

D R A F T R E P O R T

Environmental Impact Statement for
the Proposed Alcan Gove Alumina
Refinery Third Stage Expansion

Groundwater Supply

Prepared for

Alcan Gove Pty Ltd

PO Box 21
Nhulunbuy, 0881 NT

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URS

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Executive Summary

Alcan Gove Pty Ltd (Alcan) proposes to expand their existing mining operations at Nhulunbuy, Northern Territory. This report addresses the groundwater investigations undertaken to support the Environment Impact Statement (EIS) required for the expansion of the groundwater wellfield which supplies the water requirements of the mine, refinery and the township of Nhulunbuy.

The water supply for the expanded refinery may be able to be managed within the existing licence limit (12,000 ML/an), however, a number of unknowns associated with the expansion means that an increase to the licence is proposed. As a result, an amendment to the licence is being sought to increase the groundwater extraction rate to 14,000 ML/an.

The present wellfield, of seventeen (17) production bores, is located within the mine lease area and has on average extracted approximately 9,200 ML/an. Groundwater is pumped from fluvial sands and gravels (Mullaman Beds) overlying an undulating granite basement. A thin cap of bauxite and laterite covers the sequence at the surface. The plateau is surrounded by granite outcrop and has a submerged coastline. Natural groundwater discharge occurs continuously via sub-surface drainage to the coast and as stream flow, evaporation and transpiration losses to a number of creek and river systems.

A numerical groundwater model was developed with the aid of the monitoring history of the existing wellfield operations. The aim of the modelling was to provide an understanding of the regional hydrogeology in the mine lease catchment area and as a tool for assessing whether extracting 14,000 ML/an might give rise to unacceptable impacts on surface flows and to assess the most efficient configuration for an expanded wellfield.

The primary objective in any increase to groundwater extraction is to maintain flow through Yirrkala Lagoon and other surface water systems for environmental reasons. Assessment of impacts on Yirrkala Lagoon to date has been based on the very strong correlation between discharge at Yirrkala Lagoon (Bellmouth weir) and the standing water level in OB1. This has been continued as a basis for assessing the potential impacts from the expanded wellfield.

The predictive modelling undertaken to assess a number of different expanded wellfield configurations has shown that the water level in OB1 remains above the “critical” level in all scenarios despite the markedly increased (52%) extraction rate. The preferred option is an alignment south of PB15 across Shady Gum Creek. The preferred option allows the placement of new production bores in areas already mined, and captures groundwater discharging to Rocky Bay and the lower reaches of Shady Gum Creek, rather than predominantly from Yirrkala Creek.

An investigation drilling program is necessary to confirm the geological continuity of the aquifer in the area proposed for the expanded wellfield and there is a need to better evaluate the recharge regimes as they are affected by the progression of mining and land rehabilitation across the mine lease plateau. The completion of this work must be seen as being on the critical path to confirming the wellfield location and its production capacity in the long term *** of adverse environmental and social impacts.

Executive Summary

Airstrip Plateau	Name nominated for the plateau within which the airstrip and mine are located.
Aquifer	Water bearing strata, can be either soil or rock
Bund	A raised earth mound used to control surface water drainage or screening of a facility
Catchment	The area of land that rain falling within drains to a specific creek or river
Environment Impact Statement (EIS)	A document required to be prepared for the Minister for Planning to assess the potential environmental effects of a project
Groundwater	Water which occupies openings, spaces and cavities in rocks and soil.
Permeability	Rock or soil is said to be permeable if water can pass through it. It is measured units of metres per second (m/sec). Example - a permeability of 1×10^{-9} m/sec means that, under a unit hydraulic gradient, a particle of water would take 1×10^9 sec (32 years) to move from the top of the liner to the base of the liner of 1 metre thickness
MBHD	Melville Bay Height Datum
OB	Observation Bore
PB	Production Bore
Salinity	The level of salt or total dissolved solids in water
Seepage	Diffuse groundwater emergence at the surface, as opposed to a spring (point emergence)
Total Dissolved Solids (TDS)	The level of dissolved material in water, the TDS are comprised of substances such as salts, TDS levels are generally used as indicators of water quality. The higher the TDS the lower the quality of the water.
Total Suspended Solids (TSS)	TSS are the level of non dissolved material in the water or the filterable material suspended in the water. TSS are comprised of non soluble material such as silica
Confined aquifer	An aquifer under pressure such as artesian aquifer where the level of water in a well, rises above the level of strata where the water is present
Unconfined aquifer	An aquifer exposed to the atmosphere

1.1 Background

URS Australia Pty Ltd (URS) was commissioned by Alcan Gove Pty Ltd (Alcan) to undertake studies to support a Environment Impact Statement (EIS) for expansion of the existing mining operation at Nhulunbuy. The areas of investigation included groundwater and surface water management, environmental studies, treatment plant residue and mine waste storage. This report relates to the groundwater investigation.

Groundwater and its management is one primary element on the site that will have a direct bearing on the operational ability of Alcan to process ore. The key issues related to groundwater management are:

- Groundwater supply (including aquifer hydraulics and monitoring of drawdown),
- Groundwater management (including inflow volumes, quality, storage, use and disposal/treatment), and
- Potential impacts from altering the groundwater flow regime (ie environmental flow to surface water system).

1.2 Environmental Performance Criteria

The primary objective of Alcan is to limit total consumption from the groundwater aquifer for all use of fresh water to less than 14,000 ML/an assuming a licence to increase consumption from current 12,000 ML/an is obtained. It is understood there is strong regulatory influence in this area.

The performance criteria in regard to the management of water are as follows:

- Improve design to minimise the requirement to use fresh water in the maintenance of plant and to remove spillage;
- Design to use good quality wastewater rather than fresh water wherever possible; and
- Define fresh water use targets for each Operational Area and install meters to measure real-time water use on-line.

The Alcan standards developed based on the above criteria are as follows:

1. Alcan Inc EHS Policy, which commits us to excellence in EHS through continual improvement
2. Alcan Inc EHS Policy Guiding Principle requiring efficient use of natural resources through the effective use of management systems that continually improves EHS performance.
3. Alcan Inc EHS Policy Guiding Principle that requires compliance with legal requirements and Alcan's internal standards.

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4. Alcan EHS First Procedure 4.6.2 on Resource Management, which requires each site to have a resource management program based on ISO 14001 continuous improvement principles
 5. Alcan EHS First Procedure 4.5.4 on Management of Change, which, among other things, requires changes to incorporate current regulations and standards.
 6. Gove site groundwater Extraction Permit No 305 issued by (The NT Controllers of Water) which permits extraction up to 12,000 ML/an, provided the flow in Yirrkala Creek is kept above 50L/sec
 7. URS investigations into the potential for extraction of up to 14,000 ML/an and advice on additional borehole location (to be used as a basis for an amendment to the existing permit)
 8. Alcan Gove Risk Register, which recognises raw materials consumption as a significant environmental risk
 9. Alcan Gove ISO 14001 Environmental Management System which establishes objectives, targets and EMP's for improvement in the use of raw materials
 10. Alcan Gove strategic plan which establishes resources to support EMP's aimed at optimising the use of raw materials

1.3 Scope of Works

The scope of works to be undertaken as part of the groundwater study included:

- Review all available hydrogeological investigation reports, geological maps and groundwater observation bore drilling data, water level and chemistry data;
- Develop and define the conceptual model for the groundwater system,
- Determine aquifer parameters, including transmissivity and storativity from pumping tests and assessment of previous work,
- Undertake numerical modelling for the effects that the proposed wellfield expansion and relocation will have on the aquifer and surface water systems. Outputs will include the calculation of the anticipated groundwater levels throughout the life of the mining operations and the expected area of groundwater drawdown; and
- Assess the possible impacts of a changed hydraulic gradient as a result of groundwater extraction on the aquifer and relevant surface water systems.

1.4 Study Deliverables

The deliverables for the groundwater study include:

- Numerical models to assess local and regional impacts of groundwater extraction;

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- Determine any interaction between groundwater and surface water systems; and
 - Develop a preferred configuration to the expanded wellfield, which minimises the impacts to the local surface water systems and other groundwater users of the aquifer.

2.1 Site Description

The mine operations are located on the Gove Peninsula in the northeast of Arnhem Land in the Northern Territory (Figure 1). They consist of a bauxite mine and refinery, which converts the bauxite into alumina.

The current wellfield is located within the mine lease area (Figure 2). The wellfield is made up of two alignments, one along the north-eastern edge of the airstrip and the second along Shady Gum Creek (Figure 3). In total there are seventeen (17) production bores and eighteen (18) observation bores.

The mine area and airstrip are located on a bauxite plateau (Airstrip Plateau) surrounded by granite outcrop and a submerged coastline. The bauxite plateau is eroded on its margins by the sea and a number of creeks/ivers, which have formed near vertical cliffs in the bauxite.

Five major creek/river systems intersect and bound the Airstrip Plateau (Figure 3):

- Yirrkala Creek and Lagoon;
- Latram River;
- Shady Gum Creek;
- Rocky Creek; and
- North River.

2.2 Geology

Simplistically, the geology of the Airstrip Plateau can be described as fluviatile sands and gravels (Mullaman Beds) overlying an undulating granite basement, with a thin cap of bauxite and laterite covering the sequence at the surface.

The detail stratigraphic sequence of the Airstrip Plateau is as follows:

Age	Unit	Thickness (metres)	Lithology
Quaternary	Alluvium & Coastal Deposits	0-3	Clayey carbonaceous swamp deposits, and mica/quartzose and calcareous sands
	Bauxite Laterite	0-12.5 0-5	Pisolithic & tubular ferricrete & halid zones
Lower Cretaceous	Mullaman Beds	200	Arkosic quartzose felspathic sandstones and claystones

Pre Cambrian	Bradshaw Granite	Unknown	Garnetiferous porphyritic granites, foliated granite gneiss
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2.2.1 Basement

The basement comprises the Bradshaw Granites, which is made up of foliated migmatite or granite gneiss. They are strongly porphyritic with large phenocrysts of orthoclase or microcline.

The basement surface is highly undulating, and form buried valleys, the ridges of which have a north east/south west trend under the Airstrip Plateau. The granites are typically decomposed in unexposed areas to a kaolinitic sandy remnant, and can be lithological mistaken for the overlying Mullaman Beds thus masking the granite sedimentary interface.

2.2.2 Mullaman Beds

The Mullaman Beds directly underlie both the bauxite and alluvium/coastal deposit sequences. They are Lower Cretaceous in age, and typically consist of arkosic sandstones with a feldspathic content partially kaolinized. Interbedded within the sandstones are fine textured claystones and clastic mixtures with occasional carbonaceous layers¹.

Minimal lithological correlation of specific beds has been possible between bores, however, geophysical logging (specifically natural gamma) has identified five broad units within the Mullaman Beds:

Unit A	A bauxite/laterite/sub-clay sequence
Unit B	A feldspathic to clayey sandstone sequence.
Unit C	A clean quartzose sandstone, with shales and claystones at depth. Shows a typically consistent lithology and contains the best aquifer.
Unit D	An interbedded sequence of sandstones, claystones and carbonaceous bands. Some cemented zones occur and pyritic nodules are common.

2.2.3 Bauxite

The bauxite laterite sequence overlies the majority of the Airstrip Plateau, except in areas where gully erosion has occurred along Yirrkala Creek, Shady Gum Creek, Latram River and North River. The plateau slopes gently towards these drainage lines but mostly exhibits a sharp escarpment at the edge of the main erosion gullies.

¹ AGC (1970). Gove Peninsular – Water Supply Project. Nabalco Pty Limited. September 1970.

2.2.4 Alluvium Sequence

Alluvium has been deposited in rear dune lagoons along the coastal margin. The material is silty and carbonaceous due to low rates of erosion arising from the plateau.

Coastal deposits include quartzose and calcareous beach sands with remnant calcarenite deposits along the coast interspersed with laterized rock “stacks”. A significant amount of long shore drift has contributed to a coastline, which includes rocky headlands and pocket beaches with coastal deposits terminating and burying the alluvium under dune sand and beach deposits.

2.3 Hydrogeology

Groundwater is generally encountered 25 to 35 metres below ground level across the Airstrip Plateau, which is 5 to 10 metres below the base of the bauxite/laterite sequence. As a result, the aquifer is generally unconfined, and recharge occurs by direct infiltration to the extent that the laterite clays permit.

Unit C of the Mullaman Beds forms the primary aquifer beneath the Airstrip Plateau, and from which the current wellfield extracts groundwater.

Groundwater discharges occurs continuously via sub-surface drainage to the coast and as stream flow, evaporation and transpiration losses to the Latram River, Yirrkala Creek, North Creek and lower reaches of Shady Gum Creek and Rocky Creek.

2.4 Current Licence Conditions

The current wellfield was developed progressively between 1970 and 1972 and is currently operating under Permit No. 305 (Amended), issued by the Northern Territory Controller of Waters. This permit allows Alcan to extract up to 12,000 ML over any twelve month period.

The conditions of the permit are as follows:

- Monitor groundwater extraction volumes and water levels in all production bores on a monthly basis;
- Monitor the water level in fifteen observation wells on a monthly basis ;
- Record rainfall totals on a monthly basis;
- Prepare a statutory report every three years, which outlines the following:
 - A summary of the site hydrogeology.
 - Details of the model used to define and predict the behaviour of the aquifer system.
 - Evaluation of the performance of the aquifer, the wellfield and associated Yirrkala Creek for the previous triennium based on the assessment of the results of routine hydrogeological monitoring undertaken over that period.

-
- Based on the model of the aquifer, recalibrated against observed measurements from the previous three years, prediction of performance is made for the next three years, with respect to the aquifer, wellfield and Yirrkala Creek. Predictions are based on recharge to the aquifer as a result of average rainfall conditions and no recharge to the aquifer over the three year period.
 - Impacts on the Yirrkala Creek settlement water supply that are implied by these predictions are evaluated and suitable recommendations are made to protect the viability of the supply against previously defined "sensible" effects in order that compliance with the Extraction Permit is maintained.

2.5 Proposed Groundwater Development

The proposed development incorporates expanding the current licenced groundwater extraction limit from 12,000 ML/an to 14,000 ML/an.

There is the potential that the higher water supply demand required for the expanded refinery can be managed within the existing licence limit of 12,000 ML/an. However, there are a number of unknowns associated with the expansion, which means an increase to the groundwater extraction licence is required to ensure there is no risk in supplying sufficient water to the expanded refinery in the future. As a result a revised licence limit of 14,000 ML/an has been proposed.

Any wellfield needs a level of redundancy to enable management of inefficient wells and/or failures of pumps, bores or infrastructure. The current wellfield has a capacity of approximately 12,700 ML/an, however, on average only extracts 9,200 ML/an. This level of redundancy (30%) appears to be appropriate, therefore has been maintained for the proposed expansion development. Thus assuming each production bore has a capacity of 1.95 ML/day, an extra seven (7) production wells are proposed.

The future mine plan also involves mining the bauxite south east of PB7 (Figure 3) and, as a result, removing the southern portion of the airstrip. To allow this mining, eight (8) of the existing production bores (PB7, PB 6, PB5, PB4, PB17, PB2, PB2B, PB1B and PB16) will need to be, at least temporally, decommissioned.

The proposed wellfield development therefore incorporates the following items:

- Increasing the wellfield capacity to 14,000 ML/an through an additional seven production bores; and
- Replacement of eight existing production bores.

3.1 Introduction

A number of hydrogeological parameters have been monitored on a generally continuous basis since the wellfield was first commissioned in early 1971. This data has been reviewed every three years in a triennial report required under the current licence for extracting groundwater.

The latest triennial report, just compiled, covered the period between 1999 and 2002². The following section summarises the conclusions drawn from this report and previous investigations conducted on the aquifer system.

3.2 Groundwater Levels

The results of the water level monitoring (hydrographs) are presented in Appendix A.

In general groundwater occurs 25 to 35 metres below ground level across the Airstrip Plateau, and all show a strong correlation to rainfall, with long term trends in groundwater levels reflecting either above or below average rainfall years. This is illustrated clearly in one of the observation bores (OB1) located towards the edge of the mining lease (Figure 4).

The strong correlation between trends in groundwater level and rainfall is expanded on in Section 3.6, which outlines a linear correlation and regression analysis.

3.3 Aquifer Hydraulic Properties

Transmissivity values have been determined from a number of pumping tests completed on the production wells. From all these tests it is apparent that the average hydraulic conductivity of the target horizon (Unit C)³ is approximately 40 m/day, though this varies from less than 10 m/day to greater than 100 m/day. The lower values seem to occur in production wells that lie close to basement highs, whilst the higher values occur randomly and probably relate to the presence of some more highly permeable strata in the sequence.

The storage coefficients determined during pumping tests were mainly derived from early time data and were in the range 0.0001 to 0.0002. These represent the confined reaction of the aquifers in the screened zone (Unit C) before gravity drainage and discharge diversion take place.

² URS Australia (2003). Gove Wellfield Statutory Report 1999 to 2002. 08002/137/561.

³ AGC Woodward-Clyde (1987). Gove Wellfield Consolidated Hydrogeological Report – Epilogue to Statutory Report Extraction Permit 305 (Amended).

3.4 Hydrochemistry

Groundwater extracted from the wellfield is a potassium/sodium chloride type water, with a very low salinity (<50 mg/L). The groundwater also has relatively high CO₂ levels, which result in a low pH (<5.5).

The pH measured in groundwater indicates that the water is outside the usual pH range for potability. However, analyses of pH downstream of the Aerator (Figure 3) show the waters to be only marginally outside the acceptable range.

Iron and heavy metals are low, because the salinity is low.

3.5 Historic Wellfield Extraction

Table 1 sets out the production capacity of the present production wells within the wellfield system as of October 2002. All the wells in the wellfield were operational at that time.

The total wellfield pumping capacity is currently 12,720 ML/a, which exceeds (106%) the licensed discharge of for the wellfield of 12000ML/a. The wellfield capacity has risen by 380 ML/a since the 1999 Triennium, due to the increased efficiency from new flexible rising main systems installed over the last two years, and a progressive replacement program standardising the motor and pump sets.

Figure 5 shows the wellfield production history since it commenced in 1971.

3.6 Aquifer Recharge

Recharge to the Mullaman Bed aquifer occurs across the surface of the Airstrip Plateau each wet season. The full process involves infiltration and saturation of the lower layers of the bauxite. As this occurs the tubular bauxite, in particular, passes water to discharge at higher rates to the marginal escarpment erosion channels and excavations. This is the major loss of water to aquifer recharge. Infiltrated water in temporary storage in the bauxite, moves progressively through the laterite and lateritic gravel sequences into the Mullaman Beds via fissures and “windows” in the pallid zone.

URS has, over time, been able to show a very strong relationship between water level rise in the aquifer (recharge) and recorded rainfall totals by using a linear correlation and regression analysis to the last 30 years data. The relationship (Equation 1) and derived line of best fit are plotted in Figure 6. The current correlation coefficient is extremely high ($r = 0.912$) and indicates that the relationship is highly significant.

$$Wtr = a + (b \times \text{Rain}) \quad \text{....Equation 1}$$

Where $a = -1.73$

$$b = 2.17 \times 10^{-3}$$

Wtr = rate of water table rise

Rain = water year rainfall

The equation indicates that no recharge (ie no change in the water level decline trend) will occur until approximately 800 mm of rainfall occurs during the wet season.

Less than 800mm of rainfall for a Water Year⁴ has only occurred once over the complete rainfall record. This was during 2001/02, where only 627mm fell, and resulted in no diminution in the water table decline resultant from aquifer drainage to streams and coastline and wellfield pumping.

3.7 Aquifer Discharge

Apart from wellfield extraction, discharge from the aquifer system(s) occurs continuously by way of subsurface discharge to the coast and as stream flow, evaporation and transpiration losses to the Latram River, Yirrkala Creek and North River at least.

The rate of discharge at any given time is dictated by the groundwater elevation generated by rainfall events of the preceding year.

⁴ Seasonal year (September to August)

4.1 Modelling Objectives

A numerical groundwater model was developed to provide an understanding of the regional hydrogeology in the Airstrip Plateau catchment area and to be used as a tool for assessing the potential impacts that certain mining activities may have on the environment. In particular, the modelling had the following key objectives;

- Determine whether extracting 14,000 ML/an of groundwater from beneath the Airstrip Plateau had an unacceptable impact on surface flow through Yirrkala Creek/Lagoon or any other surface water system in the region;
- Determine the most efficient configuration to the expanded wellfield to enable extraction of 14,000 ML/an of groundwater:

In order to achieve these objectives the model needed to consider the extent of the cone of depression due to groundwater extractions over time and the effect that reduced water levels had on groundwater discharge volumes to the surrounding creek and river systems.

4.2 Modelling Scope

Numerical modelling was performed using the United States Geological Survey (USGS) MODFLOW computer code (Visual Modflow V. 2.8.2.52). The modelling exercise involved following steps:

- Development of a conceptual flow model based upon our current understanding of the geology, hydrology and hydrogeology of the study area.
- Design and set up of the numerical model.
- Calibration of the numerical model, including matching of the steady-state and transient flow fields to historically observed conditions.
- Predictive simulations of several proposed well-field design scenarios and the anticipated groundwater levels.

4.3 Conceptual Hydrogeology

The essential features of the groundwater system have been described in Sections 2 and 3 in terms of a conceptual model. The numerical model must use the conceptual model to simulate the groundwater system.

Components of the numerical model are discussed in some detail in the following sections, but are summarised as follows:

- Four layers to represent the bauxite, Cretaceous deposits (layer 2 and 3), and basement;

-
- Regional rainfall recharge;
 - Groundwater inflow from neighbouring sub-catchments;
 - Evapotranspiration;
 - Groundwater and surface water outflow from the aquifer system along the creek/river systems; and
 - Wellfield extraction.

This concept has then been modelled using the available data and assumptions based on professional judgement and probability. Uncertainties are associated with the specifics of the model, but are inherent in the nature of the geology.

The model used to meet the objectives set out above has been developed through a series of steps involving discretization of the grid and hydraulic parameters until reasonable matches have been achieved to the hydraulic conditions and reactions observed.

The model at this stage is considered to be a “screening model”, the output from which gives reliable indications of the magnitudes of water level decline and groundwater discharges which can be expected, although at any specific location particular drawdowns and particular discharges volumes may vary.

As the expanded wellfield develops, and as monitoring results give a better spatial and temporal distribution, the model can be updated and its reliability improved.

4.4 Model Setup

The numerical model set up based on the conceptual site understanding is illustrated in Figures 7 to 10. General characteristics and summary of the input parameters are presented in Table 2.

4.4.1 Grid and Boundaries

The extent of the model domain was defined so as to encompass the following elements:

- Mine lease area;
- Regions where groundwater levels may potentially be impacted due to pumping from the proposed well field expansion; and
- Major hydrogeological units and boundaries assumed to define groundwater flow regime in the study area.

An area extending from 90,000 Easting/38,000 Northing to 112,000 Easting/56,000 Northing was considered to be representative of the required conditions (refer Figure 7).

The surface geometry of the top layer of the model represented an interpolation of the topographical data available for the mine lease and areas surrounding it. Elevations range between sea level and 50m MBHD⁵ on the plateau where the mine is located.

Hydraulic properties assumed for model layers were based upon site-specific and published/unpublished data. Average hydraulic conductivity of the major aquifer sequence was reported to vary from less than 10 m/d to greater than 100 m/d with an average of about 40 m/d⁶. The specific yield was estimated to be 25 – 30% and storage coefficients derived from early-time pumping tests data varied between 0.0001 and 0.0002.

4.4.2 Hydrogeological Units & Layers

The sub-surface geometry of the model was assumed to represent the typical hydro-stratigraphic profile across the well field as defined by previous investigations, and is summarised as follows (from top to bottom):

Typical Profile	Model Layer	Aquifer Sequence of the Typical Profile
A Bauxite/limonite	Layer 1	The unsaturated Units A and B and partially saturated portion of Unit C (above the typical screen interval level (upper Unit C)).
B Felspathic sandstone		
C Major aquifer sequence		
	Layer 2	Fully saturated portion of unit C (at the typical screen interval level (Lower Unit C)).
D Dispersed aquifer sands	Layer 3	Fully saturated unit D.
E Cemented aquifer sands	Layer 4	Fully saturated unit E.

The relevant part of the aquifer system for individual units were assumed to have an average maximum thickness based on the typical profile across the well field. That is, the saturated part of Layer 1 was

⁵ Melville Bay Height Datum

⁶ AGC Woodward-Clyde (1987). Gove Wellfield Consolidated Hydrogeological Report – Epilogue to Statutory Report Extraction Permit 305 (Amended).

assumed to be approximately 30 m thick, Layer 2 was assumed to be 20 m thick, maximum thickness of Layers 3 and 4 was assumed to be approximately 50 – 60 m each.

4.4.3 Recharge and Boundary Inflow

It was assumed that the major source of groundwater recharge in the model area was rainfall infiltration. Each rainfall year (from September to August inclusive) was assumed to represent one stress period with a constant recharge rate. The relationship between rainfall and water levels in representative bores OB1 and OB18 were used to evaluate groundwater recharge as a percentage of rainfall (Figure 6). The maximum possible rate of recharge for each year was assumed to represent the difference between the annual rainfall and the total rainfall estimated to be required before any change in the rate of groundwater level decline would occur (800 mm/a).

The recharge rate was assumed to represent one of the major calibration parameters given the strong relationship between the rainfall and the observed groundwater levels. It was assumed that the recharge rate was generally uniform across the model domain as no information was available with regard to historical events, which could help to define variations in the spatial distribution of the recharge in more detail.

It was recognised, however, that mining effects could have a significant effect on rainfall recharge to the aquifer system both temporally and spatially. This is based on comparing predicted water levels with a constant recharge against actual water levels (Figure 12) in an area that has undergone the following changes of surface cover:

- Pre-mining (Plate 1)
- Immediately following mining
- Early rehabilitation; and
- Established rehabilitation (Plate 2).

It is clear when comparing predicted versus actual water levels, that recharge over a certain period of time is underestimated. Further, work is needed to determine the close relationship between recharge, mining and the mined area rehabilitation and re-forestation. However, for this model, an overall average recharge volume, without the spatial changes, was used and as a result it is a conservative estimate of recharge.

In summary, the following assumptions were used during modelling with regards to recharge rates:

- For the steady-state flow simulations a fraction (26%) of the total average annual rainfall (1,500 mm) was used, and some spatial variations in recharge distribution were assumed applicable during calibration.
- During the calibration of the transient flow model, transient recharge rates were used.

-
- For the predictive scenarios, recharge was assumed to be uniformly distributed across the model domain and remain constant over time. The rate was assumed to be dependent upon the results of transient model calibration.

The model assumed that groundwater discharged via groundwater pumping and the surface water drainage systems. The rivers and the offshore discharge areas were assumed to represent major discharge areas. However, it was assumed that minor recharge occurred from some of the rivers in their upper reaches (such as the Latram River).

Assumptions with regards to surface-water levels were based on June 2003 survey data available for the Latram River. It was assumed that river stages for the other watercourses would similarly depend on ground surface topography. Due to the lack of historical data on surface water levels in the model area it was assumed that surface water levels remained constant over time.

Previous investigations concluded that regional groundwater flow in the study area was directed mainly to the east, with localised discharge areas such as rivers affecting the local groundwater flow direction. The groundwater flow regime across the model domain was assumed to be governed by the following boundary conditions:

- No-flow boundaries:
 - Granite bedrock outcrops;
 - Subsurface top of bedrock; and
 - Groundwater divide between the Latram and Giddy Rivers, which was assumed to exist along the western side of the model domain.
- Hydraulic boundaries consisting of :
 - Constant-head conditions along the Arafura Sea and Gulf of Carpentaria shoreline. Constant head boundary along the shoreline was extrapolated from the inferred groundwater contours, as it was assumed that discharge occurred some distance from the shore;
 - River boundaries along the major watercourses in the study area (Latram River, Yirrkala Creek, Shady Gum Creek, Rocky Creek and Dunnquwuy Creek). Assumptions for river boundary conditions (stage, depth, river bed conductance) were based on available river stage survey data, visual observations and stream flow data (1:250,000 Water Resources of North Eastern Arnhem Land map sheet).

