ASSESSMENT OF THE SPECIES AND BIOTOPES LIKELY TO OCCUR ON NEWLY CREATED HABITAT IN HAYLE HARBOUR

FINAL V3

(Final Version as V2 but incorporating Annex A)

REPORT PREPARED FOR BURO HAPPOLD

BY

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1. INTRODUCTION

Aquatonics Ltd have produced this report in response to a request from Natural England to provide additional information on the newly-created habitat in the harbour at the new fishermen's quay and slipway. In particular, they wanted information on the areas of each habitat, and the species and biotopes that would be likely to occur.

Buro Happold have produced a drawing (Drawing No 301) of the harbour arm and adjacent slipway. We have used this drawing and other information from Buro Happold to calculate the areas that will be created and their location within the intertidal zone.

We have produced a list of some of the most likely taxa to occur using our data for similar habitats in Hayle or in other estuaries and coastal regions of SW England. The list of species distinguishes between native and non-native species.

The harbour (apart from Cockle Bank) is one of the least polluted areas of the Hayle estuary complex, but even here there may be some impacts of contaminants, eg from antifoulants. In general, however, we expect contaminants to have a minor impact on the colonisation of the new substrates.

2. NEW HABITATS CREATED

The three new habitats that will be created in the new fishermen's harbour and adjacent slipway are:

a. Vertical timber fendering
b. Stones held behind wire mesh on metal piles
c. Boulders at the toe of the slipway

The height of each zone is described in relation to tidal heights for spring and neap tides:

MHWS	Mean High Water Spring tidal level	+6.6 m CD
MHWN	Mean High Water Neap tidal level	+4.9 m CD
MTL	Mean Tidal Level	+3.5m CD
MLWN	Mean Low Water Neap tidal level	+2.4 m CD
MLWS	Mean Low Water Spring tidal level	+0.8 m CD

The total area of new habitat is approximately 277 square metres. Details of the dimensions and areas of each unit are shown below.

2a Vertical timber fendering

Location	Inner straight edge of new fixed harbour arm (see Elevation D-D of Figure 1).
Dimensions	17 vertical timber fenders, each 300 mm wide, from +2.4 m CD to + 7.6 m CD.
Estimated area	26.5 m^2 on each face of which 21.4 m^2 on each face in the intertidal zone up to MHWS. Remainder above MHWS. The combined area of the three faces in the intertidal zone is 3 x 21.4 = 64 m^2.

Zone	Lower intertidal (approx MLWN) to upper intertidal (above MHWS).

The colonisation of the timber will be largely dependent upon which chemical treatment they have received. We will specify low toxicity treatment, but even then it may take a few years for significant colonisation. In addition, the front surface of the fenders will be rubbed by vessels as they approach and tie up at the quay.

2b Stones held behind wire mesh on metal piles

Dimensions	4 m high by 38.6 m long. Approximately 2/3 will be stones behind the mesh. There will be a lot of useful habitat in the interstices between the stones, but this has not been taken into account in the calculations.
Estimated area	103 m^2.
Zone	Subtidal (-1.4 m below MLWS) to 3.4 m CD (approx MTL)

Drawing 301 (see Figure 1) shows stones with a single size of 50 mm. We have decided to increase the median size to 100 mm and allow a stones from approximately 50 mm to 150 mm diameter. This should increase the variety of niches available. The geology of the stone also has some bearing on what colonises it (e.g. chalk and limestone will allow species that can burrow into soft stones). There will be some restrictions from an engineering perspective, as the stones must be relatively hard to ensure they are still there over the design life of the quay. Stones that are hard enough to be acceptable for engineering purposes will be colonised by some or all of the species listed below.

2c Boulders at the toe of the slipway

Location	Toe of the slipway (see Section B-B of Figure 1).
Dimensions	36.5 m along toe of slipway, x 3 m deep.
Estimated area	Plan area is 110 m^2. All surfaces of the boulders will provide useful habitat, but this has not been taken into account in calculating the area.
Zone	Low water (just below MLWS to MLWS).

The choice of boulder has not been finalised. We expect that hard rock boulders of 300-500 mm diameter will be most suitable from an ecological perspective. They should be pitted or rough in order to encourage colonisation. Any concave surface should be placed face down, to provide some space under the boulder.

