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Long-Term Groundwater Management Plan

Redevelopment of Former Brick Pit, Kirrawee

for Henroth Investments Pty Limited
October 2010

J1418.11R-rev0

CMJA

C. M. Jewell & Associates Pty Ltd

Long-Term Groundwater Management Plan –Redevelopment of Former Brick Pit, Kirrawee
October 2010

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Appendix A Groundwater Flow Model

Measures

μg/L	micrograms per litre
km	kilometre
L	litre
m	metre
m^2	square metre
μS/cm	microsiemens per centimetre
mS/cm	millisiemens per centimetre
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mm	millimetre

General

AHD	Australian Height Datum
AMG	Australian Map Grid
ANZECC	Australian and New Zealand Environment and Conservation Council
AST	above-ground storage tank
CLM Act	Contaminated Land Management Act
CMJA	C. M. Jewell & Associates Pty Ltd
COPC	contaminants of potential concern
DA	development application
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water
DLWC	Department of Land and Water Conservation
DNAPL	dense non-aqueous-phase liquid
DNR	Department of Natural Resources
DP	deposited plan
DQO	data quality objectives
EPA	Environment Protection Authority
ESA	Environmental Site Assessment
GDE	groundwater dependent ecosystems
HDPE	high-density polyethylene
MNA	monitored natural attenuation
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
PID	photoionisation detector
PQL	practical quantitation limit
ppmv	parts per million volume
PSH	phase-separated hydrocarbons
QA	quality assurance
QC	quality control
RAP	remediation action plan
RL	relative level
RPD	relative percentage difference
SWL	standing water level
TCLP	Toxicity Characteristics Leaching Procedure
THI	target hazard index
TOC	top of casing
TWA	time weighted average
UCL	upper confidence limit
UST	underground storage tank

Analytes – Organic

BaP	benzo(a)pyrene
BTEX	benzene, toluene, ethylbenzene, xylene
OCP	organochlorine pesticides
OPP	organophosphorus pesticides
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyls
SVOC	semivolatile organic compounds
TPH	total petroleum hydrocarbons
VHC	volatile halogenated compounds
VOC	volatile organic compounds

Analytes – Inorganic

As	Arsenic
Cd	Cadmium
Cr	Chromium
Cu	Copper
Fe	Iron
Hg	Mercury
Mn	Manganese
Ni	Nickel
Pb	Lead
Zn	zinc

1.0 INTRODUCTION

1.1 Background

This Long-Term Groundwater Management Plan has been prepared in support of an application for Concept Plan approval under Part 3A of the Environmental Planning and Assessment Act at 566-594 Princes Highway, Kirrawee (as shown on Figure 1), otherwise known as the former Kirrawee Brick Pit (Reference MP 10_0076). The application seeks approval for a mixed use development comprising residential, retail and commercial uses and building envelopes of between 5 and 15 storeys. The proposal also involves basement car parking and includes commuter parking, landscaping, services and the provision of a major new public park.

Specifically, this report addresses requirements related to groundwater, pit dewatering, and associated contamination issues, as detailed in the Director General's Requirements (DGR) issued by the Department of Planning on 24 August 2010 and outlined below.

The proposal to redevelop the former Kirrawee Brick Pit will include construction of basement car-parking within the existing pit. As the pit is currently flooded, dewatering will be required, and as the proposed development extends below the local water table, long-term management of groundwater inflow will also be necessary.

The DGRs included the following requirements related to groundwater, pit dewatering, and associated contamination issues.

> Plans and documents to accompany the Application.
>
> The following plans, architectural drawings, diagrams and relevant documentation shall be submitted;
>
> . . .
>
> 10. Site Contamination Assessment / Human Health Risk Assessment / documentation that demonstrates that the land is or can be made suitable for the intended purpose within the project delivery timeframe.
>
> . . .
>
> 12. Groundwater Assessment – identifying groundwater issues and potential degradation to the groundwater source that may be encountered during excavation. The assessment should identify contingency measures to manage any potential impacts.
>
> **10. Drainage and Stormwater Management**
>
> - The EA shall address drainage/groundwater/flooding issues associated with the development/site, including stormwater, drainage infrastructure and incorporation of Water Sensitive Urban Design measures.
> - An urban design integrating ‘best practice’ stormwater management principles to minimise the generation of stormwater from the development and maximise opportunities for reuse on-site.
> - Measures to ensure that water quality in the ornamental lake/compensatory pond is continuously maintained to a standard suitable for wildlife known to drink from the existing water body and to a standard compatible with public safety and amenity.
> - Measures to ensure that stormwater flows from the site including any discharges from the ornamental lake/compensatory pond are controlled and appropriately treated to ensure that there will be no short-term or long-term detrimental impacts to the receiving waters or environment.
> - A methodology to dewater the brick pit in preparation for construction of the development that specifically addresses the following issues:
>   - Measures to protect against possible environmental impacts associated with dewatering the brick pit;
>   - Opportunities to reuse the water for beneficial purposes in preference to disposal;

- Analysis of water quality and risk to the receiving environment;
- Impact of dewatering the brick pit on wildlife habitat;
- Affect of withdrawing the water from the brick pit on the groundwater resource; and
- Stability of the empty impoundment and potential for bank failure, particularly the influence on Flora Street.

11. Contamination, Human Health Risk Assessment and Geotechnical Issues.

- Contamination and geotechnical issues associated with the proposal should be identified and addressed in accordance with SEPP55.

In order to address data and information gaps, Mr Daniel Maurici of Henroth Investments Pty Limited (Henroth) commissioned C. M. Jewell & Associates Pty Ltd (CMJA) to carry out an investigation and to prepare plans for dewatering and long-term groundwater management.

This document is the Long-Term Groundwater Management Plan. A Hydrogeological Data Report (ref. J1418.9R-rev0, October 2010) setting out the results of the investigation, and a Dewatering Plan (ref. J1418.10R-rev0, October 2010) have been prepared and submitted under separate covers.

1.2 Objectives

The objectives of this document are to describe an approach to long-term management of groundwater inflow to the former brickpit, and to set out the detailed procedures required to implement that approach. It is intended to be a stand-alone document that can form the basis for detailed design. It also addresses relevant aspects of the DGRs.

1.3 Scope of Work

This report addresses management of groundwater inflow to the pit once dewatering has been completed. Dewatering issues are addressed in CMJA's Dewatering Plan.

This report deals only briefly with management of groundwater inflow during construction, as this will be the responsibility of the construction contractor and will be addressed in an environmental management plan to be prepared by that contractor. This report describes the suggested long-term groundwater management procedures in detail.

The procedures described in this report are based on data compiled in CMJA's Hydrogeological Data Report and on groundwater modelling described in Appendix A of this report.

1.4 Report Format

Section 2 of this report provides a brief summary of hydrogeological conditions on the site. For further detail, and a full list of information sources, reference should be made to the Hydrogeological Data Report.

Section 3 outlines the basis for the long-term monitoring and management plan, while management options are discussed in Section 4. Some regulatory aspects are discussed in Section 5, and conclusions and recommendations, which form the essence of the management plan, are set out in Section 6.

