DESIGN AND CONSTRUCTION OF AN IMPERMEABLE SILT CURTAIN IN A TIDAL ZONE

[1]Bob Batchelder, [2]Jillian Smith, [3]Danielle Starring, [4]Kate Cole
[1]Principal Geotechnical Engineer, GHD, Sydney, [2]Senior Maritime Engineer, GHD, Sydney, Australia,
[3]Technical Advisor, Thiess Services, Sydney, [4]Senior Project Engineer, Thiess Services, Sydney, Australia

ABSTRACT

A new design and construction solution was needed for a sediment remediation project in Homebush Bay, NSW. When faced with the requirement to remove the top 0.5 m thickness of deep very soft sediments containing persistent organic pollutants (including dioxins) and replace this with inert material laid on a geofabric, the 'traditional' earth bund coffer dam and/or sheet pile approach had an elevated risk of contaminant migration, and was a significantly more expensive methodology than the Impermeable Silt Curtain (ISC) designed by GHD and constructed/managed by Thiess Services. This is understood to be the first occasion on which an ISC was used for such purposes within a tidal zone (tidal range approximately 2 m). The final constructed length of the ISC was approximately 1100 m. The environmental advantages of this system over the 'hard' forms of construction originally proposed included: much less disturbance to the contaminated soft sediments, control of odours by conducting all works beneath water cover and an effective (impermeable) barrier against sediment migration into the bay (not able to be obtained by conventional silt curtains). The design utilised a tough impermeable geotextile, mounted on single piles at regular spacings and bottom weighted by chain link into the underlying 'muds'. It also included 'windows' with flap covers in the top 300 mm, opened at a calculated distance from the dredging/placement work, which allowed tidal water transfer while ensuring that the sediment had settled to a level below the window. The work was a resounding success, albeit it required a high degree of management as part of the design.

1 INTRODUCTION

The former Lednez/Union Carbide site was home to chemical manufacturing plants for 60 years until the late 1980s. The site became contaminated when processed lime from pesticide and herbicide plants and ash waste containing chemical residues was used for land reclamation from the 1940s to 1970s. Eventually, the surrounding waters of Homebush Bay were heavily impacted by these activities, and consequently, sediment remediation became necessary.

As part of the Rhodes Remediation Projects, Thiess Services (Thiess) was contracted to remediate sediment from a portion of Homebush Bay at the Rhodes Peninsula in Sydney's inner-west. The sediments in Homebush Bay were considered some of the most contaminated in the world, containing chlorinated and non-chlorinated organics such as dioxin, hexachlorobenzene, DDT and benzo(a)pyrene.

The approval and construction of new residential development around the Lednez site, particularly at the southern boundary, and a desire to minimise impacts on existing residents (in Rhodes and Meadowbank in particular) prompted Thiess to lodge a Section 96 application seeking approval for a modified approach to the completion of the remediation works in Homebush Bay (Ref. 4). Thiess' proposed modifications included an expansion of the scope of work performed in Homebush Bay.

The modifications were designed to:

- Further lower the post remediation bay wide average sediment dioxin concentration in Homebush Bay.
- Minimise the likely disturbance of the bay as a result of the sediment excavation and reinstatement activities.
- Shorten the duration of the remaining remediation works.
- Mitigate environmental impacts, particularly in regards to odour and volatile gaseous emissions.

The original approved area for sediment excavation occupied approximately 5.2 ha, and extended on average 45 m from the existing seawall over a length of 1160 m. Figure 1.1 shows an aerial view of the bay remediation footprint and Figure 1.2 shows interpreted surface concentration of dioxin in the eastern part of Homebush Bay. Within this area, under the site rehabilitation requirements, sediment was to be removed to a depth of 0.5 m below the seabed, and the excavation reinstated with clean materials from the Lednez site, placed over a geotextile layer.

Figure 1.1: Aerial View of Rhodes Peninsula

Thiess proposed a modified scope of works that extended further into the bay, in order to include a large dioxin "hotspot" located south-west of the Lednez site, as well as the full extent of three smaller hotspots near to the foreshore, as shown in Figure 1.2.

The proposed modified remediation footprint was approximately 45% larger than that originally approved, and covered an area of some 7.5 ha.

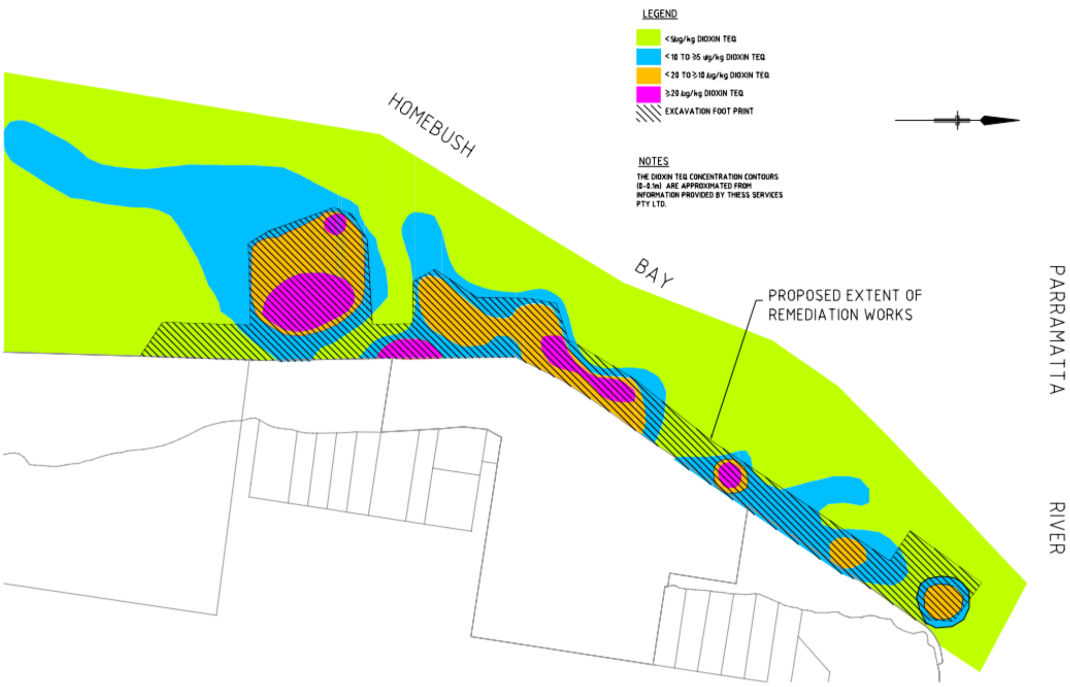


Figure 1.2: Plan View of Rhodes Peninsula Dioxin Concentrations showing extent of the modified excavation area *(GHD Dwg. 21-1460700-S021, 2007)*