For purposes of ecological monitoring of colonisation it would be preferable if the boulders are not too tightly packed, so that we can examine the sides and look underneath occasional boulders. We suggest a spacing between boulders of approximately 100 mm.

We have assumed a 3 metre wide band of boulders at the toe of the slipway. Given the expected size and spacing we estimate a total of 400 - 450 boulders.

3. TAXA THAT MAY COLONISE THE NEW HABITATS

A wide range of invertebrates and algae (seaweeds) are expected to colonise the new substrates, as they should be relatively uncontaminated and also cover a tidal range from shallow subtidal to above MHWS. Precise matches with recognised marine biotopes (Connor et al, 2003) are not possible for the vertical timber fendering and stone infill, due to their artificial substrate. However, we have indicated the likely nearest matches in Tables 1 & 2. For the boulders at the toe of the slipway a more natural flora and fauna should develop (see Table 3).

We have not attempted to produce detailed information on successional changes on the new substrates. The species listed are those that are expected to occur within the first 3-4 years following construction. Early colonisers are likely to be groups such as barnacles and green algae (eg sea lettuce *Ulva lactuca* and *Enteromorpha* spp. {now also placed in *Ulva*}), with fucoid brown algae (*Fucus* spp and *Ascophyllum nodosum*) colonising later.

A study of intertidal rock rubble groynes of varying ages at a site in Dorset showed that green algae such as *Ulva lactuca*, *Enteromorpha* spp and *Blidingia minima* colonised within a year, with brown algae (eg *Fucus* spp and *Laminaria digitata*) and molluscs (eg *Gibbula umbilicalis* and *Patella* spp.) colonising later (Pinn et al, 2005). The authors found that the number of taxa recorded on the groynes increased over time, from 17 taxa on groynes about a year old to 24 taxa at years 2 & 3 and 29 taxa at year 7. Interestingly, the green algae that colonised the groynes early on did not form a dense cover and the results instead showed a gradual increase up to year 6 in the number of taxa considered common (Pinn et al, 2005).

3.1 Control of Non-native Species

Harbours and marinas are focal points of marine introductions of non-native species. In the case of Hayle the majority of vessels will not have visited areas outside NW Europe, so the introduction of species new to the UK is less likely than for busy international harbours. The main problem is the gradual spread of non-native species from harbour to harbour around the coast. A recent rapid assessment of 12 marinas on the south coast of England recorded 20 non-native species out of a total of over 80 taxa (Arenas et al, 2006).

There is no realistic prospect of removing smaller non-native species such as the barnacle *Elminius modestus* that have been in the UK for many years. However, some of the more recent non-native seaweeds that are have been founds in marinas and harbours (e.g. *Undaria pinnatifida* and *Grateloupia turuturu*) are very conspicuous and could be removed if necessary.

It is important to note that the new habitats being provided do not increase the possibility of new non-native species colonising Hayle harbour, but the proposed monitoring should give an early warning of any new non-native species.

3.2 Vertical timber fendering

A paper that examined the effect of different levels of treatment of panels of marine timber (Scots Pine) with chromated copper arsenate (CCA) on colonisation by marine species in Langstone Harbour found that the treatment had little effect (Brown and Eaton, 2001). Colonisation was investigated at 6, 12 and 18 months. The number of species was similar on all panels, but, contrary to expectations the number of individuals was significantly higher on the treated panels, due to a few dominant species (the non-native barnacle *Elminius modestus*, the non-native serpulid tubeworm *Hydroides ezoensis* and the native bryozoan *Electra pilosa*. The dominance by non-native species on the treated panels may be due to the selective pressure on fouling species that encrust ships hulls. Recent studies suggest that non-native species that are transported on ships hulls are likely to be more resistant (compared to typical native species) to anti-foulants such as copper (Piola and Johnston, 2009). It seems possible, therefore, that if the timber is treated with any copper compounds the flora and fauna that develops on it will be dominated by non-native species.

Table 1 shows the likely species and biotopes that may occur at different tidal levels on the timber fendering within the first 3-4 years.

