Appendix D
Groundwater Resources Impact Assessment

R E P O R T

Groundwater Resources Impact Assessments, Coburn Mineral Sand Project

Prepared for

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Gunson Resources Limited proposes to develop the Coburn Mineral Sand Project; a deposit rich in zircon, located near Shark Bay (Figure 1). It is proposed to mine the mineralised Amy Zone over a 20-year period, commencing at the southern end of the deposit on Coburn Station, and finishing about 35 kilometres to the north on Hamelin Station (Figure 2). The eastern limits of the Shark Bay World Heritage Property occur adjacent to the western and northern project areas. Nilemah Embayment and Hamelin Pool, with associated algal mats and stromatolites, occur about 4 and 12 km north of the project area (Figure 3). Mining is proposed to take place using a conventional dry strip mining method, with the primary concentrators located alongside the pits. Both mining and the concentrators will progressively moved northwards at rates dependent on the volume of ore to be processed. The Heavy Mineral Concentrate (HMC) will be transported to Geraldton.

The Amy Zone consists of mostly dry sand (i.e. above the water table), being only partly saturated in localised areas in the north. The Amy Zone is a low-grade mineral sand resource lying within re-worked deposits of the Peron Sandstone, overlying the Toolonga Calcilutite. The mineral sands would be separated from the host quartz sands using banks of spiral concentrators, achieving HMC containing more than 90% heavy minerals.

Depending on the efficiency of the water recovery system the concentrators will use process water at a rate of between 0.4 and 0.6 kilolitre (kL) per tonne of ore. The concentrators are planned to derive make-up supplies from regional confined aquifer systems formed by the Birdrong Sandstone and Kopke Sandstone beneath the project area. The groundwater would be abstracted to replace process water losses incurred through wetting of the mined ore, tailings seepage and evaporation. The Birdrong Sandstone and Kopke Sandstone are regional aquifers found across most of the Gascoyne Platform. The Birdrong Formation is commonly used for pastoral and industrial water supplies in the central Gascoyne Platform whereas the Kopke Formation is more commonly utilised in northern Gascoyne Platform, due to its larger thickness and better groundwater quality. In the Shark Bay area, the Windalia Sand Member is preferentially used by pastoralists and other bore-owners because it occurs at comparatively shallow depths.

This report presents an assessment of local and regional groundwater resources, pit dewatering and tailings water management issues relating to the mining development of the Amy Zone. The report is intended to support environmental impact assessments in the Public Environmental Review for the Coburn Mineral Sand Project and applications for licensing of the groundwater abstractions.

1.1 Project Description

The mineral sand ore is to be mined by bucket-wheel excavators and processed by water-based gravity separation methods. Mining is planned to be continuous maintaining an overall 85% availability. The proposed pits follow defined ore strands within the superficial formations and will generally be linear features aligned north to south (Figure 4). The proposed operation is shown on Figure 5 and will follow a continuous cycle comprising:

- Existing vegetation and topsoil removal and immediate relocation to rehabilitated areas behind the active pit.
- Sub-soil removal and stockpile beside the mine path.
- Overburden removal and placement on the pit floor.
- Ore excavation and screening on the pit floor,
- Mixing the screened ore with water and pumping the slurry to a concentrator. The concentrator may be up to 1 km from the active pit.
- Backfilling the pit with the tailings being deposited on top of the overburden stockpiles. The sand tailings slurry is partly dewatered using two sand-stacker units which are relocated as required to build the final land profiles.
- Fine clay will be settled in trenches constructed along the eastern side of the pit.
- Tailings contoured and covered with sub-soil from stockpiles.
- Placement of topsoil and vegetation over sub-soil.
- Rehabilitation of the disturbed area.

It is proposed that the mining infrastructure be progressively relocated as mining advances at one to two kilometres per annum. From year three onwards, the entire mining system would be duplicated, providing a total processing rate of 4,600 tph to the end of the 20-year mine life.

1.2 Forecast Groundwater Resources Issues

The known groundwater resources issues (URS, 2004) linked to the proposed mining developments include:

- Recovery and reuse of process water from the tailings and slimes settling areas thereby, limiting consumptive groundwater use.
- Mounding of the water table in the superficial formations to within the root zones of vegetation.
- The dispersion within the superficial formations of process waters not recovered, given that the water table aquifer would discharge in part into Nilemah Embayment and Hamelin Pool.
- Salinisation of the process water supplies due to recycling and cumulative effects of evaporative losses.
- Drawdown impacts within the superficial formations should pit dewatering be required in the northern project area.

- Drawdown impacts within the regional confined aquifer systems due to abstractions from the Birdrong Sandstone and Kopke Sandstone for process water supplies.
- Potentials for propagation of drawdown impacts from the regional confined aquifer systems vertically upwards into the water table aquifer.
- Removal from storage of groundwater in the regional confined aquifer systems due to forecast abstractions exceeding the estimated recharge and throughflow beneath the project area.

The proximity of the Shark Bay World Heritage Property heightens the potential risks linked to these issues. This aspect lends itself to precautionary and conservative approaches to project development and associated protocols for the mitigation of risk.

1.3 Scope of Work

Three separate site investigation programmes have been completed to investigate the forecast groundwater resources issues linked to the proposed mining developments. These programmes comprised:

- A superficial formations drilling programme that comprised construction of multipiezometers and test production bore at three separate sites, with associated groundwater sampling and hydraulic tests.
- A confined aquifer drilling programme, including the construction and test pumping of a production bore screened in the Birdrong Sandstone and Kopke Sandstone and construction of one multipiezometer to provide hydrogeological data for the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone.
- A bore census that comprised the collection of historical data on existing bore locations and construction and groundwater levels and quality. The historical data were obtained from published government records and through discussions with the bore owners. The groundwater level and quality parameters were measured during site visits.

The specific parameters determined during the site investigations include:

- Determining the baseline hydrogeological characteristics of the water table aquifer in the superficial formations and underlying confined aquifer systems formed by the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone.
- Determining the likely yields from dewatering the superficial formations and impacts of mining on the water table environment.
- Determining the yields from the Birdrong Sandstone and Kopke Sandstone, and likely impacts of process water abstractions on other groundwater users in a local and regional context.

- Evaluation of the hydraulic properties of the superficial formations, Birdrong Sandstone and Kopke Sandstone.

Assessments of the various impacts of mine development on the local and regional groundwater environment have been undertaken using a series of predictive groundwater flow models. The models have been applied to predict transient water table mounding of, or drawdowns in each aquifer during the life of the mine. The results were used to determine the impacts of the mining operations on the local environment and existing groundwater users. Subsequently, the model results were used to develop strategies for mitigation of adverse impacts, groundwater resources conservation and environmental management.

2.1 Local Climate

The climate of the project area is characterised by mild winters and hot, dry summers. The average annual rainfall is about 210 mm with most rain falling between May and August. Rain can, however, fall during the other months, with a highly variable intensity. Heavier, more intense rainfall events outside the winter months are commonly associated with the passage of cyclonic and more localised thunderstorm activity.

Evaporation in the project area typically exceeds the monthly rainfall totals by factors between 2 and 160. The lowest evaporation and highest rainfall occur in the winter months, with the reverse to a greater degree in the summer months. The project area typically has average wind speeds of about 12 and 20 km/hr in the winter and summer months respectively. The wind conditions have a strong bearing on the evaporation rates.

The local climate averages for the project area are summarised in Table 1 and presented graphically on Figure 6.

Table 1

Climatic Averages for Hamelin Station

Month	Mean Monthly Rainfall (mm)	Mean Daily Maximum Temperature (deg C)	Mean Daily Minimum Temperature (deg C)	Mean Daily Evaporation (mm)	Mean Monthly Evaporation (mm)	Mean Wind Speed (km/h)	Mean Relative Humidity (%)
Jan	7.6	36.9	20.5	13.4	415.4	18.1	39.5
Feb	13.1	36.7	21.2	13.9	392.7	17.8	42.5
Mar	15.7	34.9	20.1	11.6	359.6	16.5	43.0
Apr	13.7	30.3	17.0	7.1	213.0	14.7	48.0
May	33.1	25.2	13.2	5.2	161.2	13.4	54.0
Jun	47.7	21.5	10.6	3.4	102.0	12.2	63.5
Jul	40.2	20.7	9.2	3.4	105.4	13.3	62.5
Aug	21.5	22.2	9.4	4.7	145.7	14.4	55.0
Sep	8.1	25.4	11.1	6.5	195.0	17.5	46.5
Oct	5.2	28.2	13.0	10.0	310.0	19.2	42.0
Nov	3.7	31.8	15.8	11.0	330.0	19.6	39.0
Dec	2.4	34.8	18.3	12.5	387.5	18.5	39.0
Annual	211.9	-	-	-	3,117.5	-	-
Daily	-	29.1	15.0	8.7	-	16.3	47.5

Note: Hamelin Station – Bureau of Meteorology Station No. 006025

2.2 Geomorphology and Hydrology

The project area lies mainly within the Victoria Sand Plain District. It fringes the Carbla Plateau at the northernmost end (Payne *et al*, 1987). The Victoria Sand Plain District is characterised by undulating sand plains with isolated low coastal dunes. The Carbla Plateau typically has a well developed duricrust of calcrete, ferricrete and silcrete that generally overlies the areas of Toolonga Calcilutite subcrop.

Most of the project area is traversed by sand dunes. The dunal system exhibits an apparent interference form, with cross-patterned dune alignments that have produced many isolated swales (Figure 2). The dune flanks and swales are typically covered with shrub-heath and tree-heath, dominated by proteaceous and myrtaceous species in the south and scattered or clumped mallee and tree-form eucalyptus over waynu-dominated tall shrubland in the north (Payne *et al*, 1987).

There are few drainage features within the Victoria Sand Plains District, due to the extent and characteristics of the dunal systems. Small, localised drainages occasionally occur in some of the swales where the soils are slightly silty and constrain infiltration.

In the northern project area the superficial formations thin and become intermittent between outcrops of duricrust. The Amy Zone does not extend onto the Carbla Plateau as the mineralisation is confined to the superficial formations. Surface drainages become more apparent as the topography becomes increasingly dominated by the duricrust to the northeast and east. Overall, these drainages trend northwards towards Hamelin Pool (Figure 2).

North of the project area, the foreshore and nearshore areas of Hamelin Pool and the Nilemah Embayment are characterised by small dunal ridges of shell coquina and shell sand, with salina occupying intradunal swales and depressions (Figure 3). These areas appear to have internal drainage, with the low elevation salinas forming surface water and groundwater receptors.

2.3 Geology

The project area is situated within the Gascoyne Platform of the southern Carnarvon Basin. The Carnarvon Basin is an extensive sedimentary structure that extends along and off the coast of Western Australia and comprises numerous sub-basins, shelfs and platforms. On a local scale, the geology of the superficial formations has been specifically investigated within the Nilemah Embayment and foreshore areas of Hamelin Pool during a geo-biology study (BMR, 1990) on the stromatolites and algal mats. On a region scale, the basin and sub-basin boundaries have been defined by fault and basement ridge structures. The geology of the Carnarvon Basin is also defined at regional scale by seismic and drilling investigations for petroleum exploration and limited exposure mapping. Consequently, the available information on many of the Carnarvon Basin sedimentary units has been derived from lithological and palynological logging of the petroleum exploration drilling. A comprehensive list of references to these studies is given in Iasky *et al*, (2003).

The regional geology of the southern Carnarvon Basin and specifically the Gascoyne Platform has been interpreted several times during the past 30 to 40 years. The most recent interpretation is published by Iasky *et al* (2003). Stratigraphic units in the southern Carnarvon Basin sometimes differ slightly to the northern basin due to structural controls and lithological variations resulting from different depositional settings. The stratigraphic nomenclature within and between the sub-basins has changed over the past few decades as more data have become available. For example, the Gearle Siltstone and Alinga Formation are used to represent the same stratigraphic unit in the northern and southern Carnarvon Basin.

Within the southern Carnarvon Basin, some of the geological units have lateral equivalents that probably represent facies changes. In the Gascoyne Platform, the Windalia Radiolarite and Windalia Sand Member are defined as different formations but are interpreted to represent a facies change from distal chemical deposits to proximal clastic deposits.

A local geology cross-section of the superficial formations in the vicinity of Nilemah Embayment and Hamelin Pool is shown on Figure 7. This section is predominantly based on the collation of the findings of the geo-biology study (BMR, 1990) and resource drilling to define the Amy Zone. The section shows a marked transition in the superficial formations geology profile from the dunal domains of Peron Sandstone to the marine setting of Hamelin Pool.

Regional geology cross-sections from west to east and south to north are shown on Figure 8 (a and b). The regional sections are simplified and do not show small-scale faulting or folding, the evidence of which is shown by detailed offshore seismic mapping (Iasky *et al*, 2003). The Ordovician to Devonian successions generally dip to the west, northwest and possibly north-northwest, with steeper dips near the southern and eastern margins of the Gascoyne Platform. The Cretaceous successions generally dip westwards, over an erosional unconformity that removed most of the formations above the Kopke Sandstone. This unconformity is widespread within the Carnarvon Basin and is covered by a transgressional sedimentary sequence of sandstones and shales.

2.4 Stratigraphy

The Carnarvon Basin extends between Kalbarri in the south and Dampier in the north and is underlain by Precambrian crystalline basement. This basement also forms a fault-bounded margin to the Gascoyne Platform, with the Hardabut Fault against the Northampton Complex and the Ajana Fault against the Ajana Ridge. The Ajana Ridge separates the Gascoyne Platform from the Coolcalalaya Sub-Basin to the east. However, the stratigraphic successions of the Gascoyne Platform and Coolcalalaya Sub-Basin may be hydraulically connected by a thick sequence of Tumblagooda Sandstone. The Coolcalalaya Sub-Basin is interpreted to contain elements of both the Carnarvon Basin (including the basal Tumblagooda Sandstone and possibly Kopke Sandstone) and various northern Perth Basin successions of Permian age (Mory *et al*, 1998).

The interpreted stratigraphic succession in the Gascoyne Platform region of the southern Carnarvon Basin is shown in Table 2.

Table 2

Summary of Local Stratigraphy

<table>
<tr><th colspan="2">Age</th><th colspan="2">Stratigraphy</th></tr>
<tr><td colspan="2">Quaternary & Tertiary</td><td colspan="2">Superficial Formations including marine clay, shell coquina, salina, Peron Sandstone, Bibra Limestone and Dampier Limestone.</td></tr>
<tr><td colspan="4">Unconformity</td></tr>
<tr><td rowspan="6">Cretaceous</td><td>Late</td><td colspan="2">Toolonga Calcilutite</td></tr>
<tr><td rowspan="5">Early</td><td>Alinga Formation</td><td rowspan="5">Winning Group</td></tr>
<tr><td>Windalia Radiolarite</td></tr>
<tr><td>Windalia Sand Member</td></tr>
<tr><td>Muderong Shale Formation</td></tr>
<tr><td>Birdrong Sandstone</td></tr>
<tr><td colspan="4">Major Unconformity</td></tr>
<tr><td rowspan="3">Devonian</td><td rowspan="3">Early</td><td colspan="2">Sweeney Mia Formation</td></tr>
<tr><td colspan="2">Kopke Sandstone</td></tr>
<tr><td colspan="2">Faure Formation</td></tr>
<tr><td rowspan="2">Silurian</td><td>Late</td><td>Coburn Formation</td><td rowspan="4">Dirk Hartog Group</td></tr>
<tr><td>Early</td><td>Yaringa Formation</td></tr>
<tr><td colspan="2" rowspan="3">Ordovician</td><td>Ajana Formation</td></tr>
<tr><td>Marron Member</td></tr>
<tr><td colspan="2">Tumblagooda Sandstone</td></tr>
<tr><td colspan="2">Pre-Ordovician?</td><td colspan="2">Unnamed Sandstone Unit</td></tr>
<tr><td colspan="4">Major Unconformity</td></tr>
<tr><td colspan="2">Archaean-Proterozoic</td><td colspan="2">Crystalline Bedrock</td></tr>
</table>

A brief discussion of the sedimentary successions beneath the project area is provided below:

Superficial Formations comprise Tertiary and Quaternary deposits that occur in the project area as well as in and around Hamelin Pool to the north. The Quaternary dune sand deposits in the Nanga and Peron Station areas have been described as the ***Peron Sandstone*** (BMR, 1990 and Hocking *et al*., 1987). Quaternary shallow marine, shell coquina and salina deposits have also been described in the Nilemah Embayment during a geo-biology study on the stromatolites and algal mats in Hamelin Pool (BMR, 1990). The shallow marine and salina deposits may form elements of Bibra Limestone and Dampier Limestone that onlap and possibly interfinger with the Peron Sandstone (Figure 7). The shell coquina deposits that have formed along the present-day shoreline of Hamelin Pool are known as the Hamelin Coquina. Coquina consists almost entirely of shells of *Fragum erugatum* that is weakly cemented in ridges up to 3 m high. Older Tertiary limestone and calcareous coquina deposits are described in several places around Hamelin Pool, but do not occur in the project area.

The superficial formations in the project area contain the Amy Zone. These deposits are of Quaternary age and predominantly comprise medium to fine-grained quartz sand (re-worked Peron Sandstone), with minor calcareous (calcrete) bands representing cemented fossil soil (palaeosol) profiles. Occasional silty and / or clayey lenses are present.

The superficial formations form a thinning sequence to the east, that onlaps calcrete and silcrete-capped Toolonga Calcilutite outcrop areas that typify the Carbla Plateau. The Amy Zone deposits represent a palaeo-coastline dune system that is aligned approximately north to south (Figure 1).

Toolonga Calcilutite is widespread within the Carnarvon Basin, including the Gascoyne Platform west of the Ajana Ridge, and disconformably overlies the Winning Group sediments. The unit is described as a calcilutite and calcisilitite, deposited in a low-energy marine environment (Iasky *et al*., 2003). The unit thickness increases to the northwest from the project area, to reach over 300 m beneath the northern half of Shark Bay. Further north, this formation grades into the Korojon Calcarenite.

In Coburn 1, the Toolonga Calcilutite is 57 m thick Figures 7 (a and b). Drillers logs typically describe this formation as blue-grey, greenish-grey or white clay, chalk or shale (DoE, 2004). The Toolonga Calcilutite forms the local basement below the Amy Zone. Locally, the upper successions of this formation are re-worked into sandy or silty clay beds.

Alinga Formation is referred to as the Gearle Siltstone in northern and middle parts of the Gascoyne Platform (McWhae, 1958), and as the Alinga Formation in the southern area (Yasin and Mory, 1999). The presence of radiolaria in both units that have similarities with the Windalia Radiolarite suggests there is a close relationship between these units separated by facies-controlled transgressive environments.

In Coburn 1, the Alinga Formation consists of three sub-intervals; (i) a basal pebbly, glauconitic medium-grained sandstone that is overlain by (ii) black siltstone with abundant mica, pyrite and radiolaria, and an upper unit (iii) of black carbonaceous glauconitic sandstone (Yasin and Mory, 1999).

Windalia Radiolarite overlies the Muderong Shale and is commonly described as a black, hard, cherty or flinty-shale that is also pyritic. This formation is encountered over a wide area of the Carnarvon Basin and is believed to be an accumulation of siliceous ooze on the sea floor (Wills and Dogramaci, 2000). The radiolarite does not occur below or to the east of the project area, but has been described in logs from artesian bores to the north and west, beneath the Tamala, Nilemah and Nanga stations (Playford and Chase, 1955; Kempin and Fujioka, 1973).

Windalia Sand Member (of the Muderong Shale) is distinguished by grain size, but restricted to the southeastern part of the Gascoyne Platform in the vicinity of the Coburn, Hamelin and Meadow stations. It was deposited in a moderate-energy, very shallow marine environment (Wills and Dogramaci, 2000). Historically, this unit was informally combined with the Birdrong Sandstone and referred to as the Hamelin Beds (McWhae, 1958).

Locally, this unit consists of grey, medium-grained quartz sandstone with common wood fragments (Yasin and Mory, 1999). The sand member is typically 20 m thick, but thins to the north, south and west of a "lobe-type" structure beneath the Coburn, Hamelin and Meadow stations and appears to occur exclusively in the absence of the Windalia Radiolarite. The Windalia Radiolarite and Windalia Sand Member do not occur in the same vertical successions and as such are interpreted to represent an east to west facies change in depositional environment.

Muderong Shale Formation comprises a basal mudstone/shale and in the Shark Bay area an overlying sandstone (Windalia Sand Member). The shale unit was deposited in a low-energy marine environment (Iasky *et al*., 2003). In Coburn 1, the shale forms a 5.5 m thick interval comprising dark grey, pyritic mudstone with a thin, medium-grained sandstone bed in the middle.

Birdrong Sandstone represents a basal transgressive sequence, deposited during the break-up of continental Australia from Greater India (Wills and Dogramaci, 2000). It is the lowest of several formations within the Winning Group. The formation is typically about 20 to 30 m thick and covers an unconformity throughout most of the Carnarvon Basin. Beds generally dip west and north. The lithology typically comprises pale grey to white friable sandstone and silty sandstone that is commonly glauconitic and contains wood fragments.

In Coburn 1, the Birdrong Sandstone is grey, fine grained, coarsening upwards to medium to coarse grained sandstone with common mudstone drapes (Yasin and Mory, 1999). The Birdrong Sandstone was deposited in a high-energy, near-shore, marine environment.

Kopke Sandstone conformably overlies the Faure Formation where they are both present. This formation is only present in the central to southern part of the Gascoyne Platform, with a maximum known thickness of 496 m in petroleum exploration hole Yaringa No. 1. The Kopke Sandstone has been eroded in the very southern part of the Gascoyne Platform, where it sub-crops below the Birdrong Sandstone. It is interpreted to be juxtaposed against the Tumblagooda Sandstone on the Ajana Fault (Wills & Dogramaci, 2000). In the project area, the 320 m thick succession of Kopke Sandstone was fully cored in Coburn 1 and described by Yasin and Mory, (1999).

The Kopke Sandstone comprises an upward-coarsening sequence of red to reddish-brown sandstone with minor siltstone and dolostone. The sandstone succession in Coburn 1 presents evidence of deposition in a mixed very shallow marine, fluvial to deltaic, lacustrine and eolian environment (Yasin and Mory, 1999). The coarsening-upwards sequence is associated with geological uplift of the hinterland during deposition.

Dirk Hartog Group and Faure Formation overly the Tumblagooda Sandstone over much of the Carnarvon Basin, except within the very southern part of the Gascoyne Platform, where they appear to have been eroded. The Dirk Hartog Group is subdivided into four units; namely the Ajana, Yaringa and Coburn Formations and basal Marron Member. The Dirk Hartog Group and Faure Formation are predominantly formed of shale, mudstone, dolostone and various evaporitic rocks (Iasky *et al*., 2003). In Coburn 1, these units are present between about -415 and -884 m AHD (Yasin and Mory, 1999).

Tumblagooda Sandstone was named by Clarke and Teichert in 1948 and is widespread throughout the Carnarvon Basin. A detailed account of the formation at a type section in the lower reaches of the

Murchison River is provided by Hocking *et al.* (1987). The formation is almost entirely sandstone, ranging from very fine-grained to very coarse-grained and pebbly. It is a classical “red-bed” sequence and contains characteristics of a braided fluvial to coastal depositional environment. It has been assigned various ages extending between Cambrian to Early Ordovician. Previous interpretations have placed this unit at the base of the sedimentary sequence, but more recently, another unassigned unit has been identified (mainly by seismic exploration) beneath the Tumblagooda Sandstone and overlying the granitic basement (Iasky *et al.*, 2003).

Near the project area, the Tumblagooda Sandstone is present in Coburn 1 below -884 m AHD and was not fully penetrated at –1,000 m AHD. This sequence comprised light grey to reddish-grey fine to coarse-grained sandstone, sometimes pebbly, with cross-bedding and cross-laminations of very fine sandstone to siltstone (Yasin and Mory, 1999).

2.5 Nilemah Embayment and Hamelin Pool

The Nilemah Embayment and Hamelin Pool are significant physiographic features near Shark Bay (Figure 3). Hamelin Pool is a unique hypersaline marine environment with a restricted tidal interconnection, through the Faure Sill with the outer reaches of Shark Bay. Hypersaline conditions are the result of this restricted throughflow and high evaporation rates. Hamelin Pool is fringed by extensive sublittoral and intertidal platforms that are subjected to relatively small tidal fluctuations, and shell coquina beach ridges.

A number of studies of Hamelin Pool environment were completed between 1983 and 1989 by the Baas Becking Geobiological Laboratory and Bureau of Mineral Research (BMR, 1990). The predominant focus of these studies was to determine the environmental settings contributing to sulphide mineralisation of carbonate rich sediments. Significant data were collected on the geology, biology and chemistry of the existing environments in Hamelin Pool. Several sites on the fringes of Hamelin Pool, including the Nilemah Embayment in the south, and transects that include the stromatolites near the old Hamelin Telegraph Station, are included in the database.

Geological data indicate that the Nilemah Embayment is underlain by a succession of marine sand and clay beds. Some of these beds are correlated to the Bibra Limestone and Dampier Limestone Formations as described in Hocking et al. (1987). Marine clay beds underlie the coastal beach ridge of shell coquina dunes and intertidal zone, and overlie marine equivalents of the land-based Peron Sandstone. The clay sub-crops or outcrops beneath the salinas and topographic depressions on the landward side of the beach ridge within the Nilemah Embayment. The clays form a physical and evaporative barrier in the water table aquifer and shallow groundwater environment.

The water table environment in these areas comprises of a mixture of evaporated meteoric water and seawater that is responsible for the *“reasonably homogenous brine at depth”* (BMR, 1990). Local groundwater of meteoric origin would be derived from aquifers in the superficial formations surrounding the embayment. The BMR study data suggests that the shallow groundwater becomes increasingly saline from about 65,000 mg/L TDS south of the Denham Road to about 200,000 mg/L beneath clay pans and associated salinas in the embayment.

Field work undertaken in 1983 utilised piezometric and salinity measurements to specifically investigate the hydrology of the intertidal and sub-tidal zones in the Nilemah Embayment. This work indicated tidal influences extend inland several hundred metres from the beach. Quality data indicate that shallow carbonate-rich brackish to saline groundwater discharges from below the high-tide mark during low tide. These groundwaters are of meteoric origin entering the flow system through the shell coquina beach ridges, and mix in the marine environment beneath the beach. The carbonate derived from the beach ridges precipitates as aragonite when it mixes in the presence of algae with marine waters. Field data also determined that hypersaline groundwater of salinities between 100,000 and 200,000 mg/L TDS occurs at shallow depth below the water table.

The shallow groundwater flow system described for the Nilemah Embayment is repeated along the coast to the northeast. Where stromatolites occur, carbonate-rich shallow groundwater discharges from the base of the shell coquina beach ridges at low tide and following heavy rain. In these areas, the beach ridges are underlain by either Bibra Limestone or caprock overlying the Toolonga Calcilutite. The stromatolites occur in groundwater discharge zones (extract Burne, R.V. and James N.P., 1986 in BMR, 1990).

The stromatolites near the old Hamelin Telegraph Station occur within a different catchment than the project area and Nilemah Embayment.

Site investigations have been completed that characterise both the shallow groundwater environment and the predominant confined aquifer systems. The site investigations also provide a baseline assessment of current groundwater uses.

The site investigations have focussed on developing an understanding of the local aquifer systems and groundwater environments, enabling informed assessments of the potential impacts associated with the proposed mining of the Amy Zone.

Three discrete site investigation programmes have been completed. These programmes involved:

- A superficial formations drilling programme that comprised construction of multipiezometers and test production bore at three separate sites, with groundwater sampling and hydraulic tests at each site (Figure 9).
- A confined aquifer drilling programme, including the construction and test pumping of a production bore screened in the Birdrong Sandstone and Kopke Sandstone and construction of a multipiezometer to provide hydrogeological data on the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone (Figure 9).
- A bore census that comprised the collection of historical data on existing bore locations, construction, groundwater levels and groundwater quality. The historical data were obtained from published government records and through discussions with the bore owners. The groundwater level and quality parameters were measured during site visits.

The site investigations have been supported by research of available geological, hydrogeological and petroleum exploration references. These include the findings of a geo-biology study on the stromatolites and algal mats in Hamelin Pool (BMR, 1990). Importantly, this study characterises the shallow formations and water table environment within the Nilemah Embayment and foreshore areas of Hamelin Pool.

3.1 Superficial Formations Investigations

The superficial formations and uppermost interval of the Toolonga Calcilutite were investigated. The investigation programme consisted of airlift development of an existing production bore (STB1), drilling three multipiezometers (SMB2, SMB3 and SMB4) and one test production bore (STB3). Several existing piezometers (installed as part of the BMR (1990) geo-biology studies associated with Hamelin Pool and herein termed SMB1a, SMB1b and SMB1c) in the vicinity of the project area were also included, providing groundwater level and quality data. Prior to drilling, the investigation sites were pegged and surveyed by MHR Surveys using a differential GPS.

The superficial formations drilling programme was undertaken by Aquatech Drilling between 28th July and 5th August 2004. All investigation bores were drilled using mud-rotary techniques. Multipiezometers SMB2, SMB3 and SMB4 are constructed using 50 mm nominal diameter Class 9 uPVC, with separate standpipes screened against the upper 10 to 15 m of the Toolonga Calcilutite and lower-most 6 m of the superficial formations. Screen intervals are gravel-packed using 2.0 to 3.6 mm graded quartz sand and hydraulically separated using bentonite-cement grout. The shallow standpipes are denoted with an “s” suffix, while the deep standpipes have a “d” suffix.

STB3 is constructed in the northern-most project area, near SMB3, to determine the hydraulic conductivity of the Toolonga Calcilutite and saturated interval of the superficial formations. STB3 is constructed of 155 mm nominal diameter Class 9 uPVC, screened against both potential aquifer intervals. The casing is centralised in the bore and gravel-packed using 2.0 to 3.6 mm graded quartz sand.

Each investigation bore was tested and sampled to determine hydraulic parameters and baseline groundwater quality data.

3.1.1 Superficial Formations Drilling Results

The superficial formations site investigation bores are summarised in Table 5 and on Figures 10 to 13. Details (where available) for the existing bores are also included in Table 3.

Table 3

Summary of Superficial Formations Site Investigations

Bore	MGA North (m)	MGA East (m)	Datum Elevation (m AHD)	Ref. Point Height (m agl)	Static Water Level (Oct 2004)		Depth (mbgl)	Saturated Thickness (m)	Slotted Interval (mbgl)	Lithology	Salinity (mg/L TDS)	Field pH	Comments
					(m brp)	(m AHD)							
SMB1a	7,067,820.8	210,581.7	4.07	0.36	3.38	0.69	7.3	3.9	n.d.	Superficial marine deposits	-	-	Installed by BMR 1984
SMB1b	7,067,639.1	210,586.0	4.27	0.55	3.49	0.78	4.2	0.7	n.d.	Superficial marine deposits	-	-	Installed by BMR 1984
SMB1c	7,067,169.9	210,612.8	12.50	0.00	11.35	1.15	13.3	1.9	n.d.	Superficial marine deposits	-	-	Installed by BMR 1984
SMB2s	7,060,717.6	211,125.6	41.71	0.51	23.88	17.83	24.0	0.1	18.0-24.0	Superficial Formations	14,000	6.3	
SMB2d	7,060,717.6	211,125.6	41.71	0.51	23.68	18.03	40.0	16.3	34.0-40.0	Toolonga Calcilutite	25,000	6.7	
SMB3s	7,065,001.0	208,683.0	33.50	0.49	>30.2	<3.30	30.0	0.0	24.0-30.0	Superficial Formations	-	-	Dry
SMB3d	7,065,001.0	208,683.0	33.50	0.49	30.12	3.38	43.0	12.9	37.0-43.0	Toolonga Calcilutite	-	-	
SMB4s	7,055,527.1	212,594.5	67.22	0.54	>30.0	>30.0	30.0	0.0	24.0-30.0	Superficial Formations	-	-	Dry
SMB4d	7,055,527.1	212,594.5	67.22	0.54	37.65	29.57	42.0	4.4	36.0-42.0	Toolonga Calcilutite	11,000	6.2	
STB1	7,067,732.8	210,581.0	4.20	0.40	3.45	0.75	7.0	3.6	n.d.	Superficial marine deposits	68,000	6.6	Installed by BMR 1984
STB3	7,065,001.4	208,698.7	33.76	0.41	30.63	3.13	43.0	12.4	16.0-43.0	Toolonga Calcilutite	34,000	6.2	

Abbreviations:
m AHD - metres above the Australian Height Datum
m bgl - metres below ground level
m agl - metres above ground level
m brp - metres below the reference point (usually top of bore casing)
n.d. - Not Determined
mg/L TDS - milligrams per Litre Total Dissolved Solids

The shallow standpipes in SMB3 and SMB4 are dry; that is the water table is below the base of the superficial formations. SMB2s has about 0.7 m of groundwater at the base of the superficial formations. Groundwater was intersected in the deep standpipes in SMB2, SMB3 and SMB4. STB3 intersected the water table in the upper section of the Toolonga Calcilutite, just below the base of the superficial formations.

No aquifer tests were conducted in the existing shallow bores located north of the project area as they had been scheduled for stygofauna sampling.

3.1.2 Superficial Formations and Toolonga Calcilutite Aquifer Testing

Aquifer tests were completed in SMB2 to SMB4 and STB3 to characterise the hydraulic conductivity of the superficial formations and shallow Toolonga Calcilutite. The test methods varied to cater for differences in the saturated thickness of the Peron Sandstone and lithology of the shallow Toolonga Calcilutite. Preferentially, aquifer tests in standpipes with sufficient submergence beneath the water table were conducted by pumping and measurement of drawdown responses. Elsewhere, where submergence of the standpipes is limited, the aquifer testing involved injection and falling-head methods.

Testing in SMB2

As discussed, SMB2 has groundwater in both the shallow and deep standpipes. The superficial formations standpipe does not contain sufficient groundwater for Grundfos MP1 submergence so it was sampled using an environmental bailer. The sandy interval in the Toolonga Calcilutite intersected by the deep standpipe was pumped for 40 minutes at 13.8 kL/day, resulting in a drawdown of 3.4 m (Figure 14).

The groundwater levels are essentially the same in the SMB2 standpipes, indicating locally there is a 0.2 m vertical head difference between the superficial formations and shallow Toolonga Calcilutite. This difference implies an upward potentiometric head from the Toolonga Calcilutite. After the standpipes were pumped or bailed, they were subjected to an inflow test and falling-head test (Figure 15).

The results of the aquifer testing in SMB2s and SMB2d are summarised in Table 4 and presented in Appendix B.

Table 4

Results of Aquifer Tests in SMB2

Standpipe	Static Water Level (m brp)	Pumping Rate (kL/day)	Hydraulic Conductivity (m/day)	Comments
SMB2s	23.88	Bailed	>13	Test section includes mostly unsaturated sand.
SMB2d	23.68	13.8	0.1	Aquifer is a sandy layer 5m below top of Toolonga Calcilutite.

Note: m brp = metres below reference point (top of bore casing)

Testing in SMB3 and STB3

Both SMB3 and STB3 encountered groundwater only in the Toolonga Calcilutite; the water table at this site being 2 m below the base of the superficial formations (Figure 13). The shallow Toolonga Calcilutite was tested in STB3 by pumping at a rate of 7.5 kL/day for 180 minutes after which time the groundwater level had been drawn down to the pump inlet. Constant-head and falling-head tests were completed in the SMB3 standpipes. A groundwater sample was obtained only from STB3 after 180 minutes of pumping.

The results of the hydraulic testing in SMB3 and STB3 are summarised in Table 5, on Figures 16 and 17 and in Appendix B.

Table 5

Results of Aquifer Tests in SMB3 and STB3

Standpipe	Static Water Level (m brp)	Pumping Rate (kL/day)	Hydraulic Conductivity (m/d)	Comments
SMB3s	>30.2	Dry	5.6	Test section includes mostly unsaturated sand.
SMB3d	30.2	N.D.	0.1	Storativity of Toolonga Calcilutite measured from pumping = 2.2 x 10^{-5} (dimensionless).
STB3	30.22	7.5	0.2	Aquifer is a sandy layer in upper 2 m of Toolonga Calcilutite.

Note: m brp = metres below reference point (top of bore casing)

Testing in SMB4

SMB4 encountered groundwater only in the shallow Toolonga Calcilutite. The water table is about 7 m below the superficial formations at this location (Figure 12). The constant-rate pumping test conducted in SMB4d lasted 14 minutes before the groundwater level was drawn below sandy beds in the Toolonga Calcilutite. Evidently, the pumping rate of 2.4 kL/day exceeded the groundwater supply capability of these beds. While drilling, an interval of lost-circulation was encountered in the unsaturated Toolonga Calcilutite. This interval accepted all of the water introduced for the constant-head test and is evidently comparatively transmissive.

The results of the aquifer testing conducted in SMB4s are summarised in Table 6, shown on Figures 18 and 19 and presented in Appendix B.

Table 6

Results of Aquifer Tests in SMB4

Standpipe	Static Water Level (m brp)	Pumping Rate (kL/day)	Hydraulic Conductivity (m/day)	Comments
SMB4s	>30.0	Dry	>5	Test section includes mostly unsaturated sand.
SMB4d	37.63	2.4	0.05 – 2.0	Aquifer is a slightly sandy layer within clay. The higher hydraulic conductivity result is due to an unsaturated transmissive zone accepting the introduced water during the constant head test.

Note: m brp = metres below reference point (top of bore casing)

3.1.3 Shallow Groundwater Quality Analyses

Sampling was undertaken using either an environmental bailer or a Grundfos MP1 electric submersible pump. The testing was conducted according to the following schedule:

Multipiezometers: Measured static groundwater levels.

Bailed or pumped a representative groundwater sample after purging.

In low-yielding standpipes, hydraulic tests consisting of a constant-head test followed by a falling-head test.

For high-yielding standpipes, pumping tests with drawdown observations in the pumped and other standpipe.

STB3: Measurement of a static water level.

Pumping for hydraulic response analysis in STB3 and nearby SMB3.

Groundwater samples were taken from all standpipes except SMB3s, SMB3d and SMB4s. Both SMB3s and SMB4s are dry. The sampling included a bailed sample from STB1 a week after airlift development. The samples were filtered, preserved and dispatched according to the following schedule:

- STB1 and SMB2s were purged and sampled by bailing, due to low-yield or limited saturated thickness.
- SMB2d, STB3, and SMB4d were purged and sampled using a Grundfos MP1.
- One unfiltered sample was taken from each site for major ions, pH, salinity (by evaporation) and electrical conductivity.
- One filtered sample (to 0.45 µm) was taken for dissolved metals; preserved with nitric acid.

- One filtered sample (to 0.45 μm) was taken for dissolved mercury; acid/potassium dichromate preservative.
- One filtered sample (pre-filter only) was taken for radionuclide analysis; using acid-washed sample bottles.

The samples were stored on ice in the field and refrigerated until transported to SGS laboratories by commercial courier. SGS Laboratories received the samples within 3 or 4 days of sampling. The radionuclide samples were submitted to Genalysis within 5 or 6 days of sampling.

Laboratory analysis reports are provided in Appendix C. The results of the radionuclide analyses are reported separately by Radiation Advice & Solutions Pty Ltd.

3.2 Confined Aquifer Investigations

The confined aquifer investigations consisted of one test-production bore (DTB1) screened within the Birdrong Sandstone and Kopke Sandstone and a multipiezometer (DMB1), with separate standpipes screened within the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone. Both investigation holes were drilled by Drilling Contractors of Australia (DCA). DTB1 was drilled using an ADS1500 rig, while DMB1 was drilled and constructed using a Midway rig.

The drill sites are located so the constructed bores could be incorporated into the operating borefield in the southern part of the project area. They were also selected on the basis of reasonable access and where the collars were at relatively low elevations. All of the drilling was conducted using mud-rotary techniques; both holes were geophysically logged by Westlog Wireline Services once the pilot-holes reached their target depths. Drilling water was derived from Coburn No. 9, located about 10 km to the northeast. The existing pastoral Mono-pump was temporarily replaced with a 100 mm electric submersible pump. The supply from Coburn No. 9 was limited to three loads per day plus minor stock water requirements. This limited the rate of progress, particularly during periods of lost circulation (in several zones in the Toolonga Calcilutite and Windalia Sand Member) as well as in the initial stages of bore development.

Once completed, DTB1 was developed by jetting the screens, using proprietary-branded break-back additives, followed by extensive airlifting and surging to reduce the returned sand content. Groundwater airlifted from the DTB1 was directed into mud pits and then to a sump where it was temporarily contained before being lost due to infiltration. Finally, DTB1 was treated with sodium hypochlorite for disinfection against microbacteria, such as iron-reducing bacteria. The standpipes in DMB1 were also developed by airlifting and surging until the abstracted groundwater was clean and free of sand. The groundwater was disposed initially to the mud pits, then into a small trench until lost by infiltration.

Following development, an electric submersible pump was installed in DTB1 to a depth of 86 m. Subsequently, DTB1 was subjected to step-rate pumping consisting of three one-hour steps and one five-hour step at increasing pumping rates of 5,620, 6,480, 7,340 and 8,640 kL/day. Pumping water levels were measured in DTB1 to determine bore efficiency characteristics and a suitable pumping rate for the constant-rate test. The constant-rate test occurred over a duration of 41-hours pumping at 7,780 kL/day, following-on immediately from the step-rate tests. Groundwater levels were measured in DTB1 and DMB1, located 1,040 m apart.

The abstracted groundwater was discharged to the mud pits and allowed to overflow to the sump for infiltration. Some of the groundwater was also diverted into adjoining areas, including a swale near DMB1, for infiltration as the constant-rate pumping could not be entirely accommodated by the sump. During the test, the groundwater was monitored for clarity, salinity, pH and temperature. Groundwater samples were taken for chemical analysis after one hour of pumping and at the end of the constant-rate test. A separate sample was taken for dissolved metals. This sample was filtered to 0.45 μm on site and acidified to pH 2. Non-preserved samples were also taken for major ion, physio-chemical analyses, and radionuclides. Samples were also collected from DMB1 at the end of the development. All samples were taken according to AS5667.1:1998 and analysed at the NATA-registered SGS Laboratories (major & minor chemistry) and Genalysis (radionuclides).

3.2.1 Confined Aquifer Drilling Results

Details of the DTB1 and DMB1 constructions are presented in Table 7 and on Figures 20 and 21.

Table 7

Summary of Confined Aquifer Site Investigations

Bore No.		MGA North (m)	MGA East (m)	Datum Elevation (m AHD)	Ref. Point Height (m agl)	Static Water Level (Oct 2004)		Depth (m bgl)	Slotted Interval (m bgl)	Formation	Salinity (mg/L TDS)
						(m brp)	(m AHD)				
DMB1	w	7,042,678.0	216,734.1	85.41	0.20	36.4	49.0	400.0	190.0-196.0	Windalia Sand Member	9,100
	b					36.2	49.2		211.0-217.0	Birdrong Sandstone	7,750
	k					35.7	49.7		394.0-400.0	Kopke Sandstone	12,000
DTB1		7,041,723.0	216,318.0	85.85	0.25	38.52	47.33	425.0	206.0-400.0	Birdrong Sandstone Kopke Sandstone	8,900

Abbreviations: m AHD - metres above the Australian Height Datum; m bgl - metres below ground level; m agl - metres above ground level; m brp - metres below the reference point (usually top of bore casing); n.d. - Not Determined; mg/L TDS - milligrams per litre Total Dissolved Solids

The construction of DTB1 provides for the isolation of both the Toolonga Calcilutite, which occasionally contains thin sand beds, and Windalia Sand Member, which is utilised by many of the local pastoralists. The pilot-hole was drilled to 485 m depth and geophysically logged (Figure 20). The formations intersected correlate with the Coburn 1 log (Figure 22) with distinctive responses for both the natural gamma and resistivity logs. The caliper log of the Windalia Sand Member and Birdrong Sandstone indicates these formations are poorly lithified, in sections, with some washouts evident in the hole diameter. The simplified stratigraphy intersected in DTB1 is shown in Table 8.

Table 8

Stratigraphy In DTB1

Formation	Depth (m bgl)		Depth (m AHD)	
	Top	Bottom	Top	Bottom
Superficial Formations	0.0	21.0	85.9	64.9
Toolonga Calcilutite	21.0	122.0	64.9	-36.1
Alinga Formation	122.0	170.0	-36.1	-84.1
Windalia Sandstone Member	170.0	197.5	-84.1	-111.6
Muderong Shale Formation	197.5	205.0	-111.6	-119.1
Birdrong Sandstone	205.0	229.0	-119.1	-143.1
Kopke Sandstone	229.0	>485	-143.1	>-399.1

DTB1 is constructed with two mild steel casings that are pressure cement-grouted within the superficial formations, Toolonga Calcilutite, Alinga Formation and Muderong Shale Formation. The upper casing, of 457 mm ND low-carbon mild steel, extends to 132 m depth, 38 m below the top of the Alinga Formation. The second casing is 132 m of 300 mm ND steel fitted with a further 73 m of 250 mm ND mild steel, which extends to 205 m, at the base of the Muderong Shale Formation. The production assembly consists of (from the bottom) a blank stainless steel baseplate, stainless steel wire-wound 0.5 mm aperture screens and an inflatable packer on a 6 m blank extension to seal against the base of the 250 mm ND casing.

The construction of DMB1 isolates the superficial formations Toolonga Calcilutite, and Alinga Formation using 200 mm ND mild steel casing installed to 132 m depth. The pilot-hole was then drilled to 400 m depth and geophysically logged (Figure 21). The stratigraphy in DMB1 is very similar to that in DTB1 with only about 3 m difference in the distribution of the stratigraphic successions above the Birdrong Sandstone.

DMB1 is constructed with three standpipe piezometers of 40 mm ND, 0.5 mm aperture stainless steel screens at 184-190 m, 210-216 m and 392-398 m within the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone. Six metre cement-grout seals are placed at 197-203 m and 227-233 m depth to seal against the Muderong Shale and Birdrong Sandstone/Kopke Sandstone boundaries. The remainder of the annulus is backfilled with 1.6 to 3.2 mm graded gravel pack.

3.2.2 Confined Aquifer Test Results

The aquifer test in DTB1 test was conducted as a single composite pumping test of the following sequence:

- Step 1 – One hour at 5,616 kL/day.
- Step 2 – One hour at 6,480 L/day.
- Step 3 – One hour at 7,344 L/day.

- Step 4 – Five hours at 8,640 L/day.
- Constant-Rate Test – Forty one hours at 7,776 L/day.

The results of the aquifer tests in DTB1 are presented in Table 9, on Figure 23 (a and b), and on Figure 24 (a and b).

Shortly after start-up, the abstracted groundwater became grey-coloured and slightly sandy as some of the Birdrong Sandstone was drawn through the screens due to the initial hydraulic shock. After about 8 minutes, the ingress of sand diminished to normal levels. After about 13 minutes, the pumping discharge became black and very sandy, probably due to some residual mud cake entering the bore. This occurrence continued for about 12 minutes before the groundwater began to clear. A minor increase in sand content was noted after one hour of pumping but cleared to become sand-free after three hours.

At 5,616 kL/day, the pumping water level in DTB1 was rapidly drawn down about 16 m in the first minute, and subsequently significantly fluctuated for about 10 minutes because the pumping rate was variable. Subsequent rate-steps were generally more controlled and hence, the corrected drawdowns follow more linear trends. The drawdown after 60 minutes of pumping at 5,616 kL/day was 18.1 m. Corrected 60-minute drawdowns for each of the subsequent steps were 23.4, 26.6 and 30.9 m with the latter step reaching a drawdown of 31.9 m after 240 minutes. After 240 minutes at 8,640 kL/day, the rate was reduced to 7,776 kL/day to allow groundwater disposal to be managed. The test was completed at 7,776 kL/day for an additional 41 hours, for a total duration of 49 hours pumping. After the 8,640 kL/day step, the pumping water level declined at an average rate of 1.5 m per log cycle until about 1800 minutes, after which the pumping rate slowly drifted from 7,776 to 8,035 kL/day. After the pumping rate was corrected, the pumping water level rose immediately by 0.71 m and then resumed a slow decline of about 1.5 m per log cycle (Figure 23a).

Table 9

Results of Aquifer Tests in DTB1 and DMB1

Bore	Aquifer	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)	Storativity (dimensionless)	Specific Storage (1/m)	Interpretation Method
DTB1	Birdrong Sandstone and Kopke Sandstone	931	4.8	-	-	Jacob (CRT)
		579	2.9	-	-	Theis Semi-log (Rec)
DMB1(b)	Birdrong Sandstone	402	13	0.00058	0.000019	Jacob (CRT)
		216	7.2	-	-	Theis Semi-log (Rec)
DMB1(k)	Kopke Sandstone	308	1.9	0.00016	0.000001	Jacob (CRT)

Note: CRT = Constant Rate Test; Rec = Recovery Test

Groundwater levels in DMB1 responded as expected (Figure 23b). The Windalia Sand Member did not respond to pumping from DTB1. The largest drawdown response was from the Birdrong Sandstone, with a final drawdown of 2.2 m. A smaller response of 0.75 m occurred in the Kopke Sandstone. Groundwater levels in the Birdrong Sandstone in DMB1 responded after 80 minutes of pumping. The Kopke Sandstone in DMB1 responded after 300 minutes of pumping. Both the Birdrong Sandstone and Kopke Sandstone drawdown responses are steepening trends that become linear on semi-log scale after about 1,700 minutes. The Birdrong Sandstone drawdown trend after 1,700 minutes declined at an average rate of 2.50 m/log cycle, while that for the Kopke Sandstone declined at 1.63 m/log cycle.

After the constant-rate test, recoveries were monitored for two days in DTB1 and DMB1. The results of these measurements are presented on Figure 24 (a and b). Groundwater levels in DTB1 recovered quickly from a maximum drawdown of 31.4 m to a residual drawdown of 8.63 m after one minute (t/t' = 2941). The recovery followed a linear trend for the first 150 minutes (t/t' = 21) and then steepened towards a 97% recovery after 3015 minutes (t/t' = 2.0). In DMB1 groundwater levels did not start to recover in the Birdrong Sandstone and the Kopke Sandstone until after 70 minutes and about 1,000 minutes.

To analyse the aquifer responses, it is necessary to assign a proportion of the total pumping rate to each aquifer interval. This was achieved by solving the laboratory-derived salinity from DTB1 against the individual piezometer salinities using the electrical resistivity logs on Figures 20 and 21. These derivations are included in Appendix B. By characterising the Formation Factors and long-normal resistivity results, it is calculated that about 46% of the abstractions (3,580 kL/day) were derived from the Birdrong Sandstone and 54% (4,204 kL/day) from the Kopke Sandstone.

The interpretations from the piezometers are considered the most representative and indicate the Birdrong Sandstone has a hydraulic conductivity of between 7 and 13 m/day, with the lower part of the Kopke Sandstone being about 2 m/day. The Kopke Sandstone is a coarsening-up sequence (DMB1 log, Figure 21). As such, it is likely that the effective hydraulic conductivity of the screened Kopke Sandstone will be higher than interpreted in DMB1(k), which is screened within an interbedded sandstone and siltstone sequence. The lithological logs from Coburn 1 and DTB1 indicate the Kopke Sandstone is predominantly a sandstone formation and that DMB1(k) intersects atypical intervals of argillaceous lithologies. An analysis of the recovery in DMB1(k) (Kopke Sandstone) is not presented, as this interval had not recovered sufficiently after two days. Evidently, the lower interval screened has a restricted hydraulic connection to the interval pumped in DTB1.

3.2.3 Confined Aquifer Groundwater Quality Analyses

The results of groundwater analyses from DTB1 and DMB1 samples and those earlier (August 2003) on samples from the nearby Coburn No. 7 and Spinifex No. 2 are presented in Appendix C.

The field-measured salinities of groundwater from DMB1 decreased from 8,660 mg/L in the Windalia Sand Member, to 6,880 mg/L in the Birdrong Sandstone and increased to 11,370 mg/L in the Kopke Sandstone. The lab-measured salinities show a similar trend with concentrations of 9,100, 7,750 and

12,000 mg/L TDS in the Windalia Sand Member, Birdrong Ssandstone and Kopke Sandstone. A combined salinity of 8,900 mg/L TDS is determined from DTB1. Based on a correlation between the measured salinities from DMB1 and the resistivity logs (Figures 20 and 21), it is likely that about 46% of the groundwater abstraction from DTB1 is from the Birdrong Sandstone and 54% from the Kopke Sandstone (Appendix B). The salinities measured in groundwater from DMB1(k) may not be representative of the sandier more transmissive beds of the Kopke Sandstone. The screen interval in DMB1(k) is within interbedded argillaceous sediments that might be expected to transect groundwater of comparatively high salinity.

3.3 Bore Census Findings

A comprehensive census of 58 local bores has been undertaken. The census determines the existing bore network in the region. Initially, the census extended out to a nominal 50 km radius from the project site, but later included bores from Pastoral Stations further afield to address concerns from the pastoralists.

The census was initiated by collating available data from the WINS database held by the DoE. Additional details were also derived from reports by Playford and Chase, (1955) and McWhae (1958). Two separate field visits were conducted to gather the following statistics:

- Current status of the bores (i.e. whether they are still operational or have recently been replaced).
- Measurement of a static water level (where possible).
- Determination of groundwater salinity and pH - collected directly from the outlet where possible.
- Visual inspection and photographs of the bores to record the current headworks and overall condition.
- Discussion with the bore owners to determine historical details, including the installed pumping equipment and intake depths where known.
- Discussion with the owners to determine (or estimate) the usage pattern of each bore where this is possible.

The locations of the bores are shown on Figure 25. The detailed results of the census are presented in Appendix D.

The findings of the census are as follows:

- There are eight artesian bores within the census area: Nanga View Homestead, Nilemah Artesian No. 1A, Hamelin Pool Telegraph Station Caravan Park, Hamelin Homestead No 2, Spinifex Bore (including 2 old bores), Sweeney Mia Bore, Carbla Homestead and Six Mile Well.
- Nilemah Artesian No. 1A is used occasionally for road-maintenance by the Shark Bay Shire. Groundwater from the Hamelin Pool Telegraph Station Caravan Park and Carbla Homestead bores is used semi-continuously for domestic purposes. Groundwater from Hamelin Homestead No. 2 is

used continuously for generating a domestic electricity supply (via a small turbine). The groundwater is subsequently used for domestic, stock and maintenance of a nearby small artificial wetland. The Sweeney Mia, Spinifex, Carbla Homestead and Six Mile bores are used by Hamelin and Carbla stations, through reticulated pipe networks, to provide stock water. A new domestic water bore is planned in the near future by a land developer near the Nanga Resort to provide a shared supply with nearby property owners.

- With the exception of Spinifex Bore, the artesian bores have hydraulic pressures ranging from about 24 to 42 m above the boreheads. Spinifex Bore flows intermittently, at low pressures, due to the elevation of the borehead and either variations in the confined aquifers or regional drawdown effects from other bores.
- Outside the nominal census range are existing artesian bores at Eagle Bluff, on the old Peron Pastoral Station, and at Denham township, about 90 km and 60 km north-northwest of the project area. The Eagle Bluff bore supplies groundwater for road maintenance.
- A new bore on the old Nanga Station, south of Useless Loop Road near the Nanga-Tamala Station boundary, is also planned to provide a road maintenance supply. This bore is planned to be installed in 2005 and is expected to provide a low-pressure artesian supply (Harold Crawford, pers. comm.)
- The closest non-artesian bores to the project area provide stock water on Hamelin and Coburn stations. Those on Hamelin Station are operated by windmills, while those on the Coburn Station are equipped with diesel-driven Mono (shaft-turbine) pumps. Some groundwater is reticulated across these stations, particularly at Coburn where all of the southern bores have been decommissioned, and groundwater is now diverted from the northern bores via pipelines and diesel-driven booster pumps. Coburn Station sources their domestic supplies on an as-needed basis from a superficial (soak) bore adjacent to the homestead.
- The bores operated by the Billabong and Overlander roadhouses and Billabong Hotel all use electric-submersible pumps. A portion of the supply is desalinated for potable use; the remainder is reticulated for non-potable domestic uses.
- All the bores on Carbla and Meadow stations are operated by windmills on an as-needed basis. Bores on Woodleigh and Nerren-Nerren stations use a mixture of windmills, Mono and electric-submersible pumps. The pump inlets for the windmills are generally about 4.6 or 6 m below the water table.
- Shallow bores are used on Tamala Station for stock and domestic supply purposes, abstracting brackish groundwater from the Tamala Limestone. Several old shallow bores (referred to as soaks) were once present on the old Cooloomia Station, south of Coburn Station, but are now all decommissioned. They derived groundwater from localised unconfined aquifers not connected to the confined regional aquifer systems.

- It is difficult in many bores to determine from which confined aquifer system groundwater is being abstracted. Most of the bores were not rigorously lithologically or geophysically logged when they were constructed. Lithological details are often incomplete and do not allow accurate correlation with the regional geology. Some sources are readily determined, where sufficient data are available, or have been previously interpreted by Wills and Dogramaci, (2000). The aquifer intercepts by the remaining bores have been interpreted as shown in Appendix D.

4.1 Background

The understanding of the hydrogeology of the Gascoyne Platform has been developing for over a number of decades, driven by the needs for groundwater supplies from production bores and the interpretation of structure and stratigraphy in petroleum exploration. Many of the existing production bores have been constructed based on groundwater quality and yield, rather than targeting specific aquifer systems. Lithological data collected by drillers are typically very brief. As a result, these data are often ambiguous and provide incomplete records.

Several studies collate the results of (mainly pastoral) drilling in the onshore Gascoyne Platform. The definition and interpreted distribution of the main aquifers, their flow-paths and salinity distributions are developed based on the groundwater data collected from groundwater bores and petroleum exploration. An initial study conducted by Playford and Chase (1955) for Australian Petroleum Pty Ltd collated the geological and hydrogeological data collected over the previous 50 years. Subsequently, a study by McWhae (1958), investigated the salinity and hydrodynamics of the main aquifers in the Carnarvon Basin utilising the results of Playford and Chase, and others, with the benefit of (then) recent petroleum exploration drilling.

More recently, Wills and Dogramaci (2000) updated the hydrogeological database utilising the results of nearly one hundred years of drilling in the Carnarvon Basin. This study, other studies regarding petroleum prospects and regional structural investigations by Iasky *et al.*, (2001 and 2003) form the basis of the current understanding of the confined aquifer hydrogeology of the Gascoyne Platform. Work has also been undertaken using geochemical and stable-isotope analyses, but findings have been limited by the distribution of bores and lack of confidence of the stratigraphic interval being sampled.

It is generally accepted that groundwater recharge is entering the confined aquifer systems where these formations outcrop or sub-crop along the Ajana Ridge. It is also understood that recharge to and the available groundwater resources in the Birdrong Sandstone and Kopke Sandstone aquifers is poorly defined (Wills and Dogramaci, 2000). Therefore, there is uncertainty regarding the rates of sustainable abstraction.

Current estimates indicate the groundwater recharge may be in the order of 0.5% of annual rainfall (Wills and Dogramaci, 2000), but may have changed historically. Lower salinity groundwater at depth in the stratigraphic profile may be the result of higher recharge rates during historical wetter climates.

Estimates of the groundwater through-flow rates in the Carnarvon Basin have generally been calculated by application Darcy's Law at a regional scale, using generalised hydraulic gradients and cross-sectional area (Allen, 1987). However, the interpretations of groundwater levels are uncertain due to bore construction (or condition) and the occurrence of structural constraints on groundwater flow. The estimated through-flow (and recharge) rates are therefore semi-quantitative. Recent studies by Hiller *et al.*, (2002) using stable-isotopes did not produce conclusively-supporting results on the flow direction and recharge rates through the Kopke Sandstone, for the same reasons that limited the reliability of earlier studies. This work, based on the extent of the Windalia Radiolarite and Birdrong Sandstone in the area between Shark Bay and Carnarvon, provided recharge estimates of 4.5 GL/annum.

The above descriptions indicate that the knowledge and understanding of the regional Carnarvon Basin hydrogeology is comparatively limited. The groundwater flow systems, rates of recharge, throughflow and discharge mechanisms are only defined in conceptual and semi-quantitative terms. The limited available relevant data will continue to restrict the understanding of the regional aquifer systems until more definitive data are available. In the meantime, the hydrogeology assessments are strongly interpretive and incorporate uncertainty.

4.2 Superficial Formations Aquifer Systems

4.2.1 Aquifer Profiles

The superficial formations beneath the project area are predominantly formed of sands of the reworked Peron Sandstone. The sand is typically medium to fine grained as shown in Table 10. The particle size distribution indicates that the sand is predominantly between 180 and 500 µm and clean, with a slimes fraction (< 45 µm) comprising 0.3 % by weight. Several calcrete bands are present in the upper sand profile representing palaeo-sols, some of which are covered by recent dunes.

Soil salinities between 120 and 800 mg/L TDS were recorded during a recent landform survey and indicate there is naturally stored salt in the soil profile (Blandford, 2004). This is probably the result of high rates of evaporation and infiltration of wind-borne salt.

Table 10

Typical Particle Size Distribution of the Amy Zone

Fraction (µm)	Weight (%)	Cumulative Weight (%)
5,000	1.6	1.6
1,980	1.0	2.5
1,500	0.2	2.7
1,000	0.3	3.0
710	0.6	3.6
500	0.1	3.7
400	31.5	35.2
250	39.8	75.0
180	15.1	90.1
125	6.5	96.5
90	2.1	98.7
63	0.5	99.1
45	0.6	99.7
-45	0.3	100.0
Total	100.0	

Source: Gunson Resources Limited.

Thin sandy beds are also present in the upper three to nine metres of the Toolonga Calcilutite. These sandy beds typically occur below clay beds. Mineral resource drillhole logs characterise the top of the Toolonga Calcilutite as predominantly sandy or silty clay. As such, the Toolonga Calcilutite is interpreted to typically form a confining layer.

Beneath the northern project area, erosion of the upper Toolonga Calcilutite has formed a shallow palaeodrainage surface. The palaeodrainage surface is interpreted from the mineral resource drilling. Figure 26 shows the interpreted basal elevation of the superficial formations and evidence of a palaeodrainage surface. Based on this interpretation, the roof structures of the Toolonga Calcilutite form groundwater divides that potentially control local groundwater flows. The roof structures dip to the west and northwest beneath the southern and northern project areas. The southern area may have localised depressions in the Toolonga Calcilutite that also control flow, but these are evidently not as well developed as in the north. Recharge from rainfall infiltration that reaches the Toolonga Calcilutite might be diverted laterally along the contact.

To the north of the project area, the Peron Sandstone is predominantly removed by erosion, has no surface expression, dips below and is interbedded with marine clay deposits (Figure 7). In this setting aquifer systems exist both in shell coquina beach ridge and estuarine to shallow marine deposits in foreshore areas of and beneath Hamelin Pool. Thin, perched groundwater lenses in the shell coquina beach ridges are recharged by direct rainfall and locally may contain fresh groundwater resources. The groundwater systems in foreshore areas of the Hamelin Pool are recharged by rainfall (meteoric), with occasional inundations by hypersaline seawater (BMR, 1990).

Superficial formations aquifers in the Shark Bay area also exist in several other settings:

- Shallow groundwater (up to about 30 m depth) utilised by Tamala Station for stock water. This groundwater resource is probably restricted to fresh to brackish water lenses overlying saline groundwater within the Tamala Limestone.
- Unconfined (or semi-confined) groundwater in recharge areas where the Windalia Sand Member and Birdrong Sandstone overly Tumblagooda Sandstone on the Ajana Ridge.
- Small-scale brackish groundwater resources in low-lying areas where the superficial formations cover depressions in the Toolonga Calcilutite. Several soaks, which possibly fall in this category, exist at the Coburn Homestead and probably existed on the now derelict Cooloomia Station. These aquifers are probably localised features that are physically separated from the Birdrong Sandstone and Kopke Sandstone by aquitards such as the Toolonga Calcilutite and Alinga Formation.

4.2.2 Groundwater Levels

The superficial formations beneath the project area are dry (above the water table) except for thin, saturated zones in depressions within the Toolonga Calcilutite.

Within SMB2, there is a vertically upward groundwater flow gradient from the Toolonga Calcilutite to the superficial formations. Based on these data, it is interpreted that the Toolonga Calcilutite and potentially the underlying confined aquifer systems are discharging into the superficial formations beneath the northern project area and Hamelin Pool.

Interpreted baseline water table elevations in the superficial formations and Toolonga Calcilutite are shown on Figure 27. These interpretations have been expanded on Figure 28 (plan view) and Figure 29 (section view) to describe areas where the superficial formations are saturated and to indicate in a more regional context the flow paths and discharge to Nilemah Embayment and Hamelin Pool.

The water table is recharged by both rainfall infiltration and upward leakage from the Toolonga Calcilutite. Most rainfall probably does not reach the water table, but is lost to evaporation and evapo-transpiration. Rainfall recharge that does pass through the soil profile is probably brackish due to the mobilisation of the stored soil salts and becomes saline as it flows down gradient towards Hamelin Pool. Groundwater level data from the site investigations show water table elevations in the range from 0.7 to 29.6 m AHD. The water table occurs within the Toolonga Calcilutite beneath most of the project area and within the superficial formations only beneath the northern project area. Groundwater flow is to the northwest and Hamelin Pool under a hydraulic gradient of about 0.002 (dimensionless). The superficial formations aquifer systems discharge into Nilemah Embayment and Hamelin Pool.

Figure 29 shows that in nearshore areas marine clay deposits control the local groundwater flow systems. The presence of the marine clays is interpreted to be linked to the salina occurrences and the predominant isolation of the water table environment beneath shell coquina dunes on the fringe of Hamelin Pool. The salinas appear to form in depressions above the water table, being basins for surface water flows and seasonal groundwater discharge by capillary rise and evaporation. The marine clay also constrains discharge from the Peron Sandstone into Hamelin Pool.

Throughflow of groundwater in the superficial formations is expected to be small-scale given the known hydraulic gradient and limited saturated thickness of the reworked Peron Sandstone.

4.2.3 Aquifer Parameters

The hydraulic characteristics of the superficial formations and water table environment have been interpreted from the aquifer tests in SMB2, SMB3 and SMB4 are summarised in Table 11.

Table 11

Interpreted Superficial Formations and Shallow Toolonga Calcilutite Aquifer Parameters

Aquifer System	Hydraulic Conductivity (m/day)		Storativity (dimensionless)
	Range	Average	
Superficial Formations[1]	5 – 15	10	Not Determined
Shallow Toolonga Calcilutite – Clay Beds	0.1	0.1	2.2×10^{-5}
Shallow Toolonga Calcilutite – Sandy Beds	0.05 – 2.0	0.6	Not Determined

Note: 1 The superficial formations test sections are predominantly unsaturated sands.

Based on the interpreted aquifer parameters, the superficial formations are comparatively homogeneous and transmissive in saturated profiles.

4.2.4 Shallow Groundwater Quality

The sampled groundwater is saline, slightly acidic with pH 6.2 to 6.7 and a sodium-chloride type. The groundwater becomes hypersaline further down gradient in the Nilemah Embayment. Salinities increase from about 11,000 mg/L TDS near SMB4 to greater than 67,000 mg/L in Nilemah Embayment (near STB1). Pore water salinities greater than 200,000 mg/L are reported (BMR, 1990) beneath clay pan areas of the salina.

The results of the superficial formations and shallow Toolonga Calcilutite groundwater quality analyses are summarised in Table 12. These quality data are also plotted on a Piper Diagram on Figure 30.

Table 12

Summary of Shallow Groundwater Quality

Sample	Units	STB1	SMB2s	SMB2d	STB3	SMB4d
Date Sampled		**13-Aug-04**	**13-Aug-04**	**12-Aug-04**	**12-Aug-04**	**12-Aug-04**
Physio-chemical Parameters						
Lab pH	pH Units	6.6	6.3	6.7	6.2	6.2
Field pH	pH Units	-	5.9	7	6.6	-
Electrical Conductivity	µS/cm	91,500	17,600	34,500	47,000	17,400
Total Dissolved Solids (grav.)	mg/L	67,840	14,052	25,388	34,476	11,172
Sum of Ions (calc.)	mg/L	67,072	11,516	25,041	30,543	10,295
Alkalinity (Total) as $CaCO_3$	mg/L	228	750	265	129	285
Colour (True)	PCU	10	60	10	10	35
Hardness (Total) by Calculation	mg/L	12,000	430	4,300	6,000	880
Major Ions						
Sodium	mg/L	21,000	4,200	8,100	10,000	3,700
Potassium	mg/L	560	72	210	280	99
Calcium	mg/L	1,200	56	420	590	88
Magnesium	mg/L	2,200	72	780	1,100	160
Chloride	mg/L	37,000	5,100	13,000	17,000	4,900
Carbonate	mg/L	<1	<1	<1	<1	<1
Bicarbonate	mg/L	278	915	324	158	348
Sulphate	mg/L	4,800	1,100	2,200	1,400	1,000
Nitrate	mg/L	34	0.99	6.88	15	<0.2
Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	mg/L	0.62	0.46	0.64	0.98	0.14
Silica (as SiO_2)	mg/L	21	193	41	60	140
Cation anion balance	%	0.86	3.06	2.89	4.71	4.71

Table 12 (continued)

Sample	Units	STB1	SMB2s	SMB2d	STB3	SMB4d
Date Sampled		13-Aug-04	13-Aug-04	12-Aug-04	12-Aug-04	12-Aug-04
Minor and Trace Ions						
Aluminium	mg/L	<0.1	12	<0.1	0.2	4.4
Arsenic	mg/L	<0.005	0.089	0.007	0.008	0.063
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	<0.5	<0.05	<0.05	0.05	<0.05
Iron – Total	mg/L	0.1	8.6	0.23	0.15	10
Manganese	mg/L	<0.5	0.5	0.85	0.1	1.1
Mercury	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lead	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
Selenium	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	<0.5	0.1	0.05	0.1	0.05

The groundwater in SMB2s and SMB4d has higher proportions of chloride and lower sulphate than in other samples. They also have higher proportions of sodium and lower magnesium than in other samples. It is apparent that the higher salinity sources may become slightly enriched in magnesium and depleted of sulphate over time.

Variable concentrations of nitrate are detected in the samples, the lowest being in groundwater from SMB2s and SMB4d, which also have the lowest salinities. Variable concentrations of iron and aluminium are detected. As the analysis of total iron was conducted on unfiltered samples, this variation may be due to the presence of particulate matter. Other minor and trace metals were close to or below the Limit of Reporting.

Stable isotope investigations of groundwater in the Nilemah Embayment (BMR, 1990) conclude that the primary recharge source is from water of meteoric origin. Shallow groundwater in the Nilemah Embayment apparently receives very little input from Hamelin Pool and only responds to tidal influences close to the shoreline.

4.2.5 Superficial Formations Conceptual Hydrogeological Model

The conceptual hydrogeological model of the superficial formations has been developed primarily to determine the likely effects of mine dewatering and disposal of tailings as a slurry on the local environment. Details of the conceptual hydrogeological model are predominantly based on:

- Data from mineral resource drilling by Gunson Resources;
- hydrogeological investigations in the project area; and
- the findings of a geo-biology study (BMR, 1990) within Hamelin Pool and surrounds.