1.5 Limitations and Intellectual Property Matters

This report has been prepared by C. M. Jewell & Associates Pty Limited for the use of the client identified in Section 1.1, for the specific purpose described in that section. The project objectives and scope of work outlined in Sections 1.2 and 1.3 were developed for that purpose, taking into consideration any client requirements and budgetary constraints set out in the proposal referenced in Section 1.1.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues that may arise in the future and that could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation. An information sheet – 'Important Information about your Environmental Site Assessment' – is provided with this report. The report should be read in conjunction with that information sheet.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

This report, the original data contained in the report, and its findings and conclusions remain the intellectual property of C. M. Jewell & Associates Pty Ltd. A licence to use the report for the specific purpose identified in Section 1.1 is granted to the persons identified in that section on the condition of receipt of full payment for the services involved in the preparation of the report.

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2.0 SUMMARY OF SITE CONDITIONS

This section includes a brief summary of hydrogeological conditions on the site. For further detail, and a full list of information sources, reference should be made to the Hydrogeological Data Report.

2.1 Site Identification

The site is located between the Princes Highway, which forms the northern boundary of the site, and Flora Street, Kirrawee. It is bounded to the east by a number of industrial units, and to the west by Oak Road.

The site address is 566-594 Princes Highway, Kirrawee, and the land title designation is Lots 1 and 2 in DP589977 and Lot 1 in DP179075.

2.2 Site Description

The site is roughly rectangular and measures approximately 250 metres east-west by 170 metres north-south, and has an area of 4.25 hectares. As shown on Figure 2, the former quarry occupies most of the southern half of the site, whilst the northern portion of the site consists of a series of shallow slopes and terraces that fall towards the Princes Highway.

2.3 Current Site Use

The site is currently disused. The former quarry pit is filled with water, and the remainder of the site is heavily overgrown with vegetation, including many species of exotic weeds.

2.4 Surrounding Area

Land use in the area surrounding the site is predominantly low-density residential, with commercial and light industrial use immediately to the east of the site and also to the north of the Princes Highway, and a small commercial area to the south-east. There is commercial (retail) development to the south-west, and light industry to the south. The Sutherland–Cronulla railway lies one block to the south, and there are a number of recreational open space areas nearby.

2.5 Topography and Drainage

The site is located on the northern flanks of the Woronora Plateau, about 30 kilometres south of Sydney. The site lies on the crest of a ridge that divides the lower Woronora River and Hacking River drainage systems.

Most of the surface of the site – excluding the area of the brick pit itself – dips gently to the east in line with the structural inclination of the region. The elevation in the south-western corner of the site – which is also the highest point of the site – is about 105 metres above Australian Height Datum (AHD), and that part of the site lies along the crest of a locally prominent ridgeline; this ridgeline generally follows the direction of the Princes Highway and forms the major surface water divide in the area. From the south-western corner, the site gently slopes to the east and south-east, with the elevation in the south-eastern corner measured at 94 metres AHD.

The height of the pit walls range from over 15 metres along the western face of the quarry, to a little over 3 metres in the south-eastern corner of the site. The quarry walls vary in slope between near vertical to 20 degrees, with the steepest faces along the southern boundary of the former quarry where some remedial works, including rock bolting and shotcrete application, have been carried out to ensure the stability of these walls.

2.6 Geology

The site is situated on one of the 'claystone, siltstone and laminite' (shale) lenses that occur within the Hawkesbury Sandstone on the Woronora Plateau. These lenses are usually mid to dark-grey, lensoidal in shape, and either grade into the overlying sandstone or have sharp boundaries. They vary in thickness from a few millimetres to more than 10 metres and may be laterally continuous for several hundreds of metres.

Geological conditions on site have been documented by URS Australia Pty Limited (URS). URS drilled four geotechnical boreholes to depths of 15 metres, logged the core for geological and geotechnical purposes, and carried out pit wall geotechnical mapping. From this work, URS then defined the geological and geotechnical units encountered during its investigations, and compiled a geotechnical cross-section across the northern part of the site. The cross-section and borehole logs from these investigations are included in the Hydrogeological Data Report whilst geological units are summarised in Table 1.

TABLE 1
Geological Units as Defined by URS

Unit No.	Geological Description	Approximate Thickness (m)	Rock Mass Classification
1	FILL: silty CLAY and sandy CLAY with assorted fragments, orange brown, low plasticity, firm to very stiff, fragments include concrete and bricks.	1.0 to 2.5	-
2	RESIDUAL SOIL: silty CLAY, red-brown and grey, low to medium plasticity, stiff to hard occasional sub-angular to angular shale fragments.	1.0 to 7.0	-
3a	EXTREMELY TO DISTINCTLY WEATHERED SHALE: extremely low to very low strength, light and dark-brown grey, laminated, fractured to fragmented, some residual clay zones, local siltstone towards the base.	3.0 to 7.0	Class V-IV shale
3b	SLIGHTLY WEATHERED SHALE: medium strength, dark grey, thinly laminated, poorly developed bedding, fractured, localised fragmented zones and low strength although stronger where iron staining is present.	3.0 to 4.5	Class III shale
4a	EXTREMELY TO DISTINCTLY WEATHERED SANDSTONE: low to medium strength, orange brown, massive to faintly cross-bedded, fine to medium-grained, fragmented to slightly fractured.	2.0 to 3.0	Class IV sandstone
4b	SLIGHTLY WEATHERED SANDSTONE: medium to high strength, light-grey brown, massive to faintly cross-bedded, fine to medium-grained, fractured to slightly fractured	Greater than 2.0	Class III sandstone

In the northern portion of the site, bedding dips very gently from west to east at about 2 degrees, which is consistent with the regional trend inferred from the Wollongong–Port Hacking geological map sheet; this was confirmed during site reconnaissance works carried out by CMJA.

The depth to and thickness of some of these units, and also their degree of weathering, vary across the site; this is most evident in the declining thickness of the weathered profile from west to east. A thicker soil horizon is also evident along the western batters of the quarry lake compared to those along the eastern batter.

Reference to the Wollongong–Port Hacking geological map sheet indicates that there are no regionally significant geological structures in the area, something that is confirmed by the URS and Australian Water Technologies (AWT) observations. Rather, discontinuities in the bedrock are dominated by jointing and bedding plane partings. URS identified two prominent sub-vertical joint sets – which it referred to as Set 1 and Set 2 – and a weak and ill-defined third set. These sets were mapped along the exposed cuttings along the southern face of the pit and were described as follows.

Set 1 (major set): strikes north-north-west and is sub-vertical in orientation; URS also noted that the strike of this set is roughly perpendicular to the east-west alignment of the southern wall of the former quarry.

Set 2 (secondary set): strikes east-south-east and is sub-vertical in orientation; the strike of this set is sub-parallel to oblique to the southern wall of the former quarry.

Set 3 (weak set): randomly orientated, and variably dipping; was also encountered along well-exposed sections of the western pit wall, although no other description of its occurrence was provided.

Spacings between joints in each of the above sets are typically between 0.5 and 1.0 metre, but quite variable.

URS also provided the following geotechnical description of the shale horizons exposed in the walls of the pit.

> Slope stability in exposed rock cuts is controlled by the presence of planes of weakness consisting of a combination of bedding plane partings and jointing that results in various modes of instability. The bedding plane is sub-horizontally orientated and thinly to very thinly spaced apart (with partings varying between 2 to 20 centimetres) and may be persistent for tens of metres or more.

2.7 Hydrogeology

Groundwater in the vicinity of the site flows predominantly within discontinuities such as joints, bedding plane partings and other fractures, which form a fractured rock aquifer within the shale and underlying weathered sandstone. Minor flows associated with weathered horizons and lithological contrasts may also occur, however these are probably restricted to the western half of the site.

