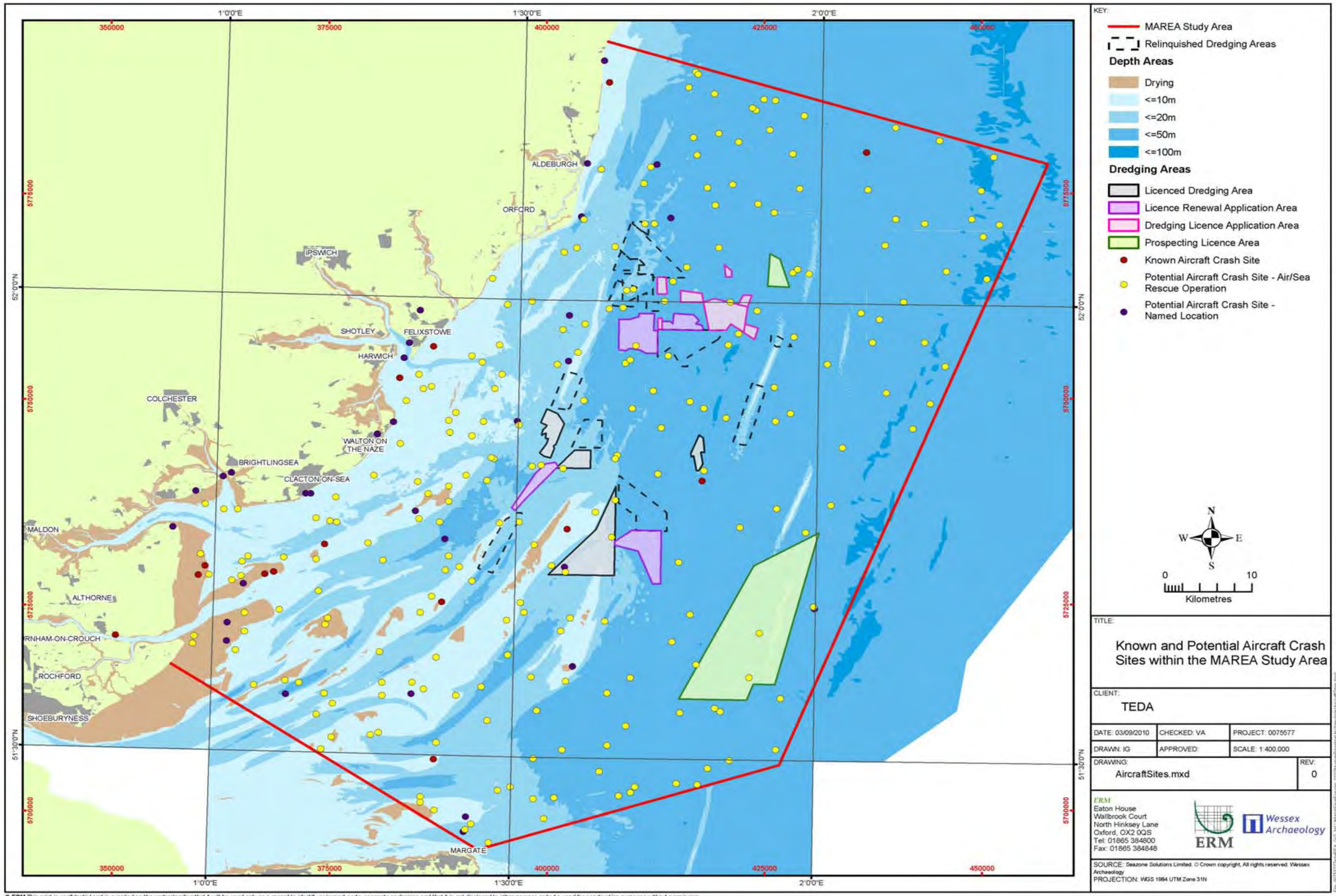
Significance of Potential Aviation Archaeology within the Study Area

Although aircraft losses are predominantly concentrated within the period between 1939 and 1945, there is the potential for aircraft crash sites which span the entire period of aviation history.

With the potential resource for aircraft crash sites large, and the number of known crash sites relatively small, the potential exists for the presence of a large number of unknown crash sites on the seabed within the Study Area. In providing favourable preservation, the seabed environment further enhances this potential, making the discovery of fairly intact aircraft on the seabed far more likely than for those discovered on land.

Despite this, due to the often ephemeral nature of their remains, aircraft crash sites are not easily distinguishable in standard geophysical survey. Further to this, the remains of military aircraft which are found receive blanket protection under the Protection of Military Remains Act 1986, whereby no disturbance of a military aircraft wreck is permitted without a licence from the MoD. Consequently, the potential for military remains to be present within the Study Area must be borne in mind during the assessment of any area ahead of seabed development and those sites classes as 'graves' will be regarded as highly sensitive.

Figure 6.45 Known and Potential Aircraft Crash Sites within the MAREA Study Area



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6.7 SUMMARY OF KEY SENSITIVITIES

6.7.1 Fisheries

The Outer Thames Estuary has long been an important area for fishing activity. The region provides spawning, nursery and feeding grounds for populations of a number of commercial fish species. A wide variety of fisheries have developed around the life cycles of target fish and shellfish to exploit these resources.

The most important species landed at local ports are shellfish, particularly cockles; the Thames Estuary Cockle fishery is now the most productive and most important cockle fishery in the UK and one of the largest in Europe. Pelagic finfish landings are dominated by sprats followed by herring, while landings of demersal species are mainly cod, skates and rays and sole.

6.7.2 Infrastructure

Infrastructure associated with the MAREA study area includes ports and harbours, marine disposal sites, offshore wind farms, pipelines and cables, military activity and oil and gas exploration.

There are a large number of ports, harbours and berths along the coastline of the MAREA study area that vary in size and purpose. Two container ports (Harwich and Felixstowe) required the deepening of the approach channel, which is marked by lights and buoys and regularly maintained to 14.5 m below CD to provide better access for deep-drafted vessels. Both Felixstowe and Harwich Ports currently have plans to expand their capacity. An additional container port is planned in Thurrock (The London Gateway), which is located outside the MAREA study area but shipping movements within the area may change and a large scale dredging project is planned in order to lower the channel and enable access to the terminal by larger container ships.

Areas of the Outer Thames estuary may be contaminated from past dumping activities at licensed sites. There are four active and two redundant offshore disposal sites in the Thames estuary (not including numerous dumping sites along the coast and associated with rivers). A license for disposal of waste at sea is only issued by DEFRA where it can be shown that the material is not seriously contaminated and it will not harm the marine environment. Dumping sites are subject to periodic monitoring by CEFAS.

There are a number of active and proposed wind farms in the MAREA study area. In Round 1 the Kentish Flats wind farm was built to the south of the MAREA study area and has been operational since September 2005. The Gunfleet Sands I wind farm, also part of Round 1, is currently undergoing construction and was due to be fully operational by the end of 2009, although this target was not met. During Round 2 four wind farms were approved within the MAREA study area; the Thanet array, the London Array (phase 1), Gunfleet Sands II and the Inner Gabbard and Galloper arrays of the Greater Gabbard development (1). The London Array (phase 1) and Greater Gabbard developments are due to be complete in 2012 and Gunfleet Sands II, although is not fully operational, started producing power in August 2009. The Crown Estate announced the proposal for a third round of offshore wind farm leasing in June 2008, however, only part of the current boundary of Zone 5 (the Norfolk Zone) is situated within the MAREA study area. The Zone 5 offshore wind farm rights have since been awarded to ScottishPower Renewables in a joint venture with Vattenfall Vindkraft.

There are a number of pipeline outfalls along the coastline and eight subsea cables that dissect the region within the MAREA study area; no submarine pipelines traverse the estuary. Most of the cables in the southern North Sea are trenched to a depth of 40-90 cm, with rock-dumping being used to anchor cables in some instances. The older, redundant cables are more likely not to be trenched (2).

A range of Military and Navy submarine exercise and practice areas are present within the MAREA study area as well as a number of small land-based firing ranges in the vicinity. In addition, due to activities during WWII unexploded ordnance may be present.

Significant oil and gas infrastructure exists within the Outer Thames Estuary but there are no producing oil and gas fields and no oil or gas pipelines (3).

6.7.3 Recreation

The Thames Estuary is intensively used by recreational sailing and motorised vessels for training, pleasure cruising and racing. Other recreational activities such as sea angling from boats and diving also occur but are limited. Some inshore racing occurs within the Thames Estuary; the EAORA is organising a total of seven races in 2010; five start and finish within the Thames Estuary and a further two start or finish in the estuary. The Thames Estuary is one of the most heavily used areas for recreational cruising in the UK and cruising routes within the MAREA study area are popular, however, no statistics of usage are available.

(1) The British Wind Energy Association (BWEA). 2009. Website available at http://www.bwea.com/ (accessed 26/01/09).
(2) DECC (formerly DTI). 2002. Human Activities in the SEA 3 Area. Available at: http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).
(3) DECC (formerly DTI). 2002. Human Activities in the SEA 3 Area. Available at: http://www.offshore-sea.org.uk/consultations/SEA_3/TR_SEA3_ExistingActivities.pdf (accessed 27/01/09).

6.7.4 Navigation and Shipping

The MAREA study area is a busy region with approximately 145 ships passing through each day (the vast majority above 300 GRT) (4). Most of the vessels in the region were cargo vessels; dredgers and other subsea operation vessels accounted for 6% of all the tracks (the majority of these were aggregate or maintenance dredgers as opposed to other types of subsea operations vessels). Most of ships were inbound to ports in the outer Thames estuary, including Felixstowe and Harwich and the Inner Thames (Tilbury, Coryton) or outbound from the Thames Estuary and European ports.

6.7.5 Archaeology and Cultural Heritage

Evidence suggests hominid activity within the MAREA study area from c.380,000-245,000 BP and also during the warming stages of the Windermere Interstadial (13,500-11,000 BP) of the Late Upper Palaeolithic. The depressions and gulleys between the banks and ridges north east of the Essex coast provide an environment favourable for prehistoric site survival and visibility. As do the relict estuaries and river valleys of the Study Area, which although likely to be concealed within marine alluvium may be exposed during dredging operations.

There is archaeological evidence of maritime sites dating from the Mesolithic period to the present day within the Study Area. There are a total of 1537 charted sites within the MAREA study area listed in SeaZone data. The highest density of wreck sites occur in the north and another concentration of wreck sites occur in the centre of the MAREA study area, which possibly reflects the relatively high density of shipping activity within this vicinity. To the south concentrations of wreck sites appear to correlate with the Margate Sands and Maplin Sands, which is expected due to a large number of vessels lost after foundering on the extensive shallow sand banks. Previous archaeological studies in the area have found there is the potential for uncharted and unknown wreck sites within the Study Area.

Aircraft losses at sea span the entire period of aviation history and although records of aircraft losses at sea are extensive, data regarding their location is often limited. There is the potential for the presence of a large number of unknown crash sites on the seabed within the MAREA study area, however, due to the often minimal nature of their remains aircraft crash sites are often not easily distinguishable. The remains of military aircraft which are found receive blanket protection under the Protection of Military Remains Act 1986. SeaZone data contains only 14 references to aircraft crash sites within the Study Area. Of the 14 records, four were post 1946 in date while the remaining 10 were of unknown dates.

(4) Based on the analysis of Automatic Identification System (AIS) data over a 40 day period (10 April – 22 May 2008).

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7 POTENTIAL EFFECTS OF DREDGING

7.1 INTRODUCTION

This chapter discusses the potential effects of dredging on the environment within the MAREA area.

The immediate effects of the dredging process include:

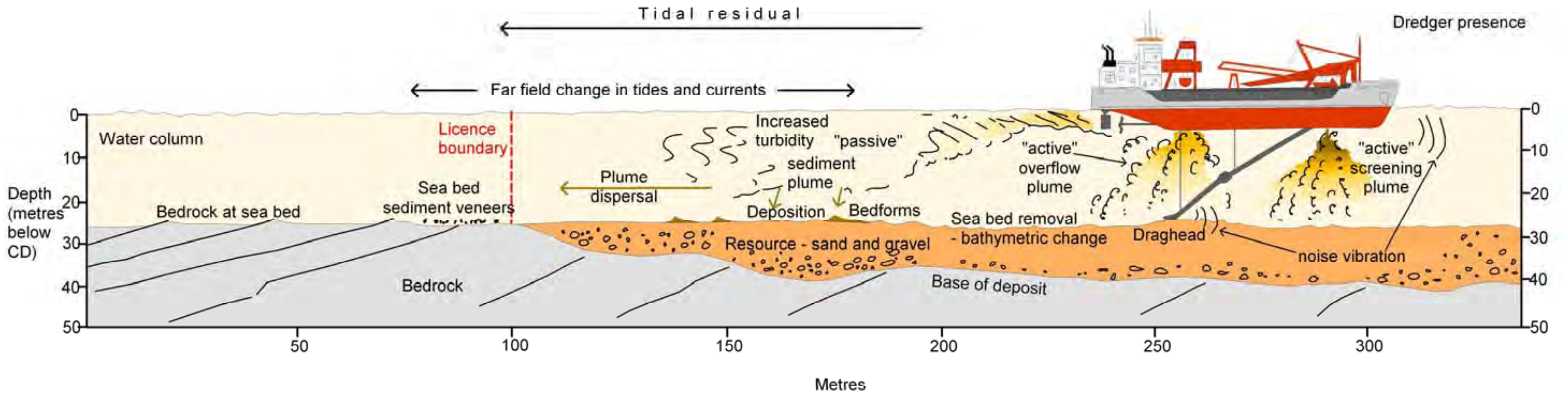
- the presence of the vessel and the risk of collision;
- emissions and discharges from the vessel;
- seabed modification and changes to bathymetry from the draghead cut;
- elevated turbidity from the passage of the drag head;
- the generation of a fine sediment plume from the overflow;
- the generation of a fine sediment plume from screening; and
- noise generated by the dredging operation.

The changes brought about by these effects are likely to be greatest in the immediate vicinity of the dredger. In addition, dredging activity could potentially result in a number of secondary effects due to the alteration of bed morphology which may ultimately lead to:

- changes in tidal currents and local circulation;
- changes in wave propagation and wave conditions at the coast and throughout the region; and
- changes in sediment supply to beaches and sand banks.

Figure 7.1 is a conceptualisation of the physical effects of dredging that are discussed throughout this chapter. It is important to note that the potential effects of dredging discussed here are not necessarily considered to represent impacts. They represent changes in the ambient conditions that may or may not be translated into impacts as a result of their interaction with the environment. This will be considered further in Chapters 8 to 10.

Figure 7.1 Conceptualisation of Aggregate Dredging and its Physical Effects on the Marine Environment



7.2 SOURCES OF INFORMATION

This section is based on a number of specialist studies that have been undertaken for the MAREA:

- Navigation Impacts Review – Thames Estuary Dredging Areas (Technical Note). Anatec UK Limited (2009).
- Licensed Dredging Areas for the Thames Estuary Region. The Crown Estate (2009). Available at http://www.thecrownestate.co.uk/licensed_dredge_chart_thames_oct09.pdf. Accessed 27/12/2009.
- MAREA: High-level Plume Study (Technical Note DDR4318-03). HR Wallingford Limited (2010).
- Dredging Plume Sedimentation Study. Brian D'Olier (2008).
- Sediments of the Thames Estuary. Brian D'Olier (2008).
- Assessment of Underwater Noise Impacts from Marine Aggregate Dredging in the Outer Thames Estuary. Environmental Resources Management Limited (2009).
- Assessment of underwater Noise from Dredging Operations on the Hastings Shingle Bank (Report Number 758R0137). Subacoustech (2008).
- Regional Environmental Assessment: Tidal Flows and Sediment Transport Study (Technical Note DDR4318-05). HR Wallingford Limited (2009).
- Regional Environmental Assessment: Wave studies (Technical Note DDR4318-04). HR Wallingford Limited (2009).
- Other information sources include relevant scientific studies and industry reports, which have been referenced throughout.

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7.3 PRIMARY EFFECTS

7.3.1 Vessel Presence

Emissions and Discharges

Engine exhausts from the dredging vessels contribute to atmospheric emissions. Bilge waters, cooling waters and treated domestic waste water (sewage) constitute the liquid emissions. These will be discharged in accordance with MARPOL requirements. Solid waste is collected onboard as part of standard waste management practices, and transferred to an appropriate licensed facility when the vessel reaches port. The dredging vessels are therefore considered no different to other vessels operating in international waters and this issue has not been taken forward into the regional impact assessment.

Collisions

The high traffic density of commercial and recreational vessels in the Outer Thames Estuary introduces the increased risk of collisions taking place given the increased number of dredging vessel movements. Ship-to-ship collisions are mainly caused by manoeuvring or navigational failures including equipment and communication failures, and in some cases human error.

The principal concern associated with an increase in the number of dredging vessels in the region is the obstruction caused by slow-moving dredgers to other vessels in the area. The likelihood of collision depends on the following:

- The expected frequency that vessels fail initially to identify that the vessel is a slow-moving dredger and to assess correctly its course and speed, and subsequently collide (generally bow to stern).

- The probability that the dredger fails to observe vessels bearing down and does not move out of the way before collision occurs.

The consequences of collision will be dependent on the:

- type and size of vessel which collides with the dredger;
- speed of collision;
- type of collision (sideways/head-on); and
- the degree of loading of the vessels involved.

A modelling study designed to assess the potential increase in ship-to-ship collision risk due to dredging was carried out for the period of the MAREA (ie until approximately 2030). This study used baseline shipping data and future dredging tonnages, ie maximum regional tonnage scenarios provided by TEDA members. Full details on the modelling study are available in Appendix I. The Outer Thames Estuary is characterised by relatively high levels of commercial shipping, of which aggregate dredging by TEDA member companies currently contributes to approximately 1-2% of movements annually. A potential 150% increase in dredging activity may be seen based on the Future Case scenario, which increases dredger activity to a still low proportion of approximately 3% of the total vessel traffic. The increase in dredger activity increases the risk of collision from approximately 1 major collision in 1.44 years to 1 in 1.39 years, which is a small increase of approximately 3% relative to baseline levels. The additional dredger traffic will mainly use existing, established routes to/from the dredge areas. Areas with the highest shipping densities (Harwich and Felixstowe (via Sunk TSS) and the Inner Thames) are estimated to have the highest likelihood of ship-to-ship encounters/collisions.

7.3.2 Passage of the Drag-head

Elevated turbidity

The majority of marine aggregate extraction in the UK is carried out by Trailer Suction Hopper Dredgers, where a pipe is trailed along the surface of the seabed removing sediment as the ship moves slowly forward at a speed of around 1 knot [(1)].

The passage of the drag-head disturbs fine sediment and forces some into suspension. Measurements of plumes generated by the movement of the drag-head have shown that the volume of sediment introduced into the water column is barely detectable, in the order of 1% of the material introduced by the overflow and screening processes (Hitchcock *et al*, 1998; John *et al*, 2000) and the effect is extremely localised. This effect is therefore not considered further and the much larger effects on turbidity generated by overflow and screening are described in Section 7.3.3.

Seabed Deepening

The drag-head will remove strips of the target sediment, creating furrows 2-3 m wide and up to 0.5 m deep along the seabed in a single visit. Repeated passage of the drag-head across the same area can lower the seabed by more than 4 m in this region if the deposits are thick enough. As a result all the benthic infauna and epifauna associated with the dredged sediment will be removed.

The removal of sediment inevitably results in changes to the bathymetry, and the loss of seabed features such as sand waves and ripples. Research has shown that it can take between 3 and 7 years for dredging scars to recover in areas of relatively low wave exposure and reduced tidal currents(ICES, 2001) such as those found within the Outer Thames region.

(1) Personal communication with Robert Langman of Hanson Aggregate Marine Ltd, March 2010.

The surface sediments that are removed may be coarser than the underlying sediment; in areas where this is the case the increased proportion of sand on the seabed may encourage the formation of sand bedforms in which sand can be transported as bedload. In addition, furrows provide bed roughness in which slower current velocities may allow the accumulation of finer grained sediment. This is anticipated to be a medium-term effect, dependent on the life of the dredging project and the time taken to re-establish the coarse surface layer by winnowing.

It should be noted that rather than covering the whole of the licence area, the vessel will typically operate within an allocated zone determined by factors including resource location, exclusion zones, wreck sites and dredging conditions.

Figure 7.2 compares the 'present day' bathymetry, in which seabed levels in existing or relinquished [(2)] dredging areas have been established using the latest survey of those areas, with a baseline 'pre-dredged' bathymetry, in which the seabed levels in each existing or relinquished dredging area represent the situation before any dredging was started.

Figure 7.3 shows the difference between the 'present day' and 'post-dredged' bathymetry, showing the predicted further bed lowering over the next 15 years. The extraction plans were provided by each of the TEDA member companies for their licence areas and are based on the operating company's understanding of resource availability. The exception to this is the large prospecting Area 504 in the southeast of the study area for which information on resource distribution was not available at the time of writing. This area has since been surrendered but due to the schedule of the REA it has still been included in the assessment (see Industry Statement). The spatial and temporal trends are described on the following pages.

In general, Figure 7.2 shows that past dredging took shallow layers of the available resource across a large portion of the licence area whereas planned future dredging (Figure 7.3) will target the known available resource at a particular site, meaning proposed future dredging will be deeper where deep resource deposits occur, while parts of some licence areas remain undredged. Past dredging has generally lowered the seabed by between 1 and 2 m.

(2) Please note that in addition to the relinquished areas shown on these figures, there are other relinquished area in the region within which no dredging is thought to have taken place, and for which no bathymetric data could be provided, therefore these are not included in the figures. Any dredging that may have occurred pre-1993 in other relinquished areas is unquantifiable, however the resultant bed changes will have been captured by the UK Hydrographic Office bathymetries which is included in these figures.

The south and southwest parts of Area 257 and the Long Sand Head licence (Area 108/3, 109/1, 113/1) were subject to the deepest dredging, with small parts of the latter being dredged up to 3 m.

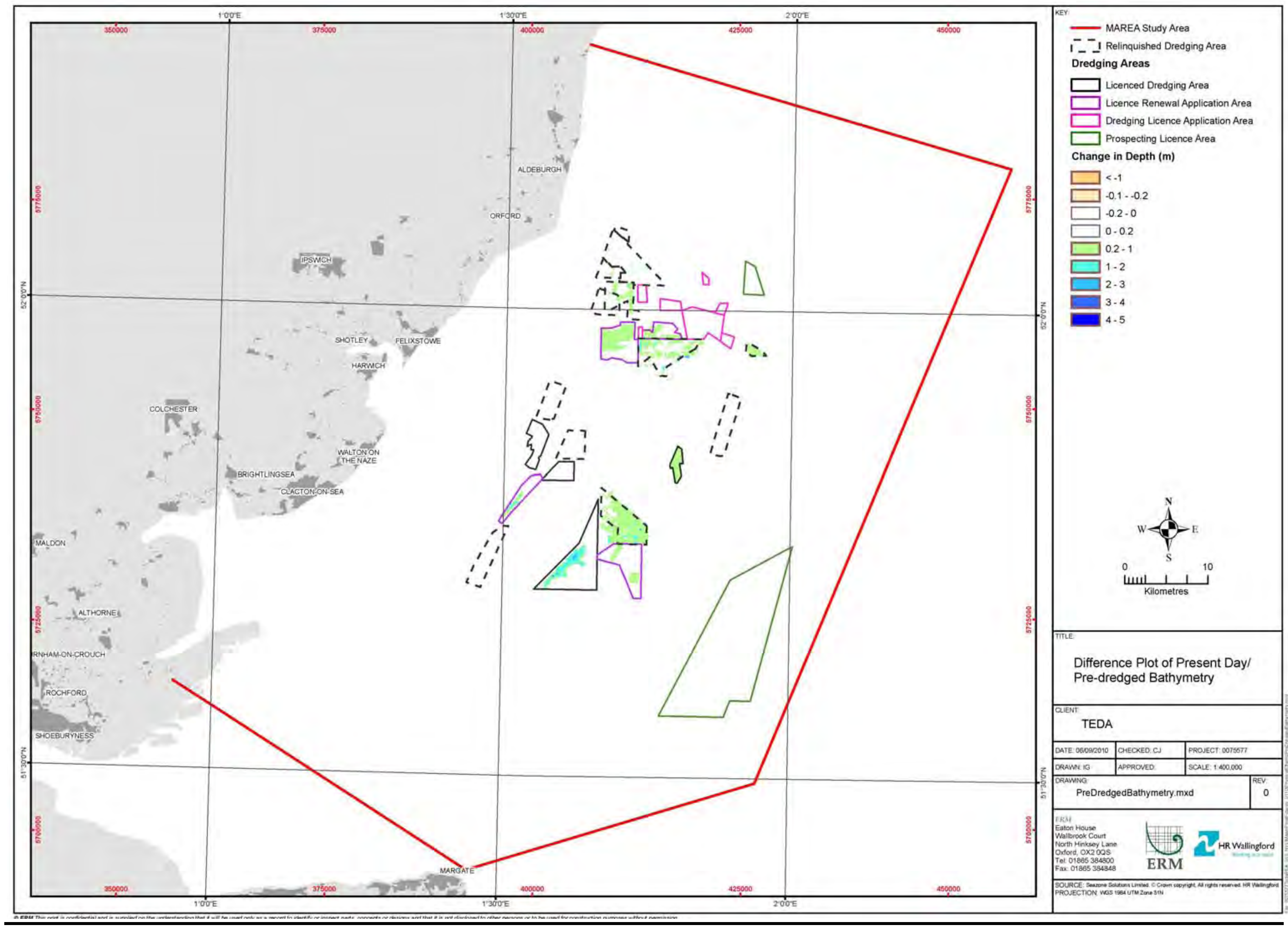
In the northern part of the MAREA study area, licence Areas 118/2, 239/1 and the adjoining relinquished Area 364/1 experienced patchy dredging of up to 1 m. Area 119/3 in the east of the dredging area was completely dredged to a depth of 1 m.

The proposed areas for future dredging have been developed using the results of surveys of the depth of the available resource in the licence areas, and reflect current understanding of known sensitivities such as wrecks and biogenic reefs. The proposed extraction plans for the MAREA area are as follows:

- The majority of the Long Sand Head licence (Area 108/3, 109/1, 113/1) will be dredged, with a large proportion being dredged to depths of 3 -5 m and the remainder of the dredged area being dredged up to 3 m.
- Areas 257, 447 and 119/3 will be predominantly dredged to depths of 2-5 m. The remainder of Areas 257, 447 and 119/3 will be dredged to lesser depths and in parts (especially the northeast of Area 447 and the north of Area 119/3) there is no planned dredging.
- The northwest and southern parts of Area 327 will be predominantly dredged to depths of 2 m and in some very small areas up to 4 m.
- In the north, existing licence Areas 118/2 and 239/1 will receive patchy dredging to a depth of 2 m and in very small parts up to 4 or 5 m.
- The current proposals indicate that the application and prospecting areas in the north of the MAREA area will also receive patchy dredging predominantly to depths of 2 m.

As described above, information about the resource and the eventual licence area boundaries of prospecting Area 504 in the southeast of the MAREA study area were not available for inclusion in this MAREA. However, it was agreed that if the resources were available then parts of the area may be dredged to depths of 4-5 m and this depth is therefore presented across the licence area in
Although this represents a total tonnage that is much greater than could ever be removed in practice, this conservative approach was adopted to ensure that any possible cumulative effects on the environment with adjacent licence areas were identified by the MAREA.

Figure 7.2 Difference plot of present day/pre-dredged bathymetry



7.3.3 Overflow and Screening

Information in this section has originated from the plume modelling studies and associated report conducted specifically for the MAREA by HR Wallingford. The full Plume Studies Report is presented in Appendix H.

Inputs of Sediment to the Water column

During dredging a mix of solids and water is pumped from the seabed into the hopper of the dredger. To allow the vessel to land a full and dry cargo of sand and gravel, the excess water is returned overboard via overflow spillways. The returned water contains a proportion of suspended solids (typically fine sands and silts), which will be dispersed horizontally and vertically as a plume by tidal flows and wave action and will be advected by tidal currents. Advection and dispersion continue until sediment concentrations are reduced to near background levels.

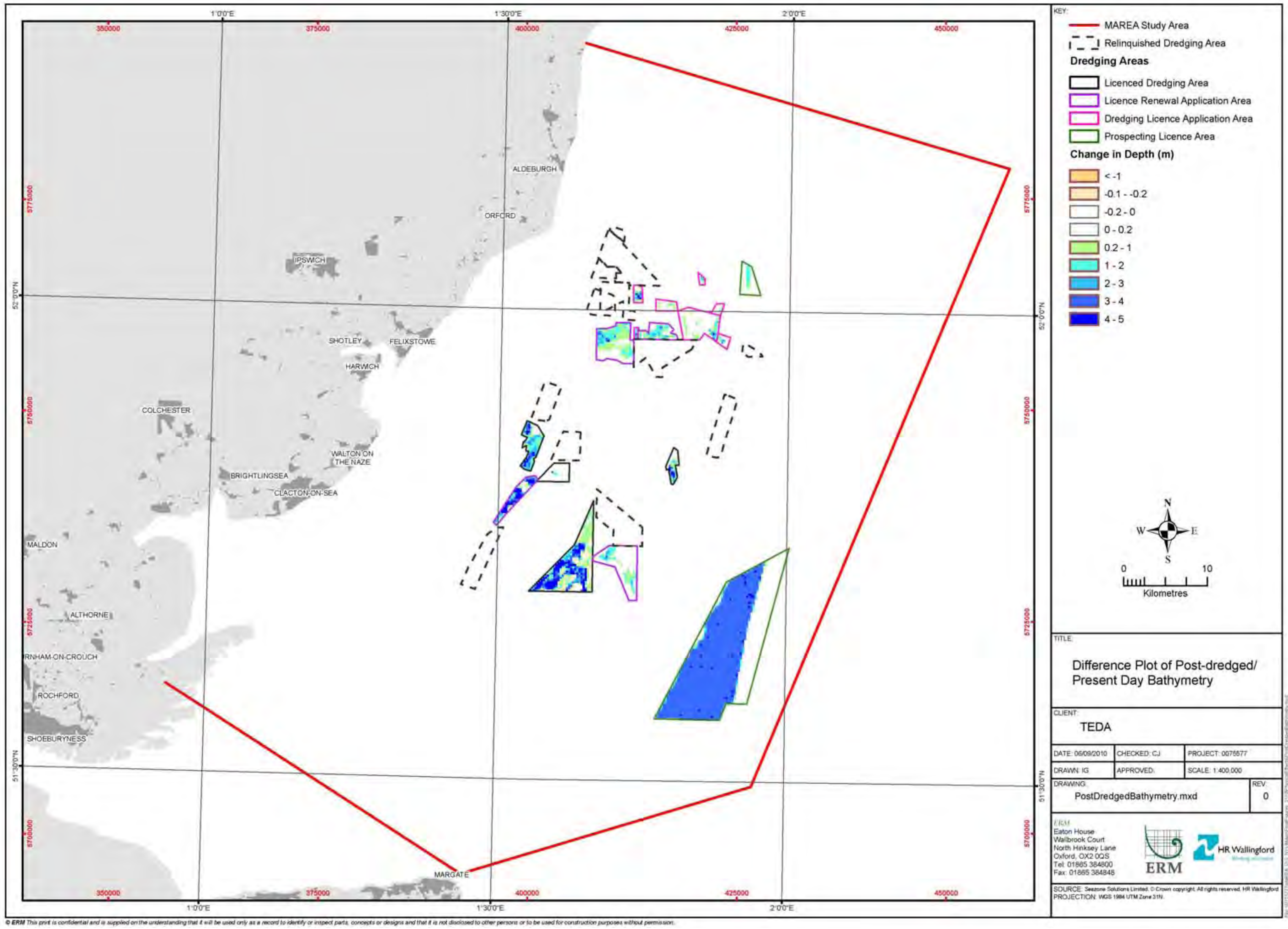
Most aggregate dredgers have the ability to screen off a proportion of the unwanted sediment size fractions to influence the composition of the final cargo. Accordingly, during screening, certain fractions of preferred sediment type (eg gravel) are retained within the hopper. Screening occurs in areas where commercial requirements for ratios of gravel to sand are not naturally present.

During screening the unwanted fine or coarse-grained fractions of dredged sediment are rejected before they reach the hopper. This rejected sediment is directly returned to the sea via the reject chutes or through the keel. This mixture of rejected sediment and seawater typically contains coarser material and usually has a greater density and velocity on entering the water surface than the overflow mixture. As a result it descends rapidly to the seabed as a density flow. When screening for gravel (undersize screening) there is usually a significant proportion of fine sand (and a smaller proportion of silt) released back to the water column that can potentially be transported by tidal currents and waves outside of the dredging area.

'Scalping' or 'reverse screening' occurs when coarser sediment, such as pebbles or cobbles, are rejected from the load. Sediment rejected during reverse screening will fall directly back to the seabed and will not be transported out of the dredging area.

Although screening is common practice in the study area, not all cargos are screened. At some sites where the aggregate resource is coarse-grained or where a sand-rich cargo is required, an all-in (unscreened) cargo is taken. In this instance, there are no losses via the reject chutes or through the ship's keel, instead losses of sediment and sea water are entirely via the overflow spillways on the side of the vessel.

Figure 7.3 Difference plot of post-dredged/present day bathymetry



The processes affecting the plume are strongly influenced by the composition of the marine aggregate resource targeted for dredging. The turbulent overflow water contains proportionally higher volumes of clay, silt and fine-grained sand, whilst screening typically results in the rejection of sediments up to about 5 mm diameter. The majority of fines are ejected in the overflow discharge; the additional discharge of fines from the screening process is small in comparison (Hitchcock *et al*, 1998). Together, these effects of dredging create a turbid plume of suspended fine-grained sediment.

Overview of Plume Dispersion

A study was undertaken by HR Wallingford to identify the potential footprints relating to the dispersion of fine sediment plumes and the potential footprints relating to the dispersion of sand released into the water column as a result of dredging at existing and proposed licence areas in the Outer Thames Estuary. For full details see Appendix H. The study used field data plume measurements from dredging areas around the east and south coasts of the UK (as summarised in Table 7.1) to validate the established turbulent flow dispersion theory model. An existing flow model (HR Wallingford *et al*, 2002) of the Thames Region was used as a source of information on tidal currents and water depth. Comparison of the reference flows and water depths and dredger capacity (used as a proxy for the release rate of overflow) with spring tide current speeds and water depths at the sites considered in the REA allowed the likely maximum plume dispersion distances at each of these sites to be deduced.

Table 7.1 Summary of Measured Plume Data in the Literature

Site	Water depth	Current speed	Dredger pumping rate	Plume excursion
	[m]	[m/s]	[m^3/s]	[km]
Owers Bank City of Rochester (Screening for gravel)	18	0.25	1.25 (1)	0.3
Owers Bank Arco Severn (All-in load)	18	0.6	1.25 (2)	0.55
Hastings Shingle Bank (All-in load)	25-30	0.5	1.7 (3)	1.5
Eastern English Channel (Screening for gravel)	40-50	1.1	2.0 (4)	6
Area 107/Race Bank	15-20	Up to 1.0	2.0 (5)	2.5

(1) Pumping rate based on estimate for information from Hitchcock (1997).
(2) Pumping rate based on estimate for information from Hitchcock (1997).
(3) Pumping rate based on figures presented in Resource Management Association (2002).
(4) Pumping rate estimated based on (as yet) unpublished analysis of monitoring in the Eastern English Channel (pers.comm. Dr Tom Benson, HR Wallingford, 2009).

The dispersion of aggregate dredging plumes is the result of a number of dispersion processes:

- The entry into the water column of the overflow (or screening) jet to form a dense plume of material.
- The 'dynamic plume' phase whereby the plume accelerates downward under its own weight and accelerates horizontally due to the ambient current flow.
- The dynamic plume will then either encroach on to the seabed where it forms a density current (if depths are sufficiently small and the density difference sufficiently large), which eventually mixes with the overlying waters; **or** the plume becomes so dilute it is no longer accelerated by its own density (and forms a passive plume directly).
- The final phase where the plume (now termed 'passive') is mixed by turbulent diffusion (caused by random fluctuations in current speed and direction) and shear dispersion (caused by parts of the plume encountering different current speeds).
- In addition, less significant plumes can be formed near the bed from disturbance by the drag-head or at the surface as some of the main plume is trapped in the vessel wake or brought to the surface by air bubbles.

The proportion of fines in the overflow is also important in terms of the dispersion of the plume, as settling generally occurs at a rate proportional to grain size. Whilst the proportion of silt in the aggregate dredged is typically in the range 0-5%, the proportion of silt in the overflow is significantly larger by up to ten times (HR Wallingford, 1998) and (Resource Management Association, 2002). Clay and silt (<63 µm) may be transported several kilometres by tidal streams and wave driven currents, whilst sands settle more rapidly, closer to the dredged areas. For the purposes of the plume modelling study it is assumed that over the distances that plumes have been observed to disperse, the sand fractions (with the possible exception of very fine sand (<120 µm)) settle to the seabed. Therefore only the rate of release of the finest fractions is considered here (and the section below on Seabed Deposition and Sediment Transport considers the potential footprint of sand deposition).

Plume dispersion can be characterised into near-field mixing during the dynamic plume descent and far-field mixing during the passive plume phase. Although near-field mixing is considered to be a complex process, using a relatively simple model the radius of a dynamic plume is predominantly established as a product of the discharge parameters, plume density and local oceanographic conditions. Far field mixing, which occurs when the plume no longer has sufficient density and momentum to induce mixing through its own motion, becomes a function of turbulent diffusion (caused by changes in current speed and direction) and shear dispersion (caused by different current speeds). A more detailed account of dispersion theory for both near-field and far-field mixing can be found in the plume studies report in Appendix H. In general it is considered that the distance over which the dispersion of the plume occurs is proportional to the product of the current speed, water depth and sediment input.

(5) The report (Cefas, 1998) suggests, on the basis of the information given about other measurements, that the capacity of the dredger which was being monitored would be in the range 2300-3500m3 and therefore a pumping rate of 2m3/s has been estimated.

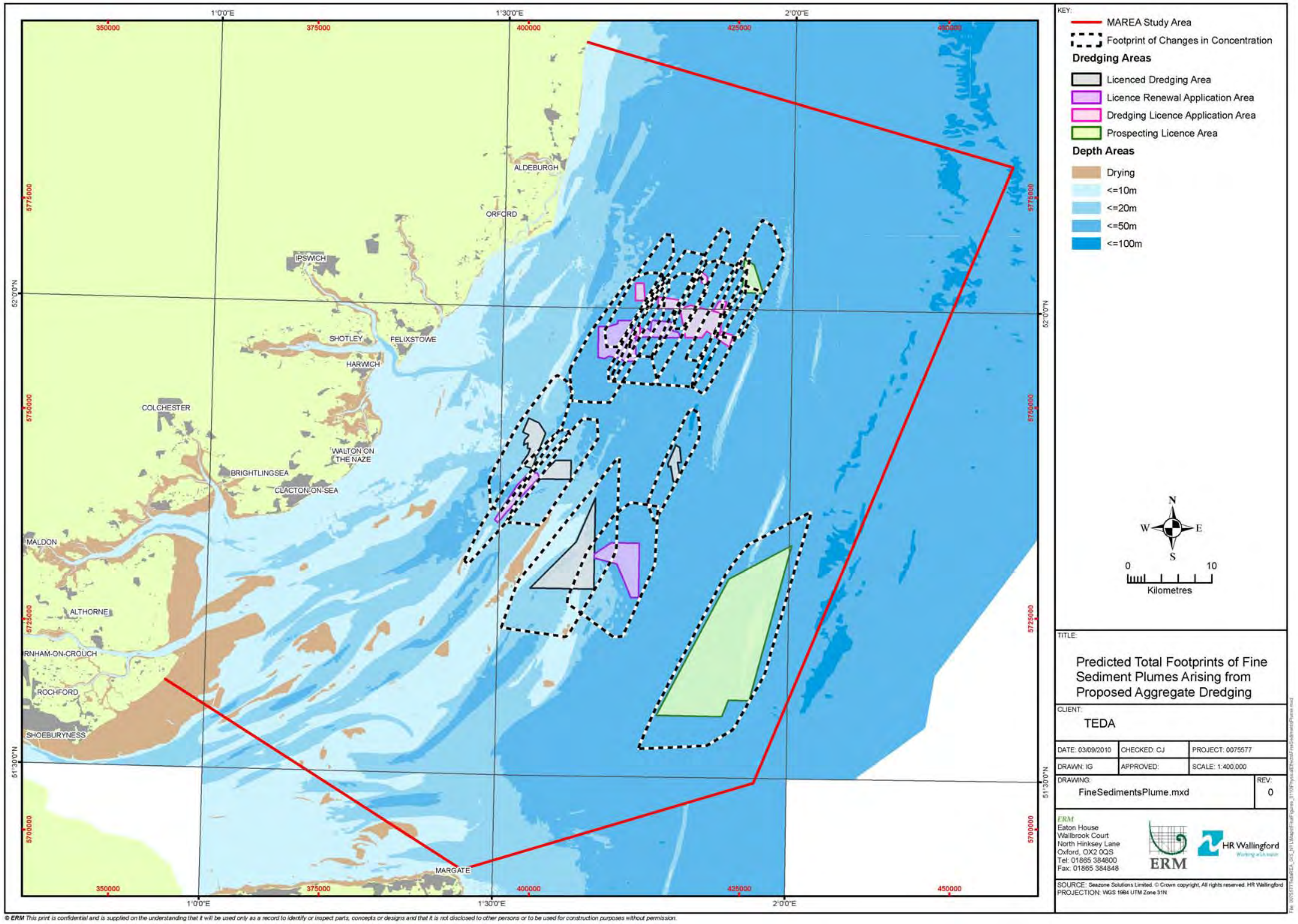
Prediction of Fine Sediment Plume Footprints

Using the theory described above the probable maximum plume dispersion distances at each site in the MAREA area were modelled using the reference flows, water depths and vessel pumping rate along with spring tide current speeds and water depths.

Although the dredging pumps of most UK aggregate dredgers are comparable, there are certain dredgers which can pump at significantly higher rates from the average (approximately 70% higher). To establish the regional footprints of fine sediment plumes, the dredger with the highest pump rate was used in the model to give a "conservative" estimate of the footprints (ie maximum potential footprint).

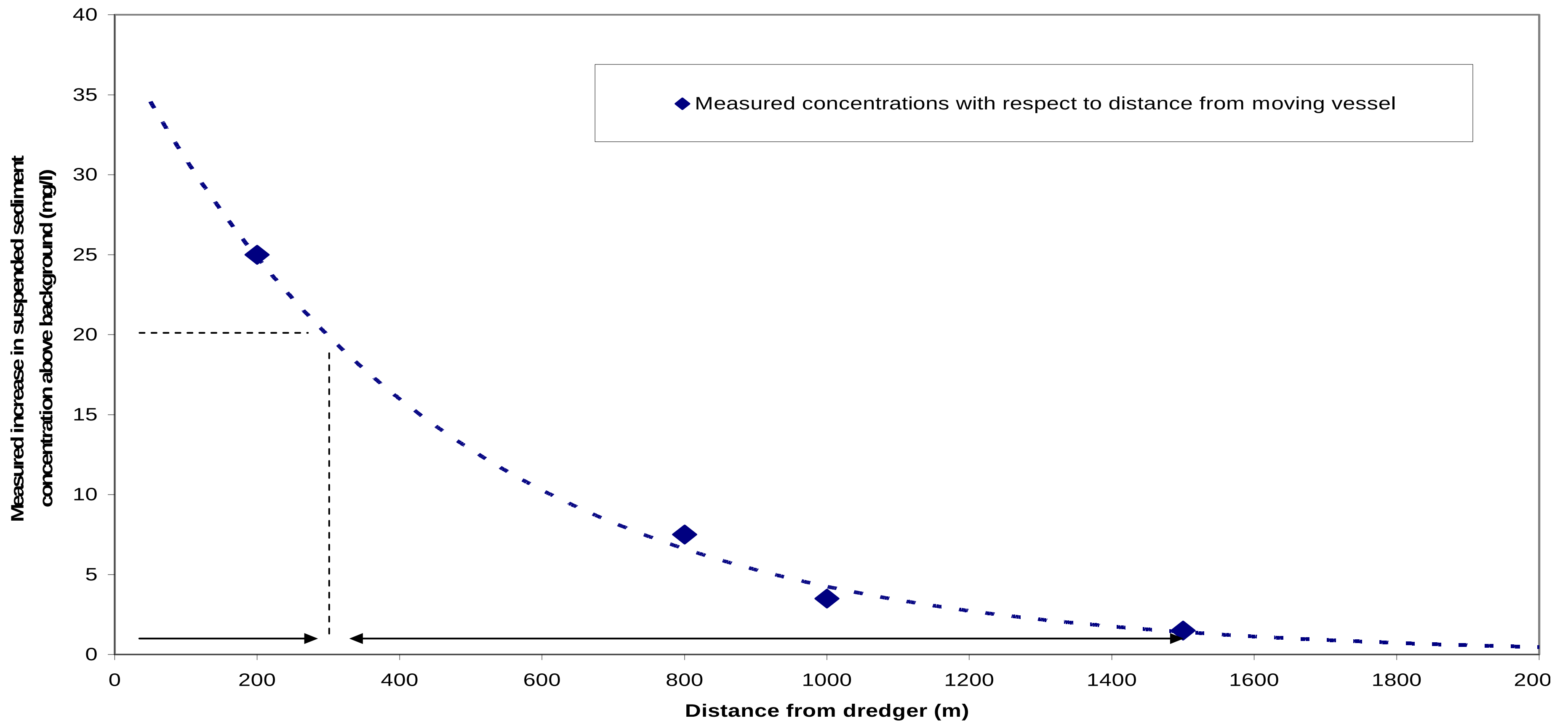
The distribution of points along the boundary of each licence area was calculated at distinct time intervals and current patterns every 20 minutes throughout a spring tide. Flow model information on the path of each plume event was tracked and the point when the plume disperses into the background (ie background +1 mg l^{-1}) was derived. This produced a large scatter of points; the envelope of these points was taken as the footprint of plume dispersion from the licence area (Figure 7.4).

Figure 7.4 Predicted Total Footprints of Fine Sediment Plumes Arising from Proposed Aggregate Dredging



In addition, footprints of peak (depth-averaged) concentrations of 20 mg l^{-1}, 50 mg l^{-1} and 100 mg l^{-1} above background were also derived. The footprint of the 20 mg l^{-1} contour was derived by using the measured relative rate of decay of the plume at Hastings Shingle Bank (Cefas, 2001) to describe the general decay of plumes in the Thames Estuary Region, as shown in Figure 7.5. This figure indicates that approximate background concentrations are reached at a distance of 1,500 m from the dredger. The distance at which concentrations are 20 mg l^{-1} above background is shown in the figure at approximately 300 m from the dredger. The figure suggests that the concentration falls to 20 mg l^{-1} within approximately 20% of the distance at which the concentrations in the plume approach background concentrations. These distances have been used as an approximation in this study.

Figure 7.5 Summary of CEFAS Measurements of Dredging Plumes from the Arco Adur at Hastings Shingle Bank 1999



As the majority of dredgers that operate in the Thames Estuary have a lower pumping rate than that used in the model, the distance from the dredger to the 20 mg l^{-1} contour and the point where the plume approaches background conditions would be reduced (except for the dredgers with the highest pumping rates).

Footprints of peak (depth-averaged) concentrations of 50 mg l^{-1} and 100 mg l^{-1} above background were derived from measured field data from Owers Bank (HR Wallingford, 1996) and existing numerical models (Spearman *et al*, 2003) and (Spearman *et al*, 2005). This approach was necessary as these concentrations are likely to be experienced within a few hundred metres of the dredger (near-field) where the plume exhibits dynamic plume behaviour.

Measurements of suspended sediment concentration from the dynamic plume of an anchored dredger on Owers Bank show that high concentrations (hundreds of mg l^{-1}) were rapidly reduced to 10-15 mg l^{-1} over approximately 100 m. Since the dredger was at anchor, this distance also represents the distance from the release point. Additional modelling (using the same existing numerical models) confirmed the rapid settling observed at Owers Bank and also suggested that concentrations may reduce below 100 mg l^{-1} and 50 mg l^{-1} at distances below 100 m and 200 m from the release point respectively. These distances would be further reduced in times of low current speed.

Figure 7.6 and Figure 7.7 show the predicted footprints of the peak concentrations of the fine sediment plume at 20 mg l^{-1}, 50 mg l^{-1} and

100 mg l^{-1} above background levels, which are situated relatively close to the dredging area boundaries.

It is important to note that footprints shown in Figure 7.4, Figure 7.6 and Figure 7.7 represent the total envelope of the plume throughout the 15 years of any dredging permission assuming that dredging takes place at all locations in the licence area; they do not represent the footprint of the plume itself at any one point in time or for one load. Consequently they are useful for identifying static receptors that may be exposed to the turbid plume from dredging operations at some point in the future but are of little use when considering the proportion of habitat for mobile receptors that will be affected at any one time. Figure 7.8 helps to address this by providing a 'real-time' context to Figure 7.4, Figure 7.6 and Figure 7.7. It represents a snapshot in time (during an ebb tide) based on simultaneous dredging

operations on three licence areas. It shows that at any given point the plumes cover a small area of the Outer Thames Estuary and areas of the plume at any time with concentration increases of over 50 mg l^{-1} cover a smaller area still.

With reference to Figure 7.8 predicted increases in suspended sediment concentration experienced outside each of the proposed licence areas will be less than 20 mg l^{-1} above background, except when dredging occurs close to the boundary of a licence area. In such cases suspended sediment concentrations more than 50 mg l^{-1} and 20 mg l^{-1} above background levels are only likely to be experienced within 200 m and 1 km of the licence area boundary respectively

Suspended sediment concentration increases will only be experienced during (and for up to one tidal cycle following) dredging and only in the streamline of the dredger (ie along the tidal axis of the dredger). As a result, for the vast majority of the time over the licensing period at any given point in the study region there will be no increases in suspended sediment concentration above background levels. Even when concentration increases of few tens of mg l^{-1} above background levels occur, they are still less than natural increases that occur regularly due to tidal conditions and waves.

Seabed Deposition and Sediment Transport

The sediment particles in the turbid plume will settle out of the water column over time, and deposit on to the seabed. Sand will be deposited in closer proximity to the dredged area than fine silts, which will remain in suspension for longer and settle further afield. Some sand will be available for reworking by tidal currents although the volume of sand available for transport is much less than that deposited. Some of the finer grains will be mixed in with larger particles and trapped in the void spaces between them, thus being prevented from moving on the seabed. As a result, the majority of sediment rejected via the overspill and screening will be returned to the seabed and be contained within the dredged area.

A second study was undertaken by HR Wallingford to identify the potential footprints relating to the dispersion of sand from each of the licence areas within the Outer Thames Estuary.

Figure 7.6 Predicted Footprints of Fine Sediment Plume Peak Concentrations Arising from Proposed Aggregate Dredging (Northern Area)

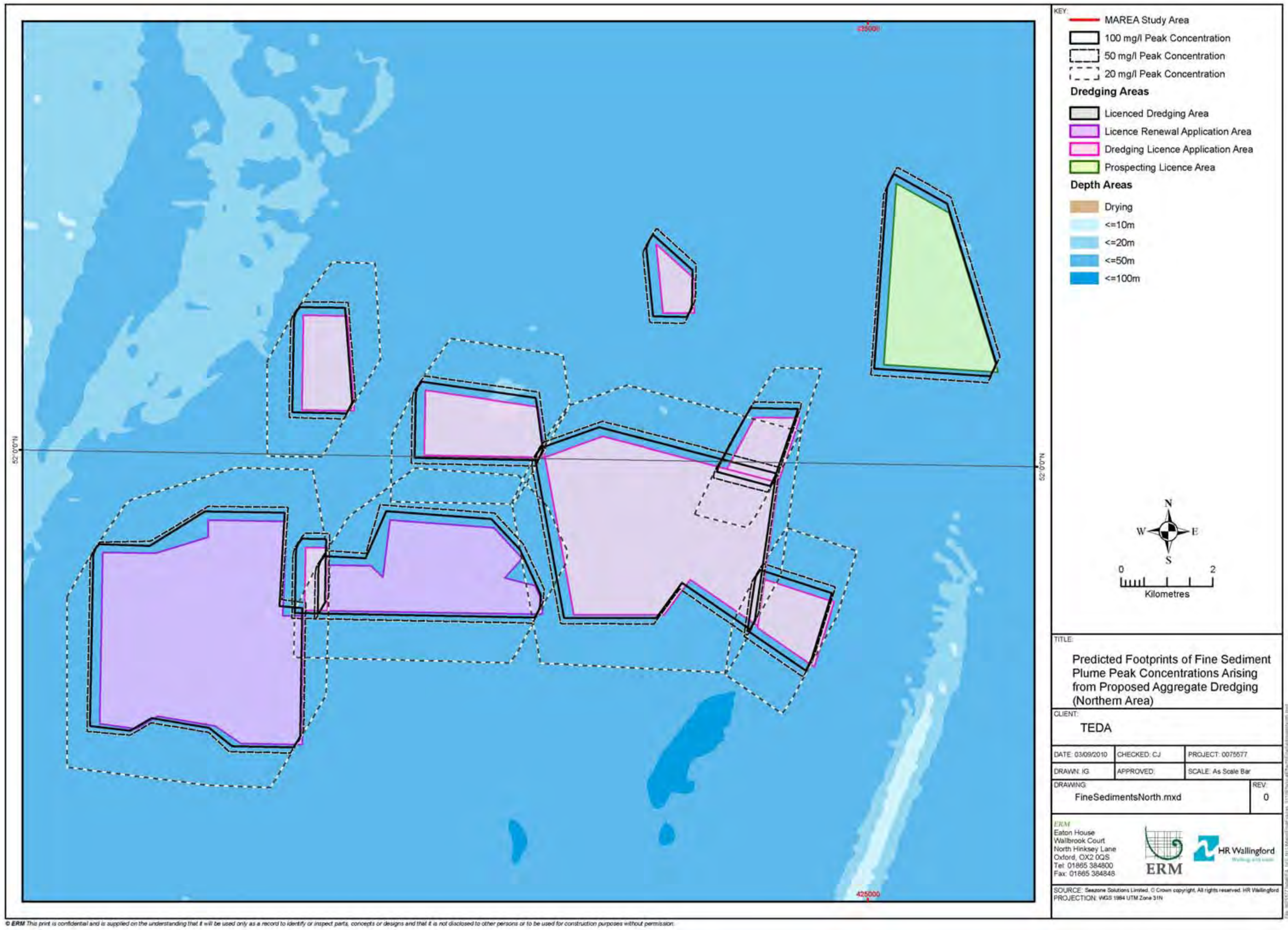


Figure 7.7 Predicted Footprints of Fine Sediment Plume Peak Concentrations Arising from Proposed Aggregate Dredging (Southern Area)

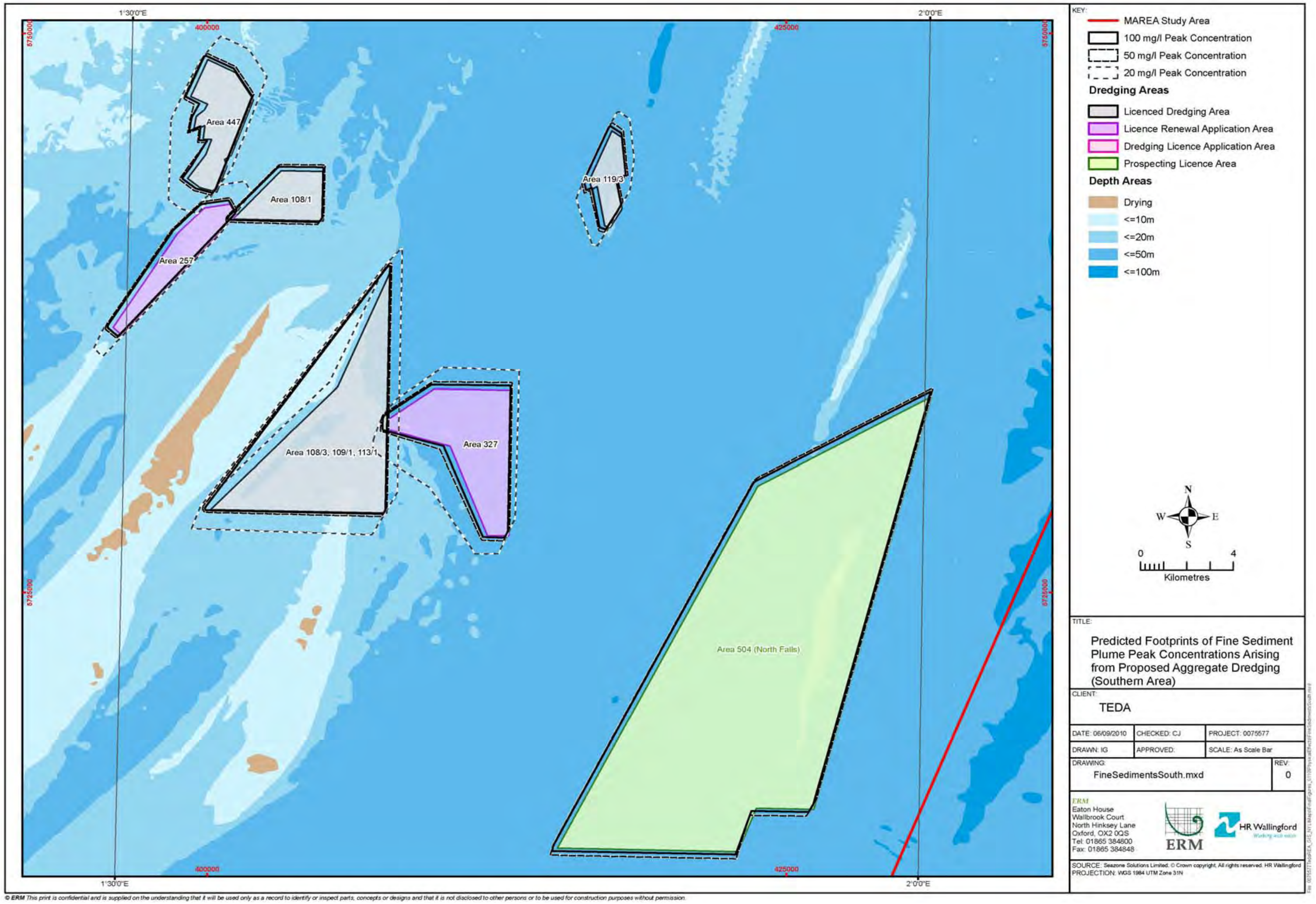


Figure 7.8 Snapshot of Typical Plumes Resulting from Dredging at Three Areas on the Ebb Tide

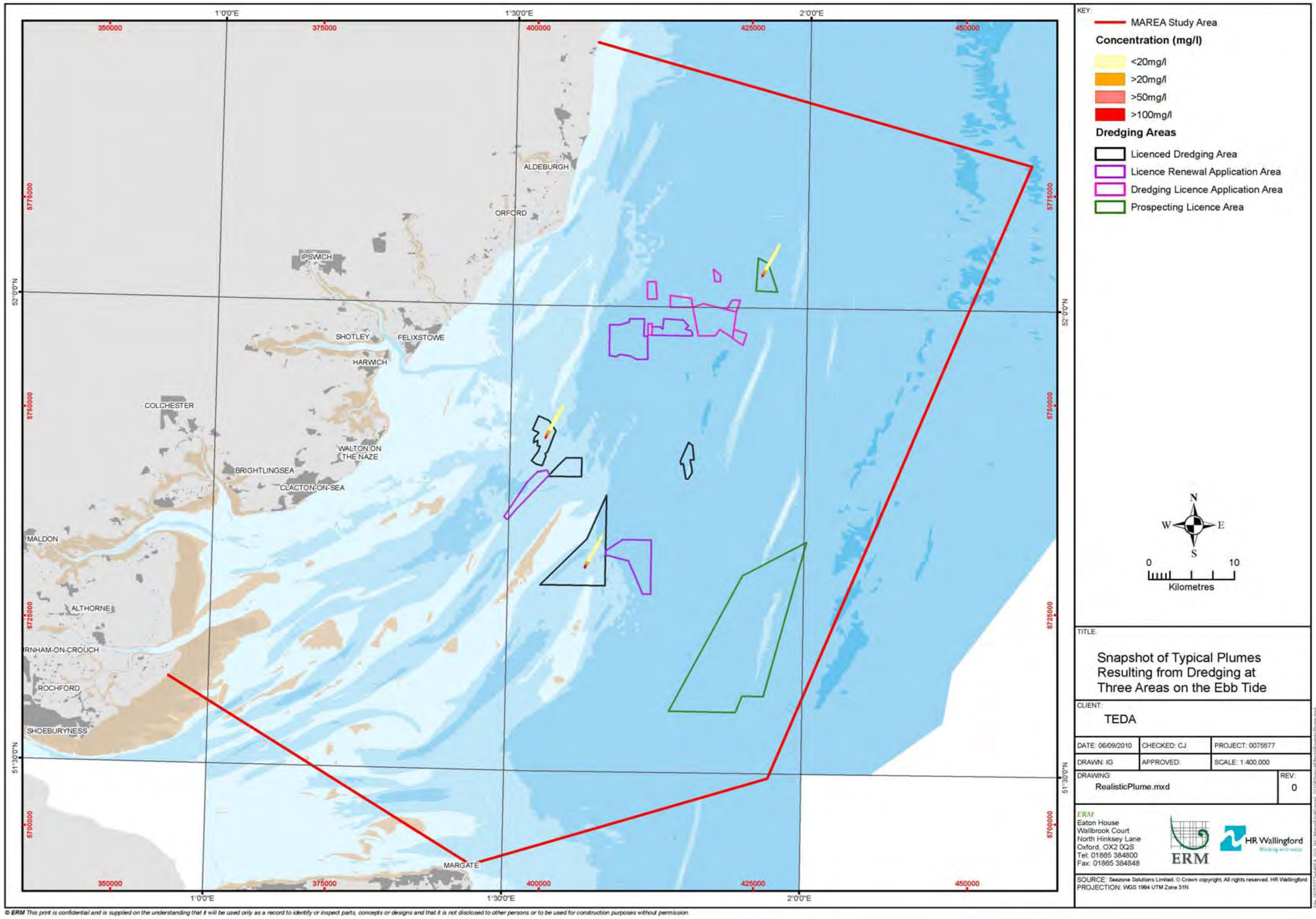
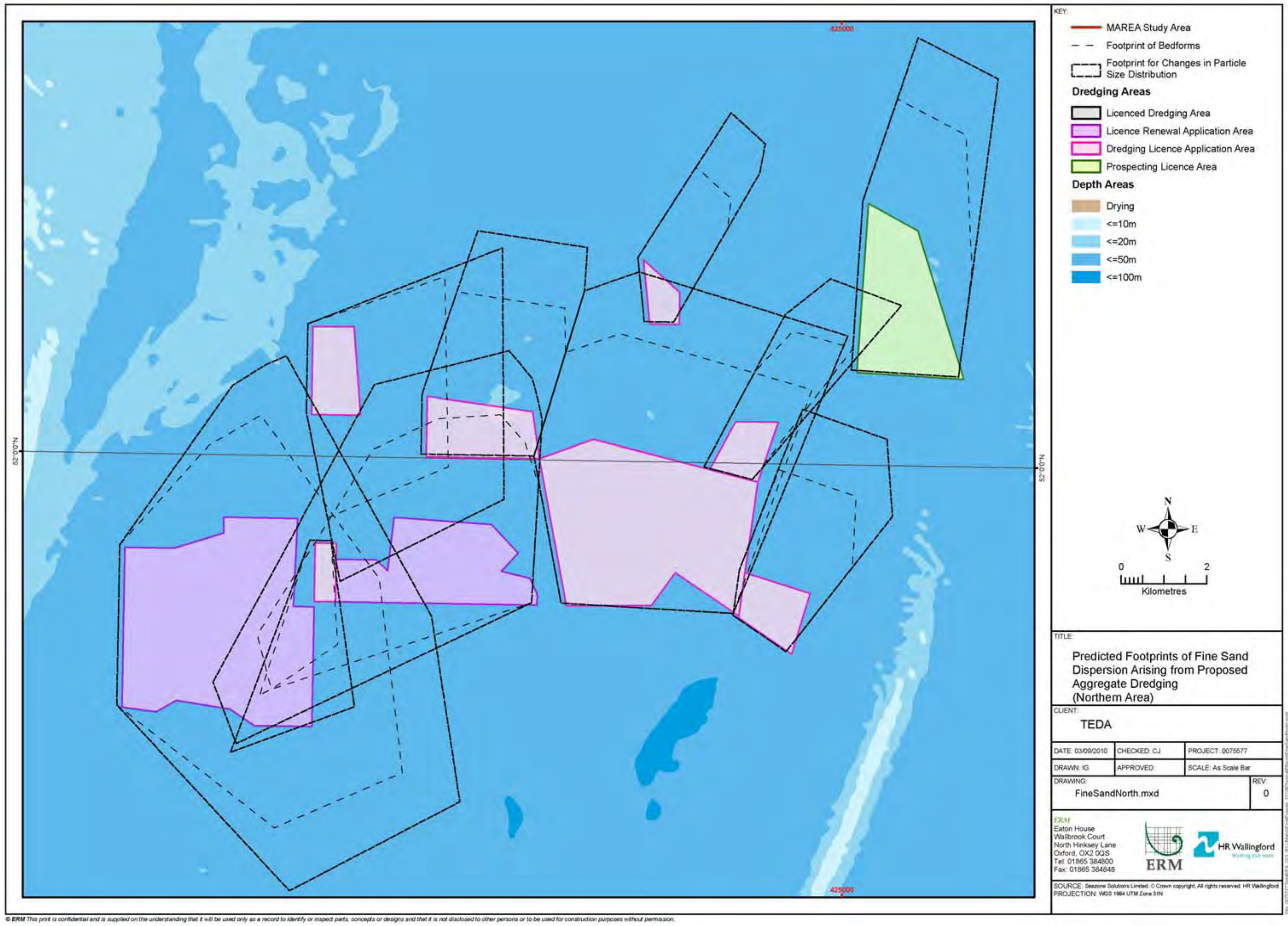


Figure 7.9 Predicted Footprints of Fine Sand Dispersion Arising from Proposed Aggregate Dredging (Northern Area)



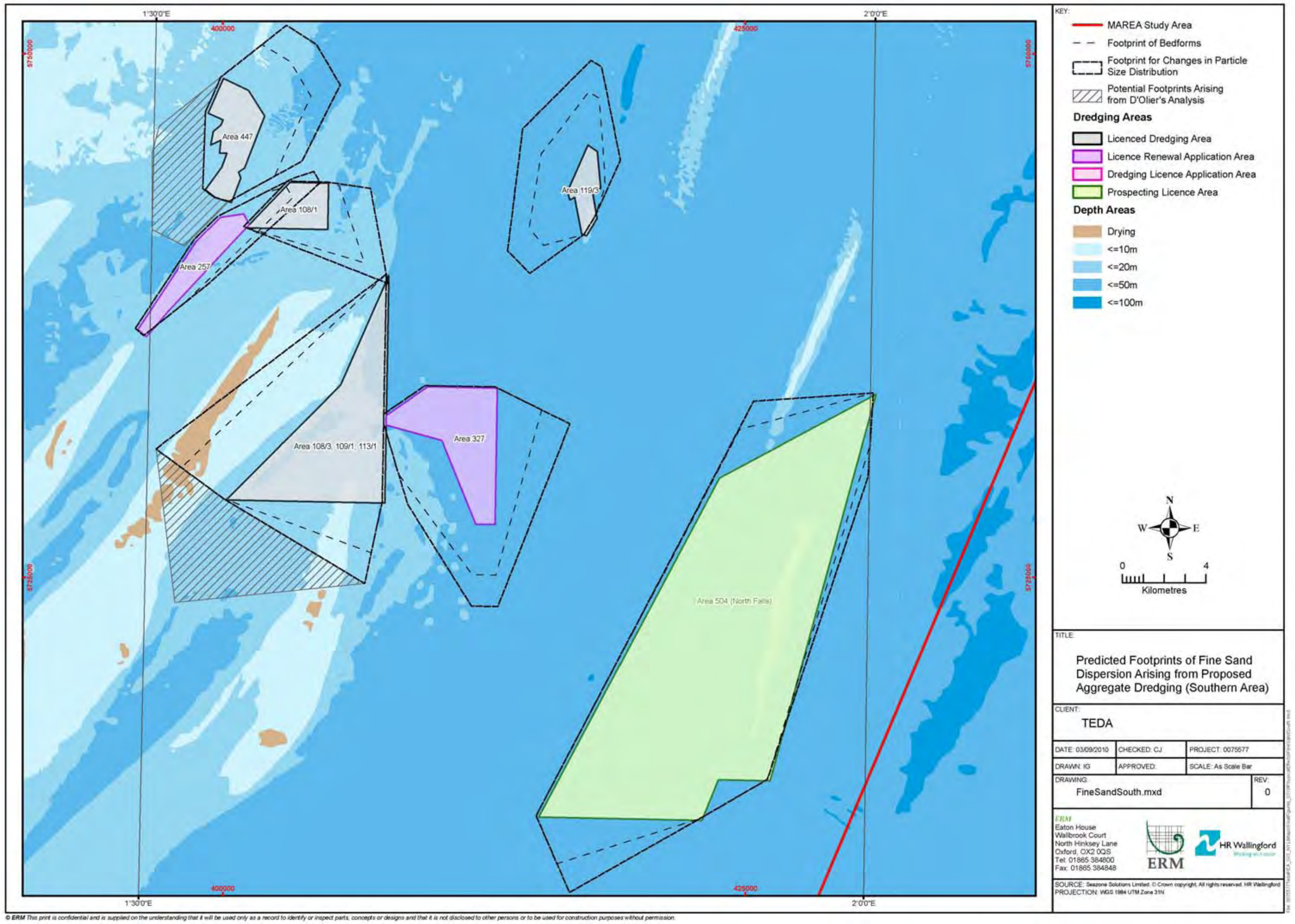
Data derived from field measurement studies from other licence areas around the coast (Boyd *et al,* 2002, 2003; Evans, 2002; Newell *et al*, 2002, 2004a, 2004b; Hitchcock & Bell 2004; Andrews, 2004) identified that the maximum potential footprints of fine sand dispersion from dredging could be up to 4 km in terms changes in the particle size composition of the substrate and up to 2.5 km for bedforms. These field measurements were used in conjunction with a flow model (HR Wallingford *et al*, 2002) to calculate the direction of net residual sediment transport for a mean spring tide for each point of the boundary of each licence area. The 4 km envelope corresponds to the footprint of the maximum distances where changes in particle size distribution of the sediments on the seabed surface might be observed (taken as the envelope of all these points together with the original boundary points). The 2.5 km envelope corresponds to the maximum distance at which the potential dispersion of sediments could form bedforms as a result of dredging.