Thus a total area of 7.5 hectares of bay sediments was remediated between 2008 and 2010 involving excavation of the top half a metre of contaminated sediment in the wet and its replacement with Virgin Excavated Natural Material (VENM-site excavated shale), forming a cap. Dredged sediments (silt and clay) were treated through a process of Direct Thermal Desorption (DTD).

Prior to the GHD involvement, a coffer dam approach had been originally approved, as a standard 'hard' method of isolating the remediation area sediments/silt plume from the surrounding Homebush Bay environment. However, the recommendations of the GHD desktop study review were to use a much lower construction impact solution. In particular, it was noted that control of odour (Thiess Services needed to be able to control odour in addition to controlling sediment dispersion into the wider area of Homebush Bay), reduction of treated water requirements and avoiding significant disturbance of the deep soft sediments could all be achieved by replacing this construction methodology with a soft 'sediment barrier', and by conducting the remediation works under a water cover. The use of the Impermeable Silt Curtain (ISC), coupled with closed bucket dredging, as recommended by GHD, provided this methodology (Ref 6-10).

2 PREVIOUS DESIGN SOLUTION

The original bay sediments remediation design comprised a series of earthfill cofferdams constructed out into the bay, to cover the full 1100m length of foreshore. These structures would have required 'end dumping' earthfill into deep, soft mud to form the embankments, which would settle and likely mix (even with geoxtextile underlay) with the underlying very soft mud. The embankments thus produced would have been up to some 7m in depth of construction and of approximate base width between 26 m to 35 m as shown in Figure 2.1.

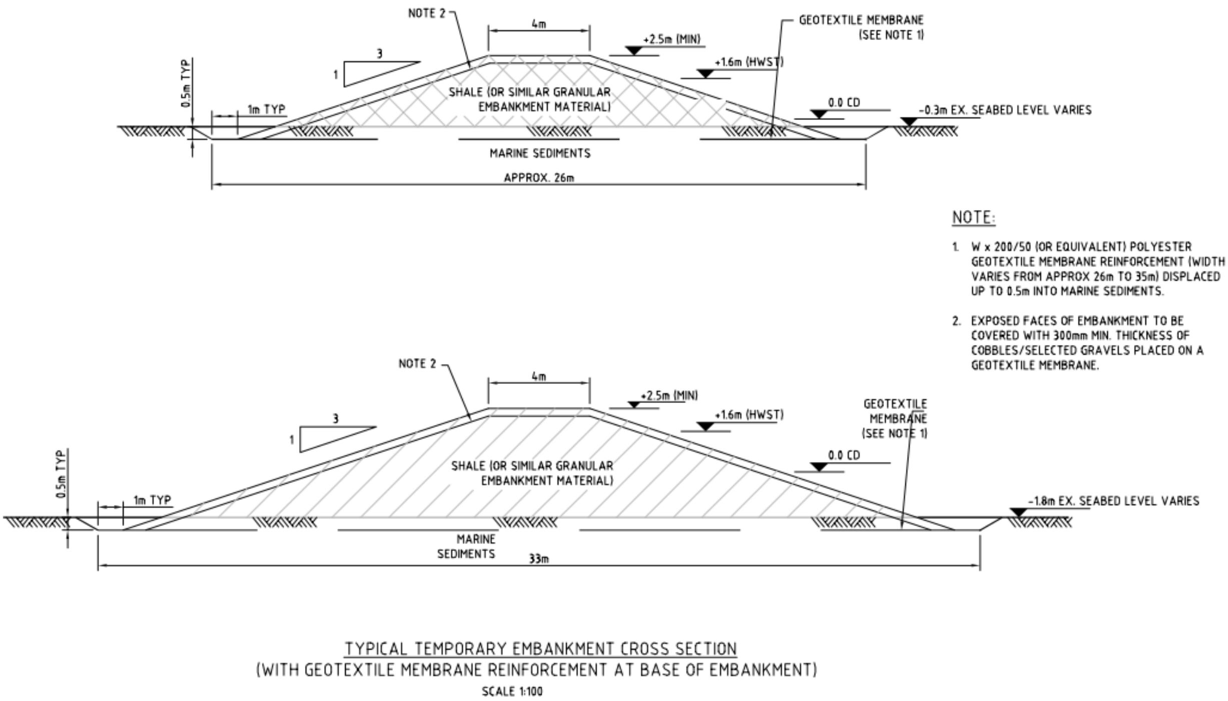


Figure 2.1: Typical cross section of reinforced embankment in line with original approval.
(GHD Dwg. 21-1460700-S008, 2007)

The sediments disturbed in this process were to be retained behind conventional silt curtain construction. Once sufficiently above the waterline, the bunds were to be compacted, and on completion of construction, the (contaminated) water was to be pumped out and treated. The removal of sediment and placement of the geotextile and VENM cover was to have been conducted in 'the dry' using plant based on the embankments and from the existing foreshore area. On completion of VENM placement, the embankments were to be removed, again creating significant disturbance and turbidity, shielded by conventional silt curtains, which are pervious, with perforations down to some 30 microns only (clay is 2 microns and less in particle size, thus easily passing through the curtain).

