Construction and Quality Management of a Bentonite-Cement Slurry Containment Wall, Perth, W.A.

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Summary The Omex site, located in the eastern suburb of Bellevue in Perth Western Australia, is undergoing remediation. The site is contaminated with heavy metals, sulphuric acid, polynuclear aromatic hydrocarbons (PAH) and hydrocarbons from the past disposal of wastes from an oil-refining plant to a series of shallow clay pits. As part of the remediation program a Bentonite-Cement Slurry Containment Wall was constructed to isolate the contamination. Given the levels of contamination and the sensitive nature of the remedial works, Quality Management systems represented an important aspect of the project. It involved detailed on-site supervision and testing and extensive laboratory testing of excavated materials and the containment wall slurry. This paper documents the practical aspects of the Quality Management System developed, gives details of the supervision and testing of the containment wall installation required to ensure compliance with design requirements as well as an outline of the procedures adopted for management of excavated material and surface water during construction.

1 INTRODUCTION

The Omex site, located in the eastern suburb of Bellevue in Perth Western Australia, is undergoing remediation. The site is contaminated with heavy metals, sulphuric acid, polynuclear aromatic hydrocarbons (PAH) and hydrocarbons from the past disposal of wastes from an oil-refining plant to a series of shallow clay pits.

As a part of the remediation program, a Bentonite-Cement Slurry Containment Wall was constructed over the period 2 September to 2 December 1998, for the Department of Environmental Protection (DEP). The project involved the potential risk of human exposure to hazardous material and further contamination of the environment.

2 SITE DESCRIPTION

2.1 Location

The Omex site is located 17 km east of the Perth Central Business District, in the suburb of Bellevue. The surrounding area is comprised of a mix of light industrial and residential land uses.

2.2 Hydrogeological Setting

The site is located close to the Darling Fault, on the Swan Coastal Plain with a surface elevation of approximately 19 m AHD. The Quaternary superficial formation consists of Guildford Clay, which is underlain at an approximate depth of 16 m by the Cretaceous Leederville Formation.

Guildford Clay contains layers of sandy clay, clayey sand and minor sand beds with local groundwater flow systems as well as individual confined aquifers formed in discontinuous sand beds. At the site the formation is about 16 m thick with approximately 13 m saturated thickness (1). The regional groundwater flow is to the south west towards the Helena River.

The Leederville Formation contains layers of sands and clays and forms part of the Leederville aquifer, a major confined aquifer which flows regionally to the west. Its potentiometric head at the site is approximately 15 m AHD (1).

2.3 Contamination History

During the 1940's the site was mined for clay leaving a series of shallow clay pits as shown on Figure 1. Between approximately 1957 to 1975, the site was utilised for a waste oil recycling operation. The process involved the refining of used lubricating oils by mixing with concentrated sulphuric acid to remove non-oil material and unstable oil. The waste sludge consisted of bitumen residue, spent Fullers Earth, acid and traces of heavy metals and was deposited into the clay pits.

Subsequently the major pit was progressively backfilled with building rubble, sand, clay, plaster wastes, car bodies and drums from 1976 onwards. In 1989 the major pit and minor pits 1 and 3 were infilled and covered with yellow sand and then in 1996 a 1 mm thick HDPE (high density polyethylene) cover was placed over the major pit. Between 100 and 500 mm of clean sand was placed over the pit prior to covering to ensure runoff directed to the perimeter drain and sump.

The contaminated wastes are known to be located within at least two of the clay pits. The major pit is about 7 m deep and contains approximately 12 400 m^3 of waste. The second (minor pit 1) is about 2 m deep containing approximately 240 m^3 of waste (1). Typical concentrations of the main contaminants in the clay pits and the current DEP landfill classifications are set out in Table 1. Generally the solid wastes fall into Class III and occasionally Class IV of the

DEP Waste Classification Guidelines (2). Groundwater samples taken in the vicinity of the clay pit were generally found to be of low pH with elevated levels of sulphate and sulphur.

