

APPENDIX

ASSESSMENT OF MODIFIED DESIGN - GROUNDWATER AND CONTAMINATION







Douglas Partners
Geotechnics | Environment | Groundwater

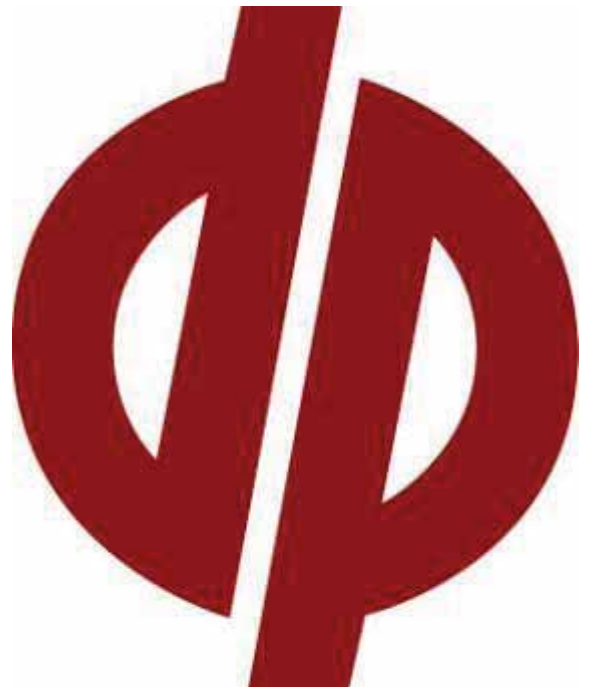
Assessment of Mitigation Measures for
Groundwater Contamination

Proposed Terminal 4 Project
Kooragang Island

Prepared for
Port Waratah Coal Services Limited

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Executive Summary

This report provides an assessment of mitigation measures for groundwater contamination for the Coal Export Terminal 4 (T4) Project. The assessment also takes into consideration design changes to the T4 Project since the Environmental Assessment (EA) was lodged. Douglas Partners Pty Ltd (DP) prepared five reports that formed part of the EA covering matters related to contamination, groundwater and remediation. The report has assessed the effects of the design changes on the previous work, most notably the groundwater modelling in the Groundwater Assessment report.

It was assessed that four design changes affected the previous work in relation to contamination, groundwater and remediation:

- Changed construction schedule;
- Revision to stockyard size and layout;
- Different dredging and reclamation plan; and
- Changed water management configuration.

Additional groundwater and contamination modelling has been undertaken of the following proposed mitigation measures:

- Barrier wall around Ponds 5 and 7;
- Barrier wall around northern side of Deep Pond;
- Low permeability liner on southern side of Deep Pond;
- Lining of the eastern batters of Deep Pond to form water treatment ponds;
- Barrier wall to south of Easement Pond;
- Permeable Reactive Barrier (PRB) along northern side of site;
- PRB along eastern site of site; and
- Low permeability Geosynthetic Clay Liner (GCL) liner in Site C (Delta).

The primary project goal for the contamination assessment of the T4 Project is to protect off-site receiving environment from unacceptable impacts. These environments include adjacent landholdings, the South Arm of the Hunter River, wetlands of the Hunter Wetlands National Park and the ecological attributes which characterise these areas. A secondary objective is to implement a land use option which effectively minimises exacerbation and reduces the long term risks posed by the legacy contamination on the site.

The results of the assessment indicate that the proposed mitigation measures can lead to an overall reduction in the potential for mobilisation of existing legacy contamination, compared to the existing site conditions. The groundwater concentrations reaching the off-site receiving environment, including the Hunter River and wetlands of the Hunter Wetlands National Park, within 100 years, are predicted to be less than the relevant Australian and New Zealand Environmental and Conservation Council (ANZECC) criteria or background concentrations. Subject to appropriate detailed design and construction of the required mitigation measures, it is expected that these measures will protect the off-site receiving environment from unacceptable impacts.

Table of Contents

	Page
1. Introduction.....	1
1.1 Overview	1
1.2 Changes to the Proposed Development	2
1.3 Project Changes Affecting Design	2
2. Remediation Action Plan.....	3
3. Landfill Closure Plan.....	4
4. Groundwater Modelling of Revised Design	5
4.1 General.....	5
4.2 Incorporation of Changes to Development in Model.....	5
4.3 Model Refinements.....	8
4.4 Incorporation of Remediation Measures in Model	8
4.5 Results of Flow Modelling	10
4.5.1 Initial Conditions.....	10
4.5.2 Salinity from Emplacement of Dredge Material.....	12
4.5.3 Groundwater Hydrographs Across Construction Stages.....	13
4.6 Final Capped Site	25
4.7 Long Term Travel Times.....	28
4.8 Contaminant Transport Modelling	30
4.8.1 Methodology.....	30
4.8.2 Ponds 5 / 7	32
4.8.3 Lead Dust Area	35
4.8.4 FDF	41
4.9 Conclusions – Contaminant Transport Modelling	47
5. Summary and Conclusions	47
6. References	49
7. Limitations	50
Appendix A: About this Report	
Appendix B: Drawing 1 – Site Location Plan	
Drawing 2 – Proposed Remediation Measures	
Drawing 3 – Proposed Development	

Abbreviations

ANZECC	Australian and New Zealand Environmental and Conservation Council
BHPB	BHP Billiton Pty Ltd
DP	Douglas Partners Pty Ltd
EIS	Environmental Impact Statement
EMD	Electrolytic Manganese Dioxide
EPA	Environmental Protection Authority
EPL	Environment Protection Licence
FDF	Fines Disposal Facility
GCL	Geosynthetic Clay Liner
HDC	Hunter Development Corporation
KI	Kooragang Island
KCT	Kooragang Coal Terminal
LNAPL	Light Non-Aqueous Phase Liquid
Mn	Manganese
MNA	Monitored Natural Attenuation
NCIG	Newcastle Coal Infrastructure Group
NHTG	Newcastle Harbour Tide Gauge
NSW	New South Wales
OEH	NSW Office of Environment and Heritage
PAH	Polycyclic Aromatic Hydrocarbons
PRB	Permeable Reactive Barrier
PWCS	Port Waratah Coal Services Limited
RL	Reduced Level
T4	Coal Export Terminal 4

Assessment of Mitigation Measures for Groundwater Contamination

Proposed Terminal 4 Project

Kooragang Island

1. Introduction

1.1 Overview

Port Waratah Coal Services Limited (PWCS) proposes to construct and operate a new coal export terminal at the Port of Newcastle, New South Wales (NSW). PWCS owns and operates the Kooragang Coal Terminal (KCT) at Kooragang Island (KI) and Carrington Coal Terminal (CCT) at Carrington, both in the Port of Newcastle. The proposal, known as the Coal Export Terminal 4 Project (T4 Project), is essentially an extension to KCT. The T4 Project would provide additional port capacity required to accommodate the projected future growth in coal exports from the Hunter Valley and broader NSW.

This report provides an assessment of mitigation measures for groundwater contamination for the T4 Project. The assessment also takes into consideration design changes to the T4 Project since the EA was lodged. The work was carried out for PWCS.

The Environmental Assessment (EA) for the project was lodged with the government in February 2012 and subsequently on public display. Douglas Partners Pty Ltd (DP) prepared five reports that formed part of, and were annexed to the EA. Table 1 lists four of these reports (one is no longer relevant) and notes whether the design changes to the project are covered in this assessment or elsewhere by a report issued since the EA was lodged.

Table 1: DP Reports in EA and Whether Design Changes are Covered in this Report

Report Number	Short Title	Included in this Report?	Ref
49533.02-02	Contamination Assessment	Yes	5
49533.02-05	Groundwater Assessment	Yes	6
49533.02-06	Remediation Options	Yes	7
49533.02-08	Outline Remediation Action Plan	No ¹	8

Notes to Table 1:

1. This report has been superseded by the Remediation Action Plan (Pre-Detailed Design) – Ref 10

The location of the T4 Project and general site features are shown in the Site Location Plan – Drawing 1 in Appendix B.

The T4 Project is proposed to include new rail tracks, coal stockyard, conveyors and ancillary facilities on KI, adjacent to KCT, and wharves, berths, ship loaders and ancillary facilities along the north bank of the Hunter River South Arm.

It is noted that infrastructure previously proposed to service the south bank of the Hunter River South Arm (i.e. One Steel area) no longer forms part of this project.

1.2 Changes to the Proposed Development

The proposed T4 Project was described in detail in the EA and DP reports that formed part of the EA. The revised design layout of the T4 Project is shown in Drawing 3 in Appendix B.

The principal changes to the project since the EA that relate to DP's work are:

- Changes to construction staging and scheduling;
- Four coal stockpiles instead of seven, ranging in length from 1225 m to 1440 m, and extension of the stockyard 40 m to the east;
- Five machinery berms to carry four stackers and four reclaimers;
- Revised dredging and reclamation plan: dredged material will be deposited into the Delta Electrolytic Manganese Dioxide (EMD) waste site and mechanically moved to other parts of the site. The dredge water return route will be an open lined channel to the west of the rail lines;
- Stockyard bench levels lowered by 0.6 m, altering cut and fill earthworks volumes; and
- New water management pond configuration.

Other changes to the proposed development relevant to other disciplines are covered in the report by the consultant for each discipline.

1.3 Project Changes Affecting Design

The design changes that affect DP's assessments related to contamination, groundwater or remediation are shown in Table 2.

Table 2: Project Changes

Project Change	Comment
Changed construction schedule: Construction in single stage with overall duration of about three years.	Groundwater model altered to match construction staging and generate new hydrographs.
The stockyard size: Stockpiles reduced from seven to four and stockyard extended east by 40 m.	Groundwater model updated with new geometry.
Change in dredging and reclamation plan: Dredged material to be deposited in lined cells at the Delta EMD site and then trucked elsewhere for preloading and filling. Dredge material emplacement on the site will be undertaken in one campaign.	This significant change required modifications to the groundwater model. The contaminant transport model was also re-run.
Changed water management configuration	Groundwater model updated with new layout.

In addition, while the proposal is for the provision of either a skeletal or sheet pile wall wharf structure, modelling undertaken in the EA was only based on a skeletal structure. This assessment assumes the provision of a sheet pile wall wharf structure which affects groundwater drainage to the Hunter River.

As noted in Table 2 the majority of design-related changes relate to the groundwater assessment and required revised modelling of groundwater effects. The results are presented in Section 4.

2. Remediation Action Plan

It is proposed to remediate specific areas of the T4 Project area in conjunction with construction of the terminal.

A Remediation Action Plan (Pre-Detailed Design), herein referred to as the RAP, has been prepared to assist the T4 Project approval process. The objectives of the RAP were to demonstrate the appropriateness and feasibility of the proposed remediation measures for the purposes of T4 Project approval.

Preliminary design of the preferred remediation options for each of the identified contamination issues indicates that the objectives of the remediation can be achieved subject to further targeted investigations, remediation trials and detailed design, including modelling when required.

The detailed design will be conducted during the project approval process to enable the RAP to be updated with the detail design features and finalised prior to construction. If any conditions of consent impact on the RAP the relevant matters would also be addressed in the updated document. The site Auditor will conduct the relevant reviews during investigations, remediation trials and final RAP preparation. A Site Audit Statement (SAS) will be prepared following completion of the final RAP prior to the commencement of any remediation works at the site. The SAS will confirm the suitability of the final RAP to meet its stated objectives. Upon implementation of the remediation measures it is considered that the site will be rendered suitable for the proposed landuse.

The details of the environmental condition of the site and the proposed remediation activities are presented in the following documents:

- Contamination Assessment Report (Ref 5), which presents the environmental condition of the site and identifies the need for remediation of certain parts of the T4 Project site;
- Assessment of Remediation Options (Ref 7), which reviewed available remediation methods and identified the preferred remediation options for each contamination issue; and
- RAP for the Kooragang site (Ref 10), which provides details of each remediation measure to be implemented.

The contamination issues identified at the T4 Project area and the preferred remediation options are shown in Table 3.

Table 3: Contamination Issues and Preferred Remediation Options

Location	Contamination Issue	Preferred Remediation Option
Ponds 5 and 7 (Site A, Area K5)	Soil and groundwater impact associated with coal tar waste.	Barrier wall.
Asbestos Burial Area (Site A, Area K7)	Lead dust co-disposed with asbestos could come into contact with groundwater due to settlement from T4 loads.	Permeable reactive barrier ('funnel and gate' type).
Site B North, Area K10	Free phase oil contamination in the vicinity of Bores B-01 and T-222.	Multi-phase extraction.
Delta EMD (Site C, Area K8)	Potential mobilisation of contaminants and adverse groundwater interactions (mainly Easement Pond) during the dredging phase.	Low-permeability capping prior to dredging.
Fines Disposal Facility (Site D, Area K13)	Potential mobilisation of contaminants associated with settlement under T4 load and a rise in the water table.	Permeable reactive barrier ('funnel and gate' type).
All of Kooragang T4 site	General industrial contamination and localised 'hot spots'.	Capping to meet intent of Environmental Protection Authority (EPA) Benchmark 28 guidelines.

The details of the proposed remediation and other mitigation measures listed in Table 3 are presented in the RAP. The final entry in Table 3, relating to general industrial contamination and localised 'hot spots', will be managed through the capping strategy discussed herein.

3. Landfill Closure Plan

The proposed T4 Project will be partly constructed upon three licenced landfill areas on KI. A Landfill Closure Plan (LCP) has been prepared for the integration of the T4 Project, if approved, with the closure of these landfills. The LCP is presented in a separate document (Ref 9).

The LCP includes four key elements, as set out in Protection of the Environment Operations Act 1997 (POEO Act) and Waste Minimisation and Management Act 1995 (WMM Act). A summary of these elements and where they are addressed is shown in Table 4.

Table 4: Closure Plan Elements

Element	Description	Where Addressed
Consistency with any EMP relating to the waste facility	The site is subject to three EPLs, but no current specific EMPs	See Section 4.5 of the LCP for a summary of the existing EPLs and closure requirements.
Specification of the steps taken in closing, stabilising and rehabilitating the premises and the time-frame	Remedial measures to manage site contamination issues will be undertaken as part of the T4 Project construction program	Remediation Action Plan (Ref 10) – see a summary in Section 2 of this report Timeframe as per Engineering Procurement and Construction Management (EPCM) contractor construction schedule – see Section 6.1 of the LCP
Provision of a post-closure monitoring and maintenance program	Regular monitoring of environmental performance of remediation measures and capping	Long-Term Monitoring and Maintenance Program – see a summary in Section 8.2 of the LCP
Identification of proposed future uses of the premises	T4 Project	Section 1.2 of the LCP and of this report present a summary of the Proposed Development and design changes respectively

4. Groundwater Modelling of Revised Design

4.1 General

The groundwater and contaminant transport models developed for the EA were modified to take into account changes to the proposed development as well as a number of minor refinements to the models. The following provides a summary of how the changes have been incorporated into the model as well as a summary of the revised results. Reference should be made to the Groundwater Report (Ref 6), contained in Appendix E of the EA for specific details regarding the modelling process.

4.2 Incorporation of Changes to Development in Model

As previously discussed, the provision of a skeletal type wharf or sheetpile wall is proposed. The assessments undertaken as part of the EA were based on a skeletal wharf structure incorporating a revetment wall. The modelling now incorporates a sheet pile wall, which is proposed to be installed to a depth of about 30 m to 35 m. This will result in the interlocking sheet piles extending to the depth of the Estuarine Aquifer, effectively cutting off flow across this section of the Fill and Estuarine Aquifers. A sheet pile wall is also proposed around the north bank swing basin to allow construction, however this can be removed at the end of construction, if required. While the swing basin is subject to a separate approval and does not form part of the proposed T4 Project, the modelling was undertaken for cases with and without the swing basin sheet pile wall in place.

These sheet pile walls were incorporated into the model by placing low permeability material, of one cell width, along the alignment of the proposed wharf and swing basin. A hydraulic conductivity of 0.0135 m/day (over 12.5 m wide cells) was adopted for the wall. For the case that the swing basin sheet pile wall is removed at the completion of construction the conductivity of the general head boundary was increased to simulate the removal of low permeability sediments on the river floor due to the dredging process.

The overall footprint of the water treatment ponds located within the existing Deep Pond area, post construction, has been adjusted to reflect the new overall layout of the ponds. The frog habitat ponds have not been incorporated into the model as it is assumed that these will be lined and therefore will not interact with the groundwater.

The reclamation process has been refined. Dredged wet sand is no longer proposed to be placed across the site in general, it is proposed to place the wet sand into the Delta Site which will contain a Geosynthetic Clay Liner (GCL) liner with low permeability bund walls (as per previous design). A lined channel or pipe will transfer saline decant water to Deep Pond.

A low permeability barrier wall is proposed to be installed along the north and western perimeter of Deep Pond (in place of the previously proposed GCL liner) to reduce the migration of saline water towards the wetlands to the north-west. The southern batter of the pond is also to be lined during construction to prevent migration of saline water to the south (as per previous design). A low permeability barrier wall is also proposed to be installed along the southern side of Easement Pond to reduce the migration of saline water below the Newcastle Coal Infrastructure Group (NCIG) rail embankment, towards the wetlands to the south.

Sand will be transferred to the site by way of truck / scraper in a moist state, rather than being over-saturated (previous design) thereby substantially reducing the volume of saline water placed with the sand over the general site.

The liner within the Delta site (Site C) has been modelled in a similar manner to the previous model, as a recharge equivalent to a head of about 4 m on the liner (0.76 m/yr) across the whole lined Site C, with an applied salinity of 35,000 mg/L. The actual average head across the liner is expected to be less than this, probably closer to 2 m, however an upper-bound head has been adopted to allow for potential defects etc. in the liner.

General head boundaries are no longer required to replicate the placement of wet sand. These have been replaced with salinity recharge equivalent to 50% of rainfall to replicate the presence of permeable sand. The placed sand will still contain some residual saline water and this has been applied as a concentration added to Fill Aquifer squeezing flows during the placement of the fill. The concentration was calculated on a basis of the placed sand having a residual volumetric water content of about 10% (about 30% to 50% of pore space containing water).

The various barrier walls and the liner at the southern end of Deep Pond are incorporated into the model as a cell wide line of low permeability material, with hydraulic properties equivalent to a 0.8 m wide wall with a hydraulic conductivity of 1×10^{-8} m/s (0.001 m/day).

A summary of changes to the proposed development is provided in Table 2. The proposed construction schedule is over approximately a three year period. The adopted stress-period set-up was based on preliminary construction program and is summarised in Table 5 below. The footprint of each stage of preloading and construction was adjusted to match the reduced number of stockpiles.