The conceptual hydrogeological model of the superficial formations and water table environment is shown on Figure 31. Key elements of the conceptual hydrogeological model include:

- Reworked deposits of Peron Sandstone predominantly form the superficial formations within the project area.
- Thin saturated intervals of the reworked Peron Sandstone only occur within the northern project area. Elsewhere, the superficial formations are dry.
- In areas where the superficial formations are dry, the water table occurs in the underlying Toolonga Calcilutite. Upper beds of the Toolonga Calcilutite are characterised by sandy or silty clay, with irregular thin sandy interbeds.
- Where the superficial formations are saturated, the water table is recharged by both rainfall infiltration and upward leakage from the regional confined aquifer systems through the Toolonga Calcilutite. Most rainfall is anticipated not to reach the water table, being lost to evaporation and evapotranspiration.
- Where saturated, the superficial formations are comparatively homogeneous and have interpreted average hydraulic conductivity of about 10 m/day.
- The upper Toolonga Calcilutite typically forms a low-transmissivity, low-storage groundwater environment. The range of interpreted hydraulic conductivity for the shallow Toolonga Calcilutite is 0.05 to 2.0 m/day, average 0.6 m/day. Groundwater flow would occur in the upper sandy beds but is expected to be small-scale.
- Groundwater flow is towards the northwest and Hamelin Pool under a hydraulic gradient of 0.002 (dimensionless). Groundwater flow within the superficial formations is locally controlled and constrain by:
  - small-scale palaeodrainage features on the Toolonga Calcilutite contact; and
  - marine clay deposits in foreshore areas of Hamelin Pool.

  Both of these aspects influence the location of and mechanisms for discharge into Hamelin Pool.
- Both the superficial formations and Toolonga Calcilutite discharge into Hamelin Pool. The discharge occurs by upward leakage through overlying marine clay deposits.
- Marine clay outcrops or subcrops in the Nilemah Embayment are characterised by topographic depressions, clay pans and salina. The salina areas overlie a shallow water table, hypersaline groundwater and are interpreted to form groundwater discharge zones. The groundwater discharge is understood to be predominantly from evaporation losses; the water table occurs beneath the ground surface.

- Shell coquina beach ridges that overlie marine clay deposits on the fringe of Hamelin Pool form discrete catchment zones wherein direct infiltration of rainfall leads to local lenses of fresh groundwater and discharge occurs locally at low tide.

- Groundwater in the superficial formations and shallow Toolonga Calcilutite is saline to hypersaline, slightly acidic and a sodium-chloride type. Salinities increase along the flow paths in the measured range from 11,000 to 67,000 mg/L TDS. Salinities within the Peron Sandstone and salina areas become increasingly hypersaline nearer Hamelin Pool and associated salina discharge areas.

4.3 Confined Aquifer Systems

4.3.1 Aquifer Profiles

There are five significant confined aquifers in the Gascoyne Platform:

1. Windalia Radiolarite
2. Windalia Sand Member
3. Birdrong Sandstone
4. Kopke Sandstone
5. Tumblagooda Sandstone

Windalia Radiolarite is interpreted to be present beneath the northern project area. Where present, this aquifer yields significant supplies, presumably from secondary porosity (i.e. fracturing) in the siliceous, cherty or flinty beds. Very strong anisotropy of the hydraulic conductivity has been observed from bores drilled into this formation; usually in old bores that were drilled using cable-tool methods. Upwards heads of between 7 and 22 m have been recorded during the drilling of Yaringa No. 5 and Yaringa No. 15, with further head rises after the deeper Birdrong Sandstone was intersected. The upward head distributions may indicate that vertical flow between these aquifer systems is limited. Locally, Spinifex Bore exhibited upward heads of about 20 m while drilling through the Windalia Radiolarite between 125 and 128 m depth (Playford & Chase, 1955).

Spinifex Bore 2 and Nilemah Artesian No. 1A source groundwater from the Windalia Radiolarite nearest the project area, although there is doubt whether abstraction is only from this aquifer system.

The Windalia Radiolarite is typically about 15 m thick, but probably thins towards the areas where the Windalia Sand Member is present. There are no aquifer parameters available in either the literature or bore completion reports.

Windalia Sand Member is restricted to the southern Gascoyne Platform, beneath Coburn, Hamelin, Meadow and possibly Nerren Nerren stations. This aquifer system overlies the Birdrong Sandstone and is utilised by many of the pastoralists east of the project area as it provides adequate groundwater supplies of acceptable quality. Where the supply is inadequate or the groundwater quality exceeds stock limits for salinity, pastoral bores have been extended down into the Birdrong Sandstone.

The Windalia Sand Member is typically in excess of 20 m thick, but thins towards the west (near Spinifex Bore, Nilemah Artesian No. 1A), and to the north (near Hamelin No. 5 and Kevin's Bore). In Coburn 1, this formation is 32 m thick. Groundwater levels are typically lower than in the Birdrong Sandstone and Kopke Sandstone, indicating upward hydraulic heads due to the presence of Muderong Shale or intrinsic transmissivity anisotropy within the sedimentary bedding. The aquifer properties of the Windalia Sand Member are not known precisely; they have not been measured or published.

Birdrong Sandstone is the most commonly used aquifer in the Carnarvon Basin due to its regional distribution and capability to yield large groundwater supplies.

Typically, the hydraulic conductivity of the Birdrong Sandstone is between about 5 and 10 m/day. There are no published storage coefficients for this aquifer. Static groundwater level measurements in non-flowing bores reported by McWhae, (1958) indicate the Birdrong Sandstone has a westerly-dipping hydraulic gradient of about 5×10^{-4} (dimensionless).

Kopke Sandstone is probably the second most important groundwater source in the middle and southern Gascoyne Platform. Where the formation is shallow, it is utilised as a lower salinity groundwater source in preference to the Birdrong Sandstone. In more westerly parts, the Kopke Sandstone is generally too deep (greater then 300 to 500 m) for widespread use. Apart from the large volume of groundwater in storage in the Kopke Sandstone, it is possible that this formation is in hydraulic connection with the Tumblagooda Sandstone beneath the Ajana Ridge.

This formation has been investigated during petroleum exploration drilling programmes. Porosities of 23 to 28% have been reported from Yaringa 1, Yaringa 1 East and Coburn 1 (Wills and Dogramaci, 2000) with hydraulic conductivities of about 4 m/day. The hydraulic gradient is in the order of 1×10^{-4} (dimensionless) to the west.

The age and flow direction of groundwater in the Kopke Sandstone was examined by Hiller *et al*., (2002) using analyses of stable isotopes and their ratios. The bores they tested on Carbla and Yaringa stations suggested the groundwater probably entered the formation during wetter climatic conditions and subsequently has had low rates of throughflow. They inferred that this historical recharge and low rates of throughflow have has resulted in lower salinities in this aquifer as a whole.

Tumblagooda Sandstone is a large regional aquifer. This formation is generally too deep to be significantly exploited to date, except in areas on the eastern and southern margins of the Carnarvon Basin. Presently, the only significant abstraction from the Tumblagooda Sandstone is in the Kalbarri region, where it outcrops. The formation has been investigated in petroleum exploration activities.

A summary of the hydraulic parameters derived from petroleum exploration work is presented by Wills and Dogramaci (2000). In general, the Tumblagooda Sandstone is described as having a porosity of about 22 % and a hydraulic conductivity of about 1 m/day. Hydraulic gradients in this formation are unknown. At depths less than 1,000 m, this formation is generally of lower transmissivity due to pore space clogging by silica overgrowths and kaolinitic clay (Wills and Dogramaci, 2000).

4.3.2 Potentiometric Levels

Few reliable Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone groundwater level data are available. The absence of reliable groundwater level data constrains knowledge of the regional groundwater flow systems, both in terms of the individual aquifers and the confined aquifer systems as a whole. At present, the groundwater flow systems are characterised only in conceptual terms. There is a comparatively poor understanding of recharge and discharge flow paths, vertical flow gradients and leakage between the confined aquifers and, drawdown responses to large-scale historical abstraction.

The groundwater levels from bores with reasonably reliable stratigraphic determinations are shown on Figure 32 (Windalia Sand Member) and Figure 33 (Birdrong Sandstone). In a regional context, the interpreted groundwater level contours show westerly hydraulic gradients and groundwater flow, with discharge offshore beneath the Indian Ocean. Local gradients show northwest and southwest groundwater flow aspects. Within the Windalia Sand Member, comparatively high groundwater levels are aligned with the mapped distribution of sand beds: the groundwater levels decline near the interpreted facies change to the Windalia Radiolarite.

Regional groundwater flow gradients of 10^{-3} to 10^{-4} (dimensionless) to the west are interpreted in the Birdrong Sandstone. Groundwater throughflow, based on these hydraulic gradients and average hydraulic conductivities, has a regional average of about 3 m/annum per unit cross-sectional area or 2.7 GL/annum beneath the 33 km length of the project area. No through-flow rates are interpreted for the Kopke Sandstone.

Large upward hydraulic gradients occur within the Windalia Radiolarite, interpreted to be linked to strong vertical anisotropy in the transmissivity of fractured flint beds. Upward hydraulic gradients are also extrapolated within and between the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone. These upward hydraulic gradients indicate vertical discharge into the overlying confining layers formed by the Alinga Formation and Toolonga Calcilutite and also the superficial formations.

4.3.3 Aquifer Characteristics

Data on the hydraulic characteristics of the regional confined aquifer systems are available from petroleum exploration activities and the findings of the completed site investigations. A summary of the available aquifer parameters data is provided in Table 13.

Table 13

Confined Aquifers Hydraulic Parameters

Aquifer System	Hydraulic Conductivity (m/day)		Storativity (dimensionless)	
	Research References	Site Investigations	Research References	Site Investigations
Windalia Radiolarite	No Record	No Record	No Record	No Record
Windalia Sand Member	No Record	No Record	No Record	No Record
Birdrong Sandstone	5 – 10	7 – 13	No Record	5.8×10^{-4}
Kopke Sandstone	4	2	No Record	1.6×10^{-4}
Tumblagooda Sandstone	1	No Record	No Record	No Record

The interpretations from the site investigations are compatible with those from research literature.

The Toolonga Calcilutite, Alinga Formation, Faure Formation and Dirk Hartog Group form thick successions of predominantly argillaceous and/or chemical sediments that are interpreted to characterised by low-transmissivity. These successions confine the regional aquifer systems, constraining vertical groundwater flow. There are no data on the hydraulic conductivity of these formations. Interpreted lateral and vertical hydraulic conductivities range from 1×10^{-2} to 1×10^{-4} m/day and 1×10^{-3} to 1×10^{-5} m/day.

4.3.4 Confined Aquifer Groundwater Quality

Generally, the salinities of the regional confined aquifers are interpreted to decrease with depth as described in Table 14. Variations in quality of the confined aquifer groundwater resources have historically been the driving factor for deeper drilling for groundwater supplies and hence the occurrence of more Kopke Sandstone than Birdrong Sandstone intersections in some areas.

Table 14

Summary of Interpreted Regional Groundwater Salinities

Formation	Typical Salinity Range (mg/L TDS)
Superficial Formations	14,000 (on site) >60,000 (Marine Deposits in Nilemah Embayment)
Toolonga Calcilutite	11,200 – 34,400 (on site)
Windalia Sand Member	5,000 – 9,000
Birdrong Sandstone	3,500 – 8,000
Kopke Sandstone	1,500 – 12,000
Tumblagooda Sandstone	<1,000

Mention is made in the literature of heterogeneity in the groundwater quality within the main aquifers such as the Kopke Sandstone (Wills and Dogramaci, 2000). Many of the bores in the Carnarvon Basin have dissimilar salinities to neighbouring bores and are not easily correlated to groundwater level maps that attempt to differentiate the confined aquifers. In general, however, the trends given in Table 14 are a reasonable indicator of the groundwater source quality, except where a bore is screened within (or corroded through to) multiple aquifers.

Beneath the project area, the groundwater from the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone is near neutral to weakly alkaline, brackish to saline and of a sodium-chloride type. The results of the site investigation sampling and groundwater quality analyses are summarised in Table 15. These quality data are also plotted on a Piper Diagram on Figure 30.

Table 15

Summary of Confined Aquifers Groundwater Quality

Sample	Units	Spinifex 2[1]	Coburn 7[2]	DMB1(k)	DMB1(b)	DMB1(w)	DTB1
Date Sampled		**21-Aug-03**	**21-Aug-03**	**8-Dec-04**	**7-Dec-04**	**6-Dec-04**	**17-Jan-05**
Physio-chemical Parameters							
Lab pH	pH Units	7.15	8.0	7.3	7.7	7.9	7.3
Field pH	pH Units	-	-	7.0	6.8	7.0	7.0
Electrical Conductivity	µS/cm	11,000	15,000	17,000	11,000	14,000	15,000
Total Dissolved Solids (grav.)	mg/L	7,300	10,000	12,000	7,750	9,100	8,900
Sum of Ions (calc.)	mg/L	7,166	10,021	11,091	6,647	8,166	9,898
Alkalinity (Total) as CaCO3	mg/L	-	-	300	350	300	140
Hardness (Total) by Calculation	mg/L	1,200	1,900	2,200	1,280	1,420	2,300
Major Ions							
Sodium	mg/L	2,100	2,900	3,280	1,960	2,480	3,000
Potassium	mg/L	92	120	135	99	105	120
Calcium	mg/L	160	200	360	220	200	330
Magnesium	mg/L	210	340	320	180	220	350
Chloride	mg/L	3,600	5,200	5,540	3,210	4,080	4,900
Carbonate	mg/L	<1	<1	<1	<1	<1	<1
Bicarbonate	mg/L	230	310	371	425	371	160
Sulphate	mg/L	880	1,100	1,270	765	895	1,100
Nitrate (as Nitrate)	mg/L	0.8	<0.1	0.33	<0.05	<0.05	0.2
Nitrite	mg/L	<0.1	<0.1	-	-	-	<0.2
Fluoride	mg/L	-	-	0.6	0.8	0.7	0.5
Silica (as SiO_2)	mg/L	8	6	-	-	-	17

Table 15 (continued)

Sample	Units	Spinifex 2[1]	Coburn 7[2]	DMB1(k)	DMB1(b)	DMB1(w)	DTB1
Date Sampled		21-Aug-03	21-Aug-03	8-Dec-04	7-Dec-04	6-Dec-04	17-Jan-05
Minor and Trace Ions							
Aluminium	mg/L	-	-	-	-	-	<0.1
Arsenic	mg/L	-	-	-	-	-	<0.005
Cadmium	mg/L	-	-	-	-	-	<0.005
Copper	mg/L	-	-	-	-	-	<0.05
Iron - Total	mg/L	<0.01	<0.01	-	-	-	3.0
Manganese	mg/L	<0.01	0.12	-	-	-	0.3
Mercury	mg/L	-	-	-	-	-	<0.0005
Lead	mg/L	-	-	-	-	-	<0.05
Selenium	mg/L	-	-	-	-	-	<0.005
Zinc	mg/L	-	-	-	-	-	0.05

Notes: 1 - Sample derived from tank at Hamelin No. 22
2 - Sample derived from tank beside Coburn No. 7
DMB1(k) - Kopke Sandstone
DMB1(b) - Birdrong Sandstone
DMB1(w) - Windalia Sand Member
DTB1 – Birdrong Sandstone and Kopke Sandstone combined

The salinities have similar discrepancies between the values determined by evaporation and sum of ions as reported by Wills and Dogramaci, 2000. Typically, the sum of ions values are lower than that determined by evaporation.

Minor ion and trace metals analyses (Table 15) show only iron and manganese were detected at concentrations 3.0 and 0.3 mg/L. A concentration of 0.05 mg/L for zinc is at the Limit of Reporting.

4.3.5 Confined Aquifer Conceptual Hydrogeological Model

The conceptual hydrogeological model of the confined regional aquifer systems is based on published regional geology and hydrogeology and results of site investigations. The conceptual hydrogeological model of the confined aquifer systems is shown on Figure 34.

Key elements of the confined aquifer conceptual hydrogeological model include:

- Main aquifers in the southern Gascoyne Platform being:
  - Windalia Radiolarite
  - Windalia Sand Member
  - Birdrong Sandstone
  - Kopke Sandstone

- Tumblagooda Sandstone

- The relationship of the Windalia Radiolarite and Windalia Sand Member is interpreted as a facies change from east to west.
- The Muderong Shale Formation is probably discontinuous, particularly in the eastern regions of the study area. Continuous intersections have been recorded in western and far-northern parts of the Shark Bay area, but not in the eastern parts of Hamelin and Coburn stations as well as Meadow Station.
- There are no conclusive indications of an aquitard between the Birdrong Sandstone and Kopke Sandstone. However, groundwater level and salinity differences are apparent, suggesting both structural and stratigraphic influences on recharge zones and groundwater flow.
- The confined aquifers are recharged where they outcrop (or sub-crop below superficial cover) along the Ajana Ridge and to south and southeast (near the old Murchison House Station area). The southern recharge area extends to the groundwater divide with the Murchison River catchment.
- Potentially, there is a regional groundwater resource in the Tumblagooda Sandstone that recharges the Kopke Sandstone beneath the Ajana Ridge.
- Regional groundwater flow is westward under hydraulic gradients of 1×10^{-3} to 1×10^{-4} (dimensionless), with discharge into the Indian Ocean. On a local scale flow is also to the northwest, with discharge into Hamelin Pool.
- Upward hydraulic gradients are interpreted between most of the confined aquifers in the western groundwater flow domains. As such, the confined aquifers discharge through the Alinga Formation and Toolonga Calcilutite in the vicinity of the project area and Hamelin Pool.
- The aquifers formed by the Birdrong Sandstone and Kopke Sandstone are characterised by hydraulic conductivities in the range from 5 to 13 and 2 to 4 m/day. Confined storage coefficients of 5.8×10^{-4} and 1.6×10^{-4} have been interpreted from results of site investigations.
- Groundwater resources of the confined aquifer systems are brackish to saline, with TDS concentrations of 1,000 to 35,000 mg/L. In a regional context, the salinity is interpreted to progressively decrease with depth.
- Groundwater in the confined aquifers beneath the project area is brackish to saline (TDS 6,650 to 11,100 mg/L), weakly alkaline and a sodium-chloride type. The lowest and highest salinity groundwater occurs in the Birdrong Sandstone and underlying Kopke Sandstone.
- Regional groundwater chemistry and ionic ratios indicate that the lower salinities in the confined aquifers are probably the result of higher recharge rates in the past, when the climate was wetter. Higher salinities in shallow formations near recharge areas overlying the Ajana Ridge, suggest that recharge rates are presently about 0.5% of total annual rainfall. Recharge to the Windalia Radiolarite

and Birdrong Sandstone is estimated at 4.5 GL/annum based on the distribution of these aquifer systems in the area between Shark Bay and Carnarvon.

- The large losses of groundwater from the Gascoyne Platform aquifer systems (through uncontrolled flow from artesian bores) may be above the natural recharge rate.

4.4 Groundwater Management

The DoE manages the groundwater resources in the Carnarvon Basin, although many of the pastoral bores drawing from the confined aquifers are unlicensed. Either plugging for abandonment or re-lining and re-capping has recently rehabilitated many of the older bores that were flowing uncontrollably under artesian conditions. This programme has involved several bores in the Shark Bay area, but is incomplete. Near the project area, uncontrolled artesian bores still remain on Hamelin Station (Spinifex Bore Nos. 1 and 2), Six Mile Well on Carbla Station and possibly also old Nanga Station (Nilemah No. 2). These bores may be rehabilitated in the future.

Prior to the recent rehabilitation programme, it was estimated that of the approximately 140 artesian bores have been drilled within the Carnarvon Basin since the early 1900s and only 40 still have substantial uncontrolled flows. The remainder have either stopped flowing or flows or were reduced to a trickle (Astill *et al*. 2002). From these 40 bores, it is estimated that about 15 GL/annum is currently being lost to seepage and evaporation.

Several superficial formations groundwater flow models have been developed to assess sand tailings water recovery concepts, mounding of the water table due to tailings disposal, consumptive process water demand, the potential fate of tailings waters that are not recovered and pit dewatering. One set of models is generic, simulating the sand-stacker operations in a suite of variable pit settings. The other model is specific to sand-stacker operations in the proposed northern mining developments, predicting the impacts of tailings waters that are not recovered. The northern pit is specifically investigated due to its setting, including proximity to outcrops of Toolonga Calcilutite and discharge zones of the superficial formations within Hamelin Pool.

5.1 Superficial Formations Groundwater Flow Modelling

The generic set of models is simple, with only one active layer that represents the superficial formations. The northern pit model conforms to the conceptual hydrogeological model. The simulated superficial formations are isotropic, homogeneous and transmissive. The models have a base representing the low-transmissivity and low-storage domain formed by the Toolonga Calcilutite. Sandy and silty intervals within the upper Toolonga Calcilutite are not represented.

In all generic model simulations the superficial formations are dry but being recharged locally in domains compatible with the sand-stacker operations and traverses. Initially, the ground-surface topography and roof structure of Toolonga Calcilutite were incorporated into the groundwater flow models. It was found, however, that this caused unnecessary complications for the assessment of sand tailings water recovery and pit dewatering, and made an insignificant difference to the outcomes. Subsequent models use a flat basement and surface topography.

The model of the northern pit incorporates all of the key characteristics of the generic model. The primary difference is that it is site-specific in terms of topography and Toolonga Calcilutite occurrence with the northern pit. It also simulates dual sand-stacker operations (four sand-stackers) with comparatively long traverses.

5.1.1 Model Code

The models are developed in MODFLOW-SURFACT, which is a three-dimensional block-centred finite-difference code developed by the USGS. This code allows groundwater flow within saturated and unsaturated media. This aspect is critical for the re-wetting of the superficial formations due to sand tailings disposal and subsequent drainage and groundwater recovery aspects. Visual MODFLOW from Waterloo Hydrogeologic Inc. is used as the pre- and post-processor.

5.1.2 Generic Model Domains

The generic sets of models consist of 254 by 132 rows and columns forming matrices of 33,528 cells. The dimensions of the rows were varied between the models to allow for sand-stacker advance rates of 5, 10, 15, 35, 55 and 80 m/day across increasingly wider pits, Figure 35 (a and b).

5.1.3 Boundary Conditions

The models are sized such that the boundaries occur beyond the forecast extent of any significant impacts due to mining. Several separate models have been developed to simulate different rates of tailing and in all cases the boundaries are set to general no-flow conditions/characteristics.

The models do not include rainfall recharge.

5.1.4 Hydraulic Parameters

The hydraulic characteristics of the generic superficial formations groundwater flow models are shown in Table 16. They are based on the results of the site investigation and typical values for well-sorted medium to fine-grained sands.

Table 16

Simulated Peron Sandstone Hydraulic Parameters

Model Layer	Formation	Hydraulic Conductivity (m/day)			Specific Yield (dimensionless)
		K_x	K_y	K_z	
1	Peron Sandstone	10	10	10	0.2

5.2 Predicted Sand Tailings Water Recovery

To determine practical and reasonable strategies for recovery of groundwater from the disposed sand tailings, the operational aspects of the mining and tailings processes have been considered. These aspects include materials handling, pit dimensions, sand-stacker operations and local aquifer setting. Some of these aspects are constant and others are variable, as shown in Table 17. The typical mine profile within the superficial formations (Figure 36) is also considered.

Table 17

Sand Tailings Water Recovery – Constraints and Variables

Variables	Constants
Pit width, depth and length	Ore processing rate
Pit shape	Ore processing time
Mining rate	Sand tailings disposal rates
Thickness of sand beneath the pit floor	Specific yield of sand tailings
Number of plants operating per pit	Plant water throughput rate

The developed sand tailings water recovery concepts are compatible with the mine plans and schedules, and have been iterated several times to refine the developed strategies and optimise water recovery. The predominant theme behind the water recovery concepts is the minimisation of the flow paths for release of water from the disposed sand tailings. Successive developments of the conceptual mine water recovery strategies are shown on Figures 37 (a and b) and 38 (a to d).

1. The initial concept on Figure 37a uses open drains, corresponding to low areas on the pit floor, to recover water from the advancing front of disposed sand tailings. An underdrain along one side of the pit captures water from the slimes disposal area. This strategy is adequate for narrow pits, but not for wide pit areas.

2. The second concept (Figure 37b) is based on the sand-stackers traversing the pits and using the bottoms of the swales between overburden stockpiles as open lateral drains. Longitudinal drains would also be maintained along the sides of the pits to collect residual seepage from previous sand-stacker traverses and from the slimes disposal area. This concept assumes that two sand-stackers would each backfill half of the pits. Variations on this theme were also assessed using sand-stackers traversing inwards from the outside of the pit, outwards from the centre of the pit, or from one side to another.

3. The third concept adopts most of the ideas from the second, but assumes that two sand-stackers traverse the entire pit area in tandem Figure 38 (a to d). Open drains would also be present on both (western and eastern) sides of the pit, with one underdrain also collecting seepage from beneath the slimes disposal areas. Open drains would be maintained where possible behind the operating sand-stackers to collect residual water. Control of the slimes content in the process water stream would be maintained by periodically and temporarily diverting some of the return water through the slimes disposal areas for settlement.

5.2.1 Controls on Sand Tailings Water Recovery

Findings of the iterative development of sand tailings water recovery concepts indicate that numerous factors control water recovery. These factors include:

- Number of drains.
- Drain efficiency (conductance) - 1,000 m^2/day.
- Drain spacing – variable, see model domains on Figure 37 (a and b).
- Sand thicknesses beneath the pit floor of 0, 2, 5, and 10 m.
- Sand-stacker advance rate of 5, 10, 15, 35, 55 or 80 m/day laterally across the pit.
- Sand-stacker cyclone underflow density of 65 % solids (i.e. 35% water).
- Discharge rate (water fraction of sand tailings) of 28,130 kL/day.

Numerous versions of the generic models have been applied to predict tailings water recovery rates and potential impacts of artificial recharge and water table mounding. Notwithstanding, it is understood that the key variables that will influence rates of tailings water recovery include the rate of sand-stacker advance and the thickness of undisturbed sand beneath the pit floor. As such, each model version simulates a different rate of sand-stacking traverses within the pit, reflecting different pit dimensions and rates of mining advances. These models were then used to simulate the rate of tailings water recovery and extent of water table mounding within the superficial formations due to variations in the thickness of sand beneath the pit floor.

The conceptual sand tailings water recovery plan shown on Figure 38 (a to d) with the preferred typical drain configurations at four stages of pit development:

(a) The beginning of the pit with no trailing lateral drain behind the first sand-stacker traverse.

(b) The middle of a typical sand-stacker traverse, with all drains active.

(c) The change-over from one sand-stacker traverse to the next, with significant residual flows from the previous traverse and full flows at the start of the new sand-stacker traverse.

(d) The end of the pit with no facing lateral drain in front of the last sand-stacker traverse.

The generic set of models incorporate the following features:

- Two sand-stackers operating in tandem at a rate of advance dictated by pit depth and overall mine advancement rate.
- Each traverse by the sand-stackers would backfill the pit (on top of the overburden) to a height compatible with rehabilitation requirements.
- Tailings water disposal from the sand-stackers is simulated using recharge cells, with rates of recharge compatible with the forecast underflow characteristics of the sand-stackers.
- Steady and constant operation of the sand-stackers has been simulated, but in practice, the units are forecast to operate for only about 81% of the time.
- Lateral (across the pit) and longitudinal (along the western and eastern sides of the pit) drains are simulated using rows or columns of drain cells. The base of each drain cell is set to the base of the pit floor, except in the trailing lateral drain that is set 5 m higher to simulate partial backfilling. The drain conductance is maintained at 1,000 m^2/day.
- Lateral drains are in-filled once sand is stacked over them. As such, these drains progressively lose their functionality and are deactivated once the sand-stacker passes-by.
- The longitudinal drains remain open for at least one sand-stacker traverse, or long enough to collect residual seepage from the previous sand-stacker traverse.

- Of the three lateral drains in front of the sand-stacker, the trailing lateral drain is assumed to be partially backfilled (by about 5 m) with sand from the previous sand-stacker traverse.

The variable sand-stacker operating settings are outlined in Table 18.

Table 18

Simulated Sand-Stacker Operating Settings

Model Setting	Sand-Stacker Advance Rate (m/day)	Sand Thickness (m, below pit-floor)
1	5	0
2	5	2
3	5	5
4	5	10
5	10	0
6	10	2
7	10	5
8	10	10
9	15	0
10	15	2
11	15	5
12	15	10
13	35	0
14	35	2
15	35	5
16	35	10
17	55	0
18	55	2
19	55	5
20	55	10
21	80	0
22	80	2
23	80	5
24	80	10

5.2.2 Characterisation of Sand Tailings Water Recovery

In all settings, the sand-stacker operations result in temporary mounding of the water table within the superficial formations. The mounding distributions, and magnitudes are constrained by the lateral and longitudinal drains. The predicted build-up of the mound during the first 20 days of operation is shown on Figure 39 for a sand-stacker advance rate of 5 m/day and no sand beneath the pit floor. As there is no trailing lateral drain in the first sand-stacker traverse, some tailings water is lost to storage beyond the pit perimeter. The mound grows in height to about 18 m beneath the sand-stackers, after 20 days operation (Figure 39).

Tailings water recovery rates are calculated using zone budget data from the predictive generic set of models. There are four components to the zone budgets:

1. Rate of tailings water use (A, constant at 28,130 kL/day) based on a maximum throughput rate of 2,200 tph. Actual rates of tailing water use will vary depending on throughput rates, cyclone underflow densities, slimes contents and slurry densities.

2. Water accumulation in aquifer storage (B) due to mounding of the water table within the superficial formations.

3. Water captured by the drains (C) from direct disposal (A) and release from storage (B).

4. Net tailings water recovery (D).

The tailings water recovery rate (as a percentage) is calculated as follows:

Tailings Water Recovery Rate (D) = Tailings water disposal rate (A) / Tailings water captured by the drains (C) x 100

A graphical representation of the predicted zone budget where there is 2 m of sand below the pit floor during six traverses of the sand-stackers is shown on Figure 40. A plan view snapshot of the water mound after one sand-stacker traverse is also provided on Figure 40.

The following description broadly frames the transient zone budgets for a pit area characterised by a sand-stacker advance rate of 5m/day and a 2 m thickness of sand beneath the pit floor.

1. **Start of Pit, Days 1 to 10**. The rate of tailings water lost into aquifer storage is initially about 2,500 kL/day, and rises to about 4,200 kL/day after 7 to 10 days. In these earliest stages, the tailings water is predominantly released directly into the drains, resulting in a recovery rate of about 91%. The remaining tailings water is lost to aquifer storage, saturating the 2 m thickness of sand beneath the pit floor in the vicinity of the sand-stacker. The rate of tailings water recovered by the drains begins to stabilise after 7 to 10 days, as the mound builds sufficiently to promote flow from storage to the drains. The recovery rate at this stage has dropped to about 85%. After about 10 days, the mound height is sufficient to enable flow from storage to the drains.

2. **Days 10 to 100**. After about 10 to 15 days, the contribution of tailings water lost to aquifer storage has nearly stabilised. During this period, the recovery of tailings water steadily increases as the mound intersects more drains. The recovery rate increases from 85% to about 90%. After 100 days, the rate of flow from aquifer storage into the drains has increased to about 2,000 kL/day, and the amount being lost to storage has stabilised at about 4,750 kL/day.

3. **Days 100 to 150**. As the sand-stacker traverse approaches the far side of the pit, the longitudinal drain on the pit-edge begins to intercept and recover tailings water. The quantity of water going into storage decreases. The contour plan shown on Figure 40 shows the residual mound left after the first sand-stacker traverse.

4. **Days 150 to 151**. One sand-stacker traversal of the pit will take 150 days. One day later, the sand-stacker is relocated back at the start, to commence tailings disposal beside the first longitudinal drain. This movement sees mound developments beneath the relocated sand-stacker. At this stage, the tailings water is mostly collected by the drains on three sides. Also, water is still being released from the mound on the far side of the pit. The net result is a brief period where the recovery rates are more than 100% of the sand-stacker rate.

5. **Day 150 onwards**. The second sand-stacker traverse will develop a mound of residual tailings water that is superimposed on the residual mound from the initial sand-stacker traverse. This cumulative impact results in a slightly higher overall recovery rate as the hydraulic gradients within the sand tailings steepen and stabilise at a faster rate. This response is more prominent in the faster mining rates.

6. **End of Pit**. As the sand-stackers reach the final traverse across the end of the pit, the recovery rates begin to fall. This is a function of fewer drains near the operating sand-stacker and losses to aquifer storage beyond the end of the pit. The graph on Figure 40 indicates the reduced rates of recovery are predominantly linked to extra losses of water into aquifer storage.

The characterisation of the sand tailings water recovery has been applied to predict the most effective drainage system that would promote water use efficiency. It is understood that recovery efficiencies are improved by:

- limiting of the length of the flow paths to the drains: and
- retention of drains, where practical, on all perimeters of the sand-stackers.

Conversely, the water use efficiency is diminished if the length of flow path is increased and the number of drains is decreased.

Predictive simulations that explore these aspects and associated variation in sand tailings water recovery are outlined below.

5.2.3 Predicted Sand Tailings Water Recovery for Six Drains

The predicted net recovery rates for the simulated sand-stacker operating with six drains are summarised in Table 19 and on Figure 41 (a to b). The six active floor drains include the four oriented laterally and longitudinally as shown on Figure 38 (a to c). Similar overall recovery patterns are depicted for each setting, with lower recoveries at the start of each pit cycle and generally higher recovery rates during the middle and end stages of each pit development. Comparatively high rates of recovery are also observed during each turn-around stage of the sand-stackers.

Table 19

Predicted Rates of Sand Tailings Water Recovery for Six Drains

Model Setting	Sand-Stacker Advance Rate (m/day)	Sand Thickness (m, below pit-floor)	Predicted Tailings Water Recovery (%)			
			First Sand-Stacker Traverse (Start of Pit)	Normal Sand-Stacker Traverse (Middle of Pit)	Last Sand-Stacker Traverse (End of Pit)	Overall Weighted Average
1	5	0	87	92	95	93
2	5	2	85	90	94	92
3	5	5	80	86	91	88
4	5	10	70	76	84	79
5	10	0	81	88	91	89
6	10	2	78	85	90	87
7	10	5	71	78	85	81
8	10	10	58	65	76	70
9	15	0	76	84	88	85
10	15	2	72	80	85	82
11	15	5	63	70	79	74
12	15	10	48	55	67	60
13	35	0	61	71	75	73
14	35	2	53	63	71	67
15	35	5	37	45	59	51
16	35	10	16	22	36	28
17	55	0	51	63	68	65
18	55	2	40	51	61	56
19	55	5	18	26	43	34
20	55	10	3	5	15	9
21	80	0	43	57	63	59
22	80	2	27	39	53	46
23	80	5	3	10	29	19
24	80	10	0	0	2	1

The simulations indicate an average recovery rate of 68%. Tailings water losses will generally be greatest during the first traverse in each pit. Higher recoveries will result where mining is continuous. High recovery rates are also expected where rates of sand-stacker advance are less than about 15 m/day and there is less than 2 m of sand beneath the pit floor. The predicted recovery rates decrease significantly where faster sand-stacking rates (>35 m/day) and greater sand thicknesses (>5 m) occur. The results indicate there would be limited sand tailings water recovery in areas where sand thicknesses of 5 to 10 m beneath the pit-floor are linked to rates of sand-stacker advance of 55 to 80 m/day.

5.2.4 Predicted Sand Tailings Water Recovery for Two Drains

To test the sensitivity of the simulated tailings water recovery strategies, the generic models were reconfigured with only two lateral drains in front of the sand-stacker units, as shown on Figure 42. A reduced drain configuration comprising only two lateral drains is simulated to predict sand tailings water recoveries under less efficient conditions.

The lower-bound net recovery rates for the simulated sand-stacker operating settings are summarised in Table 20 and on Figure 43 (a and b). These simulations indicate an average recovery rate of about 43%.

Table 20

Predicted Rates of Sand Tailings Water Recovery for Two Drains

Model Setting	Sand-Stacker Advance Rate (m/day)	Sand Thickness (m, below pit-floor)	Predicted Tailings Water Recovery (%)			
			First Sand-Stacker Traverse (Start of Pit)	Normal Sand-Stacker Traverse (Middle of Pit)	Last Sand-Stacker Traverse (End of Pit)	Overall Weighted Average
1	5	0	71	79	85	81
2	5	2	70	78	84	80
3	5	5	67	75	82	77
4	5	10	62	69	76	71
5	10	0	60	70	79	73
6	10	2	58	68	78	71
7	10	5	55	64	74	68
8	10	10	42	48	59	52
9	15	0	49	62	73	65
10	15	2	47	59	71	63
11	15	5	44	53	67	58
12	15	10	37	43	56	48
13	35	0	16	35	55	42
14	35	2	14	30	51	38
15	35	5	10	18	41	28
16	35	10	4	7	21	12
17	55	0	4	25	47	33
18	55	2	1	17	41	26
19	55	5	0	3	26	13
20	55	10	0	0	3	1
21	80	0	1	22	44	30
22	80	2	0	12	35	21
23	80	5	0	0	15	6
24	80	10	0	0	0	0

5.3 Water Recovery from Slimes Tailings

Water recovery from the slimes disposal trench and associated underdrain has not been simulated. Actual water recovery from the disposed slimes tailings will be controlled by operational practises, concentrations of fines, rates of seepage into the adjoining sand tailings, clogging of adjoining sand tailings and evaporation. These aspects are largely uncertain and consequently difficult to adequately frame in a predictive groundwater flow model.

Conservatively low recovery of waters from slimes tailings has been estimated and used in the assessments of consumptive water requirements (Appendix E). The estimates incorporate:

- Evaporation losses over the design slimes settling areas of about 27,000 kL/annum.
- Seepage losses into the superficial formations, Toolonga Calcilutite and sand tailings backfill that amount to about 1.6 GL/annum. This estimate is based on the loss of 80% of the water from the slimes settling area.

The aggregate estimated loss is about 1.63 GL/annum.

Actual water losses from slimes settling are anticipated to be less than those estimated. Seepage losses would be intercepted in part by the in-pit drains used to recover the sand tailings waters.

5.4 Estimated Consumptive Groundwater Use

In the predictive modelling, the rates of tailings water recovery from the sand-stacker operations is predominantly shown to be dependent on the rates of sand-stacker advance and the thickness of sand beneath the pit floor.

In order to estimate consumptive groundwater use, the mining schedule for the first 10 years of the project has been reviewed in context of these controls. The mining schedule (Appendix E) for the first ten years comprises the following:

- Mining from 7,033,000 to 7,050,250 m N with the following milestones:
  1. End of year one at about 7,035,625 m N
  2. End of year two at about 7,036,375 m N
  3. End of year three at about 7,037,000 m N
  4. End of year four at about 7,037,750 m N
  5. End of year five at about 7,039,625 m N
  6. End of year six at about 7,040,875 m N
  7. End of year seven at about 7,043,000 m N

8. End of year eight at about 7,048,000 m N
9. End of year nine at about 7,049,250 m N
10. End of year ten at about 7,050,250m N

- Northern mining advance rate of between 0.4 and 40 m/day (averaging 7 m/day).
- Rate of sand-stacker advance between 2.5 and 95 m/day (averaging 27 m/day).
- Pit floor elevation ranging from 55 and 86 m AHD, generally becoming lower to the north.
- Pit width ranging from about 70 to 2,700 m.
- Sand thickness below the pit floor ranging between 0 and 9 m.

Based on the findings of the predictive groundwater flow modelling, key elements of the estimated consumptive groundwater use include:

- Average annual rates of sand tailings water recovery range from 53 to 78%, with a long-term average of 68%.
- With only one concentrator operating during the first two years of mining, the annual water losses from the disposal of sand tailings are estimated to range between 2.0 and 2.3 GL/year, averaging 2.2 GL/year.
- With two concentrators operating, the annual water losses from sand tailings disposal are estimated to range between 2.9 to 5.9 GL/year, with a long-term average of 3.6 GL/year.
- The estimated sand tailings water recovery rates range from about 1,400 to 33,700 kL/day, averaging 11,200 kL/day.

Other variables used in estimates of consumptive water use include:

- Water In:
  a) Recharge from an annual mean rainfall of 112 mm on dams and active tailings operations of 50 ha in area.
- Water Out:
  a) Losses associated with the sand-stacker operations. This loss will only occur for the times (about 80%) that the sand-stackers are operational. On a gross scale, this loss is likely to average about 32% of the cyclone underflow volume.
  b) Losses from water retention by and seepage from disposed slimes. It is assumed that about 20% of this water will be recovered, primarily by decantation. These estimates are anticipated to be conservatively low.

c) Evaporation losses from process water dams (about 10 ha), slimes settling areas totalling 1.2 ha, stacked sand tailings (0.5 ha), and dust suppression over roads areas of 30 ha.

d) A small proportion of the confined aquifer supply will be used for a camp water supply, sourced from a dedicated bore near the camp site. It is estimated that about 270 kL/day will be required during construction to feed a reverse osmosis plant. The requirement is expected to drop to about 200 kL/day during normal operations.

Estimates of the annual consumptive water use based on an average tailings water recovery rate of 68% are provided in Table 21 and Appendix E. These estimates are expected to broadly frame the lower-bound consumptive water use.

The annualised water balance indicates that during first two years of operation, a minimum make-up supply of about 5.9 GL/year is required. Once two concentrators are operational, a minimum make-up supply range of between 9.9 and 11.3 GL/year is required for a long-term average of 10.4 GL/year.

Table 21

Estimates of Annual Consumptive Water Use Based on a 68% Tailings Water Recovery Rate

Year	Water Budget		Annual Make-Up Requirements (kL)
	Inputs (kL)	Outputs (kL)	
1	10,595	5,942,564	5,931,969
2	10,595	5,942,564	5,931,969
3	10,595	9,917,228	9,906,633
4	10,595	9,917,228	9,906,633
5	10,595	11,267,228	11,256,633
5 to 10	52,975	53,185,085	10,626,422
10 to 15	52,975	52,285,085	10,446,422
15 to 20	52,975	51,385,085	10,266,422
Average Water Requirement (1 concentrator)			5,931,969
Average Water Requirement (2 concentrators)			10,401,528

There are uncertainties in the estimates of consumptive groundwater uses. There are numerous factors and variables that will determine actual consumptive groundwater use. Variables that will control the actual consumptive groundwater use include:

- Operational practises, including:
  - water contents of disposed sand tailings;
  - sand-stacker operating strategies;

- dust suppression requirements;
- slimes tailings strategies;
- in-pit water management;
- capacity of the water storage dam(s); and
- lining of the water storage dam(s).

- Hydraulic conductivity of both the disposed sand tailings and *in-situ* superficial formations.
- Hydraulic conductivity of the shallow Toolonga Calcilutite.
- Structure and form of the Toolonga Calcilutite contact with the superficial formations
- Climatic factors (rainfall and evaporation).
- Fines contents of the disposed sand tailings.
- Distributions of overburden in the backfill and sand tailings profile.

Results of the predictive sand tailings water recovery modelling have been applied to frame estimates of consumptive water use based on a sub-optimal average tailings water recovery rate of 43%. These estimates are shown in Table 22.

Table 22

Estimates of Annual Consumptive Water Use Based on a 43% Tailings Water Recovery Rate

Year	Water Budget		Annual Bore Confined Aquifer Make-Up (kL)
	Inputs (kL)	Outputs (kL)	
1	10,595	7,856,440	7,845,845
2	10,595	7,856,440	7,845,845
3	10,595	13,744,980	13,734,385
4	10,595	13,744,980	13,734,385
5	10,595	15,094,980	15,084,385
5 to 10	52,975	72,323,845	14,454,174
10 to 15	52,975	71,423,845	14,274,174
15 to 20	52,975	70,523,845	14,094,174
Average Water Requirement (1 concentrator)			7,845,845
Average Water Requirement (2 concentrator)			14,229,280

These estimates might be exceeded under some operational settings. Based on the long-term average consumptive uses for the 43 and 68 % tailings water recoveries, it is estimated that a minimum long-term average tailings water recovery rate in the order of 30% may arise. For two concentrators, this would lead to a maximum consumptive water use of 18 GL/year

5.5 Predicted Extents of Water Table Mounding During Mining

The height and extent of water table mounding beneath individual southern dry pits has been predicted for each of the operational sand-stacker settings described in Table 18. The predictions are focussed on the period of mining, intending to show the short-term mounding distributions. The predictions are intended to represent upper-bound mound heights, assuming the mounding would progressively decay once sand-stacker operations cease in respective pits. Mounding in the vicinity of the northern-most pit is separately assessed due to shallowing depths of the proposed mining and consequent increased potentials for impacts on near-surface and surface environments.

5.5.1 Southern Pit Areas

The current mine plans typically have pit developments with less than 2 m of sand below the pit floor. Under these conditions, it is expected that the mounding may typically reach heights of about 11 m beneath the sand-stackers. The simulated mounds would propagate about 800 to 900 m behind the initial pit area and about 500 m beyond the pit sides as mining advances. The mounding is also estimated to extend about 400 m beyond the end of individual pits.

Mounds accumulated in aquifer storage for the typical case of a 5 m/day sand-stacker advance at several sand thicknesses below the pit floor are shown on Figure 44a. Differences in the mounding caused by rates of sand-stacker advance up to 80 m/day and range of sand thicknesses are shown on Figure 44 (b to f) for the optimum drain configuration.

Under circumstances where only two drains are operating and the sand tailings water recovery is comparatively inefficient, the mounding is of greater magnitude, as shown on Figure 45 (a to f).

In all cases, the outer portions of the mounds are predicted to be less than 2 m in height. Mounding of this magnitude locally poses potential risks if the water table propagates into the root zone of the overlying vegetation. This may occur in areas adjacent to the mining operations where the thickness of the superficial formations is less than 10 m. These areas are described on Figure 46 and shown to be predominantly aligned both west and east of the southern pits and to the north of the northern pit. The western and northern areas occur within the Shark Bay World Heritage Property.

Pits occur within several hundred metres of the Shark Bay World Heritage Property in four places along the western and northern project area boundaries. In these areas, the mine plans (Appendix E) indicate sand-stacker rates of advance between 4 and 60 m/day and sand thicknesses below the pit floor of up to 4 m. Predicted mounding during the development of these pits may extend up to 400 m inside the Shark Bay World Heritage Property. Predicted water table mounding during mining in proximity to the Shark Bay World Heritage Property is summarised in Table 23.

Table 23

Estimated Mound Heights at the Shark Bay World Heritage Property Boundary

Domain	Sand-Stacker Advance Rate (m/day)	Pit Floor Sand Thickness (m)	Model Setting	Predicted Mound Extent		Mound Height at SBWHP Boundary (m)
				Lateral (m)	Into SBWHP (m)	
7,032,800 to 7,034,800	35	0	13	400	300	2.0
7,036,000 to 7,038,500	30	0 – 1	13 - 14	400-500	300-400	2.0 – 2.5
7,044,500 to 7,050,000	24	0 – 4	10 & 14	400-500	200-400	2.0 – 2.5

Note: SBWHP - Shark Bay World Heritage Property

Importantly, the actual thickness of the superficial formations is unknown outside of the Amy Zone. Also, the accuracy of the ground surface topography is constrained by poor access and limited resolution of photogrammetry mapping. As such, errors of 5 m or more might be manifest in the superficial formations thickness isopachs. Consequently, the potential risks to vegetation can only be framed in semi-quantitative terms.

The mitigation of potential risk to stands of vegetation in perimeter areas of the proposed pits should be approached in a staged manner that enables collection of additional data and informed decision-making on actual risks. The staged approach includes:

- mapping of any currently unmapped areas of susceptible vegetation and investigation of typical depths of root penetration;
- the installation of multipiezometers in specific locations to characterise the ground surface elevation, thickness of the superficial formations, shallow Toolonga Calcilutite lithologies and water table elevations;
- enhancement of the Digital Terraine Model and topographic elevations;
- use of the additional data to refine the potential risks;
- monitoring of actual water table mounding; and
- where appropriate, maintain active drains in the pit(s) adjacent to areas at risk in order to intercept and abstract tailings waters locally contributing to the mounding.

The mitigation of all risks associated with mounding of the water table beneath shrubland areas is considered to be best and most practicably achieved through the localised use of drains in the developed pits. As shown on Figure 39 and Figure 40 the drains do effectively limit the transmission of tailings waters by locally dewatering to the pit-floor elevation. To be effective, such drains would need to be installed as early as practical during pit development and operated for the duration of subsequent mining in respective pits.

The drawdown impacts on the mounded water table might also be controlled in-part by variations in drain length and excavation of the drain beneath the pit floor. Longer and deeper drains would be more effective than shorter and shallower drains. These additional controls may be important in areas where the thickness of the superficial formations beneath the pit floor exceeds several metres.

5.5.2 Northern Pit Areas

The model of the northern pit conforms to the conceptual hydrogeological model, incorporating the interpreted Peron Sandstone, marine clay and Toolonga Calcilutite distributions. Also included in the model are:

- Surface topography and bottom elevations of the superficial formations compatible with the digital terrain model.
- Four layers that discretely represent:
  - Peron Sandstone and foreshore shell coquina dunal terrain;
  - marine clay beds;
  - Peron Sandstone; and
  - Toolonga Calcilutite.
- Hamelin Pool, as a suite of fixed-head cells.
- Hydraulic parameters for Peron Sandstone that are compatible with those in the generic models.

Hydraulic parameters applied in the model are outlined in Table 24. Both the marine clay and Toolonga Calcilutite are represented as low transmissivity domains.

Table 24

Northern Pit Model Form and Hydraulic Parameters

Model Layer	Formation	Hydraulic Conductivity			Specific Yield (dimensionless)
		k_x (m/day)	K_y (m/day)	K_z (m/day)	
1	Peron Sandstone/Shell Coquina	10	10	10	0.2
2	Marine Clay	0.001	0.001	0.001	0.3
3	Peron Sandstone	10	10	10	0.2
4	Toolonga Calcilutite	0.0001	0.0001	0.0001	0.00001

The domain and form of the model are described on Figure 47 and Figure 48.

Simulated groundwater levels (Figure 49) are broadly compatible with those interpreted and shown on Figure 27 and Figure 31. Lateral variations in fixed-head boundary conditions have been applied to enable the simulated water table elevations to conform to those interpreted.

Subsequent to calibration, the northern pit model has been applied to evaluate the impacts during mining of water table mounding due to disposal of sand tailings. The predictive simulations were undertaken in three stages, using previous outputs as impacts to consecutive stages. Sand tailing is simulated as in the generic models, but rates of recharge are doubled to represent four sand-stacker units operating together.

Importantly, the simulations provide for pit development from the north to south (the opposite from all southern pits) and east to west. This development approach is intended to:

- Provide temporary drains along the northern pit floor, with the drains operating for periods compatible with mining in adjacent areas. In the east, the initial northern drain remains operating for 374 days.
- Limit the mounding that occurs in the north and east.
- Enable the focussing of residual mounding in western pit areas, where the water table occurs within the superficial formations and consequently provides higher transmissivity profiles within which the mound tailings waters would more readily dissipate.

Also, several areas north and east of the northern mining limits are characterised by interpreted depths to the water table of <1.0 to 3.0 m. These areas reflect a change in geomorphology from the Victoria Sand Plains to Carbla Plateau, and associated subcrop or outcrop of Toolonga Calcilutite. They also reflect the topography sloping towards Nilemah Embayment and the occurrence of intradunal swales where the thickness of the superficial formations is constrained.

The predictive findings for the northern pit areas are shown on Figure 50 (a to c) for incremental periods during the mining. These predictive findings show:

- The progressive development of a west to east elongate mound that is about 10 m and 3 m in height within the western and eastern pit areas at the end of mining.
- In the eastern areas, the mound distribution and height steadily increases during the period of mining, despite mining having previously retreated from these areas. This characteristic shows preferential re-wetting of and flow within the deposited sand tailings. This aspect is interpreted to be linked to the comparatively high transmissivity of the saturated sand tailings as opposed to that of the dry superficial formations or saturated shallow Toolonga Calcilutite.
- The mounding during mining encroaches on areas to the north and east of the pit where the interpreted water table occurs at depths of <1.0 to 3.0 m. This encroachment is predicted to cause shallowing of the water table to depths of <1.0 m in two local settings, perhaps to within the root zones of the vegetation stands. These settings occur outside of the Shark Bay World Heritage Property.
- Beneath the western pit limits and adjoining Shark Bay World Heritage Property areas in the northwest, the mounding typically occurs in settings where the superficial formations are thickening and depths to the water table predominantly exceed 15 m. Mounding propagates distance up to

about 500 m into the domain of the Shark Bay World Heritage Property, with heights of up to about 5 m.

As for the southern project areas, the mitigation of potential risks to stands of vegetation should be approached in a staged manner involving the investigation of any currently unmapped areas of susceptible vegetation, typical depths of root penetration, installation of multipiezometers to accurately define the local water table environment and monitoring of actual water table mounding. Where appropriate, active remediation would involve the retention of active drains in northern pit areas to intercept and enhance recovery of the tailings waters. Based on the predictive simulations, the potential risks linked to water table mounding would be mitigated by the retention of active drains within the eastern half of the pit coupled with a north to south spur drain that evenly subdivides the pit. These drains would be installed as early as practicable and maintained in operation for the duration of mining.

5.6 Predicted Fates of Tailings Waters

The estimates of tailings water recovery and consumptive water uses indicate that large volumes of groundwater are residual within tailings profiles and the adjoining superficial formations after development of individual pits. The residual volumes and associated water table mounds would dissipate over time, along subsurface flow paths towards the Indian Ocean, Freycinet Reach and Hamelin Pool controlled by the regional water table.

The water table mounds in each pit would decay in height after the removal of the sand-stackers. Subsequently the residual mound would migrate down gradient, progressively dissipating within the water table environment. These aspects have been investigated using one of the developed generic models and the northern pit model of the sand-stacker operations and sand tailings water recovery.

The simulations are intended to broadly frame:

- the rate of decay of the height of the mound;
- rate and distance that the leading edge of the mound propagates;
- dissipation of the mound;
- influences on the mound and its decay imposed by the structure of the Toolonga Calcilutite contact;
- fate of the residual waters; and
- potential environmental impacts, if any, due to encroachment of the mound within the root zones of vegetation and outcrop of the water table in discharge zones.

The predictive results of the modelling are semi-quantitative. They are intended to broadly characterise potential environmental risks linked to the migration of the tailings waters. It is anticipated that the models represent a worst case, understanding that actual rates of mound dissipations would be enhanced by:

- downward leakage to the regional water table within the Toolonga Calcilutite;
- the dipping surface of the Toolonga Calcilutite and associated palaeovalleys that would control groundwater flow directions; and
- occurrence of preferred groundwater flow paths in the shallow Toolonga Calcilutite.

5.6.1 Southern Project Areas

The generic model selected for use is characterised by 2 m of superficial formations beneath the pit floor and a 15 m/day rate of sand-stacker advance, conditions that broadly typify most pits. Each model has been applied to predictive simulations that commence upon cessation of sand-stacker operations and continue for a period of 50 years.

The predictive results from the generic model are shown on:

- Figure 51 (a and b), outlining the incremental changes in mound distribution over a period of 50 years; and
- Figure 52 (a and b) outlining the potential transient mound distributions on four transects to the west of the proposed pits and beneath the Shark Bay World Heritage Property.

The predicted results for the southern project areas show:

- The distributions of the mounds are constrained by the structure contours of the Toolonga Calcilutite.
- Dissipation of the mounded waters in the immediate pit areas and on the boundary of the Shark Bay World Heritage Property takes time. On the four sections shown on Figure 52b, the height of the mound on the boundary of the Shark Bay World Heritage Property diminishes by about 1.5 m over a 50-year period after mining of the local pit.
- The mounds propagate laterally distances in the order of 1,000 m during the initial five years after cessation of local mining.
- After 50 years, the leading edges of the mounds occur at distances up to 2,000 m from the local pits. Heights of the mounding at distances of 1,000 to 2,000 m from the pits are typically less than 1.0 m.
- The mounding is small-scale compared to the interpreted thickness of the superficial formations and typically would occur at least 10 m below the ground surface. Beneath intradunal swales the mounding would be closest to the ground surface. Projections of the predicted mounding onto cross-sections beneath the Shark Bay World Heritage Property, shown on Figure 52, indicate a minimum depth to the water table of about 4 m at one location.

Based on the outlined predictive findings, it is interpreted there would be low environmental risks associated with the long-term transport and fate of the tailings waters from the southern project areas. That said, it needs to be recognised that these findings are semi-quantitative, due to constraints imposed by the available data (as per Section 5.6.1), and need to be re-appraised in an operational environment based on a staged approach to mapping of vegetation, determining typical depths of root penetration, installation of multipiezometers and monitoring of actual water table mounding.

As discussed earlier, the mitigation of all risks associated with mounding of the water table beneath shrubland areas is considered to best and most practicably achieved through the localised use of drains in the developed pits. The recovery of tailings water locally during mining operations would reduce the mound dimensions and volumes. This approach is directed at source removal and avoidance of access and intrusive activities within the Shark Bay World Heritage Property.

Northern Project Areas

The northern pit model is characterised by regional flow towards the Nilemah Embayment and Hamelin Pool. The water table environment naturally shallows as the topography slopes towards the Nilemah Embayment and associated groundwater discharge zones. The predictive results from the northern pit model are shown on Figure 53 (a to h) and Figure 54 (a to c). Results of the predictive simulations show:

- Residual mound heights within the pit area progressively decay from 3 to 10 m at the end of mining to a maximum of 3 m after 10 years. Subsequently, the residual mound becomes increasingly segregated. After 50 years the mounding has a 2 m peak, is widely distributed and has entered groundwater discharge zones formed by salina landscapes within the Nilemah Embayment.

- Residual tailings waters in the mound progressively migrate to the north. After 10 years the leading edge of the mound has reached salinas within the Nilemah Embayment at distances up to 1.8 km from the northern pit crest. The mound propagates faster in areas where the thickness of the saturated superficial formations is greatest. This occurs to the northwest rather than northeast of the pit.

  In the northwest, beneath the Shark Bay World Heritage Property, the mound is simulated to reach a quasi steady-state distribution after about 20 years. Thereafter, the mounding magnitude and distribution does not significantly change.

  In the northeast, the mounding continues to propagate over the 50-year post-mining period. The rates of propagation are comparatively slow because the superficial formations locally are thin and predominantly dry.

- The mounding propagates beneath both dunal terrain and salina areas where the interpreted water table occurs at depths of <1.0 to 3.0 m. The predicted rises in the water table elevations in these areas would be to within 1 m of the ground surface. The simulations do not show discharge of groundwater onto the ground surface.

  Potential impacts in terms of invasion of vegetation root zones and groundwater discharge would be linked to intradunal swales and the southern perimeter of the salinas, along the fringe of the dunal terrain.

- Rates of increased groundwater throughflow into the salina areas due to the presence of the residual mounding (Figure 54c) are predicted to peak in the order of 185 kL/day, about 17% above that simulated during baseline conditions. A throughflow increase of this magnitude may be predominantly intercepted by evaporation in fringe areas of or within the salinas. Evaporation losses would locally increase the salt loadings within the shallow water table environment and shallow soils.

The predictive simulations have investigated several mining and sand tailings water recovery scenarios. These scenarios incorporate drains along the northern wall of the pit and vary regarding lengths of and periods of operations for the drain systems. All of the predictive simulations show that the practical variations in drain lengths and operating periods do not substantially reduce the height of the residual mound where the interpreted water table occurs at depths of <1.0 to 3.0m. These outcomes reflect the local environment where residual mounding of 0.5 to 1.0m poses potential risks.

The predictive simulations broadly characterise the northern pit and Nilemah Embayment hydrogeology. However, the simulations do not incorporate evaporation losses and consequently do not replicate potential groundwater discharge within the salina environment. As such, the simulations might overestimate the heights of the residual mounds that propagate into areas of shallow depths to the water table. Notwithstanding, additional investigations are required in the northern pit areas and Nilemah Embayment to characterise the vegetation and water table environments. These investigations should include vegetation mapping, quantifying the typical depths of root penetration, installation of multipiezometers (within the superficial formations, marine clay and Toolonga Calcilutite) and aquifer testing. These investigations should be coupled with reviews of the northern pit mining plans. To mitigate environmental risks linked to the development of the northern pit, there is a potential need to reduce the rate of mining, limit the number of sand-stackers in operations and reduce the residual mound height.

5.7 Predicted Pit Dewatering Requirements

The proposed northern pits would intersect the water table within the reworked successions of the Peron Sandstone. Typically, the saturated thickness of the profile to be mined is less than one to two metres, thus representing a low-transmissivity, limited-extent aquifer setting. Nevertheless, groundwater abstraction will accompany the northern pit mining developments.

The northern pit dewatering requirements have been assessed using the conceptual hydrogeological model. Based on this assessment, the effects of dewatering to provide comparatively dry mining conditions are considered to be negligible because:

- The water table is generally about 30m below ground surface in the immediate vicinity of the northern Amy Zone.
- The local aquifer is of limited extent and of low-transmissivity.
- Groundwater abstractions required to dewater to the pit-floor elevation are expected to be of small-scale, predicted to be less than 500 kL/day for a period of about one year.

- Drawdown of the water table beyond the pit limits would be of small-scale due to the limited thickness of the saturated profile and its low-transmissivity.

In addition to these aspects, it is expected that the water table is not supporting any dependent ecosystems (due to the depth and known salinity of the shallow groundwater resources) and artificial recharge of the water table by water from the sand tailings would predominantly offset any drawdown impacts.

5.8 Mine Water Salinity Issues

The salinity of the mixed groundwater abstracted from Birdrong Sandstone and Kopke Sandstone in DTB1 is 8,900 mg/L TDS. Once the abstracted groundwater enters the processing circuit, the salinity is expected to progressively increase due to evaporative effects both in the process water dam(s), sand-stacker operations, slimes tailings disposal and tailings water recovery drains. It is also likely that comparatively small concentrations of salt would be mobilised from the parent sandstone.

An assessment of forecast increases in salinity of the process water due to evaporation is presented in Table 25. This assessment is predominantly based on potential water losses from the process water dam(s) and sand-stacker traverses.

Table 25

Forecast Salinity of Process Water

Year	Raw Water Salinity (mg/L TDS)	Raw Water Abstraction (kL)	Total Evaporative Losses[1] (kL)	Salinity Multiplier[2]	Process Water Salniity[3] (mg/L TDS)	Cumulative Salinity Increase[4] (%)
1	8,900	4,568,742	30,302	0.00663	8,959	0.7
2	8,900	4,568,742	30,302	0.00663	9,018	1.3
3	8,900	9,727,870	49,381	0.00508	9,063	1.8
4	8,900	9,729,622	49,381	0.00508	9,108	2.3
5	8,900	9,727,870	49,381	0.00508	9,154	2.8
10	8,900	9,565,372	246,904	0.02581	10,302	16
15	8,900	9,729,622	246,904	0.02538	11,431	28
20	8,900	9,729,622	246,904	0.02538	12,561	41

Notes:
1 These calculations are based on recirculating the same process water stream for the entire mine life. Evaporation is assumed to be from active process water dams, slimes settling trench and sand-stacker sites.
2 Salinity Multiplier = Evaporation Losses divided by Abstraction
3 Forecast Process Water Salinity = Raw Water Salinity + (previous forest process water salinity x salinity multiplier)
4 Actual salinities will be lower if the process water circuit is purged between concentrator relocations.

The completed assessment indicates that salinity increases due to evaporation in the first five years are likely to be insignificant. This is due to the relatively large volume of make-up water used compared to that evaporated. The actual salinity increases may be higher than indicated in Table 25 due to the addition of stored soil salt from the processed ore. The increases in salinity from 8,900 to 12,600 mg/L TDS are not significant in context to the local groundwater environment or potential impacts.

5.9 Summary of Predicted Impacts on Flora and Fauna

The findings of the groundwater resources impact assessments indicate that the predominant environmental issues and potential risks within the superficial formations linked to the Amy Zone development include:

- recovery of sand tailings waters and limiting the potentials for mounding of the water table, within both the southern and northern project areas, propagating into the root zones of vegetation stands;
- potentials for discharge from the northern water table mounds into salina domains within the Nilemah Embayment and the Shark Bay World Heritage Property.

These assessments also indicate that the potentials for adverse environmental impacts linked to the outlined issues is low and broadly acceptable in the south, but medium in the north and requiring the identification of further risk reduction options. Within the superficial formations, the predictive modelling results show that:

- water table mounding within the southern project areas that potentially threatens vegetation root zones can be mitigated by the dedicated operation of in-pit trench drains that intercept and enhance recovery of tailings waters;
- water table mounding within the northern project areas that potentially threatens vegetation root zones can be mitigated by refining knowledge of salina water table and groundwater discharge environments and reviewing mining plans to reduce the rate of northern pit development, the number of sand-stackers in operation and the magnitudes of the residual mounds; and
- the simulated mounds do not actually have a surface expression within the salinas.

Studies of the local fauna, flora and stygofauna undertaken during environmental impact assessments include:

- Flora studies by Mattiske Consulting (Mattiske, 2005).
- Stygofauna studies by the University of Western Australia (UWA, 2005).
- Vertebrate fauna studies by Ninox Environmental Services (Ninox, 2005).

No groundwater-dependent flora or fauna are known in the project area. No stygofauna were found following a survey conducted on shallow groundwater bores in and near the project area (UWA, 2005).

The proposed mining developments would temporarily alter the water table environment. In several areas along the flanks of the Amy Zone in the south, and beyond the northern boundary of the northern pit, within Nilemah Embayment, there may be insufficient thickness of the superficial formations to prevent potential interaction between the mounded water table and vegetation root zones. Residual tailings waters may rise close to the surface near the base of the Peron Sandstone dunes around the fringes of the Nilemah Embayment. The residual water table mounding due to sand tailings disposal is predicted to remain within about 3 km of the project area. Throughflow would be towards the Nilemah Embayment, with discharge being controlled in part by evaporation-dominated hydro-cycle in salinas, presence of marine clay beds and rates of groundwater throughflow.

The nearest groundwater dependent ecosystem is likely to be the salina and estuarine ecology associated with the Nilemah Embayment and Hamelin Pool. Both are groundwater discharge areas.

The stromatolites along the shoreline of Hamelin Pool, near the old Hamelin Telegraph Station, are located in groundwater discharge zones about 12 km from the northern project area. The groundwater discharge is from a different catchment than the project area and Nilemah Embayment. There are no predicted impacts on the Hamelin Pool ecosystem due to occurrence of residual tailings waters in the superficial formations and water table environment.

Additional investigations are required to refine the understanding of the local vegetation systems and water table environment. Results of these investigations would be applied to refine the potential environmental risks and develop appropriate and practical mitigation strategies.

These aspects might be aligned with reviews of the mine plans for the northern pit that consider options for scheduling and/or staging of the developments to lengthen the mining period, minimise the number of sand-stackers in use and consequently reduce the volumes of tailings waters in residual mounds.

Based on the assessments of sand tailings water recovery and consumptive water use forecasts it is evident that large-scale groundwater abstractions would be required to meet process water supply demands. These abstractions are proposed to be sourced from the regional confined aquifers formed by the Birdrong Sandstone and Kopke Sandstone. Predictive assessments of the potential impacts of the forecast large-scale process water supply abstractions are outlined below.

6.1 Confined Aquifer Groundwater Flow Modelling

A groundwater flow model of the confined aquifer systems has been developed to predict the impacts of large-scale abstractions for make-up of process water supplies.

The simulated southern Carnarvon Basin structure is derived from that interpreted by Wills and Dogramaci (2000); original bore logs are used to interpolate between areas of higher confidence. Most stratigraphic units are simulated as separate hydrogeological domains and assigned hydraulic parameters that correspond with the findings of the site investigations, published data or assumed values.

6.1.1 Model Code

The confined aquifer model is developed in MODFLOW. MODFLOW is a three-dimensional block-centred finite-difference code developed by the USGS to simulate groundwater flow in the saturated subsurface. Visual MODFLOW from Waterloo Hydrogeologic Inc. is used as the pre- and post-processor.

6.1.2 Model Domain and Form

Surface topography is derived either from a local domain model in the project area or digitised spot heights from published 1: 100,000 scale topographic maps. Coastlines are set to have a sea level elevation with fixed-head cells set to a similar level offshore. The model domain encompasses an area of 175 by 280 km centred on the project site (Figure 55). The developed model incorporates 12 layers compatible with the stratigraphy as shown in Table 26. The structure of the confined aquifer model is shown in cross sectional form on Figure 56.

Table 26

Layered Form of the Confined Aquifer Model

Layer	Description
1	Superficial Formations
2	Toolonga Calcilutite
3	Alinga Formation
4	Windalia Radiolarite
5	Windalia Sand Member
6	Muderong Shale Formation
7	Birdrong Sandstone
8	Kopke Sandstone
9	Sweeney Mia Formation
10	Faure Formation
11	Dirk Hartog Group
12	Tumblagooda Sandstone

Several layers are sub-divided to assist with the simulation of vertical groundwater level distributions within the confined aquifer systems.

6.1.3 Boundary Conditions

Boundary conditions are broadly configured to simulate the interpreted groundwater levels and throughflow dynamics of the confined aquifer systems. Where possible, the model boundaries correspond with regional structural or geological boundaries such as:

- Ajana Ridge and Hardabut Fault (eastern and southeastern boundaries).
- Tectonic faults evident in seismic interpretations (western boundary).
- Pinching-out of the Kopke Sandstone to the west.
- Groundwater divides interpreted from surface drainage catchments.

The northern boundary of the model is chosen on the basis of its physical remoteness from the project area.

Boundary types used by the model include:

- Fixed-head in east, to simulate regional throughflow from the Ajana Ridge.
- Fixed-head corresponding to the Murchison River catchment divides in the south and local unconfined groundwater levels.

- Fixed-head river cells in the west and northwest, representing sea level. These cells enable groundwater to enter or leave the Gascoyne Platform at a controlled rate, thus allowing the observed regional gradients to be broadly simulated under steady-state conditions.

- No-flow in the north.

The river cells in MODFLOW act as groundwater sinks when the specified river cell elevations are below the water table. By setting the river cell drain elevations to sea level, the model removes groundwater that is above this elevation in each river cell. Inclusive in the river cell specification is the conductance, which can be used to retard flow into the drain cell. The river cell conductance was iterated during the steady-state simulations, arriving at values typically between 1 x 10^{-2} and 1 x 10^{-8} m^2/day to simulate the interpreted regional groundwater levels and both lateral and vertical groundwater flow gradients.

The simulated boundary conditions are described on Figure 57.

6.1.4 Hydraulic Parameters

The hydraulic parameters applied in the model are shown in Table 27.

Table 27

Confined Aquifer Model Hydraulic Parameters

Model Layer	Formation	Hydraulic Conductivity			Specific Storage (1/m)	Specific Yield (dimensionless)
		K_x (m/day)	K_y (m/day)	K_z (m/day)		
1	Superficial Formations	10	10	10	$1x10^{-5}$	0.2
2	Toolonga Calcilutite	0.0001	0.0001	0.00001	$1x10^{-5}$	0.01
3	Alinga Formation	0.001	0.001	0.0001	$1x10^{-5}$	0.005
4	Windalia Radiolarite	1	1	0.0001	$1x10^{-5}$	0.01
5	Windalia Sand Member	2	2	0.2	$1x10^{-5}$	0.1
6	Muderong Shale Formations	0.0001	0.0001	0.00001	$1x10^{-5}$	0.005
7	Birdrong Sandstone	13	13	1.3	$1x10^{-5}$	0.1
8	Kopke Sandstone	1.9	1.9	0.19	$1x10^{-5}$	0.1
9	Sweeney Mia Formation	0.01	0.01	0.001	$1x10^{-5}$	0.01
10	Faure Formation	0.01	0.01	0.001	$1x10^{-5}$	0.005
11	Dirk Hartog Group	0.001	0.001	0.0001	$1x10^{-5}$	0.005
12	Tumblagooda Sandstone	1	1	0.1	$1x10^{-5}$	0.05

Uniform horizontal hydraulic conductivities are assigned to all layers. Generally, the vertical hydraulic conductivity is one order of magnitude below the horizontal value, to take into account normal differences observed in sedimentary aquifers. Several of the aquitard formations and the Windalia Radiolarite have been assigned stronger horizontal to vertical anisotropy, to simulate observed relatively large groundwater level differences over small vertical depths.