Table 1. Species likely to occur on the vertical timber fendering

TIDAL LEVEL	LIKELY SPECIES AFTER 3-4 YEARS	MOST SIMILAR JNCC HARD SUBSTRATE BIOTOPES THAT MAY OCCUR
Above MHWS	A few lichens (eg *Caloplaca* spp) and small green algae. Grey and yellow lichens, possibly with small green algae where water splashes above MHWS level. Perhaps sea slater (*Ligia oceanica*) and sea bristletail (*Petrobius* spp.) in any crevices.	LR.FLR.Lic Lichens or small green algae on supralittoral rock and/or LR.FLR.Lic.YG Yellow and grey lichens on supralittoral rock
MHWS to MHWN	Spiral wrack (*Fucus spiralis*) channelled wrack (*Pelvetia canaliculata*). The small periwinkle *Melarhaphe neritoides* may be present, along with barnacles (eg *Semibalanus balanoides*, *Chthamalus montagui* and the non-native *Elminius modestus*)	LR.LLR.F.Fspi.FS *Fucus spiralis* on full salinity moderately exposed to very sheltered upper eulittoral rock and/or LR.MLR.BF.PelB *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
MHWN to MTL	Bladder wrack (*Fucus vesiculosus*) and knotted wrack (*Ascophyllum nodosum*), gutweed (was in *Enteromorpha*, now in *Ulva*) occasional limpets (*Patella vulgata*). Possibly juvenile mussels (*Mytilus edulis*) and shore crabs (*Carcinus maenas*) in any fissures or gaps. Various periwinkles (*Littorina saxatilis*, *Littorina littorea*, *Littorina mariae* and *Littorina obtusatus*) amongst fucoid seaweeds. Top shells (*Gibbula* spp.) Occasional beadlet anemones (*Actinia equina*) in fissures/gaps. Gammarids such as *Eulimnogammarus obtusatus* amongst algae.	LR.LLR.F.Fves.FS *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock and/or LR.LLR.F.Asc *Ascophyllum nodosum* on very sheltered mid eulittoral rock
MTL to MLWN	Upper part may be dominated by *Fucus vesiculosus* and *Ascophyllum nodosum* (see above). Lower part probably dominated by serrated wrack (*Fucus serratus*),	LR.LLR.F.Fserr *Fucus serratus* on sheltered lower eulittoral rock

	gutweed (was in *Enteromorpha*, now in *Ulva*), sea lettuce (*Ulva lactuca*), *Actinia equina* in fissures/gaps. Carragheen (*Mastocarpus stellatus*) serpulids tubeworms (*Pomatoceros* spp and *Hydroides* spp.) The small isopod *Jaera* spp. may also be present.	

3.3 Stone infill of metal piles

The stones (nominally 50 – 150 mm diameter) will be confined behind a metal mesh (see Figure 1).

There is some uncertainty over the biotopes that will occur on the stones in the infill of the metal piles. Although the size of stones is relatively small, they are not expected to move much as they will be confined in all directions. The biotopes could therefore range from those typical of mixed substrates to those typical of solid rock or seawalls. This uncertainty is reflected in Table 2, which includes biotopes that are based on mixed substrates or solid rock. There is also some uncertainty over whether the voids between the stones will become filled with finer sediment or whether this will tend to wash out. It is likely that there will be some accumulation of mineral particles and organic matter over time. This is likely to enhance the range of species found.

Monitoring of colonisation of the stone fill will be restricted to the visible front surface, but much of the ecological interest could be in the voids and surface that are not visible. These will support a range of cryptic species, belonging to groups such as polychaete worms, nemertean worms and amphipod crustaceans. We have not attempted to predict these in detail, as the monitoring will not be able to determine whether they occur.

