Structurally engineered designs

Where there is not room for a more gentle slope, so a steep or near-vertical solution is required, habitat can still be created by establishing plant communities on steps, terraces or 'ledges' on hard engineered walls. This may also be the solution where storm forces are such that bioengineered solutions could not be relied on. In these designs, plant material does not contribute appreciably to flood risk management but does add considerable value in other respects.

Vegetated terraces

The first option is to create some form of terrace between hard engineered elements. The nature of this will depend on many factors:

- The more limited the space available, the steeper the terrace will need to be.
- The steeper the terrace and the greater the erosion forces, the larger the particle size distribution required for a slope that does not have additional biotechnically engineered reinforcement.

Such steep slopes with cobbles and large gravel may not be suitable for growing intertidal plants, but may still provide many refuges for invertebrates... In brackish and saline environments, where slopes of around 1:7 or less are achievable, terraces in which the substrate is stabilised solely by saltmarsh vegetation may be established fairly readily in the intertidal zone.

Examples of this are shown in Case Study 6, which illustrates different types of terrace arrangement on the Greenwich Peninsula in London (these terraces having been first established 1999).

The design of terraces will differ depending on their location or position within an estuary. The aim is to promote successful establishment of vegetation through providing a revetment that will trap and hold silt and water at the optimum tidal levels for plant growth, but not become waterlogged. Wherever possible the aim should be to install at least 1m depth of gravel and growing medium, generally above a geotextile liner.

A typical specification for a retained substrate might be:

Lower 50cm	100% gravels from 25–10mm with a geotextile mat above to prevent rapid loss of fines.
Upper 50cm	95% gravels from 25mm to dust with an additional 5% sand, topsoil and silt.

Where space permits, a continuous sloping beach profile at a stable angle of repose between the new retreated flood defence wall and the truncated, capped remnant of the former wall can be considered. Such installations may have considerable value for intertidal and littoral fringe invertebrates. This is illustrated in Case Study 6, Site 1, which also shows how dense natural colonisation (in this case of Sea Aster) can occur as long as finished levels are correct. However, where plants did not establish well it was found that finished levels were lower than in the design drawing and outside the optimal saltmarsh growth zone. This example clearly illustrates the critical importance of finished levels matching the design to within a few centimetres.

In Case Study 6, Site 2, simple stepped terraces were created with gabions. Locally, at the highest tidal levels, wooden palisade was used to create the terrace, a technique also illustrated in Case Study 8 at the River Roding Mill Pool in a more protected location. Case Study 6, Site 2, also illustrates some of the issues relating to terrace substrate stabilisation using coir matting before planting. It is possible that the coir

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matting may help to retain the material in severe storms prior to natural sorting and packing of infill material. If, however, the matting is not firmly installed, it may lift. Any plants planted early through the matting may be ripped out of location and lost, and require replanting. It may be appropriate to allow the substrate in the terraces to reach a stable equilibrium under such matting, and then remove the matting (if there is no accretion above it) and plant the terrace. Planting, however, through exposed protection matting is not recommended in an intertidal environment.

One drawback with a stepped terrace form is that flat fish such as Flounder and some other fish such as adult Common Goby appear reluctant to cross up and over submerged terrace steps, and hence cannot access this valuable habitat in any number. A possible solution is to ensure that terraces are sloping in two planes so that there is some point along the profile where the terrace height falls to zero to permit such species of fish to move onto the terrace. This type of design is illustrated in Case Study 6, Site 3.

Plants are best installed in the early spring when they are growing, and from pre-grown stock so that they can survive the tidal forces. Case Study 6 (Sites 1 and 3) demonstrate the value of using estuarine two-year-old container-grown Common Reed.

In some cases it may be considered valuable to install a pre-planted coir pallet as in the example in Case Study 7. This can help promote good early establishment of appropriate plant species especially at higher tidal levels. It should be noted that the quality and handling of the pallet and plant establishment within it can be very important in ensuring success. Case Study 6 also illustrates the problem of over-dominance by one species (for example, Common Reed). If this is not desired, then rhizome barriers should be included in the substrate and/or the reed should be regularly cut.

Case Study 7 also illustrates the problems that may arise. In this example, problems arose due to the very limited fine sediment deposition as the site was on the outer bank of a meander. As a precaution against erosion of the substrate, the decision was taken to contain the terrace growth and habitat substrate within sturdy gabion mattresses closed over the pre-planted coir pallets. It is now considered that this solution was probably over-engineered and terraces, as in Case Study 6, would probably have been more appropriate.

When gabion mattresses are used the installation of a substrate of a smaller particle size than the gabion mesh is not recommended as washout may occur, even if the substrate is covered by a planted coir matting. Also coir may break down too rapidly if exposed to the air and hence its use in areas of limited sediment availability is not recommended.

Case Study 6: Greenwich Peninsula Terraces (completed 1997)
Grid References: (1) TQ 399 794 (2) TQ 390 805 (3) TQ 391 803

The site

- Tidal range 7m.
- Over 1300m of sheet piling was in poor condition and needed to be replaced.
- Peninsula being redeveloped for high-density, high-value housing and facilities.

What the developers did

- In all locations, the existing sheet pile wall was cut down to near beach level and capped.
- Approximately 7–15m inland, either sheet pile or an L-shaped concrete wall were installed.
- Site 1: infill material was installed over wide area at stable angle of repose and allowed to colonise naturally.
- Sites 2 and 3: terraces were created between the new wall and the foreshore using gabions and wooden piles, maximising the area between Mean High Water Neap and Mean High Water Spring tide levels wherever possible at slopes of 1:7 or less. Growing medium initially protected under coir matting.
- Sites 2 and 3 were planted with a variety of saltmarsh plants through coir matting. Substrate particle size distribution was a close match to foreshore for both stability in local area and habitat value.

