

Modelling Shallow Groundwater - Lot 1001 Tomago

For Proposed Northbank Enterprise Hub Business and Industrial Park

Prepared for:
ADW Johnson Pty Ltd

On behalf of:
Northbank Enterprise Hub Pty Ltd

Prepared by:
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Date:
23 August 2012

Project Number:
AS130310

ENVIRON

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VERSION CONTROL RECORD

Document File Name	Date Issued	Version	Author	Reviewer
AS130310_modelrep1	15 August 2012	Draft 1	SC	FR
AS130310_modelrep1	21 August 2012	Final	SC	FR
AS130310_modelrep1	23 August 2012	Final_1	SC	FR

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Executive Summary

The following report presents the hydrogeological review and numerical groundwater flow modelling conducted by Environ Australia Pty Ltd (Environ) to assess the proposed development of Lot 1001 (DP 1127780), Tomago, NSW (“the site”), as an industrial/business park. The proposal will amend the current site drainage and will require earthworks to raise up to 160 ha of the land area to the 100 year flood level.

The site is located to the north-west of a SEPP 14 wetlands reserve managed by NSW Parks and Wildlife, and further conservation lands currently being rehabilitated back to a saltwater estuarine environment/habitat as part of the overall Tomago Wetland Swamp Rehabilitation Project.

Initial responses to approvals submissions included a request from the NSW Office of Water (NOW) to provide:

- an assessment of groundwater conditions (on the site and adjacent SEPP14 wetlands), including groundwater flow conditions; and
- an assessment of the potential impacts of the proposal including mitigation measures and mitigation action threshold criteria.

Data from previous site investigation reports was reviewed and this information was used to construct a conceptual hydrogeological model of the site and surrounds. A three-dimensional finite difference numerical model (MODFLOW) was used to model current groundwater conditions and to predict changes to the groundwater flow regime following site development.

Modelling objectives included: the definition of current hydrogeological conditions for the site; the prediction of changes in shallow groundwater conditions on the site following the proposed development of Lot 1001; and an assessment of potential impacts on the neighbouring wetlands area.

The model was calibrated against observed water levels and model properties adjusted to reflect site development. Groundwater flow conditions were then assessed under the simulated development model and compared with existing site conditions.

The following conclusions were drawn from the results of the modelling:

- the proposed development will not impact measurably on the groundwater flow relationship between the site and the wetlands, given that the flow from the project site represents only 5% of the groundwater recharge within the wetland footprint;
- no measurable change in the groundwater potentiometric surface within the wetland was predicted by the model simulation; and
- as a contingency, a programme of groundwater monitoring (pre-development and during development) and review of trends in groundwater levels will be implemented as part of the Statement of Commitments to develop the site.

1 Introduction

1.1 Background

Please find the following report presenting results of an Environ Australia Pty Ltd (Environ) hydrogeological review and numerical groundwater flow modelling conducted to assess impacts that may result from the proposed development of Lot 1001 (DP 1127780), Tomago, NSW ("the site"), as an industrial/business park.

The approximately 240 ha site is located on the southern side of Tomago Road, immediately to the east of the Tomago aluminium smelter and is currently undeveloped. Immediately to the south-east is a SEPP 14 wetlands reserve within Lot 1002 conservation lands and further conservation lands, currently being rehabilitated back to a saltwater estuarine environment/habitat as part of the overall Tomago Wetlands Rehabilitation Project.

The site is shown in **Figure 1.**

Environ understands that the development of the site will require initial earthworks to raise up to 160 ha of the land area to the 100 year flood level, to allow subsequent construction. Planning approvals are currently being sought for the works and are being coordinated by ADW Johnson Pty Ltd (ADW) for Northbank Enterprise Hub Pty Ltd (NEH), the site developers.

Among the initial responses to submissions is a request from the NSW Office of Water (NOW) to provide:

- an assessment of groundwater conditions (on the site and adjacent SEPP14 wetlands), including groundwater flow conditions; and
- an assessment of the potential impacts of the proposal including mitigation measures and mitigation action threshold criteria.

This report presents a review of geological and hydrogeological conditions for the site, based on previous investigations, conducted mainly by Douglas Partners Pty Ltd (Douglas Partners), in a 2011 study (Reference 1).

Results of the review were used to construct a conceptual hydrogeological model of the site and surrounds, subsequently translated into construction of a three-dimensional finite difference numerical model (MODFLOW) used to model current groundwater conditions and to predict changes to the groundwater flow regime following site development.

1.2 Objectives

The objectives of this modelling study were to:

- Define the current hydrogeological conditions for the site;
- Predict the changes in shallow groundwater conditions on the site following the proposed development of Lot 1001, and assess potential impacts on the neighbouring wetlands area (Lot 1002); and
- To identify contingency monitoring and management measures as required.

1.3 Scope of Work

The following scope of work was undertaken as part of this study:

- Review of existing site data, in particular data relating to site topography geology/hydrogeology (including water level data from 21 installed groundwater monitoring wells across the site and the data from five installed water level data loggers), the results of investigation mainly sourced from the 2011 Douglas Investigation, (Reference 1.).

- Creation of a conceptual groundwater flow model for the site, based on the geology/hydrogeology information;

- Input of the data to develop a three dimensional, numerical, hydrogeological model using Modflow; and conduct groundwater modelling involving:

  - calibration of the model against observed water levels to establish current conditions; and

  - groundwater modelling to simulate impacts on the groundwater flow regime from proposed development/construction of Lot 1001.

2 Site Background Information

2.1 Site Description and Topography

The site is 240 ha in area, located on the eastern and south-eastern side of Tomago Rd, Tomago and comprises a low lying, undeveloped area between the road and the northern bank of the North Arm of the Hunter River.

The Hunter River curves around the west and south west of the site with industrial development located off the northwest boundary (between Tomago Road and the river) and across the northern side of the road (dominated by the Tomago Aluminium smelter). NEH's Business and Industrial Park Estate (MP07-0086) is located immediately to the northeast of the site.

On the site's eastern boundary are located RAMSAR wetlands including a SEPP14 wetland associated with the estuarine margins of the Hunter River and Fullerton Cove (approximately 2 km east of the site). A buffer of approximately 380m has been provided to the RAMSAR boundary from the edge of the development area of Lot 1001. The wetlands area is currently being rehabilitated as salt water marshland in conjunction with the Tomago Wetland Rehabilitation Project.

The site is a flat, low-lying area, generally grading from Tomago Road (RLs of 5 to 6 mAHD) down towards the river at elevations of less than 1mAHD. Of the current site, 145 ha is grassed or cleared area, 75 ha is freshwater wetlands and 20 ha is covered with casuarina trees.

The site is traversed by a number access tracks, constructed on filled embankments.

Site drainage occurs through a series of open drains which ultimately discharge to the river. Some controls are present including (one-way) flood gates. A low bund, maintained by the Hunter Valley Flood Mitigation Scheme, was improved along the river margin following the 1956 Maitland floods.

It is understood that the site was historically used for farming.

Figure 1 shows the location and pertinent site features.