Groundwater levels reported for observation bores in July 1971 (before the development of the well field) were assumed to represent initial conditions for transient calibration simulations. Simulated groundwater levels corresponding to the current conditions were assumed to represent initial conditions for predictive simulations.

4.5 Steady State Calibration

The steady-state flow model was created to simulate pre-well field development groundwater conditions at the site. The average annual recharge rate of 384 mm/a was used. Calibration was performed to match the July 1971 groundwater levels. During the calibration process hydraulic conductivities and recharge spatial distribution were varied in order to achieve the best possible match between the observed and simulated groundwater levels. During the calibration process an area approximately covering the extent of bauxite was assigned with the recharge rate of 100mm/a, the rest of the model domain remained at 384 mm/a.

Calibration results (refer Figure 11) were analysed both qualitatively and quantitatively. It was considered that simulated steady-state groundwater flow matched July 1971 inferred groundwater flow and observed heads with an acceptable degree of accuracy (mean error 0.2 m).

4.6 Transient Calibration

The transient-flow model was created to simulate changes in groundwater conditions during the past 30 years.

The transient model calibration incorporated the following assumptions:

- The calibrated steady-state flow field was used as initial conditions for the transient simulations
- Groundwater extraction from the wellfield was simulated by the pumping wells.
- The pumping schedule for the wells had an annual stress period basis, based on a Water Year (September through to August).
- Individual pumping wells assumed to represent existing wells were assigned with pumping rates constant over one stress period
- Annual pumping rate for each individual well was calculated as a representative fraction of the total well-field discharge for any particular year.
- It was assumed that the recharge rate was uniform across the model domain, as no details were available with regards to historical activities in the study area (for example, re-vegetation) which might have affected the rate of recharge in certain areas.
- Transient calibration was performed to match the simulated water levels with the water levels reported for the observation bores over time, with annual recharge rate as the major calibration parameter.

Simulated pumping rates are presented in Table 3 and transient recharge rates applied in Table 4.

During the calibration process observed and simulated water levels over time (hydrographs) were compared. Representative calibration results for observation bores OB1 and OB8 are presented in

Figure 12. Water levels predicted when the model recharge was set for each model year to a value equal to 50% of maximum possible recharge rate matched the changes in groundwater levels reasonably well. Although during certain periods of time during the model timeframe simulated heads were under- or over predicted, the calibration results were considered acceptable because of consistent times when those under- or over predictions had occurred for majority of the observation bores.

Transient calibration results were also assessed with regards to water budget.

The modelled groundwater discharge into the Latram River was 92.8 ML/day (vs 40 ML/day⁷), and into the Yirrkala, Shady Gum and Rocky Creeks – 40 ML/day (vs 32 ML/day). These results again confirm model conservatism. It should be noted that no-flow boundary along the west edge of the model domain forced water to flow north, which could then discharge into the river boundary cells representing the Latram River. Some underflow probably continues to the west, but the lack of bores in that area precluded defining the western edge of the model as anything but a no-flow boundary.

⁷ AGC Woodward-Clyde (1999). Gove Wellfield Report. Stream Flow Data

5.1 Basis for Assessment

Late in 1995, a groundwater supply bore for the Yirrkala community (RN30257), equipped to supply up to 30 L/sec, was installed by Waters and Rivers Department (Figure 3). This largely removed the concern over the maintenance of the Yirrkala Lagoon overflow for public water supply purposes. However, the primary objective now in maintaining flow through Yirrkala Lagoon is for environmental reasons. All Statutory Triennial reports for the wellfield, therefore still assess the impacts to Yirrkala Lagoon against the water level in the OB1 "sentinel bore" located adjacent to the lagoon. The assessment of impacts on Yirrkala Lagoon is based on the very strong correlation between discharge at Yirrkala Lagoon (Bellmouth weir) and the standing water level in OB1. This correlation has been built up on over 30 years of monitoring records.

As a management tool, a second level was assigned to warn of potential impacts and allow time to implement strategies. The reduced level of 11m MBHD (equal to a depth to water table of 31.11m) was adopted as the "warning level", previously signifying at least three years lead time before water levels dropped to the critical level of 10 m MBHD, indicating minimum flow conditions in Yirrkala Lagoon.

In an agreement between Alcan and the NT Controller of Waters, the water levels in OB1 were accepted as an indicator of discharge to Yirrkala Creek. The critical level in OB1 reflecting the discharge through Yirrkala Creek being at or less than 50 L/s is considered to be 10m MBHD or a water level of 32.11m below casing collar. This latter water level, as established in the 1985 Report, does not directly represent a danger of saltwater intrusion or destruction of the wetland environment, rather it is "the agreed onset of sensible effects" on Yirrkala Creek.

Over the history of wellfield extraction, the water level in OB1 has never dropped below the critical level, however it has fallen below the warning level over two periods:

- September 1992 to January 1995. Lowest recorded level during this time was 10.38m MBHD in January 1994; and
- March 1998 to February 1999. Lowest recorded level during this time was 10.58m MBHD in December 1998.

On both these occasions no observable impact was noted in Yirrkala Lagoon, and the critical level of 10m MBHD remains as a conservative indication of potential risks to flow through the Bellmouth weir.

5.2 Wellfield Extraction

A total groundwater extraction rate of 14,000 ML/an was used, as the volume required to ensure that there will be sufficient water supply for the proposed expanded refinery.

To incorporate the redundancy needed in the wellfield, the increased capacity required of the wellfield, is proposed to be covered with the installation of seven (7) additional production wells. This could give a

total capacity in the wellfield of approximately 17,000 ML/an, which allows just over 20% redundancy in the system.

5.3 Predictive Models

The predictive scenarios were assumed to simulate the existence of the proposed expansion for 30 years from now (anticipated remaining lifespan of mining). The predictive scenarios simulated different expanded well field configurations in terms of well position with respect to future mining operations and groundwater flow direction.

5.3.1 Scenario 1 – Existing Wellfield

In order to compare the various impacts to Yirrkala Lagoon from the different scenarios, the first predictive model run (Scenario 1) involved the existing wellfield configuration extracting 12,000 ML/an. This set a benchmark upon which the subsequent scenarios could be compared.

The output from Scenario 1 shows the level in OB1 stabilising at approximately 11.6 m MBHD. This appears to be realistic considering the observed monitoring record to date (Figure 13) and the predictive modelling undertaking during each triennial period⁸.

5.3.2 Scenario 2 – Expanding South East of PB16

The first scenario run to predict a 14,000 ML/an extraction volume (Scenario 2) incorporated extending the wellfield along the airstrip alignment to the south east.

For mining reasons this is not ideal as the wellfield would extend into unmined areas and either create expensive logistical considerations during mining or sterilise an area of bauxite.

The eight production bores located along the airstrip which are needed to be moved are assumed to be relocated in effectively the same location as they are today. This is logistically feasible, and is discussed further in Section 6.1.4.

The output from Scenario 2 (Figure 14) shows the level in OB1 stabilising at approximately 10.4 m MBHD, which is approximately 1.2 metres below Scenario 1 and 0.4 metres above, the critical level.

5.3.3 Scenario 3 – Expanding Due South of PB2

The second scenario run to predict the 14,000 ML/an extraction (Scenario 3) incorporated a more mining “friendly” extension to the wellfield. In Scenario 3 the new production bores are located in an area already mined of bauxite and along an existing road, due south of Production Bore PB2.

As with Scenario 2 the eight production bores located along the airstrip which are needed to be moved are assumed to be relocated in effectively the same location as they are today.

The output from Scenario 3 (Figure 15) shows the level in OB1 stabilising at approximately 10.3 m MBHD, which is approximately 1.3 metres below Scenario 1 and 0.3 metres above, the critical level.

5.3.4 Scenario 4 – Scenario 3 with northern extension

The third scenario run to predict the 14,000 ML/an extraction (Scenario 4) was effectively the same as Scenario 3, with the only difference a small northern extension to the wellfield.

This predictive model was run to assess the sensitivity of Yirrkala Creek flow to groundwater extraction occurring across a broader length of the aquifer discharging the creek. As was expected the model output (Figure 16) produced the lowest stabilised level in OB1 (10.1 m MBHD).

5.3.5 Scenario 5 – Second Wellfield to the East

The fourth scenario run to predict the 14,000 ML/an extraction (Scenario 5) was the same setup as Scenario 3, with five (5) of the existing production bores moved to a second wellfield almost 5.5 km to the west of the Airstrip. The production wells were arbitrarily located along the sealed road currently circling the mined area to the west.

The scenario was run to assess the hydrogeological benefits from capturing groundwater discharging to the Latram River rather than Yirrkala Lagoon/Creek.

The output from Scenario 5 (Figure 17) shows the level in OB1 stabilising at approximately 11.1 m MBHD, which is approximately 0.5 metres below Scenario 1 and 1.1 metres above the critical level.

5.3.6 Scenario 6 – Shady Gum Creek Alignment

The final scenario run to predict the 14,000 ML/an extraction (Scenario 6) was the existing wellfield configuration with an additional arm to the wellfield extending across Shady Gum Creek to the south of PB15.

This scenario was run to assess the hydrogeological benefits from capturing groundwater discharging to Shady Gum Creek and Rock Creek/Bay.

The new production bores are located within an area already mined of bauxite and along a current access road.

⁸ URS Australia Pty Ltd (2003). Gove Wellfield Review 1999 to 2002. 08002/137/561

The output from Scenario 6 (Figure 18) shows the level in OB1 equilibrating out at approximately 10.4 m MBHD, which is approximately 1.2 metres below Scenario 1 and 0.4 metres above the critical level.

5.4 Summary

The following summaries the predictive modelling results:

Scenario No.	Description	Modelled Extraction Rate ML/an	OB01 Level m MBHD
1	Current Wellfield	12,000	11.6
2	Current Wellfield, plus an extension south east of PB16.	14,000	10.4
3	Current Wellfield, plus an extension due south of PB2	14,000	10.3
4	Scenario 3, plus a northern arm to the wellfield	14,000	10.1
5	Scenario 3, plus a 2 nd wellfield 5km west of the airstrip.	14,000	11.1
6	Current Wellfield, plus second arm south of PB15	14,000	10.4

Based on the modelling results the following is concluded

- The stabilised level in OB1 is above the “critical” level of 10 m MBHD in all scenarios run. Thus predicted flow to Yirrkalā Lagoon remains above 50 L/sec no matter the configuration of wellfield for 14,000 ML/an extraction. Scenarios 2 and 6 show marginally less drawdown in OB1 as compared to Scenario 3, with Scenario 4 the lowest OB1 level and only 0.1 metres above the “critical” level of 10 m MBHD;
- Creating a second wellfield to the west of the airstrip, to capture groundwater discharging to the Latram River, produces minimal benefit in terms of a water level in OB1;
- Scenarios 3, 4 and 6 incorporate an expanded wellfield configuration that takes into account mined areas and existing access roads. Thus are the more practical in term of mine planning.
- Scenario 6 produces the least impact to OB1 water level, of the three sceneries taking into account mined areas. Scenario 6 is therefore preferred option in term of wellfield configuration.

6.1 Yirrkala Lagoon

A flow of 50 L/sec was established as the minimal flow required through Yirrkala Lagoon, which correlates to a level in OB1 of 10m MBHD or a water level of 32.11m below the bore casing collar. This latter water level, as established in 1985, does not directly represent a danger of saltwater intrusion or destruction of the wetland environment, rather it is "the agreed onset of sensible effects" on Yirrkala Creek.

In all of the predicted scenarios run (Section 5) the stabilised level in OB1 never falls below 10 m MBHD, and in the preferred option (Scenario 6 – Figure 19) the predicted level in OB1 stabilises at 10.4 m MBHD. This is considered to be a conservative estimate of the stabilised level in OB1 given thirty years of average rainfall, and is only 1.2 metres below the predicted level given the current wellfield configuration extracting 12,000 ML/an.

It should be noted, however, that in the event the water level in OB1 nears the 10 m MBHD “critical” level, the recommendation outlined in the report entitled "Contingency Water Supply Source for Yirrkala Lagoon Outflow Maintenance"⁹ would be considered. The recommendations in this report are based on the drilling of a test well, Gunya Binya No 1 (Figure 3), located below the old prospecting camp near the edge of Yirrkala Lagoon, and which suggest it is possible to supplement flow in the lagoon if required, through a 50L/s well point system. This would be achieved utilising up to 25 well point spaced at 12m intervals parallel to the lagoon margin. The system would be pumped by one or two pumps direct into the lagoon for a period of 2 to 4 months.

6.2 Latram and North River

The preferred option for expanding the wellfield is towards Shady Gum Creek and Rocky Creek and as a result the groundwater levels in the vicinity of the Latram and North River appear to show no measurable difference between the current wellfield configuration and the preferred expanded wellfield alignment.

Thus there appears to be no potential for any change in base flow in the Latram and North River from expanding the wellfield as proposed.

6.3 Other Groundwater Users

The only groundwater user in the vicinity of the wellfield that may potentially be impacted from the expanded wellfield is the Yirrkala Settlement bore (Figure 3).

⁹ Australian Groundwater Consultants (1988). Contingency Water Supply Source for Yirrkala Lagoon Outflow Maintenance. Ref JN142, June 1988.

The modelling results indicate a potential reduction in the available drawdown of this production well of less than 1 metre. There are no details on the construction of the production well, however, a reduction in available drawdown of less than 1 metre is not considered significant and should not effect the ability of the well to produce and maintain the design duty of 30 L/sec.

The modelling undertaken for this report incorporated all the available information on the wellfield, plus the monitoring data that has been collected over the last 30 years. However, in generating the model a number of key assumptions had to be made in order to address spatial data gaps and temporal unknowns.

The two key data gaps, which have the greatest potential to impact on the validity of the model, are the following:

1. The basement depth and aquifer depth/thickness along the proposed wellfield extension, and towards the groundwater discharge zones of Rocky Bay and Shady Gum Creek. This is significant, because if there is a basement high or the aquifer unit is thinner in the vicinity of the expanded wellfield bores then groundwater level drawdown caused by pumping will be greater. Currently the basement and aquifer units are assumed to be similar in depth and thickness to that encountered at beneath Airstrip; and
2. Recharge variance in mined areas (ie no vegetation cover) as compared to rehabilitated and pre-mined areas. This has obvious implications in terms of the volume of recharge (recovery) to the aquifer following each dry season.

In order to address these key data gaps the following investigations are recommended to be undertaken as soon as practicable:

- **Aquifer Investigation**– Undertake drilling and geophysical logging in three locations south west of the existing wellfield. Figure 19 outlines the proposed location. The primary objectives of each drilled hole would be the following:
 - OB19 – To confirm the geology along the proposed expanded wellfield alignment, and finalise the general design parameters for the new production bores.
 - OB20 – Confirm the geology/hydrogeology in the vicinity of Shady Gum Creek and Rocky Bay.
 - OB21 – Confirm the geology in the vicinity of Rocky Creek and Rocky Bay

This work is seen as being critical since it may require further evaluation of the wellfield layout.

- **Installation of Sentinel Bores** - Convert all three proposed investigation holes (OB19 to OB21) into long term observation bores to monitor water levels in the region and therefore potential changes to discharge rates to Shady Gum and Rocky Creek.
- **Assess the effect mining and mine rehabilitation has on aquifer recharge** – The mining and rehabilitation process that occurs across the Airstrip Plateau appears to have a temporally significant effect on aquifer recharge. It is therefore recommended to scope an assessment program to quantify this sensitivity and to subsequently re-calibrate the model developed for this report.

The work would involve compiling the progressive mining expansion, rehabilitation and re-forestation activities against the observation well hydrographs, which exist.

This work is seen as very important, albeit that it is unlikely to represent a fatal flaw in the strategy proposed for establishing a wellfield to meet 14,000 ML/an. The *** of the results may allow redesign of the wellfield in terms of extent and *** containment. The present model is quite conservative in this regard.

8.1 Wellfield Configuration

The current wellfield configuration has for the last 30 years successfully extracted groundwater from the Airstrip Plateau aquifer without any observable impacts to Yirrkala Lagoon or drawdown interference between production bores.

The proposed expanded wellfield design and configuration, outlined below, is therefore based on the success of the existing wellfield as well as the modelling results (Section 5).

8.1.1 Alignment

The predictive modelling outputs indicate that three of the scenarios (2, 3 and 6) result in a similar steady-state water level to OB1. All of which are above the assigned critical level of 10 m MBHD.

As discussed in Section 5.4 the preferred option based modelling results and the mine plan is Scenario 6, where the expended wellfield is south of PB15 across Shady Gum Creek and along an existing access road (Figure 19).

8.1.2 Production Bore Spacing

The original production bore spacing of 500 metres was designed from a series of aquifer tests conducted during the initial wellfield investigation conducted between 1970 and 1971 to ensure minimal drawdown interference. This design has proven to be effective over the last 30 years of wellfield production, and it is clear that the assumptions used and the validity of the results still hold.

Further, the scenarios created for the predictive modelling (Section 5) show that a production bore spacing of 500 metres will continue to efficiently extract groundwater without interference issues in all configurations run.

The expanded wellfield is therefore based on a 500 metre production bore spacing.

8.1.3 Production Bore Design

The general design of the new production bores follows the current understanding of the aquifer system and lessons learnt over the life of the existing wellfield. The specific details in the design, such as casing and screen depth cannot be finalised until the bore holes have been drilled and lithological and geophysically logged by an experienced qualified hydrogeologist.

The general production bore design is as follows:

- 380mm drilled diameter to full depth of well (approximately 100 metres);
- Production string incorporating the following:

-
- 60 metres of 200mm fibre glass casing to just above the target aquifer zone (Unit C of Mullaman Beds); and
 - 6 to 10 metres of 150mm stainless steel screen (0.030 slot size)

8.1.4 Wellfield Installation

The installation and commissioning of the expanded wellfield will need to give consideration to scheduling a number of key tasks to ensure there is a risk free transition from the current system.

In summary, the following tasks will need to be carefully detailed and scheduled:

1. **Confirm the geology and hydrogeology** of the aquifer along the proposed expanded wellfield alignment. It is proposed that this will incorporate the drilling and logging of three (3) investigation holes (Figure 19).

Based on the result of this drilling program the expanded wellfield alignment and design may need to be modified.

2. **Ordering of production bore materials.** The casing materials used in production bores of this size typically come from Singapore, with delivery times in the order of 3-6 months. The most efficient method would be a container shipment from Singapore directly to Gove.
3. **Installation and commissioning** of the seven new production wells along the expanded wellfield to be installed with associated infrastructure (pipeline and power supply) prior to the decommissioning of the airstrip bores. It is anticipated that this could be conducted over a six month period.
4. **Decommissioning** of the eight existing production bores located along southern section of airstrip for mining purposes.
5. **Production Bore Replacement** of the decommissioned bores on an as need basis during the refinery expansion.

8.2 Groundwater Extraction Volumes

The current design duty from each of the existing production bores is in the order of 2.7 ML/day (31 L/sec), although on average, across the current wellfield, each production bore extracts in the order of 1.95 ML/day. A similar yield range can be expected from the production bores along the new alignment, although this needs to be confirmed by the proposed investigation program (Section 7).

Maintaining the efficiency of the wellfield and reducing the risk of bore and/or equipment failure is a process of continuous monitoring and review.

The minimum monitoring to be undertaken across the wellfield to ensure sufficient data is collected to allow effective management is as follows:

- Monitor groundwater extraction volumes and water levels in all production bores on a monthly basis;
- Monitor the water level in all observation wells on a monthly basis, including the three new proposed observation bores (OB19 to OB21);
- Monthly specific capacity testing of all production bores;
- Record rainfall totals on a monthly basis;
- Record stream flow volumes in the following surface water systems:
 - Yirrkala Lagoon (Bellmouth Weir)
 - Latram River
- Conduct a detailed review of the monitoring data every three years. The objective of the review should be the following:
 - Evaluate of the performance of the aquifer, the wellfield and associated surface water systems;
 - Recalibrate the model developed against observed measurements from the previous three years, prediction of performance is made for the next three years, with respect to the aquifer, wellfield and Yirrkala Creek.

The conclusions from the groundwater review and modelling are as follows

- Currently Alcan are licenced to extract 12,000 ML of groundwater from the Airstrip Plateau aquifer over any twelve month period. The average actual extraction is currently in the order of 9,200 ML/an;
- Groundwater extraction from the existing wellfield has produced no identifiable adverse impacts on the surface water environment of Yirrkala Lagoon since its commissioning in 1971;
- An increase to the groundwater extraction limit of 12,000 ML/an to 14,000 ML/an has been proposed to ensure there is sufficient water to supply the expanded refinery in the future. There is the potential that the higher water supply demand required for the expanded refinery can be managed within the existing licence limit, however, there are a number of unknowns within the expansion, and as a result a revised licence limit of 14,000 ML/an has been proposed.
- Predictive modelling on the resultant groundwater levels from an expanded wellfield extracting 14,000 ML/an indicates the following:
 - The stabilised level in OB1 remains above the “critical” level of 10 m MBHD in all six scenarios that were run;
 - Creating a second wellfield to the west of the airstrip to capture groundwater discharging to the Latram and Giddy Rivers produces minimal benefit in terms of a water level in OB1;
 - The preferred configuration of the expanded wellfield is an alignment south of PB15 across Shady Gum Creek, which captures groundwater discharging to Rocky Bay and the lower reaches of Shady Gum Creek, and indicates that there will be no discernible impact to base flow in the Latram and North Rivers.
- Some investigation drilling is necessary to confirm the geological continuity of the aquifer in the areas proposed for the extended wellfield. Similarly, there is a need to better evaluate the recharge regimes as they are affected by the progression of mining and land rehabilitation across the Airstrip Plateau.

Based on the conclusions from the groundwater modelling the following recommendations are made in relation to the groundwater supply:

- Confirm the geological and recharge assumptions incorporated into the groundwater model for the groundwater system along the new proposed wellfield alignment through an investigation program of drilling and geophysical logging and analysis of past mining and rehabilitation effects;
- Regularly update and recalibrate the model developed for this report, and report on any potential impacts to the groundwater receiving environments of Yirrkala Lagoon, Shady Gum Creek and Rocky Creek.
- Incorporate of a number of additional “sentinel” observation bores in locations that will effectively assess groundwater discharge changes along Shady Gum Creek and Rocky Creek. These location should be agreed in advance with the Department of Water and Rivers;
- Expand the current groundwater and surface water monitoring system undertaken across the Airstrip Plateau to include the additional observation bores recommended.

URS Australia Pty Ltd (URS) has prepared this report for the use of Alcan Gove Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated ***, 2002.

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

This report was prepared between January 2003 and August 2003 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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

This report contains information obtained by inspection, sampling, testing or other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. The borehole logs indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of conditions as constrained by the project budget limitations. The behaviour of groundwater and some aspects of contaminants in soil and groundwater are complex. Our conclusions are based upon the analytical data presented in this report and our experience. Future advances in regard to the understanding of chemicals and their behaviour, and changes in regulations affecting their management, could impact on our conclusions and recommendations regarding their potential presence on this site.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, URS must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

Table 1
Production Bore Details
Wellfield Review (99-02)

Production Bore	Capacity				Motor			Wellmaster Hose System Installed	Pump		Comments
	m3/hour	m3/day	ML/year	L/sec	Type	Date Installed	Serial #		Type	Serial #	
1B	88	2,112	771	24.4	Franklin	Sep-02	02-819-27-0053	May-02	5 Stage Weir	56-3-611-C23	No issues with new motor/pump since installation.
2	83	1,992	727	23.1	Franklin	Jun-02	01-M19-04-0008	Jun-02	5 Stage Weir	207505-2	Missing locking screw when initially installed. No issues since.
2B	89	2,136	780	24.7	Franklin	Oct-01	00-F19-21-0009 338716945	Jan-01	5 Stage Weir	?	No issues with new motor/pump since installation.
4	80	1,920	701	22.2	Old 6" Franklin	?	?	Apr-01	6" Pleuger	06-12	No issues with old motor/pump system over the last three years. Pleuger pump #709, 6stg, with 1stg removed.
5	89	2,136	780	24.7	Franklin	Sep-02	02-819-27-0038	Jul-01	5 Stage Weir	?	No issues with new motor/pump since installation.
6	80	1,920	701	22.2	Franklin	Jul-01	00-M19-12-93 338710945	Apr-01	5 Stage Weir	206455-01	Impellors needed to be reduced, when initially bought, has been OK installation.
7A	80	1,920	701	22.2	Old 6" Franklin		20-0019	Mar-01	Pump51	1612	Drawing high Amps in April-01, and motor was replaced with a spare Franklin. Motor cables found tight in Oct-01, and needed to be released, possibly due to motor vibration. New Franklin/Weir system to be installed.
8	88	2,112	771	24.4	Franklin	Jun-02	01-G19-26-0008	Mar-01	5 Stage Weir	207505-01	No issues with new motor/pump since installation.
9A	98	2,352	858	27.2	Franklin	May-02	01-G19-26-0013	May-02	5 Stage Weir	?	No issues with new motor/pump since installation. However no SWL due to loss of tape recently
10	80	1,920	701	22.2	Old 8" Franklin	?	?	Mar-02	?		No issues with old motor/pump system over the last three years.
11	89	2,136	780	24.7	Franklin	Feb-02	01-E19-29-0063	Feb-02	5 Stage Weir	207083-01	Old pump system failed in Dec-99, and new Franklin/Weir system installed. It was noted during installation that base of bore was higher than original, possible silting. Development needed.
12	78	1,872	683	21.7	Franklin	May-02	01-E19-31-0023 336710945	Sep-01	5 Stage Weir	206455-01	No issues with new motor/pump since installation. However, transformer shorted in June-00.
13	85	2,040	745	23.6	Franklin	Nov-01	01-F19-21-0043 338710945	Nov-01	5 Stage Weir	56-3-611-C23 206455-03	No issues with new motor/pump since installation. However old system failed with blown fuses in Oct-01. Reason unknown
14A	78	1,872	683	21.7	Franklin	Oct-02	02-A19-11-0033	Oct-02	5 Stage Weir	207550-03	When new system was initially installed the power dropped out, with no known reason. Has been OK since
15	80	1,920	701	22.2	Franklin	Jan-02	01-E19-22-0003 338710945	Jan-02	5 Stage Weir	?	No issues with new motor/pump since installation.
16	89	2,136	780	24.7	Old 6" Franklin	?	9-0013-A96	Jul-02	8" Warman	32441 #2	No issues, however, Franklin/Weir system still to be fitted.
17	98	2,352	858	27.2	Old 8" Franklin	?	9-0028-A96	Jan-01	8" Warman	6968	No issues with old motor/pump system over the last three years. Further, it was pulled in Dec-00 and serviced, no issues found.
	1,452	34,848	12,720	403							

ELPRO	427	10,248	3,741	119
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% of total capacity **29.4%**

Table 2
Model Parameters

Parameter	Input	Rationale
Geometry	22km x 18km	Encompass the mine site and potentially impacted areas (such as Yirrkala Creek) Mine Grid Eastings: 90000 – 112000 Mine Grid Northings: 38000 - 56000
Grid Size	Maximum cell 100m x 100m	
Inactive Cells	Cells beyond the outflow head boundaries and no flow boundaries.	Areas assumed inactive for flow, eg. basement outcrops, offshore areas.
Layers (from the topmost) and Layer Types assigned (S – storage coefficient, T – transmissivity)	Layer 1 - Unconfined Top elevation between 70 MBHD and 0 MBHD Bottom elevation –30 MBHD	Unsaturated bauxite and felsphatic sandstone sequence, and major aquifer sequence above the screen zones of typical profile. Ground surface topography interpolated by Modflow from 2.5MBHD, 10MBHD, 30MBHD, 50MBHD and 70MBHD contours (minemap.dwg). Bottom elevation based on typical profile (WOODWARD-CLYDE, 1999).
	Layer 2 - Confined/unconfined, variable S, T Bottom elevation –50 MBHD	Major aquifer sequence at screen levels of typical profile.
	Layer 3 - Confined/unconfined, variable S, T Bottom elevation between – 120 MBHD/-50 MBHD and - 105/-110 MBHD	Dispersed aquifer sands. Bottom elevation based on typical profile.
	Layer 4 - Confined/unconfined, variable S, T Bottom elevation between –150 MBHD and -65 MBHD	Cemented aquifer sands. Bottom elevation interpolated from basement contours (WOODWARD-CLYDE, 1999).

