FINAL WORKPLAN

Ecological Monitoring Plan for the Groundwater Treatment Plant and its Operations

Prepared for

Orica Australia Pty Ltd

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* Figure 2 is located in Section 3.1

1.1 Background

URS Australia Pty Ltd (URS) has been commissioned by Orica Australia Pty Ltd (Orica) to prepare a workplan and to monitor the ecological health of the receiving environments which may be affected by operation of the groundwater treatment plant (GTP) . This is required by the conditions of approval for the Botany Groundwater Cleanup (BGC) Project (outlined below in Section 1.4). This Workplan was developed following meetings with Orica on 8 April and 3 May 2005 and in accordance with the proposal dated 28 April 2005. The Ecology Lab and Avifauna Research & Services have contributed to the preparation of this plan.

An Environmental Impact Statement (EIS) was exhibited for the BGC Project in November and December 2005. A Joint Determining Authority Report for the project was issued by the Department of Environment and Conservation (DEC) and a number of the other determining authorities for the project in February 2005. The conditions of approval, relevant to ecological monitoring, are outlined in Section 1.4.

1.2 Hydraulic Containment and the Groundwater Treatment Plant

Groundwater contaminated with a number of volatile chlorinated hydrocarbons (CHC's) is currently migrating toward Botany Bay. To prevent the contaminant plumes from reaching the bay, the NSW DEC issued a Notice of Clean Up Action (NCUA) in 2003. This notice set a framework and timeframe for Orica to contain the contaminant plumes. Orica has elected to use hydraulic containment as contaminant containment in several locations, including Foreshore Road. The most downgradient of the containment lines is on Foreshore Road, north of Penrhyn Estuary and the Bay (See Figure 1).

In common with most estuaries, groundwater currently discharges to Penrhyn Estuary and is controlled by tidal pumping. Monitoring of groundwater over numerous events has indicated that freshwater is not discharged into Penrhyn Estuary (see Section 3.1). The amount of saline groundwater discharged to the estuary will be reduced by the hydraulic containment, however, this is not considered likely to impact upon the ecological receptors in the estuary.

This document presents the workplan for the required monitoring program. Interim hydraulic containment is already in place with extraction of approximately 1 to 2 ML/day. Full hydraulic containment via the operation of the GTP is expected to commence by 31 October 2005 where extraction will be up to 15 ML/day. Achieving steady state water levels is dependent on the pumping regime, however, this will change over the life of the program to optimise the extraction of groundwater. Although the timing of changes in groundwater quality in the receiving environments due to the operation of the GTP cannot be accurately predicted, it is considered that potential changes to the receiving ecosystems should be evident within the first two years of monitoring. The potential changes in water quality would be monitored by a physico-chemical monitoring program.

1.3 Objectives

The broad objective of the ecological monitoring program is to assess the potential for adverse impacts to the receiving environments following interception of groundwater and during operation of the GTP and full hydraulic containment. Specifically, this program will:

- review current physico-chemical conditions and the potential for changes in physico-chemical conditions in and near the estuary;
- review the conclusions of the EIS and review the likelihood of changes to physico-chemical parameters and ecological receptors;
- monitor the physico-chemical conditions in Penrhyn Estuary both before and during operation of the GTP and full scale hydraulic containment;
- Monitor the key ecological receptors in Penrhyn Estuary both before and during operation of the GTP and full scale hydraulic containment; and
- Review the requirements for future monitoring following commencement of full scale hydraulic containment.

This monitoring plan covers the monitoring for the period July 2005 to July 2007 which extends from interim containment (current) to full scale hydraulic containment and the operation of the GTP.

1.4 Conditions of Approval

A number of approvals are required for the BGC Project. Two of these approvals stipulate specific ecological monitoring requirements. These are:

1. The special conditions in the revised Environment Protection Licence (EPL2148) – issued by DEC under the *Protection of the Environment Operations Act, 1997*; and
2. The Permit issued by the NSW Department of Primary Industries (specifically NSW Fisheries) under Part 7 of the Fisheries Management Act, 1994.

The ecological monitoring requirements of each of these approvals are summarised below.

1.4.1 Environment Protection Licence 2148 - Special Condition E9.2.4

The Environment Protection Licence (EPL2148) – issued by DEC under the *Protection of the Environment Operations Act, 1997*, requires monitoring of the discharge of treated waters to ensure compliance with the licence conditions and also requires assessment of the potential impacts to the receiving environment. The licence conditions and requirements of the assessment of the treated discharge water are reviewed in Section 2.1. The licence conditions regarding assessment of the potential impacts to receiving ecosystems are summarised below.

"The licensee must conduct an ambient environmental monitoring program which must include but not be limited to the following:

a) develop and implement a program to monitor ecological health of habitats in the locality and water quality in the receiving environment, including specification of sampling locations, sampling frequencies and parameters to be tested;

b) include quality control elements;

c) include monitoring sites at Penrhyn Estuary, Botany Bay and Bunnerong Canal as well as other relevant off-site locations;

d) assess whether the project will result in any actual or potential impacts to surface waters or habitats / in the locality from the operation of the groundwater treatment plant and associated plant and equipment;

e) review the conclusions of the ecological and ambient water quality assessments that were undertaken as part of the EIS, including using monitoring data collected under this licence or other approvals for this project;

f) include a mechanism to regularly review the effectiveness of the monitoring program to ensure it is effective in detecting the presence of actual or potential impacts not already identified; and

g) make recommendations about changes to existing monitoring, including substances monitored and frequency of monitoring.

The program must be prepared in consultation with the DEC, DIPNR, DPI, Sydney Ports Corporation, Sydney Water Corporation, NSW Maritime and City of Botany Bay Council."

1.4.2 NSW Fisheries Permit Number 05-030

The two conditions of the permit relevant to the health of the receiving ecosystems are

- Condition 4 of this Permit states "A program to monitor the continuing health of the marine vegetation in Penrhyn Estuary is to be developed in conjunction with the Department of Primary Industries. *Reason – The Department has concerns about the potential impact of the groundwater interference on the marine vegetation and the only method of detecting such an impact is to develop a comprehensive monitoring program*".