Hydraulic conductivity test results (detailed in the Hydrogeological Data Report) indicate that the hydraulic conductivity of the shale and the upper part of the weathered sandstone on the site (AWT screened its monitoring wells across both units) varies between 1.3×10^{-6} and 6.4×10^{-6} metres per second (m/s^{-1}); values of transmissivity vary between about 1.4×10^{-5} and 3.7×10^{-5} metres squared per day (m^2/day^{-1}).

Whilst these measured values of hydraulic conductivity lie within the regional range (as described in the data report) they are towards the upper end of that range. It is possible that in the vicinity of the former quarry the aperture and connectivity of defects (which together control the hydraulic conductivity) have been enhanced by the combined effects of blasting and ground movement, and that further away from the quarry, the hydraulic conductivity is lower.

Standing water levels have been measured during a number of monitoring events since May 1999, as described in the data report. During each event, water levels were measured from each of the groundwater monitoring wells installed by AWT – namely GW1, GW2 and GW3, whilst during the November 2001 and December 2008 monitoring events, water levels were also measured in the two wells installed by URS in 2006 (i.e. BH1 and BH4).

The elevation of the water table is greatest in the north-western corner of the site (i.e. in monitoring well GW1), and falls gently with distance to the east. The groundwater flow direction coincides with both the local topographic expression and the regional inclination of the Hawkesbury Sandstone, with groundwater flowing from the north-western corner of the site to the east and south-east.

Discharge from the aquifers is thought to occur primarily through natural flow from springs, both perennial and ephemeral, and baseflow into perennial watercourses.

A review of records held by the Department of Water and Energy (DWE), covering boreholes within 2 kilometres of the centre of the site, identified seven registered boreholes, the closest being GW103885 located about 150 metres east of the site. The bore was drilled for monitoring purposes and screened between the ground surface and 6 metres depth.

Groundwater in the area does not appear to be used beneficially, other than for maintenance of ecosystems by natural discharge.

Groundwater quality is described in the data report and discussed in Section 3.3 of this report.

3.0 DESIGN BASIS

3.1 Levels

CMJA understands from Woodhead Masterplan Drawing No. 0300 (21/10/10) that the finished floor level of the basement car park will be 85.00 metres AHD. This implies a pre-construction floor level of about 85.40 metres, and, to provide safe and effective working conditions and an allowance for inhomogeneous conditions, requires that the average groundwater level be lowered to 83.90 metres AHD.

3.2 Groundwater Inflow Rates

Table 2 and Figure 3 define the estimates of groundwater flow rates that form the basis for the proposed groundwater management plan, and describe the status of those estimates.

Estimates were derived from a 3-dimensional (MODFLOW 2000) finite difference groundwater flow model of the site and surrounding area (Appendix A).

TABLE 2
Estimated Groundwater Inflow Rates

Time	Inflow (m^3/d)	Source	Assumptions	Status
End of pit dewatering	109	Transient flow model (MODFLOW 2000)	Recharge on site	Conservative
3 months after dewatering	75	Transient flow model	Recharge on site	Conservative
12 months after dewatering	64	Transient flow model	Recharge on site	Conservative
Long-term (10 years)	57	Transient flow model	Recharge on site	Conservative
Long-term average (conservative)	44	Steady state flow model	No recharge on site, based on fracture hydraulic conductivity	Conservative, used for design purposes
Short-term peak (short duration – up to 1 week)	130	Factored steady state flow model	Major rainfall events result in rise in groundwater level sufficient to triple average hydraulic gradient towards pit	Maximum used for design purposes
Long-term average (likely)	32		No recharge on site based on probable lower average hydraulic conductivity	Probable

Figure 3 shows the predicted decline in inflow in the 12 months following completion of dewatering.

Conservative inflow rates are based on the assumption that the hydraulic conductivity values for the shale and weathered sandstone facies that were measured on site apply to the entire groundwater catchment area. Likely inflow rates are based on the assumption that fracture conductivity in the area around the quarry has been enhanced by the effect of blasting and subsequent ground movement, and that at distances greater than 100 metres from the quarry, lower values, more typical of regional values in sandstone and shale facies of the Hawkesbury Sandstone, apply.

3.3 Groundwater Chemistry

Table 3 shows the predicted quality of groundwater inflow to the pit for both the short term (up to two years following dewatering) and the long term. These data are derived as follows:

- Short-term – average composition of water in pit, assuming that this is in equilibrium with groundwater immediately adjacent to the pit.
- Long-term – average composition of groundwater in on-site monitoring bores, excluding BH04.
- Transition time – particle tracking model (MODFLOW).

TABLE 3
Estimated Groundwater Quality
(mg/L unless otherwise indicated)

Analyte/Parameter	Short-Term Concentration	Long-Term Concentration
pH	8.5	6.0
Conductivity (µS/cm)	1000	1500
Dissolved oxygen	5	0.4
Temperature (°C)	20	20
Turbidity (NTU)	<10	<10
BOD	5	1
DOC	8	1
Calcium	30	20
Magnesium	35	20
Sodium	125	300
Potassium	27	3
Carbonate/bicarbonate	250	250
Sulphate	<1	200
Chloride	190	300
Nitrate/Nitrite	<0.01	<0.01
Ammonia	<0.01	0.2
Phosphorus	0.04	0.2
Boron	0.7	<0.05
Iron	<0.05	8
Manganese	0.01	1
Arsenic	<0.001	0.001
Cadmium	<0.0001	<0.0001
Chromium	<0.001	<0.001
Copper	<0.001	<0.001
Lead	<0.001	0.03
Mercury	<0.0001	<0.0001
Nickel	<0.001	0.01
Zinc	<0.001	0.05
Monocyclic aromatic hydrocarbons	Below detection limits	Below detection limits
Polycyclic aromatic hydrocarbons	Below detection limits	Below detection limits
Aliphatic hydrocarbons	Below detection limits	Below detection limits
Chlorinated hydrocarbons	Below detection limits	Below detection limits
Organochlorine pesticides	Below detection limits	Below detection limits
Other pesticides	Below detection limits	Below detection limits

Notes: NTU nephelometric turbidity units
BOD biological oxygen demand
DOC dissolved organic carbon

4.0 MANAGEMENT OPTIONS

4.1 During Construction

Groundwater will seep into the pit during construction operations. It will be difficult to segregate groundwater seepage from rainfall and overland flow, although if this is possible – for example where groundwater flow occurs through identifiable rock defects – then it may be advantageous to segregate the groundwater, as it would generally be of better quality than surface drainage.

In any event, groundwater will form only a small proportion of the water that will need to be managed during construction operations. Water management will be the responsibility of the construction contractor and will be carried out under a sediment and water environmental management plan, as is normal during construction operations.

It is anticipated that water will be collected in sumps and pumped to a settlement pond prior to removal from the site either by pumping to the street stormwater system, or by a liquid waste disposal contractor.

The suitability of collected water for a particular disposal route will be determined by the efficacy of general water management procedures on the site, not by the intrinsic quality of the groundwater inflow.

4.2 Long Term

As indicated in Table 2, the anticipated long-term inflow rate of groundwater is low and manageable. As indicated in Table 3 the anticipated chemical quality of inflow in both the long term and the short term is generally good, although iron and manganese concentrations will require careful management.

Two design options are being considered for the sub-surface (basement) component of the development. These are a drained basement and a tanked basement.

4.2.1 Drained Basement

A drained basement design will require long-term collection and disposal of groundwater inflow, but may have a lower construction cost than a fully tanked design.