Parameter		Input	Rationale	
Boundaries				
Constant Head		Constant head 3 MBHD along the shoreline.	Offshore discharge. Head extrapolated from inferred groundwater contours (WOODWARD-CLYDE, 1999).	
Recharge		Applied to the topmost active layer.	Schedule (refer Table A1) based upon annual stress periods (rainfall year (from September to August inclusive)). Calculated annual recharge rates adjusted during calibration. Average annual recharge rate of 300 mm/a for predictive simulations (50% of maximum possible average annual recharge).	
River		Latram River Yirrkala Creek Shady Gum Creek Rocky Creek Dunnquwuy Creek	Latram River stages based on river stage survey data June 2003. Stages assigned to the rest of the river boundaries – based on ground surface topography, adjusted during calibration. River bed conductance – uniform for all river boundaries, adjusted during calibration to 500 m ² /day.	
Hydraulic Parameters: Hydraulic Conductivity (K), Specific Yield (Sy), Specific Storage (Ss)				
	Kx K _x = K _y =10K _z	Sy	Ss	Based on reported and assumed permeability and storage characteristics, adjusted during calibration.
Layer 1	10 m/day	0.1	0.1 1/m	
Layer 2	40 m/day	0.3	0.0015 1/m	
Layer 3	1 m/day	0.2	0.00036 1/m	
Layer 4	0.5 m/day	0.1	0.0002 1/m	
Additional Stresses				
Pumping Wells		Used in transient calibration simulations and predictive simulations.	Existing well field configuration and discharge rate. Proposed expansion – varied	

Parameter	Input	Rationale
	Screens located in Layer 2.	configuration and discharge rate.

Table 3
Pumping Schedule

Calculation of Fractions of Production Well Flow Rate (cub.m/hour)

Time	16	1B	2	2B	17	4	5	6	7A	8	9A	10	11	12	13	14	15	Total Flow Rate
September - December 1996	339.23	362.73	154.57	343.96	199.83	260.32	298.10	234.24	313.02	287.92	333.68	317.10	318.66	172.69	267.25	232.31	289.81	4725.44
Total year 1997	860.29	1072.62	315.06	1079.28	490.16	709.64	867.96	779.54	736.51	721.17	713.83	660.62	690.98	373.40	877.63	785.72	920.98	12655.39
Total year 1998	849.56	1089.37	280.78	1101.24	457.55	689.76	853.27	748.31	580.44	600.23	674.28	668.07	647.84	340.87	893.00	818.73	943.64	12236.96
January - August 1999	502.78	474.10	197.26	540.35	287.13	324.32	0.63	233.15	158.82	383.79	248.83	373.89	503.14	206.37	469.58	380.32	482.37	5766.83
Fraction of Total Flow Rate	0.07	0.08	0.03	0.09	0.04	0.06	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.03	0.07	0.06	0.07	35384.61

Calculation of Simulated Production Well Flow Rate (cub.m/day)

Date	Simulated Time, days		Mean Discharge, ML/day	16	1B	2	2B	17	4	5	6	7A	8	9A	10	11	12	13	14	15
June-72	0	363	18.93	1402.35	1574.46	542.99	1617.10	795.87	1058.80	953.45	1006.66	943.55	1104.92	1065.89	1129.60	1240.75	613.65	1326.31	1155.01	1395.19
June-73	363	728	22.64	1677.43	1883.31	649.50	1934.32	951.99	1266.49	1140.48	1204.12	1128.63	1321.66	1274.97	1351.19	1484.13	734.02	1586.48	1381.58	1668.87
June-74	728	1093	24.69	1829.70	2054.26	708.46	2109.90	1038.40	1381.46	1244.01	1313.42	1231.08	1441.63	1390.71	1473.84	1618.85	800.65	1730.49	1506.99	1820.36
June-75	1093	1458	26.39	1955.07	2195.02	757.00	2254.47	1109.55	1476.12	1329.25	1403.42	1315.44	1540.42	1486.00	1574.83	1729.78	855.51	1849.06	1610.25	1945.09
June-76	1458	1823	27.01	2000.92	2246.50	774.75	2307.34	1135.57	1510.73	1360.42	1436.33	1346.28	1576.54	1520.85	1611.76	1770.34	875.57	1892.42	1648.01	1990.70
June-77	1823	2188	26.17	1938.76	2176.72	750.69	2235.67	1100.30	1463.81	1318.16	1391.72	1304.47	1527.57	1473.61	1561.69	1715.35	848.38	1833.64	1596.82	1928.87
June-78	2188	2553	25.62	1898.11	2131.07	734.95	2188.79	1077.23	1433.11	1290.52	1362.53	1277.11	1495.54	1442.71	1528.95	1679.38	830.59	1795.19	1563.34	1888.42
June-79	2553	2918	26.39	1955.52	2195.53	757.18	2254.99	1109.81	1476.46	1329.56	1403.75	1315.74	1540.77	1486.34	1575.19	1730.18	855.71	1849.49	1610.63	1945.54
June-80	2918	3283	26.22	1943.04	2181.52	752.34	2240.60	1102.73	1467.03	1321.07	1394.79	1307.34	1530.94	1476.86	1565.14	1719.14	850.25	1837.69	1600.34	1933.12
June-81	3283	3648	27.25	2018.90	2266.68	781.72	2328.07	1145.78	1524.31	1372.64	1449.24	1358.38	1590.71	1534.51	1626.24	1786.25	883.44	1909.43	1662.82	2008.59
June-82	3648	4013	24.31	1801.13	2022.19	697.40	2076.95	1022.19	1359.89	1224.58	1292.92	1211.86	1419.12	1368.99	1450.83	1593.58	788.15	1703.47	1483.46	1791.93
June-83	4013	4378	26.28	1946.83	2185.78	753.81	2244.97	1104.88	1469.90	1323.65	1397.51	1309.90	1533.93	1479.74	1568.19	1722.49	851.91	1841.27	1603.47	1936.89
June-84	4378	4743	26.45	1959.66	2200.17	758.78	2259.76	1112.16	1479.58	1332.37	1406.71	1318.52	1544.03	1489.49	1578.52	1733.84	857.52	1853.40	1614.03	1949.65
June-85	4743	5108	26.61	1971.76	2213.76	763.46	2273.72	1119.02	1488.72	1340.60	1415.40	1326.67	1553.56	1498.68	1588.27	1744.54	862.81	1864.85	1624.00	1961.69
June-86	5108	5473	26.24	1944.57	2183.23	752.94	2242.36	1103.59	1468.19	1322.11	1395.88	1308.37	1532.14	1478.02	1566.37	1720.49	850.92	1839.13	1601.60	1934.64
June-87	5473	5838	26.80	1985.42	2229.10	768.76	2289.48	1126.78	1499.04	1349.89	1425.21	1335.86	1564.33	1509.07	1599.28	1756.64	868.79	1877.77	1635.25	1975.29
June-88	5838	6203	28.12	2083.82	2339.58	806.86	2402.94	1182.62	1573.33	1416.79	1495.85	1402.07	1641.86	1583.86	1678.54	1843.70	911.85	1970.84	1716.30	2073.19
June-89	6203	6568	28.54	2114.65	2374.19	818.79	2438.49	1200.12	1596.60	1437.75	1517.97	1422.81	1666.15	1607.29	1703.37	1870.97	925.34	1999.99	1741.69	2103.85
June-90	6568	6933	27.67	2049.94	2301.54	793.74	2363.87	1163.39	1547.75	1393.75	1471.52	1379.27	1615.16	1558.11	1651.25	1813.72	897.02	1938.79	1688.39	2039.47
June-91	6933	7298	27.02	2001.78	2247.47	775.09	2308.34	1136.06	1511.39	1361.01	1436.95	1346.87	1577.22	1521.51	1612.46	1771.11	875.95	1893.24	1648.73	1991.57
June-92	7298	7663	27.05	2004.00	2249.97	775.95	2310.90	1137.32	1513.06	1362.52	1438.55	1348.36	1578.97	1523.19	1614.25	1773.08	876.92	1895.35	1650.56	1993.78
June-93	7663	8028	25.08	1858.10	2086.15	719.46	2142.65	1054.52	1402.90	1263.32	1333.81	1250.19	1464.01	1412.30	1496.72	1643.98	813.08	1757.35	1530.38	1848.61
June-94	8028	8396	24.14	1788.48	2007.99	692.50	2062.37	1015.01	1350.34	1215.98	1283.84	1203.35	1409.16	1359.38	1440.64	1582.38	782.61	1691.50	1473.04	1779.35
June-95	8396	8761	24.16	1790.26	2009.99	693.19	2064.43	1016.02	1351.69	1217.20	1285.12	1204.55	1410.56	1360.74	1442.08	1583.96	783.39	1693.19	1474.51	1781.13
June-96	8761	9127	24.97	1850.03	2077.09	716.33	2133.34	1049.94	1396.81	1257.83	1328.02	1244.76	1457.65	1406.16	1490.22	1636.84	809.55	1749.72	1523.74	1840.58
June-97	9127	9493	25.30	1874.52	2104.59	725.81	2161.59	1063.84	1415.30	1274.48	1345.60	1261.24	1476.95	1424.78	1509.94	1658.51	820.26	1772.88	1543.91	1864.95
June-98	9493	9859	24.90	1845.24	2071.71	714.47	2127.82	1047.22	1393.19	1254.57	1324.58	1241.54	1453.88	1402.52	1486.36	1632.60	807.45	1745.19	1519.79	1835.82
July-99	9859	10225	24.66	1827.42	2051.70	707.58	2107.27	1037.11	1379.74	1242.46	1311.79	1229.55	1439.84	1388.98	1472.00	1616.84	799.65	1728.33	1505.12	1818.09
June-00	10225	10561	23.06	1708.25	1917.91	661.43	1969.85	969.47	1289.76	1161.43	1226.24	1149.37	1345.94	1298.40	1376.01	1511.40	747.50	1615.62	1406.96	1699.53
June-01	10561	10927	23.26	1723.15	1934.64	667.20	1987.04	977.93	1301.02	1171.57	1236.94	1159.40	1357.69	1309.73	1388.02	1524.59	754.03	1629.72	1419.24	1714.36
June-02	10927	11293	25.31	1875.48	2105.67	726.19	2162.70	1064.38	1416.03	1275.14	1346.29	1261.89	1477.71	1425.51	1510.72	1659.36	820.68	1773.79	1544.70	1865.91

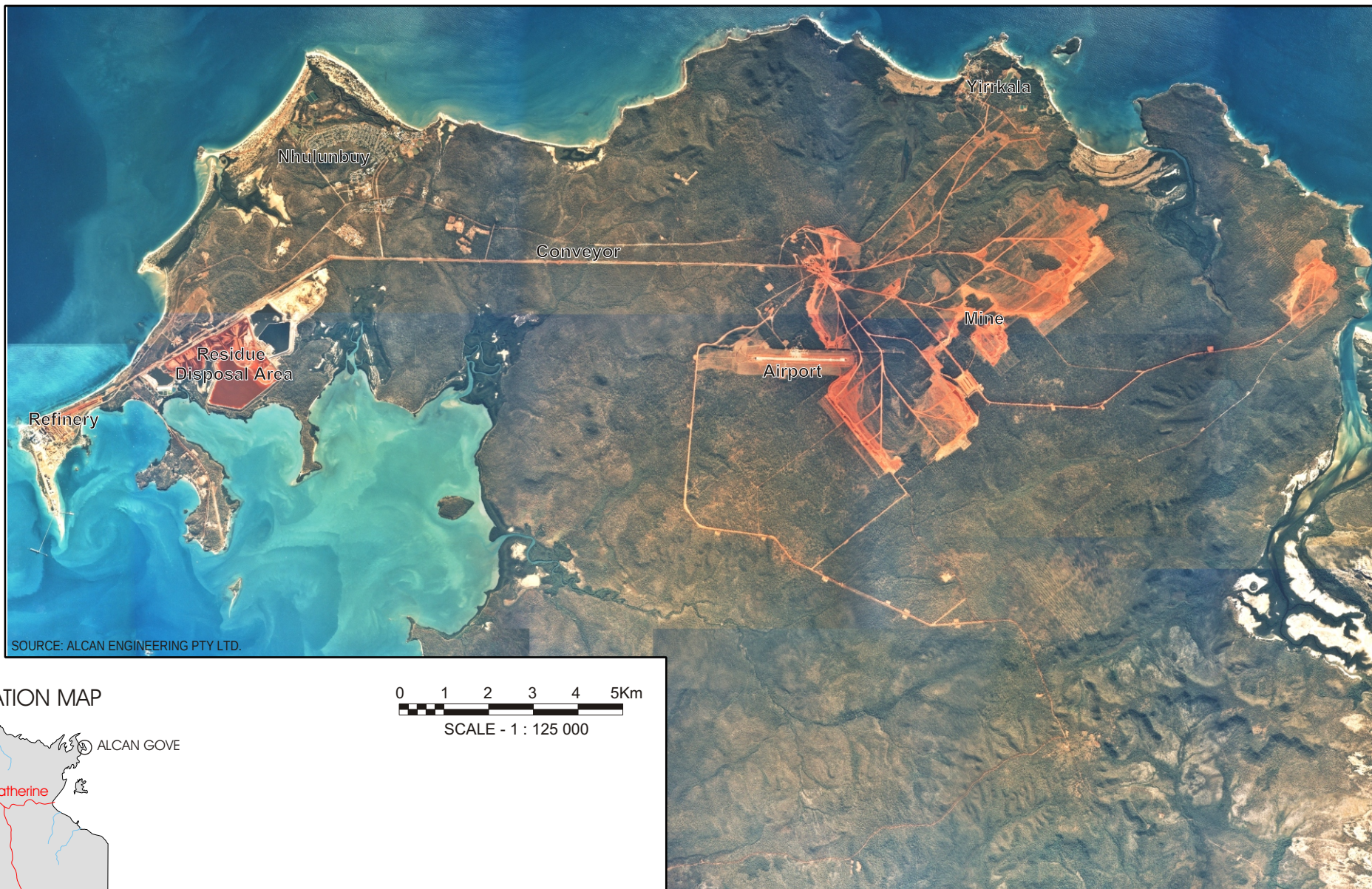
Table 4
Simulated Recharge Values

Wet Year		Rainfall (mm)	SWL Rise (mm)		Maximum Recharge * (mm)	50% of Maximum Recharge (mm)	Simulated Time Periods, days	
			OB1	OB18				
Sep-71	Aug-72	#N/A	#N/A	#N/A	#N/A	500	0	427
Sep-72	Aug-73	1905	#N/A	#N/A	1095	547.5	427	791
Sep-73	Aug-74	1098	#N/A	#N/A	288	144	791	1155
Sep-74	Aug-75	1606	#N/A	#N/A	796	398	1155	1519
Sep-75	Aug-76	2398	#N/A	#N/A	1588	794	1519	1884
Sep-76	Aug-77	2062	#N/A	#N/A	1252	626	1884	2248
Sep-77	Aug-78	1393	#N/A	#N/A	583	291.5	2248	2612
Sep-78	Aug-79	1243	#N/A	#N/A	433	216.5	2612	2976
Sep-79	Aug-80	2,000	2,240	1,940	1190	595	2976	3341
Sep-80	Aug-81	931	0	0	121	60.5	3341	3705
Sep-81	Aug-82	1,422.0	430	130	612	306	3705	4069
Sep-82	Aug-83	1,572.0	1,010	#N/A	762	381	4069	4433
Sep-83	Aug-84	1,089.0	750	#N/A	279	139.5	4433	4798
Sep-84	Aug-85	1,560.6	1,110	1,500	750.6	375.3	4798	5162
Sep-85	Aug-86	1,146.0	220	240	336.8	168.4	5162	5526
Sep-86	Aug-87	1,426.5	930	1,510	616.5	308.25	5526	5890
Sep-87	Aug-88	969.4	450	370	159.4	79.7	5890	6255
Sep-88	Aug-89	1,703.4	1,330	1,420	893.4	446.7	6255	6619
Sep-89	Aug-90	2,220.9	140	20	1410.9	705.45	6619	6983
Sep-90	Aug-91	829.7	120	180	19.7	9.85	6983	7347
Sep-91	Aug-92	1,055.4	220	140	245.4	122.7	7347	7712
Sep-92	Aug-93	1,236.7	360	290	426.7	213.35	7712	8076
Sep-93	Aug-94	1,552.2	920	1,340	742.2	371.1	8076	8440
Sep-94	Aug-95	1,643.8	1,160	1,670	833.8	416.9	8440	8804
Sep-95	Aug-96	1,430.3	440	840	620.3	310.15	8804	9169
Sep-96	Aug-97	1,116.3	200	210	306.3	153.15	9169	9533
Sep-97	Aug-98	1,127.8	160	180	317.8	158.9	9533	9897
Sep-98	Aug-99	2,562.6	3,530	3,540	1752.6	876.3	9897	10261
Sep-99	Aug-00	1,928.4	1,240	#N/A	1118.4	559.2	10261	10626
Sep-00	Aug-01	2,018.3	2,630	#N/A	1208.3	604.15	10626	10990

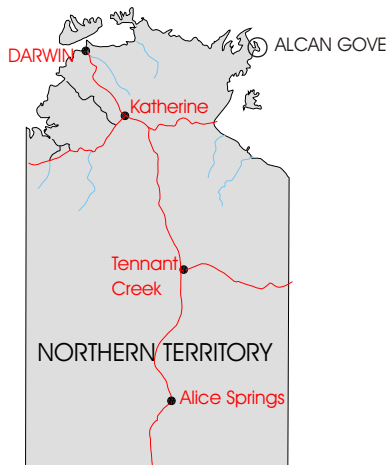
N/A - not applicable

Recharge = Rainfall - Total rainfall estimated to be needed before any recharge will occur (810 mm)

Figures



LOCATION MAP



0 1 2 3 4 5Km
SCALE - 1 : 125 000

CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Regional Location

DESIGNED: **B.R.C.**
DRAWN: **L.L.B.**
DATE: **22/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137**
CAD FILE: **eis third stage - fig 1**
REVISION: **A**

URS

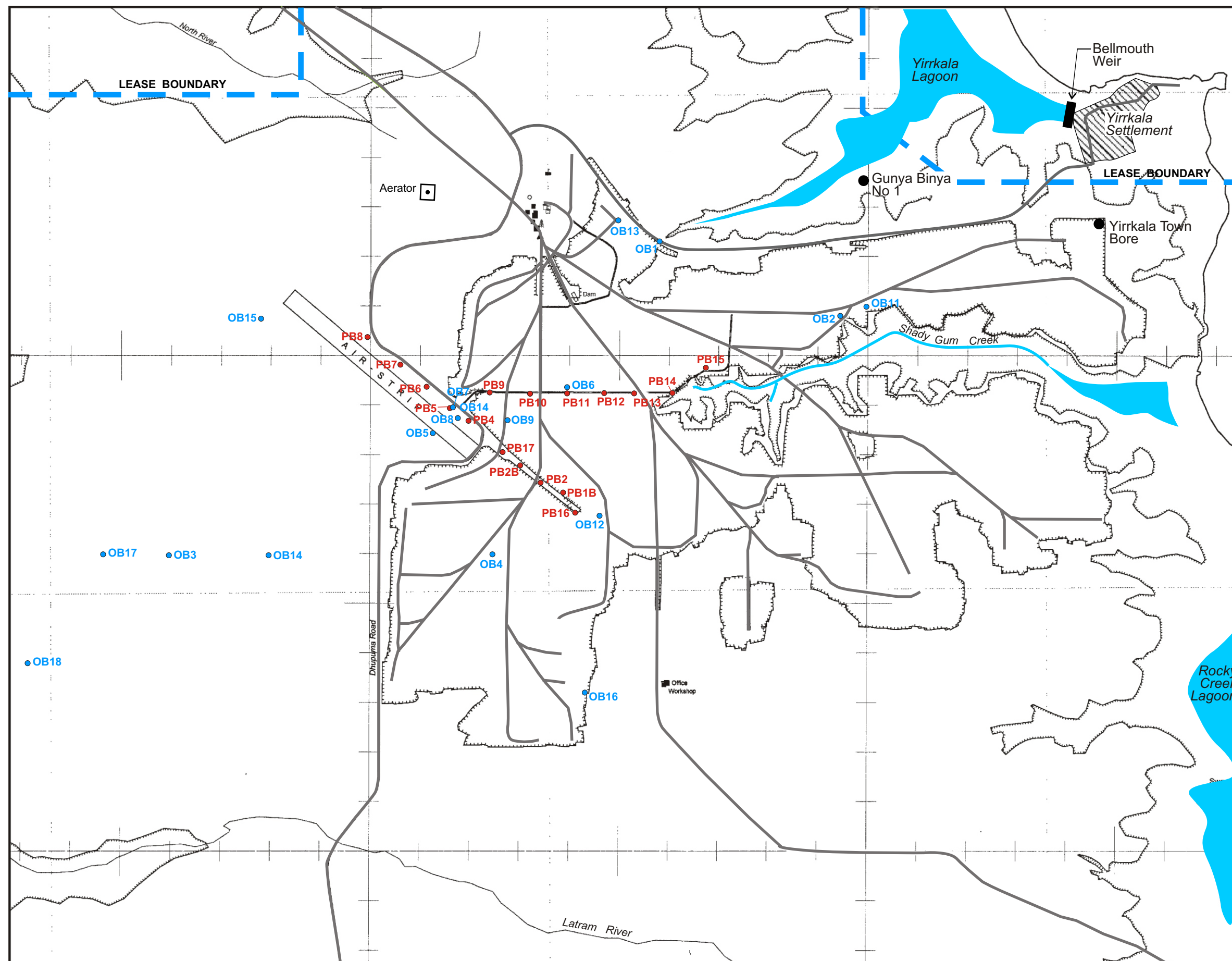
FIGURE
1



CLIENT: ALCAN GOVE PTY LTD			TITLE: WELLFIELD LOCATION	
PROJECT: EIS - THIRD STAGE EXPANSION				
	DESIGNED: B.R.C.	APPROVED:	PROJECT: 08002-137	
	DRAWN: L.L.B.	DATE:	CAD FILE: eis third stage - fig 2	
	DATE: 18/07/03	STATUS: Draft	REVISION: A	

A3

FIGURE
2



LEGEND:

- **PB8** Production bores
- **OB16** Observation bores

CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Wellfield Location Map

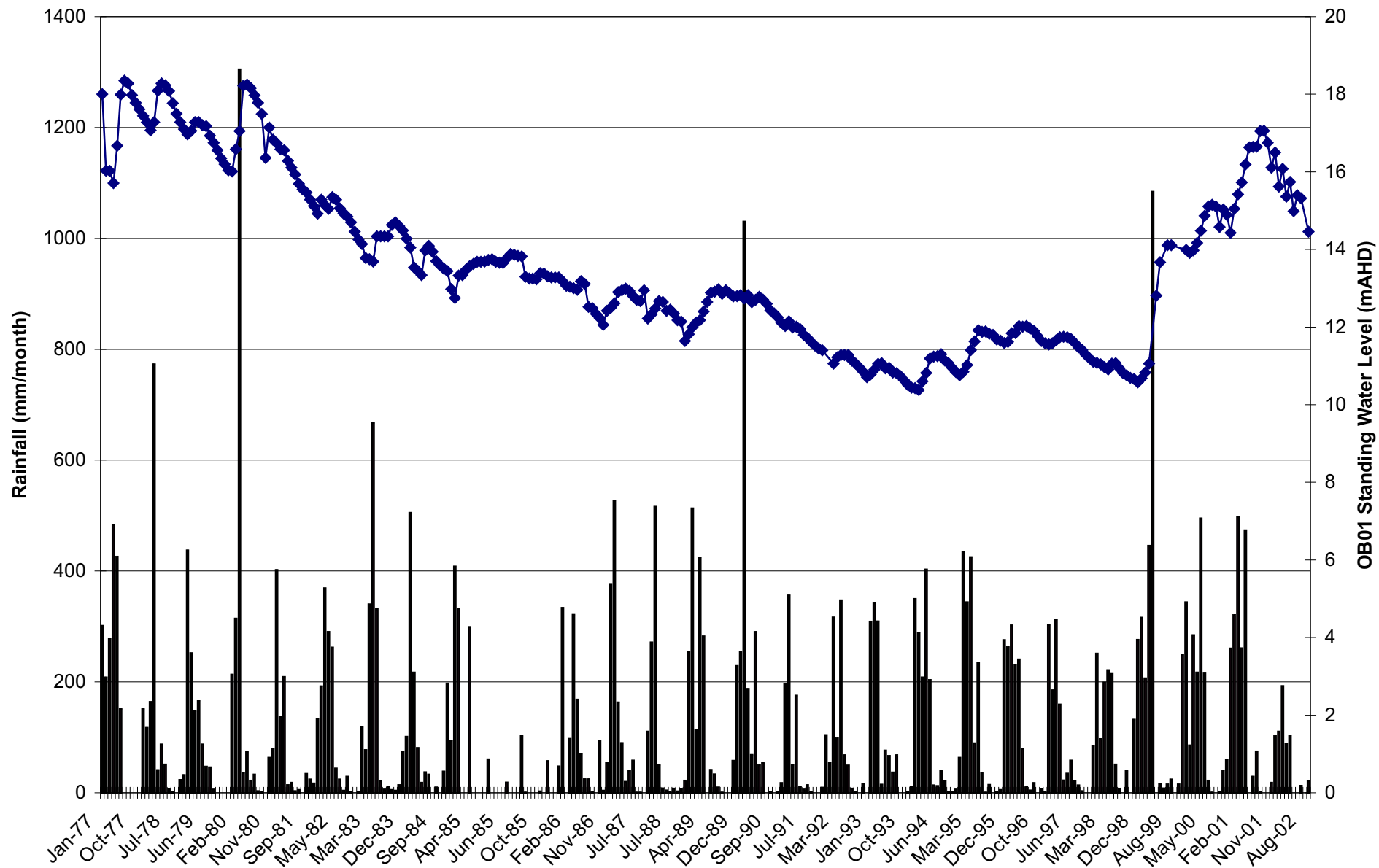
DESIGNED: **B.R.C.**
DRAWN: **L.L.B.**
DATE: **18/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137**
CAD FILE: **eis third stage - fig 3**
REVISION: **A**



FIGURE
3



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Rainfall and Reduced Water Levels - OB01