Table 5: Adopted Stages and Timing of Construction

Modelled Stage of Construction	Stages of Construction	Period (months)
Not modelled	Installation of sheet piles and barrier walls etc.	6
Stress Period 1	Saline dredged material placed in lined Delta Area. Barriers Pond 5/7 and Deep Pond in place. Northern Permeable Reactive Barrier (PRB) not in place. Swing Basin Sheet Piles in place.	3
Stress Period 2	Saline dredged material placed in lined Delta Area. Northern PRB in place. Consolidation due to fill of Stockyards 3 and 4 (Delta), Ch 800-1200 m. Fill of Stockyards 1 and 2 , Ch 0-800 m.	6
Stress Period 3	Saline dredged material placed Delta Area. Western section of Main Wharf Sheet Piles in place. Preload of Stockyards 1 and 2, Ch 0-800 m. Fill of Stockyards 3 and 4, Ch 0-800 m. Fill of Stockyards 1 and 2, Ch 800-2000 m.	6
Stress Period 4	Saline dredged material placed Delta Area. Complete Wharf Sheet Piles in place. Dump Station in place. Preload of Stockyards 1 and 2, Ch 800-1800 m. Preload of Stockyards 3 and 4, Ch 0 to Ch 800 m and Ch 800 to Ch 1200 m.	6
Stress Period 5	Saline dredged material placed Delta Area. Fill and Preload of Stockyards 3 and 4, Ch 1200-1800 m. Fill of Area to south of stockyards. Capping of Stockyards 1 and 2 Ch 0-800 m complete.	6
Stress Period 5	Capping of Stockyards 1 and 2, Ch 800-1800 m complete. Capping of Stockyards 3 and 4, Ch 0-1200 m complete.	6
Stress Period 6	Capping of all remaining areas complete, including south of stockyards. Removal of swing basin sheet pile walls (if undertaken).	12
Stress Period 7	No changes	96 yr

4.3 Model Refinements

A number of refinements to the groundwater model were undertaken, including:

- More recent monitoring of water levels in Railroad pond and Deep Pond, during wetter conditions than present for the calibration data set, suggested a higher reliance on groundwater flow than from the initial calibration and therefore the hydraulic connectivity between the two water bodies was increased slightly. This change possibly over emphasises impacts on the NSW Office of Environment and Heritage (OEH) Wetland 1 and Rail Road Pond from the development, however was made as a precautionary measure;
- The use of dynamic replacement on parts of the adjacent NCIG site and wick drains at KCT have likely increased the hydraulic connection between the Fill Aquifer and the Estuarine Aquifer to the east of the T4 Project area and this was incorporated in the model, with an associated slight adjustment to the recharge in this area. This results in an improvement in the calibration of Fill Aquifer heads to the south east of the Fines Disposal Facility (FDF) with no significant changes to the calibration otherwise;
- The proposed capping by Hunter Development Corporation (HDC) is to comprise a 0.5 m thick layer of coal fines with a hydraulic conductivity of 1×10^{-7} m/s. Previous modelling had been undertaken on the basis of recharge through general areas of capping being equivalent to 5% of rainfall recharge (or about an annual average of 60 mm/yr). A previous assessment undertaken on behalf of HDC (Ref 22) has indicated an average recharge rate from the proposed HDC capping of about 140 mm/yr (12.5% annual recharge) and this has been adopted for sections of the site and surrounds subject to HDC capping. The proposed capping on site is proposed to have a hydraulic performance equivalent to or better than EPA Benchmark 28 (0.5 m with a hydraulic conductivity of 10^{-8} m/s) and a recharge rate of 5% of annual average rainfall (about 60 mm/year) has been used; and
- The horizontal hydraulic conductivity in the FDF fill was increased to 8.64 m/day to better account for the presence of the basal sand drainage layer.

4.4 Incorporation of Remediation Measures in Model

The proposed remediation measures are detailed in the RAP (Ref 10) and shown in Drawing 2 Appendix B. The remediation measures were included in the groundwater model and those specifically analysed were:

- Barrier wall around Ponds 5 and 7;
- Barrier wall around northern side of Deep Pond (as outlined above);
- Low permeability liner on southern side of Deep Pond;
- Lining of the eastern batters of Deep Pond to form water treatment ponds;
- Barrier wall to south of Easement Pond;
- PRB along northern side of site.
- PRB along eastern site of site; and
- Low permeability GCL liner in Site C (Delta).

It is noted that free phase oil contamination has been identified in Area B, however active remediation is proposed on the Light Non-Aqueous Phase Liquid (LNAPL) source zones and remediation of the dissolved-phase plumes is proposed by Monitored Natural Attenuation (MNA) with contingencies for active remediation in the event that the plumes approach sensitive ecological receptors (e.g. receiving surface water bodies). Modelling of these remedial measures was not considered relevant to demonstrate their effectiveness.

The PRB system is proposed to comprise a barrier wall (funnel), nominally about 0.8 m thick with regularly spaced gates of permeable reactive material, nominally about 2 m thick. Hydraulic parameters for the funnels and gates were based on typical published parameters. The 12.5 m square grid of the MODFLOW SURFACT model was adapted to simulate the proposed funnel and gate system by adjusting the hydraulic conductivity of the cells to compensate for the varied width of the funnel/gate as show in Table 6.

A 6:1 ratio was adopted for the funnel and gate system with 12.5 m wide gates and 75 m barrier (funnels) between.

Table 6: Simulated and Equivalent Model Parameters for Funnel and Gate

Element	Simulated Width (m)	Simulated Hydraulic Conductivity (m/s)	Model Width (m)	Model Hydraulic Conductivity (m/day)
Barrier Wall	0.8	10^{-8} m/s	12.5	0.0135
Gate	2.0	10^{-6} m/s	12.5	0.54

Groundwater flows were simulated for the various stages of construction as well as long term conditions once the site is capped. It was assumed that the eastern side of Deep Pond would be lined at the completion of construction, once reclamation was complete along the eastern side of the pond. This liner was left out until following filling and preloading to limit heads occurring upstream of the PRB during these construction activities.

Figure 1 shows the hydraulic conductivity zoning for the Fill Aquifer, with the location of the various barrier walls shown as black lines. The gates of the PRB are shown as green cells at regular spacing along the barrier wall to the north and east of the main site.

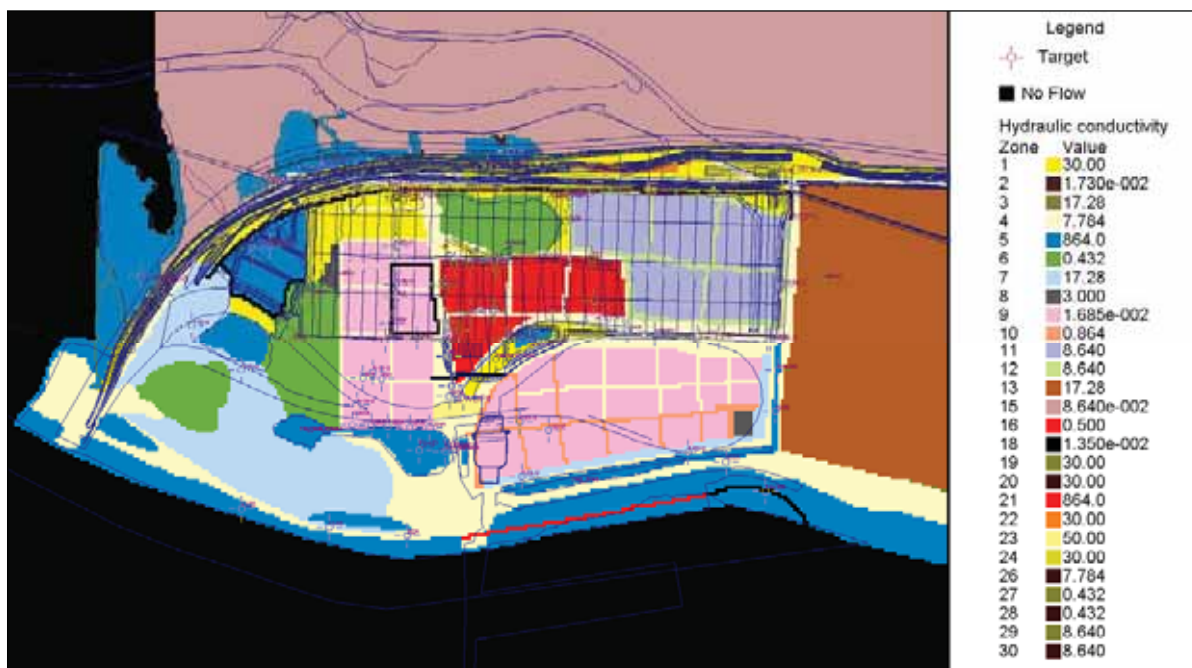


Figure 1: Hydraulic Conductivity Zoning

4.5 Results of Flow Modelling

4.5.1 Initial Conditions

The initial head distributions used as a baseline for the Fill Aquifer and Estuarine Aquifers are presented in Figure 2 and Figure 3. The figures also include the magnitude of residuals at target points, which are the difference between the observed head at monitoring wells and the computed heads from the model. Where residuals are negative / red the observed head was lower than the computed head and where residuals are positive / blue the observed head was higher than the computed head. The results are very similar to the steady state calibration presented in the Groundwater Assessment, with slightly improved calibration around the eastern parts of the site and provide a good representation of the groundwater levels at a single point in time.

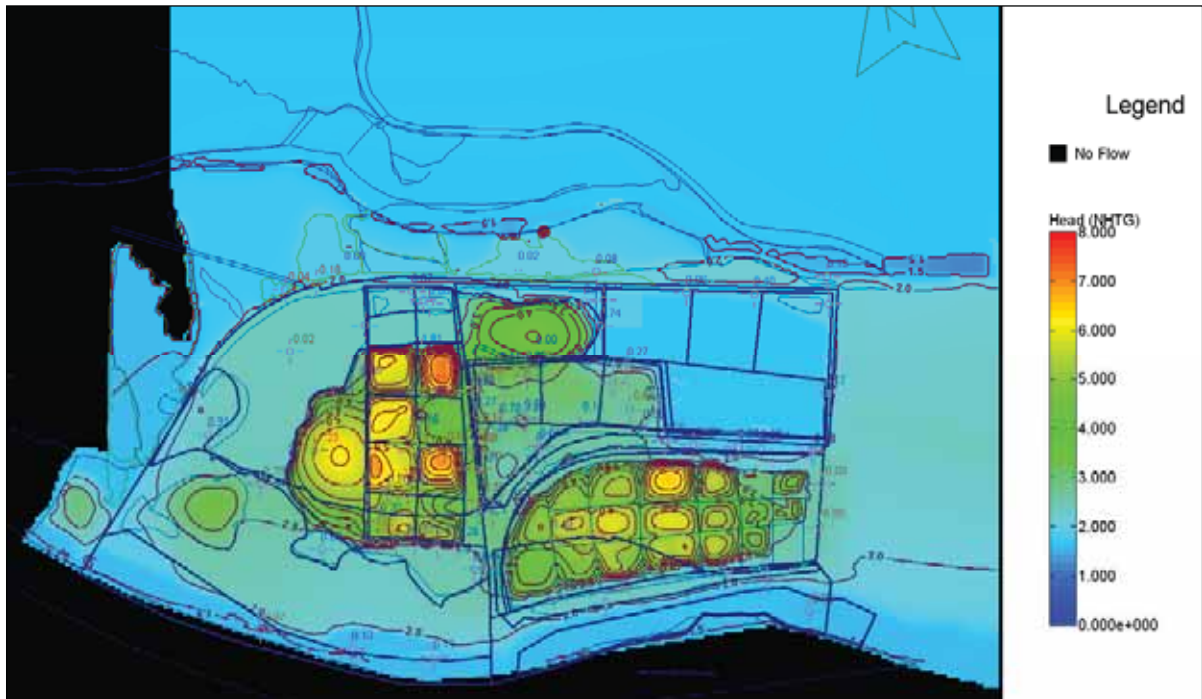


Figure 2: Computed Contours and Colour Flood of Groundwater Head in Layer 1 (Fill Aquifer), 0.5 m Newcastle Harbour Tide Gauge (NHTG) Contour Intervals – Initial / Baseline Conditions

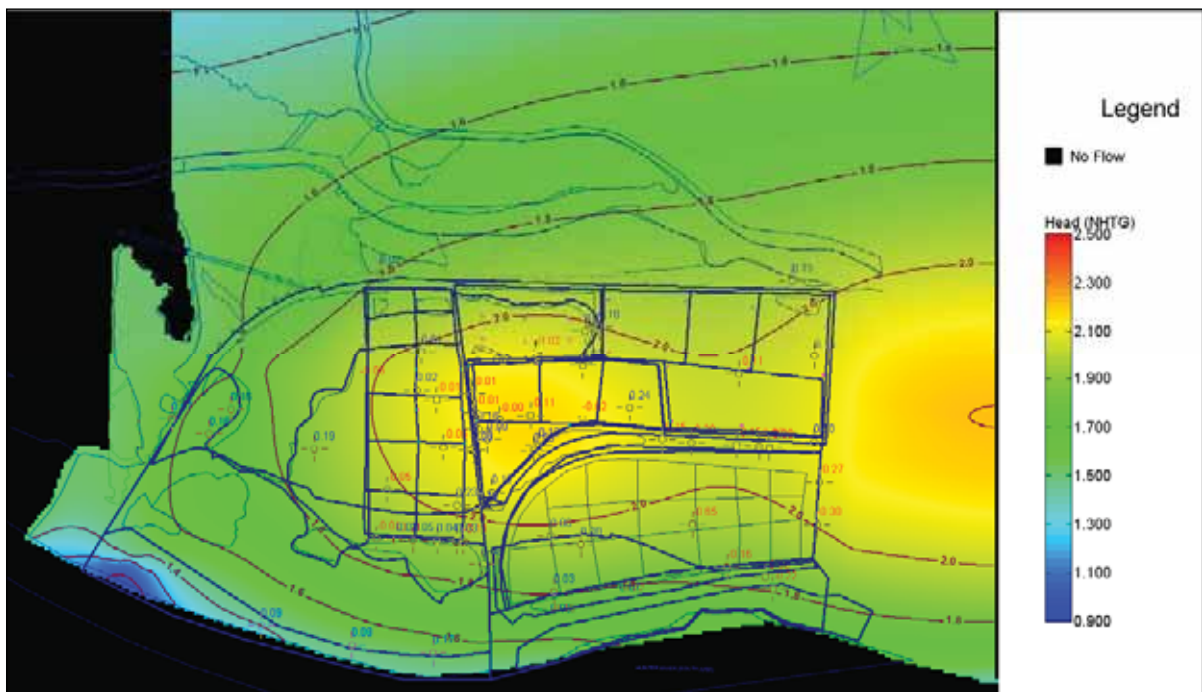


Figure 3: Computed Contours and Colour Flood of Groundwater Head in Layer 3 (Estuarine Aquifer), 0.2 m NHTG Contour Intervals – Initial / Baseline Conditions

4.5.2 Salinity from Emplacement of Dredge Material

The resulting logarithmic contours of salinity concentration, with the mitigations in place (including the PRB) are presented in Figure 4 for completion of dredging and Figure 5 for 3 years following completion of the emplacement of dredge material.

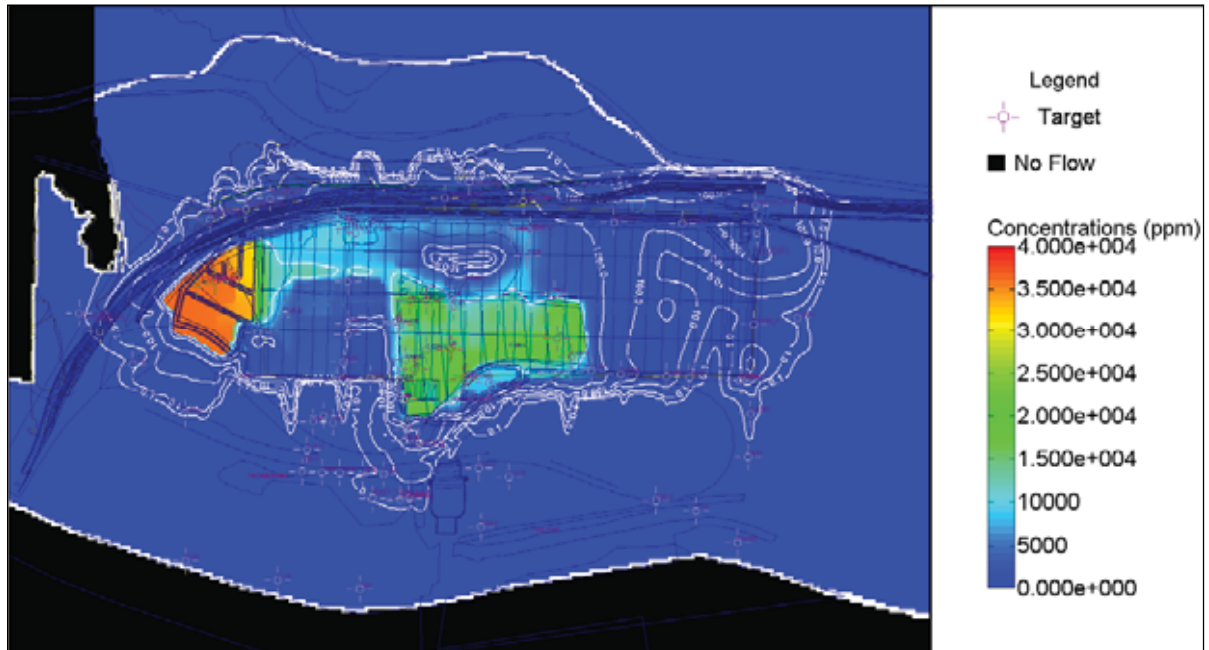


Figure 4: Logarithmic Contours of Salinity Concentrations (mg/L) with Mitigations at the Completion of Emplacement of Dredge Material

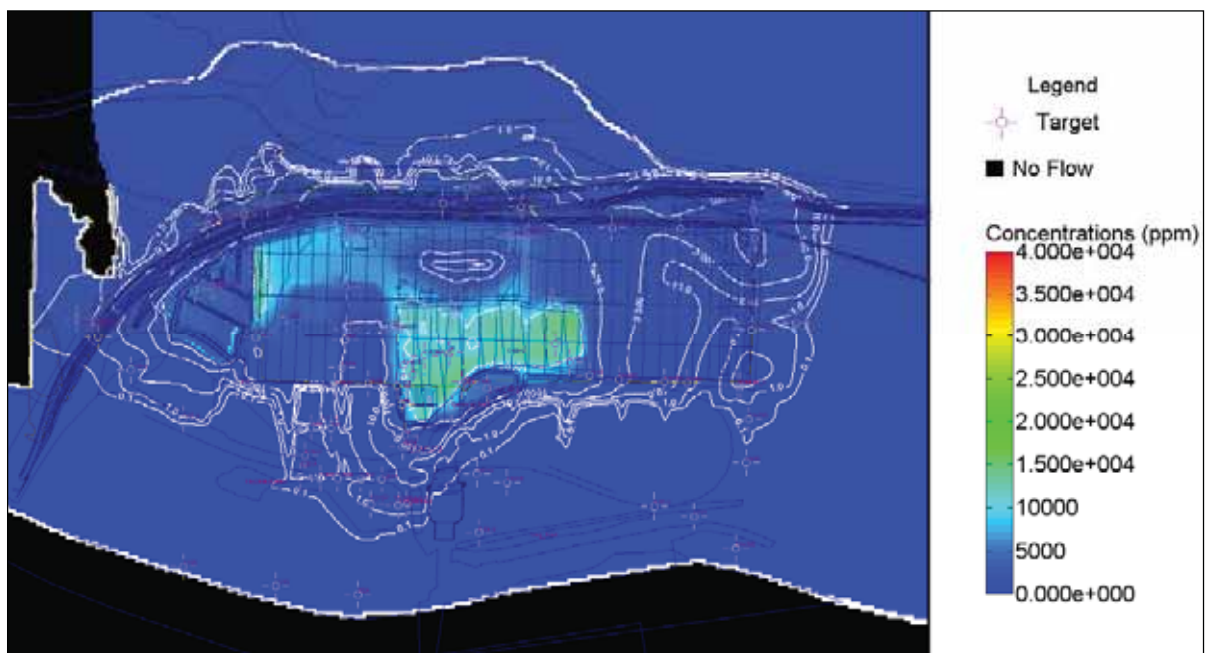


Figure 5: Logarithmic Contours of Salinity Concentrations (mg/L) with Mitigations at the Completion of Capping (3 years after completion of emplacement)

The results of the modelling indicate an overall reduced risk related to salinity compared to those for the previous development scenario, as presented in the EA, as the emplacement is now proposed to be undertaken within a lined area in Delta / EMD (Area C). Specific points are as follows:

- The overall extent of predicted salinity concentrations greater than 10,000 mg/L is limited to Pond 5 and Delta EMD; and
- Peak predicted net changes in salinity at Blue Billed Duck Pond, OEH Wetland 1 and Railroad Pond are less than 1,000 mg/L.