The line of the slurry wall lies approximately 4 m outside the edge of the major pit, therefore the level of contamination expected during the installation of the containment wall was thought to be fairly limited. Prior investigation along the line of the wall suggested that the soil to be excavated during the installation was generally suitable for disposal at a Class II landfill site (3).

The waste within the major pit is partly submerged beneath the watertable. Groundwater contamination has been found below the pit and laterally at least 13 m from the edge of the pit (1).

2.4 Remediation Process

The remediation process developed for the site involves two stages.

STAGE 1: Isolation of the contaminants within the major pit to prevent further lateral migration to the surrounding aquifers, achieved through the construction of a bentonite cement slurry containment wall. The containment wall also acts to prevent the inflow of groundwater into the pit, facilitating Stage 2 works.

STAGE 2: Removal of all wastes, solid and liquid, to a suitable waste disposal facility.

3 BENTONITE-CEMENT SLURRY CONTAINMENT WALL

3.1 Design

To prevent further lateral migration of contaminated groundwater, an impermeable boundary both around and beneath the clay pit was required. The black clay of the Leederville Formation identified at approximately 27 m depth has low permeability, thus forming a relatively impermeable base. To contain the contaminants, the surrounding bentonite cement slurry containment wall had to:

i. be continuous, uniform and of low permeability;
ii. have its base intersect the black clay layer by at least 1 m;
iii. have sufficient strength to support loading imposed by its construction and subsequent remediation works; and
iv. be chemically resistant to low pH and high sulphate groundwater conditions.

The required characteristics of the containment wall imposed by these conditions are described in Table 2. The layout of the containment wall around the waste pit is depicted on Figure 1 while Figure 2 shows a typical cross section through the containment wall and major pit.

	SAMPLE		WA DEP LANDFILL WASTE CLASS		
Contaminant	**CMA**	**CMB**	**Class II**	**Class III**	**Class IV**
Phenol	<0.2	1.6	1	10	100
PAH's	18	45.8	20	200	2 000
Total Petroleum Hydrocarbons (TPH) C6-C9	14	79	100	1 000	10 000
Total Petroleum Hydrocarbons (TPH) >C9	1 100	9 400	1 000	10 000	100 000
Benzene (TCLP)	- 0.004	- 0.025	- 0.01	- 0.1	- 1.0
Benzo-a-pyrene (TCLP)	- <0.000 1	- <0.000 1	- 0.000 1	- 0.001	- 0.01
pH	3.1	1.6	-	-	-
As (TCLP)	1 0.02	1 <0.01	30 0.07	300 0.7	3 000 7.0
Cd (TCLP)	<0.01 <0.002	<0.01 <0.002	5.0 0.02	50 0.2	500 2.0
Cr (TCLP)	36 1.4	13 0.77	250 0.5	2 500 5	25 000 50
Cu (TCLP)	7 0.04	22 0.15	100 20	1 000 200	10 000 2 000
Hg (TCLP)	<0.02 <0.000 2	<0.02 <0.000 2	2.0 0.01	20 0.1	200 1.0
Ni (TCLP)	4 0.13	2 0.06	100 0.2	1 000 2.0	10 000 20
Pb (TCLP)	190 0.6	1 200 2.8	300 0.1	1 000 1.0	30 000 10
Zn (TCLP)	420 17	170 9.4	300 0.1	1 000 1.0	30 000 10

Table 1: Typical contaminant concentrations within main pit (mg/kg) (3), the location of samples CMA and CMB are shown on Figure 1. TCLP is the Toxicity Characteristic Leaching Procedure test.