DESIGNED: **B.R.C.**
DRAWN: **L.L.B.**
DATE: **22/07/03**

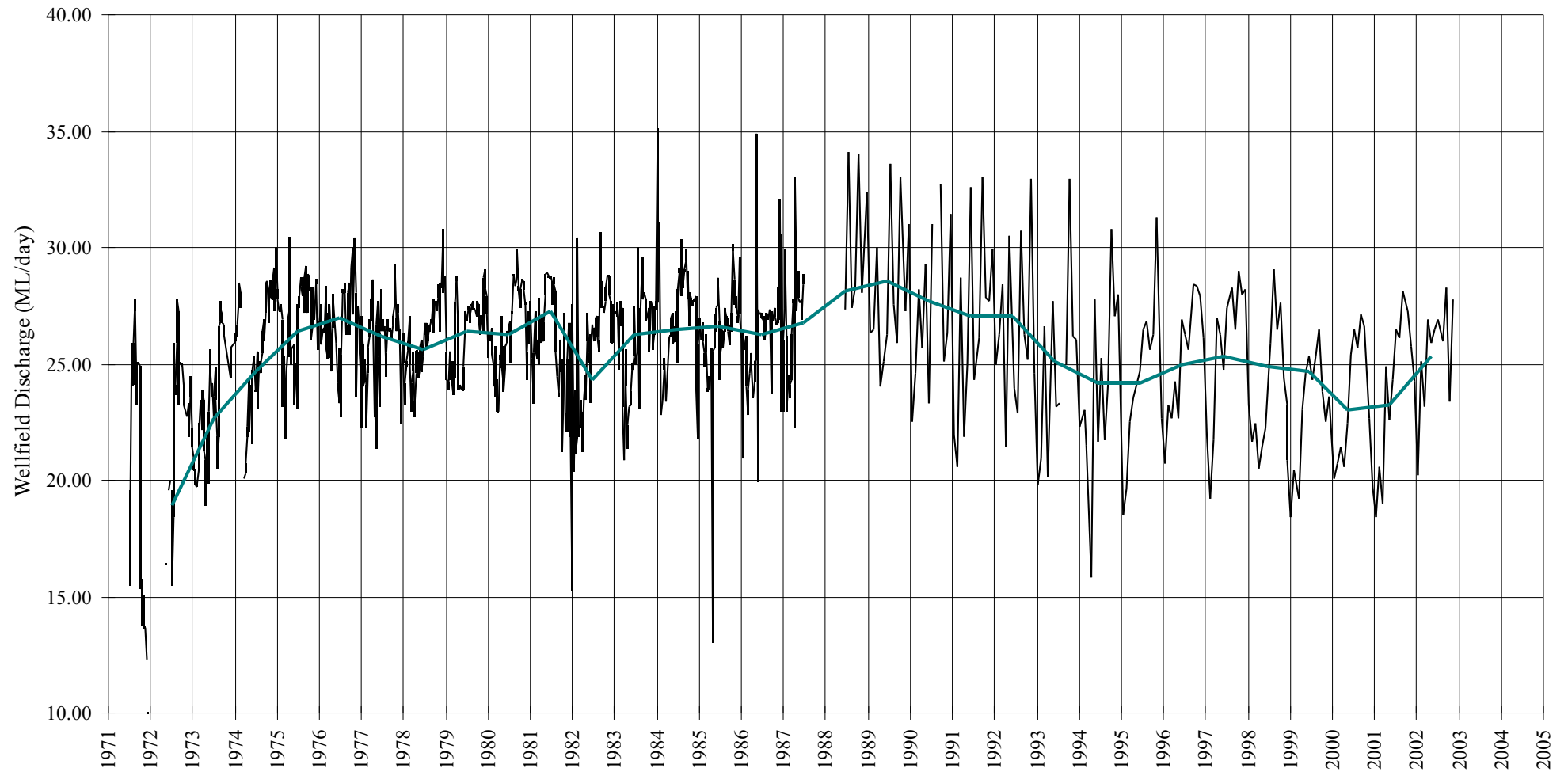
APPROVED:
DATE:
STATUS:

PROJECT: **08002-137**
CAD FILE: **eis third stage - fig 4**
REVISION: **A**



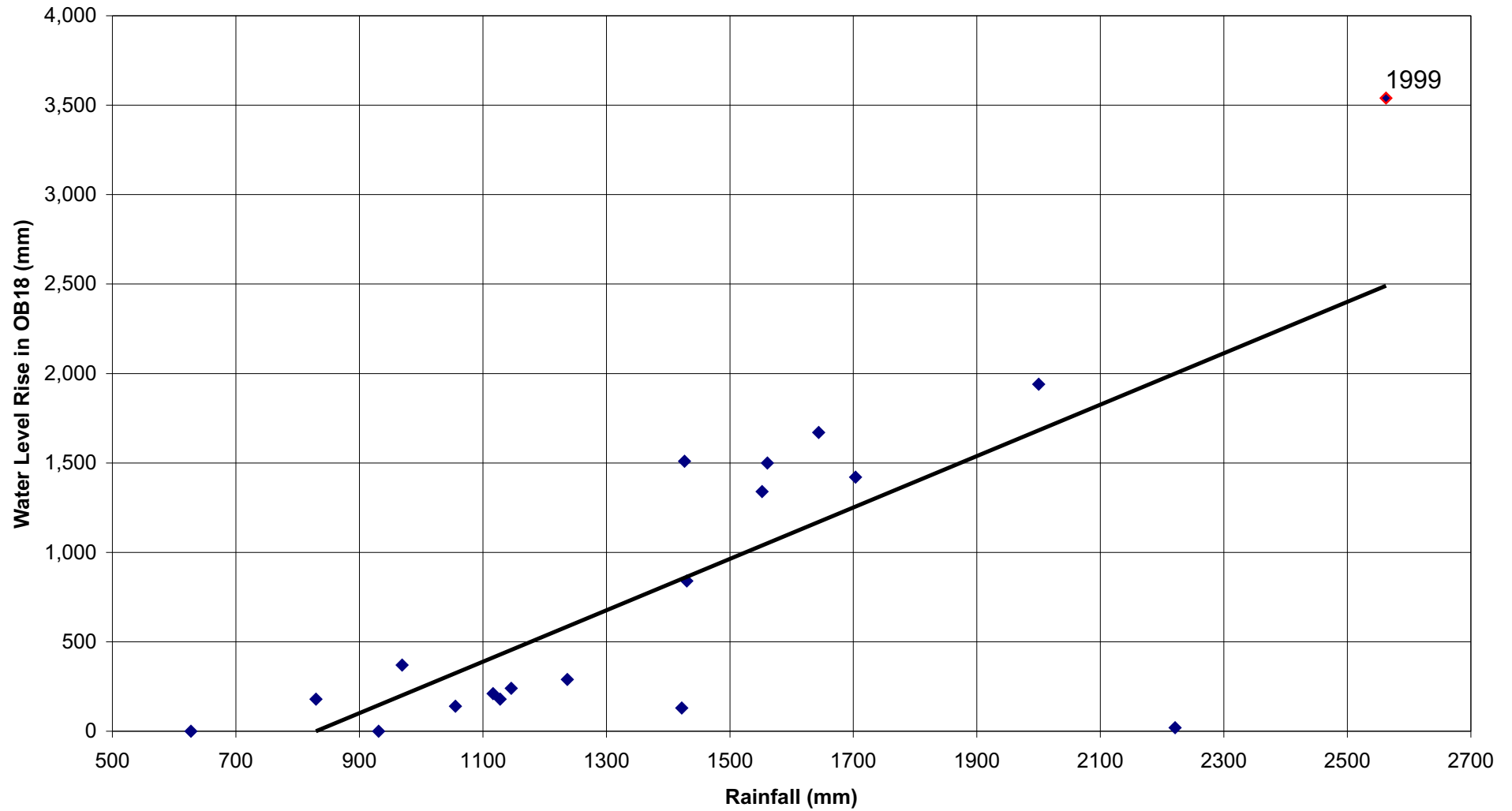
FIGURE
4

A4

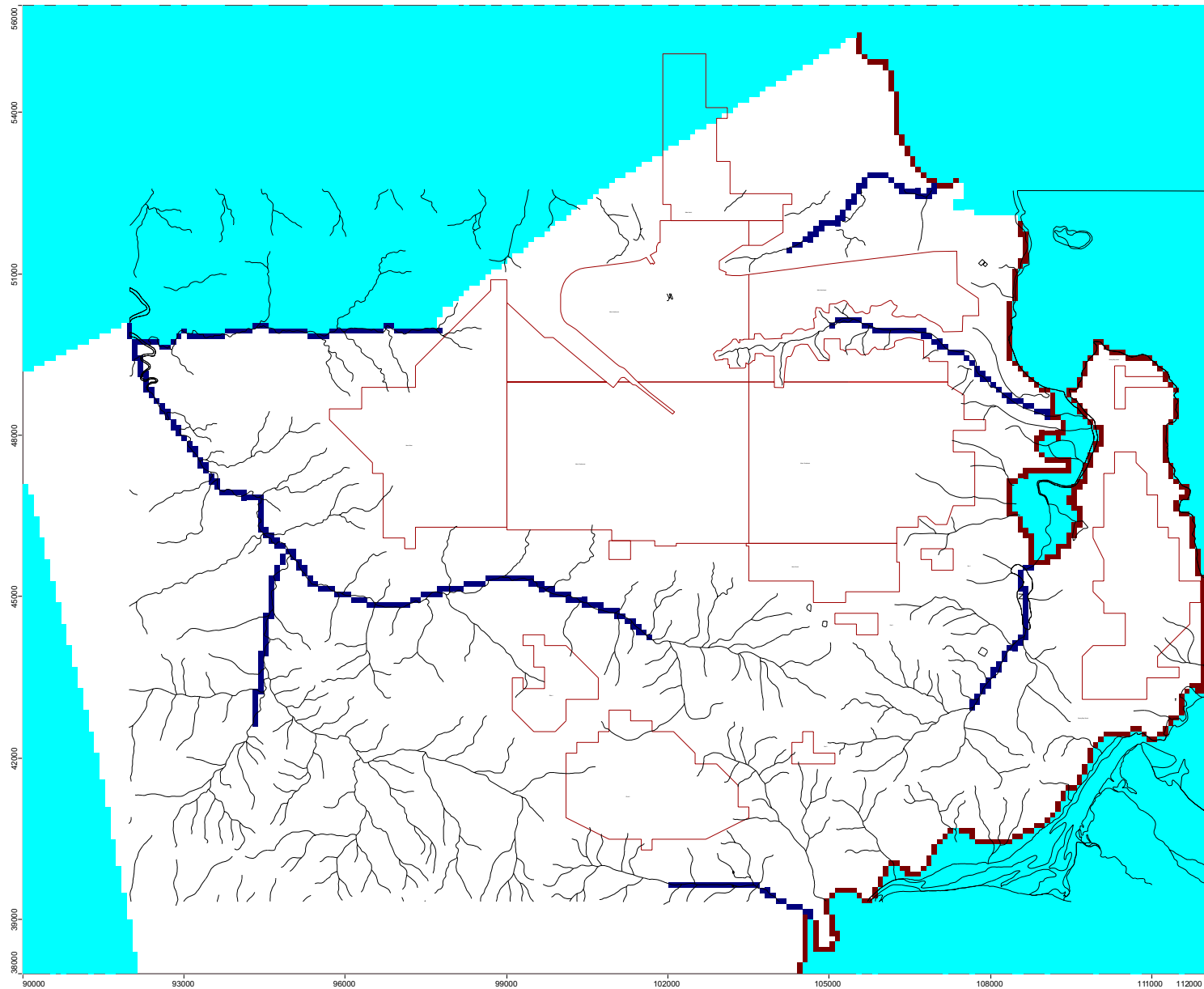


CLIENT: ALCAN GOVE PTY LTD			TITLE: Wellfield Production History	
PROJECT: EIS - THIRD STAGE EXPANSION				
	DESIGNED: B.R.C. DRAWN: L.L.B. DATE: 22/07/03	APPROVED: DATE: STATUS:	PROJECT: 08002-137 CAD FILE: eis third stage - fig 5 REVISION: A	FIGURE 5

OB18



CLIENT: ALCAN GOVE PTY LTD			TITLE: Recharge Threshold	
PROJECT: EIS - THIRD STAGE EXPANSION			A3	
DESIGNED: V.L.		APPROVED:	PROJECT: 08002-137-figures	
DRAWN: L.L.B.		DATE:	CAD FILE: eis third stage - fig 6	
DATE: 31/07/03		STATUS:	REVISION: A	
			FIGURE 6	



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Model Set Up - Layer 1

A3

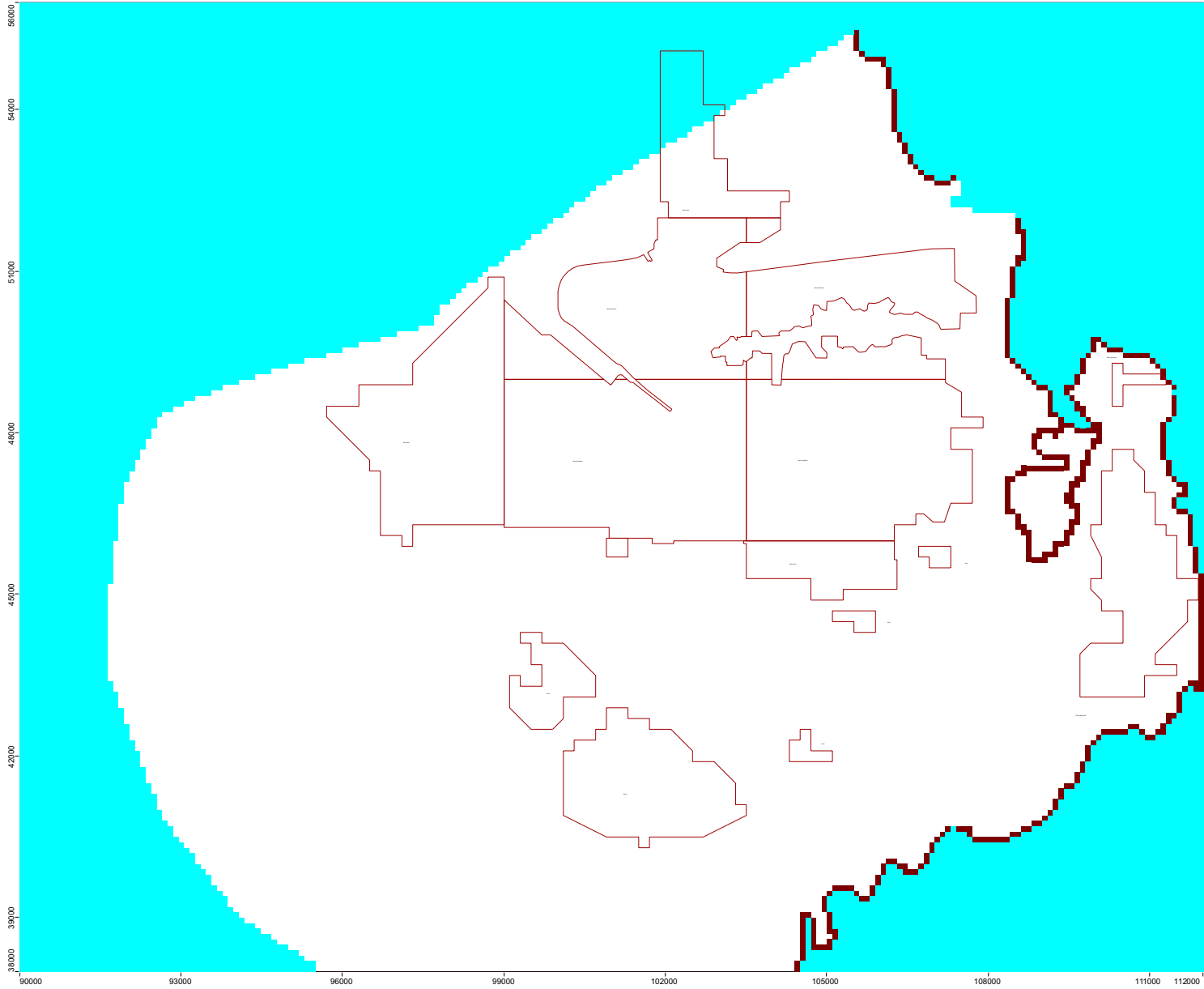
DESIGNED: **VL.**
DRAWN: **L.L.B.**
DATE: **31/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 7**
REVISION: **A**

URS

FIGURE
7



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Model Set Up - Layer 2

A3

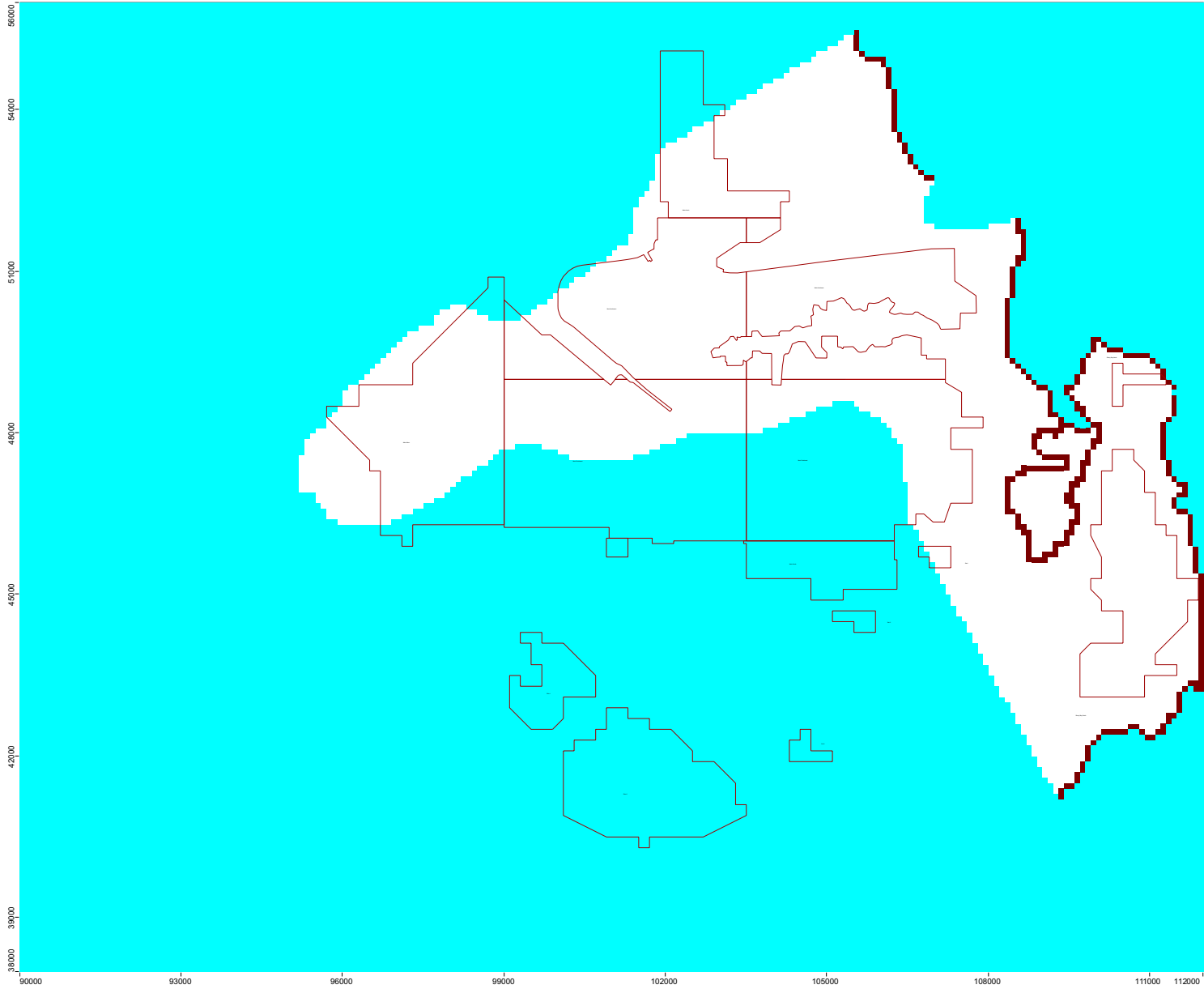
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **31/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig8**
REVISION: **A**

URS

FIGURE
8



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
Model Set Up - Layers 3 and 4

A3

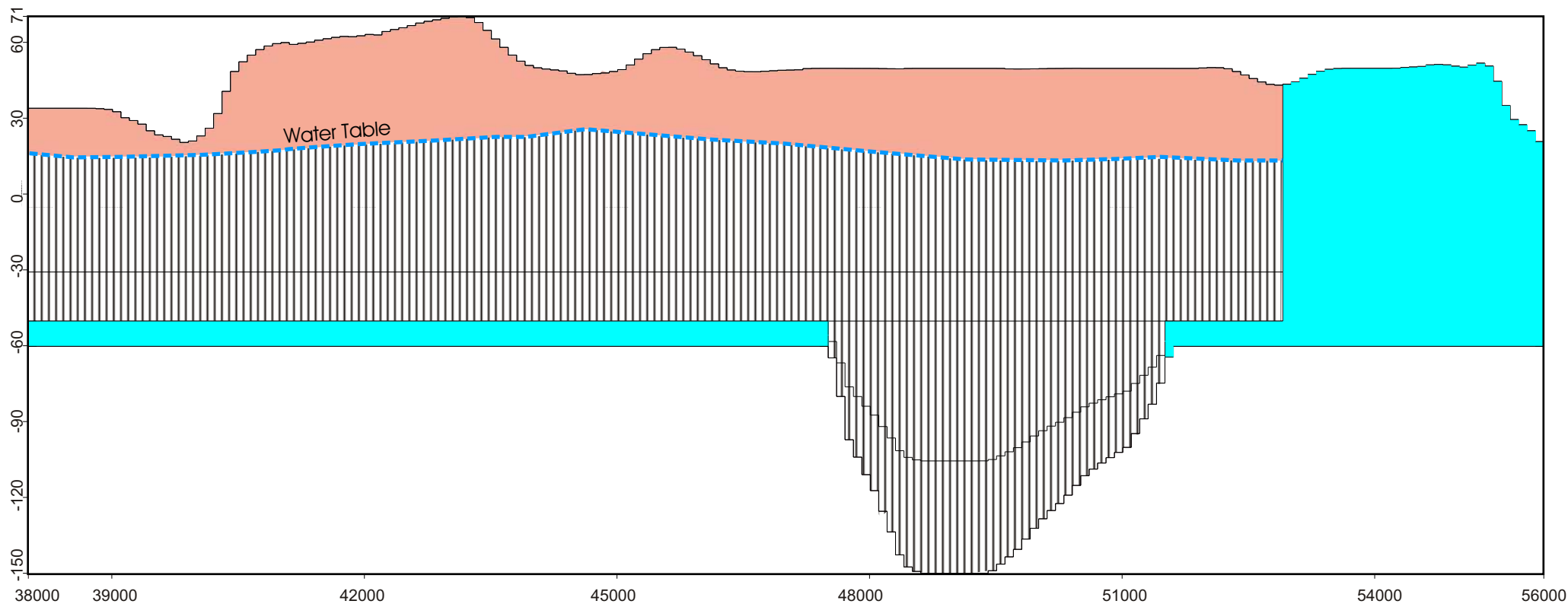
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **31/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 9**
REVISION: **A**

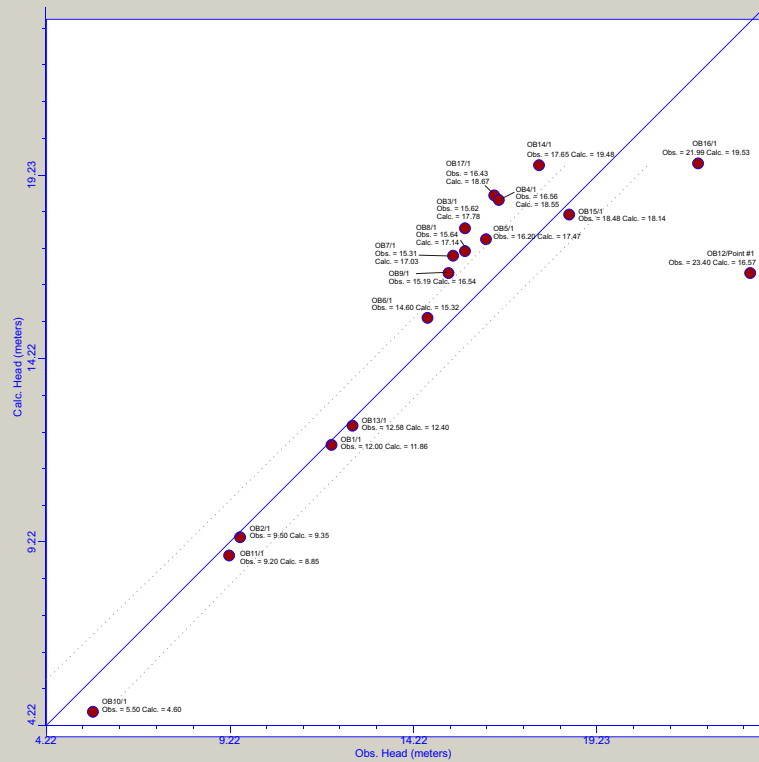
URS

FIGURE
9

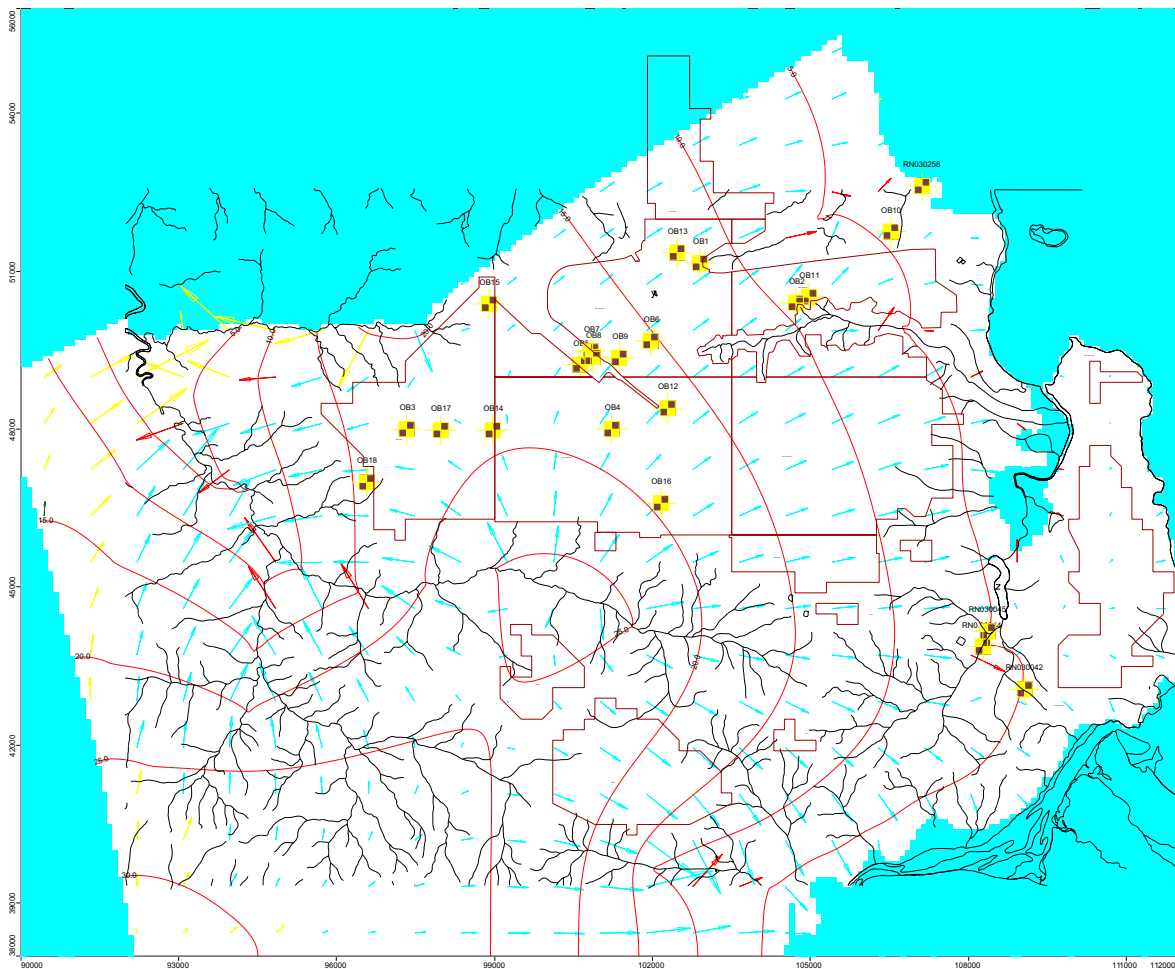


CLIENT: ALCAN GOVE PTY LTD				TITLE: Model Set Up - North-South Cross Section along 101250 Easting		
PROJECT: EIS - THIRD STAGE EXPANSION				A3		
		DESIGNED: V.L.	APPROVED:	PROJECT: 08002-137-figures CAD FILE: eis third stage - fig 10 REVISION: A		FIGURE 10
		DRAWN: L.L.B.	DATE:			
		DATE: 31/07/03	STATUS:			