The predicted salinity concentrations presented in Figure 5 represent potential net increases in salinity of groundwater and do not take into account the transient variations in salinity which will occur in the Wetlands and ponds due to cycles of rainfall and evaporation. Field measurements indicate that salinity concentrations in the wetlands / ponds vary over a range from about 1,500 mg/L to greater than 10,000 mg/L due to these natural cycles.

Overall the results of the modelling indicate that with the proposed mitigations in place, the net impact on salinity concentrations would be insignificant, provided that fluctuations in pond levels due to rainfall and evaporation are maintained in a similar manner to what currently occurs, and the mitigation measures are appropriately designed and constructed and they are appropriately maintained over the period of dredging.

4.5.3 Groundwater Hydrographs Across Construction Stages

Groundwater hydrographs for the Fill and Estuarine Aquifers were exported from the model at five critical locations across the T4 Project area which have been identified as potential contamination hot spots (see Drawings 5.27, 5.28 and 5.29 of Ref 6), namely:

- Pond 5 ('Pond 5 Upper' / 'Pond 5 Lower');
- Pond 7 ('Pond 7 Upper' / 'Pond 7 Lower');
- Area K7 ('Area K7 Upper' / 'Area K7 Lower'); and
- Two locations within the FDF ('FDF Upper' / 'FDF Lower' and 'FDF2 Upper' / 'FDF2 Lower').

The hydrographs provide a plot of predicted groundwater levels at these specific locations on the site. The groundwater level variations provide an indication of the potential head driving groundwater flow from a particular location. In basic terms, a higher groundwater level will result in a higher flow rate towards the relevant downstream receptor, such as the Hunter River, with a lower level having a relatively lower flow rate. The hydrographs are useful to provide an overall sense of the impact of the various development stages on groundwater flow rates and therefore the impact on mobility of any existing contamination.

The expected water levels pre and post development, over the construction period and several years beyond are shown in Figure 6 to Figure 11. The water levels shown on these figures represent 'average' conditions and do not take account of fluctuations due to variations in rainfall and evaporation which can occur on a daily basis. The figures provide a comparison of long term water levels changes due to the T4 Project development (with and without the swing basin sheet pile walls left in place long term) compared to a no development case, assuming identical climatic conditions for each scenario. The no development case includes HDC capping of Sites A and B proposed to be completed by the end of 2013 independent of the T4 Project. It has been assumed that Site C would also be capped at this time.

The figures include hydrographs for two cases as follows:

- Swing Basin Sheet Pile Wall Retained: Swing basin sheet pile wall left in place long term, leading to all flow in Estuarine Aquifer from below the FDF towards the north; and
- Swing Basin Sheet Pile Wall Removed: Swing basin sheet pile wall removed at completion of construction, providing a flow path to the south.

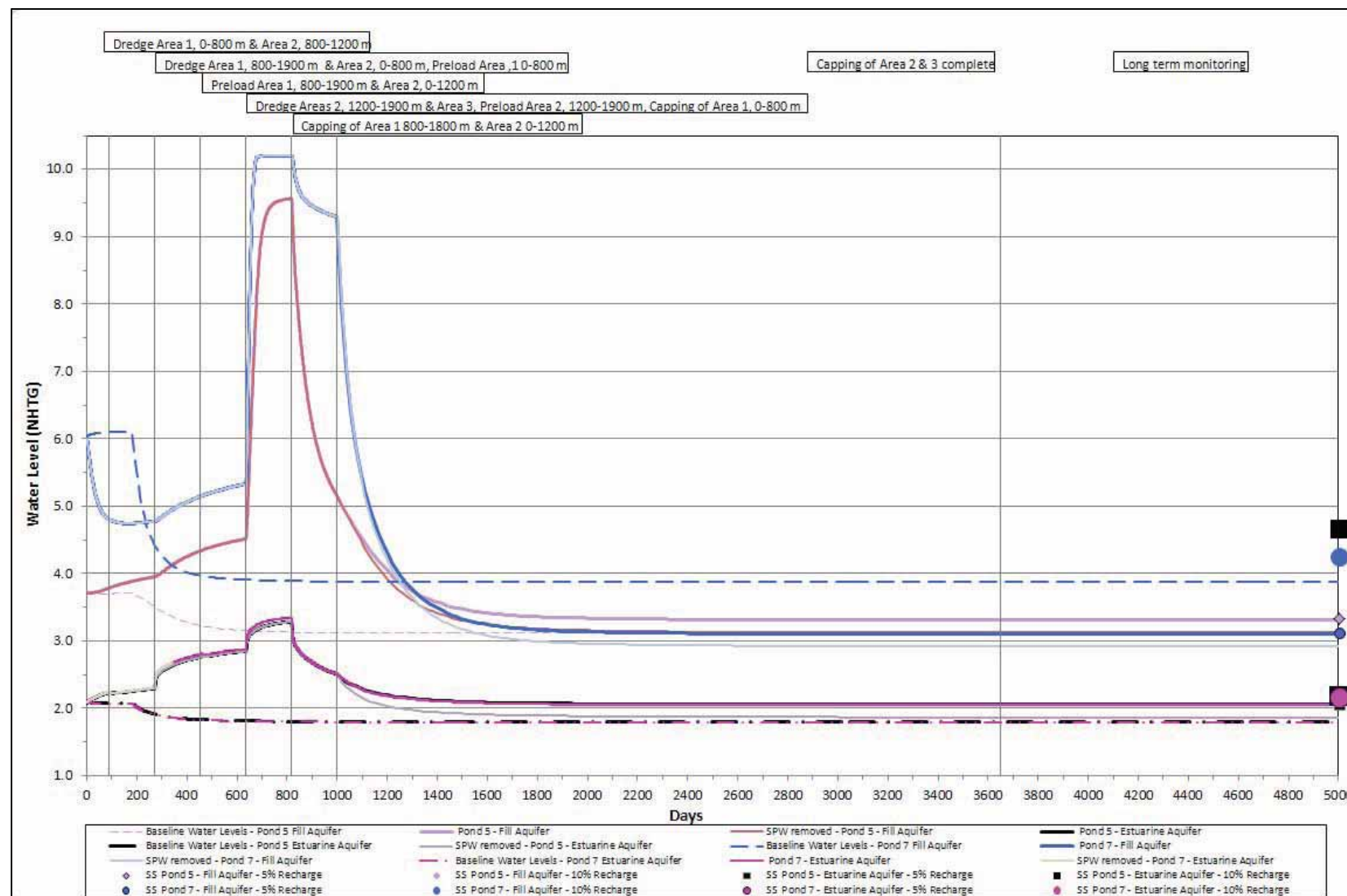


Figure 6: Baseline and Post Development Water Levels in Ponds 5 and 7 (Site A) – Indicative Staging Presented

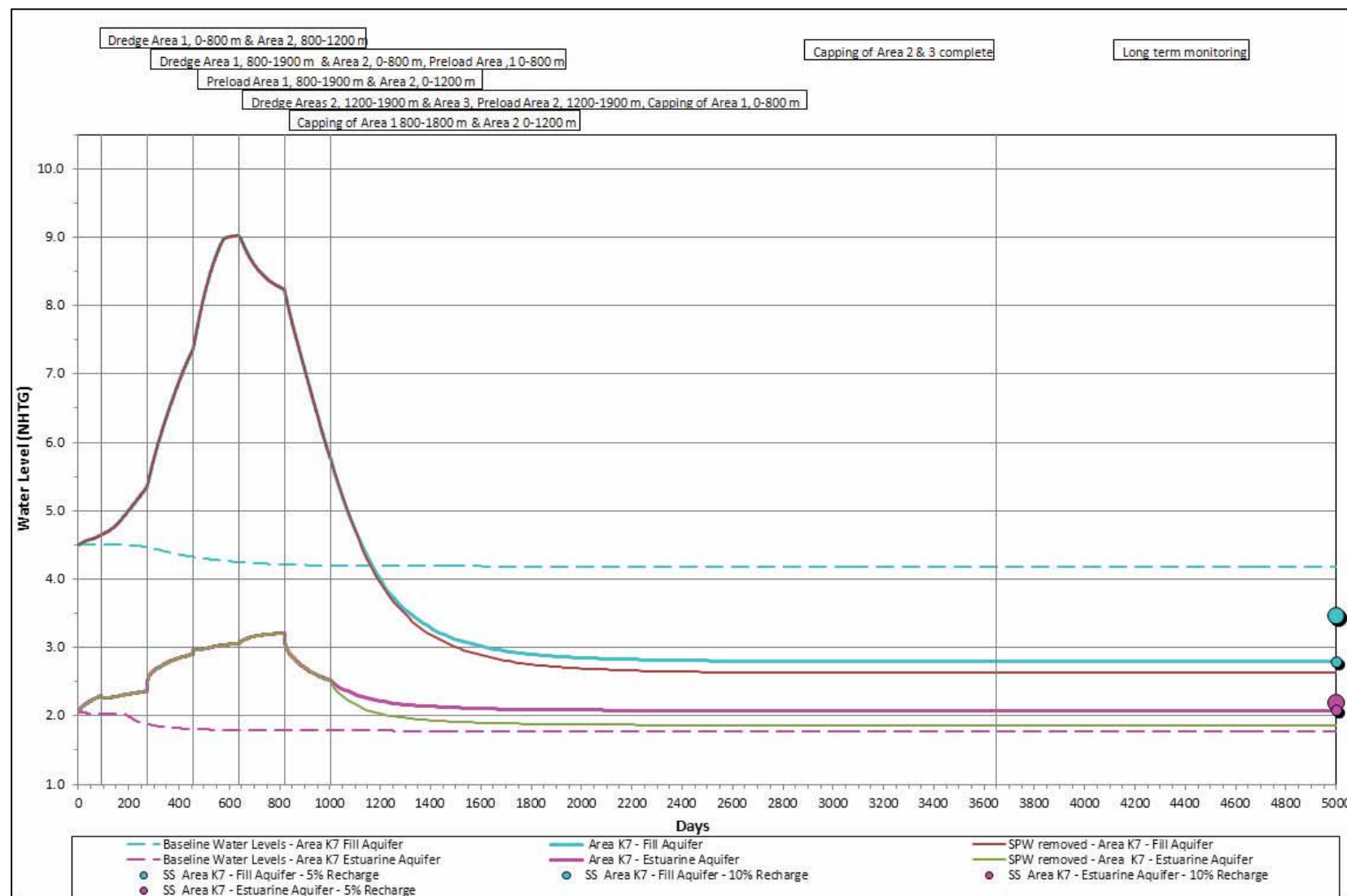


Figure 7: Baseline and Post Development Water Levels in Area K7 (Site A) – Indicative Staging Presented

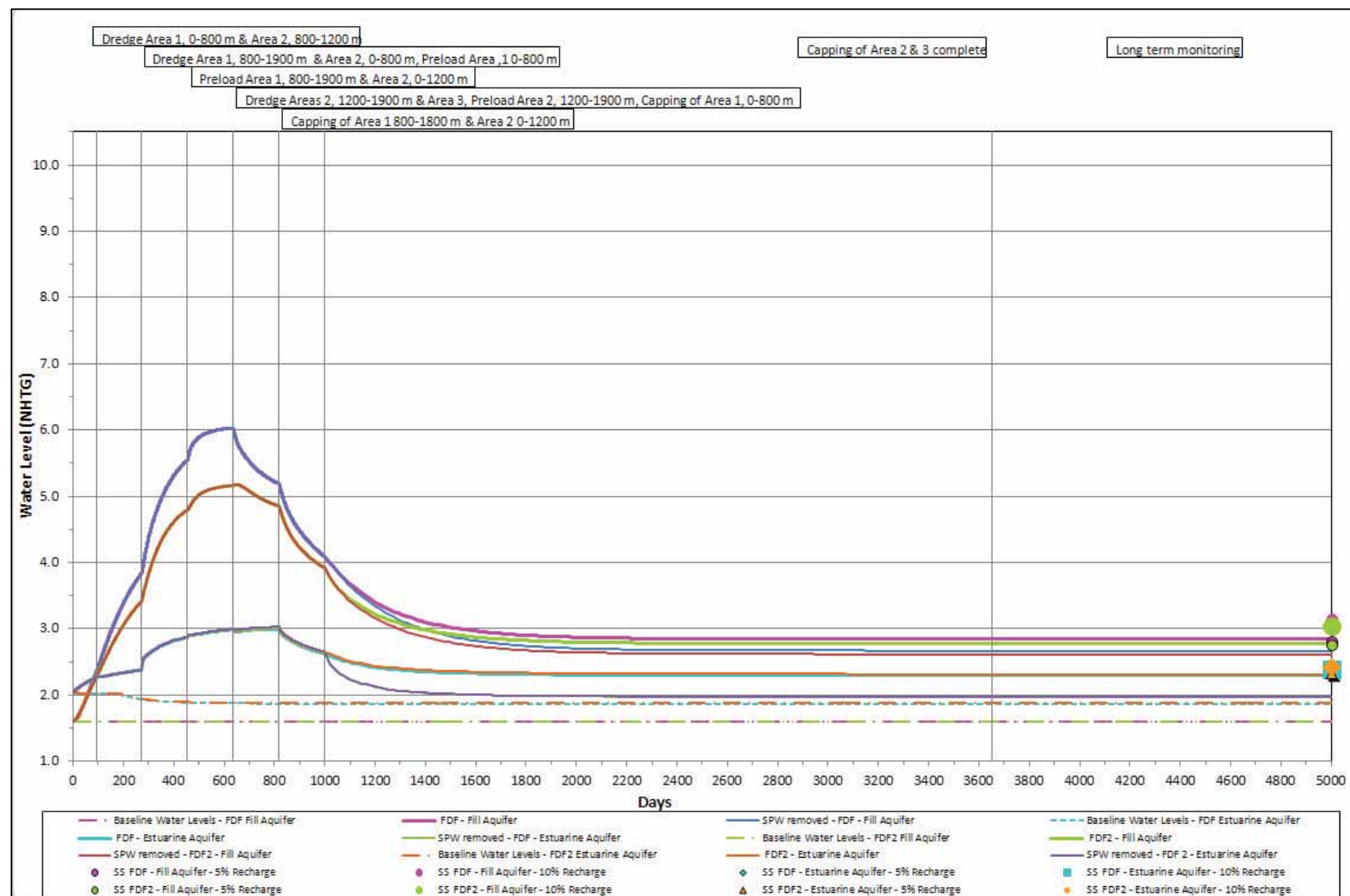


Figure 8: Baseline and Post Development Water Levels in Site D (FDF) – Indicative Staging Presented

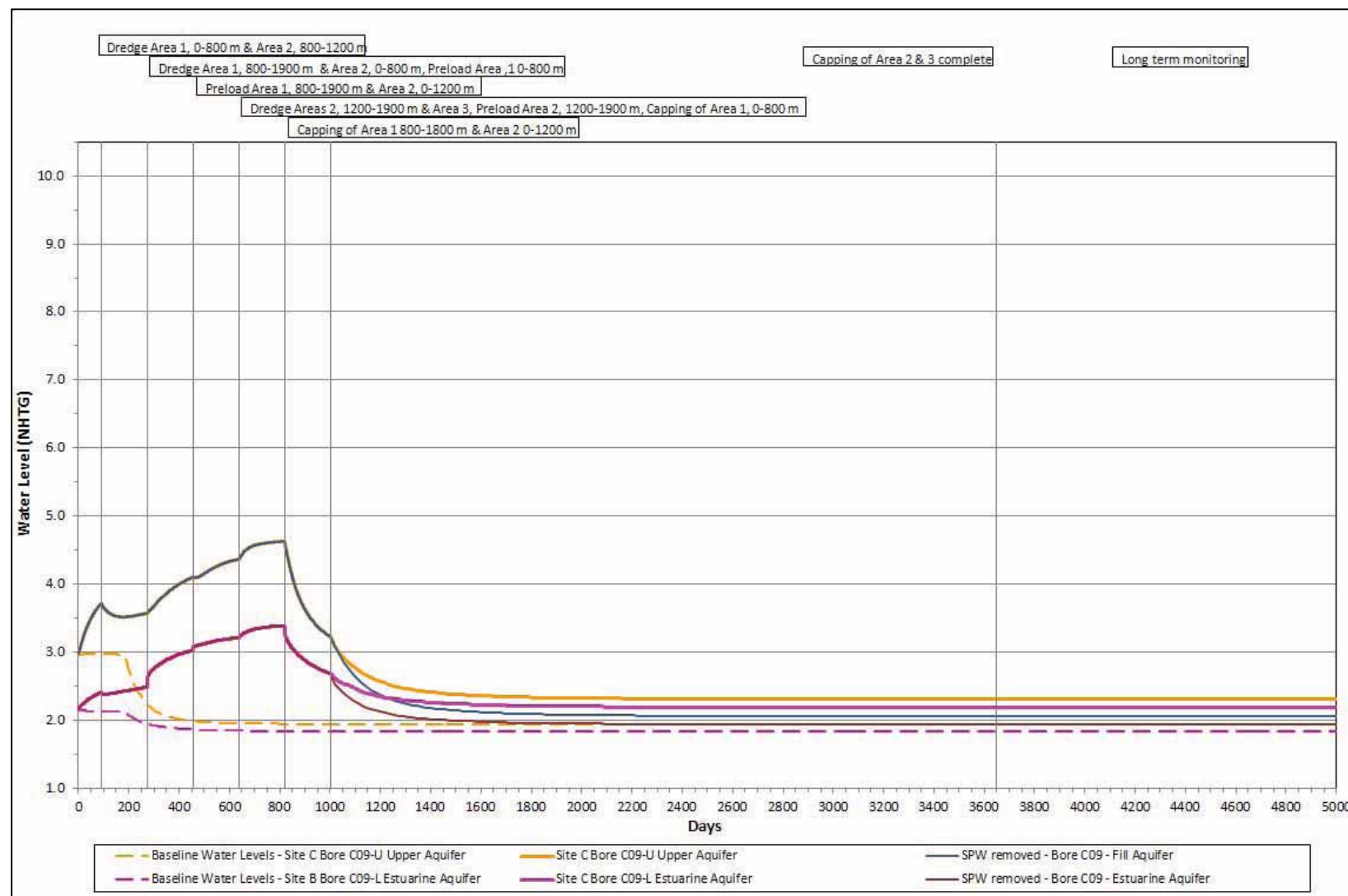


Figure 9: Baseline and Post Development Water Levels in Site C (Delta/EMD) – Indicative Staging Presented