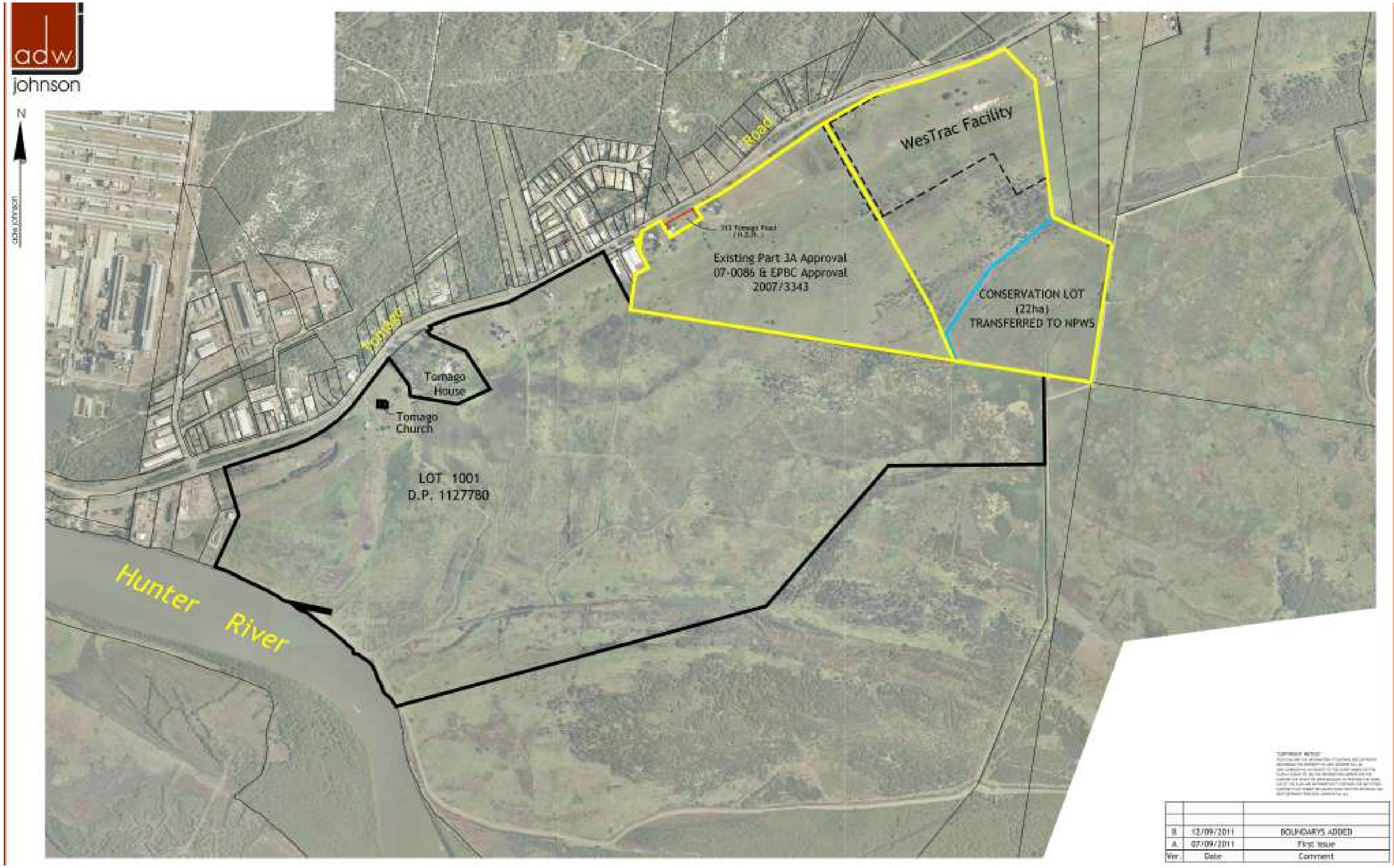

Figure 1: Site Location (after ADWJ, 2011)

2.2 Site Geology

The 1:250,000 Newcastle geology map (Reference 2) indicates the site is underlain by Quaternary-aged alluvial sediments (sand, clay, silts), overlying Permian-aged Newcastle Coal Measures (siltstone, sandstone and coal).

The investigations conducted by Douglas Partners for environmental and geotechnical assessment comprised excavation of test pits and boreholes, including the installation of 25 groundwater monitoring wells.

These (and previous) investigations indicated the site geology comprises:

- In the north-western area of the site, a 4 to 5m layer of loose sand (interpreted to be Pleistocene-aged dune barrier) in a strip approximately 200m wide along the road, overlying approximately 10m thickness of dense sands, overlying a residual clay/weathered siltstone bedrock profile; and

- In the remaining area of the site, (south-eastern area), a 4 to 10m thick layer of clays/silty clay and clayey sands, overlying between 7 and 15m thickness of loose to very dense sands, overlying a residual clay/weathered siltstone bedrock profile.

The Douglas Partners report noted that the clay layer increased to over 60m south of the site towards the river with residual clay/bedrock greater than 70m depth (Reference 1).

2.3 Hydrogeology

Shallow groundwater is present within the sands and clays on the site at depths between 0 and 2m below surface. Wells installed across the site indicated groundwater flow directions generally towards the south-east to the south-west and toward the adjacent SEPP14 wetlands and Hunter River, respectively. Groundwater reportedly discharges (ex-filtration) to the surface from the shallow sands in the slightly elevated northern sandy strip onto the lower surface of the south-eastern area. The interpolated groundwater potentiometric surface (from monitoring undertaken by Douglas Partners on 5 September 2011) is represented in **Figure 2**.

The groundwater flow directions were interpreted to be strongly influenced by rainfall recharge and the presence of the adjacent Hunter River.

The Douglas Partners report presented a conceptual hydrogeological model comprising unconfined aquifers within the surface sands in the north-western area and upper clays (low permeability) in the south-eastern area, and a semi-confined aquifer in the underlying sands in the south-eastern area with the overlying clays acting as a leaky aquitard.

The base of the aquifer comprises the low permeability clay and bedrock.