Calculated vs. Observed Head : Steady state
30/6/2003



Num.Points : 17
Mean Error : 0.2033517 (meters)
Mean Absolute : 1.536803 (meters)
Standard Error of the Estimate : 0.5400702 (meters)
Root mean squared : 2.169831 (meters)
Normalized RMS : 12.12196 (%)



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Steady State Flow Model
Calibration Results**

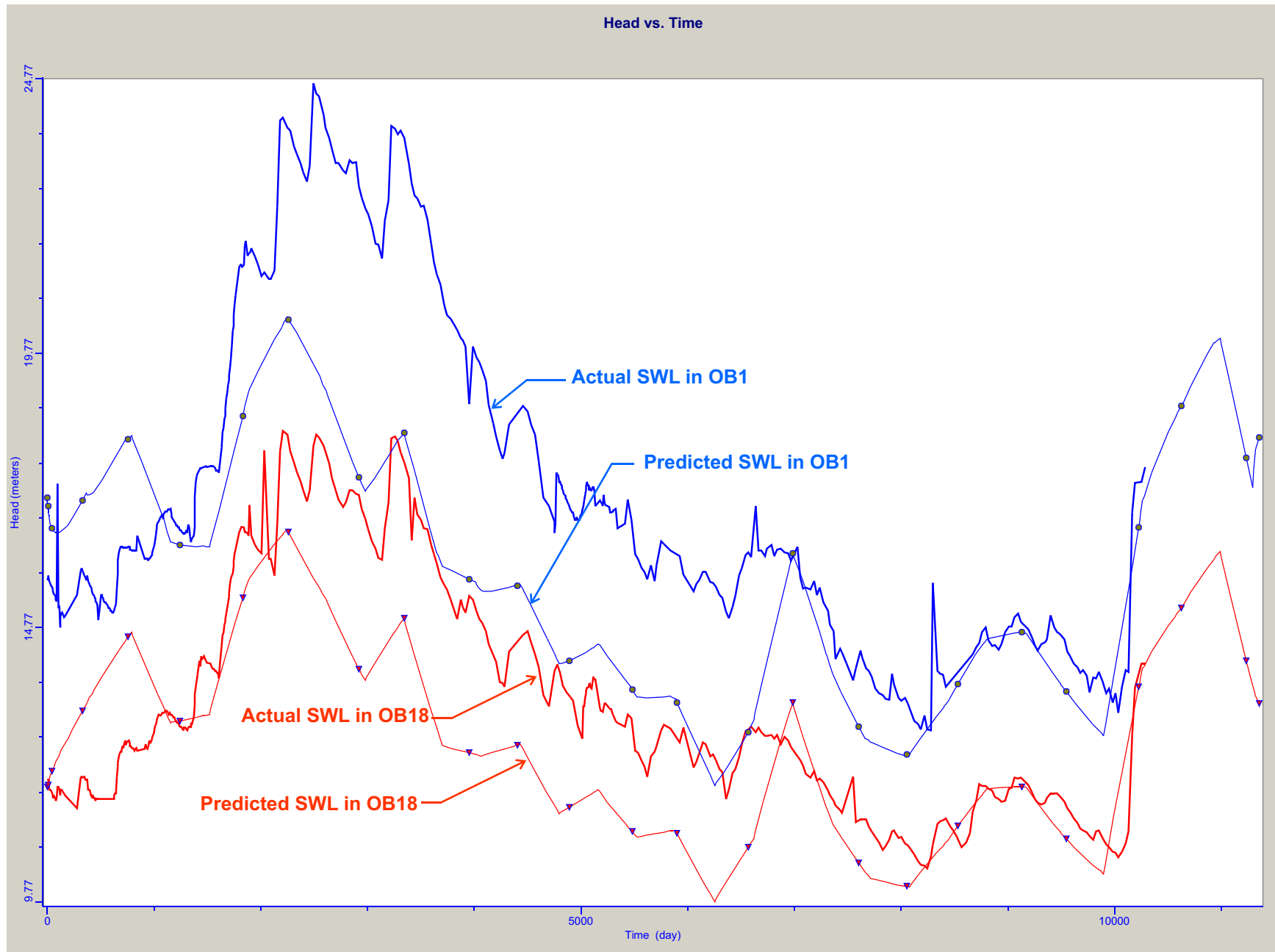
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **31/07/03**

APPROVED:
DATE:
STATUS:

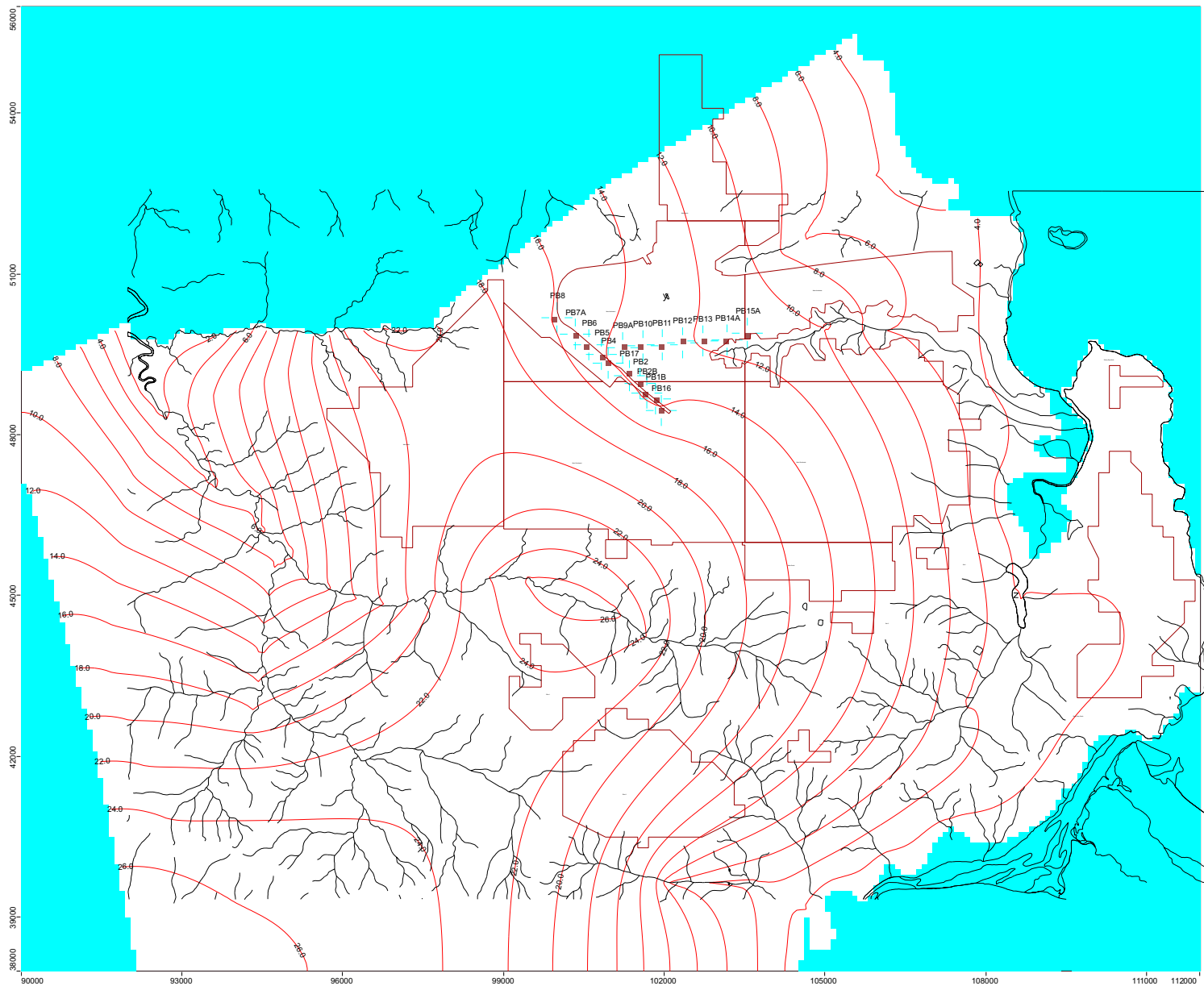
PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 11**
REVISION: **A**

URS

FIGURE
11



CLIENT: ALCAN GOVE PTY LTD			TITLE: Transient Flow Model Calibration Results		
PROJECT: EIS - THIRD STAGE EXPANSION			A3		
		DESIGNED: V.L. DRAWN: L.L.B. DATE: 31/07/03	APPROVED: DATE: STATUS:	PROJECT: 08002-137-figures CAD FILE: eis third stage - fig 12 REVISION: A	 FIGURE 12



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 1 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

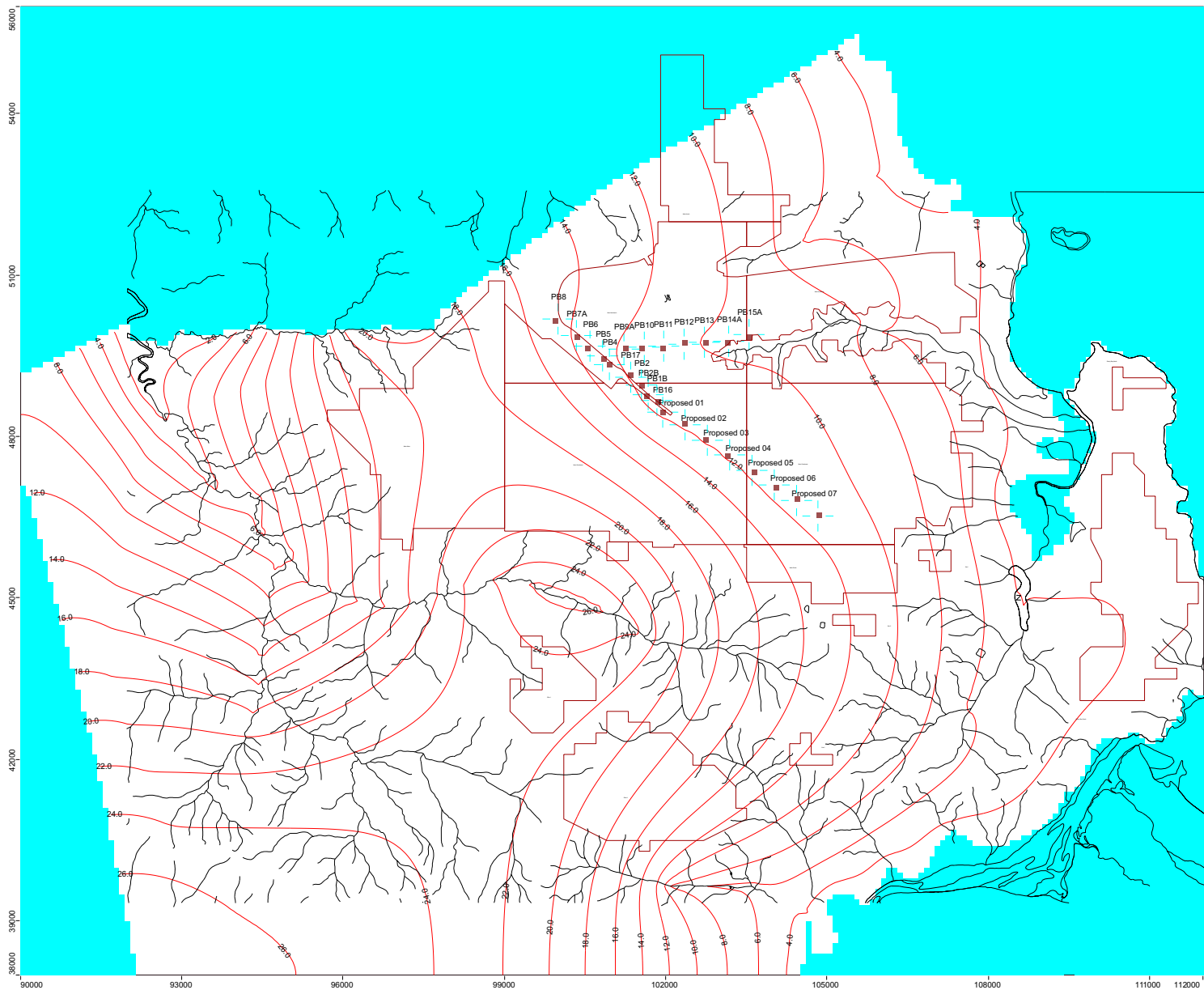
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 13**
REVISION: **A**

URS

FIGURE
13



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 2 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

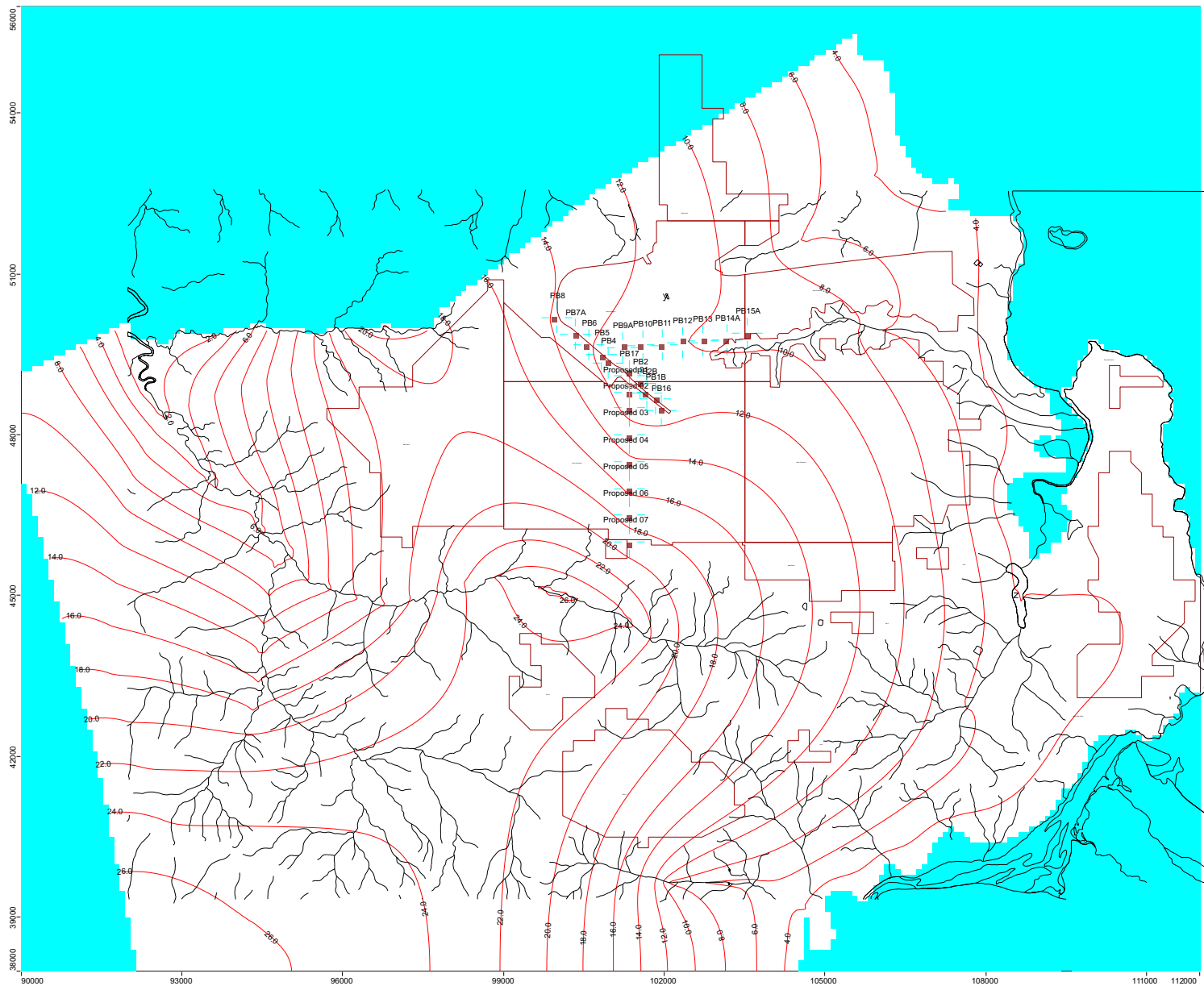
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 14**
REVISION: **A**

URS

FIGURE
14



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 3 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

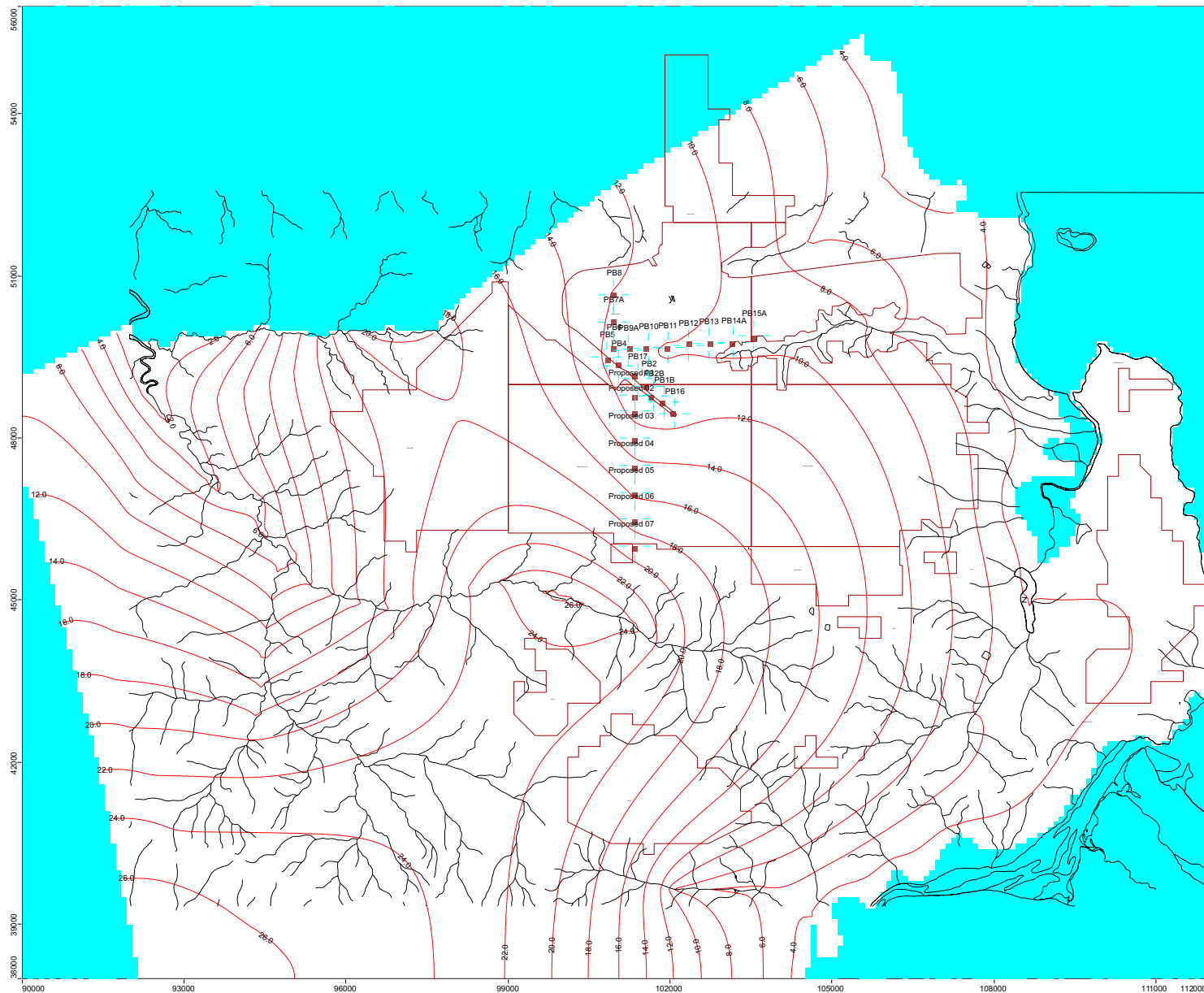
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 15**
REVISION: **A**

URS

FIGURE
15



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 4 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

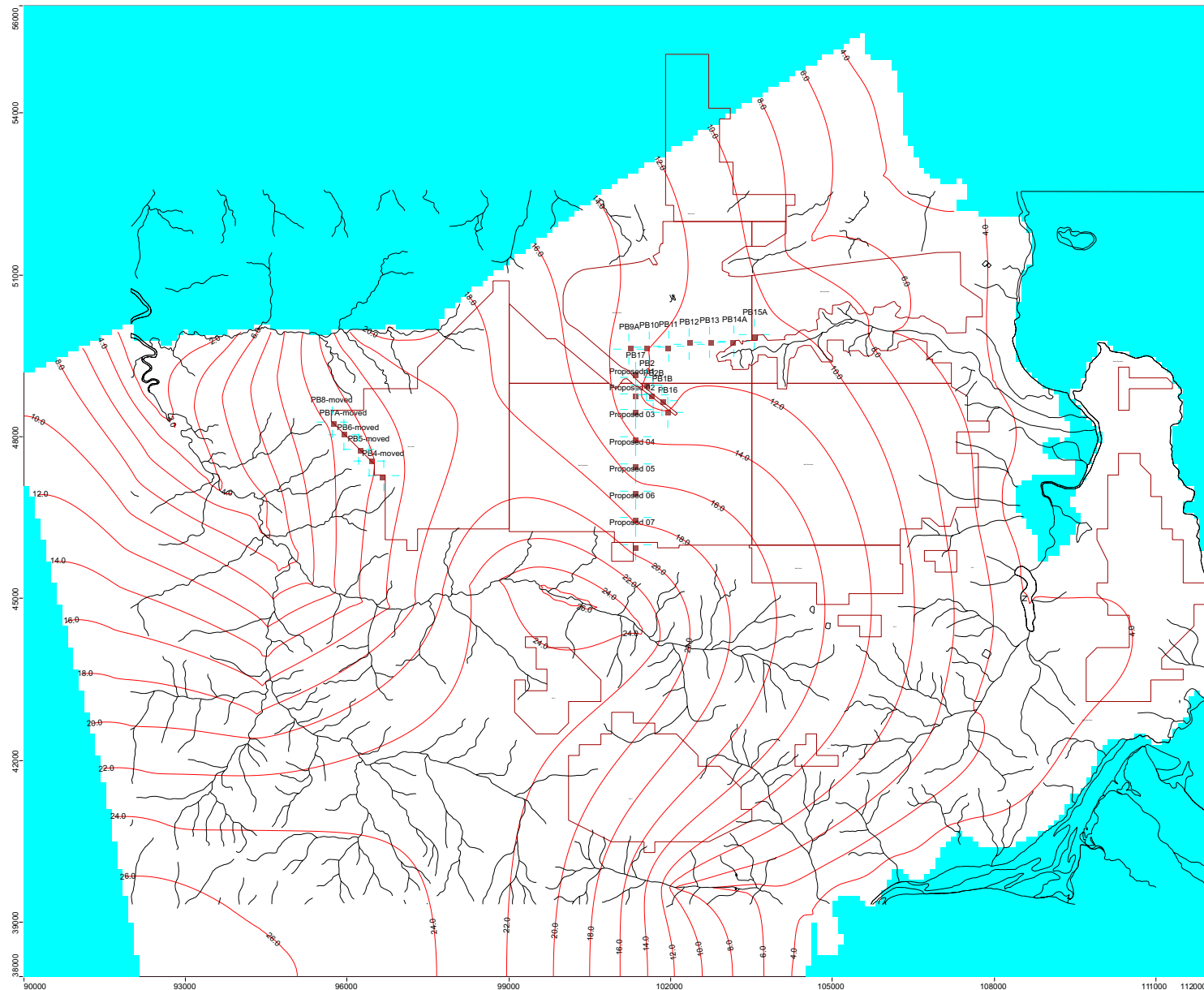
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 16**
REVISION: **A**



FIGURE
16



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 5 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

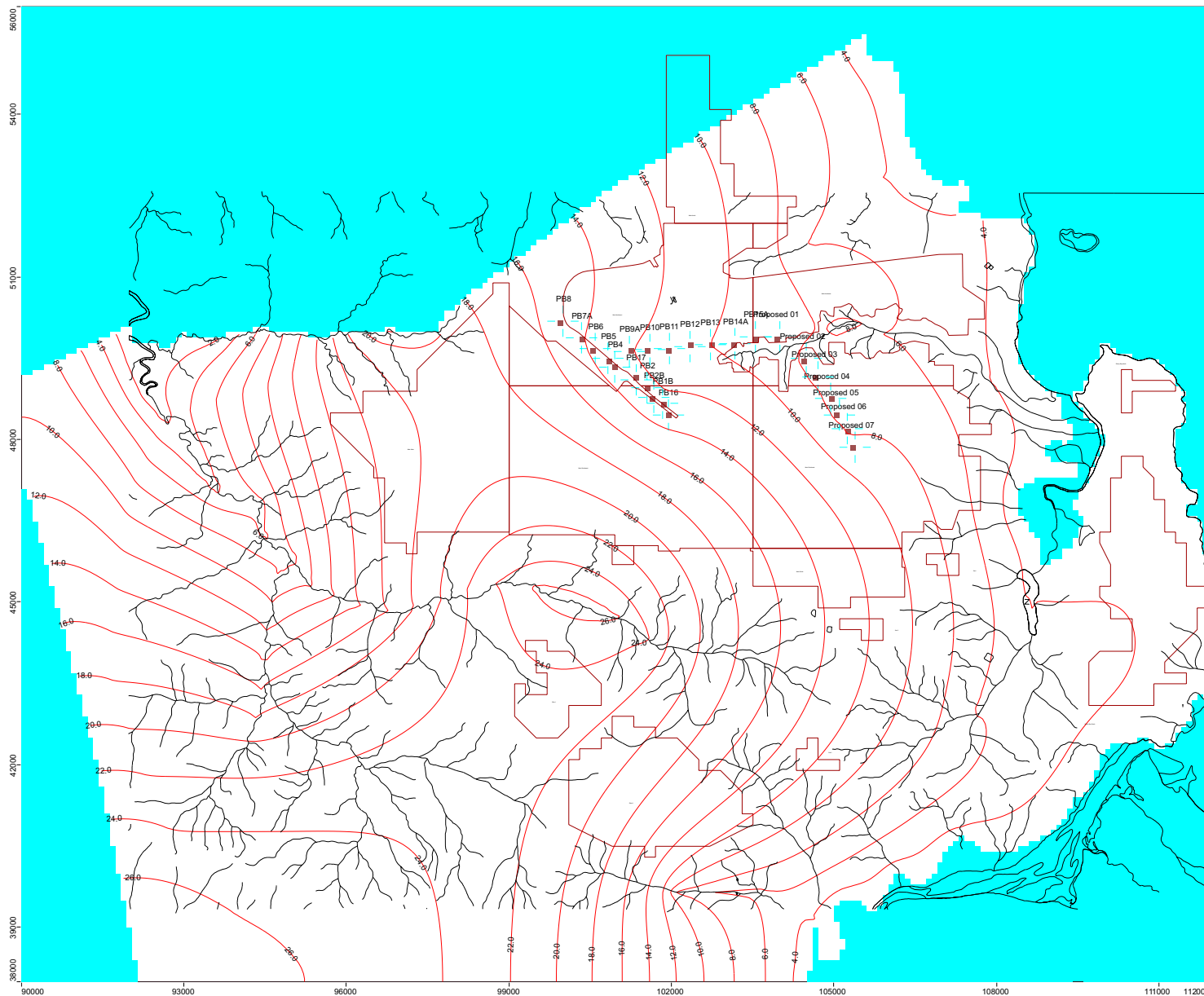
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 17**
REVISION: **A**



FIGURE
17



CLIENT:
ALCAN GOVE PTY LTD

PROJECT:
EIS - THIRD STAGE EXPANSION

TITLE:
**Scenario 6 - Pumping Wells
Location and Predicted Groundwater
Contours (31 years)**