Table 2. Species likely on the stone infill of the metal piles

TIDAL LEVEL	LIKELY SPECIES AFTER 3-4 YEARS	POSSIBLE JNCC HARD SUBSTRATE BIOTOPES THAT MAY OCCUR
MTL to MLWN	**More sheltered inner wall** Upper part may be dominated by *Fucus vesiculosus* and *Ascophyllum nodosum*. Invertebrates likely to include occasional limpets (*Patella vulgata*), with juvenile mussels (*Mytilus edulis*) and shore crabs (*Carcinus maenas*) in any fissures or gaps. Various periwinkles (*Littorina saxatilis*, *Littorina littorea*, *Littorina mariae* and *Littorina obtusatus*) amongst fucoid seaweeds. Top shells (*Gibbula* spp.) Occasional beadlet anemones (*Actinia equina*) in fissures/gaps. Gammarids such as *Eulimnogammarus obtusatus* amongst algae.	LR.LLR.F.Fves.FS *Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock and/or LR.LLR.F.Asc *Ascophyllum nodosum* on very sheltered mid eulittoral rock

	The lower part is likely to be dominated by serrated wrack (*Fucus serratus*). Gutweed (was in *Enteromorpha*, now in *Ulva*) present, along with sea lettuce (*Ulva lactuca*). Beadlet anemones (*Actinia equina*) in fissures/gaps. Carragheen (*Mastocarpus stellatus*) serpulids tubeworms (*Pomatoceros* spp and *Hydroides* spp.) also present. The small isopod *Jaera* spp. may also be present. **More exposed outer wall** The increased exposure of the outer wall may lead to a greater range of sponges and ascidians (sea squirts). Invertebrates may include Dominant species include the sponges *Halichondria panicea* and *Hymeniacidon perleve*, the sea squirts *Ascidiella aspera, Ascidiella scabra*, *Styela clava* and *Botryllus schlosseri*. Molluscs may include top shells *Gibbula* spp. and dog whelks *Nucella lapillus.* Seaweeds may include *Mastocarpus stellatus* and *Chondrus crispus.*	LR.LLR.F.Fserr *Fucus serratus* on sheltered lower eulittoral rock LR.HLR.FT.FserTX *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata.
MLWN to MLWS	**More sheltered inner wall** A biotope dominated by *Fucus serratus* is expected. Some laminarians (kelps) may also be present. **More exposed outer wall** Although *Fucus serratus* may be the dominant seaweed, the species present will be different from the more sheltered inner harbour wall. In particular more sponges and ascidians (sea squirts) are expected. Some laminarians (kelps) may also be present.	LR.LLR.F.Fserr *Fucus serratus* on sheltered lower eulittoral rock SLR.FserX.T *Fucus serratus* with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
MLWS to -1.4 m CD	**More sheltered inner wall** *Laminaria digitata* and *Laminaria saccharina* (now *Saccharina latissima*). Beneath the kelp canopy the red seaweeds may include *Chondrus crispus, Dumontia contorta, Bonnemaisonia hamifera* and *Plocamium cartilagineum*. The surface of the stones may be covered with encrusting coralline algae and tubes of *Pomatoceros* spp. The sponge *Halichondria panicea* may occur in crevices. *Carcinus maenas and* Gibbula spp. probably present.	IR.LIR.K.Lsac.Ldig *Laminaria saccharina* and *Laminaria digitata* on sheltered sublittoral fringe rock

	More exposed outer wall Note: description adapted from the JNCC biotope description for IR.MIR.KT.LdigT *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock, but other biotopes could occur. Seaweeds are likely to include *Laminaria digitata*, *Chondrus crispus*, *Palmaria palmata*, *Cryptopleura ramosa* and *Mastocarpus stellatus* as well as the calcareous *Corallina officinalis*. Green seaweeds present include *Ulva lactuca, Enteromorpha intestinalis* (now *Ulva intestinalis*) and *Cladophora rupestris*. Note: other species of *Ulva* also likely. Sponges may include Halichondria *panicea*, *Scypha ciliata* and *Hymeniacidon perleve.* Bryozoans may include *Electra pilosa*, *Membranoptera Membranipora & Alcyonidium hirsutum*. Ascidians (sea squirts) may include *Ascidiella scabra*, *Dendrodoa grossularia* and the colonial ascidians *Botryllus byssoides* and *Botryllus leachi*. The tube-building polychaete *Pomatoceros* spp. and the barnacle *Balanus crenatus* are likely on the rock. Gastropods may include *Gibbula cineraria* and *Calliostoma zizyphinum.* Shore crabs (*Carcinus maenas*) and the starfish *Asterias rubens* may occur.	IR.MIR.KT.LdigT *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock

3.4 Boulders at the toe of the slipway

The species shown in Table 3 are likely to occur on the boulders, within a period of 3-4 years). The list is not intended to be exhaustive, as there are a large number of species that could occur. The biotope that occurs on the boulders after 3-4 years (perhaps longer) could be similar to LR.LLR.F.Fserr *Fucus serratus* on sheltered lower eulittoral rock.