- Condition 5 of this Permit states "The Department of Primary Industries is to be notified immediately of any detected harm to marine vegetation. In such case mitigation measures or remediation must take place immediately. *Reason – The Department of Primary Industries needs to be aware of monitoring results as they are potentially contentious incidents from the public perspective. Work practices may need to be modified to reduce the impacts upon the aquatic environment".*

1.5 Proposed Sydney Ports Development

It should be noted that there is currently a Development Application submitted for the proposed redevelopment of Penrhyn Estuary as part of the port expansion. The Port Botany Expansion EIS (URS, 2004d) outlines the potential changes that would occur in Penrhyn Estuary if the development is approved and proceeds. The development includes:

- development of the wharf facilities resulting in a doubling of container handling capacity;
- removal of the dune vegetation and creation of intertidal sand and mud flats as part of habitat enhancement for wading shorebirds;
- removal of the mangroves to increase the area of saltmarsh habitat; and
- changes to the tidal prism[1] and hydrological conditions in Penrhyn Estuary.

The changes to the morphology of Penrhyn Estuary would be substantial with removal of existing vegetation and re-shaping of intertidal areas. After a period of recovery, the habitat would be recolonised by vegetation and benthic fauna and frequented by wading shorebirds. However, this development would have a considerable effect on the ability to monitor the potential impacts arising as a result of the operation of the GTP and DPI permit 05-030 conditions relating to the monitoring of impacts would require review.

[1] The tidal prism is the volume of water that is drawn into an embayment from the ocean through the inlet during a flooding tide.

The two identified sources of potential impact to the receiving ecosystems include:

1. discharge of treated waters; and
2. extraction of groundwater.

The areas requiring monitoring to assess potential impacts are discussed in the following sections.

2.1 Treated Water Discharge

Discharge of excess treated water from the GTP is licensed under Orica's Environment Protection Licence 2148 (EPL2148). The quality and quantity limits outlined in that licence were under review at the time of writing in response to a project modification which changed the discharge location and composition from that presented in the EIS.

The Project described in the EIS included discharge of excess treated water (mixed with slightly saline water from the reverse osmosis (RO) unit) to the estuarine eastern arm of Bunnerong Canal (adjacent to where it crosses beneath Bumborah Point Road) which flows into Brotherson Dock. Since exhibition of the EIS, Orica has modified the proposal for excess treated water disposal.

Excess treated water from the GTP is now to be discharged into a Sydney Water stormwater channel which flows into Brotherson Dock. The discharge point is to be located within a culvert under Perry Street, Matraville. From there the stormwater channel leads into Long Dam and then through the northern arm of Bunnerong Canal to Brotherson Dock. This change is possible because the discharge water will now be freshwater. Orica has improved the project by adding an additional RO unit to the GTP which will result in a smaller salty stream, that can be discharged to sewer, and produce a greater quantity of freshwater that is suitable for reuse.

A Review of Environmental Factors (REF) prepared by Orica in June 2005 outlines the modified discharge scenario and provides an assessment of the potential impact of that discharge on the receiving environment. Table 1 presents the proposed amendments (as outlined in the REF) to the quality limits currently included in EPL2148 (n.b. the licence stipulates a much wider number of parameters but only those that are proposed to be changed are shown in Table 1). Default trigger values for south-east Australia for slightly disturbed ecosystems (ANZECC 2000) are also shown.

Table 1 Proposed Amendments to Excess Treated Water Discharge Quality Limits

Source	pH	Total NH3 (mg/L)	Oxidised N (mg/L)	Total N (mg/L)
ANZECC freshwater lakes and reservoirs*	6.5-8.0	0.010 (0.9)**	0.01 (0.7)**	0.35
EPL2148 limits	7-8.5	0.015^	0.015^	0.1^
Orica's proposed revised EPL 2148 limits	**6.5-8.5**	**0.5**	**0.1**	**1**

* *Default trigger values for south-east Australia for slightly disturbed ecosystems (ANZECC 2000).*

*** Based on toxicity at a pH of 8*
^ subject to review and change

The REF concludes that discharge of excess treated water which meets the limits stipulated in EPL2148 (and as amended to the extent shown in Table 1) will not have a detrimental effect on the receiving waters. Under EPL 2148 Orica is required to monitor both the quantity and quality of treated water discharged from the GTP. Compliance with these monitoring requirements will provide adequate data to ensure that there is no ecological impact as a result of the discharged water. As such, direct ecological monitoring is not proposed for the receiving waters of Long Dam, Bunnerong Canal or Brotherson Dock. This would be reconsidered in the event that there was any significant and sustained change to, or breach of, licence conditions for the excess treated water discharge. Details of the quantity and quality monitoring of discharge waters, as required by EPL2148, are provided below.

Quantity

Volume is to be continuously monitored during discharge. EPL2148 currently stipulates a daily limit of 1200 kL or 12 ML. This volume was proposed in the EIS as it is the capacity of the pipeline that was proposed to be used at that stage. With the decision to install a new treated water discharge line to the stormwater channel Orica has been able to design for discharge of the maximum potential flow from the GTP.

The GTP has been designed to treat up to 15 ML/d of groundwater. If 15 ML/d of water is treated, 13.5 ML/d of high quality treated water will be available for reuse (with 1.5 ML/d of concentrated waste water sent to sewer). An average of 6.24 ML/d of treated water can be utilised by existing industrial processes on the BIP (with a potential peak demand of 7.5 ML/d). Orica and the NSW government are investigating reuse opportunities for the remainder of the treated water (i.e. on average up to 7.26 ML/d) but it is essential to have a discharge option available for any unused water. Average volumes of excess treated water discharged at the commencement of operation (October 2005) are expected to be approximately 6.5 ML/d. Maximum discharges to the stormwater channel, during periods of zero consumption by BIP users (eg. during infrequent site-wide maintenance activities) would be 13.5 ML/d. As such, Orica will seek an amendment to EPL2148 to increase this volume to 13.5 ML/d. The volume of excess treated water to be discharged will vary over time depending on the volume of extraction necessary to maintain hydraulic containment and the amount of reuse available.