6.1.5 Model Calibration

The purpose of calibration is to establish that the model can reproduce observed groundwater levels, hydraulic gradients and regional flow paths. Calibration of the model comprised three stages. Firstly, a series of steady-state simulations were conducted to establish the regional groundwater flow, hydraulic gradients and groundwater elevations near the project area. Subsequently, the model was applied in transient mode, using the steady-state groundwater levels as the initial conditions.

The calibration process involved adjusting the boundary positions, conditions and hydraulic parameters, within realistic ranges, so that the simulated groundwater levels in each of the main aquifers broadly matched those interpreted.

The final calibration stage involved simulation of the local aquifer responses to test pumping in DTB1.

The simulated steady-state groundwater levels in the Windalia Radiolarite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone are shown on Figure 58 (a to d).

Groundwater throughflow mechanisms from recharge to discharge zones are shown on south to north and east to west section views on Figure 59 (a and b) and Figure 60 (a and b). These figures show both simulated potentiometric levels and flow vectors in profile.

The figures show a predominance of vertical upward groundwater flow throughout the stratigraphic profile, with discharge into the Alinga Formation, Toolonga Calcilutite and the superficial formations. Potentiometric levels in the stratigraphic profile and rates of discharge are predominantly controlled by the simulated vertical hydraulic conductivity of the Muderong Shale Formation, Alinga Formation and Toolonga Calcilutite. Outcomes of the predictive modelling are sensitive to these hydraulic conductivity values. Notwithstanding the vertical upward groundwater flow characteristics are compatible with the conceptual hydrogeological model of the confined aquifer systems.

No allowance has been made in the model calibration of regional impacts resulting from the long-term abstraction of groundwater from uncontrolled artesian and non-artesian bores. There is insufficient evidence available to determine the impacts of such abstractions, either before or after the recent bore rehabilitation programme. If the groundwater system has been historically depressurised, any recent recovery linked to the bore-rehabilitation programme would tend to reduce the predicted drawdowns.

6.2 Simulated Large-Scale Abstraction

The confined aquifer predictive simulations are based on the estimates of annual consumptive groundwater use of 11 and 15 GL/annum, assuming make-up supply demands would be met by abstractions from the Birdrong Sandstone and Kopke Sandstone. These simulations have been applied to enable predictive determinations of:

- Locations of the production bores and overall borefield layout, cognisant of drawdown interference effects that may influence production bore designs.

- Local and regional drawdown distributions due to the forecast abstraction.
- Potential drawdown impacts on private bores.
- To assess the impact of the forecast abstraction on the regional groundwater flow budget.

The design production bores are nominally spaced 3 km apart along the eastern perimeter of the Amy Zone, as shown in Table 28 and on Figure 61. This spacing is based on a cost-benefit analysis incorporating the predicted drawdown interference. Actual production bore spacings may vary depending on location of suitable drilling sites, distances to the nearest power source and actual consumptive water use. In practice, all production bores would preferentially be located adjacent to the access road that is planned to run the length of the mine site.

Table 25

Design Production Bore Locations

Production Bore	Location (m MGA)	
	Eastings	Northings
CPB1	216,200	7,036,100
CPB2	216,150	7,039,100
CPB3 (DTB1)	216,318	7,041,723
CPB4	215,050	7,044,300
CPB5	215,200	7,047,500
CPB6	215,300	7,050,950
CPB7	214,750	7,053,850
CPB8	214,200	7,055,900
CPB9	212,350	7,058,700
CPB10	211,700	7,061,700
CPB11	212,300	7,063,700
CPB12	213,625	7,065,000
CPB13	220,340	7,034,250

The large-scale abstraction simulations are based on each of the production bores pumping at the same rate. In reality, some production bores would operate continuously, whilst others would be used as required or be on standby. Short-term variations in supply demand would be offset where practicable by storage capacity in the process water dam(s). On a short-term basis, water demands are expected to peak:

- when sand tailings disposal has commenced in a new pit and initial tailings water volumes are lost to storage;
- when the rate of sand-stacker advance exceeds 15 m/day;
- when the sand-stackers are operating in areas where thick intervals of sand occur beneath the pit floor; and

- where the pit-floor drains have become backfilled, in part, by overburden or tailings.

The simulated production bores abstracted groundwater from both the Birdrong Sandstone and Kopke Sandstone, as in DTB1. They are activated and deactivated at selected times, to retain the concentrators near the centre of the borefield to minimise infrastructure and operating costs.

The simulated borefield operations include:

Abstraction of 11 GL/annum:

- Three production bores operating, with an aggregate pumping rate of 15,060 kL/day for one concentrator.
- The pumping rate is increased to an aggregate of 30,140 kL/day, from four production bores, with two concentrators operating after two years.
- Recovery of the aquifer systems after 20 years of abstraction.

The simulated schedule for abstractions of 11 GL/annum from individual production bores is provided in Table 29.

Table 29

Simulated Schedule for Abstraction of 11 GL/annum

Production Bore	Production Bore Commissioning (Year)	Production Bore Decommissioning (Year)	Operating Period (Years)	Individual Production Bore Abstraction (kL/day)	
				Years 1 and 2	After 2 Years
CPB1	0	7	7	5,022	7,534
CPB2	0	10	10	5,022	7,534
CPB3 (DTB1)	0	12	12	5,022	7,534
CPB4	3	13	10	0	7,534
CPB5	7	15	8	0	7,534
CPB6	10	17	7	0	7,534
CPB7	12	17	5	0	7,534
CPB8	13	17	4	0	7,534
CPB9	15	21	6	0	7,534
CPB10	17	21	4	0	7,534
CPB11	17	21	4	0	7,534
CPB12	17	21	4	0	7,534

Abstraction of 15 GL/annum

- Three production bores operating, with an aggregate pumping rate of 18,500 kL/day for one concentrator.
- The pumping rate is increased to an aggregate of 41,120 kL/day from four production bores, with two concentrators operating after two years.

- Recovery of the aquifer systems after 20 years of abstraction.

The simulated schedule for abstractions of 15 GL/annum from individual production bores is provided in Table 30.

Table 30

Simulated Schedule for Abstraction of 15 GL/annum

Production Bore	Production Bore Commissioning (Year)	Production Bore Decommissioning (Year)	Operating Period (Years)	Individual Production Bore Abstraction (kL/day)	
				Years 1 and 2	After 2 Years
CPB1	0	7	7	7,300	10,280
CPB2	0	10	10	7,300	10,280
CPB3 (DTB1)	0	12	12	7,300	10,280
CPB4	3	13	10	0	10,280
CPB5	7	15	8	0	10,280
CPB6	10	17	7	0	10,280
CPB7	12	17	5	0	10,280
CPB8	13	17	4	0	10,280
CPB9	15	21	6	0	10,280
CPB10	17	21	4	0	10,280
CPB11	17	21	4	0	10,280
CPB12	17	21	4	0	10,280

6.3 Extent of Predicted Drawdowns

6.3.1 Abstraction of 11 GL/annum

The predictive simulations show that drawdowns in the Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone will propagate outwards from the project area in a semi-radial pattern. The outer limit of measurable drawdowns is likely to extend 60 to 75 km from the project area.

The predicted drawdowns in Windalia Radiolarite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone after 1, 2, 5 10 and 20 years of 11 GL/annum abstraction are shown on Figures 62 to 65. The predicted drawdown also propagate vertically upwards in the stratigraphic profile, being manifest in decreasing magnitudes in the Alinga Formation, Toolonga Calcilutite and superficial formations, as shown on Figure 66 (a to c).

Drawdowns in the ***Windalia Radiolarite*** have been filtered to remove data from areas where this formation is absent. The drawdowns are predicted to propagate radially outwards from the borefield as shown on Figure 62 (a to e). The predicted 1 m drawdown contour propagates radial distances of 30, 40, 55, 65 and 75 km after 1, 2, 5, 10 and 20 years of abstraction. Where the Windalia Radiolarite and the

Windalia Sand Member coalesce, drawdowns of about 5 m are predicted after 20 years. The Nilemah No. 1A, Caravan Park and Hamelin Homestead bores lie between the 5 and 6 m drawdown contours after 20 years of abstraction.

Predicted drawdowns in the ***Windalia Sand Member*** shown on Figures 63 (a to e) have also been filtered to remove regions where this formation is absent. Drawdowns are predicted to propagate outwards from the southern project area to distances of 30, 35, 40, 50 and 55 km after 1, 2, 5, 10 and 20 years of abstraction. The northern, western and southern margins of the predicted drawdown cone on Figure 63 are truncated, but it is assumed there is sufficient aquifer continuity with the adjoining Windalia Radiolarite to limit any significant effects of aquifer discontinuity.

Radial drawdowns for the ***Birdrong Sandstone*** are shown on Figure 64 (a to e). The predicted drawdowns extend to distances of 30, 35, 50, 60 and 65 km after 1, 2, 5, 10 and 20 years of abstraction. The nearest artesian bores, including Nilemah No. 1A, Caravan Park and Hamelin Homestead, are approximately positioned on the 6 m drawdown contour after 20 years of abstraction. Nanga Resort and Sweeney Mia bores are located near the 2 m and 4 m drawdown contours. Drawdowns of about 15 m are predicted within the area traversed by the planned process water supply borefield between the 5 and 20-year periods.

Within the ***Kopke Sandstone***, the predicted drawdown distribution is generally radial, except where the aquifer system is juxtaposed the Tumblagooda Sandstone along the Ajana Fault. Drawdowns are predicted to propagate distances of 30, 40, 55, 60 and 65 km after 1, 2, 5, 10 and 20 years of abstraction, as shown on Figures 65 (a to e).

6.3.2 Abstraction of 15 GL/annum

The predicted drawdowns due to aggregate abstractions of 15 GL/year over the period of mining are of about 1.0 to 3.0 m greater magnitude that those associated with abstraction of 11 GL/year. Predicted drawdown impacts are shown on Figures 67 to 70 for the Windalia Radiolarite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone.

The shape of the predicted drawdown cone resulting from 15 GL/year are very similar to the 11 GL/year case. Although slightly larger, the predicted drawdowns resulting from 15 GL/year are not likely to cause significant impacts over that predicted from 11 GL/year. Predicted drawdowns after 20 years in the Windalia Sand Member at 50 km distance are about 0.5 m larger from 15 GL/year, while at 25 km they are only about 1 m larger. Similar trends are apparent within the other aquifers between the two abstraction rates.

Impacts of pumping 15 GL/year on the confining and superficial layers such as the Alinga Formation, Toolonga Calcilutite and superficial formations are expected to be similar to 11 GL/year. Propagation of the additional potentiometric head vertically through the Alinga Formation and lower sections of the Toolonga Calcilutite may only be measurable within 25 km of the mine and have no net impact on either the resource or other groundwater users.

6.4 Predicted Impacts on Private Bores

Drawdown impacts on private bores are likely to vary depending on the aquifer zones that they intersect and the local characteristics of vertical hydraulic connections with the Birdrong Sandstone and Kopke Sandstone. The predicted drawdown impacts on selected private bores are shown in Table 31 and on Figures 71 (a to d) and 72 (a to d), for abstractions of 11 and 15 GL/annum. The magnitude of drawdown impacts in bores that intersect only the Windalia Radiolarite or Windalia Sand Member are expected to be less than those intersecting the Birdrong Sandstone and Kopke Sandstone. Actual drawdown impacts will depend on the local and regional characteristics of vertical hydraulic connections between the Windalia Sand Member and the Birdrong Sandstone.

Table 31

Predicted Drawdown Impacts of 11 GL/annum Abstraction on Private Bores

Name / No.	Predicted Maximum Drawdown (m)	Predicted Time for Recovery to < 0.5 m (years)	Predicted Adverse Impacts	Equipped With	Proposed Remediation (if required)
Hamelin Station					
Hamelin Homestead No.3	6.28	6.0	Lower pressure for power generation	Artesian Headworks	
Hamelin No. 4	2	4.5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 5	5.5	5.5	Deeper pumping water level	Windmill	Lower pump inlet / Upgrade windmill
Outcamp Bore	2	4.5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 8	5.61	6	Deeper pumping water level	Windmill	Lower pump inlet / Upgrade windmill
Hamelin No 9	3.00	5.50	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 11	3.8	5.5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 13	1.4	4	None	Windmill	
Hamelin No. 14	2	5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 16	1.34	4	None	Windmill	
Hamelin No. 17 New	4.5	6.5	Deeper pumping water level	Not Equipped	Lower pump inlet
Hamelin No. 18	2.1	5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin No. 20B	1.32	4	None	Windmill	
Hamelin No. 23	4.2	6	Deeper pumping water level	Windmill	Lower pump inlet / Upgrade windmill
Hamelin No. 24	1.5	4	None	Not Equipped	
Hamelin No 26	1.2	3.5	None	Not Equipped	
Hamelin Spinifex 1	8.9	6	As for Spinifex 2	Flowing	As for Spinifex 2
Hamelin Spinifex 2	8.86	6	May stop flowing	Flowing	Provide alternative external source.
Hamelin Kevins Bore	3.26	5.5	Deeper pumping water level	Windmill	Lower pump inlet
Hamelin Five Mile Bore	4.8	5.5	Deeper pumping water level	Windmill	Lower pump inlet / Upgrade windmill
Hamelin Ten Mile Bore	3.26	5	Deeper pumping water level	Windmill	Lower pump inlet
Sweeney Mia Bore 2001	3.68	5	Lower flow pressure	Nil - Artesian Headworks	
Coburn Station					
Coburn No. 7	7.72	6	Deeper pumping water level	Mono Pump 54.8m	Lower pump inlet
Coburn No. 8	3.52	7	Deeper pumping water level	Mono Pump 60.96m	Lower pump inlet
Coburn No. 9 B	8.16	7	Deeper pumping water level	Mono Pump 60.96m	Lower pump inlet
Coburn No. 11 B	2.5	5.5	Deeper pumping water level	Mono Pump 60.96m	Lower pump inlet
Coburn No. 14	5.54	7	Deeper pumping water level	Mono Pump 60.96m	Lower pump inlet
Overlander Roadhouse (Main Roads Bore)					
Overlander Roadhouse	2.27	5	Deeper pumping water level	Electric Submersible	Lower pump inlet
Billabong Roadhouse					
Billabong Roadhouse	0.93	3	None	Electric Submersible	

Table 31 (continued)

Name / No.	Predicted Maximum Drawdown (m)	Predicted Time for Recovery to < 0.5 m (years)	Predicted Adverse Impacts	Equipped With	Proposed Remediation (if required)
Hamelin Telegraph Station & Caravan park					
Hamelin Telegraph Station	5.88	6	Lower flow pressure	Nil - Artesian Headworks	
Meadow Station					
Meadow No. 1	1.15	3.5	None	Mono Pump	
Meadow No. 3	0.96	3	None	Electric Submersible	
Meadow No. 4	*0.5*	*3*	None	Windmill	
Meadow No. 5	*0.5*	*3*	None	Windmill	
Meadow No. 6	*0.5*	*3*	None	Mono Pump	
Meadow No. 7	*1.2*	*3.5*	None	Windmill	
Meadow No. 8 (New)	*1.7*	*4.5*	None	Not Equipped	
Nerren Nerren Station					
Nerren Nerren 1A	1.03	3	None	Mono Pump	
Nerren Nerren 5A	*<0.5*	*<3*	None	Mono Pump	
Carbla Station					
Carbla Homestead	*3.3*	*5*	None	Artesian Headworks	
Carbla No. 12	*2.5*	*5*	Deeper pumping water level	Windmill	Lower pump inlet
Carbla No. 13	3.07	5	Deeper pumping water level	Windmill	Lower pump inlet
Carbla No. 14	1.9	4.5	None	Windmill	
Carbla No. 16	2.47	4.5	Deeper pumping water level	Windmill	Lower pump inlet
Carbla No. 17	*2.2*	*4.5*	Deeper pumping water level	Windmill	Lower pump inlet
Six Mile Well	1.67	4	None	Leaking Artesian Headworks	
SEC Bore	*2.5*	*4.5*	None	Windmill	Lower pump inlet
Nanga Station					
Nanga Homestead	2.15	4	Lower flow pressure	Artesian Headworks	
Nilemah Artesian No. 1A	6.32	6	Lower flow pressure	Nil - Artesian Headworks	
Tamala Station					
Cape Well Bore	*None*	*N/A*	None	Mono Pump	
Beethen Outcamp Well	*None*	*N/A*	None	Mono Pump & Windmill	
Natta Outcamp Bore	*None*	*N/A*	None	Windmill & Electric Submersible	
Woodleigh Station					
Woodleigh No 10C	*1.5*	*3.5*	None	Electric Submersible	
Woodleigh No 11	*2.0*	*4.5*	Deeper pumping water level	Windmill	Lower pump inlet
Woodleigh No 22	*1.0*	*3.5*	None	Electric Submersible	
Woodleigh No 25	*1.0*	*3.5*	None	Electric Submersible	
Toolonga Station					
SB2	*<0.5*	*<3.0*	None	Not Equipped	

Note: Italicised and underlined data has been interpolated between modelled observation points.

Predicted impacts due to abstraction of 11 GL/annum include:

- Drawdowns at the Nanga Resort are predicted to reach 2 m after 20 years of abstraction (Figure 71a).
- Drawdowns on all three of the Carbla Stations bores are likely to increase as mining advances northwards. Predicted drawdowns include 1.7 m at Six Mile Bore and about 2.5 m in Carbla No. 16 (Figure 71a).
- The predicted responses in the Hamelin Station bores vary with distance from the mine as shown on Figures 71 (b to d).
  - Drawdowns of about 9 m in Spinifex Bore after about 20 years of pumping (Figure 71b). It is likely that Spinifex Bore will cease to flow after about 1 to 2 years of pumping from the southern project area. This bore is barely flowing at present due to its elevation and possibly poor condition.
  - Hamelin Nos. 16 and 20 are predicted to have drawdowns of about 1.2 m after about 14 to 16 years of abstraction (Figure 71d).
  - The Hamelin Homestead Bore is predicted to experience slowly increasing drawdowns during the life of the project. Drawdowns of up to 6.1 m are predicted after about 20 years of pumping. This bore is not expected to cease flowing; the artesian head would temporarily decline from 22 to 16 m.
- Both the Nilemah No. 1A and Hamelin Telegraph Station bores are expected to be affected by drawdowns after about two years of abstraction (Figure 71b). These drawdowns are expected to slowly increase as the mine advances northwards, to peak at about 6.2 m after 20 years of abstraction. Neither bore is expected to cease flowing; artesian heads of about 34 m are predicted near the end of the mining.
- On Coburn Station (Figure 71c), drawdowns of 8 m are predicted in Coburn No. 7 and Coburn No. 9, about 5.5 m in Coburn No. 14 and 3.5 m in Coburn No. 8.
- Bores at Billabong and Overlander roadhouses are predicted to experience drawdowns of 0.8 and 2.3 m (Figures 71b and d). The drawdowns at Billabong Roadhouse are predicted to stabilise after 10 to 13 years of abstraction, as the mining moves north from this location. Drawdowns at the Overlander Roadhouse are predicted to slowly increase as the mining moves northwards.
- The Nerren Nerren and Meadow Station bores are predicted to experience up to about 1.0 m of drawdown after about 10 to 13 years of abstraction (Figure 71d). The drawdowns are expected to stabilise as the mine advances to the north.

Predicted drawdowns resulting from large-scale abstractions range between < 0.5 m at distant sites and 8.9 m in proximal sites. If depletion of the existing supply results from the predicted drawdowns, remediation should generally require the lowering of the pump inlets by several meters to maintain sufficient submergence and available drawdown. Proposed remediation measures to overcome the predicted impacts are presented in Table 31.

In the closest bores, the pumping infrastructure may also require upgrading as a result of the increased pumping heads. Further away, most of the bores have potential for lowering the pump inlets, but as the impacts are less, few would require any further action. Adjusting the pump inlets in some of the older bores may pose problems due to the effects of corrosion on casing and pump conditions.

The bores located over the Ajana Ridge to the east should experience <0.5 to about 1 m of drawdown, particularly in areas where the aquifers are unconfined. Some of these bores only penetrate the unconfined aquifers sufficiently to provide the required supply, so the pump inlets are close to, or within the aquifer intervals. It is unlikely that these bores will experience a depletion or loss of supply, but it is recognised that remediation measures may be required for relatively small drawdowns.

None of the artesian bores are expected to stop flowing, except Spinifex Bore. It is likely that relatively small pressures deliver groundwater to the header tank at the Nanga Resort. The predicted 2.1 m drawdown may decrease the supply available at the header tank and it could require a booster pump from lower level (i.e. near the borehead) is this occurs. A cessation of artesian flows at Spinifex Bore (including both holes) is likely. An alternative supply will need to be sourced when this occurs.

A decrease in the artesian pressure at the Hamelin Homestead may have a significant impact on the ability of the existing equipment to generate a local electricity supply. Further research should be undertaken to derive an equitable solution in the early stages of the mine development and prior to any impacts reaching this bore.

6.5 Aquifer Recovery After Cessation of Abstraction

After pumping has ceased, the aquifer systems will progressively recover. Predictive simulations indicate that the inner part of the drawdown cone will contract rapidly at first, with the regional drawdowns remaining after 2 years. Almost complete recovery is predicted within five years of the cessation of large-scale abstraction. Results of the predictive recovery simulations are shown for the Windalia Radiolarite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone on Figures 73 to 76 at period 1, 2, 5 and 10 years after the cessation of 11 GL/annum abstractions. Specific recovery trends in selected private bores are shown on Figure 77 (a to d).

Recoveries in all private bores are predicted to be relatively rapid in the initial 3 to 5 years after the cessation of abstraction, most private bores are predicted to fully recover (less than 0.5 m drawdown) four to six years after the completion of mining. Bores that are closer to the project are predicted to recover at the fastest rates.

6.6 Sustainability of Large-Scale Abstractions

Recharge to the Windalia Radiolarite and Birdrong Sandstone is estimated to be 4.5 GL/annum in the area between Shark Bay and Carnarvon (Hillier *et al.*, 2002). This is a reasonable estimate for the domain of these aquifers in the hinterland of the project area. Historically, large-scale uncontrolled abstractions are understood to have exceeded the rates of annual recharge. The completed bore rehabilitation programmes have reduced abstractions, but currently there may remain a deficit between abstraction and recharge.

Using the available hydrogeological data, the rate of through-flow within the Birdrong Sandstone and Kopke Sandstone beneath the project area is estimated to be in the order of 4.5 GL/annum. This estimate is based on a flow path width of 33 km, thickness of the Birdrong Sandstone and Kopke Sandstone being 25 and 270 m and hydraulic conductivity of these aquifer systems being 13.0 and 1.9 m/day.

In a regional context, the aggregate recharge over a 20-year period is 90 GL and the proposed abstraction is up to 360 GL, equating to a 270 GL temporary deficit in available groundwater resources. This temporary deficit would be enlarged, by continuance of uncontrolled abstractions from artesian bores and pastoral uses, perhaps by another 100 GL. As such, an aggregate temporary deficit in the order of 370 GL might be expected during the project duration.

Groundwater volumes in storage in the regional confined aquifers, excluding the Tumblagooda Sandstone, have been estimated using the developed groundwater flow model.

The estimates include:

• Windalia Radiolarite	9,980 GL
• Windalia Sand Member	30,120 GL
• Birdrong Sandstone	189,400 GL
• Kopke Sandstone	1,185,000 GL
Total	1,414,600 GL

The aggregate 20-year deficit of abstraction compared to recharge is interpreted to represent less than 0.03% of the estimates of groundwater volumes in storage within the Birdrong Sandstone and Kopke Sandstone.

The deficit in recharge compared to abstraction would be predominantly manifest as drawdown of the water table in areas where the regional aquifers are unconfined or semi-confined. These areas occur tens of kilometres to the east and south of the project area.

6.7 Summary of Predicted Environmental Impacts

The findings of the groundwater resources impact assessments indicate that the predominant environmental issues and potential risks linked to the large-scale abstractions from the confined aquifer systems for process water supplies include:

- potential for propagation of drawdown impacts from the regional confined aquifer systems into the water table aquifer systems; and
- temporary deficits in recharge compared to abstraction and consequent removal of groundwater from storage in unconfined zones of the regional aquifer systems.

These assessments also indicate that the potentials for adverse environmental impacts linked to the outlined issues are low. For the confined aquifer systems, the predictive simulations show drawdowns of up to 4.0 m within the Toolonga Calcilutite and that the superficial formations are not affected. Also, there are no known adverse impacts from long-term deficits in recharge compared to abstraction due the uncontrolled flows from artesian bores.

Notwithstanding these predictive outcomes, there is uncertainty in the understanding of the regional hydrogeology and confined aquifer flow systems and, the environmental impacts already imposed on both local and regional groundwater resources by uncontrolled artesian abstractions. As such, the conceptual hydrogeological model of the confined aquifer systems and predictive drawdown outcomes due to long term abstraction need to be validated during the early operational phase of the project and the potential environmental risks refined.

The findings of the groundwater resources impact assessments indicate that the predominant environmental issues and potential risks linked to the Amy Zone development include:

- recovery of sand tailings waters and limiting the potentials for mounding of the water table to propagate into the root zones of vegetation stands;
- potential for discharge from the northern water table mounds into salina domain in foreshore areas of Hamelin Pool;
- potential for propagation of drawdown impacts from the regional confined aquifer systems into the water table aquifer systems; and
- temporary deficits in recharge compared to abstraction and consequent removal of groundwater from storage in unconfined zones of the regional aquifer systems.

These assessments also indicate that the potential for adverse environmental impacts linked to the outlined issues is low if managed effectively. Within the superficial formations, the predictive modelling results show that:

- water table mounding within the southern project areas that potentially threatens vegetation root zones can be mitigated by the dedicated operation of in-pit trench drains that intercept and enhance recovery of tailings waters;
- water table mounding within the northern project areas that potentially threatens vegetation root zones can be mitigated by refining knowledge of salina water table and groundwater discharge environments and reviewing mining plans to reduce the rate of northern pit development and reduce the magnitudes of the residual mounds; and
- the simulated mounds do not actually have a surface expression within the salinas.

For the confined aquifer systems, the predictive simulations show drawdowns of up to 4.0 m within the Toolonga Calcilutite and that the superficial formations are not affected. Also, there are no known adverse impacts from long-term deficits in recharge compared to abstraction due to uncontrolled flows from artesian bores.

Notwithstanding the predictive outcomes, there is uncertainty in the hydrogeological interpretations and predictive findings. As such, these issues and potential risks need to be monitored and appropriately managed. It is important that these impacts are quantified so that they can be appropriately managed based on:

- ecological and environmental considerations; and
- the rights of other users of the local groundwater resources.

Regulatory authorisation of groundwater abstraction from the confined aquifers for process water supply should be sought through application for a Licence to Take Water from the DoE. This application should be supported by the technical content of this report and the monitoring and management protocols that form the Operating Strategy. Authorisation from the DoE should also be sought for abstractions linked to local dewatering of the superficial formations in the northern pit.

7.1 Operating Strategy

The Operating Strategy pertains to the Licence to Take Water for the provision of process water supply from a dedicated borefield and later by dewatering of the superficial formations during mining. It is anticipated that the licences would predominantly relate to the operation of a number of production bores for provision of secure process supplies and sump-pumping to dewater the northern pit. In some pits other dewatering infrastructure such as trenches, well points or production bores may also be used to increase the recovery of tailings water, improve mining conditions and promote water use efficiency. All abstracted groundwater would be used for the process water supply, camp water supply or dust suppression. No excess water will be produced by this operation that will need to be disposed.

7.1.1 Monitoring and Management of Groundwater Resources

Groundwater monitoring programmes have been developed to enable assessment and management of the shallow aquifers due to mine dewatering, residual mounding of the water table in the superficial formations and drawdown in the confined aquifers due to process water supply abstraction. The key objectives of the monitoring programmes are shown in Table 32. The monitoring programmes would involve both quantitative and qualitative measurements of the groundwater resources in:

- Multipiezometers in the superficial formations and shallow Toolonga Calcilutite including the following aspects:
  - Close to and within the active pits to characterise the shallow Toolonga Calcilutite natural water table environment and subsequent mounding magnitudes and distributions due to residual tailings waters for optimisation of mine water recovery.
  - Near the active pits, in areas identified with potential risk to vegetation root zones, to determine the water table setting, actual thickness of the superficial formations and transient data on the residual water table mounding.
  - Within the Nilemah Embayment and environs, to characterise the hydrogeology, lateral and vertical groundwater flow paths and water table environment.
- A regional confined aquifer and confining layer multipiezometer network including the following aspects:
  - Within the local and regional Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone aquifer systems to improve the baseline groundwater level interpretations and provide data on transient drawdown impacts.

  - Within the local and regional Alinga Formation, Toolonga Calcilutite and superficial formations to characterise baseline vertical flow gradients and transient drawdown impacts.

- Selected private bores in the region.
- In-pit sumps and sump-pumps.
- The process water supply production bores abstracting drawing groundwater from the confined aquifers.

The monitoring programmes should be reviewed annually and revised as appropriate to remain compatible with the needs of the operating and receiving environments.

Table 32

Objectives of Monitoring Programmes

Objective	Key Items	Outcomes
1. Definition of natural and seasonal baseline conditions – before the commencement of mining	• Groundwater level monitoring in all existing and proposed multipiezometers to define seasonal and other transient changes in superficial formations, Toolonga Calcilutite, Alinga Formation, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone. • Sampling of all multipiezometers to define hydrochemistry parameters and seasonal changes in the superficial formations, Toolonga Calcilutite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone. • Quantifying the private water use demands on the confined aquifer groundwater resources. • Installation of the superficial formations and confined aquifer/aquitard multipiezometer networks would be undertaken either 1 year in advance of mining or out to a distance of 20 km from the active process water supply borefield location.	• Baseline data for quantitative and qualitative assessments of impacts.
2. Assessment of the impacts of process water supply, pit dewatering abstraction and residual water table mounding.	• Measurement of cumulative pumping volumes from all production bores and aggregate monthly totals of in-pit sump-pumps. • Measurement of groundwater levels in local superficial formations and regional confined aquifer/aquitard multipiezometers, production bores and selected private bores. • Sampling and basic analysis of selected superficial formations multipiezometers, private bores and process water supply bores to provide transient quality data for the key aquifers. • Regular assessment and reporting on the impacts of the process water supply, mounding of the water table, pit dewatering and groundwater resource management issues.	• To develop an understanding of the impacts of mining on the groundwater resources. • To provide data to appropriately define and manage any adverse impacts from process water supply abstraction, mounding of the water table within the superficial formations and pit dewatering. • To provide sufficient data to define and manage potential adverse impacts on vegetation and other biota in the vicinity of the project.

Table 32 (continued)

Objective	Key Items	Outcomes
3. Provision of data for refinement of the groundwater flow models	• As per the Key Items for Objectives 1 and 2 above. • Refinement of model parameters based on findings of programmes to construct the process water supply production bores and local and regional multipiezometers. • Refinement of model parameters and predictive outcomes if appropriate to enhance management objectives.	• Increase confidence in the model and predictive outcomes.
4. Meeting reporting requirements of the regulators	• Annual reporting on forecasts of consumptive water uses. This reporting would be framed on the sand-stacker and slimes trench tailings water recovery strategies, measured tailings water recoveries measured distributions of the water table mounding and refined site water balance estimates. • Annual reporting of groundwater abstraction volumes and measured impacts of the abstraction. • Review of management protocols to ensure they remain effective.	• Compliance with the terms, limitations and conditions of the Licence to Take Water.

An important component of the monitoring programme will be a database that allows efficient entry and collation of data. It is recommended that a monitoring database is developed to provide:

- hydrographs for the multipiezometers and piezometers;
- graphs of monthly and cumulative groundwater abstraction; and
- groundwater quality parameters.

7.1.2 Local Superficial Formations Multipiezometers

The additional multipiezometers should be constructed to independently monitor the superficial formations, shallow Toolonga Calcilutite marine clays and/or shell coquina beach ridge deposits depending on location. Design additional multipiezometers are outlined in Table 33 and locations are shown on Figure 78 (a and b).

Table 33
Locations of Additional Superficial Formations Multipiezometers

Proposed Multipiezometer	Approximate MGA Co-ordinates		Purpose
	mE	mN	
Nilemah Embayment Monitoring			
NMB1	206,080	7,064,620	Up gradient of Nilemah Embayment on SBWHAP Boundary
NMB2	207,420	7,064,750	
NMB3	210,530	7,066,850	Lower reaches of Peron Sandstone
NMB4	208,730	7,067,190	Back Flats South of Denham Road
NMB5	209,730	7,067,320	Back Flats South of Denham Road
NMB6	210,560	7,067,710	Replacement of STB1
NMB7	208,330	7,068,050	Denham Road – west
NMB8	211,520	7,068,220	Denham Road – east
NMB9	210,460	7,068,360	Nilemah Salina
NMB10	208,980	7,068,540	Nilemah Salina
NMB11	210,420	7,068,990	Nilemah Salina
NMB12	209,820	7,069,220	Nilemah Salina
NMB13	210,390	7,069,610	Nilemah Salina
Vegetation Risk Monitoring			
VMB1	214,340	7,032,600	South end of Amy Zone
VMB2	212,420	7,032,630	South end of Amy Zone
VMB3	215,130	7,032,930	South end of Amy Zone
VMB4	212,370	7,033,530	Southwest of Amy Zone
VMB5	215,360	7,033,690	Southeast of Amy Zone
VMB6	212,390	7,033,920	Southwest of Amy Zone
VMB7	212,380	7,034,410	South west of Amy Zone
VMB8	215,350	7,034,670	Southeast of Amy Zone
VMB9	215,400	7,035,460	Southeast of Amy Zone
VMB10	212,240	7,038,840	West of Amy Zone
VMB11	212,250	7,039,370	West of Amy Zone
VMB12	215,450	7,043,080	East of Amy Zone
VMB13	212,010	7,045,970	West of Amy Zone
VMB14	215,150	7,049,360	East of Amy Zone
VMB15	215,010	7,050,060	East of Amy Zone
VMB16	214,120	7,065,070	Northeast of Amy Zone
VMB17	210,560	7,065,610	North of Amy Zone
VMB18	212,390	7,066,040	North of Amy Zone
VMB19	210,530	7,066,250	North of Amy Zone

Table 33 (continued)

Proposed Multipiezometer	Approximate MGA Co-ordinates		Purpose
	mE	mN	
Long Term Pit Perimeter Areas			
SMB5	212,380	7,033,930	Southwestern Amy Zone
SMB6	212,240	7,038,850	Western Amy Zone
SMB7	212,240	7,042,950	Western Amy Zone
SMB8	212,100	7,047,840	Western Amy Zone
SMB9	211,100	7,052,950	Western Amy Zone
SMB10	209,600	7,057,830	Western Amy Zone
SMB11	208,030	7,063,250	Northwestern Amy Zone
SMB12	212,000	7,066,050	Northeastern Amy Zone

These multipiezometers would provide data on the drawdown and mounding impacts within the superficial formations and upper Toolonga Calcilutite in the vicinity of the Shark Bay World Heritage Property to the west and north of the Amy Zone. Additional piezometers will need to be installed within the Amy Zone to establish data on the residual water table mounds. The number and locations of these piezometers will be dependent on access and pit dimensions. Piezometer locations for the first three years are shown on Figure 78a in the southern Amy Zone. Locations of nominal sites for superficial formations multipiezometers in the Nilemah Embayment and environs are shown on Figure 78b.

7.1.3 Regional Piezometers and Private Bores

The existing confined aquifer piezometers, multipiezometers and private bores are valuable facilities providing both historical/baseline hydrogeological data and enabling future access to the groundwater environments for quantitative and qualitative assessments of impacts due to mine development. Regional piezometers and private bores incorporated within the developed monitoring programmes include SMB1 (a to c), STB1, Nilemah Artesian No.1A, Coburn No.4, Hamelin MRD Bore, Hamelin 26 (SB1), and Meadow 5(old), as shown in Table 34 and on Figure 79.

Table 34
Locations of Existing Regional Confined Aquifer Monitoring Bores

Bore	MGA Co-ordinates		Interpreted Formation
	mE	mN	
Nilemah Artesian No 1A	205,888	7,073,900	Windalia Radiolarite/ Birdrong Sandstone – artesian
Coburn No. 4	249,216	7,045,002	Windalia Sand Member
Hamelin MRD Bore	253,842	7,056,239	Windalia Sand Member
Hamelin No. 26 (SB1)	266,050	7,051,196	Windalia Sand Member or Tumblagooda Sandstone
Meadow No. 5 (Old)	267,779	7,038,527	Windalia Sand Member or Tumblagooda Sandstone

Additional regional multipiezometers are also proposed to provide specific information relevant to the confined aquifers and confining layers between the planned process water supply borefield and existing artesian bores and other private bores. The planned additional regional confined aquifer and confining layers multipiezometers sites are outlined in Table 35 and also shown on Figure 79.

These multipiezometers should ideally be installed up to a year in advance of mining to provide data on seasonal piezometric level fluctuations and indicative trends. The confining layers (IMB-series) would provide a measure of vertical hydraulic gradients between the confined and unconfined aquifer systems.

Table 35

Locations of Additional Regional Confined Aquifer and Confining Layer Multipiezometers

Proposed Multipiezometer	Approximate MGA Co-ordinates		Purpose
	mE	mN	
Confined Aquifer Monitoring			
DMB2	216,520	7,049,880	Borefield Groundwater Level Monitoring
DMB3	215,548	7,058,265	Borefield Groundwater Level Monitoring
DMB4	217,656	7,070,673	Northern Region Groundwater Level Monitoring
DMB5	235,131	7,067,854	Northeastern Region Groundwater Level Monitoring
DMB6	236,821	7,052,766	Eastern Region Water Level Monitoring
DMB7	237,392	7,037,272	Southeastern Region Water Level Monitoring
Confining Layer Monitoring			
IMB1	217,880	7,033,890	Confining Layer Multipiezometer in The Southeastern Region of The Project
IMB2	216,440	7,049,890	Confining Layer Multipiezometer in The Northeastern Region of The Project
IMB3	211,880	7,066,070	Confining Layer Multipiezometer in The Eastern Region of The Project
IMB4	217,480	7,074,880	Confining Layer Multipiezometer in The Hamelin Pool Region

7.1.4 Production Bores and In-Pit Sump Pumping

The production bores associated with process water supply and in-pit sump-pumps for tailings water recovery and pit dewatering would be included in the monitoring programme. To accommodate the defined monitoring requirements, the individual production bores and individual sump-pumps or combined sump-pumping systems should be equipped with flow meter(s) to define instantaneous and cumulative groundwater abstraction and tailings water recovery rates. Pumping water levels in each production bore should also be regularly measured to enable assessments of pumping performance and sustainable yields.

7.1.5 Water Resources Monitoring Programme

A monitoring programme appropriate for the assessments of the impacts of mining on the shallow groundwater and surface water resources is outlined in Table 36. This programme should be reviewed on an annual basis as part of the annual reporting requirements.

Table 36

Monitoring Programme

Monitoring	Parameters	Monitoring Frequency
BASELINE SAMPLING		
Local Superficial Formations Multipiezometers • SMB2 to SMB4. • Additional Multipiezometers SMB5 to SMB12 • Additional Vegetation Monitoring Multipiezometers VMB1 to VMB19 Adjacent to The Active Pits. • Nilemah Embayment Monitoring Multipiezometers NMB1 to NMB13 to the north of the project area	Groundwater Levels Groundwater Quality: pH, EC, TDS. Groundwater Quality: pH, EC, TDS, Total Alkalinity, Total Hardness, Cl, CO_3/HCO_3, SO_4, NO_3, NO_2, Na, K, Ca, Mg, Fe, SiO_2, Al, Mn, As, Cd, Cu, Pb, Se and Zn.	Monthly Quarterly Annually
Regional Piezometers • Existing/Nilemah Artesian No.1A, Coburn No.4, Hamelin MRD Bore, Hamelin 26 (SB1), and Meadow 5(old), and DMB1 • Additional Multipiezometers DMB2 to DMB7 and IMB1 to IMB4	Groundwater Levels or Pressures (artesian bores) Groundwater Quality: pH, EC, TDS (artesian bores)	Monthly.
DURING MINING SAMPLING		
Local Superficial Formations Multipiezometers • SMB2 to SMB4. • Additional Multipiezometers SMB5 to SMB12 • Additional Vegetation Monitoring Multipiezometers VMB1 to VMB19 Adjacent to The Active Pits. • Nilemah Embayment Monitoring Multipiezometers NMB1 to NMB13 to the north of the project area	Groundwater Levels Groundwater Quality: pH, EC, TDS. Groundwater Quality: pH, EC, TDS, Total Alkalinity, Total Hardness, Cl, CO3/HCO3, SO4, NO3, NO2, Na, K, Ca, Mg, Fe, SiO2, Al, Mn, As, Cd, Cu, Pb, Se and Zn.	Monthly Quarterly Annually
Regional Piezometers • Existing/Nilemah Artesian No.1A, Coburn No.4, Hamelin MRD Bore, Hamelin 26 (SB1), and Meadow 5(old), and DMB1 • Additional Multipiezometers DMB2 to DMB7 and IMB1 to IMB4	Groundwater Levels or Pressures (artesian bores) Groundwater Quality: pH, EC, TDS (artesian bores)	Monthly.

Table 36 (continued)

Monitoring	Parameters	Monitoring Frequency
Sump-pumps	Abstraction Volumes	Weekly
	Pump Operating Hours	Weekly
	Collation of Cumulative Discharge	Monthly
	Groundwater Quality:	Monthly
	pH, EC, TDS	
	Groundwater Quality:	Quarterly
	pH, EC, TDS, Total Alkalinity, Total Hardness, Cl, CO_3/HCO_3, SO_4, NO_3, NO_2, Na, K, Ca, Mg, Fe, SiO_2, Al, Mn, As, Cd, Cu, Pb, Se and Zn.	
Reporting	Preparation of Aquifer Reviews that detail the operational and technical aspects of the project. It is important that the Aquifer Reviews provide definitive assessments and reviews of: • New information on baseline groundwater environments • Residual mound characteristics • Residual mound distributions • Rates of tailings water recovery • Findings of risk assessments associated with propagation of the mounds to within vegetation root zones • Refinements on the fate of the residual tailings waters • Forecasts of consumptive process water uses • Lateral drawdown impacts within the confined aquifer systems • Impacts of drawdown on other groundwater users • Vertical propagation of drawdown within the Alinga Formation and Toolonga Calcilutite. These assessments should subsequently be applied to refine the water resources monitoring and management programmes.	Annual
Production Bores	Abstraction Volumes	Weekly
	Groundwater Levels	Weekly
	Groundwater Quality:	Monthly
	pH, EC, TDS	
	Groundwater Quality:	Quarterly
	pH, EC, TDS, Total Alkalinity, Total Hardness, Cl, CO_3/HCO_3, SO_4, NO_3, NO_2, Na, K, Ca, Mg, Fe, SiO_2, Al, Mn, As, Cd, Cu, Pb, Se and Zn.	

Table 36 (continued)

Monitoring	Parameters	Monitoring Frequency
POST-MINING SAMPLING		
Local Superficial Formations Multipiezometers • SMB2 to SMB4. • Additional Long-Term Multipiezometers SMB5 to SMB12 • Additional Vegetation Monitoring Multipiezometers VMB1 to VMB19 Adjacent to The Active Pits. • Nilemah Embayment Monitoring Multipiezometers NMB1 to NMB13 to the north of the project area.	Groundwater Levels Groundwater Quality: pH, EC, TDS. Groundwater Quality: pH, EC, TDS, Total Alkalinity, Total Hardness, Cl, CO_3/HCO_3, SO_4, NO_3, NO_2, Na, K, Ca, Mg, Fe, SiO_2, Al, Mn, As, Cd, Cu, Pb, Se and Zn.	Monthly Quarterly Annually
Regional Piezometers • Existing Nilemah Artesian No.1A, Coburn No.4, Hamelin MRD Bore, Hamelin 26 (SB1), and Meadow 5(old). • Additional Multipiezometers DMB2 to DMB7 and IMB1 to IMB4	Groundwater Levels or Pressures (artesian bores) Groundwater Quality: pH, EC, TDS (artesian bores)	Monthly. Quarterly
Reporting	Preparation of Aquifer Reviews that detail the operational and technical aspects of the project. It is important that the Aquifer Reviews provide definitive assessments and reviews of: • Residual mound distributions • Refinements on the fate and potential impacts of the residual tailings waters • Recovery of the confined aquifer systems • Impacts of drawdown on other groundwater users	Annual for at least 5 years after mining

Note: 1 The duration of post-mining monitoring is not closely defined. It is linked to, and dependent on the need to manage rehabilitation programme schedules and rates of water table recovery. The minimum duration would be three years.

The Amy Zone mineral sand resource is located adjacent to the eastern limits of the Shark World Heritage Property, south of Hamelin Pool; on the Hamelin and Coburn stations. Development of the mineral sand resource is proposed over a 20-year period, using conventional dry strip mining and wet gravity concentrators. Development is proposed to commence in the southern Amy Zone and progress to the north.

The Amy Zone is predominantly comprised of reworked Peron Sandstone, has typical slimes contents less than 1% by weight and is dry except in localised northern areas. Mined ore would be mixed with groundwater and processed in slurry form to extract ilmenite and zircon sands. Once mined, the developed pits would be backfilled with slurried sand tailings. Groundwater is proposed to be abstracted from regional confined aquifer systems formed by the Birdrong Sandstone and Kopke Sandstone for meeting of process water supply demands. Process water supply demands up to about 18 GL/annum are forecast.

The known groundwater resources issues linked to the proposed Amy Zone developments include:

- Recovery and reuse of process water from the disposed sand and slimes tailings, limiting consumptive groundwater use.
- Mounding of the water table in the superficial formations, due to disposal of sand and slimes tailings in slurry form, to within the root zones of vegetation stands.
- The transport and fate within the superficial formations of residual process waters not recovered from the disposed sand and slimes tailings, given the water table aquifer would discharge in part into Nilemah Embayment and Hamelin Pool.
- Salinisation of the process water supplies due to recycling and cumulative effects of evaporative losses.
- Drawdown impacts within the superficial formations resulting from pit dewatering in the northern project area.
- Drawdown impacts within the confined aquifer systems due to large-scale abstractions from the Birdrong Sandstone and Kopke Sandstone for process water supplies.
- Potential for propagation of drawdown impacts from the regional confined aquifer systems vertically upwards into the water table aquifer.
- Removal from storage of groundwater in the regional confined aquifer systems due to rates of forecast abstractions exceeding the estimated recharge and throughflow beneath the project area.

Each of these known groundwater resources issues has been specifically addressed in order to frame the potential environmental impacts and effects on existing groundwater supply amenities and use. The hydrogeology of the Carnarvon Basin is comparatively poorly defined. Consequently, there is uncertainty in the interpreted hydrogeology. The findings of hydrogeological site investigations and geo-biology research in the vicinity of Hamelin Pool have been applied in order to understand and manage the outlined issues.

The findings of the site investigations and research literature have initially been consolidated to develop conceptual hydrogeological models of the superficial formations and the regional confined aquifer systems. Key elements of these models include:

- **Superficial Formations Conceptual Hydrogeological Model**

  The water table occurs in the northern superficial formations, in areas proximal to Hamelin Pool, and the underlying predominantly silty or sand clay beds of the Toolonga Calcilutite. The water table is recharged by both rainfall infiltration and upward leakage from the regional confined aquifer systems. Where saturated, the Peron Sandstone forms a comparatively homogeneous and transmissive aquifer system. Conversely, the Toolonga Calcilutite typically forms a low-transmissivity low-flow groundwater environment. Groundwater flow is towards the northwest, north, with discharge into Nilemah Embayment and Hamelin Pool.

  On a local scale, groundwater flow is controlled by palaeodrainage features on the Toolonga Calcilutite contact and marine clay deposits in foreshore areas of Hamelin Pool. Both influence the location and mechanisms for discharge of groundwater. Subcrop or outcrop zones of the marine clay deposits are characterised by topographic depressions, clay pans and saline. These zones overlie a shallow water table, hypersaline groundwater and are interpreted to form groundwater discharge (by evaporation) zones.

  Groundwater in the superficial formations and shallow Toolonga Calcilutite is saline to hypersaline, slightly acidic and a sodium-chloride type. Salinities increase along the flow paths, being highest beneath the saline discharge zones.

  Localised aquifer systems occur beneath the shell coquina beach ridges that support flow of groundwater and chemical nutrients to stromatolite and algal mat colonies within the intertidal zone of Hamelin Pool.

- **Confined Aquifer Conceptual Hydrogeological Model**

  The predominant confined aquifer zones are formed by the Windalia Radiolarite, Windalia Sand Member. Birdrong Sandstone, Kopke Sandstone and Tumblagooda Sandstone. Each aquifer is regional in extent, with recharge zones occurring where they subcrop beneath the Ajana Ridge and along the southern and southeastern catchment divides. Regional groundwater flow is westwards, with discharge into Hamelin Pool, Freycinet Reach and the Indian Ocean. Upwards hydraulic gradients are interpreted between the confined aquifer systems, with resultant discharge through the overlying argillaceous deposits of the Alinga Formation and Toolonga Calcilutite.

  The aquifer formed by the Birdrong Sandstone and Kopke Sandstone are characterised by hydraulic conductivities in the range from 5 to 13 and 2 to 4 m/day beneath the project area. The salinity of mixed groundwater abstracted from these aquifer systems is 8,900 mg/L TDS in DTB1.

Recharge to the confined aquifer systems is estimated to be 0.5% of annual average rainfall, equivalent to about 4.5 GL/annum. Long-term historical abstractions from uncontrolled artesian bores are understood to exceed the annual rates of recharge.

Assessments of the known groundwater resources issues linked to the proposed Amy Zone developments have been undertaken using representative groundwater flow models of the superficial formations and regional confined aquifer systems. These models have been applied to determine:

Superficial Formations

- Proactive sand tailings water recovery strategies. Outcomes show an average annual recovery rate of between 43 to 68%. The differences in recoveries are predominantly linked to the numbers and locations of pit-floor drains to intercept the tailings water and the length of flow paths to the drains. Maximum recoveries occur where more rather than fewer drains are employed and the lengths of the flow paths are comparatively short.

- Consumptive process water supply demands that range from 11 to 15 GL/annum, to service two 2,200 tph concentrators. Differences in the consumptive use are directly linked to the sand tailing water recoveries. Under extremely adverse operating conditions the consumptive water use might reach 18 GL/annum.

- The magnitude, extent and propagation of water table mounding within the superficial formations are due to sand tailings water that is not recovered. Mounds up to 15 to 20 m in height are predicted in the immediate vicinity of active sand-stackers. Individual mounds would occur in each pit during backfilling with sand tailings, with characteristics dependent on the thickness of the superficial formations beneath the pit floor and rates of sand-stacker advance. In broad terms, the typical mounds are forecast to propagate during the mining operations distances up to 900 m behind the initial sand-stacking area, 500 m beyond the pit sides and 400 m beyond the end of individual pits.

- The fate of tailings waters that contribute to residual mounds, given that discharge in part would ultimately be into Hamelin Pool. The groundwater flow models show that the residual mounds progressively decay in height after cessation of sand-stacker operations. Also, the mounds migrate down gradient along regional flow paths and gradually dissipate within the water table environment. Rates of mound dissipation would be linked to the local water table environment and transmissivity of the saturated superficial formations and shallow Toolonga Calcilutite profiles.

- The outcomes of the predictive groundwater flow modelling indicate residual mounds remain evident after a 50-year duration.

- Salinisation of the process water supplies, due to cumulative effects of evaporation losses, in forecast to progressively increase salt loadings by about 40%. Over the 20-year mining period, the salinity of the process water would increase from 8,900 to 12,600 mg/L TDS.

- Pit dewatering in the northern project area. Typically, the saturated thickness of the superficial formations to be mined in less than one to two metres, representing a low-transmissivity, limited-extent aquifer setting. Abstractions to facilitate dry mining would be small-scale (<500 kL/day) and would not impose any adverse impacts on the water table environment in areas adjoining the northern pit.

The findings of the superficial formations groundwater resources impact assessments indicate that the predominant environmental issues and potential risks linked to the Amy Zone development include:

- recovery of sand tailings waters and limiting the potentials for mounding of the water table, within both the southern and northern project areas, propagating into the root zones of vegetation stands; and
- potentials for discharge from the northern water table mounds into salina domains within the Nilemah Embayment and the Shark Bay World Heritage Property.

The proposed mining developments would temporarily alter the water table environment. Mounding of the water table due to tailings processes has the potential to invade the root zones of vegetation. This may occur in several locations adjacent to the proposed pits where the thickness of the superficial formations is less than 10 m. These areas occur both west and north of the proposed pits, in the Shark Bay World Heritage Property, and further east. Residual tailings waters may rise close to the surface near the base of the Peron Sandstone dunes around the fringes of the Nilemah Embayment. The residual water table mounding due to sand tailings disposal is predicted to remain within about 3 km of the project area. Throughflow would be towards the Nilemah Embayment, with discharge being controlled in part by evaporation-dominated hydro-cycle in salinas, presence of marine clay beds and rates of groundwater throughflow.

These assessments also indicate that the potentials for adverse environmental impacts linked to the outlined issues is low and broadly acceptable in the south, but medium in the north and requiring the identification of further risk reduction options. Within the superficial formations, the predictive modelling results show that:

- water table mounding within the southern project areas that potentially threatens vegetation root zones can be mitigated by the dedicated operation of in-pit trench drains that intercept and enhance recovery of tailings waters;
- water table mounding within the northern project areas that potentially threatens vegetation root zones can be mitigated by refining knowledge of salina water table and groundwater discharge environments and reviewing mining plans to reduce the rate of northern pit development, the number of sand-stackers in operation and the magnitudes of the residual mounds; and
- the simulated mounds do not actually have a surface expression within the salinas.

The mitigation of potential risks to stands of vegetation in perimeter areas of the proposed pits should be approached in a staged manner. This staged approach includes:

- mapping of the vegetation and typical depths of root penetration;
- the installation of multipiezometers to characterise thickness of the superficial formations and depths to the water table;
- use of the additional knowledge to refine the potential risks;
- monitoring of actual water table mounding;
- where appropriate, maintain active drains in the pit(s) adjacent to areas at risk in order to intercept and abstract tailings water locally contributing to the mounding; and
- where appropriate review the mining plans to increase the duration of mining and reduce the residual mounding.

No groundwater-dependent flora or fauna are known in the project area. No stygofauna were found following a survey conducted on all shallow groundwater bores in and near the project area (UWA, 2005). The nearest groundwater dependent ecosystem is likely to be the estuarine ecology associated with Hamelin Pool and the Nilemah Embayment. Both are groundwater discharge areas. The stromatolites along the shoreline of Hamelin Pool, near the old Hamelin Telegraph Station, are located in groundwater discharge zones about 12 km from the northern project area. The groundwater discharge is from a different catchment than the project area and Nilemah Embayment. There are no predicted impacts on the Hamelin Pool ecosystem due to occurrence of residual tailings waters in the superficial formations and water table environment.

Additional investigations are required to refine the understanding of the local vegetation systems and water table environment. Results of these investigations would be applied to refine the potential environmental risks and develop appropriate and practical mitigation strategies. These aspects might be aligned with reviews of the mine plans for the northern pit that consider options for scheduling and/or staging of the developments to lengthen the mining period, minimise the number of sand-stackers in use and consequently reduce the volumes of tailings waters in residual mounds.

Regional Confined Aquifers

- Drawdown impacts due to forecast abstractions of 11 to 15 GL/annum. Abstractions in this range have been simulated from three and four production bores, with pumping rates of 15,060 to 18,500 kL/day.
- Predicted drawdowns in the Windalia Radiolarite, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone will radially propagate 60 to 75 km from the project area. The magnitudes of the predicted drawdowns would vary from about 9 m beneath the project area to <1.0 m in a regional context.

- The predicted drawdowns would impact on private bores. Impacts on private bores that intersect only the Windalia Radiolarite and Windalia Sand Member are expected to be less than those intersecting the Birdrong Sandstone and Kopke Sandstone. Predicted impacts on about 60 private bores have been quantified, together with proposed remedial actions (if required) to enable the monitoring of existing supplies and amenity. In most bores, remedial actions are linked to lowering of pump inlets to maintain sufficient submergence and available drawdown. The pumping infrastructure in bores closest to the project area may also require upgrading. Spinifex Bore is the only artesian bore expected to stop flowing. A decrease in the artesian pressure at the Hamelin Homestead may adversely impact on the ability of the existing equipment to generate local electricity supplies.

- The predicted drawdowns due to abstractions from the confined aquifer systems would propagate vertically upwards in the stratigraphic profile, being manifest in decreasing magnitudes in the Alinga Formation, Toolonga Calcilutite and superficial formations. No measurable drawdowns are forecast in the superficial formations beneath the northern project area. Within the Toolonga Calcilutite, the predicted drawdowns range up to 3 m beneath the project area and 1 m at distances of 12 km. The predicted drawdowns in the Toolonga Calcilutite propagate beneath Hamelin Pool.

- Almost complete recovery of the confined aquifer systems is predicted within five years of the cessation of process water supply abstractions.

- The developed and calibrated regional confined aquifer groundwater flow model is characterised by a predominance of vertical upward groundwater flow throughout the stratigraphic profile. Outcomes from the predictive modelling are sensitive to the simulated vertical hydraulic conductivity values.

The findings of the groundwater resources impact assessments indicate that the predominant environmental issues and potential risks linked to the large-scale abstractions from the confined aquifer systems for process water supplies include:

- potentials for propagation of drawdown impacts from the regional confined aquifer systems into the water table aquifer systems; and

- temporary deficits in recharge compared to abstraction and consequent removal of groundwater from storage in unconfined zones of the regional aquifer systems.

These assessments also indicate that the potentials for adverse environmental impacts linked to the outlined issues are low. For the confined aquifer systems, the predictive simulations show drawdowns of up to 4.0 m within the Toolonga Calcilutite and that the superficial formations are not affected. Also, there are no known adverse impacts from long-term deficits in recharge compared to abstraction due the uncontrolled flows from artesian bores.

Notwithstanding these predictive outcomes, there is uncertainty in the understanding of the regional hydrogeology and confined aquifer flow systems and, the environmental impacts already imposed on both local and regional groundwater resources by uncontrolled artesian abstractions. As such, the conceptual hydrogeological model of the confined aquifer systems and predictive drawdown outcomes due to long term abstraction need to be validated during the early operational phase of the project and the potential environmental risks refined.

A reasonable estimate for recharge to the domain of the confined aquifer systems in the hinterland of the project area is 4.5 GL/annum. Historical abstractions from uncontrolled artesian bores are understood to have exceeded the rates of annual recharge. In a regional context, the aggregate recharge over a 20-year period is 90 GL. Proposed abstraction is up to 360 GL over the same period, equating to a 270 GL temporary deficit in available groundwater resources. This temporary deficit would be enlarged by continuance in the future of uncontrolled abstractions from artesian bores, perhaps by another 100 GL. As such, the aggregate temporary deficit would be in the order of 370 GL during the project period. A deficit of this magnitude is interpreted to represent <0.03% of the groundwater volumes in storage within the Birdrong Sandstone and Kopke Sandstone in the recharge domain. The deficit in recharge compared to abstraction would be predominantly manifest as drawdown in unconfined aquifer zones.

An Operating Strategy has been developed to facilitate appropriate monitoring and management both local and regional groundwater resources and associated potential impacts. Key elements of the Operating Strategy include:

- The establishment of investigation and monitoring facilities linked to:
  - characterising tailings water recovery and residual water table mound magnitudes and distributions;
  - characterising the baseline groundwater environment in areas of potential risk due to water table mounding invading the root zones of overlying vegetation;
  - refining the understanding of the hydrogeology of the superficial formations in areas between the northern pit and Hamelin Pool;
  - improving the quantitative and qualitative water table baseline and relationships, in terms of groundwater levels and groundwater flow, between the superficial formations and Toolonga Calcilutite;
  - characterising the vertical potentiometric level distributions within the Alinga Formation, Toolonga Calcilutite and superficial formations;
  - measurement of drawdown magnitudes and distributions in the superficial formations (if any), Toolonga Calcilutite, Alinga Formation, Windalia Sand Member, Birdrong Sandstone and Kopke Sandstone due to the process water supply abstractions; and
  - assessment of vertical hydraulic conductivities in the groundwater flow systems.
- Establishment of monitoring programmes that provides both quantitative and qualitative baseline, operating phase and post-mining data on the relevant groundwater environments and aquifer systems.

- Specification of reporting schedules whereby measured actual impacts are compared with those predicted and the implications of differences can be investigated and assessed.

Development of the Coburn Mineral Sand Project would result in both local and regional impacts on the groundwater resources, groundwater environments and other users. The developed conceptual hydrogeological models and several input parameters to the predictive groundwater flow models used in the reported groundwater resources impact assessments incorporate uncertainty. As such, there are requirements to verify, through investigation, monitoring and operational practises, several of these aspects in order to refine the understanding of the aquifer systems and potential risks to the environment and existing groundwater users. The following recommendations are made on this basis:

- Use of this report in support of the Public Environmental Review for the project and Groundwater Well Licence applications for abstractions of up to 18 GL/annum from the confined aquifer systems for process water supplies.

- Trial and implement robust, practical and secure tailings water recovery strategies that strongly promote and demonstrate groundwater conservation principles. Such strategies are fundamental to limiting the environmental risks associated with the project. Sustained recovery rates would be predominantly linked to implementation of effective drain systems in proximity to the operational sand-stackers and limiting the length of the flow paths from the deposited sand tailings and drain systems.

- Implement monitoring programmes, particularly in the initial three years of the project, that enable the magnitudes and dimensions of the water table mounding beneath the sand-stackers to be characterised. The monitoring data are fundamental to demonstrating actual fates of the residual sand tailings waters and the refinement of potential environmental risks.

- Implement investigation and monitoring programmes in known areas of potential environmental risk due to water table mounding encroaching on the root zones of vegetation stands. These programmes are forecast to include:

  – mapping of vegetation and typical depths of root penetration;

  – installation of multipiezometers to characterise ground surface elevations, thickness of the superficial formations, shallow Toolonga Calcilutite lithologies and water table elevations;

  – use of the additional data to refine the potential environmental risks;

  – monitoring of actual water table mounding;

  – where appropriate, maintain active drains in the pit(s) in order to intercept and abstract tailings waters locally contributing to the water table mounding; and

  – Where appropriate review the mining plans to increase the duration of mining and reduce the residual mounding.

- Develop practical operating strategies linked to the sand-stackers that would facilitate the retention and tailing waters abstraction from localised in-pit drains required to limit environmental risks to nearby vegetation stands. The mitigation of all risks associated with mounding of the water table beneath woodland areas is considered to be best and most practicably achieved through the localised retention and use of drains in the developed pits. This approach seeks to intercept the tailings waters nearer their source, promote recovery by reducing the lengths of flow paths and avoid access and intrusive activities within the Shark Bay World Heritage Property.

- Implement investigation and monitoring programmes within the Nilemah Embayment to refine the understanding of the stratigraphy hydrogeology and shallow groundwater environments. The Nilemah Embayment and adjoining Hamelin Pool would form discharge zones for the residual tailings water mounds. The understanding of potential impacts in shallow water table settings needs refinement given small-scale changes in water table elevations might promote direct impacts on salinas in the Nilemah Embayment. The investigation programmes should involve the installation of multipiezometers that enable characterisation of the lateral and vertical groundwater gradients and flow paths and, aquifer tests that enable interpretation of the hydraulic conductivity of the predominant stratigraphic units. Data from these investigations would be applied to demonstrate baseline groundwater environments.

- Review mining plans to reduce the rate of northern pit development, the number of sand-stackers in operation and the magnitudes of the residual mounds.

- Investigate and monitor the vertical hydraulic gradients and hydraulic conductivities within the Alinga Formation and Toolonga Calcilutite. Refinement in the understanding of these parameters is integral to quantifying, in both a local and regional context, the propagation of drawdown impacts from the confined aquifer systems to the water table environment.

- Establish a multipiezometer network in the confined aquifer systems that provide a robust pre-development baseline and subsequently enables an accurate assessment of local and regional drawdown impacts.

  Existing bores identified in the monitoring programmes should be assessed to ensure construction details, screened intervals and datum elevation are known. Otherwise alternative bores might be used.

  Regional multipiezometers specifically installed in the predominant aquifer zones should be lithologically and geophysically logged and constructed similar to DMB1.

- Develop and implement a communication strategy to broadcast to individual pastoralists the predicted drawdown impacts on their production bores. Subsequently, agreed monitoring and remediation (if required) strategies need to be framed in terms of responsibilities and commitments.

- Process water supply production bore designs should be reviewed in context of the use of corrosion-resistant casings and the use of finer aperture screens or a gravel-pack construction.

Allen, A.D., 1987 Groundwater contributions to the Geology of the Carnarvon Basin, Western Australia, pp 237-244. Bulletin 133 of the Geological Survey of Western Australia, Department of Mines Western Australia, Perth 1987.2" edited by P. G. Purcell and R.R. Purcell: Petroleum Exploration Society of Australia Symposium, Perth, W.A., 1998, Proceedings, pp 599-611.

Astill, W., Baston K., and Shepherd, R. Carnarvon Artesian Basin: 90% Saved, What Now? Paper presented at the GAB Fest 2002 Conference held by the Great Artesian Bain Consultative Council, 11 March 2002.

Blandford, D.C., Coburn Mineral Sands Project, Soils and Landforms of the Amy Zone Ore Body. Unpublished report prepared for URS Australia. May 2004.

Bureau of Mineral Resources (BMR), 1990. The Geobiology of Hamelin Pool, Research Reports of the Baas Becking Geobiological Laboratory's Shark Bay Project. Record 1990/89, Compiled by RV Burne and G Hunt.

Department of Environment, 2004. Drillhole data extract derived from the WINS database held at Plain St, East Perth.

Geo-Eng Australia Pty. Ltd., 1999. Carnarvon Basin Rehabilitation Project – Stage 1. Geophysical Logging and Bore Assessment, Report No. 3 of 38 – Nanga No. 1 Bore. Report 1700/9518/103, October 1999.

Geo-Eng Australia Pty. Ltd., 1999. Carnarvon Basin Rehabilitation Project – Stage 1. Geophysical Logging and Bore Assessment, Report No. 32 of 38 – Hamelin Station – Homestead No. 2 Bore. Report 1700/9518/132, November 1999.

Geo-Eng Australia Pty. Ltd., 1999. Carnarvon Basin Rehabilitation Project – Stage 1. Geophysical Logging and Bore Assessment, Report No. 37 of 38 – Hamelin Spinifex No. 2 Bore. Report 1700/9518/137, November 1999.

Hiller, B.T. Dogramaci S, Clement P, & Wills R. Solutes, Stables Isotopes and Radiocarbon Isotopes as Tracers of Groundwater Flow, Carnarvon Basin, Western Australia. Paper presented to IAH Conference "Balancing the Budget, Darwin, May 2002.

Hocking, R.M. and Moors, H.T. and Van De Graaff, W.J.E., 1987. Geology of the Carnarvon Basin, Western Australia, Bulletin 133 of the Geological Survey of Western Australia, Department of Mines Western Australia, Perth 1987.

Iasky, R.P., Ercole, C.D., Ghori, K.A.R., Mory, A.J., and Lockwood, A.M., 2003. Structure and Petroleum Prospectivity of the Gascoyne Platform, Western Australia. Report 87, Geological Survey of Western Australia, Perth, 2003.

Kempin, E., and Fujioka, N., 1973. Tamala No. 1 Well, Western Australia, Well Completion Report for Oceania Petroleum Pty Ltd. September 1973.

Knott, B & Goater, S., 2005. Coburn Mineral Sand Project Amy Zone Operation - Stygofauna Pilot Survey. Unpublished draft report prepared for Gunson Resources Ltd. M092 Zoology, The University of Western Australia, January 2005.

Mattiske, pers. comm. 2005. Key Issues related to the Potential Impacts of proposed mine water mounding on the Gunson Project Area. Undated document No. URS0501r5.doc.

McWhae, J.R.H., 1958. Hydrodynamic and Salinity Studies of the Chief Aquifers of the Carnarvon Basin. Unpublished report to West Australian Petroleum Pty Ltd.

Mory, A.J., Iasky, R.P., and Shechenko, S.I., 1998, The Coolcalalaya Sub-Basin: A Forgotten Frontier 'between' the Perth and Carnarvon Basins, WA. In "The sedimentary basins of Wester Australia.

Ninox, 2005. Vertebrate Fauna Survey, Coburn Mineral Sands Project. Unpublished report to URS Australia Pty Ltd. And Gunson Resources Limited by Ninox Wildlife Consulting, January 2005.

Playford, P.E., and Chase, R.E., 1955. Carnarvon Basin Water Bores: Unpublished report to West Australian Petroleum Pty Ltd.

URS, 2003. Environmental Referral Submitted Under Chapter 4 of the Environment Protection and Biodiversity Conservation Act, 1999 for the Coburn Mineral Sands Project. Unpublished report prepared for Gunson Resources Limited, 9 September 2003. Report No. 52830-001-562/552-F5940.0

URS, 2003. Environmental Referral Submitted Under Section 38(1) of the Environmental Protection Act, 1986 for the Coburn Mineral Sands Project. Unpublished report prepared for Gunson Resources Limited, 16 September 2003. Report No. 52830-001-562/552-F5941.2

URS, 2004. Preliminary Water Resources Study, Coburn Project. Unpublished report to Gunson Resources Limited. 1 April 2004. Report No. 52830-001-562/580-F6240.1.doc.

Water & Rivers Commission, 1996. Gascoyne Region Water Resources Review and Development Plan. Vols. I and II. Water and Rivers Commission Report, Water Resource Allocation and Planning Series, 1996.

Wills, R and Dogramaci S, Hydrogeology Report No. 170, Carnarvon Basin, Hydrogeology and Hydrochemistry of the Confined Groundwater Systems, WA. Water & Rivers Commission, Perth, 2000.

Yasin, A.R. and Mory, A.J., 1999. Coburn 1 Well Completion Report, Gascoyne Platform, Southern Carnarvon Basin, Western Australia. Record No. 1995/5 of the Geological Survey of Western Australia, Department of Minerals and Energy, Perth 1999.

URS Australia Pty Ltd (URS) has prepared this report for the use of Gunson Resources Limited 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 10 March 2004.

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.