It is possible that in certain flow conditions sand could potentially fall outside the dredging area in a different direction to the main transport direction (as shown in Figure 7.9 and Figure 7.10). This is not expected to be a significant feature resulting from the proposed dredging.

In general the model prediction of the direction of residual sand transport agrees with that proposed by D'Olier (D'Olier, 2008) based on the direction of bedform movement shown in geophysical survey data collected for the MAREA and REC (see Figure 4.7 in Section 4.2.6). There are two exceptions where due to these differing information sources the footprint has been extended to incorporate the interpretation of geophysical survey data and to present a conservative interpretation, seen as shaded areas in Figure 7.10. The first exception is the Long Sand Head licence (Area 108/3, 109/1, 113/1). The geophysical data suggested that transport in this area would be predominantly southward whereas the model predicts a very small movement to the west. The second exception is Area 447 (Cutline) where the model predicts and monitoring data (EMU's, 2009) shows a northward residual but the interpretation of geophysical data suggests a predominantly southward residual.

Section 4.2.6 discusses the sediment types in the region and the predicted directions of sediment transport. Bedforms and changes in substrate may occur in coarse sediments, which is the case for the vast majority of the dredging areas in the region. The exceptions to this include the North Inner Gabbard Area, Area 119/3, Area 447 and the North Falls Initial Prospecting Area, where patches of fine to medium sand can be found. In these areas the locally active bedforms will commonly mask any bedforms that may be the result of dredging, and the presence of mobile fine sand will mask any transport of fine sand from dredging. The results of the plume modelling can be compared with the conceptual transport model developed by the East Channel Association (East Channel Association, 2002).

Figure 7.10 Predicted Footprints of Fine Sand Dispersion Arising from Proposed Aggregate Dredging (Southern Area)



This suggests that during the dredging of a licence area, the proportion of the fine to medium-grained sand transported away from the dredged area as bedload will form a 10 to 25 cm thick continuous sand sheet, which will lie adjacent to the dredging areas along the tidal axis. The sheet will also consist of a smaller proportion of sand, up to 1 mm diameter, which will only be mobile on the highest spring tide currents.

Further along the sediment transport pathway, the sands will be increasingly dispersed and form isolated bedform (ripple) fields which will degrade into discontinuous patches in the dispersed zone. This is likely to occur within a distance of 1 to 2 km of the limit of each dredging area (refer to).

The ECA model therefore describes a similar process of sediment transport, but predicts the effects will occur over a shorter distance than the plume modelling in the Thames, ie up to 2 km compared with 4 km. Both models are based on a sound understanding of the key processes, however, there are clear data gaps in quantifying the effects and caution should be applied when interpreting modelling results.

As dredging has been taking place at a number of licence areas within the Outer Thames Estuary for many years, the geophysical survey data collected for the REC and MAREA projects were examined by an independent sedimentologist to investigate whether there was any evidence of dredging plume sediment deposition. Out of the three licence areas examined (109/1, 109/2 and 257) Area 109/2 showed little evidence of dredging activity. This suggests that screening and/or natural sediment movement has masked the dredge trails, and it is therefore not possible to assess whether, and over what area a dredge plume has contributed to the sand cover at this site.

At licence Area 109/1 evidence strongly suggests that screened sand had been recently redeposited on the seabed and had been formed into a rippled mobile bedform by tidal currents. As licence Area 109/1 is subject to natural sand transport, some or all of the rippled sand patches may be part of a naturally moving sediment pathway. However, pre-dredging survey data did not show the same bedforms in such abundance which suggests that dredging activity has released mobile sediment.

Licence Area 257 showed the strongest association between dredging and thin rippled sands. An area approximately 4 km long shows a southwest/northeast trend of dredge trails and thin rippled sands. This indicates that the thin rippled sand could be entirely due to the effects of the dredging operations. However, due to the direction of transport, it is likely that some of the sand is extending NE from the head of Sunk Sand and could be naturally passing across the licence area.

Impacts arising from dispersion of fine sand, if any should occur, will tend to increase in magnitude throughout the lifetime of the licence period. The effect will continue for years (potentially decades if the impact is large) after the licence period has ended as there will still be fine sand within the licence area at the end of the licence period which will disperse over time. Eventually the area will return to a pre-dredging state of very coarse sands and fine gravels; however this process may take several years to decades.

Potential for Cumulative Effects

Where any two or more of the proposed dredging areas lie close to one another there is the possibility (as shown in Figure 7.4) that plumes from dredgers in two adjacent areas might interact. There are two possible ways for the plumes to interact:

- Plumes generated in different areas meet and coalesce to form one larger plume.
- A dredger is dredging within the plume generated by a dredger in a different area.

Either event is unlikely to occur often as the chances of two dredgers dredging in the relevant parts of adjacent areas so that their plumes interact with each other is likely to be relatively low.

For plumes that meet and mix together, a larger plume with similar concentrations to those of the separate plumes will be formed and disperse according to dispersion theory. Peak concentrations would not be exceeded in areas where the plume footprints overlap, but instead they would be experienced slightly more frequently. For plumes created by a dredger operating in the plume of another dredger the two plumes would be additive and have a cumulative effect. However, for this cumulative effect to be significant it would require two dredgers (in different licence areas) dredging in each others streamline within 200 m or so of each other, which is unlikely to occur during the licence period. As a result of these considerations there is little potential for significant cumulative effects resulting from plume interaction between licence areas; the impact assessments in Chapters 8 to 10 therefore focus on the cumulative effects to regional receptors that result from the existence of plumes from multiple licence areas at the same time.

In order for cumulative effects related to the dispersion of fine sand to occur it is necessary for the dispersion footprints to overlap in areas outside the licence area boundaries. This interaction is possible in the northeast corner of the study region between licence Areas 452 (A, B, C1, C2, C3 and D) and 118/2 (Figure 7.9). The footprints identified in Figure 7.9 are a maximum based on the regional tonnage scenario provided by TEDA members and the extent of any cumulative effect in practice will in fact be smaller than shown.

7.3.4 Mobilisation of Contaminants

Contaminants released from sediment during dredging could potentially affect marine organisms through direct toxic effects to the organism and through bioaccumulation. Contaminants such as metals and hydrocarbons may become mobilised during dredging activity either from the release of porewater or by desorption from sediment particles. It would be generally expected that release of contaminants could be expected in sediments with a history of direct contamination, that are close to sources of contamination (eg fluvial inputs) and which have high concentrations of fine particles. It is worth noting that there is no such history of direct contamination of the sediments to be dredged, they are some distance from fluvial inputs (also discussed below) and have a low fine particle content.

Once released metals can be bioavailable to organisms when they are released from the sediment to the water column in the dissolved state. However the degree of bioavailability will vary between metals and also be affected by the extent to which complexes are formed with dissolved organic material.

For example copper, amongst trace metals, has a high tendency to form complexes (ie non-labile species) with organic material in seawater. Such organic complexes can account for proportions reported between 14 and 98% in coastal waters. Certainly the proportions decrease in the order estuary>coastal waters>open ocean. Once complexed with organic material, copper is less reactive to particle scavenging. It is also less bio-available. This is because labile/non-labile speciation is extremely important in determining the behaviour of a trace metal in the bio-sphere with respect to its uptake by phytoplankton. During the uptake of trace metals from seawater, phytoplankton discriminate against strongly complexed, especially organically complexed (non-labile) species (Chester, 1990).
The concentration of dissolved metals released to the water column is therefore dependent on the chemical form and concentration in sediments and pore water, and the volume and nature (especially particle size) of the contaminated sediments that are resuspended and the depth and ambient flow characteristics) of the water.

Studies have shown that chemical desorption to the dissolved phase can vary from a few hours to 180 days and that the majority of sediments settle close to the dredging site within one hour (Anchor Environment C.A.L.P, 2003). Therefore it is unlikely that the majority of contaminants would have time to desorb before the sediment settles out of the water column. Even if high levels of total (solid and dissolved) metals were to be released during dredging, the proportions of dissolved metals that would be bioavailable, even in highly contaminated areas, would be low (EVS, 1997). This indicates that there is a low potential for direct toxicity or bioaccumulation from resuspended metal contaminated sediments.

In addition, samples taken from three estuaries in the MAREA area generally show metal concentrations to be below the Canadian Probable Effect Level (PEL) ie the level above which adverse effects are expected to occur frequently. Where they do exceed the PEL (copper, mercury, zinc), it is only in a single estuary for a single year. It is likely that the concentrations of these metals will be even lower in the licence areas given their distance from the estuaries and the relatively high energy environmental present that would limit the settlement of fine, potentially contaminated, particles.

Major sources of hydrocarbons to the marine environment exist in the estuaries that discharge to the Outer Thames Estuary. Hydrocarbon concentrations decrease with distance away from the source, indicating that lower levels of hydrocarbon exist in the offshore MAREA area. This is supported by hydrocarbon concentrations at the Medway Estuary increasing in recent years, while offshore concentrations remain low. When sediments contaminated with hydrocarbons are resuspended some of the hydrocarbons are desorbed and diffused into the water column. However, releases of hydrocarbons have been observed to be small in comparison to dilution by the receiving water body and any changes in the water quality were temporary, even when highly contaminated sediments were dredged (Ludwig, 1988).

Within the assessment of impacts to water quality (Section 8.4), the available information on baseline contaminant levels within the Outer Thames Estuary is considered together with the likely levels of mobilisation and bioavailability that have been derived from the results of the various modelling studies that are described within this chapter.

7.3.5 Noise

Potential Effects on Sensitive Receptors

Underwater noise and vibrations from marine activities have the potential to adversely impact upon receptors (marine mammals and fish) in the marine environment. Marine mammals and fish have been shown to produce behavioural responses and at high levels, underwater noise can cause temporary and permanent deafness (Turnpenny *et al*, 1994). All marine mammals and some fish species may be affected by underwater noise to some extent, depending on their underwater hearing sensitivity in the frequency range of most anthropogenic underwater noise. Due to a lack of available detailed data in the MAREA area, the assessment of underwater noise caused by dredging has been based on measurements of underwater noise from dredging in a similar environment along the Sussex coast. Information in this section has been based on ERM's assessment of underwater noise impacts from marine aggregate dredging in the Outer Thames Estuary (Appendix K).

The underwater noise study on the Hastings Shingle Bank (Parvin *et al*, 2008) assessed the levels of noise from dredging and determined them to be below the thresholds for auditory injury. Therefore the study concentrates on the potential for behavioural responses and has defined three categories of behavioural response to underwater noise for key species:

- low likelihood of disturbance;
- mild avoidance reaction; and
- strong avoidance reaction.

Expected behavioural reactions of some selected marine species along with the distance that the reaction will occur in are reported in Table 7.2.

Table 7.2 Reactions of Marine Species to Noise

	Criteria		
Species	Strong Behavioural Avoidance Reaction, m	Mild Behavioural Avoidance Reaction, m	Low Likelihood of Disturbance, m
Harbour Porpoise	500	2000	5000
Common Seal	70	500	7000
Cod	4	30	1100
Herring	6	60	1900
Dab	<1m	3	130

It should be noted that for the purpose of conservatism, dredging is assumed to occur continuously throughout the dredging areas up to the licence area boundary, which represents the maximum area within which a given behavioural response could occur at any point in time. In reality, whilst dredging activity may occur at the edge of the licence areas at times, it will generally be focused in one particular zone and in most cases be carried out by one vessel. The actual area of noise impact at any given time will therefore be much smaller. In addition, the behavioural responses will only happen during times when dredging activity is occurring. Where two dredging areas are in close proximity, dredger noise may combine to produce a greater overall noise level and associated impact, however, this occurrence is likely to be infrequent and short-lived.

The behavioural response distances listed in Table 7.2 are dependent on the following factors:

- the level of ambient noise that already exists in the area;
- the noise source;
- noise attenuation due to propagation through the water; and
- the sensitivity of the marine animals to noise and their behavioural responses.

These factors are discussed in more detail in the following sections.

Existing Ambient Noise Levels

Details on the ambient noise levels in the MAREA area can be found in the noise baseline section (Section 4.6). In order for underwater noise from dredging activities to have an effect on marine receptors, the noise from dredging must be above the existing noise levels. Ambient noise levels around the Hastings Shingle Bank are likely to be lower than those within the outer Thames Estuary study area due to lower levels of anthropogenic activity, and as such the distances in Table 7.2 can be considered to be conservative.

The Noise Source

Underwater noise from dredging is a result of both the aggregate extraction activities and the dredging vessel itself. Underwater noise measurements of a vessel considered representative of dredging vessels likely to be used within the outer Thames Estuary MAREA area have been taken. The vessel is a trailer suction hopper dredger with a length of 99.9 m, a beam of 17.35 m, a maximum draft of 6.69 m and is powered by two 1950 kW Wartsila engines. The vessel can load 5,200 tonnes per cargo working at a loading rate of 2.5 m^3/second. This usually allows the vessel to complete loading of a full cargo in 2.5 to 3.5 hours.

Underwater noise measurements were undertaken at ranges of 250 m to 16 km with a hydrophone deployed at water depths of between 7 m and 10 m. By fitting the measured data to a conventional underwater sound propagation model, the data indicate a broadband source sound pressure level of 186 dB re. 1 μPa at 1 m from the dredging vessel. Minor differences in dredger specification are not expected to significantly alter the results of this report. To put these levels into perspective, this noise level is considerably below levels at which lethal or physical injury to species of fish and marine mammal might occur, due to the avoidance reaction of many species.

Noise Attenuation Due to Propagation through the Water

Underwater noise decreases (attenuates) with distance away from the source of the noise and in general, attenuation in deep water is greater than in shallow water, but in very shallow water excess attenuation can sometimes occur. The Hastings Shingle Bank and Outer Thames Estuary areas comprise comparable shallow water environments from an acoustic perspective, so the modelling of underwater noise propagation that resulted in behavioural responses of receptors being defined will be valid for both areas.

Marine Animal Hearing Sensitivity and Behavioural Responses

Some species display behavioural responses at lower noise levels than others and this depends largely on the sensitivity of a particular species to noise. Fish are commonly classified according to their sensitivity to noise as either *hearing specialists* or *hearing generalists* (Fav *et al*, 1999). Hearing specialists have a high sensitivity to underwater sound and vibration as a consequence of their physiology. The majority of fish are hearing generalists.

Some species of marine animal assessed in the Hastings report are also present in the MAREA area. Where species in the MAREA area have not been assessed in the Hastings report, results for similar species that are considered representative were used. The sensitivity of each species to underwater noise is considered within the biological impact assessment chapter (Sections 9.3 and 9.4).

Based on the distance of behavioural response to marine noise, the magnitude of the impact of marine noise on each species is determined together with the overall sensitivity of each receptor group. In the case of underwater noise from dredging, given that the impact is a temporary avoidance reaction, receptor sensitivity depends predominantly on the reliance of the species on specific sites that are within the predicted zones of behavioural response. Consequently species that have a high reliance on haul out sites or specific spawning areas, or which migrate within a narrow corridor will generally be more sensitive to the effects of underwater noise than species that utilise a wide range of habitats. The sensitivity of each receptor is discussed in the relevant impact assessment section (Sections 9.3 and 9.4).

7.4 SECONDARY EFFECTS AS THE RESULT OF CHANGES TO BED MORPHOLOGY

7.4.1 Changes to the Behaviour of Waves

Potential Effects on Sensitive Receptors

Dredging activities result in an alteration to seabed morphology which can cause changes in wave propagation. The majority of dredged depressions may be permanent (ie they will not infill) due to aggregate extraction taking place in areas of limited sediment flux, therefore any changes to the behaviour of waves in the region are also likely to be long lasting. Ultimately, in certain environments, this could lead to changes to wave conditions at the coast and could theoretically result in impacts at the coast.

Dredging operations can also lower the banks and bars that provide protection to the coast from wave action and which are important features of the environment of the Outer Thames Estuary in their own right. The crest level of a bank could be lowered as a result of dredging the bank itself, or by dredging close to the foot of a bank, causing draw-down of the sediment into the dredged depressions. If the sandbank normally caused wave breaking, because of the shallow water depths over its crest, then lowering it will increase wave heights landward of the bank.

It is therefore important to consider in detail the magnitude and extent of potential changes to wave heights in the MAREA study area and at the coast, including any cumulative interactions between licence areas and in-combination interactions with other developments.

Summary of Methodology for Predicting Changes to Wave Behaviour

A study was carried out to assess how past and proposed future dredging might alter wave conditions in the MAREA area using the SWAN **(S**imulating **W**aves **N**earshore) wave transformation model, developed by the Technical University of Delft (TU Delft) in the Netherlands.

Three bathymetries were considered as described in Section 7.3.2:

- Pre-dredged bathymetry (based on present day bathymetry with licence areas re-constructed).
- Present day bathymetry, including all marine aggregate dredging in the study area to date.
- Future seabed levels, based on plans for further dredging over the next 15 years supplied by TEDA member companies.

To assess the potential effect of aggregate dredging on wave conditions, it was necessary to choose suitable combinations of wave direction, height and period for input into the SWAN model. It is standard practice in such assessments to concentrate on the severe conditions that pose the greatest dangers to coastal defences, shipping and the natural environment, and also tend to have the longest wave periods. The longer the period of a wave train, the greater the effect that changes in bed levels as a result of dredging will have on those waves, through the processes of refraction, diffraction and energy dissipation mechanisms such as frictional effects at the seabed.

The model was therefore set up for each bathymetry and run for a 200 year return period storm condition, ie a 0.5% chance of occurrence in any single year, for a range of directions and tidal levels. It is assumed that the changes on these severe waves caused by dredging will be at least as large as and probably larger than those on more frequently occurring waves. Realistic wind and wave data for the region were obtained from the UK Met Office European wave model for the period April 1990 to March 2006 and were extrapolated to estimate much rarer events.

The model was run for 5 storm conditions (Table 7.3). To assess the impact of dredging at different tidal levels, two still water levels were considered which correspond to MHWS (+4.5 m CD) and MLWS (+0.5 m CD) at Clacton. However, it should be noted that in the large study area, tidal ranges vary quite considerably and will be slightly different to the values of MHWS and MLWS at Clacton.

Table 7.3 Extreme Incident Wave Conditions

Return period (years)	**Direction (°N)**	**Wind speed (ms^{-1})**	**Significant wave height (m)**	**Peak wave period (s)**
200	30	24.98	5.86	11.1
200	60	20.80	5.49	10.8
200	90	22.52	5.43	10.7
200	120	21.21	3.76	8.9
200	150	23.24	4.22	9.4

In addition to the model runs described above, sensitivity tests with different wave conditions were carried out. SWAN model runs to test sensitivity were carried out using only waves that approached from 30°N, as these waves have the longest wave period and cause the greatest changes in wave conditions. Significant waves from other directions than 30°N are reasonably assumed to have smaller effects as they have smaller wave periods. Two further wave conditions were tested as follows:

- A wave condition that occurs more frequently than the 200 year return period wave condition.
- An even more extreme wave condition than the 200 year return period wave that represents possible effects of climate change on wave conditions [(1)].

The first sensitivity testing wave condition (above) represents an increase from a wave with a 0.5% chance of a single occurrence in any one year to a wave condition that is exceeded 5% of the time in any one year. Generally, long-term changes in the morphology of the seabed are likely to be predominantly caused by moderate but frequently occurring events, rather than by rare and short-lived severe storms. Examining the effects of aggregate extraction on a more frequently occurring wave condition (5% exceedance) therefore provides some indication of whether there might be changes in the morphology of the seabed in and around the dredging areas.

(1) Extreme wave conditions that may represent the effects of climate change due to global warming are tested when building coastal defence, it is also sensible to test the possible effects of marine aggregate dredging together with climate change on wave conditions.

The second sensitivity testing wave condition, which represents an increase in storm events due to global warming, increased the present day 200-year significant wave height by 10% and wave period by 5%.

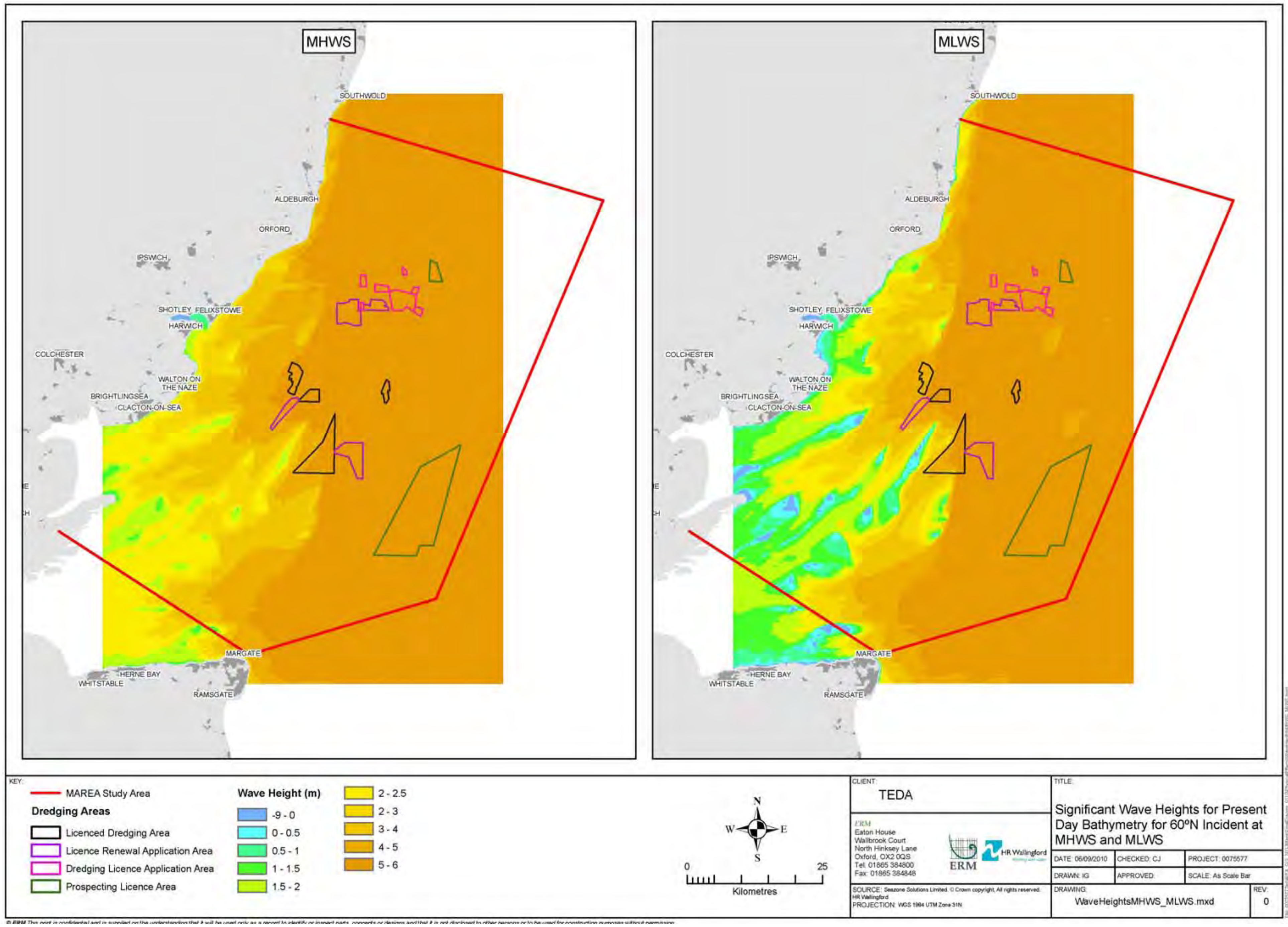
The full technical report providing comprehensive details on the methodology, including sensitivity testing is provided in Appendix H.

Predicted Changes to Wave Heights

Figure 7.11 presents wave height plots for the present day bathymetry, in relation to the 60 ºN incident for MHWS and MLWS. Similar results were obtained for all five of the incident wave direction considered (ie 30 ºN, 60 ºN, 90 ºN, 120 ºN and 150 ºN) for all three bathymetries and for both tidal levels. The example figures here show a clear gradual reduction in wave heights as they enter shallow water. There is also a trend for reduction in wave heights around the sandbanks; the exact location of the reduction is dependant on the direction of the wave. For the 60 ºN incident wave direction, as shown in Figure 7.11, the reduction is to the southwest of the banks.

The effects of seabed lowering as a result of dredging on waves can be shown by comparing the wave heights predicted using the three different bathymetries described above. Figures 17 to 26 in the Wave Study Report in Appendix H present the percentage change in significant wave heights [1] at MLWS and MHWS between the future dredging scenario and pre-dredge scenario ie they show that extremely severe wave conditions might be altered as a result of all past dredging and proposed future aggregate dredging in the Thames Estuary region. Figure 7.12 and Figure 7.13 are examples of the figures representing percentage change of significant wave heights found in Appendix H. Figure 7.12 shows the percentage change in wave height for a 30ºN wave with a return period of 200 years at MLWS. Figure 7.13 shows the percentage change in wave height for a 30ºN wave with a return period of 200 years at MHWS, which is of greater concern because a combination of severe waves and a high tidal level have a greater chance of affecting coastal defences. As with all five wave directions the percentage change of significant wave heights is greater for low tide than high tide levels.

Figure 7.11 Significant wave heights for present day bathymetry for 60°N incident at MHWS and MLWS



(1) Significant wave height is the wave height that is approximately equal to the mean of the highest third of the individual wave heights in a wave record.

Licence Area 257 and Long Sand Head licence (Area 108/3, 109/1, 113/1) experience the greatest predicted changes in wave height in and around the licence area, especially for the 30 ºN incident wave direction (Figure 7.12 and Figure 7.13). At MLWS extreme waves in the Long Sand Head licence (Area 108/3, 109/1, 113/1) may be changed by over 10% for up to 7 km beyond the boundary of the licence area for some of the incident wave directions and changes of 2% might be expected at twice this distance away from the southern boundary. At MHWS wave height changes of greater than 2% only extend up to 10 km away from the dredging area boundaries.

There is no alteration to wave heights at or near the coast for either MLWS or MHWS for any of the incident wave directions.

The results of the sensitivity testing at MHWS are of greater concern than the results at MLWS when considering impacts to the coast, however, as percentage difference is greater for MLWS sensitivity test results are presented for both tidal levels. Results are only presented for 30ºN as this wave direction was found to exhibit the most extreme wave changes in the model runs described previously.

Sensitivity testing for extreme wave conditions that occur more frequently than the 200 year wave (ie 5% exceedance wave scenario) caused by past and proposed future dredging show that changes in wave heights are small and localised (Figure 7.14 and Figure 7.15). Where changes occur outside the licence area wave height only increases by up to 2% and decreases by up to 5%. There is no increase in wave height at the coast.

The sensitivity test results for increased wave height (by 10%) and wave period (by 5%) of the present day 200-year significant wave caused by past and proposed dredging show some increase in wave heights to the south and a decrease in wave height to the southwest of licence Area 257 and Long Sand Head licence (Area 108/3, 109/1, 113/1), similar to the pattern and magnitude of results found in Figure 7.13. Again, there is no change to wave heights at or near the coast.

The former of these extra wave conditions, ie the 5% exceedance wave scenario (wave height that is exceeded 5% of the time), was therefore chosen to indicate the possible effects of changes in wave height on the morphology of the MAREA study area, and is taken forward along with the 200 year wave condition into the impact assessment.

Figure 7.12 Percentage difference plot of significant wave height due to past and future dredging for 30°N incident, 200 year condition, at MLWS.

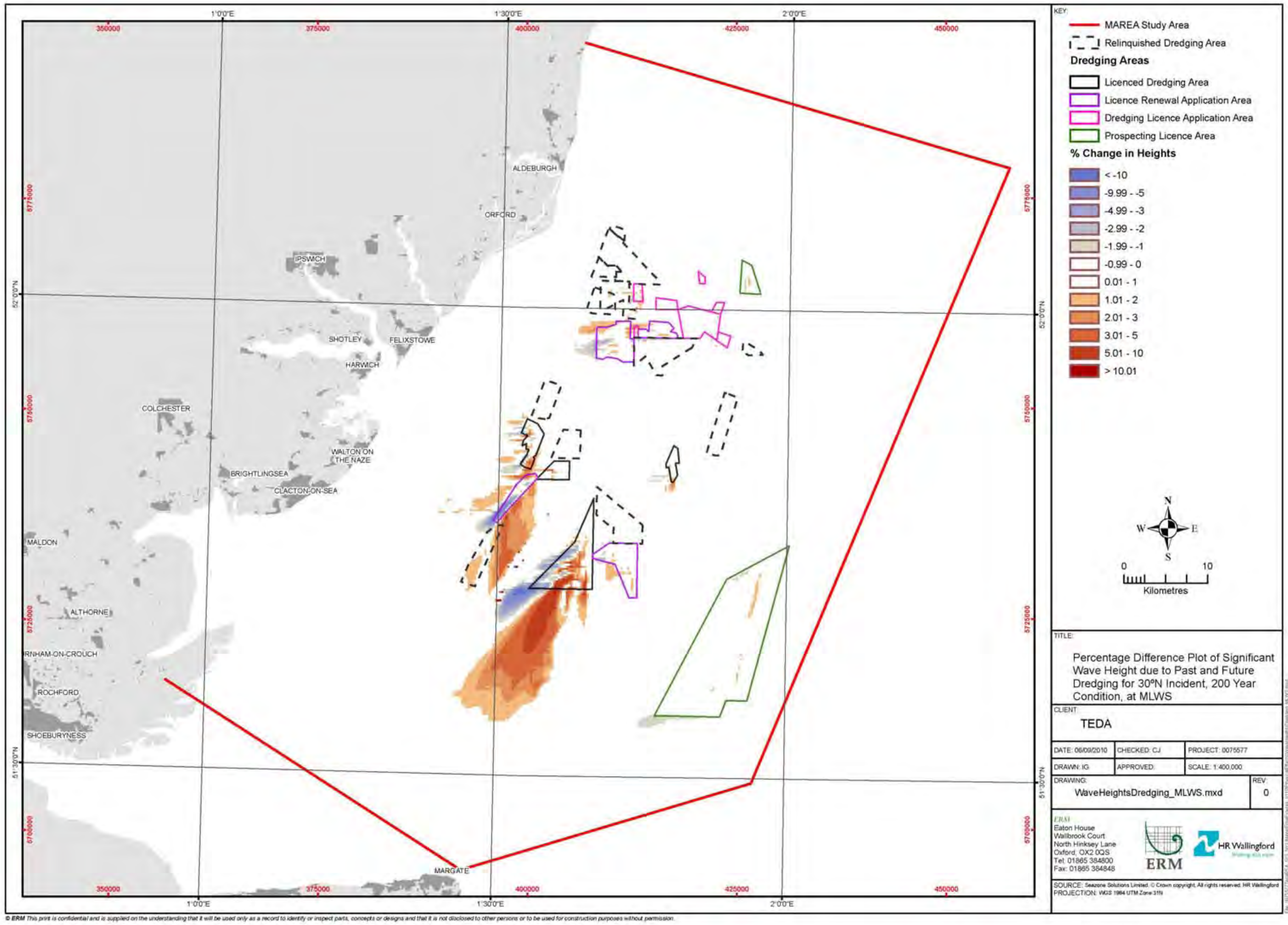


Figure 7.13 Percentage difference plot of significant wave height due to past and future dredging for 30°N incident, 200 year condition, at MHWS

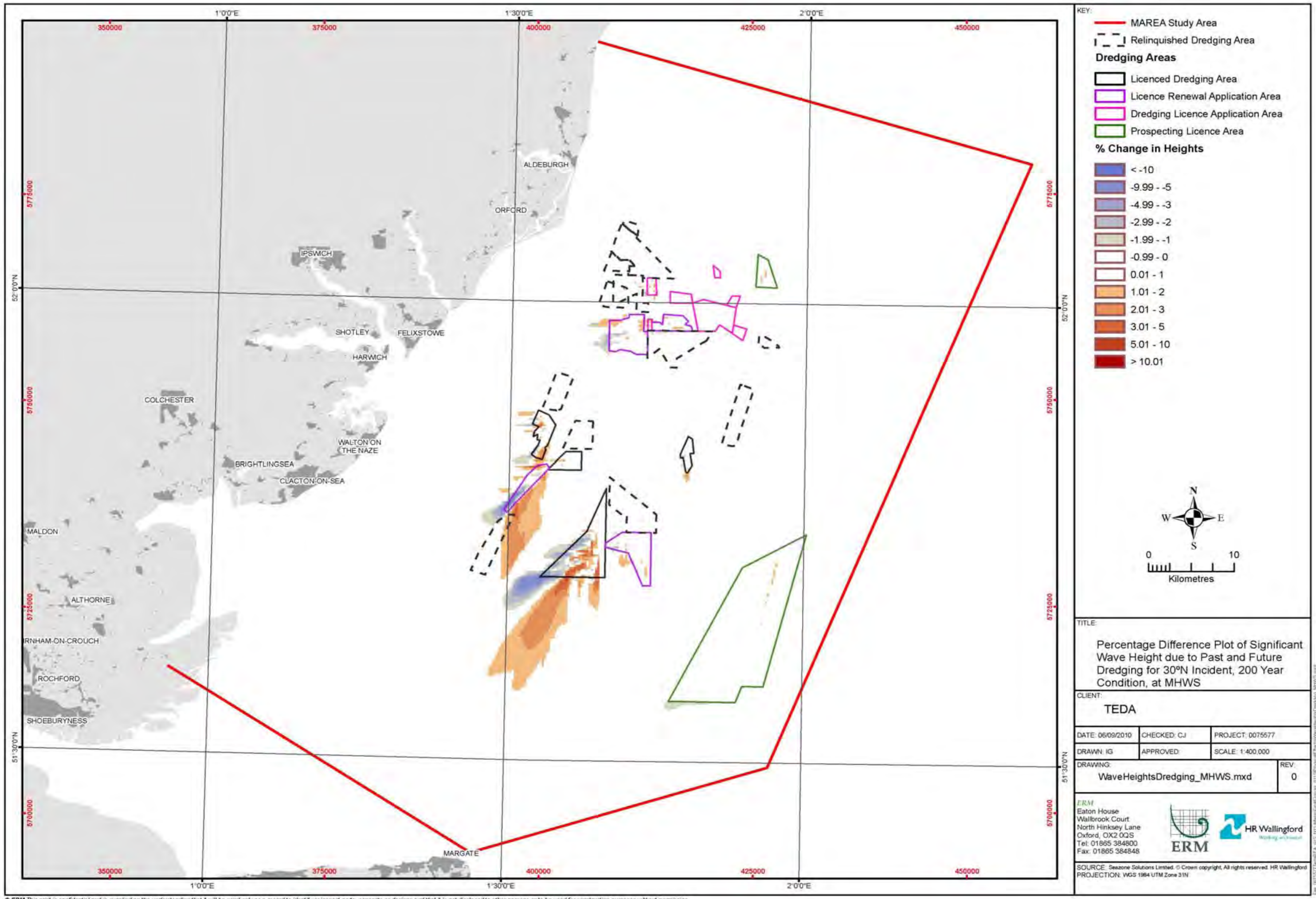


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Figure 7.14 Percentage difference plot of post-dredged/pre-dredge significant wave height for 30°N incident, 5% exceedance, at MLWS

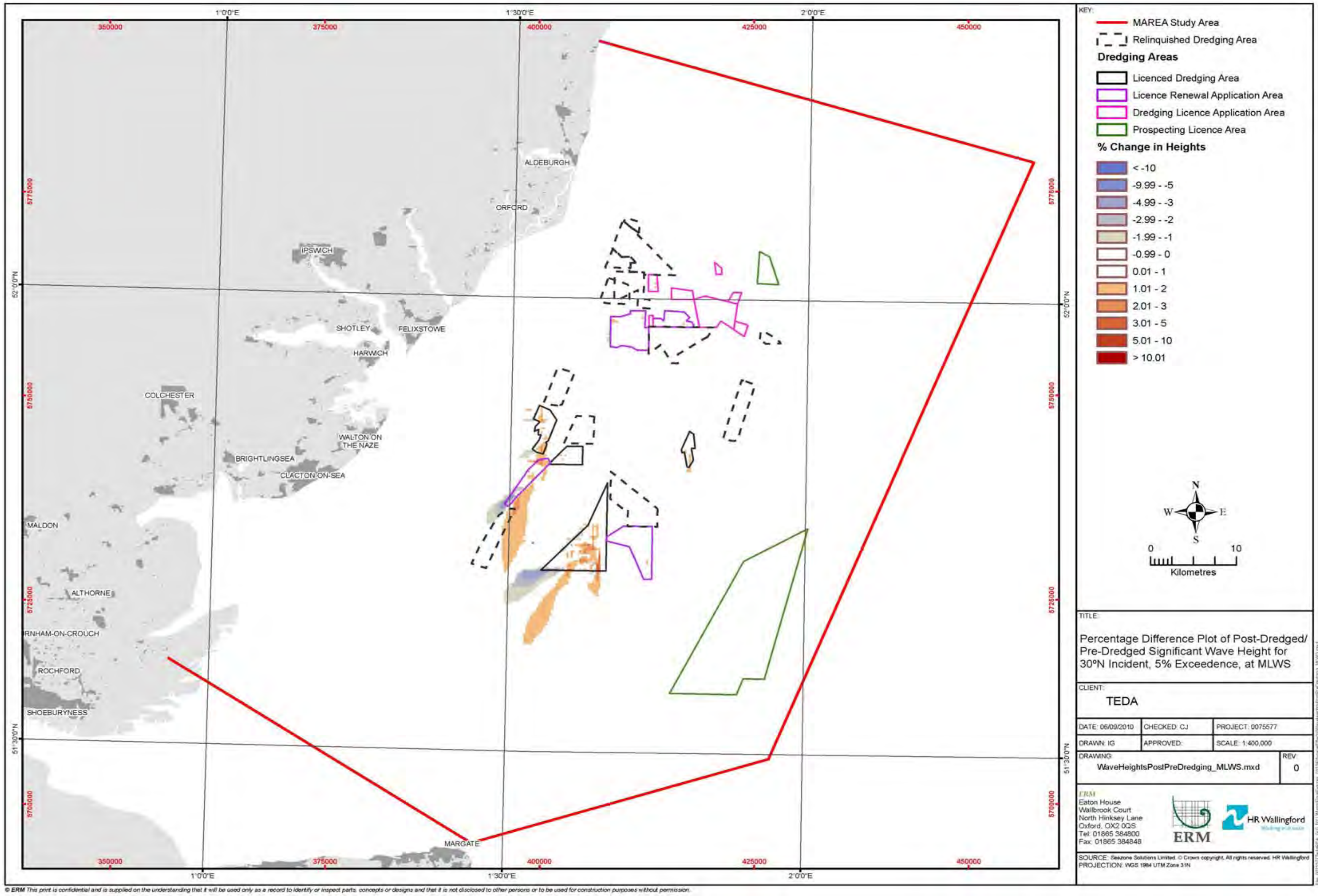


Figure 7.15 Percentage difference plot of post-dredged/pre-dredge significant wave height for 30°N incident, 5% exceedance, at MHWS

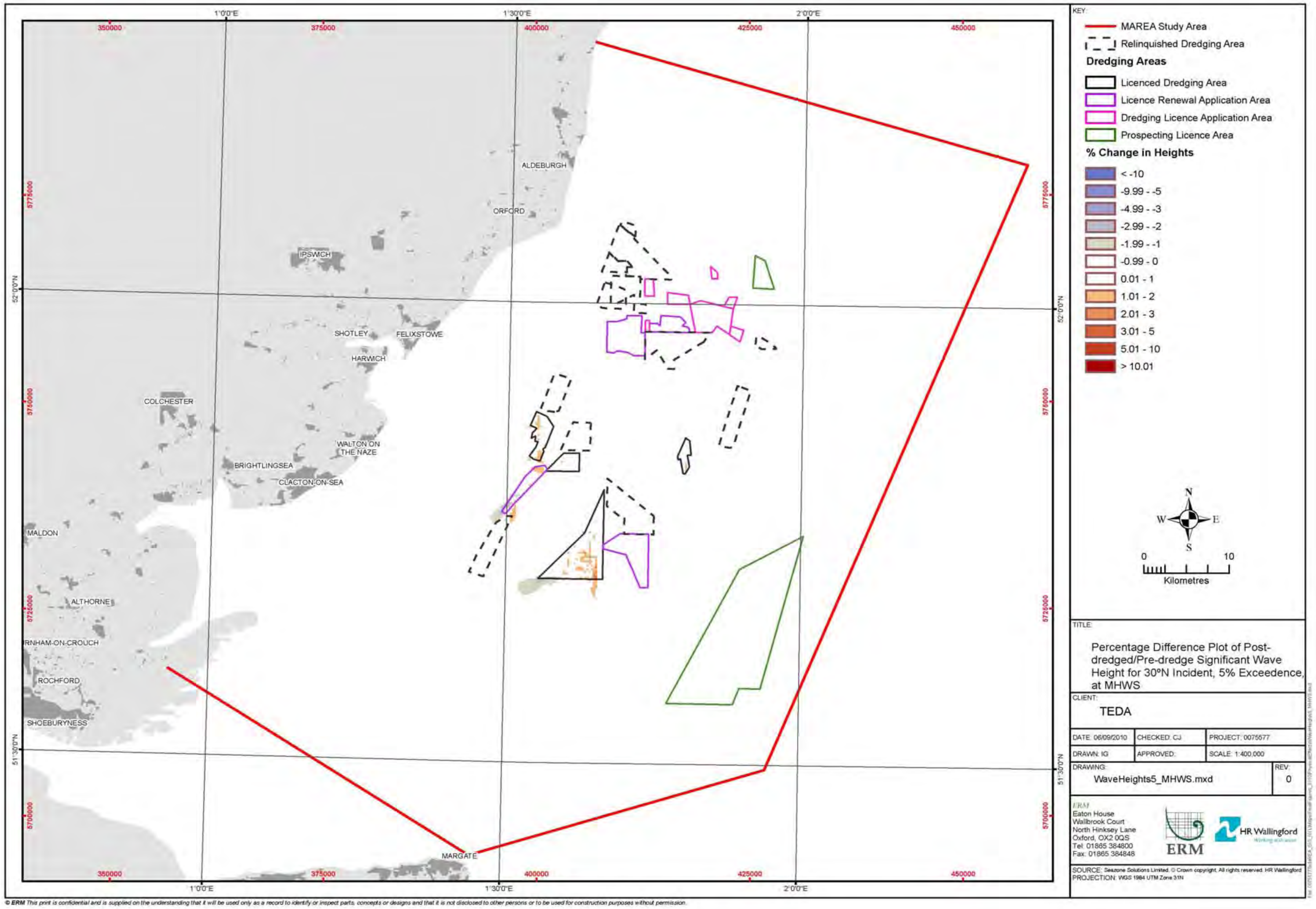
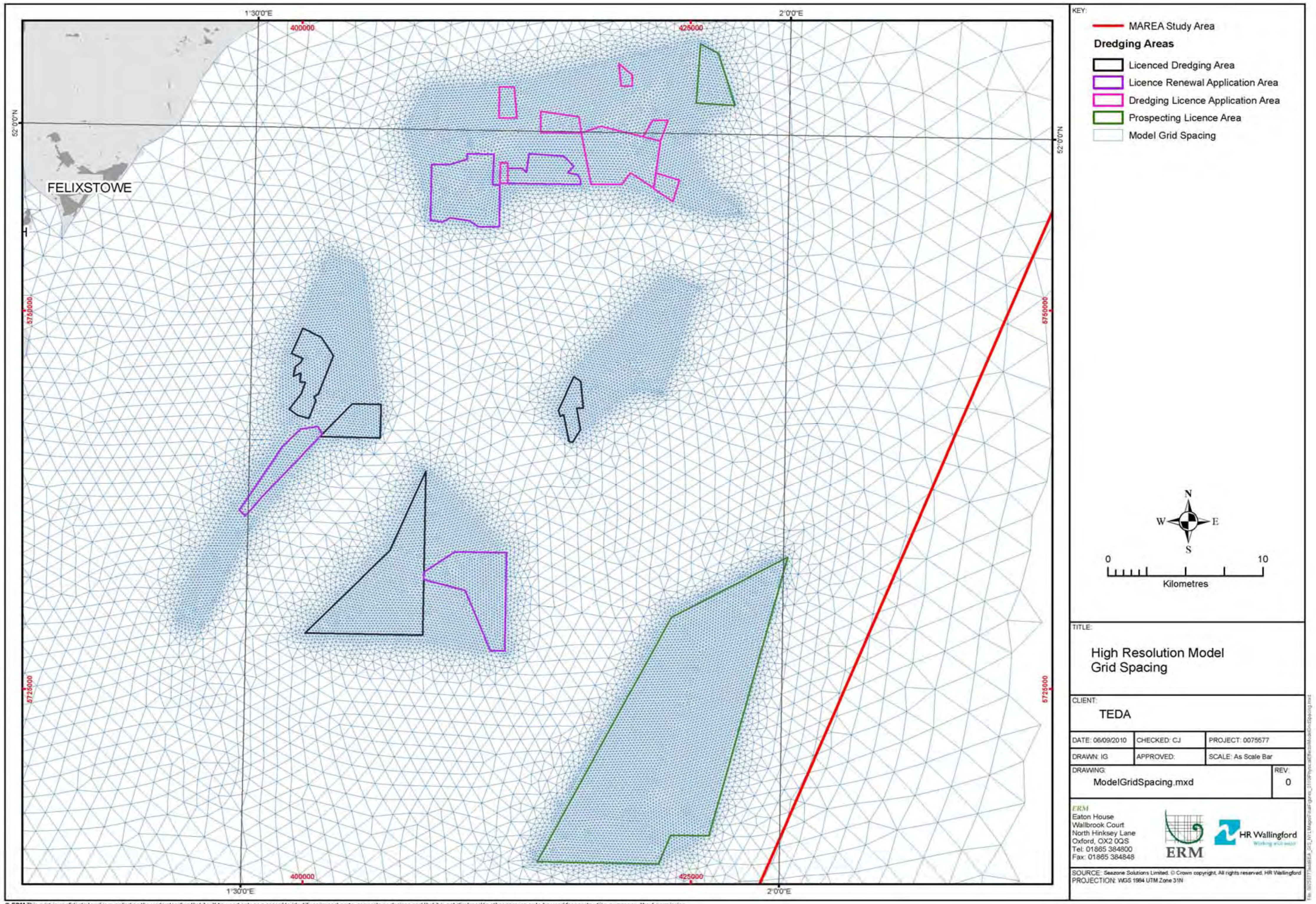


Figure 7.16 High Resolution Model Grid Spacing



7.4.2 Changes to Tidal Currents/Local Circulation

Potential Effects on Sensitive Receptors

Changes to seabed morphology as a result of dredging activities could lead to changes in tidal currents. Aggregate extraction is usually carried out in a direction parallel to tidal currents. Tidal currents are most strongly increased at the northeast and southwest ends of the dredging areas as the increased water depth attracts a greater tidal discharge through those areas. As this increased discharge enters and leaves the dredged areas it causes faster current speeds over the un-dredged areas of the seabed, while flows alongside the dredging areas tend to reduce. Within the dredging areas themselves, the increase in water depths and discharge often result in little change in the depth-averaged current speeds. Variations in tidal currents are therefore restricted to a zone approximately twice the size of the dredged area.

Summary of Methodology for Predicting Changes to Tidal Flows

A full account of the methodology used to predict changes in the tidal flows in the MAREA area can be found in Appendix H. A summary of the key points in the methodology is presented in this section.

Changes to tidal flows in the MAREA study area were modelled based on Phase 2 of the Southern North Sea Sediment Transport Study (SNSSTS2). SNSSTS2 used a model called TELEMAC (which was developed by LNH-EDF of France) to predict tidal flows in the MAREA area. TELEMAC was adapted for this study to model changes in tidal flow in the MAREA area caused by past and proposed future dredging. The model grid spacing was adjusted to a higher resolution in and around the dredging areas, as shown in Figure 7.16. This allowed TELEMAC to not only simulate flows over a large area but to also generate a more detailed description of the flow field in areas of particular complexity. As a result more accurate predictions of tidal flows were generated. Details of the model can be found in Annex 1 to the HR Wallingford Tidal flows report in Appendix H. TELEMAC used a set of parameters to run its computational model, which included:

- A single tidal range equivalent to a mean Spring tide.
- A time history of water levels along the two open boundaries (north and east in the North Sea and in the southwest approaches of the English Channel).
- A seabed roughness that varied spatially to reflect the different sediments and was consistent with SNSSTS2.
- A median grain size of 0.3 mm.

Three bathymetries were also considered as follows:

- Pre-dredged bathymetry (based on present day bathymetry with licence areas re-constructed).
- Present day bathymetry, including all marine aggregate dredging in the study area to date.
- Future bathymetry, based on plans for further dredging over the next 15 years supplied by TEDA member companies.

As the changes in tidal flow caused by dredging is the focus of the MAREA, the bathymetry maps used only differ where past or proposed dredging has taken/will take place. Changes in tidal flow due to natural alterations to the bathymetry over time have not been accounted for. The bathymetry maps used have been created using the best available data collected by the Hydrographic Office over the last 15 years and as a result cannot be assigned to a particular year.

Results of the pre-dredging and post-dredging bathymetries were compared so that any changes in tidal flow that have already occurred were considered together with anticipated future changes. Achieving all the post-dredging depth changes shown in Figure 7.3 by 2030 would require a larger volume of aggregate to be extracted than is expected, based on past dredging rates in this region. Therefore although the predicted tidal flow changes in and around any individual dredging area could occur it is likely to mean that changes around another area, or areas, are over estimated.

It is important to note that licence Area 504 in the southeast corner of the study region was still being investigated for the depth of sand and gravel deposits, so the change of depth in this area is a maximum hypothetical depth change. The area has since been surrendered but is still included in the assessment due to the schedule of the REA (see *Industry Statement*).

Predicted Changes to Tidal Flows

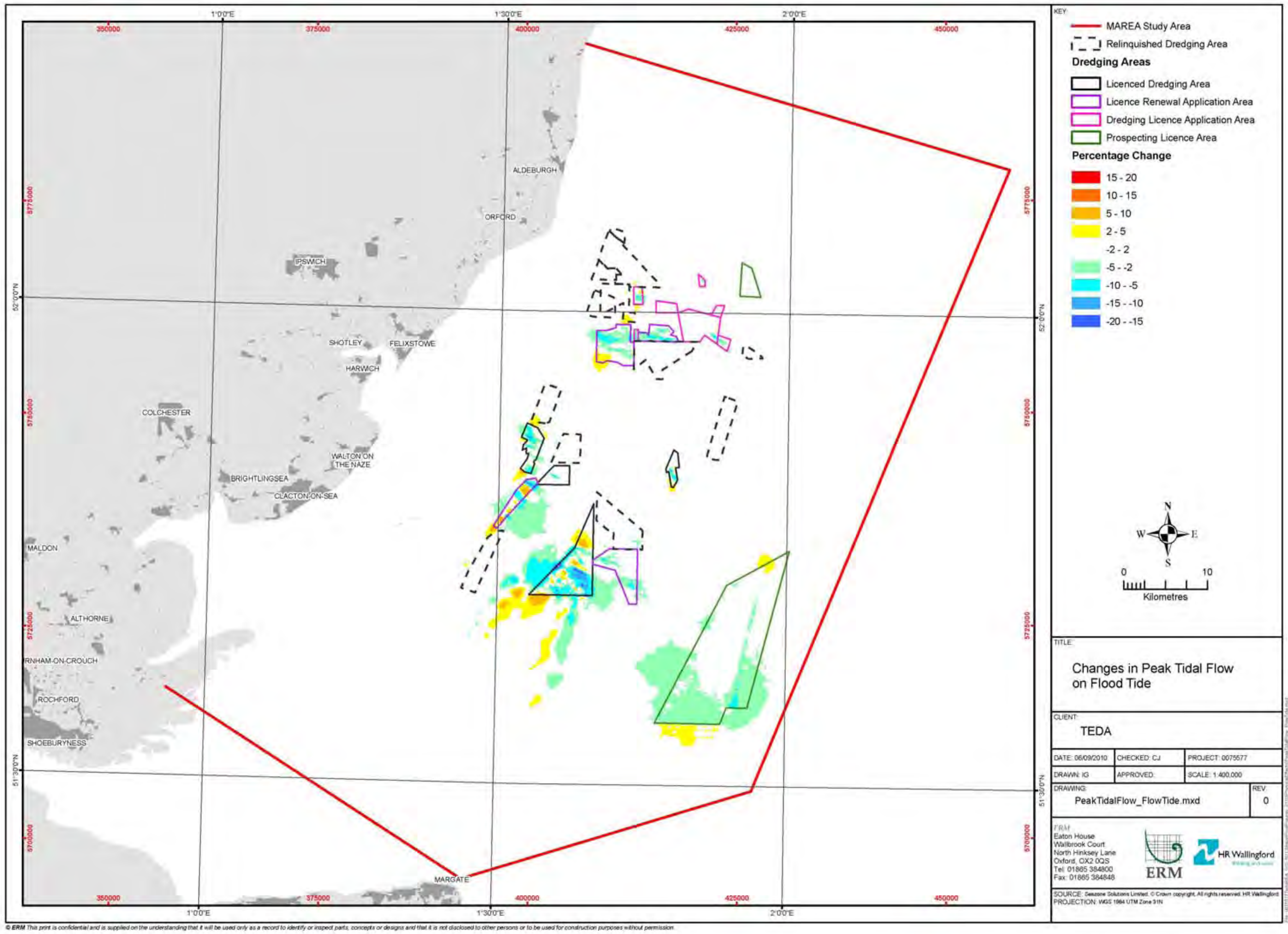
The TELEMAC flow model allowed predictions of instantaneous current speeds and directions in the MAREA area to be generated for any point in a tidal cycle. The present day predicted peak flow rates across the seabed in the vicinity of the dredging areas flow roughly to the southwest on the flood tide and roughly northeast during the ebb tide. Faster flows were found in the channels between sandbanks to the south and west of the dredging areas. For the present day predictions flows at the peak of the flood tide are generally greater than the flows at the peak of the ebb tide.

Changes in peak tidal flow for pre-dredging and post-dredging bathymetries on the flood tide can be seen in Figure 7.17 and changes in peak tidal flow for pre-dredging and post-dredging bathymetries on the ebb tide can be seen in Figure 7.18.

For this study it has been assumed that changes of 5% or more at peak flood or ebb tide would represent a change to the environment that might be detected within the context of natural variability. Although it is unlikely that changes in peak current speed of less than 5% could have any damaging effect, it cannot be entirely ruled out since the receptor sensitivity may vary.

Figure 7.17 and Figure 7.18 show that significant changes in tidal flow only occur in the dredging areas or a small area, no more than a few hundred meters wide, beyond the dredging areas. Tidal currents close to the coast in the MAREA area are not affected. Tidal flow is most strongly increased in the northeast and southwest margins of the dredging areas but tidal flows to the NW and SE of the dredging areas are commonly reduced. Results within the dredging areas are variable; tidal flows are increased, decreased or not changed. The modelling results show that any changes in tidal currents are unlikely to result in significant changes to the environment, although the potential exception to this may be where either existing features of interest or existing/planned developments are very close to the boundaries of the dredging areas. The results of the modelling also show little evidence of cumulative effects of any increased/decreased tidal flow.

Figure 7.17 Changes in Peak Tidal Flow on Flood Tide



7.4.3 Changes in Sediment Transport

Potential Effects on Sensitive Receptors

The supply of sediment to beaches may potentially be affected by nearby dredging operations via the direct extraction of the sediment source, or by indirectly altering the pattern of sediment transport across the seabed. If sand transported as bedload became trapped in the dredged depressions, then the sediment supply to the coast could become restricted. In addition changes to wave patterns and tidal currents, or the release and settlement of fine material by screening and overspill, may result in changes to sediment transport pathways. Studies were therefore conducted as part of the MAREA to explore the nature of any potential changes to sediment transport and to quantify them where possible.

The modelling methodology adopts a conservative approach but when assessing impacts it is important to remember that any changes to the sediment transport pathways as a result of dredging should be considered in context of the natural seabed fluctuations that have taken place in the region. A recent study from The Crown Estate - Caird Fellowship Research Project showed that at a local level the seabed is highly dynamic, with banks and channels displaying significant lateral shifts over the last 180 years which account for depth changes in the order of tens of metres (Burningham *et al*, 2009). Dredged depressions will be significantly shallower than these natural depth changes. In addition the Southern North Sea Sediment Transport Study (Hr Wallingford *et al*, 2002) indicates that there is no major supply of sediment to the coast from the southern North Sea and that sediment is transported alongshore by tidal currents rather than from offshore by weak wave activity.

Summary of Methodology for Predicting Changes to Sediment Transport

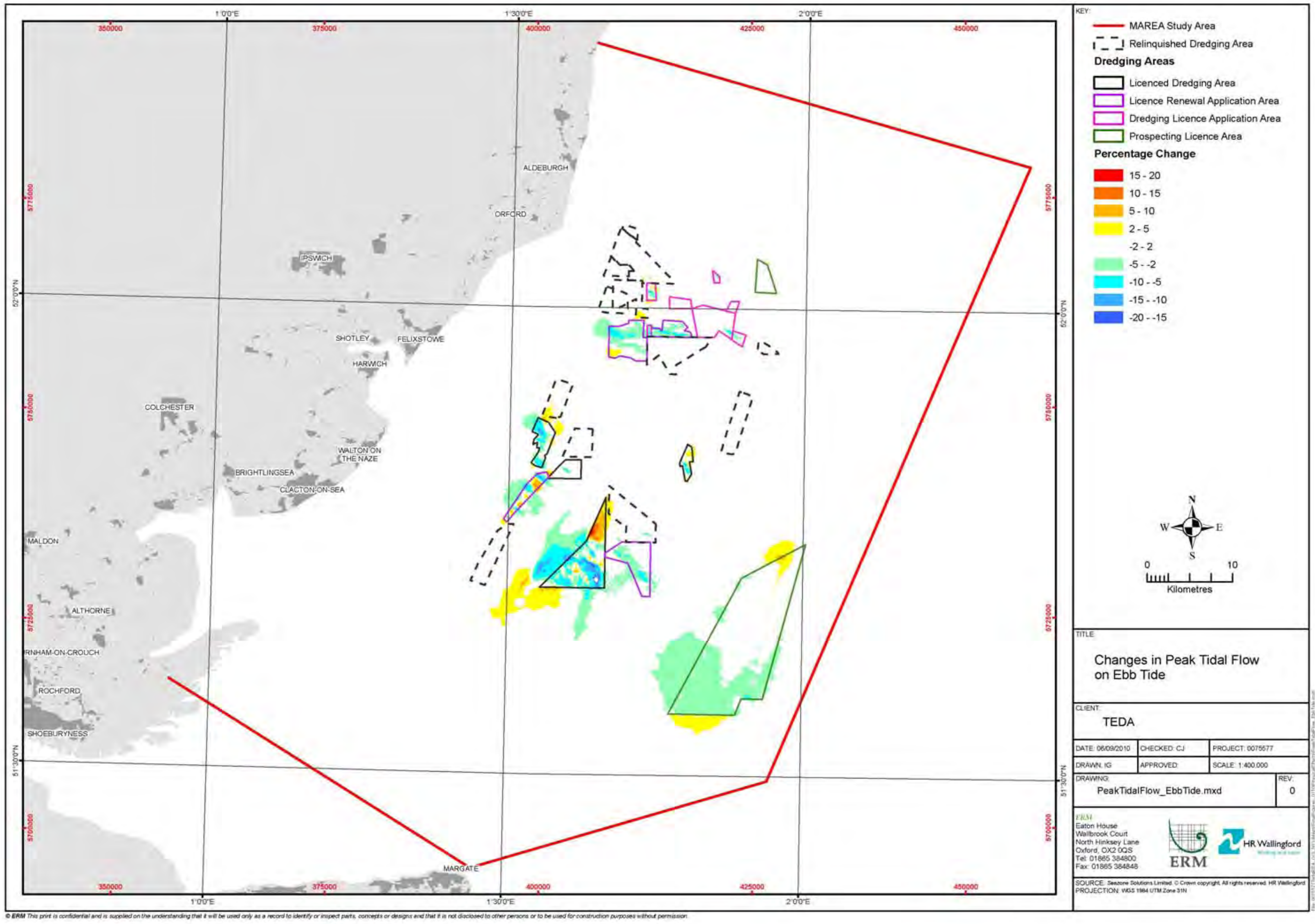
A full account of the methodology used to predict changes in sediment transport patterns in the MAREA area can be found in Appendix H. A summary of the key points in the methodology can be found in this section.

Changes to sediment transport in the MAREA study area were modelled based on Phase 2 of the Southern North Sea Sediment Transport Study (SNSSTS2). SNSSTS2 resulted in a detailed understanding of sediment transport along the east coast of England from Flamborough Head in Yorkshire to North Foreland in Kent. Several methods were used to collect sediment transport data for SNSSTS2, including a consultation exercise, new field data and seabed maps and numerical modelling. The SNSSTS2 numerical model studies provided complementary information to observations and measurements of sediment transport. The comprehensive outcomes of SNSSTS2 can be found in HR Wallingford *et al* (2002) [(1)].

Adaptations to SNSSTS2 were made so that the effects of past aggregate dredging were included and the possible effects of proposed future aggregate dredging and changes to tidal flows within the Thames Estuary could be predicted (see Appendix H). The model grid spacing (see Figure 7.16) was adjusted to a higher resolution in and around the dredging areas, which allowed alterations in bathymetry to be made so that more detailed and accurate predictions of sediment transport patterns could be generated. As described in Section 7.4.2 TELEMAC was used to model changes in tidal flow due to past and future dredging activities. Changes predicted by TELEMAC may alter sediment transport patterns and magnitudes caused by tidal flows. Output flows from TELEMAC were input into a sand transport model (SANDFLOW [(2)]), which then simulated the total load (suspended and bedload) in the MAREA area. The effects of wave action on sediment transport have not been included in the SANDFLOW model. SANDFLOW was configured to assume that there was an abundant supply of sand all over the MAREA area. This is likely to predict a higher rate of sediment transport than would actually occur due to the presence of less mobile sediment fractions, such as gravel, in the study area. SANDFLOW was used to predict the net sediment transport rate of sand (0.3 mm grain size) over a spring tide so that deposition (siltation) or erosion (scour) around the dredging areas can be examined.

SANDFLOW and TELEMAC used the same parameters as described in Section 7.4.2. The bathymetries described in Sections 7.3.2 and 7.4.2 were again used to define the seabed depths pre- and post-dredging (see Figure 7.2 and Figure 7.3) See Section 7.4.2 for further details or refer to Appendix H for a comprehensive methodology containing all of the parameters used.

Figure 7.18 Changes in Peak Tidal Flow on Ebb Tide



(1) Available at http://www.sns2.org/project-outputs.html
(2) Created by HR Wallingford. Details can be found in Appendix 2 of the HR Wallingford's Tidal Flows and Sediment Transport Study.

Predicted Changes to Sediment Transport

Predicted changes in sediment transport rates as a result of past and proposed dredging activity can be seen in Figure 7.19. Only changes greater than 100 kg m^{-1} $tide^{-1}$ are shown as this is the smallest change that could be identified with any certainty using the modelling methods outlined above. Figure 7.19 shows that changes to sediment transport rate are mainly contained within the dredging areas and around their boundaries. The southern parts of the dredging areas, which correspond with the direction of the flood tide, are predicted to experience the greatest changes in sediment transport rates. Just outside the dredging areas there is an increase in sediment transport rate whilst inside rates are commonly lower. There is no change to sediment transport rates near the coast. There is no evidence of cumulative effects; there are no hotspots of change in sediment transport rate where licence areas are close to each other.