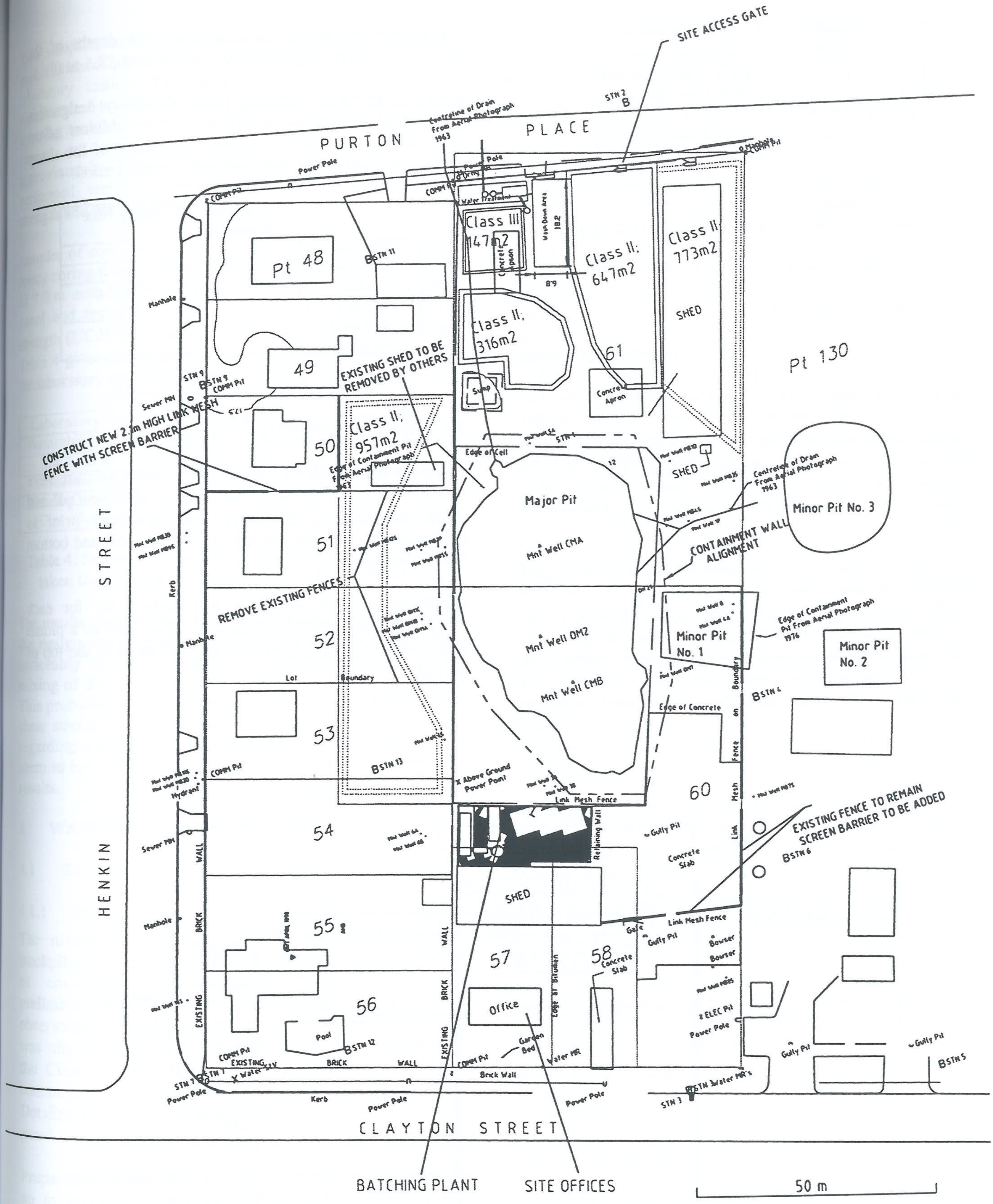

Figure 1: Omex site plan (4).

Property	Compliance
Permeability	Max of 1×10^{-8} m/s at 60 days under 150 kPa water pressure
Erosion Resistance	Pinhole test classification of ND1.
Unconfined Compressive Strength	Min of 150 kPa at 90 days.
Undrained Shear Strength	Min of 25 kPa at 14 days.
Modulus of Elasticity	Min of 20 MPa at 28 days.

Table 2: Containment wall characteristics.

3.2 Installation Process

The containment wall was constructed by the excavation and placement of 88 slurry wall panels created by a mechanical clamshell grab suspended from a track-mounted crane. The dimensions of the clamshell grab were 2800 mm length, 600 mm width and 6000 mm height. As the natural ground material was excavated, slurry was pumped into the excavation to maintain stability of the excavation sides. When set, this slurry formed the fabric of the containment wall.