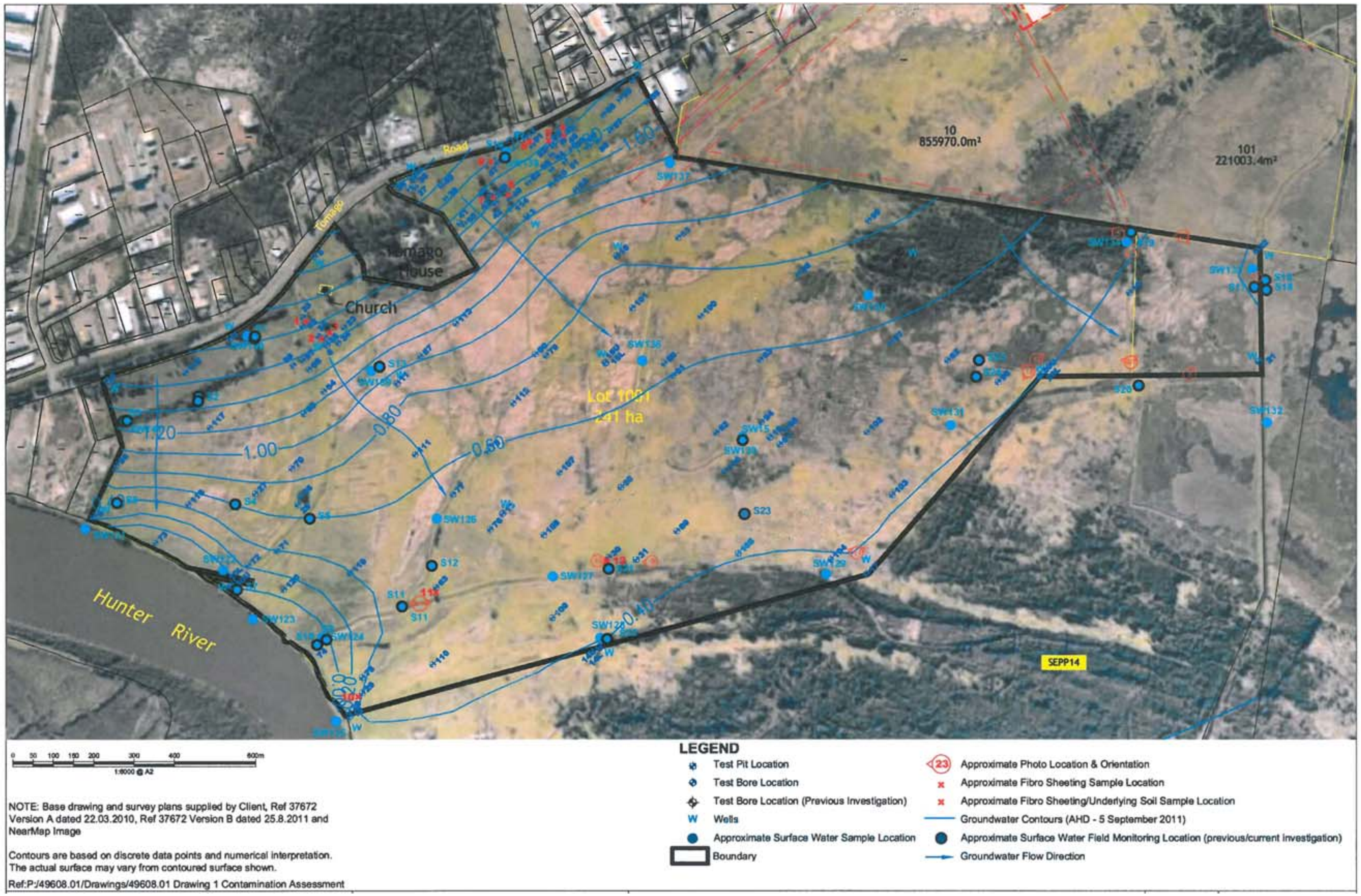

Figure 2: Interpolated Groundwater Potentiometric Surface (after Douglas, 2011)

A summary of the conceptual hydrogeological model is presented in **Figure 3,** below.

The report also assigned tentative aquifer parameters to the model, based on “field pump tests” from a 2001 investigation.

These parameters are summarized in **Table1,** below.

A surficial aquifer (sands/silts/clays) is indicated on the Douglas figure showing the conceptual model (**Figure 2**), however, based on logs, this was a maximum of 0.2 to 0.3m thick and was not considered significant in terms of groundwater flows on the site and was incorporated as part of the leaky aquitard component.

Table 1: Aquifer Parameters – Lot 1001 Conceptual Hydrogeological Model .

Aquifer Component	Porosity	Hydraulic Conductivity (m/s)	Hydraulic Gradient	Velocity Range (m/yr)
Aquitard (upper clays)	0.6	1e-5 to 6e-5	0.0045[#]	2.4 – 14
			0.0004[##]	0.21 - 0.3
Sand Aquifer	0.35	2e-4 to 3e-4	0.0045[#]	80 – 120
			0.0004[##]	7.2 – 11

Notes:
In western area of site near Hunter River
In southern site area towards Lot 1002
(Parameters taken from Douglas 2011)

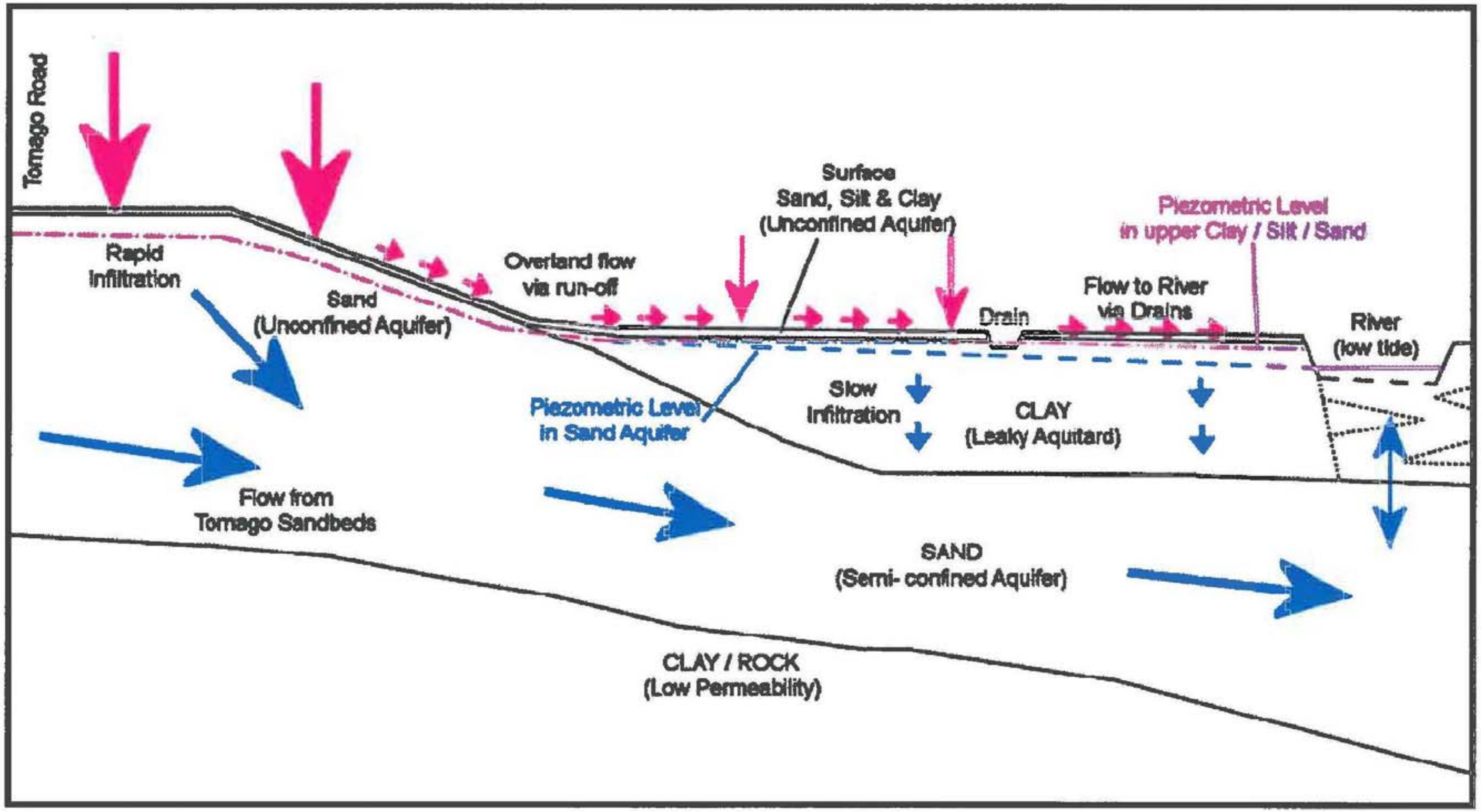

Figure 3: Site Hydrogeological Model (after Douglas, 2011)

3 Site Development Proposal

The site (Lot 1001) is proposed for development as a commercial/industrial precinct ("Northbank Enterprise Hub") involving filling of selected site areas to achieve required levels above the 100 year flood level, and construction of infrastructure (roads, drainage and other services). The proposed development is presented in **Figure 4**.

Of particular relevance is the proposed construction of a perimeter berm between Lot 1001 and the Lot 1002 wetlands area. The berm will have a toe drain on the up-gradient side (ie, Lot 1001 side), to control runoff onto the wetlands site. It is understood that storm overflow points will be installed through the berm at the locations of the existing flow controls.