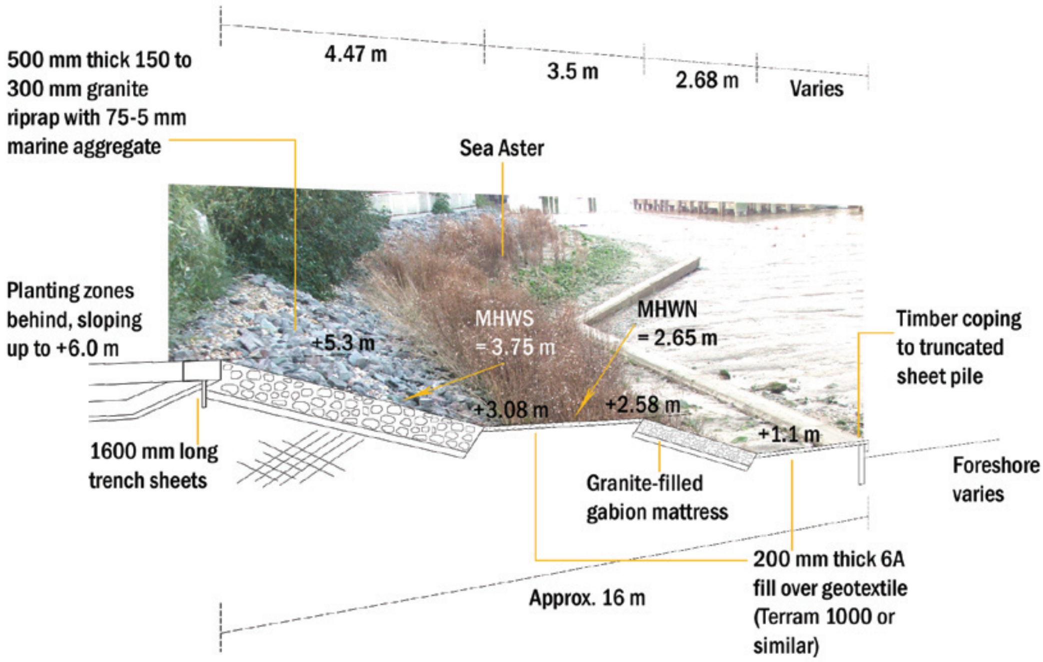
Eastern wall, Greenwich Peninsula, London: Site 2 during construction

The result

- Wave action led to lifting of the matting and extraction of many young plants, necessitating some replanting, though there was also considerable natural colonisation.
- Re-planting of Sites 2 and 3 directly into substrate without erosion matting was most successful with Common Reed, Grey Club-rush Sea Club-rush and Sea Aster, several species surviving well below or above the main ‘saltmarsh zone’.
- Failure to install rhizome breaks has led to excessive dominance by Common Reed, which may need to be corrected.
- Freshwater outfall locations became areas bare of much vegetation, and reinforced geotextile mat used at these locations eventually looked unsightly.
- Extensive monitoring has shown intense use of the terraces by Sea Bass and other species.
- Flounder and adult Common Goby did not appear to ascend submerged terrace steps. One solution

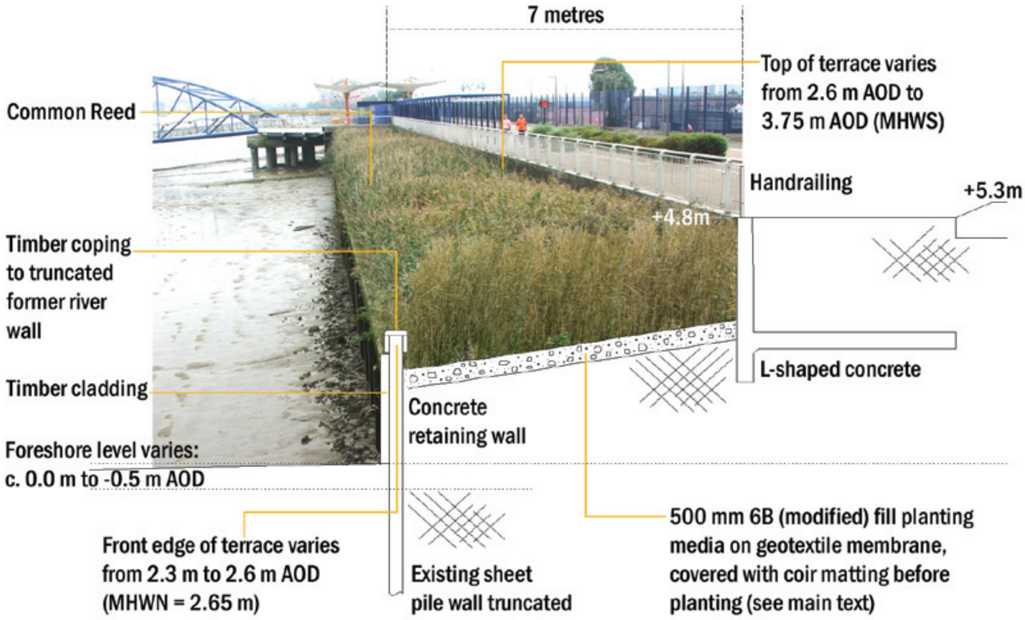
to this is shown in the design for the terracing at Site 3, where a series of terraces sloping in three dimensions was created in the form of an 'ecological sculpture'. (In future schemes, cutting down of the old sheet pile to beach level should be considered to avoid the creation of barriers to certain fish species).

- Limited scope for human access, which might be addressed in future schemes by a variety of slipways or floating pontoons (where ecological and safety constraints permit).
- Overall considered to be a highly successful, benchmark design, though a few gabions appear to be breaking down after ten years (probably due to use of welded gabions) and repairs/renewals may be necessary to retain certain terraces (woven and plastic-coated gabions are always the preferred option if gabions are to be used).