A3

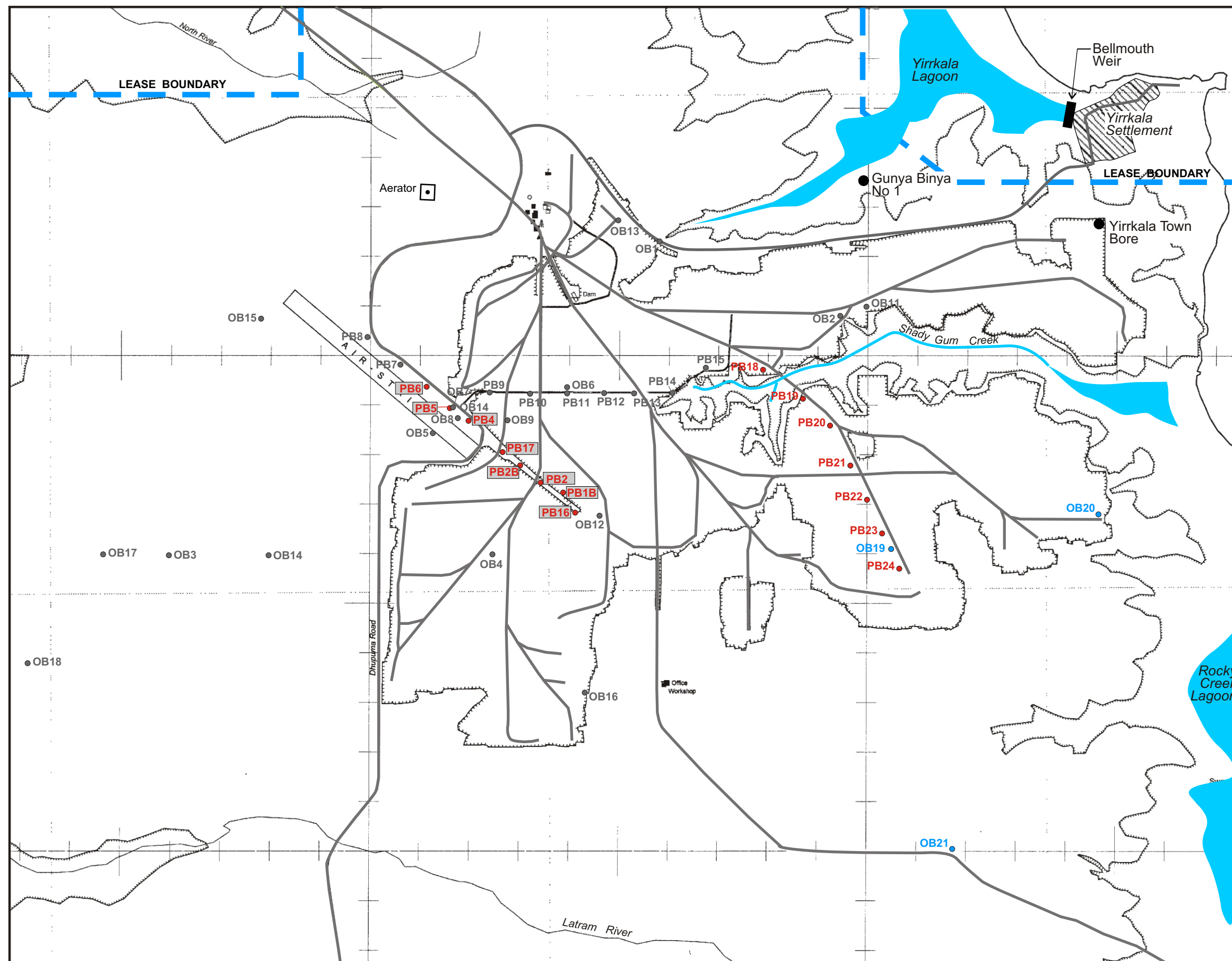
DESIGNED: **V.L.**
DRAWN: **L.L.B.**
DATE: **20/07/03**

APPROVED:
DATE:
STATUS:

PROJECT: **08002-137-figures**
CAD FILE: **eis third stage - fig 18**
REVISION: **A**

URS

FIGURE
18



LEGEND:

- **PB20** Additional Production bores
- **OB19** Additional Observation bores
- **PB16** Production Bores to be removed

CLIENT:

ALCAN GOVE PTY LTD

PROJECT:

EIS - THIRD STAGE EXPANSION

TITLE:

Proposed Expanded Wellfield

DESIGNED: **B.R.C.**

DRAWN: **L.L.B.**

DATE: **18/07/03**

APPROVED:

DATE:

STATUS:

PROJECT: **08002-137**

CAD FILE: **eis third stage - fig 19**

REVISION: **A**

URS

FIGURE

19



Plate 1 - Pre-Mining Vegetation Cover



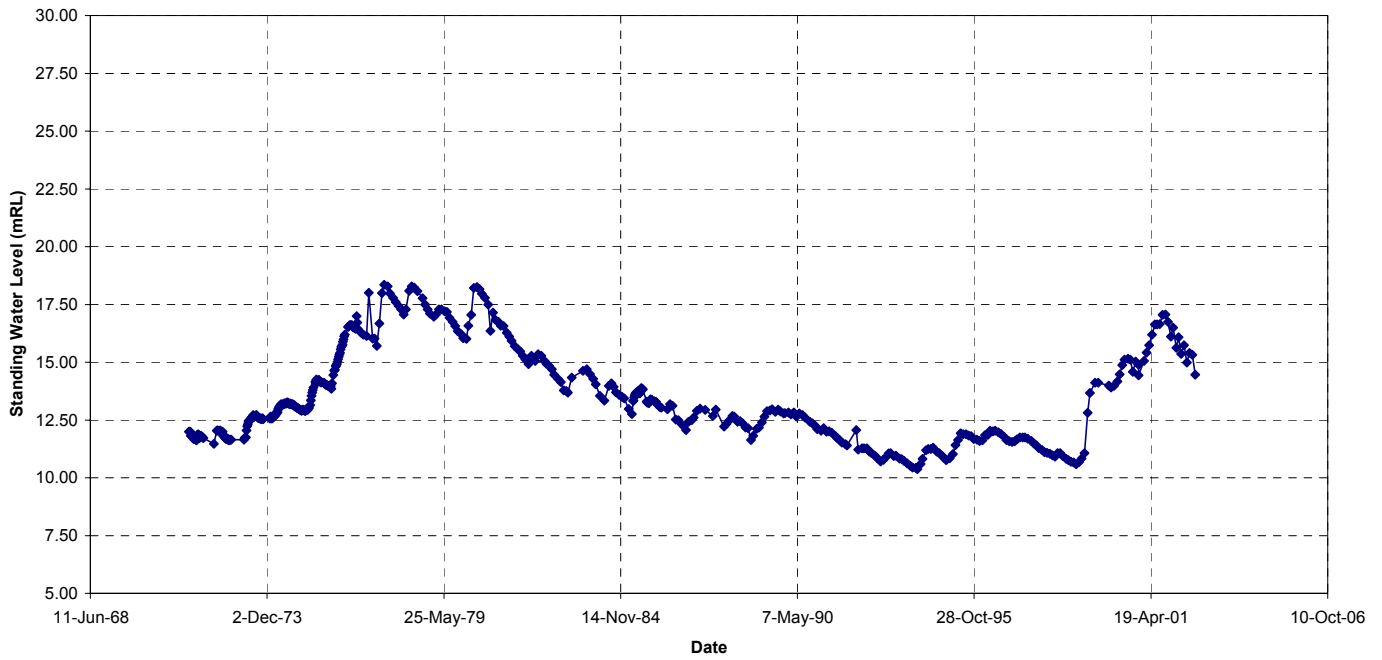
Plate 2 - 5 Year Old Rehabilitation Growth

CLIENT: ALCAN GOVE PTY LTD			TITLE: PLATES	
PROJECT: EIS - THIRD STAGE EXPANSION				
	DESIGNED: V.L. DRAWN: L.L.B. DATE: 31/07/03	APPROVED: DATE: STATUS:	PROJECT: 08002-137-plates CAD FILE: plates.cdr REVISION: A	A3  PLATES 1 & 2