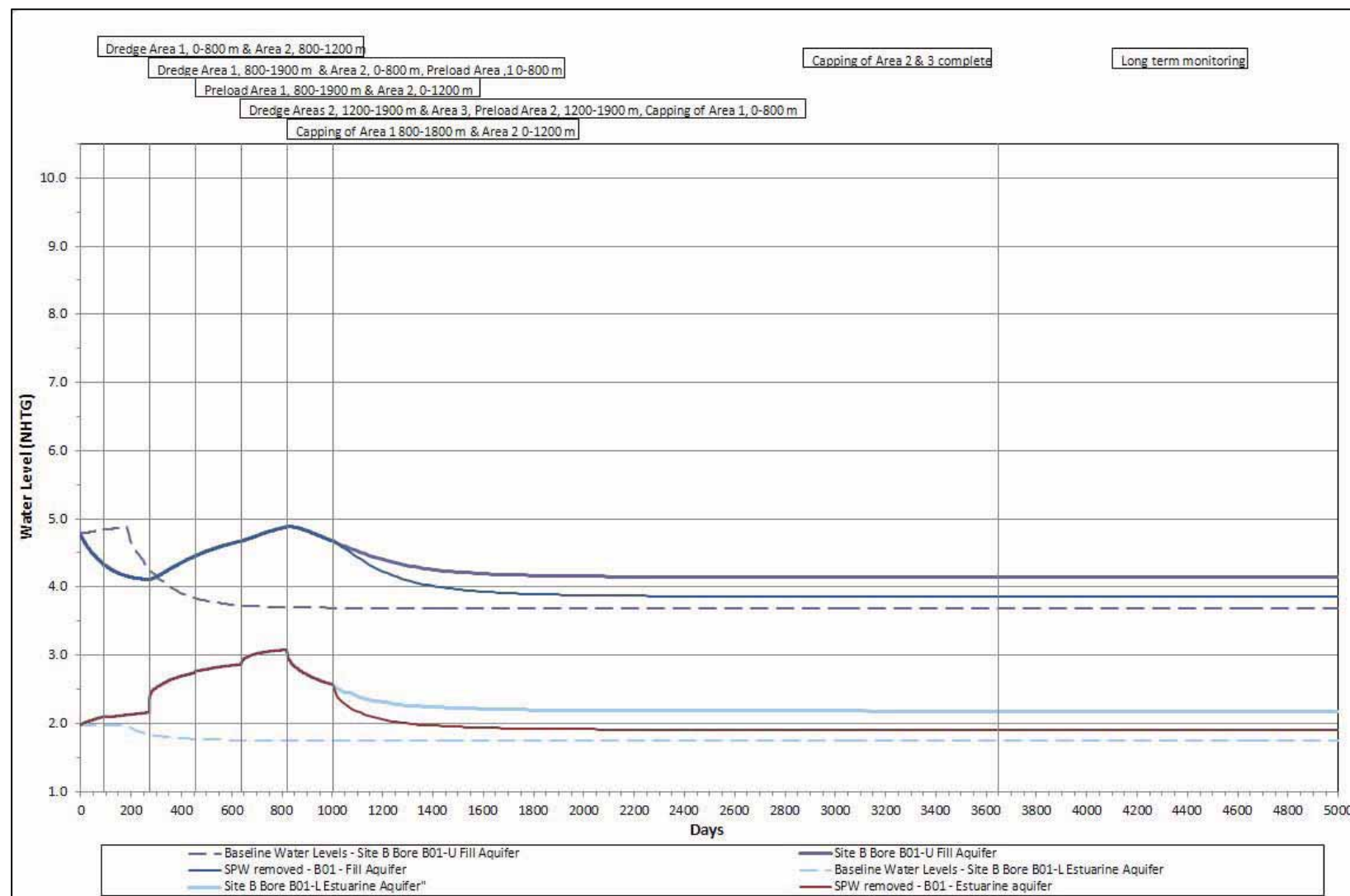


Figure 10: Baseline and Post Development Water Levels in Site B – Indicative Staging Presented

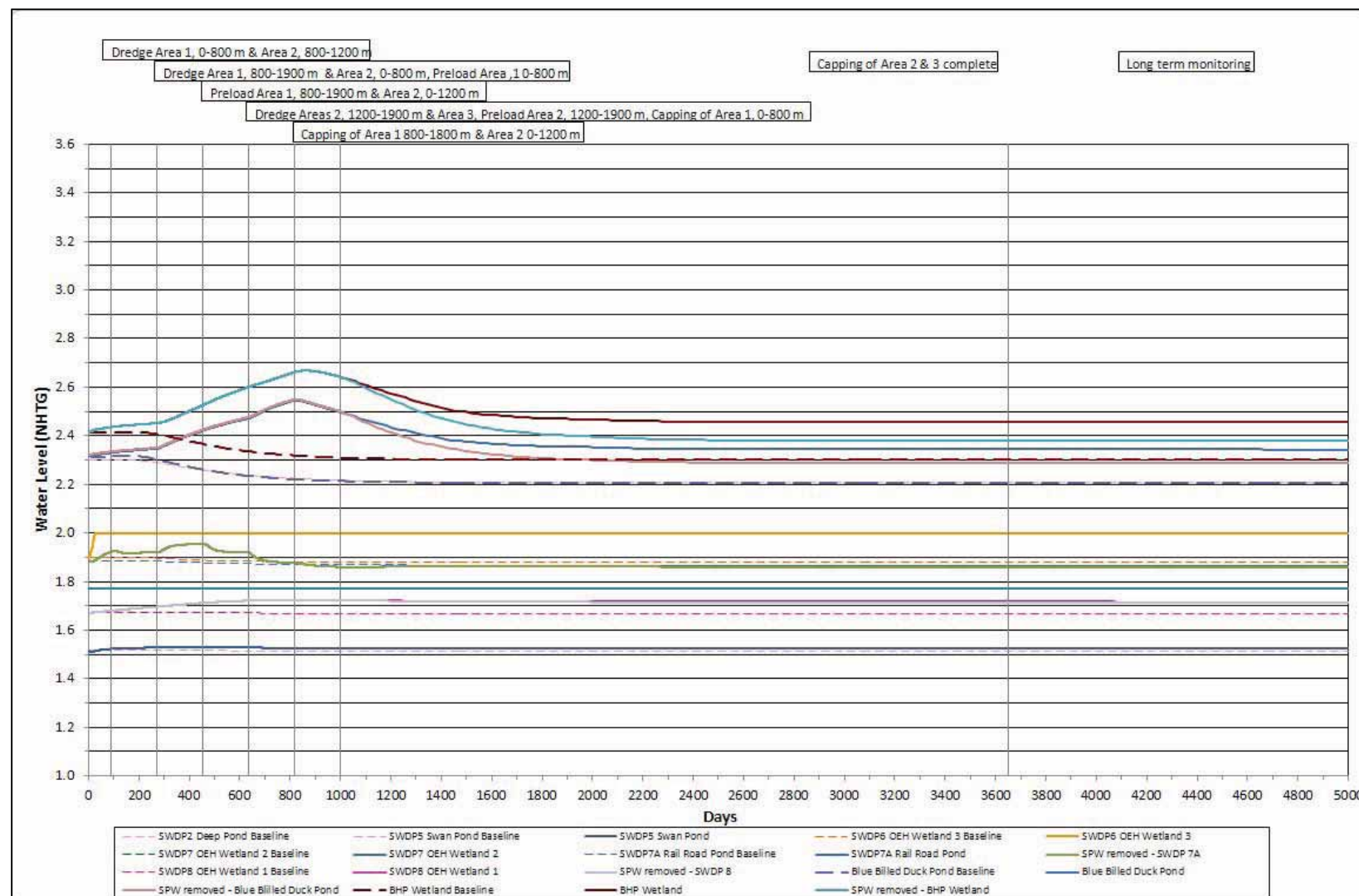


Figure 11: Baseline and Post Development Water Levels for Surface Water Bodies – Indicative Staging Presented

Overall Comparison with Hydrographs from EA Report

The hydrographs presented in Figure 6 to Figure 7 above are broadly similar to those presented in the EA report, however differ slightly due to changes in the development which has been modelled, including incorporation of mitigation measures.

The change of dredging strategy from emplacement of dredge materials across the site as a whole, to emplacement solely within a lined area has resulted in lower heads during the initial dredging stages and therefore less potential for mobilisation of existing contamination as well as reducing the risk associated with saline waters entering sensitive habitats.

Removal of preloading on the southern parts of the site, due to the proposed reduced footprint of the overall development, has removed peaks in head (an associated squeezing flows) for the southern parts of the site and therefore overall.

Inclusion of a PRB on the northern and eastern sides of the site has led to a slight damming effect, and the heads in the Fill Aquifer within the PRB, mostly in the area of the FDF. Although the PRB still lets flows through, the lower overall permeability of the PRB leads to a back-up of water within it. The increased heads lead to slight increases in vertical leakage rates in to the Estuarine Aquifer.

Modelling of a sheet pile wall along the man berth in the Hunter River South Arm has resulted in some changes to the flow regime in the Estuarine Aquifer. Overall there is less flow to the south and increased flow to the north, with more flow from the site now flowing to the north. This change in flow direction leads to a slight increase in the heads within the Estuarine Aquifer, in particular for the long term case, when compared to the No Development Case. This effect on the Estuarine Aquifer does not however represent an overall increase in long term flow rates or mobility of contamination. In fact the final capping proposed for the T4 Project will lead to an overall decrease in overall long term flow rates and mobility of contamination compared to the Existing and No Development Case.

In the case where the swing basin sheet pile walls are removed at the end of construction, the overall impact on heads in the Estuarine Aquifer are reduced, as flow is allowed to the south in the location of the swing basin.

Specific comments with regard to each hydrograph are provided below.

Ponds 5/7 (Site A)

Figure 6 shows similar changes in heads in Ponds 5/7 across the development stages to the previous development scenario presented in the EA Groundwater Assessment (Ref 6). Specific comments are as follows:

- Average groundwater levels in the Fill Aquifer pre development are in the range Reduced Level (RL) 3.5 to 4.5 in Pond 5 and 3.5 to 6.0 NHTG in Pond 7. The modelled peak heads developed in the Fill Aquifer from squeezing due to the placement of the filling are limited by the ground surface elevation, at about RL 10 NHTG. Although this represents a significant increase in heads compared to the existing site conditions, it does not represent an increase in flow rates as flow is constrained by the presence of the proposed barrier wall. Flow which would have otherwise have travelled in the fill aquifer past the extents of the barrier wall, will now be collected by a drainage system within the barrier wall during this period of construction;
- Final heads in the Fill Aquifer are predicted to be of the order of 2 m to 3 m NHTG, significantly less than pre-development due to the provision of site capping. This reduces the potential mobility of any background contamination which may be present in the Fill Aquifer, outside of the proposed Barrier Wall; and
- For the Estuarine Aquifer pre development heads are typically about RL 2.0, with flow from below Ponds 5/7, generally expected to be in a westerly and north-westerly and south-westerly direction. During the construction period the heads increase to a short term peak of about RL 3.3 and more generally less than RL 3.0. Mass balance calculations suggest that flow rates temporary increase by between 35 % and 75% on average over about a 4 year period. This relates to about and additional one to three years of normal pre-development flow, or in other words, it decreases the travel time towards the Hunter River by between one and three years. Therefore there is some risk of short term increases in mobilisation of any existing background contamination. However, as discussed in more detail in Section 4.7, this is offset by the long term reduction in flow rates (and therefore mobility of background contamination) due to capping and is insignificant with respect to the overall flow time to the Hunter River, which are predicted to be in the order of 70 to 140 years, post development.

Contaminant transport modelling of Ponds 5/7 is presented in Section 4.8.2.

Area K7 (Site A)

Figure 7 indicates a similar trend in Area K7, where buried lead dust has been reported, to that of Ponds 5/7. For the construction phases water levels in the Fill Aquifer rising to about RL 8 NHTG to 9 NHTG, followed by a decline following site capping. Long term levels are expected to drop to about RL 3.0 NHTG, below pre-development water levels and also below water levels expected to be achieved from the HDC capping alone.

There is potential for the combination of elevated water levels during preloading and settlement of the filling to lead to saturation of buried lead dust and subsequent leaching of lead into the groundwater. Specific contaminant transport modelling of this scenario is presented in Section 4.8.3.

FDF (Site D)

Figure 8 indicates a similar trend in the FDF to that of K7 and Ponds 5/7, during preloading, however long term heads increase in both the Fill Aquifer and Estuarine Aquifer compared to the existing site conditions and the No Development Case.

The heads increase due to a combination of decommissioning of the existing leachate collection system (which currently maintains groundwater levels in both aquifers to less than RL 2.0) as well as some damming effect from the PRB, which is proposed for the northern and eastern boundaries of the FDF.

The damming effect leads to increased flow towards the south, when compared to the existing site conditions and there is some risk of seepages occurring at the southern toe of the FDF, particularly prior to capping of the site. Specific contaminant transport modelling is presented in Section 4.8.4.

Long term heads in the Estuarine Aquifer are about 0.5 m higher if the swing basin sheet pile walls are left in place (as compared to removing them at completion of construction), as the flow to the south is dammed, forcing the flow towards the north. If the sheet pile walls are removed the long term heads are similar to the no-development case.

Delta (Site C)

Figure 9 represents the predicted variations in ground water levels in the existing fill located below the proposed liner in Site C. The modelling indicates similar trends in heads to K7 and the FDF. The heads in the Estuarine Aquifer during construction range up to about RL 3.3, about 1 m higher than pre-development and therefore there is a temporary increase in the hydraulic gradient towards the Hunter River North Arm.

The temporary increase in flow will lead to some additional mobilisation of background contamination which may be present in this area, in particular Manganese (Mn). Mass balance calculations suggest that flow rates temporary increase by between 35 % and 100% to the north and west and less than 20% to the south, on average over about a four year period. This relates to about and additional one to four years of normal pre-development flow, or in other words, it decreases the travel time towards the Hunter River by between one and four years. Therefore there is some risk of short term increases in mobilisation of any existing background contamination. However, as discussed in more detail in Section 4.7, this is offset by the long term reduction in flow rates (and therefore mobility of background contamination) due to capping and is insignificant with respect to the overall flow time to the Hunter River, which are predicted to be in the order of 70 to 140 years, post development.

K10 (Site B North)

Figure 10 represents the predicted ground water levels in Site B, which is remote from both the dredging and the preloading. The slight response in head in the Fill Aquifer, which occurs during dredging and preloading is not related to increased flow in the Fill Aquifer. On the contrary, it is due to the indirect effect of increases in the Estuarine Aquifer heads, which subsequently lead to reduced leakage from the Fill Aquifer to the Estuarine Aquifer at this point and cause a temporary 'backing up' of the water in the Fill Aquifer. Therefore the hydrographs do not indicate an increased mobility of existing contamination in the Fill Aquifer.

Surface Water Bodies

Figure 11 represents the predicted variations in surface water levels. The figure indicates that the variations in surface water levels for OEH Wetlands 1 to 3 and Rail Road Pond, to the north of the site are expected to vary by about 0.1 m. The water levels in Rail Road Pond are more responsive to change in water level of Deep Pond than for the previous model, due to the increase in hydraulic connectivity incorporated in this model, however this is offset by the presence of the barrier wall and PRB. Much of the groundwater recharge to the pond will come from recharge into granular filling between the existing rail line and the proposed barrier wall.

The figure indicates that for BHP Billiton (BHPB) Wetland and Blue Billed Duck Pond, water levels are expected to drop by about 0.1 m due to the HDC capping (dashed line). This is considered to be mainly due to reduction in heads in the Estuarine Aquifer, increasing vertical leakage, as well as some reduction in flow from the Fill Aquifer to the north. When the impacts of the dredging and preloading are superimposed (solid line) there is a temporary increase in water levels of about 0.25 m (again due to increase in the Estuarine Aquifer Heads), followed by a decrease in water levels, to similar to the pre-development levels.

It is noted that the actual construction sequence may vary from that modelled, however changes to the sequencing of filling and preloading events are unlikely to have significant impact on the additional flows generated due to squeezing from the filling and preloading.

Summary

In summary the hydrographs indicate the following:

- During the dredge emplacement and preloading there are short term increases in the heads in both the Fill Aquifer and the Estuarine Aquifer, commensurate with a temporary increase in flow rates and therefore temporary increase in mobility of existing contamination;
- Once the site is capped, at the completion of construction, for the majority of the site heads in both the Fill Aquifer and Estuarine Aquifer decrease to below the existing site condition and similar to the No Development Case and this is commensurate with a long term reduction in the mobility of existing contamination on site;
- At the FDF groundwater levels are predicted to increase, compared to the current site condition, due to the decommissioning of the existing leachate collection system;
- Construction of the sheet pile wall in the wharf area leads to an increase in Estuarine Aquifer levels, when compared to the skeletal wharf option, however this is not representative of an overall increase in flow rates; and
- Predicted changes in surface water ponds / wetlands are up to about 0.25 m increase during construction and about 0.1 m or less in the long term.