It is anticipated that development of the site will greatly reduce recharge to the groundwater. The stormwater assessment study, conducted by BMT WBM as part of the planning approvals process (Reference 3), indicated that approximately 80% of the site will be impervious (in the developable areas), following development.

This will result in an estimated 75% reduction in groundwater recharge over the site area when accounting for undeveloped portions (Reference 3).

Figure 4: Proposed Lot 1001 Site Development (after ADW Johnson, 27 July 2012)

4 Groundwater Modelling

4.1 Data Sources

All data input into the groundwater model was derived from existing records. No additional field investigations were undertaken as part of this study.

The following information was used to construct the groundwater model for this study:

Table 2 Model Data Input

Data Component	**Source**
Topography/Site Boundary Definition:	ADWJ-derived documentation including data files and .dxf files from survey of the site (Suters). Site topography was generated from survey data files (in X,Y,Z format) input into the Golden Software "Surfer" package to generate surface contours for the site (and surrounding area within the model domain). Spot heights required to generate topography for the area outside the Lot 1001 site were sourced from the 1:25,000 series topographic map for "Beresfield". Plans and maps, outlining site boundaries, drainage were provided by ADW Johnson.
Geology/Site Stratigraphy:	Review of Douglas Partners report, including logs from 25 boreholes and 88 excavator and/or hand dug excavations. It should be noted that of the boreholes drilled (in the 2011 investigation), none were drilled to the base of the sands and only five were drilled to the base of the clay aquitard (where present).
Groundwater Information:	Logs from 25 groundwater monitoring wells across the site. Data from manual water level measurement and records from dataloggers installed into 6 wells (from Douglas Partners).
Climate/Rainfall/Recharge Data	Bureau of Meteorology website/Data supplied by Douglas. Recharge information from the BMT-WBM Stormwater Assessment (2011).
Note. All data was taken as correct and no independent assessment was conducted to verify validity of the information	

4.2 Model Design

Groundwater flow modelling was undertaken using Visual Modflow 2009.1, a three dimensional modular finite difference groundwater flow model. The model is based on Modflow – 83, Modflow – 88, Modflow – 96 and Modflow – 2000 which have been widely used by the profession for over 20 years.

The model domain comprised of an area of 3.3 km in the east-west direction by 6.2 km in the north-south direction, in which the proposed development site was located towards the centre of the model. The model origin was Easting 379300 and Northing 6362700 (in the MGA co-ordinate system).

The cell size adopted was 20m by 20m in the vicinity of the site and increased to 100m by 100m towards the model boundaries. This cell size is considered to give sufficient resolution to model impacts from the proposed site development.

Boundary conditions adopted for the site are described as follows.

- A constant head boundary was assigned along the edge of the Hunter River and set to 0mAHD to represent approximately mid-tide for 5 September 2011, the date when the groundwater level measurements were made (which were used for model calibration).
- Cells to the south of the Hunter River (south of the constant head boundary) were assigned as no-flow cells.
- Drain functions were input along and around the site approximating their actual location. Drain heights were approximated from the site topography and from specific points measured as part of a recent survey of drain inverts undertaken by ADW Johnson.

4.3 Model Assumptions

4.3.1 Model Layer

The model comprises eight layers as follows.

- Layers 1 – 5 comprise approximately a 14m thickness below the topographic surface. These layers represent the upper soil and alluvial clays across that area of the site (south-eastern area) where the clay is encountered. The layers contain a water table over the majority of the model domain. In the northern area of the site where the sands are exposed at the surface (vicinity of Tomago Road) all these layers are attributed to sands. It was also assumed that the remaining areas outside the site all layers 1 - 5 comprise the sands. Layer parameters reflect either the clay aquitard (where present) or the aquifer sands.
- Layers 6 and 7 comprises approximately 15m thickness contains the same properties as the layer 1 - 5 sands.
- Layer 8 – is a layer approximately 30m below ground surface representing the weathered rock profile forming the base of the sand aquifer. The layer comprises low permeability properties across the model domain and is a nominal 20m thick.

The model surface for the site area was developed from recent (Suters) survey while the surrounding was developed as a contour plot interpolated from the 1:25,000 topographic map for the region. This data was combined with a surface survey across the Project Site and contoured using ‘Surfer’, a commercially available contouring software package.

Layer interfaces were determined from geological information collated from bore logs presented in the Douglas Partners report (Reference 1).

Each layer was imported to the model and a minimum layer thickness of 1m was assigned. The minimum layer thickness is required to ensure model convergence as model instability can occur where cells become too small relative to the surrounding cells.

4.3.2 Aquifer Parameters

Initial hydraulic conductivity and storage parameters are presented in **Table 3**.

Table 3 Initial Parameter Assignments

Layer	Hydraulic Conductivity Kx,y (m/s)	Hydraulic Conductivity Kz (m/s)	Effective Porosity [1] %	Storativity [2] (1/m)
Clay (Aquitard)	6.0E-05	6.0e-06	0.45	0.0001
Sand Aquifers	2.0E-4	2.0e-5	0.15	0.001
Bedrock	5.0E-08	5.0e-09	0.35	0.0001 ^

Note 1: Freeze and Cherry (1979).

Note 2: Fetter (1988) unless shown.

^ Represented as specific storage for a confined aquifer.

Storage and porosity values were based on available published data for similar material (Fetter, 1988) in consideration with the parameters assessed in the Douglas report which was reportedly based on field testing. Storage values were used for the transient model analysis, which was conducted to assess impact from the project site.

5 Model Calibration and Validation

5.1 Calibration Criteria

The objective of model calibration is to adjust model parameters until the model provides a close approximation of the monitored system. The model was calibrated to water levels measured on one occasion at the site. The limited data set available for calibration limits the reliability of the model, however the reliability is increased when the validity of the calibration parameters are considered together. For example, a realistic adoption of recharge and hydraulic conductivity parameters that provide a close approximation to a measured water level distribution improves model reliability.

The parameters modified to achieve model calibration were hydraulic conductivity in all layers and recharge. Drain conductance was also considered but was not effective in achieving calibration.

Accepted criteria to ensure a representative model calibration was adopted as follows.

- Model convergence of 0.01m was adopted and is one order of magnitude lower than the required model resolution.
- Water balance error of <1% over the whole model domain.
- Normalised root mean square (RMS) of <15%. This is based on the observed groundwater fluctuation in excess of 1.0m and therefore the lower reliability of the measured head;
- Test of reasonableness. The final chosen model parameters must be considered reasonable when compared to field and literature data.

1.1 Parameters adopted for the calibration model

Through trial and error a combination of model parameters was identified that provide a close approximation to the observed field conditions. The final parameters adopted are outlined in Table 4.

Table 4 Model Parameterisation

Parameter	**Value**	**Field measured**	**Other data sources**
Recharge			
Undeveloped areas	35mm	no	
Developed industrial areas (90% paved)	5mm	no	
High area of recharge area along Tomago Road	80mm	no	
Site (combined developed and undeveloped)	90ML pa	no	88ML pa[1]
Hydraulic Conductivity			
Sandy clays	5e-6 m/s to 8e-6 m/s	yes	1e-5 to 6e-5m/s[3]
Sands	1e-4 m/s to 2e-5m/s	yes	4e-4 m/s [2,] 2e-4 to 3e-4m/s[3]
Bedrock	5e-8 m/s	no	

[1] WBM BMT 2011 [2] Data for Tomago Sandbeds, SKM 2005. [3] Refer to Table 1. [4] Freeze and Cherry.

NB Colours refer to distribution shown in Figures 6 and 7.