It is important to note that this is a predicted 'maximum case' scenario. SANDFLOW assumed sand covered the entire area, whereas in reality parts of seabed in the dredging areas are covered in gravelly sand, which is unlikely to be moved by weak tides and currents. As for the tidal flows, discussed above, licence Area 504 is unlikely to be exploited to the extent allowed for in this study, so changes in sediment transport rates in and around this area would be less extensive.

7.5 MAGNITUDE OF EFFECTS

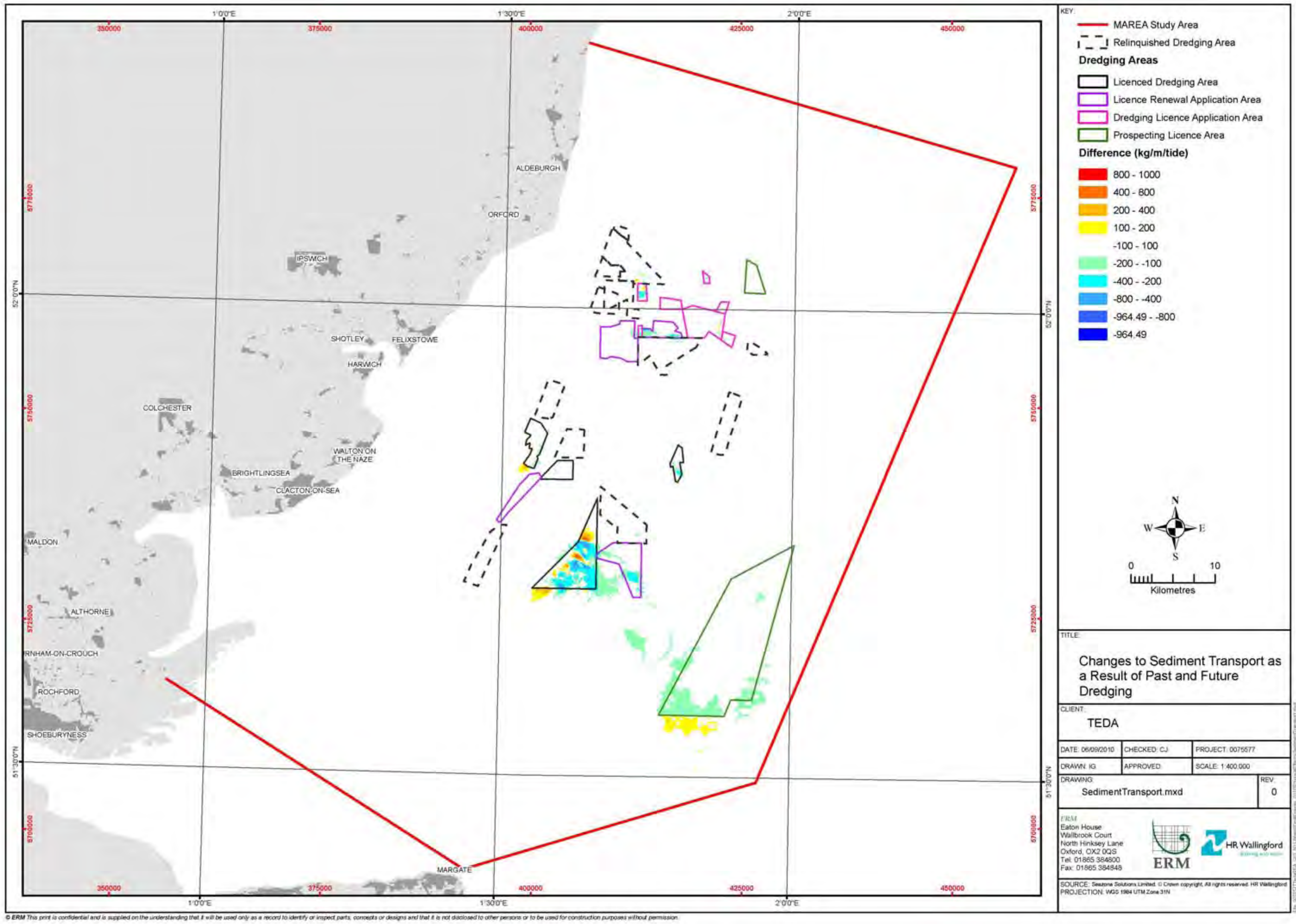
As discussed, the effects of dredging have been modelled during a number of specialist studies that have been undertaken for the MAREA. These studies have predicted the spatial extent of each effect. In most cases a number of different thresholds or concentrations of the effect have been identified to help establish the degree of change from baseline conditions.

This is important because it is often the case that the spatial extent of the effect is inversely correlated with the amount of change from baseline conditions and using a single contour showing return to background concentrations may not always provide sufficient information for the impact assessment.

Other effects that do not involve predictive modelling, such as the occupancy of vessels on licence areas and the areas of seabed lowering are based directly on the predictions of the aggregate companies that operate each licence.

This information on spatial extents is used, together with the frequency and duration of the effect, plus the amount of change from baseline conditions [1], to classify the overall magnitude of the effect. Table 7.4 below shows the overall magnitude categories that have been determined for each of the effects of dredging. These magnitudes are taken forward into the impact assessment sections in Chapters 8 to 10.

Figure 7.19 Changes to Sediment Transport as a Result of Past and Future Dredging



(1) It should be noted that the 'change relative to the baseline' is taken to mean the change relative to the regional baseline conditions for the parameter in question, which is not just based on the baseline effects of dredging but incorporates all natural and anthropogenic influences.

Table 7.4 Magnitude Categories for the Physical Effects of Dredging

Physical Effects	Extent of Effect	Duration of effect	Frequency of effect	Change relative to baseline	Magnitude
Presence of the vessel	Site Specific	Temporary	Routine	Low	Small
Removal of sediment	Site Specific	Long term	Routine	Medium	Medium
Fine sediment plume/elevated turbidity above background	Sub Regional	Temporary	Routine	Low	Medium
20mg l^{-1} plume	Local	Temporary	Routine	Low	Small-Medium
50mg l^{-1} plume	Local	Temporary	Routine	Medium	Medium
100mg l^{-1} plume	Site Specific	Temporary	Routine	Medium	Medium
Sand deposition (formation of bedforms)	Local	Short term	Routine	Low	Small
Changes to sediment particle size	Local	Short term	Routine	Low	Small
Changes to 1 in 200 year wave heights - >5% change	Local	Long term	Rare	Low	Small-Medium
Changes to 1 in 200 year wave heights - 2-5% change	Sub Regional	Long term	Rare	Low	Small-Medium
Changes to 5% exceedance wave heights >5% change	Site Specific	Long term	Occasional	Medium	Small-Medium
Changes to 5% exceedance wave heights 2-5% change	Local	Long term	Occasional	Low	Small-Medium
Changes to tidal currents - 10-20% change	Site Specific	Long term	Routine	Medium	Medium
Changes to tidal currents 2-10% change	Local	Long term	Routine	Low	Medium
Changes to sediment transport rates - 100-400 kg/m/tide	Local	Long term	Routine	Low	Medium
Changes to sediment transport rates - 400-1000 kg/m/tide	Site Specific	Long term	Routine	Medium	Medium
Underwater noise - strong behavioural response	Site Specific	Temporary	Routine	High	Medium
Underwater noise - mild behavioural response	Local	Temporary	Routine	Medium	Small-Medium
Underwater noise - low likelihood of effects - marine mammals	Sub Regional	Temporary	Routine	Low	Small-Medium
Underwater noise - low likelihood of effects - fish	Local	Temporary	Routine	Low	Small
Loss of access	Site Specific	Temporary	Routine	Low	Small
Change to benthic community composition*	Local	Medium term	Intermittent	Medium	Medium-Large
Change to distribution of fish	Local	Temporary	Routine	Low	Small
Change to sandbanks	Local	Medium term	Routine	Low	Small

* Intermittent has been selected for changes to benthic community composition because much dredging occurs along tracks that have previously been dredged so the frequency of previously un-dredged seabed being impacted is low.

7.6 SUMMARY

This chapter summarises a number of studies into the effects of aggregate dredging in the Outer Thames Estuary on the physical environment. Primary effects investigated include the risk of vessel collision, the generation of a fine sediment plume from the overflow and screening process, and noise generated by the dredging operation. Secondary effects as the result of changes to bed morphology include changes in wave conditions, changes in tidal currents and changes to sediment transport.

This chapter has discussed the potential effects of dredging, which are not necessarily considered to represent impacts. The effects investigated represent changes in the baseline conditions that may or may not be translated into impacts as a result of their interaction with the environment. Impacts will be considered further in Chapters 8 to 10.

In summary:

- Dredging activity may increase by a potential 150% based on the Future Case scenario, which results in an increase in dredger vessel traffic to approximately 3% of the total vessel traffic in the Outer Thames Estuary. The increase in dredger activity increases the risk of vessel collision from approximately 1 major collision in 1.44 years to 1 in 1.39 years, which is a small increase of approximately 3% relative to baseline levels.

- The dispersion of the fine sediment plume associated with dredging activity was modelled. Approximate background concentrations of suspended sediment are reached at a distance of 1,500 m from the dredger. Concentrations of 20 mg l^{-1} above background levels are reached at approximately 300 m from the dredger, which is approximately 20% of the distance at which the concentrations in the plume approach background concentrations. For the vast majority of the time over the licensing period at any given point in the study region there will be no increases in suspended sediment concentration above background levels. Even when concentration increases of a few tens of mg l^{-1} above background levels occur, they are still less than natural increases that occur regularly due to tidal conditions and waves.

- It was determined that the maximum potential footprints of fine sand dispersion from dredging could be up to 4 km from the licence areas in terms of changes to particle size composition of the substrate, and up to 2.5 km for changes to bedforms. Coarse sand will fall to the seabed within tens of metres of the dredger.

- Wave height changes due to bathymetry alterations were modelled. At MLWS extreme waves in Long Sand Head licence (Area 108/3, 109/1, 113/1) may change by greater than 10% for up to 7 km beyond the boundary of the licence area, and changes of 2% might be expected at twice this distance away from the southern boundary. At MHWS wave height changes of greater than 2% extend up to 10 km away from the licence area boundaries. MHWS is generally of greater concern than MLSW because a combination of severe waves and a high tidal level have a greater chance of affecting coastal defences. There is no alteration to wave heights at or near the coast for either MLWS or MHWS for any of the modelled incident wave directions.

- Tidal current changes due to bathymetry alterations were modelled. Significant changes in tidal flow (>5%) only occur within the licence areas or a small area, no more than a few hundred meters wide, beyond the licence area boundaries. Tidal currents close to the coast in the MAREA area are not affected.

- Sediment transport rate changes due to bathymetry alterations were modelled. Changes to sediment transport rate are mainly contained within the licence areas and around their boundaries. There is no change to sediment transport rates near the coast and no evidence of cumulative effects; there are no hotspots of change in sediment transport rates where licence areas are close to each other.

8 THE PHYSICAL ENVIRONMENT – ASSESSMENT OF REGIONAL IMPACTS

8.1 INTRODUCTION

This chapter describes the potential regional impacts on the physical environment as a result of future marine aggregate extraction activities in the Outer Thames Estuary.

The topics covered in this Chapter include:

- impacts to sandbanks (Section 8.2);
- impacts to the coastline (Section 8.3); and
- impacts to water quality (Section 8.4).

In all cases, the potential impacts as a result of the effects of dredging discussion in Chapter 7 are considered.

8.2 IMPACTS TO SANDBANKS

8.2.1 Introduction

Sandbanks may be subject to impacts from changes in physical processes caused by dredging activities. Sandbanks have great importance in marine sediment systems as they trap large amounts of sand for long periods of time and are thought to reduce the energy of waves and storm surges. They also provide important benthic habitats. Many sandbanks in the MAREA area have their origin in the geological past, however, the formation and maintenance of sand banks requires both ample available sediment and currents strong enough to induce bedload movement (Dyer *et al*, 1999), consequently sandbanks may be sensitive to changes in these parameters.

The Outer Thames Estuary is characterised by dynamic sandbanks, which over the last 180 years have displayed significant lateral shifts that account for depth changes in the order of tens of metres (Burningham *et al*, 2009). Some of the central estuary mouth banks including Sunk Sand, the Barrows, Long Sand and Kentish Knock have moved up to 2 km in places. However, the position of these ridges relative to each other appears to be stable over the historical timescale.

For the purpose of this impact assessment the impacts considered are with regard to the physical structure of the sandbanks and the physical processes that maintain the sandbank and its natural dynamics. Impacts to the associated benthos are considered in Section 9.2, impacts to the sandbanks when regarded as protected areas and their conservation objectives are considered in Section 9.6 and impacts to the infrastructure associated with some sandbanks are considered in Section 10.3. As a result, for all sections in this impact assessment the **value** of sandbanks is rated as **low**. The individual assessments of value of the benthic ecology associated with sandbanks and sandbanks that are protected are considered separately in their impact assessment chapters.

Dredging has occurred in some parts of the Outer Thames Estuary since the 1960s and since then data and observations on aggregate extraction close to sandbanks have been accumulated by the industry. Figure 8.1 shows a cross section through the Long Sand Head licence area (Area 108/3, 109/1, 113/1), which is bordered in the west by Long Sand and overlaps Kentish Knock to the south. The figure shows that the north east margin of Long Sand locally overlies the gravelly sands of the dredging area and that the bank margin approximately occurs along the 20 m isobath. The location of most aggregate extraction since 1998 shows that dredging has not removed any significant amount of sediment from the Long Sand sandbank. In addition, even though dredging has occurred since the 1960s, the bank's position has not been affected by this activity.

8.2.2 Identification of Potential Impacts to Sandbanks

Table 8.1 shows the predicted effects of dredging with reference to whether or not they have the potential to impact sandbanks. Only impacts that have the potential to affect the physical structure or processes that govern sandbank formation and dynamics are considered.

Table 8.1 Matrix of Potential Impacts of Dredging on Sandbanks

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Sandbanks as physical structures		✓	×	✓	✓	✓	✓	✓					N/A

	Not affected
×	No interaction
✓	Potential interaction

The fine sediment plume created by dredging activity has been assessed as having no interaction with sandbanks. Sediment settling out of the water column onto the sandbanks is considered below in the section concerning changes to sediment particle size distribution.

8.2.3 Sandbanks

Removal of Sediment

Although there is no direct dredging of the Long Sands sandbank as a result of aggregates extraction within the Long Sand Head licence area (Area 108/3, 109/1, 113/1), there is some removal of the coarse clean sand at Kentish Knock.

Sediment removal is assessed to be a **medium magnitude** effect, as a result of it being site-specific in extent, long term in duration, routine and a medium level change relative to the baseline.

Sandbanks are considered to have a medium level of **tolerance and adaptability** to sediment removal as sandbanks are naturally subjected to sediment mobilisation, particularly during storm events. **Recoverability** of sandbanks is **not applicable** due to their highly dynamic nature and the **value** of sandbanks is rated as **low.** Taking into consideration tolerance, adaptability and value, the **sensitivity** of the sandbanks to sand deposition is **medium**.

Within the MAREA study area, it is only the dredging that takes place within Long Sand Head licence area (Area 108/3, 109/1, 113/1) that directly results in the removal of any sandbank material, at the very tip of Kentish Knock. The **degree of interaction** between sandbanks and sediment removal is therefore assessed to be very **small**.

Based on these assessments of the medium magnitude of the effect, the low value and medium sensitivity of sandbanks as physical structures, but the very small degree of interaction between the receptor and the effect, the impact of sand deposition on sandbanks is assessed to be ***not significant*** at the regional scale.

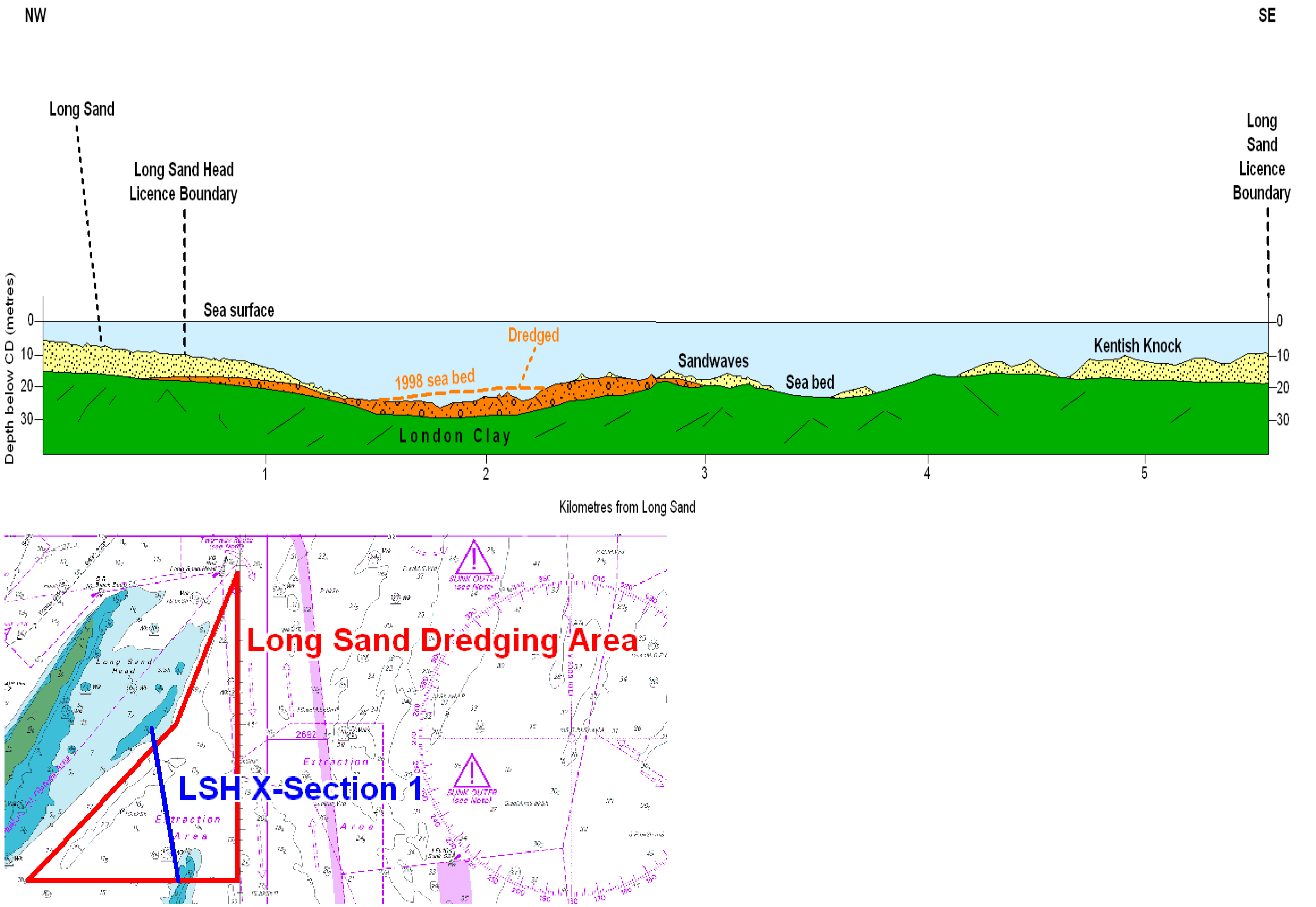
Sand Deposition

Sand deposition as a result of the overspill and screening process during dredging can be divided into two categories: the deposition of coarse sand and the deposition of finer sand. Coarse sand deposition will be mostly contained within the dredged area up to tens of metres away from the source, as this sand settles quickly out of the water column. Finer sand may be deposited further afield and cause alterations to seabed bedforms up to 2.5 km from the boundary of the licence area (HR Wallingford, 2010), shown in Figure 8.2 as the 'footprint of bedforms'. It is expected that only a very localised, thin and discontinuous veneer of sand may be deposited as far as 2.5 km from the licence area boundary and this sediment would be subject to regular reworking by waves and tidal currents and so would quickly disperse, merging with the naturally occurring sands found commonly in the region. It can therefore be considered that the sandbanks contained wholly or partly within the licence area or those that are in close proximity to the licence area (ie <2.5 km) may potentially be affected (see Figure 8.2).

Enhanced deposition of coarse sand on sandbanks as a result of dredging constitutes a longer term changes than enhanced deposition of fine sand. Coarse sand deposition is only likely to occur inside the licence areas and may cause some changes to sandbank topography if the sand is deposited on the sandbank. Finer sand will only form a localised, thin and discontinuous veneer as it will be deposited over a larger area (up to 2.5 km from the licence area boundaries) and then redistributed on successive tides. Sand deposition on sandbanks as a result of dredging activity is assessed as being a **small magnitude** effect based on the low level of change, it being localised in extent, routine in terms of frequency of occurrence but short-term in duration.

Sandbanks are considered to have a high level of **tolerance** to sand deposition as sandbanks are naturally subjected to sand deposition following episodic storm events, and there may only be a small change at the local scale if a large quantity of coarse sand is deposited on or near the sandbank. Sandbanks are assessed as having **high adaptability** to sand deposition due to their high mobility and regular geomorphological changes, which may make it difficult to determine which regional scale changes are natural and which are caused as a result of dredging activity. **Recoverability** of sandbanks is **not applicable** due to their highly dynamic nature and as discussed above the **value** of sandbanks is rated as **low.** Taking into consideration tolerance, adaptability and value, the **sensitivity** of the sandbanks to sand deposition is **low**.

Figure 8.1 Cross Section of the South East Flank of Long Sand Head, across the Long Sand Licence Area and Kentish Knock



Source: Dr Andrew Bellamy, Tarmac Marine Dredging Ltd.
Notes: Vertical exaggeration x 10 LSH = Long Sand Head

Only 1.3% of sandbanks in the MAREA area are found inside or within 2.5 km of the licence areas, so only a small proportion of sandbanks may be subject to sand deposition. This assumes dredging occurs continuously throughout the dredging areas up to the licence area boundary. In reality, whilst dredging activity may occur at the edge of the licence areas at times, it will generally be focused in one particular zone. Therefore a dredger in the MAREA area will only produce a plume of sediment covering a small area at any time and the proportion of this settling on to sandbanks is likely to be smaller still. This is because coarse sand settles out of the water column quickly and close to the dredger while finer sand travels further but only forms a very thin discontinuous veneer, meaning the proportion of sand capable of settling on sandbanks is extremely small relative to their volume. It can therefore be assumed that only a **small degree of interaction** between sandbanks and sand deposition may occur (see Figure 8.2).

Based on these assessments of the small magnitude of the effect, the low value and sensitivity of sandbanks as physical structures and the small degree of interaction between the receptor and the effect, the impact of sand deposition on sandbanks is assessed to be ***not significant*** at the regional scale.

Changes to Sediment Particle Size

This section considers the changes in sediment particle size with respect to the physical structure of sandbanks. The sediment particles in the fine sediment plume will settle out of the water column over time, and may deposit on to sandbanks. Some of the finer grains will be mixed with larger particles and trapped in the void spaces between them, thus altering the sediment composition of the sandbank. It has been determined in Chapter 7 from modelling results that the potential maximum footprint of changes in sediment composition could be up to 4 km from the site of dredging, except where sediment transport survey data interpretation by D'Olier (2008) suggests it could be extended to approximately 7 km to the southwest of the Long Sand Head licence area (Area 108/3, 109/1, 113/1) (see Section 7.3.3). Figure 8.3 shows which sandbanks may be affected by sediment particle size changes caused by dredging. The amended footprints of changes to particle size based on the geophysical survey interpretation by D'Olier (2008) are shown in addition to the modelled 4 km footprints. The figure shows that sandbanks that have the potential to be affected by changes in sediment particle size composition must either be contained wholly or partly within the licence area or be in close proximity to the licence area.

Figure 8.2 Potential Sandbank and Bedform Change Interactions

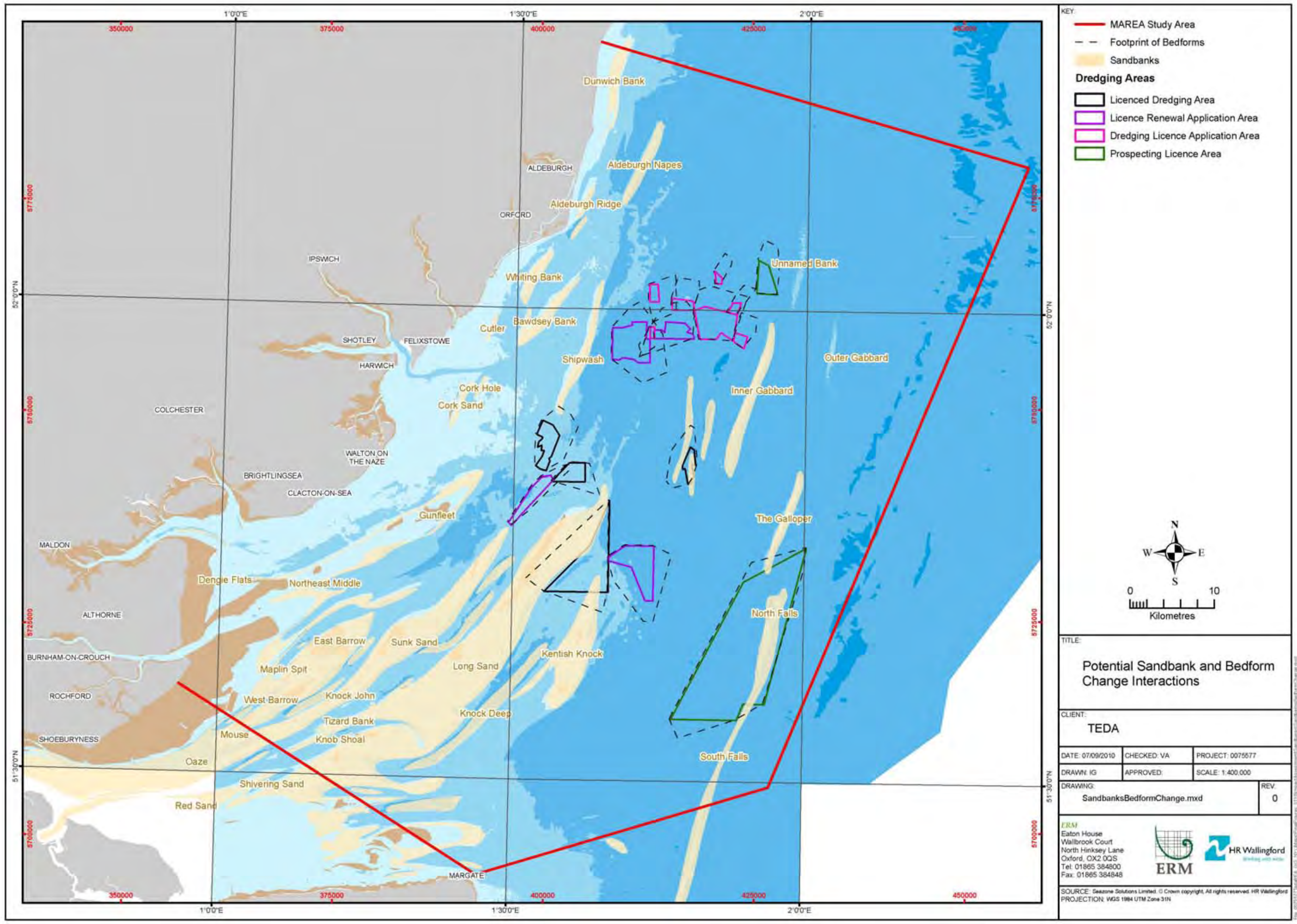
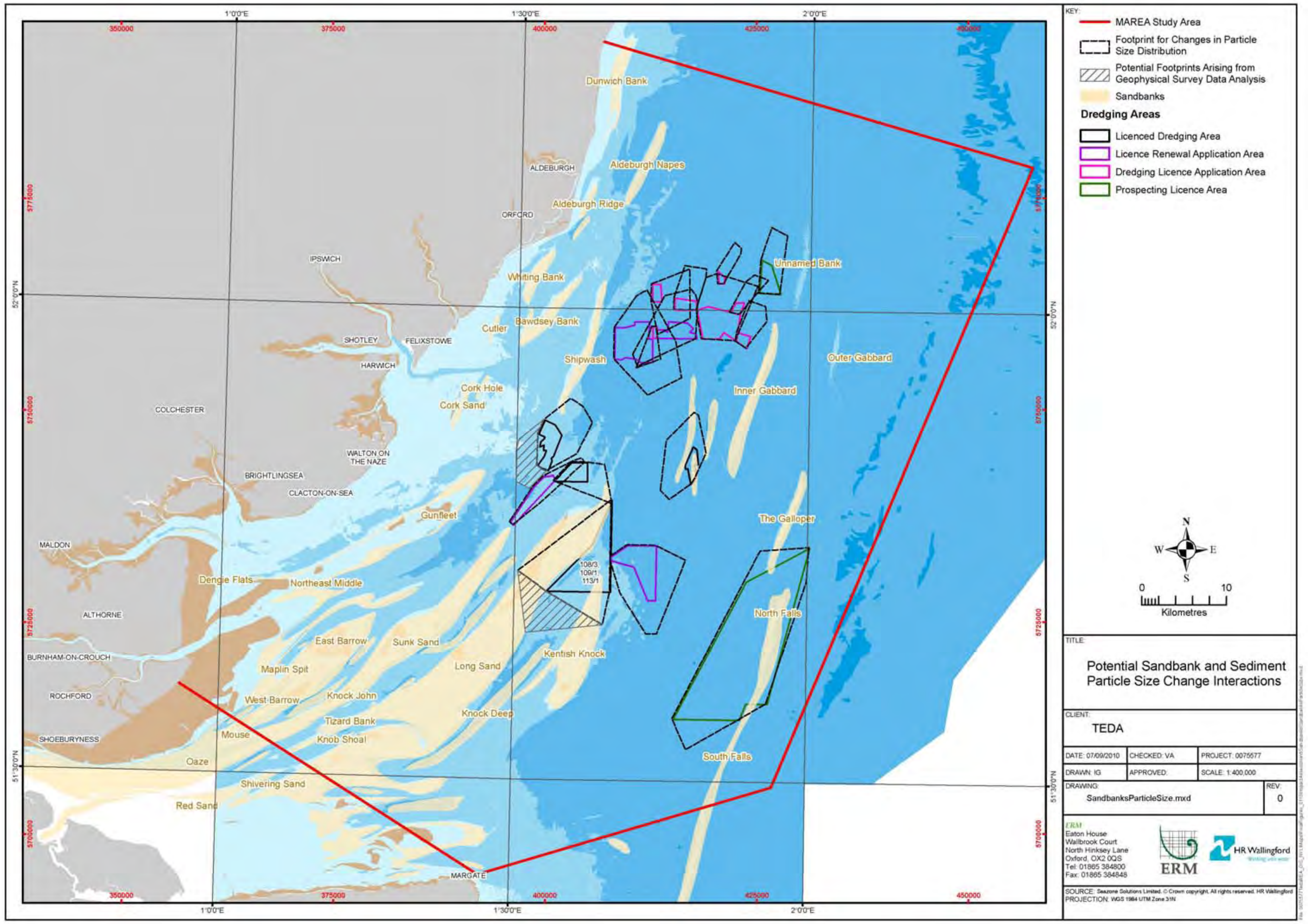


Figure 8.3 Potential Sandbank and Sediment Particle Size Change Interactions



The extent of effect of changes in sediment particle size distribution is at most local but is often site specific. However, there is a level of uncertainty regarding the potential for sandbanks to move into or very close to the licence areas over time. Based on the current situation, the impact will be localised, and the fines that settle will temporarily change the sediment composition in the top few centimetres of sediment. The duration of effect is considered short-term as the sediment will be continually re-worked and redistributed. The frequency of effect is routine and it is expected to represent a low level of change relative to the existing conditions. Overall, the impact of changes in sediment particle size distribution on sandbanks has been assessed as being a **small magnitude** effect.

Sandbanks can be considered to have a **high** level of **tolerance** and a **high adaptability** to changes in sediment particle size distribution at the regional scale, as there will be minimal or no detectable changes to the topography of sandbanks in general. This is especially noteworthy considering the natural reworking of the sediment by storms, which have been shown to alter sediment particle size distribution on sandbanks (Houthuys *et al*, 1994). As discussed above, **recoverability** of sandbanks is **not applicable** and the **value** of sandbanks is rated as **low**. Taking into consideration tolerance, adaptability and value, the **sensitivity** of the sandbanks to changes in sediment particle size distribution is **low**.

The majority of the fine sediment plume will settle inside the licence area, however, settlement of sediment that causes changes in sediment particle size distribution may occur up to 4 km from the licence area. Figure 8.3 shows that 1.6% of sandbanks are within this 4 km boundary and may be affected by changes in sediment particle size distribution, which is a small proportion of all sandbanks in the Outer Thames estuary. This assumes dredging occurs continuously throughout the dredging areas up to the licence area boundary. In reality, whilst dredging activity may occur at the edge of the licence areas at times it will generally be focused in one particular zone. Therefore a dredger in the MAREA area will only produce a plume covering a small area (see Figure 7.8 in Chapter 7) at any time, the proportion of this settling on to sandbanks and altering sediment particle size composition is likely to be smaller still. It can therefore be assumed that only a **small degree of interaction** between sandbanks and changes in sediment particle size distribution may occur with the sandbanks in their current location.

Based on the assessment of the small magnitude of the effect, the low value and sensitivity of sandbanks and the small degree of interaction between receptor and effect, the significance of impact of changes in sediment particle size distribution on the physical structure of sandbanks is assessed to be ***not significant*** at the regional scale.

Changes to Wave Heights

This section considers physical presence and structure of sandbanks with respect to changes in wave height. This is based on modelling the propagation of waves that are only expected to occur on average once every 200 years, which is the same wave condition that would be used in modelling related to the design of coastal defences, and a more frequent wave condition that is expected to be exceeded 5% of the time in one year.

Predicted changes to wave height due to bathymetry alteration from aggregate dredging and a discussion on the modelling have been presented fully in Chapter 7. This impact assessment presents predicted percentage change in wave height (greater than ± 2%) due to past and future dredging and assesses the impact this may have on sandbanks in the MAREA area.

A change greater than 5% to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the localised extent of the change and the rarity of the effect, however, the effect is long-term and the change relative to the baseline is low.

A change of 2-5 % to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the sub-regional extent of the change, the rarity of the effect and the low level change relative to the baseline, however, the effect is long-term.

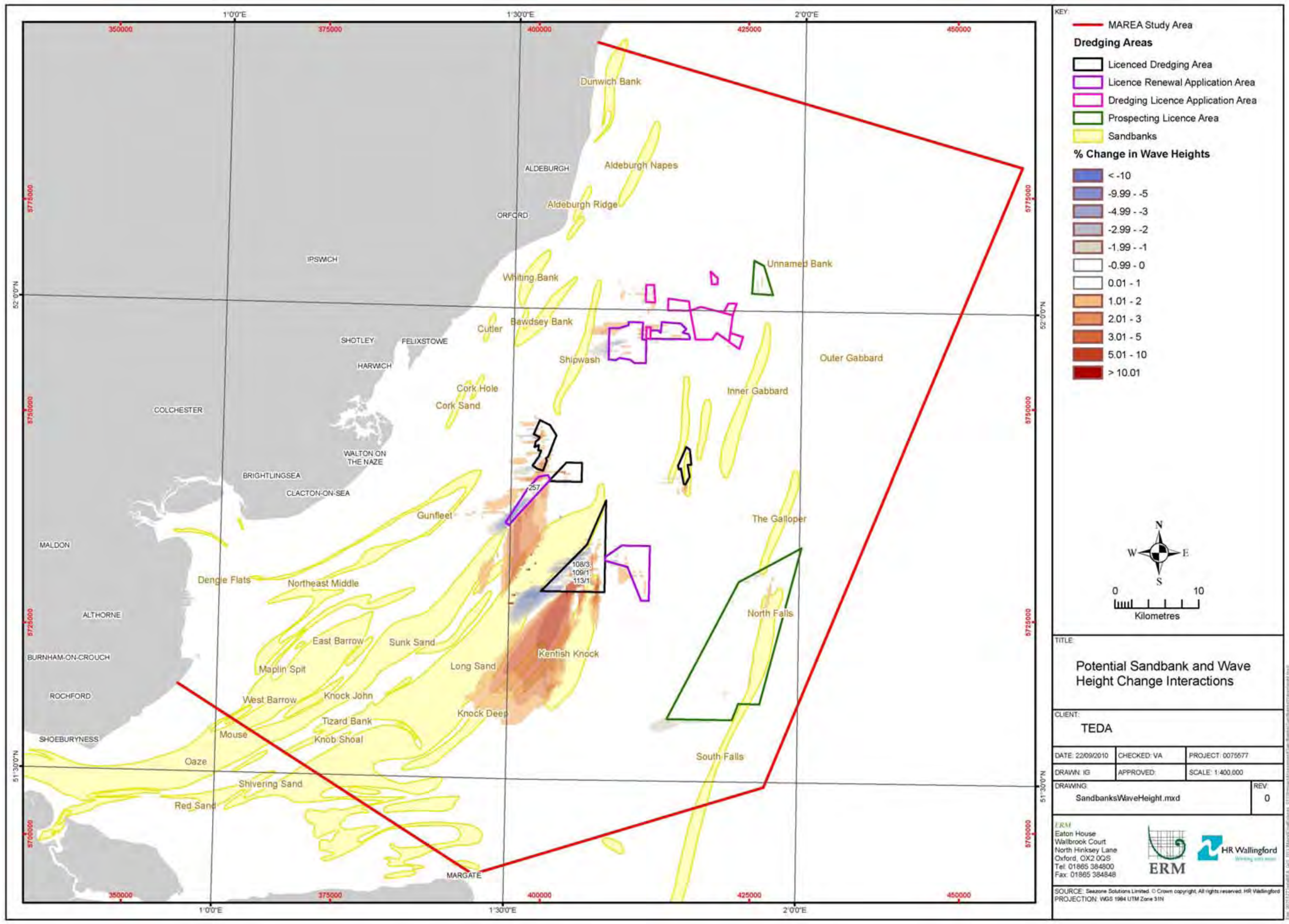
A more than 5% change to a 5% exceedance in wave height scenario is a **small magnitude** effect. This is because of the isolated extent of the effect (site-specific) and its infrequent occurrence (occasional), however, the duration is long-term and the change relative to the baseline is medium.

A change of between 2-5% to a 5% exceedance in wave height scenario is a **small to medium magnitude** effect. This is because of the localised extent of the effect (local), its infrequent occurrence (occasional), and low level change relative to the baseline, however, the duration is long-term.

It has been determined that the 30° N incident 200 year wave condition at MLWS has the greatest percent change in wave height due to dredging. Figure 8.4 shows which sandbanks may interact with changes in wave height for a 1 in 200 year wave condition under these conditions and shows that there are potential changes in wave heights over the various sandbanks in the estuary.

As shown in Figure 8.4 only a very small proportion of sandbanks may interact with wave height changes of more than 5% in a scenario of 30°N incident 200 year wave conditions at MLWS.

Figure 8.4 Potential Sandbank and Wave Height Change Interactions



The waves around Area 257 and Long Sand Head (Area 108/3, 109/1, 113/1) show changes of over 10% up to 7 km beyond the boundary of the extraction area and changes of 2% twice this distance away from the southern edge of Long Sand Head. It is unlikely, however, that such changes in wave heights would be detectable in reality except very close to the licence areas themselves (HR Wallingford, 2009). Wave height changes of 2-5% will affect a larger area of sandbanks, however, this still remains a small proportion of all sandbanks (Figure 8.4).

Changes to the 5% exceedance wave condition (ie a wave height that will be exceeded 5% of the time in one year) have a much smaller footprint and do not substantially change beyond the boundary of each licence area, and thus there is very little overlap with any sandbanks. These are therefore not considered further. In addition scenarios with waves coming from a different direction are likely to have an even smaller footprint (see Section 7.4.1).

Overall it is considered that only a **small degree of interaction** between sandbanks and changes in wave height may occur with the sandbanks in their current location. In addition, the modelling assumes that dredging occurs continuously throughout the licence areas up to their boundaries. In reality, whilst dredging activity may occur at the edge of the licence areas at times, it will generally be focused in one particular zone.

As the potential effects of the predicted wave height changes on the sandbanks would be comparatively small compared to the alteration of the sandbanks by natural processes, it is unlikely any impacts would be seen at a regional scale. In addition, sandbanks to the south west of licence areas are likely to receive smaller waves as a result of dredging due to frictional effects and breaking over the banks, which may reduce sediment transport away from the sandbank. Sandbank **adaptability** is therefore assessed as **high**. At the regional level sandbanks are expected to be unaffected therefore they are assessed as having **high tolerance** to wave height changes. As discussed above, **recoverability** of sandbanks is **not applicable** and the **value** of sandbanks is rated as **low**. Taking into consideration tolerance, adaptability and value, the **sensitivity** of the sandbanks to changes in wave height is **low**.

Overall based on the small-medium magnitude of the impact, low value and sensitivity of the receptor and small degree of regional interaction, the significance of the sandbanks to changes in extreme wave height is ***minor***, however, for more frequently occurring wave conditions the impact is likely to be less and is rated as ***not significant***.

Changes to Tidal Currents

Tidal currents may impact the physical structure of sandbanks by altering the sediment transport rates to and from sandbanks. These interactions are considered below in the section concerning how changes in sediment transport rate may affect sandbanks.

Changes to Sediment Transport Rates

This section considers the physical presence and structure of sandbanks with respect to changes in sediment transport rate (bed load and suspended load) based on predicted sediment transport rate changes due to bathymetric change as a result of dredging. Details of the modelling procedure and a discussion on the modelling have been presented in Chapter 7. Sediment transport is a major factor in sandbank formation, growth and maintenance and is strongly linked to tidal flows. Alterations to sediment transport to the sandbanks due to past and planned dredging in the MAREA area have the potential to impact sandbanks, as shown in Figure 8.5.

Changes to sediment transport rates are restricted to within or to quite small areas close to the boundaries of the individual extraction areas. Where interactions do occur only small changes in sediment transport (100 to 400 kg/m/tide) affect very limited areas of the sandbanks. This effect is therefore localised and long term in duration. The change relative to existing sediment transport rates is low and the effect is considered a routine occurrence. The overall **magnitude** of changes in sediment transport on sandbanks is therefore considered **medium**.

A small proportion of Kentish Knock may be affected by a small reduction in sediment transport inside the licence area. However, as only very small proportions of the sandbanks may be affected and the sandbanks themselves are highly dynamic, it is unlikely any changes will be seen at the regional level therefore sandbank **tolerance** to predicted changes in sediment transport is assessed as **high**. Similarly **adaptability** is assessed as **high** as detectable changes to sandbanks are unlikely at the regional scale. As discussed above, **recoverability** of sandbanks is **not applicable** and the **value** of sandbanks is rated as **low**. Taking into consideration tolerance, adaptability and value, the **sensitivity** of the sandbanks to changes in sediment transport is **low**. In addition it should be noted than an increased rate of sediment transport may simply mean that sediment is cycled around the bank at a greater rate than previously, and is unlikely to result in the destabilisation or loss of sand from sandbanks.

As stated above, the **degree of interaction** between sandbanks and changes in sediment transport rate is **small** as changes to sediment transport rate are generally within the licence area boundaries, and in places where interactions may occur, changes in sediment transport are small (up to 400 kg/m/tide) (Figure 8.5). In addition, the modelling assumes that dredging occurs continuously throughout the dredging areas up to the licence area boundary. In reality, whilst dredging activity may occur at the edge of the licence areas at times, it will generally be focused in one particular zone. Only a low number of sandbanks will be potentially affected by changes in sediment transport and the proportion of those sandbanks affected is smaller still (see Figure 8.5). Overall based on the medium magnitude of the impact, low value and sensitivity of the receptor and small degree of regional interaction, the significance of the impacts on sandbanks due to changes sediment transport is ***not significant.***

8.2.4 Summary of Impacts

Cumulative effects of dredging on sandbanks may occur in two ways. The first way is by two dredging areas in close proximity to each other creating a potential for the effects to overlap and impact the same area of sandbank. However, the modelling studies, as presented above, show that dredging in any two licence areas will not impact the same area of a sandbank. The second way is that multiple effects (ie two or more from: sand deposition, changes to sediment particle size, changes to wave height and changes to sediment transport rates) may occur over the same area of sandbank. However, the modelling studies show that outside the licence areas cumulative effects may only be seen up to 7 km from the licence area boundary (the extent of D'Olier's geophysical interpretation) but generally within 4 km (the extent of the modelling of sediment particle size changes), which has the potential to only effect a very small proportion of sandbanks. Table 8.2 summarises the significance of the cumulative impacts of dredging on sandbanks as physical structures at the regional scale.

Table 8.2 Regional Significance of Impacts to Sandbanks from Dredging in the Outer Thames

Effect of Dredging	**Sandbanks as physical structures**	
Removal of Sediment	*Not significant*	
Sand deposition	*Not significant*	
Changes to sediment particle size	*Not significant*	
Changes to wave height	*Regularly occurring wave conditions – not significant*	*Extreme wave conditions - minor*
Changes to tidal currents	*See changes in sediment transport rate*	
Changes to sediment transport rates	*Minor*	
Overall significance of dredging	*Minor*	

Impacts to sandbanks from the effects of changes to wave heights and changes to sediment transport rates associated with dredging are predicted to be ***minor***.

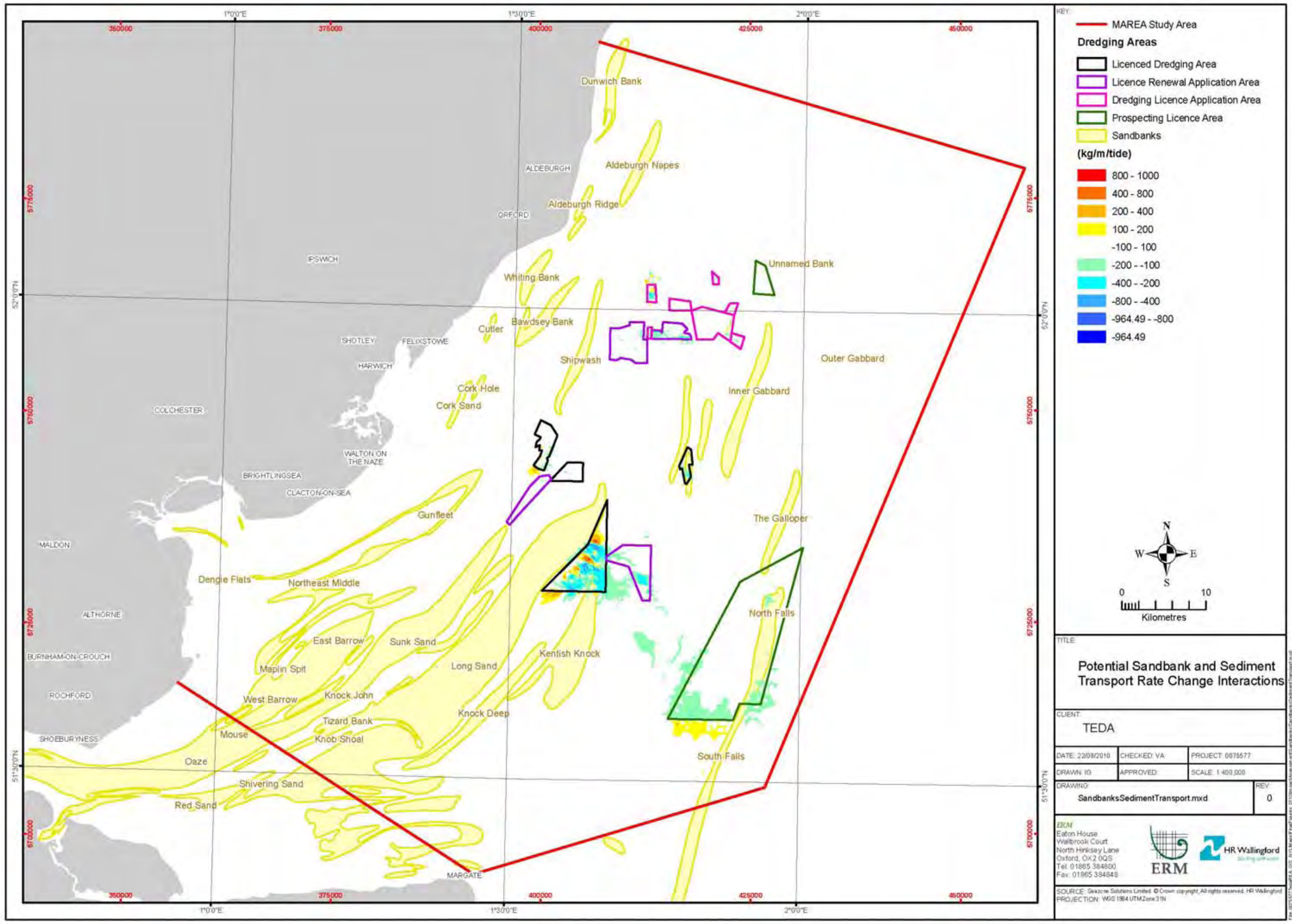
The following licence areas will need to refer to the wave height modelling work that has already been undertaken for the MAREA and report this on a site-specific basis:

- **Area 108/1** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the Long Sand sandbank at the EIA stage.

- **Long Sand Head licence area (Area 108/3, 109/1, 113/1)** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the Long Sand and Kentish Knock sandbanks at the EIA stage.

- **Area 119/3** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the sandbank within the licence area itself and the sandbanks to the north of the area.

Figure 8.5 Potential Sandbank and Sediment Transport Rate Change Interactions



8.3 IMPACTS TO THE COASTLINE

8.3.1 Introduction

Within the context of the present assessment, the coastline refers to the shore and foreshore environment from mean low water spring to mean high water spring. The coastline not only provides a variety of habitats for a diverse range of organisms but it also can act as a natural flood defence and a local amenity. The coastline of the study area gradually shifts in position and morphology due to the collective action of waves, tidal currents and sediment transport. Any changes to these processes have the potential to impact this dynamic equilibrium and therefore shift the relative position of the coastline over longer timescales, possibly at the expense of valuable land or intertidal habitat.

For the purpose of this impact assessment the impacts considered refer to the physical processes that naturally affect the dynamic equilibrium of the coastline, and not its role in providing intertidal habitats or for coastal defence. As a result, the value of the coastline is rated as low. If impacts are perceived to be of an order of magnitude that suggests habitats or coastal defence may be compromised, then this will be subject to further assessment.

8.3.2 Identification of Potential Impacts to the Coastline

Table 8.13 shows the predicted effects of dredging with reference to whether or not they have the potential to impact the coastline. Only impacts that have the potential to affect the physical structure of the coastline are considered.

Table 8.3 Matrix of Potential Impacts of Dredging on the Coastline

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Coastline as a physical structure	■	■	■	×	×	×	×	×	■	■	■	■	

■	Not affected
×	No interaction
✓	Potential interaction

As shown in Table 8.13 all of the physical effects of dredging that have the potential to impact the coastline do not interact with the coastline. This is based on several studies that are summarised in Chapter 7. A brief explanation of why these impacts have been assessed as having no interaction with the coastline is presented below:

- Sand deposition – occurs within the licence areas and can change bedforms up to 2.5 km from the licence area boundary; this does not reach the coast (see Figure 7.9 and Figure 7.10).

- Changes to sediment particle size – studies have shown up to a 4 km footprint around the licence area may be affected; this does not reach the coast (see Figure 7.9 and Figure 7.10).

- Changes to wave height – modelling has shown that changes to wave height at MHWS of greater than 2% only extend up to 10 km from licence areas and there are no predicted changes to wave height at the coast (see Figure 7.13 and Figure 7.15).

- Changes to tidal currents –modelling has shown that any predicted change to tidal currents does not occur within 8 km from the coastline; moreover the reported change only corresponds to a small reduction of up to 5% in tidal currents over a very small area. There are no predicted changes to tidal currents at the coast (see Figure 7.17 and Figure 7.18).

- Changes to sediment transport rate –modelling has shown that changes to sediment transport rates are predominantly within licence areas and there are no predicted changes to sediment transport rate at the coast.

- Changes to sandbanks – the sandbank impact assessment (Section 8.2) has assessed changes to sandbanks as having minor significance; with resulting indirect changes to wave height, tidal currents and sediment transport rate being of insufficient magnitude to impact the coastline.

As no impacts to the coastline are predicted from the supporting studies, even using maximum dredging tonnages and footprints, further investigations into the potential impacts on coastal habitats or coastal defences are not required.

8.4 IMPACTS TO WATER QUALITY

8.4.1 Introduction

The water quality in the Outer Thames Estuary, which has previously been discussed in Section 4.5, may be subject to impacts from dredging activities. Suspended sediment, nutrient and dissolved oxygen levels are indicators of water quality. Elevated metal and hydrocarbon concentrations can have an impact. Water quality is important on both local and regional scales; as well as directly affecting marine organisms, water quality changes in the Thames Estuary have been shown to affect the distribution of fish populations, which in turn impact other species in the wider region such as birds and marine mammals. Due to the relatively small volume of water being affected by dredging operations at any one time compared with the whole MAREA area, the offshore location of the licence areas and the fact that the water within the licence areas is not covered by the Bathing Waters Directive or Shellfish Waters Directive, the **value** of water quality is **low.**

8.4.2 Identification of Potential Impacts to Water Quality

Table 8.4 presents the predicted effects of dredging with reference to whether or not they have the potential to impact water quality.

Table 8.4 Matrix of Potential Impacts of Dredging on Water Quality

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Water Quality			✓			✓	✓						

.	Not affected
×	No interaction
✓	Potential interaction

8.4.3 Water Quality

Fine Sediment Plume

The fine sediment plume has the potential to impact water quality by:

- increasing turbidity (the amount of suspended sediment in the water column); and
- releasing nutrients, organic material and contaminants (e.g. metals and hydrocarbons).

Increased turbidity can result in changes in fish distribution and community composition as well as reducing light penetration, which affects primary production. A change in nutrient concentration could either improve or reduce water quality depending on the quantity of nutrients released; a relatively small increase in nutrients could boost primary production, while a large increase in nutrients and organic matter has the potential to reduce oxygen concentrations. Metals and hydrocarbons released from the sediment and associated porewater can reduce water quality, which may potentially impact on marine organisms.

Although the fine sediment plume may potentially result in increased turbidity and release of nutrients, metals and hydrocarbons to the water column, impacts to water quality are first assessed by the individual factors that affect water quality leading to an overall impact assessment of the fine sediment plume.

Increased Turbidity

The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

At the regional scale, water quality has a **high** level of **tolerance** to increased turbidity. Any one dredger will produce a plume covering a small proportion (0.02%) of the MAREA area, and a far smaller area still (0.0009%) will have a plume concentration of above 100 mg l^{-1} above background levels primarily as a result of overflow and screening. As a result, for the majority of time over the licensing period at any given point in the study region there will be no increase in suspended sediment concentration above background levels. The water column is assessed as having **high adaptability** to turbidity as the Outer Thames Estuary is regularly subjected to natural turbidity increases of a few tens of mg l^{-1} above background concentrations as a result of river run off, tidal currents and waves, particularly during and following frequent storm events. Water quality **recoverability** is assessed as **high** as turbidity increases will only be experienced while dredging occurs or up to the extent of one tidal cycle and only in the streamline of the dredger. As discussed above, the **value** of water quality is **low.** Taking into consideration tolerance, adaptability, recoverability and value, the **sensitivity** of the water column to increased turbidity is **low**.

Increased turbidity will occur inside the licence areas and increases of 20 mg l^{-1} above background levels are likely to be experienced within 1 km of the licence area boundary. However this assumes dredging occurs continuously throughout the dredging areas up to the licence area boundary when in reality, dredging will generally be focused in one particular zone and in most cases be carried out by one vessel. Therefore at any given time the 20 mg l^{-1}l above background plumes associated with dredging will cover a small area, and concentration increases of over 100 mg l^{-1} above background associated with the plumes will cover a smaller area still. The **degree of interaction** between water quality and the elevated turbidity associated with the sediment plume is therefore considered to be **small**.

Cumulative effects of the fine sediment plume may occur in two ways, either by plumes from dredgers in two adjacent areas interacting and coalescing to form one larger plume, or by a dredger operating in the plume of another dredger from a different area.

For plumes that meet and coalesce, the physical laws of dispersion theory mean concentrations within the plumes are not additive, but instead create a larger plume with similar concentrations to those of the separate plumes. Peak concentrations of suspended sediment within each plume will therefore not be exceeded, but will be experienced slightly more frequently in these areas over the lifetime of the licensing period.

For plumes created by a dredger operating in the plume of (ie in the streamline of) another dredger, the two plumes in this case would be additive. However for this cumulative effect to be significant it would require two dredgers (in different licence areas) dredging in each other's streamline within 200 m or so of each other. As this is unlikely to occur there is little potential for significant cumulative effects resulting from plume interaction between licence areas.

Based on these assessments of the small-medium magnitude of the effect, the low value and sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of increased turbidity on water quality is assessed to be ***not significant*** at the regional scale.

Nutrients, Organic Matter, Metals and Hydrocarbons

Organic material, which generally has high levels of nutrients, is commonly associated with very fine sediments (mud and silt). The proportion of silt in the material dredged in the MAREA area is typically in the range of 0-5% (see Section 7.3.3). Sediment samples taken from within the licence areas show a low proportion of organic matter of less than 3% (see Appendix J). Therefore it is likely that only low levels of nutrients may be released during dredging.

Fine sediments are also often associated with a risk of increased contamination due to their relatively large surface area for the contaminants to bind to. The low proportion of silt in the Outer Thames Estuary indicates that only a low level of contamination may exist. Samples taken from three inshore estuaries in the MAREA area generally show metal concentrations to be below the Canadian Probable Effect Level (PEL) which, as described in the baseline chapter (Chapter 4), have been used as the most appropriate guidelines as the UK does not currently have sediment quality guidelines. Where they do exceed the PEL (copper, mercury, zinc), it is only in a single estuary for a single year. It is likely that the concentrations of these metals will be reduced within the licence areas given their further distance from the estuaries and source of pollutants. Even in highly contaminated areas it has been concluded that the release of dissolved metals (the bioavailable metals) due to dredging is minimal, even though release of total metals (not available to organisms) may be relatively high (EVS, 1997), (Miller, 2000) and (Van den Berg, 2001).

Hydrocarbon concentrations have been found to be lower offshore than near the estuaries, where major sources of hydrocarbons exist. Although hydrocarbon concentrations at the Medway Estuary have increased in recent years, offshore concentrations remain low. Low levels of contaminants combined with high settling rates that are likely to limit the amount of desorption from the sediment during resuspension indicate that only small quantities of contaminants may be released during dredging.

Released nutrients, metals and hydrocarbons as a result of dredging may temporarily affect local water quality. It is a frequently occurring (routine) effect that produces only a low change relative to the baseline (as discussed). The overall **magnitude** of released nutrients, metals and hydrocarbons is therefore assessed as **small**.

Water quality has a **high** level of **tolerance** at the regional scale as changes in water quality are not likely to be observed at this level due to the small predicted quantities of nutrients, metals and hydrocarbons that may be released during dredging activity. The water quality is assessed as having **high adaptability** to the release of nutrients, metals and hydrocarbons as the Outer Thames Estuary is regularly subject to natural resuspension and the release of nutrients, metals and hydrocarbons as a result of variation in tidal conditions and waves. Water quality **recoverability** is assessed as **high** due to the strong tidal currents in the area having a mixing/diluting effect on the water column. Therefore it is likely that any increased concentrations of nutrients and contaminants will be of short duration. As discussed in Section 8.4.1 above, the **value** of water quality is **low**. Considering the tolerance, adaptability, recoverability and value of water quality, its **sensitivity** to increased levels of nutrients, metals and hydrocarbons is **low**.

As the concentrations of released nutrients, metals and hydrocarbons due to dredging activities are not known it is not possible to predict the geographical extent of raised concentrations in and around the licence areas. However, it can be reasonably assumed that the largest increases in concentrations will be experienced within the plume itself, which can extend to 1 km around the licence area boundary at suspended sediment concentrations of 20 mg l^{-1}. It can also be reasonably assumed that initial nutrient and contaminant concentration increases will be largely reduced at 1 km from the licence area due to mixing. As the plume only covers a very small area at any one point in time (see previous section), nutrient and contaminant concentrations will also only affect a small area at any one time. The **degree of interaction** between water quality and the release of nutrients, metals and hydrocarbons associated with the sediment plume is therefore considered to be **small**.

As discussed above with respect to elevated turbidity, it is also unlikely that significant cumulative effects associated with increased concentrations of nutrients, metals and hydrocarbons resulting from plume interaction between licence areas, will occur.

Based on the assumptions of the small magnitude of the effect, the low value and sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of increased nutrient, metal and hydrocarbon concentration on water quality is assessed to be ***not significant*** at the regional scale.

Taking into consideration the separate impacts of increased turbidity and increased nutrient, metal and hydrocarbon concentrations on water quality, the overall cumulative impact of the fine sediment plume on water quality is assessed as ***not significant***.

Changes to Wave Heights

Increased wave height may affect water quality in the same ways as described above for the fine sediment plume; increased wave height may result in sediment resuspension, which increases turbidity and releases nutrients, metals and hydrocarbons stored in the sediment. Changes in wave height are unlikely to produce greater effects than the fine sediment plume from dredging, due to the much smaller quantity of sediment that can be resuspended by waves compared to the quantity of material discharged from the dredging vessel. This indicates that the impact of changes to wave height on water quality will be less than the impact of the sediment plume; therefore the impact of changes in wave height on water quality is also assessed as ***not significant***.

Changes to Tidal Currents

Changes in tidal currents, particularly increases in speed, may affect water quality in the same ways as described above for the fine sediment plume. Changes in tidal currents are unlikely to produce greater effects than the fine sediment plume from dredging due to the much smaller quantity of sediment that can be resuspended by tidal currents compared to the quantity of material discharged from the dredging vessel. This indicates that the impact of changes to tidal currents on water quality will be less than the impact of the sediment plume; therefore the impact of changes in tidal currents on water quality is also assessed as ***not significant***.

8.4.4 Summary of Impacts

Table 8.5 summarises the significance of the cumulative impacts of dredging on water quality at the regional scale.

Table 8.5 Regional Significance of Impacts to Water Quality from Dredging in the Outer Thames

Effect of Dredging	Water Quality
Fine sediment plume/elevated turbidity	*Not Significant*
Changes to wave height	*Not Significant*
Changes to tidal currents	*Not Significant*
Overall significance of dredging	*Not Significant*

Impacts to water quality from dredging are predicted to be not significant. No action is required to study the potential impacts further at the licence specific EIA stage other than describing the mitigation measure that contribute to normal good working practice.

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9 THE BIOLOGICAL ENVIRONMENT – ASSESSMENT OF REGIONAL IMPACTS

9.1 INTRODUCTION

This section describes the potential regional impacts on the offshore biological environment as a result of future marine aggregate extraction activities in the Outer Thames Estuary.

The topics covered in this section include:

- impacts to benthic ecology (Section 9.2);
- impacts to fish ecology (Section 9.3);
- impacts to marine mammals (Section 9.4);and
- impacts to designated sites (Section 9.5).

In all cases, the potential impacts as a result of the effects of dredging discussion in Chapter 7 are considered.

9.2 IMPACTS TO BENTHIC ECOLOGY

9.2.1 Introduction

The Outer Thames Estuary has highly varied and patchy sediments which support a range of benthic communities. These communities are subject to naturally high turbidity levels as a result of the strong tidal currents and wave action in the area (see Section 4.4). The majority of benthic communities within the study area are therefore adapted to high turbidity levels and strong wave action, particularly in the shallower regions of the study area. The communities are also adapted to a high level of anthropogenic activity (see Section 6.3) in addition to this natural variability.

The following groups are discussed when considering the potential impacts to benthic ecology as a result of marine aggregate extraction:

- 9.1.2 Benthic Species and Communities;
- 9.1.3 Biotopes;
- 9.1.4 Rare and/or Protected Species; and
- 9.1.5 Commercial Species.

It is important to consider the value of each species when discussing the significance of potential impacts to receptors. Overall benthic communities are a major link in the food chain and provide an important ecosystem function. The filter feeders remove sediments and organic water from the water column, effectively cleaning the water in the process. Organic matter that is not used within the water column is deposited on the seabed and remineralised by the deposit feeders into nutrients which are put back into the water column. This is particularly important for maintaining the high primary production rates of estuaries and coastal waters. Overall benthic species and communities are therefore assigned a **medium-high value** due to their role in the ecosystem.

Biotopes are assigned a **medium-high value** as a result of their ecological importance as outlined in Table 5.3 in Section 5.2.

Rare and/or protected species are assigned a **high value** due to their rarity and/or conservation status.

Commercial species hare assigned a **high value** due to their importance as a source of income for the commercial shellfish fishing industry within the region.

9.2.2 Benthic Species and Communities

The benthic communities within the Outer Thames Estuary were found to be highly patchy and variable in their distribution and abundance (see Section 5.2). This heterogeneity reflects the variable and mobile or frequently disturbed nature of the sediment (see Section 4.3). This variability is experienced temporally as well as spatially throughout the study area.

Generally, statistical testing of survey data has shown that there is no significant difference between licence areas that have been dredged historically, their plume footprints, and reference sites (see Section 5.2.3). The one exception to this is the ANOVA test which recorded a significant difference between sites in relation to mud content. Reference group sites contained more muddy stations, where as sites within the licence areas recorded higher sand and gravel content. This is to be expected as gravel is the targeted resource for marine aggregate extraction activities.

Overall this indicates that at the regional scale, differences in species compositions between the dredged and un-dredged areas are not apparent. This is likely to be due to the high natural variability of sediment types across the region and the fact that other sources of disturbance (natural or anthropogenic) can affect sites within any of the groups. These regional findings do not imply that it would not be possible to detect differences between the licence areas, plume footprint and surrounding areas at the site-specific level, but that significant differences are not apparent at the regional scale of the MAREA survey. That said, differences may be detectable at the licence-area site-specific scale.

It is therefore concluded that future dredging is also unlikely to result in any significant differences in benthic species compositions between dredged and un-dredged areas at a regional scale. The effects of dredging on benthic species and communities are therefore assessed to be ***not significant*** at the regional scale.

9.2.3 Biotopes

As described in the baseline (Section 5.2), it was not possible to produce a biotope map at the regional level as the Outer Thames Estuary proved to have very patchy distribution of biotopes. Figure 5.9 shows the spot points where different biotope complexes were found. This assessment has therefore taken the precautionary approach of assuming that all of the biotopes could be affected by the impacts of marine aggregates extraction.

The term 'biotope' refers to the combination of the physical environment (habitat) and its distinctive assemblage of conspicuous species. As discussed above, the sedimentary habitats and their associated benthic species within the study area are highly dynamic and the composition of the benthic communities alters naturally through time.

Marine aggregates extraction has been carried out within the Thames Estuary for over 40 years (see Industry Statement). Historically, no significant differences in benthic community composition have been found between areas that have been subject to the influences of dredging and un-dredged sites.

It is therefore concluded that future dredging is also unlikely to result in any significant differences, and thus the effects of dredging on biotopes is assessed as ***not significant*** at the regional scale. Again it should be noted that differences may be detectable at the licence-area site-specific scale.