Table 3. Species Likely to Occur on the Boulders

Group	Species (* indicates non-native species)
Seaweeds	Serrated wrack (*Fucus serratus*), knotted wrack (*Ascophyllum nodosum*), carragheen (*Mastocarpus stellatus*), *Chondrus crispus* and *Ceramium* spp. It is possible that *Undaria pinnatifida** and *Grateloupia turuturu** may eventually spread to Hayle
Sponges	The most likely sponges include *Hymeniacidon perleve* & *Halichondria panicea*
Hydroids and anemones	A wide variety of hydroids that tolerate sand scour may occur, eg *Dynamena pumila*, *Hydrallmania falcata* and *Sertularia* spp. Anemones may include *Actinia equina* and *Sagartia elegans*
Polychaete worms	Spirorbid worms (eg Janua pagenstecheri) and serpulid worms (eg *Pomatoceros* spp. and *Hydroides* spp (eg *H. norvegica*). Under the boulders a wide range of polychaetes may occur, including members of the families Cirratulidae, Terebellidae, Sabellidae, Nereididae, Phyllodocidae and Polynoidae (scale worms).
Amphipods	Mainly those associated with seaweeds, eg *Corophium acutum*, *Ampithoe helleri* & *Microdeutopus anomalus*. Caprellid amphipods may include native species such as *Pariambus typicus* & *Phtisica marina* and the non-native *Caprella muticus**.
Other crustaceans	Various isopods (eg *Idotea* spp), crabs eg shore crab (*Carcinus maenas*), edible crab (*Cancer pagurus*) juveniles, velvet swimming crab (*Necora puber*) & perhaps young lobsters (*Homarus gammarus*)
Barnacles	*Balanus crenatus* & *Elminius modestus**
Molluscs	*Hinia* spp, *Gibbula umbilicalis* & *Gibbula cinerea*, *Crepidula fornicata** (slipper limpet) and chitons
Sea squirts or tunicates	*Ascidia* spp, *Ascidiella* spp & *Styela clava**

4. CONSERVATION GAIN

The new habitats that will be created will add to the diversity of habitats present within the harbour. The boulders at the toe of the slipway are likely to develop the highest diversity of species on an area basis, and will also be the most natural. The vertical timber fenders and stones within the steel piles will cover a wide tidal range and the overall diversity is expected to be high. The timber fenders are expected to be the least valuable habitats of the three that will be created, but even these will support some seaweeds and invertebrates.

Overall, the newly created habitats will provide a small conservation gain, but more importantly perhaps the monitoring planned will show which are perform best and this will presumably inform future decision making for any further developments in Hayle or other harbours in SW England and elsewhere.

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Annex A - Rock Armouring and habitat creation - Suggestions from CCC, Natural Environment Service, as provided for Penzance.

1 Relevant statements from the draft extract of the new CIRIA guidance for the rock armouring

The structure will be partly above the high water mark, and partly below the low water mark due to the migration seaward into a slightly deeper area, therefore the following statements are relevant to the proposed rock armouring at Penzance:

- Methods are available to encourage colonisation of aquatic life which is naturally attracted to hard surfaces.
- Structure should aim to reproduce natural rock environments.
- Typical features should be a range of stone and crevice sizes, irregular outlines and surface orientation to provide a variety of micro- habitats for small and immobile species as well as larger ones.
- In the coastal zone, rocky shore may be reproduced by providing hollows and crevices to form rock pools, projections to create overhangs.
- For marine structures, elements at or below low water level may be colonised by kelp which attract a wide range of animal communities for shelter of feeding.
- Submerged shelters can be incorporated - for edible crab (crevices on the outside of the structure) and lobsters (galleries within the structure), and shelter for fish species such as wrasse, lumpsuckers and conger eels can be incorporated.
- At mid beach levels, seaweeds like bladder wrack may colonise.
- Fish and crustaceans can use the crevices between stones and concrete blocks to hide from predators, lay eggs, or feed on organisms growing on the structure