Model simulations adopting the above parameters produced a water balance error of 1.0% across the model and equal to the acceptable error of 1%. The good correlation demonstrates robustness and stability within the model.

The values adopted for each parameter are considered reasonable when compared to measured data or literature based data. With regards to hydraulic conductivity it is not unusual for models to adopt a lower value than measured in the field as the model considers a macro scale unit whereas field testing is concentrated over a smaller and often shallower area where higher micro permeability can dominate.

Figure 5 represents the RMS distribution. The data shows an acceptable normalized RMS of <15% and a maximum residual head of approximately 0.8m. This head value is considered reasonable when considering the variability in the measured site data shown to be in excess of 1.0m.

The final adopted hydraulic conductivity and recharge distributions are shown on **Figures 6** and **7,** below.

This combination of recharge and permeability is considered plausible for the project site and surrounds although is not likely to be a unique solution. It is possible that other combinations of recharge and permeability are available that can provide a similar approximation to the steady state condition.

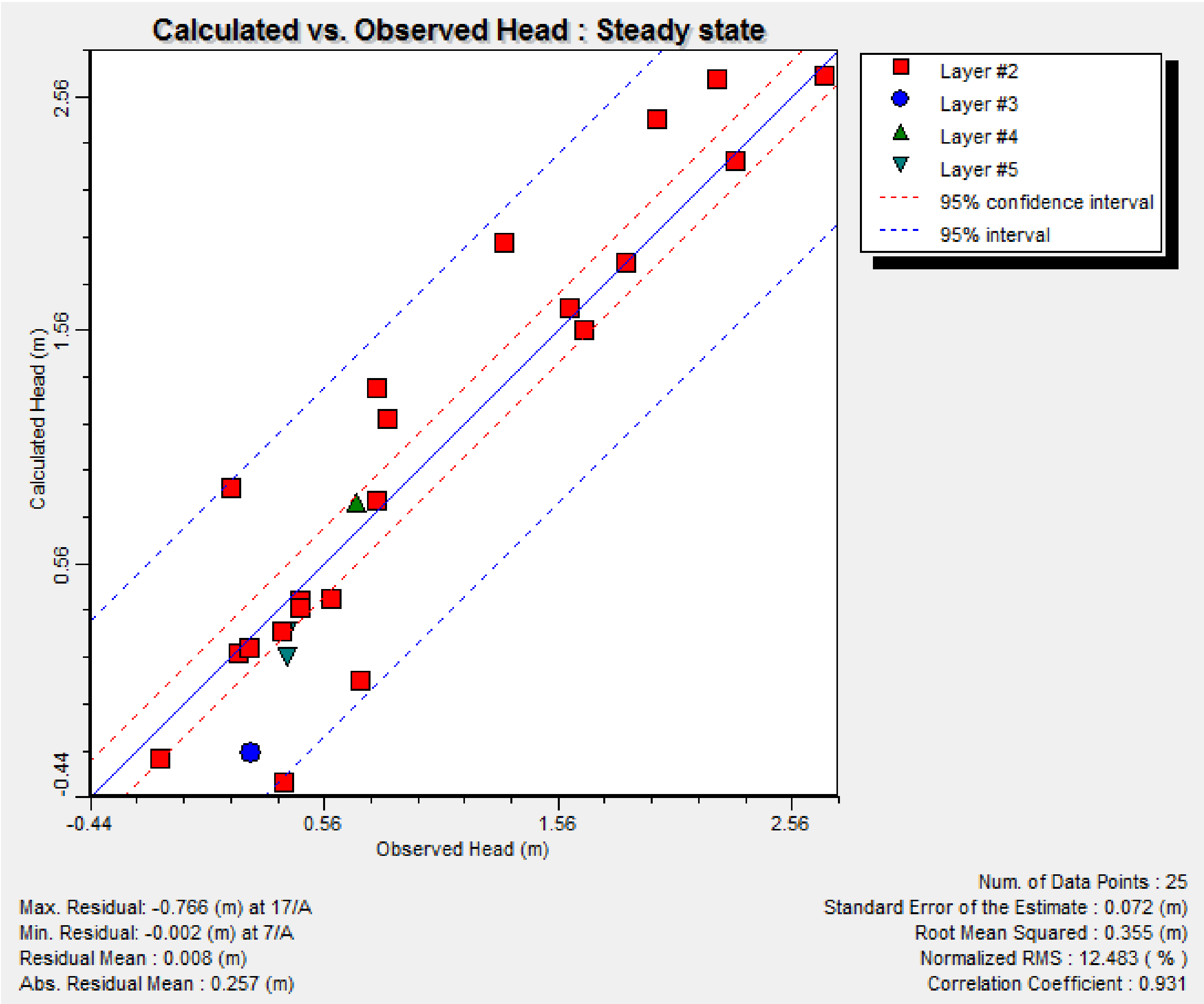

Figure 5: RMS Distribution: Simulated vs Observed Head (steady state)