Once steady-state conditions have been reached, most groundwater inflow will occur around the base of the quarry walls. However, some inflow will occur from bedding planes, joints and other defects at higher levels on the walls, and some upflow will occur through the floor of the pit, beneath the basement.

The most effective means of seepage collection would be to install a perimeter drain around the base of the quarry wall. A slotted agricultural drain laid in a shallow trench and bedded in coarse aggregate with a filter-fabric envelope, with a permeable surface and protective layer, would be effective in collecting both the toe seepage and higher-level seepage flowing down the walls.

A drainage layer – a filter fabric and granular medium, or a modular drainage system – installed beneath the floor slab, could collect upflow from the quarry floor most effectively. Flow would be directed radially to the perimeter drain, by appropriate grading.

The most challenging aspect of drainage design will be managing clogging by precipitated iron and manganese hydroxides. Iron and manganese are present in the groundwater as reduced (ferrous and manganous) ions. Once the groundwater comes into contact with oxygen in the atmosphere, the redox potential rises substantially; ferric and manganic hydroxides are formed and precipitate. The orange-brown floc that is thus formed can rapidly clog the drainage system.

Two options are available for overcoming this problem. One is to design a system that is always fully submerged, so that the groundwater does not come into contact with the atmosphere until it enters the treatment plant. The second option is to incorporate a cleaning mechanism into the drainage system at the time when it is built (retrofitting would not be possible). Both of these options are feasible.

4.2.2 Alternative Design

An alternative construction design involves a fully tanked or waterproof basement. With this design, once construction is complete, groundwater is allowed to return to its natural level. The waterproof construction effectively prevents seepage into the basement, and collection of only very small volumes will be required.

A fully tanked basement would have to be designed to resist groundwater uplift (buoyancy) pressure, and construction of such a basement would generally be more expensive than for a drained basement.

4.3 Treatment and Disposal Options

Collected groundwater will require treatment to remove iron and manganese, prior to disposal. Treatment involves raising the pH by addition of an alkali, aeration, precipitation and settlement of the iron and manganese hydroxides, and then addition of an acid to bring the pH back to a suitable level for disposal to the stormwater system. This could be designed as a batch or continuous process.

Once treated, there is no reason why the relatively small flow of long-drainage could not be discharged to the stormwater system; indeed, this is regularly done in other areas, even when the stormwater system discharges directly to a major waterway.

5.0 REGULATION AND PERMITTING

Discharge of the treated groundwater drainage to the stormwater system is subject to the approval of Sutherland Shire Council, but would be expected to be incorporated in the approval of the general stormwater management system for the site, as the flow involved is very small in comparison with the peak stormwater flows.

The discharge would also be subject to the general prohibition of pollution of waters prescribed in s120 of the Protection of the Environment Operations Act 1997 (POEO Act).

Pollution of waters is defined in the Act as:

(a) placing in or on, or otherwise introducing into or onto, waters (whether through an act or omission) any matter, whether solid, liquid or gaseous, so that the physical, chemical or biological condition of the waters is changed, or

(b) placing in or on, or otherwise introducing into or onto, the waters (whether through an act or omission) any refuse, litter, debris or other matter, whether solid or liquid or gaseous, so that the change in the condition of the waters or the refuse, litter, debris or other matter, either alone or together with any other refuse, litter, debris or matter present in the waters makes, or is likely to make, the waters unclean, noxious, poisonous or impure, detrimental to the health, safety, welfare or property of persons, undrinkable for farm animals, poisonous or harmful to aquatic life, animals, birds or fish in or around the waters or unsuitable for use in irrigation, or obstructs or interferes with, or is likely to obstruct or interfere with persons in the exercise or enjoyment of any right in relation to the waters, or

(c) placing in or on, or otherwise introducing into or onto, the waters (whether through an act or omission) any matter, whether solid, liquid or gaseous, that is of a prescribed nature, description or class or that does not comply with any standard prescribed in respect of that matter, and, without affecting the generality of the foregoing, includes:

(d) placing any matter (whether solid, liquid or gaseous) in a position where:

  (i) it falls, descends, is washed, is blown or percolates, or

  (ii) it is likely to fall, descend, be washed, be blown or percolate, into any waters, onto the dry bed of any waters, or into any drain, channel or gutter used or designed to receive or pass rainwater, floodwater or any water that is not polluted, or

(e) placing any such matter on the dry bed of any waters, or in any drain, channel or gutter used or designed to receive or pass rainwater, floodwater or any water that is not polluted, if the matter would, had it been placed in any waters, have polluted or have been likely to pollute those waters.

With regard to Part (a) of the definition, as the condition of Dents Creek and Oyster Gully under all flow conditions in all seasons has not been established, it is impossible to be certain that the discharge may not change the condition of the waters in some way. However, with regard to Parts (b) and (c), on the basis of a thorough review of the data presented in the hydrogeological data report, such pollution would not be caused by discharge of groundwater provided that it is treated to remove iron and manganese.

6.0 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that long-term groundwater drainage during the life of the development can be effectively managed by collection, treatment and discharge to the stormwater drainage system without adverse impact on either that system or the natural watercourses to which the stormwater system itself discharges. Alternatively, if a fully tanked basement design is adopted, no long-term management should be required.

This management plan therefore recommends that either:

(a) a fully tanked basement design is adopted, or

(b) if a drained basement design is adopted, then

i. A drainage system should be installed that incorporates a perimeter drain around the base of the quarry wall and a drainage layer installed beneath the floor slab.

ii. The drainage system should be designed for an average flow of 45 m^3/d (0.5 L/s) and a peak flow of 130 m^3/d (1.5 L/s).

iii. The drainage design should also incorporate a system to manage clogging by precipitated iron and manganese hydroxides.

iv. Collected groundwater should be treated to remove iron and manganese, which are likely to be present at concentrations of approximately 8 mg/L and 1 mg/L respectively.

v. Treated water can then be discharged to the stormwater system.

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Important Information About Your Environmental Site Assessment

These notes will help you to interpret your hydrogeological and Environmental Site Assessment (ESA) reports.

Why are ESAs conducted?

An ESA is conducted to assess the environmental condition of a site. It is usually, but not always, carried out in one of the following circumstances.

- As a pre-purchase assessment, on behalf of either purchaser or vendor, when a property is to be sold.
- As a pre-development assessment, if a property or area of land is to be redeveloped, or if its use is to change (for example, from a factory to a residential subdivision) – to meet a requirement for development approval.
- As a pre-development assessment of a ‘greenfield’ (undeveloped) site - to establish baseline conditions and to assess environmental, geological and hydrological constraints to the proposed development.
- As an audit of the environmental effects of an ongoing operation.

Each type of assessment requires its own specific approach. In all cases, however, the aim is to identify and if possible quantify the risks posed by unrecognised contamination. Such risks may be financial (for example, clean-up costs or limitations on site use), or physical (for example, health risks to site users or the public).

What are the limitations of an ESA?

Although the information provided by an ESA can reduce exposure to these risks, no ESA, however diligently carried out, can eliminate risks altogether. Even a rigorous professional assessment may not detect all contamination on a site. The following paragraphs explain why.

ESA ‘findings’ are professional estimates

The ground surface conceals a complex 3-dimensional subsurface environment. Subsurface materials, whether placed by geological processes or human activities, are always heterogeneous. Large variations in lithology and hydraulic properties can occur over short distances. Surface observation, and data obtained from boreholes and test pits, can never give us a complete picture of the subsurface.