The panel installation process involved the excavation and placement of three consecutive 'primary' panels (2800 mm length) within a prefabricated steel guide assembly. Two 'secondary' panels (2000 mm length) between the primaries were then completed to intersect the adjacent panels. The 400 mm overlap between panels ensured the integrity of the wall structure. This process was repeated to complete the construction of the containment wall. The depths of the slurry wall panels ranged between 24.5 m and 28.5 m (5).

Mixed in an on-site batching plant, the slurry design mix proportions are shown in Table 3. The addition of an additive (Thermathin) to improve workability of the slurry mix was carried out during most of the works period.

	Hydrated Bentonite	Slurry Mix
Bentonite	50 kg	-
Water	1000 L	-
Marine Cement	-	200 kg
Hydrated Bentonite	-	940 L

Table 3: Design mix proportions (5).

3.3 Quality Management

To ensure that the characteristics of the slurry mixture were consistent it was tested daily for density, viscosity, pH and bleed. Sampling of the slurry was conducted prior to placement and after placement from the top third and bottom third of the trench.

Monitoring of wall verticality was carried out for each panel. This was achieved by using the clam shell as a plumb with measurement referenced to the steel guide at the top of the panel.

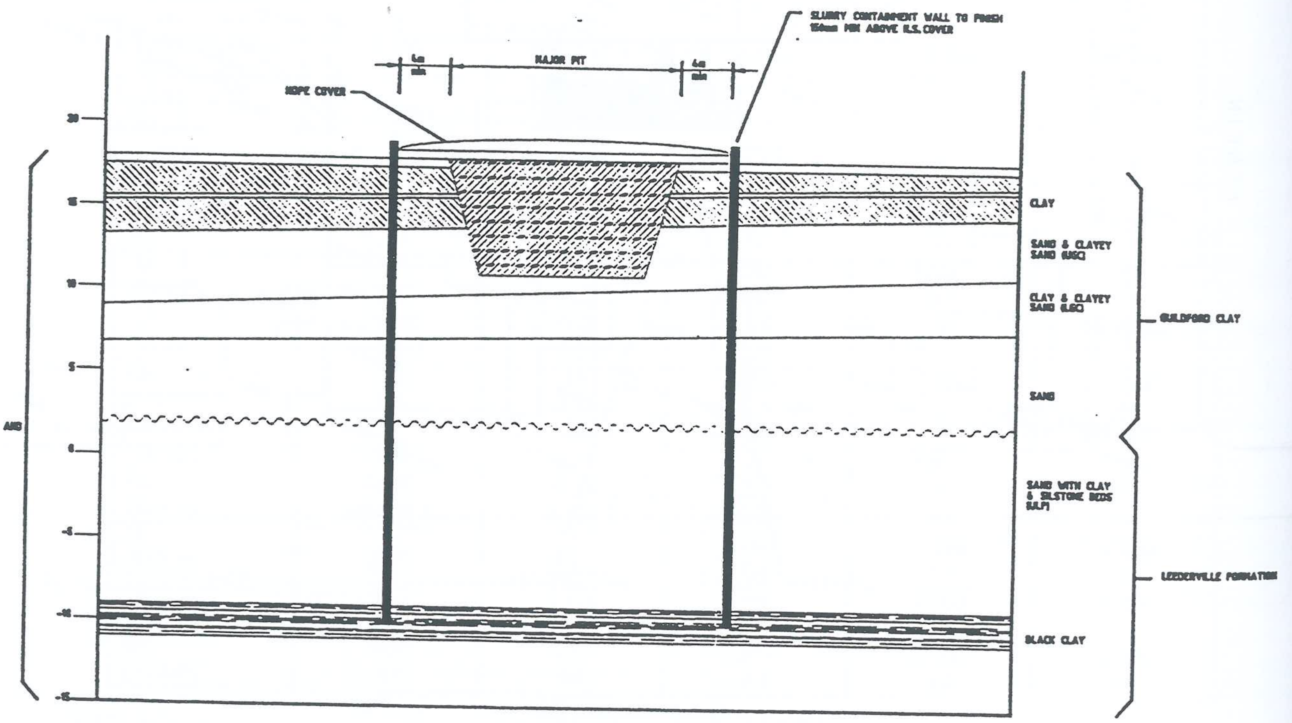

Figure 2: Typical cross section of containment wall (4).