9.2.4 Rare and/or Protected Species

Identification of Potential Impacts on Rare and/or Protected Species

Table 9.1 shows which of the predicted effects of dredging has the potential to impact sensitive species.

Table 9.1 Matrix of Potential Impacts of Dredging on Rare and/or Protected Species

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to sandbanks
Sabellaria spinulosa	▪	✓	▪	✓	✓	▪	✓	✓	▪	▪	▪		▪
Leptocheirus hirsutimanus	▪	✓	✓	✓	✓	▪	✓	✓	▪	▪	▪	▪	
Modiolus modiolus	▪	✓	✓	✓	✓	▪	✓	✓	▪	▪		▪	▪
Barnea candida	▪	✓		▪	✓	▪	✓	✓	▪	▪		▪	▪
Ostrea edulis	▪	×	×	×	×	▪	×	×	▪	▪	▪	▪	
Echinus esculentus	▪	×	×	×	▪	▪	×		▪	▪		▪	▪

▪	Not affected
×	No Interaction
✓	Potential Interaction

For each dredging effect, the sensitivity of the receptor to the effect has been determined. As described in Chapter 3, the overall sensitivity of each species or biotope is determined based on the tolerance, adaptability and recoverability of the receptor to the effect. A range of useful information is available for the benthic environment on the MarLIN website [1]. MarLIN, the Marine Life Information Network, is an initiative of the Marine Biological Association of the UK. The site provides quality assured information on many species and biotopes present around the coasts of Britain and Ireland. The species and biotopes that have been assessed for sensitivity to various effects by MarLIN were used for this assessment. For species or biotopes that have not been assessed by MarLIN, a comparison was made to species or biotopes which were functionally similar and the sensitivity of the receptor in this assessment was inferred based on this comparison.

Most of the sensitive species that are assessed in this chapter are rare. With the exception of *Sabellaria spinulosa*, only small numbers of individuals of these rare species were recorded during the MAREA, REC and previous EIA surveys. This means that the areas in which these species may be found cannot be accurately determined. The remainder of this section provides information on the known distribution of each of these species.

The distribution of the Ross worm, *Sabellaria spinulosa,* within the Outer Thames region is widespread and does not show any obvious pattern. Individual worms have been found in many of the licence areas and so this species is likely to have a high recoverability in relation to the effects of dredging.

The distribution of the burrowing amphipod, *Leptocheirus hirsutimanus,* is unknown. A total of 12 individuals were found across eight MAREA grab stations and 11 individuals were recorded at two REC grab stations. There is insufficient information on the distribution of this species at the regional level to conduct a meaningful impact assessment. However, a scientific study on the impacts of dredging on benthos found that *L. hirsutimanus* was found within and in the vicinity of aggregate extraction sites, and was in fact more abundant in the vicinity of active trailer dredging (Boyd *et al*, 2003). The authors postulate that it may be responding positively to some feature of the disturbance associated with extraction activity. As a result, impacts to this species are not assessed further.

The distribution of the horse mussel, *Modiolus modiolus*, within the Outer Thames region is unknown. However, *M. modiolus* can be found from the lower shoreline to approximately 280 m depth on soft or coarse substrates or attached to hard substrata. A total of three individuals were recorded at three MAREA grabs stations and three were recorded at two REC grab stations. *M. modiolus* beds are a candidate nationally important marine feature and populations are scarce but not in decline. Extensive horse mussel beds are most common on the northern or western coasts of the UK, but are absent south of the Severn and Humber estuaries (Tyler-Walters, 2008). A small number of single scattered individuals are more likely to be found within the Outer Thames Estuary. As a result this species is not assessed any further.

The three largest landings of the white piddock, *Barnea candida*, were in the central areas of the region from one REC grab sample and two MAREA trawls. A small number of piddocks were recorded in a REC grab to the north of North Falls. Some of the piddocks recorded were within the zones of dredging effects (close to Areas 118/2 and 452A).

Only one individual oyster, *Ostrea edulis*, was recorded at a MAREA grab station. No oysters were recorded during the REC survey. There is therefore insufficient information from the surveys on the distribution of this species throughout the MAREA study area. However, this species is also of commercial importance and is targeted by an inshore fishery within the Thames Estuary. It is assumed that the highest distribution of oysters will be located within the area that the fishery targets. The potential impacts to oysters in the context of where the oyster fishery operates are covered under Section 9.2.5 below.

A total of four edible sea urchins, *Echinus esculentus*, were recorded during two MAREA trawls and three individuals during one REC trawl. There is also insufficient information on this species at the regional level. However *E. esculentus* is normally found on rocky substrate from the shoreline to approximately 40 m depth (but it can be found in water depths greater than 100 m). This type of substrate is not targeted by the marine aggregate extraction industry, therefore there is unlikely to be any significant interaction between this species and the effects of dredging, and as a result impacts to this species are not considered further.

The impact assessment for rare and/or protected species therefore focuses on two species: *Sabellaria spinulosa* and *Barnea candida*.

Removal of Sediment

Dredging typically occurs in 2-3 metre wide 'strips' within lanes or 'Active Dredge Zones' that are up to 200m wide. Species that are removed from the dredging strips are expected to recolonise the area once dredging activities have ceased following recruitment from nearby undisturbed areas. Removal of sediment is assessed to be of **medium magnitude** as the effect is long term, routine and is a medium level change relative to the baseline but is site specific.

S. spinulosa is fixed to the substrate therefore direct sediment removal in areas where this species is present will result in mortality. It has a **low tolerance** to sediment removal, and is unable to avoid the effect so has a **low adaptability** to sediment removal. However, its **recoverability** is assessed as **high**, which is demonstrated by its presence within areas previously subject to dredging. Based on the consideration of tolerance, adaptability and recoverability it is therefore assessed as having **medium sensitivity** to the effects of sediment removal.

S. spinulosa has been found in patches throughout the region and the **degree of interaction** between the whole population and this effect is **small**.

Based on these assessments of the medium magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of sediment removal on *S. spinulosa* is assessed to be of ***moderate significance*** at the regional level.

B. candida is a rock-boring species and sediment removal will also result in mortality for this species. It has a **low tolerance**, **low adaptability** and **low recoverability** to this effect. As a result, this species is considered to have a **high sensitivity** to the effects of sediment removal.

However, it worth noting that *B. candida* bores into hard substrates, peat and wood which are not likely to occur in areas targeted by the dredging industry. The **degree of interaction** between the effects of sediment removal with the distribution of this species is therefore likely to be **small**.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of sediment removal on *B. candida* is assessed to be of ***moderate significance*** at the regional level.

Sand Deposition

Sediment particles that have been suspended in a plume during dredging activities will eventually settle out and have the potential to smother sessile benthic organisms. They can be partially smothered causing increased survival effort or completely smothered resulting in death. Sand deposition is assessed to be of **small magnitude** as the effect is localised, routine in terms of frequency of occurrence, short-term in duration and constitutes a low level change relative to the baseline.

S. spinulosa can tolerate smothering by sediment for up to several weeks (Angus *et al*, 2008). This is demonstrated by its presence within the Outer Thames Estuary, which is a highly turbid area. It is postulated that dredging will result in a sand sheet approximately 10-25 cm thick in the areas adjacent to the licence areas along the tidal axis (see Section 7.3.3 for details). *S. spinulosa* is expected to have a **low sensitivity** to this level of smothering

(1) http://www.marlin.ac.uk/

as it has **high tolerance** and **high recoverability** to the effect, although it cannot avoid it and thus has a **low adaptability**.

S. spinulosa has been found in patches throughout the region and the **degree of interaction** between the whole population and this effect is **small**.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of sand deposition on *S. spinulosa* is assessed to be *not significant* at the regional level.

There is no impact to *B. candida* as a result of sand deposition from dredging as it can use a feeding siphon to maintain contact with the surface and is capable of extending the siphon through loose material.

Tidal Currents, Changes to Sediment Particle Size and Changes to Sediment Transport Rates

Both *S. spinulosa* and *B. candida* are suspension feeders that actively sort particles for particular grain sizes. These organisms may be adversely affected by changes in sediment particle size and sediment transport rates as a result of dredging activities.

Modelling for this MAREA has shown that tidal flows are expected to increase in the northeast and southwest margins of the licence areas whereas in the north-west and south-east areas flows will be commonly reduced (Section 7.4.2). An increase in tidal flow has the potential to locally transport fine sand and potentially alter the grade of the sediment. The change in sediment particle size is local, short-term in duration, routine and is a low level change relative to the baseline and has therefore been assessed to be of **small magnitude** as previously described in Chapter 7.

S. spinulosa requires particles of a certain size to build its tubes (usually sand or shell fragments). If the particle sizes change to become unfavourable for tube building it will put a strain on survival of the worm. *S. spinulosa* has a **medium tolerance**, **low adaptability** and **high recoverability** to changes in particle size whereas *B. candida* has a **high tolerance**, **low adaptability** and **high recoverability**. *S. spinulosa* therefore has a **medium sensitivity** to changes in particle size whereas the burrowing white piddock *B. candida* is assessed as having **low sensitivity**.

As described above, the **degree of interaction** between *S. spinulosa* and the effects of dredging is small at the regional level.

Based on these assessments of the small magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of changes to sediment particle size on *S. spinulosa* is assessed to be of ***minor significance*** at the regional level.

Large numbers of *B. candida* were only found in the centre of the study area near Area 452A, Area 118/2 and north of Area 108/1. The potential level of interaction between this species and the effect is therefore small.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of changes to sediment particle size on *B. candida* is assessed to be ***not significant*** at the regional level.

Changes in tidal flow will also affect sediment transport rates which determine the amount of food available in the water column for suspension feeders such as *S. spinulosa* and *B. candida*. If tidal flow increases greatly, the larger grain sizes that *S. spinulosa* commonly inhabits could become mobile resulting in scour and mortality of individuals, however this scale of tidal flow increase is not expected to occur.

A change in sediment transport rates of 100-400 kg/m/tide has a **medium magnitude** as it is local, long term, routine and is a low level change relative to the baseline. A change in sediment transport rates of 400-1,000 kg/m/tide has a **medium magnitude** as it is site specific, long term, routine and is a medium level change relative to the baseline.

Changes in sediment transport rates affect a very small number of individuals and recovery is expected to occur within a year once conditions return to normal. *S. spinulosa* has a **medium tolerance**, **low adaptability** and **high recoverability** to changes in particle size whereas *B. candida* has a **high tolerance**, **low adaptability** and **high recoverability**. *S. spinulosa* therefore has a higher sensitivity (**medium**) to changes in sediment transport rates than *B. candida* (**low**).

The interaction between both *S. spinulosa* and *B. candida* and this effect of dredging is small at the regional scale.

Based on these assessments of the small magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of changes to sediment transport rate on *S. spinulosa* is assessed to be of ***minor significance*** at the regional level.

Based on these assessments of the medium magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of changes to sediment transport rate on *B. candida* is assessed to be ***not significant*** at the regional level.

9.2.5 Commercial Species

Identification of Potential Impacts on Commercial Benthic Species

Table 9.2 shows how the predicted effects of dredging have the potential to impact commercial species.

Table 9.2 Matrix of Potential Impacts of Dredging on Commercial Benthic Species

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to sandbanks
Ostrea edulis	■	×	×	×	×	■	×	×	■	■	■	■	■
Crangon crangon	■	✓	■	■	■	■	■	■	■	■	■	■	■
Cancer pagurus	■	■	■	✓	■	■	■	■	■	■	■	■	■
Homarus gammarus	■	■	■	✓	■	■	■	■	■	■	■	■	■
Cerastoderma edule	■	×	■	×	×	■	×	×	■	■	■	■	■

■	Not affected
×	No interaction
✓	Potential interaction

The benthic grabs and otter trawls that were conducted as part of the MAREA and REC surveys are not designed to target the commercial species listed in the table above. As such, the abundance and distribution of these species are not accurately represented in the survey results. In order to assess where interactions may occur the areas targeted by fishermen were used as representative of where commercially important species will be concentrated.

Oysters, *Ostrea edulis*, are usually harvested using surface dredges. The number of oyster dredge vessels operating in the Outer Thames region is very low (only 4 vessels in total observed between 2004 and 2008). During the 2001 Thames Estuary Fisheries Knowledge Project, an oyster fishing ground was identified to the southwest of the study area limit off the coast near Herne Bay (see Figure 6.8 in Section 6.2). No other oyster grounds have been identified within the MAREA study area during fishing consultations. None of the mapped dredging effects will extend into the identified oyster fishing area. For example, the effects of removal of sediments are shown in Figure 9.1 which uses present day bathymetry and highlights areas where dredging will alter bathymetry. As none of the dredging effects will interact with the fishing areas for oysters, potential impacts to this species have not been assessed.

The brown shrimp, *Crangon crangon*, is targeted by shrimp trawlers. Few shrimp trawlers appear in the Outer Thames region and only during winter and spring. Generally shrimp fishing is further north towards the Wash and the vessels within the Outer Thames region are probably fishing at the extremities of the fishery. The results of the MAREA and REC surveys indicate that *C. crangon* may be found throughout the Outer Thames region but in larger numbers in shallow waters (see Figure 5.10 in Section 5.2).

The edible crab, *Cancer pagurus*, and the common lobster, *Homarus gammarus* are targeted by potting vessels which are concentrated in the Suffolk region of the study area and are close to shore throughout the entire year (see Figure 6.10 in Section 6.2). The fishing areas are therefore located largely outside of the mapped zones of dredging effects. Sand deposition is the only effect of dredging that has the potential to interact with crabs and lobsters within a potting area to the northeast of Area 447 (Figure 6.10). None of the other mapped effects will interact with crabs and lobsters within the potting areas.

The region is one of the most important in the UK for mollusc landings, especially landings of cockles, *Cerastoderma edule*, from the Thames Estuary cockle fishery. Cockles are only fished in coastal waters in the southwest of the region (see Figure 6.11 in Section 6.2). None of the mapped dredging effects extend into these areas. For example Figure 9.2 shows the maximum extent of a sediment plume in comparison with the cockle fishing area, which is the most far-reaching of all the potential impacts. As none of the dredging effects interact with the cockle fishing areas, potential impacts to this species have not been assessed.

Figure 9.1 Predicted Changes to Bathymetry in the Outer Thames Estuary Region as a Result of Sediment Removal from Dredging in relation to Oyster Fishing Areas

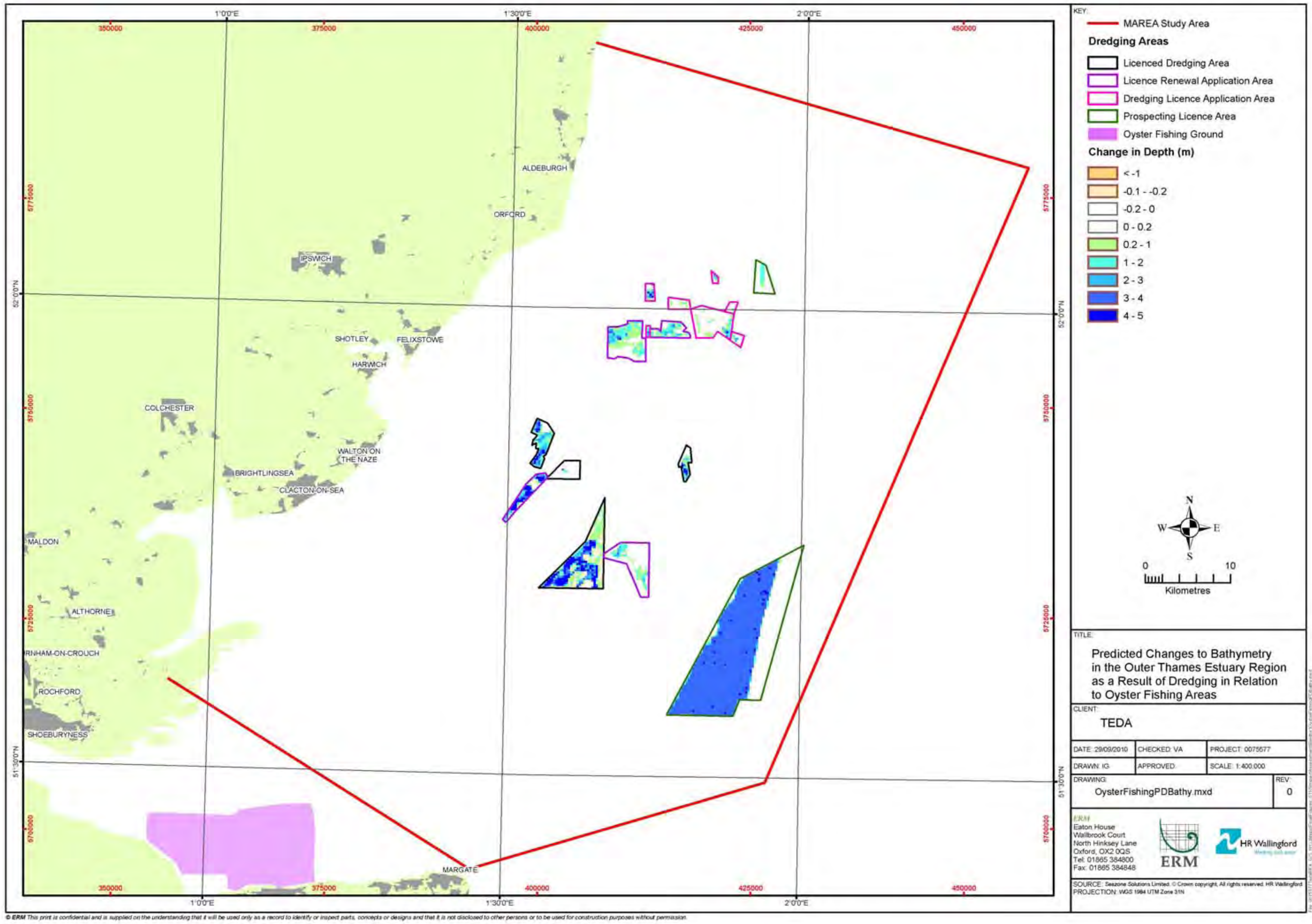
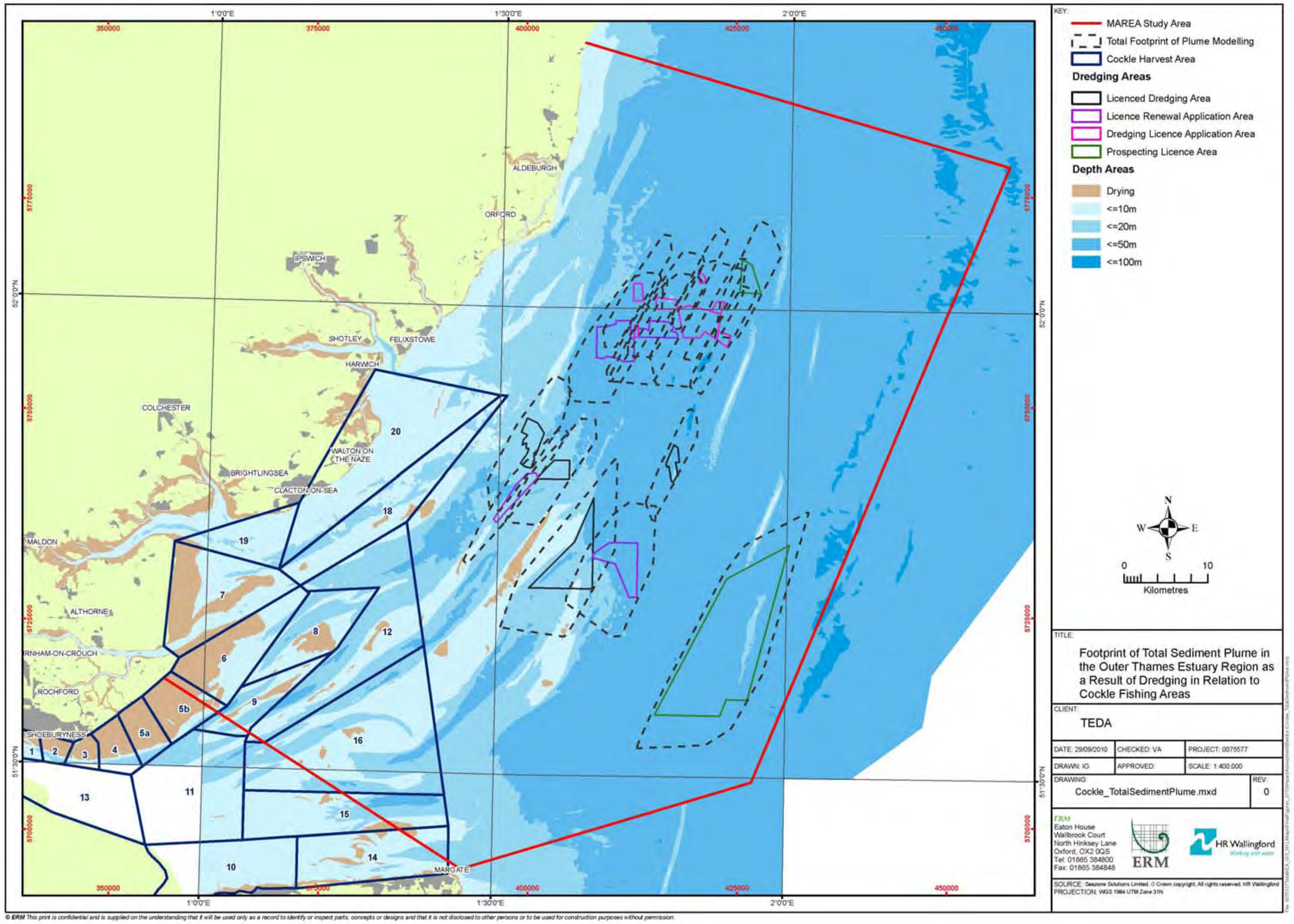


Figure 9.2 Footprint of Total Sediment Plume in the Outer Thames Estuary Region as a Result of Dredging in Relation to Cockle Fishing Areas



Removal of Sediment

Dredging typically occurs within 2-3 m wide strips within lanes or 'Active Dredge Zones' that can be up to 200m wide. Individuals that are removed from the dredging strips are expected to recolonise the area once dredging activities have ceased following recruitment from nearby undisturbed areas. Removal of sediment is assessed to be of **medium magnitude** as the effect is long term, routine and is a medium level change relative to the baseline but is site specific.

The brown shrimp, *Crangon crangon*, buries itself to ambush prey and avoid predation itself. Removal of the sediment will result in direct mortality of some individuals and may result in increased predation of individuals displaced by dredging activities. It has a **low tolerance** to the effect but has a **medium adaptability** as it is a mobile species that can move away from dredging activities and has a **high recoverability**. Overall it has a **medium sensitivity** to removal of sediment.

Only a few shrimp trawlers operate in the north of the MAREA study area in winter and spring (see Figure 6.6 in Appendix M). Generally the shrimp fishery is further north towards the Wash and these vessels are probably fishing at the extremities of the fishery (see Section 6.2). As a result there is likely to be little if any overlap between the effects of the removal of sediment, and the distribution of *Crangon crangon* that are targeted commercially. The degree of interaction is therefore assessed to be small.

Based on these assessments of the medium magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and effect, the overall impact of sediment removal on *Crangon crangon* is of ***minor significance*** at the regional level.

Sand Deposition

Sand deposition is assessed to be of **small magnitude** as the effect is localised, routine in terms of frequency of occurrence, short-term in duration and constitutes a low level change relative to the baseline.

The crab, *Cancer pagurus*, and the common lobster. *Homarus gammarus* have been assigned a **high tolerance** to smothering (Ken Neal *et al*, 2008). They are highly mobile species and will migrate away from disturbance and are therefore classified as having **medium adaptability** and **high recoverability**. Overall, *C. pagurus* and *H. gammarus* have a **low sensitivity** to this effect of dredging.

The level of interaction between crabs and lobster potting areas and sand deposition effects is very small (approximately 0.44 km^2 in the area to the north-east of Licence Area 447, see Figure 9.3).

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptors and the small degree of interaction between the receptor and effect, the overall impact of sand deposition on *Cancer pagurus* and *Homarus gammarus* is ***not significant*** at the regional level.

9.2.6 Summary

Table 9.3 summarises the significance of the cumulative impacts of dredging on benthic ecology at the regional scale.

The overall impacts to benthic species and communities as a result of dredging are assessed as being ***not significant*** at the regional scale, as the benthic communities are highly patchy and variable and no significant differences have been found between dredged and un-dredged areas. Impacts to protected and commercial benthic species range from ***minor*** to ***moderate*** due to the high sensitivities and high values of these species.

Any benthic surveys that may be carried out for individual licence area EIAs should look into the distribution of *Sabellaria spinulosa*, *Barnea Candida* and *Crangon crangon*, and assess the impacts to these species at the localised scale.

Figure 9.3 Predicted Areas of Sand Deposition in the Outer Thames Estuary Region as a Result of Dredging in Relation to Crab and Lobster Potting Areas

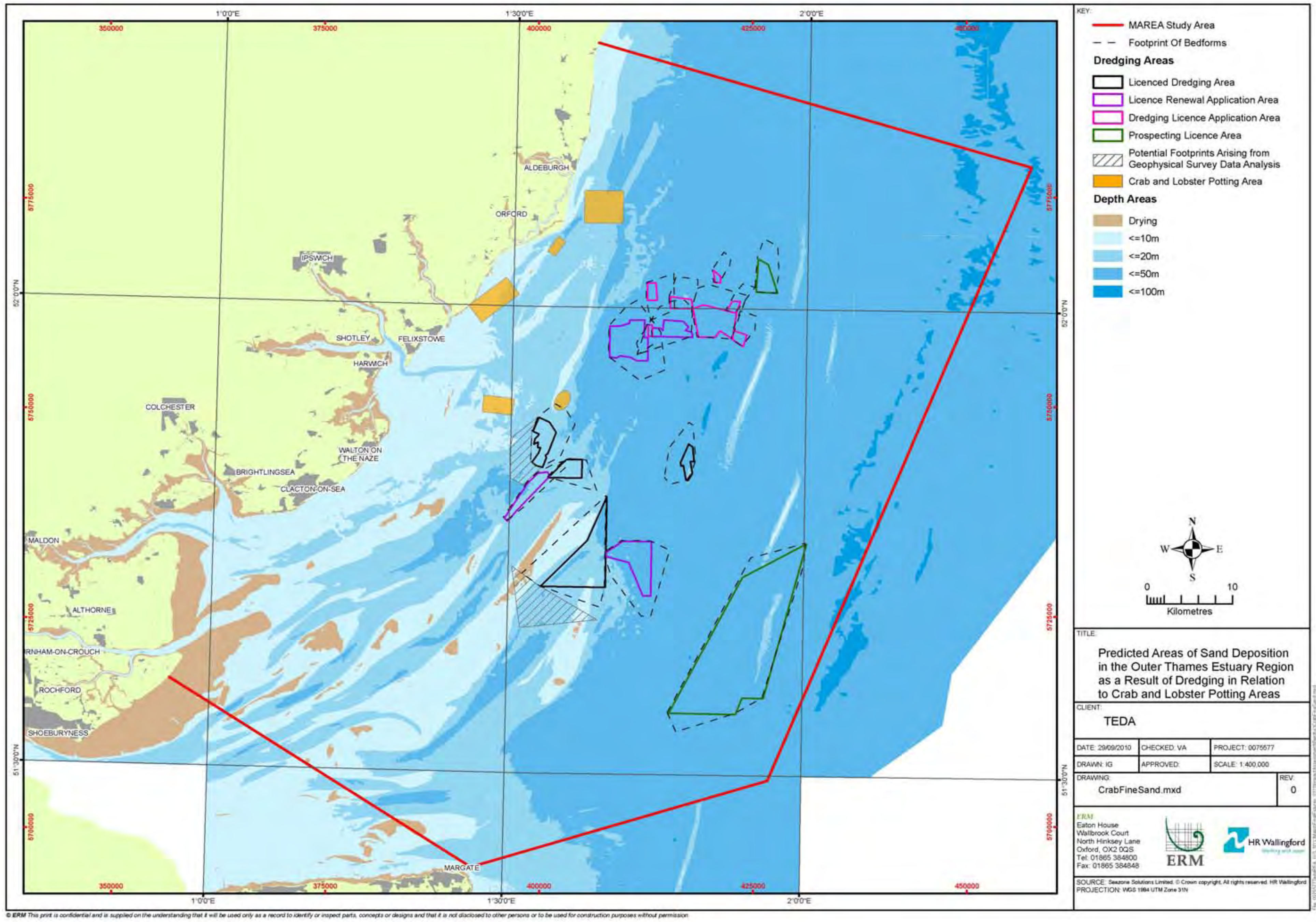


Table 9.3 Regional Significance of Impacts to Benthic Ecology from Dredging in the Outer Thames

	Benthic Species and Communities	***Biotopes***	***Sabellaria spinulosa***	***Barnea candida***	***Crangon crangon***	***Cancer pagarus***	***Homarus gammarus***
Removal of sediment	Not significant	Not significant	Moderate	Moderate	Minor		
Fine sediment plume/elevated turbidity	Not significant	Not significant					
Sand deposition	Not significant	Not significant	Not significant	Not significant		Not significant	Not significant
Changes to sediment particle size	Not significant	Not significant	Minor	Not significant			
Changes to tidal currents	See changes to sediment particle size and changes to sediment transport rates						
Changes to Sediment Transport Rates	Not significant	Not significant	Minor	Not significant			
Overall Significance of Dredging	Minor-Moderate						

9.3 IMPACTS TO FISH ECOLOGY

9.3.1 Introduction

As discussed in Section 5.3, the fish that will be considered in this impact assessment are three protected species (sea lamprey, seahorses, sand goby), four demersal species (cod, bass, plaice, sole), three pelagic species (herring including Thames Estuary herring, sprat, mackerel) and two elasmobranches (lesser-spotted dogfish and thornback ray). These species are considered the most important in the MAREA study area for reasons including protection status, commercial value, ecological importance (spawning location and migration route) and in some cases the local (Thames) population comprising a significant proportion of the national population (see Section 5.3 for more detail). As a result it is important to assess the impacts to these species.

It is important to consider the value of each species when discussing the significance of potential impacts to receptors. However, throughout this impact assessment chapter fish species are grouped and assessed together in relation to their sensitivity to the effects of dredging where appropriate. A brief explanation of the value of each receptor species can be found below.

Sea Lamprey

Sea lampreys are protected under the Berne Convention and EC Habitats directive. They are also a UK BAP species. There is evidence that lampreys have recently begun to recolonise the catchment areas in the region. Lampreys have therefore been assigned a **high value.**

Seahorses

The short snouted seahorse which may be found in the MAREA area is protected under the Berne Convention and CITES. It is also a UK BAP species. The population in the Thames may represent an important proportion of the UK population. Seahorses have therefore been assigned a **high value**.

Sand Goby

The sand goby is protected under the Berne Convention and provides an important food source for birds, larger fish and seals. Sand gobies have therefore been assigned a **medium-high value**.

Cod

Cod is a UK BAP species and listed as vulnerable on the IUCN Red List of Threatened Species. It is an important commercial species. Cod have therefore been assigned a **high value**.

Bass

Bass are an increasingly important commercial species in the Thames region and are an important target species for artisanal fisheries [1]. Bass have therefore been assigned a **medium value**.

Plaice

Plaice are a UK BAP species. They are also an important commercial species targeted in the Outer Thames and have been assigned a **medium-high value**.

Sole

Sole is a UK BAP species. It is one of the most important commercial species targeted in the area and the Thames is a particularly important nursery ground for sole. They have therefore been assigned a **medium-high value**.

Herring

Herring is a UK BAP species. The Thames is an important nursery area for herring and they are targeted by the inshore fishing industry. The Thames Estuary herring population is confined to the Thames region; however it does not have such a high market value as Atlantic herring. Herring also have specific habitat requirements. The species has been assigned a **high value**.

Sprat

Sprat are targeted by inshore fisheries in the region and have been assigned a **medium value**.

Mackerel

Mackerel are a UK BAP species. As well as being a commercial species, mackerel is also targeted by anglers and sport fishermen. The Outer Thames Estuary is an important nursery ground for mackerel. The species has been assigned a **medium value**.

Lesser Spotted Dogfish

Lesser spotted dogfish are targeted commercially in the region and have been assigned a **medium value**.

(1) Small scale local fisheries.

Thornback Ray

Thornback ray are targeted commercially and the Thames region is thought to be an important spawning area for this species. Thornback ray have been assigned a **medium-high value**.

9.3.2 Identification of Potential Impacts on Fish Ecology

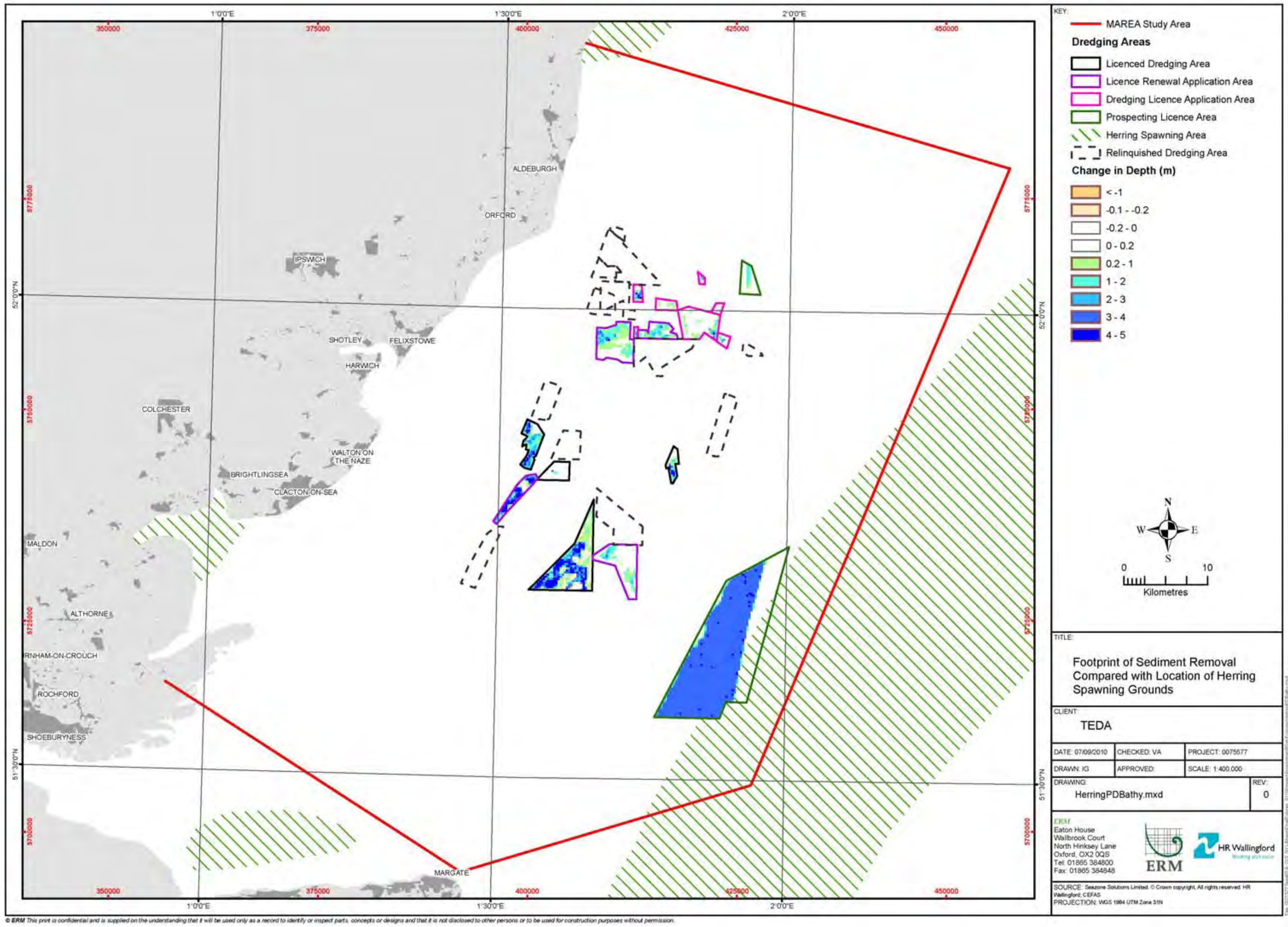
Table 9.4 details the predicted effects of dredging with reference to whether or not they have the potential to impact fish species within the MAREA study area.

Table 9.4 Matrix of Potential Impacts of Dredging on Fish Ecology

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to sandbanks
Sea lamprey	·	·	✓	·	·	·	·	·	✓	·	·	✓	·
Seahorses	·	·	✓	·	·	·	·	·	·	·	✓	·	·
Sand goby	·	✓	✓	·	·	·	·	·	·	·	✓	·	·
Cod	·	✓	✓	✓	·	·	·	·	✓	·	✓	✓	·
Bass	·	✓	✓	✓	·	·	·	·	·	·	✓	✓	·
Plaice	·	✓	✓	✓	·	·	·	·	·	·	✓	·	·
Sole	·	✓	✓	✓	✓	·	·	·	✓	·	✓	·	✓
Herring	·	✓	✓	✓	✓	·	✓	·	✓	·	✓	·	·
Sprat	·	·	✓	·	·	·	·	·	✓	·	✓	·	·
Mackerel	·	·	✓	·	·	·	·	·	·	·	✓	✓	·
Lesser-spotted dogfish	·	✓	✓	✓	·	·	✓	·	·	·	✓	✓	·
Thornback Ray	·	✓	✓	✓	·	·	✓	·	✓	·	✓	·	✓

·	Not affected
×	No interaction
✓	Potential interaction

Figure 9.4 Footprint of Sediment Removal compared with Location of Herring Spawning Grounds



9.3.3 Removal of Sediment

Magnitude of Effect

The removal of sediment by dredging is considered to be site-specific in extent, but long-term in duration, regularly occurring (routine) and a high change relative to baseline levels. As such it is assessed as being a **medium-large magnitude** effect.

Sand goby, cod, bass, plaice, sole, lesser-spotted dogfish and thornback rays are all assessed as having a medium level of tolerance and adaptability to removal of sediment via dredging, however, a change in their distribution may occur as they move away from dredging activity. Following the cessation of dredging, these species will rapidly return to any areas they have moved out of and are therefore assessed as having high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to fine sediment plumes is considered to be **low** to **medium**.

These fish species are all widely distributed throughout the study area. However the area within which dredging and the removal of sediment will take place only constitutes a very small amount of this overall habitat. As a result the **degree of interaction** of these species with the removal of sediment is assessed as being **small**.

Based on these assessments of the medium-large magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment removal on these fish species is considered to be ***not significant*** at the regional scale.

Herring have a low tolerance and adaptability to the removal of sediment as herring eggs are laid directly onto the seabed and their direct removal via dredging may result in reduced recruitment to the herring population. The recoverability of herring is assessed as being medium as any reduced recruitment to the herring stock is likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of herring species to sediment removal is considered to be **high**.

There is a small area of herring spawning ground within the MAREA study area to the east of Area 504 (North Falls), in the Blackwater estuary and in the northernmost corner of the study area. As such there is likely to be a **very small degree of interaction** between the removal of sediment from dredging in Area 504 and herring spawning grounds (see Figure 9.54).

Based on these assessments of the medium-large magnitude of the effect, the high value and high sensitivity of the receptor but the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on herring is considered to be ***minor*** at the regional scale.

9.3.4 Fine Sediment Plume

Magnitude of Effect

The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

Sea lampreys, seahorses, cod, bass, sprat, mackerel, lesser-spotted dogfish and thornback rays are all assessed as having a medium level of tolerance and adaptability to the presence of a sediment plume and the associated increase in turbidity, however a change in their distribution may occur as they avoid and move away from areas of high turbidity. Following the cessation of dredging, these species will rapidly return to any areas they previous avoided; and are therefore assessed as having high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to fine sediment plumes is considered to be **low** to **medium**.

Sea lampreys and seahorses are not common within the MAREA study area and are predominantly distributed inshore. They are therefore unlikely to overlap in distribution with the presence of the sediment plumes associated with dredging operations. Cod, bass, sprat, mackerel, lesser-spotted dogfish and thornback rays are all widely distributed throughout the study area and are highly mobile. As a result the **degree of interaction** of these species with the presence of sediment plumes is assessed as being **small**.

Based on these assessments of the small-medium magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on these fish species is considered to be ***not significant*** at the regional scale.

Sand gobies, plaice and sole are assessed as having a high level of tolerance and high adaptability to the presence of the plume, as they live in sandy and often turbid environments. Their recoverability in relation to this effect of dredging is also high as they will recover rapidly at the end of the dredging period if they are adversely impacted in any way. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to fine sediment plumes is considered to be **low**.

These species are widely distributed throughout the MAREA study area, and as a result will only have a **small degree of interaction** with the presence of sediment plumes associated with dredging.

Based on these assessments of the small-medium magnitude of the effect, the medium-high value and low sensitivity of the receptors and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on sand gobies, plaice and sole is considered to be ***not significant*** at the regional scale.

Herring have a low tolerance and adaptability to the presence of a fine sediment plume, as an increase in turbidity in the water column can have a detrimental effect on spawning grounds; herring eggs are laid directly onto the seabed and need clear, well oxygenated water to survive. The recoverability of herring is assessed as being medium as any reduced recruitment to the herring stock as a result of impacts to spawning grounds is likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of herring species to fine sediment plumes is considered to be **high**.

There is a small area of herring spawning ground within the MAREA study area to the west of Area 504 (North Falls), in the Blackwater estuary and in the northernmost corner of the study area. As such there is likely to only be a **very small degree of interaction** between sediment plumes from dredging in Area 504 and herring spawning grounds (see Figure 9.5).

Based on these assessments of the small-medium magnitude of the effect, the high value and high sensitivity of the receptor but the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment plumes on herring is considered to be of ***minor significance*** at the regional scale.

9.3.5 Sand Deposition

Magnitude of Effect

The deposition of sand onto the seabed (ie formation of bedforms) as a result of dredging operations is assessed as being a **small magnitude** effect, based on it being a localised and short-term effect that will be a routine occurrence, and constitutes a low level change relative to the baseline.

Cod and bass are assessed as having a medium level of tolerance and adaptability to the deposition of sand on the seabed, however a change in their distribution may occur as they avoid and move away from areas where this occurs. When dredging has finished, these species will rapidly return to any areas they previously avoided and are therefore assessed as having high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to sand deposition is considered to be **low** to **medium**.

Cod and bass are widely distributed throughout the study area and are highly mobile. However the area within which dredging and the deposition of sand onto the seabed will take place constitutes a very small amount of this overall habitat. As a result the **degree of interaction** of these species with the effect of sand deposition is assessed as being **small**.

Based on these assessments of the small magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors and the small degree of interaction between the receptors and the effect, the cumulative impact of sand deposition on these fish species is considered to be ***not significant*** at the regional scale.

Herring, lesser-spotted dogfish and thornback rays all lay their eggs or egg cases (dogfish and rays) directly on the seabed. As a result the survival of these eggs and thus successful recruitment into the population is at risk if sand deposition takes place directly onto any spawning grounds. These species therefore have a low tolerance and adaptability to sand deposition and this may result in a shift in spawning grounds to other areas. Their recoverability is assessed as being medium as any impaired levels of recruitment are likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to sand deposition is considered to be **high**.

There is a small area of herring spawning ground within the MAREA study area to the west of Area 504 (North Falls), in the Blackwater estuary and in the northernmost corner of the study area (see Figure 9.6). Little is known about where the egg cases of lesser spotted dogfish are deposited, but they are not reported as being found in high numbers throughout the MAREA study area. Thornback rays deposit their egg cases throughout the study area, but consultation with fisherman has also revealed a small coastal area where spawning frequently occurs (see Figure 9.7). As such there is likely to only be a **very small degree of interaction** between areas of sand deposition and the spawning grounds of herring, lesser-spotted dogfish and thornback rays within the MAREA study area. Based on these assessments of the small magnitude of the effect, the medium to high value and high sensitivity of the receptors but the very small degree of interaction between the receptors and the effect, the cumulative impact of sand deposition on these species is considered to be ***minor*** at the regional scale.

Figure 9.5 Footprints of Fine Sediment Plumes (above background concentrations and 100 mg l^{-1}) compared with location of Herring Spawning Grounds

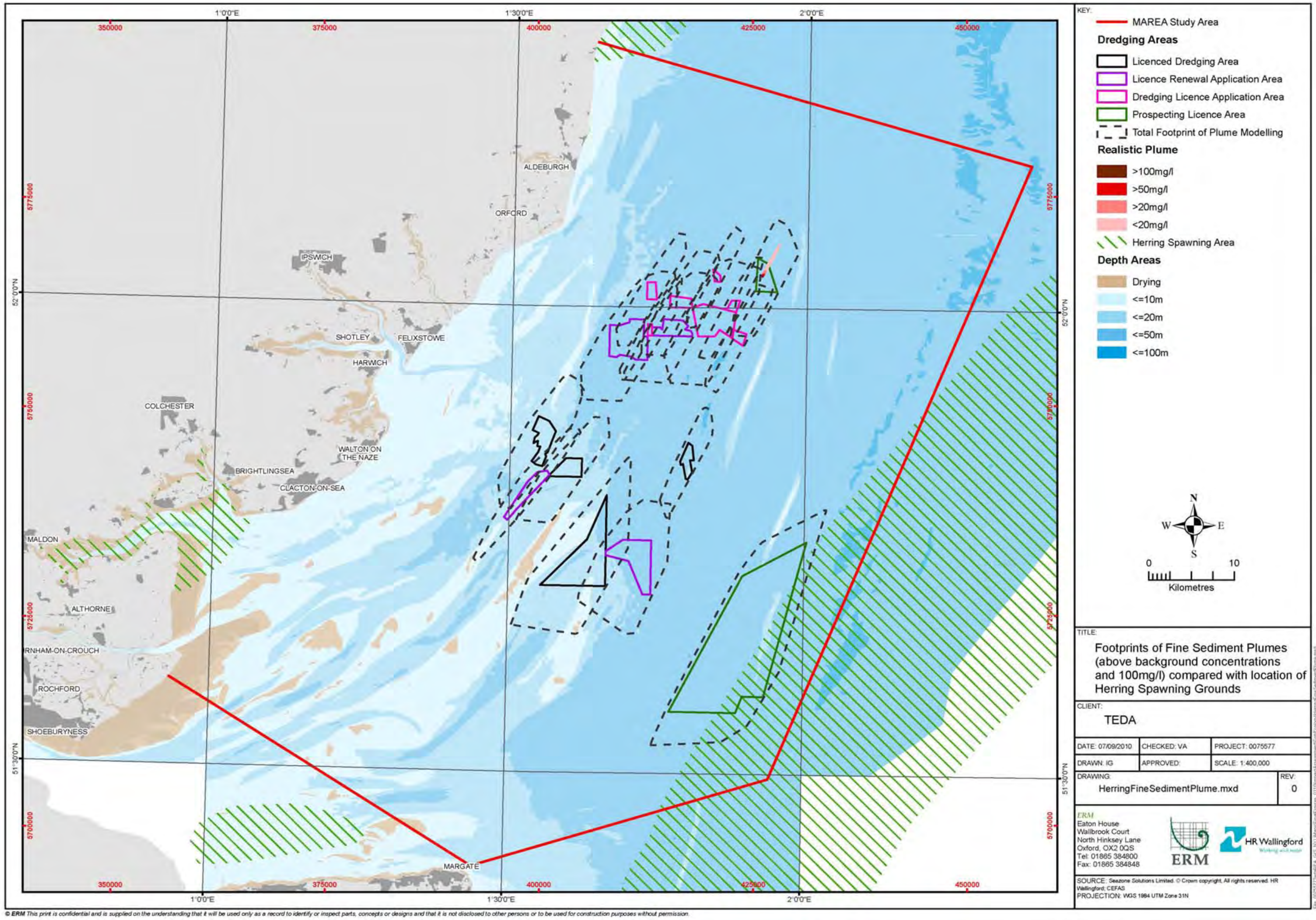


Figure 9.6 Sand Deposition Footprint compared with Location of Herring Spawning Grounds

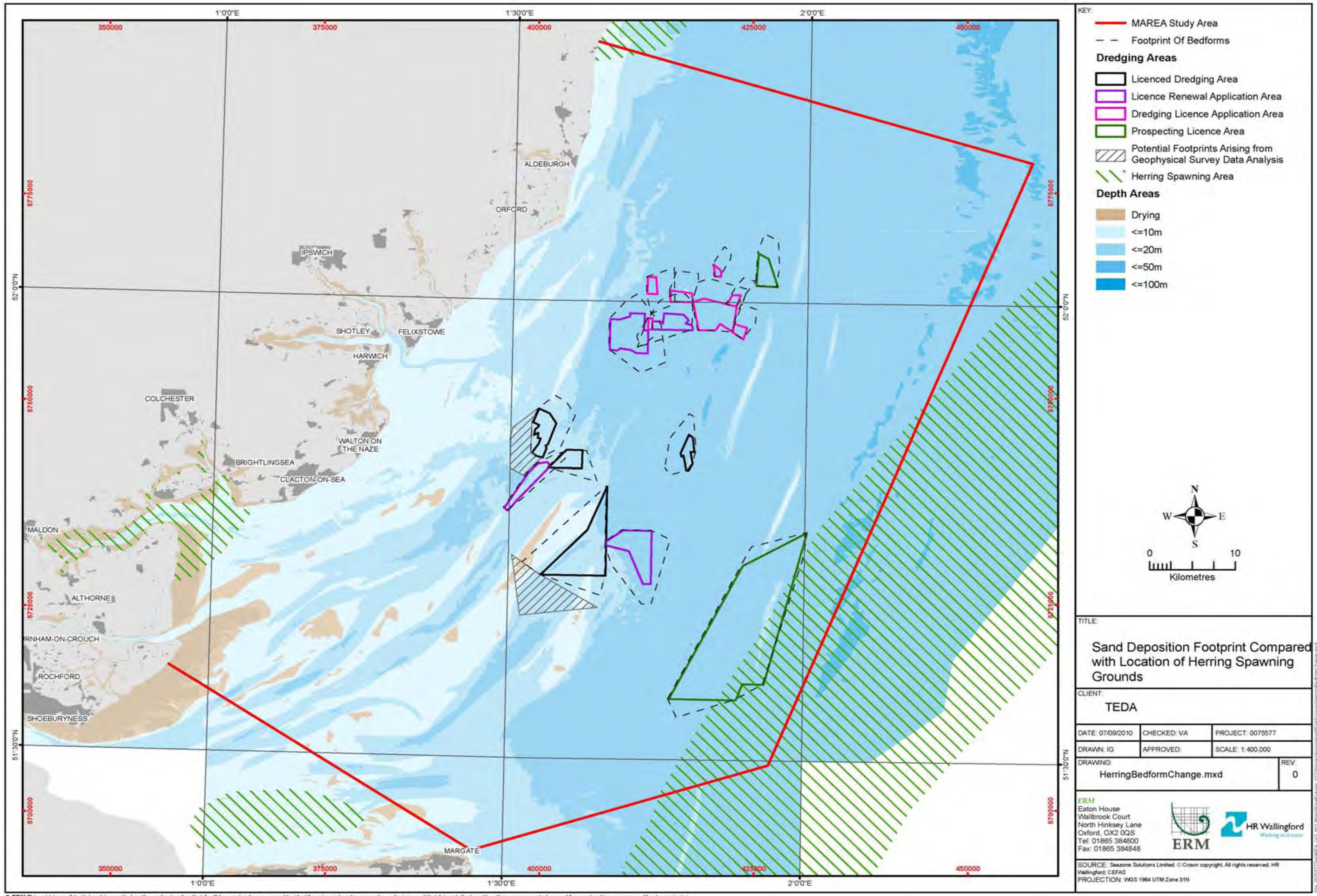
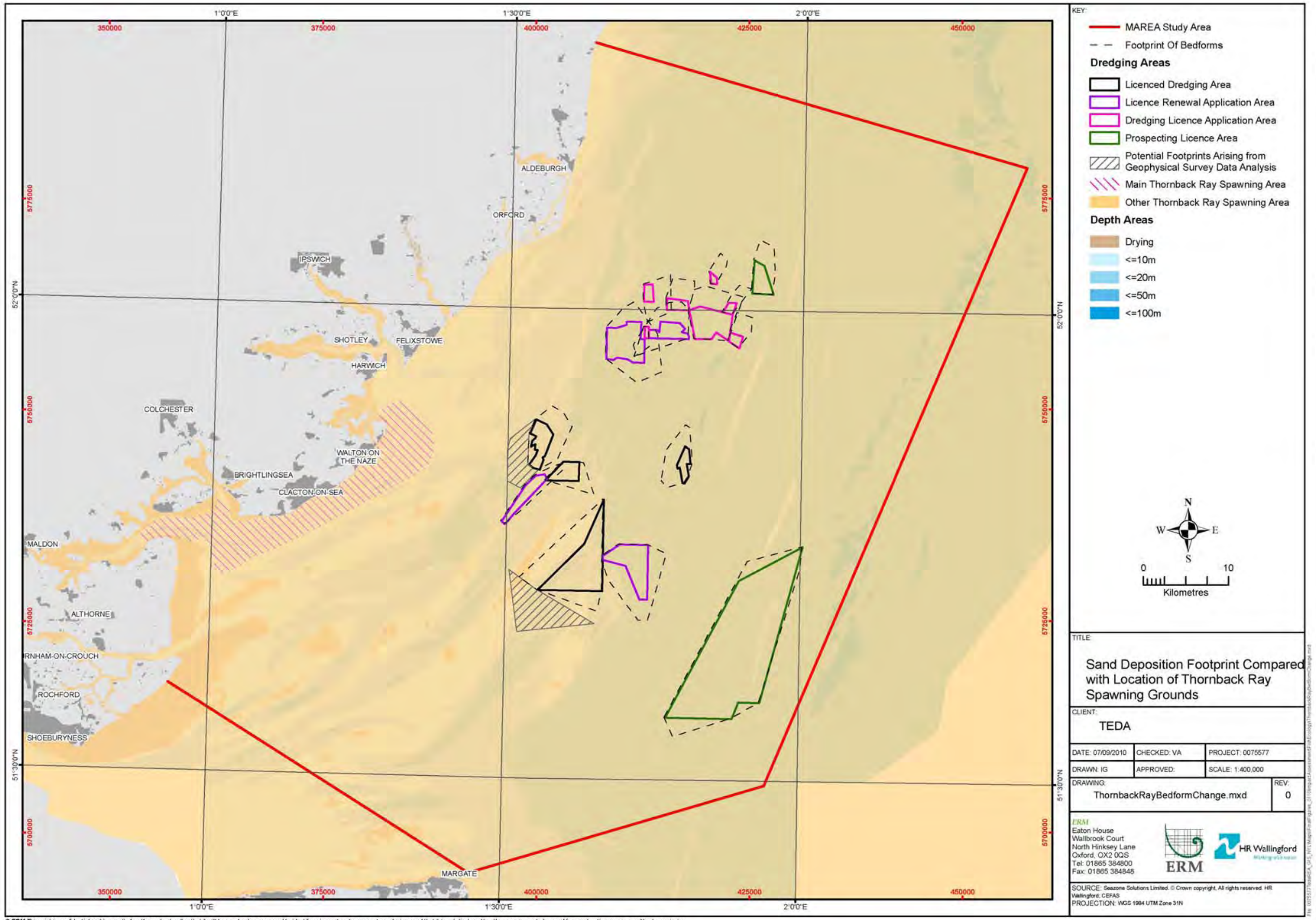


Figure 9.7 Sand Deposition Footprint compared with location of Thornback Ray Spawning Grounds



9.3.6 Changes to Sediment Particle Size

Magnitude of Effect

Any changes to sediment particle size as a result of dredging activity will be localised, short-term in duration and will represent a low level of change relative to the baseline. However they will be routine in occurrence. Particle size changes are therefore assessed as being a **small magnitude** effect.

Sole are assessed as having a medium level of tolerance and adaptability to changes in particle size, as they predominantly prefer sandy substrates as habitats, and as a result may move away from an area if the particle size changes significantly and is no longer suitable. However following the cessation of dredging, sole will rapidly return to any areas they have been displaced from and are therefore assessed as having high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of sole to changes to particle size is considered to be **low** to **medium**.

Sole are widely distributed throughout the study area. However the area within which dredging activities occur and where changes to particle size may take place only constitutes a very small amount of this overall available habitat. As a result the **degree of interaction** of sole with the effect of changes to particle size is assessed as being **small**.

Based on these assessments of the small magnitude of the effect, the medium-high value and low-medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to sediment particle size on sole is considered to be ***not significant*** at the regional scale.

Herring are assessed as having a medium tolerance and adaptability to the changes to particle size, as they lay their eggs on gravelly substrates, and as a result may be unable to spawn within previous spawning grounds if the particle size characteristics of the substrate were to change significantly. The recoverability of herring is assessed as being medium as any reduced recruitment to the herring stock as a result of the displacement from spawning grounds is likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of herring species to changes to sediment particle size is considered to be **medium**.

There is a small area of herring spawning ground within the MAREA study area to the west of Area 504 (North Falls), in the Blackwater estuary and in the northernmost corner of the study area. As such there is likely to be only a **small degree of interaction** between the effect of a change in particle size as a result of dredging in Area 504 and herring spawning grounds.

Based on these assessments of the small magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment plumes on herring is considered to be ***not significant*** at the regional scale.

9.3.7 Changes to Tidal Currents

Magnitude of Effect

A 10-20% change to tidal currents as a result of dredging operations, is a **medium magnitude** effect, based on the fact it is site-specific in extent, regularly occurring (routine), long-term in duration and constitutes a medium level change relative to the baseline. A 2-10% change to tidal currents is a localised effect and is a low level of change relative to the baseline, however it is long-term in duration and regularly occurring (routine). It is therefore also assessed as being a **medium magnitude** effect.

Herring, lesser-spotted dogfish and thornback rays all lay their eggs or egg cases (dogfish and rays) directly on the seabed. These eggs survive best in well oxygenated environments with good water flow over the eggs. As a result, significant changes to tidal currents could impact upon the survival of eggs and as a result recruitment into the species' populations could be impacted. Herring, lesser-spotted dogfish and thornback rays therefore have a medium tolerance and adaptability to changes to tidal currents as this may result in a shift in spawning grounds to other less suitable areas. Their recoverability is assessed as being medium as any impaired levels of recruitment are likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to changes in tidal currents is considered to be **medium**.

There is a small area of herring spawning ground within the MAREA study area to the west of Area 504 (North Falls), in the Blackwater estuary and in the northernmost corner of the study area. Little is known about where the egg cases of lesser spotted dogfish are deposited, but they are not reported as being found in high numbers throughout the MAREA study area. Thornback rays deposit their egg cases throughout the study area, but consultation with fisherman has also revealed a small coastal area where spawning frequently occurs. As such there is likely to only be a **very small degree of interaction** between areas of changes to tidal currents and the spawning grounds of herring, lesser-spotted dogfish and thornback rays within the MAREA study area.

Based on these assessments of the medium magnitude of the effects, the medium to high value and medium sensitivity of the receptors but the very small degree of interaction between the receptors and the effects, the cumulative impact of changes to tidal currents on these species is considered to be ***not significant*** at the regional scale.

9.3.8 Underwater Noise

Magnitude of Effect

The following discussion is a summary of the Underwater Noise Assessment presented in Appendix K.

Underwater noise that elicits a strong behavioural response from fish species is a regularly occurring (routine) effect and constitutes a high level of change relative to the baseline, however, it is temporary and site-specific in nature. It is therefore assessed as being a **medium magnitude** effect.

Noise levels that result in a mild behavioural response are localised, temporary, regularly occurring and are a medium level of change relative to baseline noise levels. Therefore this is a **small-medium magnitude** effect.

Impact Significance

Sole and thornback ray are relatively insensitive to noise as their hearing ability is thought to be poor. They are only expected to react to dredging noise within 130 m of a vessel at the most, with strong responses occurring within less than 1 m from the dredging vessels and mild reactions within 3 m. As a result only very minor distribution changes may occur, which due to the widespread nature of these species throughout the study would not be detected at the regional scale. Therefore sole and thornback ray are assessed as having a high tolerance and adaptability to underwater noise. Their recoverability is assessed as being high, as once dredging has ceased they are likely to return to the areas they are displaced from. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to underwater noise is considered to be **low**.

The zones of behavioural response do not interact with the important sole nursery areas or any known thornback ray feeding grounds around the coast or at the mouth of the Thames Estuary. In addition the proportion of the study area within which behavioural responses of either species are predicted to occur at any given time is a very small proportion of the overall distribution of these species in the region and their spawning areas. Consequently the **degree of interaction** between underwater noise zones of behavioural response and spawning and feeding grounds for sole and thornback ray is **very small**.

Based on these assessments of the small-medium and medium magnitudes of the effects, the medium-high value and low sensitivity of the receptors combined with the very small degree of interaction between the receptors and the effects, the cumulative impact of underwater noise on these species is considered to be ***not significant*** at the regional scale.

Cod are found throughout the study area and exhibit behavioural responses predicted to occur up to 1.1 km from dredgers, with strong and mild reactions occurring within 4 m and 30 m respectively. As a result some distribution changes may occur; cod have been assessed as having medium-high tolerance and adaptability to underwater noise. Their recoverability is assessed as high, as once dredging has ceased they are likely to return to the area. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of cod to underwater noise is considered to be **low-medium**.

For some licence areas the zones of mild and strong behavioural response overlap with cod spawning or nursery grounds in the region, however, the cumulative area that may potentially be impacted is a small proportion of the available spawning and nursery ground in the Outer Thames (Figure 9.8). The **degree of interaction** between underwater noise and cod spawning and nursery grounds is therefore **small.**

Based on these assessments of the small-medium and medium magnitudes of the effects, the high and medium-high value of cod and low-medium sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of underwater noise on cod is considered to be of ***minor significance*** at the regional scale.

Sprat are hearing specialists that are predicted to react to dredging noise at a distance up to 1.9 km from a dredging vessel, with mild behavioural reactions expected within 60 m of dredgers and strong reactions within 6 m therefore the tolerance and adaptability of these species is assessed as medium. Their recoverability is assessed as high as once dredging has ceased they are likely to return to the area. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of sprat to underwater noise is considered to be **medium**.

Sprat spawning and nursery grounds extend through much of the North Sea and consequently all of the licence areas overlap with potential sprat nursery areas in the region and many overlap with the sprat spawning areas. However, the area of available habitat within which mild or strong behavioural reactions could potentially occur constitutes a very small proportion of this available habitat (Figure 9.9). In addition, sprat are not limited by benthic habitat conditions as they have no specific requirements in this regard. The **degree of interaction** between underwater noise and sprat spawning and nursery grounds is therefore assessed as being **very small**.

Based on these assessments of the small-medium and medium magnitudes of the effects, the medium value and medium sensitivity of the receptors combined with the very small degree of interaction between the receptor and the effects, the cumulative impact of underwater noise on sprat is considered to be of ***minor significance*** at the regional scale.

Sea lampreys are highly active migratory fish, capable of moving widely throughout the Thames Estuary and surrounding area (Maitland,2003). They are predicted to react to dredging noise at a distance up to 1.9 km from a dredging vessel, with mild behavioural reactions expected within 60 m of dredgers and strong reactions within 6 m. Behavioural reactions (eg avoidance behaviour) within the licence areas are not anticipated to have any impact on ecologically important behaviours (such as migration or reproduction) in this species. However, a change to the distribution of its prey fish species may result in a detectable change to the distribution of lampreys at a regional scale. A precautionary approach has been adopted in the absence of any species-specific data and consequently tolerance and adaptability have been assessed as medium-low and recoverability is assessed as low. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of sea lamprey to underwater noise is considered to be **medium-high**.

Sea lampreys are not common within the study area and are predominantly distributed inshore close to the rivers into which they migrate for spawning. The proportion of the study area within which behavioural responses are predicted to occur is a very small proportion of the overall available habitat for this species. The **degree of interaction** between underwater noise and sea lamprey is assessed as very **small**.

Based on these assessments of the small-medium and medium magnitudes of the effect, the high value and medium-high sensitivity of the receptors combined with the very small degree of interaction between the receptor and the effects, the cumulative impact of underwater noise on sea lamprey is considered ***not significant*** at the regional scale. Behavioural reactions (eg avoidance behaviour) within the licence areas are not anticipated to have any impact on ecologically important behaviours (such as migration, reproduction or feeding) in this species.

Herring occur throughout the study area. Behavioural responses due to noise from dredging activities may occur up to approximately 1.9 km from dredging vessels with mild behavioural reactions expected within 60 m of dredgers and strong reactions within 6 m. Herring have well-developed hearing for a fish species and require the gravel sediments that are often found within aggregate licence areas for spawning. As a result they are assessed as having low adaptability and medium tolerance, coupled with low-medium ability to recover due to the currently poor status of the North Sea herring stock. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of herring to underwater noise is considered **high**.

The locally important spawning areas within the Blackwater estuary are not within the predicted zones of behavioural response for any of the licence areas. However, for some licence areas the potential area of mild and strong reactions to noise disturbance overlaps with herring nursery areas (Figure 9.10). Adult herring are found throughout the study area, therefore a small amount of their available habitat overlaps with the zones of behavioural response to noise. Overall there is a **small degree of interaction** between herring and underwater noise.

Based on these assessments of the small-medium and medium magnitudes of the effect, the high value and high sensitivity of the receptor combined with the small degree of interaction between the receptor and the effect, the cumulative impact of underwater noise on herring is considered to be of ***minor significance*** at the regional scale.