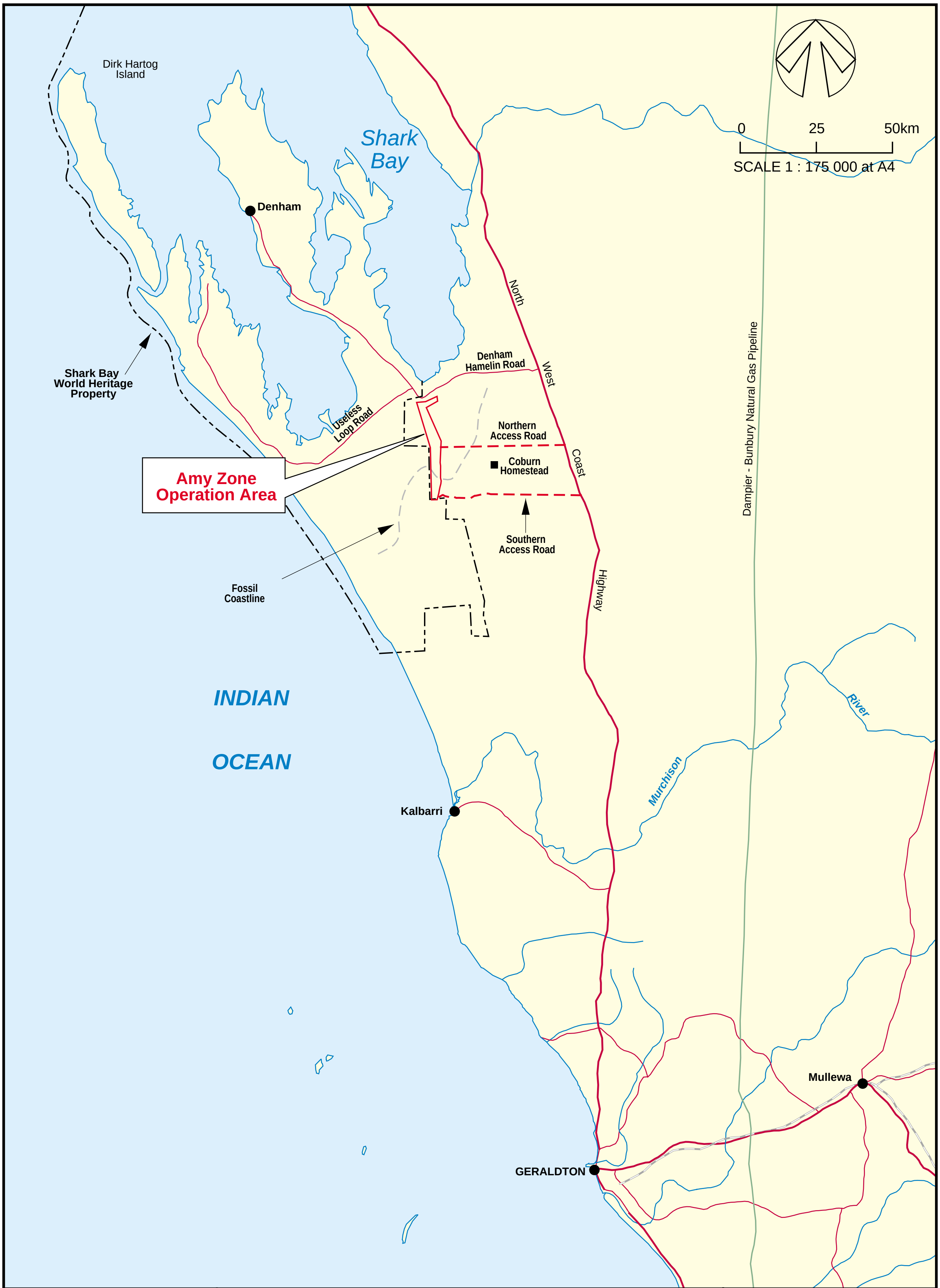
This report was prepared between 23 July 2004 and 14 January 2005 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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

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.



Thu 31 Mar 05

			Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **REGIONAL SETTING**	**Figure 1**
Job No.	42905541			URS
Prep. By	RW	3 Mar 05		
Chk'd By	RW	3 Mar 05		
Revision No.		0		

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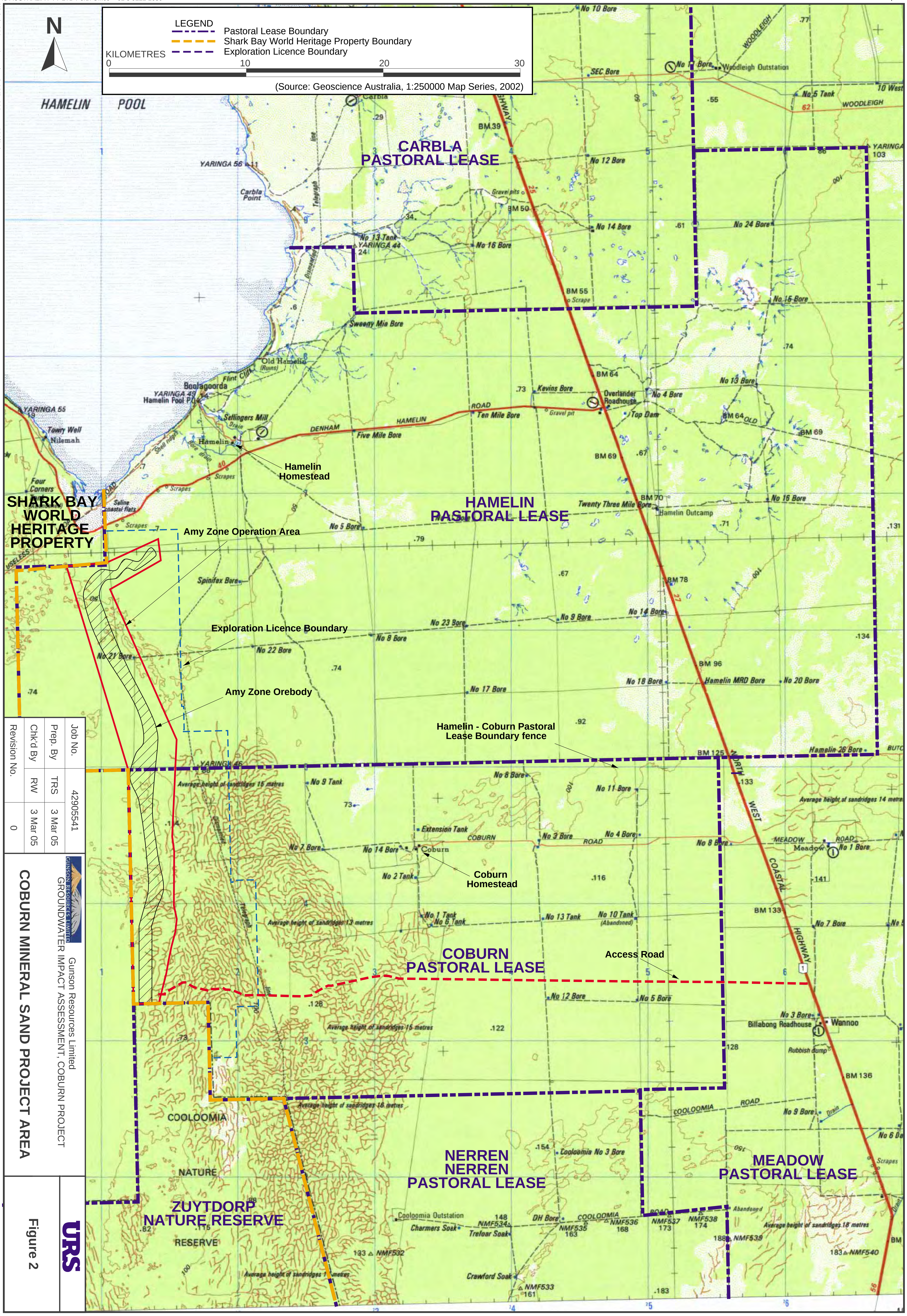


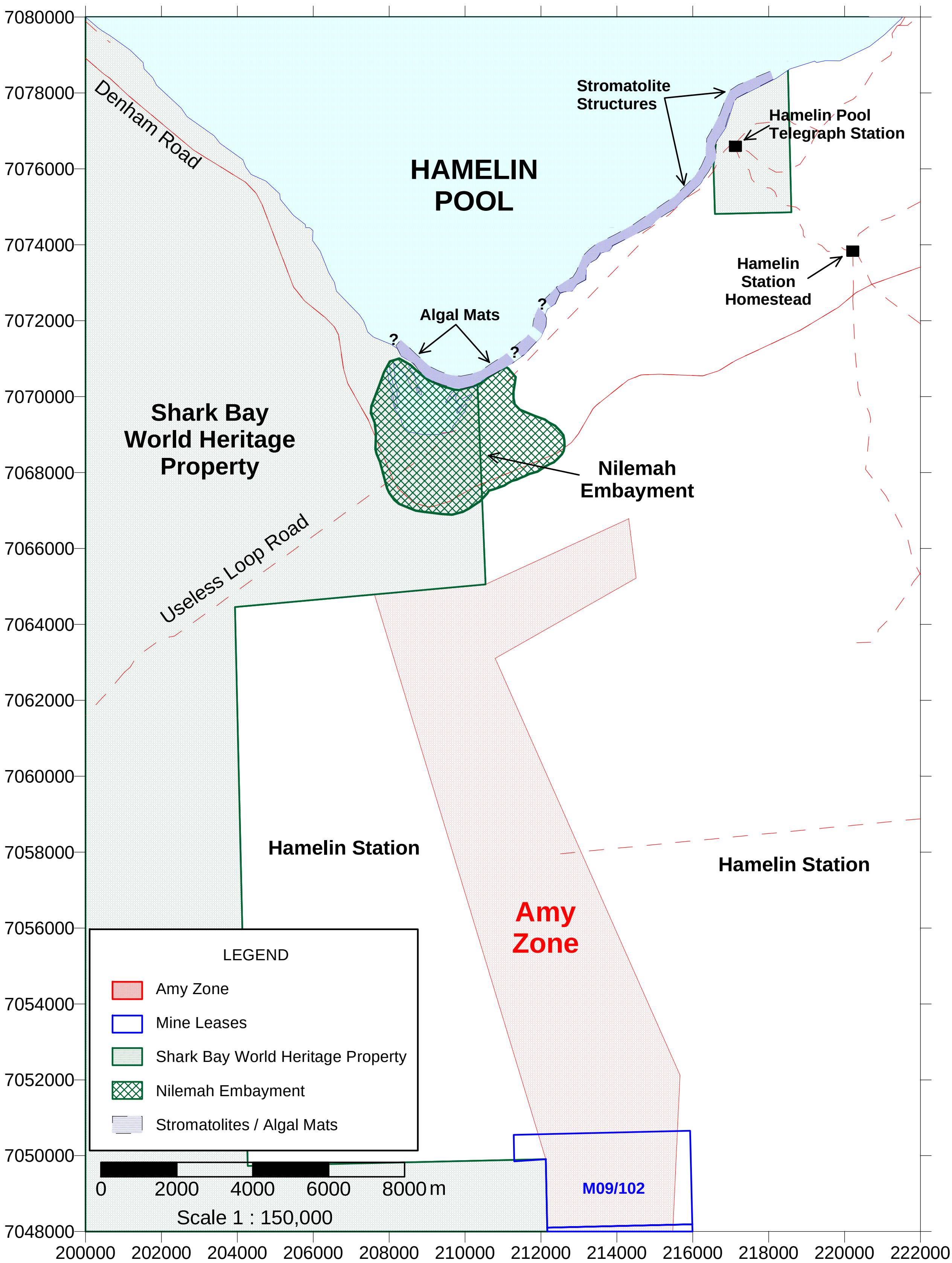
Job No. 42905541
Prep. By TRS 3 Mar 05
Chk'd By RW 3 Mar 05
Revision No. 0

Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

COBURN MINERAL SAND PROJECT AREA

URS

Figure 2



Job No.	42905541		Gunson Resources Limited	**Figure 3**
Prep. By	RBW	31 Mar '05	GROUNDWATER IMPACT ASSESSMENT, CORURN PROJECT	URS
Chk'd By	RBW	31 Mar '05	**PROXIMITY OF NILEMAH EMBAYMENT AND HAMELIN POOL**	
Revision No.		0		

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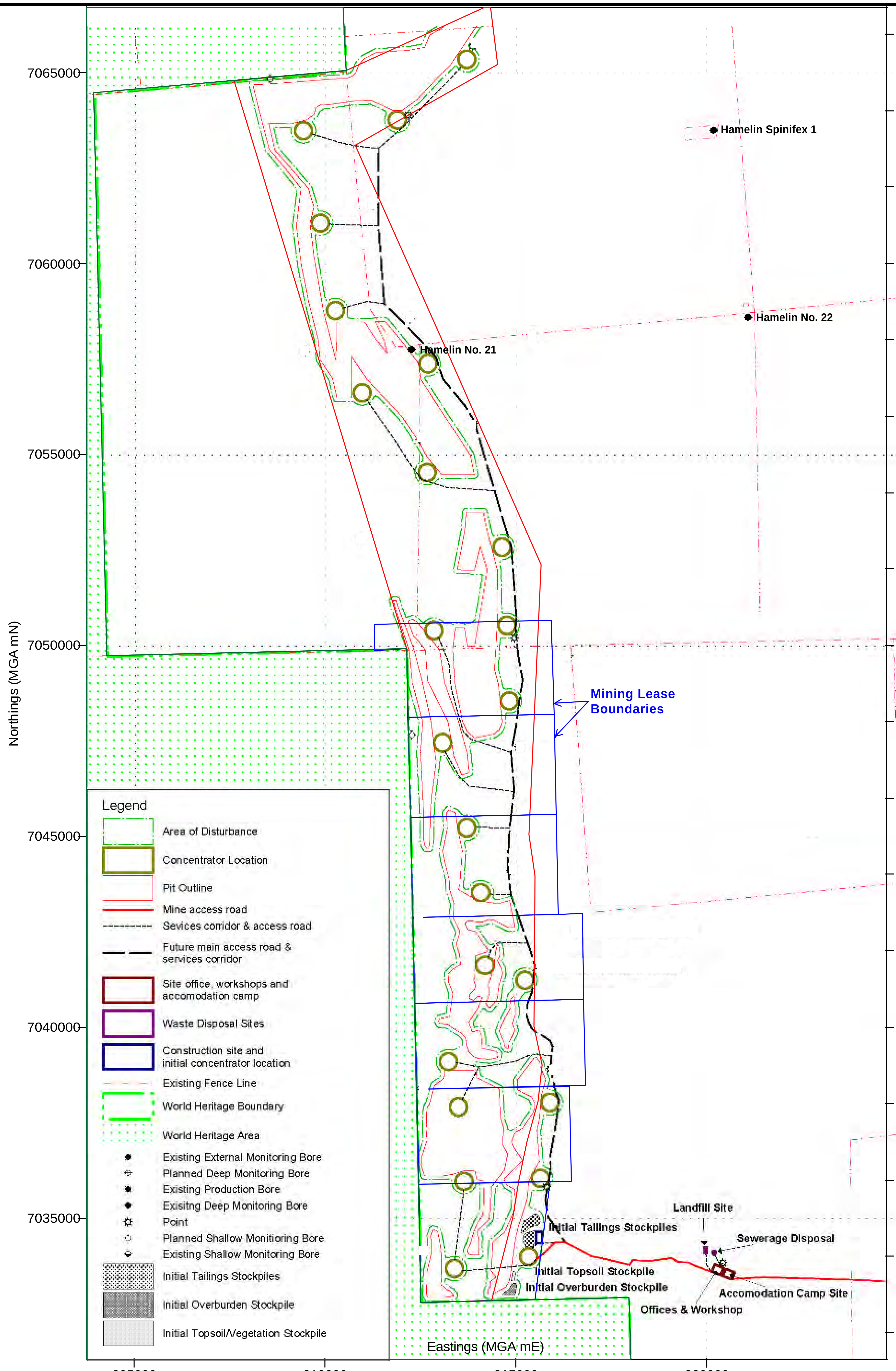
Nilemah Embayment Location Map.srf



Job No.	42905541	
Prep. By	RBW	27 Feb 05
Chk'd By	RBW	27 Feb 05
Revision Indicator	1	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PLANNED MINE LAYOUT

Figure 4

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Planned Mine Layout.srf

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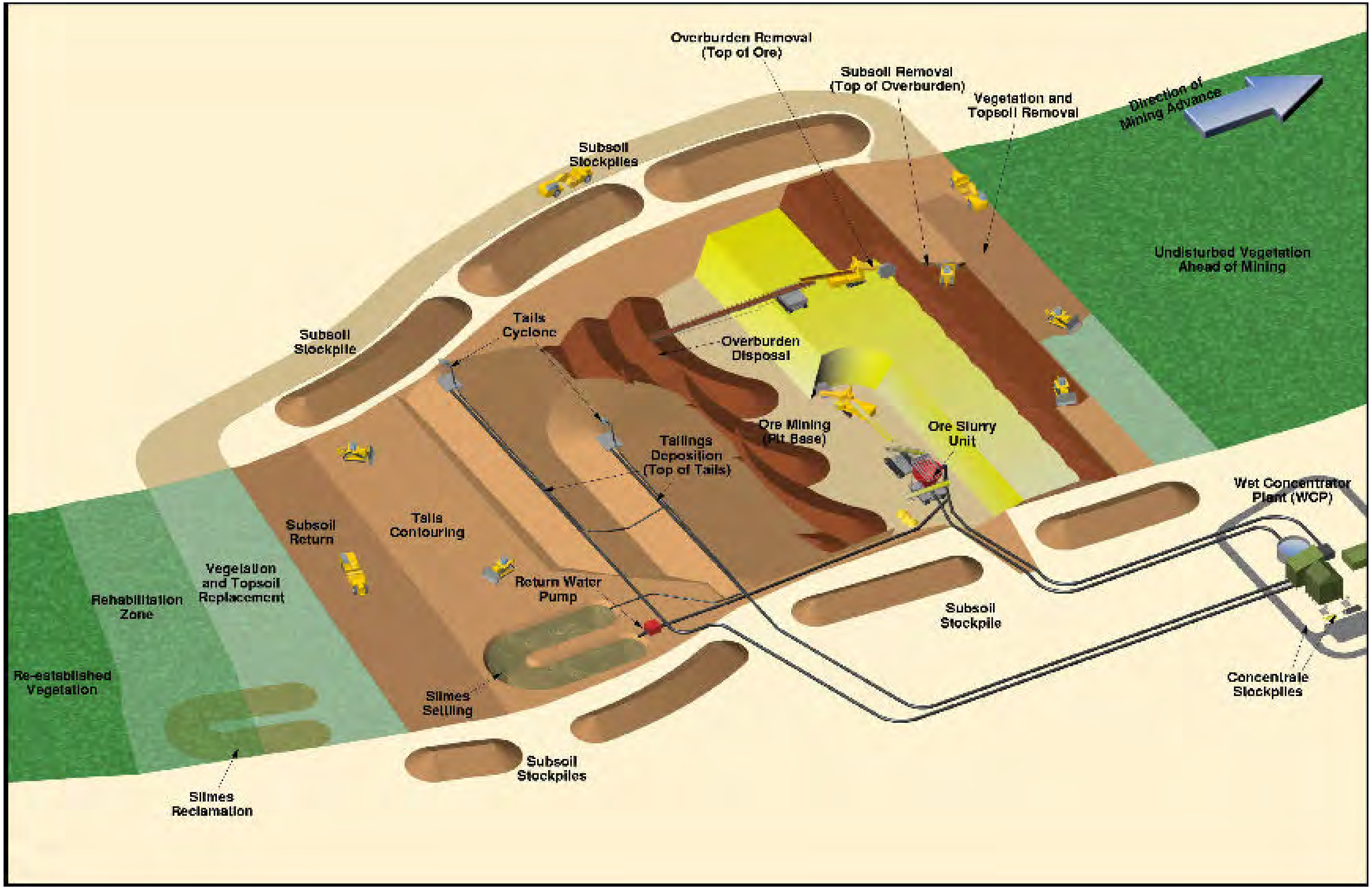

Job No.	42905541
Prep. By	RBW 3 Dec '04
Chk'd By	RBW 3 Dec '04
Revision Indicator	0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PROPOSED OPERATIONAL LAYOUT

Figure 5

URS

Proposed Operational Layout.srf

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Rainfall.xls/Climatic Data.grf

Job No.	42905541
Prep. By	RBW	20 Oct 04
Chk'd By	RBW	20 Oct 04
Revision No.	0

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GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

METEOROLOGICAL DATA

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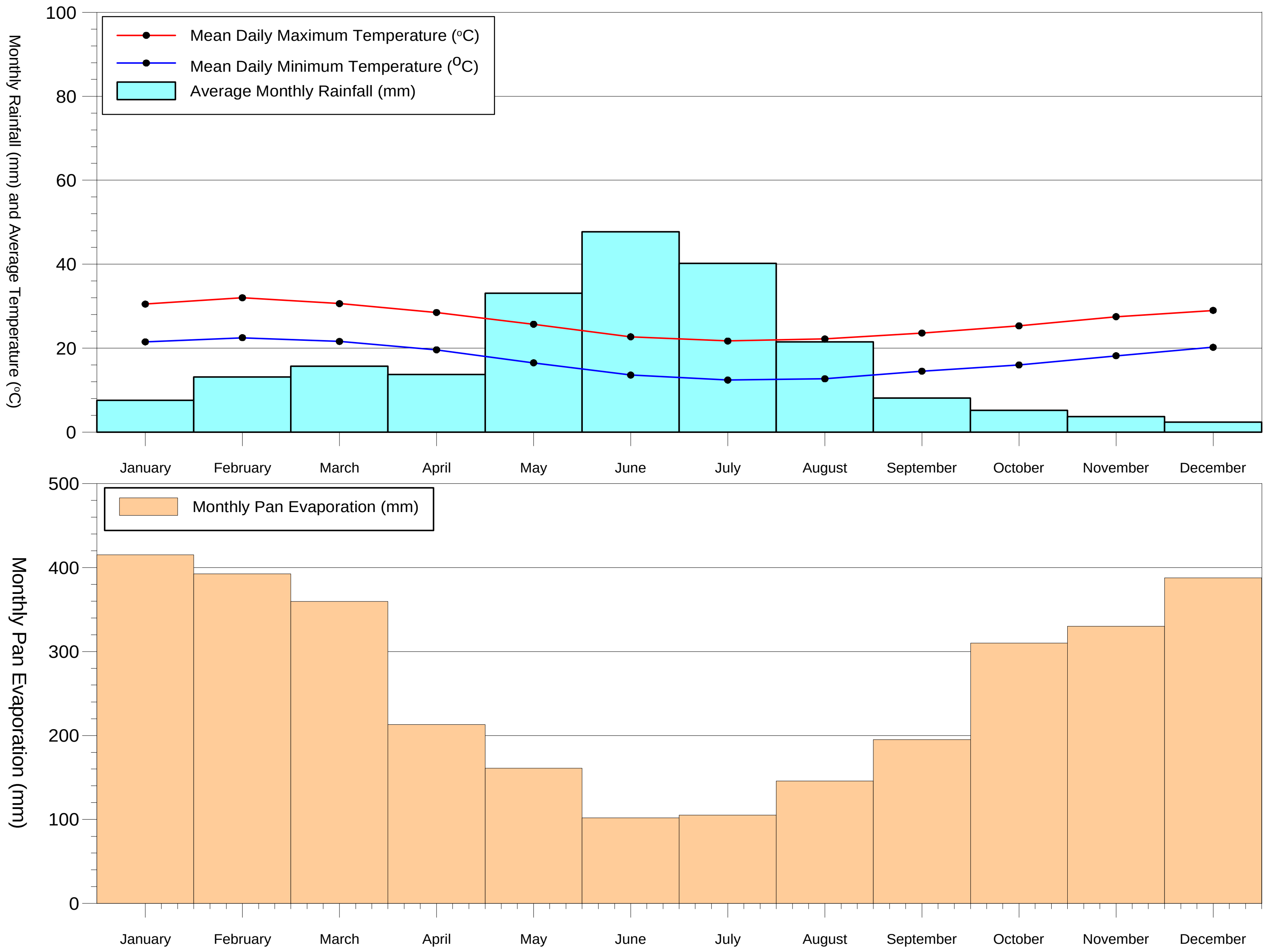
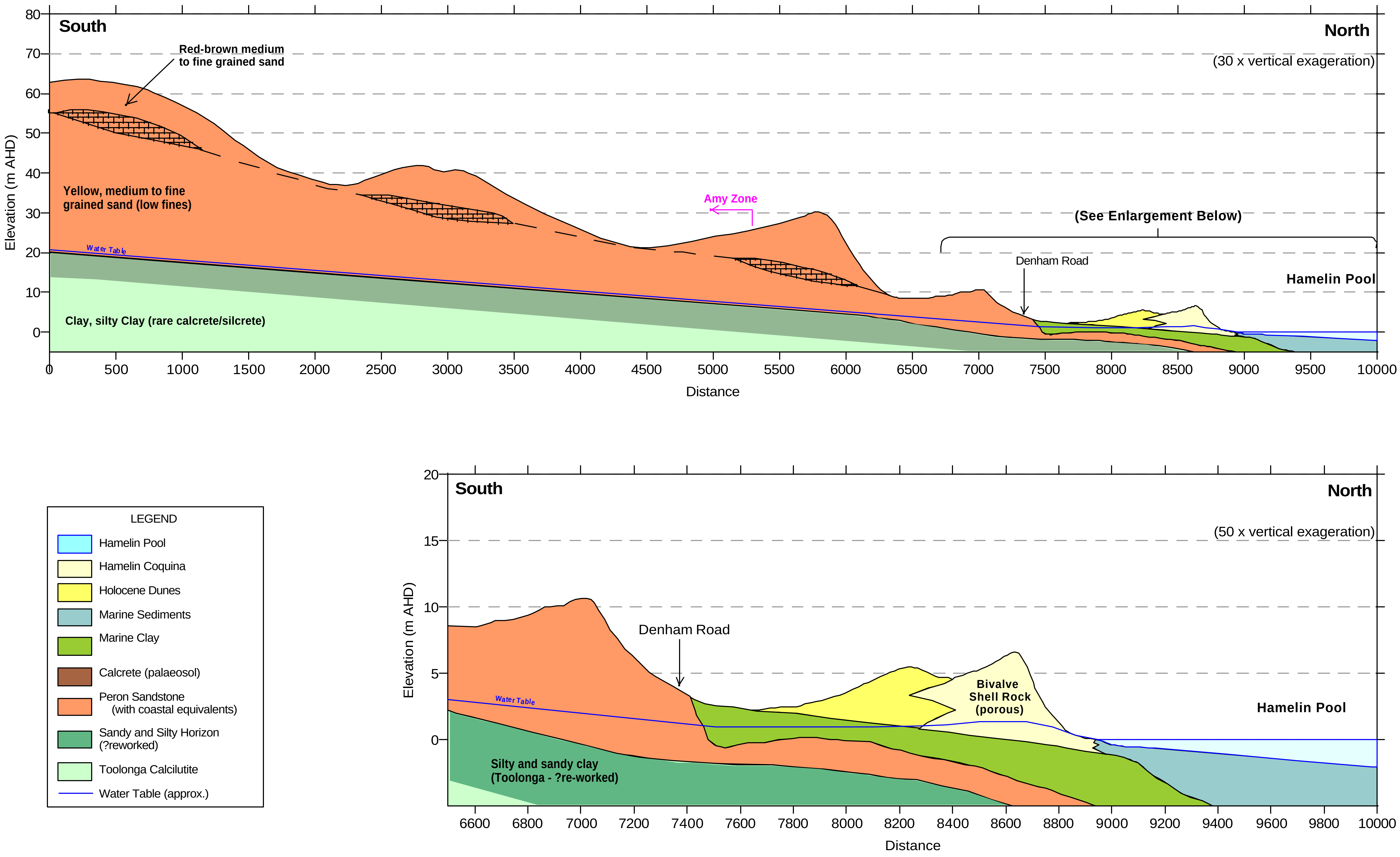
Figure 6

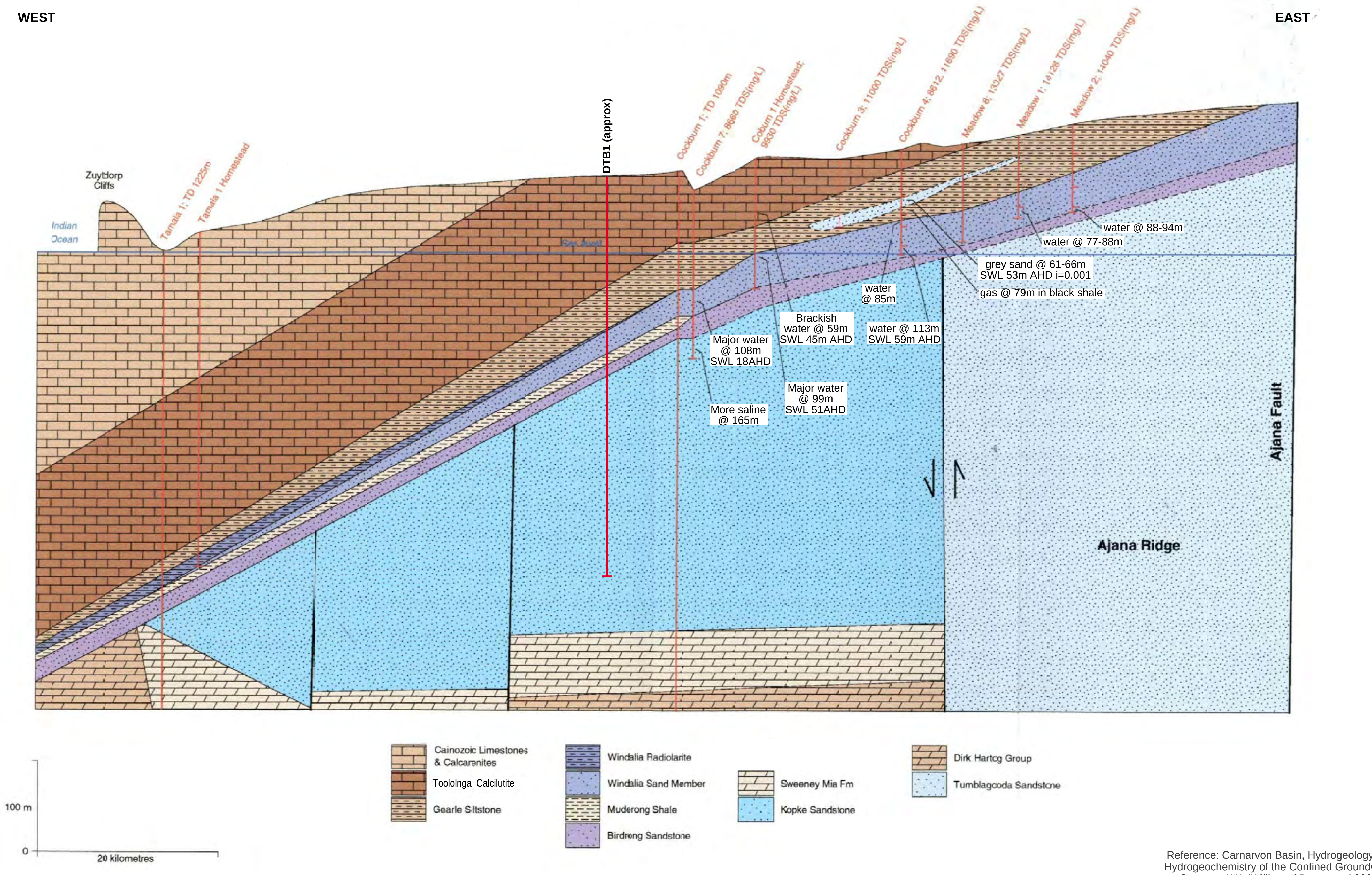




Near coastal geology from Bureau of Mineral Resources, 1990.

Job No.	42905541		Gunson Resources Limited	Figure 7
Prep. By	DL	4 April 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	4 April 05	**LOCAL GEOLOGICAL CROSS-SECTION OF THE SUPERFICIAL FORMATIONS**	URS
Revision Indicator		0		

Local Geological Cross-section.srf



Reference: Carnarvon Basin, Hydrogeology and Hydrogeochemistry of the Confined Groundwater Systems, WA (Willis and Dogramaci,2000)

Job No.	42905541	
Prep. By	RBW	3 Mar 05
Chk'd By	IGB	3 Mar 05
Revision No.	1	

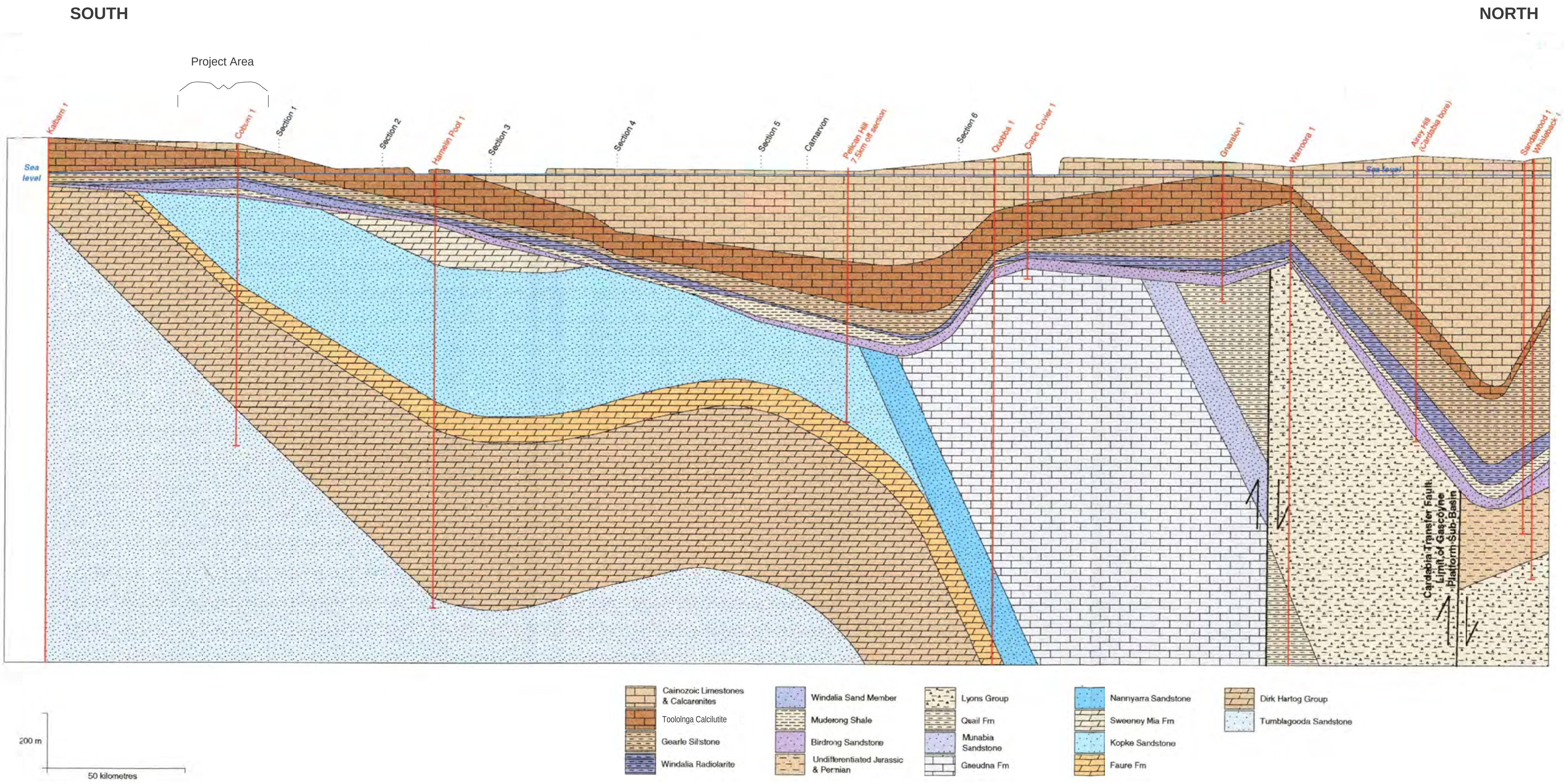
Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

GASCOYNE PLATFORM
WEST- EAST STRATIGRAPHY PROFILE

URS

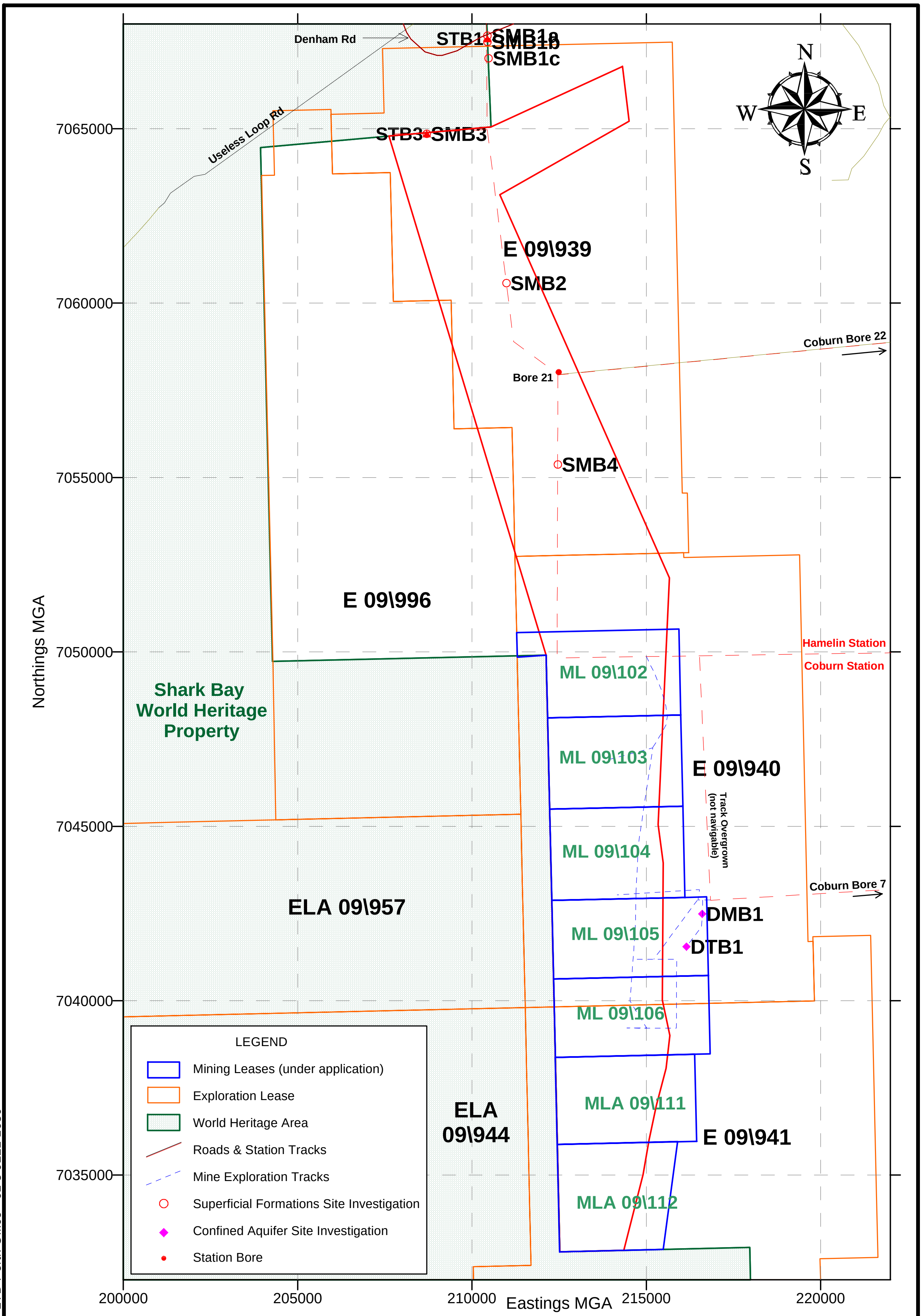
Figure 8a

Thu 31 Mar 05



Reference: Carnarvon Basin, Hydrogeology and Hydrogeochemistry of the Confined Groundwater Systems, WA (Willis and Dogramaci,2000)

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **GASCOYNE PLATFORM SOUTH - NORTH STRATIGRAPHY PROFILE**	URS	
Prep. By	RBW	3 Mar 05		Figure 8b	
Chk'd By	IGB	3 Mar 05			
Revision No.		0			



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			Gunson Resources Limited	Figure 9
Job No.	42905541		GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Prep. By	RBW	2 Dec '04	**LOCATIONS OF SITE INVESTIGATION BORES**	
Chk'd By	RBW	2 Dec '04		
Revision No.	2			

Locations of Site Investigation Bores.srf

BORE COMPLETION REPORT

BOREHOLE: SMB2 S & D

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

DRILLING CO:	**Aquatech Drilling**
DRILL METHOD:	**Mud-rotary**
PROJECT NAME:	**Coburn Mineral Sands Project**
PROJECT NUMBER:	**42905541.1841**
CLIENT:	**Gunson Resources Ltd**
LOCATION:	**Hamelin Station, Shark Bay**

SHALLOW PIEZOMETER

RL of Collar (S):	41.71
Total Cased Depth (S):	24
Casing/Screen Dia (S):	54mmID
Screen Interval (S):	18 - 24
Static Water Level (S):	23.36 mbgl
Final Salinity (S):	14,052 mg/l
Final pH (S):	6.3
Pump Test:	bailed

INTERMEDIATE PIEZOMETER

RL of Collar (I):	N/A
Total Cased Depth (I):	N/A
Casing/Screen Dia (I):	N/A
Screen Interval (I):	N/A
Static Water Level (I):	N/A
Final Salinity (I):	N/A
Final pH (I):	N/A
Pump Test:	N/A

DEEP PIEZOMETER

RL of Collar (D):	41.71
Total Cased Depth (D):	40
Casing/Screen Dia (D):	54mmID
Screen Interval (D):	34 - 40
Static Water Level (D):	23.16 mbgl
Final Salinity (D):	34,500 mg/l
Final pH (D):	6.7
Pump Test:	13.8 kL/d, 40min

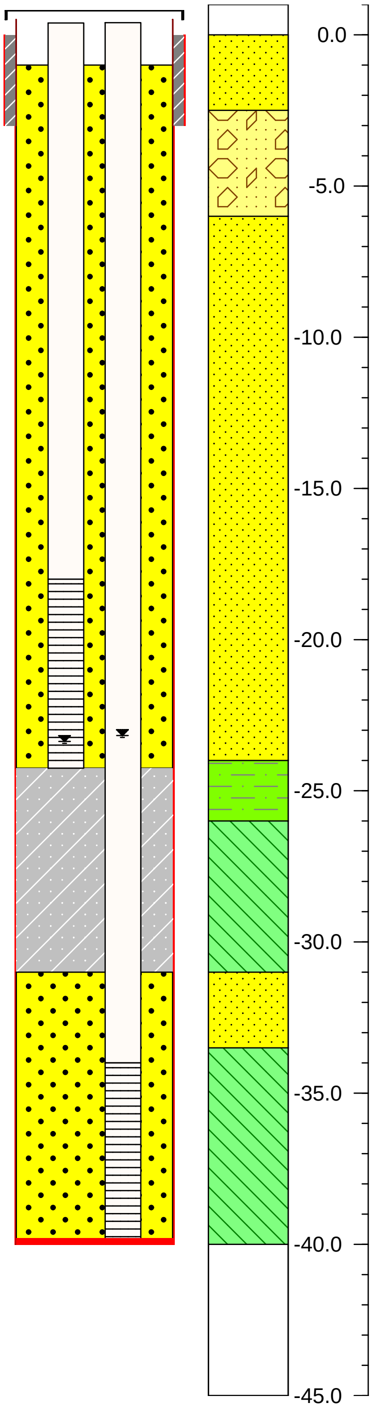
GENERAL DATA

Total Drilled Depth:	40m
Coordinates	
Datum:	GDA 94
Easting (mE):	211125.3 mE
Northing (mN):	7060717.7 mN

START DATE: **4/8/04** FINISH DATE: **5/8/04** LOGGED BY: **RBW**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FORMATION	pH	TDS (mg/L)

Bore construction labels:
- Lockable Steel Riser and Lid
- 250mm Cement Grout
- 219mm OD Steel Surface Casing
- 200mm Hole
- Graded Gravel Pack 2.0-3.6mm Dia.
- 54mm ID, 60mm OD, Class 12 uPVC
- 54mm ID, 60mm OD, Class 12 uPVC Slotted (0.3mm)
- Cement Grout Seal
- 54mm ID, 60mm OD, Class 12 uPVC Slotted (0.3mm)
- 40m End of Hole



Description	Formation
SAND: Red-brown, medium to fine grained, quartz, poorly sorted, non-cemented?	Superficial Sand
SAND/CALCRETE: Light grey, light brown-grey, slightly to well cemented, sand medium to fine grained	Superficial Sand
SAND: Yellow-brown, light red-brown, medium minor fine grained quartz, round to sub round, non-cemented, moderate-poorly sorted Below 15m yellow, medium to fine grained, non-cemented, poorly sorted, round to sub round	Superficial Sand
SILT: White, slightly clayey, chalky	Toolonga Calcilutite
CLAY: Light yellow-grey, light grey, silty, plastic	Toolonga Calcilutite
SAND: Light grey, light brown, medium to fine grained, some coarse sand, rounded to sub rounded, some polished grains, poorly sorted, non-cemented	Toolonga Calcilutite
CLAY: Light grey, light yellow-grey, stiff, silty, plastic Below 33m light grey, cream, white	Toolonga Calcilutite
40m End of Hole	

DRAWN BY: GPL DATE: 23/8/04
CHECKED BY: RBW DATE: 24/8/04
FIGURE: 10

BORE COMPLETION REPORT

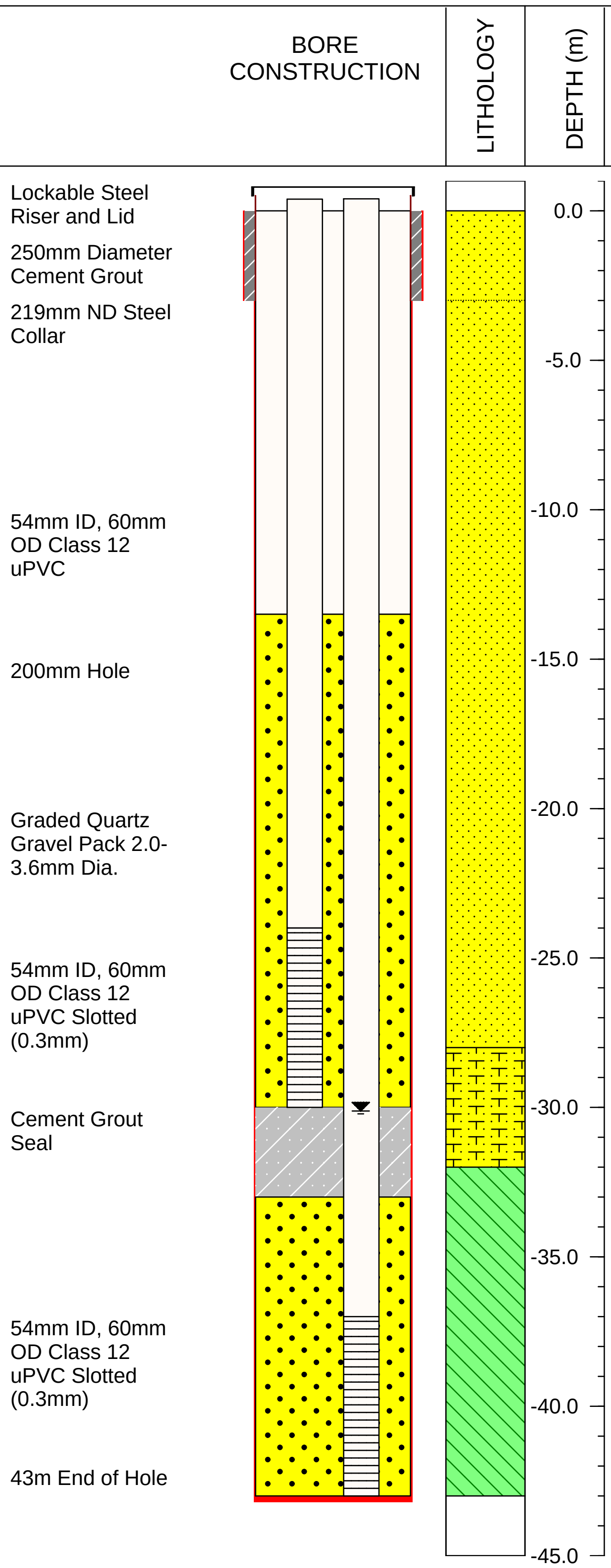
BOREHOLE: SMB3 S & D

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

PROJECT NAME:	**Coburn Mineral Sands Project**
PROJECT NUMBER:	**42905541.1841**
CLIENT:	**Gunson Resources Ltd**
LOCATION:	**Hamelin Station, Shark Bay**
DRILLING CO:	**Aquatech Drilling**
DRILL METHOD:	**Mud-rotary**

SHALLOW PIEZOMETER		INTERMEDIATE PIEZOMETER		DEEP PIEZOMETER		GENERAL DATA	
RL of Collar (S):	33.50mAHD	RL of Collar (I):	N/A	RL of Collar (D):	33.50mAHD	Total Drilled Depth:	43m
Total Cased Depth (S):	30m	Total Cased Depth (I):	N/A	Total Cased Depth (D):	43m		
Casing/Screen Dia (S):	54mm ID	Casing/Screen Dia (I):	N/A	Casing/Screen Dia (D):	54mm ID	Coordinates	
Screen Interval (S):	24 - 30	Screen Interval (I):	N/A	Screen Interval (D):	37 - 43	Datum:	GDA 94
Static Water Level (S):	Dry	Static Water Level (I):	N/A	Static Water Level (D):	30.12 mbtoc	Easting (mE):	208683.0
Final Salinity (S):	N/A	Final Salinity (I):	N/A	Final Salinity (D):	34,476mg/l	Northing (mN):	7065001.0
Final pH (S):	N/A	Final pH (I):	N/A	Final pH (D):	6.2		
Pump Test:	N/A	Pump Test:	N/A	Pump Test:	Not pumped		

START DATE: **1/8/04** FINISH DATE: **2/8/04** LOGGED BY: **RBW**



DESCRIPTION	FORMATION	pH	TDS (mg/L)
SAND: Red-brown, medium to fine grained, slightly silty, quartz, trace black sand, rounded-subrounded, poorly sorted	Superficial Sand		
SAND: Pale red-brown, yellow-brown, medium to fine grained, moderate-poorly sorted, rounded-subrounded, quartz, loose Below 13m medium, some fine grained, moderately sorted, loose Below 19m pale yellow, light yellow-brown, medium to fine grained, loose	Superficial Sand		
SILTY SAND: Light grey, minor red-brown streaks, fine to coarse grained, quartz, sand with silty matrix, minor clay in bricks, rounded-subrounded, trace pink garnet	Toolonga Calcilutite		
CLAY: Cream, light yellow-grey, silty, minor fine sand, plastic	Toolonga Calcilutite		
43m End of Hole			

DRAWN BY: GPL DATE: 23/8/04
CHECKED BY: RBW DATE: 24/8/04

FIGURE: 11

BORE COMPLETION REPORT

URS

BOREHOLE: SMB4 S & D

URS Australia Pty Ltd
20 Terrace Rd, East Perth, 6004
Phone 08 92211630
Fax 08 92211639

PROJECT NAME: **Coburn Mineral Sands**
PROJECT NUMBER: **42905541**
CLIENT: **Gunson Resources Ltd**
LOCATION: **Hamelin Station, Shark Bay**

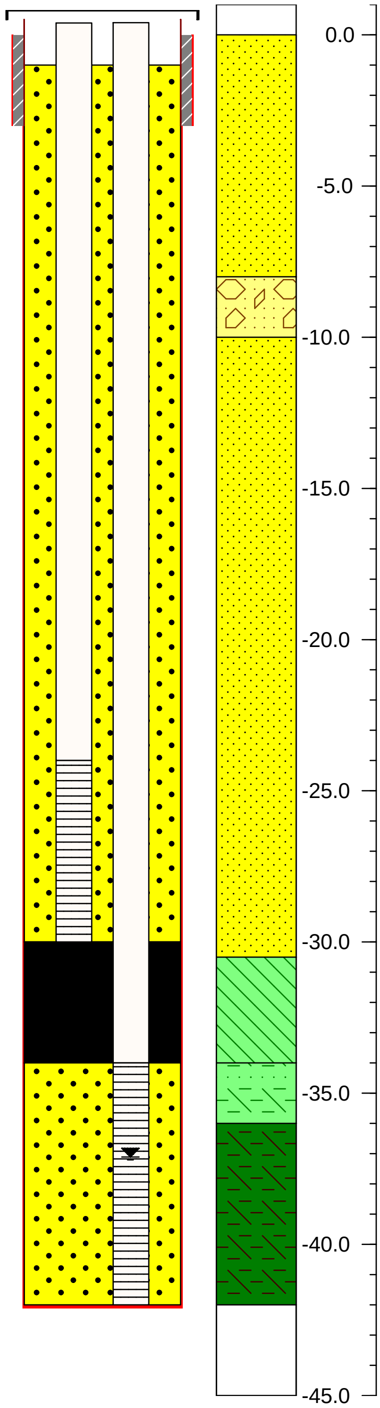
DRILLING CO: **Aquatech Drilling**
DRILL METHOD: **Mud-rotary**

SHALLOW PIEZOMETER		INTERMEDIATE PIEZOMETER		DEEP PIEZOMETER		GENERAL DATA	
RL of Collar (S):	67.22m AHD	RL of Collar (I):	N/A	RL of Collar (D):	67.76m AHD	Total Drilled Depth:	42m
Total Cased Depth (S):	30m	Total Cased Depth (I):	N/A	Total Cased Depth (D):	42m		
Casing/Screen Dia (S):	54mm ID	Casing/Screen Dia (I):	N/A	Casing/Screen Dia (D):	54mm ID	Coordinates	
Screen Interval (S):	24-30	Screen Interval (I):	N/A	Screen Interval (D):	36-42m	Datum:	GDA 94
Static Water Level (S):	Dry	Static Water Level (I):	N/A	Static Water Level (D):	37.11mbgl	Easting (mE):	212594.1mE
Final Salinity (S):	N/A	Final Salinity (I):	N/A	Final Salinity (D):	11,172	Northing (mN):	705527.1mN
Final pH (S):	N/A	Final pH (I):	N/A	Final pH (D):	6.2		
Pump Test:	N/A	Pump Test:	N/A	Pump Test:	2.4kL/d,25min		

START DATE: **2/8/04** FINISH DATE: **3/8/04** LOGGED BY: **RBW**

BORE CONSTRUCTION

Lockable Steel Riser and Lid
250mm Diameter Cement Grout
219mm ND Steel Surface Casing
200mm Hole
Graded Gravel Pack 2.0-3.6mm Dia.
54mm ID, 60mm ND, Class 12 uPVC
54mm ID, 60mm OD, Class 12 uPVC Slotted
Cement Grout Seal
54mm ID, 60mm OD, Class 12 uPVC Slotted
42m End of Hole



DESCRIPTION	FORMATION	pH	TDS (mg/L)
SAND: Red-brown medium to fine grained, quartz, poorly sorted, non-cemented	Superficial Sand		
SAND/CALCRETE: Light brown, cream, fine to medium grained, slightly to well cemented, poorly sorted	Superficial Sand		
SAND: Yellow, light yellow, medium grained, rare fine sand, moderately sorted, quartz, round to sub round, non-cemented. Below 21m light brown, light yellow-brown, medium to fine grained, rare coarse sand	Superficial Sand		
CLAY: Green-yellow	Toolonga Calcilutite		
SAND AND CLAY: Light brown	Toolonga Calcilutite		
SHALE/CLAYSTONE: Light brown	Toolonga Calcilutite		
42m End of Hole Scale: 1 : 250			

DRAWN BY: GPL DATE: 23/8/04
CHECKED BY: RBW DATE: 24/8/04

FIGURE: 12

BORE COMPLETION REPORT

BOREHOLE: STB3

URS Australia Pty Ltd — Phone 08 92211630
20 Terrace Rd, East Perth, 6004 — Fax 08 92211639

PROJECT NAME:	**Coburn Mineral Sands Project**
PROJECT NUMBER:	**42905541.1841**
CLIENT:	**Gunson Resources Ltd**
LOCATION:	**Hamelin Station, Shark Bay**
DRILLING CO:	**Aquatech Drilling**
DRILL METHOD:	**Mud-rotary**

TOTAL DRILLED DEPTH:	**43m**	OPEN INTERVAL:	**16-43m**	R.L OF COLLAR:	**33.76**
TOTAL CASED DEPTH:	**43m**	STATIC WATER LEVEL (mbgs):	**30.22mbgl**	COORDINATES:	**208698.5 mE**
CASING DIAMETER:	**154mm ID**	DATE OF MEASUREMENT:	**10/8/04**		**7065001.6 mN**
SCREEN DIAMETER:	**154mm ID**	PUMPING TEST: **7.5kL/d for 3hrs**		DATUM:	**GDA 94**
		FINAL SALINITY:	**mg/L**		

START DATE: **28/7/04** FINISH DATE: **31/7/04** LOGGED BY: **RBW**

BORE CONSTRUCTION	LITHOLOGY	DEPTH (m)	DESCRIPTION	FORMATION	pH	TDS (mg/L)

Lockable Steel Riser and Lid

311mm Diameter Cement Grout

250mm ND Steel Collar

154mm ID, 168mm OD Class 9 uPVC

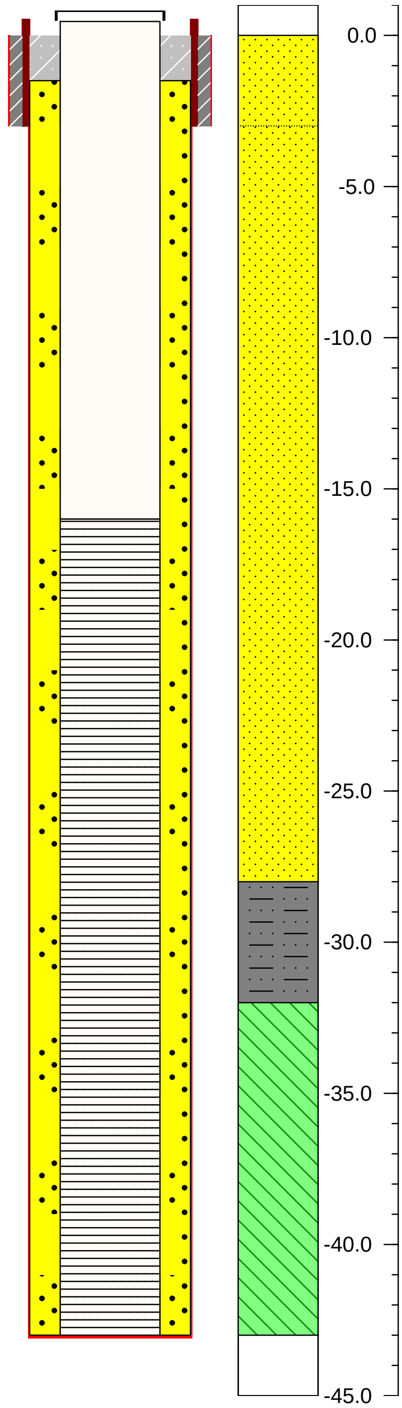
250mm Hole

154mm ID, 168mm OD Class 9 Slotted uPVC

2 - 3.6mm Dia. Graded Quartz Gravel Pack

Casing Centralisers

43m End of Hole



Description	Formation
SAND: Red-brown, medium to fine grained, slightly silty, quartz, trace black sand, rounded-subrounded, poorly sorted	Superficial Sand
SAND: Pale red-brown, yellow-brown, medium to fine grained, moderate-poorly sorted, rounded-subrounded, quartz, loose Below 13m medium, some fine grained, moderately sorted, loose Below 19m pale yellow, light yellow-brown, medium to fine grained, loose	Superficial Sand
SANDY SILT: Light grey, minor red-brown streaks, fine to coarse grained, quartz, sand with silty matrix, minor clay in bricks, rounded-subrounded, trace pink garnet	Toolonga Calcilutite
CLAY: Cream, light yellow-grey, silty, minor fine sand, plastic	Toolonga Calcilutite
43m End of Hole	

DRAWN BY: GPL DATE: 23/8/04

CHECKED BY: RBW DATE: 24/8/04

FIGURE: 13

URS AUSTRALIA PTY LTD, Perth Office +61 8922 11630

SMB2d CRT.xls/.grf

Job No.	42905541.1841	
Prep. By	RBW	20 Aug 04
Chk'd By	RBW	20 Aug 04
Revision No.		0

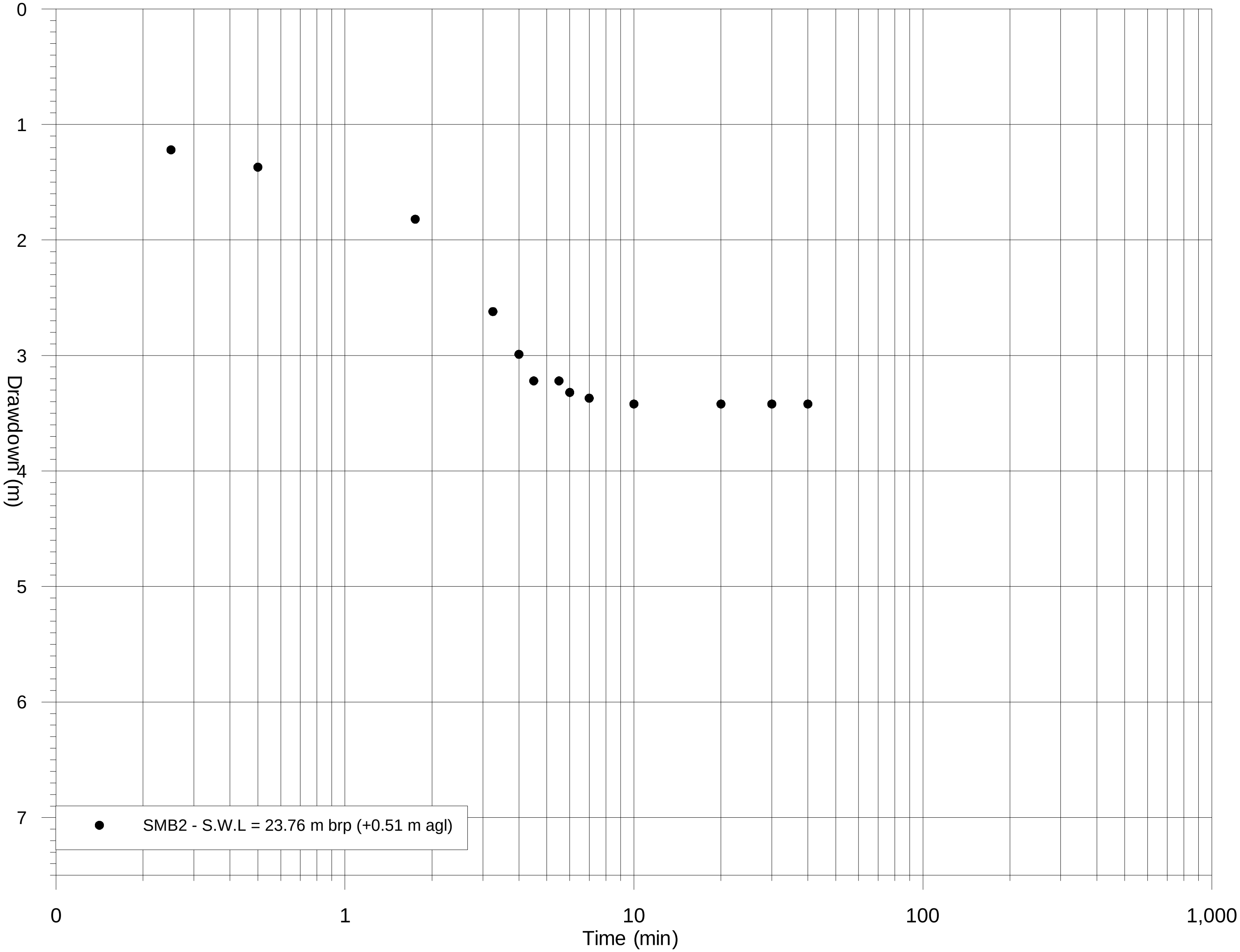
Gunson Resources Limited

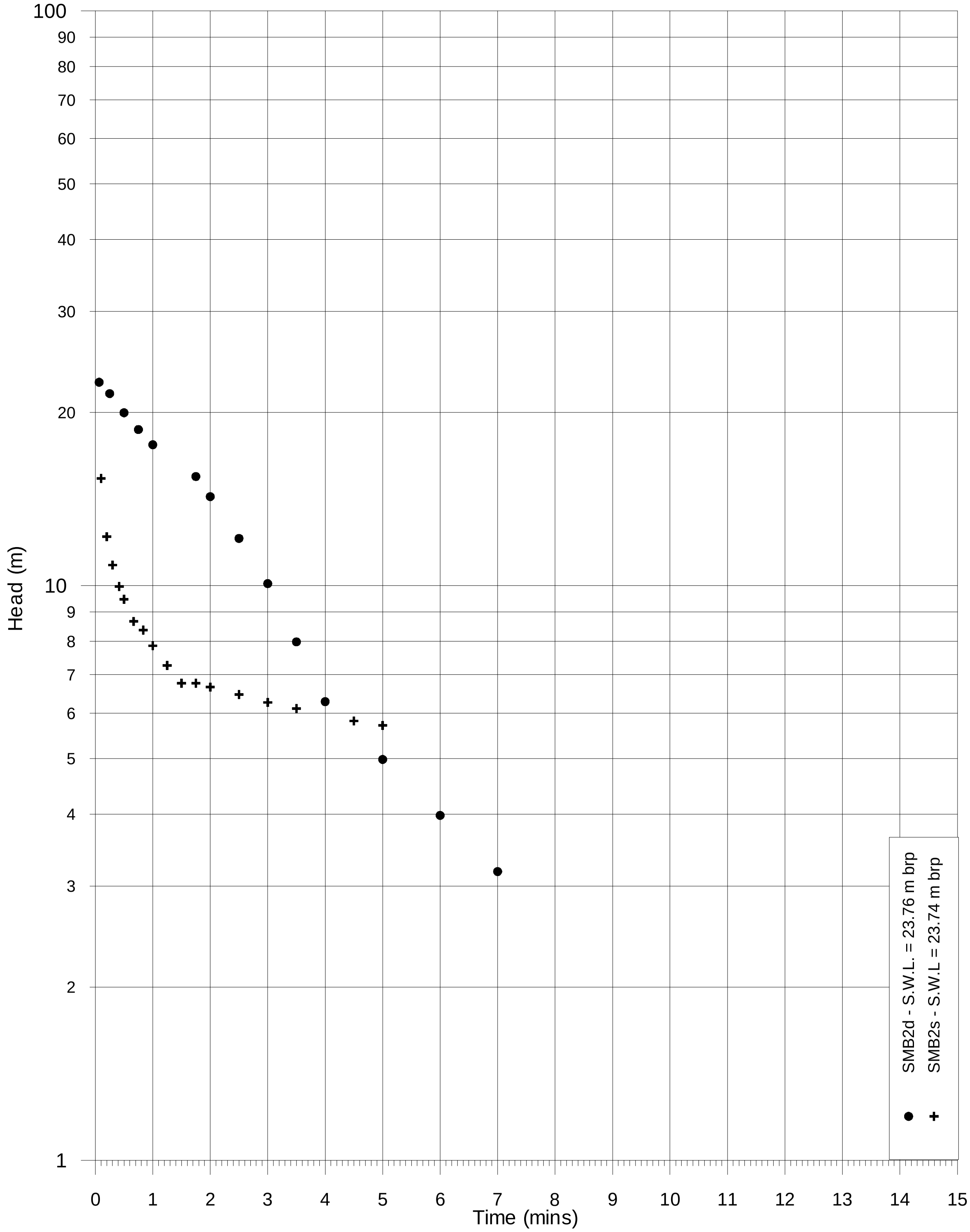
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SMB2d PUMPING TEST RESULTS

URS

Figure 14





Job No.	42905541.1841	
Prep. By	RBW	20 Aug 04
Chk'd By	RBW	20 Aug 04
Revision No.		0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SMB2s AND SMB2d, FALLING HEAD TESTS

Figure 15

URS

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STB3 CRT.xls/.grf

Job No.	42905541.1841	
Prep. By	RBW	20 Aug 04
Chk'd By	RBW	20 Aug 04
Revision No.	0	

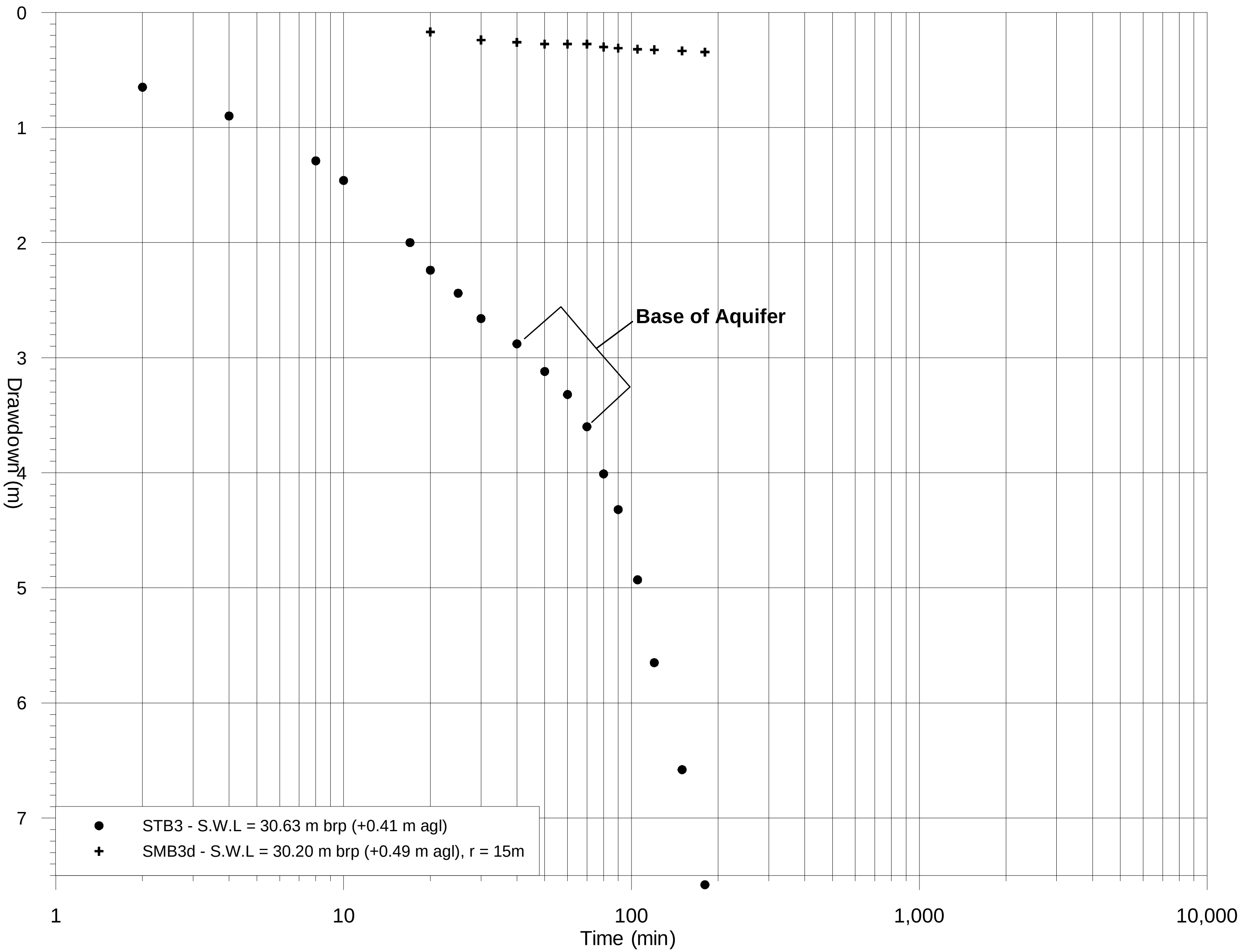
Gunson Resources Limited

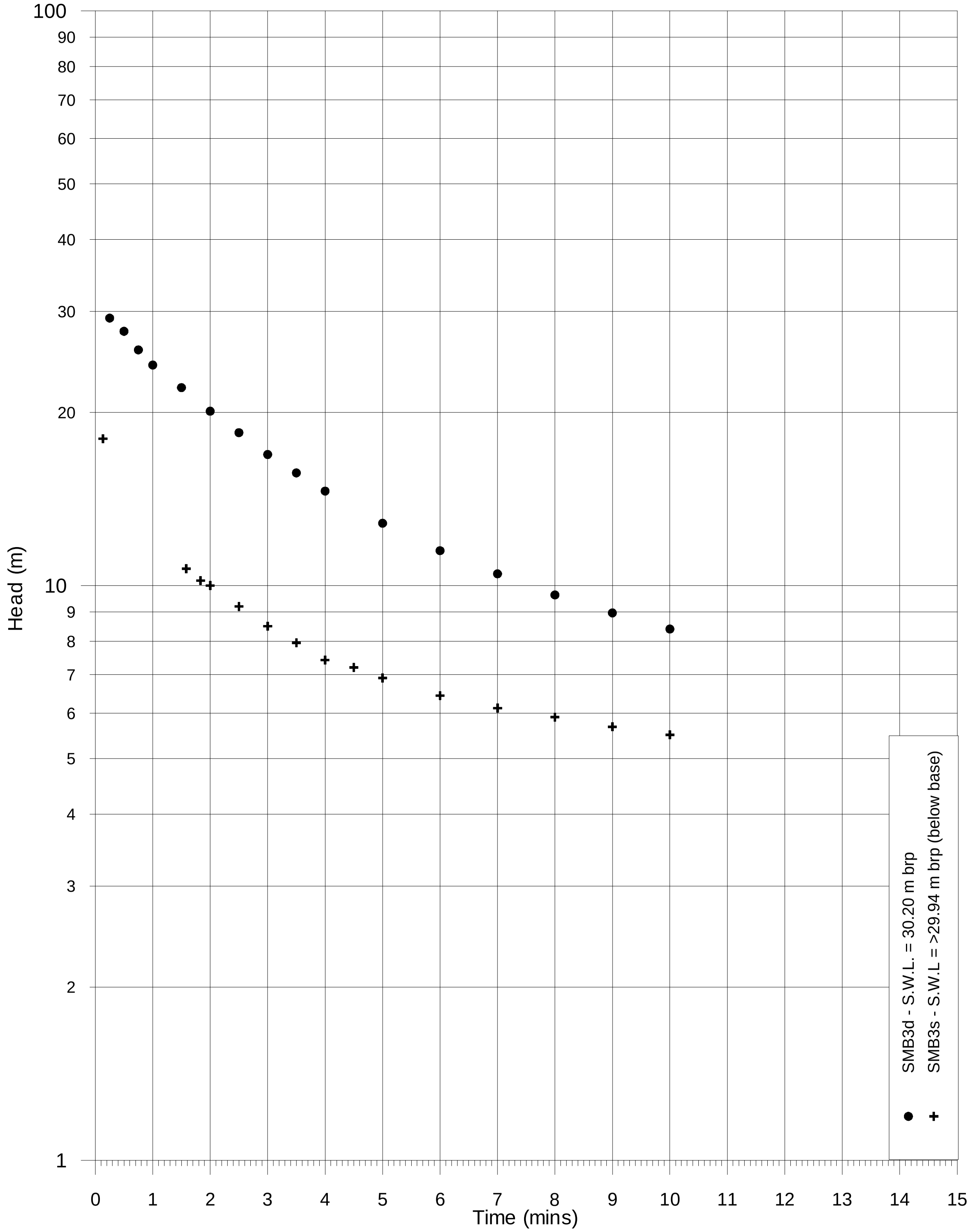
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