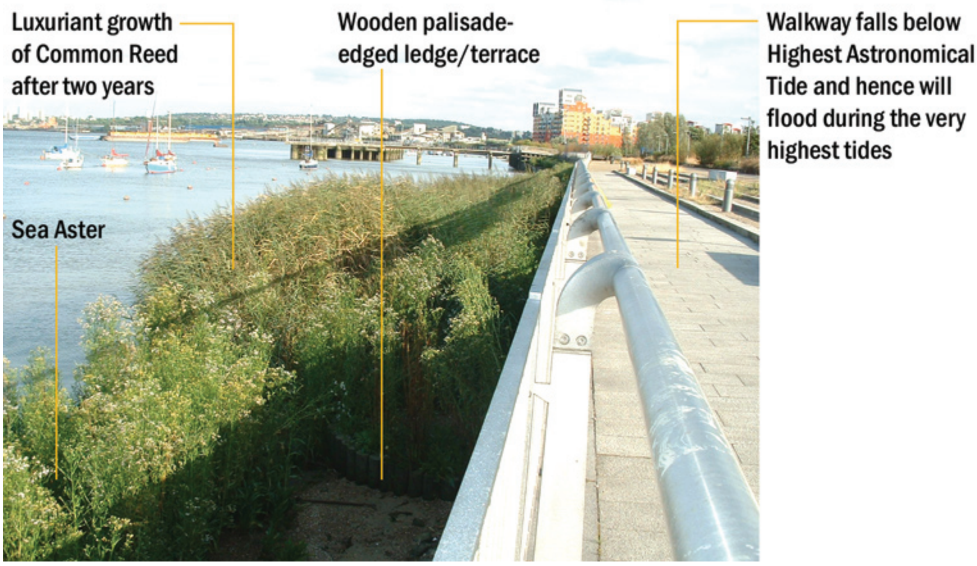


Greenwich Peninsula, London: Site 1 from south, eight years after implementation (winter)

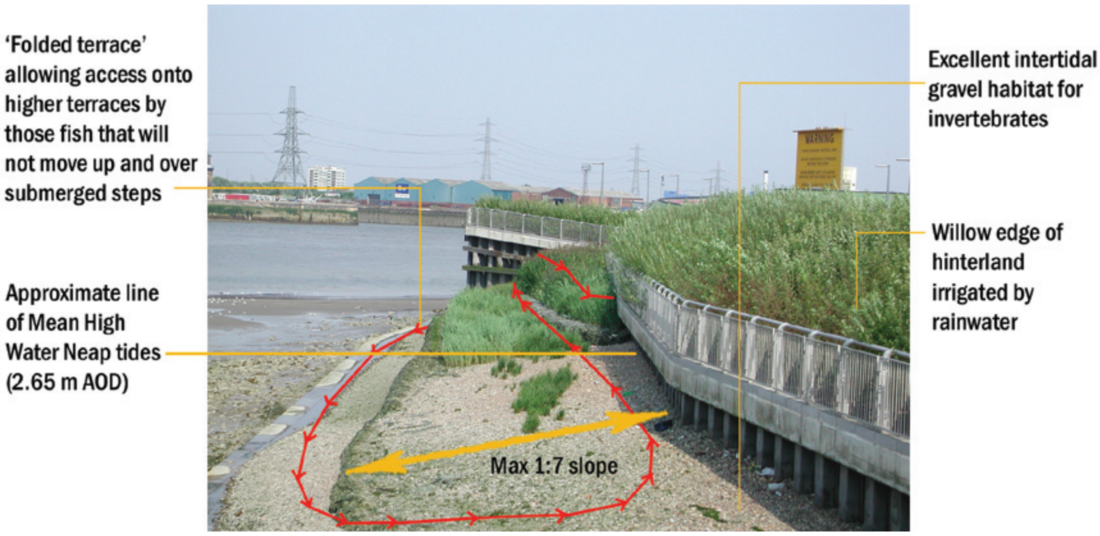
Greenwich Peninsula, London: Site 1 from north, eight years after implementation (winter)



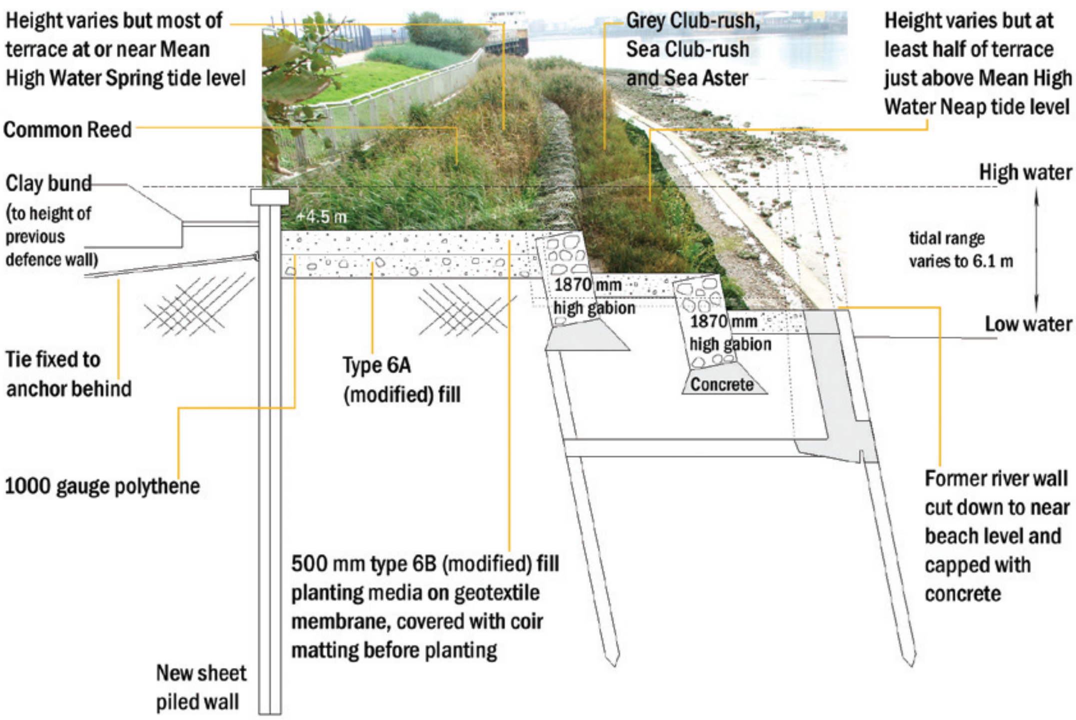
Eastern wall, Greenwich Peninsula, London: Site 2 north end, six years after implementation (autumn)