Figure 9.8 Zones of Behavioural Response of Cod to Dredging Noise

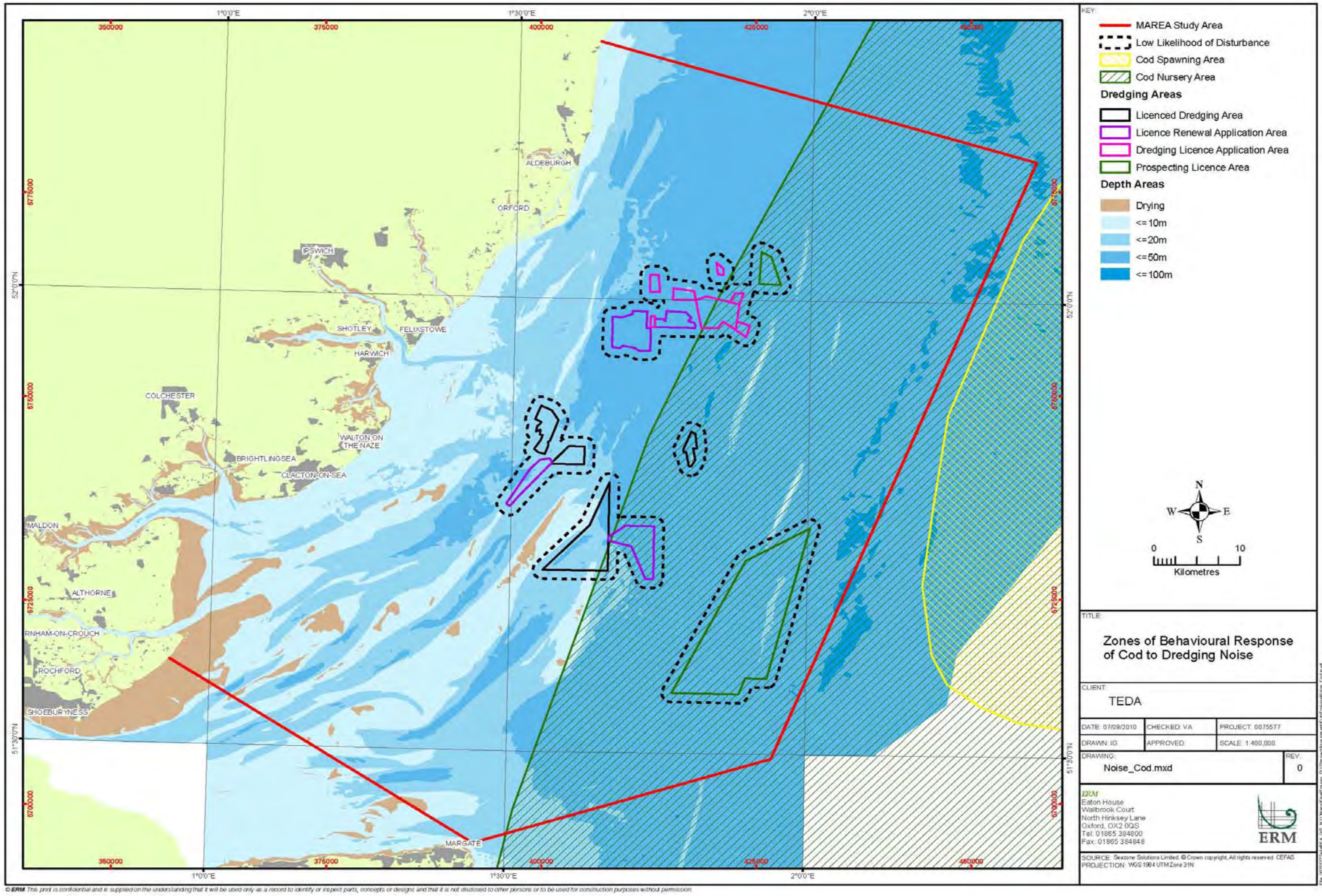


Figure 9.9 Zones of Behavioural Response of Sprat to Dredging Noise

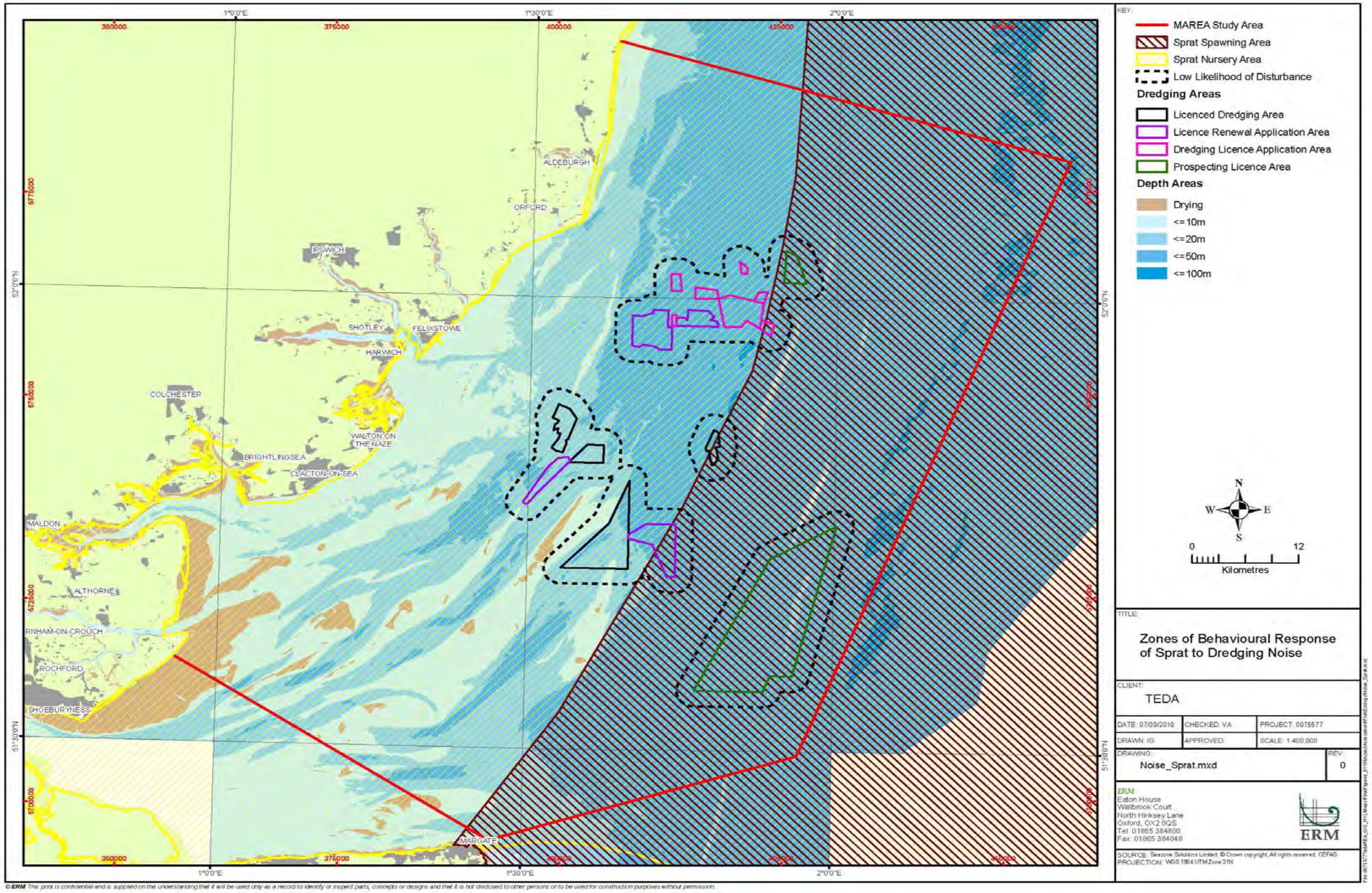
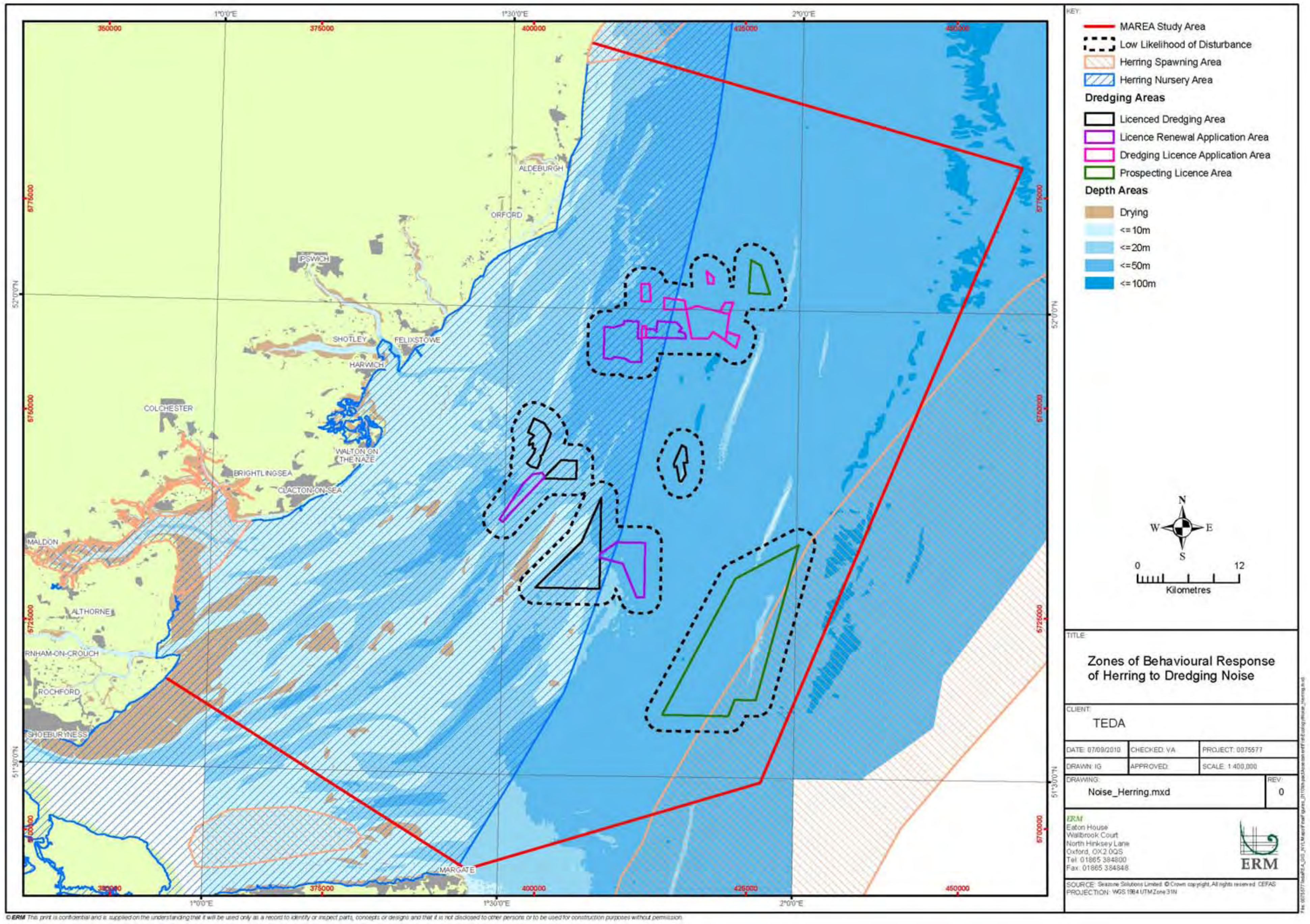


Figure 9.10 Zones of Behavioural Response of Herring to Dredging Noise



9.3.9 Change to Benthic Community Composition

Magnitude of Effect

A change to the composition of the benthic community as a result of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence because the majority of dredging occurs along tracks that have been dredged before and therefore the frequency of previously un-dredged seabed (and the associated benthic communities) being affected is low. As a result it is classified as a **medium-large magnitude** effect.

Impact Significance

Herring, sprat and mackerel are pelagic organisms that predominantly feed on small fish and plankton in addition to a small number of benthic organisms. As they do not solely rely on benthic organisms as prey items, they can be considered to have high tolerance, adaptability and recoverability to changes in benthic communities. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to changes in benthic community composition is considered to be **low.**

Herring, sprat and mackerel are all widely distributed throughout the study area and are highly mobile. As a result there will be a **very small degree of interaction** between these species and changes in benthic communities as a result of dredging within the MAREA area.

Based on these assessments of the medium-large magnitude of the effect, the high and medium value and low sensitivity of the receptors combined with the very small degree of interaction between the receptor and the effects, the cumulative impact of changes in benthic communities on herring, sprat and mackerel is considered to be ***not significant*** at the regional scale.

Seahorses, sand goby, cod, bass, plaice, sole, lesser spotted dogfish and thornback ray feed on a variety of prey including plankton, benthic invertebrates and fish. Their tolerance and adaptability to changes in benthic communities is assessed as medium as they depend on some benthic species as a food source but are able to forage over a large area. Recoverability is assessed as high as they are generally found throughout the study area (seahorses are found along the coast) and these species are not limited to foraging in a small area and are capable of preying upon a wide variety of species. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to changes in benthic community composition is considered to be **low-medium.**

Seahorses are not common within the MAREA study area and are predominantly distributed inshore. They are therefore unlikely to overlap in distribution with the change in benthic community composition associated with dredging operations. Sand goby, cod, bass, plaice, sole, lesser spotted dogfish and thornback ray are more widely distributed throughout the study area. However, the area within which dredging activities occur and where changes in benthic communities may take place only constitutes a very small amount of this overall available habitat. As a result the **degree of interaction** of these species with the effect of changes in benthic communities is assessed as **small**.

Based on these assessments of the medium-large magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of changes in benthic communities on seahorses, sand goby, cod, bass, plaice, sole, lesser spotted dogfish and thornback ray is considered to be ***not significant*** at the regional scale.

9.3.10 Changes to Distribution of Fish Prey Species

Magnitude of Effect

A change to the distribution of fish prey species as a result of dredging operations is a **small magnitude** effect based on its localised and transient nature, the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

Impact Significance

Mackerel feed on small fish including herring and Norway pout. As a result changes to the distribution of prey species may affect the distribution of mackerel as they forage. Tolerance, adaptability and recoverability have all been assessed as high due to the large foraging area mackerel have access to, and following cessation of dredging, prey species and therefore mackerel are likely to return to the area. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of mackerel to changes to fish prey distribution is considered to be **low**.

Mackerel are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the **degree of interaction** of mackerel with the effect of changes in fish prey distribution is assessed as being **small**.

Based on these assessments of the small-medium magnitude of the effect, the medium value and low sensitivity of the receptors combined with the small degree of interaction between the receptor and the effect, the cumulative impact of changes in fish prey distribution on mackerel is considered to be ***not significant*** at the regional scale.

Sea lamprey, cod, bass and lesser spotted dogfish all feed at least partially on other fish species, therefore a change to the distribution of fish prey species may result in a detectable change to the distribution of these species at a regional scale. However they are assessed as having a medium level of tolerance and adaptability to this effect as a result of their ability to target other fish species as prey or move to other areas. Recoverability is assessed as high since following the cessation of dredging prey species are likely to return to the area and attract these predator species back. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to changes to fish prey distribution is considered to be **low-medium**.

Sea lampreys are not common within the study area and are predominantly distributed inshore close to the rivers into which they migrate for spawning. The dredged area and thus area within which changes to fish distributions may occur, will therefore only comprise a very small part of this available habitat. Cod, bass and lesser-spotted dogfish are generally more widely distributed throughout the study area. However, the area at any one time within which dredging activities occur is relatively small, and only small changes to fish prey distributions at any one time are expected. As a result the **degree of interaction** between these species and the effect of changes in fish prey distribution is assessed as **small**.

Based on these assessments of the small magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors combined with the small degree of interaction between the receptor and the effect, the cumulative impact of changes to fish prey distributions on sea lamprey, cod, bass and lesser spotted dogfish is considered to be ***not significant*** at the regional scale.

9.3.11 Changes to Sandbanks

Magnitude of Effect

Information from the sandbanks impact assessment (Section 8.2) suggests that there may be impacts of significance to sandbanks, but these will be minor at most. A change to sandbanks as a result of dredging operations is a **small magnitude** effect based on the fact that it is a routine effect that is medium term in duration; however, any changes are very localised and constitute a low level of change relative to baseline levels (sandbanks are naturally mobile features).

Impact Significance

Sole and thornback ray are commonly found on or along the sides of sandbanks. Changes to sandbanks such as sediment particle size changes, tidal current changes or sand deposition may affect sole and thornback ray distribution to due a change in their habitat conditions. Therefore tolerance and adaptability to changes to sandbanks have been assessed as medium. Recoverability is assessed as high as sandbanks are naturally dynamic and thus habitat conditions would be subject to natural changes. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of these species to changes to sandbanks is considered to be **low-medium.**

Although sole and thornback ray are found associated with sandbanks they are also distributed throughout the entire MAREA study area and are not limited to using sandbanks as their habitat. As a result the **degree of interaction** of these species with changes to sandbanks is assessed as being **small**.

Based on these assessments of the small magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of changes to sandbanks on sole and thornback ray is considered to be ***not significant*** at the regional scale.

9.3.12 Summary of Impacts

Table 9.75 summarises the significance of the cumulative impacts of dredging on fish ecology at the regional scale.

The impacts to fish ecology from dredging that are predicted to be significant are assessed as being ***minor*** at most and are likely to only affect individuals or small groups of species at any one time.

It should be noted that Area 504 contributes significantly to the assessment of significant impacts on herring, as a result of the overlap of the area with herring spawning grounds. However this prospecting area has now been surrendered (see Industry Statement). Without the contribution of Area 504 to the cumulative impacts of dredging, the significance of the impacts related to the removal of sediment, sediment plume and sand deposition on herring are regarded as ***not significant***.

Area 452 A, **Area 452 B**, **Area 452 E**, **Area 118/2**, **Area 239/1**, **Area 108/1**, **Area 257**, **Long Sand Head licence (Area 108/3, 109/1, 113/1),** and **Area 327** overlap with the herring nursery area. The potential for impacts on juvenile herring within the nursery area will need to be addressed at the licence EIA stage by referring to the MAREA and discussing the findings in a site-specific context.

Area 452 C, North Inner Gabbard, Long Sand Head licence (Area 108/3, 109/1, 113/1), Area 327, and **Area 119/3** overlap with the cod nursery area. Cod may exhibit behavioural responses up to 1.1 km from dredgers, with strong and mild reactions occurring within 4 m and 30 m respectively. There is overlap of all these contours from these licence areas with the cod nursery area, therefore this impact will need to be referred to in the EIAs for these licence areas and discussed at a localised scale.

Sprat may react to dredging noise at a distance up to 1.9 km from a dredging vessel, with mild behavioural reactions expected within 60 m of dredgers and strong reactions within 6 m. Sprat are distributed throughout the area therefore their distribution is likely to overlap with the low likelihood of disturbance, mild and strong behavioural response contours. Sprat spawning and nursery areas extend across much of the southern North Sea and sprat do not have the same specific habitat requirements as other species. The area of available habitat within which mild or strong behavioural reactions from dredging in this area could potentially occur constitutes a very small proportion of available habitat. Therefore despite impacts to sprat assessed as being of minor significance at the regional level, it is unlikely that any of the individual licence areas will have a significant effect on this species, and no further assessment is required.

Table 9.5 Significance of Impacts to Fish Ecology from Dredging in the Outer Thames

Effect of Dredging	**Sea lamprey**	**Seahorses**	**Sand goby**	**Cod**	**Bass**	**Plaice**	**Sole**	**Herring**	**Sprat**	**Mackerel**	**Lesser spotted dogfish**	**Thornback ray**
Removal of sediment			*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**			*Not significant*	*Not significant*
Fine sediment plume/elevated	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Sand deposition				*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**			*Minor*	*Minor*
Changes to sediment particle size							*Not significant*	*Not significant*				
Changes to tidal currents								*Not significant*			*Not significant*	*Not significant*
Underwater noise	*Not significant*			*Minor*			*Not significant*	*Minor*	*Minor*			*Not Significant*
Changes to benthic community composition		*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Changes to distribution of fish	*Not significant*			*Not significant*	*Not significant*					*Not significant*	*Not significant*	
Changes to sandbanks							*Not significant*					*Not significant*
Overall Significance of Dredging	*Minor*											

* Downgraded from 'minor' when the contribution of Area 504 (surrendered) to the assessment is disregarded.

9.4 IMPACTS TO MARINE MAMMALS

9.4.1 Introduction

As discussed in Section 5.4, the harbour porpoise, common seal and grey seal are considered to be the only resident and most frequently recorded marine mammal species in the Outer Thames Estuary. As a result they are more likely to experience impacts from dredging operations, and will therefore be the focus of this impact assessment.

Harbour porpoise are the most abundant cetacean and indeed the most common marine mammal recorded within the study area and are thought to be resident, using the area for breeding and foraging. They are listed on Appendix II of CITES, Appendix II of the Berne Convention and Annexes II and IV of the EC Habitats Directive [(1)]. They are also listed on Appendix II of the Bonn Convention, Annex V of OSPAR, Section 74 of the Countryside and Rights of Way Act 2000 and are protected under the Wildlife and Countryside Act 1981. The 'Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas' (ASCOBANS), formulated in 1992, has now been signed by seven European countries including the UK. There is a UK Species Action Plan for the harbour porpoise, and the species forms part of the local Biodiversity Action Plan for Essex (see Section 5.4). Studies suggest that the Outer Thames Estuary is a particularly important feeding area for the harbour porpoise population of the southern North Sea during the winter.

Common seals and grey seals are present within the study area, particularly in nearshore areas, with common seals being more abundant. Common and grey seals are listed on Annexes II and V of the EC Habitats Directive [(1)], Appendix II of the Bonn Convention and Appendix II of the Berne Convention. Seals are protected under the Conservation of Seals Act, 1970 (see Section 5.4). The Outer Thames Estuary is not thought to contain nationally important numbers of common or grey seals, however the UK as a whole supports approximately 40% and 50%of the world population of common and grey seals respectively (Davies *et al*, 2001) and (Hiby *et al*, 1996).

Common seals and grey seals are found within similar areas and may therefore be similarly impacted by the affects of dredging. In reality, grey seals may be less sensitive to any impacts than common seals as they are known to prefer rocky coastlines and are found in lower numbers within the MAREA area than common seals. However on the basis of the available data, a conservative approach is taken and the same impact assessment criteria are applied to both. The following impact assessment therefore discusses 'seals' as a group rather than the individual species.

(1) Under the EC Habitats Directive, Annex I covers habitats, Annex II species requiring designation of special areas of conservation, Annex IV species in need of strict protection, and Annex V species whose taking from the wild can be restricted by European law.

Under the amended Habitats Regulations and the new Offshore Marine Regulations, it is an offence to deliberately disturb European Protected Species in such a way that it is likely that there will be a significant effect on:

- The ability of any significant group of animals of that species to survive, breed or rear or nurture their young.
- The local distribution or abundance of that species.

The only European Protected Species that is strictly protected under Annex IV of the Habitats Directive and recorded in the study area is the harbour porpoise. The MAREA must therefore consider the amended Habitats Regulations during the assessment of any potential impacts to this species that could result from dredging operations in the Outer Thames Estuary.

In light of the designations described above and their keystone role in the ecosystem, all three marine mammal species are considered to be **high value** receptors.

9.4.2 Identification of Potential Impacts on Marine Mammals

Table 9.6 identifies the predicted effects of dredging with reference to whether or not they have the potential to impact harbour porpoises, common seals and grey seals.

Table 9.6 Matrix of Potential Impacts of Dredging on Marine Mammals

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Harbour porpoise	✓	·	✓	·	·	·	·	·	✓	·	·	✓	·
Common seal	✓	·	✓	·	·	·	·	·	✓	·	✓	✓	✓
Grey seal	✓	·	✓	·	·	·	·	·	✓	·	✓	✓	✓

·	Not affected
×	No interaction
✓	Potential interaction

9.4.3 Harbour Porpoise

Presence of Vessel

Future shipping density predictions (see Appendix I) incorporate the future tonnage applications and associated numbers of vessel movements for current licence areas, application areas and prospecting areas within the study area, based on the regional tonnage scenario (i.e. maximum dredging scenario). However, it is worth noting that the presence of other vessels in the region is far greater than the presence of dredging vessels. The future scenario is predicted to result in a potential 150% increase in dredging activity relative to the baseline (which is an average of eight dredgers a day). However, overall dredging activity will still represent a low proportion (approximately 3%) of total shipping traffic in the Outer Thames Estuary.

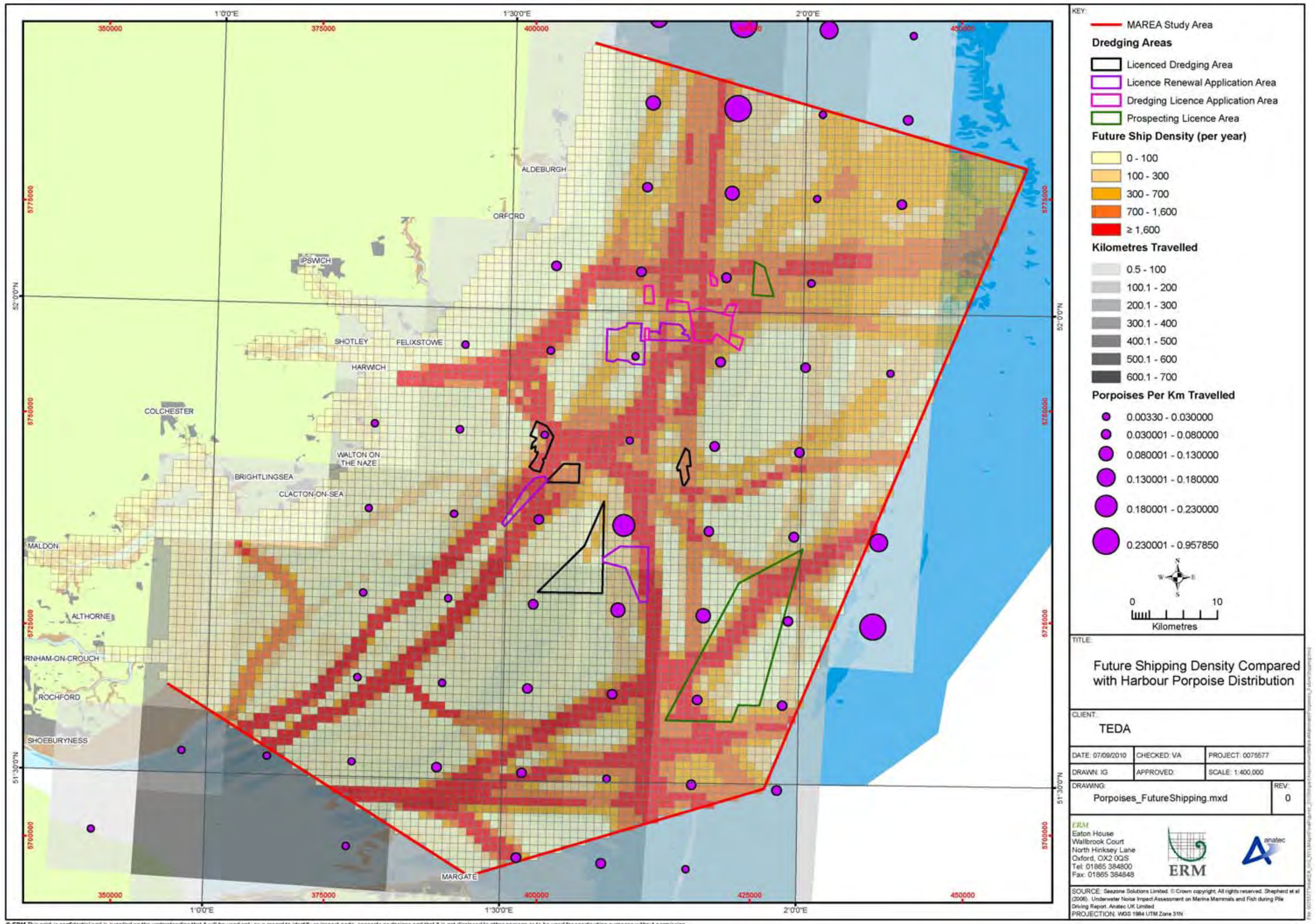
The presence of additional dredging vessels is a **small magnitude** effect, based on it being site-specific in extent, and regularly occurring (routine), however it is transient (temporary) and constitutes a low level change relative to the baseline.

A common response to vessel activity by marine mammals, especially timid species such as harbour porpoise, is to avoid the vessel either by diving or swimming away. This species is therefore classified as having a **medium tolerance** to vessel presence. Its **adaptability** is **high** due to this ability to avoid the vessel by moving away. After the vessel has gone, the harbour porpoise will recover rapidly from any adverse affects, it is therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of harbour porpoise to vessel presence is considered to be **low** to **medium**.

Harbour porpoises are highly mobile and widely distributed throughout the study area. Approximately 20% of the available habitat for harbour porpoises in the study area will be subject to a high level of vessel density based on future dredging scenarios in addition to baseline shipping activity (Figure 9.11). However the additional dredger traffic will mainly use existing, established routes to and from the dredge areas, which harbour porpoises are already likely to avoid.

Based on these assessments of the small magnitude of the effect, the high value and low-medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of dredging vessel presence on this species is considered to be of ***not significant*** at the regional scale.

Figure 9.11 Future Shipping Density Compared with Harbour Porpoise Distribution



Fine Sediment Plume

The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

The harbour porpoise has a **high** level of **tolerance** to an increase in turbidity as a result of the presence of a fine sediment plume, as it uses echo-location rather than sight to forage for play, therefore its ability to feed will not be affected by reduced visibility in the water column. It has a **high adaptability** to the plume as it is capable of swimming away and avoiding areas of elevated turbidity. After dredging activities have ceased, the population will return to its baseline status, as individuals will return to any areas they have avoided, therefore its **recoverability** is **high**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of harbour porpoise to a fine sediment plume is considered to be **low**.

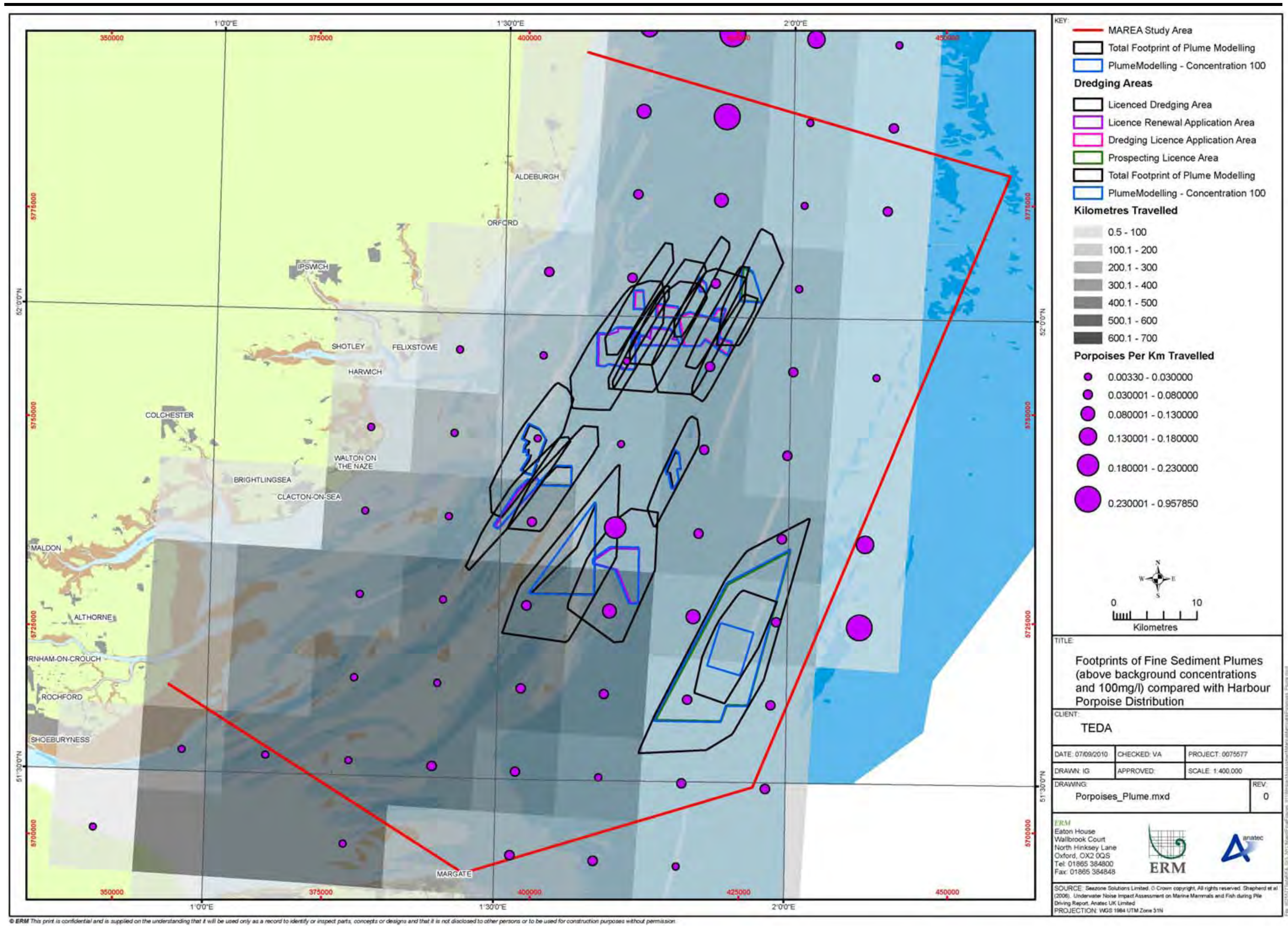
Harbour porpoises are widely distributed throughout the study area. Fine sediment plumes with concentrations above background levels are predicted to impact on approximately 16.6% of this region at some point over the next 15 years, and plumes with concentrations of 100 mg l^{-1} or higher are predicted to impact on approximately 5.7% of the available habitat (Figure 9.12). However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in a licence area would be much smaller than the modelled plumes in Figure 9.12; the plume >50 mg l^{-1} from a single vessel would cover approximately 0.0018% of the available habitat for harbour porpoise.

Based on these assessments of the small-medium magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the fine sediment plumes on this species is assessed to be ***not significant*** at the regional scale.

Underwater Noise

Several studies have investigated hearing in harbour porpoises using auditory brainstem-responses (ABR) or behaviourally, using psychometric methods.

__Figure 9.12 Footprints of Fine Sediment Plumes (above background concentrations and 100mg l^{-1}) compared with Harbour Porpoise Distribution__



Harbour porpoises exhibit a very wide hearing range and are most sensitive from 16 – 140 kHz (Kastelein *et al*, 2002).

Behavioural responses due to noise from the dredging activities may occur at up to approximately 5 km from dredging vessels, but within this zone there is considered to be a 'low likelihood of disturbance' (as discussed in the Underwater Noise Assessment in Appendix K). Mild behavioural reactions may occur within 2 km of dredging vessels, and strong reactions within 500 m.

Underwater noise that elicits a strong behavioural response from a harbour porpoise is regularly occurring (routine) and constitutes a high level of change relative to the baseline, however it is temporary and site-specific in nature. It is therefore assessed as being a **medium magnitude** effect.

Noise levels that result in a mild behavioural response are localised, temporary, regularly occurring and are a medium level of change relative to baseline noise levels. Therefore this is a **small-medium magnitude** effect.

Underwater noise levels that are classified as having a low likelihood of effect on harbour porpoises are widespread (sub-regional), temporary, routine and a low level of change relative to baseline noise. This is therefore a **small-medium magnitude** effect.

The harbour porpoise has a **high tolerance** and **adaptability** to underwater noise, as it is highly mobile and capable of avoiding noise disturbances caused by dredging. It also has a **high** level of **recoverability**, as individuals will return to an area quickly, following the cessation of dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of harbour porpoise to underwater noise from dredging is considered to be **low**.

The proportion of the study area which will be subject to noise disturbance within the 'strong behavioural reaction or 'mild behavioural reaction' thresholds (i.e. up to 2 km) from any single dredger is very small relative to the total available habitat for the species (12.6 km^2 out of a total available area of 5520 km^2 in the MAREA study area, or 0.22%). However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, and when the potentially impacted areas around all of the licence areas are considered together (as shown in Figure 9.13) the area covered represents 15% of the habitat available in the Thames region. Based on this assumption the cumulative impact of dredging noise on this species is assessed to be of ***moderate significance*** at the regional scale.

In practice, this level of dredging is clearly not possible, not least because it would require a fleet of at least 65 vessels. However, as it is not possible for TEDA member companies to specify the maximum numbers of dredgers within each licence area at the present time, this is the only scenario that can be assessed within the MAREA. Consequently it is expected that during the licence-specific EIAs, when the maximum numbers of vessels per licence area has been defined and the licence areas have been provisionally zoned, the predicted cumulative impact to harbour porpoise will be considerably lower than stated here.

Changes to Distribution of Fish species

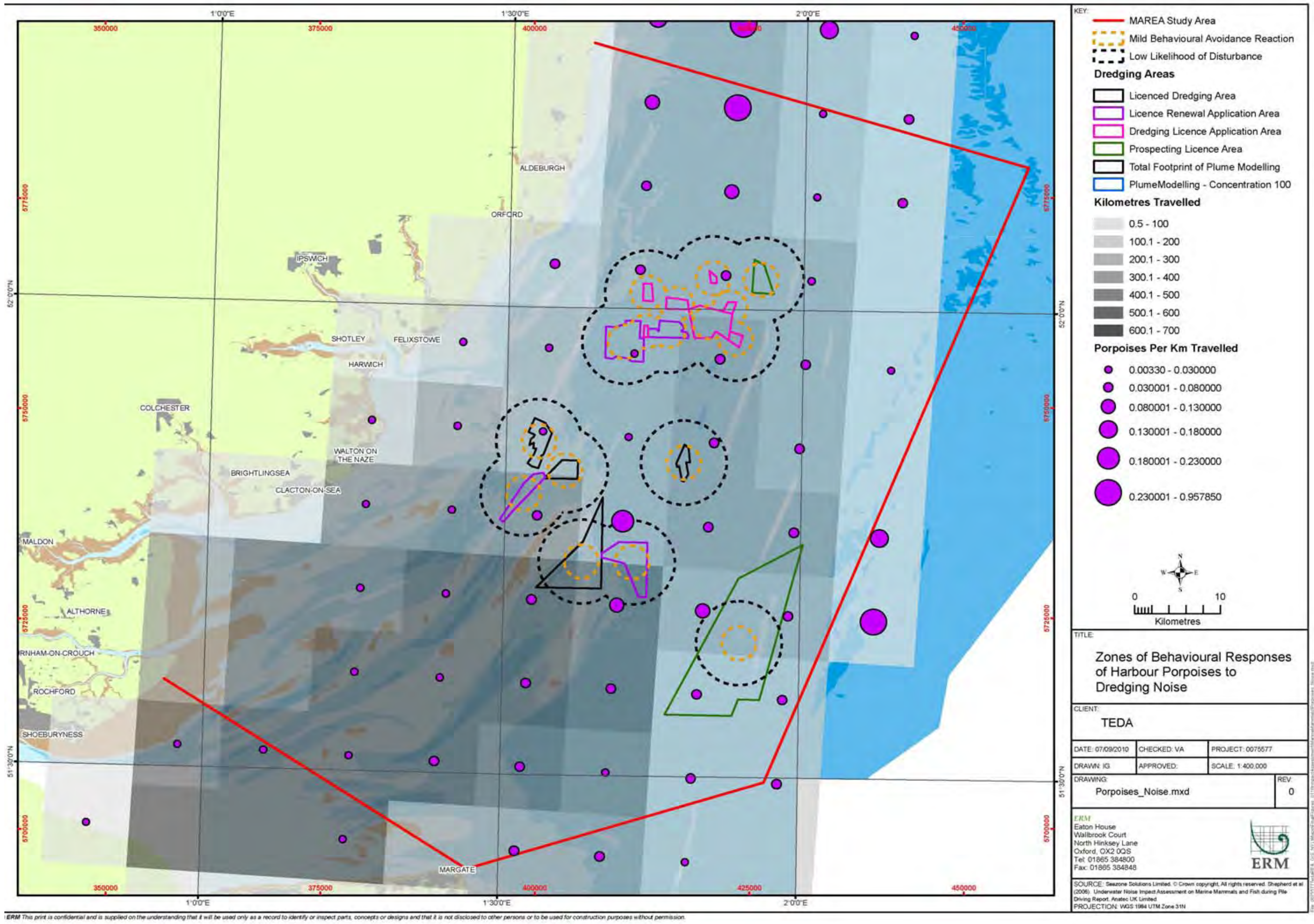
Information from the fish ecology impact assessment (Section 9.3) suggests that with regard to fish species that are important prey items for harbour porpoises, there may be impacts of significance to sprat, herring, and whiting, but these will be minor at most. A change to the distribution of fish species as a result of dredging operations is a **small magnitude** effect based on its localised and transient nature, the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

The harbour porpoise has a **medium** level of **tolerance** to changes in the distribution of its prey as it may be adversely affected through the loss of foraging opportunities. Its level of **adaptability** to this effect of dredging is assessed to be **high** as it preys on a wide variety of fish species over wide ranges, therefore it may be capable of altering its diet as well as its foraging areas if a particular prey species is impacted. Harbour porpoises are likely to return to the area rapidly after dredging has stopped, particularly as impacts to fish populations are expected to be temporary and small in the context of impacts from fishing; therefore its **recoverability** is assessed as **high**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of harbour porpoise to a change to the distribution of fish is considered to be **low**.

Harbour porpoises and their prey species are widely distributed throughout the study area, but the dredged area and thus the proportion of the fish populations which will be redistributed, will only comprise a very small part of this available habitat. Therefore only a small proportion of the population will be affected.

Based on these assumptions on the magnitude of the effect, the value and sensitivity of the receptor and the degree of interaction between the receptor and the effect, the cumulative impact of changes to the distribution of fish species on the harbour porpoise is assessed to be of ***minor significance*** at the regional scale.

Figure 9.13 Zones of Behavioural Responses of Harbour Porpoises to Dredging Noise



9.4.4 Seals

Presence of Vessel

As described in Section 9.4.3, future shipping density predictions show a potential 150% increase in dredging activity over the baseline (Appendix I). However, in overall traffic terms, dredging activity will still represent a low proportion of total vessel movements; approximately 3%.

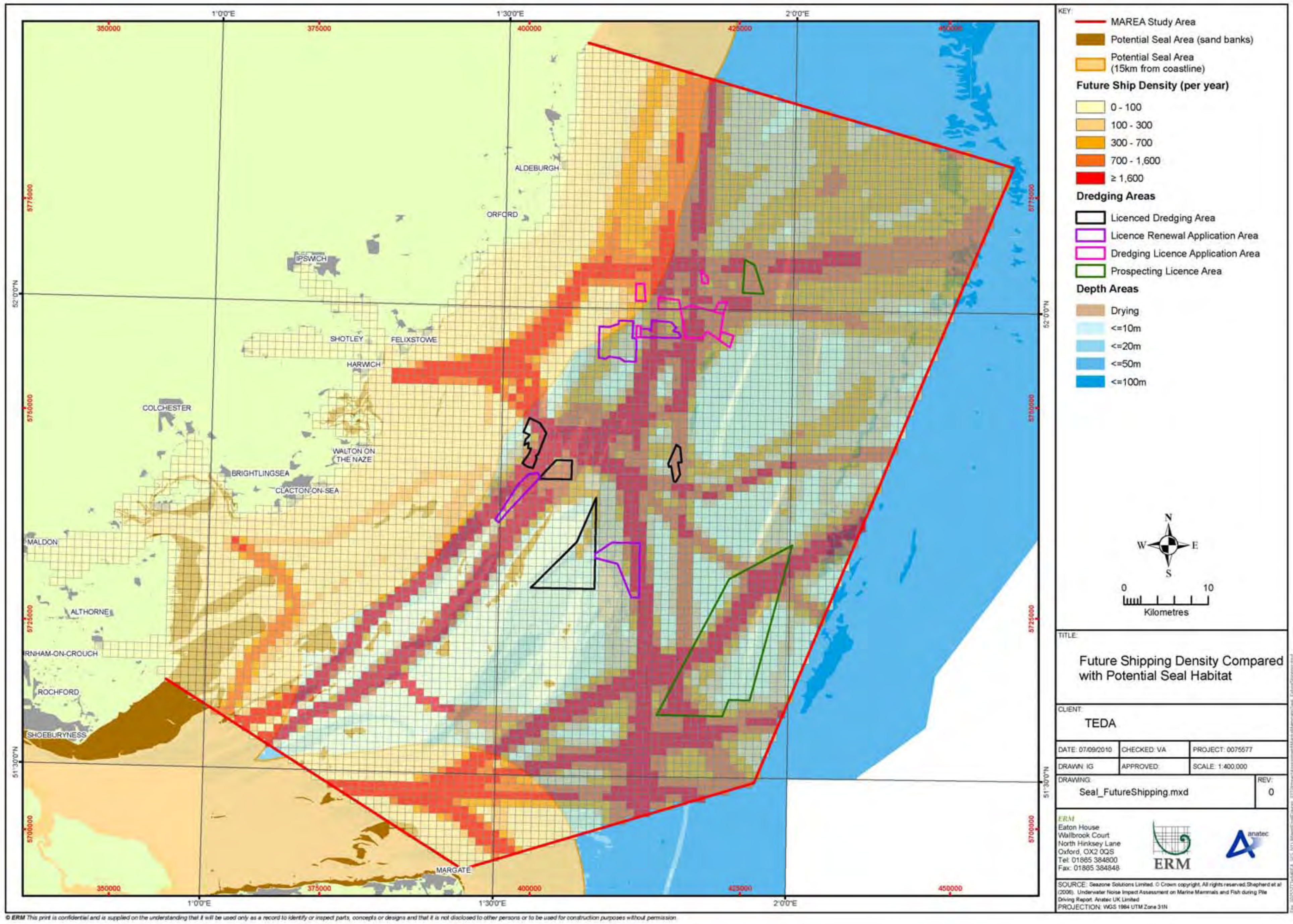
The presence of the dredging vessel is a **small magnitude** effect, based on it being site-specific in extent, and regularly occurring (routine), however it is transient (temporary) and constitutes a low level change relative to the baseline.

A common response to vessel activity by marine mammals is to avoid the vessel either by diving or swimming away. However seals are by their nature inquisitive and have been known to approach fishing vessels (EON, 2008). Seals are therefore classified as having a **high tolerance** to vessel presence, and a **high adaptability** as a result of being able to avoid the vessel by moving away. After the vessel has gone, seals will recover rapidly from any adverse affects, and are therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to vessel presence is considered to be **low**.

Approximately 11.8% of the available habitat for seals in the study area will be subject to a high level of vessel density based on future dredging scenarios compared to 11.7% for baseline shipping activity (i.e. an increase of just 1%) (Figure 9.14). However the additional dredger traffic will mainly use existing, established routes to and from the dredge areas, which seals are already likely to be accustomed.

Based on these assumptions on the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of vessel presence on seals is assessed to be ***not significant*** at the regional scale.

Figure 9.14 Future Shipping Density compared with Potential Seal Habitat



Fine Sediment Plume

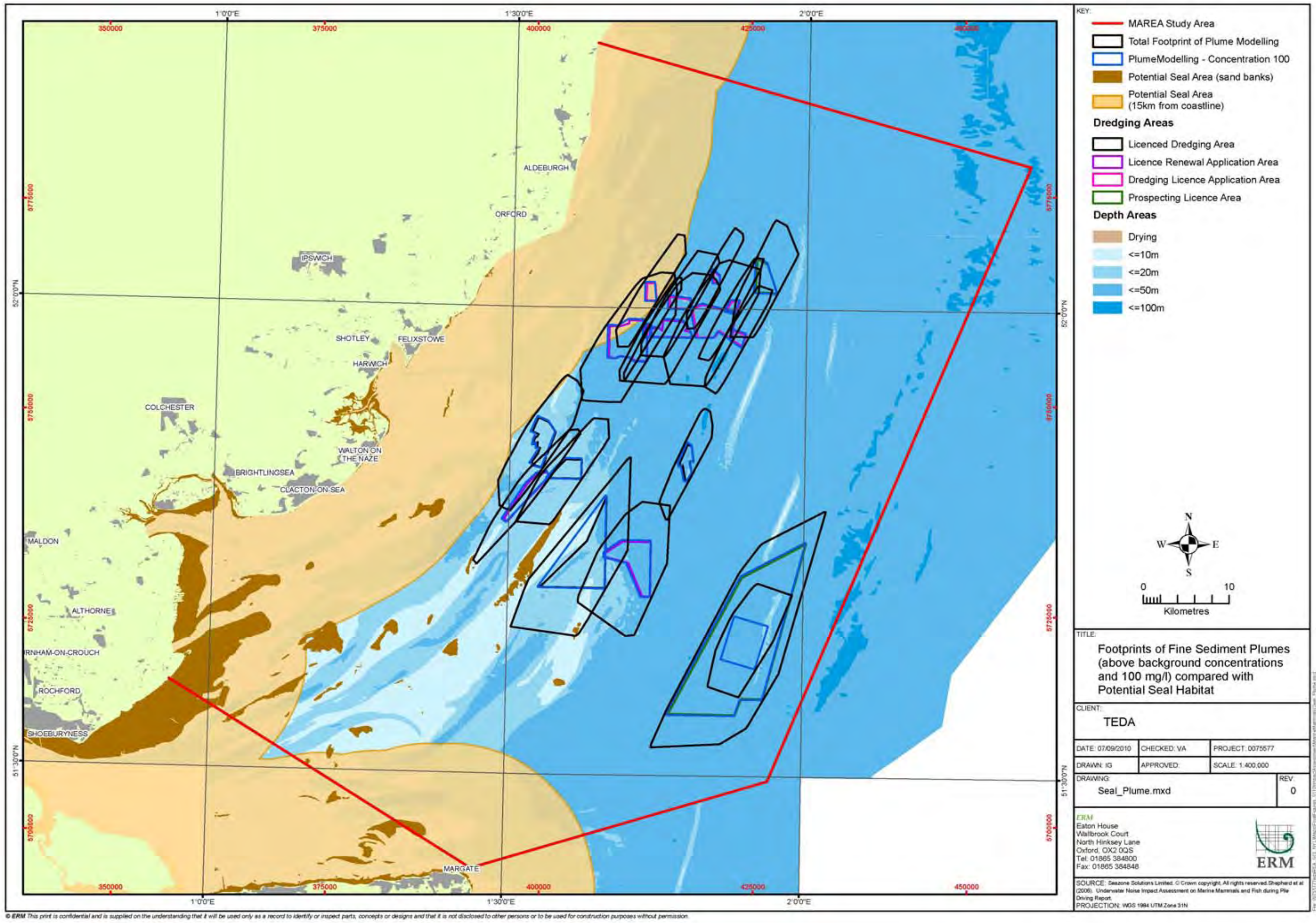
The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

Seals primarily use vision to locate their prey. An increase in turbidity as the result of the presence of a fine sediment plume, will reduce visibility in the water column, therefore seals are considered to have a **low-medium tolerance** to this effect of dredging. They have **high adaptability** to the plume as they can swim away and avoid areas of turbidity, and following cessation of dredging they will re-populate dredged areas rapidly, therefore their **recoverability** is assessed to be **high**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to vessel presence is considered to be **medium**.

Seals generally remain in close proximity to coastal haul out sites away from areas where elevated turbidity as a result of dredging is predicted to occur. Fine sediment plumes with concentrations above background levels are predicted to impact on approximately 3.1% of potential seal habitat, and plumes with concentrations of 100 mg l^{-1} or higher are predicted to impact on approximately 0.4% of the available habitat at some point during the period of the MAREA (Figure 9.15). However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in a licence area would be much smaller than the modelled plumes in Figure 9.15; the plume >50 mg l^{-1} from a single vessel would cover approximately 0.005% of the available habitat for harbour porpoise.

Based on these assessments of the small-medium magnitude of the effect, the high value and medium sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of the fine sediment plumes on seals is assessed to be of ***minor significance*** at the regional scale.

Figure 9.15 Footprints of Fine Sediment Plumes (above background concentrations and 100 mg l^{-1}) compared with Potential Seal Habitat



Underwater noise

Seals are mostly found on sandbanks and haul-outs close to the coast. Some suitable areas in the vicinity of application area 452 and licence areas 118/2, 239/1, 447, 108/1, 257 and 119/3 fall within the boundary of a 'low likelihood of disturbance' (as discussed in the Underwater Noise Assessment in Appendix K). However this level of potential impact is not thought to be significant. Mild and strong behavioural reactions are expected within 500 m and 70 m respectively of dredgers active in Areas 452A and 118/2.

Underwater noise that elicits a strong behavioural response from a seal is regularly occurring (routine) and constitutes a high level of change relative to the baseline; however it is temporary and site-specific in nature. It is therefore assessed as being a **medium magnitude** effect.

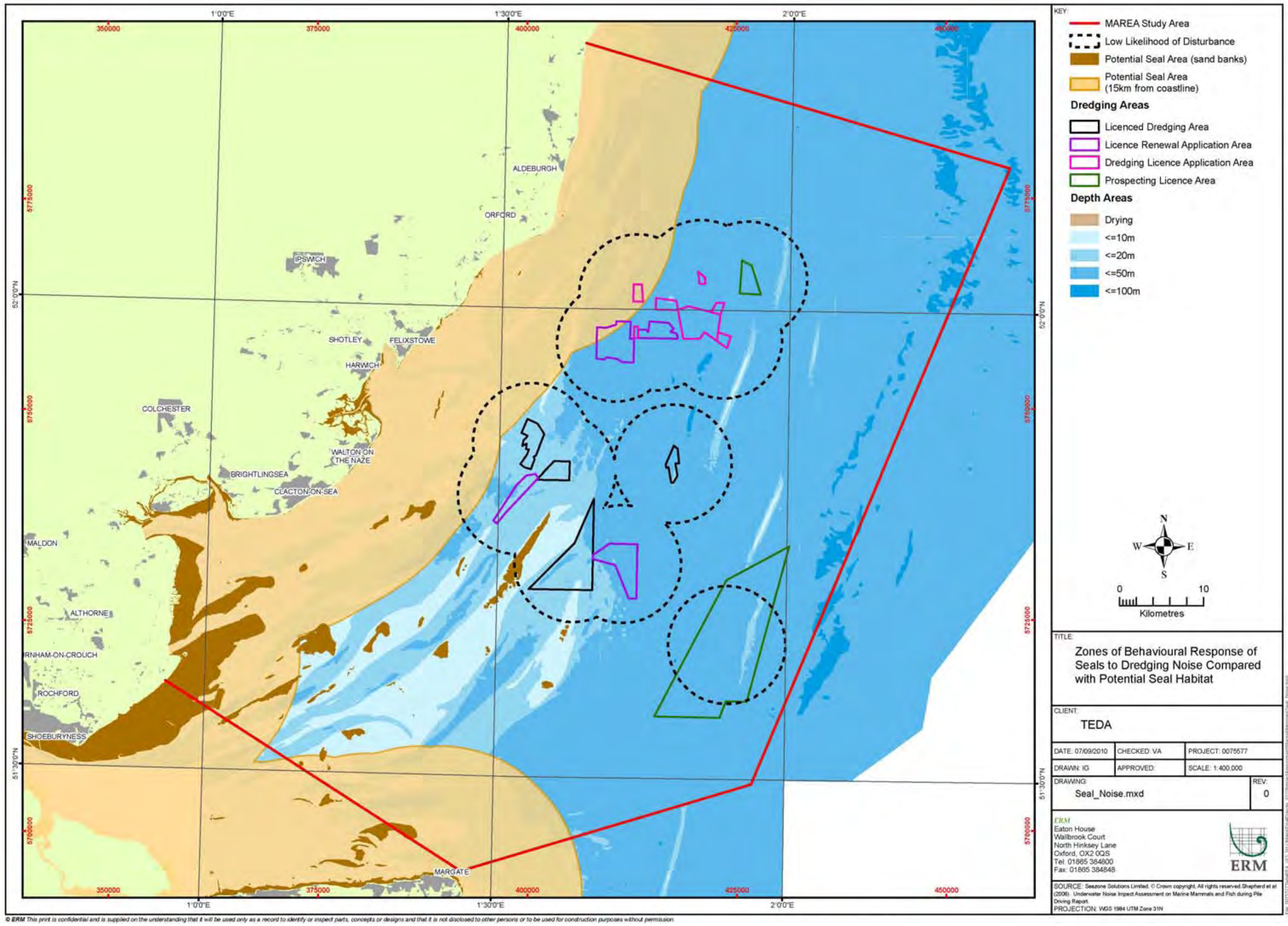
Noise levels that result in a mild behavioural response are regularly occurring but are localised, temporary and represent a low level of change relative to baseline noise levels. Therefore this is a **small-medium magnitude** effect.

The effect of underwater noise levels that are classified as having a low likelihood of effect on seals are widespread (sub-regional) and routine but are temporary and represent a low level of change relative to baseline noise. This is therefore a **small-medium magnitude** effect.

Seals have **medium tolerance** to underwater noise, as their hearing range extends over a very wide frequency range. The area of best hearing is between 8 and 16 kHz, with acute hearing also at lower frequencies. They are more sensitive to underwater noise than harbour porpoises (Appendix K). Seals are considered to have **medium adaptability** to underwater noise as they will be able to avoid noise sources by swimming away, however they are restricted to staying within the vicinity of specific haul out sites in the study area. Their **recoverability** to noise disturbance is **high**, and they will repopulate an area rapidly at the end of the dredging period. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to underwater noise is considered to be **medium**.

However the potentially impacted area constitutes a very small proportion of the study area which this species is thought to inhabit (Figure 9.16). In addition this assessment is based on the assumption that dredging takes place throughout each licence area at all times. Based on these assumptions on the magnitude of effect, the value and sensitivity of the receptor and the degree of interaction between the receptor and the effect, the cumulative impact of dredging noise on the seals is considered to be of ***minor significance***.

Figure 9.16 Zones of Behavioural Response of Seals to Dredging Noise compared with Potential Seal Habitat



As described in Section 9.4.3 above, the noise footprint at any single time will be much smaller than shown in Figure 9.16 and once the maximum numbers of vessels per licence area has been defined and the licence areas have been provisionally zoned, the predicted area of noise impact to seals is likely to be considerably lower than stated here.

Changes to Benthic Community Composition

A change to the composition of the benthic community as a result of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence in the existing licence areas as in the majority of cases the seabed that is dredged will have been dredged previously. As a result it is classified as a **medium-large magnitude** effect.

Seals do eat crustaceans and other benthic species; however these represent a very small proportion of their diet compared to fish species. Consequently seals have **high tolerance** to local changes to benthic community composition, **high adaptability** as a result of their ability to find other prey species elsewhere, and **high recoverability** as they will quickly return to eating benthic species when they are available again. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to changes to benthic community composition is considered to be **low**.

Seals generally remain in close proximity to coastal haul out sites away from the majority of the dredging activity. Therefore the dredged area and thus the proportion of the benthic community that will be impacted, only comprises approximately 0.25% of the available habitat for seals and the degree of regional interaction is therefore **very small**.

Based on these assessments of the medium-large magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to benthic community composition on seals is assessed to be of ***not significant*** at the regional scale.

Changes to Distribution of Fish Species

Information from the fish ecology impact assessment (Section 9.3) suggests that with regard to fish species that are important prey items for seals, there may be impacts of significance to sprat and herring, but these will be minor at most. A change to the distribution of fish species as a result of dredging operations is a **small magnitude** effect based on its localised and transient nature, the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

Seals have a **high tolerance** to a change in the distribution of fish species, as they feed on a wide variety of prey and will be able to exploit other food sources. They have **medium adaptability** as they can avoid dredging locations by moving to other areas to forage, however this will result in a decrease in available foraging opportunities. Seals are thought to have a **moderate** level of **recoverability** as they will re-populate an area rapidly following dredging, but it may take some time for the populations of prey species to recover. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to a change in the distribution of fish is considered to be **medium**.

However their distribution is concentrated in the inshore areas of the estuary, away from the majority of the dredging activity. Therefore the dredged area and thus the proportion of the prey fish populations that will be redistributed will only comprise a very small part of available habitat for seals. In addition it is possible that fish from licence areas further offshore will be displaced into the coastal areas where seals forage, potentially increasing the availability of prey for seals in the coastal environment.

Based on these assumptions on the small magnitude of the effect, the high value and medium sensitivity of the receptor, the very small degree of interaction between the receptor and the effect, and the potential for positive (compensatory) effects on prey availability, the cumulative impact of changes to the distribution of fish species on seals is assessed to be ***not significant*** at the regional scale.

Changes to Sandbanks

Information from the sandbanks impact assessment (Section 8.2) suggests that there may be impacts of significance to sandbanks, but these will be minor at most. A change to sandbanks as a result of dredging operations is a **small magnitude** effect based on the fact that it is a routine effect that is medium term in duration; however any changes are very localised and constitute a low level of change relative to baseline levels (sandbanks are naturally mobile features).

Seals have a **high tolerance** to a change to sandbanks, as the sandbanks which they use as haul outs are currently subject to high levels of natural mobility. They have **medium adaptability** as they can move to other available haul outs; however as they have a high tolerance to a change to sandbanks they should not need to adapt. Seals are thought to have a **moderate** level of **recoverability** as they will re-populate an area rapidly following disturbance by dredging, but it may take some time for the populations of prey species to recover. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of seals to a change in to sandbanks as a result of dredging is considered to be **low**.

The **degree of interaction** between potential changes to sandbanks and seal distribution is assessed to be very **small** as any significant changes to sandbanks are most likely to occur within the licence area boundaries, which only overlap with a very small proportion of available sandbank habitat and do not include the sandbank drying areas which seals haul out on.

Based on these assumptions on the small magnitude of the effect, the high value and medium sensitivity of the receptor, the small degree of interaction between the receptor and the effect, the cumulative impact of changes to the sandbanks on seals is assessed to be ***not significant*** at the regional scale.

9.4.5 Summary of Impacts

Table 9.7 summarises the significance of the cumulative impacts of dredging on marine mammals at the regional scale.

Table 9.7 Regional Significance of Impacts to Marine Mammals from Dredging in the Outer Thames

Effect of Dredging	Harbour Porpoise	Common Seal	Grey Seal
Presence of the vessel	*Not sig*	*Not sig*	*Not sig*
Fine sediment plume/elevated turbidity	*Not sig*	*Minor*	*Minor*
Underwater noise	*Moderate*	*Minor*	*Minor*
Change to benthic community composition		*Not sig*	*Not sig*
Change to distribution of fish	*Minor*	*Not sig*	*Not sig*
Changes to sandbanks		*Not sig*	*Not sig*
Overall significance of dredging	*Minor-Moderate*		

The impacts to marine mammals from dredging that are predicted to be significant range from ***minor*** to ***moderate*** significance and are likely to only affect individuals or small groups of species at any one time.

Impacts to marine mammals will be discussed in all the individual EIAs in the context of 'deliberate disturbance' to European Protected Species (EPS), and the measures employed to avoid this.

In addition **Area 452 A** and **Area 118/2** will also need to discuss the potential for impacts from dredging noise on seals at the localised scale, as these licence areas are situated within the area that is predicted to be an important habitat for common and grey seals.

Area 452 A, **Area 452 E**, **Area 118/2**, **Area 108/1**, **Area 257**, and **Long Sand Head licence (Area 108/3, 109/1, 113/1),** will need to refer to the effects of the sediment plumes generated within their licence areas on seals, based on the modelling carried out as part of the MAREA.

9.5 BIRDS

9.5.1 Introduction

This section presents the assessment of impacts to birds as a result of the proposed dredging operations within the TEDA area. The impacts are presented by the following species or species group, highlighted as being of importance to the study area within the baseline (Section 5.5):

- Red-throated divers;
- Gannets;
- Auks;
- Seaducks;
- Gulls; and
- Terns

Red-throated Divers

Red-throated divers are only present within the TEDA MAREA area (the study area) during the winter (see Section 5.5) and so this assessment relates to the impacts to the wintering population. They are a **high value** species due to their conservation status. They are listed on the Amber List of Species of Conservation Concern and in Annex I of the Birds Directive, and Schedule 1 of the Wildlife and Countryside Act.

Gannets

Gannets may be found within the study area during all seasons as sub-adult birds may disperse over wide areas and breeding pairs may forage over large distances from breeding colonies. Although the majority of records came from the winter period there were some records of gannets during the summer (see Section 5.5) and so the sections below relate to the impacts to both the wintering and summer populations. Gannet numbers are relatively low within the study area and they are considered to be bird species of **medium value** as a receptor as they are listed on the Amber List of Species of Conservation Concern.

Auks

Auks were recorded in very low numbers during the summer surveys but in relatively high numbers during the winter season. Therefore this assessment relates to impacts to the wintering population. Auks are widespread and common throughout the study area in winter (see Section 5.5) and are considered to be of **medium value** as receptors as they are listed on the Amber List of Species of Conservation Concern.

Common Scoters

Common scoters were the most common seaduck species recorded during the winter surveys and so this impact assessment concentrates on impacts to this species. Common scoters were only present within the study area during the winter (see Section 5.5) and therefore this assessment relates to impacts to the wintering population. Common scoters are considered to be **medium value** as a receptor within the study area, as they are listed on the Red List of Species of Conservation Concern, although this is because of their decreasing breeding population rather than their wintering population.

Gulls

Gull species were recorded within the study area during both the summer and winter survey periods (see Section 5.5) and so the impacts discussed are relevant to both summer and winter populations using the area. Although gull numbers in the study area are relatively high, in most cases they represent a small proportion of the regional populations of each species and are considered to be of **medium value**. Herring, lesser black-backed, black headed, common and Mediterranean gull are all on the Amber List of Species of Conservation Concern. The exception to this is little gull which passes through the area on passage in potentially nationally important numbers and is considered to be of **high value**.

Terns

Terns were recorded as being present within the study area during the summer surveys only (see Section 5.5) and so this assessment reflects the potential impacts to the summer breeding population. Tern numbers are relatively low within the study area and they are considered to be of **medium value** as receptors. All species of tern are listed in *Annex I of the Birds Directive*, in *Schedule 1 of the Wildlife and Countryside Act*. Sandwich, little and arctic tern are all on the Amber list of Species of Conservation Concern.

9.5.2 Identification of Potential Impacts on Birds

Table 9.8 highlights the impacts from dredging which may potentially interact with the relevant groups of birds identified within the baseline.

Table 9.8 Matrix of Potential Impacts of Dredging on Birds

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Red-throated diver	✓		✓									✓	✓
Gannets	✓		✓									✓	✓
Auks	✓		✓									✓	✓
Seaducks	✓		✓								✓	✓	✓
Gulls	✓		✓									✓	✓
Terns	✓		✓									✓	✓

·	Not affected
×	No interaction
✓	Potential interaction

The effects of dredging most likely to interact with and have the potential to impact bird species within the MAREA area, are presence of the vessel, fine sediment plume/elevated turbidity, changes to benthic community composition, changes to the distribution of fish and changes to sandbanks.

Presence of the Vessel

Future shipping density predictions incorporate the future tonnage application and associated number of vessel movements for current licence areas, application areas and prospecting areas within the study area, based on the regional tonnage scenario (ie maximum tonnage scenario). The future scenario is predicted to result in a potential 150% increase in dredging activity relative to the baseline. The overall dredging activity will still represent a low proportion (approximately 3%) of total shipping traffic in the Outer Thames Estuary.

The presence of additional dredging vessels has been identified as a **small magnitude effect**, due to the site specific, regularly occurring and transient nature of the impact which represents a small level change relative to the baseline.

Fine Sediment Plume/Elevated Turbidity

Dredging will result in elevated levels of suspended sediments against background levels, with zones around the dredged areas of different sediment concentrations. The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

Changes to Benthic Community Composition

A change to the distribution of benthic communities as a result of dredging is predicted to be an intermittent local impact which will last over the medium term. The scale of the impact is predicted to be a medium impact with respect to the baseline and the overall magnitude is predicted to be **medium-large**.

Changes to Distribution of Fish

A change to the distribution of fish species as a result of dredging operations is a **small magnitude** effect. This is based on the localised and transient nature of the change and the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine). Herring are a common prey species for a number of bird species in the Thames Estuary. However, without the contribution of Area 504 to the cumulative impacts of dredging, the significance of the impacts related to herring are regarded as ***not significant*** (see Section 9.3).

Changes to Sandbanks

Information from the sandbanks impact assessment (Section 8.2) suggests that there may be impacts of significance to sandbanks, but these will be minor at most. A change to sandbanks as a result of dredging operations is a **small magnitude** effect based on the fact that it is a routine effect that is medium term in duration; however, any changes are localised and constitute a low level of change relative to baseline levels (sandbanks are naturally mobile features).

The following sections assess the impacts of these interactions by species group.