STB3 PUMPING TEST
DRAWDOWN IN STB3 and SMB3d

URS

Figure 16





Job No.	42905541.1841		Gunson Resources Limited	**Figure 17**
Prep. By	RBW	20 Aug 04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	20 Aug 04		URS
Revision No.	0		**SMB3s AND SMB3d FALLING HEAD TESTS**	

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SMB3s Falling Head.xls/SMB3d Falling Head.xls/SMB3 Falling Head Tests.grf

SMB4d CRT.xls/.grf

Job No.	42905541.1841	
Prep. By	RBW	20 Aug 04
Chk'd By	RBW	20 Aug 04
Revision No.	0	

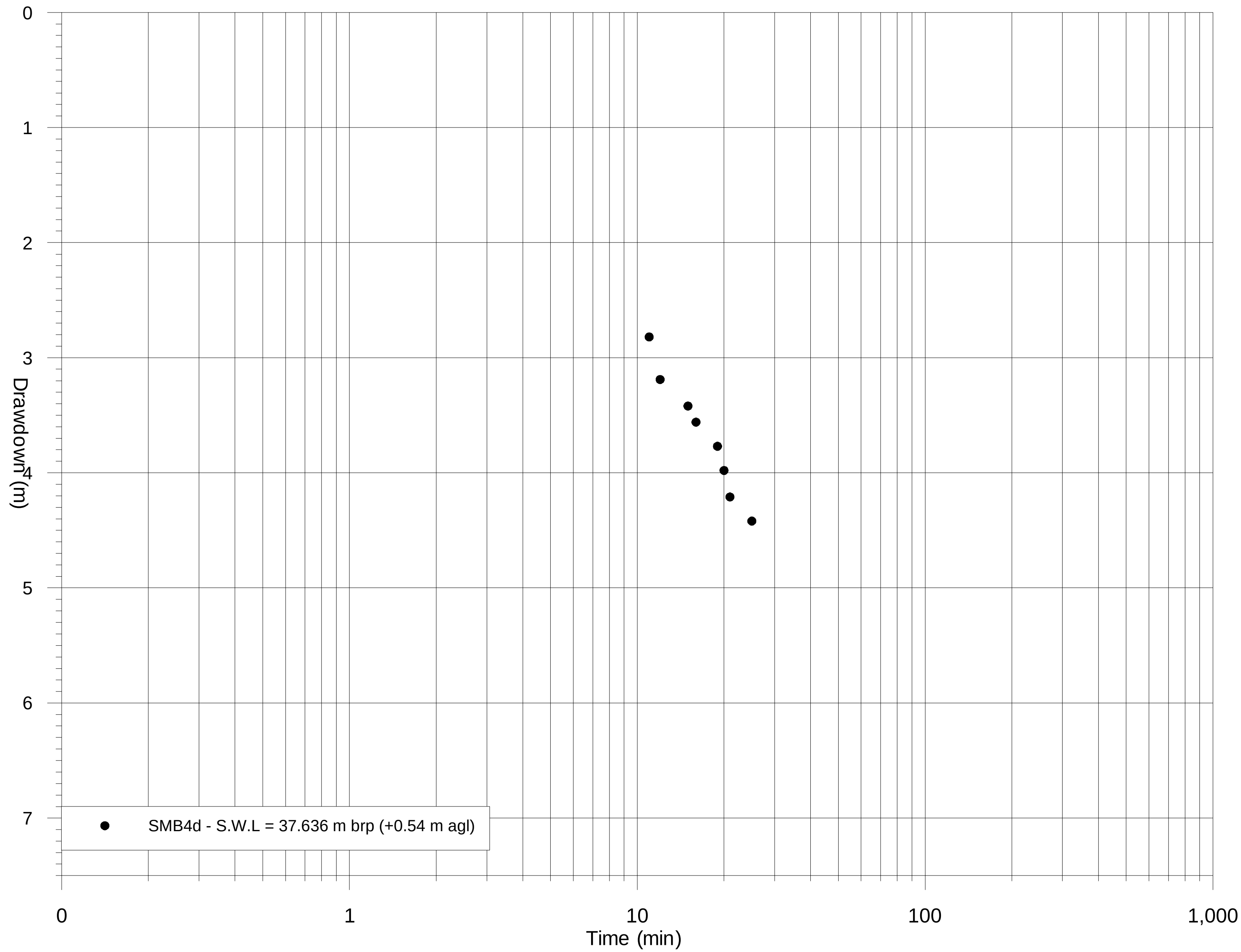
Gunson Resources Limited

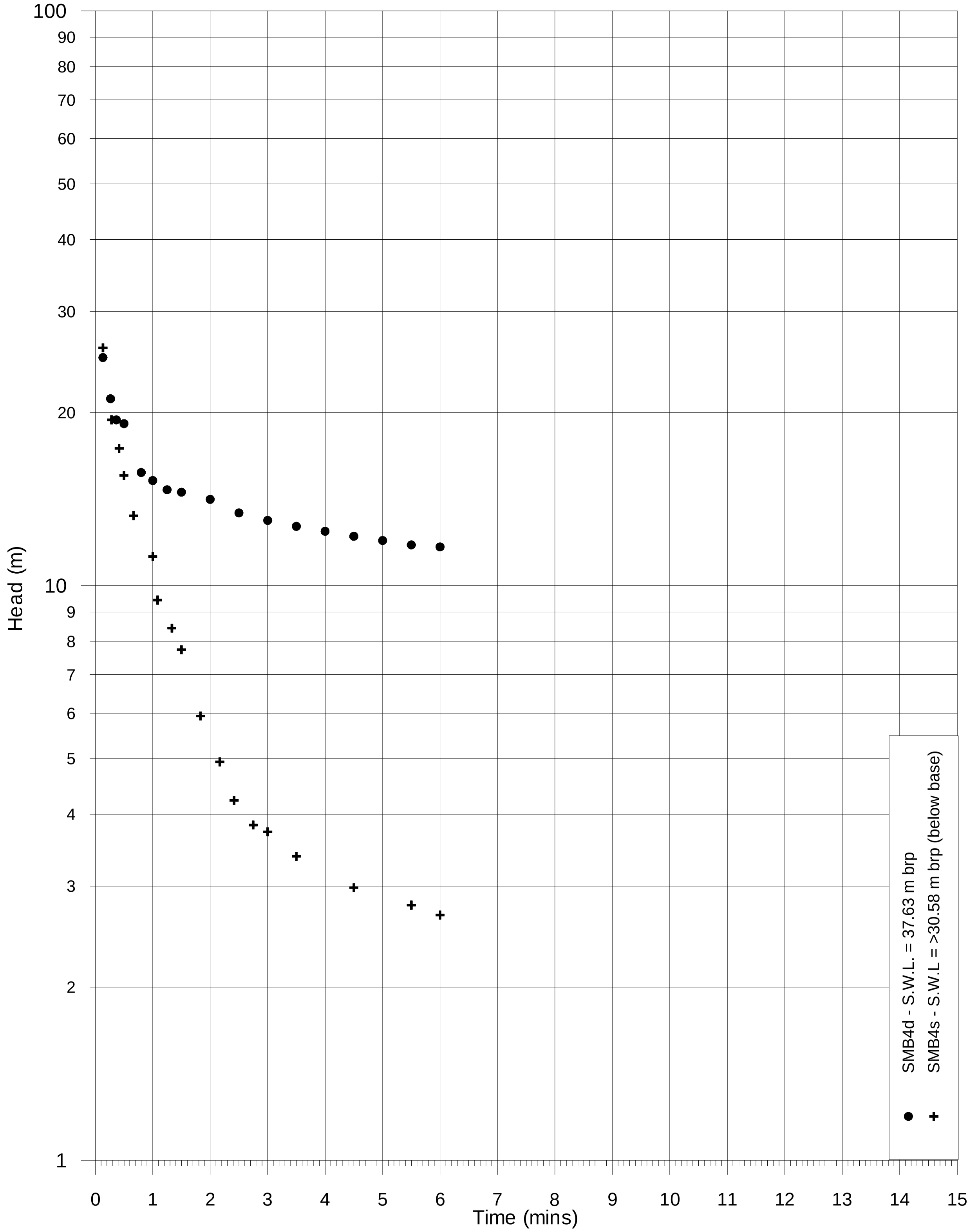
GROUNDWATER IMPACT ASSESSMENT

SMB4d PUMPING TEST RESULTS

URS

Figure 18





URS AUSTRALIA PTY LTD, Perth Office +61 8922 11630

Job No.	42905541.1841		Gunson Resources Limited	Figure 19
Prep. By	RBW	20 Aug 04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Chk'd By	RBW	20 Aug 04	**SMB4s AND SMB4d FALLING HEAD TESTS**	
Revision No.		0		

SMB4s Falling Head.xls/SMB4d Falling Head.xls/SMB4 Falling Head Tests.grf

COMPLETION REPORT

BOREHOLE: **DTB1 (Test Production Bore)**

URS Australia Pty Ltd — Phone 08 92211639
20 Terrace Rd, East Perth, 6004 — Fax 08 92211639

DRILLING CO:	**Drilling Contractors of Australia**
DRILL METHOD:	**Mud Rotary**
PROJECT NAME:	**GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT**
PROJECT NUMBER:	**42905541.1841**
CLIENT:	**Gunson Resources Limited**
LOCATION:	**Coburn Station, W.A**

TOTAL DRILLED DEPTH:	**485 m**
TOTAL CASED DEPTH:	**400 m**
CASING'S DIAMETERS:	
Surface Casing	**457 mmOD, 428mmID**
Pump Chamber:	**324 mmOD, 301 mmID**
Intermediate Casing:	**273 mmOD, 254 mmID**
Production string:	**220 mmOD, 200 mmID**
SCREEN DIAMETER:	**200 mmOD**
OPEN INTERVAL:	**206.5 - 400.0m**
STATIC WATER LEVEL (mbtoc):	**38.52**
DATE OF MEASUREMENT:	**16/12/04**
PUMPING TEST:	
FINAL SALINITY:	
R.L OF COLLAR:	**85.85 mAHD**
COORDINATES:	**216,160mE**
	7,041,547 mN
DATUM:	**GDA 94**

START DATE: **12 Sept 2004** FINISH DATE: **11 Nov 2004** LOGGED BY: **RW**

BORE CONSTRUCTION | DESCRIPTION | DEPTH (m) | LITHOLOGY | GAMMA LOG (0–100) | RESISTIVITY: SHORT NORMAL (0–10), LONG NORMAL (0–10) | CALIPER (100–500) | FORMATION

Bore construction:

- Cap
- Cement Grout (0 - 132m) (low heat, sulphate-reduced)
- Casing Centralisers
- 300mm NB API 5/L Sch 40 ERW Steel Casing (0 - 132m) (324 mmOD, 301 mmID)
- SWL - 40m
- 450mmNB API 5/L ERW Steel Casing (0 - 132m) (457 mmOD, 428 mmID)
- 533mm Diameter Hole (0 - 132m)
- Concentric Reducer
- Grout Shoe
- Casing Centralisers
- 250mm NB API 5/L Sch 40 ERW Steel Casing (132 - 205m) (273 mmOD, 254 mmID)
- 381mm Diameter Hole
- Cement Grout (low heat sulphate-reduced)
- Grout Shoe (205m)
- 250mm NB (6m tube, 1m packer)
- 316 Stainless Steel Screen (205 - 485m) (220 mmOD, 200 mmID) (0.5mm aperture)
- 250mm Diameter Hole
- Cement Grout (400 - 420m)
- Back Fill (420 - 485m)
- End of hole -

Description:

SAND: Channel sample sand red-brown, medium-fine, minor coarse quartz, very poorly sorted (Bag not marked with depths).

9-15m: Fine-medium grained, light brown, brown, slightly silty with minor clay.

CLAY: White, cream, silty, slightly fine-coarse sandy, talcose.

24-27m: Grey, brown-grey, slightly silty.

27-39m: Interbedded grey clay, slightly silty with silcrete, weakly-moderaely cemented, yellow-orange, orange, white, cream.

SHALE: Grey, stiff, slightly silty.

SILTSTONE: Light grey, white clayey.

CLAY: Clay to shale, black, carbonaceous, silty, hard and soft layers.

SILTY SAND: Sand grey, fine-medium grained, slightly silty-moderately silty, quartz.

SILTSTONE: Grey to light grey sandstone, minor sandstone, fine-coarse grained, very poorly sorted, slightly silty, quartz/feldspar, siltstone, clayey and fine sandy.

SANDSTONE: Grey, fine-corase grained, silty, very poorly sorted, minor siltstone, grey, fine sandy, quartz, feldspar, subrounded to sub-angular.

SILTSTONE: Siltstone/Shale grey, dark grey, silty, some sandy bands, fine-coarse grained.

SANDSTONE: Grey fine-medium grained, subrounded to sub-angular, poorly sorted, quartz, trace glauconite

SILTSTONE: Grey siltstone, minor sandstone, fine-medium grained quartz, poorly sorted.

SANDSTONE: Grey, fine-medium grained, quartz, minor thin sandy/silt bands, poorly sorted.

Below 246m pale red, light grey, variably Bedded.

258-295m: Pale red, pink-red, grey, fine, rare medium grained, poorly sorted. Below 264 red-brown, pale red.

295-307m: Medium-fine grained, quartz, poorly to very poorly sorted, sub-rounded to sub-angular, becoming finer with depth (fine grained below 301 m).

307-318m: Medium-fine grained, grey, red-grey, light grey-brown, very poorly sorted.

318-322m: sandstone as above but with siltstone; grey, light grey, slightly clayey, fine sandy.

322-340m: Pale red, pale red-brown, pinkish-red, fine grained, minor medium grained sand, quartz, poorly sorted.

340-343m: Grey pinkish grey, fine grained with fine sandy, slightly clayey siltstone, very poorly sorted.

391-400m: Grey, light grey, fine-medium grained, quartz, poorly sorted.
Below 346 pale red-brown, pinkish-red-brown.

SILTSTONE: Grey, fine sandy with fine-medium sandstone bands (very poorly sorted).

SANDSTONE: Pale red, pinkish grey, light grey, fine-medium, minor coarse sand, quartz, sub-rounded to sub-angular. Occasional thin grey siltstone bands.

439-485m: Pale red-brown, pinkish-red, fine-medium grained quartz, poorly sorted.
Below 481 m white, light grey.

Formation: Tertiary Alluvium; Toolonga Calcilutite; Alinga Formation; Windalia Sand Member; Mdg Sh; Birdrong Sandstone; Kopke Sandstone

DRAWN BY: BWJ	DATE: 31 Nov 2004	**FIGURE 20**
CHECKED BY: RW	DATE: 1 Apr 2005	Page 1 of 1

COMPLETION REPORT

BOREHOLE: **DMB1 (Monitoring Bore)**

URS Australia Pty Ltd — Phone 08 92211639
20 Terrace Rd, East Perth, 6004 — Fax 08 92211639

DRILLING CO:	**Drilling Contractors of Australia**
DRILL METHOD:	**Mud Rotary**
PROJECT NAME:	**Coburn Groundwater Impact Assessment**
PROJECT NUMBER:	**42905541.1841**
CLIENT:	**Gunson Resources Ltd**
LOCATION:	**Coburn Station, W.A**

	Windalia Sand Piezometer	Birdrong Piezometer	Kopke Piezometer
RL of Collar:	85.9	85.9	85.9
Casing/screen Dia. (mm):	40 mmND	40 mmND	40 mmND
Total Depth (m):	190 m	216	400
Screen Interval:	184 - 190 m	210 - 216 m	392 - 398 m
Static Water Level (mbtoc):	36.41 (16/12/04)	36.20 (16/12/04)	35.74 (16/12/04)
Final Salinity:			
Final pH:	7.0	6.8	7.0

General Data

Total Drilled depth (m):	400
Coordinates	
Datum:	GDA94
Eastings (mE):	216,734 mE
Northings (mN):	7,042,678 mN

START DATE: **12 Nov 2004** FINISH DATE: **9 Dec 2004** LOGGED BY: **RW**

BORE CONSTRUCTION

- Cap
- 311mm Diameter Hole (0 - 132m)
- Casing Centralisers
- 219mm OD, 206mm ID API 5/l ERW Steel Surface Casing (0 - 132m)
- Grout Shoe
- 200mm Diameter Hole (132 - 400m)
- 3 x 40mm NB Schedule 10, 316 Stainless Steel Tubing 0 - 185m 0 - 209m 0 -394m
- 40mm NB, 316 Stainless Steel Screen, 0.5mm Apeture, 185 - 191m
- Cement Seal
- 40mm NB, 316 Stainless Steel Screen, 0.5mm Apeture, 209 - 215m
- Cement Seal
- Graded Quartz Gravel Pack
- 40mm NB, 316 Stainless Steel Screen, 0.5mm Apeture, 394 - 400m
- End of hole -

DESCRIPTION

SAND: Red-brown, speckled yellow, yelow-brown, medium-fine grained, very poorly sorted, loose.

CLAY: Green, brown, grey-brown, slightly silty, stiff.

NO SAMPLE: Lost circulation

Clay: Grey, silty, stiff.

Below 27 m some yello, yellow-brown bands, Minor weakly cemented clasts (orange-brown, red-brown).

NO SAMPLE: Lost circulation

CLAY: Black, soft, carbonaceous, silty.

SHALE: Dark grey with minor light grey and grey, silty.

Below 138 m, dark grey only.

CLAY: Black, soft, carbonaceous, silty.

SHALE: Dark grey, slightly silty.

SAND: Grey, medium-fine quartz, poorly sorted.

SHALE: Dark grey, slightly silty (weakly cleaved).

SAND: Grey, light grey, medium-fine grained, quartz,

177 - 180 m: shale bands, dark grey (cleared);

186 - 192 m: shale bands, dark grey (cleared).

SHALE: Dark grey, grey.

SAND AND SILT: Dark grey, silty fine-medium sand with bands of clayey silt. Some weakly carbonaceous material.

SANDSTONE: Grey, light grey, quartz, medium-fine and fine in bands, poorly sorted.

210 - 216 m: minor siltstone bands (thin), dark grey.

222-225m: Grey, light grey, sand, fine-medium grained, quartz, poorly sorted.
Minor siltstone sandy, dark grey.

225-262m: Light grey, grey, medium-fine grained quartz, poorly sorted.

SHALE: Dark grey to grey, minor fine sand.

SANDSTONE: Light brown, light red-brown, medium-fine grained, quartz, poorly sorted.
Bands of grey/dark grey fine sandy siltstone.

249-255m: Light brown, light red-brown, medium-fine grained, poorly sorted. Some bands, light grey, white.

SHALE: Grey, dark grey, silty, minor fine-medium sandy bands.

SANDSTONE: Lightly brown, light red-brown, medium-fine grained, poorly sorted. Minor siltstone/shale dark grey, black, interbeds in sandstone.

273-282m: Light red-brown, red-brown, medium-fine grained, poorly sorted.

282-298m: Lightly brown, light red-brown, medium-fine grained, poorly sorted. Minor siltstone/shale dark grey, black, interbeds in sandstone.

298-312m: Light red-brown, red-brown, medium-fine grained, poorly sorted.

312-321m: Lightly brown, light red-brown, medium-fine grained, poorly sorted. Minor siltstone/shale dark grey, black, interbeds in sandstone.

SHALE: Grey, dark grey, silty, some medium-fine thin sandy bands.

SANDSTONE: Grey, light grey, medium-fine grained, very poorly sorted, slightly silty, minor thin shale bands (dark grey).

SHALE: Grey, minor siltstone, light grey, minor sandstone, grey, light brown, light red-brown, medium-fine grained, poorly sorted.

357-366m: Grey, dark grey, silty, some medium-fine thin sandy bands.

Sandstone: Light brown, light grey, medium-fine grained, poorly sorted. Minor siltstone/shale bands (dark grey).

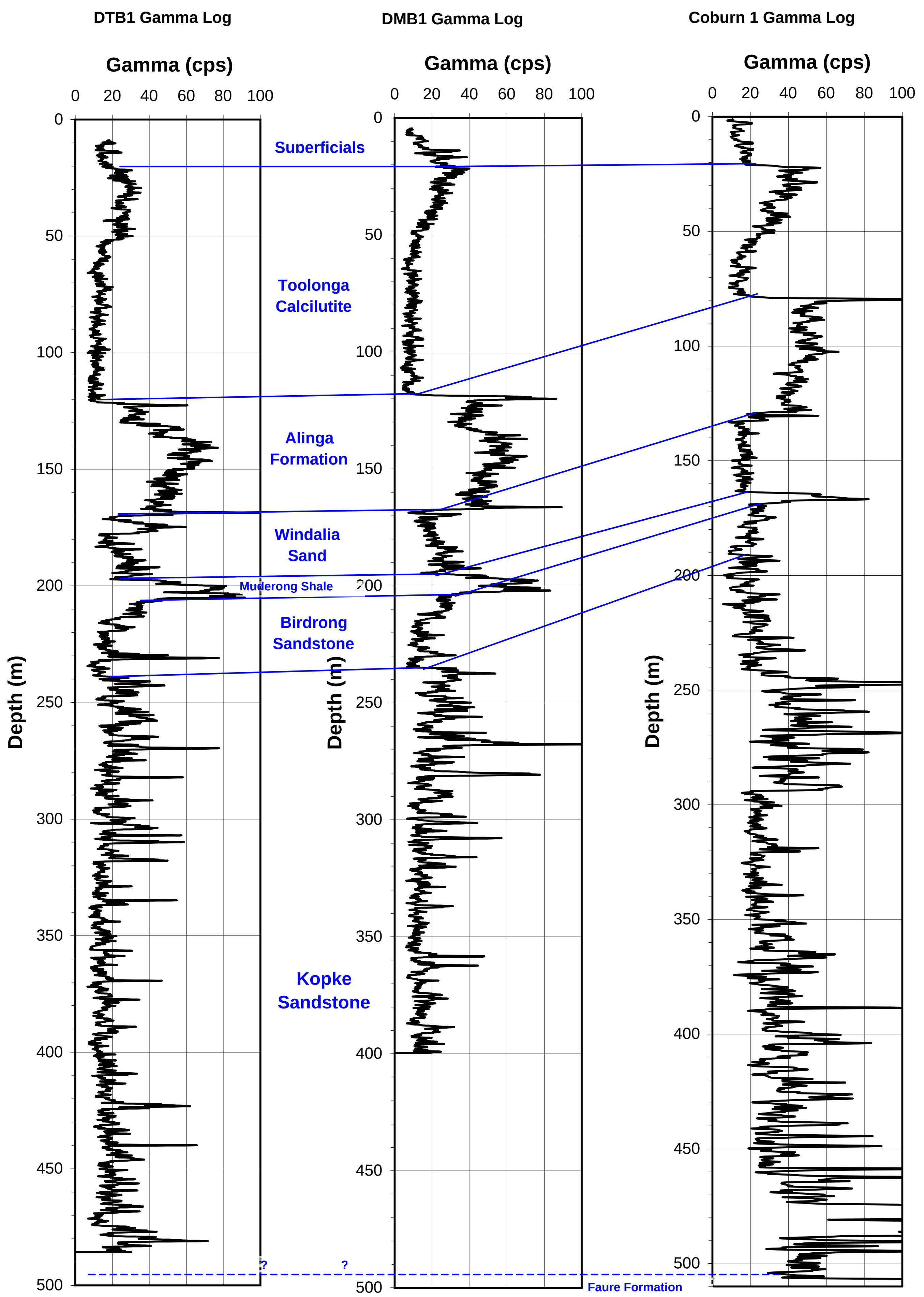
SHALE: Grey, minor siltstone, light grey, minor sandstone, grey, light brown, light red-brown, medium-fine grained, poorly sorted.

SANDSTONE: Light brown, light grey, medium-fine grained, poorly sorted. Minor siltstone/shale bands (dark grey).

SHALE: Grey, minor siltstone, light grey, minor sandstone, grey, light brown, light red-brown, medium-fine grained, poorly sorted.

DEPTH (m) / LITHOLOGY / GAMMA LOG / RESISTIVITY / CALIPER / FORMATION

DRAWN BY: BWJ	DATE: 31 Nov 2004	**FIGURE 21**	Page 1 of 1
CHECKED BY: RW	DATE:		



Job No.	42905541	Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 22
Prep By.	RBW		URS
Date	23 Dec '04	**Geophysical Log Correlations DTB1, DMB1 & Coburn 1**	

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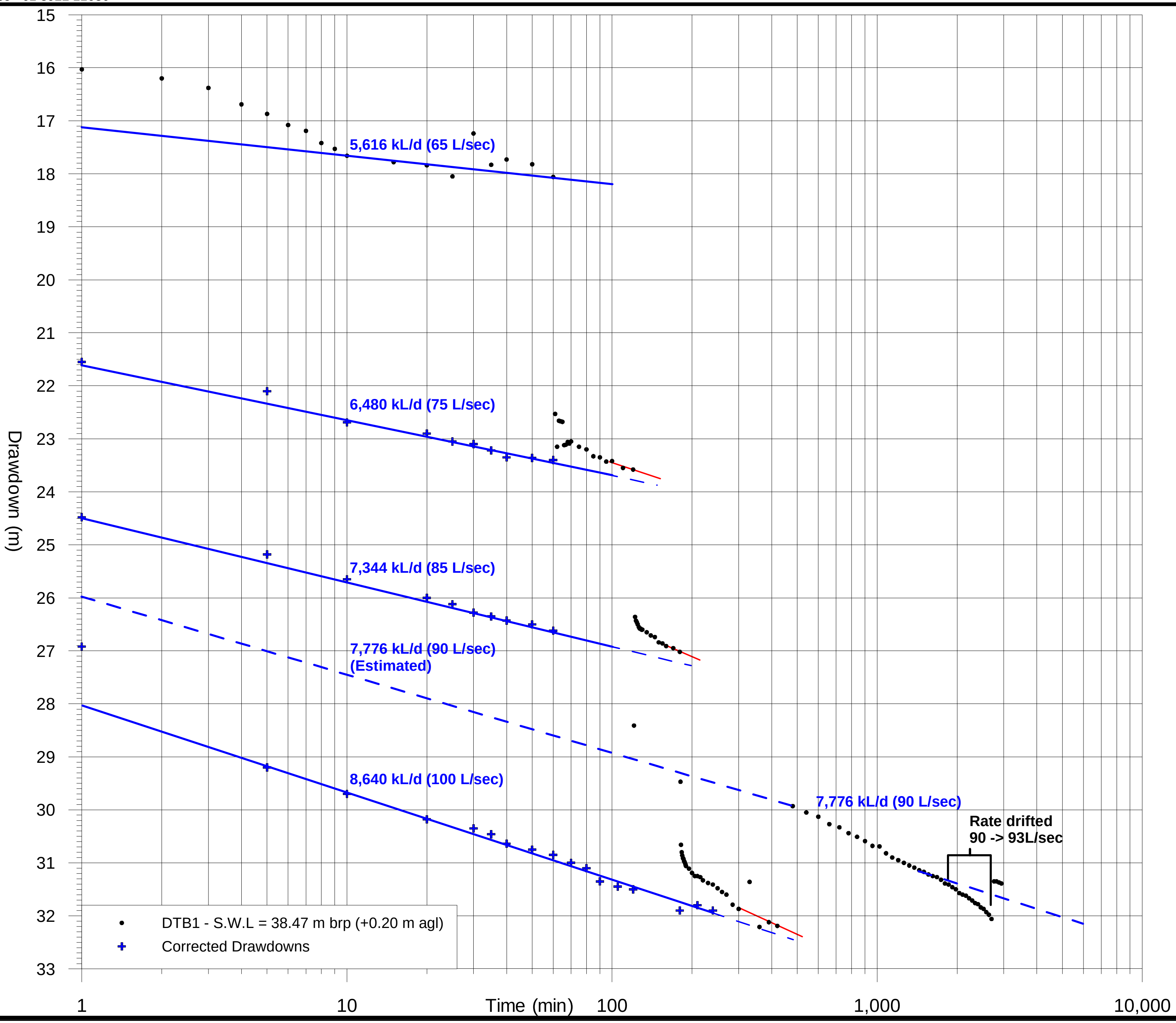

Job No.	42905541
Prep. By	RBW 18 Jan 05
Chk'd By	RBW 18 Jan 05
Revision No.	0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

DTB1 STEP AND CONSTANT RATE PUMPING TEST DRAWDOWN IN DTB1

Figure 23a

DTB1 Steps + CRT.xls/.grf

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DTB1 Steps + CRT.xls/DTB1obs CRT.grf

Job No.	42905541	
Prep. By	RBW	18 Jan 05
Chk'd By	RBW	18 Jan 05
Revision No.	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

DTB1 CONSTANT RATE PUMPING TEST DRAWDOWN IN DMB1b and DMB1k

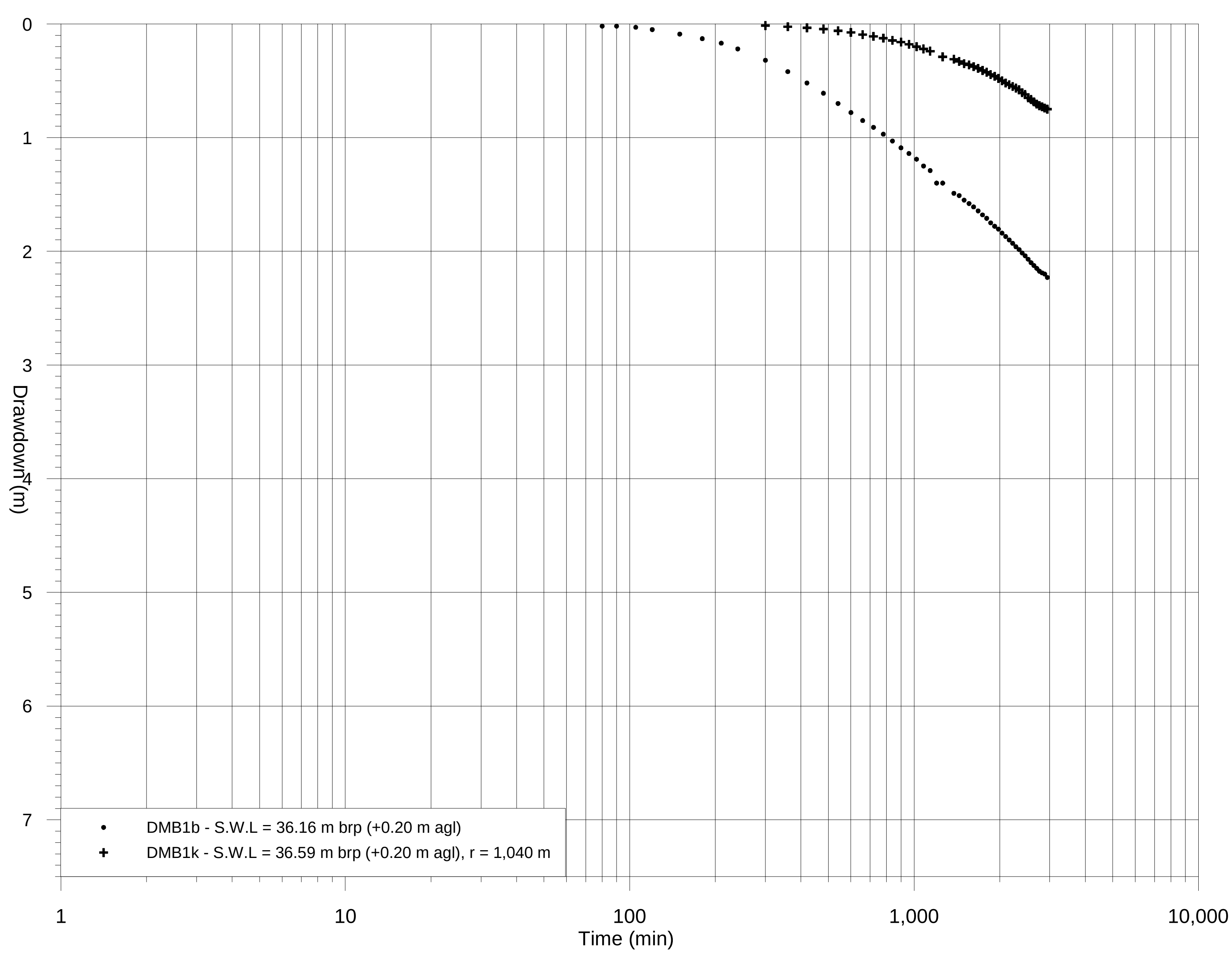


Figure 23b

URS AUSTRALIA PTY LTD, Perth Office +61 8922 11630

DTB1 Steps + CRT.xls/DTB1 Rec.grf

Job No.	42905541
Prep. By	RBW 18 Jan 05
Chk'd By	RBW 18 Jan 05
Revision No.	0

Gunson Resources Limited

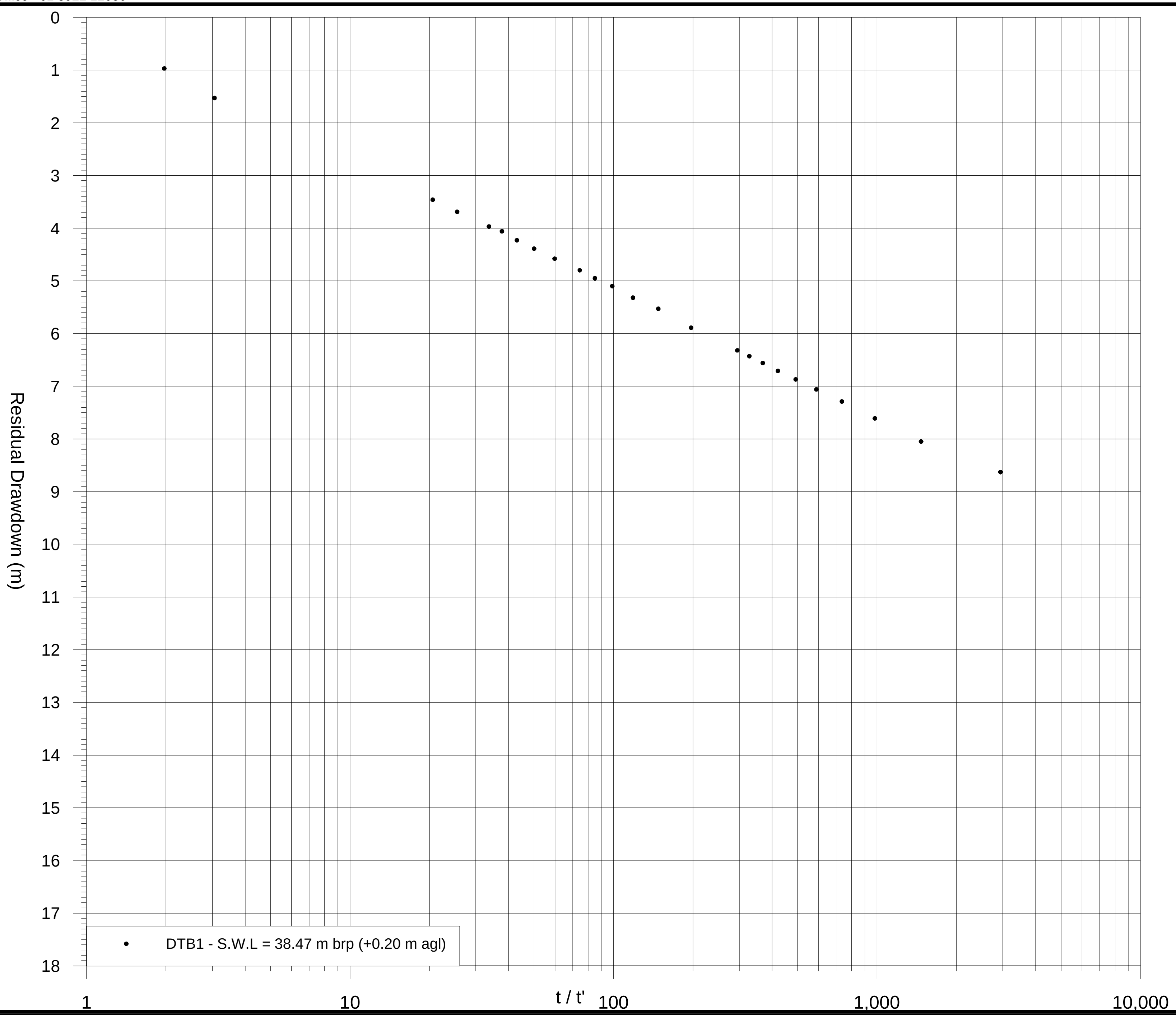
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

DTB1 RECOVERY TEST

RESIDUAL DRAWDOWN IN DTB1

URS

Figure 24a



URS AUSTRALIA PTY LTD, Perth Office +61 8922 11630

Job No.	42905541	
Prep. By	RBW	18 Jan 05
Chk'd By	RBW	18 Jan 05
Revision No.		0

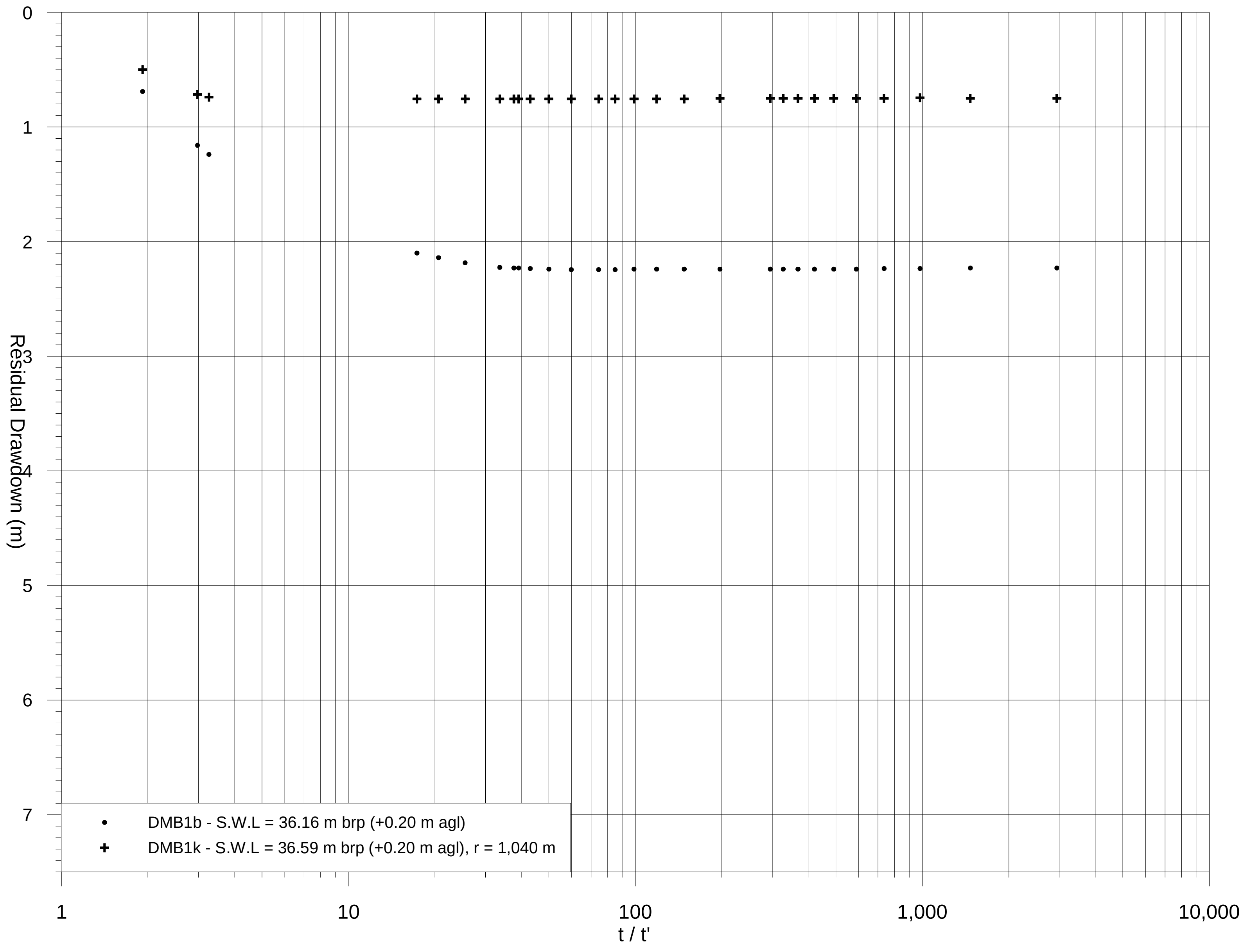
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

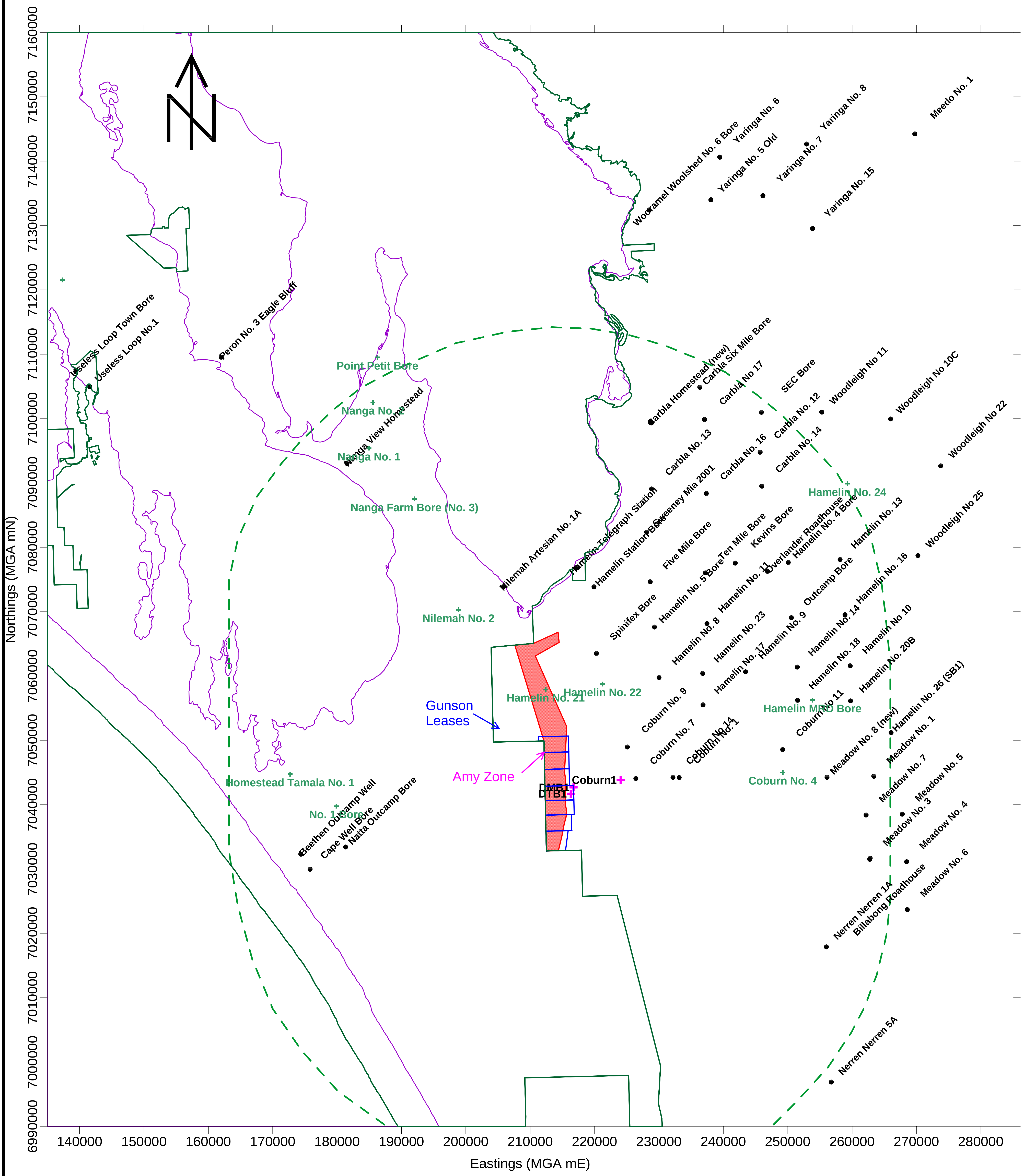
DTB1 RECOVERY TEST

RESIDUAL DRAWDOWN IN DMB1b and DMB1k

Figure 24b



DTB1 Steps + CRT.xls/DTB1obs Rec.grf



LEGEND

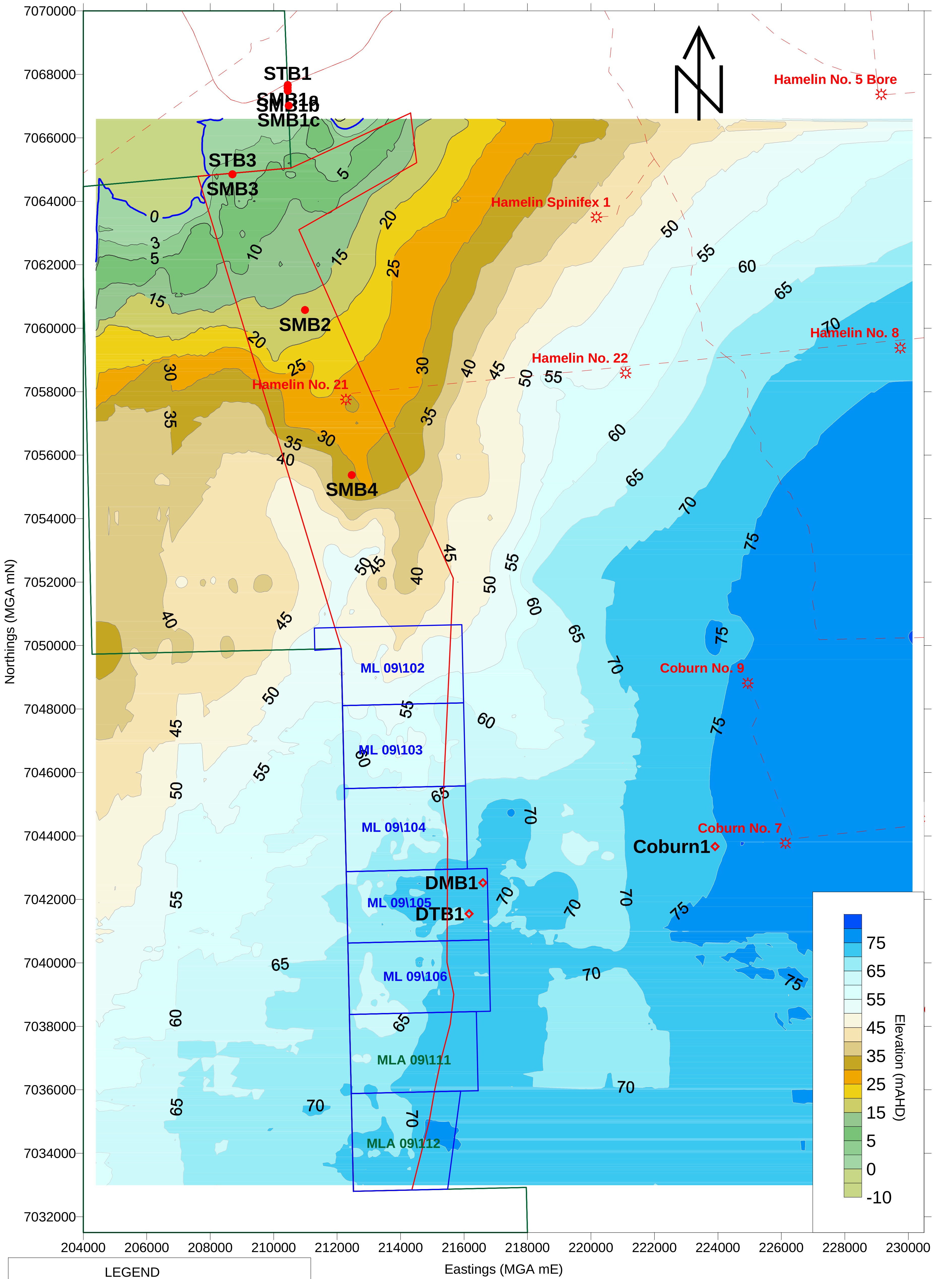
- Existing Active Private Water Bore
- Inactive Private Water Bore or Site
- Nominal Bore Census Coverage
- Amy Zone
- Mining Leases
- Shark Bay World Heritage Property

0 10,000 20,000 30,000 40,000 m

Scale 1 : 60,000

Job No.	42905541		Gunson Resources Limited	Figure 25
Prep. By	RBW	24 Dec 04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	24 Dec 04	**REGIONAL PRIVATE BORE LOCALITY MAP**	URS
Revision Indicator		2		

Regional Bore Loc Map Rev2.srf



0 2,000 4,000 6,000 8,000 m

LEGEND

- Superficial Forrmations Site Investigation
- Confined Aquifer Site Investigations
- Private Bore
- Interpreted Elevations of the Superficial Formations

Job No.	42905541	
Prep. By	RBW	3 Dec '04
Chk'd By	RBW	3 Dec '04
Revision Indicator		0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESMENT, COBURN PROJECT

INTERPRETED BASAL ELEVATIONS OF THE SUPERFICIAL FORMATIONS

Figure 26

URS

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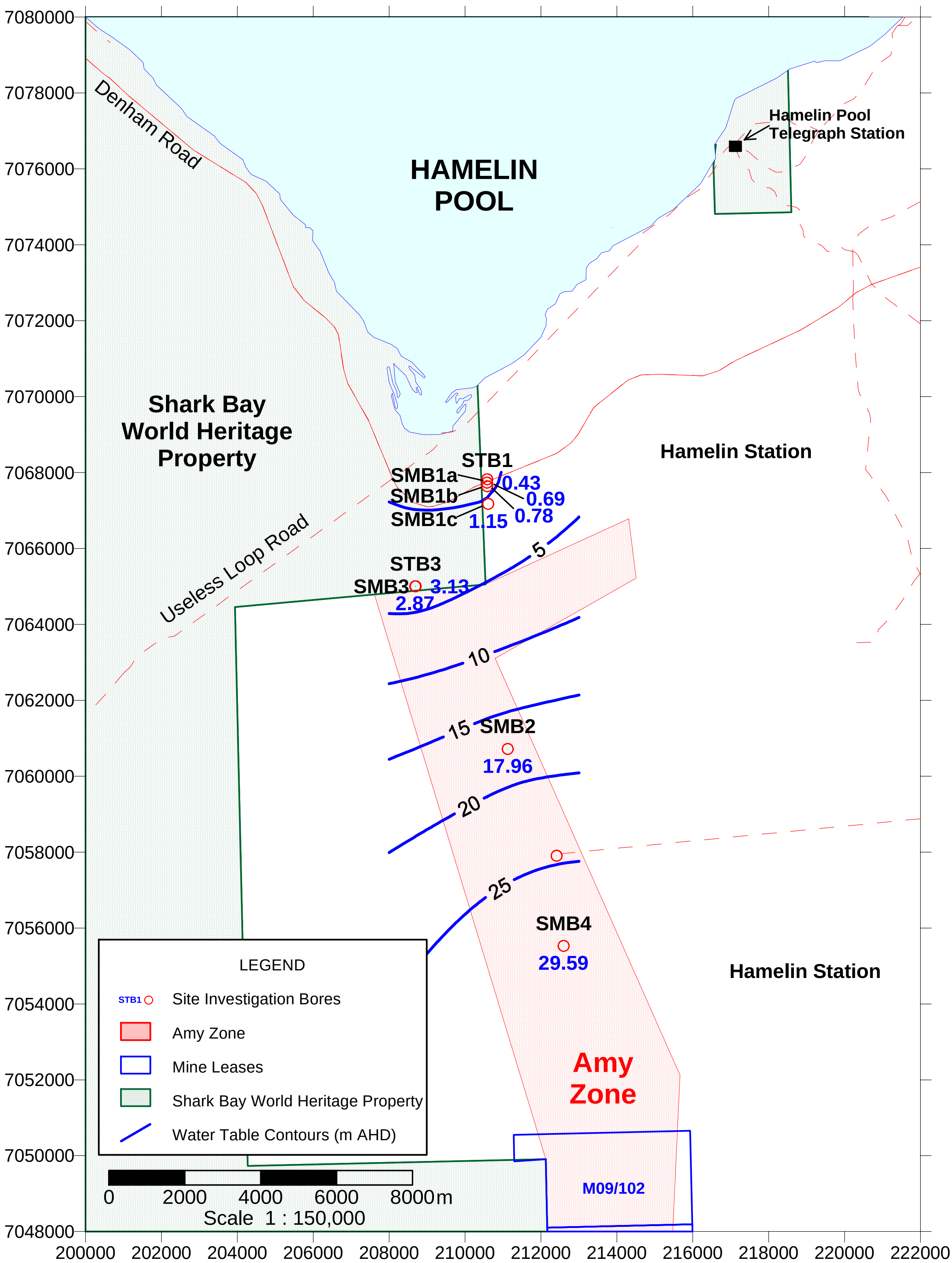
Basement Contours.srf



Job No.	42905541		Gunson Resources Limited	Figure 27
Prep. By	RBW	15 Oct '04	GROUNDWATER IMPACT ASSESSMENT, CORURN PROJECT	URS
Chk'd By	RBW	15 Oct '04	**BASELINE SUPERFICIAL FORMATIONS AND TOOLONGA CALCILUTITE WATER TABLE ELEVATIONS**	
Revision No.		1		

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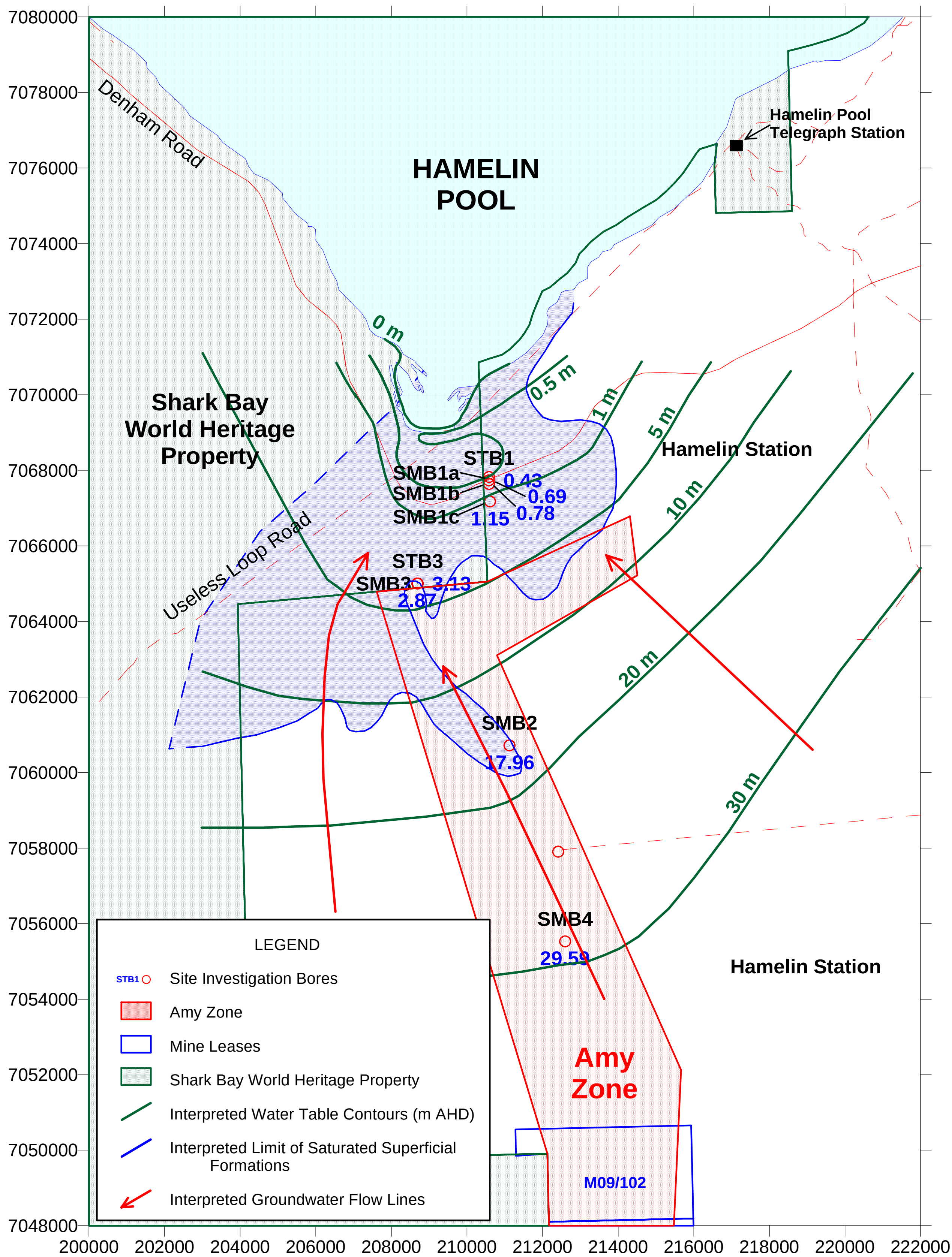
Shallow Water Level Map.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, CORURN PROJECT	**Figure 28**
Prep. By	RBW	15 Oct '04	**SATURATED AREAS OF SUPERFICIAL FORMATIONS IN CONTEXT WITH REGIONAL FLOW**	URS
Chk'd By	RBW	15 Oct '04		
Revision No.		0		

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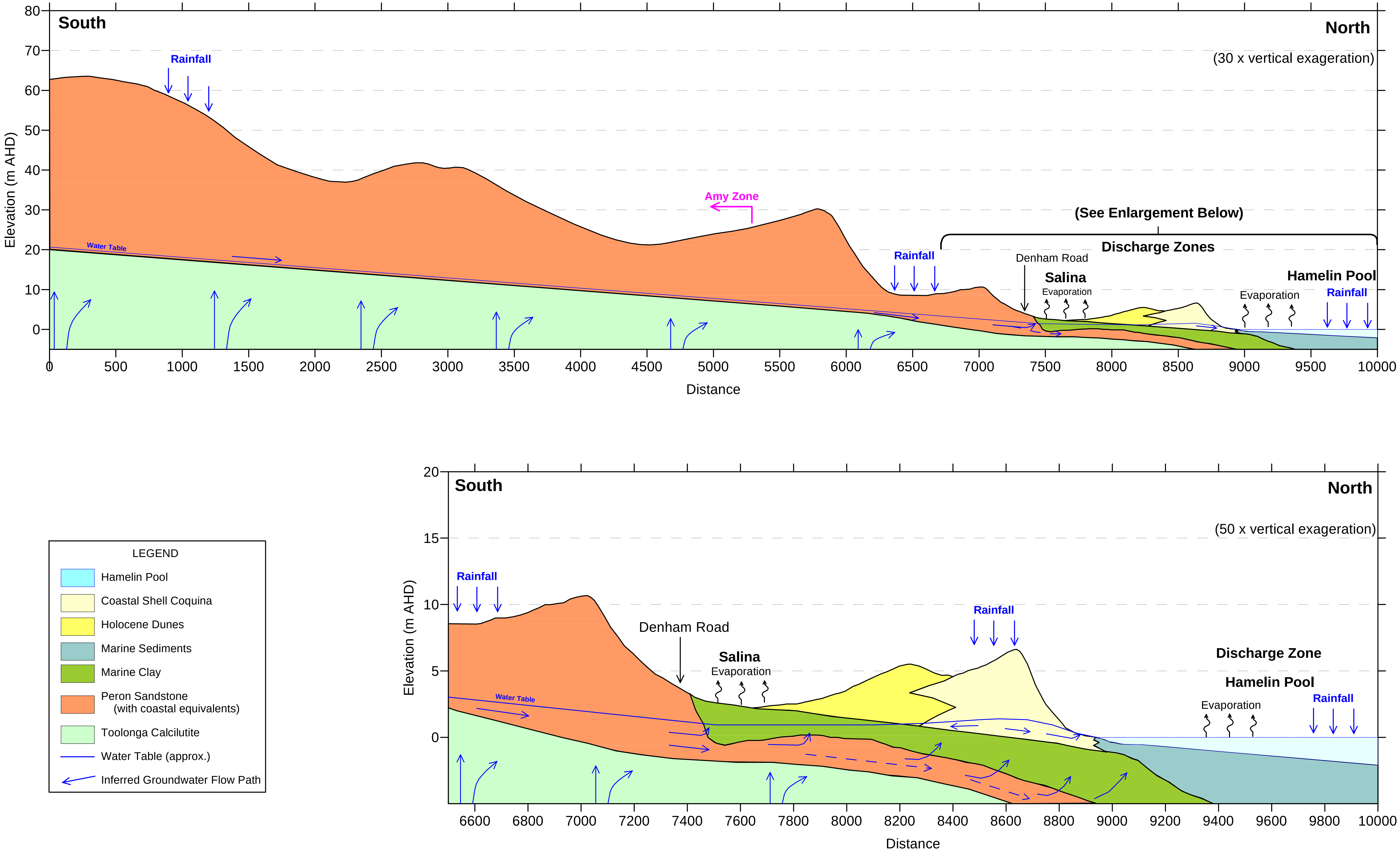
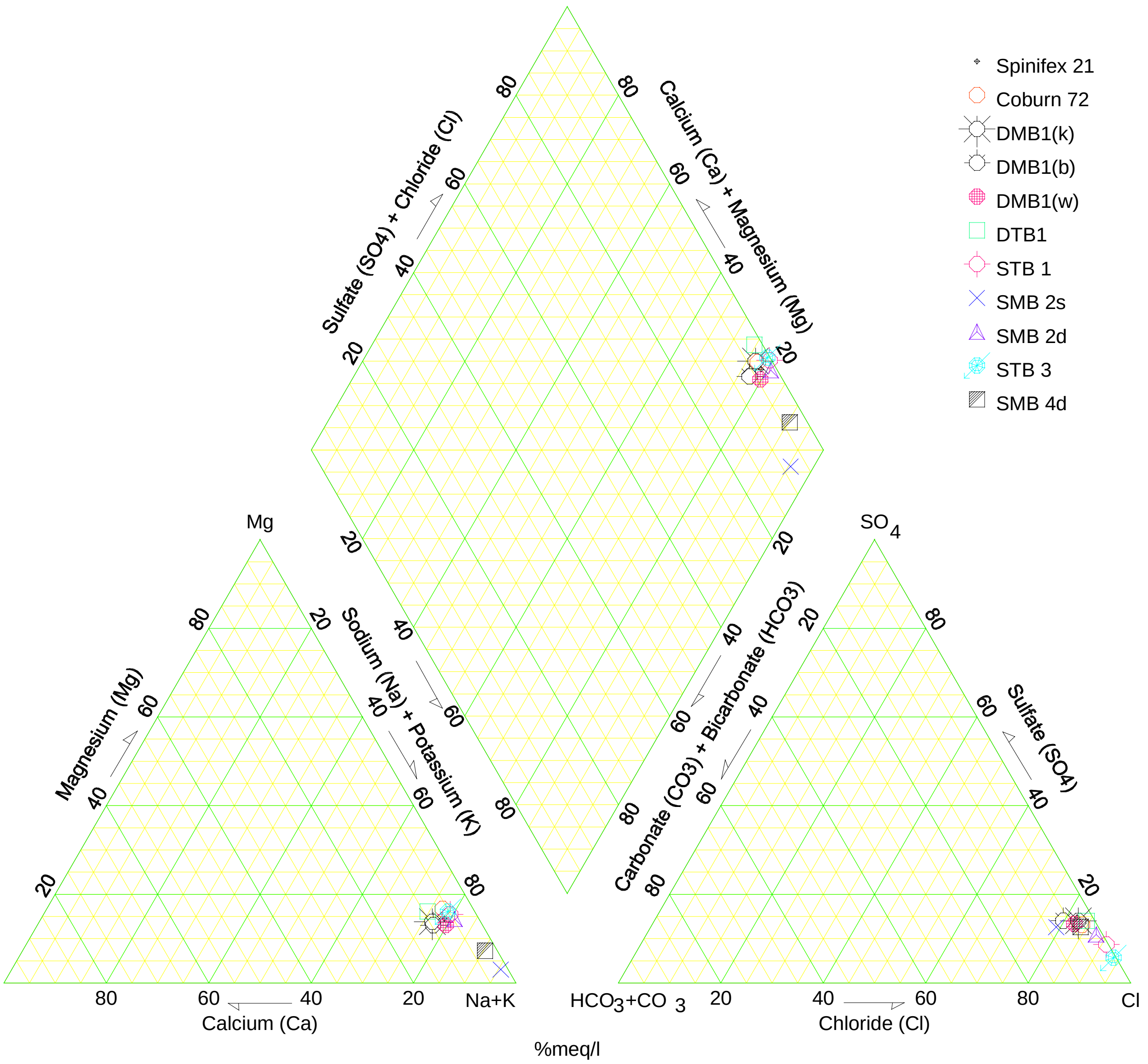
Regional Shall WL Map.srf



Job No.	42905541		Gunson Resources Limited	Figure 29
Prep. By	RBW	31 Mar 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	31 Mar 05	**WATER TABLE ELEVATIONS IN CROSS SECTION**	URS
Revision Indicator		0		

Near coastal geology from Bureau of Mineral Resources, 1990.