Eastern wall, Greenwich Peninsula, London: Site 2, south end, three years after implementation



Eastern wall, Greenwich Peninsula, London: Site 3 from west, two years after implementation (summer)



Eastern wall, Greenwich Peninsula, London: Site 3 from east, six years after implementation (autumn)

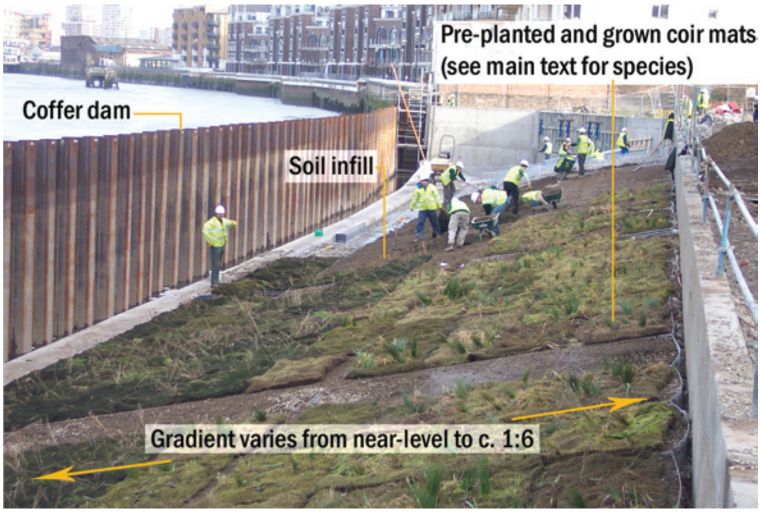
Case Study 7: Battersea Reach Terracing (completed February 2005)
Grid Reference: TQ 261 755

The site

- South bank of Thames just north of Wandsworth Bridge on the outer bend of a meander with little obvious fine sediment deposition on the shingle foreshore.
- Here the estuary is typically less than 1% of the salinity of seawater, but true saltmarsh plant species do still occur in patches.

What the developers did

- The design was similar to that of the Greenwich terraces, but due to perceived erosion risk a gabion mattress slope was built with pre-established coir pallets placed inside the lid.
- The lower slope was planted with inter-tidal species and the upper slope with more general freshwater bankside species.



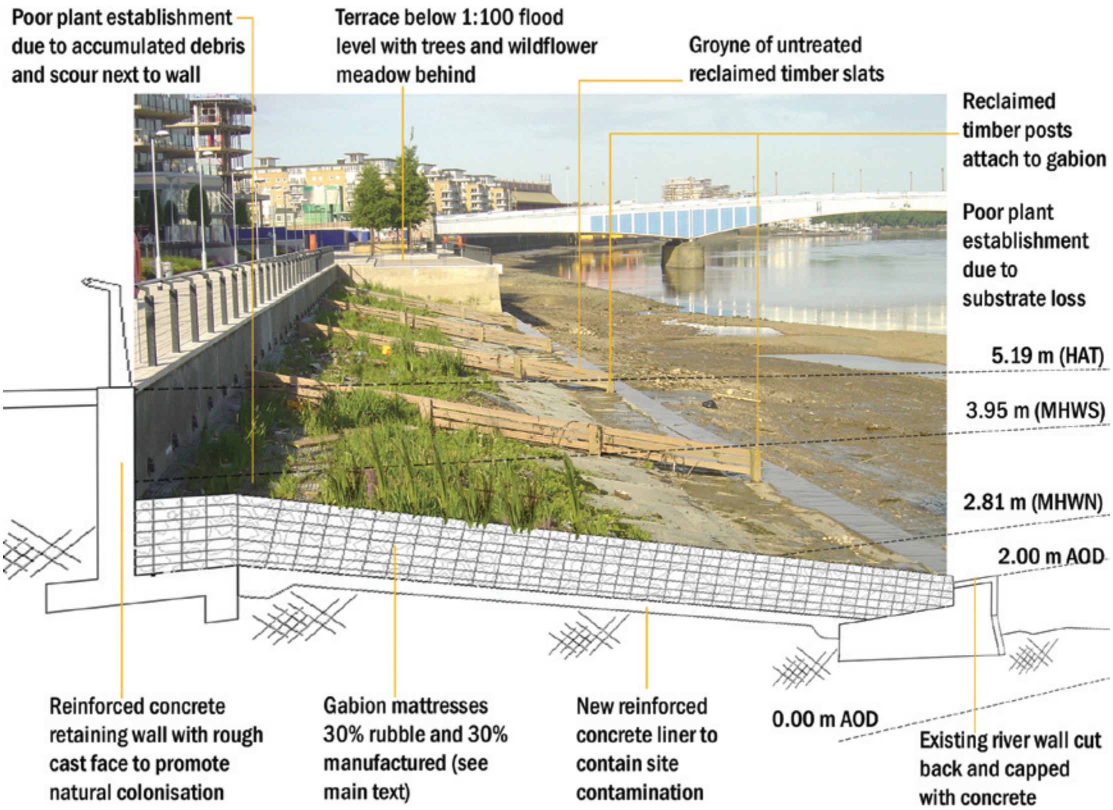
Battersea reach, Thames, London: During construction