All data from sampling and laboratory testing must be interpreted by a qualified professional – a geologist, engineer or scientist. They then render an opinion - about overall subsurface conditions, the nature and extent of contamination, its likely impact on the proposed development, and appropriate remediation measures.

Interpretation and professional judgement are thus essential to the assessment process.

Accuracy depends on the scope of work

Site assessment identifies actual subsurface conditions only at those specific points where samples are taken and when they are taken. The accuracy of the entire process depends on sampling frequency and sampling methods - yet the extent of sampling and soil analysis must necessarily be limited.

Sampling generally targets those areas where contamination is considered to be most likely, on the basis of visual observation and the site’s history. This approach does maximise the probability of identifying contaminants, but it may not identify contamination in unexpected locations or from unexpected sources.

No professional, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. For example, there may be contaminants in areas not surveyed or sampled; furthermore, they may migrate to areas that showed no signs of contamination at the time of sampling.

Conditions between sample locations can only be inferred – from estimates of geological and hydrogeological conditions, and from the nature and extent of identified contamination. Soil, rock and aquifer conditions are often variable, and so the distribution of contaminants across a site can be difficult to assess. Actual conditions in areas not sampled may differ from predictions.

The accuracy of an assessment is therefore limited by the scope of work undertaken.

Statistical tools can be helpful, but the validity of conclusions still depends entirely on the degree to which the original data reflect site conditions.

Uncertainty is also inevitable when it comes to assessing chemical fate and transport in groundwater and surface water systems, and calculating human health and environmental exposure risks. It is inevitable, too, when estimating remediation performance and time frames.

Your CMJA report includes a statement of the uncertainty associated with this particular project; you should read it carefully.

We can offer solutions

We cannot prevent the unanticipated, but we can minimise its impact. For this reason we recommend that you retain CMJA's services through the remediation and development stages. We can identify differences from predicted conditions, conduct additional tests as required, and recommend solutions for problems encountered on site.

Don't rely on out-of-date information

Subsurface conditions are changed by natural processes and the activity of people. Your ESA report is based on conditions that existed at the time of subsurface exploration. Don't make decisions on the basis of an ESA report whose adequacy may have been affected by time. Speak with CMJA to learn if additional tests are advisable.

If things change, contact us

Every report is based on a unique set of project-specific factors. If any one of these factors changes after the report is produced, its conclusions and recommendations may no longer be appropriate for the site.

Your environmental report should not be used:

- if the nature of the proposed development is changed - for example, if a residential development is proposed instead of a commercial one;
- if the size or configuration of the proposed development is altered;
- if the location or orientation of the proposed structure is modified;
- if there is a change of ownership; or
- for application to an adjacent site.

To help avoid expensive problems, talk to CMJA. We will help you to determine how any factors that have changed since the date of the report may affect its recommendations.

Your ESA report is prepared specifically for you

Every hydrogeological study and ESA report is prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even for another consulting civil engineer. A report should not be used by anyone other than the client, and it should not be used for any purpose other than that originally intended. Any such proposed use must first be discussed with CMJA.

Beware of misinterpretation

Costly problems can occur if plans are based on misinterpretations of an ESA. These problems can be avoided if CMJA is retained to work with appropriate design professionals. We will explain the relevant findings and review the adequacy of plans and specifications.

Logs and laboratory data should not be separated from the report

Final borehole or test pit logs are developed by CMJA's environmental scientists, engineers or geologists, using field logs (assembled by site personnel) and laboratory evaluation of field samples. Our reports usually include only the final logs, which must not under any circumstances be redrawn for inclusion in other documents.

Similarly, our reports often include field and laboratory data, and laboratory reports. These data should not be reproduced separately from the main report, which provides guidance on their interpretation and limitations.

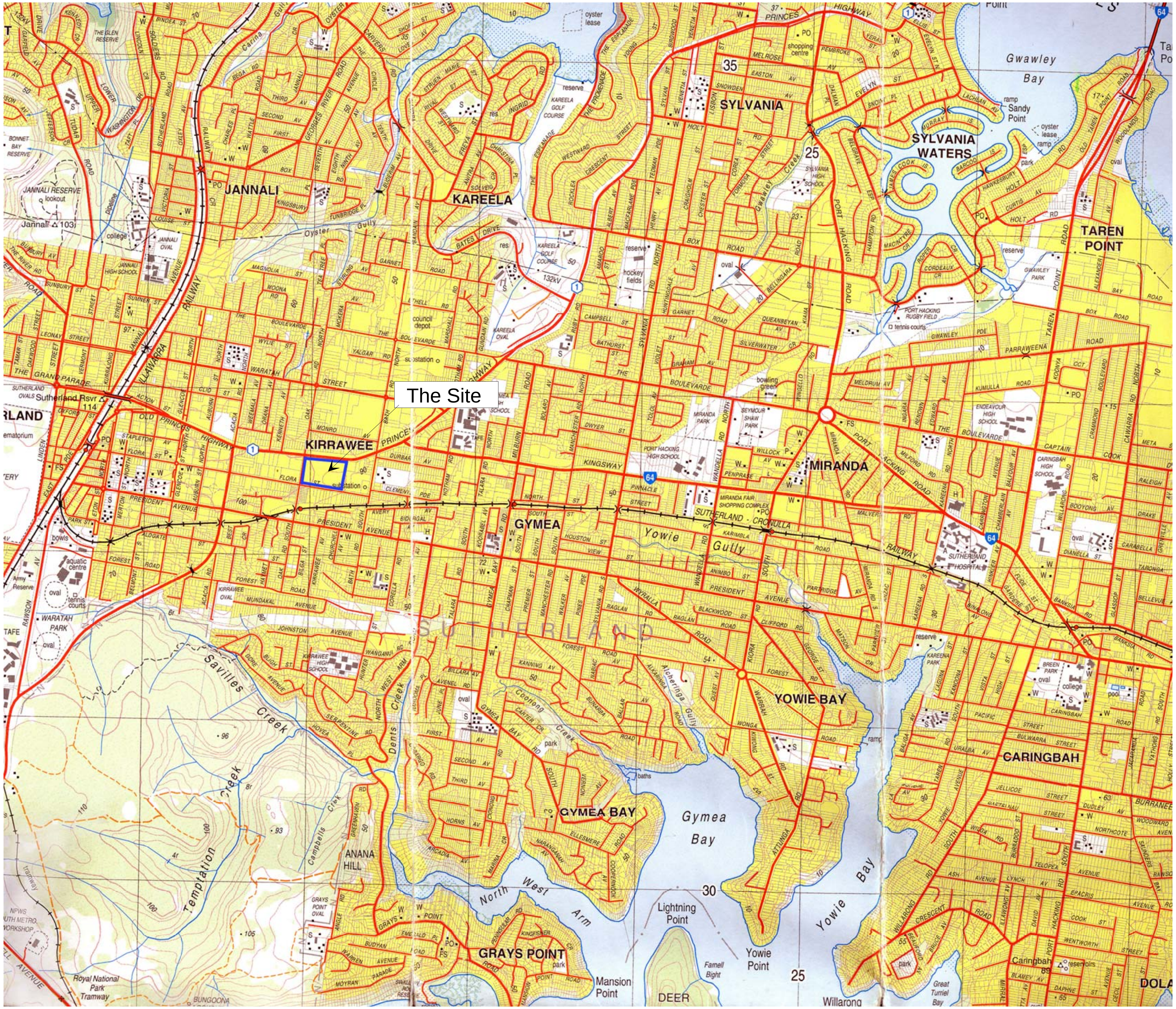
To reduce the likelihood of misinterpretation, only the complete report should be made available for the use of persons or organisations involved in the project, such as contractors. Consult CMJA before distributing reports, and we will assist with any additional interpretation that is required.