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT **PIPER DIAGRAM OF GROUNDWATER CHEMISTRY**		**Figure 30**
Prep. By	RBW	04 Feb '05			URS
Chk'd By	RBW	04 Feb '05			
Revision No.		0			

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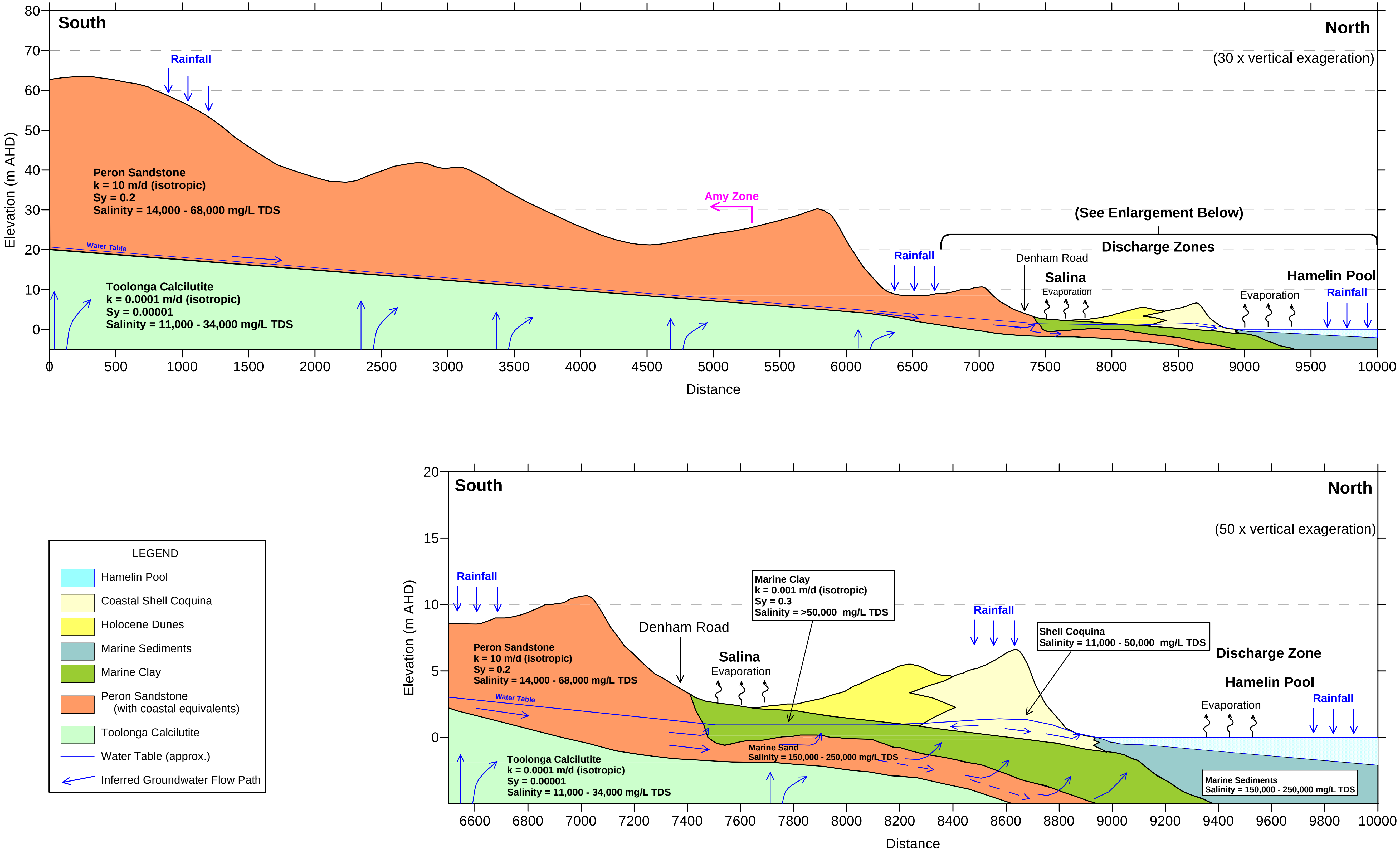
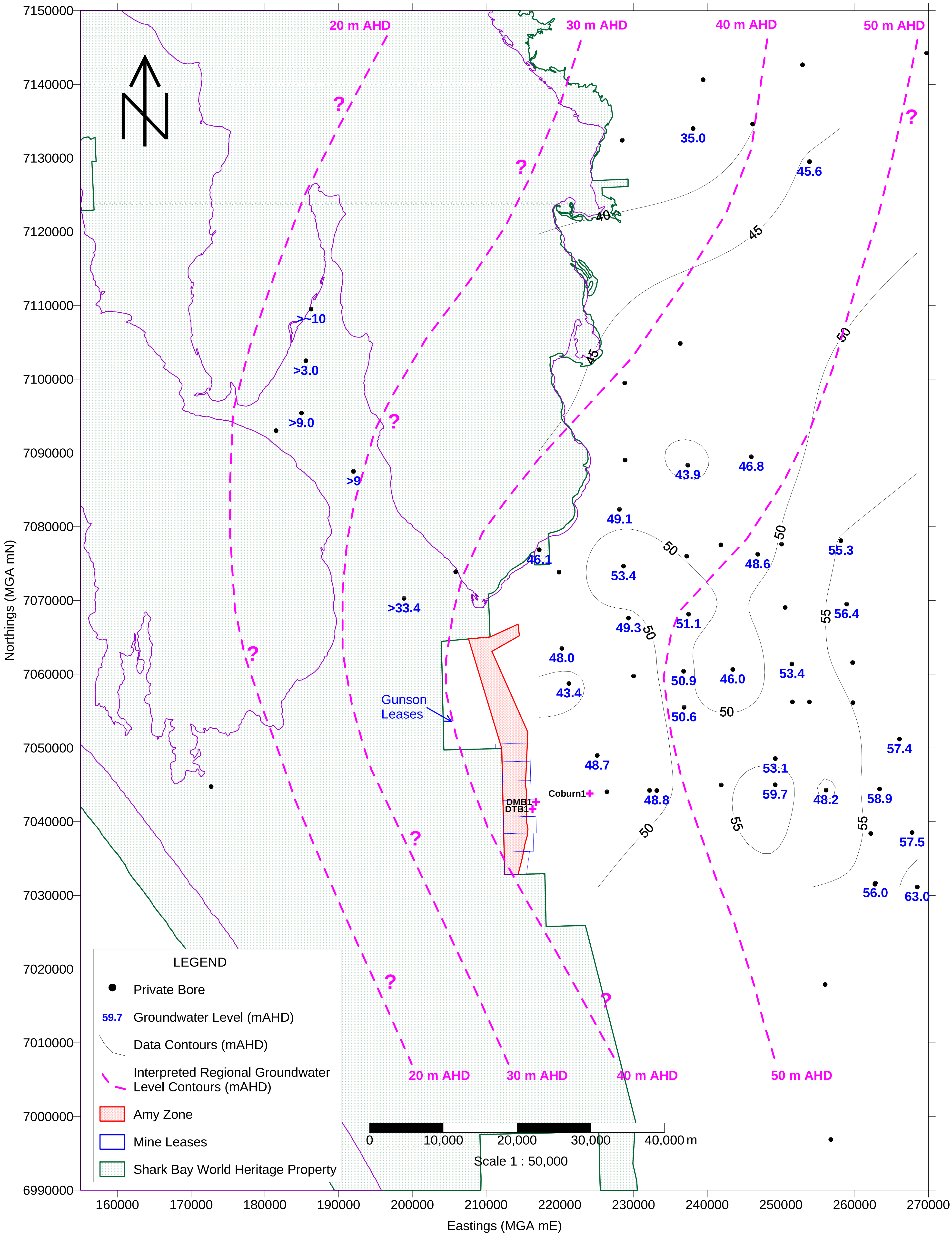
Piper Plot.srf



Job No.	42905541		Gunson Resources Limited	Figure 31
Prep. By	RBW	31 Mar 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	31 Mar 05	**CONCEPTUAL HYDROGEOLOGICAL MODEL WITH HYDRAULIC AND WATER QUALITY PARAMETERS**	URS
Revision Indicator	0			

Near coastal geology from Bureau of Mineral Resources, 1990.

Unconfined Conceptual Hydro Model.srf



Job No.	42905541	
Prep. By	RBW	03 Dec 04
Chk'd By	RBW	03 Dec 04
Revision Indicator		1

Gunson Resources Limited

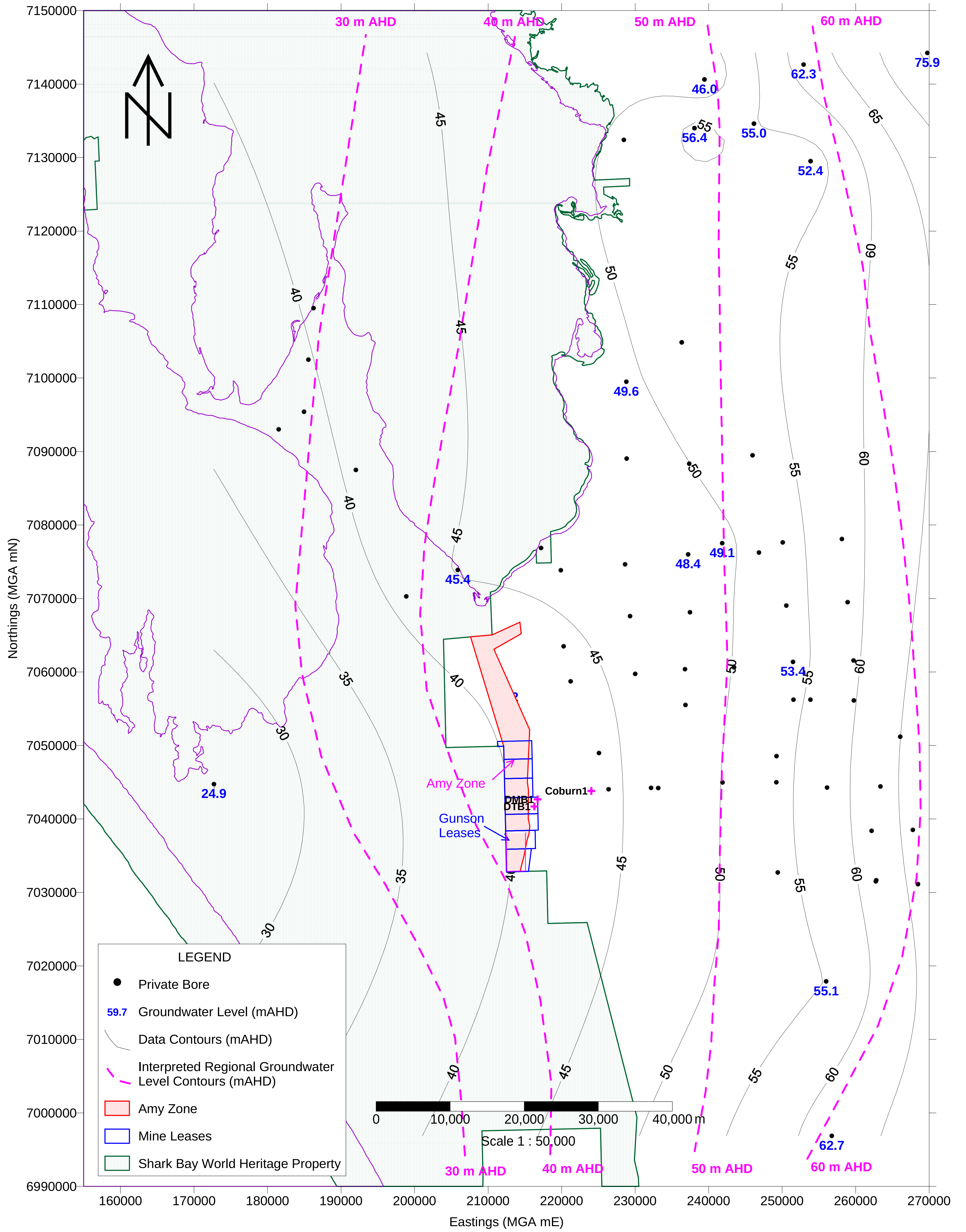
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

INTERPRETED GROUNDWATER LEVELS WINDALIA SAND MEMBER

Figure 32

URS

Windalia Sand SWLs.srf



Job No.	42905541		Gunson Resources Limited	Figure 33
Prep. By	RBW	3 Dec '04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	3 Dec '04	**INTERPRETED GROUNDWATER LEVELS BIRDRONG SANDSTONE**	URS
Revision Indicator		1		

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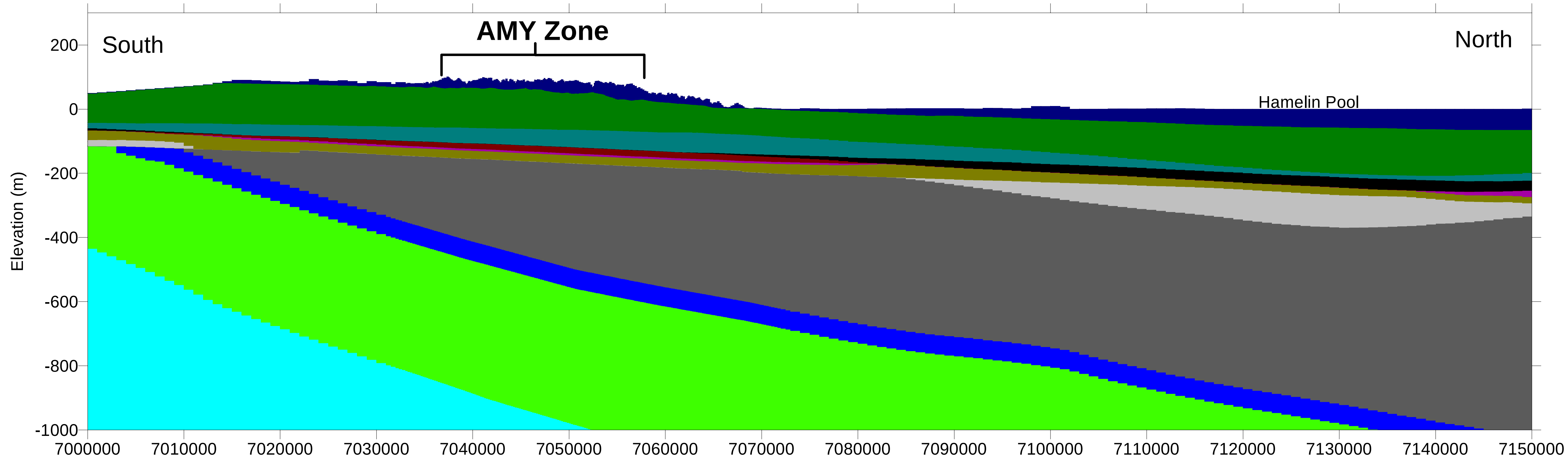
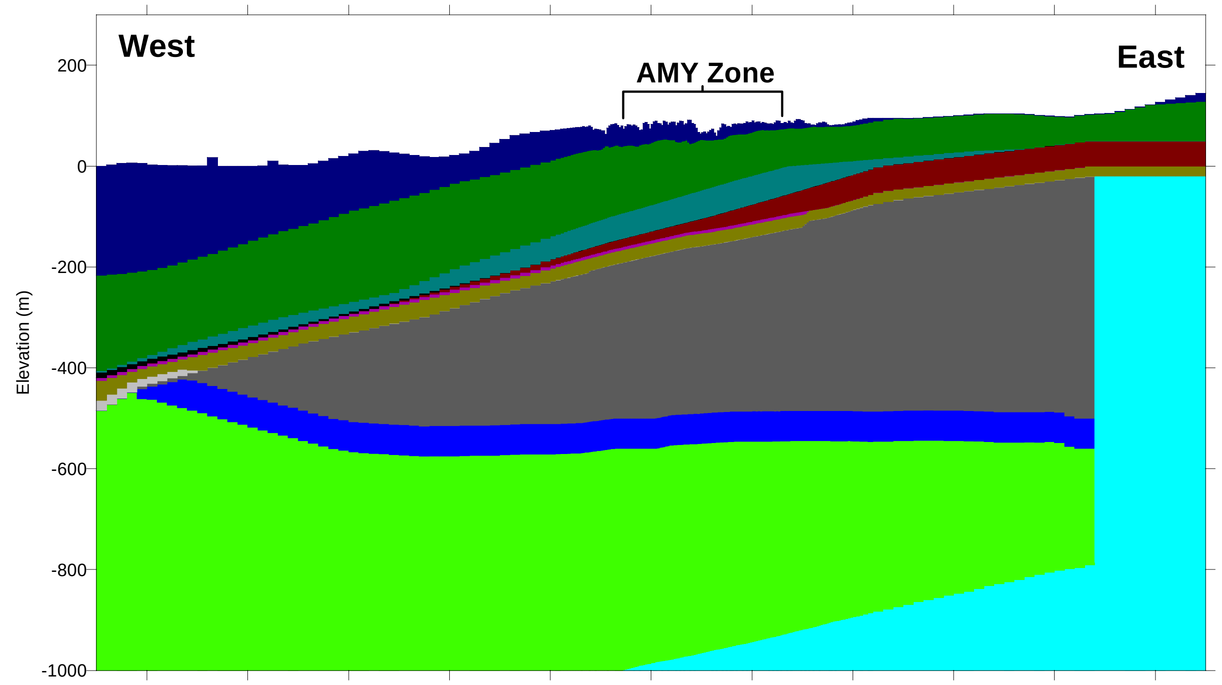
Birdrong SWLs.srf

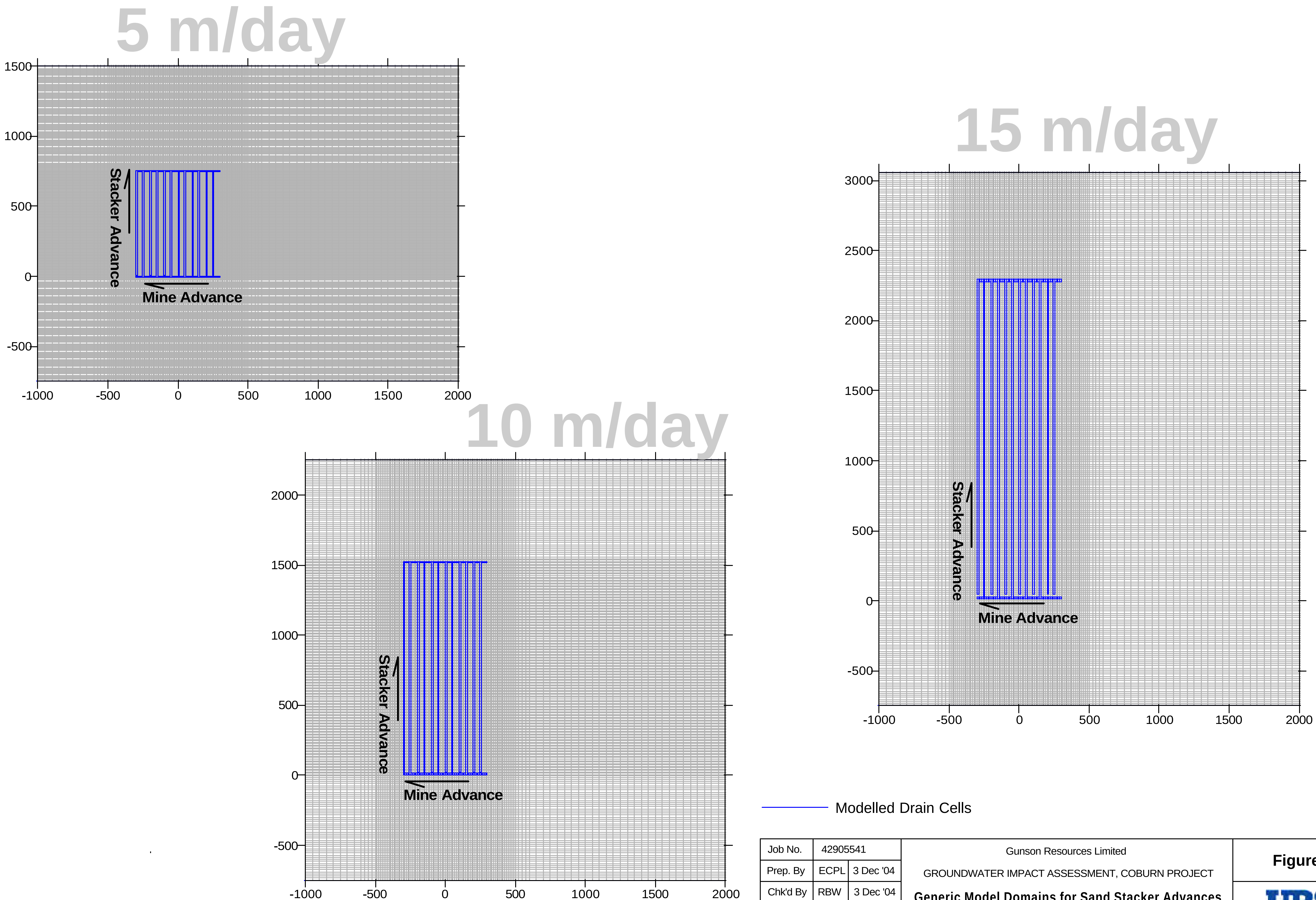




LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation (Gearle Siltstone)
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

Job No.	42905541		Gunson Resources Limited	Figure 34
Prep. By	RBW	3 Dec '04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	3 Dec '04	**CONFINED AQUIFER CONCEPTUAL HYDROGEOLOGICAL MODEL**	URS
Revision Indicator		0		



Job No.	42905541		Gunson Resources Limited	Figure 35a
Prep. By	ECPL	3 Dec '04	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	3 Dec '04	**Generic Model Domains for Sand Stacker Advances of 5 m/day, 10 m/day and 15 m/day**	URS
Revision Indicator	0			

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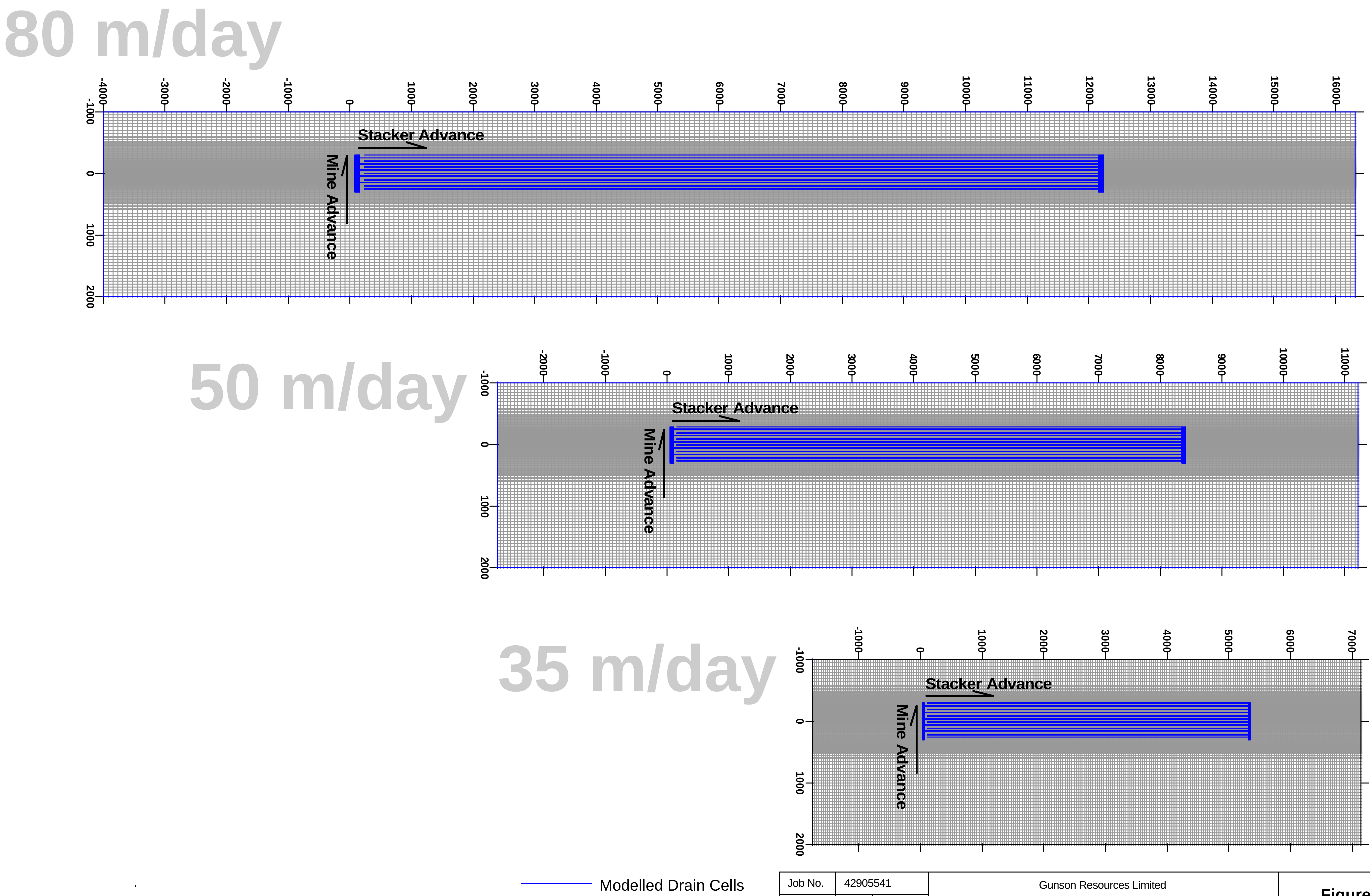
Fig31aShallow Aquifer Conceptual Pit Model.srf



Job No.	42905541		Gunson Resources Limited	**Figure 35b**
Prep. By	ECPL	23 Feb 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	23 Feb 05	**Generic Model Domains for Sand Stacker Advances of 35 m/day, 50 m/day and 80 m/day**	URS
Revision Indicator		0		

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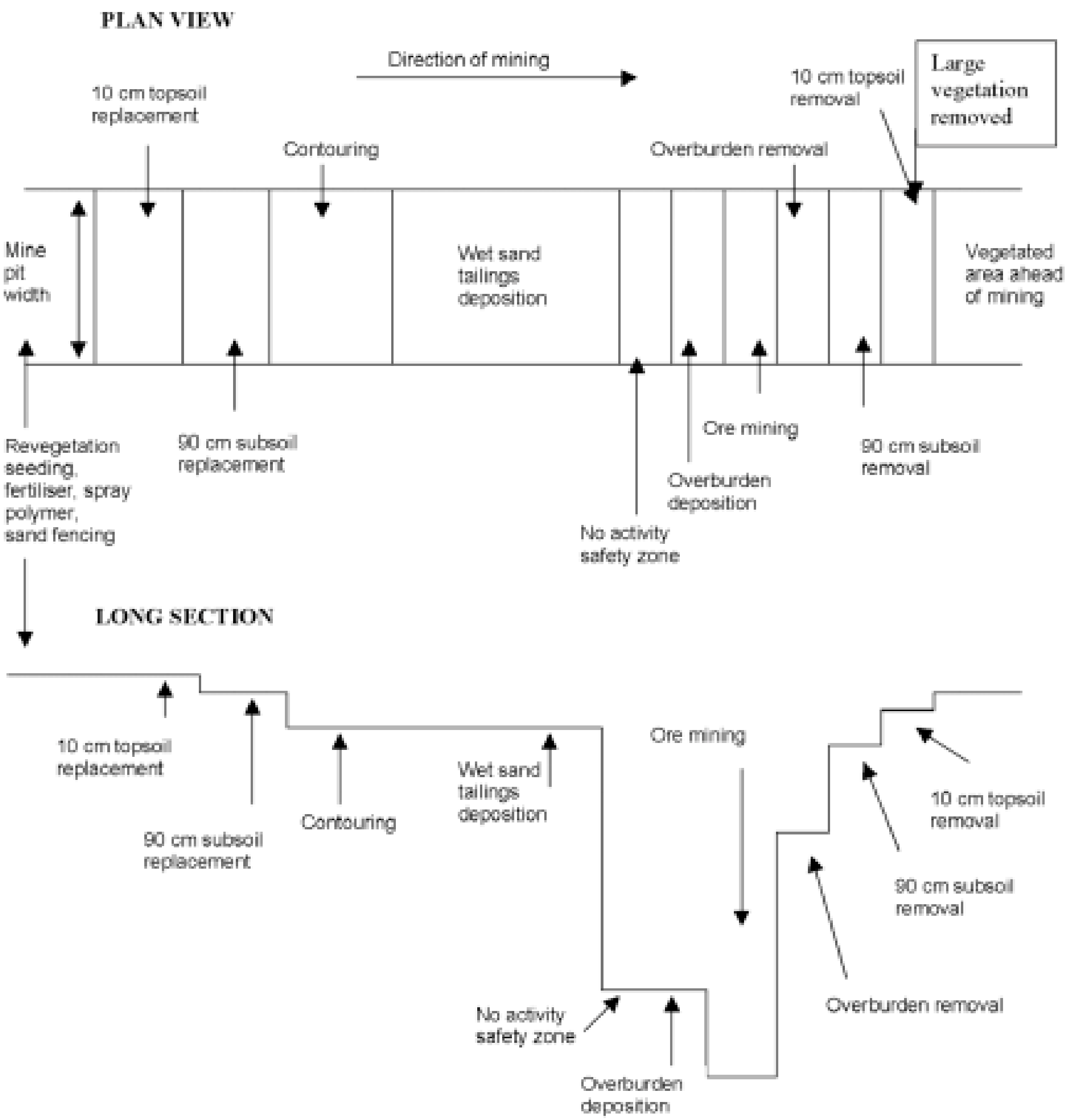
Fig31bShallow Aquifer Conceptual Pit Model.srf



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Job No.	42905541		
Prep. By	RBW	3 Mar '05	
Chk'd By	RBW	3 Mar '05	
Revision No.		0	

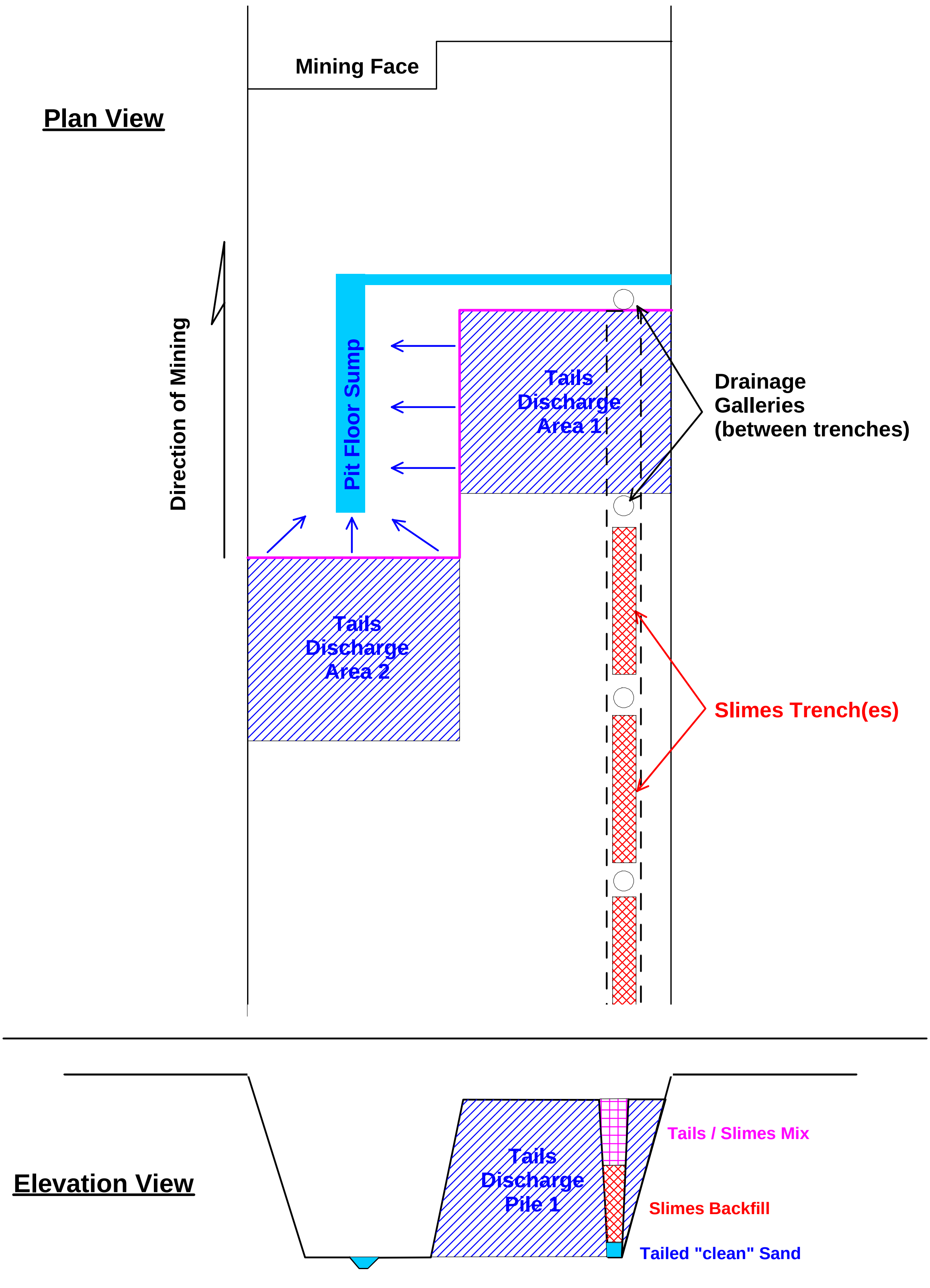
Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

TYPICAL MINE PROFILE WITHIN THE SUPERFICIAL FORMATIONS

Figure 36

URS

Mine Profile.srf



(Not to Scale)

Job No.	42905541-1841		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Development of the Conceptual Sand Tailings Water Recovery Systems Initial Plan**	**Figure 37a**
Prep. By	RBW	15 Oct '04		URS
Chk'd By	RBW	15 Oct '04		
Revision No.		1		

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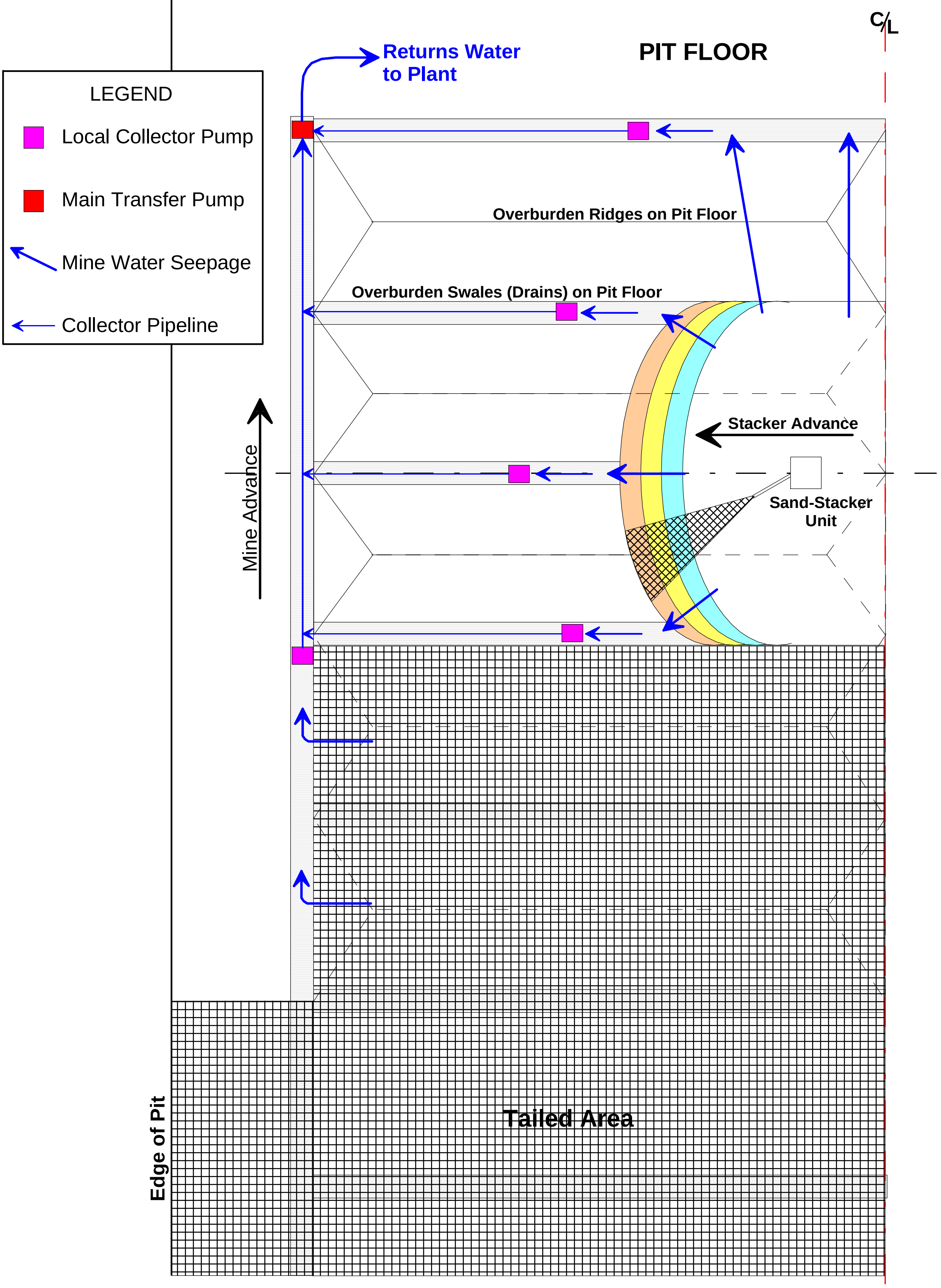
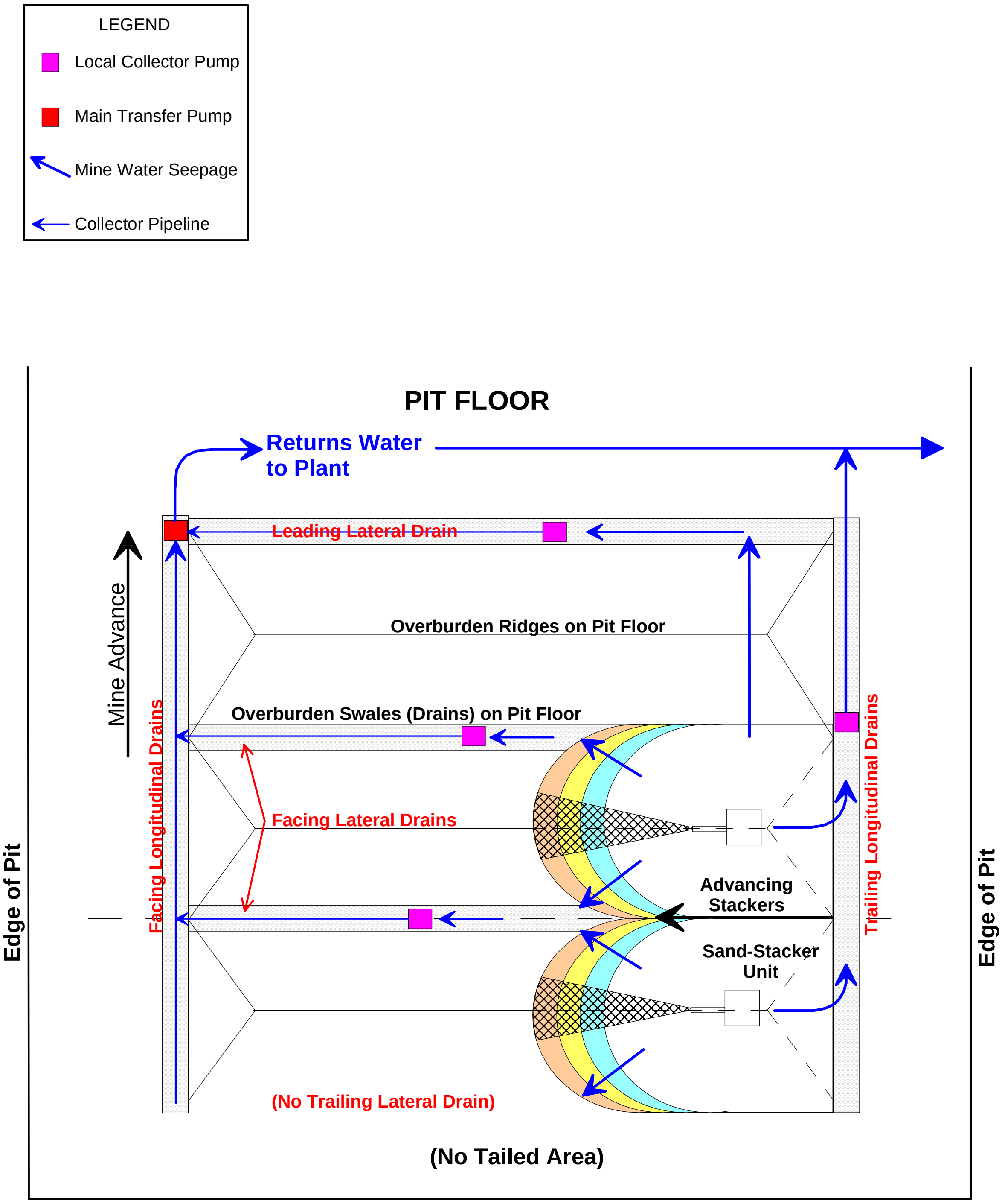
Conceptual Shallow Model.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 37b
Prep. By	RBW	24 Nov '04	**Development of the Conceptual Sand Tailings Water Recovery Systems Second Plan**	URS
Chk'd By	RBW	24 Nov '04		
Revision No.		1		

Conceptual Stacker-Drains.srf



Job No.	42905541	
Prep. By	RBW	24 Nov '04
Chk'd By	RBW	24 Nov '04
Revision No.		1

Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

FINAL CONCEPTUAL SAND TAILS WATER RECOVERY PLAN (START OF PIT)

Figure 38a

URS

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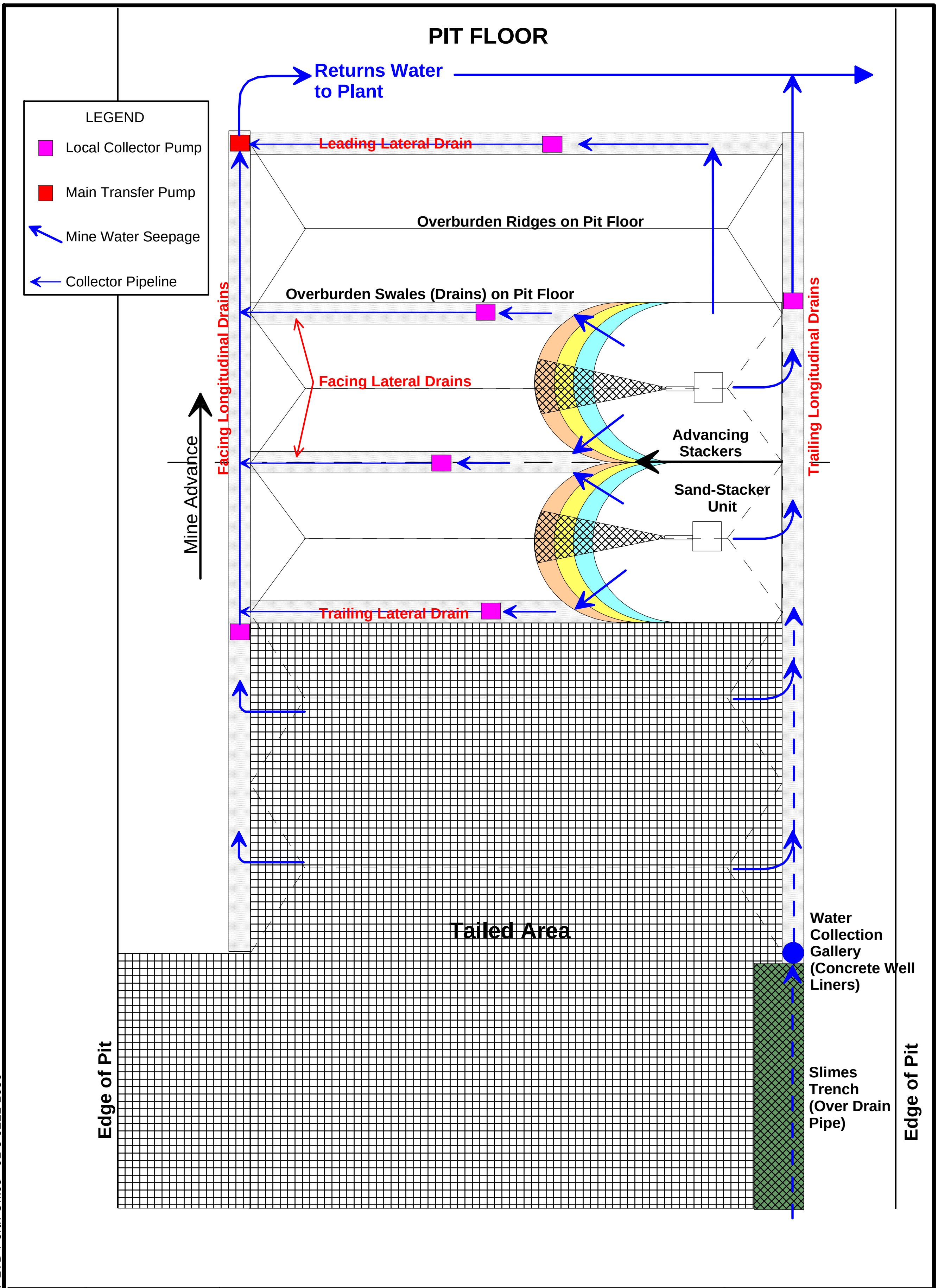
Conceptual Stacker-Drains Final Start-Pit.srf



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Job No.	42905541-1841	
Prep. By	RBW	24 Nov '04
Chk'd By	RBW	24 Nov '04
Revision No.		1

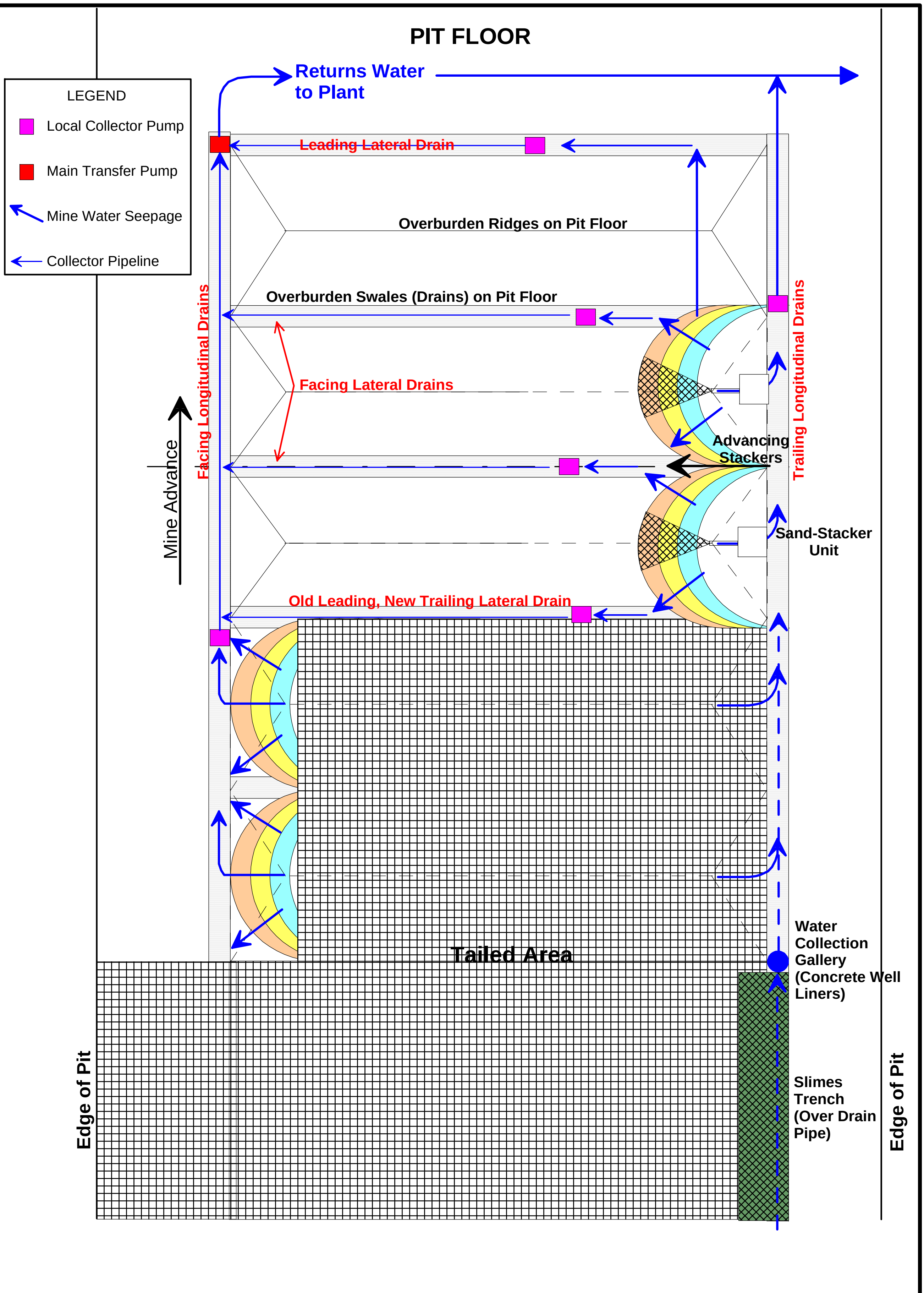
Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

FINAL CONCEPTUAL SAND TAILS WATER RECOVERY PLAN (MIDDLE OF SAND-STACKER TRAVERSE)

Figure 38b

URS

Conceptual Stacker-Drains Final Mid-Pass.srf



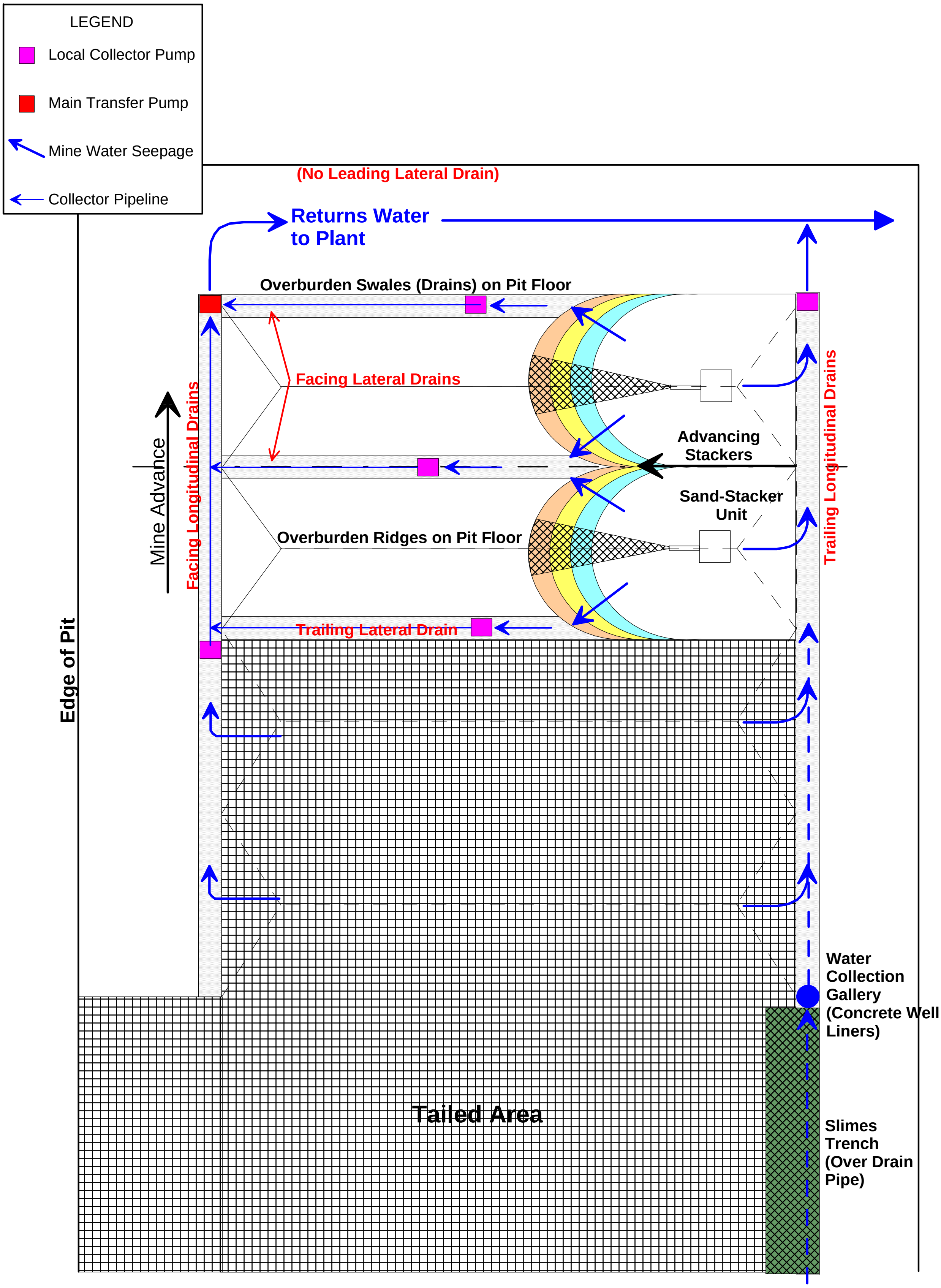
Job No.	42905541-1841		
Prep. By	RBW	24 Nov '04	
Chk'd By	RBW	24 Nov '04	
Revision No.		1	

Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

FINAL CONCEPTUAL SAND TAILS WATER RECOVERY PLAN (SAND-STACKER CHANGEOVER)

Figure 38c

URS



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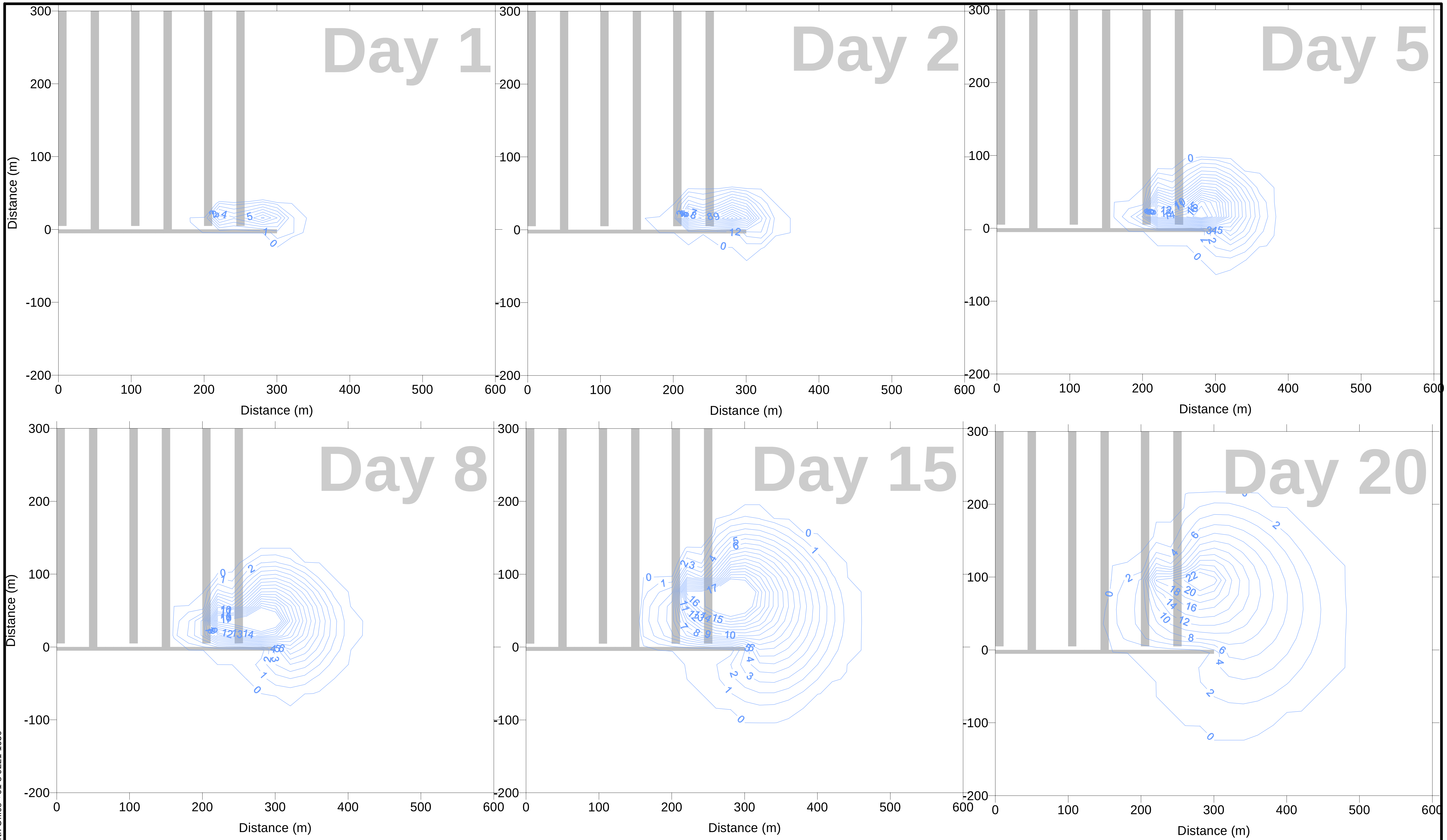
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **FINAL CONCEPTUAL SAND TAILS WATER RECOVERY PLAN (END OF PIT)**	**Figure 38d**
Prep. By	RBW	24 Nov '04		URS
Chk'd By	RBW	24 Nov '04		
Revision No.		1		

Conceptual Stacker-Drains Final End-Pit.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED SAND MOUNDING** **5m/day Sand-Stacker Advance and No Sand Beneath Pit Floor**	**Figure 39**
Prep. By	ECPL	3 Dec '04		URS
Chk'd By	RBW	3 Dec '04		
Revision Indicator		0		

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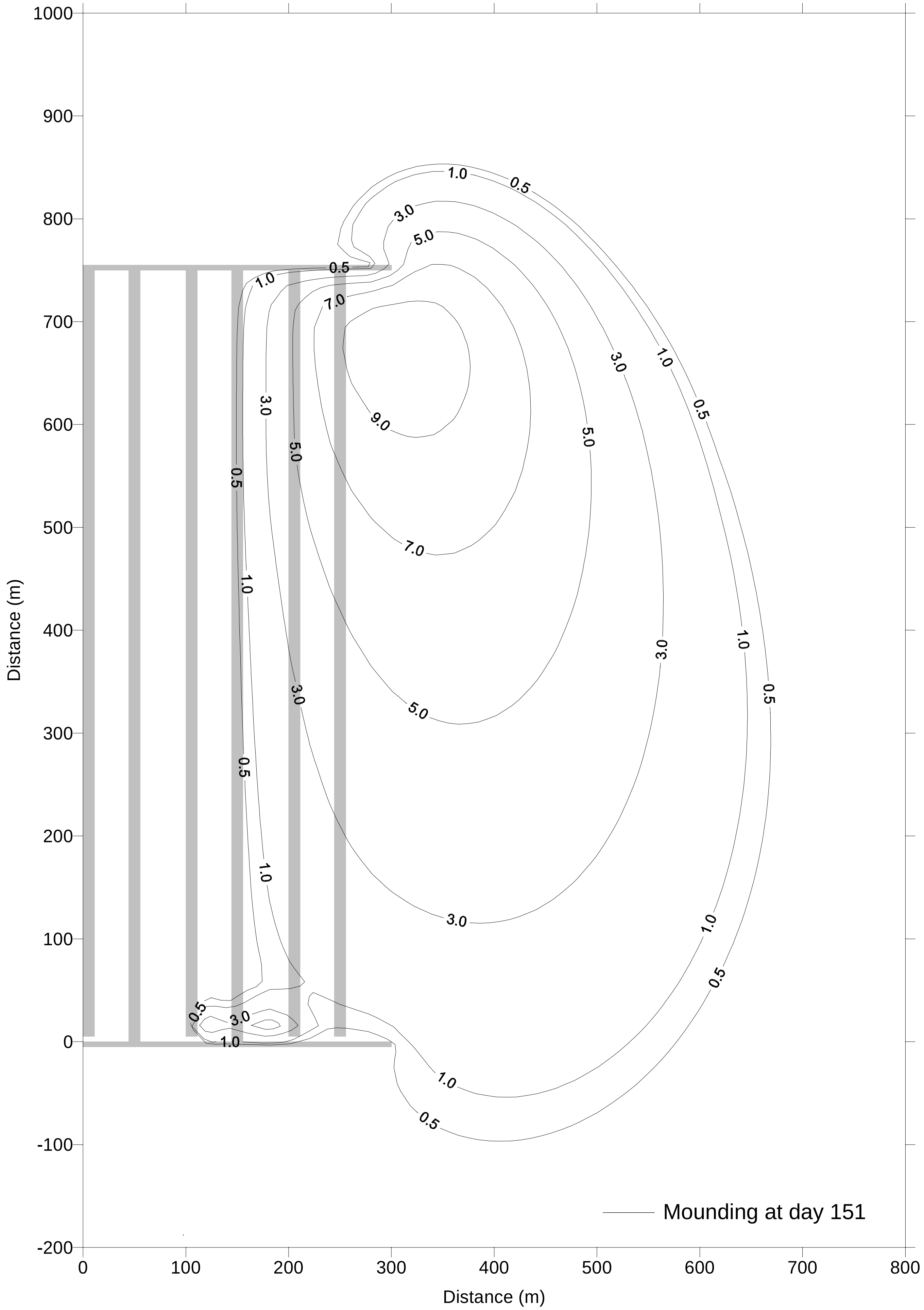
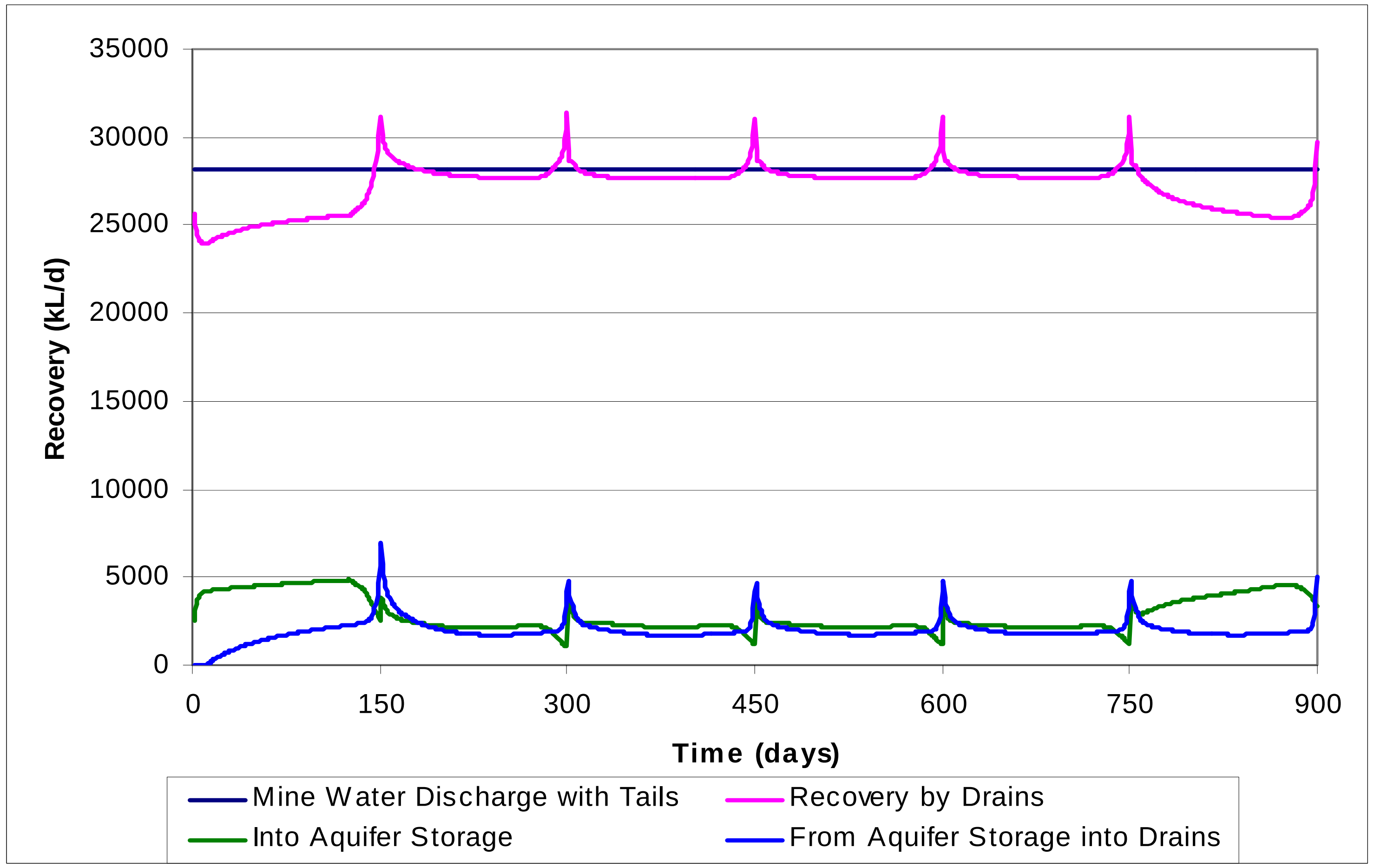
figure32 Simulated mounding beneath tails mine.srf





Job No.	42905541		Gunson Resources Limited GROUNDATER IMPACT ASSESSMENT, COBURN PROJECT **RECOVERY RATE CALCULATIONS: 5 m/day Sand-Stacker Advance and 2m Sand Beneath Pit Floor**	**Figure 40**
Prep. By	ECPL	22 Feb 05		URS
Chk'd By	RBW	22 Feb 05		
Revision Indicator	0			

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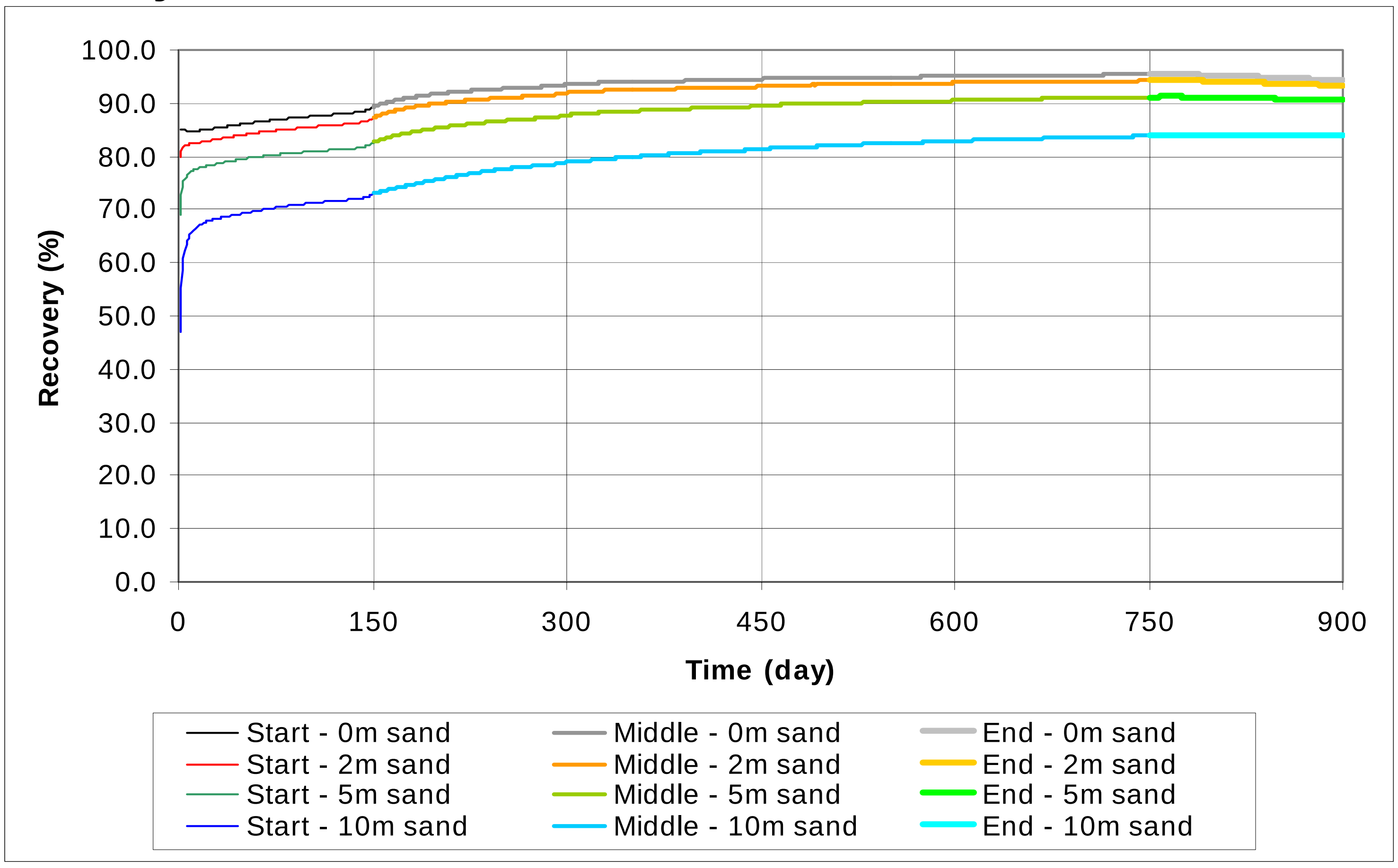
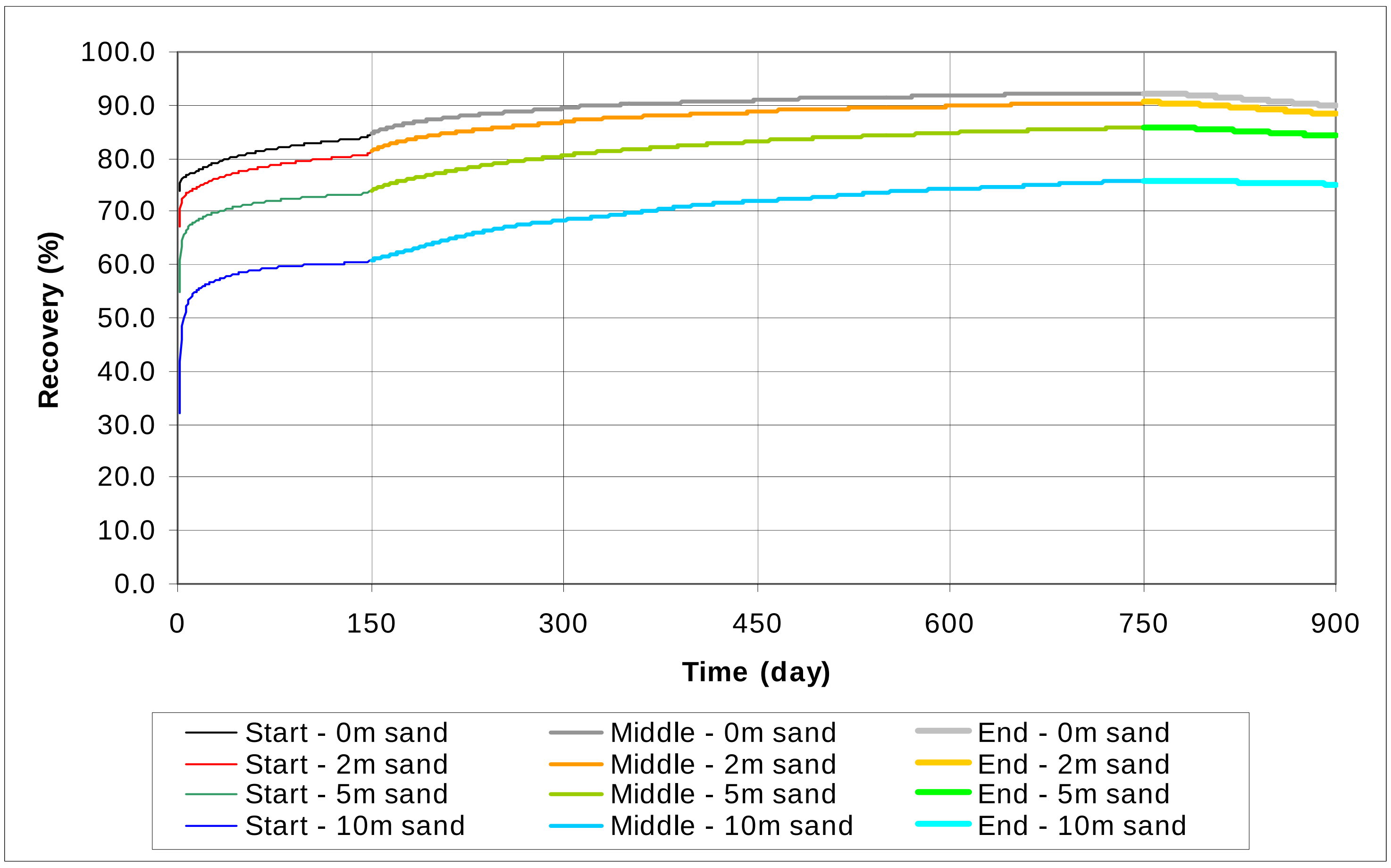
figure33 RECOVERY RATE CALCULATIONS.srf

figure34a Simulated mine water recovery rates 5-15 mpd.srf

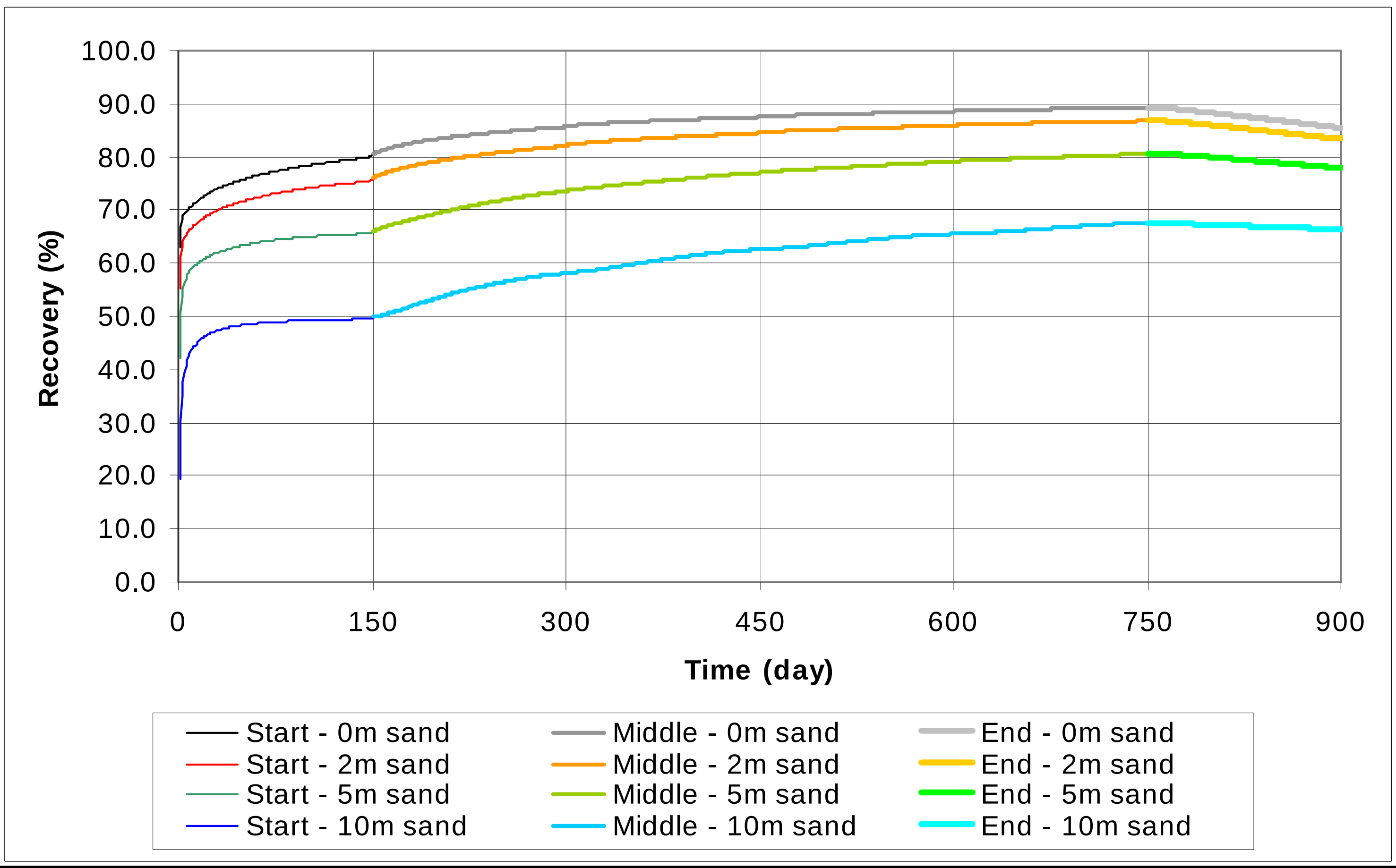
5m/day



10m/day



15m/day



Job No.	42905541	
Prep. By	ECPL	21 Feb 05
Chk'd By	RBW	21 Feb 05
Revision Indicator	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