The result

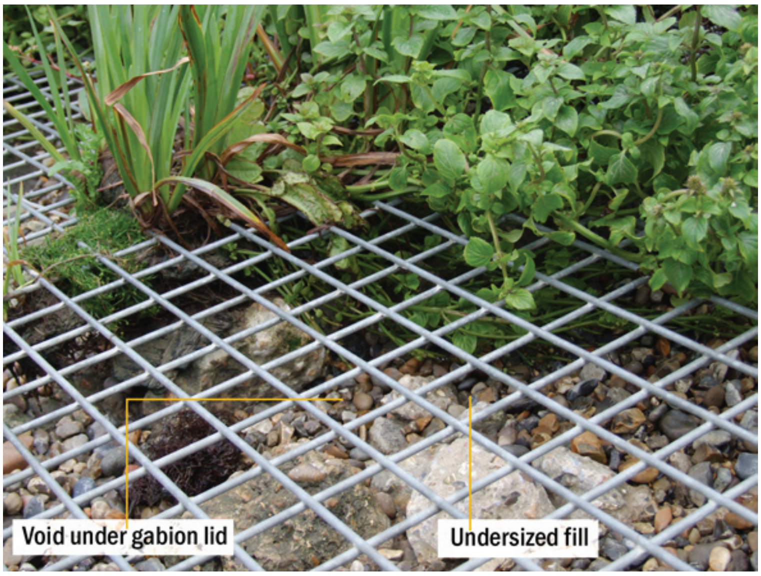
- As with most of the Greenwich Peninsula terraces, the presence of a major 'step' at the waterside edge of the terrace and another at the edge of the gabions prevents access by bottom-dwelling fish.
- After two growing seasons the upper half of the terrace had established well. The coir pallets used in the upper terrace were more mature than those used in the lower areas and this may have affected their establishment.
- However, significant loss of fine sediment from within the gabion mattresses in the lower part of the slope occurred and few plants established. Little new sediment was deposited over the monitoring period. This sediment loss below the matting then led to movement of the matting and the plants were then pulled against the gabion mattress lids and damaged or severed. Fine substrate loss then continued up the terrace leading to failure of most of the planting.
- Grazing of plants by waterfowl and smothering of plants with tidal rubbish may also have also had adverse impacts on establishment.
- After two-and-a-half years there was sediment loss throughout the revetment, though significant natural colonisation by a variety of bankside species including Great Willow-herb, Gypsywort and a wide variety of ruderals.

- Fine sediment was beginning to accumulate in the lower parts of the terrace with reasonable growth of Sea Club-rush and Grey Club-rush.
- Alternatives here might have been to follow the Greenwich Peninsula technique more closely, not using gabion mattresses, ensure all coir pallets were better grown, and add further fine sediment trap features such as brushwood fascines and to remove flotsam and jetsam promptly.
- Having said this, it is difficult to predict how the design will develop in the longer term, and the fine sediment accumulation and plant establishment at lower levels might eventually permit further accretion at higher levels.

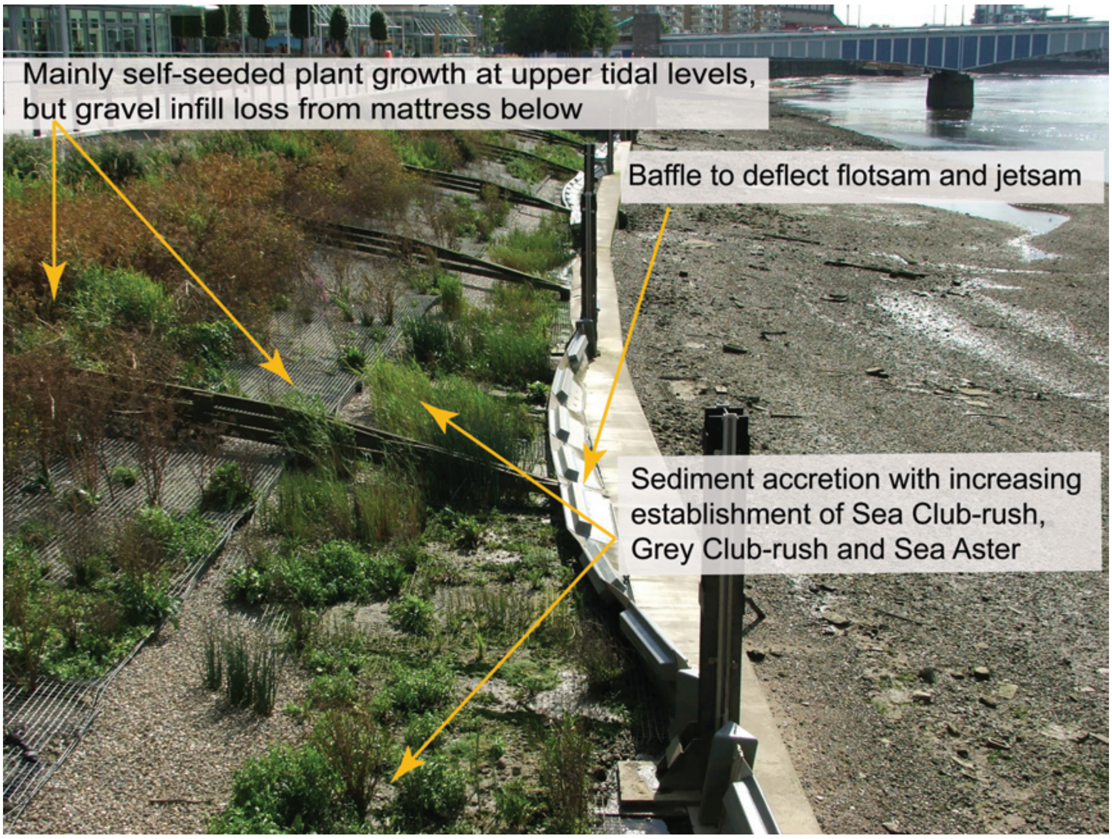
Battersea Reach, Thames, London: Top of slope after one year



Battersea Reach, Thames, London: Poor colonisation at toe after one year



Battersea Reach, Thames, London: Loss of infill after one year



Battersea Reach: Lower slope after two-and-a-half years

Case Study 8: Mill Pool, River Roding (completed March 2006)
Grid Reference: TQ 439 837