Two samples, taken from the top third and bottom third of each finished panel, were recovered for the purpose of laboratory testing. The samples were obtained using a wireline steel tube and ball sampling device and then stored in a curing tank on site prior to testing. Laboratory tests were carried out on selected slurry samples at periods of approximately 28 days, 60 days and 90 days. The tests performed were for permeability, UCS, modulus, shear strength and pinhole dispersion.

Samples of completed sections of the wall were obtained by rotary coring through the structure at four locations. At depths of 7.0 m and 15.0 m, cores of 1.5 m were taken from each panel and tested for permeability, unconfined compressive strength (UCS), modulus of elasticity and pinhole dispersion. Table 4 gives the range and average values of the results of the laboratory tests conducted on the rotary cores.

Laboratory Test	Range	Average
Permeability (m/s)	$2.7\times10^{-10} - 1.2\times10^{-8}$	5.3×10^{-9}
UCS (kPa)	503 – 1528	938
Modulus (Mpa)	54 – 299	196
Pinhole Dispersion (Classification)	-	ND1

Table 4: Summary of laboratory test results of rotary cores taken from completed wall sections at 60 and 90 days.

The results of the tests were generally found to greatly exceed the design requirements. Slurry density after placement was noticeably higher than prior to placement because of the mixing of the slurry and the natural sandy soil in the trench. This probably attributed to the increase of UCS, modulus and shear strength well above the design specification. Concerns regarding a possible corresponding reduction in permeability seem to have been discounted by the laboratory permeability results.

4 WASTE QUALITY MANAGEMENT

4.1 Excavated Material

4.1.1 On-site

The natural soil excavated for the wall installation was stockpiled on-site according to its preliminary classification as contaminated or non-contaminated material. The preliminary classification was made using visual and odour observations. Visibly contaminated material, which typically was oily in texture, was stockpiled in an area designated as the Class III area. Material with very low or no visible contaminants was stockpiled in the designated Class II areas. Detailed logs of the excavated material were made for each panel.

Preparation of the Class II areas involved the placement of up to 300 mm of limestone fill to enable trafficking and prevent potential mixing of contaminated material with the clayey surface soils. Drainage of these areas was directed to the existing sump receiving stormwater from the HDPE liner. Volumes of the Class II stockpiles ranged between approximately 800 to 1 500 m^3. The total amount of excavated Class II material was approximately 7 000 m^3.

The Class III area formed part of a purpose built concrete washdown and sump area and was 10 m × 10 m in plan with 1 m high walls. The Class III area was covered by tarpaulins and drainage of the area was via four oil and silt interceptor tanks to the sewer. The volumes of the Class III stockpiles ranged between approximately 100 to 150 m^3. The total amount of Class III material excavated was approximately 500 m^3. The location of the Class II and 3 stockpile areas is shown on the site plan, Figure 1.

Once a stockpile area was filled to its maximum capacity the excavated material was then placed in one of the alternate stockpile areas. The completed stockpile was then tested, classified and disposed of at the appropriate land fill facility. After the removal of the excavated material the area was reused for stockpiling.

4.1.2 Disposal

For each completed stockpile one soil sample for every 100 m^3 of stockpiled waste, with a minimum of six samples, were taken for laboratory testing. The samples were tested for TPH, PAH, As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, pH, Phenol and Sulphate. In addition, TCLP tests were carried out (1 per 500 m^3) for heavy metals, Benzene and Benzo-a-Pyrene.

Based on the results of the laboratory tests, the stockpiled waste was classified according to the DEP Waste Classification Criteria (2). Class II material was sent to the Flynn Drive waste disposal facility at Wanneroo and Class III material was sent to the waste disposal facility at Red Hill. Detailed chain of custody records prepared for each stockpile included the results of laboratory tests, estimated volume and weight, and gate dockets for trucks entering landfill sites.