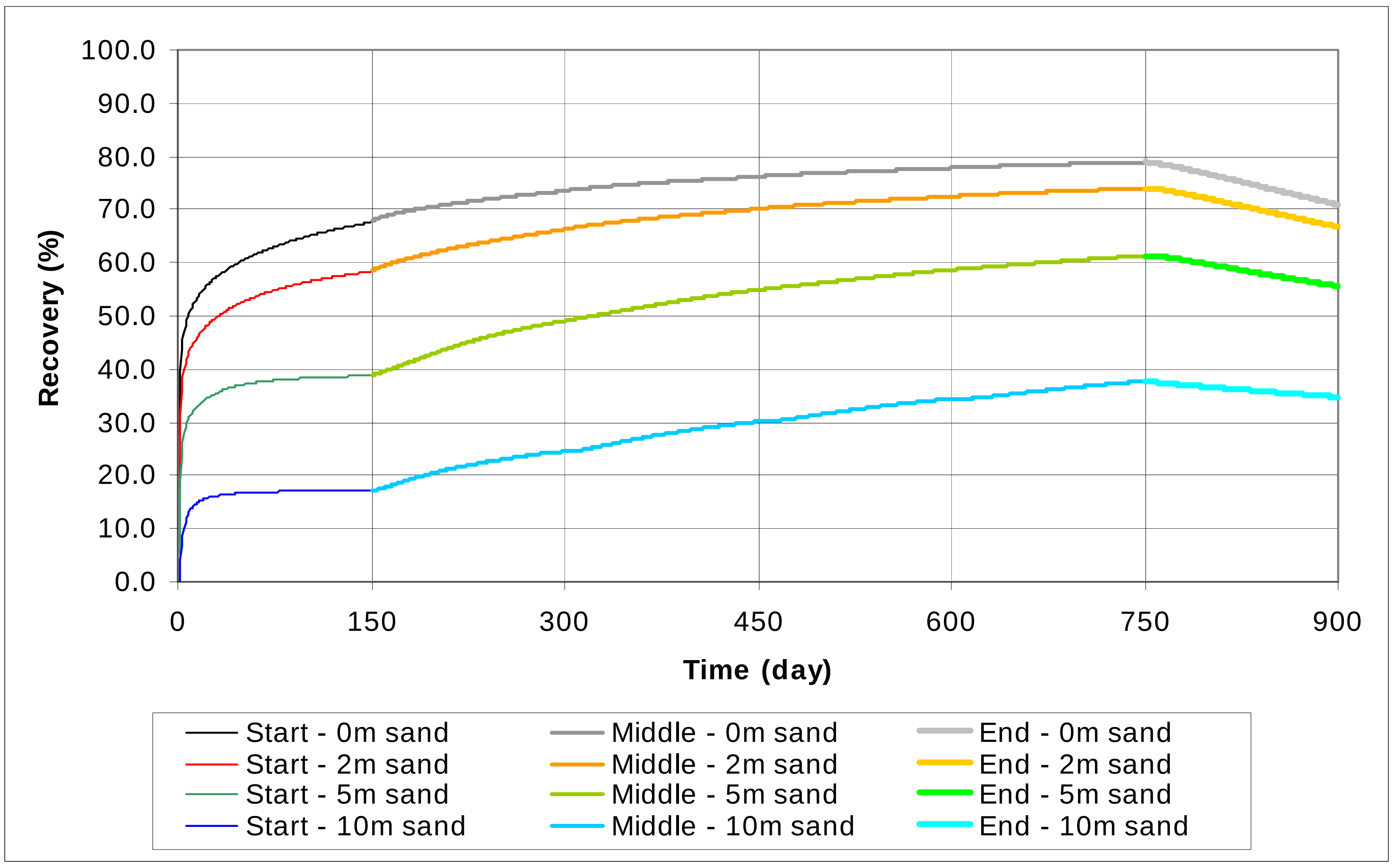
Simulated Upper-Bound Tailings Water Recovery Rates 5 to 15 m/day Advance With All Active Drains

URS

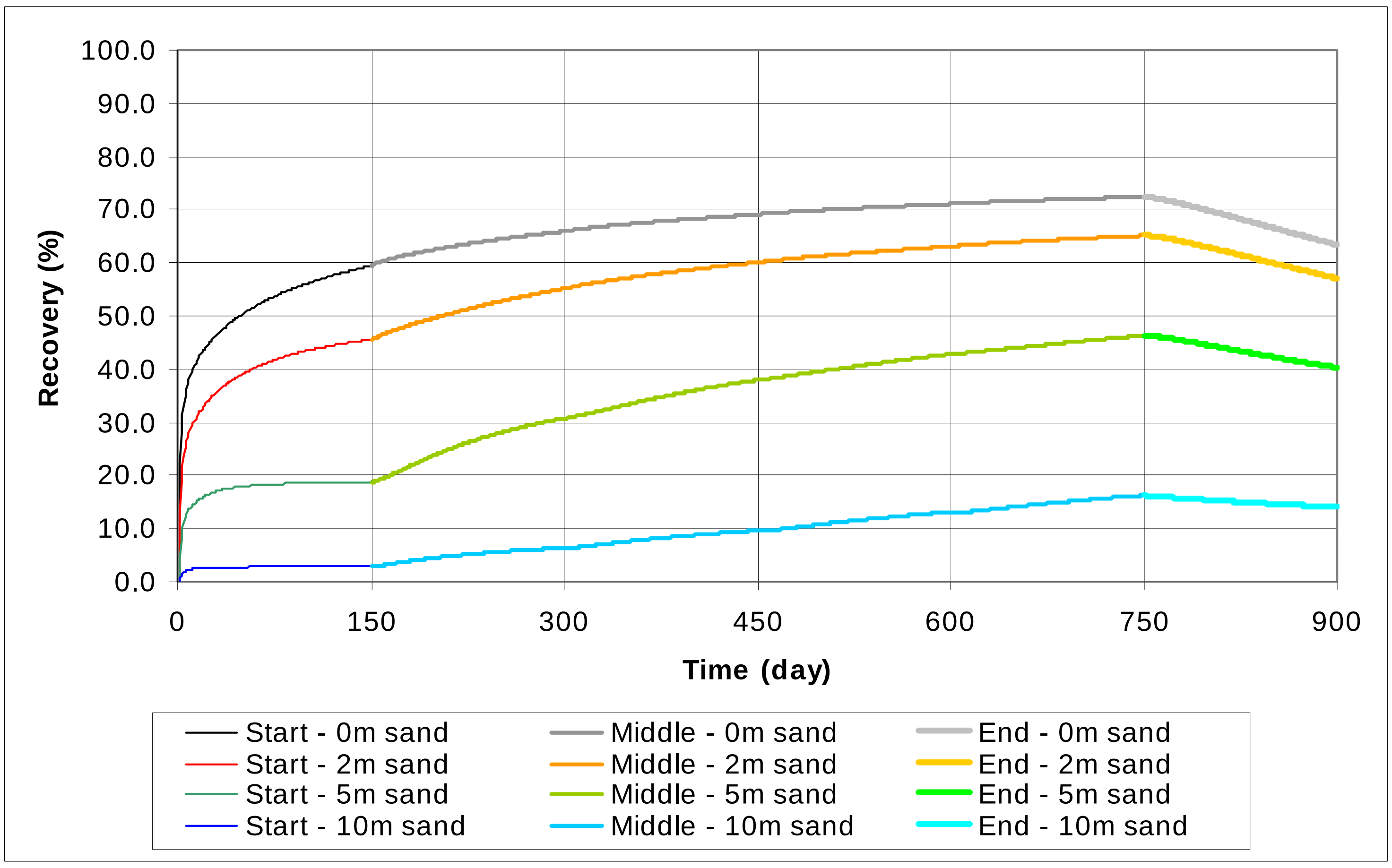
Figure 41a

figure34b Simulated mine water recovery rates 35-80 mpd.srf

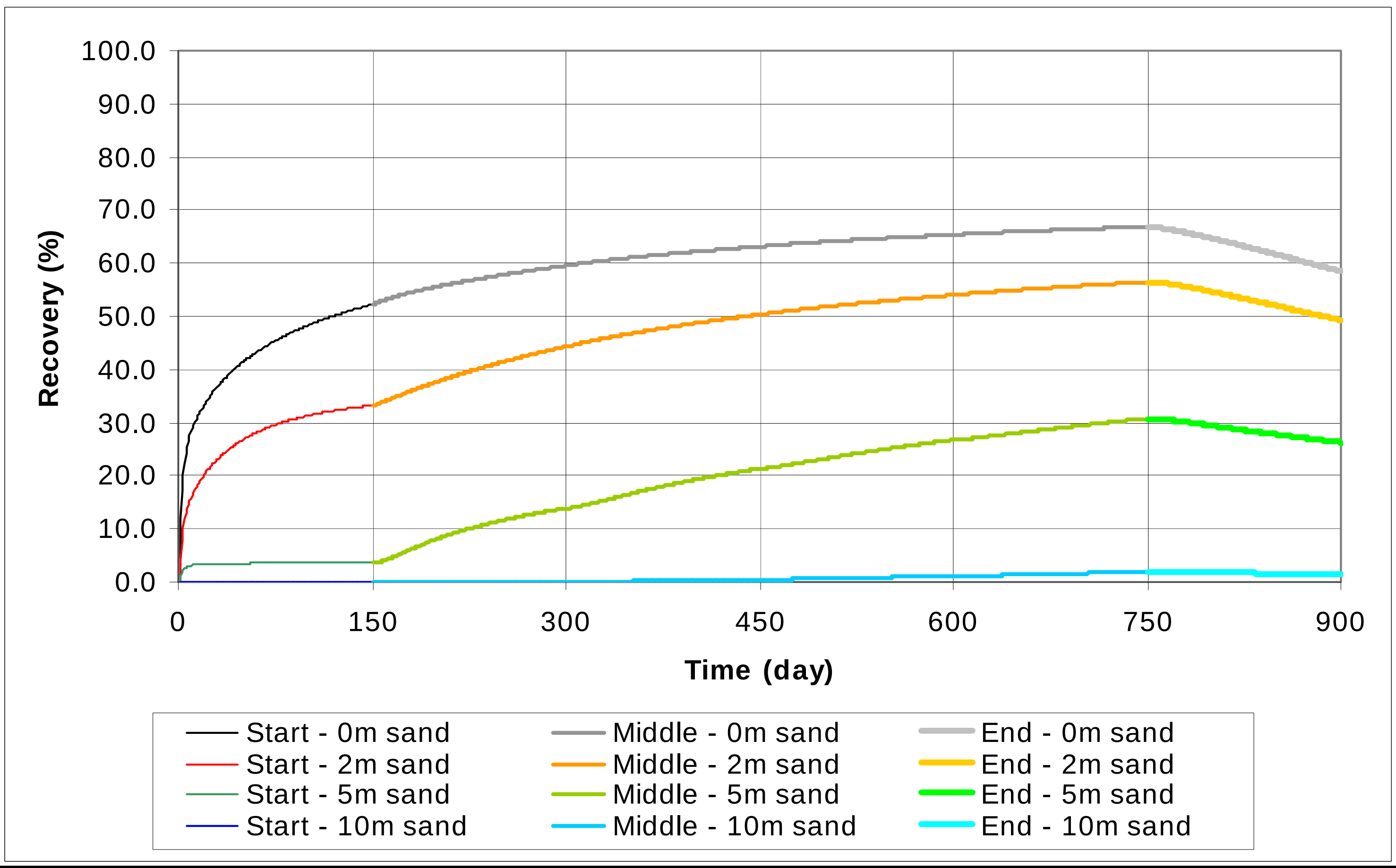
35m/day



55m/day



80m/day



Job No.	42905541	
Prep. By	ECPL	21 Feb 05
Chk'd By	RBW	21 Feb 05
Revision Indicator	0	

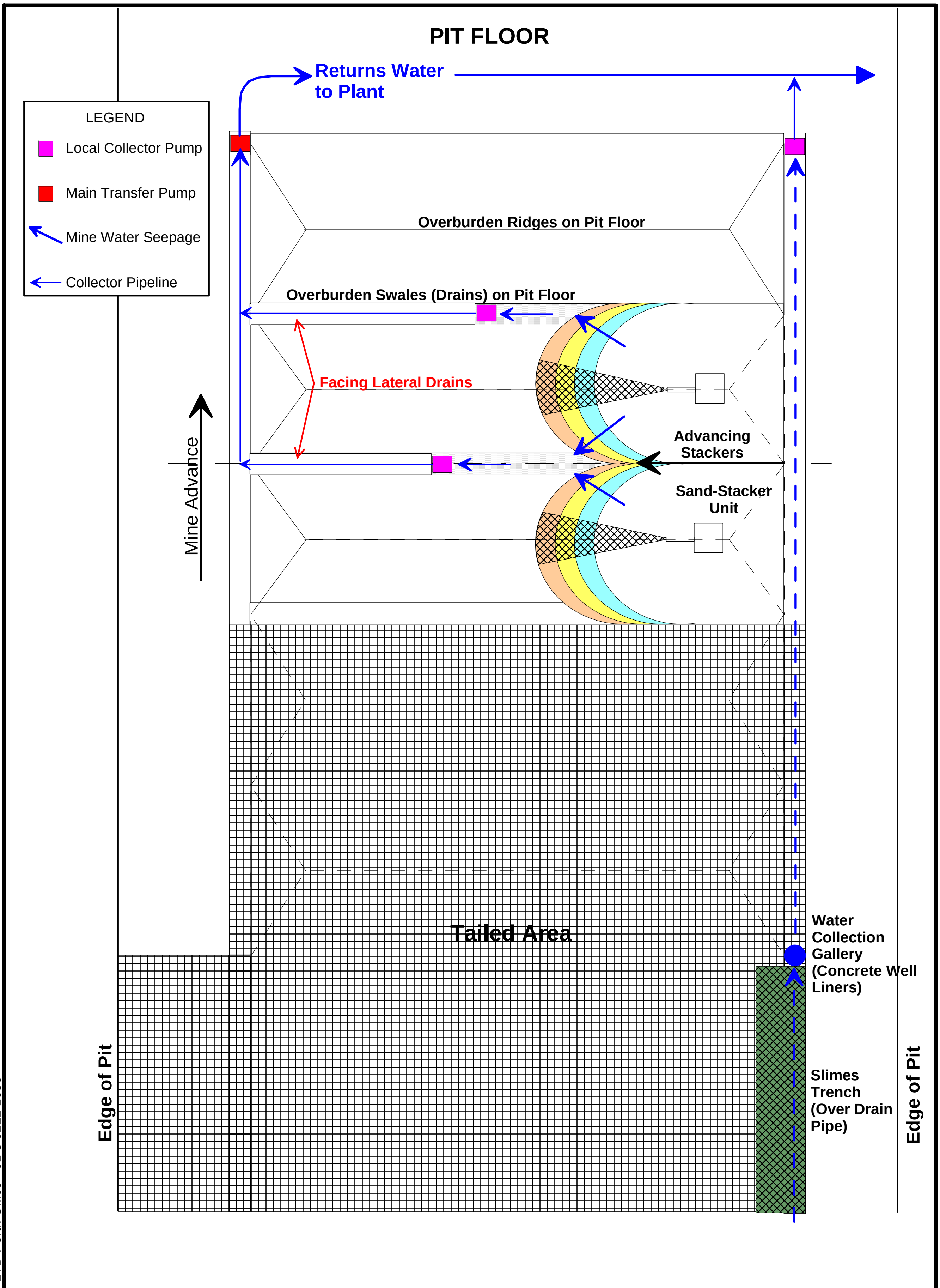
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Simulated Upper-Bound Tailings Water Recovery Rates 35 to 80 m/day Advance Rate With All Active Drains

URS

Figure 41b



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **ALTERNATIVE CONCEPTUAL SAND TAILINGS WATER RECOVERY PLAN 2 DRAINS ONLY**	**Figure 42** URS
Prep. By	RBW	26 Feb 05		
Chk'd By	RBW	26 Feb 05		
Revision No.		1		

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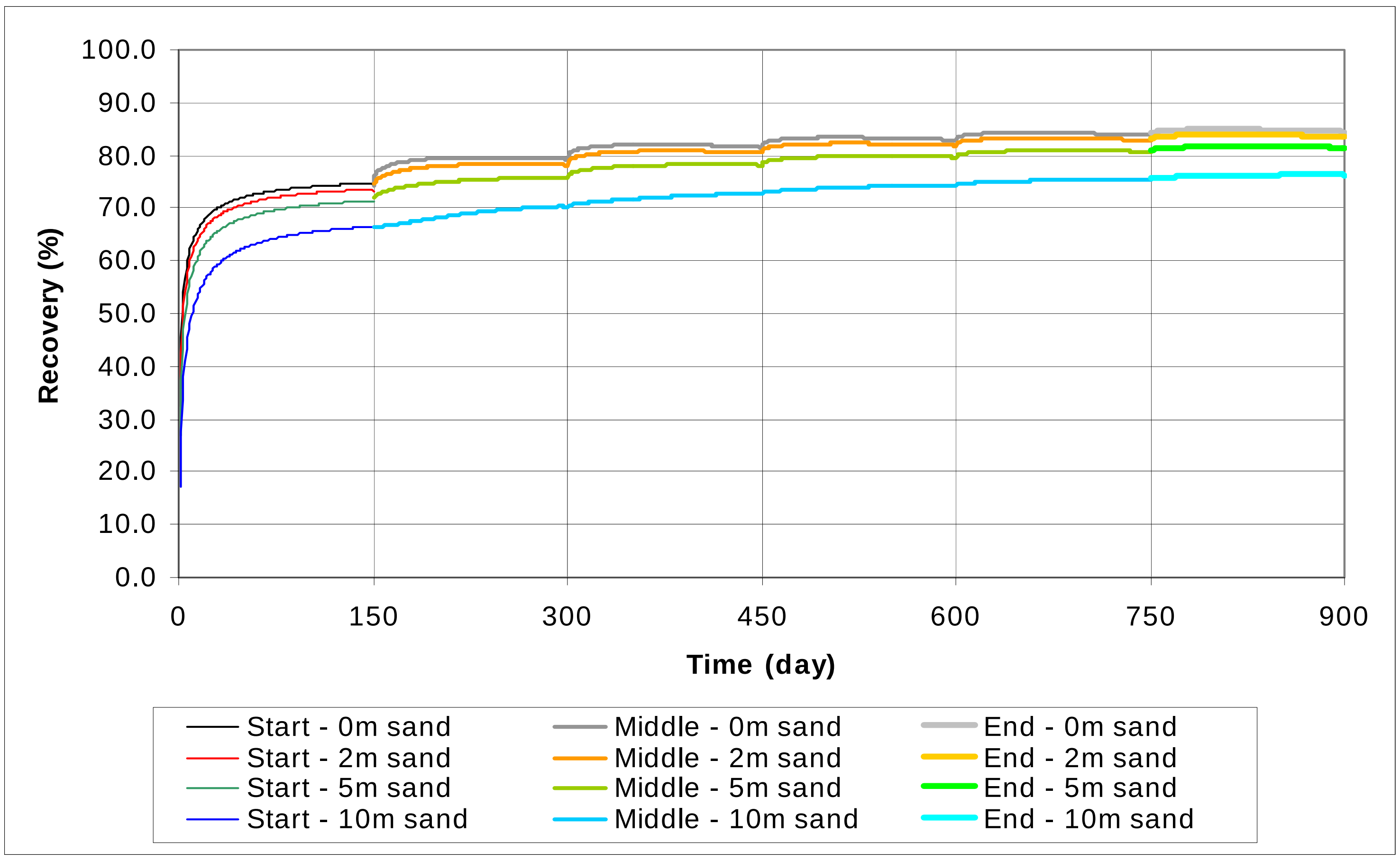
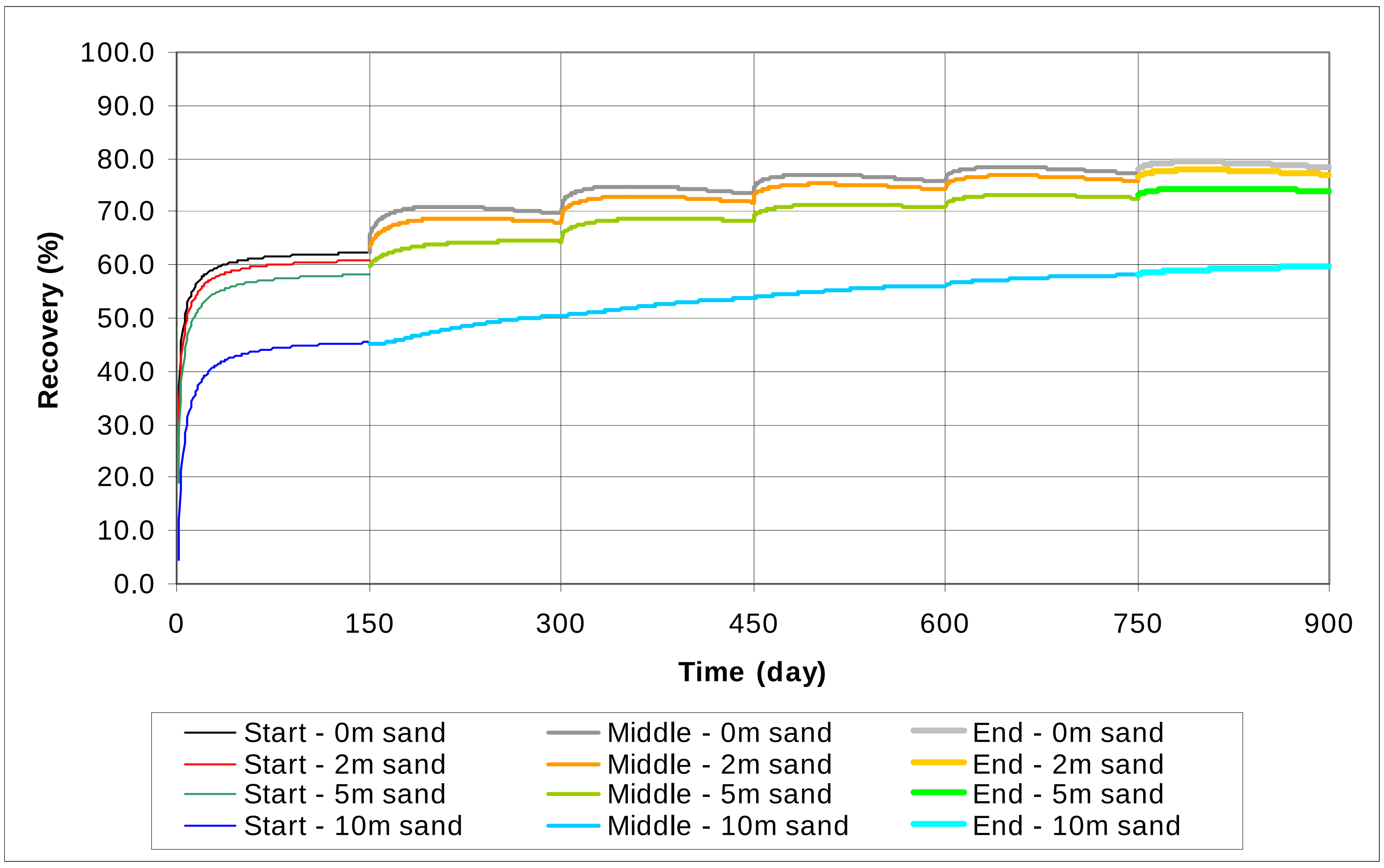
Conceptual Stacker-Drains Alternative 2-Drains.srf figure34a Simulated mine water recovery rates 5-15 mpd.srf

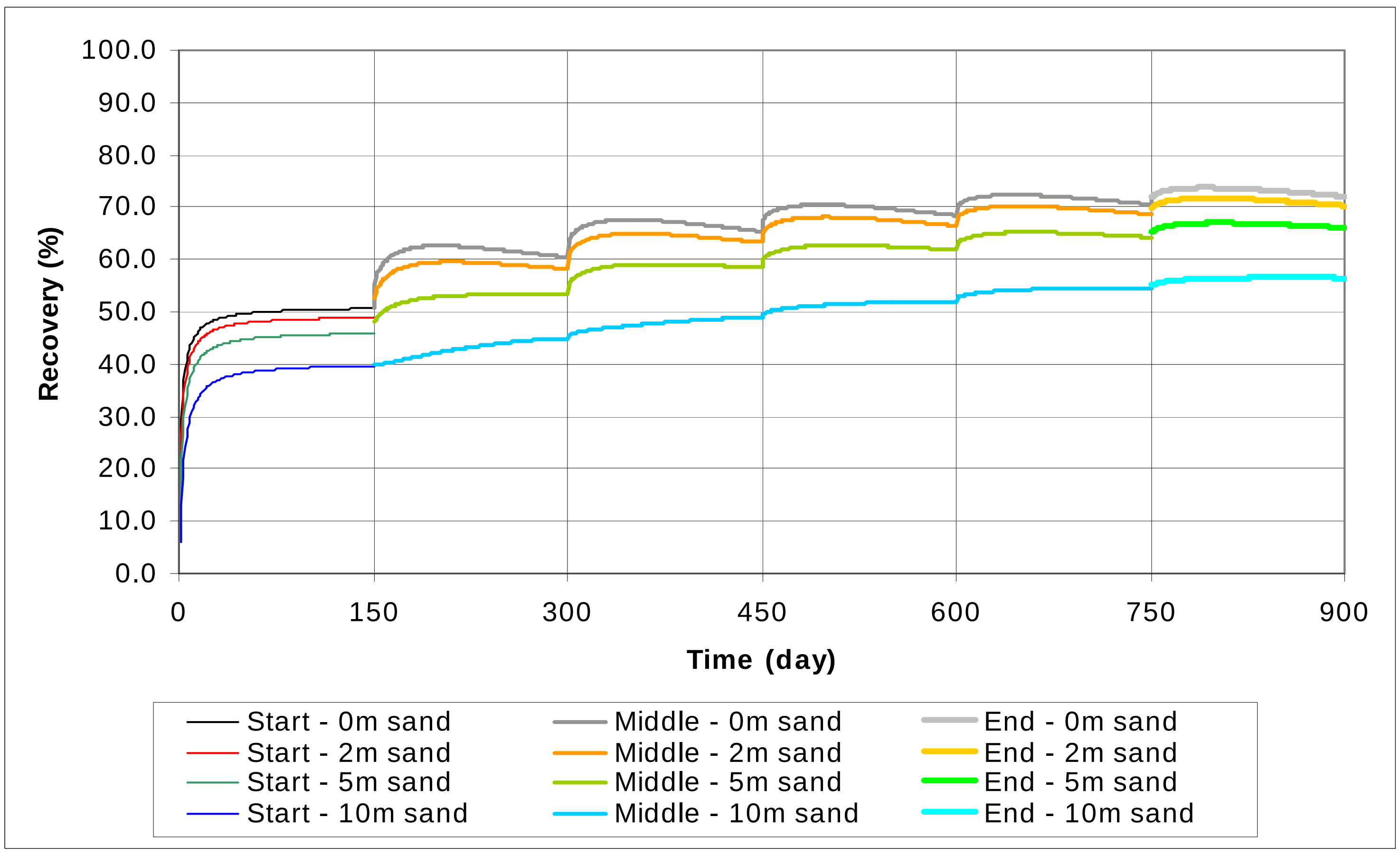
5m/day



10m/day



15m/day



Job No.	42905541	
Prep. By	ECPL	21 Feb 05
Chk'd By	RBW	21 Feb 05
Revision Indicator	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

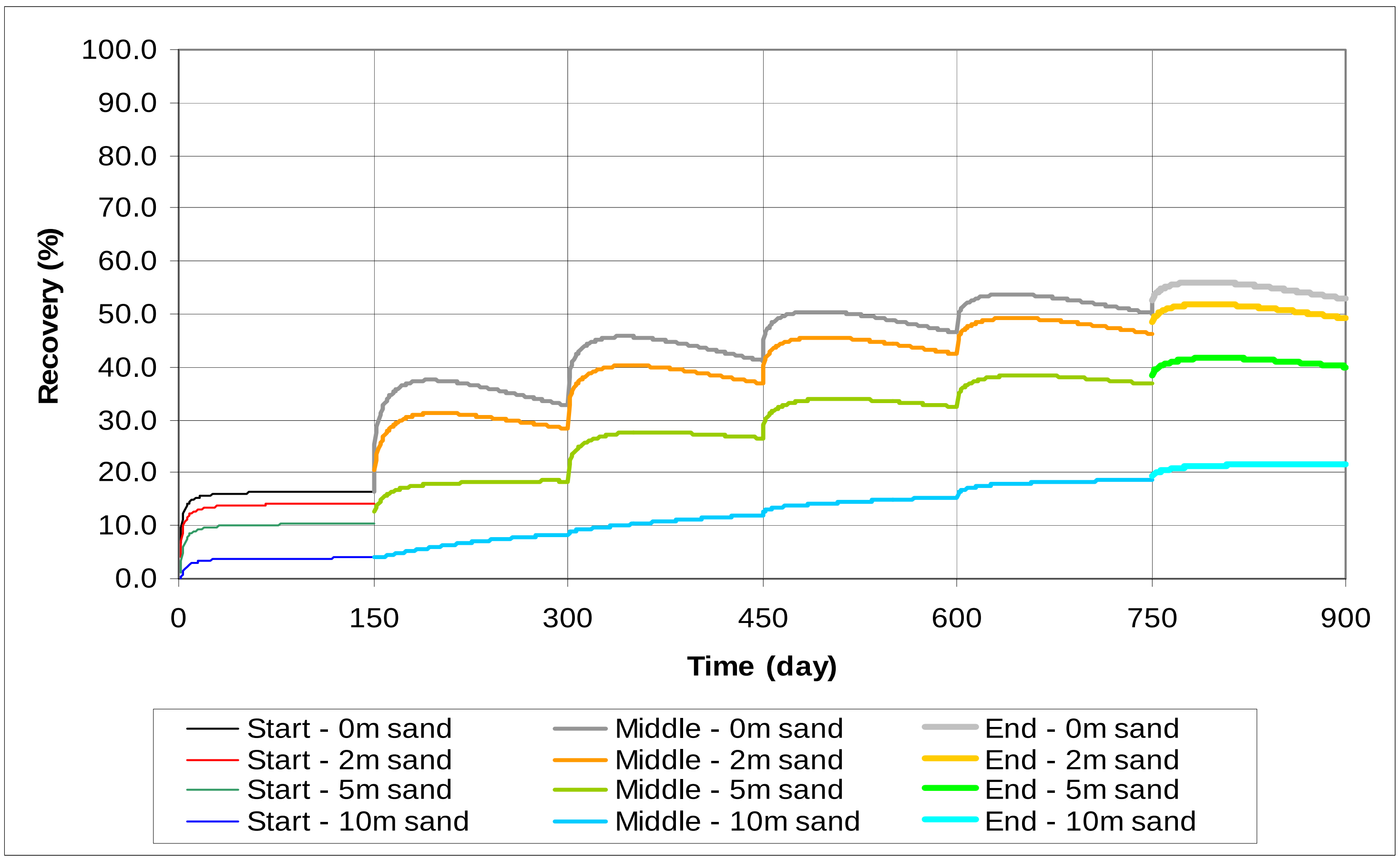
Simulated Lower-Bound Tailings Water Recovery Rates 5 to 15 m/day Advance Rate, With 2 Active Drains

URS

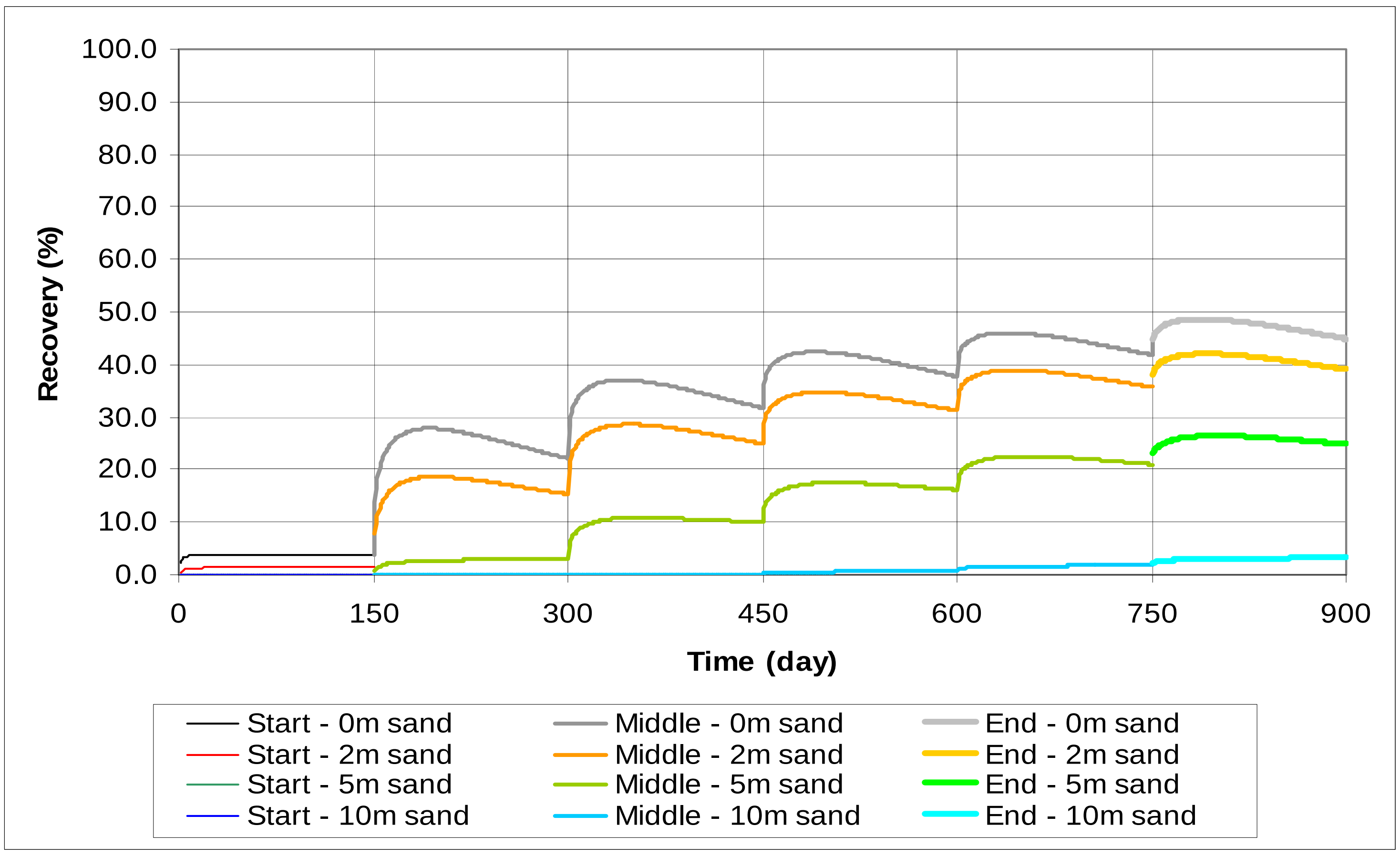
Figure 43a

figure34b Simulated mine water recovery rates 35-80 mpd.srf

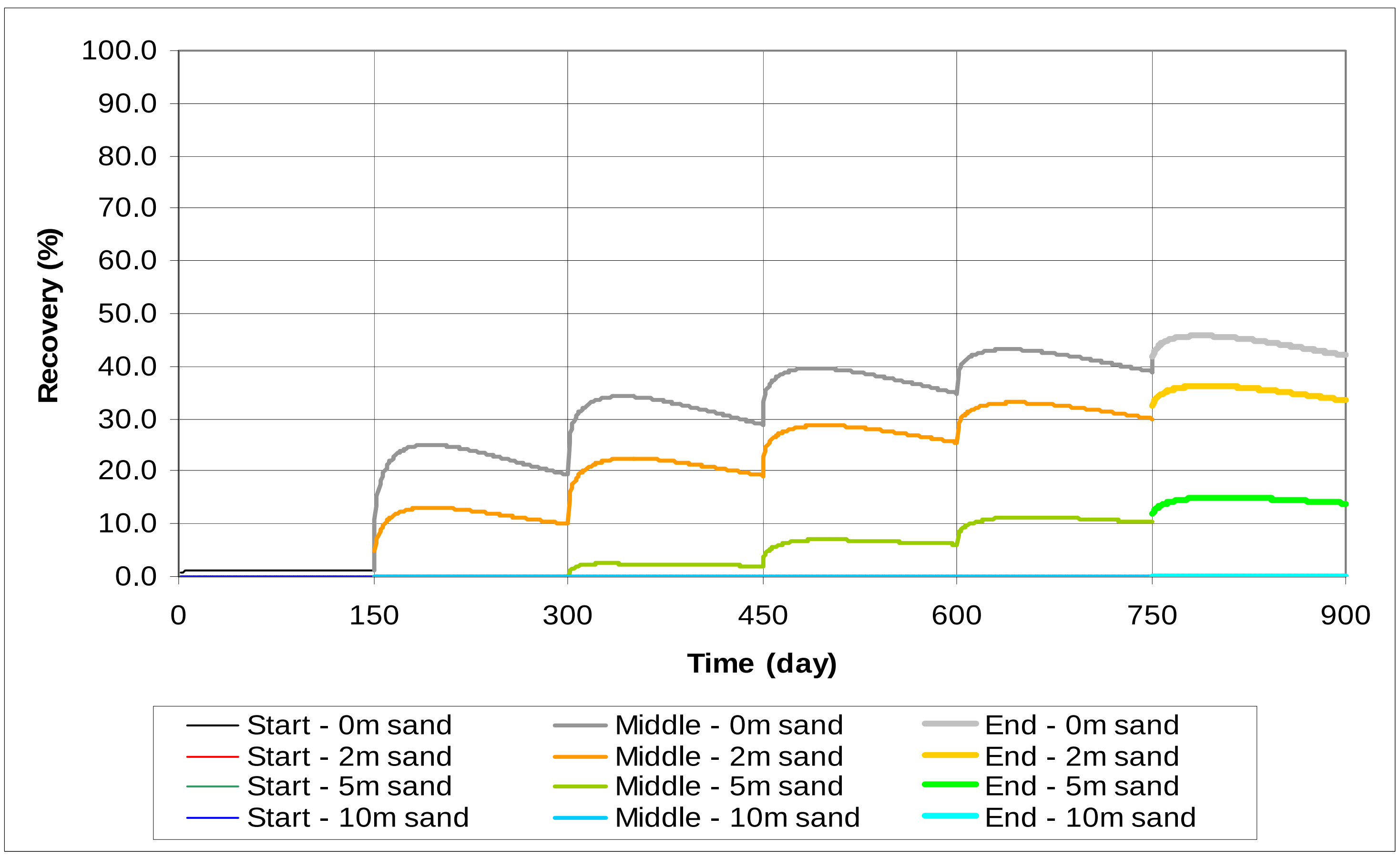
35m/day



55m/day



80m/day



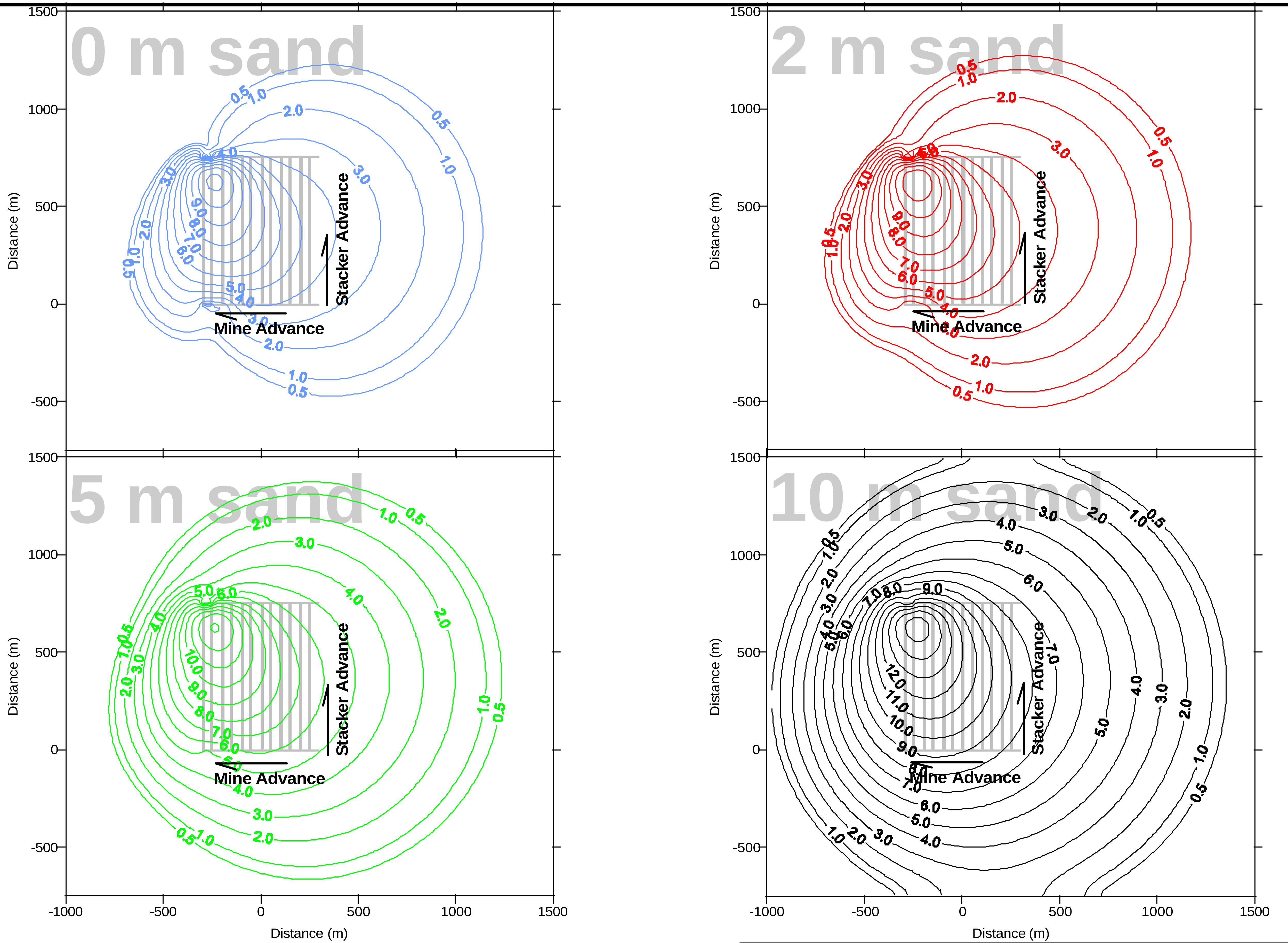
Job No.	42905541
Prep. By	ECPL 21 Feb 05
Chk'd By	RBW 21 Feb 05
Revision Indicator	0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Simulated Lower-Bound Tailings Water Recovery Rates 35 to 80 m/day Advance Rate, With 2 Active Drains

Figure 43b



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 44a
Prep. By	ECPL	3 Dec '04	**SIMULATED LOWER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 5m/day ADVANCE RATE**	URS
Chk'd By	RBW	3 Dec '04		
Revision Indicator		0		

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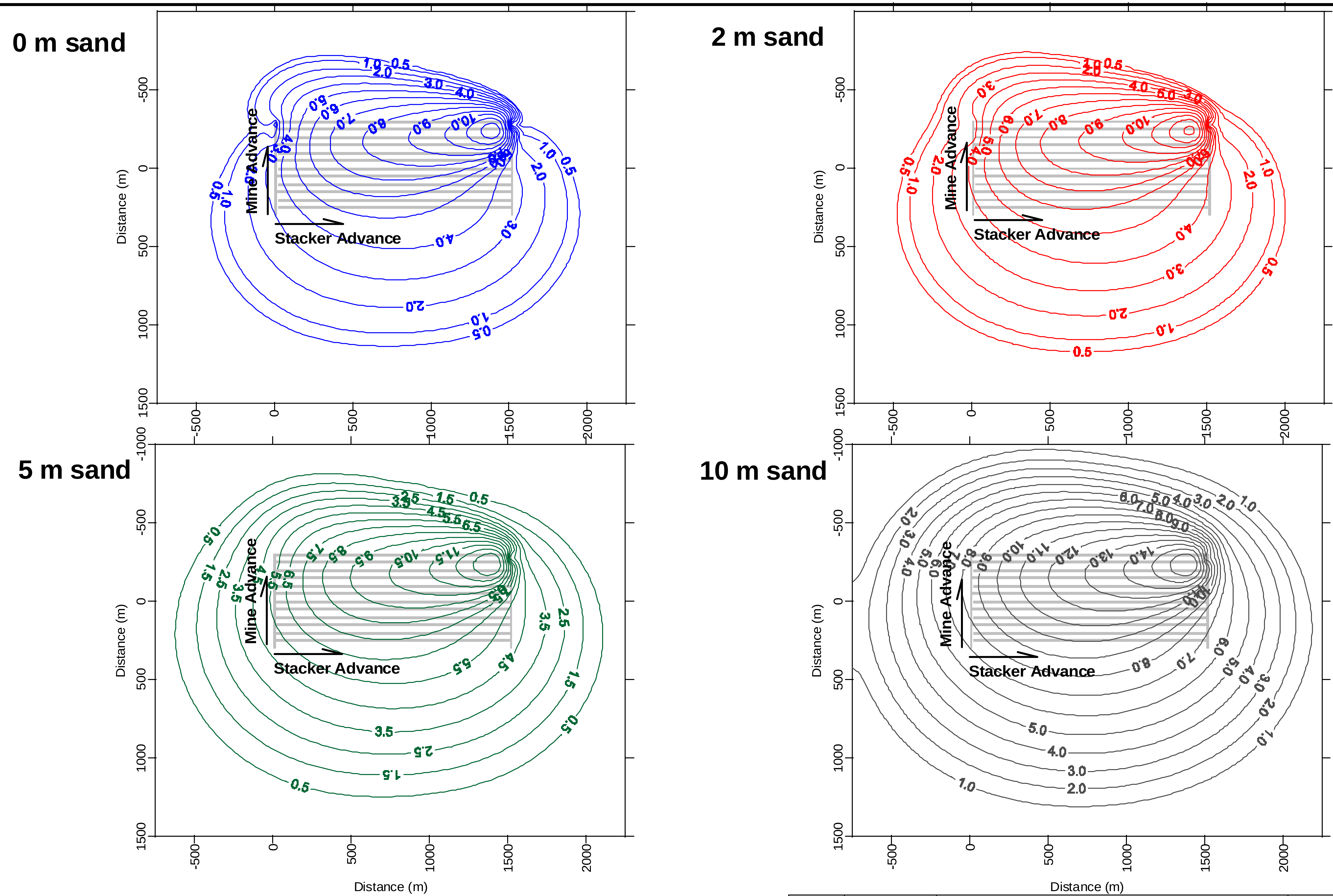
figure35aSimulated mounding at 5 mpd.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	**Figure 44b**
Prep. By	ECPL	3 Dec '04	**SIMULATED LOWER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 10 m/day ADVANCE RATE**	URS
Chk'd By	RBW	3 Dec '04		
Revision Indicator		0		

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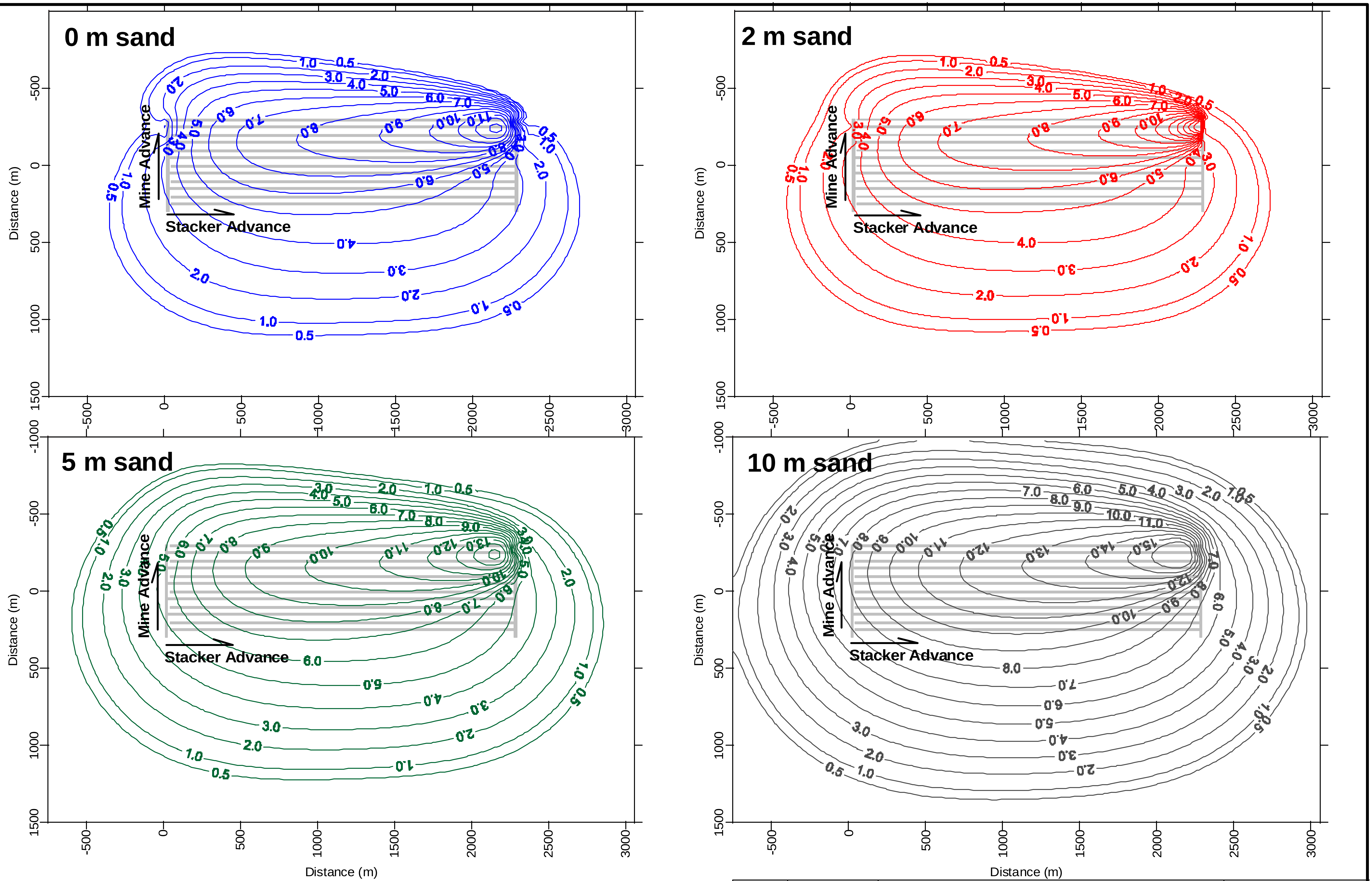
figure35bSimulated mounding at 10 mpd.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 44c
Prep. By	ECPL	3 Dec '04	SIMULATED LOWER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND PIT FLOOR @ 15m/day ADVANCE RATE	URS
Chk'd By	RBW	3 Dec '04		
Revision Indicator		0		

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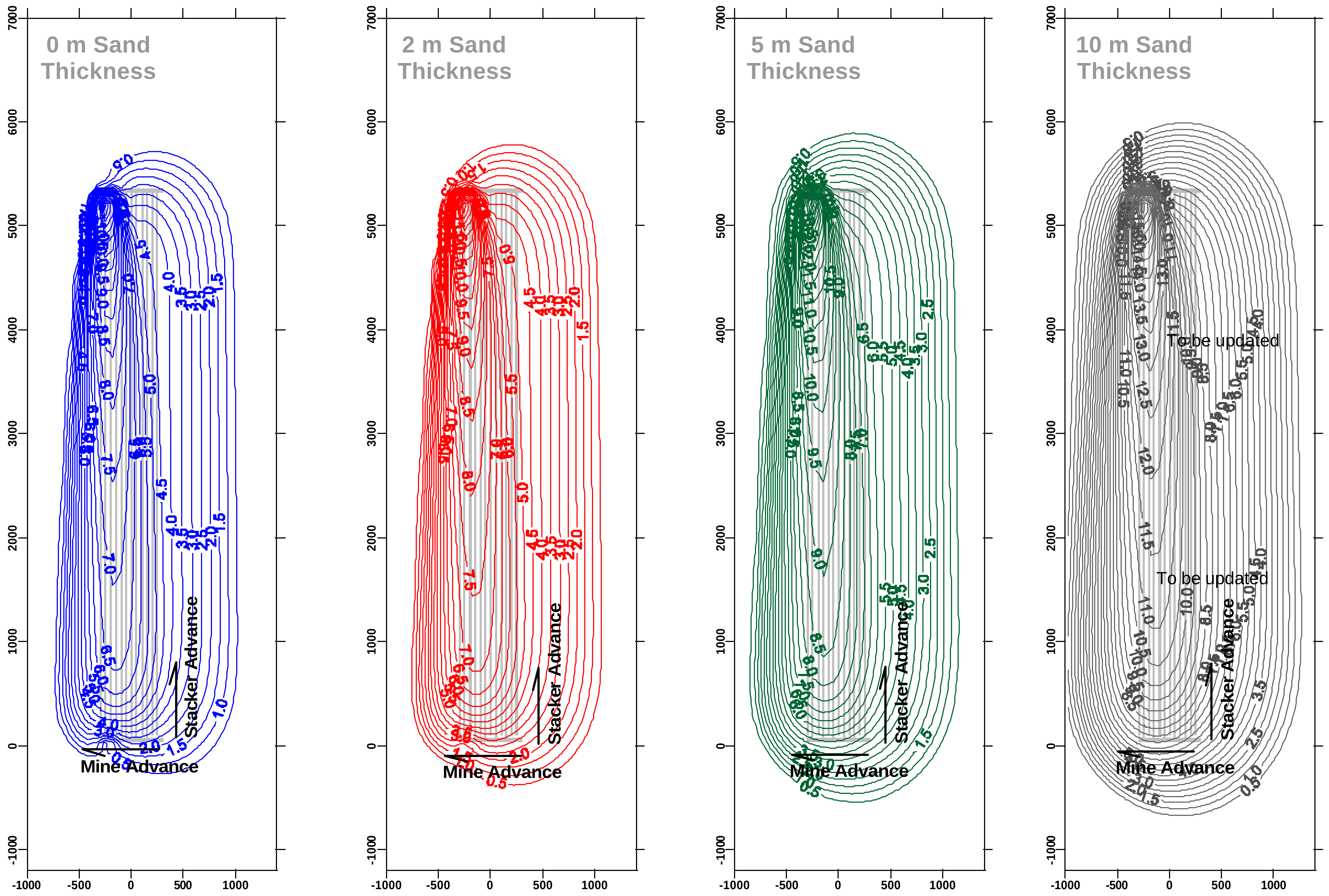
figure35cSimulated mounding at 15 mpd.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT	Figure 44d
Prep. By	ECPL	23 Feb 05	**SIMULATED LOWER BOUND MOUNDING WITH 0, 2, 5 & 10 m SAND BENEATH PIT FLOOR AT 35 m/day ADVANCE RATE**	URS
Chk'd By	RBW	23 Feb 05		
Revision Indicator		0		

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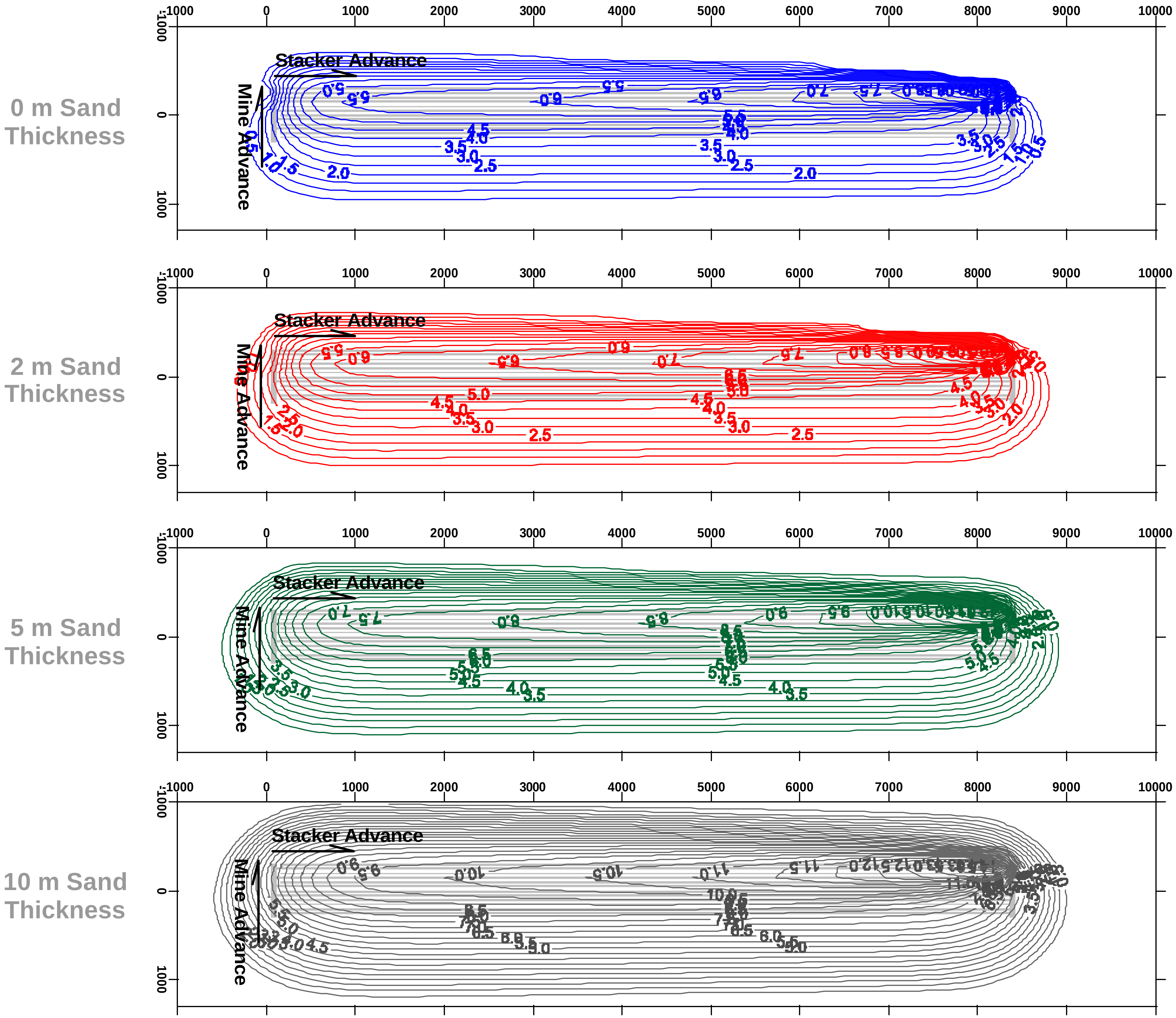
Fig35dSimulated Mounding at 35 mpd.srf



Job No.	42905541		Gunson Resources Limited	Figure 44e
Prep. By	ECPL	23 Feb 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	23 Feb 05	SIMULATED LOWER-BOUND MOUNDING WITH 0, 2, 5 & 10 m SAND BENEATH PIT FLOOR AT 55 m/day ADVANCE RATE	URS
Revision Indicator		0		

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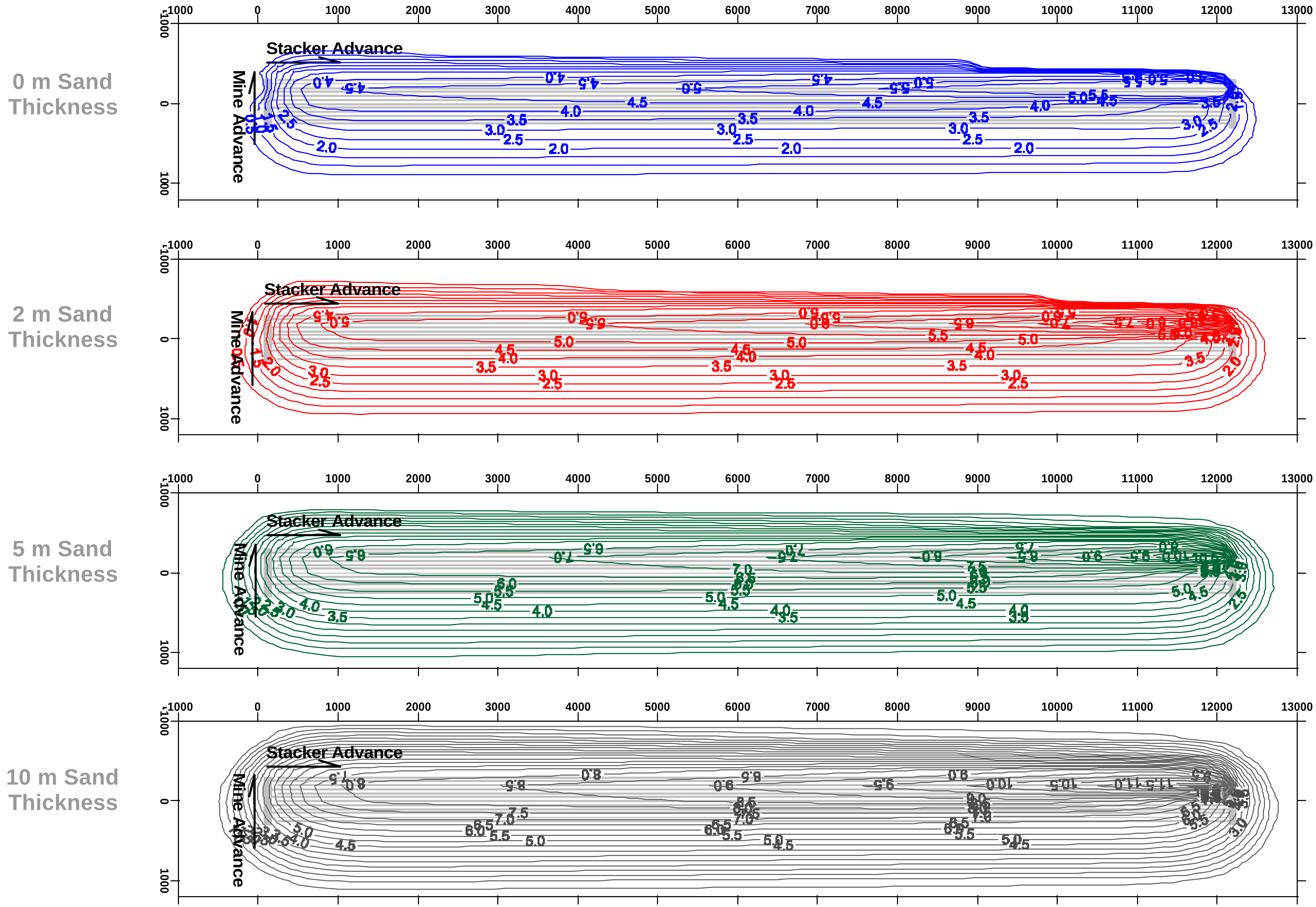
Fig35eSimulated Mounding at 55 mpd.srf



Job No.	42905541		Gunson Resources Limited	Figure 44f
Prep. By	ECPL	23 Feb 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	23 Feb 05	SIMULATED LOWER-BOUND MOUNDING WITH 0, 2, 5 & 10 m SAND BENEATH PIT FLOOR AT 80 m/day ADVANCE RATE	URS
Revision Indicator	0			

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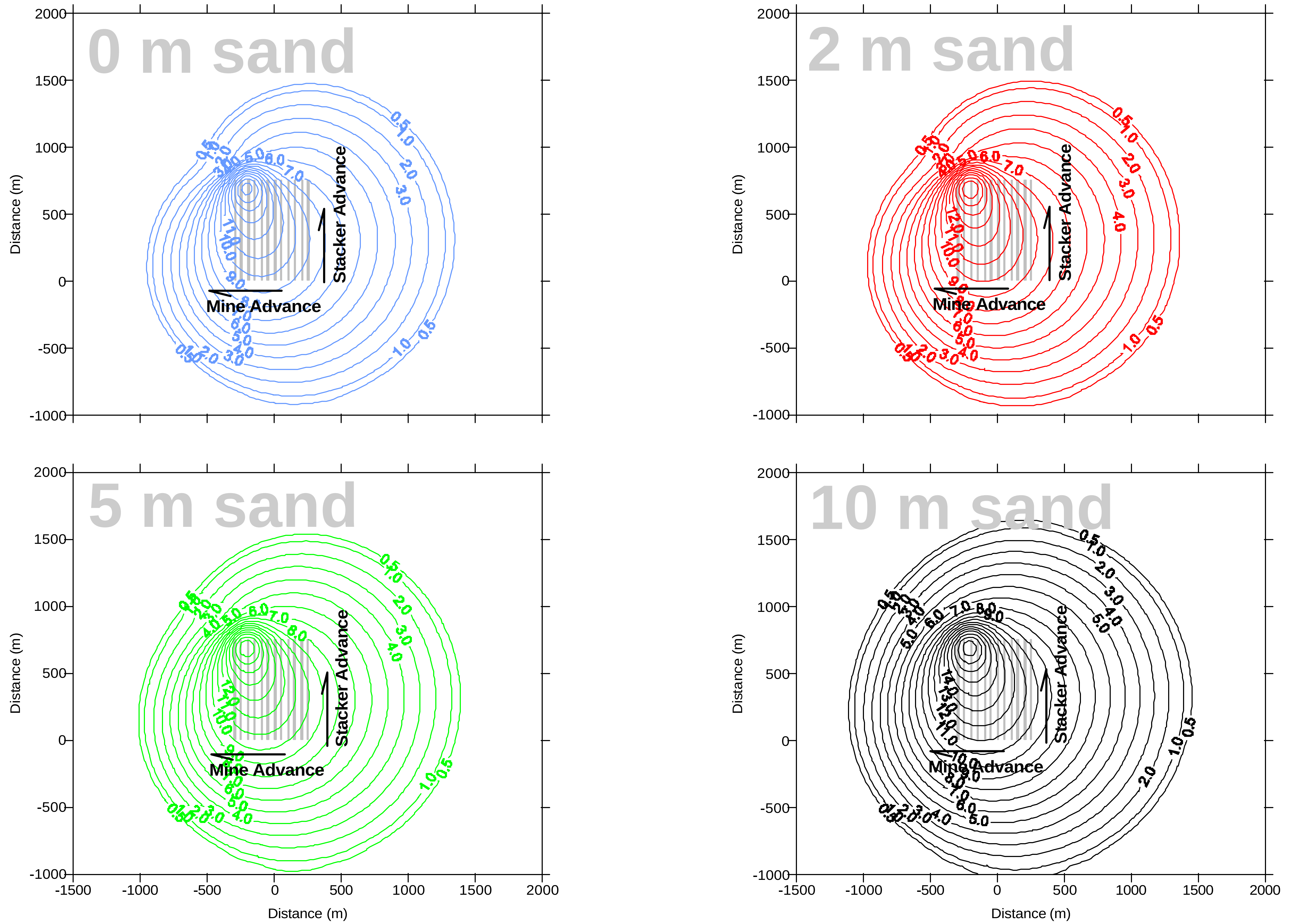
Fig35fSimulated Mounding at 80 mpd.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED UPPER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 5m/day ADVANCE RATE**	**Figure 45a**
Prep. By	ECPL	28 Feb 05		
Chk'd By	RBW	28 Feb 05		URS
Revision Indicator	0			