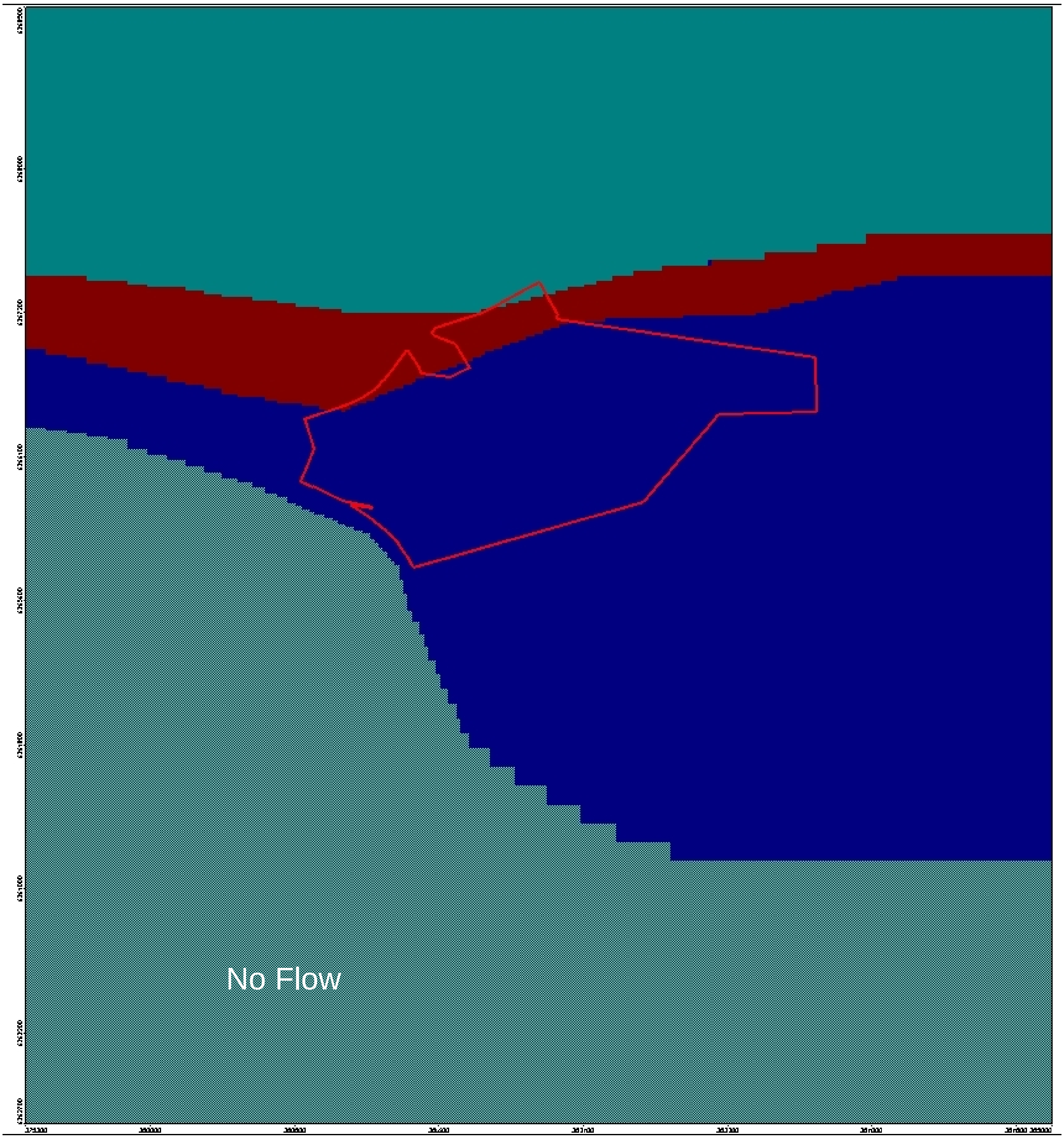

Figure 6: Model Layer 1 Hydraulic Conductivity Distribution (Site shown as Red Outline/refer to Table 4 for visible assigned hydraulic conductivity values)

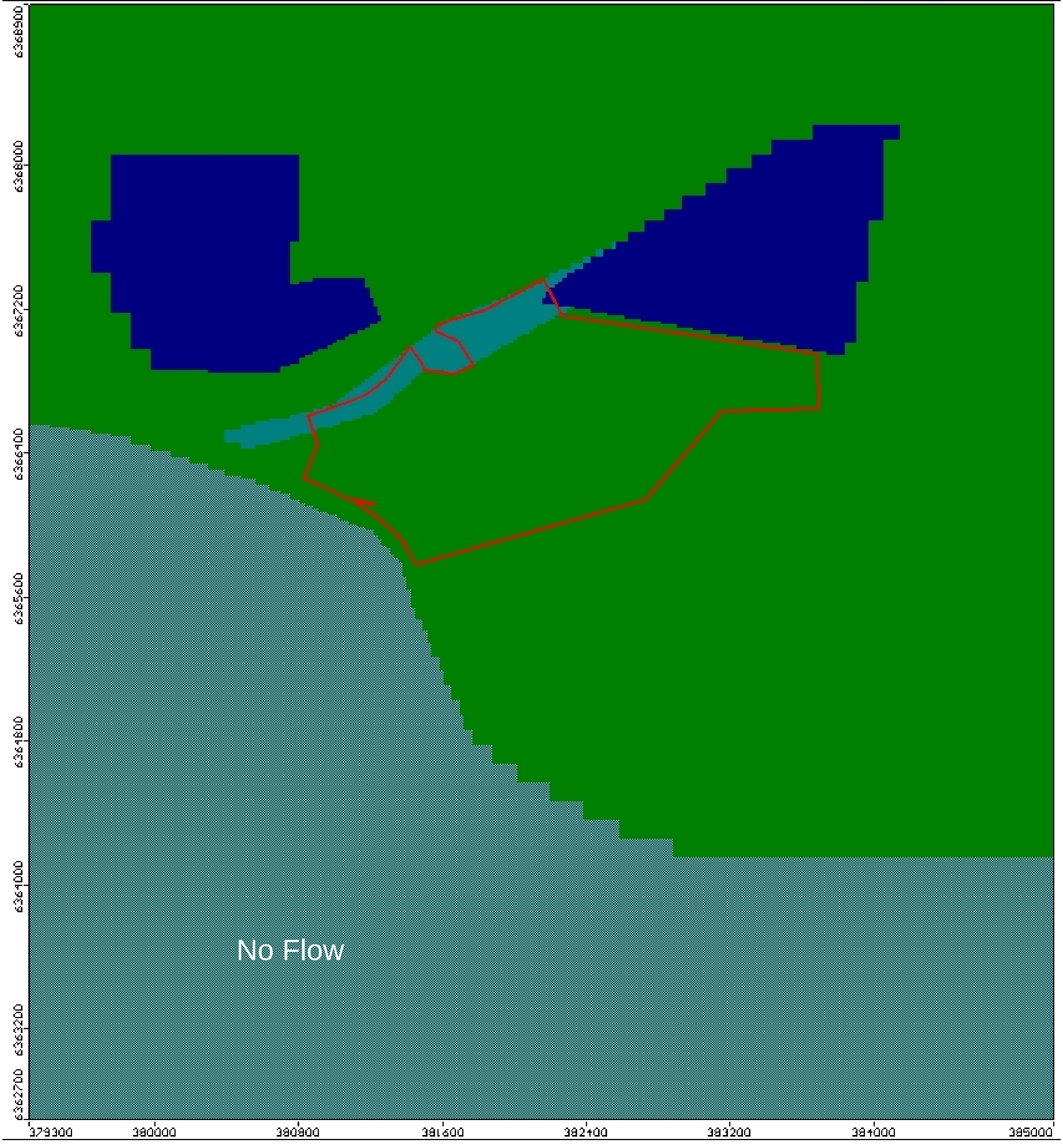

Figure 7: Model Layer 1 Recharge Distribution (Site Shown as Red Outline/refer to Table 4 for assigned recharge values)

6 Model Simulation Of The Project

Modelling of the impact to the groundwater flow regime from the proposal was undertaken by modifying the calibrated model to reflect the key proposal elements. The development proposal was simulated by adopting the initial groundwater potentiometric surface condition from the calibrated steady state model as the initial head condition for a transient solution.

Modifications to the model were then made to reflect the development as described in the following.

Recharge was reduced for the development footprint to represent the reduction in infiltration that will occur following the development of the land. The infiltration rate was reduced to 5mm per year over the developable portion of the project site which equates to site volume recharge to groundwater of 28ML per year and is comparable with the baseflow volume adopted in WBM 2011 of 23ML per year.

The drainage regime was modified to reflect the proposed drain alignments. Drain invert levels were adopted in accordance with the design information. **Figure 8** shows the modelling drain alignments in blue.

To assess impacts to the SEPP14 wetland, zones were applied to the model to assess the water balance between the site and the neighbouring wetland. The assignment of zones allows for evaluation of groundwater flow between parts of the site. The zone evaluated reflects flow from site within to a depth of approximately 4.0m. This was considered the most relevant to evaluate impacts to the wetlands. The results are presented in **Table 5**.

Table 5 Predicted groundwater flow changes following development

Zone	Groundwater Balance ML/year		
	Existing conditions	Conditions following development	% change
Flows to the wetland from the development site	2.0	1.7	15%
flows to the wetland from other sites	30.5	27.5	<10%
Recharge to wetland groundwater system	92	92	0%

The modelling has predicted that the proposed development will not impact measurably on the groundwater flow relationship between the site and the wetland. The contribution of groundwater flow from the project site to the wetland, in the upper layers (within 4.0m of the surface), represents 2% of total groundwater recharge within the wetland footprint. As groundwater flow from the project site represents a small contribution, any change to this contribution is insignificant to the overall water balance for the wetland within the shallow aquifer system.

The predicted groundwater potentiometric surface prior to and following development is presented in **Figure 8.**

Project site potentiometric surface contours reflect the change in drainage arrangements as a result of development on the project site. Similarities between pre- and post- development potentiometric surface contours indicate no measurable change for the downstream wetland site (Lot 1002).