Always read responsibility clauses closely

To avoid misunderstandings, our report includes qualifying statements that explain the level of certainty associated with our findings and recommendations, and responsibility clauses that indicate where our responsibilities to clients and other parties begin and end.

These qualifying statements and responsibility clauses are an important part of your report. Please read them carefully. They are not there to transfer our responsibilities to others but to help all parties understand where individual responsibilities lie.

These notes were prepared by C. M. Jewell & Associates Pty Ltd (CMJA) using guidelines prepared by the National Ground Water Association (NGWA) and other sources.



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Date: 15-Oct-10
Author: CBW

Figure 1

Site Location and Regional Setting

Long-Term Groundwater Management Plan - Redevelopment of Former Brick Pit, Kirrawee

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Author: CBW

Figure 2

Site Features

Long-Term Groundwater Management Plan - Redevelopment of Former Brick Pit, Kirrawee

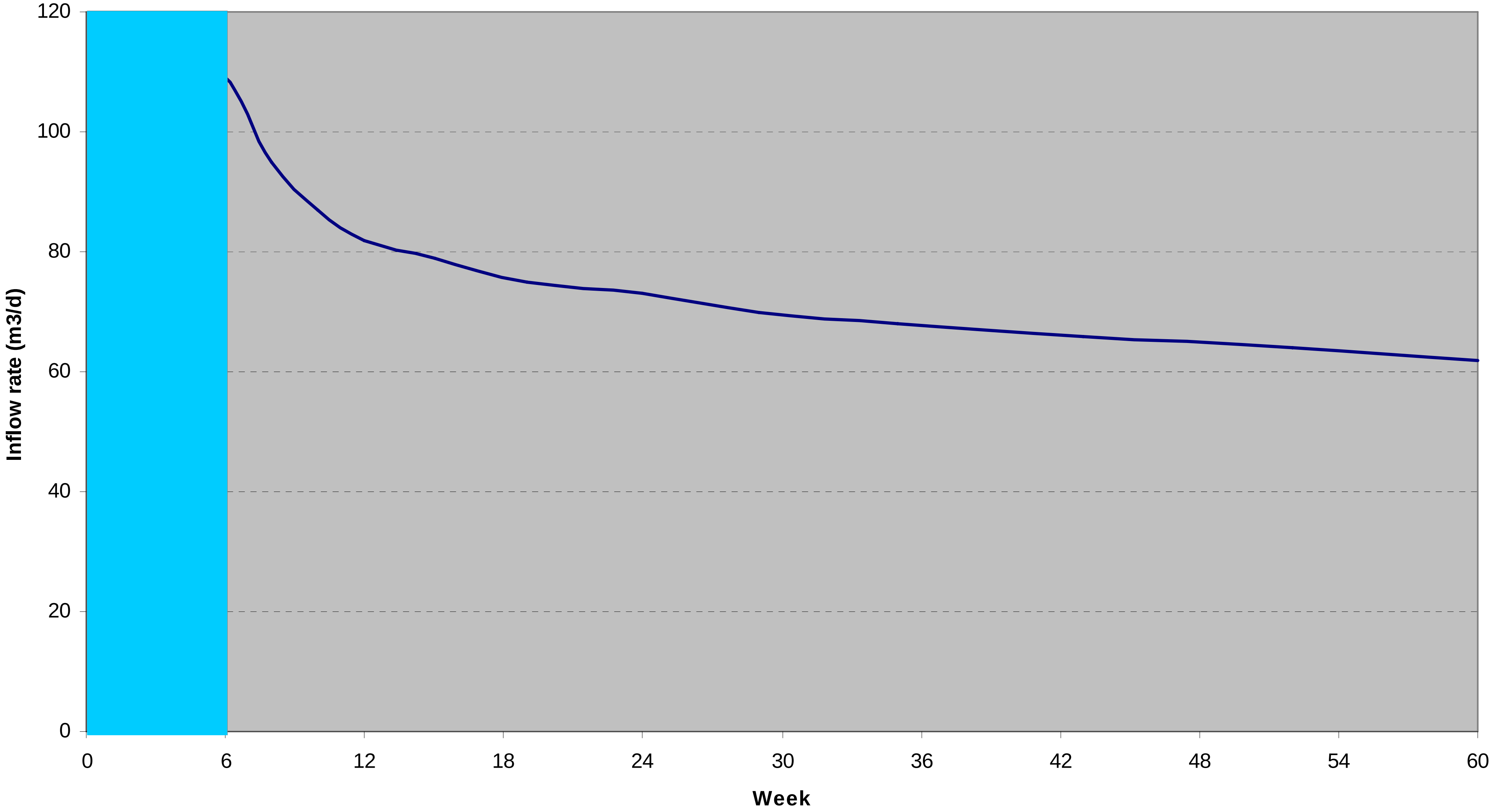

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Figure 3

Predicted Groundwater Inflow Rate

APPENDIX A
Groundwater Flow Model

Model Grid
Horizontal Discretisation 132 columns x 100 rows

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Dewatering and Groundwater Management Assessment

Current (quasi-steady-state) groundwater levels
Elevation of water table, m AHD

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Dewatering and Groundwater Management Assessment

Long-term groundwater level around pit
Post construction
Elevation of water table, m AHD