The removal trucks were covered and washed down in a special washdown facility before leaving the site to ensure no additional contamination of the environment. The location of the washdown facility is shown on Figure 1.

4.2 Surface Water

4.2.1 Site Drainage

HDPE liner runoff, Class II stockpile runoff, Class II stockpile seepage and general site runoff was directed to a pre-existing sump as shown on Figure 1. Overflow from this sump was directed to the local stormwater drain. The sump was monitored regularly for any changes in the sump water chemistry as part of the Quality Management Process. Contingency plans for dealing with contamination involved pumping sump water to the Class III treatment area, however this was not required.

Potentially contaminated surface runoff from the washdown facility, Class III stockpile runoff and Class III stockpile seepage passed through an interceptor system before being discharged to the sewer. The interceptor system comprised of a concrete lined silt trap and four covered concrete ring sumps. Discharge from the sumps was controlled by valve operation as required by the Water Corporation. This system separated suspended solids and oil components prior to discharge to sewer. Details of the design of the Water Treatment Facility, Washdown Facility and the Class III stockpile can be seen on Figure 3.

4.2.2 Monitoring

Daily monitoring of the pH of water discharged to sewer was required to ensure compliance with the water quality standards set by the Water Corporation. The acceptable pH of the water was between 6 and 10.5. On a small number of occasions, the pH was above 10.5 and was consequently dosed with Hydrochloric Acid (38% industrial grade) to lower the pH. Initially it was anticipated that lime dosing would be required due to the low in-situ pH. However, the mixing of alkaline slurry appeared to have effectively altered the pH environment from acidic to alkaline.

The pH of the Class II sump was also monitored daily to ensure the water chemistry was not changing dramatically. The measured pH was within the range of 7.7 to 9.0.

Samples from the last interceptor to the sewer and from the Class II sump were periodically taken and tested for TPH, PAH, As, Cd, Cr, Cu, Pb, Hg, Ni, Zn, pH, Phenol, Sulphate, Conductivity and BTEX (benzene, toluene, ethyl benzene and xylene). The Water Corporation also carried out periodic testing to ensure compliance of the water quality for discharge to sewer.

5 SAFETY PROCEDURES

The potential exposure of site personnel to hazardous materials created a need for well defined safety procedures. All site personnel attended a site induction outlining safety procedures and hazards associated with the site. Protective equipment required to be worn by people on site included protective gloves, protective goggles, protective footwear, overalls/long trousers and head protection. A gas monitor was worn daily by the site engineer in case of the disturbance of noxious gas pockets (SO_2, H_2S) during panel excavation. Appropriate respiratory equipment (gas masks) were also kept on site for this reason.

Areas containing contaminated material were defined as contaminated zones. Only authorised personnel were allowed to work in these zones wearing their protective equipment, no food or drink was allowed to be consumed within the zone. Dust generation was controlled using tarpaulins and sprinkler systems.