It should be noted that, to the northeast of the site, contour differences (between pre and post development are in the order of 0.2m. In this area, (ie, away from the area of principal interest), the model grid was coarser and less reliance should be made on groundwater level variations due to this and the sparser nature of the data available. The observed 0.2m in head change is within the levels of model accuracy and also within the seasonally observed variation in groundwater levels across the project site.

The model does not consider the possible rise in the groundwater level that may result from consolidation of the underlying sandy clays in response to loading by fill. It is anticipated that any rise will be temporary due to the free draining nature of the fill sands and the presence of drainage lines.

Figure 8 Drain Conditions for Development Simulation (Drain model grid shown in blue)

Head data at three simulated observation wells (OBS1, OBS2, OBS3) monitoring the groundwater head within 4.0m of the surface demonstrate the predicted change in head over the modelled period. Modelling was undertaken for a period of 80 years and **Figure 10** shows that the groundwater regime has stabilised within between 10 and 15 years from completion of development (the model assumes all development occurs concurrently). The predicted head values at the three simulated observation wells show changes in head of less than 0.05m across the wetland area. These observation wells are situated on the downgradient side of the proposed berm within the wetland area (Lot 1002).

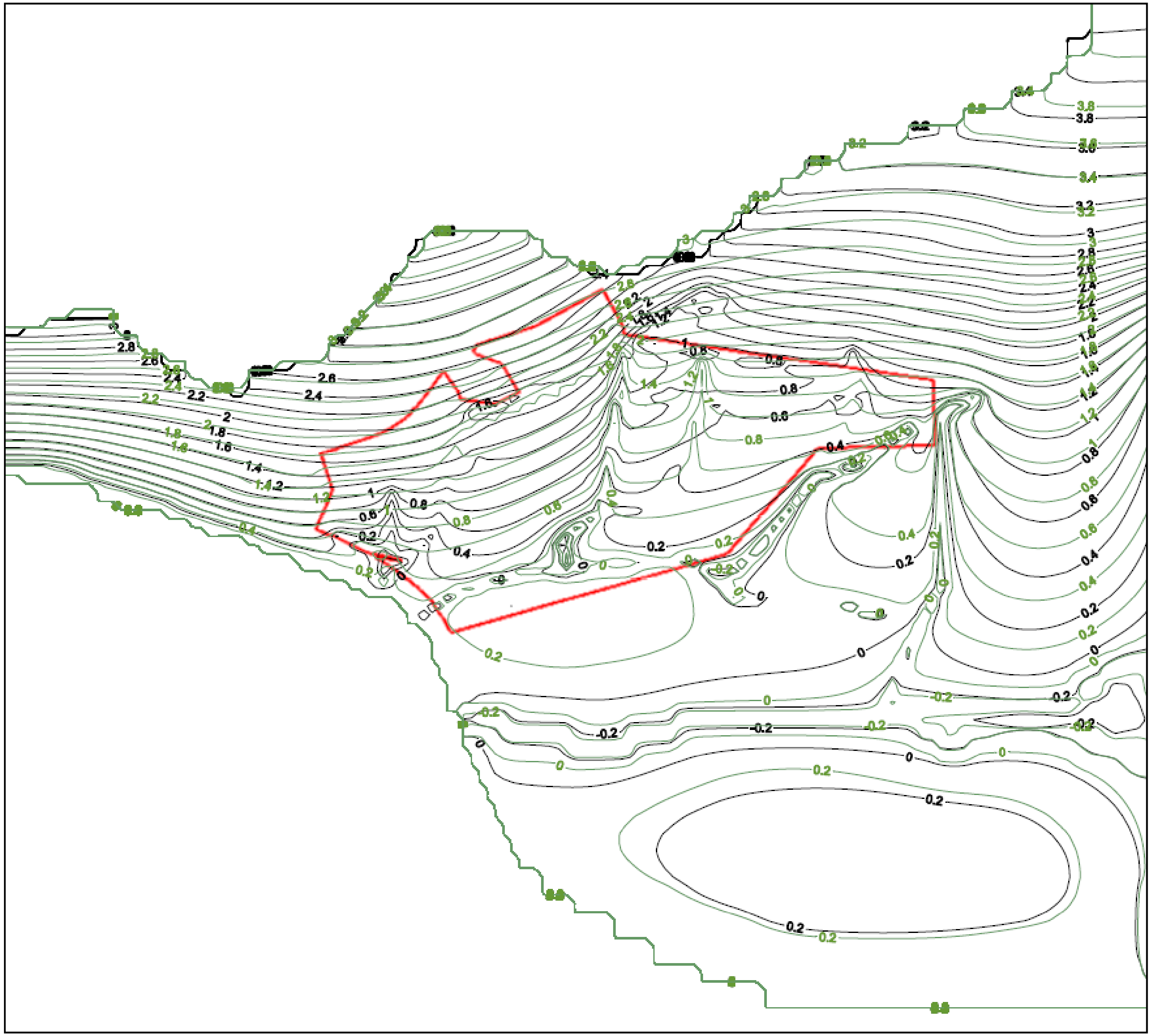

Figure 9 Predicted Potentiometric Surface Pre and Post Development (pre-development contours/Post development contours).