Conventional silt curtains rely on 'blocking' off of the geotextile and are also not normally sealed at the base into the seabed, particularly as tidal water exchange often needs to occur beneath the curtain. Thus such curtains can only be considered to 'retard' sediment transport, rather than prevent it. Another aspect of this site was the regular passing of the Parramatta 'River-Cat' ferries, creating low profile, high energy waves that would flex/shake the silt curtain, causing blanketing material to fall away.

In regard to odour, the site investigations conducted by GHD had identified strong odour detectable at some 50 m out into the bay from single small diameter geotechnical/geochemical investigation boreholes. The proposed remediation occurring after dewatering was thus viewed as a risk in terms of odour/airborne contaminant release.

In summary, the outcomes of the GHD desktop study included recommendations for:

- The deletion of the coffer dam and conventional silt curtain construction.
- The development of a low construction impact (silt curtain type) system to replace the coffer dams and conventional silt curtain.
- The required removal of the top 0.5 m thickness of sediments being conducted as an underwater operation, using a 'closed bucket' excavator dredging approach.
- Placement of the geotextile beneath the water, using a distribution of weights to provide 'controlled sinking'.
- Placing the VENM from hopper barges to achieve the required 0.5 m thickness inert cover layer placement.

3 DESIGN OPTIONS CONSIDERED

Preliminary discussions between Thiess, Houben Marine Contracting Ltd (nominated excavation contractor) and GHD canvassed a number of alternative sediment containment systems. A highly effective containment barrier system was required and as outlined above, GHD investigations had shown that traditional permeable geotextile membranes commonly used in "floating silt curtains" would not provide an acceptable solution.

GHD undertook desk-top investigations and consultation with industry specialists to determine potential alternative solutions. The following section provides an overview of the alternatives considered and describes the preferred option – a multiple containment barrier system incorporating floating permeable and impermeable membranes barriers.

3.1 SYNTHETIC FLEXIBLE INFLATABLE BARRIERS

An option to use an inflatable rubber dam was investigated with the manufacturer Bridgestone. However Bridgestone have no experience with the use of rubber dams for this purpose and recommended against the use of their product for this application, particularly due to the presence of the soft marine sediments and the large tidal range.

Aqua-barrier cofferdams have been developed in the USA (Ref 1), which consist of a portable, water inflated synthetic tube. This product has previously been used for sediment control however an Australian representative was not able to be located.

GHD considered it unlikely that these systems would be suitable to provide an effective containment system to encapsulate the work area of this project, that would accommodate the tidal range and other physical and operational requirements associated with this site. If the barrier failed due to a breach, or failed to work effectively, there would be significant adverse environment effects. For these reasons, this option was not pursued further.

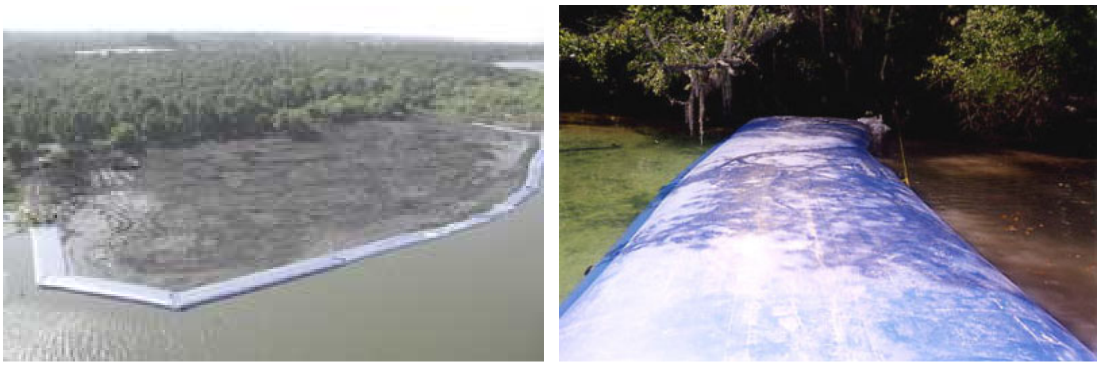


Figure 3.1: Inflatable barriers *(Aqua Barrier 2011)*

3.2 SHEET PILE SYSTEM AROUND THE IMMEDIATE EXCAVATION WORKING AREA

A proprietary system, known as the "Seaway System"(Ref 5), comprised a modular barge system that uses solid sheet piles to provide temporary containment around the excavation area as shown in Figure 3.2.

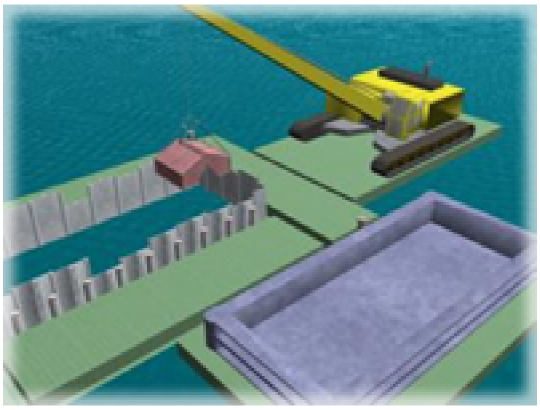


Figure 3.2: Seaway System (*Seaway Containment Technology 2000*)

This system had been effectively used in projects where there was sufficient water depth for barge mounted plant and equipment to be floated to all necessary locations of the site, even at low tide.

The area of operation was relatively limited. Accordingly, if this system had been used on the project, the main operations such as the excavation, the laying of the geotextile membrane and placing of the cover material, would have had to have been undertaken at each location before moving the barge to the adjacent location. It would have been difficult to ensure effective continuity of each of these activities across the adjacent areas.

The excavation contractor also advised that there would have been a significant reduction in productivity, compared to other alternatives, which as a result would have increased the duration of the seabed remediation works. GHD and the excavation contractor considered that this system would have had difficulty in effectively undertaking all the required activities for the seabed remediation works, and in operating within an intertidal zone with very shallow water areas.

The system was not recommended for the project due to the significant risk that it could not effectively complete the seabed remediation works, the increased project duration (resulting in increased potential for adverse environmental effects) and the additional costs involved.