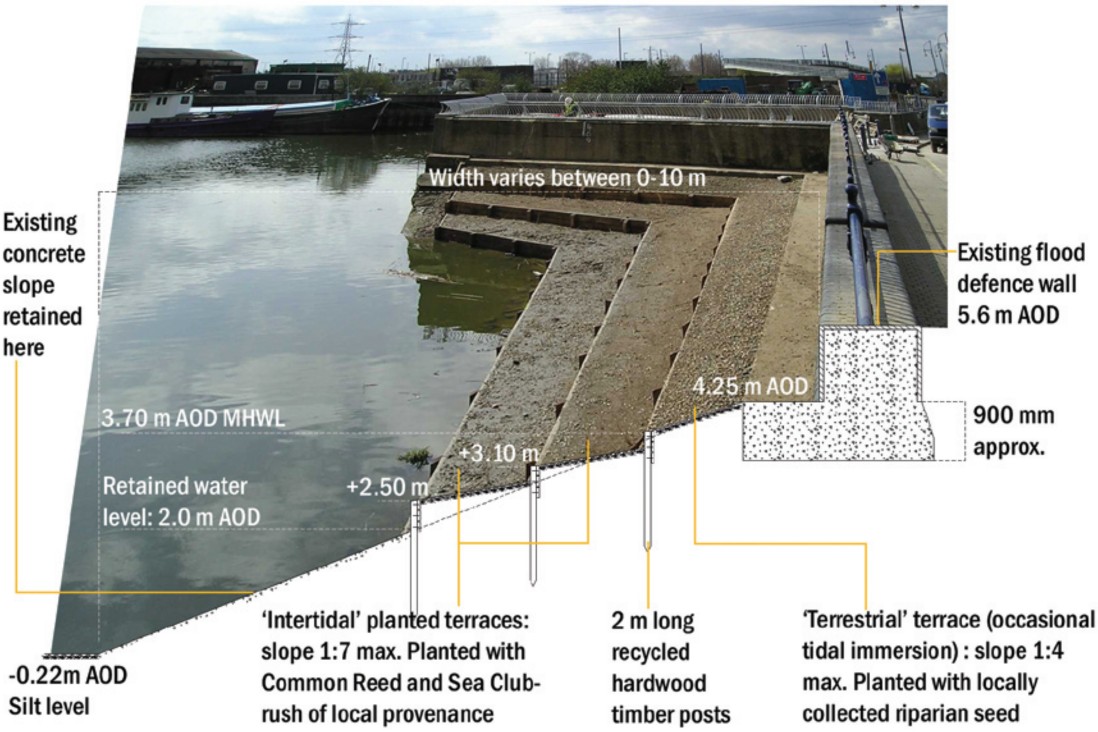
The site

- River Roding opposite the town quay in Barking.
- Decaying concrete slope with invasion of common weeds and relatively low ecological value.

River Roding, London: Mill pool before enhancement

What the developers did

- Works involved the breaking out of the existing concrete revetment and construction of terraces using wooden palisade.
- Upper two terraces were planted with locally collected riparian seed.
- Bottom terrace was planted with Sea Club-rush and Common Reed.



River Roding, London: Mill pool after terracing

The result

- Very poor establishment of Sea Club-rush and Common Reed after 16 months, but dense vegetation of tall species of London brownfield sites. Lowest tidal level dominated by Amphibious Bistort.
- Nearby ledges on the river supported good stands of Branched Bur-reed and Common Reed.
- Not clear why intended planting was unsuccessful.
- Final design with reasonable ecological value, but relatively poor aesthetic value for its setting and planting strategy with pot-grown riparian stock may have produced better results.

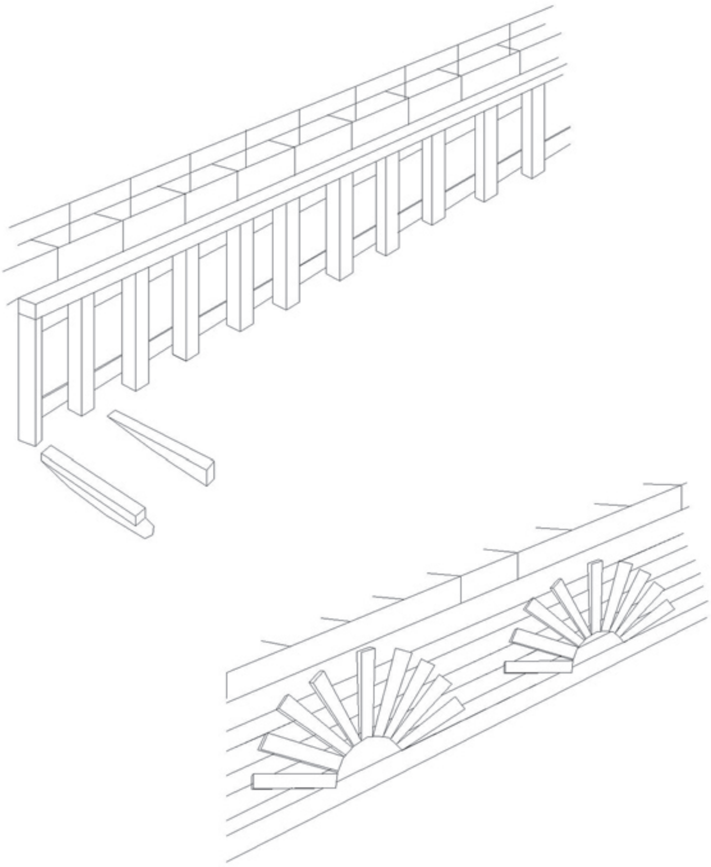
River Roding, London: Mill pool 16 months after vegetation establishment