4.6 Final Capped Site

The final capped site was modelled in steady state to replicate an annual recharge rate of 5%, commensurate with the proposed capping strategy (Ref 9) to provide an indication of final groundwater levels and flow rates across the site in the long term. The modelling was undertaken for both cases with swing basin sheet pile wall removed and retained.

It is noted that these contours do not necessarily represent absolute long term groundwater levels, rather they provide an indication of likely typical long term levels. Variations in long term levels can be expected due to variations in climatic conditions and peak groundwater levels at some point in time could be substantially higher.

Plots of the final capped site and Steady State groundwater heads are shown below. Figure 12 and Figure 13 show a comparison of the Fill Aquifer head with swing basin sheet pile wall retained and removed and show little difference in the long term heads. The figures indicate the following:

- There is little difference in Fill Aquifer head with removal of the swing basin sheet pile wall;
- Heads in the Fill Aquifer are increased inside the northern PRB. This is due to a combination of the following:
 - The recharge on the HDC capping was increased to take account of the proposed capping in this area. This is not a T4 development related change;
 - The PRB along the northern boundary will lead to some damming of flow;
 - The barrier wall around Ponds 5 and 7 will also lead to some localised damming of flow; and
 - Increases in the Estuarine Aquifer heads will lead to some increases in Fill Aquifer heads due to secondary effects.
- Typical long term 'average' conditions lead to average residence times within the 2 m wide PRB gates of about 20 to 40 days.

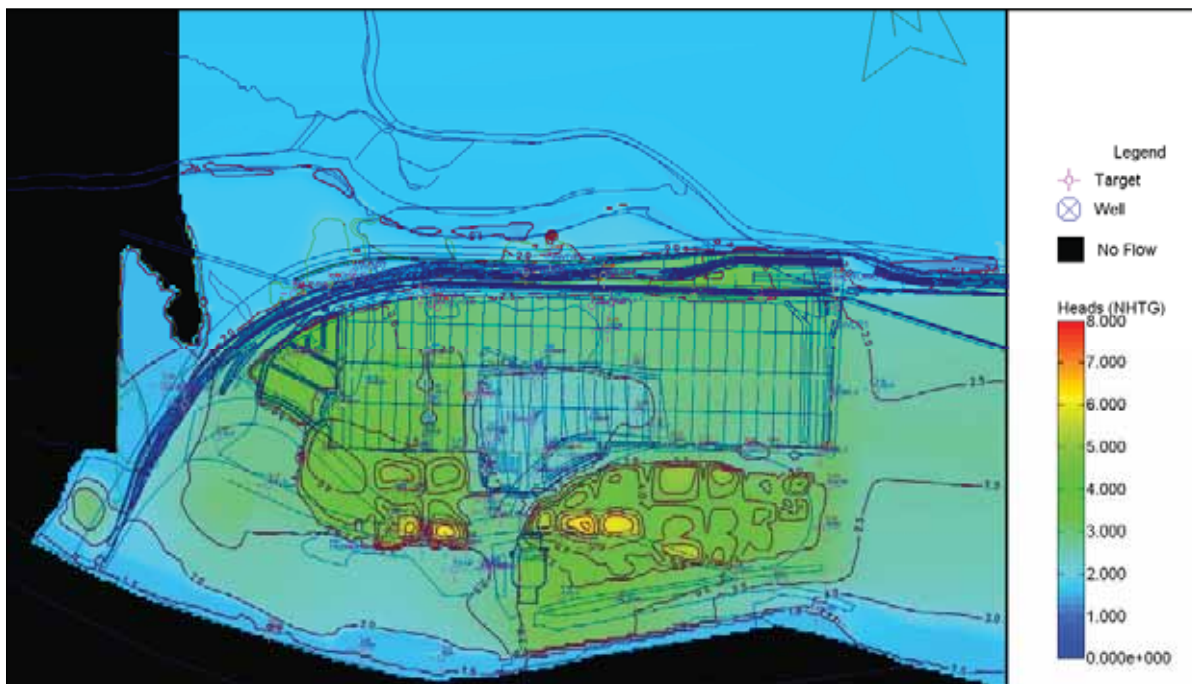


Figure 12: Steady State Fill Aquifer Heads for the Final Capped Site – 5% Annual Rainfall (0.5 m NHTG Contours) – Swing Basin Sheet Pile Wall Retained

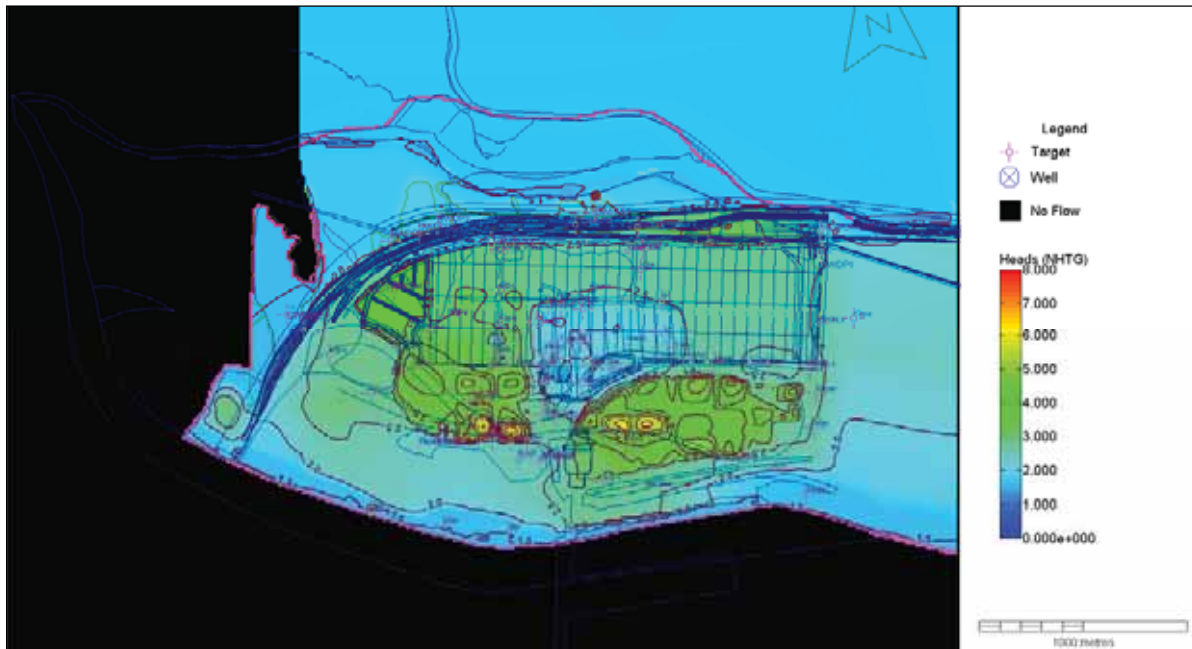


Figure 13: Steady State Fill Aquifer Heads for the Final Capped Site – 5% Annual Rainfall (0.5 m NHTG Contours) – Swing Basin Sheet Pile Wall Removed

Figure 14 and Figure 15 show a comparison of the Estuarine Aquifer head with swing basin sheet pile wall removed and retained.

For the case with the swing basin sheet pile wall retained long term (Figure 14), the wharf and swing basin sheet pile walls divert flow from the eastern parts of the site towards the north and leads to an overall increase in heads on the eastern part of the site. Removal of the swing basin sheet pile wall results less impact to flow direction, although there is some concentration of flow to the south from the FDF towards the swing basin.

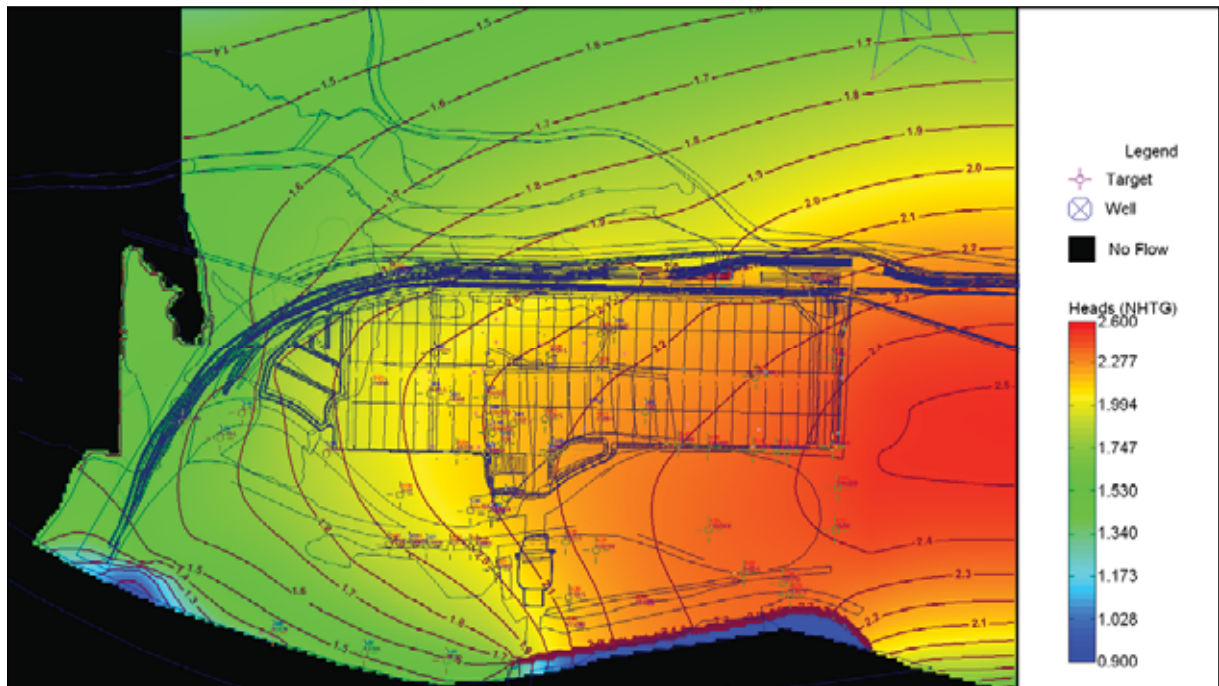


Figure 14: Steady State Estuarine Aquifer Heads for the Final Capped Site – 5% Annual Rainfall (0.1 m NHTG Contours) – Swing Basin Sheet Pile Wall Retained

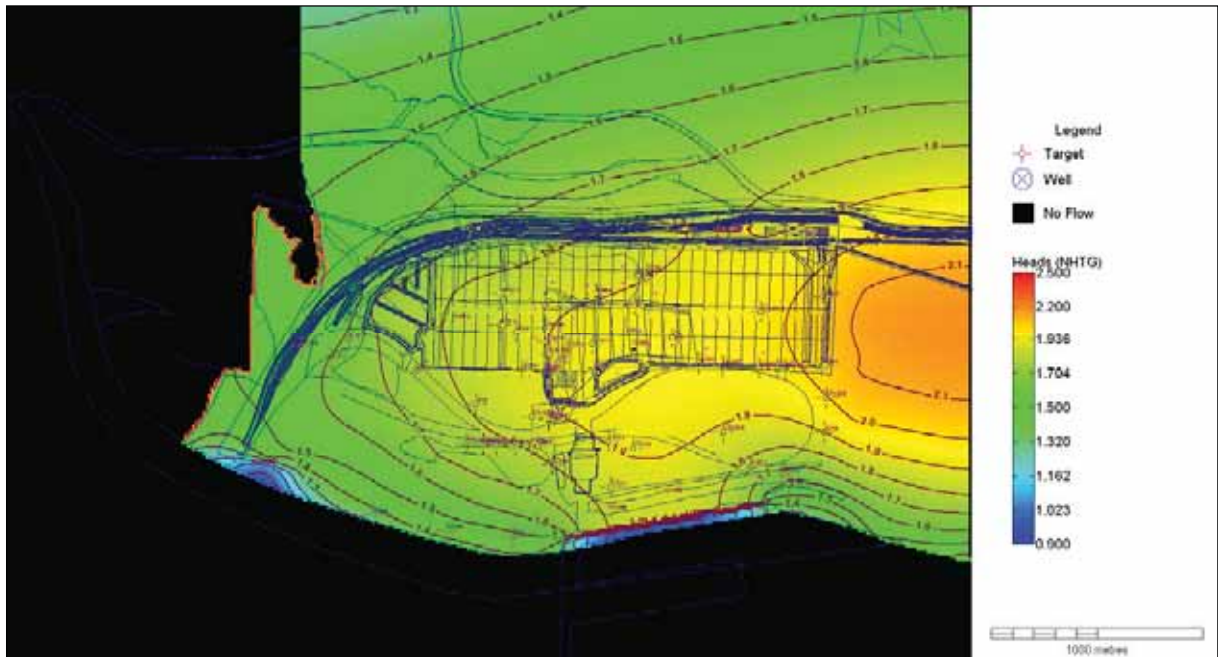


Figure 15: Steady State Estuarine Aquifer Heads for the Final Capped Site – 5% Annual Rainfall (0.1 m NHTG Contours) – Swing Basin Sheet Pile Wall Removed

4.7 Long Term Travel Times

Particle tracking has been used to compare long term particle travel times in the Estuarine Aquifer from the site towards the various surrounding receptors. The modelling was based on an effective porosity of 0.2 for the Estuarine Aquifer.

One of the mitigation measures proposed is capping of the site. This together with lining of Site C (Delta / EMD) will result in significantly reduced long term flow rates in the Estuarine Aquifer, which will in turn lead to reduced mobilisation of any existing background contamination. As no other specific mitigation measures are proposed for the Estuarine Aquifer (as compared to the Fill Aquifer which has Barrier Walls and PRBs proposed), a comparison of long term travel times to various receptors have been undertaken, to demonstrate the effectiveness of the proposed capping strategy in this regard.

Four cases have been assessed for comparison as follows:

- Existing conditions;
- HDC Capping;
- Proposed Development with swing basin sheet pile walls in place; and
- Proposed Development with swing basin sheet pile walls removed following construction.

The results are summarised in Table 7.

Table 7: Comparison of Flow Paths and Long Term Travel Times to Receptors in Estuarine Aquifer

Receptor		North Arm Hunter River	South Arm, Hunter River west of wharf	South Arm, Hunter River east of wharf	Western Model Extent (below Swan Pond)¹
Existing Conditions	Flow Path	Flow from K7 and northern sides of FDF and Delta and Pond 5	Flow from southern end of Pond 5 and western end of Delta	Flow from southern end of FDF and south eastern corner of Delta	Flow from western end of Pond 5
	Travel Time (yr)	60-90	30-50	50-70	30-50
HDC Capping	Flow Path	As above	As above	As above	As above
	Travel Time (yr)	90-120	50-120	70-90	50-100
Proposed Development	Flow Path	As above, some flow now from southern end Delta	As above	As above, no flow from southern end of Delta	As above
	Travel Time (yr)	70-140	60-100	30-100	50-60
Proposed Development – sheet pile wall in swing basin permanent	Flow Path	All of flow from FDF now travels north	As above	No flow to south	As above
	Travel Time (yr)	50-130	40-50	NA	40-60

Notes to Table 7:

1. This is not an actual receptor, rather an artificial boundary. Flow times to the ultimate receptor (probably South Arm Hunter River) would be significantly greater

Table 7 indicates that the proposed HDC capping will lead to longer particle travel times and therefore reduced mobility of existing contamination compared to the existing case. When the proposed development is considered the predicted travel times are generally similar or longer than for the proposed HDC capping indicating a further reduction in mobility, with the exception of flows south from the southern side of the FDF, which are funnelled to the north of the wharf sheet piling.

Long term retention of the sheet pile wall in the swing basin removes the potential flow path from the southern end of the FDF towards the South Arm of the Hunter River and diverts it towards the north, with resulting longer travel times to the North Arm. The presence of this sheet pile wall, leads to overall increased flow rates towards the North Arm from the remaining parts of the site, however these flow rates are still generally longer than those for the existing site condition.

In summary, this modelling demonstrates that the proposed site capping strategy will lead to an overall decreased mobility of existing contamination in the Estuarine Aquifer, compared to the existing site conditions of similar order to the No Development Case. The case with the sheet pile wall removed from the swing basin provides a better overall result, however lead to increased mobility to the south-east towards the swing basin. The influence of this localised increase in flow rates is assessed in more detail in Section 4.8.4.

4.8 Contaminant Transport Modelling

4.8.1 Methodology

Contaminant transport modelling undertaken for the EA Groundwater Assessment was for the purposes of identifying pathways with an unacceptable risk of causing harm to environmental receptors and identification of where mitigation measures were required. The purpose of the modelling, presented in the following sections, was to assess the likely effectiveness of the proposed mitigation measures with respect to managing contamination from identified contamination hot-spots. The key contamination issues and the associated primary mitigation measures are presented in Table 8 below.

Table 8: Key Contamination Issues and Associated Mitigation Measures Modelled

Contamination Hot-Spot	Proposed Mitigation
Polycyclic Aromatic Hydrocarbons (PAH) associated with Ponds 5/7.	Barrier wall in Fill Aquifer around Ponds 5/7.
Lead Dust in K7.	PRB in Fill Aquifer around the northern boundary.
Aluminium in the FDF.	PRB in Fill Aquifer around the northern and eastern boundary.

The model also incorporated other mitigations, put in place to manage salinity during construction, as these have indirect effects on overall groundwater flow, and therefore affect the transport of contamination. These include the following::

- Lining of Area C (Delta/EMD) with low permeability GCL;
- Barrier Wall around the northern and eastern side of Deep Pond;
- Barrier wall at southern end of Easement Pond; and
- Lining of southern batter of Deep Pond.

As discussed in Section 4.4, no modelling is proposed for the LNAPL identified in Site B as this is proposed as both the free phase and dissolved phase plumes are proposed to be directly remediated, as required.

There is considerable uncertainty in the various parameters required for assessment of contaminant transport and therefore the computer program CONSIM (Ref 12) has been used to take account of this. Each input parameter is given a probability distribution. The model is then run many times, each time selecting parameters based on their likelihood (from the individual probability distributions). The results are then presented as a total probability distribution. The process allows the uncertainty to be taken into account and provides an indication of the range of potential outcomes and associated likelihood.

One limitation of CONSIM is that it is based on a fixed constitutive model (as outlined in Ref 12) which involves a series of 1D flow paths and it can be difficult to accurately represent complex geometries and multi directional flows which occur in the Fill Aquifer, due to the PRB and Barrier Wall. Therefore the contaminant transport in the Fill Aquifer was modelled using the transport module of MODFLOW SURFACT.

The modelling of mitigations has been based on a prediction period of 100 years, as this is well beyond the design life of the project (50 years) and the potential influence of external impacts such as climate variations add considerable uncertainty to any predictions over such time.