3.3 SOLIDS DISPLACEMENT PUMP DREDGING SYSTEMS

These systems use a combination of floating plant fitted with articulated heads and attachments, such as mud cutters and clay degraders, enabling excavation of polluted sediments in a three phase process, with minimum agitation or dilution. Systems have been developed by Australian Environmental Dredging (Giles Group, Ref 2) and Conbar International (Ref 3) who have an Australian licensee located in WA.

- This system had a significantly lower productivity than the preferred option, and therefore incurred an increased potential for adverse environmental impacts due to the considerably longer remediation period required.
- The dredging process would also have destroyed/disturbed the existing matrix of the marine sediments more than other systems such as the close bucket excavator dredge, thus further increasing the potential for sediment generation and the release of contaminants into the bay.
- The system would need to be used in conjunction with an impermeable containment system that encapsulated the dredge working and the seabed remediation works area.

As a consequence, GHD did not recommend this system be adopted for this project

3.4 STEEL SHEET PILE SYSTEMS

A sheet pile system would have comprised an interlocking steel sheet pile wall, driven into the seabed, and extending above the intertidal zone to about 3 m above chart datum, to form an impermeable wall around the seabed remediation works site.

Two options were considered for the sheet pile wall, depending on the sea water levels on each side of the wall. One option involved dewatering the area encapsulated by the sheet piling and the other involved retaining the same sea water level on both sides of the sheet pile wall. Preliminary concept drawings of the sheet pile wall options were prepared and the following considerations noted:

- The sheet piles would be required to extend through the marine sediments and the underlying residual clays into the top of the bedrock. Therefore the marine sediments surrounding the sheet piles would have been disturbed during installation and removal of the sheets.
- The duration of the remediation works, and in particular the commencement date for the excavation work would have been considerably delayed, due to the lead time for installation of the sheet pile system.
- The sheet pile wall would have present operational difficulties during excavation.
- The exposed portion of the sheet pile wall would have had greater visual impact than other options.

The sheet pile options were not recommended due to the adverse environmental consequences associated with the sediment disturbance to the seabed sediments during the installation and removal of the sheet piles and the adverse environmental consequences associated with delayed start and the longer duration of the seabed remediation works.

3.5 FLOATING RELOCATABLE BARRIER SYSTEMS INCORPORATING PERMEABLE AND IMPERMEABLE MEMBRANES.

A system involving a combination of relocatable floating permeable and impermeable barriers, as shown in Figure 3.3 was developed by GHD. It was proposed that the remediation works would be undertaken in three stages, commencing in the southern most area, and a multiple containment barrier system was developed to contain sediments during excavation of each area.

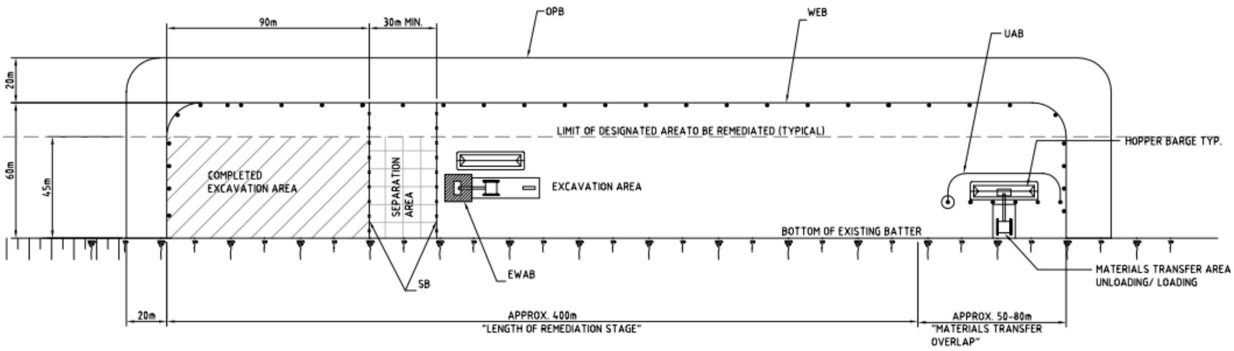


Figure 3.3: Multiple containment barrier system.
(GHD Dwg. 21-1460700-S004, 2007) (Ref Plates 1 to 5 attached)

The multiple containment barrier system incorporated the barriers described below.

Excavator Working Area Barrier (EWAB)

The EWAB was the primary sediment control barrier and was designed to fully encapsulate the excavator working area. It was constructed from an impermeable membrane attached to the pontoon barge and covered an area of approximately 12 m square.

Segregation Barriers

Segregation Barriers were designed to be placed at convenient divisions between active and completed work areas, in order to minimise the recontamination of completed areas by re-distribution of disturbed sediments.

The Segregation Barriers consisted of floating conventional permeable geotextile membranes and were designed to limit the dispersion potential of the sediment generated during the excavation and the restoration activities.

Works Encapsulation Barrier (WEB)

The WEB was designed to be placed beyond the working area to completely encapsulate all working mobile water borne plant and equipment. The WEB was located approximately 15 m beyond the remediation boundary to allow for access for water borne plant and equipment. The design of impermeable silt curtain which formed the WEB is described in Section 4.

Outer Perimeter Barrier (OPB)

This curtain was designed to be placed at a location approximately 20 m seaward of the WEB to provide a level of redundancy to the other containment devices, and as a marker to prevent interaction between vessels within Homebush Bay and the WEB. The OPB comprised a traditional floating geotextile curtain similar to those commonly found on marine projects.

Unloading Area Barrier (UAB)

The UAB was situated around the barge unloading area. As for the OPB, it comprised a traditional floating geotextile curtain.

This system was recommended as the preferred option as:

- It had minimum adverse effects on the disturbance of the existing marine sediments.
- It required the least intrusion into Homebush Bay and least working area footprint size.
- It had minimum adverse effects on the operations of the excavation contractor, which would reduce the time taken to complete the remediation works and the associated adverse environmental risks.
- It could be deployed relatively easily compared with other systems considered.
- If required the membrane could be modified and/or the operations modified to ensure the membrane performed to achieve the environmental objectives of the project.
- Only the top portion of the barriers would be visible reducing negative visual impact.
- The system enabled the excavation works to proceed under water, using a hydraulic excavator that would have less adverse effect on the matrix of the sediment and less adverse consequences with respect to odour generation.