Quality

EPL2148 requires Orica to monitor the quality of discharge waters on a weekly basis (with the exception of conductivity and temperature which are to be monitored continuously).

As described above, the quality limits for the excess treated water discharge stipulated in EPL 2148 were based on the original discharge to the Bunnerong Stormwater channel. EPL2148 notes that a number of the set concentration limits for this discharge may be subject to review and change as details of the project are refined. The revised quality limits proposed by Orica (as listed in Table 1 above) are discussed

below (full details, including results of water quality sampling conducted in Long Dam, are provided in the Orica REF issued in June 2005).

pH

Orica has sought an amendment to the EPL2148 pH limit range (of 7-8.5) to 6.5-8.5. This is achievable within the specification of the GTP and is not expected to result in an unacceptable impact on the receiving waters as pH in the receiving waters has recently been recorded as low as 6.5.

Total Ammonia

The current EPL2148 limit for total ammonia as N is 0.015 mg/L (based on the original saline discharge point location). Orica has proposed to DEC that this limit be amended to 0.5 mg/L. The ANZECC trigger limit for total ammonia as N is 0.010 mg/L to prevent eutrophication and 0.9 mg/L (at a pH of 8) based on toxicity. Samples taken in Long Dam reveal concentrations of total ammonia as N ranging between <0.03 and 0.11 mg/L (with pH between 6.5 and 7.1). There are two things to consider when establishing acceptable ammonia limits as N for the discharge:

1. Toxicity

Total ammonia is composed of non-ionised NH3 and ionised $NH4^+$. The form of ammonia that is primarily toxic to aquatic organisms is NH3. The ionised $NH4^+$ is a bioavailable form of total N, along with nitrate and nitrite. The percentage of total ammonia present as NH3 increases with both pH and temperature. It is much more dependent on pH than temperature. At pH 7.4 the trigger value for total NH3 as N is 1.75 mg/L, at pH 8 it is 0.9 and pH 8.5 it is 0.4. The predicted GTP treated water discharge has a pH of 7.4 (with a range of 6.5-8.5). At a pH of 7.4 the proposed Orica limit of 0.5 mg/L would be within the guidelines for toxic non-ionised NH3. Even if the discharge water reaches the upper pH limit of 8.5 the proposed NH3 limit as N of 0.5 mg/L is only slightly higher than the toxic trigger value and would not be detrimental in this highly disturbed environment. Further, mixing with other water in the channel would lower the concentration of ammonia.

2. Eutrophication

The ANZECC guideline of 0.01 mg/L is based on eutrophication concerns. Elevated levels of phosphorus and nitrogen can cause eutrophication. Nitrogen alone, however, will not cause eutrophication. If sufficient phosphorus is not present, eutrophication is unlikely. The existing EPL2148 limit for total phosphorus is 0.1 mg/L. The GTP treated water discharge is expected to meet this limit for phosphorus, which is the key nutrient for eutrophication in freshwater systems. No change to this limit is proposed by Orica. Given the low levels of phosphorus it is not expected that eutrophication is a concern in this case. Orica proposes a discharge limit of 0.5 mg/L for ammonia. This will not be a toxic hazard and will not pose an unacceptable risk of eutrophication, given the low levels of phosphorus that will be present in the discharge water.

Oxidised Nitrogen

Nitrogen in the environment moves dynamically between the different species. As such, it is the total nitrogen (as discussed below) that is more important than the individual species (eg, oxidised nitrogen). The limit proposed by Orica for oxidised nitrogen is 0.1 mg/L. This is well below the existing levels in the receiving waters.

Total Nitrogen

Orica has proposed that the original EPL2148 limit for Total N, 0.1 mg/L, be revised to 1 mg/L. This is significantly lower than ambient water quality in Long Dam (1 mg/L compared with 2-6 mg/L). The discharge would not, therefore, contribute further to the existing concentration of total N in the dam.

2.2 Extraction of Groundwater

The potential receiving environments that could potentially be affected by the extraction of groundwater are reviewed below:

- Springvale and Floodvale Drains;
- Lachlan Swamps / Botany Wetlands;
- Sir Joseph Banks Park; and
- Penrhyn Estuary.

2.2.1 Springvale and Floodvale Drains

It is anticipated that Springvale Drain and Floodvale Drain will virtually dry up during low flow conditions and therefore result in the cessation of discharge of fresh groundwater to the drains and, subsequently, to Penrhyn Estuary. This would achieve a positive effect by preventing the 'short circuiting' of the containment lines (URS, 2004b). The drains are considered to have little ecological value due to a lack of undisturbed habitat, infestation by introduced weed species and adjoining industrial land use. No ecological monitoring is proposed for the either of the drains, however, it is expected that surface water monitoring would continue to be conducted by Orica as part of the groundwater and surface water monitoring program.

2.2.2 Lachlan Swamps / Botany Wetlands

The groundwater extraction is predicted to reduce the groundwater recharge to the swamps by approximately 3%. The water levels in the swamps, which are currently controlled by weirs, are not expected to change and therefore, it is considered that there would not be impacts to the wetlands arising from the operation of the GTP (URS, 2004b). No further monitoring of the Lachlan Swamps is proposed.

2.2.3 Sir Joseph Banks Park

The groundwater modelling conducted for the project predicted a change of 15 cm in the water level in the ponds at Sir Joseph Banks Park. The predicted changes were considered to be within the range of the long-term seasonal fluctuation. Additionally, the ponds do not support significant flora or fauna species and no significant impacts would be expected to arise from the operation of the GTP (URS, 2004b). Therefore, no further monitoring of the park is proposed.

2.2.4 Penrhyn Estuary

The EIS concluded that there was uncertainty regarding the potential impacts to the ecological receptors present in the estuary. Ecological monitoring for the project is, therefore, focussed on Penrhyn Estuary. Further discussion is provided in the following sections.