9.5.3 Red-throated Diver

Presence of the Vessel

Red throated divers are known to be a shy species which will avoid boats and may maintain a stand off distance of up to 4 km from vessels (Maclean *et al*, 2006), although they have been known to become habituated to vessel movements in some areas. The current distribution of red-throated divers shows that they are present at moderate to high relative densities within active licence areas including Area 108/3, 109/1, 113/1 and Area 327. There is likely to be most interaction between divers and new licence areas within Area 452, which represents approximately 0.46 % of the study area.

Given their avoidance of boats, red-throated divers have been classified as having a **low** level of **tolerance** to the presence of vessels, and a **low adaptability** as they have fairly specific habitat requirements in terms of water depth preferences. They have a **high recoverability** however, and are likely to return to favoured feeding areas once vessels have left an area. Their overall **sensitivity** to the presence of dredging vessels has been classified as **medium**.

Based on these assessments of the small magnitude of the effect, the high value and medium sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on this species is assessed to be of ***minor significance*** at the regional scale.

Fine Sediment Plume/Elevated Turbidity

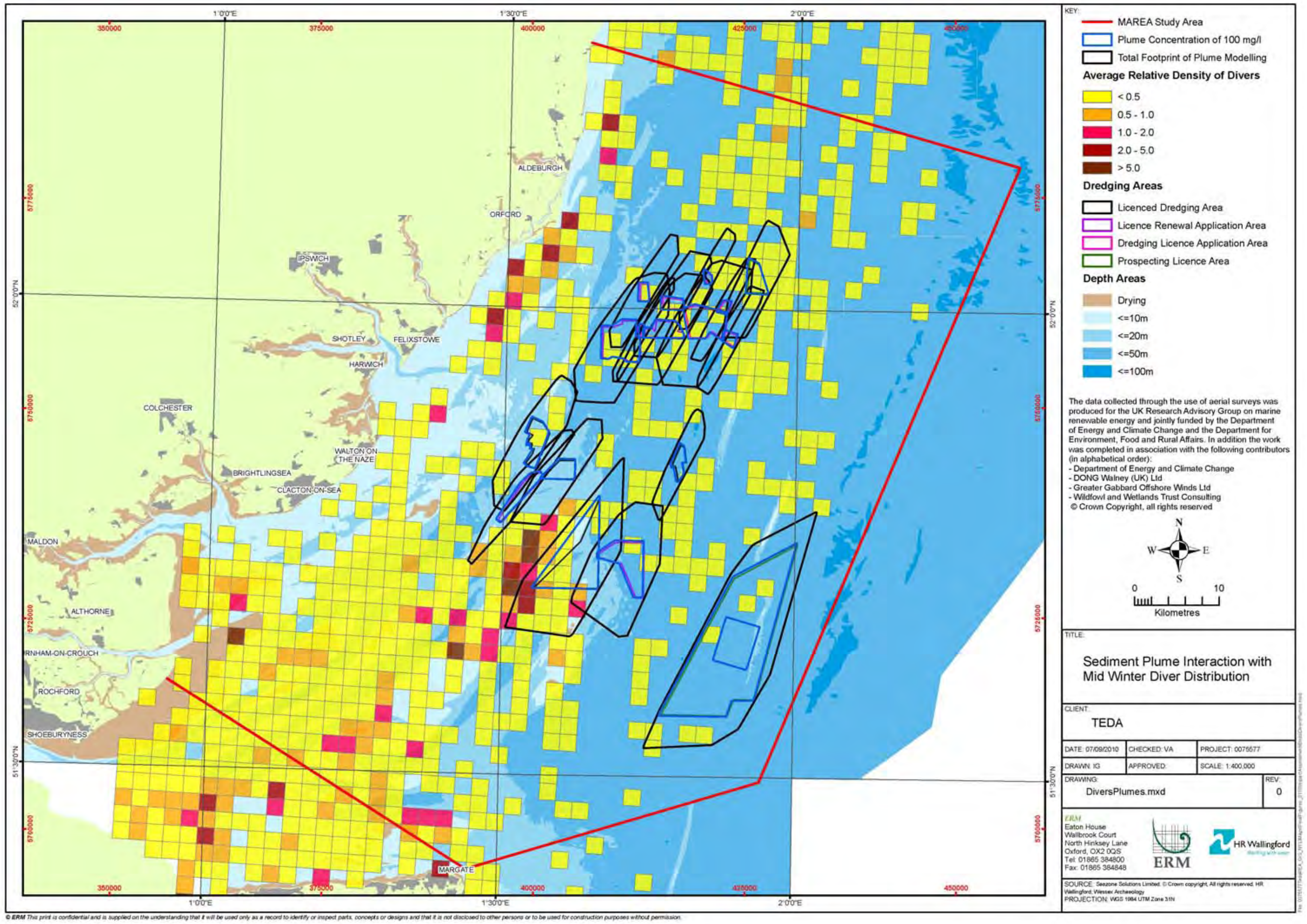
Divers feed predominantly by sight and although they often forage in estuary habitats with elevated levels of suspended sediment, highly elevated levels may reduce feeding success. Hence they have been assigned a **medium** level of **tolerance** to elevated levels of suspended sediment. They are believed to have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns to take advantage of changing prey distribution, and will follow fish prey if they move away from areas of elevated suspended sediment. The **recoverability** of red throated divers to elevated suspended sediment levels is also believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to normal. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of this species to the sediment plume is considered to be **low**.

Fine sediment plumes with concentrations above background levels are predicted to impact on approximately 16.55% of the MAREA study area at some point over the next 15 years, and plumes with concentrations of 100mg l^{-1} or higher are predicted to impact on approximately 5.68% of the area. These areas equate to approximately 16.38% and 4.83% of the available foraging habitat for red-throated divers (areas that have water depth equal or less than 30 m). The main areas of interaction between suspended sediment plumes and red throated divers are predicted to be around Area 108/3, 109/1, 113/1, Area 108/1 and Area 257, where the average density of wintering divers is highest (see Figure 9.17).

The assessment of the area impacted is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will only be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in a licence area would therefore be much smaller than the modelled plumes.

Based on these assessments of the small-medium magnitude of the effect, the high value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of the fine sediment plumes on this species is assessed to be of ***minor significance*** at the regional scale.

Figure 9.17 Sediment Plume Interaction with Mid Winter Diver Distribution



Change to Distribution of Fish

Divers are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns in line with changing prey distribution. The **recoverability** of red throated divers to changes to the distribution of fish is also believed to be **high** as their foraging strategy will focus on areas with high prey availability and they will follow shoals of fish in response to changes in distribution. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species is considered to be **low**.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the predicted distribution of divers and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the high value and low sensitivity of the red-throated diver, and the degree of interaction between receptor and effect, the cumulative impact of changes to the distribution of fish is assessed as ***not significant*** at the regional scale.

Changes to Sandbanks

Red-throated divers have a preference for areas with water less than 30m deep (Cork Ecology, 2004). In addition sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on distribution of red-throated diver.

Divers are believed to have a **medium** level of **tolerance** to changes to sandbanks as they have fairly narrow habitat preferences. They have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns in line with changing habitat or prey distribution at a local level. The **recoverability** of red throated divers to changes in sandbanks is also believed to be **high** as they will rapidly return to suitable habitats following the cessation of dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to changes to sandbanks is considered to be **low**.

Given the small magnitude of the impact of changes to sandbanks, the high value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks on red throated divers is assessed as being of ***minor significance*** at the regional scale.

9.5.4 Gannets

Presence of the Vessel

Gannets are a highly mobile species, which forage over a wide area. They are believed to have a **high** level of **tolerance** to the presence of vessels within the study area, a **high** level of **adaptability**, and also a **high** level of **recoverability** once vessels are no longer present. Given their high levels of tolerance, adaptability and recoverability, the overall **sensitivity** of gannets to the presence of vessels is considered to be **low**.

Gannets are thought to occur in relatively low numbers within the study area, though data on their spatial distribution is not available (see Section 5.5). They are therefore assessed as having a relatively small degree of interaction with the licence areas in the MAREA area, and any associated dredging vessel activity.

Taking into consideration the small magnitude of the presence of vessels, the low sensitivity of the receptor, and the small degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on gannets is assessed as ***not significant*** at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Gannets are believed to have a **medium** level of **tolerance** to elevated levels of suspended sediment. They hunt by plunge diving from height and rely on sight to locate prey and very elevated levels of suspended sediment may reduce feeding success. They are believed to have a **high** level of **adaptability** as they are a very mobile species which will forage over a very wide area and are capable of adapting foraging patterns in line with changing prey distribution. The **recoverability** of gannets to elevated suspended sediment levels is also believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to normal. Given their medium level of tolerance to elevated suspended sediment and their high level of adaptability and recoverability, the **sensitivity** of the species to this effect is considered to be **low**.

Gannets are thought to occur in relatively low numbers within the study area, though data on their spatial distribution is not available (see Section 5.5). They are therefore assessed as having a relatively small degree of interaction with the licence areas and their associated sediment plumes within the MAREA area.

Given the small-medium magnitude of the impact of the fine sediment plume and elevated turbidity, the medium value and low sensitivity of gannets, and the degree of interaction between receptor and effect, the cumulative impact of changes to levels of suspended sediment on gannets is assessed as ***not significant*** at the regional scale.

Change to Distribution of Fish

Gannets are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a highly mobile species which forage over a very large area. The **recoverability** of gannets to changes to the distribution of fish is also believed to be **high** as they will alter their foraging patterns in response to changes in prey distribution and will readily exploit changes in prey distribution once any impacts have ceased. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to this effect of dredging is considered to be **low**.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the potential distribution of gannets and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the medium value and low sensitivity of gannets, and the degree of interaction between receptor and effect, the cumulative impact of changes to the distribution of fish is assessed as ***not significant*** at the regional scale.

Changes to Sandbanks

Sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on the gannet population.

Gannets are believed to have a **high** level of **tolerance** to changes to sandbanks as they forage over wide areas taking a variety of prey species and are not tied to any particular habitat features. They are believed to have a **high** level of **adaptability** as they are a very mobile species capable of adapting foraging patterns in line with changing habitats or prey distribution at a regional level. The **recoverability** of gannets to changes in sandbanks is also believed to be **high** as they will exploit prey species independent of their distribution within the study area and so will exploit sand bank habitats once they recover. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to changes to sandbanks is considered to be **low**.

Given the small magnitude of the impact of changes to sandbanks, the medium value and low sensitivity of gannets to these impacts, and the degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks on gannets are assessed as ***not significant*** at the regional scale.

9.5.5 Auks

Presence of the Vessel

Auks are known to be disturbed by some vessel traffic and show a **medium tolerance** of vessels (Garthe *et al*, 2004). However they are very mobile and widely distributed within the study area and will readily move back to areas once vessels have moved away so they are considered to be **highly adaptable** with a **high ability to recover** from any impacts. The overall **sensitivity** of auks to the presence of additional dredging vessels is therefore considered to be **low**.

The majority of the interaction between the dredging activity and the known distribution of auks occurs during the midwinter period, when moderate to high densities of auks are present across all licence areas. Later in the winter, auks appear to move offshore and are present within the licence areas further offshore such as Area 504 (North Falls). Auks are likely to be temporarily displaced from these areas at some point during the next 15 years of dredging activity. However the increase in dredging vessel numbers is approximately 3% of the total shipping traffic in the Thames Estuary, and the area within which dredging will occur constitutes a small amount of the overall habitat available to Auks within the MAREA area (approximately 5,520 ha).

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on auks is assessed to be ***not significant*** at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Auks are believed to have a **medium** level of **tolerance** to elevated levels of suspended sediments. They rely on sight to locate prey and very elevated levels of suspended sediments may reduce feeding success. They have a **medium** level of **adaptability** as although they disperse widely during winter they spend much of the winter on the sea surface moving by swimming rather than flying. This means they cannot take advantage of widely dispersed sources of prey as readily as some other species. The **recoverability** of auks to elevated suspended sediment levels is believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to background levels. Given their medium level of tolerance and adaptability and high level of recoverability, the **sensitivity** of the species group is considered to be **medium**.

The majority of the interaction between the dredging activity and the known distribution of auks occurs during the midwinter period, when moderate to high densities of auks are present across all licence areas. Later in the winter, auks appear to move offshore and are present within the licence areas further offshore such as Area 504 (North Falls). Auks are likely to be temporarily displaced from these areas at some point during the next 15 years of dredging activity.

Given the small-medium magnitude of the impact of fine sediment plumes and elevated turbidity, the medium value of auks and their medium sensitivity to this impact, and the small degree of interaction between receptor and effect, the cumulative impact of changes to levels of suspended sediment to auks are assessed as being of ***minor significance*** at the regional scale.

Change to Distribution of Fish

Auks are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a mobile species which will forage over a very large area. The **recoverability** of auks to changes to the distribution of fish is also believed to be **high** as they will alter their foraging patterns in response to changes in prey distribution and will readily exploit changes in prey distribution once any impacts have ceased. Following the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to this effect of dredging is considered to be **low**.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the potential distribution of auks and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the medium value and low sensitivity of auks, and the degree of interaction between receptor and effect, the cumulative impact of changes to the distribution of fish is assessed as ***not significant*** at the regional scale.

Changes to Sandbanks

Sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on auks within the MAREA area.

Auks are believed to have a **high** level of **tolerance** to changes to sandbanks as they forage over wide areas taking a variety of prey species and are not tied to any particular habitat features. They are believed to have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns in line with changing habitat or prey distribution at a regional level. The **recoverability** of auks to changes in sandbanks is also believed to be **high** as they are widely distributed across the study area and can exploit other areas if sandbanks features are affected as a result of dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of auks to this effect of dredging is considered to be **low**.

Given the small magnitude of the impact, the medium value and low sensitivity of auks, and the degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks on auks is assessed as being ***not significant*** at the regional scale.

9.5.6 Seaducks

Presence of the Vessel

The most common seaduck recorded within the study area over winter was the common scoter. Common scoters are known to be a shy species which will avoid boats and may maintain a stand off distance of up to 4 km from vessels (Maclean *et al*, 2009). Given their avoidance of boats, common scoter have been classified as having a **low** level of **tolerance** to the presence of vessels, and a **low adaptability** as they have fairly specific habitat requirements in terms of suitable water depth for foraging. They have a **high recoverability** however, and are likely to return to favoured feeding areas once dredging vessels have left an area. The overall **sensitivity** of scoters to the presence of dredging vessels within the study area has therefore been classified as **medium**.

In addition to these factors, the majority of areas where common scoter were recorded during aerial surveys are further inshore than the licence areas, with the greatest concentration of birds found in the south western corner of the study area. There is therefore a limited overlap between vessel presence and areas where scoter have been found, with the majority of interaction occurring during vessel transit to and from the licence areas within existing shipping lanes where there is disturbance from other vessels.

Based on these assessments of the small magnitude of the effect, the medium value and medium sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on this species is assessed to be ***not significant*** at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Common scoters are believed to have a **medium** level of **tolerance** to elevated levels of suspended sediment. They have a **low** level of **adaptability** as they have specific habitat requirements, favouring areas with water depth below 20 m (Maclean *et al*, 2009). Only four of the licence areas considered within the REA area occur within the water depth and so possible impacts are believed to be limited to these licence areas (see Figure 5.37 in Section 5.5). The **recoverability** of common scoters to elevated suspended sediment levels is believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to normal. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to this effect of dredging is considered to be **medium**.

The majority of the common scoter records from the study area are from areas which do not overlap with the licence areas, and only small numbers of scoter are predicted to be affected by sediment plumes.

Based on the above assessments of the small-medium magnitude of the effect, the medium value and medium sensitivity of the receptor, considered together with the very small degree of interaction between receptor and effect, the cumulative impact of the fine sediment plumes on this species is assessed as ***not significant*** at the regional scale.

Change to Benthic Community Distribution

Common scoters are believed to have a **medium** level of **tolerance** to changes to benthic community distribution, as they are largely benthic feeders and so are sensitive to changes in benthic prey distribution which may decrease foraging opportunities. They are assessed as having a **medium** level of **adaptability** as they have specific habitat requirements and require certain benthic habitats to forage in. The **recoverability** of common scoters to changes in benthic community distribution is believed to be **high** however as they will return to areas with high prey availability once benthic communities recover from the effects of dredging. Based on these assessments the sensitivity of common scoters to this effect of dredging is considered to be low-medium.

The known distribution of common scoters within the study area does not overlap with any current or proposed licence areas, therefore the degree if interaction between the receptor and effect is likely to be very small. Only four of the licence areas are in water with depths < 20 m which are

considered suitable for common scoter foraging and so possible impacts are believed to be limited to these licence areas.
Based on the medium-large magnitude of the impact, the low-medium sensitivity of the species, and the small degree of interaction between receptor and effect, the overall impact of changes to the benthic community on common scoter are predicted to be ***not significant.***

Change to Distribution of Fish

Common scoters are believed to have a **high** level of **tolerance** to changes to the distribution of fish, as only a small part of their diet is made up of small fish species. They are believed to have a **high** level of **adaptability** as fish only form a small part of their diet they are more likely to adapt to targeting their preferred bivalve prey. The **recoverability** of common scoters to changes in the distribution of fish is believed to be **high** as they will return to areas with high fish prey availability once areas recover from the effects of dredging. Common scoters are therefore considered to have a **low** level of **sensitivity** to changes to the distribution of fish.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the potential distribution of common scoters and any changes to the distribution of fish is assessed as being small.

Based on the small magnitude of the impact, the low sensitivity of the species, and the degree of interaction between receptor and effect, the overall impact of changes to the distribution of fish on common scoter is predicted to be ***not significant***.

Changes to Sandbanks

Sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on common scoters within the MAREA area.

Common scoters are believed to have a **medium** level of **tolerance** to changes to sandbanks as they show a strong association with habitats with water depths below 20 m of which sand banks may form a part. They are believed to have a **medium** level of **adaptability** as although they are a mobile species which is able to take advantage of different areas of similar habitat over a wide area, they still have a requirement for habitats with relatively shallow water depths and cannot exploit food resources in deeper water. The **recoverability** of common scoter to changes in sandbanks is believed to be **high** as they are mobile and will be able to take advantage of newly formed sand bank areas once dredging ceases. The **sensitivity** of this species to this effect of dredging is therefore assessed as being **low-medium**.

The majority of the records of common scoter lie outside the proposed and current licence areas where they may have an impact and so the degree of interaction between the receptor and effect is small.

Given the small magnitude of the impact of changes to sandbanks, the low-medium sensitivity of the common scoter, and the small degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks to common scoter are assessed as being ***not significant*** at the regional scale.

9.5.7 Gulls

Presence of the Vessel

Gulls are a highly mobile group of species, which forage over a wide area. They are believed to have a **high** level of **tolerance** and **adaptability** to the presence of vessels within the study area, and also a **high** level of **recoverability** once vessels are no longer present. Given their high levels of tolerance, adaptability and recoverability, the overall **sensitivity** of gulls to the presence of vessels is considered to be **low**.

Gulls are widely distributed throughout the area. However the area within which dredging activities occur at any one time is relatively small. The majority of interaction is likely to occur during vessel transit to and from the licence areas within existing shipping lanes where there is disturbance from other vessels.

Given the small magnitude of the presence of vessels, the medium value and low sensitivity of most gulls to the effect, and the degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on gulls is assessed as being ***not significant*** at the regional scale. For little gull which is considered to be of high value, due to the low sensitivity of gulls to disturbance from vessels and the small predicted degree of interaction, the impact of the cumulative impact of the presence of vessels on little gull is also assessed as being ***not significant***.

Fine Sediment Plume/Elevated Turbidity

Gulls are believed to have a **high** level of **tolerance** to elevated levels of suspended sediment. As a group they adopt a range of feeding techniques from scavenging to hunting fish from the sea surface and so are not dependent on water clarity for foraging. They are believed to have a **high** level of **adaptability** as they are a very mobile group of species which will forage over a very wide area and are capable of adapting foraging patterns in line with changing prey distribution. The **recoverability** of gulls to elevated suspended sediment levels is also believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to normal. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of gulls is therefore considered to be **low**.

Gulls are widely distributed throughout the area. However the area within which dredging activities occur at any one time is relatively small, and therefore only small numbers of gulls are predicted to be affected by sediment plumes.

Given the small-medium magnitude of the impact of fine sediment plumes and elevated turbidity, the medium value and low sensitivity of most gulls, and the degree of interaction between receptor and effect, the cumulative impact of changes to levels of suspended sediment on most gulls is assessed as ***not significant*** at the regional scale. For little gull which is considered to be of high value, due to the low sensitivity of gulls to elevated turbidity and the high level of adaptability and recoverability of gulls, the impact on little gull is assessed as ***not significant***.

Change to Distribution of Fish

Gulls are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a highly mobile group of species which will forage over a very large area. The **recoverability** of gulls to changes to the distribution of fish is also believed to be **high** as they will alter their foraging patterns in response to changes in prey distribution and will readily exploit changes in prey distribution once any impacts have ceased. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of gulls is therefore considered to be **low**.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the potential distribution of gulls and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the medium value and low sensitivity of most gull species, and the degree of interaction between receptor and effect, the cumulative impact of changes to distributions of fish on gulls is assessed as being ***not significant*** at the regional scale. For little gull which is considered to be of high value, due to the low sensitivity of gulls to changes to the distribution of fish and the high level of adaptability and recoverability of gulls, the impact on little gull is assessed as ***not significant***.

Changes to Sandbanks

Sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on the gannet population.

Gulls are believed to have a **high** level of **tolerance** to changes to sandbanks as they forage over wide areas taking a variety of prey species and are not tied to any particular habitat features. They are believed to have a **high** level of **adaptability** as they are a very mobile species capable of adapting foraging patterns in line with changing habitats or prey distributions at a regional level. The **recoverability** of gulls to changes in sandbanks is also believed to be **high** as they will exploit prey species independent of their distribution within the study area and so will exploit sand bank habitats once they recover. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of gulls is therefore considered to be **low**.

Given the small magnitude of the impact, the medium-high value and low sensitivity of gulls, and the degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks on gulls is assessed as being ***not significant*** at the regional scale. For little gull which is considered to be of high value, due to the low sensitivity of gulls to changes to sandbanks and the high level of adaptability and recoverability of gulls, the impact on little gull is assessed as ***not significant***.

9.5.8 Terns

Presence of the Vessel

Terns are a highly mobile group of species, which forage over a wide area. They are therefore assessed as having a **high** level of **tolerance** and **adaptability** to the presence of vessels within the study area, as they can exploit prey in other areas where dredging vessels are not present, and a **high** level of **recoverability** as they will quickly return to an area when dredging stops and dredging vessels are no longer present. Given their high levels of tolerance, adaptability and recoverability, the overall **sensitivity** of terns to the presence of vessels is considered to be **low**.

There is little overlap between the predicted distribution of terns and the licence areas within the MAREA area. The majority of interactions are likely to occur when the dredging vessels are steaming to and from the licence areas. Interaction between licence areas and the likely distribution of terns decreases with distance from shore, with Area 504 having no interaction with the distribution of terns.

Given the small magnitude of the presence of vessels, the medium value of terns and low sensitivity to this effect, and the small degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on terns is assessed as ***not significant*** at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Terns are believed to have a **medium** level of **tolerance** to elevated levels of suspended sediment. They hunt by plunge diving from height and rely on sight to locate prey and very elevated levels of suspended sediment may reduce feeding success. They are believed to have a **high** level of **adaptability** as they are a very mobile group of species which will forage over a very wide area and are capable of adapting foraging patterns in line with changing prey distribution. The **recoverability** of terns to elevated suspended sediment levels is also believed to be **high** as they will return to areas with high prey availability once turbidity levels have returned to normal. Given their medium level of tolerance to elevated suspended sediment and their high level of adaptability and recoverability, the **sensitivity** of terns is considered to be **low**.

The interaction between terns and sediment plumes is highest in the north of the study area, around Areas 118/2, Area 452 Area 239, which may be related to the higher numbers of breeding pairs of terns along the shore of the north of the study area. Interaction between dredging areas and foraging terns decreases with distance from shore, with Area 504 having no interaction with the known distribution of terns.

Given the small-medium magnitude of the impact of fine sediment plumes and elevated turbidity, the medium value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of changes to levels of suspended sediment on terns is assessed as ***not significant*** at the regional scale.

Change to Distribution of Fish

Terns are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a highly mobile group of species which will forage over a very large area. The **recoverability** of terns to changes to the distribution of fish is also believed to be **high** as they will alter their foraging patterns in response to changes in prey distribution and will readily exploit changes in prey distribution once any impacts have ceased. As a result of the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species is considered to be **low**.

The majority of fish species are widely distributed throughout the study area. However, the area within which where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction between the potential distribution of gulls and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the medium value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of changes to the distribution of fish is assessed as ***not significant*** at the regional scale.

Changes to Sandbanks

Sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on the gannet population.

Terns are believed to have a **medium** level of **tolerance** to changes to sandbanks as although they forage over wide areas taking a variety of prey species, they are known to forage over sandbanks which attract shoals of fish. They are believed to have a **high** level of **adaptability** as they are a very mobile group of species which are capable of adapting foraging patterns in line with changing habitat or prey distribution at a regional level. The **recoverability** of terns to changes in sandbanks is also believed to be **high** as they will exploit prey species over a range of habitats, and will move back to exploit sand bank habitats once they recover. Following the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species is considered to be **low**.

Given the small magnitude of the impact of changes to sandbanks, the medium value and low sensitivity of the receptor, and the degree of interaction between receptor and effect, the cumulative impact of changes to sandbanks on terns is assessed as ***not significant*** at the regional scale.

9.5.9 Summary of Impacts

Table 9.9 summarises the significance of the cumulative impacts of dredging on birds at the regional scale.

Table 9.9 Regional Significance of Impacts to Birds from Dredging in the Outer Thames

RECEPTOR	Presence of the vessel	Fine sediment plume/elevated turbidity	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Red-throated diver	Minor	Minor		Not significant	Minor
Gannets	Not significant	Not significant		Not significant	Not significant
Auks	Not significant	Minor		Not significant	Not significant
Seaducks	Not significant	Not significant	Not significant	Not significant	Not significant
Gulls	Not significant	Not significant		Not significant	Not significant
Terns	Not significant	Not significant		Not significant	Not significant
Overall Significance of Dredging	Minor				

Impacts to birds will need to be revisited within the individual EIAs in the light of any new data that may become available form other sources and studies, but the conclusions are unlikely to change. The significant impacts listed above will need to be referenced within each of the EIAs, as these bird species may be present within any of the licence areas.

9.6 DESIGNATED SITES

9.6.1 Introduction

There is currently one site designated under international or national legislation for its nature conservation value within the offshore MAREA study area. This is the Outer Thames Estuary Special Protection Area (SPA), designated for the protection of bird populations. Another site has been identified and selected for designation but is not yet fully ratified, the Margate and Long Sands candidate Special Area of Conservation (cSAC) (see Section 5.6). In addition there are several coastal designated sites which occur around the study area (see Figure 5.42).

For the purposes of the MAREA, the designated sites around and within the study area have been divided into those offshore sites which may be directly affected by dredging activities, and the coastal sites which could only be affected by secondary impacts. Three receptors have therefore been identified; Margate and Long Sands cSAC, the Outer Thames SPA and coastal designated sites.

9.6.2 Identification of Potential Impacts to Protected Areas

Table 9.10 highlights where the impacts from dredging may potentially interact with the designated sites within the Outer Thames Estuary.

Table 9.10 Matrix of Potential Impacts to Designated Sites

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Coastal Designated Sites – Habitats	•	•	•	•	•	•	•	•	•	•	•	•	•
Coastal Designated Sites – SPA species	✓	•	✓	•	•	•	•	•	•	•	•	✓	✓
Margate and Long Sands cSAC		×	•	✓	✓	✓	✓	✓	•	•	•	•	•
Outer Thames Estuary SPA	✓	•	✓	•	•	•	•	•	•	•	•	✓	✓

•	Not affected
×	No Interaction
✓	Potential Interaction

The impacts to the Margate and Long Sands cSAC and the Outer Thames Estuary SPA are discussed in Section 9.6.5 and Section 9.6.6 below. The potential impacts to coastal designated site habitats are outlined in Section 9.6.3 below, and the potential impacts to coastal SPA bird species are discussed in Section 9.6.4. None of the coastal SACs support marine mammals or fish as qualifying interest features and so impacts on these species groups have not been considered in this section.

The removal of sediment has been assessed as having no interaction with the Margate and Long Sands cSAC sandbanks. **Error! Reference source not found.** in Section 8.2 shows that although the Long Sands sandbank is partly within the Long Sand Head licence (Area 108/3, 109/1, 113/1) dredging since 1998 has not removed sediment from the sandbank as the surrounding coarser sediments in deeper water were targeted. The aggregates industry will implement avoidance measures to prevent the direct dredging of any sandbank material that is associated with the cSAC, and thus the conservation objectives of the cSAC will not be compromised.

9.6.3 Impacts to Coastal Designated Sites - Habitats

There is the potential for impacts to occur to coastal designated sites either through impacts to the qualifying interest habitats or species for which a particular site is designated.

The results of the modelling studies undertaken and presented in Chapter 7 show that there will be no significant impacts to coastal habitats (see Section 8.3). Therefore it is considered that there will be no impacts to coastal designated sites as a result of impacts to habitats.

9.6.4 Impacts to Coastal Designated Sites - SPA Species

A number of the coastal SPA sites support highly mobile bird species which may forage or otherwise move through the study area at certain times of year and potentially be subject to impacts from the proposed dredging activities. Those SPA species which are thought to be likely to interact with the effects of dredging are sandwich tern and gull species. Those sites which support these species are listed in Table 9.11 below.

Table 9.11 Coastal Designated Sites which support Species which may occur within the Study Area

Site	Designation	Species
Alde-Ore Estuary	Ramsar site, SPA	Sandwich tern, lesser black-backed gull, greater black-backed gull, herring gull
Foulness (Mid-Essex Coast Phase 5)	Ramsar site, SPA	Common tern, sandwich tern
Medway Estuary and Marshes	Ramsar site, SPA	Common tern
The Swale	Ramsar site, SPA	Mediterranean gull, black-headed gull

The impacts to these species are considered in Section 9.5 which concludes that the proposed dredging activities will have ***no significant effects*** on terns or gulls. Therefore no significant impacts are predicted to occur to these SPAs as a result of impacts to the component species of interest.

9.6.5 Impacts to the Margate and Long Sands cSAC

The conservation objectives of the Margate and Long Sands cSAC require that the favourable conservation status of the site will be met by maintaining, subject to natural fluctuations:

Sandbanks slightly covered by seawater all the time in particular:

- dynamic sand communities; and
- muddy sand and gravel communities.

The impacts to the sandbank habitats are discussed below. Impacts to individual benthic habitat communities which the cSAC may support are discussed in Section 9.2 impacts to benthic ecology. Overall it was found that there are no significant effects of dredging on benthic species and communities, however there may be impacts to two rare (*Sabellaria spinulosa* and *Barnea candida*) and one commercial species (*Crangon crangon*) if these species are directly removed from the sediment by the draghead, or in the case of *S. spinulosa* if it is present within the footprints of changes to sediment particle size or sediment transport rates. As discussed above the aggregates industry will avoid the direct removal of any sediments associated with the cSAC, therefore this effect is not considered further. In addition *B. candida* are not highlighted as being associated with the cSAC, however the potential impacts to *S. spinulosa* (which is supported by the cSAC, see Section 5.6) from changes to sediment particle size or sediment transport rates are referred to where appropriate in the following sections.

Fine Sediment Plume

The interaction between the fine sediment plume created by dredging activity and sandbanks is predominantly from the settlement of the sediments out of the water column onto the sandbanks. These interactions are considered below in the section concerning changes to sediment particle size distribution.

Sand Deposition

General impacts to sandbanks as a result of the proposed activities are considered in Section 8.2.

Sand deposition is regarded as a local, short-term but routine impact resulting in a low level change from baseline conditions. The volume of sand deposited on the banks is extremely small when compared with the total volume of sand in the bank. In addition, any sand deposited as a result of dredging will be sorted under the hydrodynamic conditions in the region and find its way naturally to places where deposition occurs, therefore the various sand fractions from dredging will accumulate in places where such sand fractions are deposited naturally. Overall, sand deposition is predicted to have a **small magnitude** effect (see Chapter 7).

Natural England guidance on the conservation objectives of the site considers the sandbank habitats of the site to have a **high tolerance** to smothering (NE, 2009). Sandbanks are assessed as having **high adaptability** to sand deposition due to their high mobility and regular geomorphological changes, which may make it difficult to determine which regional scale changes are natural and which are caused as a result of dredging activity. **Recoverability** of sandbanks is **not applicable** due to their highly dynamic nature**.** Taking into consideration tolerance and adaptability, the sensitivity of sandbanks to this effect is assessed as **low**.

Due to their status as qualifying interest features of a designated site, the value of the cSAC sandbanks is considered to be **high**.

According to the modelling undertaken, there is the potential for sand deposition from dredging within Long Sand Head licence (Area 108/3, 109/1, 113/1) to interact with the cSAC. The modelling undertaken assumes that dredging will be undertaken across the whole licence area and as a result assumes dredging will take place adjacent to and within the cSAC. Modelling of changes to bedforms as a result of sand deposition shows that there is a degree of interaction of approximately 47.8 km^2 which is equivalent to 7.37% of the cSAC. There is therefore predicted to be a **small degree of interaction** between sand deposition and the cSAC.
This is a based on a scenario which assumes dredging taking place across the licence area. In reality a much smaller area will be dredged, resulting in reduced impacts compared to those predicted in the modelling.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor, and the small degree of interaction between the impact and the cSAC, the impact of sand deposition on the cSAC is assessed as being ***not significant*** at the regional scale.

Changes to Sediment Particle Size

Changes to sediment particle size will comprise a local effect that is short term in duration, of routine frequency, but is expected to cause a low level change relative to the existing conditions. Overall, the impact of changes in sediment particle size distribution has been assessed as being a **small magnitude** effect (see Chapter 7).

Natural England guidance on the conservation objectives of the site considers the sandbank habitats of the site to have a **high tolerance** to smothering and siltation (NE, 2009). Sandbanks are assessed as having **high adaptability** to sand deposition due to their high energy environment, high mobility and regular geomorphological changes, which may make it difficult to determine which regional scale changes are natural and which are caused as a result of dredging activity. **Recoverability** of sandbanks is **not applicable** due to their highly dynamic nature**.** Taking into consideration tolerance and adaptability, the **sensitivity** of the sandbanks to changes in sediment particle size distribution is **low**.

As they are a qualifying interest feature of a designated site, the value of the cSAC sandbanks is considered to be **high**.

Modelling of potential changes in sediment particle size distribution shows an area of interaction between the cSAC and potential impacts from the Long Sand Head licence (Area 108/3, 109/1, 113/1) of approximately 62 km^2 which equates to approximately 10% of the cSAC. It is therefore predicted that there will be a **small degree of interaction** between changes to sediment particle size and the cSAC. This is a worst case scenario which assumes dredging taking place across the entire licence area. In reality a much smaller area will be dredged, resulting in reduced impacts compared to those predicted in the modelling.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor, and the small degree of interaction between the impact and the cSAC, the impact of changes to sediment particle size on the cSAC is assessed as being ***not significant***.

The impacts of changes to sediment particle size on *Sabellaria spinulosa* which may be associated with the cSAC are assessed to be of minor significance (see Section 9.2). However within the cSAC, their distribution is patchy and aggregations form crusts rather than reefs (see Section 5.6), therefore the degree of interaction between the effect and these patches is likely to be very small. The impact upon the population within the cSAC is therefore assessed as ***not significant***.

Changes to Wave Heights

Modelling was carried out to assess changes in wave heights for various parameters of metocean conditions, including incident wave direction and tidal state, associated with pre-dredge, present day and post-dredge (15 years from now) bathymetries (see Section 7.4.1). The modelling looked at an extreme event (a one in 200 year storm) in terms of changes to wave heights and also looked at an extreme wave condition that occurred more frequently than a 200 year wave (ie a wave that is exceeded 5% of the time in any one year).

A change greater than 5% to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the localised extent of the change and the rarity of the effect, however, the effect is long-term and the change relative to the baseline is low.

A change of 2-5 % to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the sub-regional extent of the change, the rarity of the effect and the small change relative to the baseline, however, the effect is long-term.

A more than 5% change to a 5% exceedance in wave height scenario is a **small magnitude** effect. This is because of the isolated extent of the effect (site-specific) and its infrequent occurrence (occasional), however, the duration is long-term and the change relative to the baseline is medium.

A change of between 2-5% to a 5% exceedance in wave height scenario is a **small to medium magnitude** effect. This is because of the localised extent of the effect (local), its infrequent occurrence (occasional) and its low level change relative to the baseline (low) however, the duration is long-term.

Within the study area sandbank **adaptability** to wave height changes has been assessed as high (see Section 8.1), and sandbanks are assessed as having a **high** level of **tolerance** to these changes**.** As discussed above, **recoverability** of sandbanks is **not applicable**. Taking into consideration tolerance and adaptability, the **sensitivity** of the sandbanks to changes in wave height is **low**.

Due to their status as qualifying interest features of a designated site, the value of the cSAC sandbanks is considered to be **high**.

Figure 8.4 in Section 8.2 presents those sandbanks which may interact with changes in a 1 in 200 year wave height and shows that there are potential changes in wave heights over the various sandbanks in the estuary, including areas of sandbank within the cSAC.

The areas around Area 257 and Long Sand Head licence (Area 108/3, 109/1, 113/1) show wave height changes to a 1 in 200 year wave condition of over 10% up to 7 km beyond the boundary of the extraction area and changes of 2% twice this distance away from the southern edge of Long Sand Head licence area, which both interact with the cSAC.

The degree of interaction between wave height changes to a 1 in 200 year wave with the cSAC sandbanks is approximately 56 km^2 which corresponds to approximately 9% of the area of the cSAC. It is therefore predicted that there will be a **small degree of interaction** between changes to sediment particle size and the cSAC. This area represents a worst case scenario if dredging were to take place within the entire area of overlap between the licence area and the cSAC. In reality a much smaller area will be dredged, resulting in reduced impacts compared to those predicted in the modelling.

The degree of interaction between wave height changes to a 5% exceedance in wave height scenario and the cSAC is approximately 22 km^2 which is 3% of the total cSAC area. The **degree of interaction** is therefore assessed as **small**. Again this is based on a scenario where dredging takes place within the entire licence area. In reality the degree of interaction will be even smaller.

Based on these assessments of the small-medium magnitude of the effect, the high value and low sensitivity of the receptor, and the small degree of interaction between the impact and the cSAC, the impact of changes to wave heights is assessed as ***not significant*** at the regional scale.

It should be noted that any potential effects of the predicted wave height changes on the sandbank features of the cSAC are likely to be small in comparison to the natural changes that occur in an ongoing manner and in response to extreme events.

Changes to Tidal Currents

Tidal currents may impact the physical structure of sandbanks by altering the sediment transport rates to and from sandbanks. These interactions are considered below in the section concerning how changes in sediment transport rate may affect sandbanks.

Changes to Sediment Transport Rates

Sediment transport is a major factor in sandbank formation, growth and maintenance and is strongly linked to tidal flows. Alterations to sediment transport due to past and planned dredging in the MAREA area have the potential to impact sandbanks where the two interact, as shown in Figure 8.5 in Section 8.2.

Changes to sediment transport rates are restricted to within or to quite small areas close to the boundaries of the individual extraction areas. Where interactions do occur only small changes in sediment transport (100 to 400 kg/m/tide) affect very limited areas of the sandbanks. This effect is therefore localised and long term in duration. The change relative to existing sediment transport rates is low and the effect is considered a routine occurrence. The overall **magnitude** of changes in sediment transport on sandbanks is therefore considered **medium**.

At a regional level, the **tolerance** and **adaptability** of sandbanks to changes in sediment transport is expected to be high; therefore the sensitivity of sandbank features to changes to sediment transport rates is considered to be low (See Section 8.2). The Natural England advice on the cSAC considers the sand bank features to be 'low/moderately sensitive' to smothering or sediment loss (NE, 2009), both potential impacts of changes in sediment transport rates and therefore for the purposes of the MAREA the sensitivity of the cSAC to changes in sediment transport rates is taken to be **low-medium**. It should also be noted than an increased rate of sediment transport may simply mean that sediment is cycled around the bank at a greater rate than previously, and is unlikely to result in the destabilisation or loss of sand from sandbanks.

As they are a qualifying interest feature of a designated site, the **value** of the cSAC sandbanks is considered to be **high**.

The level of interaction of changes in sediment transport rates with the cSAC is approximately 11 km^2 or 1.75% of the overall cSAC, and is considered to be a **small degree of interaction***.* In reality this will be even smaller, as the modelling has conservatively been based on a maximum tonnage scenario where dredging takes place throughout the licence area.

Based on these assessments of the small magnitude of the effect, the high value and low/medium sensitivity of the receptor, and the small degree of interaction between the impact and the cSAC, the impact of changes to sediment transport rates is assessed as being ***not significant*** at the regional scale.

The impacts of changes to sediment transport rates on *Sabellaria spinulosa* which may be associated with the cSAC are assessed to be of minor significance (see Section 9.2). However within the cSAC, their distribution is patchy and aggregations form crusts rather than reefs (see Section 5.2), therefore the degree of interaction between the effect and these patches is likely to be very small. The impact upon the population within the cSAC is therefore assessed as ***not significant***.

9.6.6 Impacts to the Outer Thames Estuary SPA

The conservation objectives of the Outer Thames Estuary SPA require that the favourable conservation status of the site will be met by maintaining, subject to natural fluctuations:

- the population size of red throated diver;
- the extent of sandbank habitat within the site; and
- the abundance and distribution of diver prey species.

Impacts to each of these features across the study area have been assessed in other chapters, and these are referred to where appropriate below.

Presence of the Vessel

Future shipping density predictions incorporate the future tonnage application and associated number of vessel movements for current licence areas, application areas and prospecting areas within the study area, based on the regional tonnage scenario (ie maximum tonnage scenario). The future scenario is predicted to result in a potential 150% increase in dredging activity relative to the baseline. The overall dredging activity will still represent a low proportion (approximately 3%) of total shipping traffic in the Outer Thames Estuary.

The presence of additional dredging vessels has been identified as a **small magnitude effect**, due to the site specific, regularly occurring and transient nature of the impact which represents a small level change relative to the baseline.

Red throated divers are known to be sensitive to disturbance and it is possible that the increased level of vessel traffic may have an impact on the SPA population. Section 9.5.3 outlines the predicted effects of vessel presence on red throated divers and concludes that the cumulative impact of the presence of vessels on this species is assessed to be of **minor significance** at the regional scale.

As the majority of the red throated divers present within the study area are likely at one time or other to contribute to the SPA population, the impacts to the SPA are also predicted to be of **minor significance**.

Fine Sediment Plume/Elevated Turbidity

Dredging will result in elevated levels of suspended sediments against background levels, with zones around the licence areas of differing suspended sediment concentrations. The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20 mg l^{-1} plumes and a

medium magnitude effect for plumes of 50mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

Recent measurements by EMU Ltd (2008) indicate that offshore suspended sediment concentrations to the north of the study area ranged between 1.7 -219 mg l^{-1}. Increases of 20-100 mg l^{-1} are therefore within the natural fluctuation of concentrations within the offshore waters of the outer Thames Estuary (see Section 4.5.3).

Section 9.5.3 describes the assessment of the **sensitivity** of red-throated divers to increased suspended sediment, which is considered to be **low**, and the **magnitude** of the impact which is considered to be **medium**.

The value of the red-throated diver qualifying interest feature of the SPA is considered to be a **high value** receptor.

According to the modelling undertaken, zones of sediment concentration of above 20 mg l^{-1} (ie the 20 mg l^{-1}, 50 mg l^{-1} and 100 mg l^{-1} together) will interact with approximately 261.7 km^2 of the SPA, which equates to approximately 7% of its area. However, it should be noted that the modelling is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time, therefore the interaction with the SPA will be smaller than modelled in reality. The **interaction** with the SPA is therefore considered to be small.

Given the consideration of the medium impact magnitude, the high value but low sensitivity of the receptor and the small degree of interaction between receptor and effect, to the impact of the fine sediment plume on the SPA is predicted to be of **minor significance**.

Changes to Distribution of Fish

Section 9.3.10 assesses the impacts to the distribution of fish as a result of the proposed dredging activities, and Section 9.5.3 assesses the impacts of these changes to divers.

Changes to the distribution of fish as a result of dredging is a small magnitude effect based on it being localised, temporary, routine in occurrence and a low level change relative to the baseline.

Section 9.5.3 states that divers are believed to have a **high** level of **tolerance** to changes to the distribution of fish. They have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns in line with changing prey distribution. The **recoverability** of red throated divers to changes to the distribution of fish is also believed to be **high** as their foraging strategy will focus on areas with high prey availability and they will follow shoals of fish in response to changes in distribution. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species is considered to be **low**.

The impacts to fish ecology that were assessed as being of minor significance were underwater noise on cod, herring and sprat and sand deposition on lesser spotted dogfish and thornback ray spawning grounds.

At the scale of the SPA, the overlap between the cod, herring and noise contours (the distance up to which a behavioural response may occur) and the SPA is just 3.8%, 5.5% and 5.5% of the total SPA area respectively. The overlap between the footprints of sand deposition, the spawning grounds of dogfish and thornback ray and the SPA is equal to just 3.3% of the total SPA. Therefore the **degree of interaction** between potential changes to the distribution of fish and the SPA is **small**.

Taking into consideration the small magnitude of effect, the low sensitivity of the receptor and the small degree of interaction, the impact of changes to fish distribution on the Outer Thames Estuary SPA is assessed to be ***not significant***.

Change to Sandbanks

Changes to sandbanks are assessed to be a **small magnitude** effect based on their being localised, medium-term in duration, routine and a low level change relative to the baseline.

Red-throated divers have a preference for areas with water less than 30m deep (Cork Ecology, 2004). In addition sand banks provide a feature which can attract shoaling fish and may be favoured foraging areas for seabirds. If dredging results in alterations to sandbank size or location it is possible that there will be knock on effects on distribution of red-throated diver. Section 9.5.3 states that divers are believed to have a **medium** level of **tolerance** to changes to sandbanks as they have fairly narrow habitat preferences. They have a **high** level of **adaptability** as they are a mobile species capable of adapting foraging patterns in line with changing habitat or prey distribution at a local level. The **recoverability** of red throated divers to changes in sandbanks is also believed to be **high** as they will rapidly return to suitable habitats following the cessation of dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the species to changes to sandbanks is considered to be **low**.

The impacts to sandbanks that were assessed as being of minor significance at the regional scale were changes to wave heights and changes to sediment transport rates. In the context of the SPA, the interaction between changes to a 1 in 200 year wave height scenario and the sandbanks within the SPA is just 1.7% of the total area of the SPA. The interaction between changes to a 5% exceedance wave height scenario and the sandbanks within the SPA is just 0.57% of the total area of the SPA. The overlap between the footprint of changes to sediment transport rates and the sandbanks within the SPA is just 0.08% of the total SPA. Overall the **degree of interaction** between the changes to sandbanks and the SPA is **small**.

Based on the consideration of the small magnitude of the effect, the low sensitivity of the receptor and the small degree of interaction, the impact of changes to sandbanks on the SPA is considered to be ***not significant***.

9.6.7 Summary of Impacts

Table 9.12 summarises the significance of the cumulative impacts of dredging on sandbanks as physical structures at the regional scale.

Table 9.12 Regional Significance of Impacts to Designated Sites from Dredging in the Outer Thames

RECEPTOR	Presence of the vessel	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Changes to distribution of fish	Changes to sandbanks
Coastal designated Sites - habitats									
Coastal designated Sites – SPA species	Not Sig.	Not Sig.						Not Sig.	Not Sig.
Margate and Long Sands cSAC		*See Changes in sediment particle size distribution*	Not Sig.	Not Sig.	Not Sig.	*See changes in sediment transport rate*	Not sig.		
Outer Thames Estuary SPA	Minor	Minor						Not Sig.	Not sig.
Overall Significance of Dredging	Minor								

There are no regional impacts assessed as being of significance to the Margate and Long Sands cSAC, however due to its overlap with Long Sand Head licence (Area 108/3, 109/1, 113/1), any EIA for this licence area should explain the means whereby dredging will be managed to avoid impacts to the cSAC.

Sufficient information will need to be presented for each individual EIA to demonstrate no significant effect, and where there is potential for a significant impact, mitigation will be discussed.

10 THE HUMAN ENVIRONMENT – ASSESSMENT OF REGIONAL IMPACTS

10.1 INTRODUCTION

This section describes the potential regional impacts on the human environment as a result of future marine aggregate extraction activities in the Outer Thames Estuary.

The topics covered in this section include:

- impacts to fisheries (Section 10.2);
- impacts to infrastructure (Section 10.3);
- impacts to recreation (Section 10.4);
- impacts to shipping and navigation (Section 10.5); and
- impacts to archaeology (Section 10.6).

In all cases, the potential impacts as a result of the effects of dredging discussion in Chapter 7 are considered.

10.2 IMPACTS TO FISHERIES

10.2.1 Introduction

As discussed in Section 6.2, the most important fisheries in the area can generally be separated into four distinct types:

- the Thames Estuary cockle fishery,
- the inshore fleet (generally small less than 10 m vessels);
- the offshore fleet (vessels greater than 10 m in length from the UK and overseas); and
- recreational fisheries.

As these fisheries are the most important in the area and are most likely to experience impacts from dredging operations they will be the focus of this impact assessment.

Thames Estuary Cockle Fishery

The Thames Estuary Cockle fishery operates across the Shoebury, Maplin and Foulness Sands. Vessels here use mechanical dredges that suck up the cockles and then separate them from the sediment that is also bought up by the dredge. The landings of cockles in the area are significantly high and the value of the fishery is many times that of any other fishery or target species. In the context of fisheries in the UK, the Thames Estuary Cockle fishery is now the most productive and most important cockle fishery in the UK and one of the largest in Europe.

Inshore Fleet

The inshore fleet consists of local UK vessels operating no more than 12 nm from shore using pots, nets and trawls. UK vessels from the inshore fleet can be found fishing throughout the study area and are dispersed across the entire area. Vessels frequently use otter and beam trawls to fish for sole during summer and autumn in the estuaries and switch to nets and lines to fish for cod and whiting during colder winter months (EMU Ltd). A variety of other gears including pots, are also used to target crustaceans and other shellfish.

The majority of fishing vessels are powerful enough to steam from north to south across the region, or west to east, and back in a day's fishing; weather, tide and currents permitting. There is nevertheless a strong spatial division of the grounds depending on the vessels' base ports and due to the following factors:

- Cost of fuel and steaming time if equivalent grounds are closer to home.
- Market price of the day, for example the price of Blackwater herring could make it worthwhile for pelagic fishermen in Ramsgate.
- The knowledge necessary to work any particular ground and gear combinations.

While the small vessels may not be the most numerous and may not take the largest portion of the catch they are an important source of local income. In addition they are important to the economy of many of the towns and villages along the coast that the MAREA study area covers.

Offshore Fleet

The offshore fleet consists of vessels from both the UK and from other European nations (e.g. Belgium, Germany, France and Holland). The majority of UK flagged vessels land their catch in UK ports whereas those from European nations may land in the UK or in their home port. The UK portion of the fleet tend to carry a variety of gears, including gill nets, drift nets, trammel nets and twin, triple or multi-rigged otter trawls. However, the foreign vessels tend to use trawl gear (e.g. beam, otter or pelagic trawls) to target a wide variety of species. The majority of vessels within the MAREA area are fishing using beam trawls targeting sole and plaice that inhabit the sandier areas. These vessels take the largest portion of the catch from the area, mainly due to their size.

Commercial fishing within the study area generally follows a seasonal pattern, due to the seasonal migrations of the targeted species and their availability to the fishery. In the winter (December, January, and February) fishing by larger vessels is further offshore and generally outside or on the edges of the study area. Smaller vessels target herring, cod, whiting, sprats and plaice inshore as these species migrate towards the coast and estuaries to breed. In the spring (March, April, May) the effort expended by the larger vessels moves closer inshore and covers the study area, with the greatest effort across the dredging licence, application and prospecting areas. The smaller vessels begin to target bass and eels, and sole, cod and skate become increasingly more important.

The patterns observed in both the over and under 10m fleets is mostly driven by the biology of the targeted fish species, which move to shallower water during the spring and summer to breed. Once the adult populations migrate further offshore the fishing fleets follow them in order to continue exploiting the species as a resource.

Recreational Fisheries

Recreational fisheries are relatively widespread throughout the region and are carried out from boats or from the shore, using both rod and line methods. The boat-based activity is restricted to the late spring and summer months. All boats work between a mile and up to sixty miles from their home ports depending on the season and where the fish are expected to be.

The fisheries of the area, particularly the inshore fleet and the Thames Estuary Cockle fishery, contribute to the economy of the local area and at a regional scale also. The offshore fleet also contributes to the economy within the MAREA area but to a lesser extent as most of the fleet operates from outside the UK. Recreational sea fisheries attract visitors that support a number of businesses and livelihoods, including angling charter boats, bait-diggers, tackle shops, and angling guides. In light of the importance of each fishery at a local, regional and national scale and their value (in GBP) the value of each receptor is assessed as follows:

- Thames Estuary cockle fishery - **high;**
- Inshore fleet - **high**;
- Offshore fleet - **medium**; and
- Recreational fisheries - **medium.**

10.2.2 Identification of Potential Impacts on Commercial and Recreational Fisheries

Types of Impact

Table 10.1 details the predicted effects of dredging with reference to whether or not they have the potential to impact the Thames Estuary cockle fishery, the inshore and offshore fishing fleets and the recreational fishery.

The potential impacts to dredging may affect the ability for fisheries to operate either directly via loss of access to fishing grounds, or may follow on as a consequence of impacts to benthic (shellfish) or fish species in the region (see Sections 9.2 and 9.3).

Loss of Access

Future shipping density predictions (see Appendix I) incorporate the future regional tonnage scenarios and associated vessel movements for current licence areas, application areas and prospecting areas within the study area. This is predicted to result in a potential 150% increase in dredger vessel activity relative to the baseline. However, overall dredger vessel traffic will still represent a low proportion (approximately 3%) of total shipping traffic in the Outer Thames Estuary.

Loss of access due to the presence of additional dredging vessels is therefore a **small magnitude** effect, based on it being site-specific in extent, and regularly occurring (routine), however it is transient (temporary) and constitutes a low level change relative to the baseline.

Changes to Benthic Community Composition

A change to the composition of the benthic community as a result of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence because the majority of dredging occurs along tracks that have been dredged before and therefore the frequency of previously un-dredged seabed (and the associated benthic communities) being affected is relatively low. As a result it is classified as a **medium-large magnitude** effect.

Changes to Distribution of Fish Species

Changes to the distribution of fish species may have consequences for the fishing fleets in the area, which are influenced by direct impacts to the fish populations inhabiting the MAREA area. These changes may affect fisheries by making the areas that are usually fished less productive. If the populations move away from these areas there is the potential for the fleets to have to move to new grounds or spend greater time finding their favoured target species. However it is not anticipated that there will be any impacts from dredging on target fish species over and above a level of minor significance (see Section 9.3); therefore populations of target species are expected to recover rapidly in any impacted areas. A change to the distribution of fish species as a result of dredging operations is therefore a **small magnitude** effect based on its localised and transient nature, the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

Table 10.1 Matrix of Potential Impacts of Dredging on Commercial and Recreational Fisheries

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Thames Estuary cockle fishery	■	■	■	■	■	■	■	■	■	✓	×	■	■
Inshore fleet	■	■	■	■	■	■	■	■	■	✓	✓	✓	■
Offshore fleet	■	■	■	■	■	■	■	■	■	✓	■	✓	■
Recreational fisheries	■	■	■	■	■	■	■	■	■	✓	■	✓	■

■	Not affected
	No interaction
	Potential interaction

10.2.3 Thames Estuary Cockle Fishery

Loss of Access

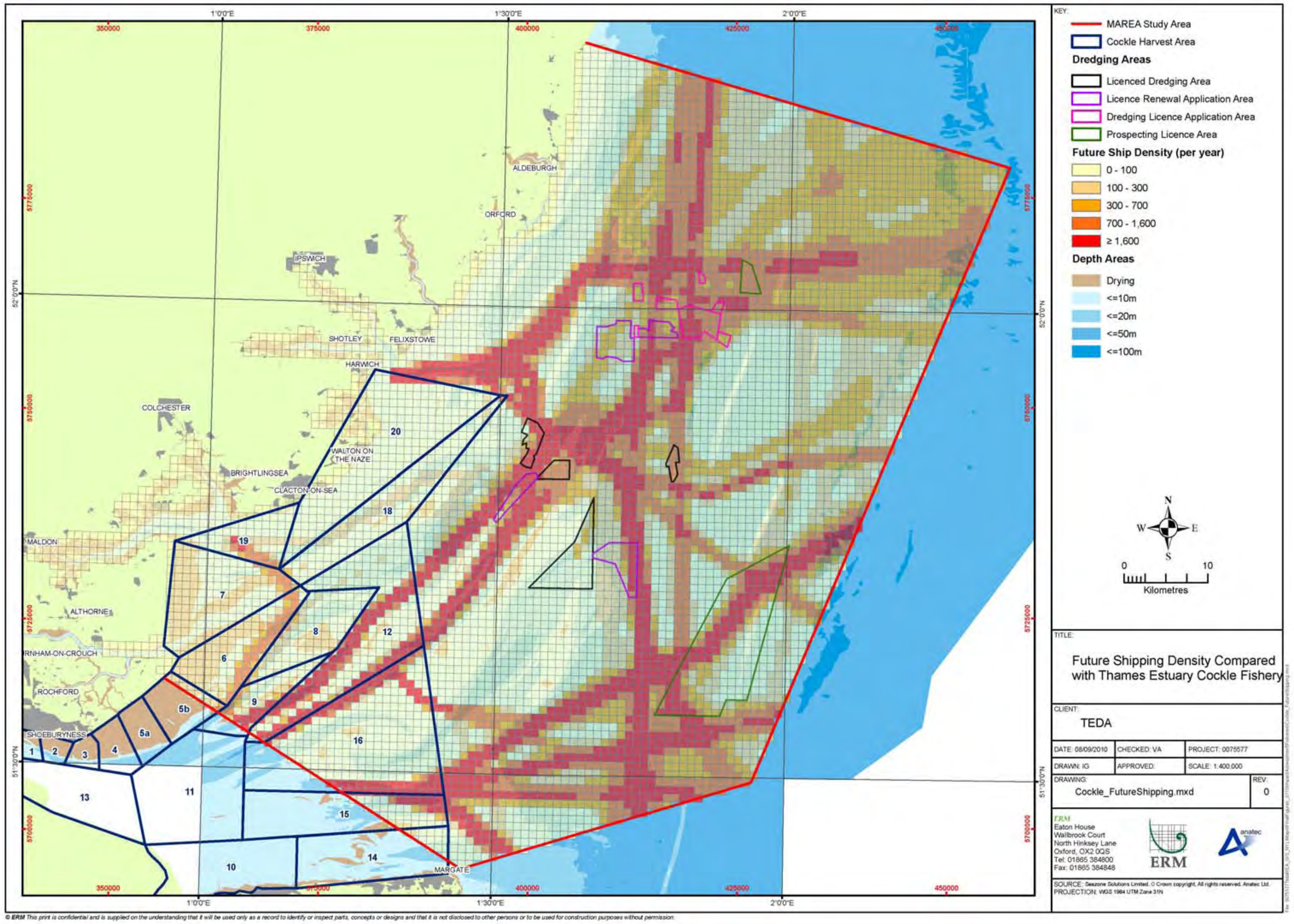
The Thames Estuary cockle fishery operates across the Shoebury, Maplin and Foulness Sands within a very specific area where its target species, the cockle (*Cerastoderma edule*) is present. The area within which the fishery operates does not contain any dredging licence areas; therefore the main interaction will be during vessel passage to and from the dredging areas (Figure 10.1). However the additional dredger traffic will mainly use existing, established routes to and from the dredge areas and this will only affect a very small proportion of the total area fished within the Thames Estuary cockle fishery. In addition the TEDA MAREA area only covers 60% of the fishery's grounds.

This fishery is therefore classified as having a **high tolerance** to dredger vessel presence as its fishing grounds are extensive. Its **adaptability** is **high** due to the ability of the fleet to avoid dredgers by moving to other areas of the fishing ground. After the dredger has passed through, the fishing activity in the area will recover rapidly from any adverse affects; the fishery is therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the Thames Estuary cockle fishery to loss of access is considered to be **low**.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect (due the effect only relating to the passage of vessels through the fishing area and not to dredging operations), the cumulative impact of loss of access on this fishery is considered to be ***not significant*** at the regional scale.

Cerastoderma edule (Cockles)

Figure 10.1 Future Shipping Density Compared with Thames Estuary Cockle Fishery



10.2.4 Inshore Fleet

Loss of Access

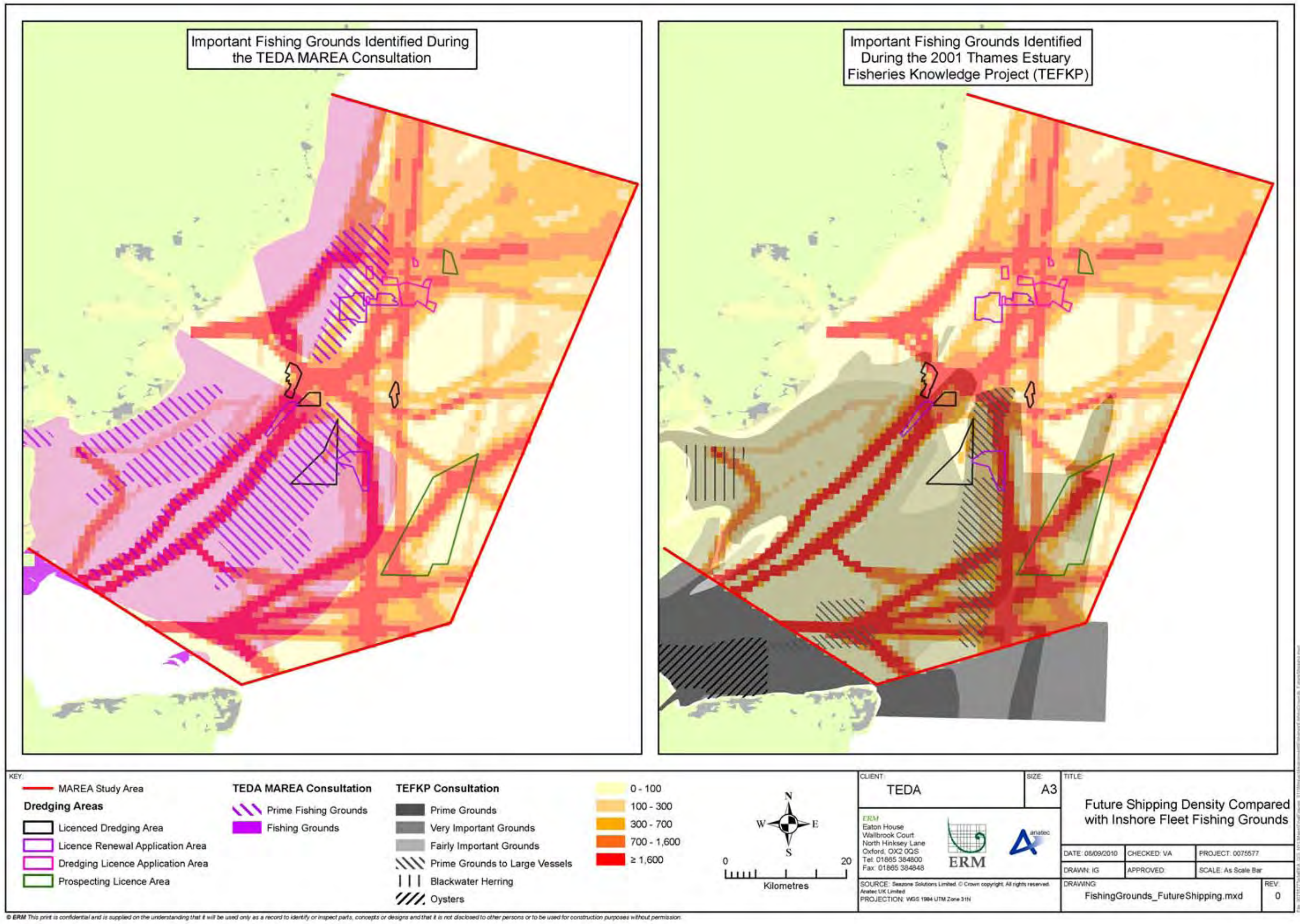
The inshore fleet (vessels <10 m in length) operates across most of the MAREA area and the most important fishing grounds are along the sandbanks in the south and across an area in the north which covers most of the northerly licence areas. If dredging vessels are present in the northern area then there is the potential need for these inshore vessels to move away from their preferred grounds to avoid an increased collision risk. In the southern area where the sandbanks are seen as the most important grounds, the overlap with the licence areas is minimal and the ability to move to new grounds would be greater, reducing the risk of collision further.

However, in both areas fishing grounds are extensive and there is a large area for fishing vessels to use in order to avoid the presence of dredging vessels. Therefore, this fishery is classified as having a **high tolerance** to vessel presence. Its **adaptability** is **high** due to the ability of the fishing vessels to avoid the dredgers and move to other areas of the fishery. After the dredger has passed through or moved on, the inshore fishing vessels will recover rapidly from any adverse affects, and are therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the inshore fleet to loss of access is considered to be **low**.

The inshore fleet covers a large proportion of the MAREA area, although the most important (prime) fishing grounds (according to consultation) cover a much smaller proportion (approximately 25%) (Figure 10.2). In the north of the MAREA area these prime fishing grounds overlap with several licence areas and the presence of dredgers will potentially cause the fishing vessels to move to other areas within their preferred fishing grounds or into areas where fishing is not as productive. In the south the majority of the licence areas overlap with fishing grounds, but the main interaction will be during vessel passage to and from the dredging areas (Figure 10.2), which will be temporary and short in duration, and will mainly use existing, established routes to and from the licence areas thus only affecting a small proportion of the total area fished.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the degree of interaction in both the north and south of the MAREA area, the cumulative impact of loss of access to this fishery on a regional scale is considered to be ***not significant***.

Figure 10.2 Future Shipping Density compared with Inshore Fleet Fishing Grounds



Changes to Benthic Community Composition

Portions of the inshore fleet target crustaceans and other benthic species. While they do not constitute a major catch in the area for some fishermen they represent a major source of income, particularly in the northern half of the MAREA area. Many others have multiple gears and target a variety of species which include crustaceans and other benthic species. However the main target benthic species of this fleet are crabs (*Cancer pagurus*) and brown shrimp (*Crangon crangon*).

The benthic impact assessment (see Section 9.2) concludes that there will be no significant impacts to crabs, and that the brown shrimp may be moderately impacted by the effects of sediment removal; however the community will recover quickly following the cessation of dredging. Consequently the inshore fleet is assessed as having a **high tolerance** to local changes to benthic community composition, **high adaptability** as a result of most vessels carrying a variety of fishing gears and being able to exploit several species, and **high recoverability** as they will quickly return to targeting any impacted benthic species when they become available again. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the inshore fleet to changes to benthic community composition is considered to be **low**.