4 IMPERMEABLE SILT CURTAIN DESIGN DEVELOPMENT

The development of an appropriate design for the Works Encapsulation Barrier (WEB) required assessment of the processes involved in the recommended revised remediation strategy, in order to provide a solution, at least as good as the coffer dam construction, to the prevention of migration of silt and clay sized particles from the remediation area into the greater Homebush Bay.

The constraints included:

1. The requirement for a tough, durable, geotextile type barrier to prevent sediment migration. This barrier to be capable of withstanding the high energy waves from the passing River-Cats.
2. The high elevation of the seabed, some of which is exposed at low tide, combined with the shallow depth of excavation (0.5 m) and the use of barge mounted plant and equipment and associated vessel movements which would generate a considerable volume of suspended sediment in the water column in close vicinity to the excavation works.
3. The system must accommodate tidal water level variations of up to 1.8 m and allow for tidal exchange of water through the barrier.
4. A means of keeping the barrier in place.
5. Sealing the barrier into the underlying soft muds.

As part of the design process, the turbidity of silt/clay laden water was measured through a range of ‘conventional’ silt curtain materials. The results of this study demonstrated that significant sediments loads were able to pass through the silt curtain material, particularly when ‘flexed’, as per the expected River-Cat wave impacts. Given the nature of the contamination associated with the subject sediments, this was considered to be unsatisfactory. The decision was taken to investigate an impermeable solution.

GHD considered the following options for the WEB:

- Fixed pile with flexible impermeable membrane - A purpose designed and built composite pile and membrane system with an impermeable flexible membrane fixed between driven piles
- Fixed sheet pile system - Solid sheet piles system using light weight sheet piles and rock
- Floating Impermeable silt curtain (ISC)- A purpose built support pile and floating system that incorporates a composite impermeable membrane with a permeable geotextile membrane ‘window’ in the top portion to accommodate tidal level variations

The ISC was determined to be the preferred solution based on the following considerations:

- Relative ease of deployment and relocation with minimal plant and equipment
- Ability to accommodate tidal variations and allow water exchange only at top of water column reducing potential for sediment transfer across the barrier
- Similarity to other floating barriers proposed as part of the multiple containment barrier system providing consistency in the water monitoring and maintenance requirements

- Ability to vary the location of the permeable window sections of the barrier (by opening and closing the windows) depending on the proximity to the excavation operations
- Less disturbance to the existing marine sediments compared to other systems during installation and removal.
- Less adverse visual impact than other fixed systems, especially at low tide

This was the only known ISC to date to have been used in static water situations. There was no ‘history’ of use in a tidal fluctuation range application.

In order to address the requirements, the settling velocity of the subject sediments was recorded within the GHD soils laboratory, using column sedimentation tests so as to assess the time taken to provide a ‘clear’ water space of up to 500 mm. Homebush Bay estuarine (tidal velocities) were calculated by GHD, and a relationship was determined between distance from a disturbance (dredging) and clear water of greater than 460 mm depth at the top of the water column which corresponded to the lower extremity of the permeable window.

Theoretical calculations were undertaken for a selection of tidal change rates and water depths, a minimum required water depth and dredging distance was determined along with corresponding minimum acceptable tide levels and potential impact on acceptable operation periods for each of the three areas.

The ISC design is outlined below and shown in Figure 4.1.