3.1 Existing Groundwater Discharge Conditions

Groundwater discharge to an estuary is controlled by a complex interaction between the tidal regime, wave action and the saline freshwater interface (Figure 2). Tidal inundation predominantly controls the salinity and moisture of the sediment in the discharge zone. Extensive sampling of surface, ground and pore waters in Penrhyn Estuary has been conducted. The results from this indicate that freshwater is not discharged directly into the estuary and that groundwater discharge is saline (Figures 3 and 4). There is clear evidence that the chemistry downgradient of the zone of diffusion is due to seawater intrusion. There is little or no contribution from fresher groundwater and most groundwater discharges to Penrhyn Estuary and Botany Bay between the high and low tide marks (Merrick, 2004).

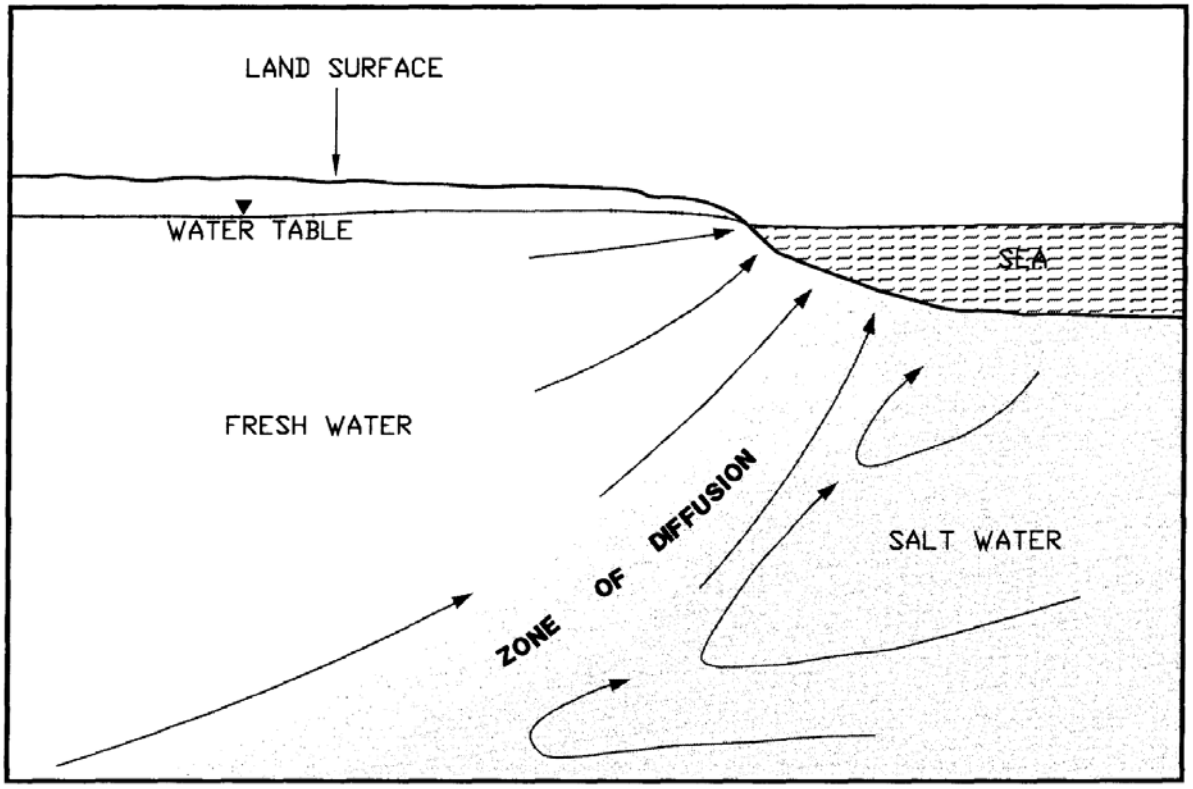

Figure 2 Conceptual Plan of Groundwater Discharge into an Estuary

Fresh surface water enters the estuary via Springvale and Floodvale Drains. However, at high tide, this discharge is reduced by the presence of saline waters which prevent the discharge of freshwater from the drains. At low tide, the brackish water discharges via two well defined, narrow rivulets, and mixes with saline waters in the central portion of the estuary.

3.2 Hydraulic Containment

Full hydraulic containment via the operation of the GTP is expected to commence by 31 October 2005. Hydraulic containment was originally predicted to remove approximately 15 ML/d from the aquifer

(Merrick, 2004). The actual volume removed may be reduced based on refinement of the hydraulic model. However, the exact volume required will be uncertain until operation of the GTP commences. Over the 30 year timeframe of the GTP, extraction volumes may vary considerably. The extraction volumes will be optimised based on performance of the hydraulic containment and plume migration.

Changes to the groundwater flow regime are expected following commencement of hydraulic containment. It is likely that the surface water discharge from the drains will cease in dry periods. Stormwater will be discharged into the estuary during rain events and wet periods.

The hydraulic gradient will decrease between Foreshore Road and Penrhyn Estuary, with little or no discharge of groundwater into the estuary or Botany Bay downgradient of the containment line (Merrick, 2004). There will still be a positive hydraulic gradient from the midpoint between Foreshore Road and the estuary (Merrick, 2004). The standing water level is expected to drop between 0.1 m and 0.5 m. There is expected to be greater intrusion of the saltwater wedge beneath the freshwater which would remain perched as a lens on top of the saltwater intrusion. This freshwater lens situated between the Foreshore Road hydraulic containment line and Penrhyn Estuary/Botany Bay is expected to be recharged by rainfall.

Changes to groundwater levels beneath the dune vegetation are expected to be minor as the standing water level of the groundwater is expected to be less than 0.5 m (Merrick, 2004). These changes would occur within the first few months of operation and would be monitored by the physico-chemical monitoring program.

3.3 Groundwater and the Saltmarsh Community

There are several saltmarsh communities present in Penrhyn Estuary. The main stands of the saltmarsh are located on the northern foreshore of the estuary (west of Floodvale Drain), on the foreshore between Floodvale and Springvale Drains and on the eastern margin of Penrhyn Estuary. These stands are regularly inundated by saline waters at high tide. These shallow rooting plants utilise rain infiltration and do not utilise the upper layer of groundwater (TEL, 2004b in URS, 2004c).