Some of the vessels that operate within the inshore fleet, particularly from Felixstowe, Harwich, Lowestoft and Orford, target crabs and lobsters in areas close to shore in the northern portion of the MAREA area. Other vessels also use pots to fish but generally their main target species consists of finfish which are targeted in other areas. As the main crab and lobster fishing grounds appear to be close to shore and do not overlap with the licence areas the degree of regional interaction is very **small**.

Based on these assessments of the medium-large magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to benthic community composition on inshore fisheries is assessed to be ***not significant*** at the regional scale.

Changes to Distribution of Fish Species

The inshore fishery has a **high tolerance** to a change in the distribution of fish species, as they target a wide variety of species and by their very nature fish are not completely predictable in their spatial and temporal distribution. It has a **medium** level of **adaptability** as inshore fishing vessels can move away from any impacted areas to fish elsewhere, although this may result in some decrease in available fishing opportunities. The inshore fleet is thought to have a **high** level of **recoverability** as it may re-enter an area rapidly following dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the inshore fleet to a change in the distribution of fish is considered to be **low**.

The prime fishing grounds in the northern part of the MAREA area are more likely to be impacted by changes in fish distribution as their grounds overlap with the licence areas to a greater extent than in the southern area. However the overall degree of interaction between the inshore fishery and any changes to fish distribution is assessed as **small**.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to fish distribution on inshore fisheries is assessed as being ***not significant*** at the regional scale.

10.2.5 Offshore Fleet

Loss of Access

The offshore fleet, which includes both UK and foreign vessels >10 m in length, operates across most of the MAREA area and throughout the adjacent waters further offshore. The density of UK vessels is relatively low and evenly distributed across the MAREA area. However, areas of higher fishing intensity may be found close to the mouth of the Thames Estuary, where populations of sole are targeted, and just outside the MAREA area. The foreign fleet fishes throughout the MAREA area, with the intensity of fishing dependent on the season. During the summer and autumn the vessels mainly fish outside the MAREA area, however during spring, fishing is also present within and in close proximity to the licence areas. During winter, fishing intensity is lower and spread evenly within the MAREA area and further offshore. As a result the offshore fleet has extensive fishing grounds to exploit.

Fishing vessels within the offshore fleet have extensive fishing grounds within which to move to avoid the presence of dredging vessels. Therefore, this fishery is classified as having a **high tolerance** to loss of access. Its **adaptability** is **high** due to the ability of the fishing vessels to avoid the dredgers by moving to other offshore areas. After the dredger has gone, the vessels operating in the fishery will recover rapidly from any adverse affects, and are therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the offshore fleet to loss of access is considered to be **low**.

The additional dredger traffic will use existing, established routes to and from the dredge areas and specific operational dredging areas, thus only affecting a small proportion of the total area fished.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor and the very small degree of interaction between the dredger routes/operational areas and the extensive fishing grounds available to the offshore fleet, the cumulative impact of loss of access on this fishery on a regional scale is considered to be ***not significant***.

Changes to Distribution of Fish Species

The offshore fishery has a **high tolerance** to a change in the distribution of fish species as they operate over an extensive area both within and outside the MAREA area, and exploit a range of fish species. They have **high adaptability** as they can avoid dredging locations by moving to other areas to fish and this is unlikely to result in a decrease in available fishing opportunities. The offshore fleet are thought to have a **high** level of **recoverability** as they may re-enter an area rapidly following dredging. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the offshore fleet to a change in the distribution of fish is considered to be **low**.

The offshore fleet is less restricted in their fishing grounds than the inshore fleet and will therefore be able to move to areas where fish populations are unaffected by dredging, should any changes to fish distribution be experienced. Therefore the degree of interaction between the offshore fishery and any changes to fish distribution is assessed as **small**.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to fish distribution on inshore fisheries is assessed as being ***not significant*** at the regional scale.

10.2.6 Recreational Fleet

Loss of Access

Recreational vessels generally have more restricted fishing grounds than the other fisheries. Therefore, this fishery is classified as having a **low tolerance** to loss of access. However, **adaptability** is **medium** due to the ability of the recreational vessels to avoid dredgers by moving to other areas, despite the grounds being generally limited. After the dredger has passed through or moved on, the recreational vessels will recover rapidly from any adverse affects and are therefore assessed as having **high recoverability**. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the recreational fleet to loss of access is considered to be **medium**.

The recreational fleet operates close to shore and does not generally overlap with dredging activity. However, during consultation in Felixstowe it was suggested that some vessels from the Suffolk coast will fish close to or within the licence areas closest to shore. In the north of the MAREA area the most important fishing grounds are close to the licence areas whereas in the south the majority are in other parts of the study area. In the north the presence of dredgers may cause recreational vessels to move from the area to avoid the risk of collision. In the south the main interaction will be during vessel passage to and from the licence areas, which will be temporary and short in duration. In addition, the additional dredger traffic will mainly use existing, established routes to and from the dredge areas and this will only affect a small proportion of the total area fished.

Based on these assessments of the small magnitude of the effect, the medium value and medium sensitivity of the receptor and the small degree of interaction between the receptor and effect, the cumulative impact of dredging loss of access on a regional scale is considered to be *not significant*.

Changes to Distribution of Fish Species

The recreational fishery has a **low tolerance** to a change in the distribution of fish species, as it is limited in terms of available fishing grounds. They have **medium adaptability** as they can avoid dredging locations by moving to other areas to fish, however this may result in a decrease in available fishing opportunities and increased fuel and time costs. The recreational fleet is thought to have a **medium** level of **recoverability** as they may re-enter an area rapidly following completion of dredging activity. Based on the consideration of tolerance, adaptability and recoverability, the **sensitivity** of the inshore fleet to a change in the distribution of fish is considered to be **medium**.

The prime fishing grounds in the northern part of the MAREA area are more likely to be impacted by changes in fish distribution as their grounds overlap with the licence areas to a greater extent than in the southern area. However the overall degree of interaction between the inshore fishery and any changes to fish distribution is assessed as **small**.

Based on these assessments of the small magnitude of the effect, the medium value and medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to fish distribution on inshore fisheries is assessed as being ***not significant*** at the regional scale.

10.2.7 Summary of Impacts

Table 10.2 summarises the significance of the cumulative impacts of dredging on commercial and recreational fisheries at the regional scale.

Table 10.2 Significance of Impacts to Commercial and Recreational Fishing from Dredging in the Outer Thames

Effect of Dredging	**Thames Estuary cockle fishery**	**Inshore fleet (vessels <10 m)**	**Offshore fleet (vessels >10 m)**	**Recreational Fleet**
Loss of access	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Change to benthic community composition		*Not significant*		
Change to distribution of fish	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Overall significance of dredging	*Not significant*			

Due to the lack of information on fishing grounds for vessels <10m, consultation to identify prime fishing grounds at the local scale will be important for the EIA process. However impacts to fisheries from dredging are predicted to be not significant. The EIAs will need to present the mitigation measures that will be adopted to avoid any impacts.

10.3 IMPACTS TO INFRASTRUCTURE

10.3.1 Introduction

As discussed in Section 6.3, within the Outer Thames Estuary there is a variety of infrastructure, some of which is important at the regional scale. Infrastructure in the area includes ports and harbours, marine disposal sites, offshore wind farms, pipelines and cables, military activity and oil and gas facilities. The infrastructure in is the region is of large scale and therefore of high value.

Shipping and maritime trade are important elements of the UK economy, with approximately 95% of the UK's international trade by volume being transported by sea. There are a large number of ports, harbours and berths along the coastline of the MAREA area. Offshore wind farms in the area are also of high importance and value as the UK has one of the largest wind resources in Europe (40% of Europe's total potential) (BWEA, 2007) and therefore the development of wind power in the UK is recognised as being one of the key means of meeting the Government's greenhouse gas emissions targets. The Greater Gabbard development, for example will be the first UK project located in international waters (beyond the 12 nautical mile limit) (Greater Gabbard Offshore Wins Limited, 2009) and at 1000MW (megawatts), the London Array will be the largest offshore wind farm in the world (London Array Limited, 2009). In addition, the study area encompasses a range of military uses, including Royal Navy submarine exercise and practice areas.

For the purposes of the assessment, infrastructure features in the same group are assessed together. For example, all wind farms are considered together, with reference made to whether particular wind farms are operational, under construction or consented for future development.

In light of the importance of infrastructure to the UK and the key role it plays in supporting the UK economy and military, all of the infrastructure features are considered to be **high value** receptors.

10.3.2 Identification of Potential Impacts on Infrastructure

Table 10.3 identifies the predicted effects of dredging with reference to whether or not they have the potential to impact various infrastructure features that are present in the MAREA study area.

Table 10.3 Matrix of Potential Impacts of Dredging on Infrastructure

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
A -Ports and harbours	■	×	■	×	■	×	×	■	■	×	■	■	■
B - Marine disposal sites	■	■	■	■	■	■	■	■	■	×	■	■	■
C - Offshore wind farms	■	×	✓	✓	■	✓	✓	✓	■	✓	■	■	■
D - Pipelines and cables	■	×	■	■	■	■	■	■	■	■	■	■	■
E - Military activity	■	■	■	■	■	■	■	■	■	✓	■	■	■
F - Oil & gas infrastructure	■	×	■	×	■	×	■	■	■	■	■	■	■

■	Not affected
×	No interaction
✓	Potential Interaction

For the effects of dredging where a potential interaction exists with a particular receptor, the effect is discussed below. In the ensuing discussion it is important to note that the standard approach to assessing sensitivity is not appropriate in relation to wind farms and military activity. Sensitivity is instead expressed without an attempt to break it down by these attributes, and is categorised based on professional judgement.

10.3.3 Offshore Wind Farms

Fine Sediment Plume

The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a **small to medium magnitude effect** for 20mg l^{-1} plumes and a **medium magnitude** effect for plumes of 50mg l^{-1} and 100mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20mg l^{-1} and 50mg l^{-1} plume) or site specific (for the 100mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20mg l^{-1} plume and a medium change relative to baseline conditions for the 50mg l^{-1} and 100mg l^{-1} plumes.

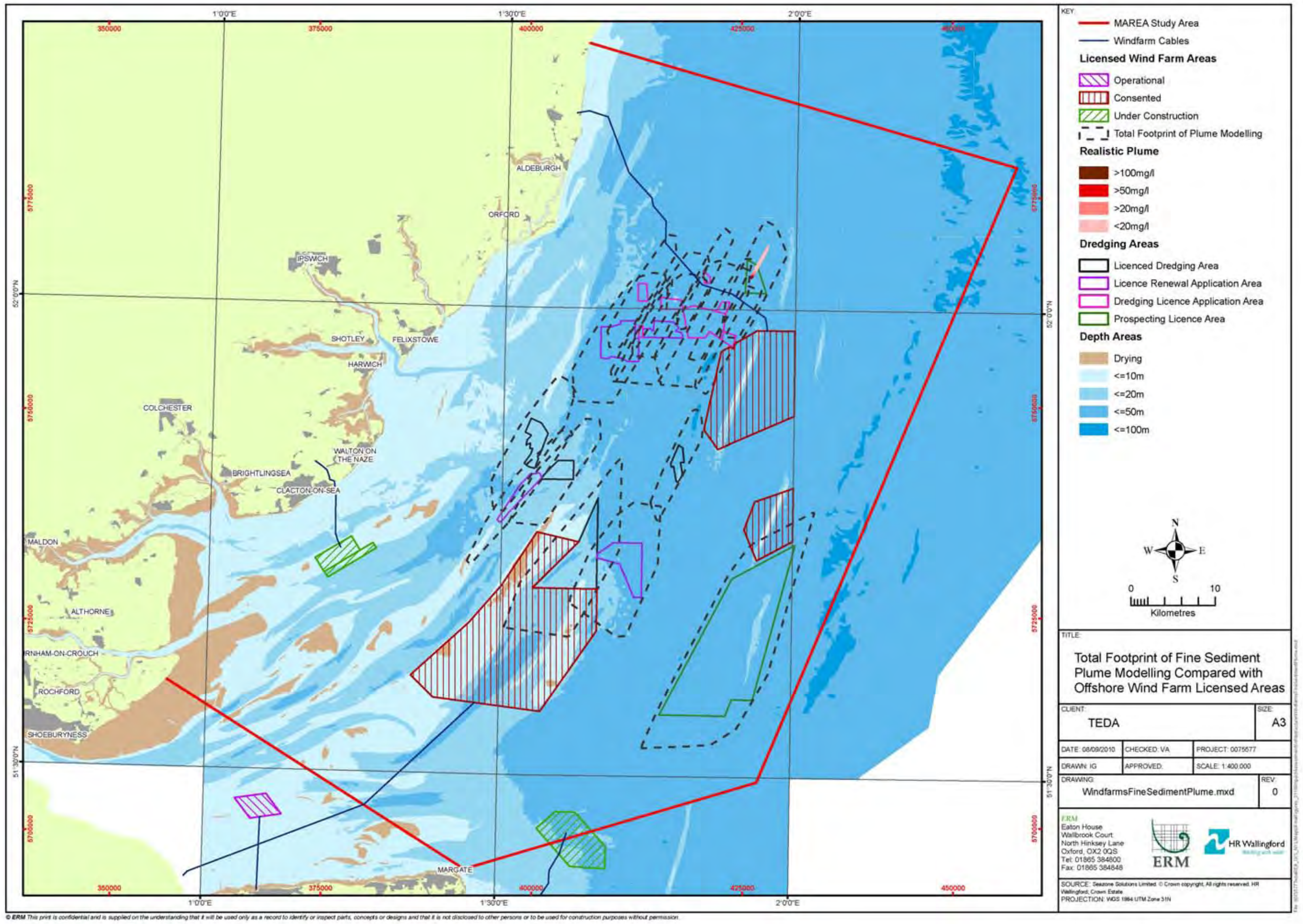
The **sensitivity** of offshore wind farms to a fine sediment plume is considered to be **low.**

Within the study area, there is one operational offshore wind farm (Kentish flats), three under construction (Gunfleet Sands, Gunfleet Sands II and Thanet) and three consented wind farms (London Array, Greater Gabbard – Inner Gabbard and Greater Gabbard – The Galloper). The modelled impact of the three sediment plume concentrations (20mg l^{-1}l, 50mg l^{-1} and 100mg l^{-1}) all predominantly affect the London Array area with a small area on the north-west side of Greater Gabbard – Inner Galloper also affected. Approximately 15% of the total wind farm area is affected by the 20mg l^{-1} plume concentration and approximately 10% of the total wind farm area is affected by both the 50mg l^{-1} and 100mg l^{-1} plume.

However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in a licence area would be much smaller than the modelled plumes in Figure 10.3.

Based on these assessments of the medium magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of the fine sediment plumes on offshore wind farms is assessed to be ***not significant*** at the regional scale.

Figure 10.3 Total Footprint of Fine Sediment Plume Modelling Compared with Offshore Wind Farm Licensed Areas



Sand Deposition

The deposition of sand as a result of dredging activities resulting in the formation of bedforms is a **medium magnitude** effect, based on the fact that it results in a medium change relative to baseline conditions and is regularly occurring (routine); however it is a short term effect and localised.

The sensitivity of offshore wind farms to sand deposition is considered to be **low**.

Within the study area, there is one operational offshore wind farm (Kentish flats), three under construction (Gunfleet Sands, Gunfleet Sands II and Thanet) and three consented wind farms (London Array, Greater Gabbard – Inner Gabbard and Greater Gabbard – The Galloper). Approximately 20% of the total areas of offshore wind farms that are either operational, under construction or consented are within the footprint of sand deposition.

However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The amount of sand deposition associated with a single dredging vessel in a licence area would be much smaller than the modelled deposition.

Based on these assessments of the medium magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of sand deposition on offshore wind farms is assessed to be ***not significant*** at the regional scale.

Change to Wave Heights

A change greater than 5% to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the localised extent of the change and the rarity of the effect, however, the effect is long-term and the change relative to the baseline is medium.

A change of 2-5 % to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the sub-regional extent of the change, the rarity of the effect and the small change relative to the baseline, however, the effect is long-term.

A more than 5% change to a 5% exceedance in wave height [1] is a **small magnitude** effect. This is because of the isolated extent of the effect (site

(1) A change greater than 5% to a wave height that is only equalled or exceeded 5% of the time in an average year.

-specific) and its infrequent occurrence (occasional), however, the duration is long-term and the change relative to the baseline is medium.

A change of between 2-5% to a 5% exceedance in wave height [(1)] is a **small-medium magnitude** effect. This is because of the localised extent of the effect (local), its infrequent occurrence (occasional), and small change relative to the baseline (low) however, the duration is long-term.

Offshore wind farms have a **high tolerance** to changes in wave heights as offshore turbines are designed to withstand changes in sea condition and therefore a low change in wave heights relative to baseline conditions is unlikely to affect the turbines. Offshore wind farms have a **high recoverability** in relation to changes in wave heights as even though the effect is long term, changes in wave heights are not anticipated to significantly impact the wind farms in the area.

The sensitivity of offshore wind farms to changes to wave heights is considered to be **low** as they are designed for the conditions for a margin for extremes**.**

It is only part of the consented area of the London Array wind farm that will experience changes in wave heights. Approximately 15% of the total area of offshore wind farms (either operational, under construction or consented) is modelled to be affected by a 2-5% change in wave height, with approximately 5% of the total area modelled to be affected by a change in wave height of greater than 5%. The affected area is marginally greater at low tide than at high tide.

Similarly, it is only the London Array that is affected by change in terms of a more than 5% exceedance in wave height (ie a wave height that is only equalled or exceeded 5% of the time). Less than 5% of the total area of offshore wind farms (either operational, under construction or consented) is modelled to be affected by a 2-5% change to a 5% exceedance of wave height. None of the wind farm areas are modelled to be affected by more than a 5% change to a 5% exceedance of wave height.

However, this assessment is based on the assumption that the complete dredging tonnage used for this assessment is taken in each licence area, whereas in practice the overall tonnage for each licence area will be much lower than stated here. The changes in wave heights associated with a smaller take in aggregates would be much smaller than the modelled effect.

Based on these assessments of the small to medium magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to wave heights on offshore wind farms is assessed to be ***not significant*** at the regional scale.

(1) A change of between 2-5% to a wave height that is only equalled or exceeded 5% of the time in an average year.

Changes to Tidal Currents

The predicted change modelled is a 10-20% change to tidal currents, as a result of dredging, will be a **medium magnitude** effect as the effect is site-specific, the duration is long-term, the event is frequent (routine) and the change relative to the baseline is medium. Similarly, the 2-10% change to tidal currents will be a **medium magnitude** effect because although the effect is localised and the change relative to the baseline is low, the duration is long-term, the event is frequent (routine).

The sensitivity of offshore wind farms to changes in tidal currents is considered to be **low** as they are designed for the physical movement of water in terms of their structural integrity and scour protection.

A 2-10% change to tidal currents will mostly affect the consented London Array wind farm site with a small portion of the consented Greater Gabbard – The Galloper site also affected. Affected areas represent approximately 28% of the total area of operational, in construction or consented wind farms in the Outer Thames Estuary MAREA (modelled using peak tidal flow based on the flood tide). Modelling of changes in peak tidal flow based on ebb tide shows a similar extent and magnitude of change, with a slightly larger area of the 'Greater Gabbard - The Galloper' being impacted. A 10-20% change to tidal currents will also impact largely on the London Array with a small portion of the Greater Gabbard also affected. However, the 10-20% change is modelled to impact less than 5% of the total area (both on the flood and ebb tide) of operational, in construction or consented wind farms in the Outer Thames Estuary MAREA.

However, this assessment is based on the assumption that the complete dredging tonnage used for this assessment is taken in each licence area, whereas in practice the overall tonnage for each licence area will be much lower than stated here. The changes in tidal currents associated with a smaller take in aggregates would be much smaller than the modelled effect.

Based on these assessments of the medium magnitude of the effect, the high value and low to medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the tidal currents on offshore wind farms is assessed to be of ***minor significance*** at the regional scale.

Changes to Sediment Transport Rates

Changes to sediment transport rates of 100-400kg/m/tide as a result of dredging activities will result in a **medium magnitude** effect, based on the fact that the effect is long term in duration and routine (regularly occurring). However, the effect is local in extent and the change is low relative to the baseline condition. Changes in sediment transport rates of 400-1000kg/m/tide will also result in a **medium magnitude** effect, as the effect is long term in duration and routine, however it is site-specific and constitutes a medium change relative to the baseline.

The sensitivity of offshore wind farms to changes in sediment transport rates is considered to be **low.**

Changes in sediment transport rates will mostly affect the consented London Array wind farm site with a small southern portion of the consented Greater Gabbard – The Galloper site also affected. The dredging is modelled to result in a change of between 100 and 400kg/m/tide in sediment transport rates relative to baseline conditions across approximately 25% of the total area of operational, in construction or consented wind farms in the Outer Thames Estuary MAREA. A change of 400-1000kg/m/tide in sediment transport rate is modelled to occur across less than 2% of the total area of operational, in construction or consented wind farms in the Outer Thames Estuary MAREA.

However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The changes in sediment transport rates associated with a single dredging vessel in a licence area would be much smaller than the modelled effect.

Based on these assessments of the medium magnitude of the effect, the high value and low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to sediment transport rates on offshore wind farms is assessed to be ***not significant*** at the regional scale.

Loss of Access

Loss of access to areas as a result of dredging activities result in a **medium** to **large magnitude** effect, based on the fact that the effect is routine (frequently occurring) and result is high relative to baseline conditions, however the effect is short term (temporary) in duration and site specific.

Offshore wind farms have a **medium tolerance** in relation to loss of access. Loss of, or interruption, to vessels associated with the wind farms accessing licence areas could have an impact on the construction schedule of new wind farms and may temporarily limit access during routine maintenance works on operational wind farms. Offshore wind farms have **high recoverability** in relation to loss of access as the effect would only be short term (temporary) in nature and so periods when access could not be achieved would be limited in extent whilst dredging activities are being carried out.

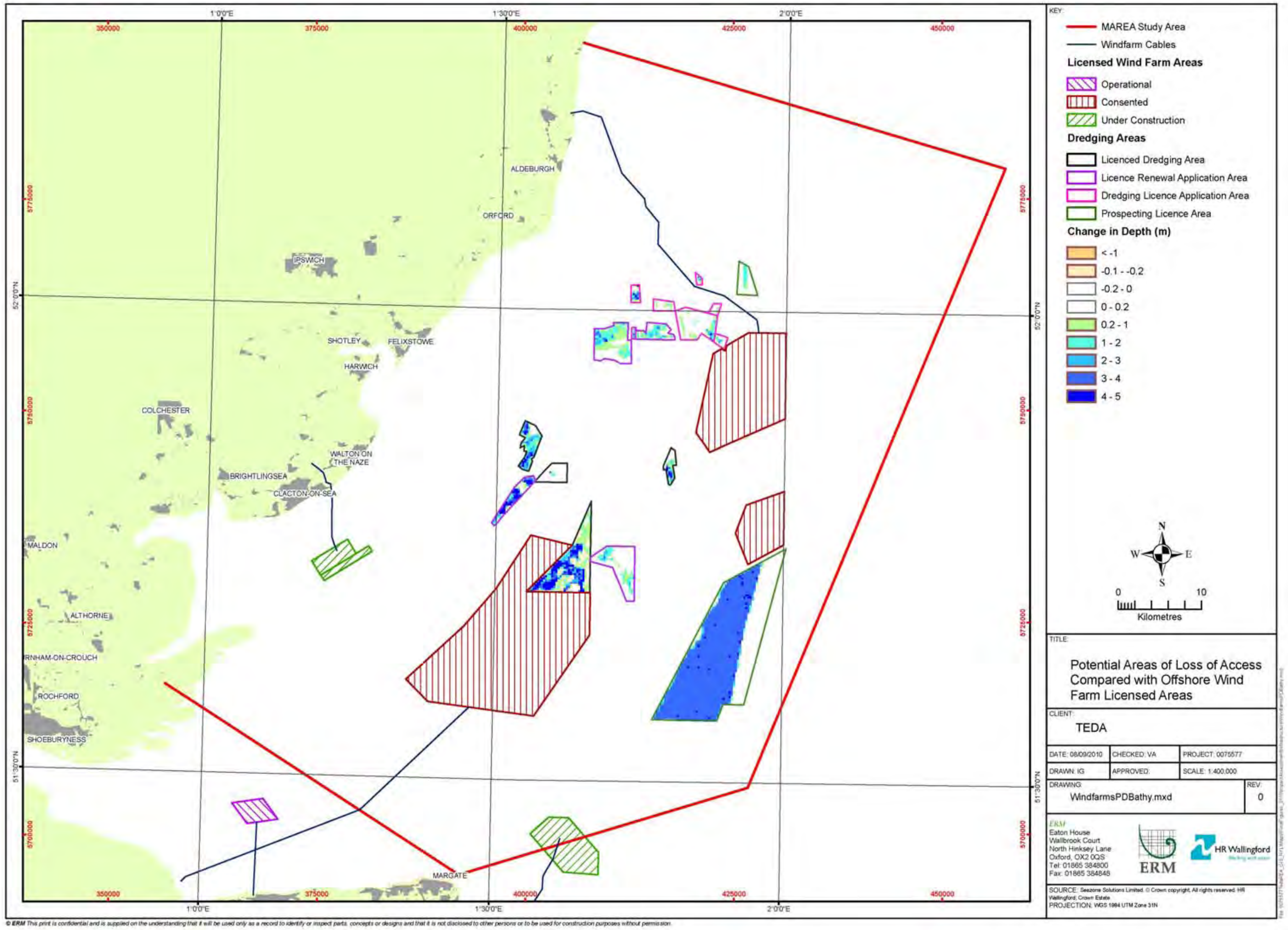
Based on the consideration of tolerance and recoverability, the sensitivity of offshore wind farms to a loss of access is considered to be **low** to **medium**.

Loss of access will mostly affect the consented London Array wind farm site with a small southern portion of the consented Greater Gabbard – The Galloper site also affected. These affected areas represent approximately 25% of the total area of operational, in construction or consented wind farms in the Outer Thames Estuary MAREA.

However, this assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The loss of access associated with a single dredging vessel in a licence area would be much smaller than the modelled affected area shown in Figure 10.4.

Based on these assessments of the medium to large magnitude of the effect, the high value and low to medium sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of loss of access on wind farms is assessed to be of ***minor significance*** at the regional scale.

Figure 10.4 Potential Areas of Loss of Access Compared with Offshore Wind Farm Licensed Areas



10.3.4 Military Activity

Loss of Access

Loss of access to areas as a result of dredging activities result in a **medium** to **large magnitude** effect on military activities based on the fact that the effect is routine (frequently occurring) and result is high relative to baseline conditions, however the effect is short term (temporary) in duration and site specific.

The sensitivity of military activities to a loss of access is considered to be **medium**.

Within the study area, there are nine military practice zones. Approximately 0.73% of the military practice areas in the Outer Thames Estuary MAREA overlap with licence areas (discounting the North Falls Area 504 which has been surrendered – see Industry Statement), therefore the degree of interaction is very small. This assessment is based on the assumption that dredging takes place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The loss of access associated with a single dredging vessel in a licence area would be much smaller than the modelled affected area shown in Figure 10.5.

Based on these assessments of the medium to large magnitude of the effect, the high value and medium sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of loss of access to on military activities is assessed to be of ***minor significance*** at the regional scale.

10.3.5 Summary of Impacts

Table 10.4 summarises the significance of the cumulative impacts of dredging on infrastructure at the regional scale.

Table 10.4 Regional Significance of Impacts to Infrastructure from Dredging in the Outer Thames

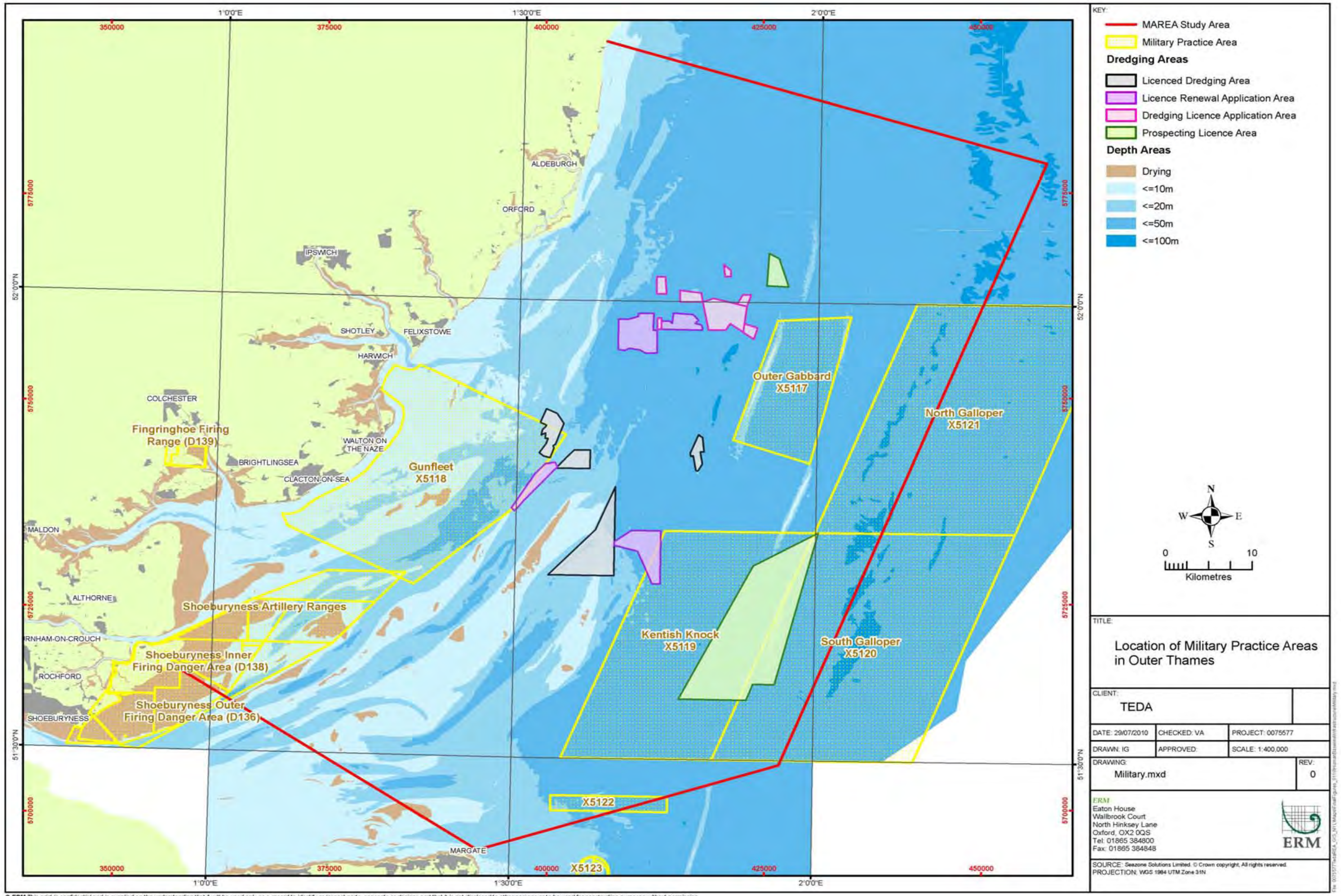
Effect of Dredging	Offshore wind farms	Military activity
Fine sediment plume/elevated turbidity	*Not significant*	
Sand deposition	*Not significant*	
Changes to particle size	*Not significant*	
Changes to wave heights	*Not significant*	
Changes to tidal currents	*Minor*	
Changes to sediment transport rates	*Not significant*	
Loss of access	*Minor*	*Minor*

The impacts to infrastructure from dredging that are predicted to be significant are of *minor* significance and are likely to only affect one or two consented wind farms, if the wind farms are constructed or operational during the time that dredging is being carried out, and small parts of the overall available area designated for military activity.

It is likely that during licence-specific EIAs, when the maximum number of vessels per licence area has been defined and the licence areas have been provisionally zoned, the predicted potential impacts to infrastructure will be considerably lower than stated here.

Depending on the timing of wind farm construction, military activities and dredging operations, it is likely that the effects of dredging may be experienced by different offshore wind farms and different military activities at different times. The overall significance to both offshore wind farms and military activities is assessed as being *minor*.

Figure 10.5 Potential Areas of Loss of Access Compared with Military Practice Areas



10.4 RECREATION

10.4.1 Introduction

As discussed in Section 6.4, racing, sailing and cruising have been identified as the recreational activities that are prevalent in the Outer Thames Estuary. As a result, they are most likely to experience impacts from dredging operations, and will be the focus of this impact assessment.

The available data regarding the recreational activity in the Outer Thames Estuary was mainly informal in nature and this assessment of impacts to recreational activity is largely based on qualitative interpretation.

The Outer Thames estuary is an important area for recreational boating on both a regional and national scale and is the most densely used offshore area for recreation on the east coast of the UK.

Racing [1] and sailing [2] areas in the Outer Thames Estuary are mainly located inshore but they do occur within the study area. A number of races take place in the Outer Thames Estuary, with seven planned in 2010.

Cruising [3] is a popular recreational activity in the MAREA study area and the routes are divided into three categories based on usage (see Section 6.4). All three types of cruising route intersect with dredging licence areas and will potentially be impacted by dredging activity.

A study carried out by Tourism South East and the South East England Development Agency (SEEDA) on the volume and value of leisure cruising in the UK found that 671,000 yachtspersons visited marinas and harbour in the region equating to £27.9 million and supporting over 697 full time equivalent jobs (as of 2003) [4] . In light of this and the national importance of the Thames estuary as a site of activity, marine recreation receptors are considered to be of **medium value**.

10.4.2 Identification of Potential Impacts on Recreation

Table 10.5 identifies the potential impacts of dredging operations in the Outer Thames Estuary on the three main receptors of marine recreation; racing, sailing and cruising.

(1) The use of racing vessels (normally under sail vessels) inshore, within close range of a sailing club through racing routes clearly marked by buoys, or offshore during organised racing events.
(2) Recreational day-sailing activities using small cruisers, dinghies or personal watercraft close to shore.
(3) The use of sail or powered vessels for long-distance offshore sailing.
(4) Tourism South East England. Leisure Cruising report available at http://www.industry.visitsoutheastengland.com/dbimgs/TSE%20Leisure%20cruising_tcm194-85918.pdf (accessed 19/04/10).

Table 10.5 Matrix of Potential Impacts of Dredging on Recreation

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to sandbanks
Racing	✓	■	■	■	■	×	×	■	■	×	■	■	■
Sailing	✓	■	■	■	■	×	×	■	■	×	■	■	■
Cruising	✓	■	■	■	■	✓	✓	■	■	✓	■	■	■

Not affected	■
no interaction	×
potential interaction	✓

It is predicted that there will be no interaction between racing and sailing with changes to waves height, changes to tidal currents, and loss of access because racing and sailing activities take place inshore and not in close proximity to any licence areas.

10.4.3 Racing

Vessel Presence

An increase in the presence of dredging vessels as a result of increased dredging activity in the study area is a **small magnitude** effect based on the effect being routine in occurrence, but site-specific, transient and a low level change relative to baseline vessel movements in the region.

The racing vessels have the ability to avoid other vessels and therefore have a **high tolerance** and **adaptability**. Also, due to the small change of the effect relative to the baseline (just 3% above baseline shipping levels), racing will have a **medium to high recoverability**. Taking tolerance, adaptability and recoverability into account, racing areas have a **low sensitivity**.

The **degree of interaction** between the racing vessels and dredger vessel presence will be **small.** The interaction between racing vessels and dredging vessels will only occur along shipping lanes while the dredging vessels are moving to and from licence areas.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor, and the small degree of interaction between the receptor and the effect, the cumulative impact of vessel presence on racing vessels is assessed to be ***not significant*** at the regional scale.

In addition it should be noted that mitigation measures are in place to prevent collisions with dredging vessels. These include having communication equipment on board dredgers to communicate with all vessels in the area. All recreational and dredging vessels are required to comply with COLREGS [5] to mitigate against collisions. Full mitigation measures can be seen in Appendix I.

10.4.4 Sailing

Vessel Presence

An increase in the presence of dredging vessels as a result of increased dredging activity in the study area is a **small magnitude** effect based on the effect being routine in occurrence, but site-specific, transient and a low level change relative to baseline vessel movements in the region.

Sailing vessels have the ability to avoid other vessels and, therefore, have a **high tolerance** and **adaptability** to this effect. Due to the small change relative to the baseline (just 3% above baseline shipping levels) sailing will have a **medium to high recoverability**. Taking tolerance, adaptability and recoverability into account, sailing areas have a **low sensitivity**.

The **degree of interaction** between the sailing vessels and dredger vessel presence will be **small**. The interaction between sailing vessels and dredging vessels will only occur along shipping lanes while the dredging vessels are moving to and from dredging licence areas.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor, and the small degree of interaction between the receptor and the effect, the cumulative impact of the risk of collision on sailing vessels is assessed to be ***not significant*** at the regional scale

(5) Collision Regulations. International Regulations on the Prevention of Collision at Sea (1972)

The mitigation measures in place for racing vessels (Section 10.4.3) apply to sailing vessels. Mitigation measures will be in place for both recreational and dredging vessels to avoid collisions.

10.4.5 Cruising

Vessel Presence

An increase in the presence of dredging vessels as a result of increased dredging activity in the study area is a **small magnitude** effect based on the effect being routine in occurrence, but site-specific, transient and a low level change relative to baseline vessel movements in the region.

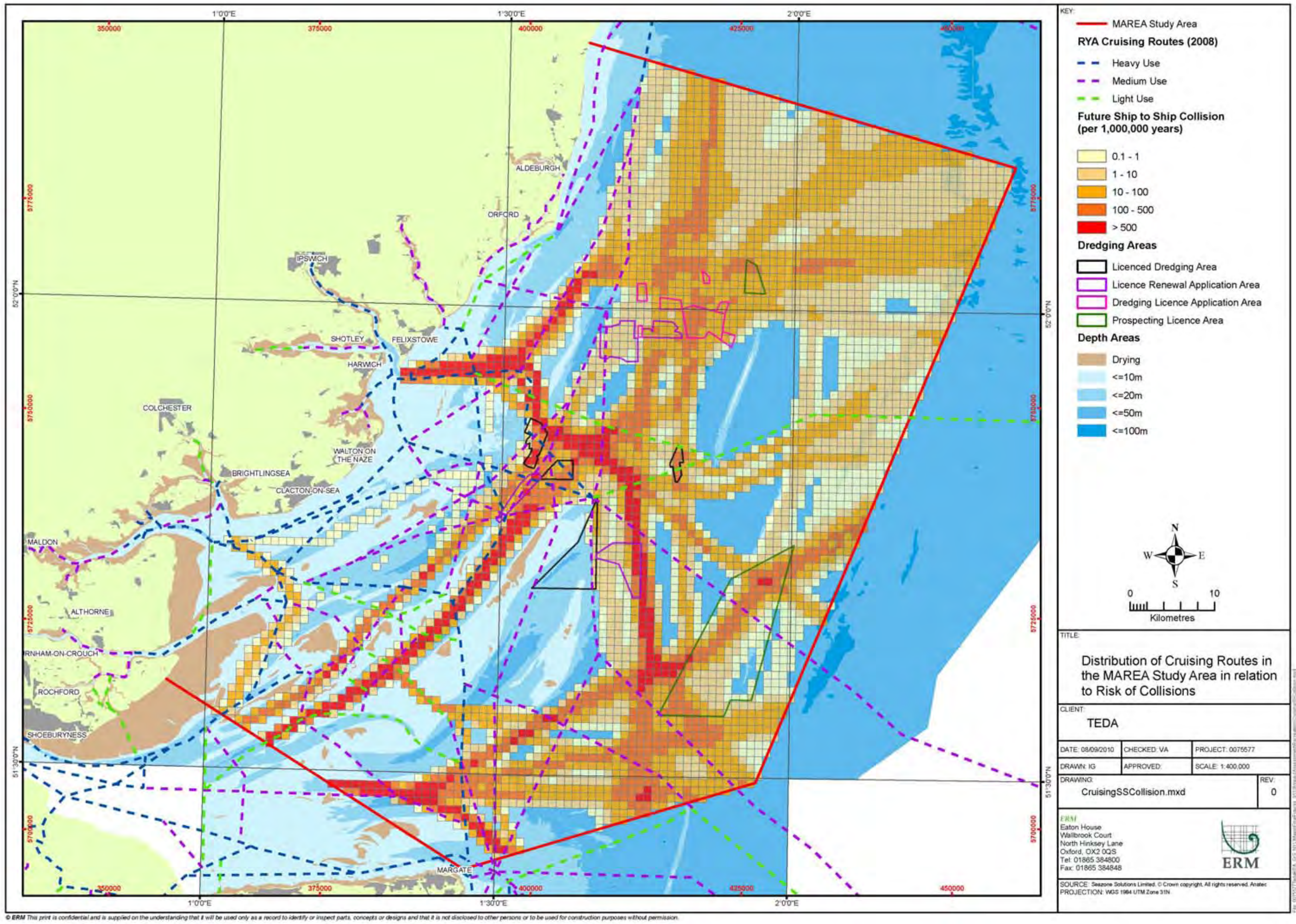
The cruising vessels have the ability to avoid dredger vessels, and therefore have a **high tolerance** and **adaptability**. Due to the small change relative to the baseline (just 3% above baseline shipping levels) cruising will have a **medium to high recoverability**. Taking tolerance, adaptability and recoverability into account, sailing areas have a **low sensitivity**.

The **degree of interaction** between cruising routes and increased vessel presence is **small**. As discussed, a total of 10 routes intersect with licence areas but 26 routes intersect with areas of high risk of future collision frequency (>500 per 1,000,000 years). Of these 26 routes 6 are high usage, 15 are medium usage and 5 are low usage. Figure 10.6 shows the distribution of cruising routes across the study area and the interaction with future ship to ship collision risk as a result of increased dredger presence.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the risk of collision on cruising vessels is assessed to be ***not significant*** at the regional scale.

As discussed in Section 10.4.3, recreational vessels, including cruising vessels, are required to comply with COLREGS [(1)] to mitigate against collisions. Under COLREGS, sailing vessels are required to give way to vessels with a restricted ability to manoeuvre (RAM). Dredging vessels will come under this category during dredging operations.

Figure 10.6 Distribution of Cruising Routes in the MAREA Study Area in relation to Risk of Collisions



(1) Collision Regulations: International Regulation on the Prevention of Collision at Sea (1972)

Changes to Wave Heights

A change greater than 5% to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the localised extent of the change and the rarity of the effect, however, the effect is long-term and the change relative to the baseline is low.

A change of 2-5 % to a 1 in 200 year wave height will have a **small to medium magnitude** effect due to the sub-regional extent of the change, the rarity of the effect and the small change relative to the baseline, however, the effect is long-term.

A more than 5% change to a 5% exceedance in wave height is a **small to medium magnitude** effect. This is because of the isolated extent of the effect (site-specific) and its infrequent occurrence (occasional), however, the duration is long-term and the change relative to the baseline is medium.

A change of between 2-5% to a 5% exceedence in wave height is a **small to medium magnitude** effect. This is because of the localised extent of the effect (local), its infrequent occurrence (occasional), and small change relative to the baseline (low) however, the duration is long-term.

Cruising vessels can tolerate changes to wave heights but the extent depends on the size of the vessel. The **tolerance** and **adaptability** of cruising vessels is **medium,** and **recoverability** of cruising is **medium.** However it should be taken into consideration that wave height is highly variable depending on natural seasonal variation, and in the context of this the **sensitivity** of cruising to changes to wave heights as a result of dredging has been designated as **low.**

The **degree of interaction** between changes to wave heights and the cruising vessels will be **small**. Four heavy usage routes, six medium usage routes and one low usage route will intersect with areas of predicted changes to wave heights but this area of interaction constitutes a small proportion of the available cruising routes.

Based on these assessments of the small to medium magnitude of the effect of all predicted changes to wave height, the medium value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the changes to wave heights on cruising vessels is assessed to be of ***not significant*** at the regional scale.

Changes to Tidal Currents

A 10-20% change to tidal currents, as a result of dredging, will be a **medium magnitude** effect as the effect is site-specific, the duration is long-term, the event is frequent (routine) and the change relative to the baseline is medium.

Similarly, a 2-10% change to tidal currents will be a **medium magnitude** effect because although the effect is localised and the change relative to the baseline is low, the duration is long-term, the event is frequent (routine).

Cruising vessels can tolerate changes to tidal currents but the extent depends on the size of the vessel. The **tolerance** and **adaptability** of cruising routes is **medium**, and the **recoverability** of cruising is **medium.** However the effects of changes to tidal currents as a result of dredging should be considered in the context of natural variation in tidal currents, which are more likely to impact the sorts of decisions a recreational sailor will make in deciding whether to go to sea or not. The overall **sensitivity** of cruising routes to changes in tidal currents as a result of dredging can therefore be regarded as **low.**

The **degree of interaction** between changes to tidal currents and the cruising vessels will be **small**. Three heavy usage routes, six medium usage routes and one low usage route will intersect with areas of predicted changes to tidal heights. However, these routes constitute a small proportion of the available cruising routes.

Based on these assessments of the medium magnitude of the effect, the medium value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the changes to tidal currents on sailing vessels is assessed to be ***not significant*** at the regional scale.

Loss of Access

Loss of access to areas of the Outer Thames Estuary caused by an increase in dredging operations is a **small magnitude** effect based on it being site-specific in extent, temporary in duration and a low level of change relative to the baseline; however, it is regularly occurring (routine).

Cruising routes will be affected by the loss of access to licence areas but the loss of access will be transient depending of the location of dredging operations within the licence areas. Cruising vessels will have a **medium tolerance** and **medium** to **high adaptability** and a **medium** to **high recoverability** in relation to loss of access. Taking these factors into account the **sensitivity** of the receptor is **low** to **medium**.

The **degree of interaction** between the cruising vessels and the impact of loss of access to licence areas is **small.** Not all of the available seabed within the licence areas will be dredged so this reduces the area cruising vessels need to avoid on their routes**.** A total of 13 cruising routes intersect with licence areas, 4 of these are heavily used routes, 8 are routes of medium usage and 1 route is low usage.

Based on these assessments of the small magnitude of the effect, the medium value and low to medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the loss of access on cruising vessels is assessed to be ***not significant*** at the regional scale.

10.4.6 Summary of Impacts

Table 10.6 summarises the significance of the cumulative impacts of recreation activities and the impacts of dredging at a regional scale.

Table 10.6 Regional Summary of Impacts to Recreational Activities

Effect of Dredging	Racing	Sailing	Cruising
Vessel Presence	*Not significant*	*Not significant*	*Not significant*
Changes to wave height			*Not significant*
Changes to tidal currents			*Not significant*
Loss of Access			*Not significant*
Overall significance of dredging	*Not significant*		

Impacts to recreation from dredging are predicted to be not significant. Therefore no action is required to study the potential impacts further at the licence specific EIA stage other than to present the specific mitigation measures to be adopted.

10.5 SHIPPING AND NAVIGATION

10.5.1 Navigational Sensitivity

Overview

Anatec UK Ltd carried out an assessment of the sensitivity of shipping and navigation to future increased dredging operations the Outer Thames Estuary. The study area was divided into 6,733 cells with an average cell size of 0.5 nm (north/south) x 0.5 nm (east/west). A navigational sensitivity ranking was assigned to each cell using shipping density, ship to ship collision risk, recreational usage, fishing vessel density and navigational features as the criteria.

Please refer to Appendix I for a more detailed methodology.

Shipping Density

Shipping density was calculated based on existing merchant shipping activity within the region with the addition of future dredging activity. The results were used to rank the cells from 1 (lowest density) to 5 (highest density).

It is noted that high shipping density leads to high sensitivity even if it is associated with existing shipping passing in the area rather than increased dredging activity.

Ship to Ship Collision Risk

The future ship to ship collision risk results were used to rank the cells from 1 (lowest risk) to 5 (highest risk) (see Box 10.1).

It is noted that high ship-to-ship collision risk leads to high sensitivity even if it is associated with existing shipping passing in the area rather than increased dredging activity.

Box 10.1 Anatec's COLLRISK Model

Anatec's COLLRISK model was used to calculate the ship-to-ship collision frequency for the Thames Study Area with the baseline ship density results used as the input.

The main factors influencing the risk are the ship densities, speeds, courses, types and sizes, and visibility conditions for the area.

Refer to Appendix I for more detail.

Recreational Usage

Close proximity to a cruising route scored 1 for low, 2 for medium and 3 for high usage. In addition, cells overlapping a general sailing or racing area scored an additional 1 per feature.

Fishing Vessel Density

Cells were ranked from 0 (no activity) to 5 (highest activity).

Navigational Features

Proximity to an existing navigational feature (e.g. Traffic Separation Scheme (TSS) Lane, Port Approach, Anchorage Area, Pilot Station or Wind Farm) was also considered within the navigational sensitivity ranking. Increased dredging activity adjacent to an established navigational feature could increase the cumulative impact and subsequent navigational sensitivity. The presence of at least one of the above features resulted in the cell being ranked as 5.

Results of Ranking

The scores per cell were summed (maximum 25) and distributed into five sensitivity ranges (very low - very high), with more than half of the cells falling within the Very Low or Low ranking, as shown in Table 10.7.

Table 10.7 Ranking of Cells by Shipping Navigational Sensitivity for Thames Study Area

Ranking	Sensitivity Scores	Percentage of Grid
Very Low	1	23%
Low	2	29%
Medium	3	17%
High	4	17%
Very High	5	14%

Figure 10.7 presents the distribution of the navigational sensitivity rankings in the Study Area.

Sensitivity Rankings in the Vicinity of each Licence Area Table 10.8 presents the breakdown of the sensitivities for each licence area. It is worth noting that dredging has been conducted in the Outer Thames Estuary for over 40 years without any major shipping incidents, even in high sensitivity areas.

Area 119/3

The majority of this area is ranked as '**Very High'** sensitivity. The area has a high density of shipping and is within the Sunk Outer Precautionary Area which results in a high collision risk.

Preliminary Results for North Falls Prospecting Area (504)

The sensitivity rankings within the North Falls area vary from **'Very Low'** to **'Very High'**. In general, the eastern part of the area tends to have the lowest sensitivity due to shallow water which is avoided by passing shipping. The highest sensitivity is associated with cells to the north which overlap one of the IMO recommended routes (Galloper Recommended) for ferries heading in/out of Felixstowe.

The North Falls area is also transited by shipping routes headed to/from the Inner Thames via Fisherman's Gat and Princes Channel resulting in a number of 'High' ranked cells through the centre of the area.

Long Sand Head Licence (Area 108/3, 109/1 113/1) and Area 327

The Long Sand Head licence (Area 108/3, 109/1 113/1) is mainly located in an area of '**Low'** sensitivity between the shallow water at Long Sand and Kentish Knock. The eastern edge of the area, however, is transited by vessels using the southbound lane of the Long Sand Head Two-way Route. The sensitivity of the south and western edges of this area will increase due to the presence of the London Array Wind Farm decreasing the sea room available for smaller craft.

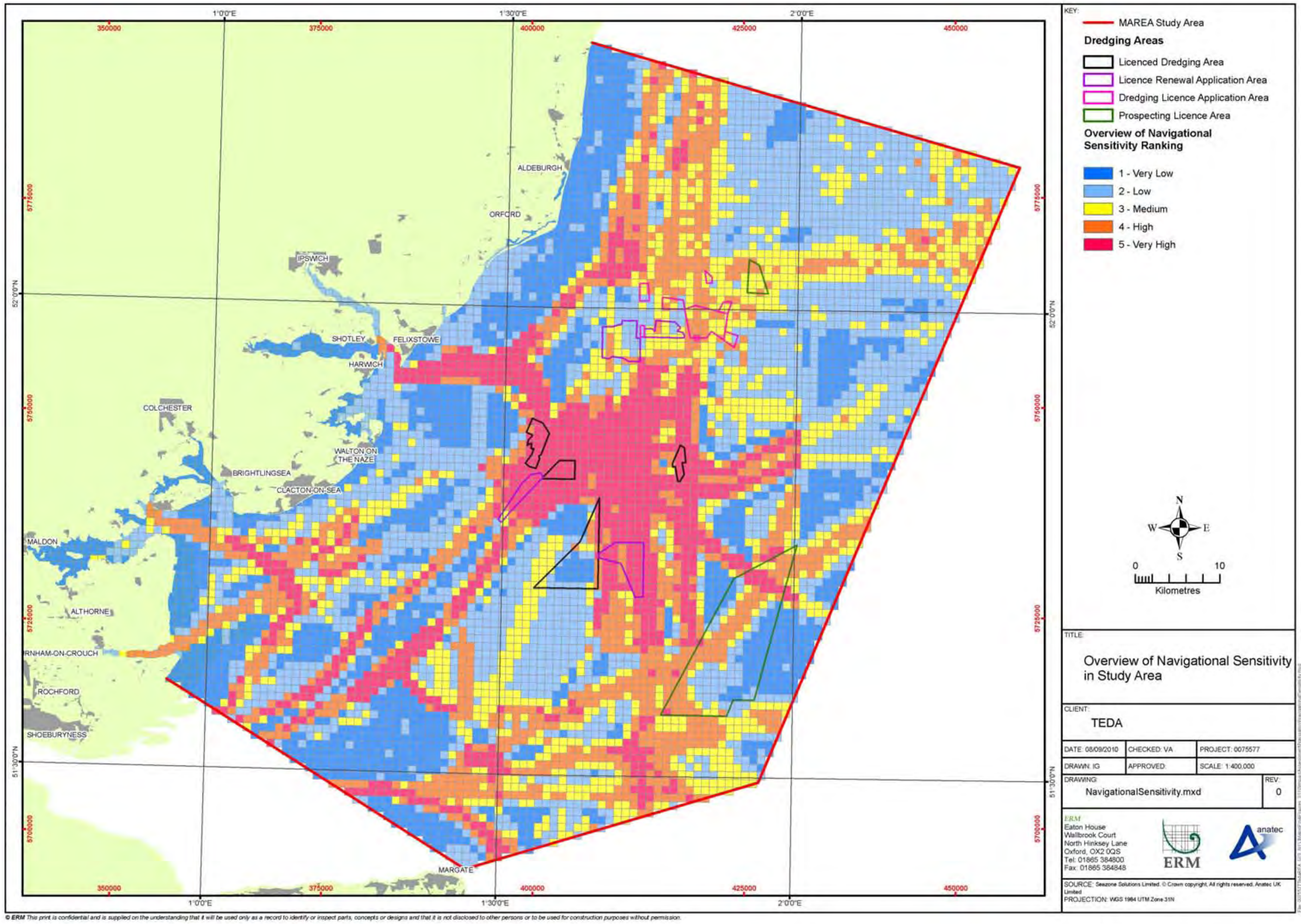
Area 327 is located within the IMO Routeing measures. Most of the area has high levels of shipping which results in a **'Very High'** sensitivity ranking.

Areas 447, 257 and 108/1

Area 447 is located within the Sunk Inner Precautionary Area and intersects part of the Harwich Deep Water Channel. Given the navigational features, high traffic density and associated ship-to-ship encounter / collision risk, the vast majority of the area is classed as **'Very High'** sensitivity. It is worth noting that this area has recently been granted a licence. The EIA for this area has a site specific Shipping and Navigation component.

The majority of Area 257 is located within the Sunk Inner Precautionary Area and has high shipping density due to vessels heading to/from the Inner Thames transiting the area bound for the main navigational channels including Black Deep and Kings Channel. The majority of cells in the area are ranked as **'Very High'** sensitivity.

Figure 10.7 *Overview of Navigation Sensitivity in Study Area*



Area 108/1 is also located within the Sunk Inner Precautionary Area and all cells are ranked as **'Very High'** sensitivity. The cells within Area 108/1 also contain medium recreational activity.

Areas 118/2, 239/1, 452A, 452B, and 452E

Area 118/2 is located to the northwest of the Sunk TSS North. The sensitivity rankings within the area mostly vary from **'Low'** to **'High'**; only the southeast corner partly overlaps a **'Very High'** sensitivity cell. The area has generally low to medium shipping density and associated ship-to-ship collision risk. The area also has some cells with moderate fishing activity.

Area 239/1 is located approximately 2-3 nm north of the Sunk TSS North and is transited by shipping heading for the southbound lane of this TSS, which results in part of the area being **'High'** sensitivity but mostly '**Moderate'** or **'Low'.**

Area 452A, 452 B and 452E are relatively small areas to the north of the Sunk TSS North with varying sensitivities (from **'Low'** to **'High'**) due to variable shipping densities, collision risks and levels of fishing activity.

Areas 452C1, 452C2, 452C3, 452 D and North Inner Gabbard

Area 452 (C1, C2, C3 & D) mostly contains '**Medium'** to **'High'** sensitivity cells. These areas have relatively high densities of shipping passing through them, mostly associated with the Sunk TSS North northbound lane, and correspondingly high ship-to-ship collision risks.

North Inner Gabbard (Area 498) is also within **'Medium'** to **'High'** sensitivity cells, which vary mainly with shipping densities and associated risks of ship-to-ship encounter / collision.

10.5.2 Summary of Sensitivities

Areas with higher sensitivity rankings are likely to be more sensitive areas, from a navigational viewpoint, for licence renewals, application and prospecting dredging areas. The results for these areas tend to be dominated by high shipping densities, associated high ship-to-ship encounter / collision risk, and in some cases IMO Routeing measures or wind farm projects in the vicinity. Table 10.8 describes the components contributing to the navigational sensitivity of each licence area.

Table 10.8 Navigational Sensitivity Factors per Dredge Area

Dredge Area	Average Sensitivity Ranking for Features in Areas						Overall Sensitivity
	Ship Density	Collision Risk	Navigational Features	Fishing	Inshore Fisheries	Recreation	
Existing Licence Areas							
119/3	High	High	Very High	Low	Medium	Low	Very High
Long Sand Head (108/3, 109/1, 113/1)	Low	Low	Medium	Low	High	Low	Low
327	High	High	Very High	Low	High	Very Low	Very High
447	High	High	Very High	Low	Medium	Medium	Very High
257	High	Very High	High	Very Low	Medium	Medium	Very High
108/1	High	Very High	Very High	Low	Medium	Medium	Very High
239/1	High	High	Very Low	Very Low	High	Very Low	Medium
118/2	Low	Low	Very Low	Low	Medium	Very Low	Low
Application Area							
452A	Medium	Medium	Very Low	Low	High	Very Low	Medium
452B	Medium	High	Very Low	Low	High	Very Low	Medium
452C1	High	High	Very Low	Very Low	High	Very Low	High
452C2	Medium	High	Very Low	Very Low	High	Very Low	Medium
452C3	Medium	Low	Low	Very Low	High	Very Low	Medium
452D	High	High	Very Low	Very Low	High	Very Low	Medium
452E	Low	Low	Very Low	Very Low	High	Very Low	Very Low
Prospecting Area							
North Falls (504)	Medium	Medium	Low	Very Low	Medium	Very Low	Low
North Inner Gabbard (498)	High	High	Very Low	Very Low	High	Very Low	Medium

10.5.3 Cumulative Effects

This section considers the potential cumulative impact of dredging vessel movements as a result of the anticipated future dredging operations in total across all licence areas within the Outer Thames Estuary Study Area.

Dredging currently takes place in eight Licence Areas within the Thames MAREA study area. In addition seven application areas and two prospecting areas are located in close proximity to the existing licence areas.
Overall, baseline dredger activity associated with TEDA member companies represents approximately 1-2% of the total ship movements within the Thames Study Area annually. In general, shipping activity is largely dominated by merchant shipping heading to/from Harwich Haven and the Inner Thames via the Sunk TSS and established channels such as Princes Channel and Fisherman's Gat.

The maximum future tonnage scenario will lead to a potential 150% increase in dredging activity over the baseline. However, in overall traffic terms, dredging activity will still represent a **low proportion of approximately 3%.**

This additional dredger traffic will mainly use existing, established routes to/from the dredge areas.

In terms of ship-to-ship collision risk for the study area, the future case risk was in the order of 1 major collision within the study area in 1.39 years [(1)], compared to 1 in 1.44 years for the Baseline, an **increase of approximately 3%,** which roughly reflects the additional traffic.

Based on the change in traffic levels and collision risk in the study area, the additional **cumulative impact from future dredging is not considered to be significant.** A similar change in traffic levels may be observed from normal fluctuations in commercial shipping in the area due to changing trading patterns between ports. In addition, the new dredge areas will be marked on charts and all are in proximity to existing licence areas. It is also worth noting that dredging has continued for many years in very high risk areas without any major incidents.

It is recommended that all licence areas validate the shipping data (densities and routeing) at the individual EIA stage to demonstrate that the baseline data reflected within the MAREA are still current.

Area 119/3, **Area 327**, **Area 257**, **Area 108/1**, **Area 239/1**, **Area 452 A**, **Area 452 B**, **Area 452 C1**, **Area 452 C2**, **Area 452 C3**, **Area 452 D** and **North Inner Gabbard** (ie those licence areas with a medium, high or very high navigational sensitivity) should carry out a site-specific assessment of the change in collision risk resulting from the proposed future dredging activity (subject to the validation of the shipping data), and carry out site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA, Harwich Haven Authority and PLA). Site-specific mitigation measures should be developed and described (see Section 12 of Appendix I for examples).

(1) Please note, predicted collisions are for any type of vessel and may not specifically involve a dredger.

10.6 Archaeology and Cultural Heritage

10.6.1 Introduction

As discussed in Section 6.6, to identify the potential impacts to archaeology and cultural heritage the archaeological resource was divided into the three sections: prehistoric archaeology, maritime archaeology and aviation archaeology. Within each of these themes a number of receptors have been identified and they will be the focus of the impact assessment.

Knowledge of the submerged prehistoric archaeological record is limited but if Palaeolithic [1] and Mesolithic [2] sites were found the material within would be of high national and possibly international archaeological importance. The prehistoric archaeological receptors are Pleistocene fluvial gravels, estuarine alluvium, peat and isolated prehistoric finds.

Pleistocene fluvial gravels could potentially contain archaeological material relating to Lower and Middle Palaeolithic periods. Any such material found within the region must be regarded as of potential national and international importance and therefore Pleistocene gravels should be regarded as **high value** receptors.

Deposits of estuarine alluvium and peat in the study area are likely to contain archaeological material from the Late Devensian [3] and early Holocene [4]. Estuarine alluvium and peat should thus be regarded as a **high value** receptor. Isolated prehistoric finds have the potential to provide valuable information and should, therefore, be regarded as **moderate value** receptors.

The maritime archaeological receptors are known, charted wreck sites, shipping casualties/recorded losses, unknown, uncharted wreck sites and isolated maritime finds. The potential importance of the known, charted wrecks in the study area varies from wreck to wreck, although they will all have archaeological potential and value to a greater or lesser degree. Due to the high variability on a regional scale, known charted wreck sites are regarded as a **high value** receptor.

Shipping casualties in the study area have varying potential importance from wreck to wreck, although they will all have archaeological potential and value to a greater or lesser degree. Due to the high variability on a regional scale, shipping casualty sites are regarded as a **high value** receptor.

(1) A prehistoric era distinguished by the development of the first stone tools.
(2) The post ice age era (8500BC - 4000BC) characterised by development of human technology.
(3) A glaciation period dating from 73000 BC to 10000 BC
(4) A geological epoch which began approximately 12000 years ago and continues to present day.

A significant proportion of unknown, uncharted wreck sites will pre-date the consistent keeping of casualty records and on that basis (i.e. their age and rarity) unknown, uncharted wrecks are a **high value** receptor.

Isolated maritime finds are considered to be of **moderate value** because they have limited archaeological importance when found individually; however, the occurrence of a number of seemingly isolated artefacts within an area can indicate historical events such as battlegrounds or wreck sites.

The receptors associated with aviation archaeology are known, charted aircraft crash sites, recorded aircraft losses and isolated aircraft finds. Any aircraft found are subject to the Protection of Military Remains Act (1986). The 14 known, charted aircraft crash sites within the study area are protected by the Protection of Military Remains Act 1986 and are therefore regarded as **high value** receptors.

The location, distribution of the physical remains of these recorded aircraft losses on the seabed is poorly understood. However, these sites are likely to be of special archaeological interest, and will be automatically protected by the Protection of Military Remains Act 1986 should they be located. Consequently at a regional scale recorded aircraft losses must be considered as a **high value** receptor.

Isolated aircraft finds are considered to be of **moderate value** because they have limited archaeological importance when found individually; however, the occurrence of a number of seemingly isolated artefacts within an area can give insights into patterns of historical aviation across the study area.

Overall, the receptor groups of prehistoric archaeology, maritime archaeology and aviation archaeology are designated as high value.

10.6.2 Identification of Potential Impacts on Archaeology

Table 10.9 details the potential impacts of dredging operations on archaeological and cultural heritage receptors.

It should be noted that when discussing the sensitivity of archaeological receptors, the parameters 'adaptability', 'tolerance' and 'recoverability' have limited applicability to historic environment. However these parameters have been referred to in the following impact assessment, along with justification as to why the various categories were chosen, to allow consistency and comparability with other impact assessment chapters.

Table 10.9 Matrix of Impacts of Dredging on Archaeology

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand and fines deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to sandbanks
Prehistoric archaeology													
Pleistocene fluvial gravels	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Estuarine alluvium	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Peat	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Isolated prehistoric finds	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Known, charted wreck sites	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Shipping casualties / Recorded losses	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Unknown, uncharted wreck sites	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Isolated maritime finds	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Known, charted aircraft crash sites		✉		✉	▪	▪	▪	▪	▪	▪	▪	▪	▪
Recorded aircraft losses	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪
Isolated aircraft finds	▪	✓		✓	▪	▪	▪	▪	▪	▪	▪	▪	▪

Not affected	▪
No interaction	×
Potential interaction	✓

* Please note that data regarding the physical location of aircraft remains on the seabed is extremely limited. The known resource lists only 14 aircraft crash sites within the MAREA area, none of which lie within a licence, application or prospecting area. On the basis of the known resource, therefore, no regional interaction is expected between the known, charted aircraft receptor and the aggregate extraction impacts. However, known aviation resource alone must not be viewed as indicative of the total number of aircraft crash sites within the Study Area.

10.6.3 Magnitude of Effects

Table 10.9 shows that the effects of dredging that have the potential to impact all the receptors related to archaeology and cultural heritage are the removal of sediment and the deposition of sand and fine material as a result of screening and overspill. The magnitudes of these effects are summarised below.

Removal of Sediment

The removal of sediment, as a result of dredging activity, is a **medium magnitude** effect based on the fact that it is site-specific (restricted to dredging licence areas), regularly occurring (routine) but will not impact upon the archaeological resource each time, it constitutes a medium level change relative to the baseline and the removal is permanent (long-term).

It should be noted that the following assessment deals with the potential impacts to archaeology should interaction occur and mitigation measures have not been considered. However dredging vessels have a number measures in place to avoid important archaeological sites, including avoidance behaviour by respecting exclusion zones, and follow reporting protocols for archaeological discoveries.

Sand Deposition

Sand deposition as a result of dredging is a **small magnitude** effect based on the fact that the effect will extend up to one tidal excursion beyond the licence area (i.e. it is local in extent), is regularly occurring (routine), however the duration is short-term and it is a low level change relative to the baseline.