1.1 Engineers should consider:

- Consider the appearance of rocky habitat and reproduce it. For structure below the low tide level, the opportunities for fishery habitat enhancement increase with water depth.
- Maximise the diversity of crevices created. The greater the heterogeneity of the habitat the more diverse the final biological community is likely to be.
- Consider using a mix of materials – does everything have to be from the same rock type?
- Be creative. Provide a structure that has rough surfaces, rather than smooth, neat symmetrical ones.
- Build in animal friendly features, intertidal rock pools, projections to create overhangs.

2 Key ideas from Jensen 1998[1]

The new CIRIA guidance draws heavily on Jensen's work, and uses his summaries which are provided above. This paper recommended by HR Wallingford provides a little bit more detail which may be useful for the engineer in considering there designs.
There has been limited work – at a European level there was EARRN (European Artificial Reef Research Network)2. In the UK, there is limited research into the enhancement of structures in the marine environment to provide benefits for the natural marine environment (other than Poole Bay reef), but there is a considerable amount spent on coastal defence structures, breakwaters and harbours – all provide considerable opportunity to enhance the natural environment.

[1] Jensen AC, Hamer BA and Wickens, JF. (1998) Ecological implications for developing coastal protection structures. *Proc. ICE conf coastlines, structures and breakwaters, 1998*. London: Thomas Telford.

[2] http://www.soes.soton.ac.uk/research/groups/EARRN/

2.1 Flora and Fauna

Creating environmental enhancement needs some specific environmental objectives, and needs of target species. These needs are not always understood, and can be based on the intuitive scientist, but preferably quantitative research into critical features.
Plants, such as seaweed need a surface to attach to and light for photosynthesis. Plants will naturally distribute themselves according to their ability to survive at various levels (i.e. height above low water, or light penetration under water).
Below the low water level, kelp will likely colonise with its associated fauna – these will shelter and feed in it (mostly from detritus and plankton in the currents).
To achieve this – the surface needs to provide a variety of orientation for settlement of sessile animals (e.g. bryozoans, hydroids, and sponges) which can attach to new hard surfaces. A variety of nooks and crannies needed for small mobile species (such as blennies, gobies, shrimps) as well as larger animals (anemones, urchins, crabs, lobsters).

2.2 Habitat

A significant drawback to colonisation of defences is exposure to wave energy. But animals and plants that live there naturally are physiologically tough and have evolved to cope – and will take advantage of habitat provided. There varying abilities provide natural zoning. When trying to recreate – for colonisation to occur in the uppershore (direct wave impact area), refuges are necessary – for example the undersides of rocks, rock pools, or deep crevices where they can avoid drying out.
Aim to expand the number of microhabitats available, thereby increasing biodiversity. Layers of variable sized rocks will produce additional habitat. Provision of hollows, crevices to form rock pools, projections to overhangs mimics many of the features of a rocky shore.
Subtidally, physiological challenges are less, and diversity of life increases – here hard structures are limited, and where the chemical and physical conditions allow, will colonise rapidly. Aim to create shelters for edible crabs, lobsters and fish etc (as in CIRIA guidance).

2.3 Coastal Structures and Fisheries

A variety of work has been done to look at the benefit of coastal structures and commercial species enhancement. In general the size of coastal structures would not support a fisheries, but if there is additional habitat for lobsters, for example, it could enhance fisheries elsewhere due to increased reproduction and migration of stock. Much laboratory work has been done to determine preferred shelter sizes for lobsters. In natural reefs there are far more small crevices and a lobster encounters fewer, an appropriately sized shelter as it gets bigger (Caddy 1986). Larger lobsters will either move to a different location, or suffer stress and reduced growth with increased competition for shelter.
Wickins (1995) therefore recommends to design in structures which provide adequate habitat for all sizes of lobsters, but especially larger ones close to the 85mm carapace length minimum landing size (NOTE: current minimum landing size in Cornwall in 87 mm).

2.4 Monitoring

There is limited work in UK – it would be beneficial to monitor the structures to quantify the re-colonisation, changes in neighbouring animal and plant communities, free- swimming fish populations, and maybe even commercially fished species.