Samples collected in December 2004 (URS, 2004c) indicate that the water present beneath the salt marshes is saline, with the exception of some locations where freshwater, which was derived from rainfall, was identified. Although there may be some landward migration of the zone of diffusion as a result of hydraulic containment, this is considered unlikely to affect the saltmarsh species. Groundwater samples were collected from seven hand-installed monitoring wells in the saltmarsh beds between Floodvale and Springvale Drains. Total salinity in these varied from 26,460 mg/L to 33,180 mg/L in all samples except one well (1,806 mg/L). This indicates that the surficial groundwater in the saltmarsh is currently saline. In the well where the salinity was 1,806 mg/L, the pH was 8.06 and the dissolved oxygen content was 5.4 mg/L indicating that the source of the water is rainfall, as the deeper groundwater is typically of pH 5 and dissolved oxygen content of 0.5 mg/L.

As the groundwater in the saltmarsh is currently saline with some small localised areas of rainfall infiltration, it is considered unlikely that there would be significant changes to the saltmarsh vegetation as a result of the operation of the GTP.

3.4 Groundwater and the Dune Vegetation Community

The dune vegetation present on the sand dunes between Foreshore Road and Penrhyn Estuary is characterised by *Banksia integrifolia* and dense thickets of introduced bitou bush (*Chrysanthemoides monolifera*) and lantana. This vegetation type is considered to be rainfall dependent rather than groundwater dependent (Saenger *et al.*, 1977). The root system is unlikely to reach the groundwater level and would be dependent on rainfall infiltration in the unsaturated zone. This vegetation should remain unaffected by a change in either the groundwater availability (i.e. depth of groundwater) or groundwater salinity.

It is considered that rainfall frequency and intensity would predominantly affect the volume and quality of water available to dune vegetation. Currently, the groundwater beneath the dune system is fresh, however, the extraction of groundwater at Foreshore Road may cause the saline interface to shift towards the dunes and increased salinity of the deeper parts of the aquifer beneath the dune system. It is considered that the freshwater would remain as a distinct lens on top of the saline water and would be recharged by rainfall.

It is considered unlikely that the dune vegetation is groundwater dependent. However, if the vegetation was dependent on groundwater and there was insufficient recharge of the freshwater lens by rainfall, there may be the potential for adverse impacts to the dune vegetation as a result of increased salinity of the groundwater.

3.5 Estuary Porewater

As discussed in Section 3.1, the groundwater discharge to the estuary is controlled by a complex interaction between the tidal regime and the saline freshwater interface. There is no direct freshwater discharge into Penrhyn Estuary other than via surface waters and rainfall. The porewater in the estuary has been measured at high and low tide and is consistently measured to be saline and similar to the surface water at the estuary mouth. Data presented in the March 2004 Quarterly Report (URS, 2004a) indicates that at low tide, conductivity in the porewater (0.1 m depth) varies from 49,900 µS/cm to 54,100 µS/cm, and at high tide the conductivity varies from 52,600 µS/cm to 56,000µS/cm (Figure 4). Similarly, the conductivity of the overlying seawater varies from 51,800 µS/cm to 58,200 µS/cm. These data indicate that the range of salinity in the porewater and the overlying seawater is essentially the same. Therefore, no significant change in the salinity of the porewater would be expected following hydraulic containment.

3.6 Benthic Community

Although the EIS (TEL, 2004a in URS, 2004b) predicted that there may be adverse impacts to the benthic community as a result of the operation of the GTP, these predictions were based on a discharge of freshwater into Penrhyn Estuary and did not take into account the tidal dynamics that affect discharge of groundwater to the estuary. The hydrogeology chapter of the EIS (Chapter 12) indicated that the current discharge of groundwater to Penrhyn Estuary is saline (URS, 2004b). Following clarification that groundwater discharge would not cease during hydraulic containment, the moisture content of the

sediment would remain unchanged and the potential increase in salinity would be negligible, these predictions were revised in the Representations Report (TEL 2004b in URS, 2004c). The revised aquatic assessment based on the correct model of groundwater behaviour concluded that intertidal and subtidal benthos would not decrease in abundance. The 'high level' range of responses was revised to potential slight changes in benthic community structure with no reduction in overall abundance (TEL, 2004b in URS 2004c).

The dynamics of benthic abundance and diversity may be complex and are poorly understood in Penrhyn Estuary. There are many factors including seasonal changes and hydrodynamics that may influence benthic abundance and diversity. Subsequent impacts of changes to benthic abundance and diversity are also unclear but the key receptor dependent on the benthic community is the wading shorebirds. The benthic community is an important food source for these birds. Given the importance of the birds, the birds presence in Penrhyn Estuary will be monitored weekly and their health will be monitored monthly. If significant changes to the bird community were to occur as a result of the operation of the GTP, these would be identified by the avifauna monitoring program directly. Direct monitoring of the benthic community is therefore unwarranted and will not be conducted.

4.1 Estimated Timeline for Monitoring

Monitoring of the physico-chemical parameters and the identified key ecological receptors will be conducted over the next two years. This period will include conditions of interim hydraulic containment[2], prior to full-scale hydraulic containment and post full-scale hydraulic containment. Given the uncertainty at the current time regarding timing and pumping rates, it is not possible to predict when or even if steady state water levels will be achieved. Therefore, it is not possible to predict conditions that would represent a baseline or pre-full-scale hydraulic containment. An indicative timeline has been included in the table below:

Table 2 Generalised Timeline For Ecological Monitoring

Date	Activity – GTP Operation	Activity - Monitoring
Oct-04	Interim containment commenced	Physico-Chemical Data available for porewater in the estuary mudflats
Jul-05		Ecological Monitoring Round 1
Oct-05	GTP commissioning and full hydraulic containment	Ecological Monitoring Round 2
Apr-06	Steady state conditions predicted to be reached (estimation only)	Ecological Monitoring Round 3
Oct-06	Ecological effects (if present) should be evident by this time (estimation only)	Ecological Monitoring Round 4
Apr-07		Ecological Monitoring Round 5
Jun-07		Conclusion of Monitoring Program and Review of Results
Jul-07		Evaluation of monitoring Requirements and Recommendations for Future Monitoring

Interim hydraulic containment is already in place with extraction of approximately 1 to 2 ML/d. Full hydraulic containment via the operation of the GTP is expected to commence by 31 October 2005 where extraction will be up to 15 ML/d. Achieving steady state water levels is dependent on the pumping regime, however, this will change over the life of the program to optimise the extraction of groundwater.