Ecologically enhanced vertical or near-vertical walls

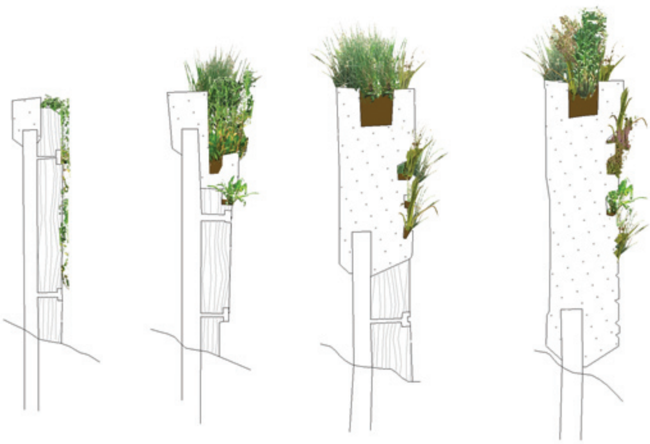
In this category we include any type of vertical or near-vertical, single elevation hard intertidal wall, made of any material, whether new or refurbished. When vertical or near-vertical walls are really the only option, techniques exist for enhancing the ecological and visual interest of such walls. Most methods involve the use of wood coverings of one form or another on the tidal side of the structure.

At one extreme, the whole wall may be panelled, as in the example in Case Study 9. The wooden panelling forms a relatively soft substrate for the colonisation of algae and invertebrates. Ideally (as in the example in Case Study 9) a gap should be left between the wall and the timbers that can be back-filled with material of fairly similar particle size distribution as the adjacent foreshore to form a vertical beach habitat. Complete covering with wood panelling may cause problems for inspection of estuary walls, and hence partial panelling solutions are recommended. In places, a full height section of the wall should be left exposed for inspection and anchor bolt locations should be left uncovered. The space allowed between exposed sections will depend on the precise nature and construction of the intertidal wall.

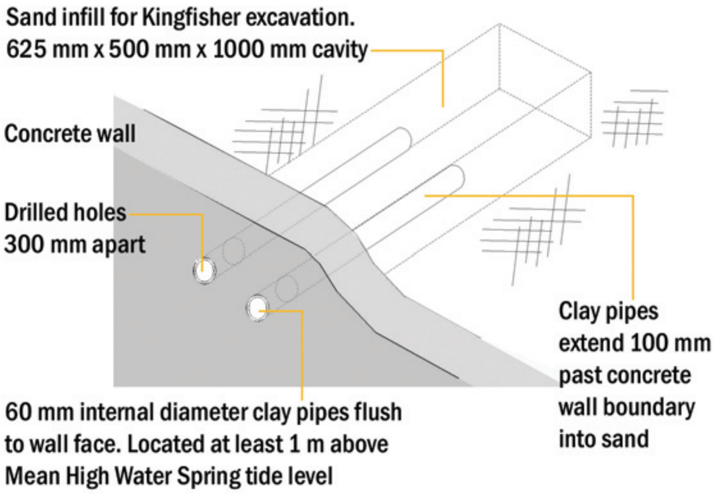
If considerations such as inspection requirements, aesthetics or other functional requirements preclude panelling, it may still be possible to install wooden timbering. This is generally vertical and/or horizontal as shown in Case Study 9 where the timbering was actually designed as intertidal planters that were filled with rubble. Horizontal timbers will be most beneficial when located in the main intertidal plant growth zone. Timbers need not, however, be placed only in vertical and horizontal directions. Other features that may be added included grab ropes and chains and also plastic fronds or ‘brushes’ as substrates for egg laying by fish. As long as the time that these ‘fish egg brushes’ are exposed to the air is limited to a few hours each day, no harm comes to several species of fish egg laid on them.



Different concepts for timbering arrangements for ecological and visual enhancement of near-vertical intertidal walls



Different concepts for modified timbers to promote silt accumulation and plant growth