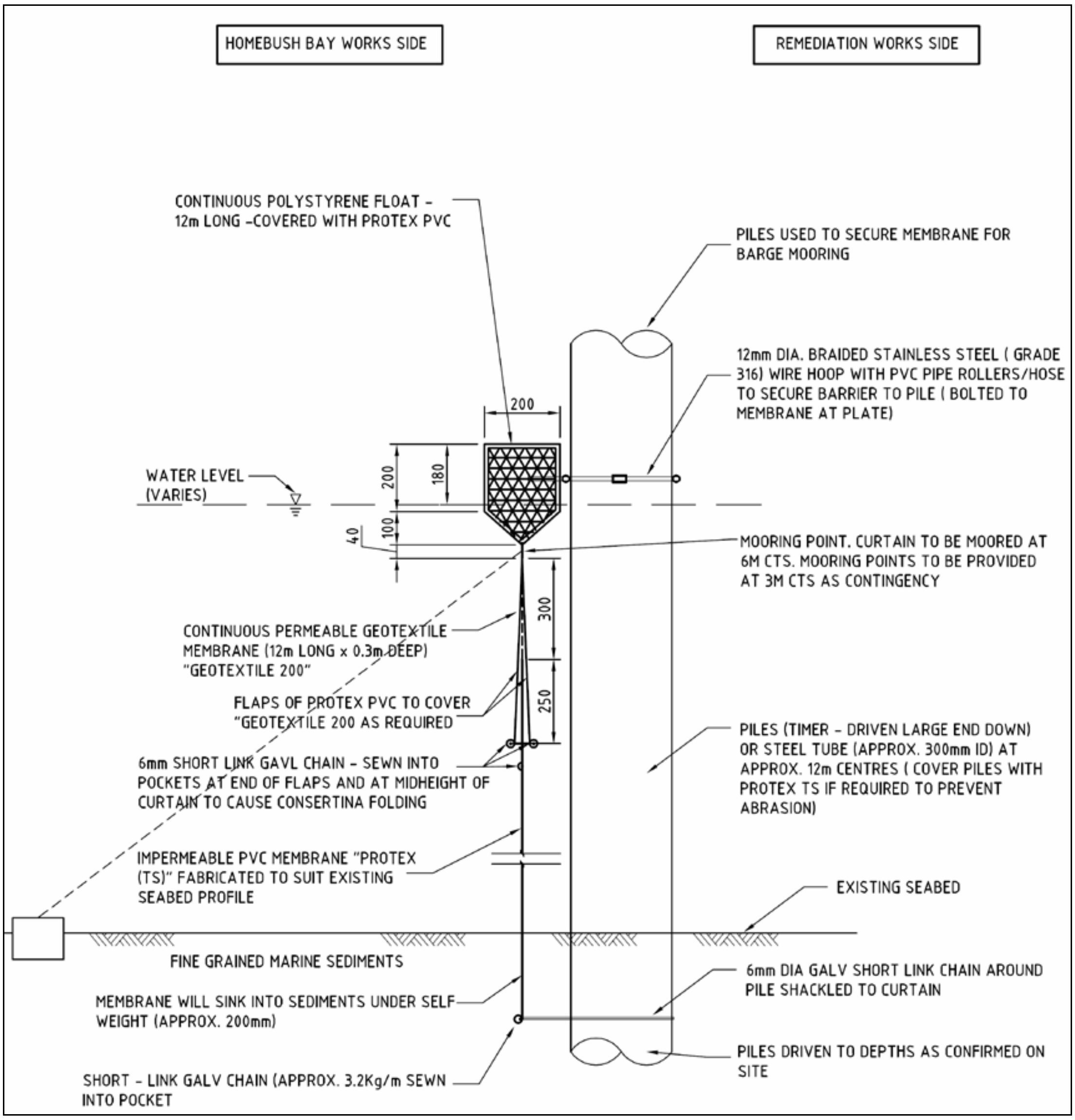


Figure 4.1 ISC Design (*GHD Dwg. 21-1460700-S006, 2006*)

- The WEB was manufactured out of Protex PVC, a solid impermeable material that prevented both water and sediment from flowing through it. A 300 mm section of ‘window’, made of Geotextile 200, allowed water to move through the upper section of the WEB to enable the tide to equalise on either side. (Ref Plate 2).

- Adjustable impermeable flaps were provided on both sides of the filter sections so that water flows in and out of the window could be controlled during tide cycles. In order to minimise turbidity loadings, only those filter sections well away (as per design minimum distances) from the excavation activity were opened.
- The WEB was held in place with steel piles designed by GHD based on the geotechnical investigation data from previous overwater investigations. The membrane was anchored to the piles at various heights with steel rings. (Ref Plates 1 and 3).
- The base of the WEB was weighted so that the membrane would be effectively sealed to the underlying sediments.
- The membrane was fabricated to suit the seabed profile with suitable allowance for immersion into the seabed sediments and for tidal level variations.
- The floating portion of the barrier was designed to provide the maximum buoyancy and to minimise the potential for wave overtopping due to wind generated waves and vessel wash.
- Special consideration was given to the design of the barrier at the connections to the shore and existing seawall. At these locations, as the seabed elevations increased, a floating system was not practical due to the shallow and in some cases complete lack of water depth at low tides. A fixed continuous impermeable curtain was designed for these areas, supported by galvanised pipes driven into the sea wall armour zone rocks.

System contingencies identified in the design phase included:

- Provision for an ongoing maintenance program.
- Provision of replacement curtain sections on site.
- Provision of spare mooring points.
- Use of land based excavation near to shore where small water depths may prove the ISC ineffective.
- Consideration of an additional WEB curtain if monitoring deemed required.

A prototype design was prepared by GHD in conjunction with Pit Bull Barrier Systems. It was originally envisaged that a trial (pilot) placement would be conducted to test the system and allow for improvements/refinements. However, within the time constraints, this did not occur and the system was implemented ‘as designed’.

The design required continuous management during dredging/placing operations, in order to coordinate window opening/closing operations with the work in progress.

5 ENVIRONMENTAL/PLANNING APPROVAL CONSIDERATIONS

5.1 DURING DESIGN PHASE

In order to allow a variation from the originally approved remediation design, GHD assisted Thiess to undertake significant consultation with the approval authorities[1] and to prepare a Section 96 Application to modify the existing approvals. The modification application was publicly exhibited from 18 October 2006 to 8 November 2006, and statutory agreement was reached in February 2007 regarding the benefits of the revised remediation approach. The Department considered that ‘the successful implementation of the proposed multiple containment barrier would minimise the release of sediments outside the remediation area to acceptable levels’ (NSW Department of Planning 2007).

Whilst the application to modify the methodology occasioned some delay, the saving in construction effort/time with the ‘minimal construction impact’ solution more than countered this approval period.

5.2 IMPACT ASSESSMENT

5.2.1 Odour

Holmes Air Sciences Pty Ltd (HAS) was engaged to assess and model the potential for odour emissions from the bay remediation works for both the approved and the proposed modified bay remediation methodologies.

[1] Authorities consulted during design phase included Department of Environment and Heritage, NSW Maritime, Department of Commerce and the nominated technical review auditors for the consent authorities, Mr Greg Britton of Patterson Britton and Partners and Dr Ian Swane of SKM.

Odour measurements were undertaken using sediment recovered from Homebush Bay adjacent to the Lednez site. A variety of studies were undertaken to simulate the conditions anticipated for each excavation methodology. Samples were measured using an Odormat in accordance with AS/NZS 4323.3:2001 *Air Quality – Determination of odour concentrations by dynamic olfactometry*.

The results showed that the odour emission rates from exposed sediment (representing the approved method) were higher by a factor of two than those observed when the sediment was stirred under water (representing the proposed modified method).

Potential impacts from the excavation activities on the surrounding area were assessed using AUSPLUME Version 6.1 with sensitivity testing conducted to determine if the time of year would influence impacts. While there were some differences in the odour impact footprint, depending upon the time of year that the excavation was assumed to occur, it was clear that regardless of timing there was likely be some detectable odour in the community.

The odour footprints modelled differed between the respective methodologies. Consistent with the emissions measurements referred to above, odour concentrations anticipated for the proposed modified method were less than that predicted for the approved methodology by a factor of two.

In addition, the proposed modified methodology had the advantage of a shorter duration (40 weeks) as compared to the approved methodology (60 weeks), thereby further reducing total odour impacts on the local community.