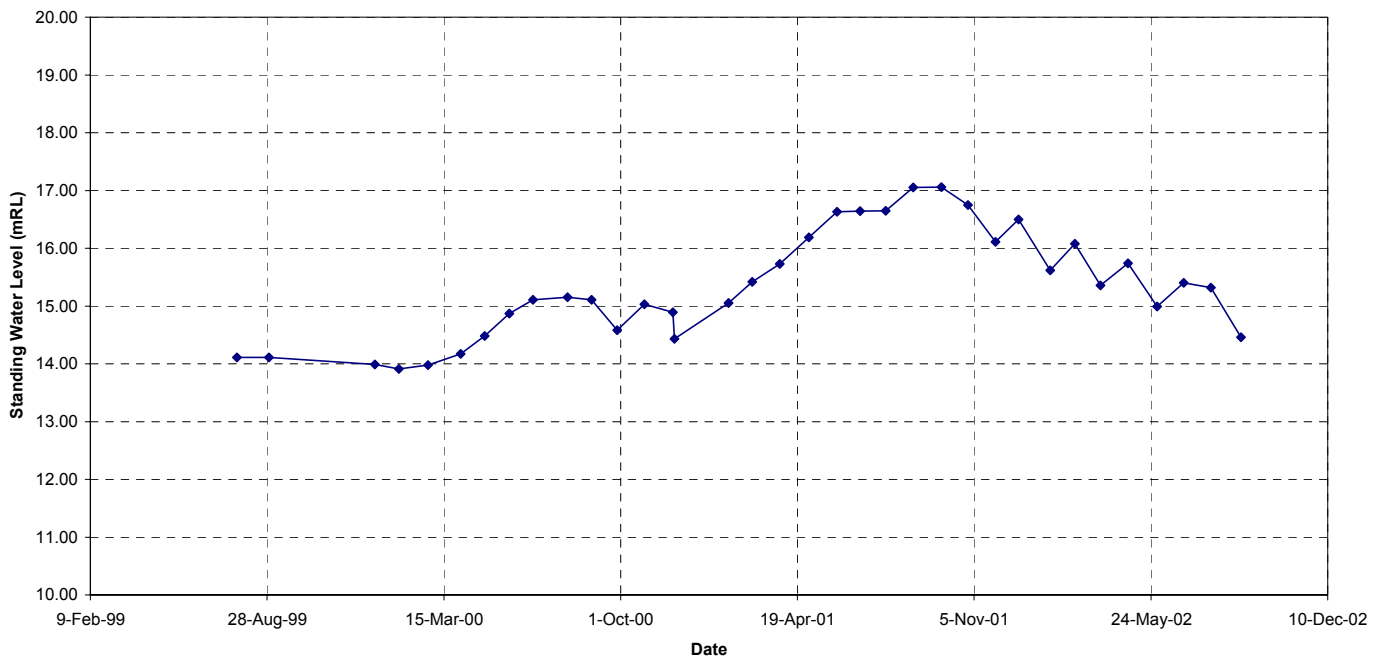
Appendix

Observation Bore - OB1

Complete Monitoring Period

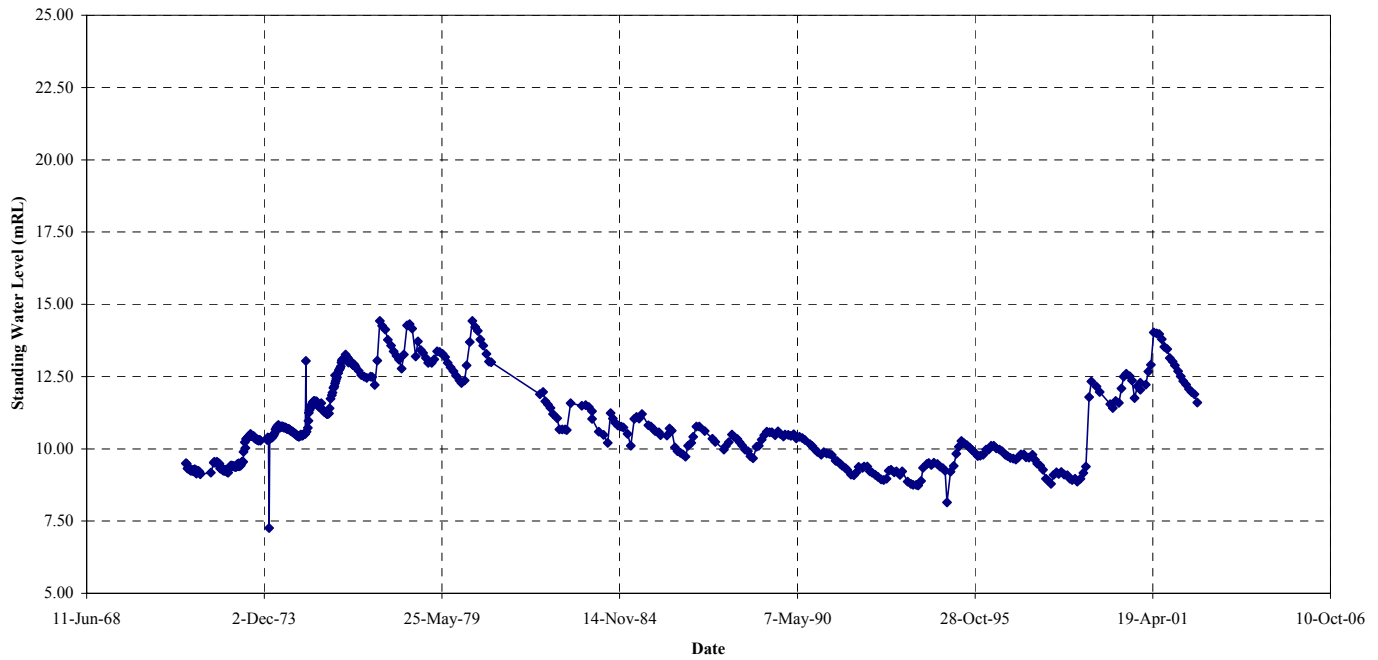


Triennium Period 1999 to 2002

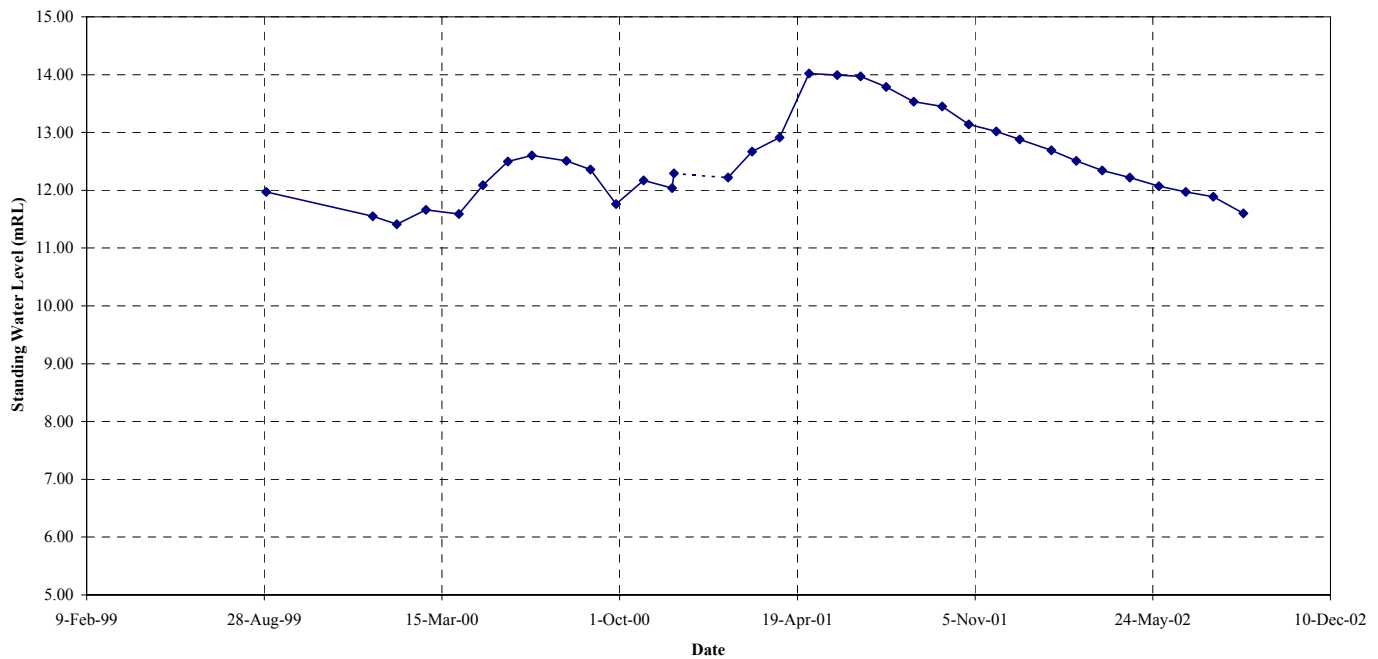


Observation Bore - OB02

Complete Monitoring Period

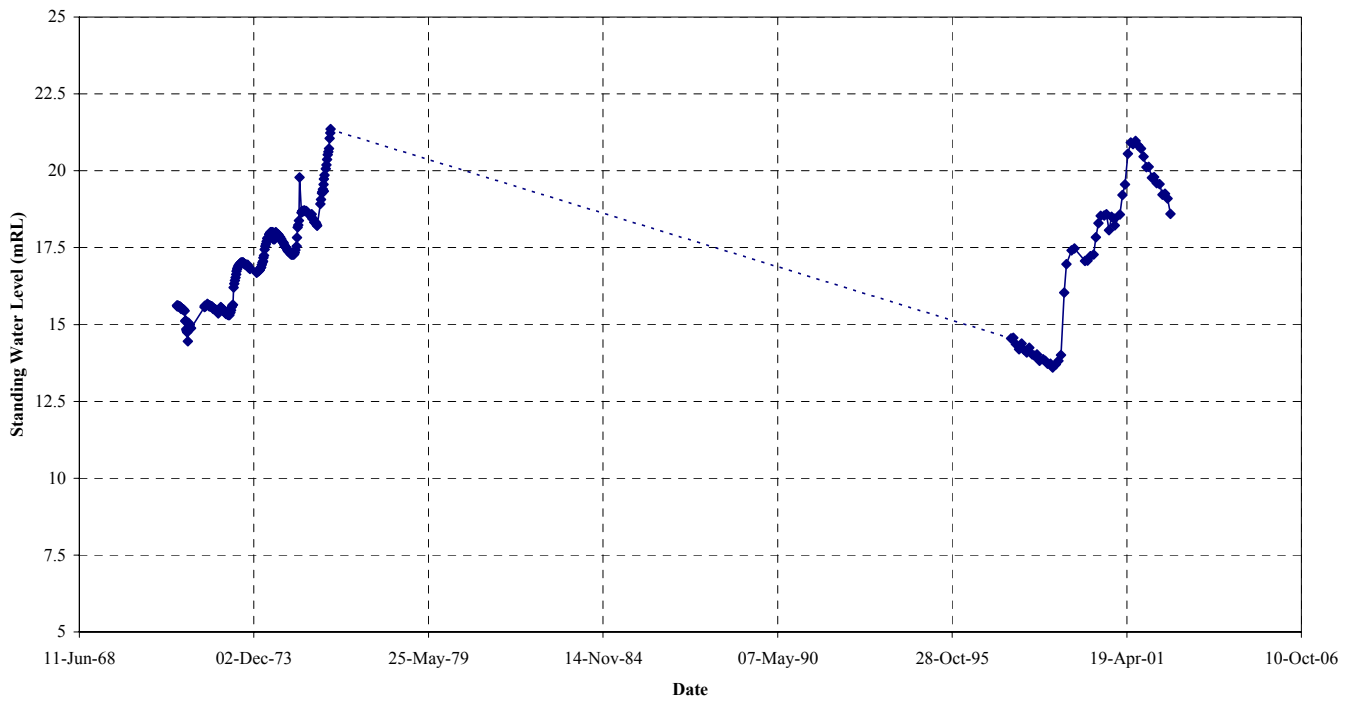


Triennium Period 1999 to 2002

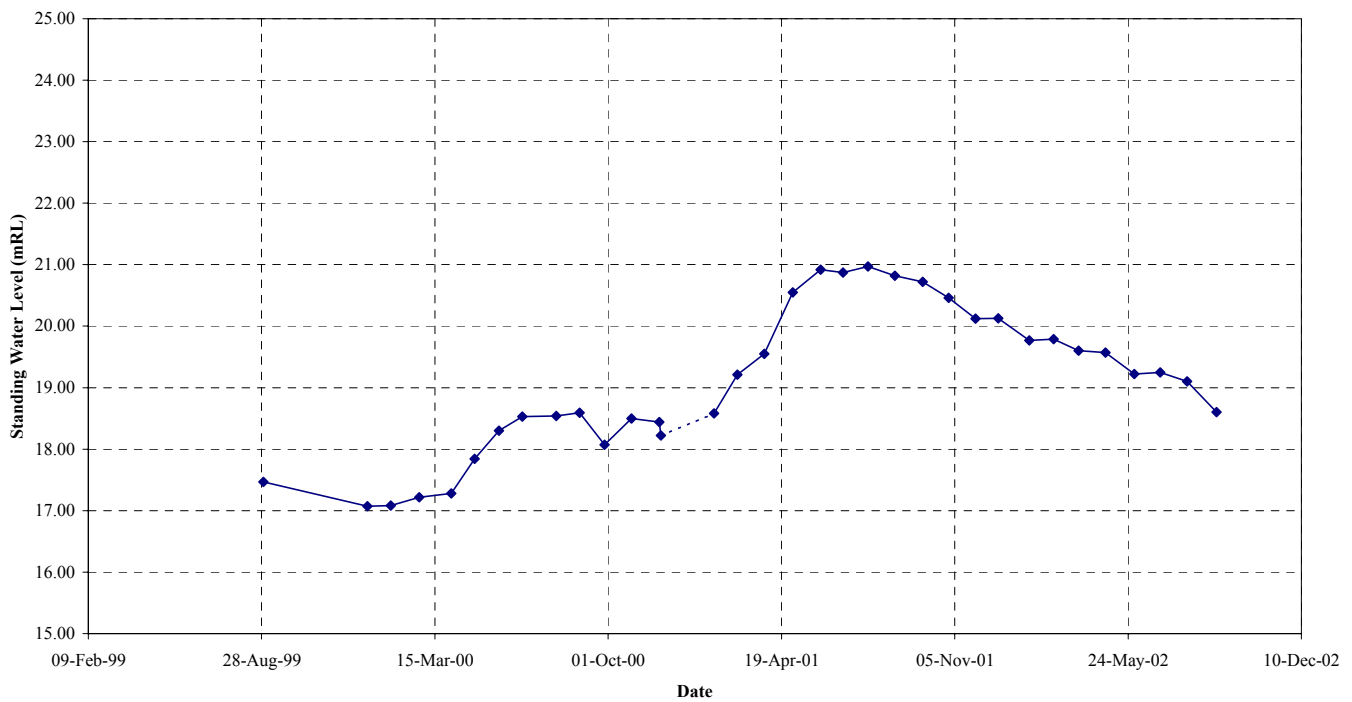


Observation Bore - OB03

Complete Monitoring Period

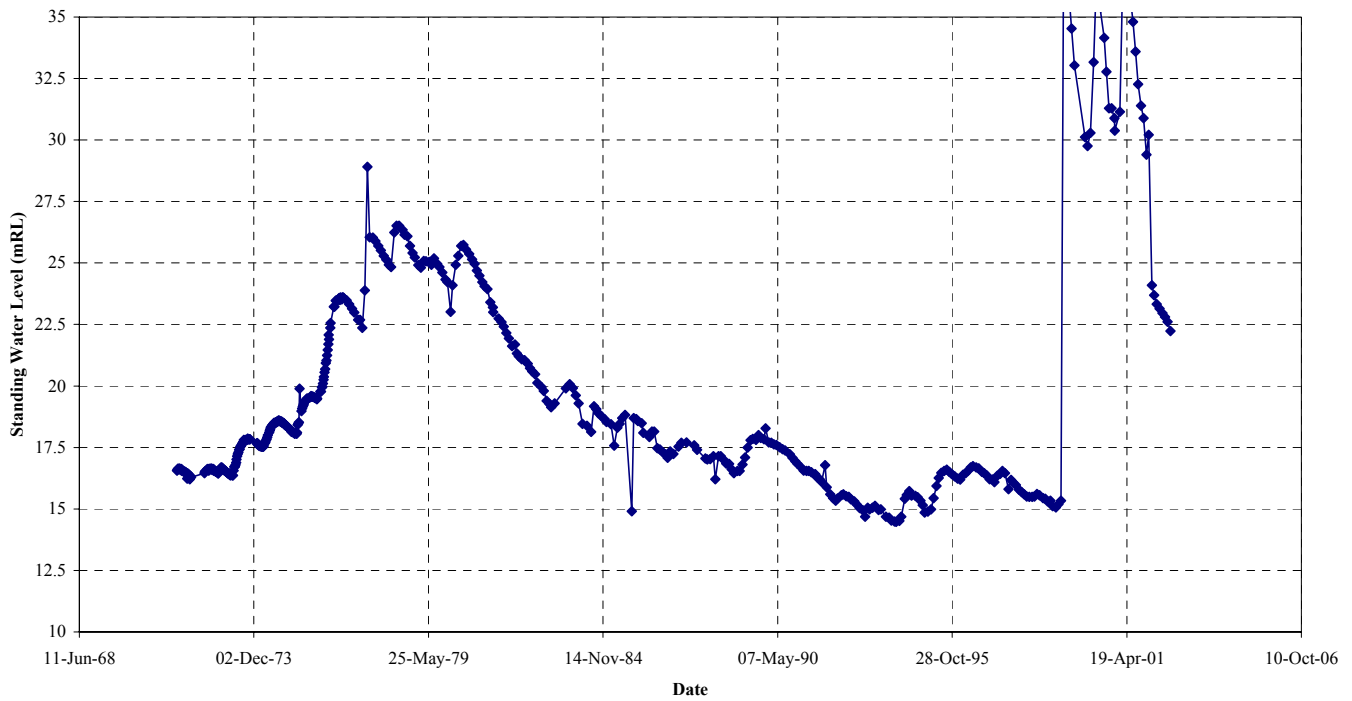


Triennium Period 1999 to 2002

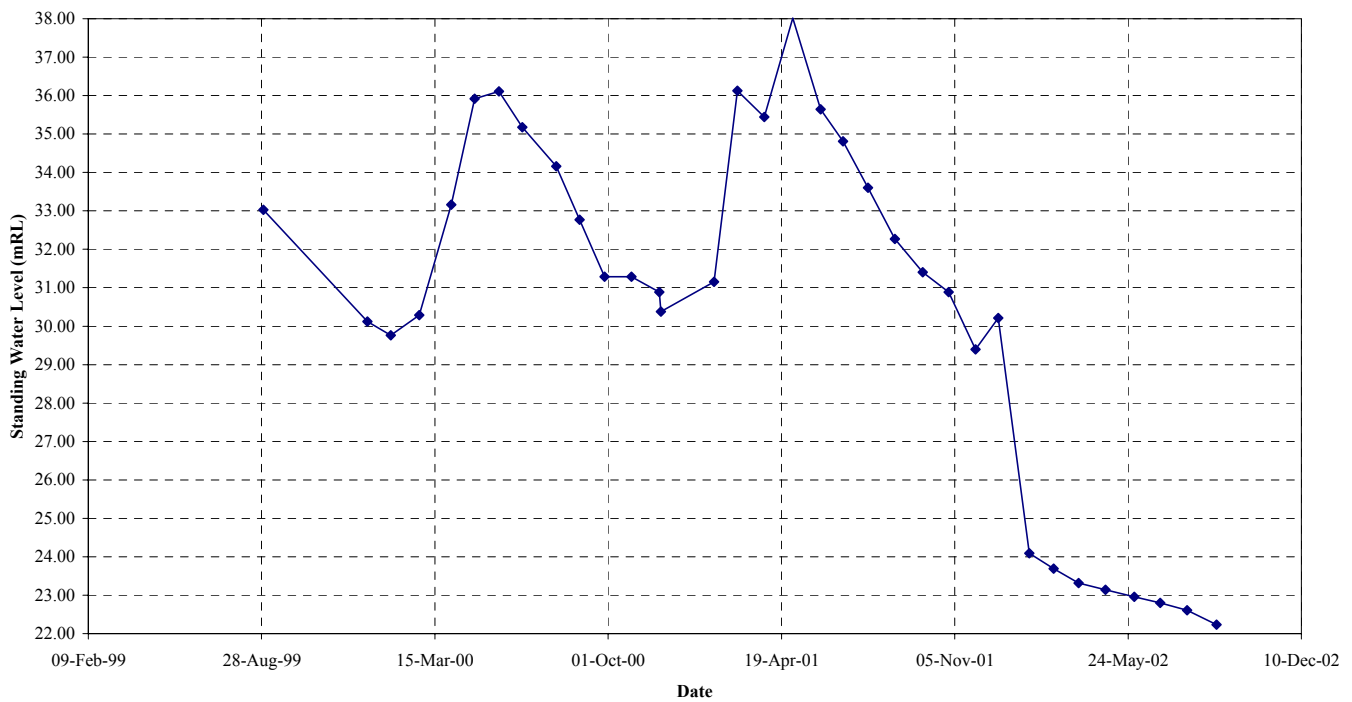


Observation Bore - OB04

Complete Monitoring Period



Triennium Period 1999 to 2002

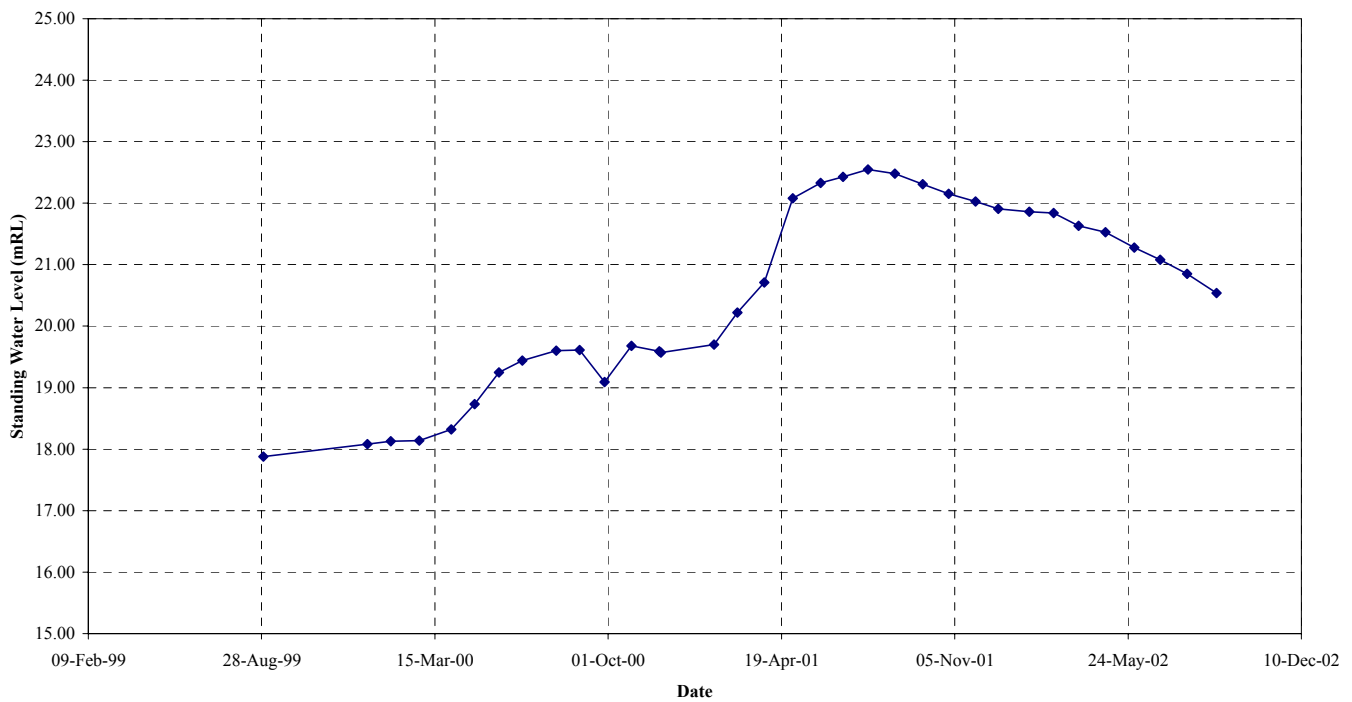


Observation Bore - OB05

Complete Monitoring Period

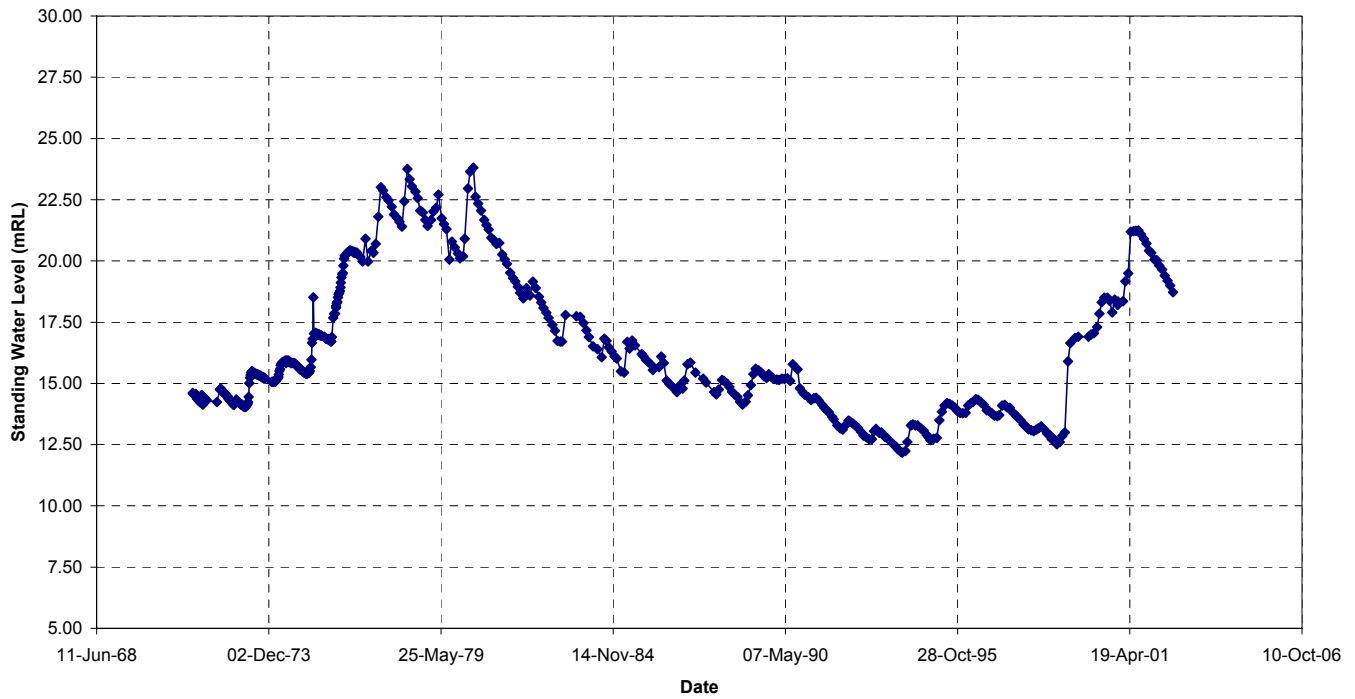


Triennium Period 1999 to 2002

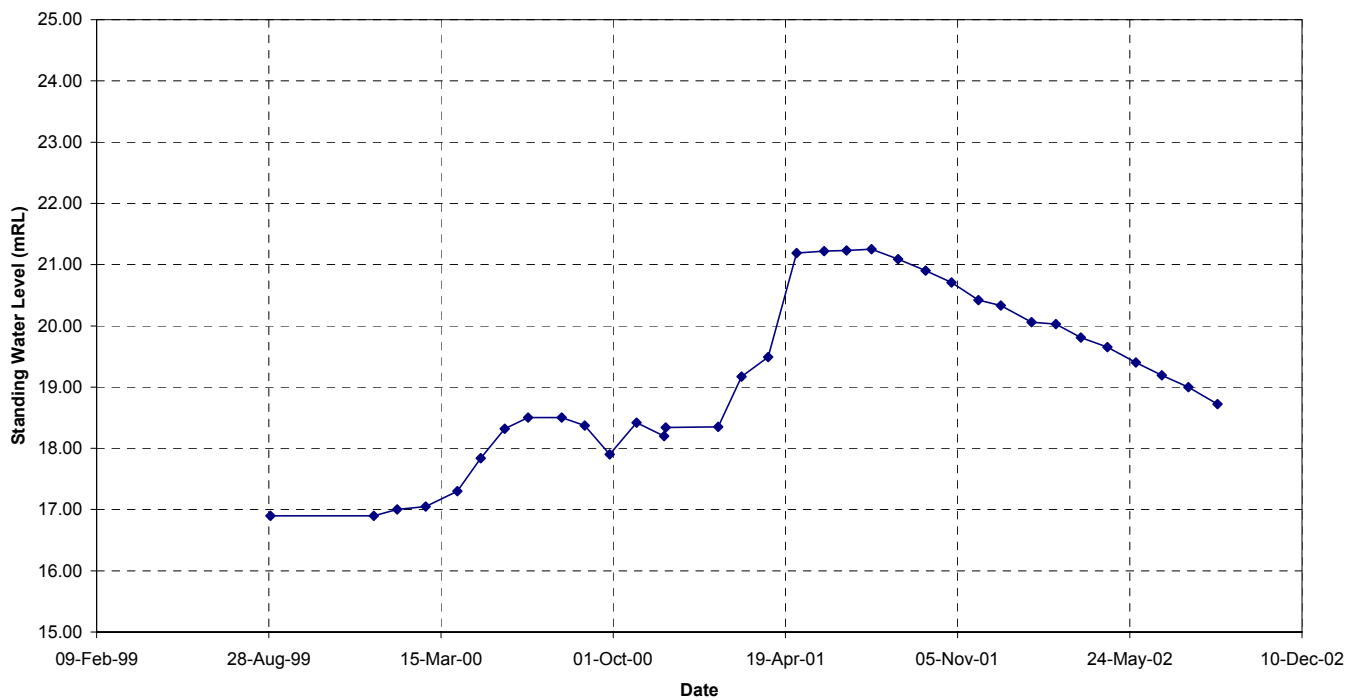


Observation Bore - OB06

Complete Monitoring Period



Triennium Period 1999 to 2002

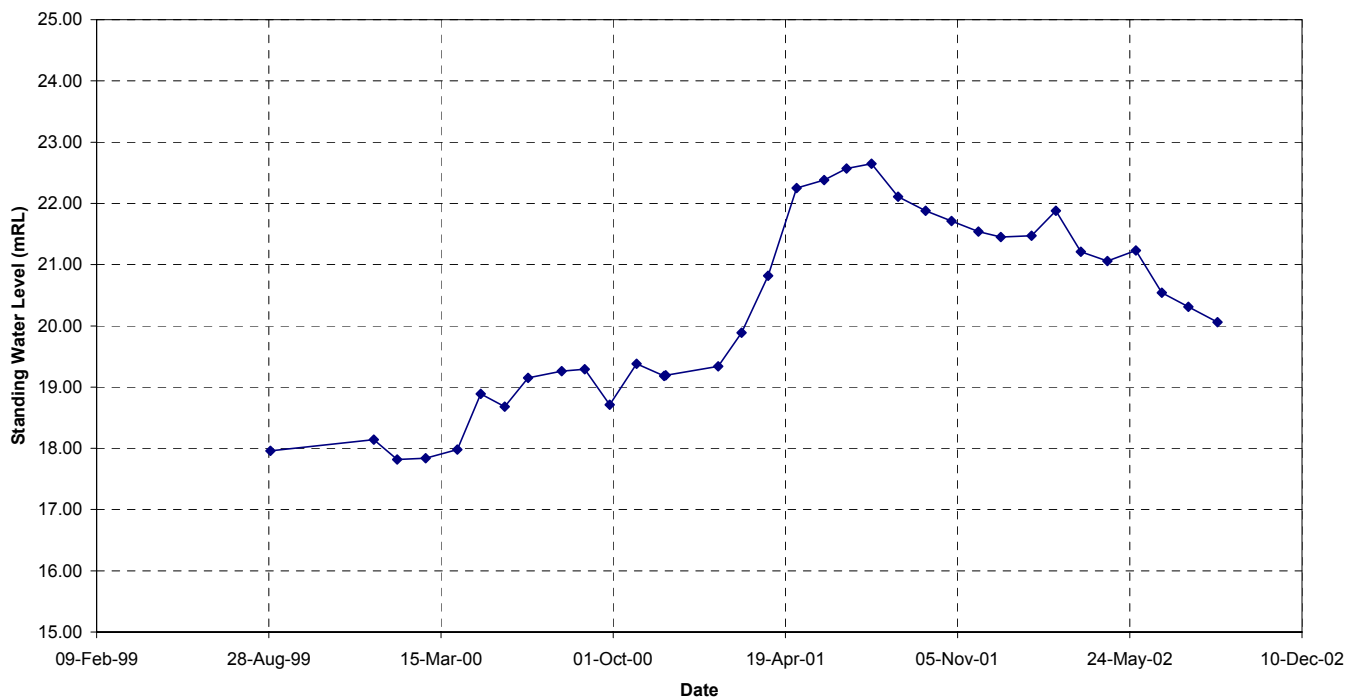


Observation Bore - OB07

Complete Monitoring Period



Triennium Period 1999 to 2002

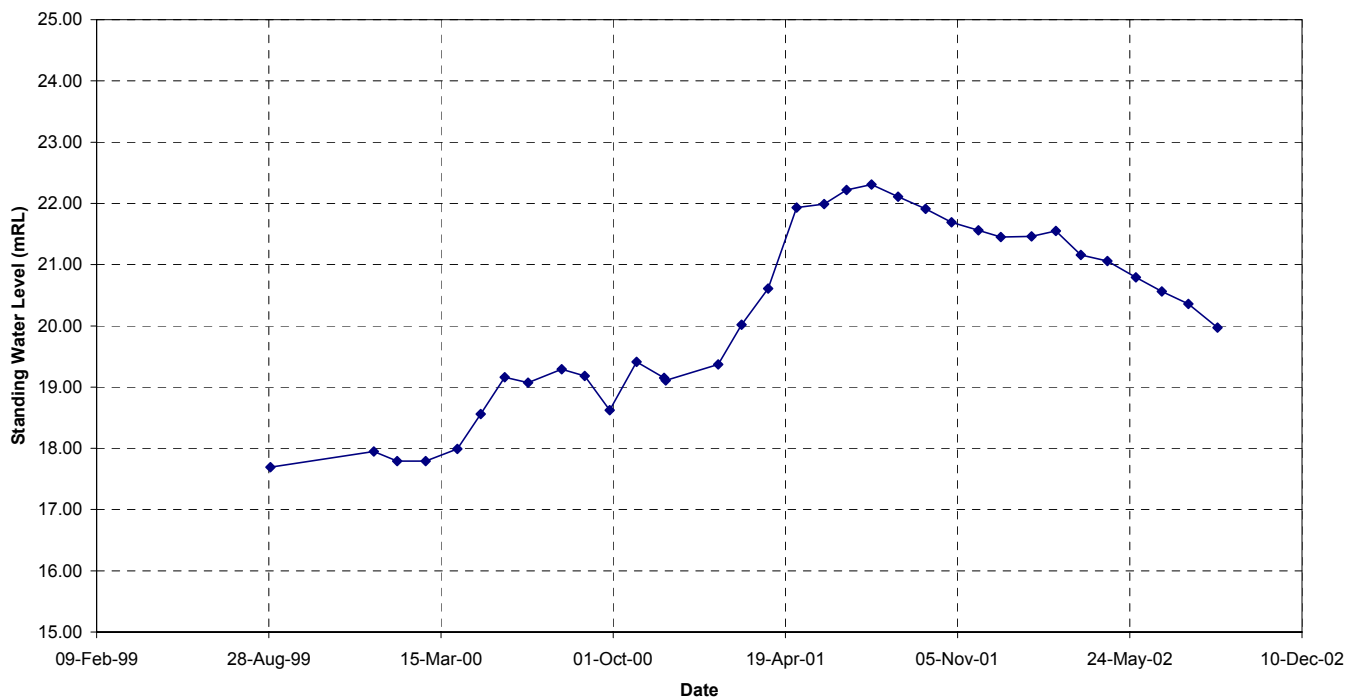


Observation Bore - OB08

Complete Monitoring Period



Triennium Period 1999 to 2002

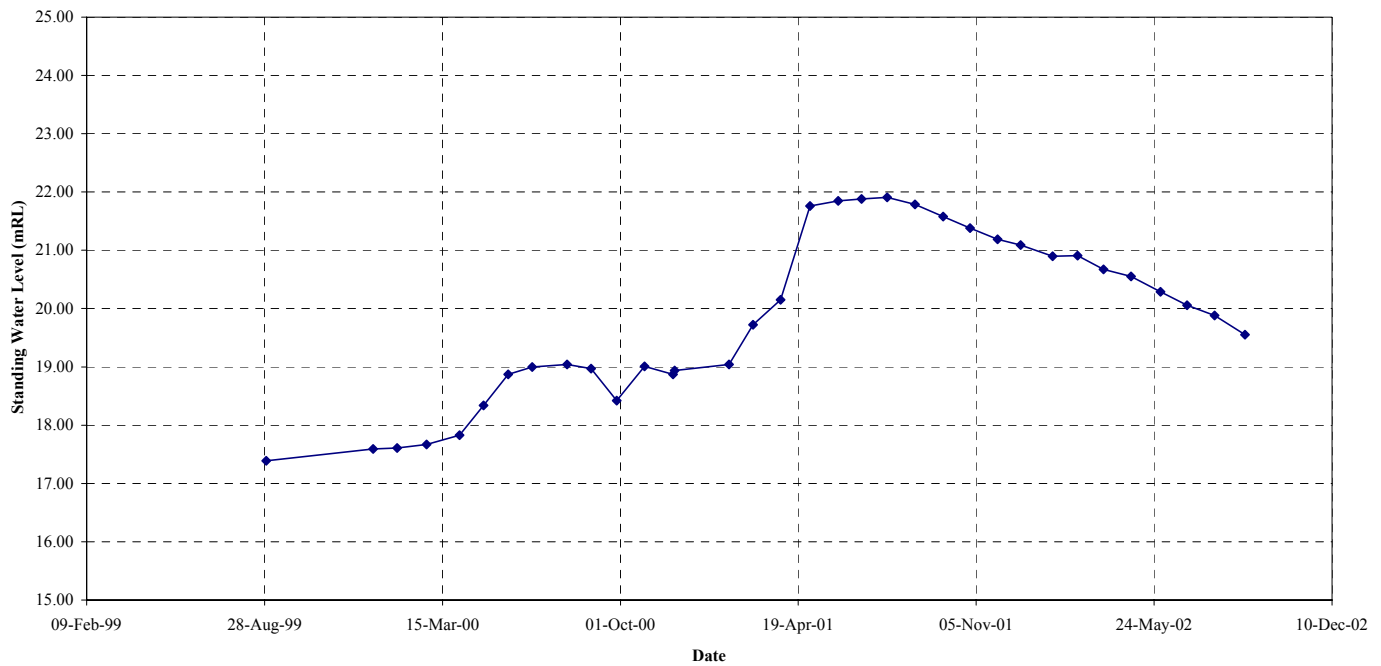


Observation Bore - OB09

Complete Monitoring Period