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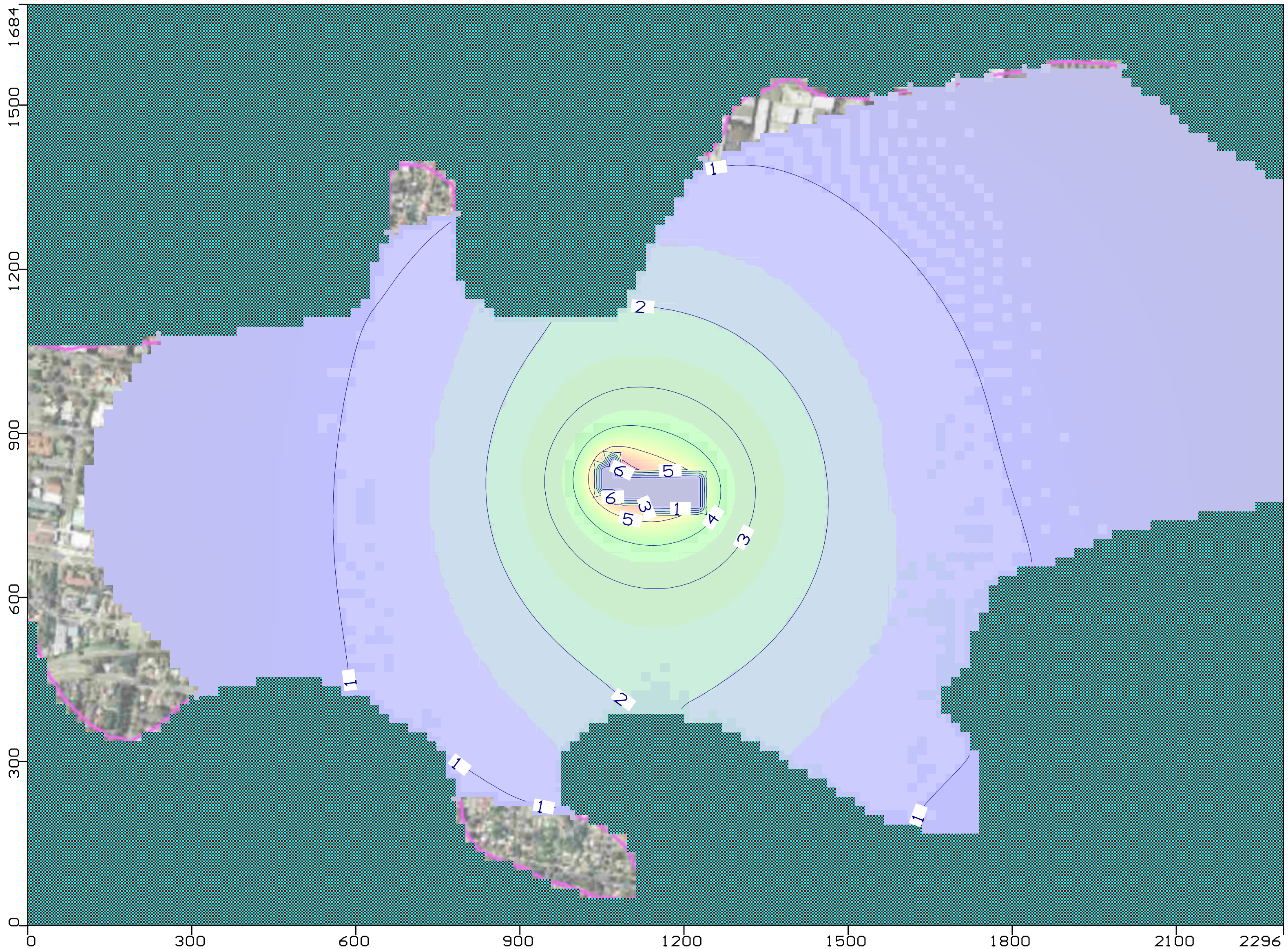
Dewatering and Groundwater Management Assessment



Long-term drawdown around pit
Post construction
Decline in groundwater level, m

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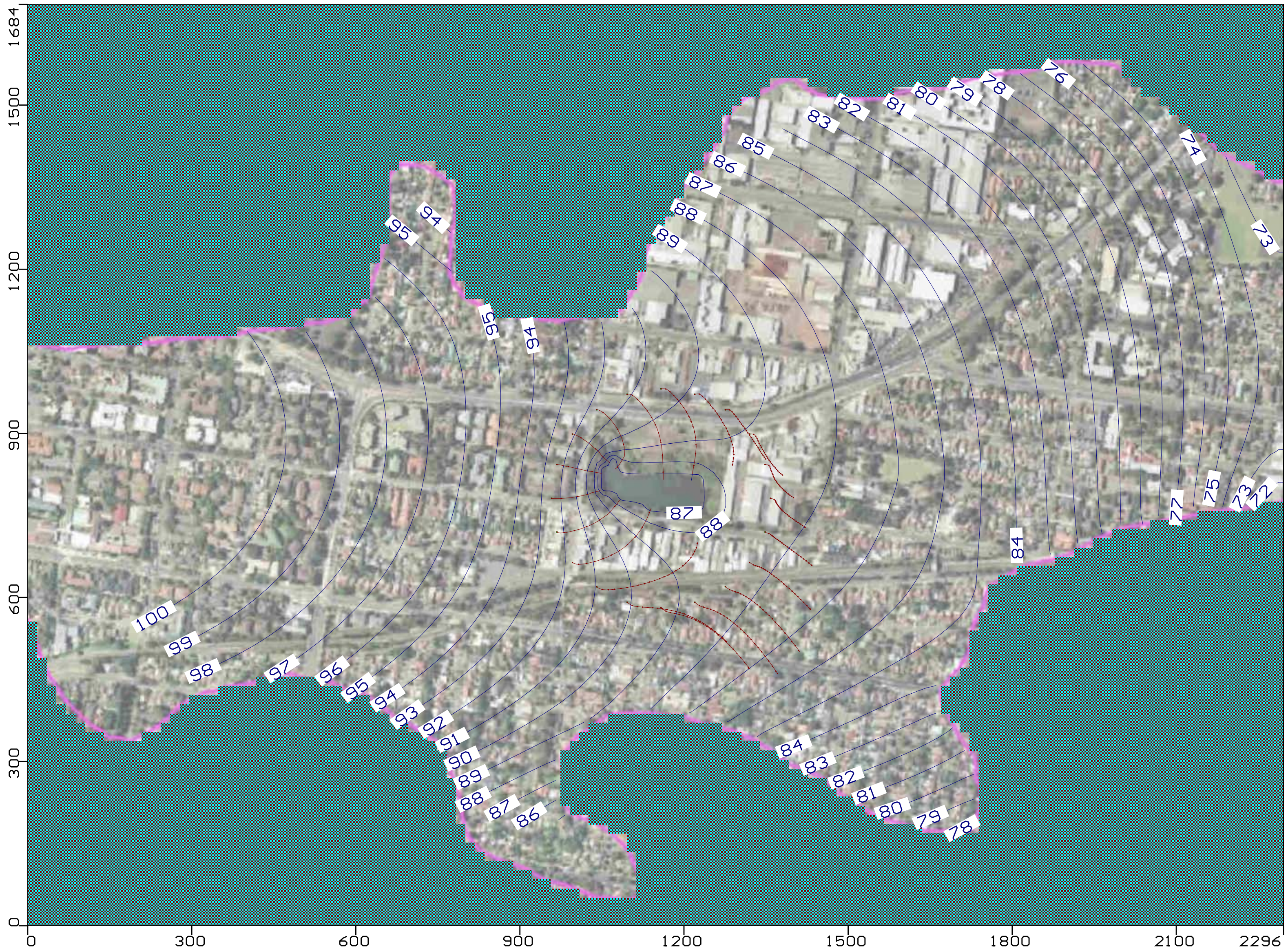
Kirrawee Brickpit
Dewatering and Groundwater Management Assessment



Water levels 12 months following start of dewatering
Contours show the level of the groundwater table in the upper (shale) aquifer in m AHD
Pathlines show groundwater flow directions - each tick represents 30 days travel time