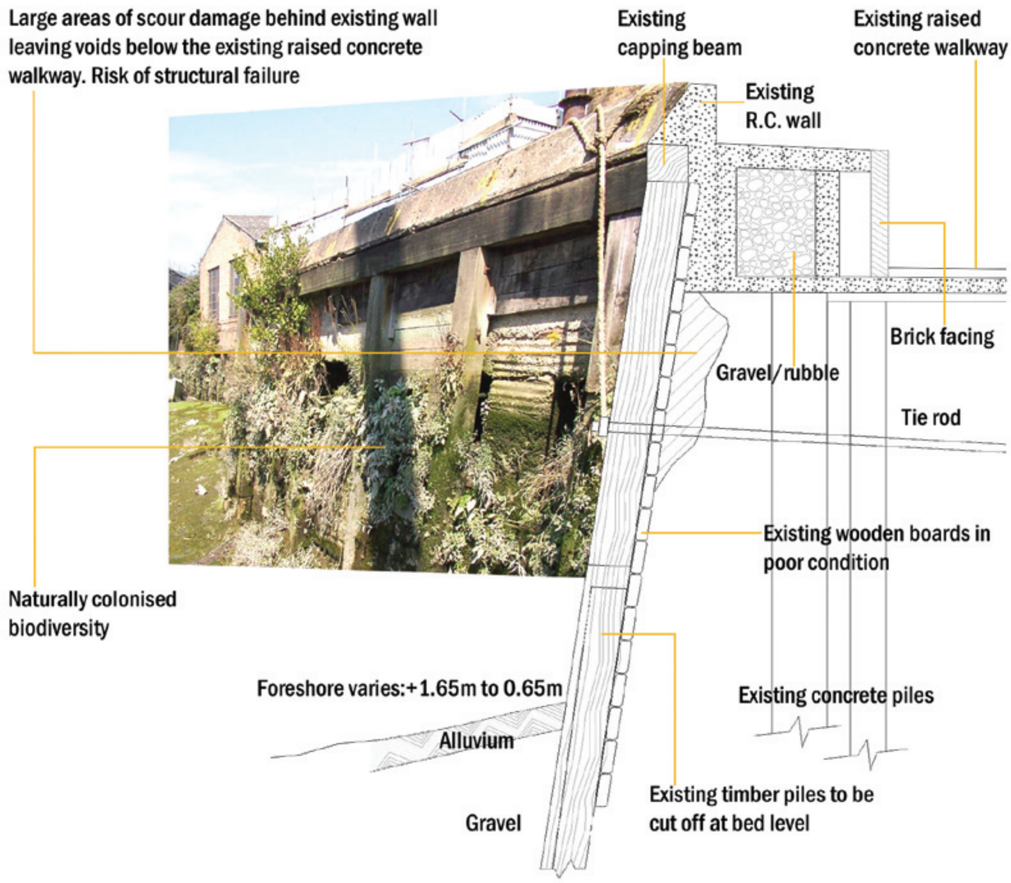
Kingfisher burrow detail

Other installations may include proprietary holes for hole-nesting birds (above the level of Highest Astronomical Tide). Even when Kingfishers do not immediately (or ever) take up the holes, such features can provide a useful habitat for uncommon invertebrates (such as burrowing bees and wasps). Other species that may use proprietary nesting holes in river edge designs include Sand Martins and Wagtails. Holes or other forms of refuge may be added for roosting bats. Specialist ecological advice should always be obtained when installing such nesting or roosting holes.

Case Study 9: Deptford Creek - Vertical Wall Renewal (completed 1997)
Grid Reference: TQ 377 775

The site

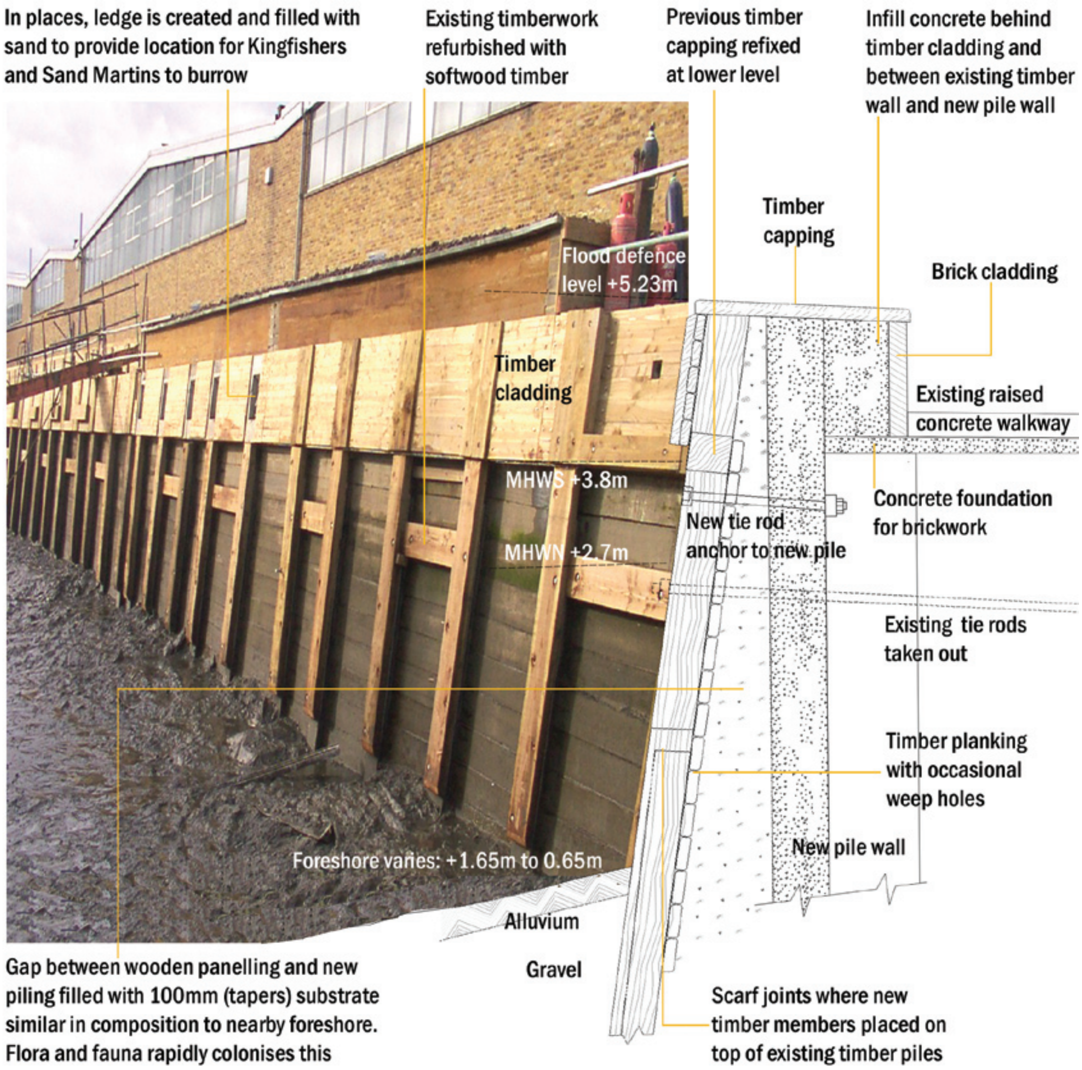
- Deptford Creek is on south bank of the Thames where the salinity regime is semi-maritime.
- Tidal range 7m.
- Old creek walls of wooden construction deteriorated to the extent that in many places only plant roots were holding the wall in place. The economic and social cost of failure of these features assessed as 'high'.



Deptford Creek, London: River wall before renovation

The result

- New sheet piling was installed and clad with wooden panelling, a variable void created between the panels and the sheet pile. This gap was filled with a substrate similar in composition to the nearby foreshore.
- Artificial burrows for Kingfisher were also installed 50cm below the top of the wall.



Deptford Creek, London: Refurbished defences with full panelling and vertical beach

Deptford Creek, London: Timbering to river wall

The result

- The ‘vertical beach’ rapidly colonised with a fauna and flora similar to that which had colonised behind the old boards.
- Kingfishers have been seen investigating the bank but no breeding has occurred. This may be the result of people using the river edge or the height of the water.
- A good range of sizes in fish species have been seen.
- The scheme has been considered a success in ecological, social and economic terms.

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