[2] Interim pumping is currently being conducted, however, it is considered that the small amount being removed would not cause measurable effects in the receiving ecosystem or receptors.

Although the timing of changes in groundwater in the receiving environments as a result of the operation of the GTP cannot be accurately predicted, it is considered that potential changes to the receiving ecosystems should be evident within the first two years of monitoring.

It is proposed that monitoring would be conducted over the next two years during the commissioning and early operational period of the GTP to monitor and assess the identified ecological receptors. It is considered that the ecological effects would be evident before the conclusion of the monitoring period in June 2007. Any change in conditions and ecological receptors in the estuary will be evaluated at the conclusion of the monitoring program along with recommendations for future monitoring.

4.2 Key Parameters to be Monitored

4.2.1 Physico-Chemical Parameters

The key physico-chemical parameters include salinity (measured as electrical conductivity), dissolved oxygen, temperature, redox potential and pH. To establish the physico-chemical parameters in the estuary prior to the operation of the GTP and after commencement of the operation of the GTP, the monitoring program will:

- compile existing data (September 2003 to June 2005); and
- measure key physico-chemical parameters during the commissioning of the GTP and over the next two years in the:
    - dune system;
    - saltmarsh community; and
    - porewater in intertidal mudflats or sandflats.

4.2.2 Ecological Receptors

The key ecological receptors to be monitored in the estuary include:

- wading shorebirds;
- seagrass;
- saltmarsh;
- dune vegetation; and
- mangroves.

5.1 Selection of Monitoring Locations

Efforts will be made to select sample locations to avoid any discontinuity if the Sydney Ports Development Application is approved and proceeds. However, there will be significant changes to the morphology of the estuary if the Ports redevelopment proceeds and selection of a full range of representative sites that would be unaffected by the development may not be possible.

5.2 Physico-Chemical Parameters

URS consider that the potential for changes in the identified ecological receptors in Penrhyn Estuary arising from hydraulic containment can only be assessed in the context of the physico-chemical conditions in the estuary and surrounding habitats. To assess the potential for changes to the dune vegetation and the saltmarsh species, the physico-chemical parameters of the groundwater will be monitored in the sand dunes and in the saltmarsh stands.

It is considered that both the dune vegetation and the saltmarsh are rainfall dependent rather than groundwater dependent. Water quality will be monitored to assess conditions to determine the presence of saline water in these areas and the potential for change following commissioning of the GTP. The intertidal porewater in the estuary is saline. This is a product of the dynamics of groundwater discharge. The estuary porewater will be monitored throughout the monitoring period.

To achieve these monitoring requirements:

- two bundle piezometers depth will be installed in the dune vegetation to monitor the surficial groundwater. It is proposed that sample ports would be placed at metre intervals from the groundwater surface (i.e. if the SWL[3] is at 3 metres bgs[4], then ports will be located at 3, 4, 5 and 6 metres bgs);
- a series of ten hand-installed shallow wells (to <1 m) will be hand-installed amongst the two main saltmarsh beds on the northern estuary foreshore and between Floodvale and Springvale Drains. The locations will be similar to the sample locations presented in URS, 2004c (Attachment 3, p106);
- existing bundle piezometers on the sand flats in Penrhyn Estuary (six in total) would be monitored at the 0.1 m sample port.

Data collected from temporary bundle piezometers installed in the saltmarsh suggest the presence of a small amount of freshwater. The physico-chemical parameters of this water indicate that the source of the

[3] SWL - the standing water level of the groundwater

[4] bgs - below ground surface

water is rainfall and therefore, salinity in the saltmarsh would be unaffected by changes in the groundwater flow regime.

The installation of the monitoring points described above is considered sufficient to characterise the physico-chemical parameters in the groundwater and porewater in and near the estuary.

5.3 Wading Shorebirds

Twenty-four species of resident and migratory shorebirds and seabirds, listed under the Threatened Species Conservation Act and/or the Environment Protection and Biodiversity Conservation Act, are known to occur or have previously been recorded in Penrhyn Estuary (Avifauna Research & Services, 2004 in URS, 2004b). The importance of Botany Bay for migratory shorebirds has been significantly reduced in recent decades due to habitat loss and disturbance. Although there are extensive bird habitats in Botany Bay, these are generally located on the southern shoreline of the bay. The monitoring program would only assess impacts attributable to the GTP operation.

The commissioning of the GTP is considered unlikely to affect the bird populations, since these species frequent a range of habitats where salinity levels vary widely within a day. If there was to be a change in the diversity of the benthic community, most birds should be able to adapt to these changes as long as the density of available prey was not reduced, (Avifauna Research & Services, 2004 in URS, 2004b).

It is proposed that potential changes to the shorebird populations would be assessed by monitoring change in the numbers of shorebirds using the estuary and also a measure of the health of the birds. Changes in the numbers and species composition of shorebirds in the estuary would be assessed by counting the birds during feeding and roosting on a regular basis. The health and condition of the shorebirds can either be carried out by catching the birds and measuring their body weight, fat deposits, plumage condition etc and/or by using high resolution digital photography in the field.

Counting birds at the study site can be carried out relatively easily by a skilled observer who is able to identify all species of shorebirds and other waterbirds that are likely to occur at a site. Counts would be carried out weekly, for two years, at both low and high tide to measure the number of shorebirds feeding in the estuary as well as the numbers of roosting birds. The difference in numbers will determine whether birds are moving into or out of the site during the various stages of the tide (if roosting habitat is affected birds may be forced to roost elsewhere). It is proposed to conduct counts of all shorebirds at the study site once a week (low/outgoing and high tide periods), avoiding weekends when the levels of disturbance may confound the results.