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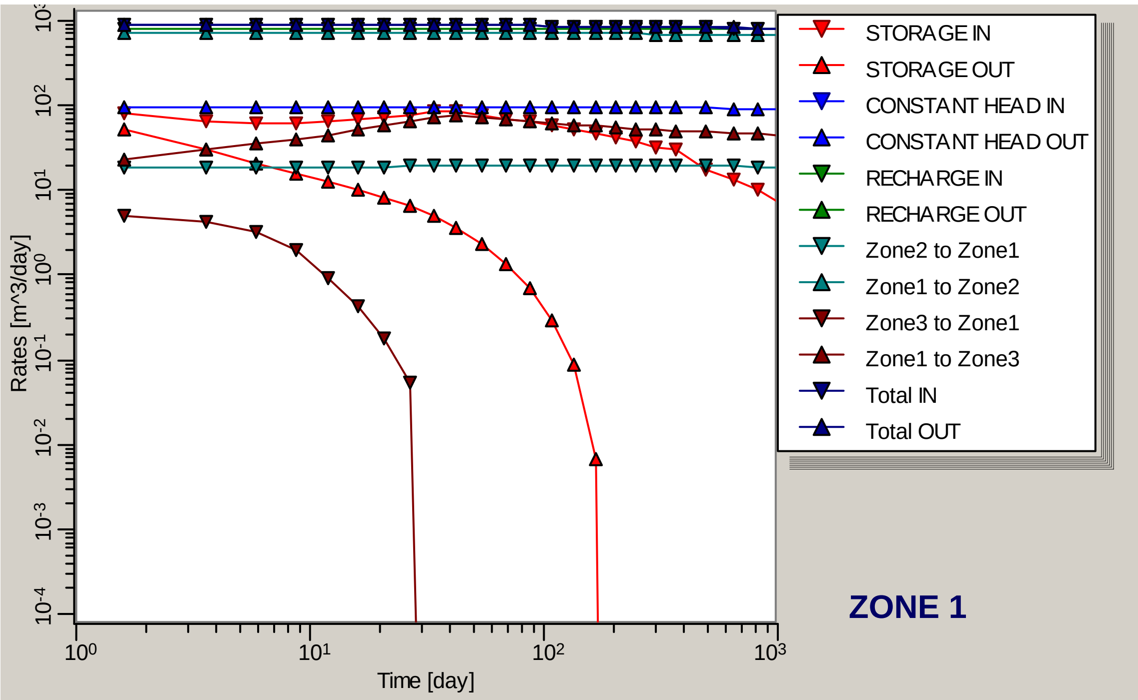
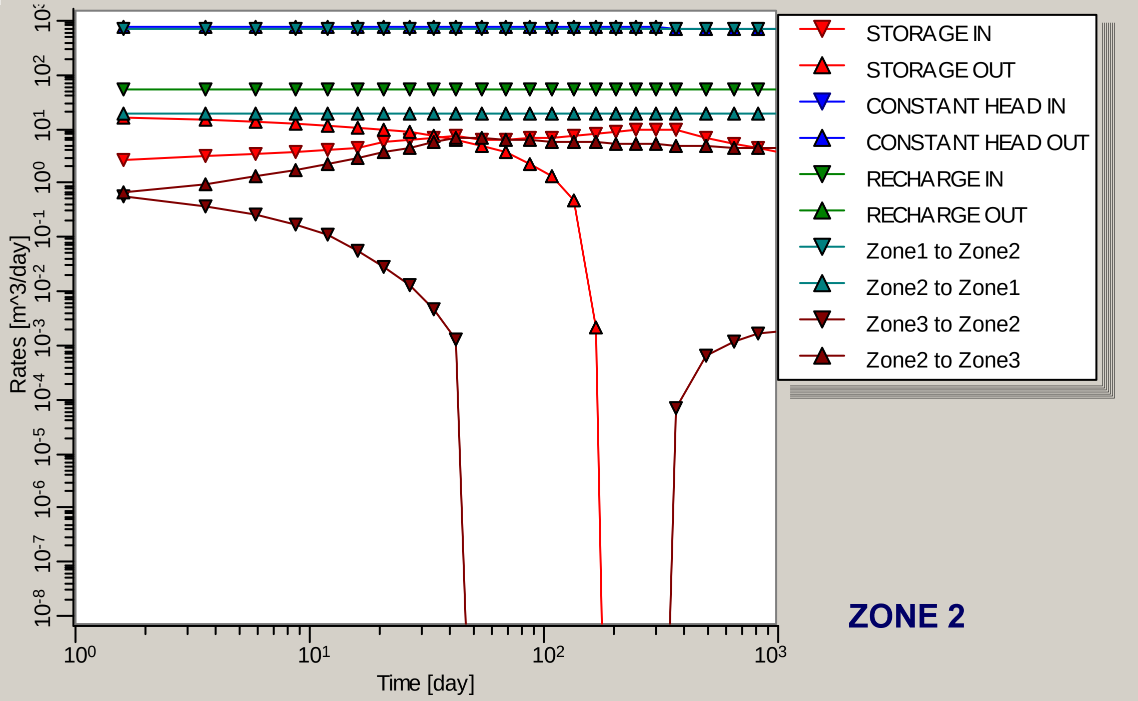
Water and Environmental Management

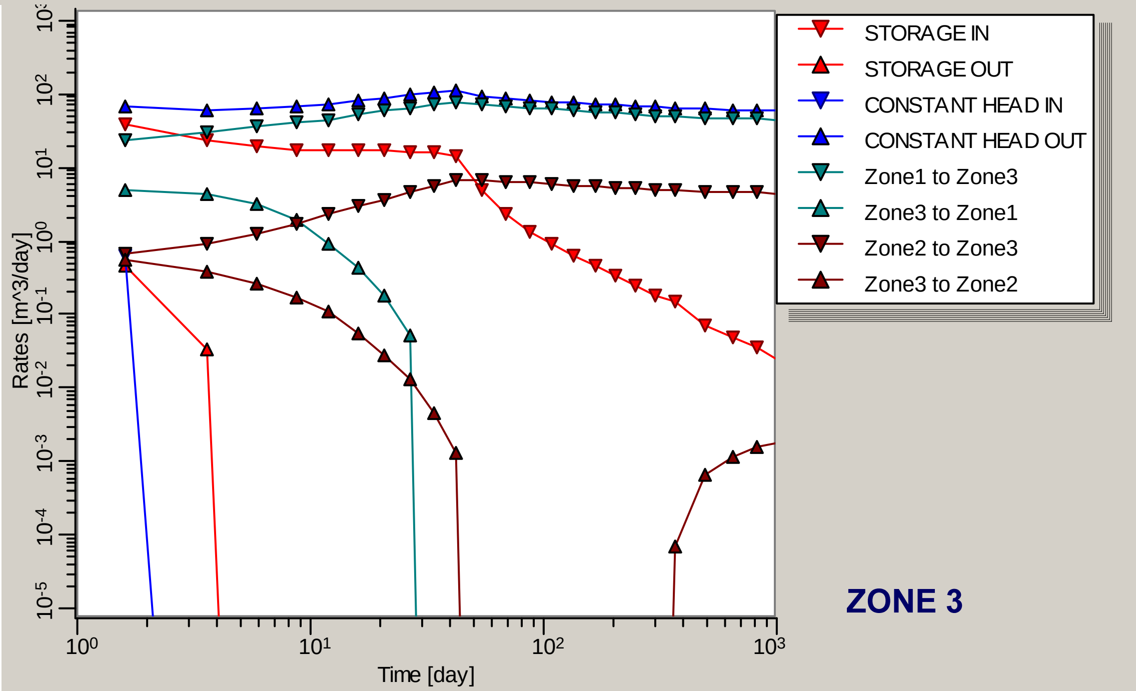
Kirrawee Brickpit
Dewatering and Groundwater Management Assessment



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
RECHARGE IN
RECHARGE OUT
Zone2 to Zone1
Zone1 to Zone2
Zone3 to Zone1
Zone1 to Zone3
Total IN
Total OUT
Rates [m^3/day]
Time [day]
ZONE 1



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
RECHARGE IN
RECHARGE OUT
Zone1 to Zone2
Zone2 to Zone1
Zone3 to Zone2
Zone2 to Zone3
Rates [m^3/day]
Time [day]
ZONE 2



STORAGE IN
STORAGE OUT
CONSTANT HEAD IN
CONSTANT HEAD OUT
Zone1 to Zone3
Zone3 to Zone1
Zone2 to Zone3
Zone3 to Zone2
Rates [m^3/day]
Time [day]
ZONE 3