5.2.2 Noise

Thiess engaged Parsons Brinckerhoff (PB) to compare the potential environmental noise impacts associated with the proposed modified methodology and the approved methodology.

The approved methodology would involve the construction of earth coffer dams by end-tipping soil from articulated dump trucks and the twenty four hour operation of dewatering pumps. A combined sound power level (SWL) of 119 dB(A) was predicted by PB for the approved methodology.

A combined SWL of 120 dB(A) was predicted by PB for the proposed modified methodology assuming simultaneous operations of all equipment. No night-time operations were required for the modified proposal.

Accordingly, it was considered that the day-time noise impact of the respective methodologies would be effectively equivalent. With respect to night-time noise, the modified proposal was superior as it did not involve any night-time activities. Again the much shorter operation duration than required for the approved methodology, further mitigated noise impacts from the bay works.

In addition, given that fewer noise sources were associated with the modified proposal, management of noise impacts from this method, if required, would be significantly more practicable than managing and mitigating noise impacts from the approved method.

With a significantly reduced duration of potential noise impacts, reduced number of noise sources and the absence of night-time noise sources PB considered that the modified proposal would result in lower socio-acoustic impacts.

5.2.3 Water Quality

Solubilised Chemicals

To assess the potential for the mobilisation of soluble contaminants from the sediment during the bay excavation, Thiess conducted a solubility trial using the most highly contaminated sediments from Homebush Bay. The trial was based upon the United States Environmental Protection Agency (USEPA) elutriate test procedure designed to predict the release of contaminants to the water column resulting from dredging and disposal of sediments in open waters. Whilst Thiess was not proposing to use a hydraulic dredge or to dispose of the sediment back into Homebush Bay, this internationally recognised and approved analytical procedure provided a conservative method for the evaluation of the potential release of soluble compounds during the excavation process.

The sediments with the greatest potential to release soluble compounds into the overlying water column during the excavation process are those sediments with the highest concentration of soluble chemicals. Evaluation of historical sediment data identified the area in which the sediments had the highest concentration of soluble compounds. It was from this area that the sediments used for the trial were sourced. As expected the sample was found to contain significantly elevated concentrations of pesticides, chlorobenzenes, phenols, polycyclic aromatic hydrocarbons and dioxin and furans.

The water used in the experiment was sourced from Homebush Bay adjacent to the Lednez site to accurately reflect the conditions that would exist during the sediment excavation. The water was tested for the chemicals of concern prior to and following the trial to enable determination of the change in concentration of the soluble chemicals of concern and hence the concentration of soluble chemicals released from the sediments during the trial.

The trial indicated that the concentration of solubilised chemicals were below (4 to 5 times lower) the bay discharge criteria documented in the current Environmental Protection Licence (No. 12146) for the site. On this basis solubilisation of chemicals during the proposed works was not anticipated to represent a significant risk to bay water quality.

Subsequent to the completion of the testing described above, additional evaluation of the potential for release of solubilised chemicals was undertaken at the request of DEC. The test method employed for this work was developed jointly with DEC and aimed to more closely simulate the proposed excavation works. The results obtained from this work were similar to the results of the earlier testing described above.

For the approved methodology, no quantitative information existed to predict the potential for solubilisation of chemicals to the waters of Homebush Bay. However, the following observations were made:

- Construction of the coffer dams would result in significant disturbance of the bay sediment, introducing contaminated sediment to the water column. During this process solubilisation would occur by similar mechanisms as anticipated for the modified proposal.
- Compression of the sediments beneath the coffer dams would displace pore water as the sediments consolidate. Such water would be released to the water column and would contain solubilised contaminants.

Turbidity/Pollutant Loads

GHD were engaged to undertake a range of testing to establish sediment particle size, settling rates, and to estimate the potential flux of sediments through the proposed silt containment systems.

The results of this study indicated that turbidity was not expected to increase discernibly above the background water quality beyond the proposed containment systems. Further with respect to the total flux of sediment GHD reported that up to 98 kg of sediment per tidal cycle was anticipated to escape from the containment system in the case of the modified proposal, compared to 1950 kg for the originally approved methodology. Accordingly, it was expected that there would be a significant improvement in water quality as a result of the modified proposal.

5.3 DURING CONSTRUCTION

Monitoring Water quality

Water quality monitoring of the works consisted of a multipoint system of floating turbidity monitors positioned in and around the work area. Monitors locations were as follows:

- Adjacent and outside the EWAB
- Between the WEB and OPB and
- Outside the OPB.

Containment barrier integrity

The containment barrier systems were to be inspected and maintained on a continuous basis during working hours by personnel dedicated to this operation. Where visible signs of deterioration were identified, the affected portion of the barrier was repaired on detection.

6 IMPLEMENTATION

6.1 PLANNED DESIGN AND IMPLEMENTATION

It was proposed that sediment removal in the bay begin from the southern end of the proposed remediation area so that the bay remediation was completed prior to further development and occupation of nearby residential developments.

The sediments were remediated in three stages, each stage representing approximately 350 - 400 linear metres of shoreline along the proposed footprint. Once the southern area (Stage 1) was completed, the work shifted to the northern section (Stage 2) and then proceeded from a north to south direction. The final stage in front of the Lednez site was conducted last (Stage 3).

Within any particular stage, it was proposed that the excavation start at one end of the area and be progressively completed along the shoreline in approximately 90 m long “cells” separated from the remaining stage area by Segregation Barriers. Once works were complete in any stage, the barrier systems would be relocated to the next stage and the works process repeated.

Prior to any sediment excavation works being undertaken in a particular area, the multiple containment barrier system was installed and made operational. These barriers were installed and continuously maintained by Pit Bull, a specialist contractor experienced in the design, construction and maintenance of floating silt curtains in a marine environment.