The assessment of the health and body condition of birds frequenting the estuary would be carried out using high quality photographic equipment from a mobile bird hide. This allows close observation of the birds and photographic interpretation of body form and shape. Prey items caught by the birds can also be determined using this technique. This would be conducted monthly for two years. If concerns arise regarding the health of birds then trapping methods may be used to acquire samples of blood or tissues without harming the birds. However, trapping is a more intrusive method and would only be carried out if there appears to be an impact on the health of birds from field observations or photographic evidence. It is

proposed that assessment of body condition and health will be conducted once each month using field observations and photographic imaging.

5.4 Saltmarsh

The saltmarsh communities are utilised by numerous species of shorebirds for roosting and feeding (e.g. sharp tailed sandpiper) and are of high conservation value (The Ecology Lab, 2004 in URS, 2004b). The saltmarsh community in Penrhyn Estuary is dominated by *Sarcocornia quinqueflora* and *Suaeda australis*. Saltmarsh are not considered to be groundwater dependent and water quality measurements obtained in the saltmarsh area suggests that the near-surface freshwater is derived from rainfall.

It is proposed that four straight line transects (maximum 100 m) would be conducted within the saltmarsh communities. All taxa would be identified and counted and given a cover abundance value based on the modified Braun-Blanquet scale. The vegetation would be classified according to Walker and Hopkins (1990). Projective foliage cover and height would be recorded for each stratum along with physiographic site attributes including general vegetation health, degree of disturbance and age classes present. This approach would allow changes to species composition, abundance and distribution to be identified. A two way table can also be produced to illustrate any changes. The distribution of saltmarsh species will be monitored for the duration of the two year monitoring program.

The monitoring would establish conditions for the saltmarsh community prior to the commissioning of the GTP and then during the operation of the GTP. It should be noted that saltmarsh species are generally being invaded by mangroves in Botany Bay and Port Jackson and mangroves have recently established in Penrhyn Estuary adjacent to the saltmarsh vegetation. Key saltmarsh habitat in Penrhyn Estuary has already been lost due to invasion by mangrove species (URS, 2004b). The water quality in the saltmarsh community will be monitored as outlined in Section 5.1.

It is proposed that the saltmarsh areas would be monitored in July 2005, October 2005, April 2006, October 2006 and April 2007 to establish pre-hydraulic containment and early operational conditions. The requirements for further monitoring would be assessed at the conclusion of the monitoring program. If significant negative trends in the health of the saltmarsh community are identified, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994).

5.5 Mangroves

The Grey Mangrove *Avicennia marina* is present in the estuary, adjacent to both Floodvale and Springvale Drains. These mangroves have invaded saltmarsh habitat which provides valuable bird roosting habitat and is considered to be of low conservation value (URS, 2004b). The mangroves are not considered likely to be affected by the GTP, however, they will be monitored to assess whether mangroves continue to invade saltmarsh areas. This would assess whether a potential reduction in saltmarsh species is due to a general loss of saltmarsh vegetation or specifically due to mangrove invasion. Mangroves will be monitored by two transects (maximum 100 m). As for the saltmarsh, all taxa would be inventoried and given a cover abundance value based on the modified Braun-Blanquet scale and

classified according to Walker and Hopkins (1990). Projective foliage cover and height would be recorded for each stratum along with physiographic site attributes including general vegetation health, degree of disturbance and age classes present. This approach would give an indication of changes to species composition, abundance and distribution.

If significant negative trends in the health of the mangrove community are identified, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994).

5.6 Seagrass

One small patch of seagrass (*Zostera capricorni*) has been identified on the southern shoreline of the inner estuary amongst the mangrove stand. It is not expected that seagrass would be affected by the commissioning of the GTP, however, its abundance, shoot density and distribution will be monitored for the two years of the monitoring program. Seagrass will be monitored using non-destructive sampling techniques, given that the patch is sparse, slow growing and would be destroyed by regular intrusive sampling. Seagrass will be monitored for potential decrease in areal extent and mangrove invasion.

If significant negative trends in the health of the seagrass community are identified, then DPI will be notified as required by Permit 05-030 issued under Part 7 of the Fisheries Management Act (1994).

5.7 Dune Vegetation

The dune vegetation is located between Foreshore Road and Penrhyn Estuary and is dominated by *Banksia integrifolia* and has been planted on sand dredged from Botany Bay. This community does not constitute part of the endangered Eastern Suburbs Banksia Scrub (ESBS) (URS, 2004b). The community is of low to moderate conservation value and in many places has become infested with dense thickets of introduced bitou bush (*Chrysanthemoides monolifera*) and lantana. This is considered to be rainfall dependent rather than groundwater dependent and would therefore, be unaffected by hydraulic containment. However, the dune vegetation will be monitored for the two years.

The dune vegetation monitoring would be completed by conducting three 400 m^2 plots (DEC, 2004). All taxa would be inventoried and given a cover abundance value based on the modified Braun-Blanquet scale. The vegetation would be classified according to Walker and Hopkins (1990). Projective foliage cover and height would be recorded for each stratum along with physiographic site attributes including general vegetation health, degree of disturbance and age classes present. This approach would give an indication of changes to species composition, abundance and distribution. A two way table can also be produced to illustrate any changes. It is proposed that the dune vegetation would be monitored in July 2005, October 2005, April 2006, October 2006 and April 2007.

The distribution of dune vegetation would be assessed using recent aerial photographs and ground truthing. In addition to the vegetation monitoring, groundwater would be monitored as outlined in Section 5.1. Following completion of the monitoring program and assessment of the source of water available to the dune vegetation, the requirements for future monitoring would be reviewed in June 2007. If any

significant changes to dune vegetation and are attributable to the GTP and hydraulic containment are observed, DEC will be notified immediately. It should be noted that regular maintenance of the vegetation (weeding) is conducted which may affect the distribution and abundance of species.

5.8 Integration of Ecological Monitoring Results

It is proposed that the results from the each of the key ecological receptors will be interpreted individually and then assessed in the context of changes to the physico-chemical conditions. These integrated results will evaluate whether any observed changes are a result of hydraulic containment and the GTP or whether changes in the ecological receptors are unrelated to hydraulic containment and the GTP. The results of this interpretation would then be used to assess requirements for further monitoring of individual ecological receptors.