A probabilistic approach is not possible with MODFLOW SURFACT and therefore the range of potential input parameters and chemical species cannot be directly incorporated into the modelling (as with CONSIM). Therefore the assessments were based on mean concentrations and conservative selection of parameters.

A key parameter with respect to travel distance is dispersivity. For longitudinal dispersivity, this parameter was set to about 10% of the distance to the nearest relevant receptor, which is higher than the methods of Xu and Eckstein (Ref 23) from the "US EPA On-Line Tools for Site Assessment Calculation" and will therefore tend to give an overestimate of the travel distance as compared to Xu and Eckstein. With regard to the vertical dispersivity through the Unit 2 clay, this parameter has been set with respect to the thickness of the clay layer, that being the relevant flow path distance, and an upper bound parameter of about half of the typical layer thickness has been adopted.

The CONSIM constitutive model is still valid for contaminant transport through the Unit 2 clay Aquitard from the Fill Aquifer to the Estuarine Aquifer. The results of flow modelling indicated that small percentage changes in heads and hydraulic gradients obtained from the MODFLOW flow modelling of the revised project layout fall well within the range of modelled parameters. Therefore the previous results of CONSIM modelling for the Estuarine Aquifer at Ponds 5/7 and the FDF are still considered valid and have not been re-modelled. The same models have been used to estimate contaminant concentrations after 100 years, as presented in this report. The results of the more detailed MODFLOW SURFACT also provide information on potential leakage to the Estuarine Aquifer and this augments the CONSIM results.

4.8.2 Ponds 5 / 7

Ponds 5 and 7 are proposed to be contained by a barrier wall, installed across the Fill Aquifer (which contains the source of the contamination) and keyed into the underlying Unit 2 clay.

The EA Groundwater Assessment used the computer program CONSIM to estimate potential migration of contamination and indicated that the key risk was the migration of PAH contamination from Ponds 5 and 7 into the surrounding Fill Aquifer via permeable pathways provided by the slag bund walls. The purpose of the barrier wall is to limit this contamination migration pathway.

The constitutive model of CONSIM does not lend itself to modelling transport through the barrier wall and therefore the contaminant transport in the Fill Aquifer was modelled using MODFLOW SURFACT.

It is noted that a probabilistic approach is not possible with SURFACT and therefore the range of potential input parameters and chemical species cannot be directly incorporated into the modelling (as with CONSIM). The previous CONSIM modelling indicated that the PAH Naphthalene was the most mobile contaminant in the Fill Aquifer and therefore the results of the assessment have been based on this target chemical parameter. Specific details regarding the parameter selection are provided below:

- The source concentration was set at the highest measured groundwater leachate concentration measured in the vicinity of Ponds 5/7 of 0.7 mg/L. This concentration was added as an initial concentration to the fill within the barrier, as well as to any recharge into this area of fill, and to any pore water squeezed from the fill due to placement of fill and preloading;
- The PAH was assumed to be present across the whole areal extent and depth of fill enclosed by the barrier wall. This is an overestimate of the extent of the material;
- An initial concentration was also applied for the area immediately around the barrier wall where some PAH impact has been recorded and this concentration was set at the average of the values recorded in the vicinity of Ponds 5/7 of 0.15 mg/L;
- A partition coefficient of 1.2 L/kg was adopted for adsorption of Naphthalene in sand, based on a published Koc of 1200 L/kg for Naphthalene and a total organic carbon content of 0.1%. These are lower bound values used from the previous CONSIM analyses;
- A partition coefficient of 12 L/kg was adopted for adsorption of PAH in clay, based on the mean a total organic carbon content of 1%, again a lower bound value from the previous CONSIM analyses;
- In the case of the barrier wall, the partition parameters as for the clay were adopted, however were reduced proportionately to account for the geometry of the model grid;
- A partition coefficient of 0 L/kg was adopted in the source zone, based on the conservative assumption that all the fill material is already saturated with respect to naphthalene;
- A longitudinal dispersivity of 1 m was used for transport through the clay, which is an upper bound figure, compared to the layer thickness (flow distance) of about 1 m to 2 m; and
- A longitudinal dispersivity of 25 m was adopted for the sand and granular fill surrounding Ponds 5 and 7, based on the flow distance of about 250 m to the northern wetlands.

The results of the MODFLOW SURFACT modelling are presented in Figure 16 and Figure 17 which provide contours of net increase in concentrations of Naphthalene for the Fill Aquifer and Estuarine Aquifer respectively.

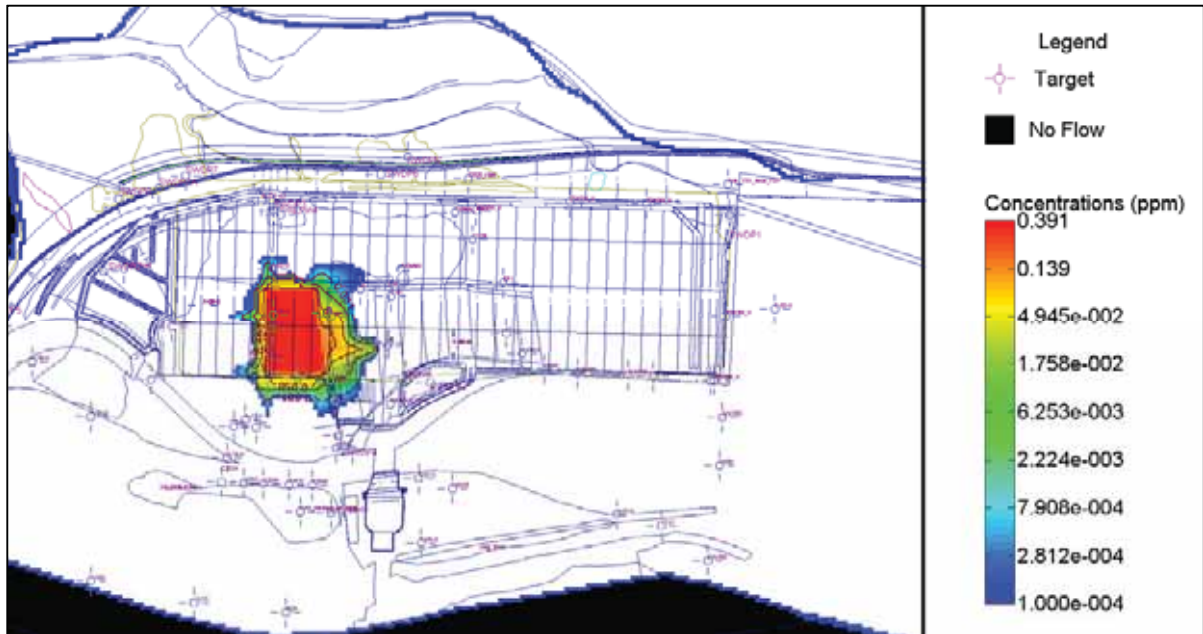


Figure 16: Net Naphthalene Concentration Contours in the Fill Aquifer 100 years After Capping

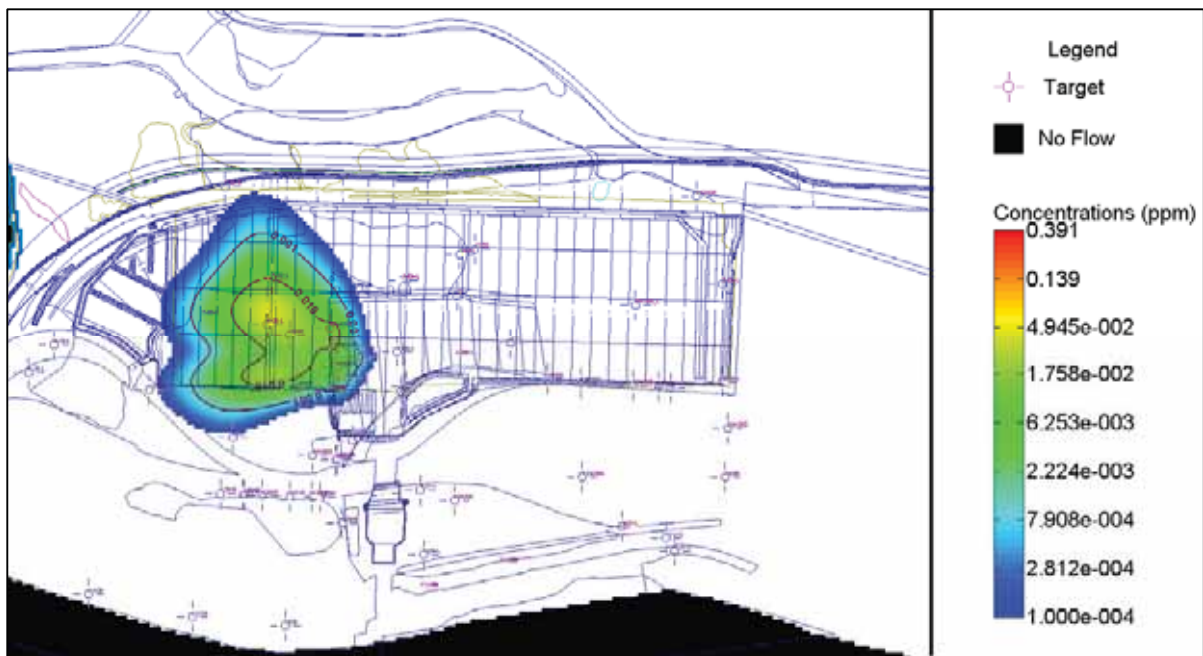


Figure 17: Net Naphthalene Concentration Contours in the Estuarine Aquifer 100 years After Capping

The results indicate that the predicted net impact on Naphthalene concentrations in the Fill Aquifer, immediately beyond the barrier wall are limited to less than about 0.3 mg/L at the end of the 100 year simulation and the extent of the impact is limited, similar to that of the existing extent of elevated groundwater concentrations.

The results also indicate net impacts on the concentrations in the underlying Estuarine Aquifer of about 0.038 mg/L, immediately below the ponds, which reduces to less than about 0.01 mg/L beyond the extent of the barrier wall.

In terms of vertical flow through the Unit 2 clay to the Estuarine Aquifer, a review of the parameters modelled during the previous assessment indicated that the minor changes in heads and hydraulic gradients obtained from the MODFLOW flow modelling of the revised project layout, fall well within the range of modelled parameters and therefore the previous results are considered valid and no changes have been made to this assessment. The previous results, when considered over a period of 100 years indicated the following:

- 50th percentile concentrations at base of clay at 100 years of 0.002 mg/L;
- 95th percentile concentrations at base of clay at 100 years of 0.38 mg/L;
- 50th and 95th percentile concentrations at north arm of the Hunter River at 100 years controlled by background concentrations; and
- The 50th percentile results from the CONSIM assessment are slightly less than the results of the MODFLOW SURFACT analyses as the MODFLOW SURFACT used an upper bound source concentration. The 95th percentile CONSIM results additionally provide an indication of the likely 'worst case' for a range of upper bound parameters.

In summary, the results of the modelling indicated the following:

- The proposed barrier wall around Ponds 5/7 will limit the migration of contamination into the surrounding Fill Aquifer compared to what would otherwise occur without the barrier wall;
- Naphthalene concentrations in the Fill Aquifer immediately around the Barrier Wall are predicted to range up to about 0.3 mg/L, which is greater than the Australian and New Zealand Environmental and Conservation Council (ANZECC) criteria of 0.05 mg/L due to the presence of some existing contamination as well as limited transport through the barrier wall over the long term. The results, however, indicate that the extent of such concentrations are predicted to be limited and are unlikely to extend to any identified environmental receptors in excess of ANZECC criteria; and
- There is some risk of transport of PAH contamination into the underlying Estuarine Aquifer, however the transport of such concentration in the Estuarine Aquifer is predicted to be limited and are unlikely to extend to the Hunter River in excess of ANZECC criteria.

4.8.3 Lead Dust Area

The PRB is proposed along the northern boundary of the Fill Aquifer to protect the wetlands to the north from potential migration of lead solute within the Fill Aquifer, from the K7 lead dust area.

The results of MODFLOW flow modelling of the proposed PRB indicated that a groundwater mound would develop in the area of the lead fines disposal with flow both towards the wetlands to the north as well as towards the Delta EMD site, where the increased leakage to the Estuarine Aquifer acts as a groundwater sink.

Contaminant transport modelling for the lead dust source had not previously been undertaken, due to uncertainty in the extent and leachable concentrations of the source. However, due to the potential flow reversal towards Delta and to assess the potential effectiveness of the PRB, the contaminant transport module of MODFLOW SURFACT has been used to assess the potential flow paths originating from the lead dust. As the leachable concentration and extent of the lead dust is unknown the following assumptions were made:

- The leachable concentration was set to unity (1.0) as an arbitrary source concentration to allow comparison of concentrations occurring across the site as a ratio of the source concentration. This concentration was added as an initial concentration to the fill, as well as to any recharge into this area of fill, and to any pore water squeezed from the fill due to placement of fill and preloading;
- The lead was assumed to be present throughout the entire notified extent of the asbestos cell due to the lack of specific burial details. This is most likely an overestimate of the extent of the materials and therefore conservative;
- A partition coefficient of 0.7 L/kg was adopted for adsorption of lead in sand, based on the lower bound of published values (as summarised in Table 26 of EA Groundwater Report);
- A partition coefficient of 486 L/kg was adopted for adsorption of lead in clay, based on the mean calculated from testing on Unit 1.2 fines on the adjacent site (as summarised in Table 25 of EA Groundwater Report);
- For the low-permeability sections of the PRB (the 'funnels'), the partition coefficient for clay was used, however it was reduced proportionately to account for the model grid size (12.5 m) with respect to the actual width of the barrier (0.8 m), with a partition coefficient of 31.1 L/kg, adopted;
- Similarly within the PRB gates, the partition coefficient for sand was used, however it was reduced proportionately to account for the model grid size (12.5 m) with respect to the actual width of the barrier (0.8 m), with a partition coefficient of 0.112 L/kg, adopted;
- A partition coefficient of 0 L/kg was adopted in the source zone, based on the conservative assumption that all the fill material is already saturated with respect to lead;
- A longitudinal dispersivity of 25 m was adopted for horizontal flow through the Fill and Estuarine Aquifers, based on the flow path length to OEH Wetland 3. Longitudinal dispersivity of 1.0 was adopted for sub-vertical flow through the Unit 2 clay layer, which is an upper bound, based on the layer thickness in the range 3 m to 4 m;
- A longitudinal dispersivity in the PRB clay walls of 25 m was also adopted, based on the conservative assumption that the PRB walls could be breached; and
- Potential treatment of the lead solute in the PRB was simulated by applying chemical attenuation using a half-life of two days.

It is noted that a probabilistic approach is not possible with MODFLOW SURFACT and therefore the range of potential input parameters and chemical species cannot be directly incorporated into the modelling (as with CONSIM). Therefore the assessment was limited to lead which is the critical parameter.

The highest flows in this area will occur during the initial preloading and in order to avoid constraining some of this one-off flow through the PRB to the north it is proposed to delay lining of the eastern side of Deep Pond until after the preloading. Therefore modelling was undertaken to assess the potential for contaminant transport from the lead dust area during this critical pre-load period, in particular towards Deep Pond to the west. For this case, in order to account for uncertainty in the partitioning coefficients, the model was first run with no adsorption (i.e. the lead is not free to leave solution and 'adsorp' to the surface of the soil), which would be expected to be a worst case and then for the absorption using the partitioning coefficients above, which is expected to be a more realistic scenario.

Figure 18 and Figure 19 show the distribution of contamination around K7 at the completion of preloading for no adsorption and adsorption cases. The results of the analyses indicated concentrations reaching the PRB of less than 10% and 0.1% for the no adsorption and adsorption cases, respectively. At Deep Pond the relative concentrations are less than 0.1% of the source concentration for both cases. This indicates that the risk of lead contamination reaching Deep Pond prior to construction of the liner on the western batter is very low. Similarly the risk of concentrations requiring treatment reaching the PRB within the period of preloading is also low.

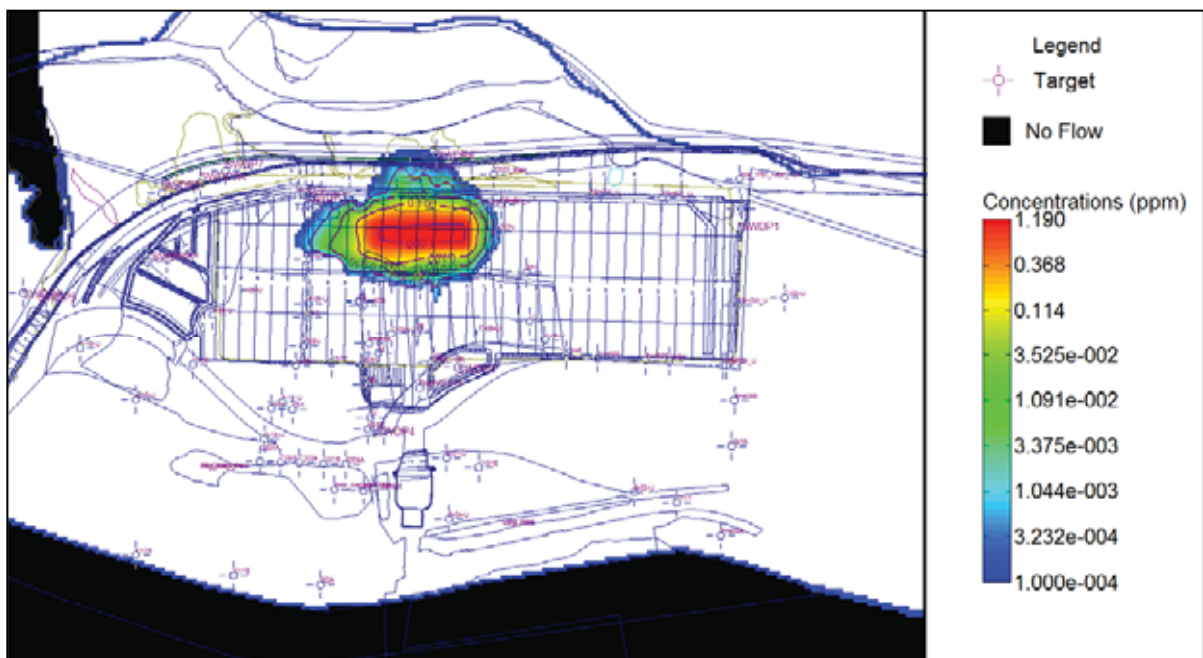


Figure 18: Relative concentration of Lead in Fill Aquifer at end of Preloading with No Adsorption

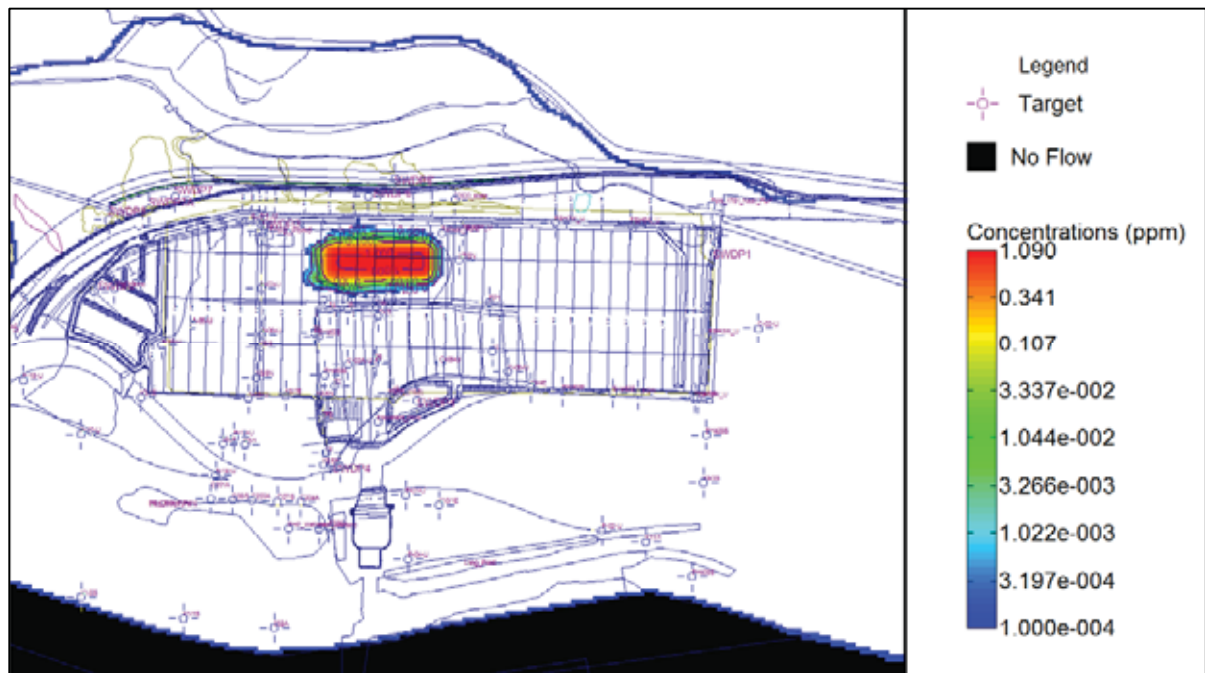


Figure 19: Relative Concentration of Lead in Fill Aquifer at end of Preloading with Adsorption

For the long-term case the modelling has allowed for adsorption for all cases. Modelling has been conducted with and without treatment in the PRB gates to demonstrate the potential effect of the PRB treatment.