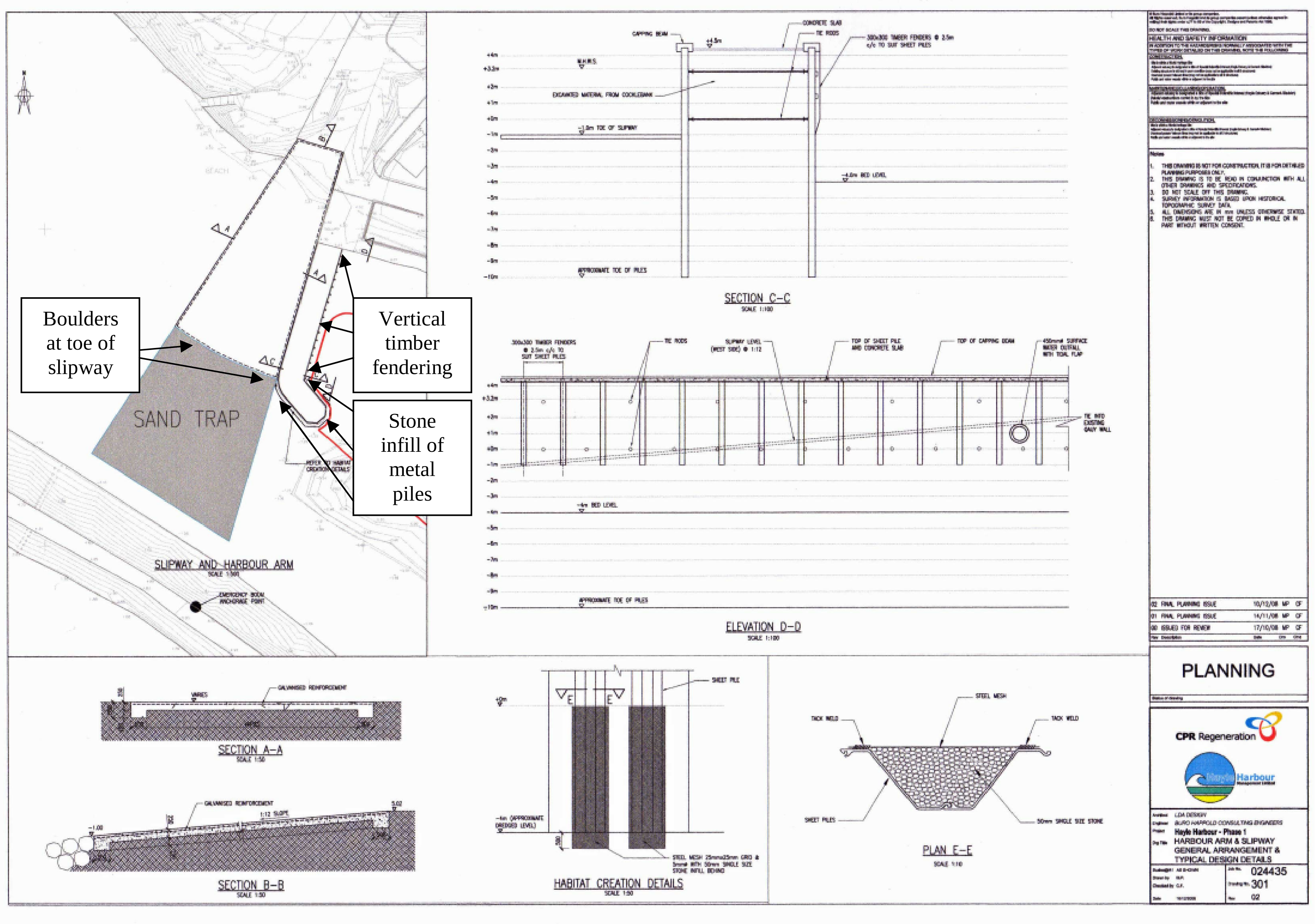

Figure 1. Drawing 301 from Buro Happold. Note that the stone size shown has been amended to a nominal 50-150 mm. The boulders at the toe of the slipway are only shown diagrammatically in Section B-B..