6.1 Monitoring Schedule

To establish conditions prior to hydraulic containment and the commissioning and operation of the GTP, the monitoring should commence as soon as possible. It is proposed that the monitoring schedule described in the following sections would be implemented for the parameters.

6.1.1 Physico-Chemical Parameters

Pre-hydraulic containment conditions have already been established for porewater in Penrhyn Estuary by quarterly monitoring of six bundle piezometers. It is proposed that additional piezometers be installed in the dune vegetation and saltmarsh beds in July 2005. Following installation, monitoring of physico-chemical parameters would be conducted quarterly (March, June, September, December 2006 and 2007) by URS. This would result in eight monitoring rounds being completed in addition to the pre-hydraulic containment data already available.

6.1.2 Wading Shorebirds

Monitoring of wading shorebirds would commence in July/August 2005 and would continue until June July 2007. This monitoring will be conducted by Avifauna Research & Services. Monitoring of bird numbers at high and low tides would be conducted weekly at high and low tides. Monitoring of shorebird health and body condition using digital photography would be assessed monthly (twelve sampling events per annum).

6.1.3 Saltmarsh, Mangroves, Seagrass and Dune Vegetation

Assessment of saltmarsh, seagrass and mangrove vegetation and dune vegetation would be conducted annually in April and October each year. The seagrass monitoring will be conducted by TEL whilst the saltmarsh, mangrove and dune vegetation will be conducted by URS. An initial monitoring event would be conducted in July 2005. Further monitoring would then be conducted in October 2005, April 2006, October 2006 and April 2007 (5 monitoring rounds in total).

6.2 Reporting Schedule

The following table summarises the proposed monitoring and reporting schedule.

Table 3 Monitoring and Reporting Schedule

Activity	Report Type	Date
Round 1 (July 2005) Monitoring		
Round 2 (October 2005) Monitoring	Initial/Progress Report	November 2005
Round 3 (April 2006) Monitoring	Annual Return (2006)	May/June 2006
Round 4 (October 2006) Monitoring	Progress Report	November 2006
Round 5 (April 2007) Monitoring	Annual Return (2007)	May/June 2007

As stated in Section 1.4.1, this monitoring program responds to Special Condition E9.2.4, which is a subset of the Environmental Review, required by EPL2148 and requirements outlined in the permit from NSW Fisheries (Section 1.4.2). Results of the Environmental Review, which will include the results of this monitoring program, are to be incorporated into a report to be submitted with each Annual return for the first two reporting periods during which the GTP is operating.

Via the Environmental Review report, details of this monitoring program will be submitted to DEC, DIPNR, Sydney Ports Corporation, Sydney Water Corporation, NSW Maritime, City of Botany Bay Council and the Independent Monitoring Committee. The report is to be made available for public inspection on request.

6.3 Recommendations and Progress for Future Monitoring

Recommendations to revise the scope of work and methodology may be made following the first monitoring round. Subsequent monitoring requirements may also be reconsidered in light of feedback provided by the various stakeholders on interim reports.

Recommendations for future monitoring requirements would be made at the conclusion of the monitoring program following assessment of potential changes in ecological receptors and physico-chemical parameters.

ANZECC/ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy.

Avifauna Research and Services (2004) *Appendix H., Groundwater Interception, Potential Impacts on Migratory and Threatened Shorebird Communities* in Botany Bay in URS 2004b. Botany Groundwater Cleanup Project: Environmental Impact Statement, Orica Botany, NSW. URS Australia Pty Ltd.

DEC (2005). Consent Conditions Determination for the Groundwater Treatment Plant, Orica Botany. New South Wales Department of Environment and Conservation.

NSW DEC (2004). Threatened Biodiversity Surveys and Assessment: Guidelines for Developments and Activities - Working Draft Nov. 2004. NSW DEC.

Merrick, N.P., (2004). Optimal groundwater Abstraction Rates for Hydraulic Containment of Contaminant Plumes and Source Areas, Botany NSW. National Centre for Groundwater Management. access:UTS, Project no. C04/444/001.

The Ecology Lab, (2004a). *Appendix H., Botany Groundwater Clean-up Aquatic Ecology Component* in URS 2004b. Botany Groundwater Cleanup Project: Environmental Impact Statement, Orica Botany, NSW. URS Australia Pty Ltd.

The Ecology Lab, (2004b). *Attachment 3, Memorandum, Re: Botany Groundwater Cleanup Project* in URS, 2004. Botany Groundwater Cleanup Project Representations Report, NSW. URS Australia Pty Ltd..

URS, (2004a). Orica Botany Environmental Survey – Stage 4 Remediation. Groundwater Cleanup Plan (GCP) Groundwater and Surface Water Monitoring Report – March 2004. URS Australia Pty Ltd.

URS, (2004b). Botany Groundwater Cleanup Project: Environmental Impact Statement, Orica Botany, NSW. URS Australia Pty Ltd.

URS, (2004c). Botany Groundwater Cleanup Project Representations Report, NSW. URS Australia Pty Ltd.

URS, (2004d). Port Botany Expansion Environmental Impact Statement, Volume 1, Main Report. URS Australia Pty Ltd.

Saenger, P., Specht, M., Specht, RL (1977) Mangal and coastal saltmarsh communities in Australasia. In Wet Coastal Ecosystems, ed. VJ Chapman, pp 293-345. Amsterdam: Elsevier Scientific Publishing Co

Walker, J. and Hopkins, M.S (1990). *Vegetation. In: Australian Soil and Land Survey Field Handbook*. (eds RCF MacDonald, RF Isbell, JG Speight, J. Walker and MS Hopkins. Department of Primary Industriesd and CSIRO, Canberra.

Limitations

SECTION 8

URS Australia Pty Ltd (URS) has prepared this Workplan in accordance with the usual care and thoroughness of the consulting profession for the use of Orica Australia and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 28 April 2005.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This Workplan was prepared between 1 June 2005 and 1 July 2005 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Figures