10.6.4 Removal of Sediment

Pleistocene Fluvial gravels

The removal of sediment as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Pleistocene fluvial gravels are the principal deposits targeted by the aggregate industry; therefore, they will be unable to tolerate the effects of substrate removal resulting in a permanent change to the receptor. The **tolerance** and **adaptability** of the receptor is **low**. Similarly, the receptor's recoverability or ability to return to its pre-impact state after substrate removal is **low** and Pleistocene fluvial gravels must therefore be regarded as a receptor of **high sensitivity** to the effects of substrate removal.

Pleistocene fluvial gravels are widespread in the Thames estuary region; however, their full extent across the study area is unknown. The degree to which removal of sediment overlaps with the location and distribution is unknown but there is likely to be a **large degree of regional interaction**.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the large degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on prehistoric fluvial gravels is assessed to be of ***major significance*** at the regional scale. It should be noted that gravel is the target resource for the marine aggregates industry, therefore an impact of major significance on this receptor is to be expected.

Estuarine Alluvium

Sediment removal as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Alluvial deposits will be unable to tolerate the effects of substrate removal resulting in a permanent change to the receptor. The **tolerance** and **adaptability** of the receptor is **low**. Similarly, the receptor's recoverability or ability to return to its pre-impact state after substrate removal is **low** and estuarine alluvium is therefore regarded as a receptor of **high sensitivity** to the effects of substrate removal.

The extent of estuarine alluvium across the study area is unknown and the degree to which removal of sediment overlaps with the location and distribution of the receptor is thus unknown. The assumption is that the marine aggregate industry will avoid areas in which estuarine alluvium is present or overlies gravel. It is therefore assumed that there is likely to be a **small degree of regional interaction**.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on estuarine alluvium is assessed to be of ***minor to moderate significance*** at the regional scale

Peat

The removal of sediment as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Deposits of peat will be unable to tolerate the effects of substrate removal resulting in a permanent change to the receptor. The **tolerance** and **adaptability** of the receptor is **low**. Similarly, the receptor's recoverability or ability to return to its pre-impact state after substrate removal is **low** and peat is therefore regarded as a receptor of **high sensitivity** to the effects of substrate removal.

The extent of peat across the study area is not fully understood and the degree to which the spatial extent of the removal of sediment overlaps with the location and distribution of the receptor is thus unknown. Along with estuarine alluvium, it is expected that the marine aggregate industry will avoid areas in which peat is present or overlies gravel it is assumed that there is likely to be a **small degree of regional interaction**.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on peat is assessed to be of ***minor to moderate significance*** at the regional scale. It should be noted that peat is not targeted by extraction activities, but may be an unavoidable consequence of dredging in some areas.

Isolated Prehistoric Finds

The removal of sediment as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). The **adaptability** and **tolerance** of the receptor to substrate removal is **low** because of potential damage to and dispersal of artefacts. The receptor's ability to return to its pre-impact state (**recoverability**) after substrate removal is **low**. Given their moderate archaeological value, however, isolated prehistoric finds can be regarded as receptors of **moderate sensitivity** to the effects of substrate removal.

It is not possible to quantify or predict the volume or distribution of isolated prehistoric finds in the study area but there is high potential for finds to be located within the study area as a whole. Due to the uncertainty regarding the location of isolated prehistoric finds, a **medium degree of regional interaction** between sediment removal and the receptor is suggested.

In consideration of these assessments medium magnitude of the effect, the moderate value and moderate sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on isolated prehistoric finds is assessed to be of ***moderate significance*** at the regional scale

Known Charted Wreck Sites

Sediment removal as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Wreck sites are unable to tolerate the effects of substrate removal leading to a permanent change if damaged, therefore **adaptability**, **tolerance** and **recoverability** of the receptor is **low.** Known, charted wrecks are therefore assessed as being **highly sensitive** to sediment removal.

The degree of interaction between sediment removal and known charted wrecks is expected to be **small** for two reasons. Firstly, the locations are known and the marine aggregate industry will try to avoid them, and secondly, 5.7% (31 sites) of the known charted wreck sites lie outside of the current licence, application and prospecting areas. Six of the 31 wreck sites lie in parts of the licence areas that will only be changed in depth by 0 - 0.2 m. Figure 10.8 shows the interaction of known, charted wreck sites and sediment removal in the study area.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on known, charted wreck sites is assessed to be of ***minor to moderate significance*** at the regional scale.

10.6.5 Shipping Casualties

Sediment removal as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Shipping casualties are unable to tolerate the effects of substrate removal leading to a permanent change if damaged therefore **adaptability**, **tolerance** and **recoverability** of the receptor are **low**. Shipping casualties are therefore classified as having **high sensitivity** to sediment removal.

There is a lack of positional data available regarding this receptor and, therefore, a precautionary approach must be adopted and a **medium degree of regional interaction** is suggested between the receptor and removal of sediment. Figure 10.9 shows the interaction of shipping casualties and sediment removal in the study area.

The assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, have lead to the assessment of the cumulative impact of the sediment removal on shipping casualties as being of ***moderate to major significance*** at the regional scale.

10.6.6 Unknown Uncharted Wreck Sites

The removal of sediment as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Where substrate removal results in a direct impact to the archaeological record of the remains of unknown, uncharted wrecks, the result would be a permanent; therefore, **adaptability**, **tolerance** and **recoverability** of the receptor are **low.** Unknown, uncharted wrecks are therefore **highly sensitive** to sediment removal.

There is a large amount of uncertainty regarding the distribution and extent of unknown, uncharted wreck sites within the MAREA study area. A precautionary approach has been adopted and a **medium degree of regional interaction** between the receptor and sediment removal is suggested.

Figure 10.8 The Interaction between Charted Wrecks and Sediment Removal within the MAREA Study Area

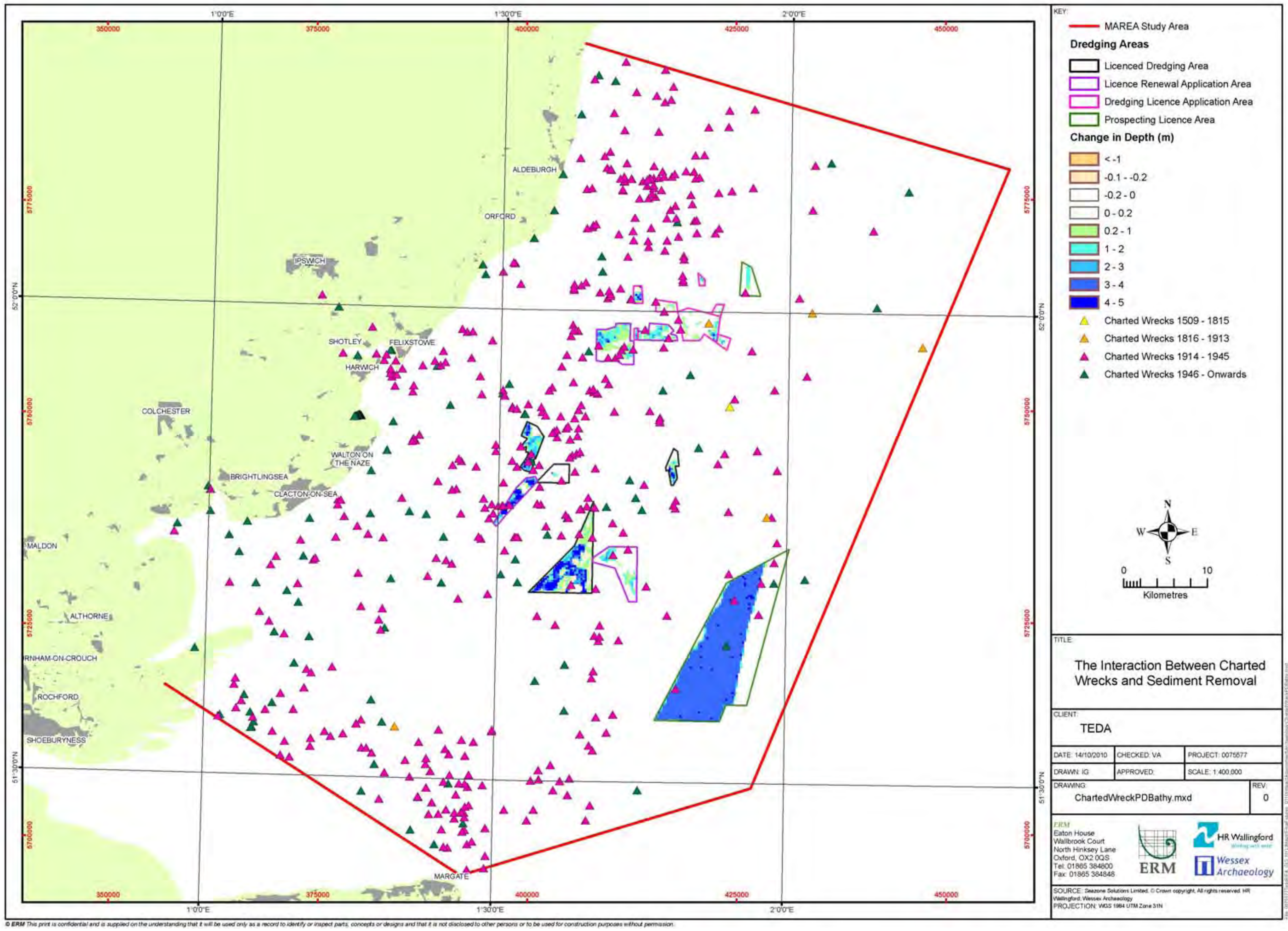
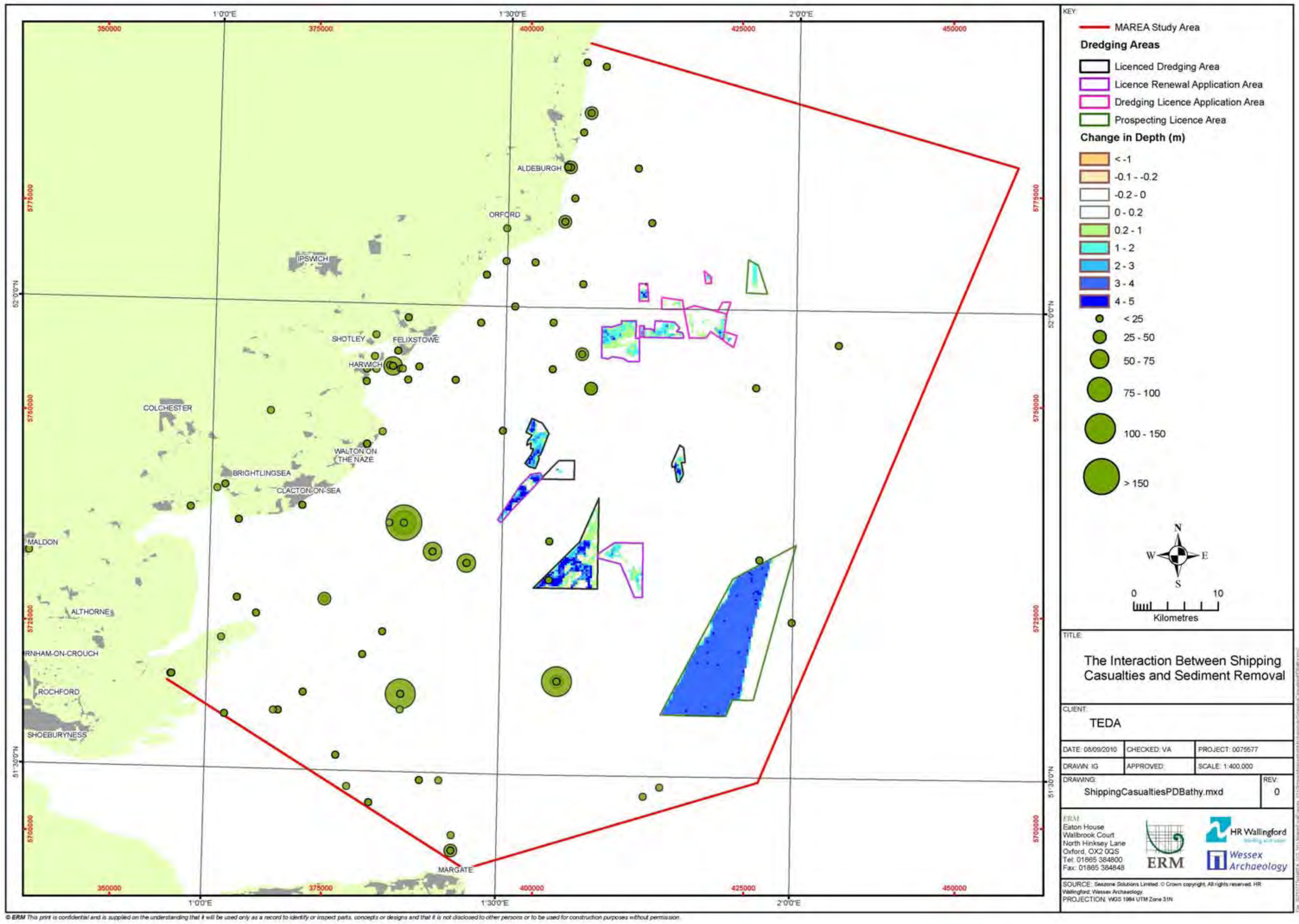


Figure 10.9 The Distribution of Shipping Casualties in the MAREA Study Area with Removal of Sediment



The cumulative impacts of sediment removal to unknown, uncharted wreck sites is assessed by considering the medium magnitude of the effect, the high value and high sensitivity of the receptor and the medium degree of interaction between the receptor and the effect. The cumulative impacts have been assessed as ***moderate to major significance*** at the regional scale.

Isolated Maritime Finds

Sediment removal as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). The **adaptability**, **tolerance** and **recoverability** of isolated maritime finds are **low** because once substrate is removed the receptor will be unable to recover leading to a permanent change. Taking this into account isolated maritime finds are classified as having **moderate sensitivity** to the removal of sediment**.**

It is not possible to quantify the volume and distribution of isolated maritime finds; however the number of known wrecks and documented losses and the inferred potential for unknown and uncharted wrecks suggests a high potential for such finds to be present on the sea bed. Due to the uncertainty regarding their location, a **medium degree of regional interaction** between the receptor and sediment removal is suggested.

Based on these assessments of the medium magnitude of the effect, the moderate value and moderate sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on isolated maritime finds is assessed to be of ***moderate significance*** at the regional scale.

Recorded Aircraft Losses

The removal of sediment as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). Where substrate removal results in a direct impact to the archaeological record the physical remains of recorded aircraft losses would be unable to tolerate the effects, resulting in a permanent change. The **tolerance, adaptability** and **recoverability** of the receptor are therefore **low**. Although the positions of recorded aircraft losses are not known, the relatively short span of time since they were deposited on the seabed suggests that wreckage should be expected to survive in some form within the study area. Due to the uncertainty regarding their precise location and the potential for impact from aggregate dredging, recorded aircraft losses should be regarded as a receptor of **high sensitivity**.

There were a total of 126 documented aircraft losses within the study area (see Appendix F for full details) during WWII, four within one licence area, and somewhere in the region of 236 Air/Sea Rescue Operations within the study area. These figures can not be definitive because there is not a single list of aircraft losses in the UK territorial waters. The uncertainty in the numbers of recorded aircraft losses and the automatic protection afforded by the Protection of Military Remains Act (1986), result in a suggested **medium degree of regional interaction** between the receptor and substrate removal. Figure 10.10 shows the interaction between recorded aircraft losses and sediment removal in the study area.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on recorded aircraft losses is assessed to be of ***moderate to major significance*** at the regional scale

10.6.7 Isolated Aircraft Finds

Sediment removal as a result of dredging activity is a **medium magnitude** effect (see Section 10.6.3). The **adaptability**, **tolerance** and **recoverability** of isolated aircraft finds are **low** because once substrate is removed the receptor will be unable to recover leading to a permanent change. Taking this into account isolated maritime finds are assessed as having **moderate sensitivity** to sediment removal**.**

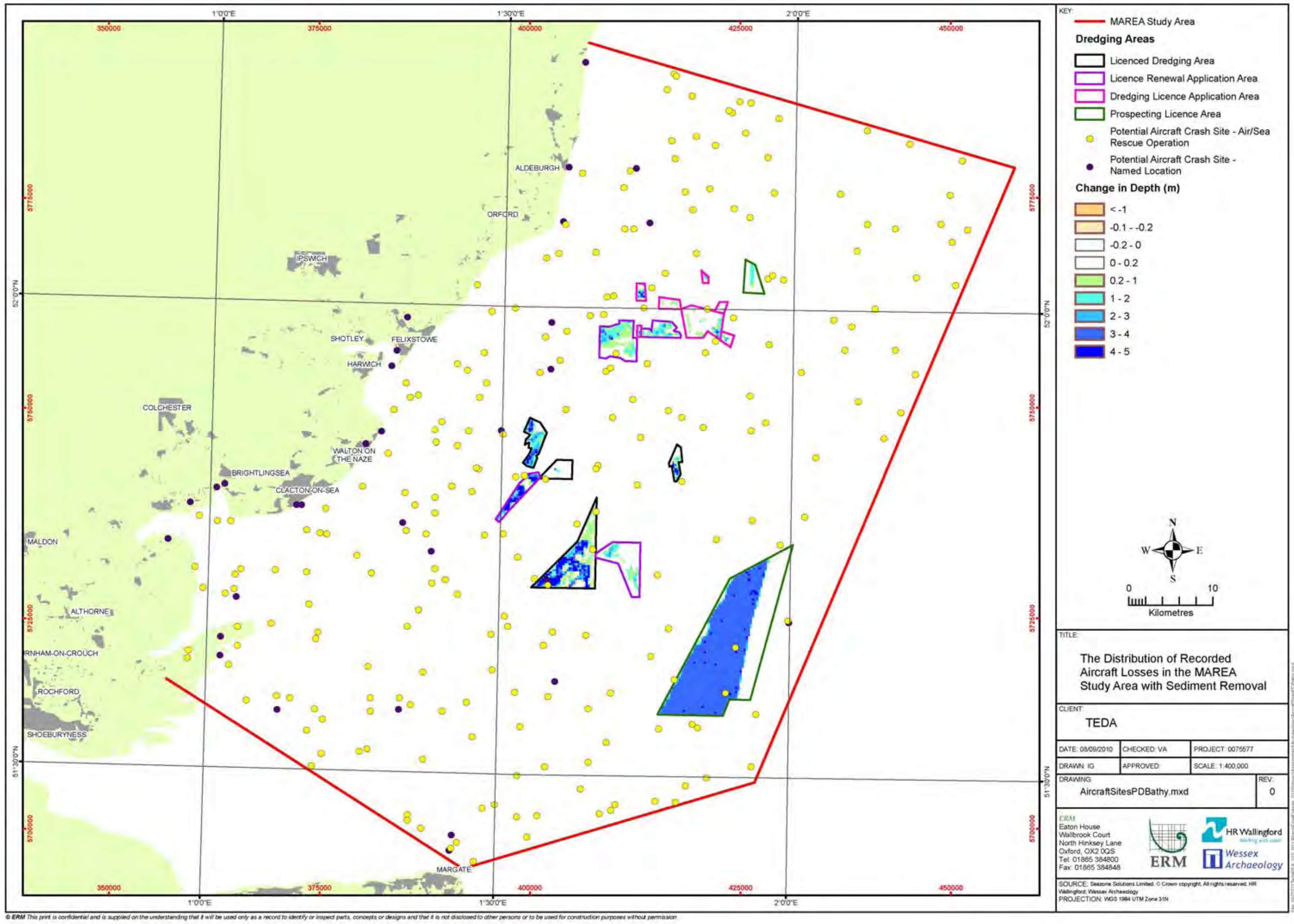
It is not possible to predict the volume and distribution of isolated aircraft finds across the study area. However, a consideration of the known aircraft crash sites and the documented aircraft losses suggests a high potential for such material in or on the seabed. Due to the uncertainty regarding their location, isolated aircraft finds must be approached with caution and as such, a **medium degree of regional interaction** between sediment removal and the receptor is suggested.

Based on these assessments of the medium magnitude of the effect, the moderate value and moderate sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of the sediment removal on isolated aircraft finds is assessed to be of ***moderate significance*** at the regional scale

10.6.8 Sand Deposition

It is assessed that in the case of each of the archaeological receptors that are considered to be present within the MAREA area, it is likely that the receptors will be unaffected or positively affected by the effects of sand deposition as a result of dredging. The cumulative impact of sand deposition on each of the archaeological receptors is therefore assessed to be **positive** at a regional scale.

Figure 10.10 The Distribution of Recorded Aircraft Losses in the MAREA Study Area with Removal of Sediment



The degree to which sand deposition overlaps with the location and distribution of Pleistocene fluvial gravels is unknown but there is likely to be a large degree of regional interaction.

The extent of estuarine alluvium and peat across the study area is unknown and the degree to which sand deposition overlaps with the location and distribution of these receptors is also unknown. As discussed, the assumption is that the marine aggregate industry will avoid areas in which estuarine alluvium and peat are present or overlie gravel. It is therefore assumed that there is likely to be a small degree of regional interaction between the receptors and sand deposition.

It is not possible to quantify or predict the volume or distribution of isolated prehistoric finds in the study area but there is high potential for finds to be located within the study area as a whole. Due to the uncertainty regarding the location of isolated prehistoric finds, a medium degree of regional interaction between sand deposition and receptor is suggested.

Interaction between sand deposition and known charted wrecks is expected to be small because 90.4% wrecks lie outside of the sediment plume footprint. Figure 10.11 shows the interaction of known, charted wreck sites and sand deposition in the study area.

There is a lack of positional data available regarding shipping casualties and isolated maritime finds, therefore, a precautionary approach must be adopted and a medium degree of regional interaction is suggested between the receptors and sand deposition. Figure 10.12 shows the interaction with shipping casualties and sand deposition in the study area.

As discussed, the uncertainty in the numbers of recorded aircraft losses and the automatic protection afford by the Protection of Military Remains Act (1986) result in a suggested medium degree of regional interaction between this receptor and sand deposition. Figure 10.13 shows the interaction between recorded aircraft losses and sand deposition in the study area.

It is not possible to predict the volume and distribution of isolated aircraft finds across the study area. However, a consideration of the known aircraft crash sites and the documented aircraft losses suggests a high potential for such material in or on the seabed. Due to the uncertainty regarding their location, a medium degree of regional interaction between sand deposition and the receptor is suggested.

Figure 10.11 The Interaction between Charted Wrecks within the MAREA Study Area with Sand deposition Footprint

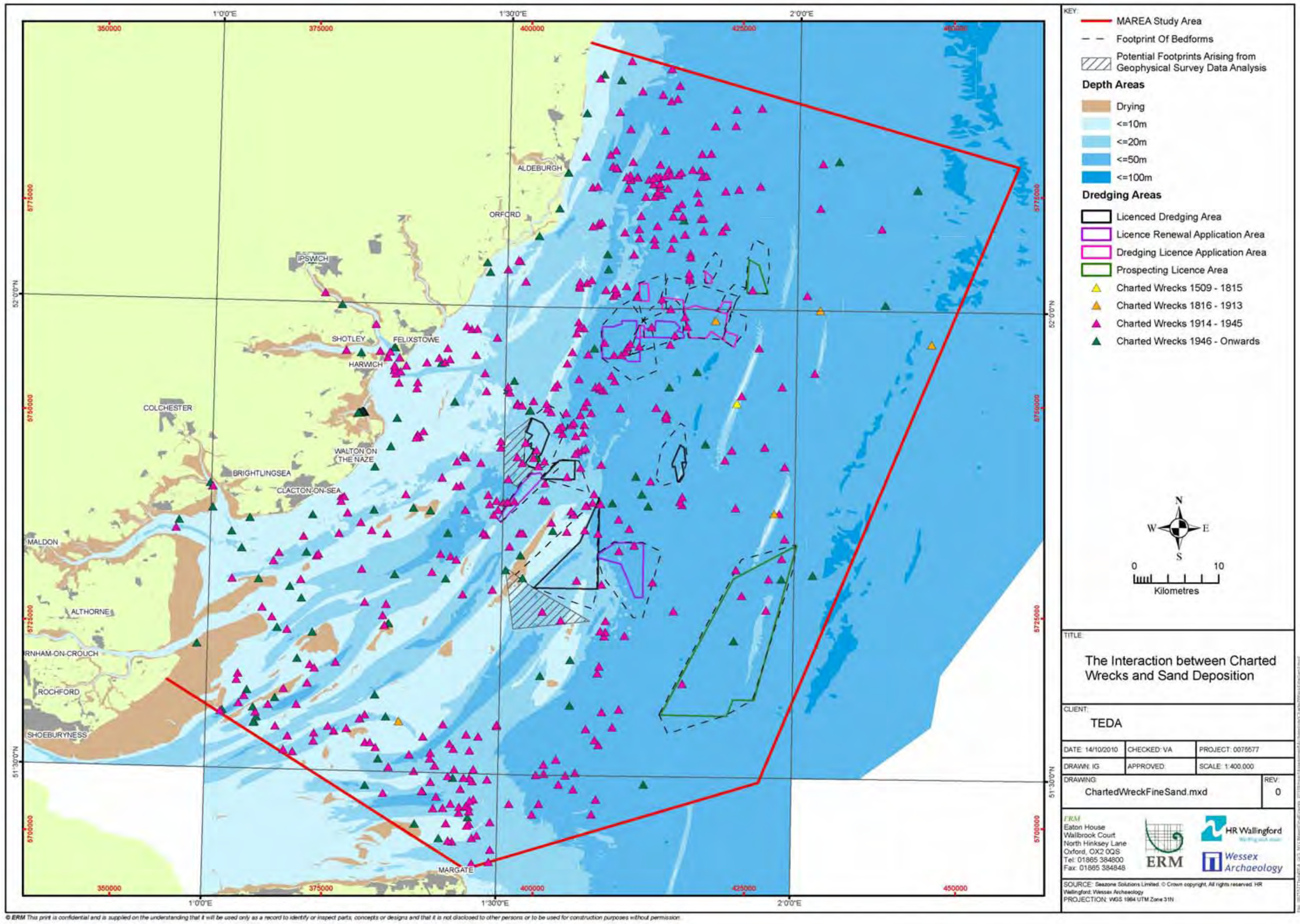


Figure 10.12 The Distribution of Shipping Casualties in the MAREA Study Area with Sand Deposition

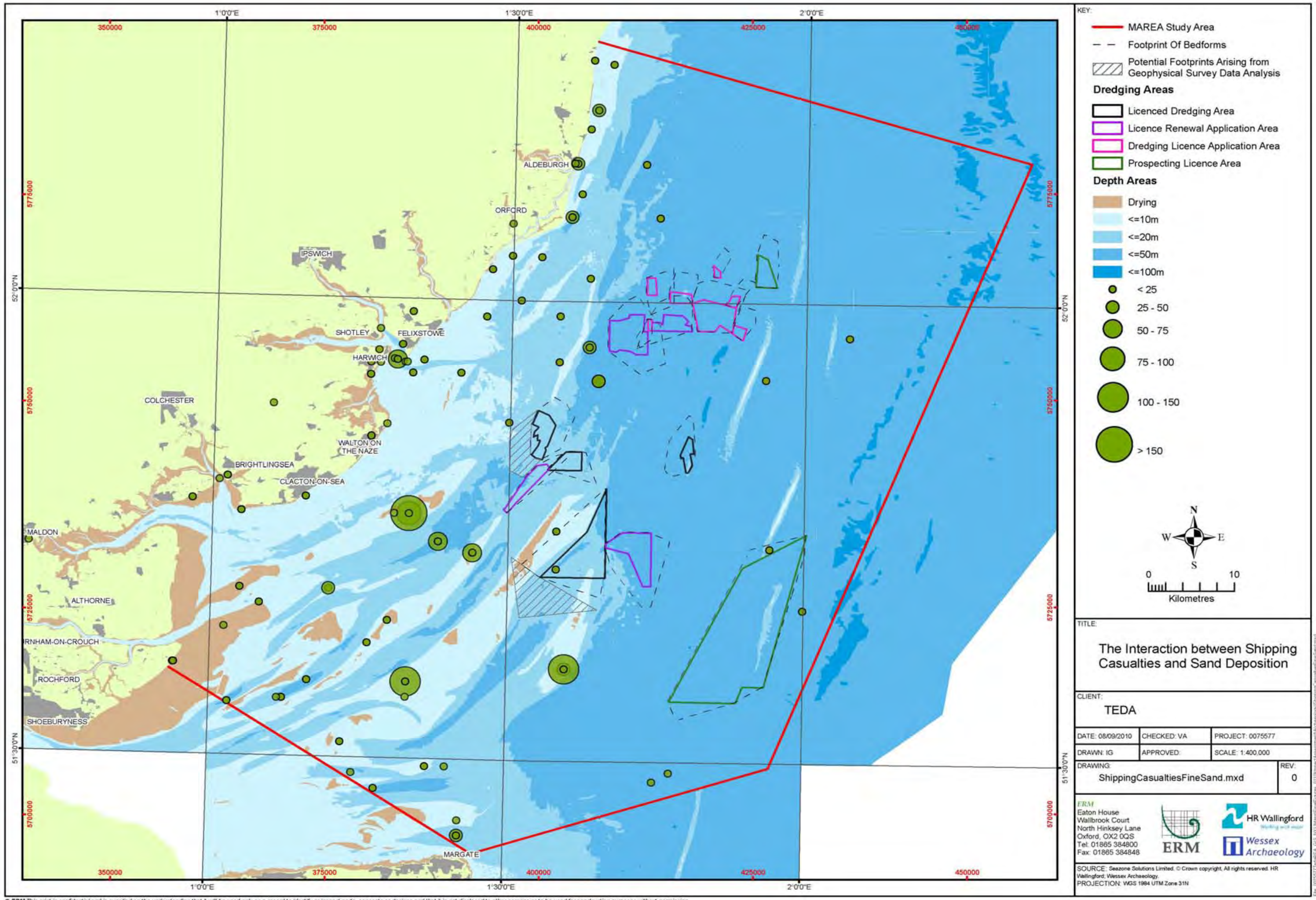
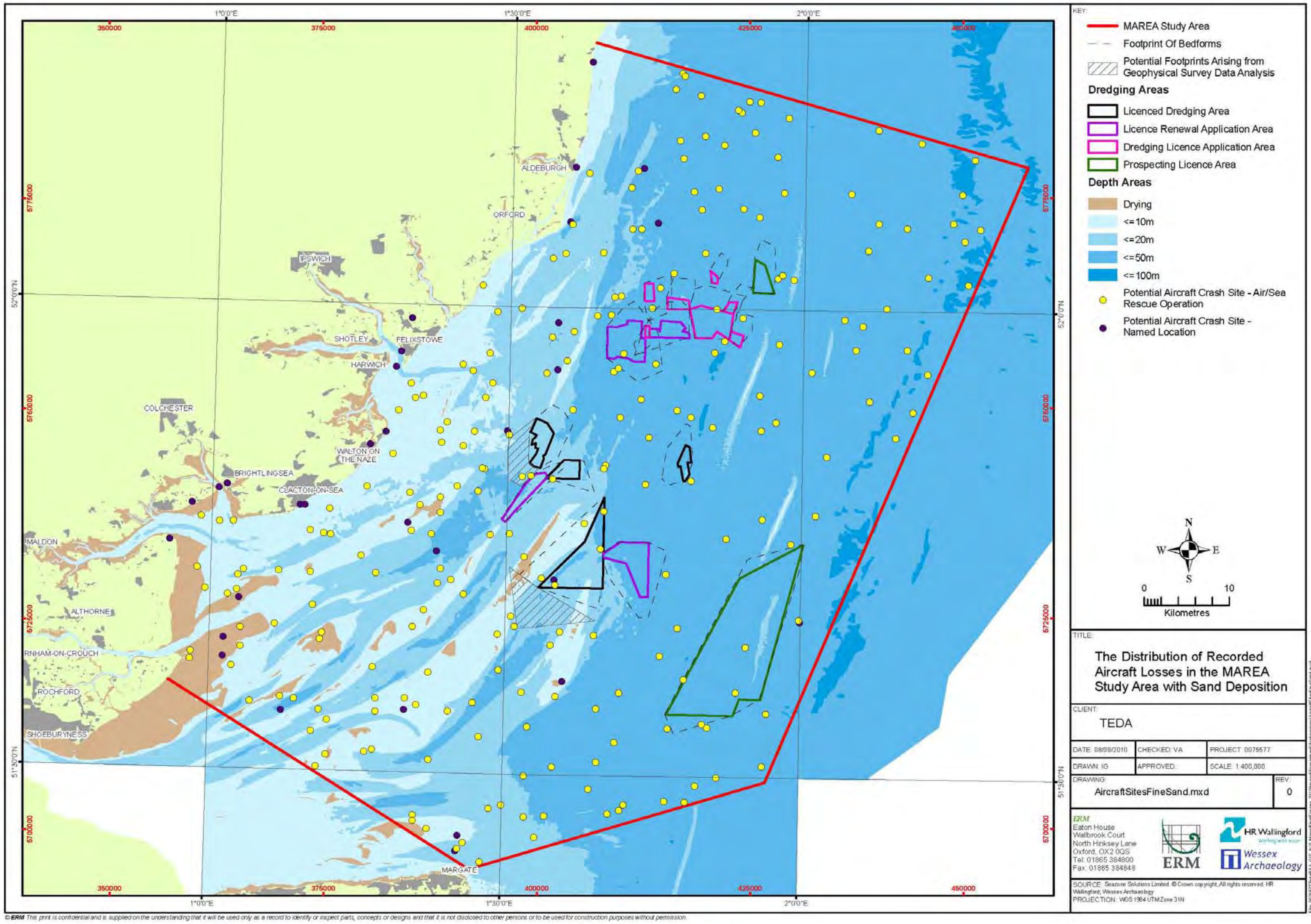


Figure 10.13 The Distribution of Recorded Aircraft Losses in the MAREA Study Area with Sand Deposition Distribution



10.6.9 Summary of Impacts

Table 10.10 summarises the significance of the cumulative impacts of dredging on archaeological and cultural heritage receptors at the regional scale.

Table 10.10 Regional Summary of Impacts to the Receptors

Receptor	Effect		
	Removal of Sediment	**Sand deposition**	**Overall significance of dredging**
Pleistocene fluvial gravels	Major	Positive	Major
Estuarine Alluvium	Minor/Moderate	Positive	Moderate
Peat	Minor/Moderate	Positive	Moderate
Isolated Prehistoric Finds	Moderate	Positive	Moderate
Known Charted Wreck Sites	Minor/Moderate	Positive	Moderate
Shipping Casualties	Moderate/Major	Positive	Major
Unknown Uncharted wreck Sites	Moderate/Major	Positive	Major
Isolated Maritime Finds	Moderate	Positive	Moderate
Recorded Aircraft Losses	Moderate/Major	Positive	Major
Isolated Aircraft Finds	Moderate	Positive	Moderate
Overall Significance of Dredging	Moderate to Major		

The impacts to archaeology and cultural heritage from the removal of sediment as a result of dredging are predicted to be significant and range from **minor** to **major.** The impacts from sand deposition are assessed as being **positive** for all receptors.

It should be noted that these impacts are assessed without the consideration of inherent mitigation measure that are undertaken by the dredging industry, such as avoidance behaviour and observing exclusion zones. These measures greatly reduce the likelihood of impacts to a number of archaeological receptors occurring.

The coincidence of licence areas and receptors is such that none of the licence areas can be regarded as 'clear' of interactions with any of the archaeological receptors that have been assessed.

Two prehistoric archaeological receptors, estuarine alluvium and peat, are present in almost all of the licence areas surveyed. Pleistocene fluvial gravels have been shown to be present in only four licence areas although deposits are known to exist throughout the Outer Thames Estuary.

There are known, charted wrecks in **all of the licence areas except Area 452 D, Area 452 C2 and Area 452 C3**. **Area 118/2** has the highest number of known, charted wrecks sites with 10 sites each within these areas. The third highest number of sites is in **Long Sand Head licence (Area 108/3, 109/1, 113/1)**, which has seven sites within its boundaries. All other licence areas have between 1 and 4 sites.

Long Sand Head licence (Area 108/3, 109/1, 113/1) has shipping casualties and recorded aircraft losses recorded within it.

More than half of the licence areas encompass reported aircraft losses; however, none contain known, charted air crash sites.

Each licence area has the potential to contain isolated aircraft finds, and possibly entire crash sites.

In conducting EIAs for individual licence areas, it will continue to be necessary for historic environment data to be sought for within each licence area and its immediate vicinity from the principal third-party records. Specifically, it will be necessary to check if any existing records have been altered or new records added as these third-party records are continually being updated.

The third-party sources of most direct relevance are the UKHO (known sites of maritime and aviation archaeology interest, plus obstructions etc. that may represent as yet unrecognised sites) and NMR (known prehistoric, maritime and aviation sites; shipping casualties; and aircraft losses). Local Historic Environment Records (HERs) should also be consulted where a Licence Area falls within a HER's territorial extent, predominantly for known prehistoric, maritime and aviation sites within the Licence Area. Reports received through the Marine Aggregate Industry Protocol are passed to third-party records including the NMR and HERs, but as there may be a lag in such reports being incorporated into records it may be advisable to consult such reports directly.

11 MAREA SUMMARY – IMPLICATIONS FOR INDIVIDUAL LICENCE AREA EIAS

11.1 OVERVIEW

The following sections provide summary tables of the conclusions of the MAREA impact assessment for each receptor topic.

If the effects associated with one or a few licence areas dominate a regional impact assessment rating, or are amenable to mitigation, then they are highlighted within this chapter. Recommendations are then made where appropriate for individual licence areas to undertake further work to be carried out at the EIA stage.

Please note that no recommendations are made in relation to Area 447 as this licence area has a Government View valid until 2023.

11.2 Impact Assessment Summaries

11.2.1 Impacts to Sandbanks

Table 11.1 summarises the findings of the impact assessment on sandbanks.

Table 11.1 Regional Significance of Impacts to Sandbanks from Dredging in the Outer Thames

Effect of Dredging	**Sandbanks as physical structures**	
Removal of sediment	*Not significant*	
Sand deposition	*Not significant*	
Changes to sediment particle size	*Not significant*	
Changes to wave height	*Regularly occurring wave conditions – not significant*	*Extreme wave conditions - minor*
Changes to tidal currents	*See changes in sediment transport rate*	
Changes to sediment transport rates	*Minor*	
Overall significance of dredging	*Minor*	

The following licence areas will need to refer to the wave height modelling work that has already been undertaken for the MAREA and report this on a site-specific basis:

- **Area 108/1** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the Long Sand sandbank at the EIA stage.

- **Long Sand Head licence (Area 108/3, 109/1, 113/1)** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the Long Sand and Kentish Knock sandbanks at the EIA stage.

- **Area 119/3** will need to discuss the effects of changes to wave heights (in the case of extreme wave conditions), and the effects of changes to sediment transport rates on the sandbank within the licence area itself and the sandbanks to the north of the area.

11.2.2 Impacts to the Coastline

All of the physical effects of dredging that have the potential to impact the coastline do not interact with the coastline. This is based on several studies that are summarised in Chapter 7. A brief explanation of why these impacts have been assessed as having no interaction with the coastline is presented here:

- Sand deposition – occurs within the licence areas and can change bedforms up to 2.5 km from the licence area boundary; this does not reach the coast (see Figure 7.9 and Figure 7.10).

- Changes to sediment particle size – studies have shown up to a 4 km footprint around the licence area may be affected; this does not reach the coast (see Figure 7.9 and Figure 7.10).

- Changes to wave height – modelling has shown that changes to wave height at MHWS of greater than 2% only extend up to 10 km from licence areas and there are no predicted changes to wave height at the coast (see Figure 7.13 and Figure 7.15).

- Changes to tidal currents – modelling has shown that any predicted change to tidal currents does not occur within 8 km from the coastline; moreover the reported change only corresponds to a small reduction of up to 5% in tidal currents over a very small area. There are no predicted changes to tidal currents at the coast (see Figure 7.17 and Figure 7.18).

- Changes to sediment transport rate – modelling has shown that changes to sediment transport rates are predominantly within licence areas and there are no predicted changes to sediment transport rate at the coast.

- Changes to sandbanks – the sandbank impact assessment (Chapter 8.2) has assessed changes to sandbanks as having minor significance; with resulting indirect changes to wave height, tidal currents and sediment transport rate being of insufficient magnitude to impact the coastline.

As no impacts to the coastline are predicted, further investigations into the potential impacts on coastal habitats or coastal defences at the EIA stage for individual licence areas are not required.

11.2.3 Impacts to Water Quality

Table 11.2 summarises the findings of the impact assessment on water quality.

Table 11.2 Regional Significance of Impacts to Water Quality from Dredging in the Outer Thames

Effect of Dredging	**Water Quality**
Fine sediment plume/elevated turbidity	*Not Significant*
Changes to wave height	*Not Significant*
Changes to tidal currents	*Not Significant*
Overall significance of dredging	*Not Significant*

Impacts to water quality from dredging are predicted to be not significant. No action is required to study the potential impacts further at the licence specific EIA stage other than describing the mitigation measure that contribute to normal good working practice.

11.2.4 Impacts to Benthic Ecology

Table 11.3 summarises the findings of the impact assessment on benthic ecology.

The requirement for a benthic survey at the EIA stage will be discussed in relation to each individual licence area. It is recommended that the licence areas listed below in particular consider the merit of conducting site-specific surveys, due to the presence of sensitive *Sabellaria spinulosa* within or in close proximity to their boundaries.

- In the cases of **Area 452 A**, **Area 452 C** and **Long Sand Head licence (Area 108/3, 109/1, 113/1)**, *Sabellaria spinulosa* has been found within the licence areas and may be significantly affected by dredging activities.

- In the cases of **Area 452 B**, **North Inner Gabbard**, **Area 257**, **Area 327** and **Area 119/3**, *S. spinulosa* has been found adjacent to the licence areas and may be significantly affected by dredging activities.

- In the cases of **Area 452 D**, **Area 452 E**, **Area 118/2**, **Area 239/1** and **Area 108/1**, whilst *S. spinulosa* was not found near the licence area, this species may be present and may be significantly affected by dredging activities.

Table 11.3 Regional Significance of Impacts to Benthic Ecology from Dredging in the Outer Thames

Effect of Dredging	*Benthic Species and Communities*	*Biotopes*	*Sabellaria spinulosa*	*Barnea candida*	*Crangon crangon*	*Cancer pagarus*	*Homarus gammarus*
Removal of sediment	Not significant	Not significant	Moderate	Moderate	Minor		
Fine sediment plume/elevated turbidity	Not significant	Not significant					
Sand deposition	Not significant	Not significant	Not significant			Not significant	Not significant
Changes to sediment particle size	Not significant	Not significant	Minor	Not significant			
Changes to tidal currents	See changes to sediment particle size and changes to sediment transport rates						
Changes to Sediment Transport Rates	Not significant	Not significant	Minor	Not significant			
Overall Significance of Dredging	Minor-Moderate						

Barnea Candida

- In the cases of **Area 452 A**, **Area 452 B**, **Area 118/2**, and **Area 239/1**, *Barnea candida* was found close to the licence area and may be significantly affected by dredging activities.

- In the cases of **Area 452 C**, **Area 452 D**, **Area 452 E**, **North Inner Gabbard**, **Area 108/1**, **Long Sand Head licence (Area 108/3, 109/1, 113/1), Area 327** and **Area 119/3** whilst *B. candida* was not found near the licence area, this species may be present and may be significantly affected by dredging activities.

11.2.5 Impacts to Fish Ecology

Table 11.4 summarises the findings of the impact assessment on fish ecology. It should be noted that Area 504 contributes significantly to the assessment of significant impacts on herring, as a result of the overlap of the area with herring spawning grounds. However this prospecting area has now been surrendered (see Industry Statement). Without the contribution of Area 504 to the cumulative impacts of dredging, the significance of the impacts related to the removal of sediment, sediment plume and sand deposition on herring are regarded as ***not significant***.

- **Area 452 A**, **Area 452 B**, **Area 452 E**, **Area 118/2**, **Area 239/1**, **Area 108/1**, **Area 257**, **Long Sand Head licence (Area 108/3, 109/1, 113/1),** and **Area 327** overlap with the herring nursery area. The potential for impacts on juvenile herring within the nursery area will need to be addressed at the licence EIA stage by referring to the MAREA and discussing the findings in a site-specific context.

- **Area 452 C, North Inner Gabbard, Long Sand Head licence (Area 108/3, 109/1, 113/1), Area 327,** and **Area 119/3** overlap with the cod nursery area. Cod may exhibit behavioural responses up to 1.1 km from dredgers, with strong and mild reactions occurring within 4 m and 30 m respectively. There is overlap of all these contours from these licence areas with the cod nursery area, therefore this impact will need to be referred to in the EIAs for these licence areas and discussed at a localised scale.

Sprat may react to dredging noise at a distance up to 1.9 km from a dredging vessel, with mild behavioural reactions expected within 60 m of dredgers and strong reactions within 6 m. Sprat are distributed throughout the area therefore their distribution is likely to overlap with the low likelihood of disturbance, mild and strong behavioural response contours. Sprat spawning and nursery areas extend across much of the southern North Sea and sprat do not have the same specific habitat requirements as other species. The area of available habitat within which

Table 11.4 Regional Significance of Impacts to Fish Ecology from Dredging in the Outer Thames

Effect of Dredging	Sea lamprey	Seahorses	Sand goby	Cod	Bass	Plaice	Sole	Herring	Sprat	Mackerel	Lesser spotted dogfish	Thornback ray
Removal of sediment			*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**			*Not significant*	*Not significant*
Fine sediment plume/elevated	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Sand deposition				*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant**			*Minor*	*Minor*
Changes to sediment particle size							*Not significant*	*Not significant*				
Changes to tidal currents								*Not significant*			*Not significant*	*Not significant*
Underwater noise	*Not significant*			*Minor*			*Not significant*	*Minor*	*Minor*			*Not Significant*
Changes to benthic community composition		*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Changes to distribution of fish	*Not significant*			*Not significant*	*Not significant*					*Not significant*	*Not significant*	
Changes to sandbanks							*Not significant*					*Not significant*
Overall significance of dredging	*Minor*											

* Downgraded from 'minor' when the contribution of Area 504 (surrendered) to the assessment is disregarded

11.2.6 Impacts to Marine Mammals

Table 11.5 summarises the findings of the impact assessment on marine mammals.

Table 11.5 Regional Significance of Impacts to Marine Mammals from Dredging in the Outer Thames

Effect of Dredging	Harbour Porpoise	Common Seal	Grey Seal
Presence of the vessel	*Not significant*	*Not significant*	*Not significant*
Fine sediment plume/elevated turbidity	*Not significant*	*Minor*	*Minor*
Underwater noise	*Moderate*	*Minor*	*Minor*
Change to benthic community composition		*Not significant*	*Not significant*
Change to distribution of fish	*Minor*	*Not significant*	*Not significant*
Changes to sandbanks		*Not significant*	*Not significant*
Overall significance of dredging	*Minor-Moderate*		

- Impacts to marine mammals will be discussed in all the individual EIAs in the context of 'deliberate disturbance' to European Protected Species (EPS), and the measures employed to avoid this.
- In addition **Area 452 A** and **Area 118/2** will also need to discuss the potential for impacts from dredging noise on seals at the localised scale, as these licence areas are situated within the area that is predicted to be an important habitat for common and grey seals.
- **Area 452 A**, **Area 452 E**, **Area 118/2**, **Area 108/1**, **Area 257**, and **Long Sand Head licence (Area 108/3, 109/1, 113/1),** will need to refer to the effects of the sediment plumes generated within their licence areas on seals, based on the modelling carried out as part of the MAREA.

11.2.7 Impacts to Birds

Table 11.6 summarises the findings of the impact assessment on marine and coastal birds.

Table 11.6 Regional Significance of Impacts to Birds from Dredging in the Outer Thames

Effect of Dredging	Red-throated diver	Gannets	Auks	Seaduck	Gulls	Terns
Presence of the vessel	Minor	Not significant	Not significant	Not significant	Not significant	Not significant
Fine sediment plume/elevated turbidity	Minor	Not significant	Minor	Not significant	Not significant	Not significant
Change to benthic community composition				Not significant		
Change to distribution of fish	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
Changes to sandbanks	Minor	Not significant	Not significant	Not significant	Not significant	Not significant
Overall significance of dredging	Minor					

Impacts to birds will need to be revisited within the individual EIAs in the light of any new data that may become available form other sources and studies, but the conclusions are unlikely to change. The significant impacts listed above will need to be referenced within each of the EIAs, as these bird species may be present within any of the licence areas.

11.2.8 Impacts to Designated Sites

Table 11.7 summarises the findings of the impact assessment on designated sites.

Table 11.7 Regional Significance of Impacts to Designated Sites from Dredging in the Outer Thames

RECEPTOR	Presence of the vessel	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Changes to distribution of fish	Changes to sandbanks
Coastal designated Sites - habitats									
Coastal designated Sites – SPA species	Not Sig.	Not Sig.						Not Sig.	Not Sig.
Margate and Long Sands cSAC		*See changes in sediment particle size distribution*	Not Sig.	Not Sig.	Not Sig.	*See changes in sediment transport rate*	Not sig.		
Outer Thames Estuary SPA	Minor	Minor						Not Sig.	Not sig.
Overall Significance of Dredging	Minor								

- There are no regional impacts assessed as being of significance to the Margate and Long Sands cSAC, however due to its overlap with **Long Sand Head licence (Area 108/3, 109/1, 113/1)**, this licence area EIA will need to explain the means whereby dredging will be managed to avoid impacts to the cSAC.
- Sufficient information will need to be presented for each individual EIA to demonstrate no significant effect, and where there is potential for a significant impact, mitigation will be discussed.

11.2.9 Impacts to Fisheries

Table 11.8 summarises the findings of the impact assessment on fisheries.

Table 11.8 Regional Significance of Impacts to Commercial and Recreational Fishing from Dredging in the Outer Thames

Effect of Dredging	Thames Estuary cockle fishery	Inshore fleet (vessels <10 m)	Offshore fleet (vessels >10 m)	Recreational Fleet
Loss of access	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Change to benthic community composition		*Not significant*		
Change to distribution of fish	*Not significant*	*Not significant*	*Not significant*	*Not significant*
Overall significance of dredging	*Not significant*			

Due to the lack of information on fishing grounds for vessels <10m, consultation to identify prime fishing grounds at the local scale will be important for the EIA process. However impacts to fisheries from dredging are predicted to be not significant. The EIAs will need to present the mitigation measures that will be adopted to avoid any impacts.

11.2.10 Impacts to Infrastructure

Table 11.9 summarises the findings of the impact assessment on other infrastructure.

Table 11.9 Regional Significance of Impacts to Infrastructure from Dredging in the Outer Thames

Effect of Dredging	Offshore wind farms	Military activity
Fine sediment plume/elevated turbidity	*Not significant*	
Sand deposition	*Not significant*	
Changes to particle size	*Not significant*	
Changes to wave heights	*Not significant*	
Changes to tidal currents	*Minor*	
Changes to sediment transport rates	*Not significant*	
Loss of access	*Not significant*	*Not significant*
Overall significance of dredging	*Minor*	

Dredging activities have taken place within the region for over 40 years, and their existence will have been considered in the design of these offshore wind farms which are relatively new features in comparison. There is therefore no added value in undertaking further assessment at the individual licence EIA stage.

11.2.11 Impacts to Recreation

Table 11.10 summarises the findings of the impact assessment on recreation.

Table 11.10 Regional Summary of Impacts to Recreational Activities

Effect of Dredging	Racing	Sailing	Cruising
Vessel Presence	*Not significant*	*Not significant*	*Not significant*
Changes to wave height			*Not significant*
Changes to tidal currents			*Not significant*
Loss of Access			*Not significant*
Overall significance of dredging	*Not significant*		

Impacts to recreation from dredging are predicted to be not significant. Therefore no action is required to study the potential impacts further at the licence specific EIA stage other than to present the specific mitigation measures to be adopted.

11.2.12 Impacts to Shipping and Navigation

Table 11.11 summarises the findings of the shipping and navigation risk assessment (see Appendix I).

Table 11.11 Navigational Sensitivity Factors per Dredge Area (1)

Dredge Area	Average Sensitivity Ranking for Features in Areas						Overall Sensitivity
	Ship Density	Collision Risk	Navigational Features	Fishing	Inshore Fisheries	Recreation	
Existing Licence Areas							
119/3	High	High	Very High	Low	Medium	Low	Very High
Long Sand Head (Area 108/3, 109/1, 113/1)	Low	Low	Medium	Low	High	Low	Low
327	High	High	Very High	Low	High	Very Low	Very High
257	High	Very High	High	Very Low	Medium	Medium	Very High
108/1	High	Very High	Very High	Low	Medium	Medium	Very High
239/1	High	High	Very Low	Very Low	High	Very Low	Medium
118/2	Low	Low	Very Low	Low	Medium	Very Low	Low
Application Area							
452A	Medium	Medium	Very Low	Low	High	Very Low	Medium
452B	Medium	High	Very Low	Low	High	Very Low	Medium
452C1	High	High	Very Low	Very Low	High	Very Low	High
452C2	Medium	High	Very Low	Very Low	High	Very Low	Medium
452C3	Medium	Low	Low	Very Low	High	Very Low	Medium
452D	High	High	Very Low	Very Low	High	Very Low	Medium
452E	Low	Low	Very Low	Very Low	High	Very Low	Very Low
Prospecting Area							
North Falls (504)	Medium	Medium	Low	Very Low	Medium	Very Low	Low
North Inner Gabbard (498)	High	High	Very Low	Very Low	High	Very Low	Medium

(1) Colour coding adopts that of the Navigational Risk Assessment.

- It is recommended that all licence areas validate the shipping data (densities and routeing) at the individual EIA stage to demonstrate that the baseline data reflected within the MAREA are still current.
- **Area 119/3**, **Area 327**, **Area 257**, **Area 108/1**, **Area 239/1**, **Area 452 A**, **Area 452 B**, **Area 452 C1**, **Area 452 C2**, **Area 452 C3**, **Area 452 D** and **North Inner Gabbard** (ie those licence areas with a medium, high or very high navigational sensitivity) should carry out a site-specific assessment of the change in collision risk resulting from the proposed future dredging activity (subject to the validation of the shipping data), and carry out site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA, Harwich Haven Authority and PLA). Site-specific mitigation measures should be developed and described (see Section 12 of Appendix I for examples).

11.2.13 Impacts to Archaeology and Cultural Heritage

Table 11.12 summarises the findings of the impact assessment on archaeology and cultural heritage.

Table 11.12 Regional Summary of Impacts to the Archaeological Receptors

Receptor	Effect		
	Removal of Sediment	**Sand deposition**	**Overall significance of dredging**
Pleistocene fluvial gravels	Major	Positive	Major
Estuarine Alluvium	Minor/Moderate	Positive	Moderate
Peat	Minor/Moderate	Positive	Moderate
Isolated Prehistoric Finds	Moderate	Positive	Moderate
Known Charted Wreck Sites	Minor/Moderate	Positive	Moderate
Shipping Casualties	Moderate/Major	Positive	Major
Unknown Uncharted wreck Sites	Moderate/Major	Positive	Major
Isolated Maritime Finds	Moderate	Positive	Moderate
Recorded Aircraft Losses	Moderate/Major	Positive	Major
Isolated Aircraft Finds	Moderate	Positive	Moderate
Overall Significance of Dredging	Moderate to Major		

- It should be noted that these impacts are assessed without the consideration of the well established mitigation procedures that are undertaken by the dredging industry to prevent such impacts, including avoidance behaviour and observing exclusion zones. These measures greatly reduce the likelihood of these levels of impact occurring. These measures will be discussed within each of the individual EIAs.

- The coincidence of licence areas and receptors is such that none of the licence areas can be regarded as 'clear' of interactions with any of the archaeological receptors that have been assessed.

- Two prehistoric archaeological receptors, estuarine alluvium and peat, are present in almost all of the licence areas surveyed. Pleistocene fluvial gravels have been shown to be present in only four licence areas although deposits are known to exist throughout the Outer Thames Estuary.

- There are known, charted wrecks in **all of the licence areas except Area 452 D, Area 452 C2 and Area 452 C3**. **Area 118/2** has the highest number of known, charted wrecks sites with 10 sites each within these areas. The third highest number of sites is in **Long Sand Head licence (Area 108/3, 109/1, 113/1)**, which has seven sites within its boundaries. All other licence areas have between 1 and 4 sites.

- **Licence Area 108/3** has shipping casualties and recorded aircraft losses recorded within it.

- More than half of the licence areas encompass reported aircraft losses; however, none contain known, charted air crash sites.

- Each licence area has the potential to contain isolated aircraft finds, and possibly entire crash sites.

- In conducting EIAs for individual licence areas, it will continue to be necessary for historic environment data to be sought within each licence area and its immediate vicinity from the principal third-party records. Specifically, it will be necessary to check if any existing records have been altered or new records added as these third-party records are continually being updated.

- The third-party sources of most direct relevance are the UKHO (known sites of maritime and aviation archaeology interest, plus obstructions etc. that may represent as yet unrecognised sites) and NMR (known prehistoric, maritime and aviation sites; shipping casualties; and aircraft losses). Local Historic Environment Records (HERs) should also be consulted where a Licence Area falls within a HER's territorial extent, predominantly for known prehistoric, maritime and aviation sites within the Licence Area. Reports received through the Marine Aggregate Industry Protocol are passed to third-party records including the NMR and HERs, but as there may be a lag in such reports being incorporated into records it may be advisable to consult such reports directly.

11.3 Regional Monitoring

It is recommended that the TEDA companies continue to work together to develop a regional approach to managing dredging activity as licence renewals are forthcoming in the coming years. This includes regional monitoring where possible that is beneficial to both operators and industry regulators. At the time of writing, the industry has already begun dialogue with the Crown Estate on this topic and an industry charter setting out a commitment by each company to do the following has been drafted:

- Monitor, mitigate and manage environmental impacts and operational activity on a regional basis.
- Develop generic monitoring, mitigation and management plans for regions based on MAREA's and other studies.
- Work together with all the other companies in the region in a constructive, flexible and timely basis to deliver plans to agreed timescales.
- Align existing permissions with regional monitoring plans over time.
- Co-operate in the planning, procurement, management and reporting of regional monitoring activities.
- Engage with the regulator and their advisors at a regional scale.
- Be transparent through making all relevant dredging and monitoring data publicly available through regular reporting.
- Share costs, effort and responsibility in a proportionate way in developing the concept in each region.
- Work with the Crown Estate to deliver plans.

12 IN-COMBINATION REGIONAL IMPACTS

12.1 INTRODUCTION

This chapter considers the interaction of aggregate extraction with other human activities in the study area to potentially create in-combination regional impacts. Section 6.3 provides an overview of the other projects and developments that are present or planned within the Thames MAREA study area. In addition to these developments, other anthropogenic activities including fishing, shipping and marine recreation are discussed in Sections 6.2, 6.4 and 6.5. Each of these activities that take place within the MAREA area have the potential to impact upon sensitive receptors, both independently and in combination with each other, and also with marine aggregate extraction.

This MAREA has reviewed a wide range of data sources and references on the activities and projects identified to be relevant to this chapter but there is commonly insufficient information to enable a detailed in-combination assessment to be carried out. For future wind farms, for example, factors such as the number of turbines, the type of foundations to be used and the size and number of safety zones are currently unknown. It should be noted that an in-combination assessment is not entirely within the remit of what the marine aggregate industry is required to assess, but is however considered a key issue for the purposes of the regional assessment. This chapter aims to highlight the significance of potential interactions by making some conservative assumptions, where necessary, about other developments and activities.

12.2 In-Combination Impacts Matrix

Table 12.1 presents a matrix outlining the potential impacts to receptors within the Outer Thames Estuary that are likely to be derived from multiple industries and users which may act in combination.

The following effects which are common to multiple activities in the MAREA area are of overall **minor significance** as a result of cumulative marine aggregate extraction activities:

- impacts to sandbanks;
- impacts to fish ecology;
- impacts to marine and coastal birds;
- impacts to designated sites; and
- impacts to infrastructure.

The following effects which are common to multiple activities in the MAREA area are of overall **minor-moderate significance** as a result of cumulative marine aggregate extraction activities:

- impacts to benthic ecology; and
- impacts to marine mammals.

Finally the impact to archaeology as a result of the removal of sediment associated with marine aggregate extraction activities is of **major significance**. However it should be noted that this impact is assessed without the consideration of the well established mitigation procedures that are undertaken by the dredging industry to prevent this impact, such as avoidance behaviour and observing exclusion zones. These measures greatly reduce the likelihood of this level of impact occurring.

The effect of sand deposition as a result of marine aggregate extraction on archaeology is in fact considered to be a **positive** impact (see Section 10.6).

Impacts to the receptors listed above have the potential to be in-combination issues as they are commonly subjected to similar effects as a result of other developments and activities in the Outer Thames Estuary.

Impacts to shipping and navigation are not given an overall significance rating as a result of aggregate extraction (see Section 10.5) but are an important in-combination issue. In addition it is important to recognise that any impacts to shipping and navigation will also have implications for the vessel movements that are associated with fisheries, other infrastructure (including windfarms and ports), and recreation and may increase collision risk (see Appendix I for the full navigational risk assessment).

Table 12.2 summarises the potential for the impacts from other developments/activities outlined in Table 12.1 to create an impact that is of a similar or greater level of significance to that of cumulative marine aggregate extraction alone. A judgment is then made as to what the potential significance of these impacts acting in-combination would be.

Table 12.1 Summary of Potential In-combination Impacts on Receptors in the MAREA Study Area

Development/Activity	Receptor: Sandbanks	Coast	Water Quality	Benthic Ecology	Fish Ecology
Marine aggregate extraction		No interaction	No significant impacts		
Offshore windfarms					
Ports and Harbours					
Fisheries	Not affected	Not affected	Not affected		
Shipping and Navigation	Not affected	Not affected	Not affected	Not affected	
Military Activity	Not affected	Not affected	Not affected	Not affected	
Recreation	Not affected	Not affected	Not affected	Not affected	Not affected

Development/Activity	Receptor: Marine Mammals	Birds	Designated Sites	Fisheries	Infrastructure
Marine aggregate extraction				No significant impacts	
Offshore windfarms					
Ports and Harbours					
Fisheries					
Shipping and Navigation					
Military Activity					
Recreation					

Development/Activity	Receptor: Recreation	Shipping and Navigation	Archaeology
Marine aggregate extraction	No significant impacts		P
Offshore windfarms			
Ports and Harbours			
Fisheries			Not affected
Shipping and Navigation			Not affected
Military Activity			Not affected
Recreation			Not affected

Vessel Presence	
Removal of sediment	
Fine sediment plume	
Sand deposition	
Changes to wave heights	
Changes to sediment particle size	
Changes to tidal currents	
Changes to sediment transport rates	
Underwater noise	
Loss of access	
Changes to benthic community composition	
Changes to distribution of fish	
Changes to sandbanks	

P denotes POSITIVE impact

denotes interaction not applicable

Table 12.2 Potential Significance of In-combination Effects

Receptor	Effect of dredging	Significance of effect	Potential for similar impact from other development/activity: Offshore Windfarms	Ports and Harbours	Fisheries	Shipping and Navigation	Military Activity	Recreation	Potential regional in-combination significance
Sandbanks	Changes to wave height	Minor	Low	Low					Minor
	Changes to sediment transport rates	Minor	Low	Low					Minor
Benthic ecology	Removal of sediment	Moderate	Low	Med	Med				Moderate
	Changes to sediment particle size	Minor	Low	Med					Minor
	Changes to tidal currents	Minor	Low	Low					Minor
	Changes to sediment transport rates	Minor	Low	Low					Minor
Fish ecology	Sand deposition	Minor		Med					Minor
	Underwater noise	Minor	High	High	High	High	High		Moderate
Marine mammals	Fine sediment plume	Minor	Low	Med					Minor
	Underwater noise	Moderate	High	High	High	High	High		Moderate
	Changes to fish distribution	Minor	Med	Med	High				Minor
Marine and coastal birds	Vessel presence	Minor	Med	Med	Med	Med	Low	Low	Moderate
	Fine sediment plume	Minor	Low	Med					Minor
	Changes to sandbanks	Minor	Low	Low					Minor
Designated Sites	Vessel presence	Minor	Med	Med	Med	Med	Low	Low	Moderate
	Fine sediment plume	Minor	Low	Med					Minor
Infrastructure	Changes to tidal currents	Minor	Low	Low					Minor
Shipping and navigation	Vessel presence	Not assigned but high navigational risk in some areas	High	High	High		Med	Med	Moderate
Archaeology	Removal of sediment	Major	Low	Med	Low	Low	Low	Low	Minor

As the table shows, the potential in-combination impact to fish ecology as a result of underwater noise, is assessed as being of *moderate significance* compared to an impact of minor significance as a result of aggregate extraction in isolation. Wind farm developments have a high potential to displace fish from their natural habitat as a result of underwater noise, particularly from piling activities. For example the Greater Gabbard Environmental Statement states that herring are expected to show avoidance up to 9km from the source of piling noise [(1)]. Activities associated with ports and harbours, general shipping and military activities, also result in noise levels that may cause behavioural disturbance and displacement of fish up to several kilometres from the noise source.

The potential in-combination impact of vessel presence on marine and coastal birds, and designated sites (due to the presence of the offshore SPA designated for the red-throated diver), is also assessed as being of *moderate significance*, as a result of the high potential for impacts from traffic associated with wind farm development, ports and harbours, fisheries and shipping. However dredging contributes a small amount to the overall impact; the predicted future increase in dredger vessel traffic will only constitute 3% of the overall shipping traffic in the Outer Thames Estuary, and in reality is likely to be much smaller as this is based on the maximum regional tonnage scenario (see Appendix I).

The in-combination impact of vessel presence on shipping and navigation is assessed as being of *moderate significance*. Vessel traffic associated with wind farms, ports and harbours and fisheries has a high potential for resulting in a similar impact to that from marine aggregate extraction, and traffic associated with military and recreational activities is assessed as having medium potential. Again, it should be noted that dredger vessels will only represent 3% of traffic in the region according to the future dredging scenario.

The impact of sediment removal on archaeology as a result of dredging has been assessed as being of major significance. However when the avoidance measures that the industry employs are taken into consideration, coupled with the low likelihood that other developments/activities in the region will have a similar impact with the exception of dredging related to port and harbour developments, the potential in-combination impact is assessed as being of *minor significance*.

Based on the above assessment it can be concluded that for the majority of effects from marine aggregate extraction, where the in-combination impacts are of potentially greater significance than from aggregate extraction alone it

(1) http://www.sse.com/SSEInternet/uploadedFiles/Media_Centre/Project_News/Greater_Gabbard/GG_NTS_June09.pdf (accessed April 2010).

is due primarily to the contribution of other human activities. However it should be noted that the in-combination impact of moderate significance to benthic ecology as a result of sediment removal, is likely to be a disproportionately influenced by marine aggregates extraction activity compared with other activities. Future aggregate extraction EIAs will therefore need to assess the potential for in-combination impacts to benthic assemblages at the scoping stage. It should be noted that if scoping did demonstrate significant potential for in-combination impacts to particular benthic assemblages then more detailed assessment could only proceed with the collaboration of other parties.

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