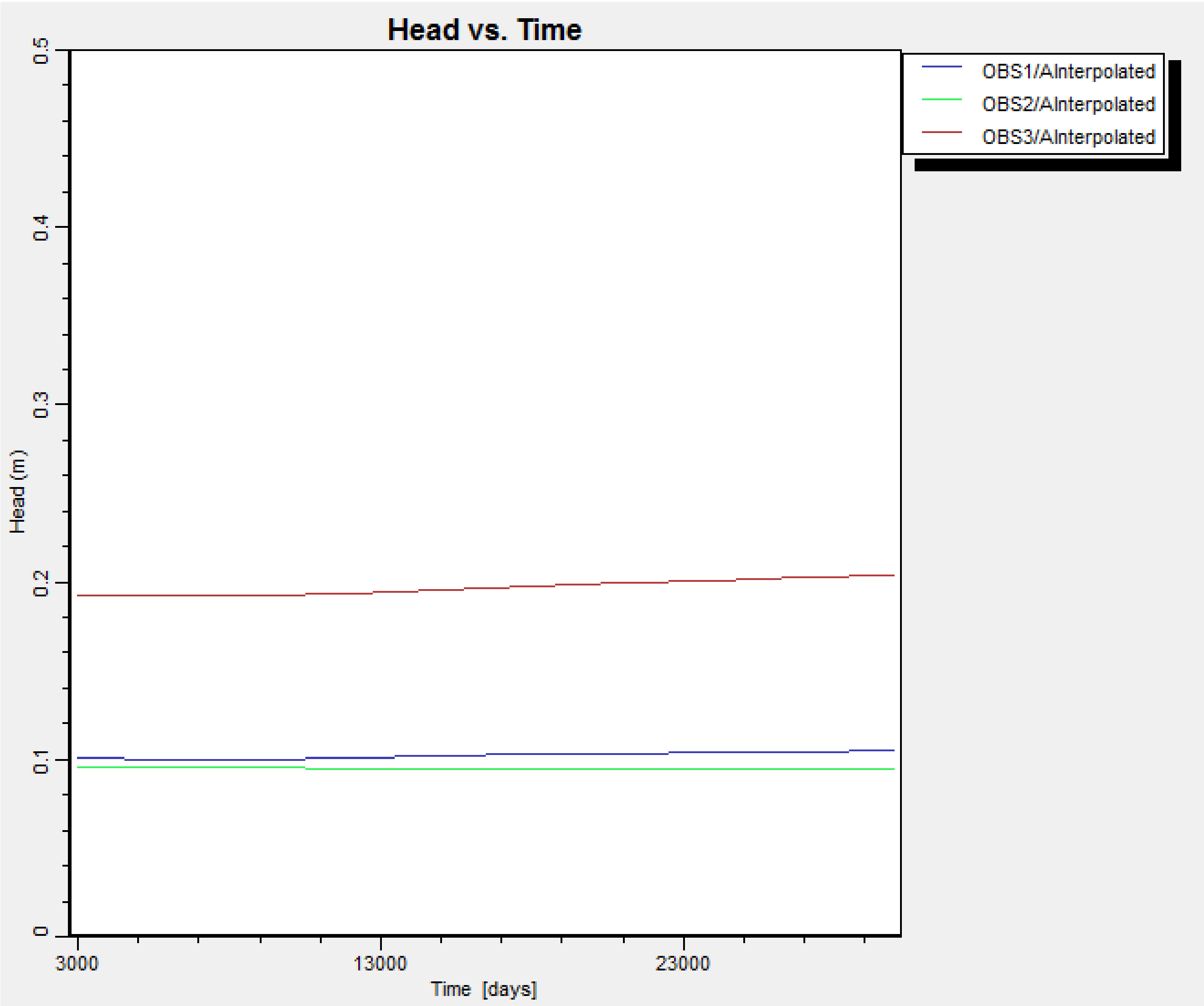

Figure 10 Predicted head within the wetland area.

The above modelled condition is considered to represent the most likely parameters of recharge, hydraulic conductivity and drainage configuration following development. However these parameters can vary from the predicted most likely case and a sensitivity analysis was undertaken.

6.1 Sensitivity Analysis

Additional simulations were undertaken to assess the sensitivity of the model to hydraulic conductivity and recharge. These parameters were used in model calibration as described in Section 5. Drain conductance has not been included in the sensitivity analysis because, although used in calibration, once the drain conductance is set there is no reason for it to change following development. However, recharge following the development is an estimated parameter that is not used in calibration and therefore variation in recharge can affect the groundwater response. Similarly, compression of the underlying clays could result following the development and the sensitivity of the model output was evaluated for a range of hydraulic conductivity values.

Table 6 Sensitivity Analysis

Zone	**Groundwater Flow Balance from the Project site to the wetland**
Existing Condition	3.1ML/year of groundwater flow in the shallow aquifer from the project site to Lot 1002.
	Conditions following development modifying rainfall and hydraulic conductivity, ML/year
Recharge = 21ML per year	1.3
Recharge = 28ML per year	1.7
Recharge = 45ML per year	1.9
Hydraulic conductivity of the clay aquitard decreased by two fold. Recharge equal to 28ML pa.	1.1
Hydraulic conductivity of the clay aquitard decreased by one order of magnitude. Recharge equal to 28ML pa.	Model becomes unstable

The sensitivity analysis demonstrates that the groundwater flow to the wetland is affected by changes in recharge and changes in hydraulic conductivity. However, the small contribution to the wetland system from this groundwater flow means that any change has little impact when evaluating the overall water balance for the wetland system.

7 Contingency Management

The modelling study results predict that there will be no significant impact on groundwater within the adjacent wetlands (downstream of the site) as a result of the project site development.

However, as a contingency against unexpected conditions or changes in existing conditions, Environ recommends the following contingency management/monitoring strategy, be incorporated in a Groundwater Monitoring Plan (GMP), for the site.

- Monitor three of the existing groundwater monitoring wells shown on the ADWJ Groundwater Monitoring Plan Figure and located on the south eastern boundary providing that these wells are immediately down-hydraulic gradient of the proposed perimeter berm (ie, on the wetlands side). If in the event that the perimeter berm is installed on the eastern (wetlands) side of the existing wells, installation of three new groundwater monitoring wells immediately down-hydraulic gradient of the proposed perimeter berm (ie, on the wetlands side), along the perimeter will be undertaken;

- Monitoring of groundwater levels in these wells to be undertaken, prior to development, to establish baseline conditions; (ie, groundwater level fluctuation, based on seasonal and regular tidal cycles), with at least one of the wells instrumented with a data logger;

- Monitoring of water levels in these three new wells be included in the groundwater monitoring programme undertaken over key site development/construction periods (based on the development timing) including:

  - Regular review of the water level data by a qualified hydrogeologist using statistical techniques (eg, Mann-Kendall, or cusum) to assess trends in water levels on the wetlands site; and

  - Where a trend in water levels is identified (and confirmed), a detailed site hydrological/hydrogeological assessment be commissioned to identify causes and potential remedial options to ameliorate the impacts on the wetland site. These may include modification of the surface water drainage system and other surface water controls.

8 Conclusions

Environ has undertaken groundwater modelling of the proposed Lot 1001, Tomago Road development site to assess the potential for groundwater impacts on the neighbouring (down-hydraulic gradient), SEPP 14 wetlands area (Lot 1002).

A numerical, three-dimensional, finite difference groundwater model of the site and surrounds was constructed, based on a conceptual model of site geology and hydrogeology, derived chiefly from investigations conducted by Douglas Partners in 2011. The model was calibrated against observed water levels and model properties adjusted to reflect site development. Groundwater flow conditions were then assessed under the simulated development model and compared with existing site conditions.

The following conclusions were drawn from the results of the modelling:

- the proposed development will not impact measurably on the groundwater flow relationship between the site and the wetlands, given that the flow from the project site represents only a small component of the groundwater recharge within the wetlands;
- no measurable change in the groundwater potentiometric surface was predicted by the model simulation; and
- as a contingency, a programme of groundwater monitoring (pre-development and during development) and review of trends in groundwater levels is recommended.

9 References

1) Douglas Partners, “Report on Stage 2 Contamination Investigation, Proposed Northbank Enterprise Hub Lot 1001 DP 1127780, 365 Tomago Road, Tomago” ref 49608.01, October 2011.
2) Douglas Partners, “Groundwater Monitoring Plan, Proposed Industrial Subdivision Tomago Road, Tomago”, ref 39920.02, January 2010
3) Department of Mines, Sydney, *Newcastle Geology Map 1:250,000 Sheet SI 56-2,* First Edition 1996.
4) LPI – NSW, 1:25,000 Topographical map – Beresfield, ref: 9232-2N,
5) BMT WBM 2011, “Northbank Enterprise Hub Subdivision – Stormwater Assessment”, ref: RN 1900.002.03, October 2011.
6) Sinclair Knight Merz, NSW Office of Water, “Modelling of Impacts of Climate Change and Groundwater Extraction on Coastal Groundwater Quality and Groundwater Dependant Ecosystems of NSW”, 2010.
7) Freeze and Cherry, “Groundwater”, Prentice Hall, 1979.

10 Limitations

ENVIRON Australia prepared this report in accordance with the scope of work as outlined in our proposal to ADW Johnson on behalf of NEH Pty Limited dated 5 July 2012 and in accordance with our understanding and interpretation of current regulatory standards.

Site conditions may change over time. This report is based on conditions encountered by others at the site at the time of the report and ENVIRON disclaims responsibility for any changes that may have occurred after this time.

The conclusions presented in this report represent ENVIRON's professional judgment based on information made available during the course of this assignment and are true and correct to the best of ENVIRON's knowledge as at the date of the assessment.

ENVIRON did not independently verify all of the written or oral information provided to ENVIRON during the course of this investigation. While ENVIRON has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to ENVIRON was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

10.1 User Reliance

This report has been prepared exclusively for ADW Johnson on behalf of NEH Pty Limited and may not be relied upon by any other person or entity without ENVIRON's express written permission.