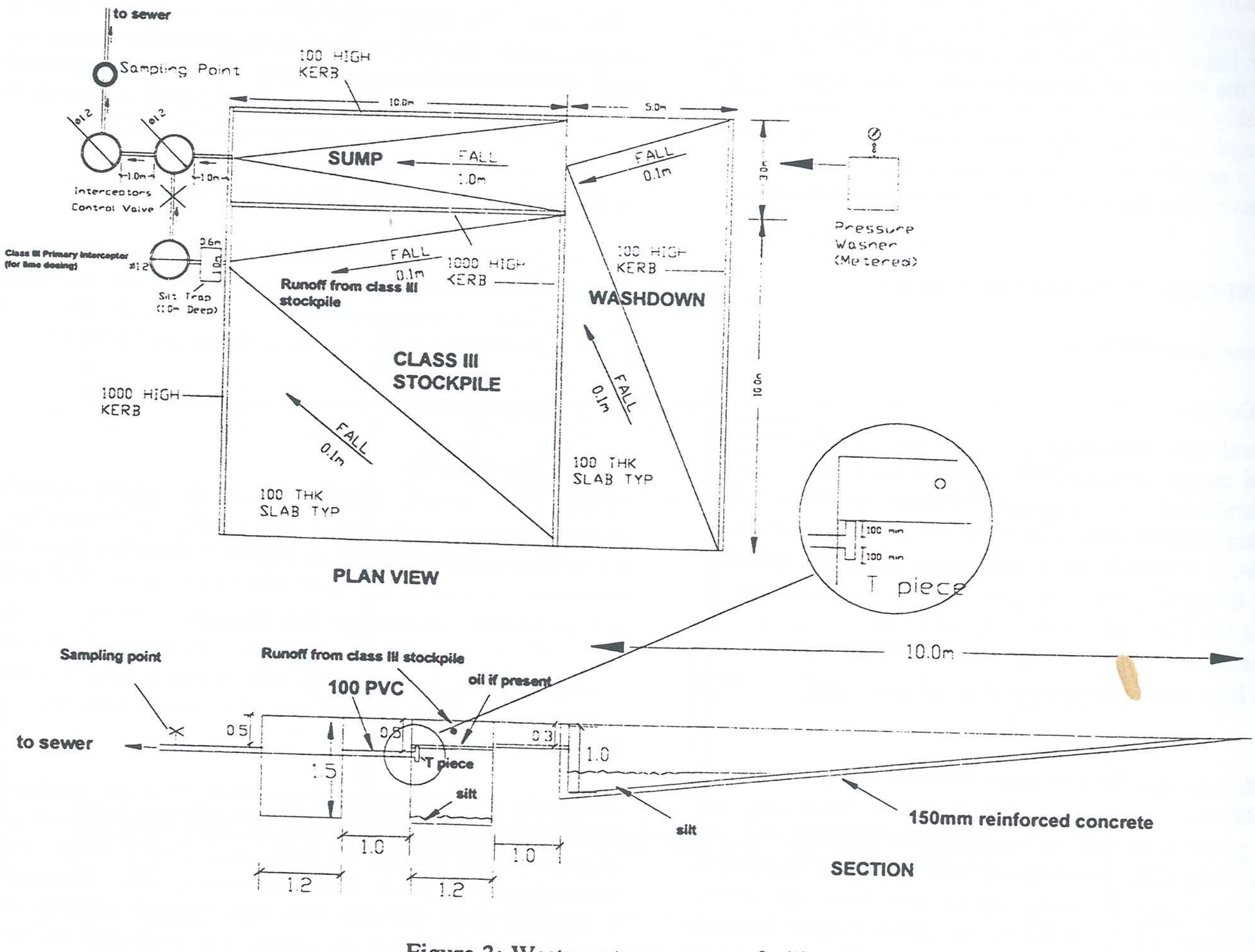

Figure 3: Waste water treatment facility (4).

6 CONCLUSIONS

6.1 Slurry Wall

Extensive testing of the containment wall to ensure compliance with the design criteria was conducted. The results of all tests complied with the requirements thus the containment wall should perform its desired role effectively.

6.2 Waste Management

The management of waste material on site was dealt with efficiently. The preliminary classification of excavated waste using visual and odour observations worked adequately. There was one instance where material with the preliminary classification of Class II contained Class III material. One sample taken from the stockpile contained elevated levels of copper. The material within the area containing this sample and extending to the surrounding sites of samples with Class II copper levels was transported separately to the landfill. Upon arrival it was lime dosed and mixed with inert material to reduce copper levels before disposal.

7 ACKNOWLEDGEMENT

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8 REFERENCES

1. Golder Associates, “Extent of Contamination and Options for Remediation: Omex Petroleum Site (Clayton Street, Bellevue)”, February 1997.
2. Department of Environmental Protection, “Landfill Waste Classification and Waste Definitions”, 1996.
3. CMPS&F, “Omex Remediation Project Containment Strategy Specification”, May 1998.
4. Bachy Pty Ltd, “Omex Site Bellevue, Design Report”, August 1998.
5. MPA Williams & Associates, “Omex Site Bellevue, Construction report”, February 1999.