Net concentrations of Lead in the Fill Aquifer and Estuarine Aquifer at 100 years following capping of the site, without treatment in the PRB gates are presented in Figure 20 and Figure 21.

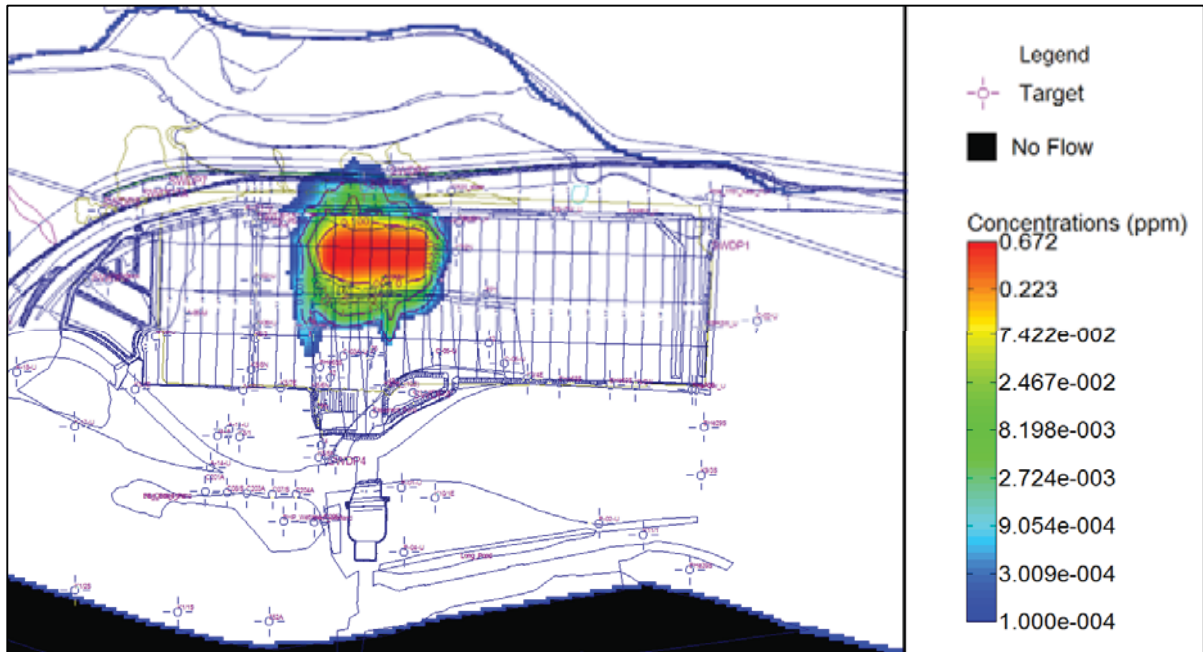


Figure 20: Lead Concentration Contours in the Fill Aquifer 100 years After Capping of Site with No Treatment in PRB

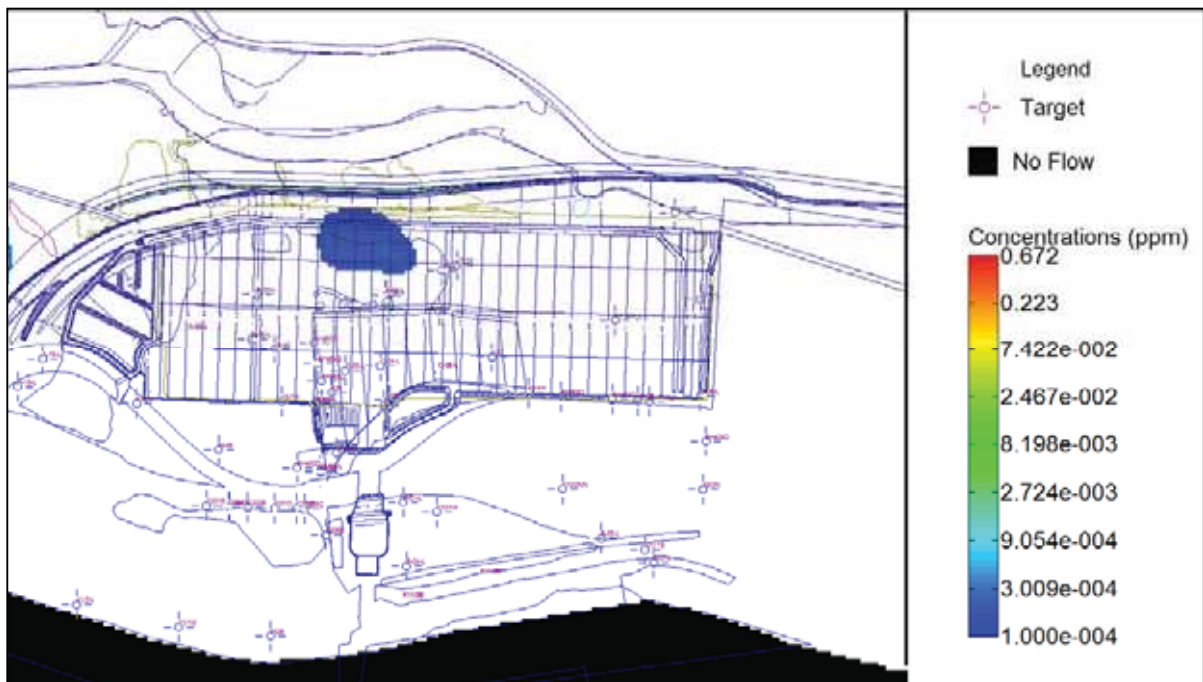


Figure 21: Lead Concentration Contours in the Estuarine Aquifer 100 years After Capping of Site with No Treatment in PRB

The results of the modelling indicated that the primary lead transport pathway is through the Fill Aquifer towards the wetlands to the north with some flow to the south, west and east, within the site boundaries. Concentrations reaching the PRB gates are in the order of 3.5% of the source concentration, and subject to simulated treatment in the PRB gates, concentrations reaching the wetlands are in the order of about 0.1% of the source concentration after 100 yrs.

These relative concentrations cannot be compared directly to the ANZECC 2000 criteria of 0.0044 mg/L, without knowing the source concentration, however the results suggest that it is possible that such concentrations could be exceeded at the PRB gates if the source leachable concentration is 0.12 mg/L or higher confirming that treatment may be required in the PRB gates.

For the Estuarine Aquifer the pathway is for transport vertically down through the Clay Aquitard and then flow in the Estuarine Aquifer towards the Hunter River. Concentrations reaching the Estuarine Aquifer immediately below the source are below 0.02% of the source concentration.

Estimated groundwater residence times in the PRB gates over the long term are estimated to be about 20 to 40 days, which is expected to be suitable to allow treatment of lead solute, if required. Figure 22 and Figure 23 show the results when treatment is included in the PRB gates, designed to limit the concentrations to the north of the gates to below 0.1% and less than 0.01% at the wetlands to the north. There is little change to the concentrations in the Estuarine Aquifer, which were already very low on a percentage basis.

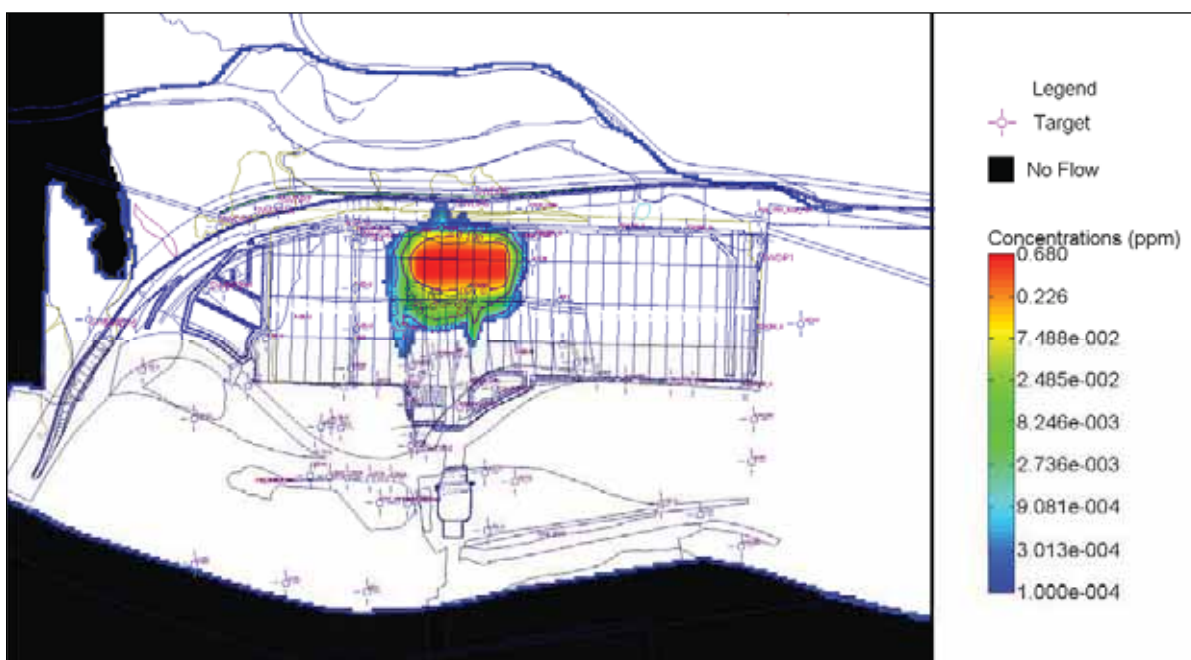


Figure 22: Lead Concentration Contours in the Fill Aquifer 100 years After Capping of Site, with Decay in the PRB Gates due to Chemical Reactions, Dispersion and Sorption



Figure 23: Lead concentration Contours in the Estuarine Aquifer 100 years After Capping of Site, with Decay in the PRB Gates due to Chemical Reactions, Dispersion and Sorption

In order to account for the uncertainty in the transport parameters, a CONSIM model was developed to replicate the key pathway to the Estuarine Aquifer. This approach was similar to that used in the EA Groundwater Report. In order to account for the uncertainty in the source concentration, a triangular distribution for the source concentration was used, ranging from 0.1 to 10 mg/L, with a best estimate of 1 mg/L. The Unit 2 clay thickness was also varied from 0.5 m to 4 m in order to account for possible unobserved variations in the thickness. The vertical dispersivity in the clay layer was in the range 0.14 to 6.5. The results indicated the following:

- 50th percentile concentrations at base of clay at 100 years within background concentrations (0.0005 mg/L);
- 95th percentile concentrations at base of clay at 100 years of 0.1 mg/L (10% of source concentration) mg/L;
- 50th percentile concentrations at northern boundary at 100 years within background concentrations; and
- 95th percentile concentrations at northern boundary at 100 years of 0.009 mg/L, compared to the ANZECC criteria of 0.0044 mg/L and several orders of magnitude lower at the northern arm of the Hunter River.

In summary of the modelling results indicated the following:

- The source concentration is unknown and therefore an arbitrary 'unit' concentration was adopted. It is possible that the source concentration could exceed this arbitrary concentration in places, however it is very unlikely that the extent of lead is as great as was modelled;
- Concentrations of leachate are very unlikely to reach Deep Pond during construction, prior to the lining of Deep Pond;
- Concentrations may reach the northern boundary during construction, and in the long term, hence treatment via the PRB may be required to limit concentrations to below ANZECC prior to reaching the wetlands to the north;
- There is some risk of transport of lead contamination into the underlying Estuarine Aquifer, however the presence of the Clay Aquitard is predicted to substantially limit such transport. The probabilistic analysis, which accounts for a possible range of source concentration up to a maximum of 10 mg/L, which is at the upper range of likely source concentrations, indicates that it is unlikely that concentrations at the Northern Site Boundary will exceed background concentrations and concentrations at the Hunter River north arm would be several order of magnitude less, limiting the potential for environmental harm, even if source concentrations are greater than modelled.

4.8.4 FDF

Previous contaminant transport modelling for the FDF indicated the potential for leaching of various metals as well as benzo(a)pyrene through the sand drainage layer at the base of the FDF and towards the northern wetlands. The results also indicated that vertical leaching through the Unit 2 clay would be limited.

A PRB is proposed to intercept and treat water leaching from the FDF in the Fill Aquifer towards the wetlands to the north.

The results of MODFLOW modelling of the proposed PRB indicated that a groundwater mound would develop in the centre of the FDF with flow radiating out both towards the OEH wetlands (via the PRB), to the east of the site (KCT) and possibly towards Delta EMD to the west. There is also potential for seepage of groundwater from the base of the southern batter slope, to a low lying area to the south of the FDF.

The contaminant transport module of MODFLOW SURFACT has been used to assess the potential flow paths originating from the FDF. The previous CONSIM modelling indicated that Aluminium was the most mobile contaminant and therefore assessment has been based on this chemical parameter. Specific details regarding the parameter selection are provided below:

- The source concentration was set at the average measured leachable concentration of Aluminium within the FDF of 2.26 mg/L, which is based on ASLP testing and is considered to be an over-estimate of the actual in-situ leachability, however has been used in the absence of more specific data. This concentration was added as an initial concentration to the fill, as well as to any recharge into this area of fill, and to any pore water squeezed from the fill due to placement of fill and preloading;
- The Aluminium was assumed to be present throughout the FDF. This is likely to be an overestimate of the extent of the contaminant;
- A partition coefficient of 2.5 L/kg was adopted for transport of Aluminium in clay and 0.7 L/kg in sand. These are typical values used from the previous CONSIM analyses, which were already considered to be lower bound values, however were adopted in the absence of site specific data for aluminium;
- A partition coefficient of 0 L/kg was adopted in the source zone, based on the conservative assumption that all the fill material is already saturated with respect to aluminium;
- A partition coefficient of 0 L/kg was adopted in the PWCS and NCIG coal stockpile areas, based on the assumption that the clay layer has been perforated by wick drains or granular columns;
- A longitudinal dispersivity of 0.5 m was used for transport through the clay, which is an upper bound figure, compared to the layer thickness (flow distance) of about 1 m to 2 m;
- A longitudinal dispersivity of 25 m was adopted for the sand and bund material, based on the flow distance of about 250 m to the northern wetlands; and
- Potential treatment of the lead solute in the PRB was simulated by applying chemical attenuation using a half-life of 1.5 days, to simulate treatment such that concentrations are less than the relevant ANZECC 2000 criteria immediately downstream of the gates.

The analyses were undertaken for two cases as follows:

- Swing Basin Sheet Pile Wall Retained: Swing basin sheet pile wall left in place long term, leading to all flow in Estuarine Aquifer from below the FDF towards the north; and
- Swing Basing Sheet Pile Wall Removed: Swing basin sheet pile wall removed at completion of construction, providing a flow path to the south.

The resulting contours of net increase in concentrations of Aluminium after 100 years for swing basin sheet pile wall retained case are presented in Figure 24 and Figure 25 below for the Fill Aquifer and Estuarine Aquifer respectively.

The results of the modelling indicate the following with respect to the Fill Aquifer:

- Flux occurs to the north, through the PRB, however concentrations reaching the wetlands to the north are well below the ANZECC 2000 criteria of 0.055 mg/L;
- Flux occurs to the east through the PRB and therefore concentrations to the east are limited to ANZECC criteria;
- The slight damming effect of the PRB leads to some flux to the south with concentrations of up to about 0.1 mg/L potentially seeping out of the toe of the batter; and
- There is some transport to the south and west, however the concentrations are relatively low compared to the ANZECC 2000 criteria of 0.055 mg/L, with concentrations of about 0.001 mg/L reaching Easement Pond.

Flux of contaminants past the western boundary of the FDF is not expected to impact on existing surface water bodies, however some surface seepage may emanate from the toe of the southern batter. If required, the flux past the southern boundary could be managed by extension of the PRB or a barrier wall on the southern boundary.

For the Estuarine Aquifer the pathway is for transport vertically down through the clay Aquitard and then flow in the Estuarine Aquifer towards the Hunter River, mostly to the north. Concentrations reaching the Estuarine Aquifer immediately below the source typically range up to about 0.1 mg/L, however attenuate away from the source and are generally less than 0.05 mg/L within the footprint of the FDF.