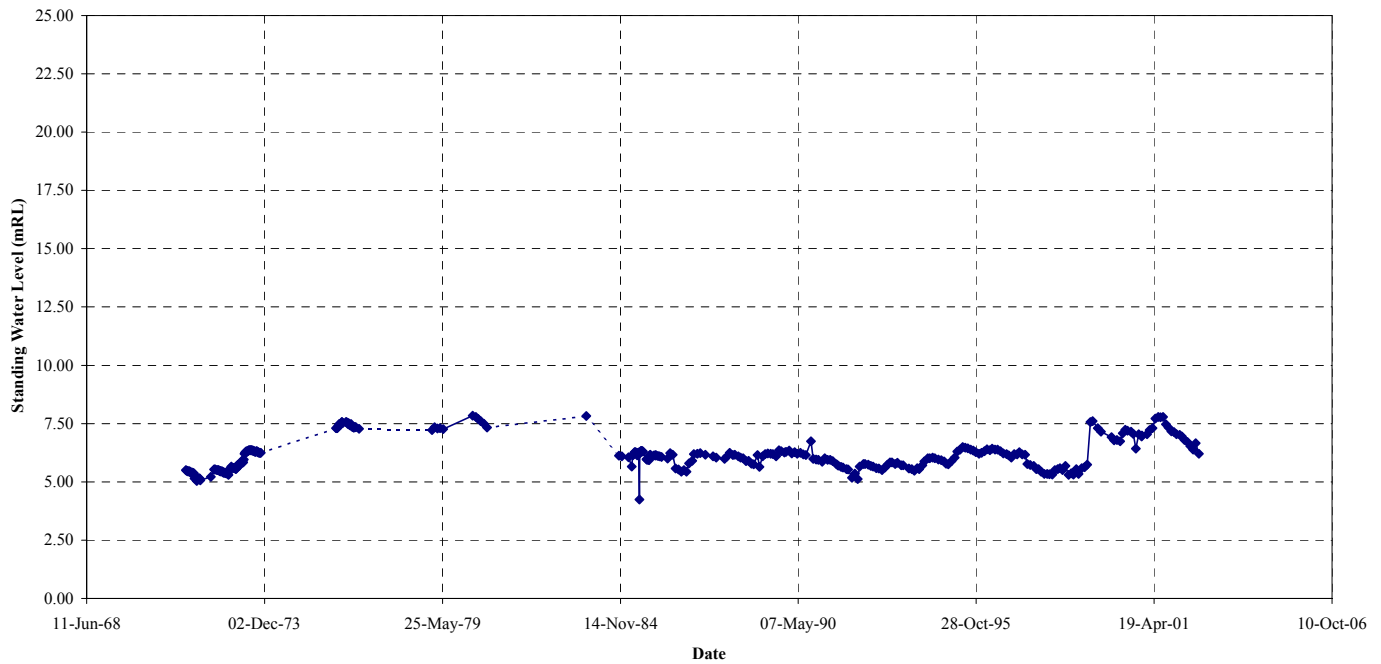


Triennium Period 1999 to 2002

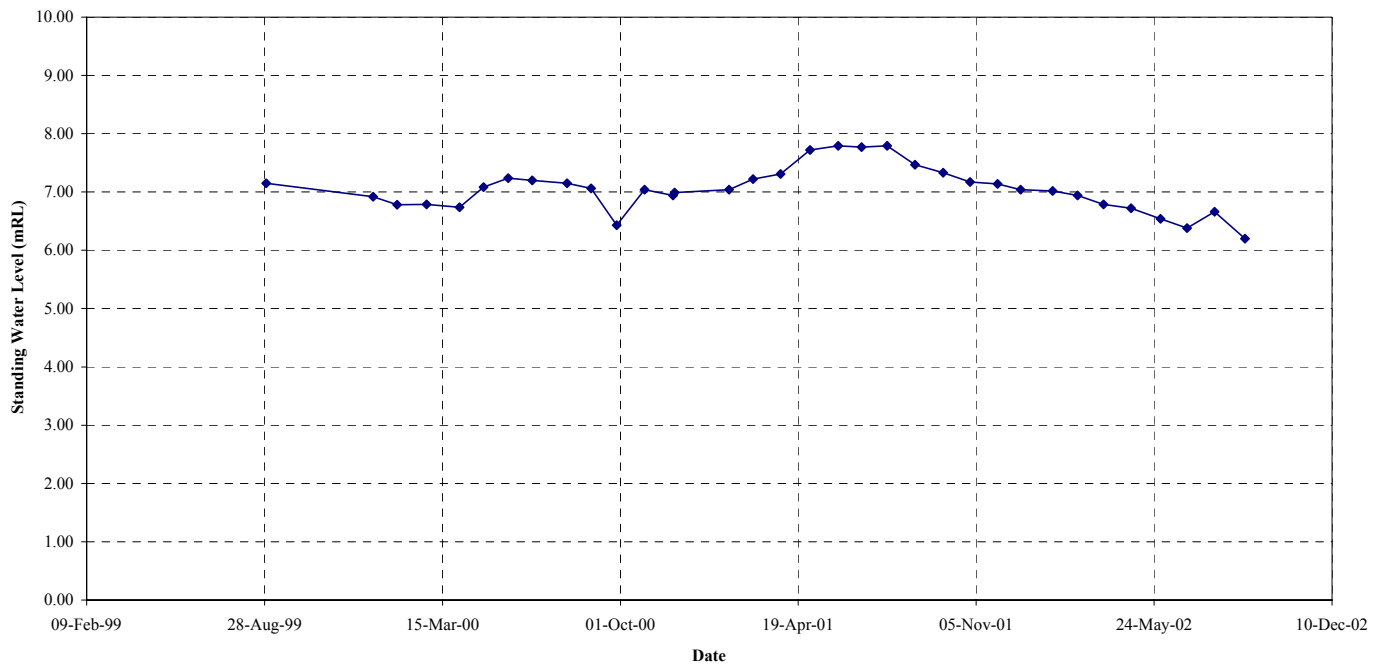


Observation Bore - OB10

Complete Monitoring Period

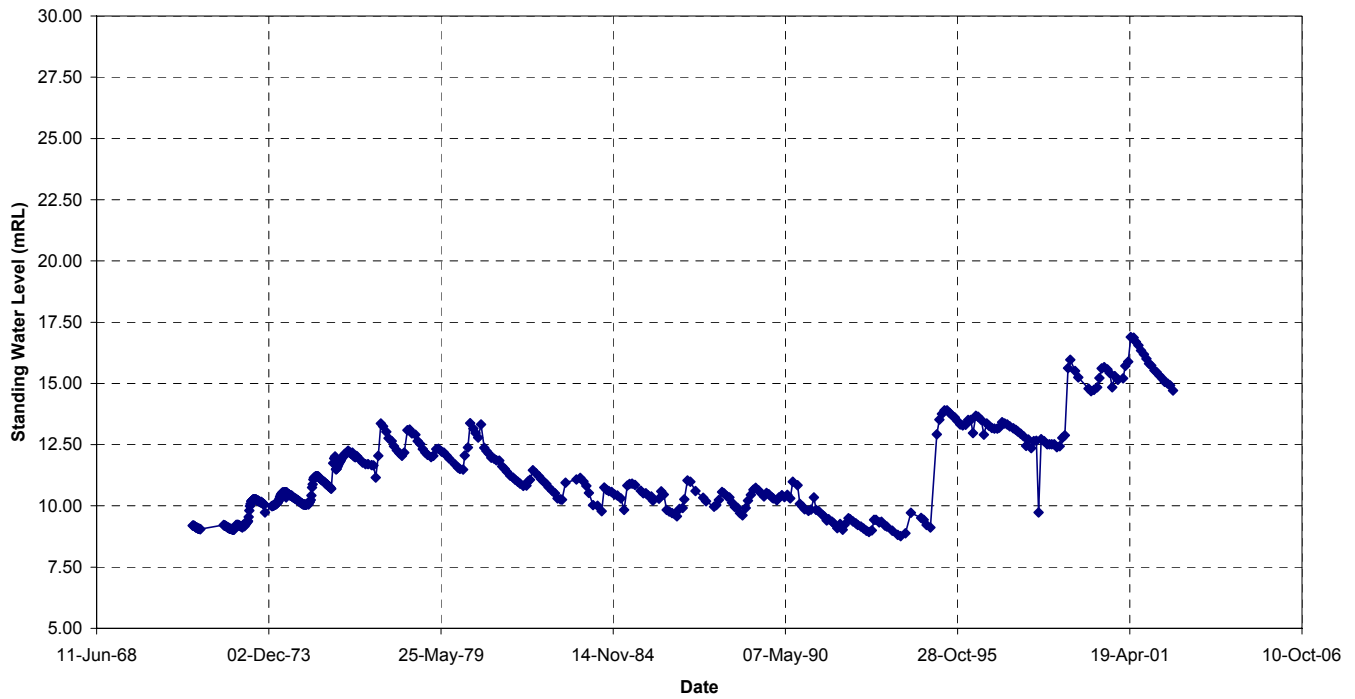


Triennium Period 1999 to 2002

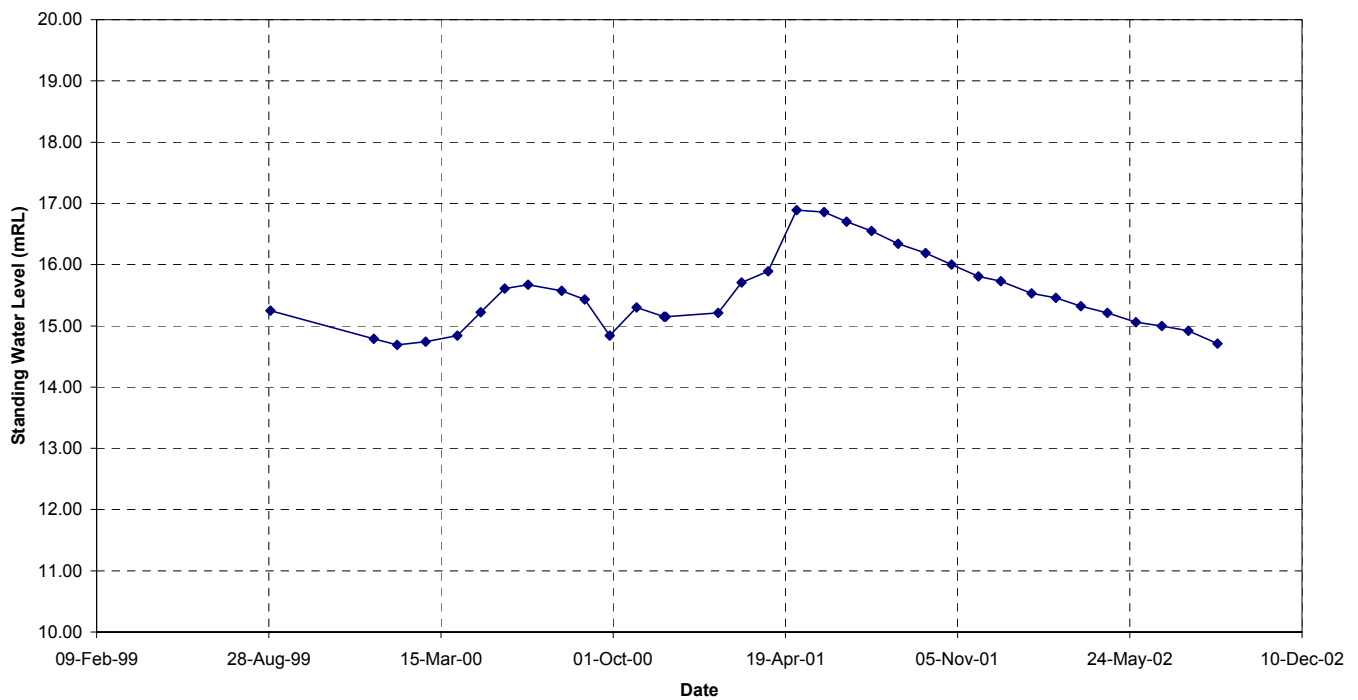


Observation Bore - OB11

Complete Monitoring Period



Triennium Period 1999 to 2002

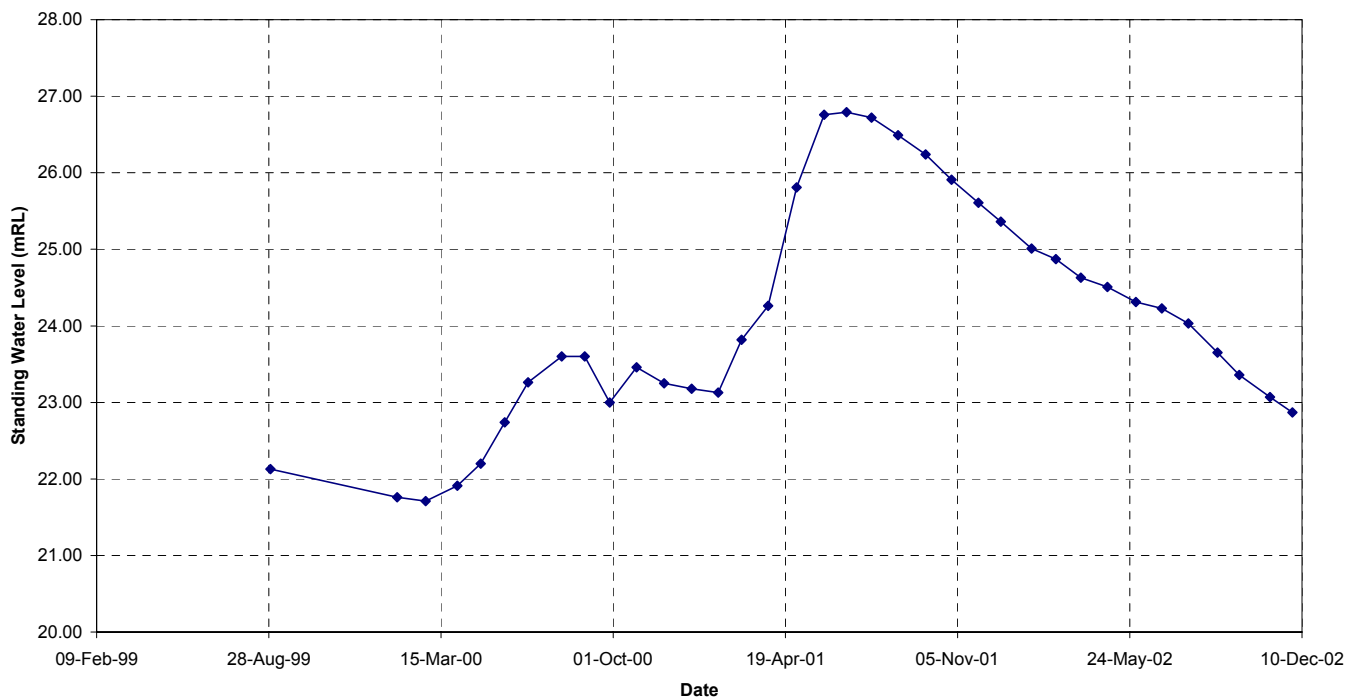


Observation Bore - OB12

Complete Monitoring Period



Triennium Period 1999 to 2002

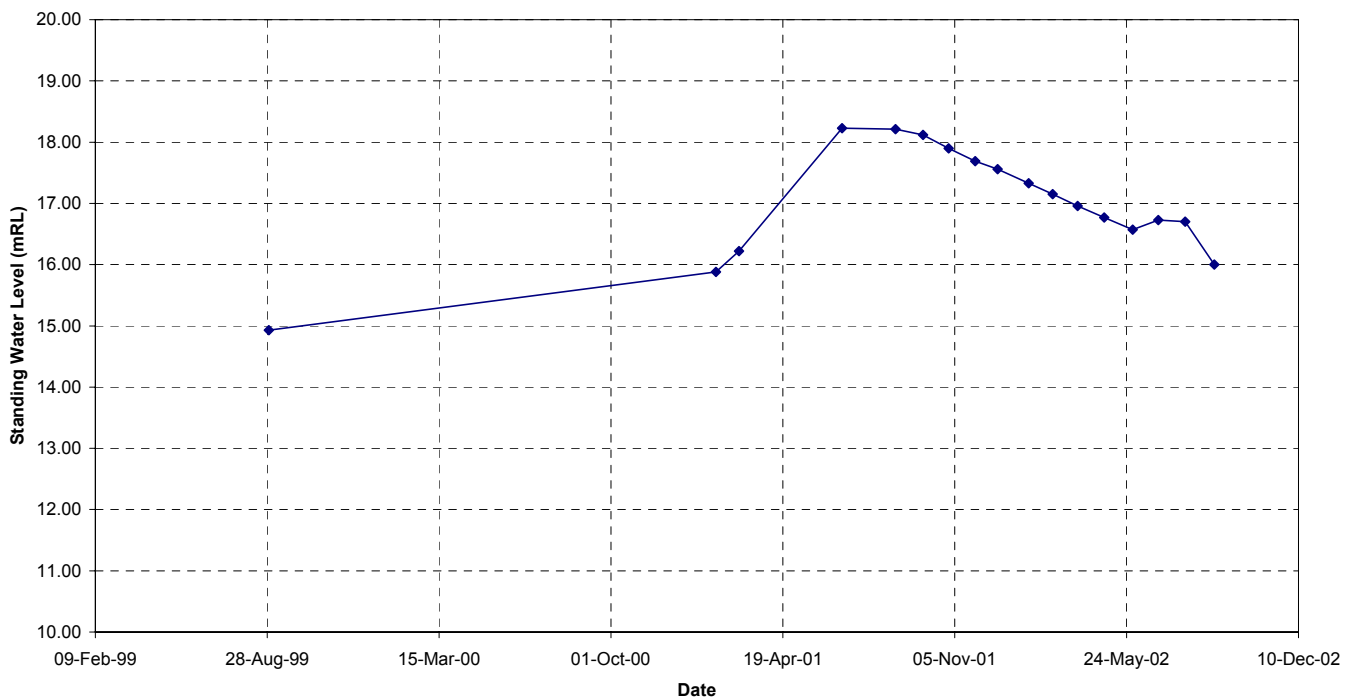


Observation Bore - OB13

Complete Monitoring Period



Triennium Period 1999 to 2002

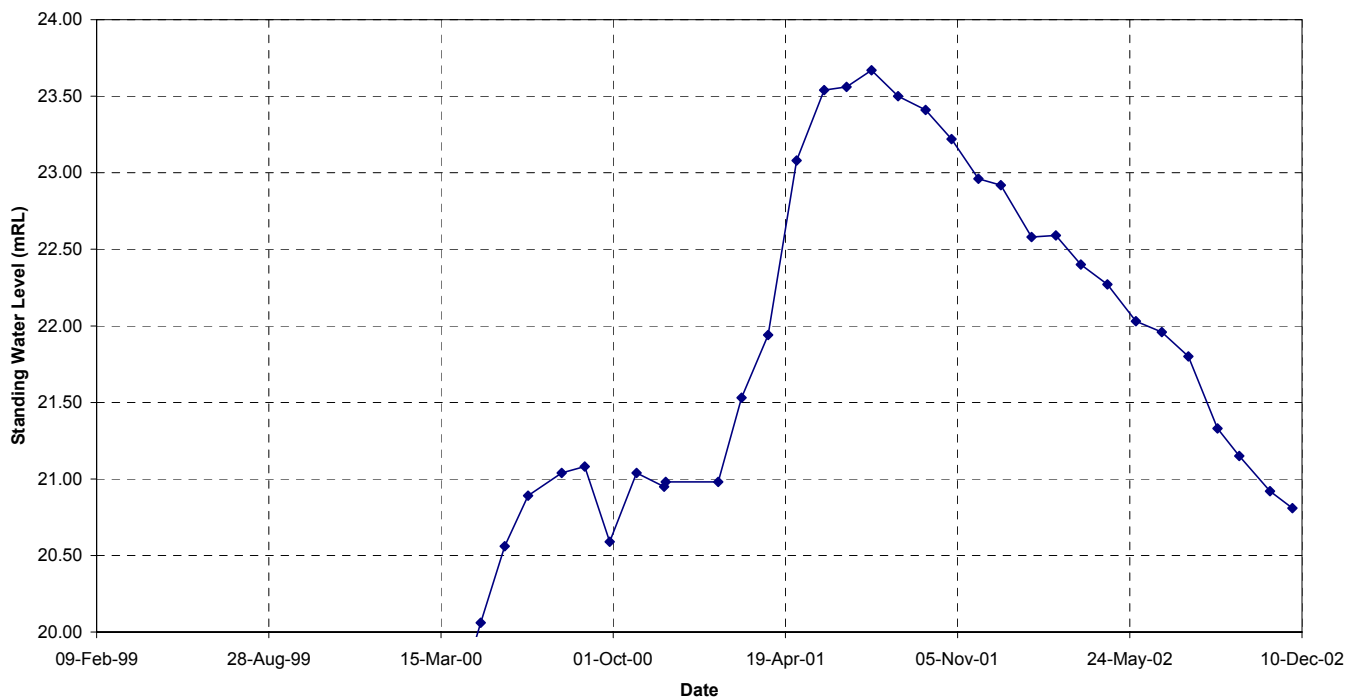


Observation Bore - OB14

Complete Monitoring Period



Triennium Period 1999 to 2002

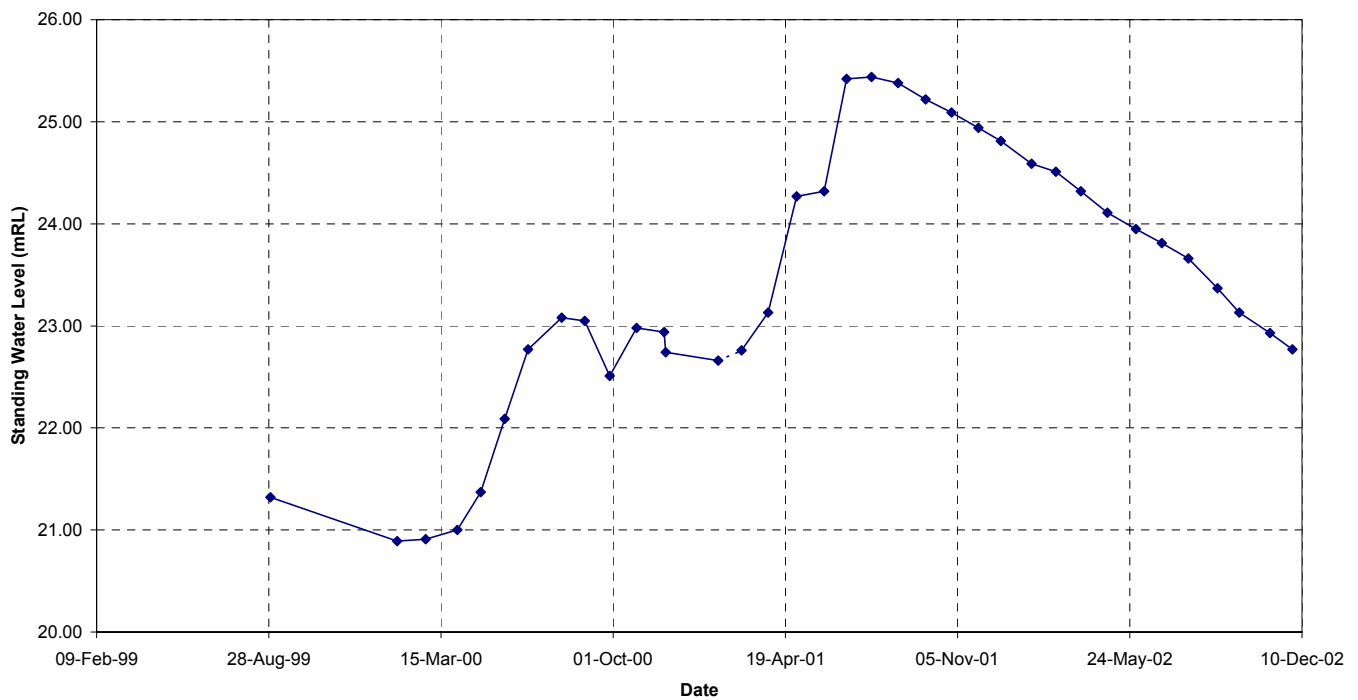


Observation Bore - OB15

Complete Monitoring Period



Triennium Period 1999 to 2002

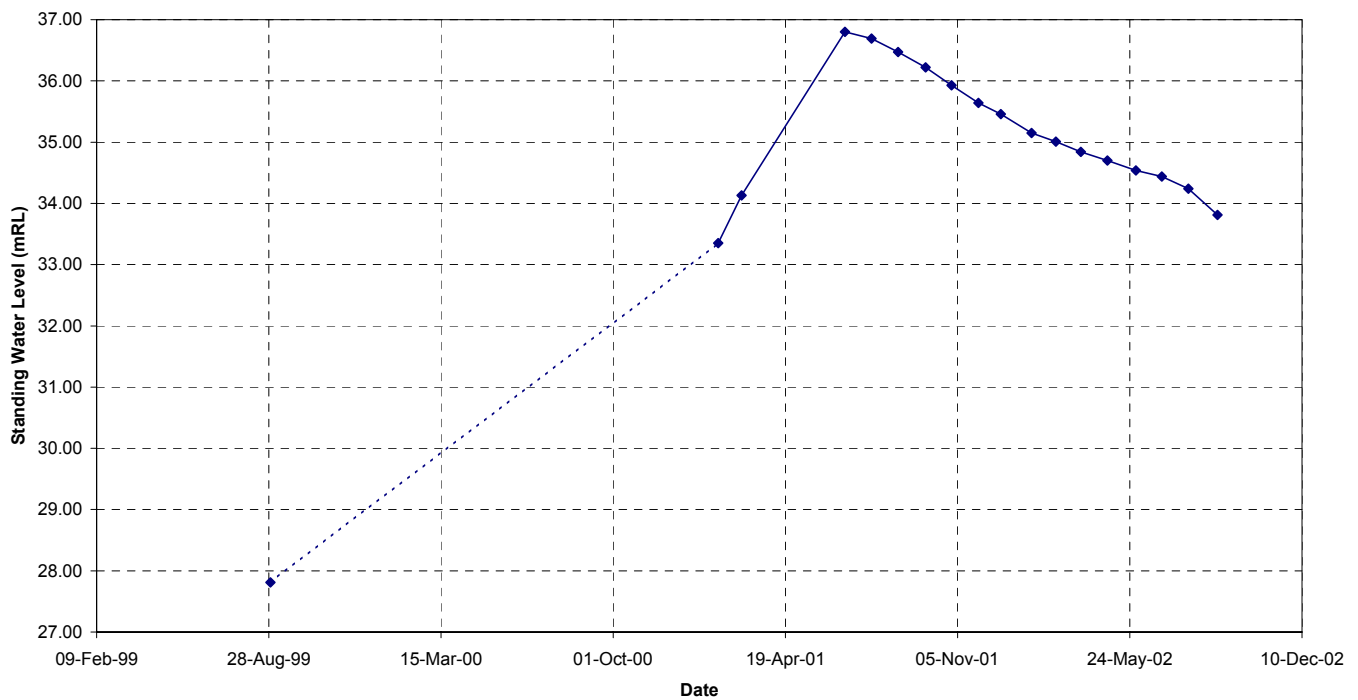


Observation Bore - OB16

Complete Monitoring Period

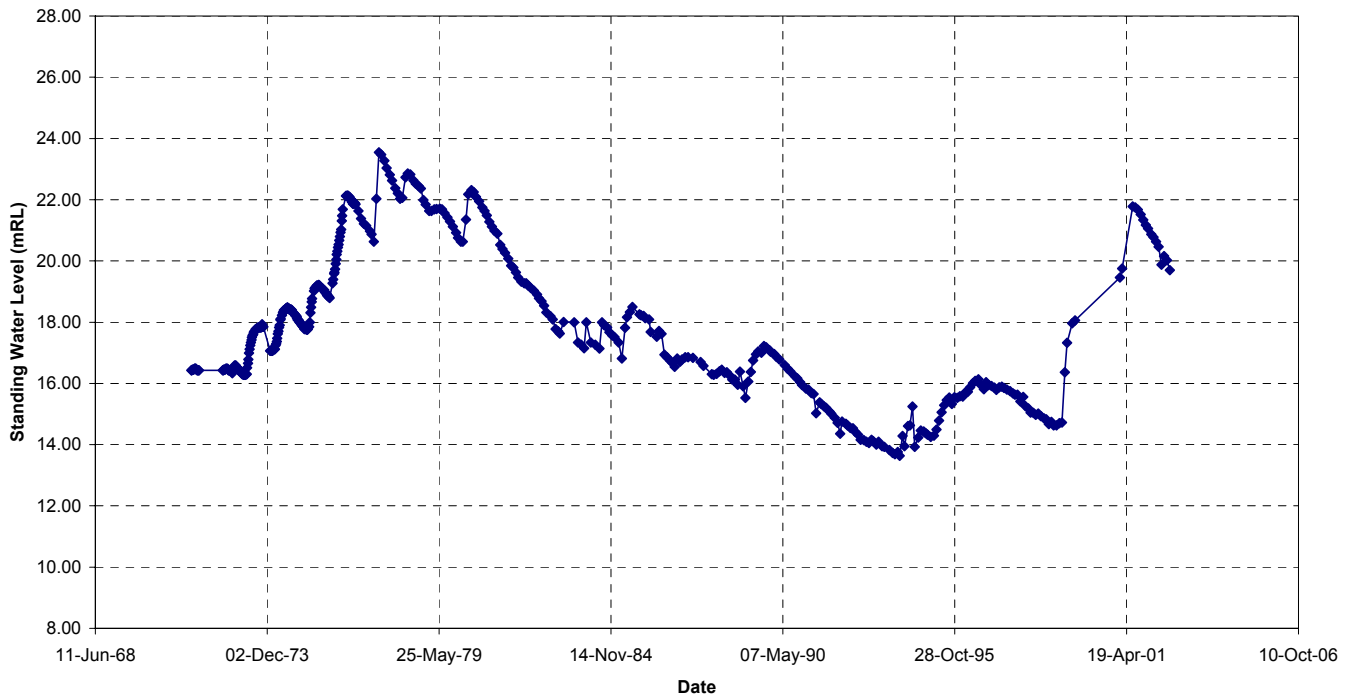


Triennium Period 1999 to 2002

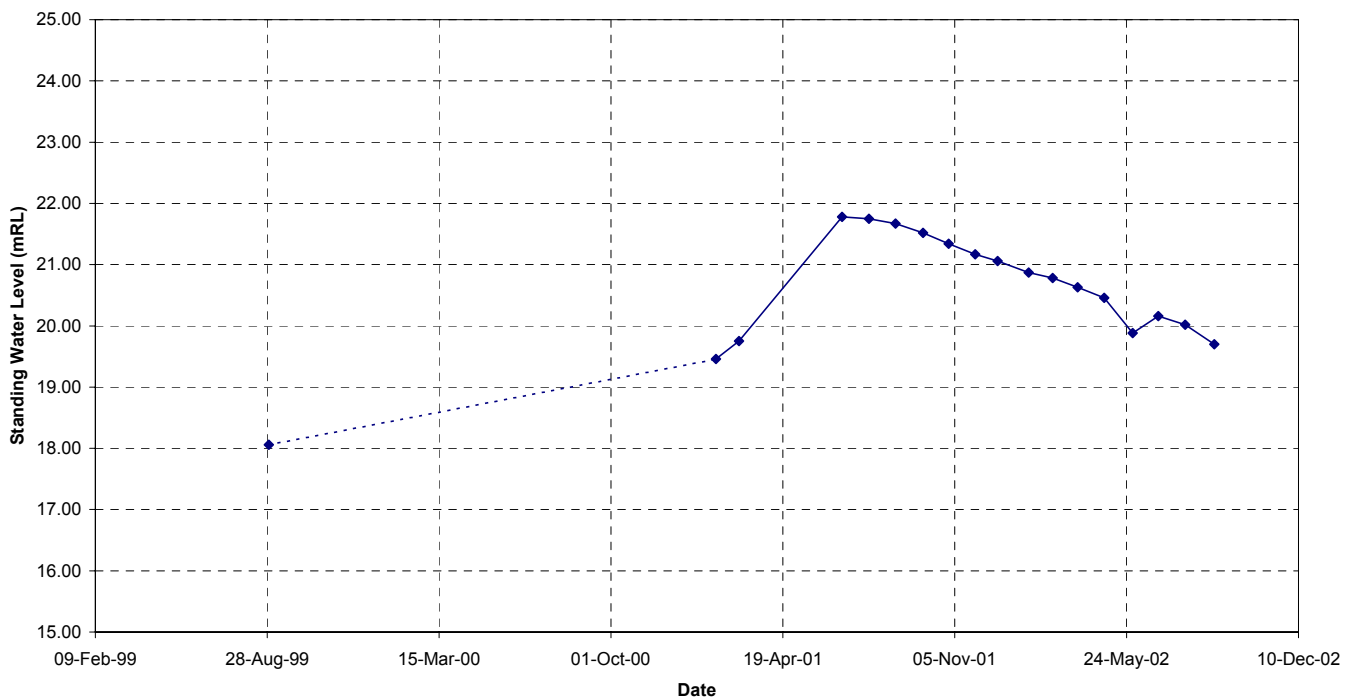


Observation Bore - OB17

Complete Monitoring Period

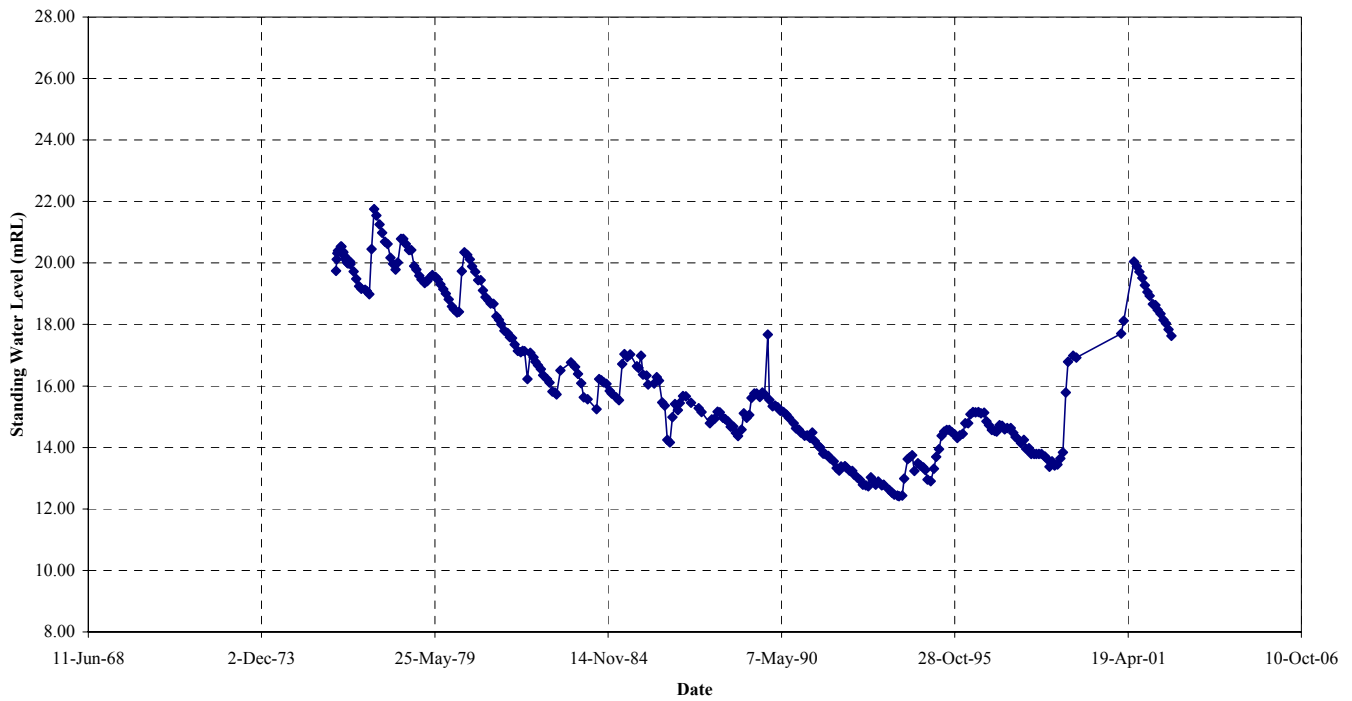


Triennium Period 1999 to 2002



Observation Bore - OB18

Complete Monitoring Period



Triennium Period 1999 to 2002