6.2 CONSTRUCTION AND OPERATION

Approximately 900 m^2 of ISC, termed the “Works Encapsulation Barrier” (WEB) was installed in October 2007 over a three week period. The first step in establishing the WEB began by installing steel piles which were placed every 18 m along the alignment of the ISC footprint. Steel piles were driven at a 15 m offset to the remediation footprint. The WEB was manufactured in 18.5 metre sections offsite at varying depths (2.5 m to 4.0 m) to account for the undulating surface of the bay footprint for each 18 m wide section. It was held in place by the steel piles but was able to move up and down the piles according to the tides with the aid of two collars. Chains installed at the base allowed the WEB to sink approximately 100 mm into the sediment bed and chains at the base of the flaps were in place to enable the windows to be closed also.

The ISC was delivered to the Rhodes jetty for assembly in sections prior to installation. Each section had Styrofoam floats installed at the jetty, the chain inserted at the base, and a series of 5 sections were welded together ready for installation. The newly welded sections were folded up upon themselves, tied with rope and floated into place whilst being pulled by a boat into position.

Once in place, the system minimised water flows through the work area by primarily allowing water to flow in or out through the windows, which were located at the top of the water column. The system reduced the water velocity within the work area and allowed for sediments to drop out. Overall, the WEB prevented sediment dispersion outside of the dredge area to the general waters of Homebush Bay.

The windows of the WEB were able to be manually opened and closed. These windows were only opened where continuous turbidity monitors were located to monitor its effectiveness. The opening and closing of windows was dependent on the location of active dredging. Open windows were located as far from active excavation as possible, in order to maximise the settling time for sediment particles, using guideline distances as per the design combined with ‘site adjustment’. Windows were opened during the incoming tide and were closed when necessary as the works progressed.

Two ‘gates’ were constructed in the WEB which enabled maritime vessels such as the dredge and support boats to enter and exit the remediation zone. The timing of ‘gate’ openings was strictly controlled to occur only during the incoming tide, thereby preventing bulk sediment transfer out of the system.

Daily inspections of the WEB occurred during operation. The purpose of this exercise was twofold: firstly to ensure and document that the main control against sediment dispersion outside of the remediation footprint was intact and operating as per design; and secondly to assist with opening and closing the ‘windows’ and ‘gate’ openings.

7 RECOMMENDATIONS

Although the ISC was measured to be effective in preventing sediment dispersion on this environmental dredging project, it required an extensive amount of monitoring and repair due to the environment that the materials were subjected to. The ISC was in Homebush Bay for approximately three years and many, if not all, sections required replacement within that timeframe. The manufacturer could only guarantee the integrity of Protex PVC for 12 months and therefore continual inspections and repairs ensued. Whilst the system was still significantly more cost-effective than the traditional coffer-dam approach, it is recommended to trial or research further resistant materials for future long-term use.

8 CONCLUSIONS

The ISC system implemented achieved all of the designated ‘targets’ for the design, and enabled a significantly ‘lower impact’ and lower cost solution in a heavily urbanised and environmentally sensitive area. While it is recognised that 'management was always part of the design', the implementation also demonstrated a number of areas for improvement. This is particularly the case for 'longer term' durability aspects of the ISC construction.

9 REFERENCES

1. Aqua Barrier 2011, Aqua Barrier, Hydrological Solutions Inc, Waller, TX, USA, viewed 31 July 2011, <http://www.aquabarrier.com/>.

2. Australian Environmental Dredging 2011, Giles Group, Mackay, QLD, viewed 31 July 2011, <http://www.gilesgroup.com.au/dredging.html>.

3. Conbar 2011, Conbar UK Ltd, Torquay, Devon, United Kingdom, viewed 31 July 2011, http://www.conbar.co.uk/.

4. NSW Department of Planning. (February 2007). "Modification Assessment - Remediation of the Former Lednez Site, Rhodes and Parts of the Bed of Homebush Bay, Environmental Assessment Report. Section 96(2) of the Environmental Planning and Assessment Act 1979".

5. Seaway Containment Technology 2000, Seaway Environmental Technologies, viewed 31 July 2011, Long Beach, New York USA, http://www.seawaytech.com/prod_contain.htm.

6. Smith, J. and Betts, A. (August 2006). "GHD Report for Homebush Bay Remediation Containment System"

7. Batchelder, AR. (August 2006). "GHD Report, Overwater Geotechnical Investigation for Temporary Sea Wall, Former Allied Feeds Site, Homebush Bay".

8. Smith, J. and Betts, A. (May 2006). "GHD Report for Homebush Bay Remediation Containment System"

9. Batchelder, AR. (November 2005). "GHD Report, Geotechnical Investigation for Sea Wall, Former Lednez Site, Homebush Bay".

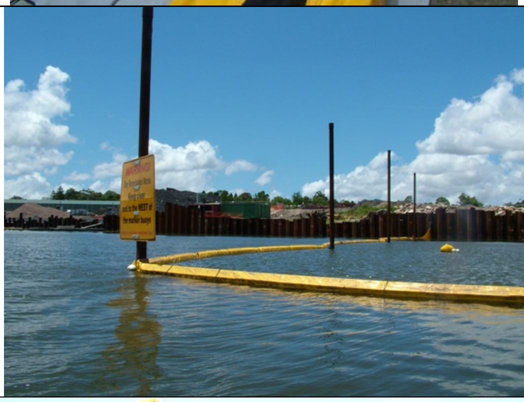
10. Batchelder, AR. (October 2005). "GHD Report, Supplementary Geotechnical Investigation for Sea Wall, Former Allied Feeds Site, Homebush Bay".

11. Batchelder, AR. (December 2004). "GHD Report, Homebush Bay Foreshore Remediation, Embankment Cofferdam Feasibility Study".

12. Batchelder, AR. (February 2004). "GHD Report, Geotechnical Investigation for Temporary and Replacement Sea Wall, Former Allied Feeds Site, Homebush Bay".

ISC CONSTRUCTION AND REMEDIATION WORKS PHOTOGRAPHS

Plate 1
Steel piles being installed at the southern portion of Stage 1

	**Plate 2** Installing floats inside the pre-manufactured WEB prior to installation in the Bay
	**Plate 3** Northern section of Stage 1 showing the WEB and one of four warning signs.
	**Plate 4** Closed Bucket Dredging in Operation
	**Plate 5** Transfer of the Excavator Dredge between Dredging Locations