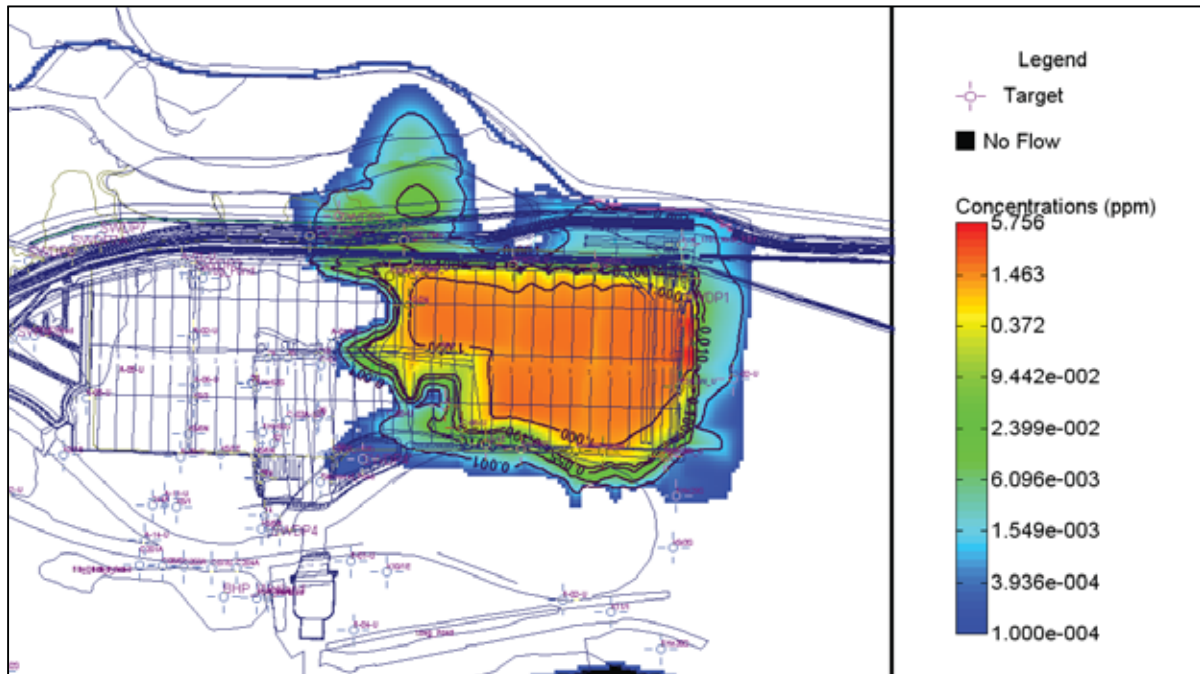


Figure 24: Net Aluminium Concentration Contours in the Fill Aquifer 100 years after capping of the Site, with Decay within the PRB Gates, Dispersion and Sorption (Eastern PRB, Swing Basin Sheet Pile Wall Retained)

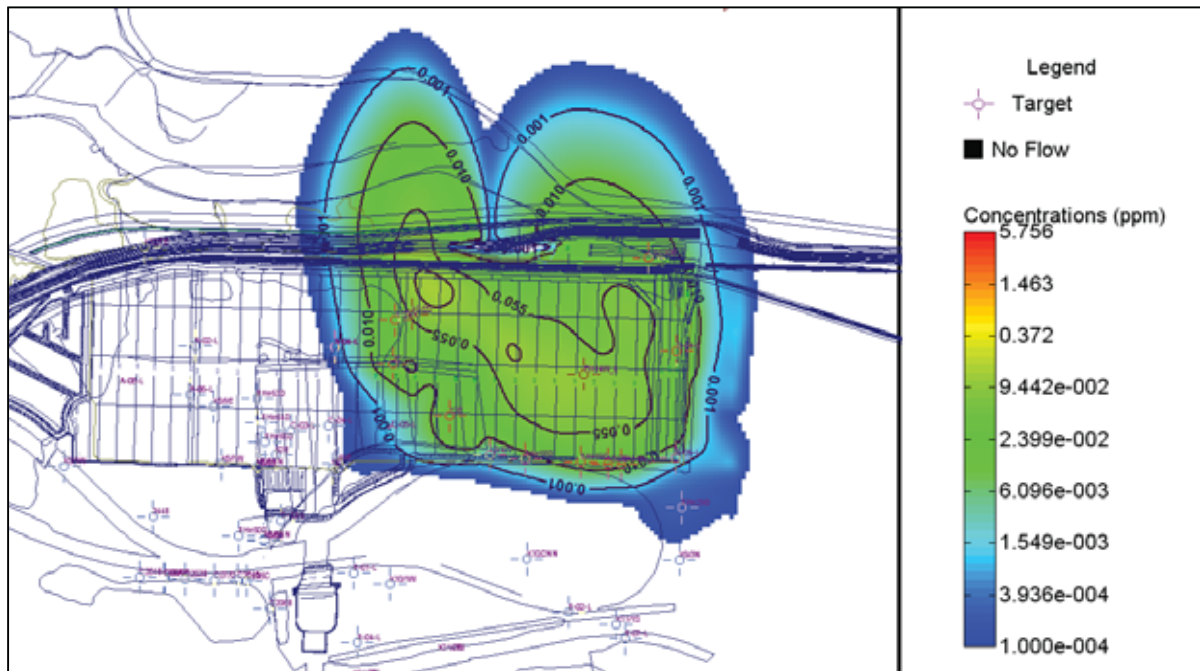


Figure 25: Net Aluminium Concentration Contours in the Estuarine Aquifer 100 years After Capping of the Site with Decay within the PRB Gates, Dispersion and Sorption (Eastern PRB, Swing Basin Sheet Pile Wall Retained)

The resulting contours of net increase in concentrations of Aluminium after 100 years for swing basin sheet pile wall removed case are presented in Figure 26 and Figure 27 below for the Fill Aquifer and Estuarine Aquifer respectively.

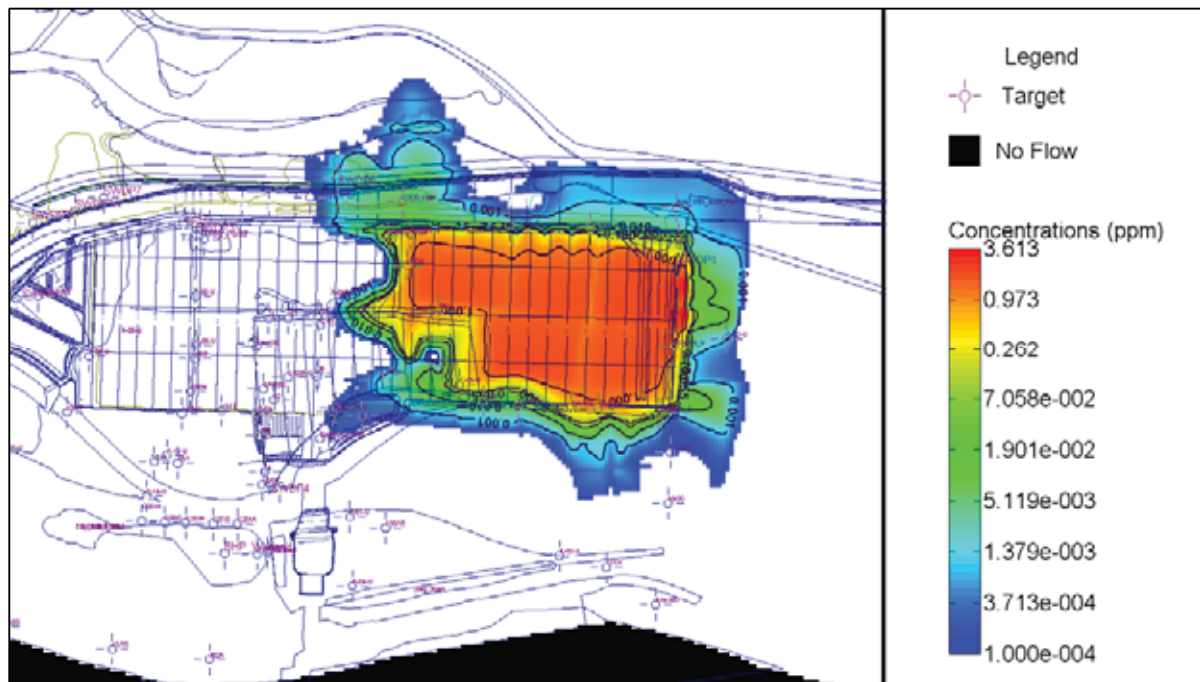


Figure 26: Net Aluminium Concentration Contours in the Fill Aquifer 100 years After Capping of the Site, with Decay within the PRB Gates, Dispersion and Sorption (Swing Basin Sheet Pile Wall Removed)

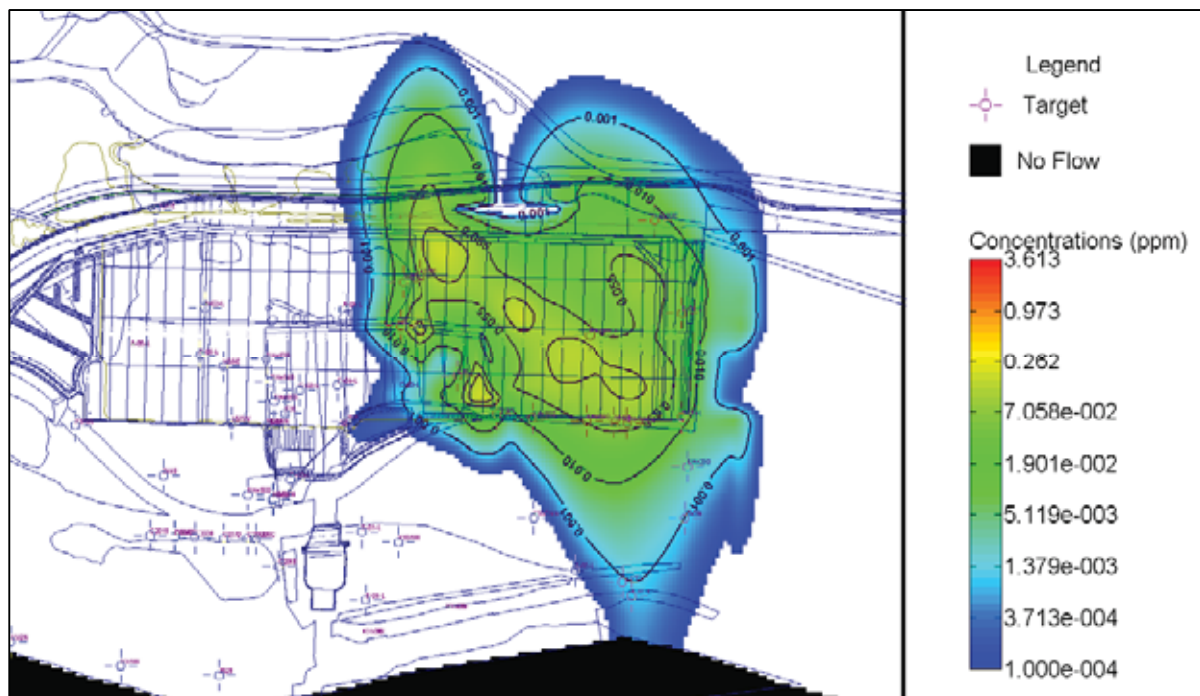


Figure 27: Net Aluminium Concentration Contours in the Estuarine Aquifer 100 years After Capping of the Site with Decay within the PRB Gates, Dispersion and Sorption (Eastern PRB, Swing Basin Sheet Pile Wall Removed)

The results of the modelling with the swing basin sheet pile wall removed indicate similar results for the Fill Aquifer. Flow in the Estuarine Aquifer is towards the Hunter River, both to the north and south. Aluminium concentrations reaching the Estuarine Aquifer immediately below the source typically range up to about 0.1 mg/L, however attenuate away from the source and are generally less than 0.05 mg/L within the footprint of the FDF.

Groundwater heads within the FDF resulting from modelling the current development, which includes the PRB, indicate slightly higher groundwater heads within the FDF and slightly higher hydraulic gradients within the underlying Estuarine Aquifer. A review of the parameters modelled during the previous assessment indicated that the minor changes in heads and hydraulic gradients obtained from the MODFLOW flow modelling of the revised project layout, fall well within the range of modelled parameters and therefore the previous results are considered valid and no changes have been made to this assessment.

The previous results of modelling, when considered over the same 100 yr time scale, indicated the following:

- 50th percentile concentrations at base of clay at 100 years of 0.16 mg/L;
- 95th percentile concentrations at base of clay at 100 years of 3.2 mg/L;
- 50th percentile concentrations at Hunter River at 100 years controlled by background concentrations;
- 95th percentile concentrations at North Arm Hunter River at 100 years controlled by background concentrations i.e. no breakthrough in 100 years; and
- 95th percentile net increase in concentrations at South Arm of 0.05 mg/L. All other chemical parameters for flow to the south were controlled by background concentrations.

The 50th percentile results from the CONSIM assessment are of a similar order to the results of the MODFLOW SURFACT analyses, with the CONSIM additionally providing an indication of the likely 'worst case'.

In summary of the modelling results indicate the following:

- Concentrations may reach the northern boundary during construction, and in the long term, hence treatment via the PRB may be required to limit concentrations to below ANZECC prior to reaching the wetlands to the north and the KCT site to the east;
- There is some risk of seepage emanating at the southern toe of the FDF with aluminium concentrations in excess of ANZECC; and
- There is some risk of transport of aluminium into the underlying Estuarine Aquifer, however the presence of the Clay Aquitard is predicted to substantially limit such transport. Concentrations of aluminium may exceed ANZECC criteria below the FDF site, however are unlikely to extend to the Hunter River in excess of ANZECC criteria.

4.9 Conclusions – Contaminant Transport Modelling

The results of modelling of the proposed mitigation measures are summarised as follows:

- The modelling of contaminant transport from the Fill Aquifer to the Estuarine Aquifer previously undertaken for the FDF and Ponds 5/7 is considered to still be valid as the previous modelling allowed for a wide range of possible parameters to account for uncertainty and the small changes in leakage and flow rates fall well within the range of parameters used. The results of this modelling indicate that concentrations reaching the Hunter River within 100 years are unlikely to exceed ANZECC criteria or background concentrations;
- Additional contaminant transport modelling has been undertaken to assess the proposed Barrier Wall around Ponds 5/7 and the results indicated that an appropriately designed and installed barrier wall can limit future migration of PAH contamination to the surrounding Fill Aquifer;
- Contaminant transport modelling has been undertaken to assess the potential for migration of Lead from K7 in the event that lead leaches into the groundwater (less likely in the short term and more likely in the long term). The results indicated that the risk of lead reaching Deep Pond would be very low during the preloading process. There would be a higher risk of lead reaching the northern boundary during the preloading period, however the PRB will be in place by this stage. In the long term there is some residual risk associated with lead contamination being transported to the Estuarine Aquifer. This risk is difficult to quantify as the leachable concentration and extent of the lead is unknown, however the results suggests very limited mobility through the Unit 2 clay Aquitard and into the Estuarine Aquifer and further limited mobility within the Estuarine Aquifer with a low risk of concentrations reaching the Hunter River within 100 years; and
- Additional contaminant transport modelling has been undertaken to assess the potential flow paths for transport of Aluminium contamination from the FDF with the PRB in place and actively treating flow to the north of the FDF. The modelling indicates that an appropriately designed PRB can limit the concentration of leachate reaching surface water receptors. The final extent of the PRB should be subject to detailed design and it may be necessary to extend the PRB along the southern batter of the FDF.

The final design, location and extent of the barrier wall and PRB should be subject to appropriate detailed design, construction and maintenance. Detailed design should include supplementary targeted investigations and remediation trials to confirm hydraulic parameters and verify chemical performance of the proposed Barrier Walls and PRBs. Additional modelling is likely to be required at this stage to confirm the final detailed arrangement of the mitigation measures.

5. Summary and Conclusions

This report provides an assessment of proposed mitigation measures for groundwater contamination, for the T4 Project. The assessment also takes into consideration the design changes to the T4 Project since the EA was lodged.

DP prepared five reports that formed part of the EA covering matters related to contamination, groundwater and remediation. The report has assessed the effects of the design changes on the previous work, most notably the groundwater modelling in the Groundwater Assessment report.

It was assessed that four design changes affected DP's previous work in relation to contamination, groundwater and remediation, including:

- Changed construction schedule;
- Revision to stockyard size and layout;
- Different dredging and reclamation plan; and
- Changed water management configuration.

Additional groundwater and contamination modelling has been undertaken for the following proposed mitigation measures:

- Barrier wall around Ponds 5 and 7;
- Barrier wall around northern side of Deep Pond;
- Low permeability liner on southern side of Deep Pond;
- Lining of the eastern batters of Deep Pond to form water treatment ponds;
- Barrier wall to south of Easement Pond;
- (PRB) along northern side of site;
- (PRB) along eastern site of site; and
- Low permeability GCL liner in Site C (Delta).

The primary project goal for the contamination assessment of the T4 Project is to protect off-site receiving environment from unacceptable impacts. These environments include adjacent landholdings, the South Arm of the Hunter River, wetlands of the Hunter Wetlands National Park and the ecological attributes which characterise these areas. A secondary objective is to implement a land use option which effectively minimises exacerbation and reduces the long term risks posed by the legacy contamination on the site.

Development of the T4 Project provides an opportunity for PWCS to develop a heavily contaminated site which currently has no beneficial use. The aim is to understand the contamination risks and identify mitigation measures to prevent or minimise potential impact, which will facilitate safe use of the T4 Project area and long-term protection of the environment.

The results of the assessment indicate that the proposed mitigation measures can lead to an overall reduction in the potential for mobilisation of existing legacy contamination, compared to the existing site conditions. The groundwater concentrations reaching the off-site receiving environment, including the Hunter River and wetlands of the Hunter Wetlands National Park, within 100 years, are predicted to be less than the relevant Australian and New Zealand Environmental and Conservation Council (ANZECC) criteria or background concentrations. Subject to appropriate detailed design and construction of the required mitigation measures, it is expected that these measures will protect the off-site receiving environment from unacceptable impacts.

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7. Limitations

DP has prepared this report for the T4 Project at KI in accordance with DP's proposal NCL120189 dated 8 May 2012 and Consultancy Agreement with PWCS dated 4 August 2010. The report is provided for the exclusive use of PWCS for this project only and for the purpose(s) described in the report. It should not be used for other projects or by a third party. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be limited by undetected variations in soil conditions between sampling locations. The advice may also be limited by constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

Douglas Partners Pty Ltd

Appendix A

About this Report

About this Report

Douglas Partners



Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;

- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.