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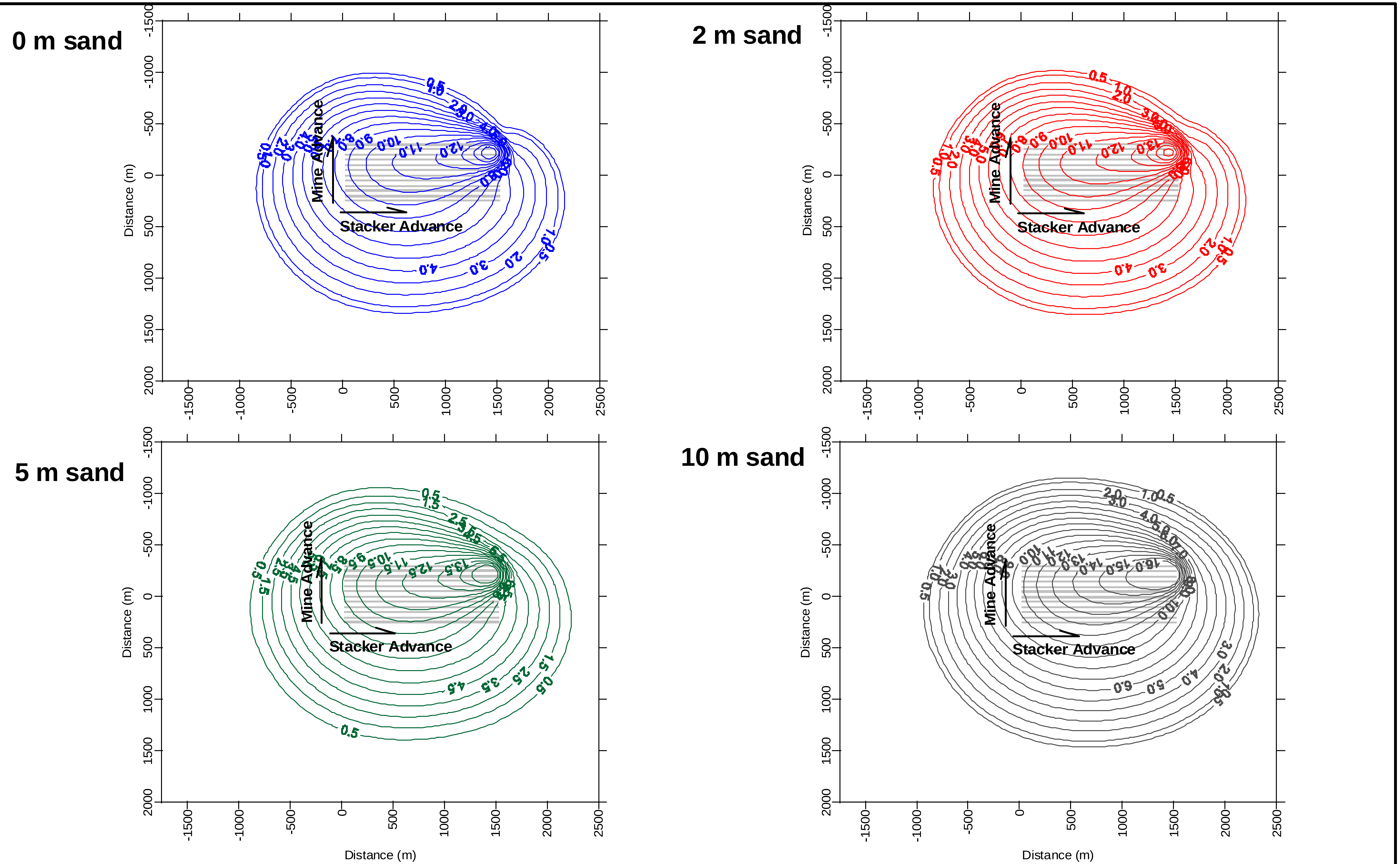
figure45a. Simulated mounding beneath tails and mine.srf



Job No.	42905541	
Prep. By	ECPL	28 Feb 05
Chk'd By	RBW	28 Feb 05
Revision Indicator		0

Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED UPPER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 10m/day ADVANCE RATE

Figure 45b

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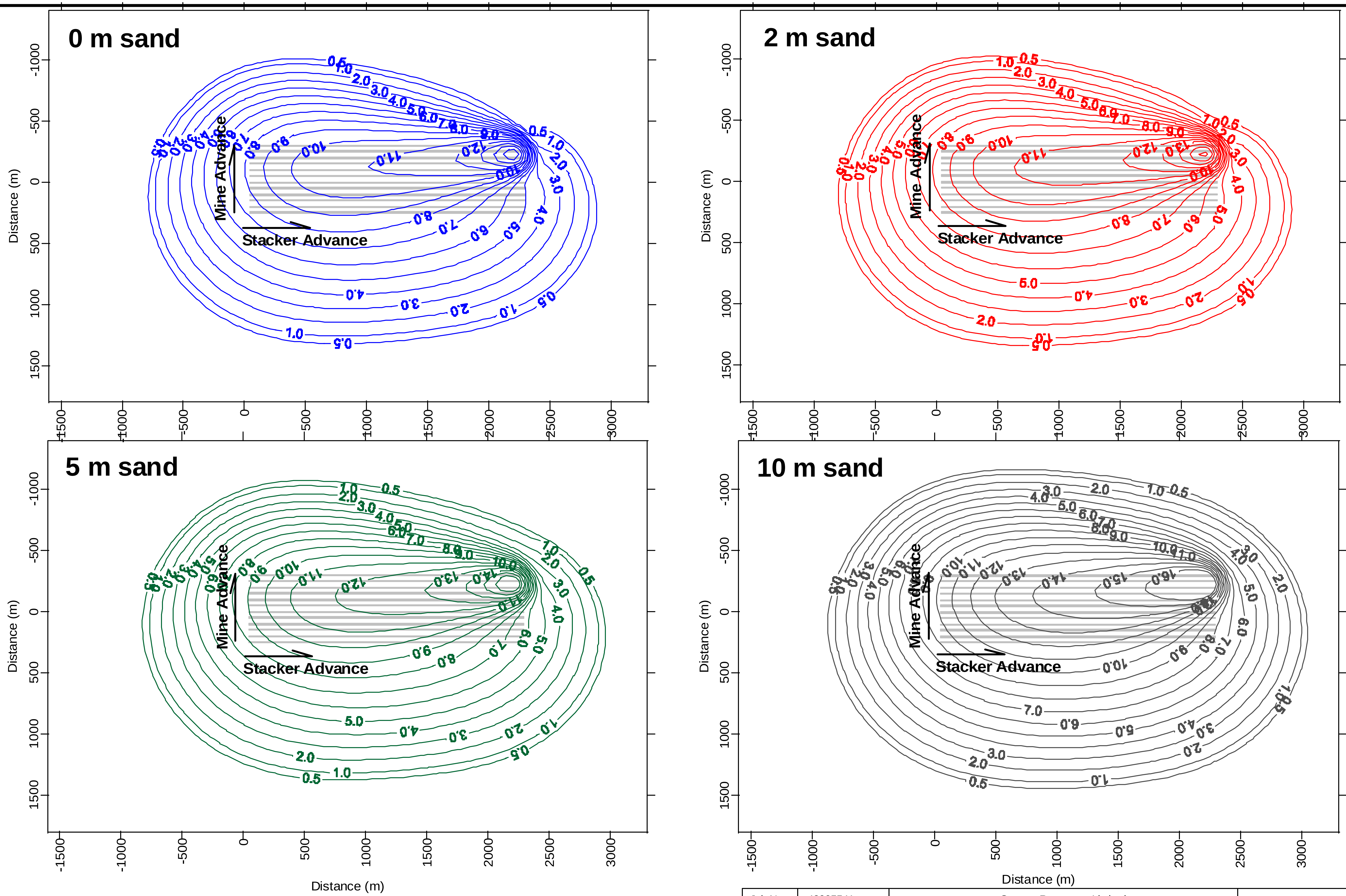
figure35hSimulated mounding at 10 mpd 2-Drains.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 45c
Prep. By	ECPL	28 Feb 05	SIMULATED UPPER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 15 m/day ADVANCE RATE	URS
Chk'd By	RBW	28 Feb 05		
Revision Indicator	0			

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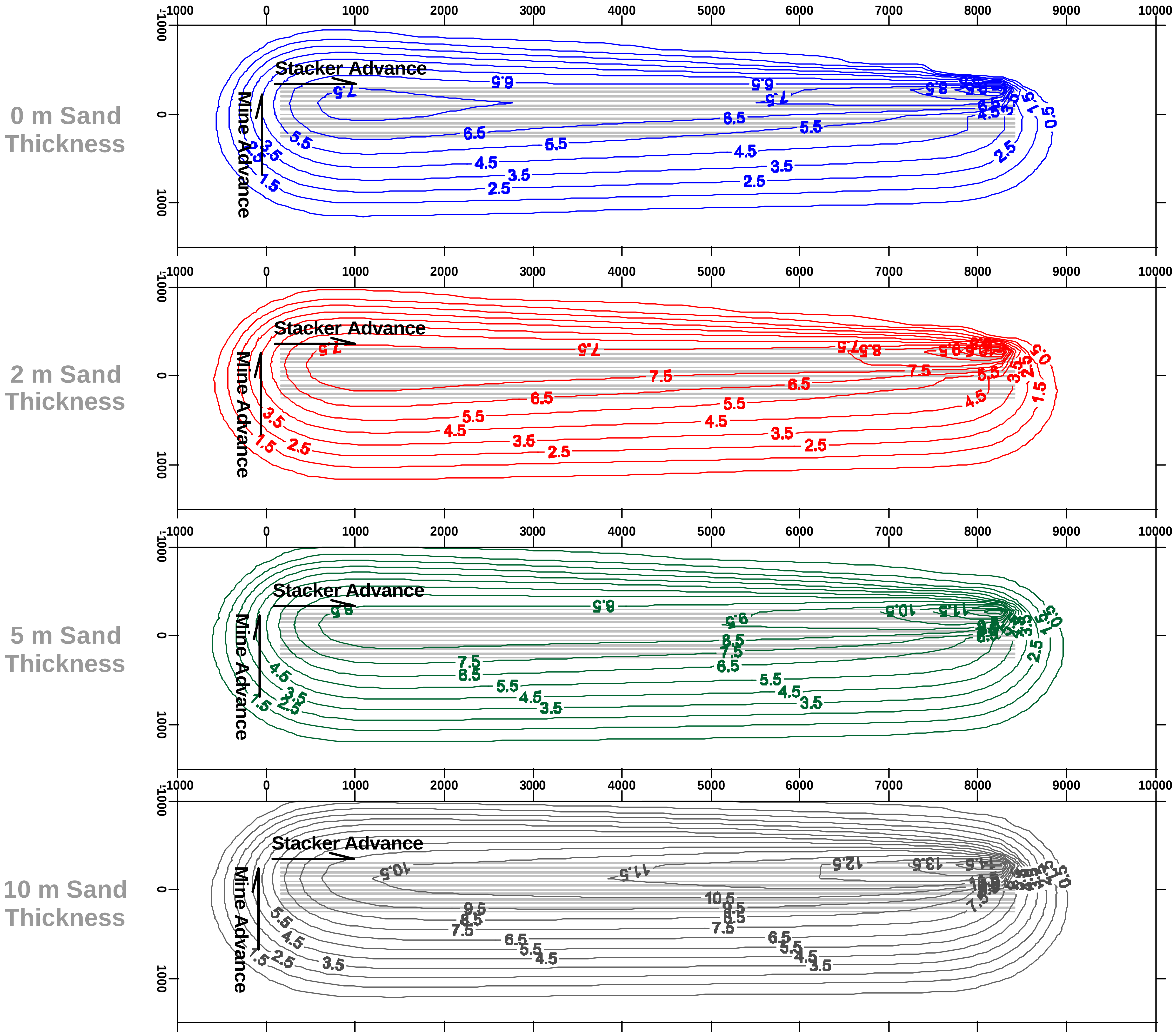
figure35iSimulated mounding at 15 mpd 2-Drains.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED UPPER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 55 m/day ADVANCE RATE**	**Figure 45e**
Prep. By	ECPL	28 Feb 05		URS
Chk'd By	RBW	28 Feb 05		
Revision Indicator		0		

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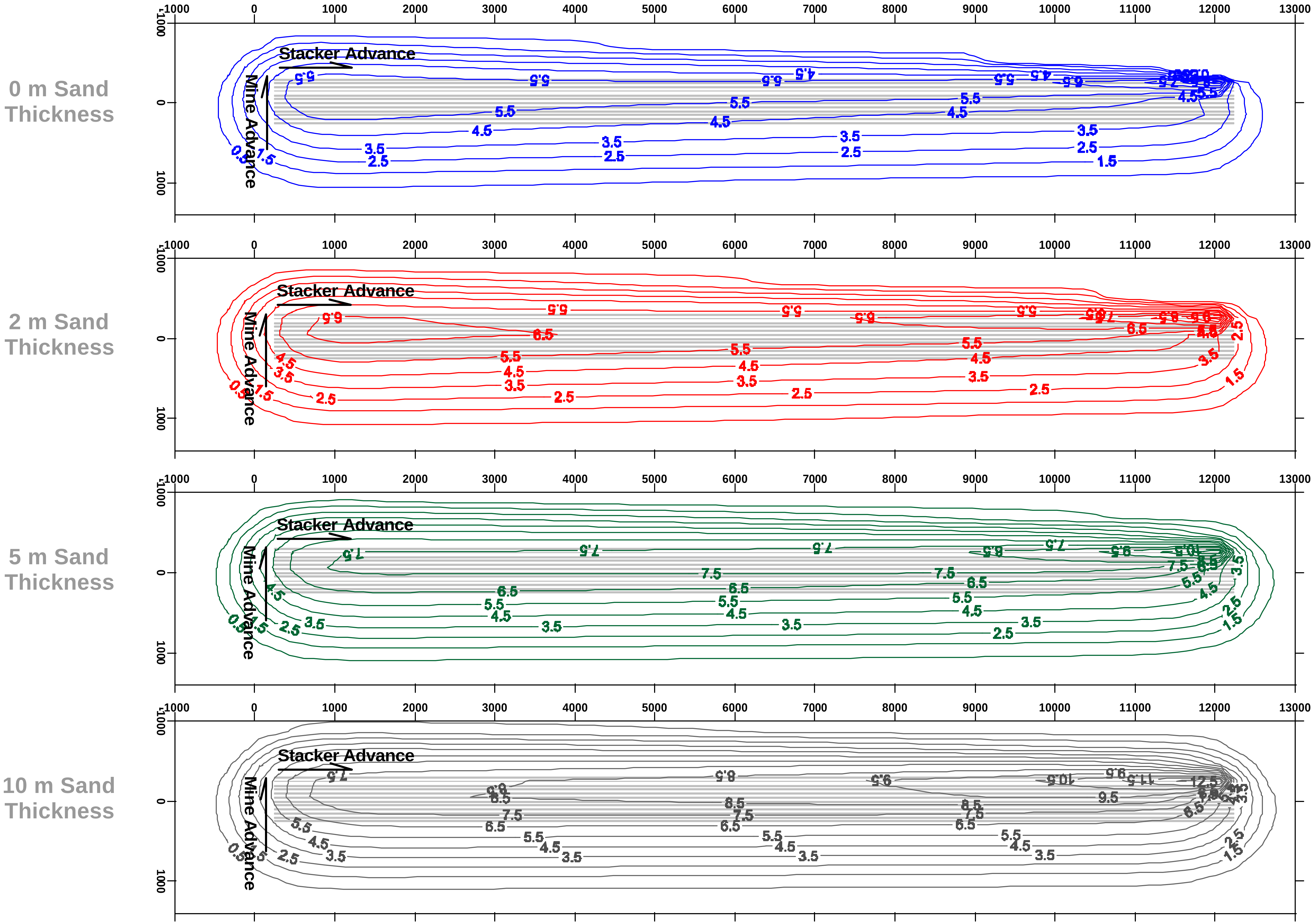
Fig35kSimulated Mounding at 55 mpd 2-Drains.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED UPPER-BOUND MOUNDING WITH 0, 2, 5, 10 m SAND BENEATH PIT FLOOR @ 80 m/day ADVANCE RATE**	**Figure 45f**
Prep. By	ECPL	28 Feb 05		URS
Chk'd By	RBW	28 Feb 05		
Revision Indicator		0		

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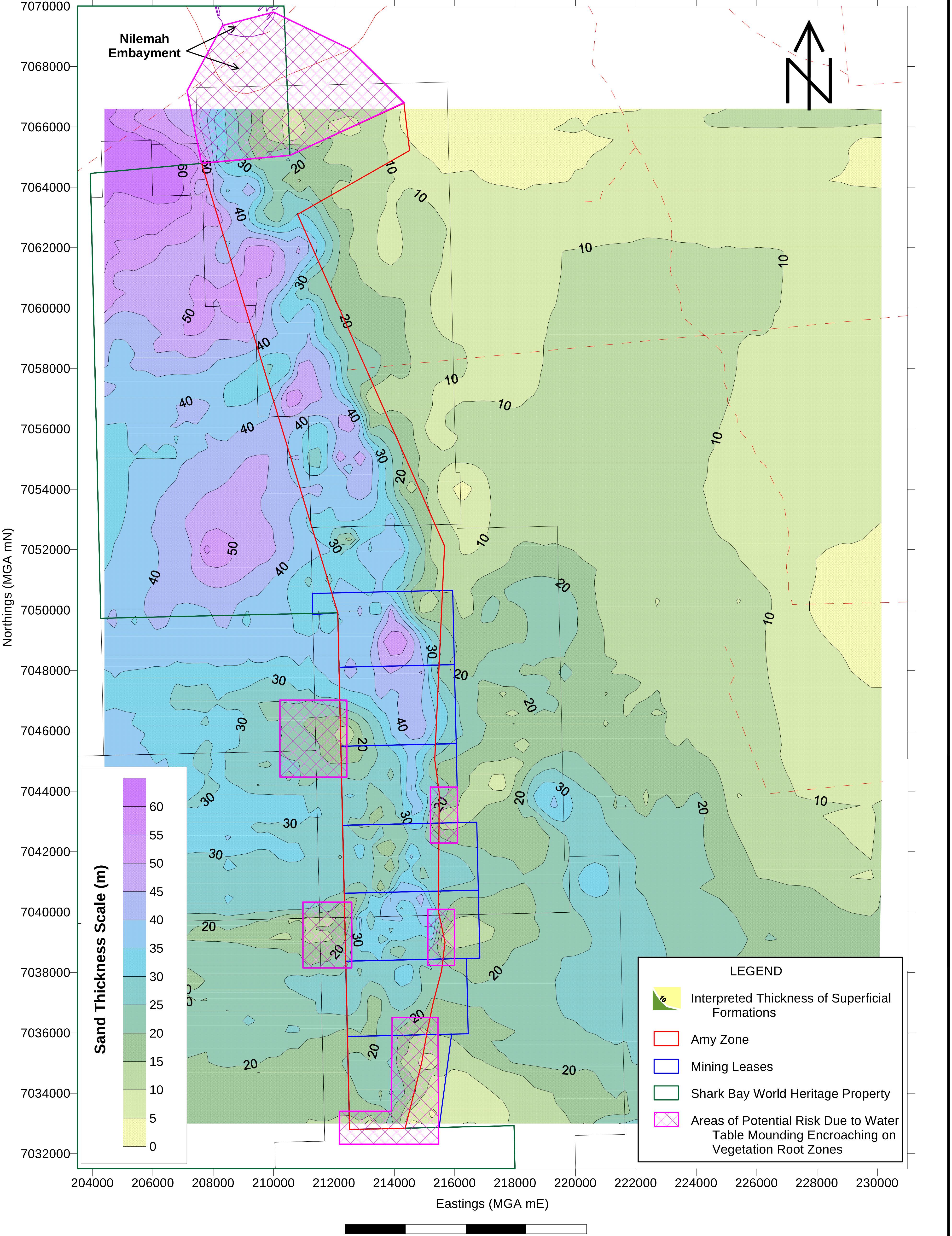
Fig35\Simulated Mounding at 80 mpd 2-Drains.srf



Job No.	42905541	
Prep. By	RBW	1 Apr '05
Chk'd By	RBW	1 Apr '05
Revision Indicator		0

Gunson Resources Limited

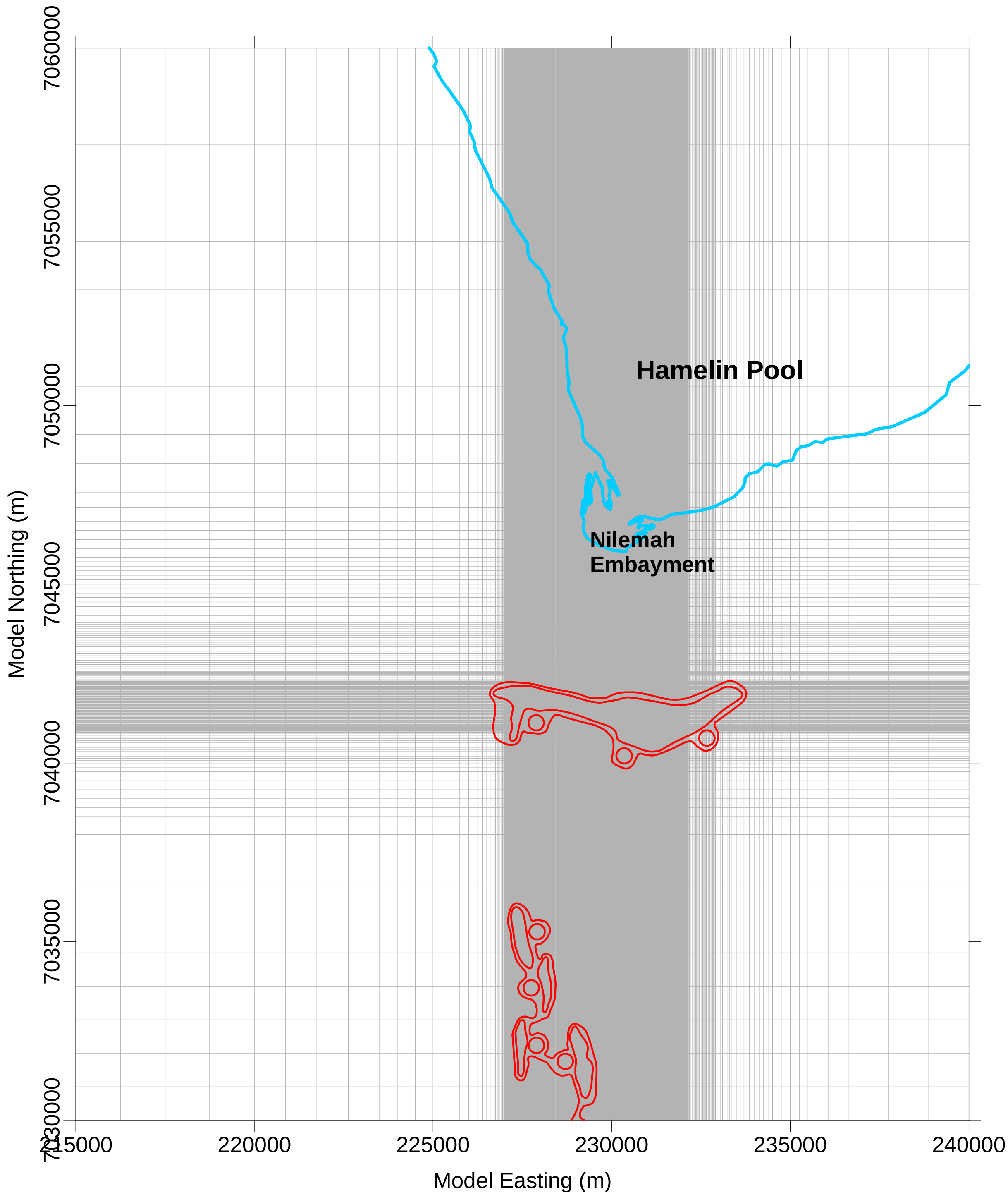
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Areas of Potential Risk Due to Mounding Encroachment Within Vegetation Root Zones

Figure 46

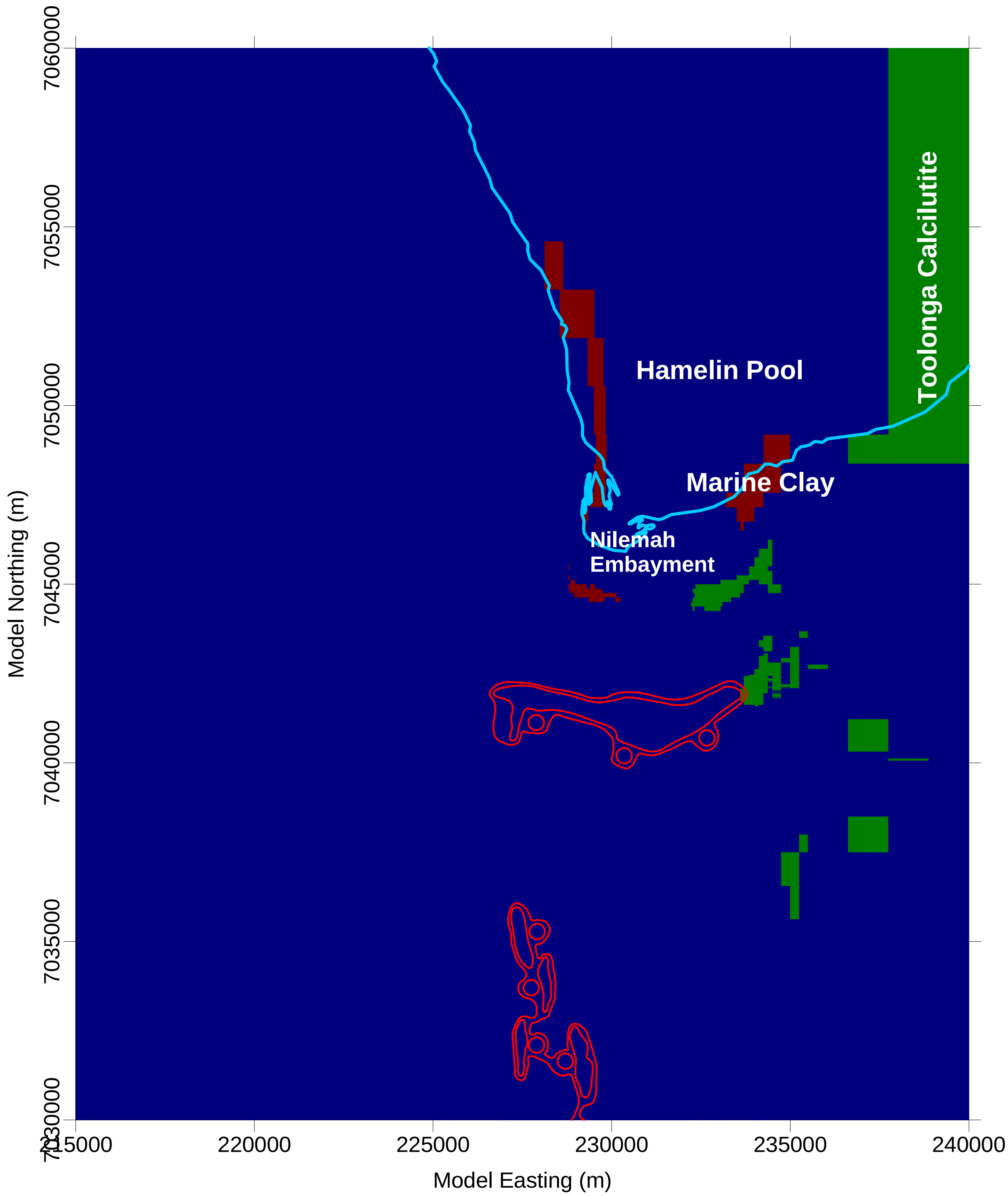
URS

Areas of Potential Risk Due to Mounding.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	**Figure 47**
Prep. By	ECPL	31 Mar '05	**NORTHERN PIT MODEL DOMAIN**	URS
Chk'd By	RWC	31 Mar '05		
Revision No.		0		

fig47.srf



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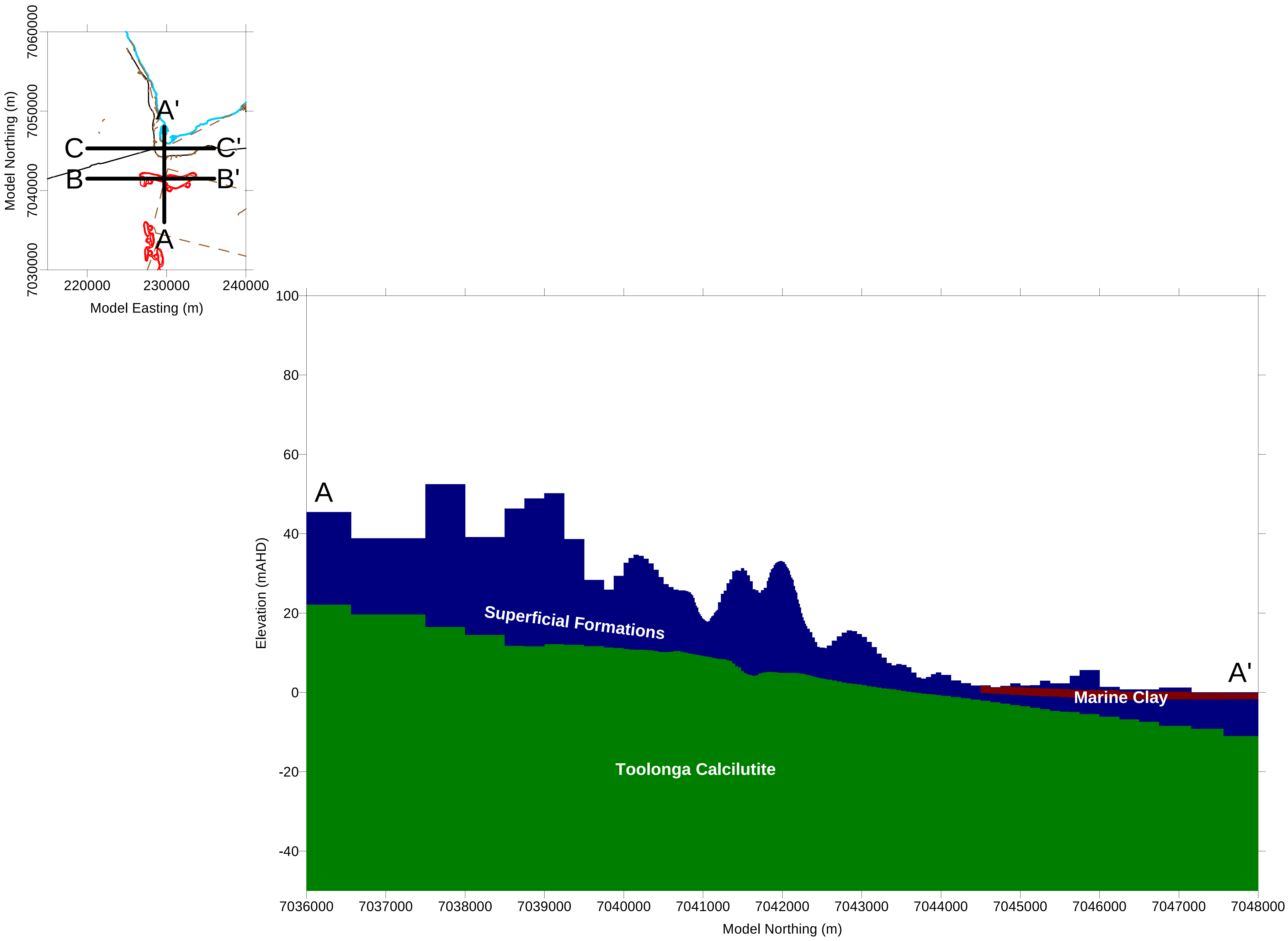
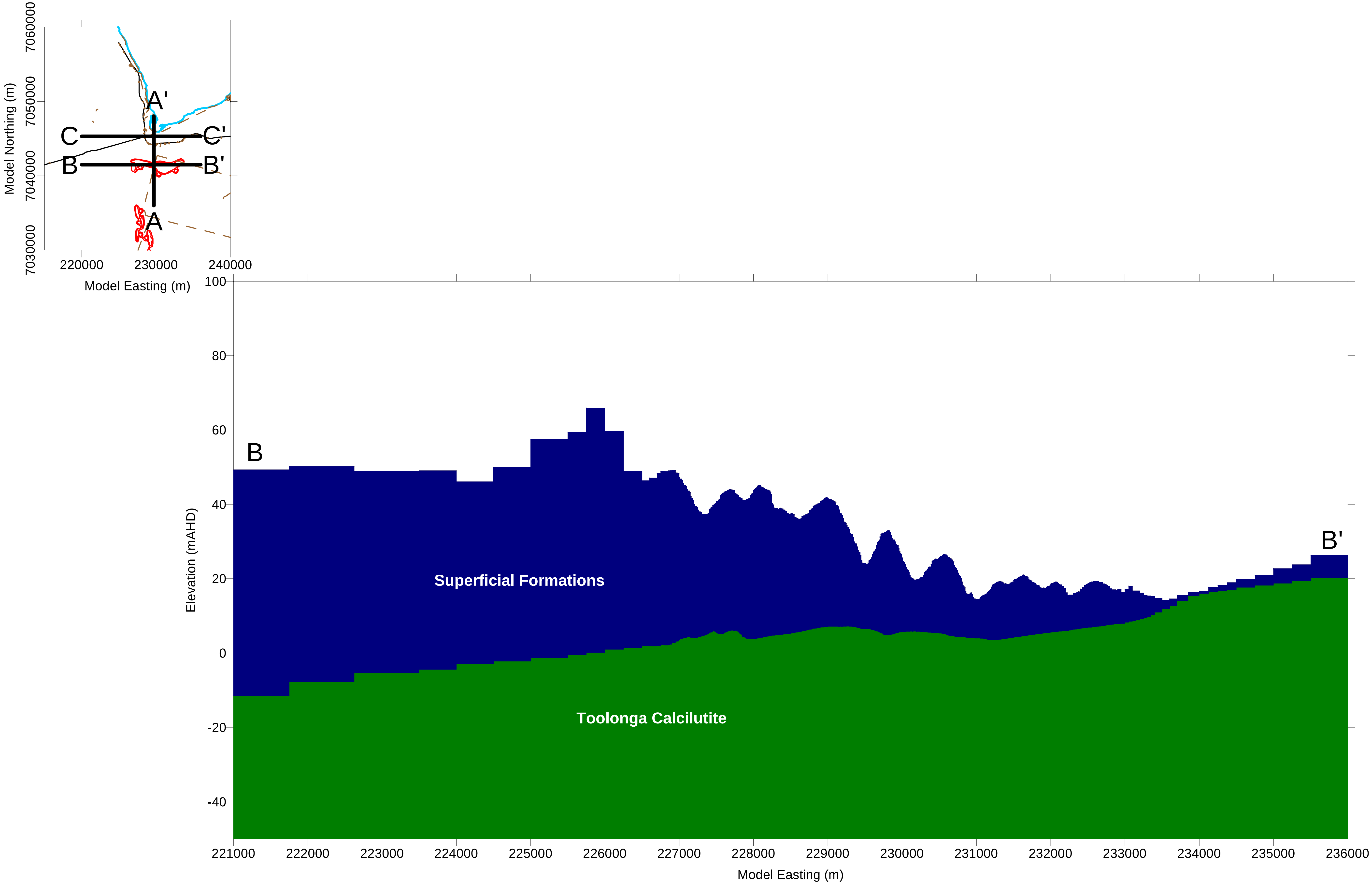
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 48a
Prep. By	ECPL	31 Mar '05		URS
Chk'd By	RWC	31 Mar '05	**FORM OF THE NORTHERN PIT MODEL PLAN VIEW OF SUB-CROP GEOLOGY**	
Revision No.		0		

fig48a.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 48b
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**FORM OF THE NORTHERN PIT MODEL NORTH-SOUTH SECTION VIEW A - A'**	URS
Revision Indicator		0		



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

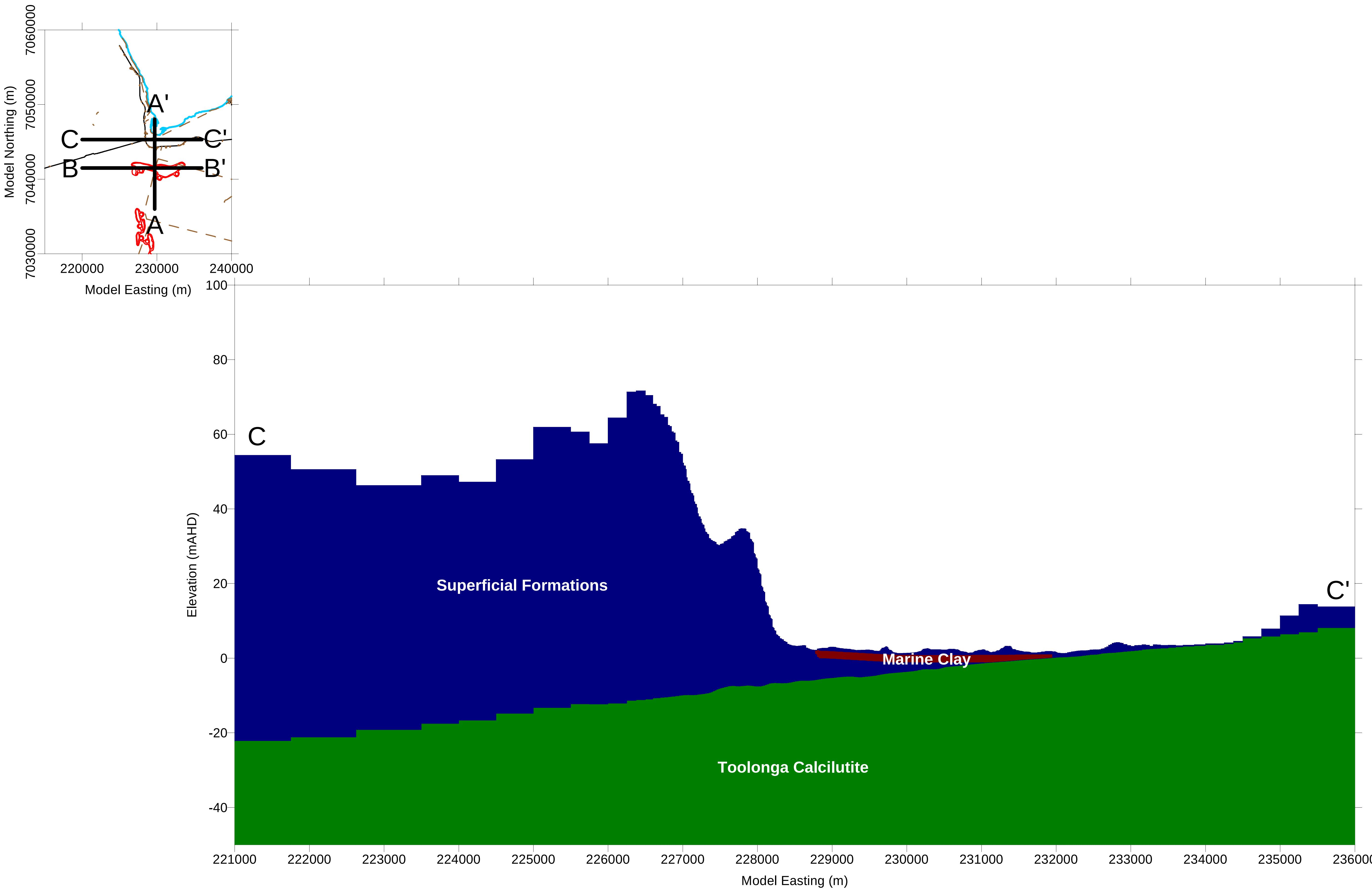
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

FORM OF THE NORTHERN PIT MODEL
EAST-WEST SECTION VIEW
B - B'

Figure 48c

URS

Fig48c.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

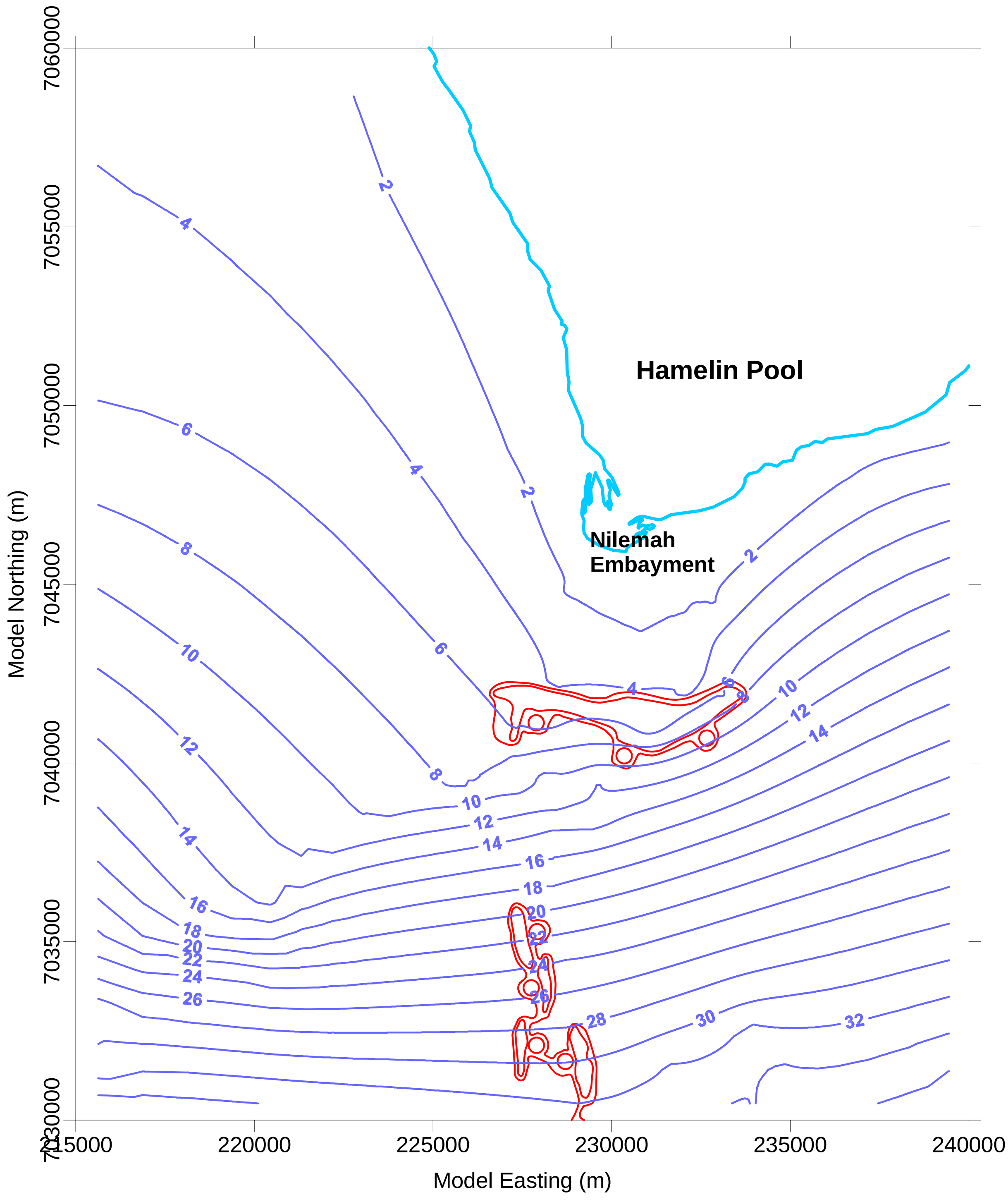
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

FORM OF THE NORTHERN PIT MODEL
EAST-WEST SECTION VIEW
C - C'

Figure 48d

URS

Fig48d.srf



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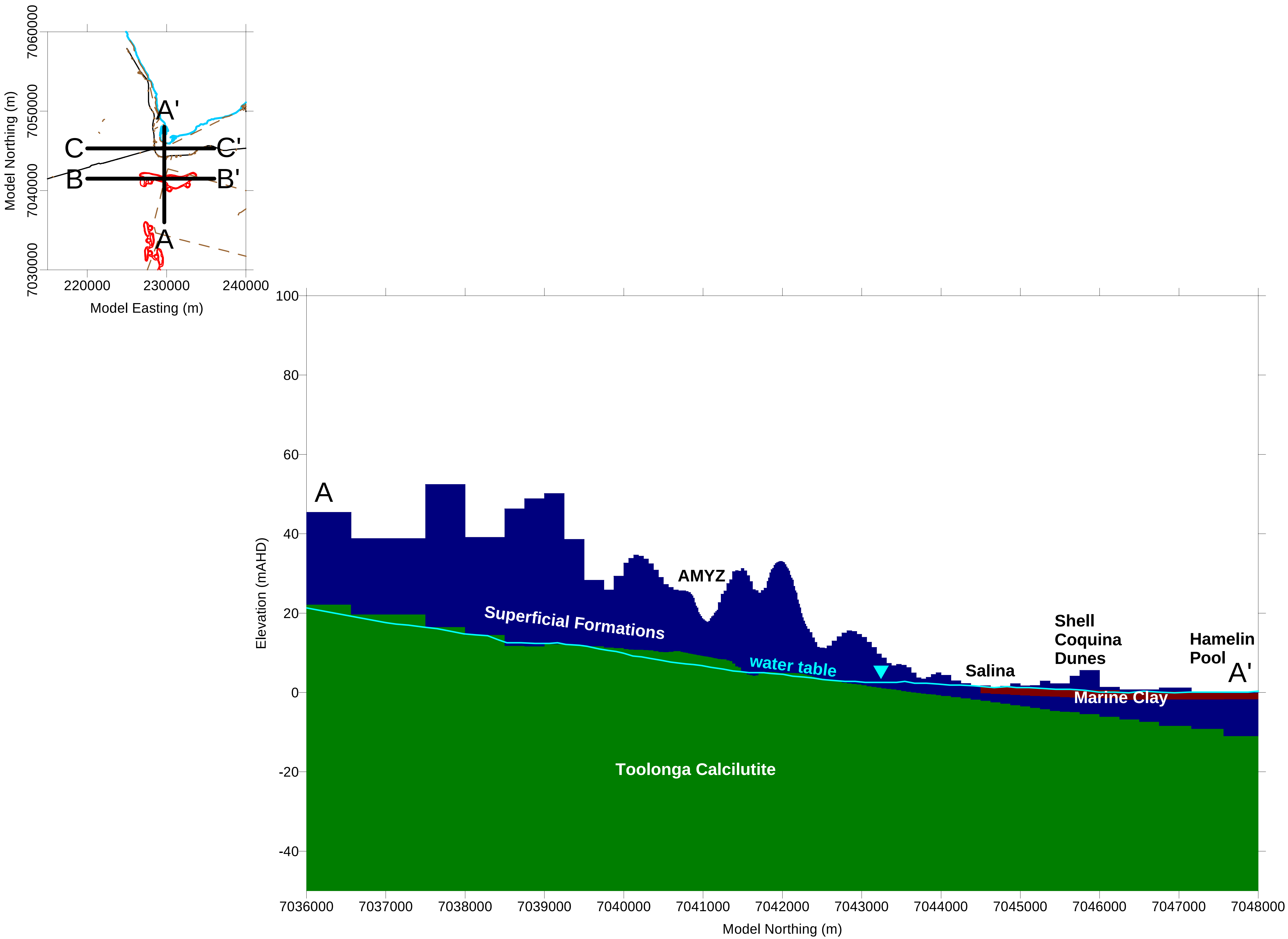
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 49a
Prep. By	ECPL	31 Mar '05	**SIMULATED WATER TABLE ENVIRONMENT PLAN VIEW**	URS
Chk'd By	RWC	31 Mar '05		
Revision No.		0		

fig49a.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

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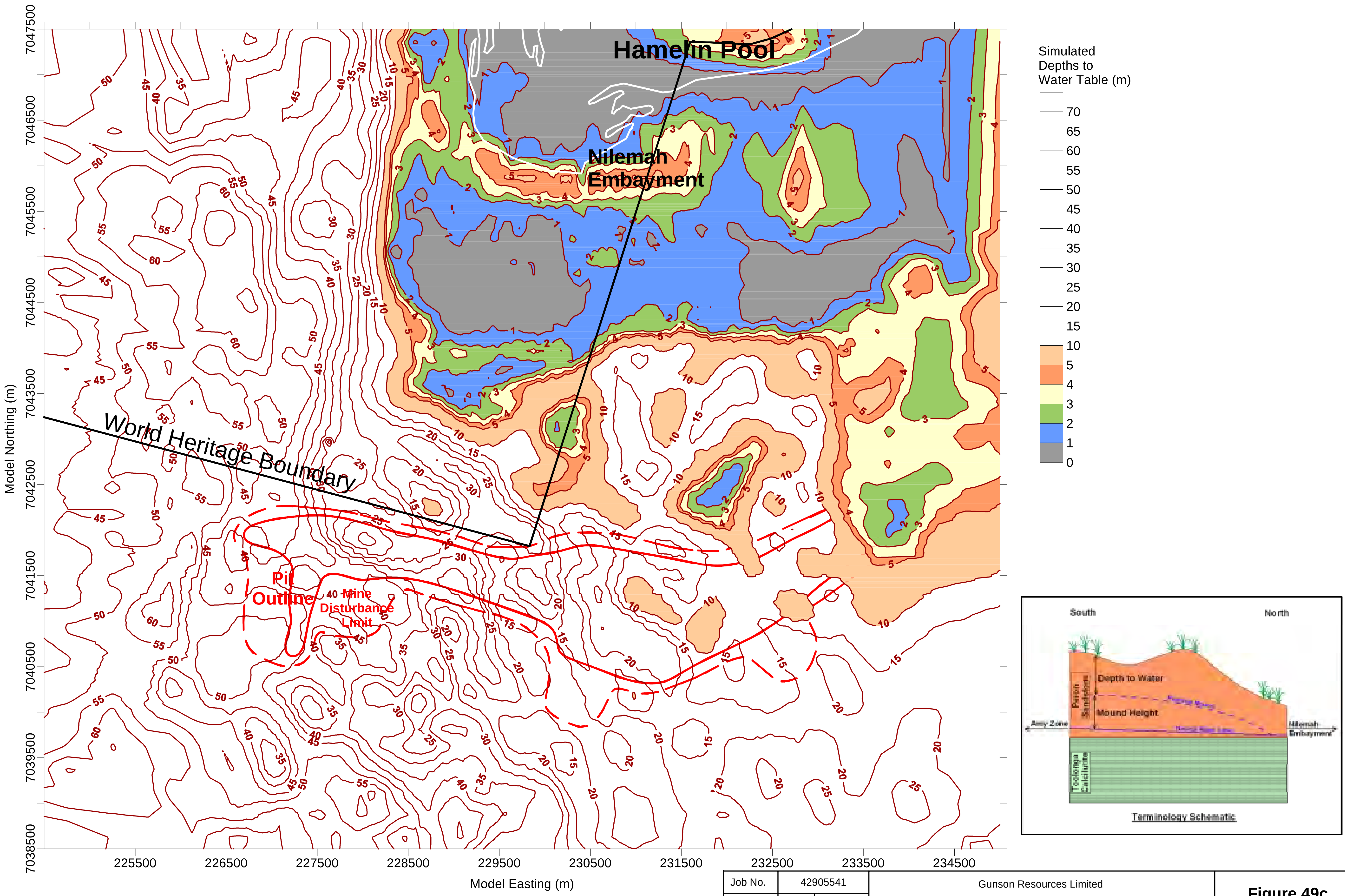
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED WATER TABLE ENVIRONMENT
NORTH-SOUTH SECTION VIEW : A - A'

Figure 49b

URS

Fig49b.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 49c
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**SIMULATED DEPTHS TO STEADY-STATE WATER TABLE**	URS
Revision Indicator		0		

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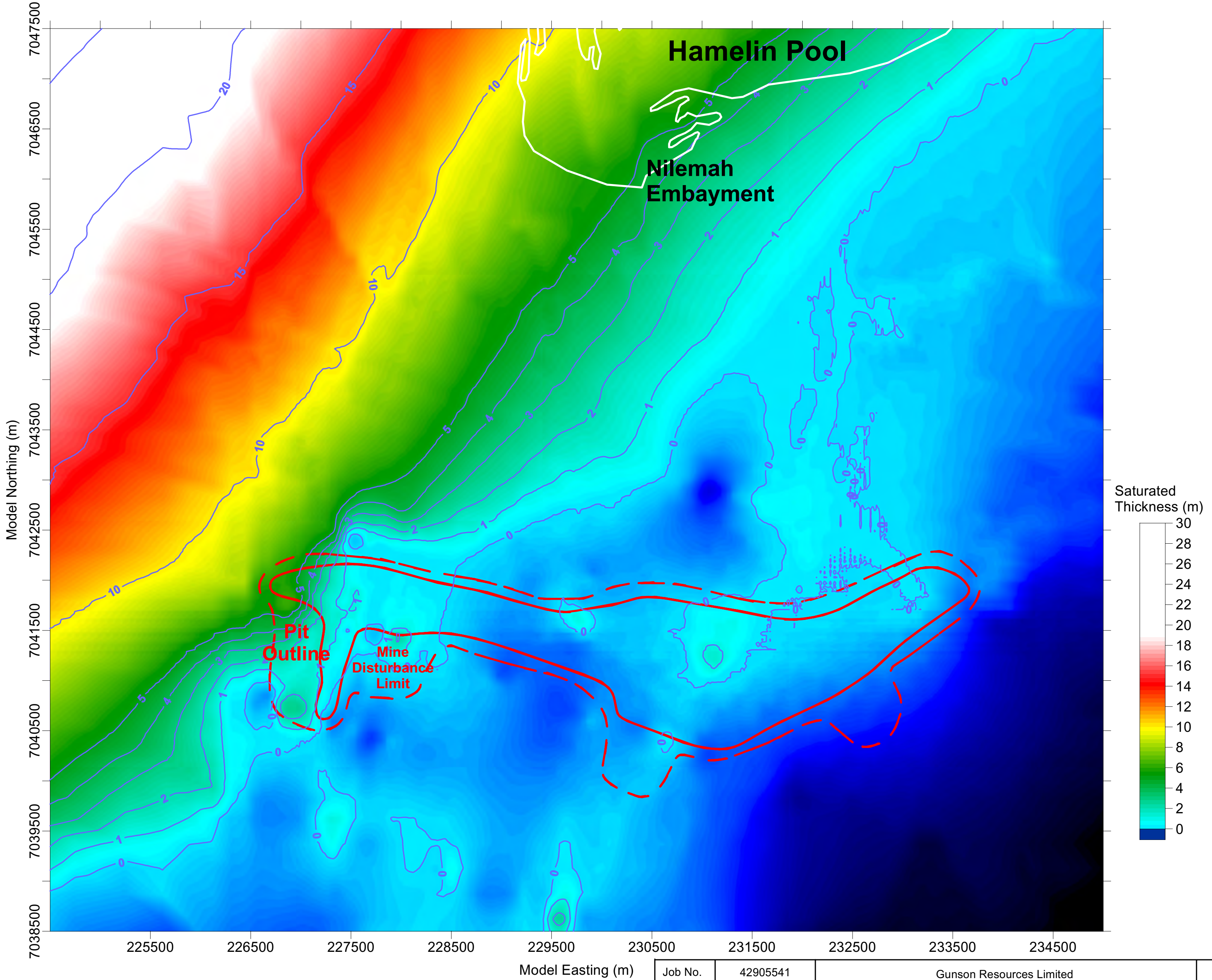
Fig49c.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED WATER TABLE ENVIRONMENT SATURATED THICKNESS OF SUPERFICIAL FORMATIONS

Figure 49d

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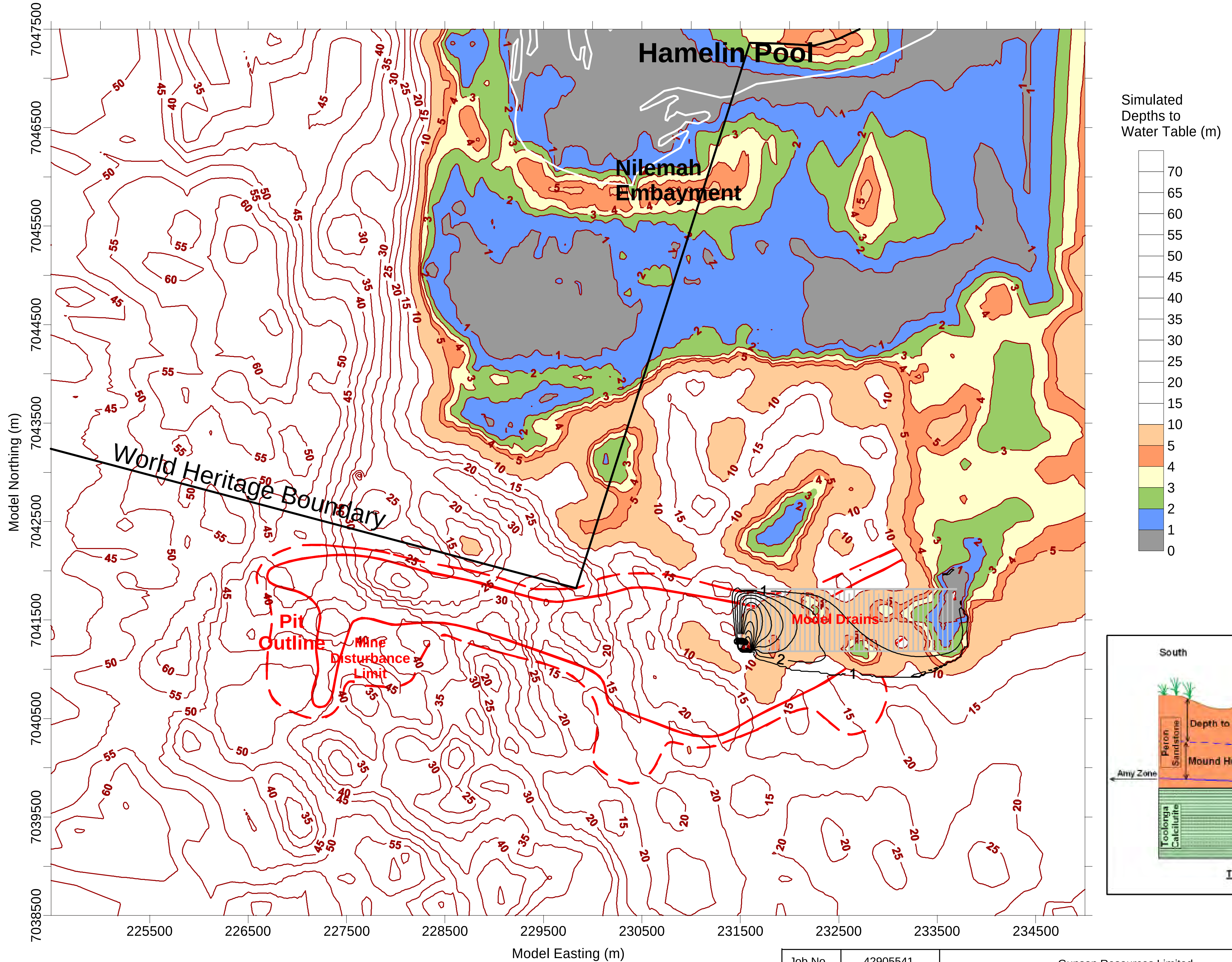
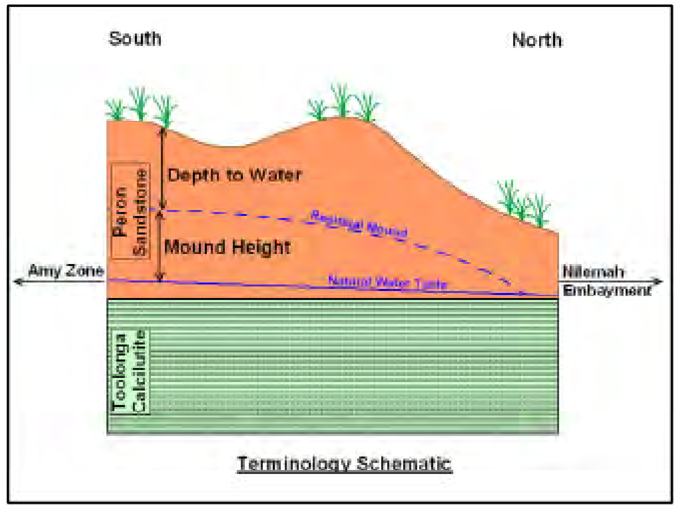
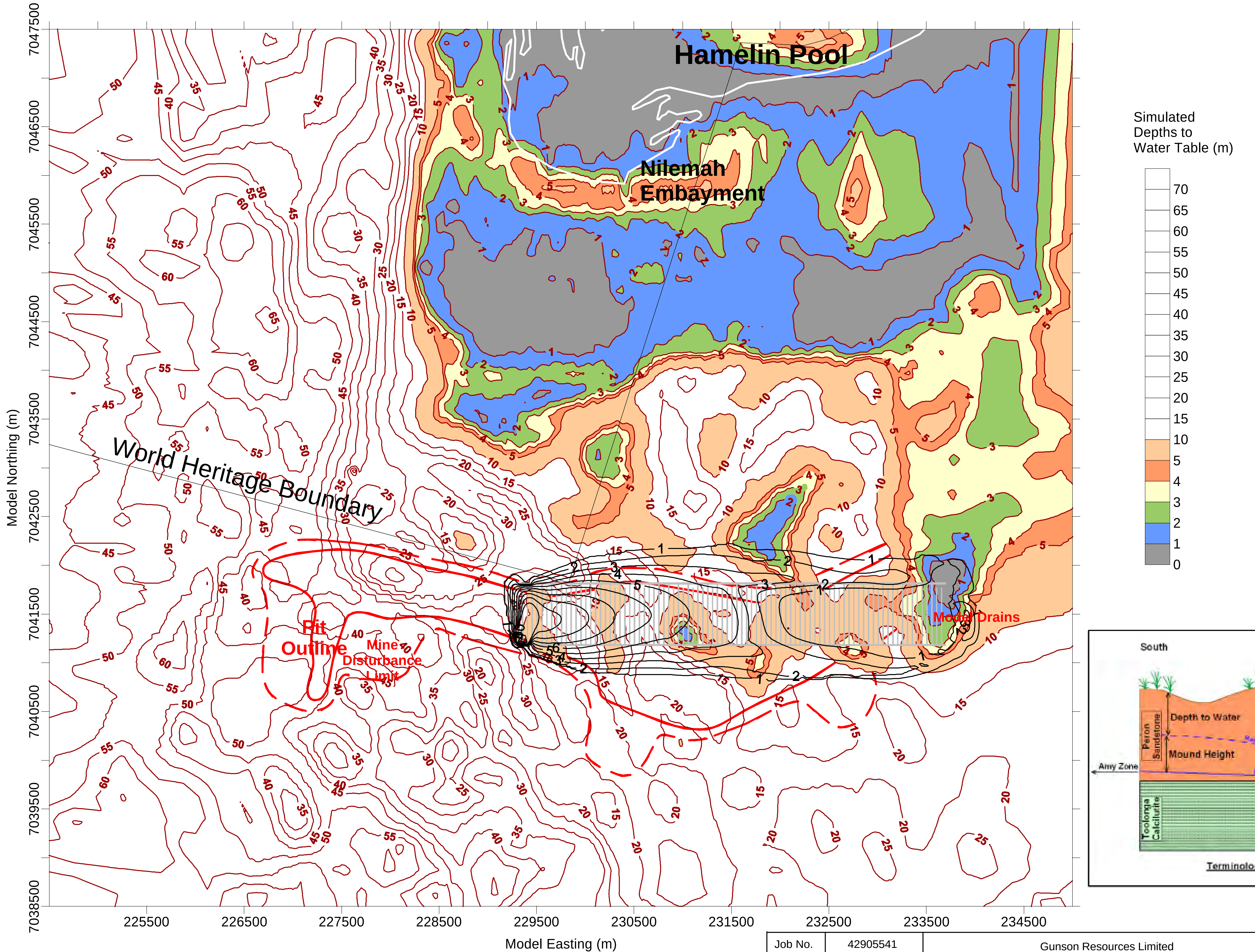
Fig49d.srf

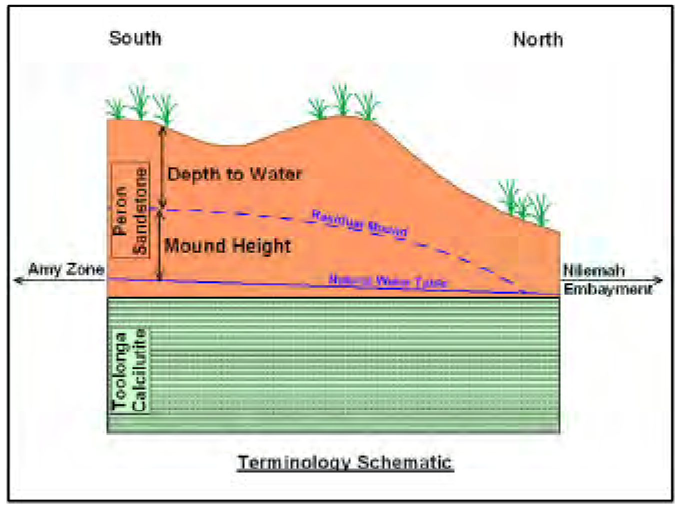




Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 50a
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT WATER TABLE MOUNDING AFTER 374 DAYS OF MINING**	URS
Revision Indicator		0		

Fig50a.srf





Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 50b
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	PREDICTED NORTHERN PIT WATER TABLE MOUNDING AFTER 748 DAYS OF MINING	URS
Revision Indicator	0			

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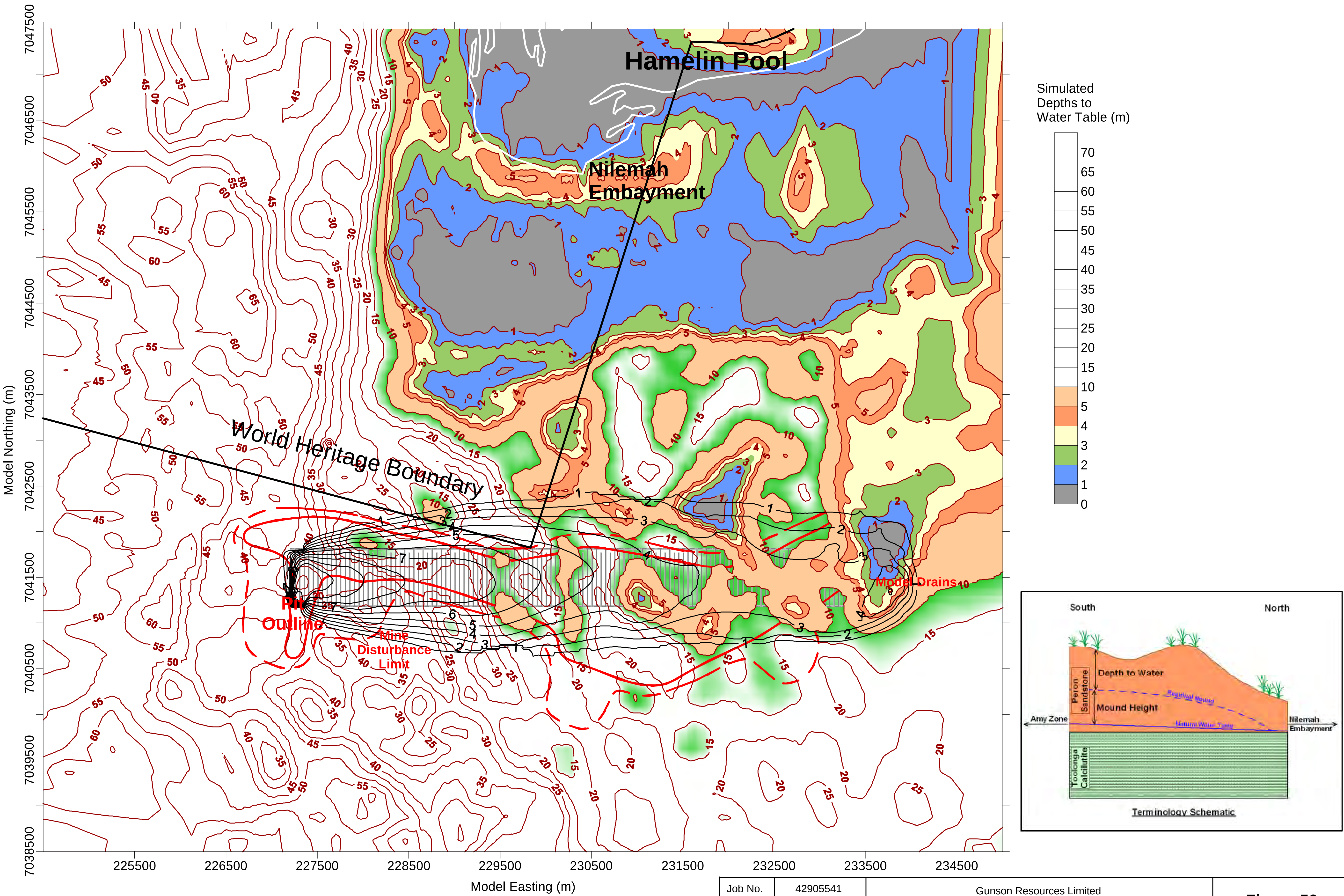
Fig50b.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED NORTHERN PIT WATER TABLE MOUNDING AFTER 1105 DAYS OF MINING

Figure 50c

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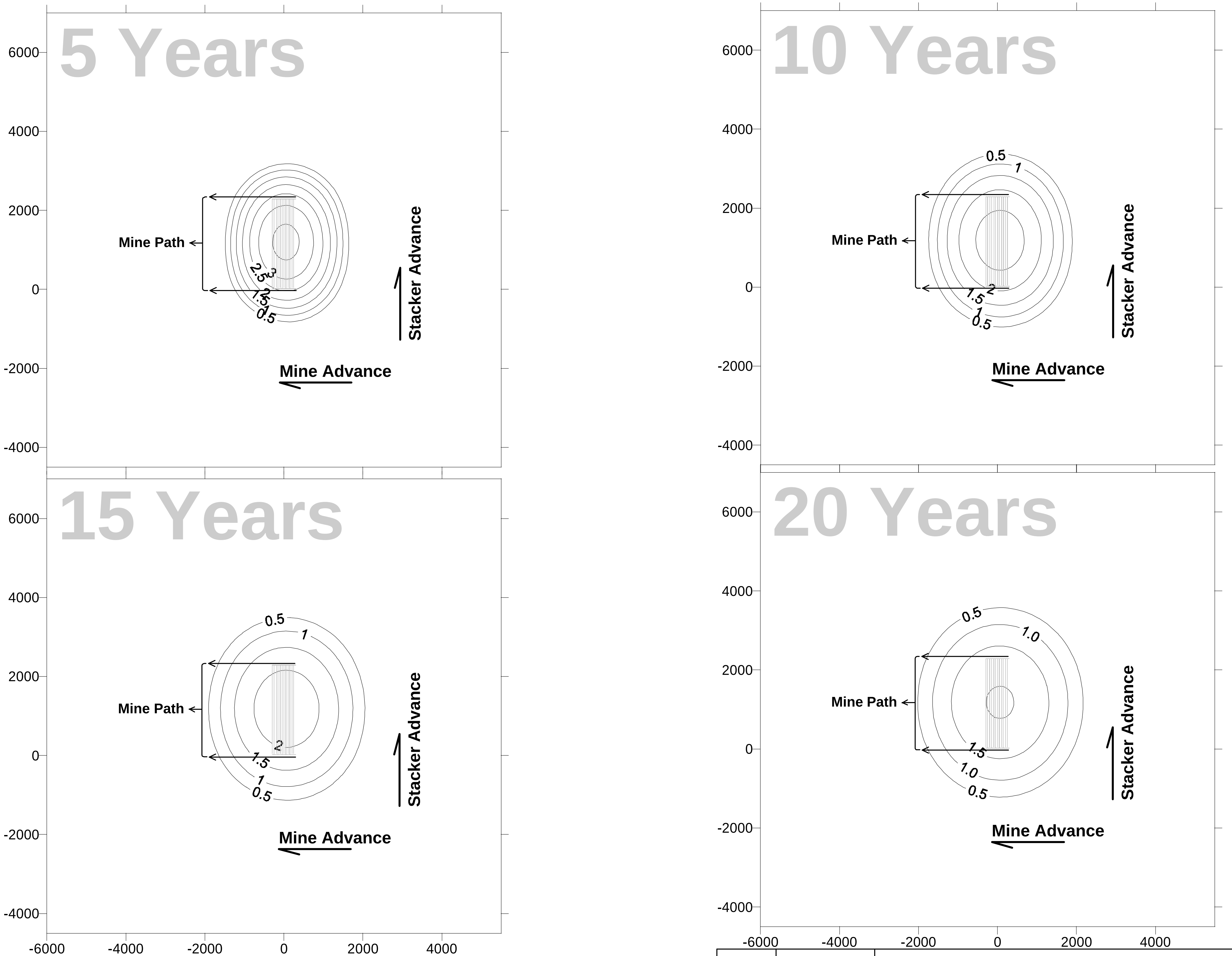
Fig50c.srf



Job No.	42905541		
Prep. By	ECPL	21 Mar '05	
Chk'd By	RBW	21 Mar '05	
Revision Indicator		0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED TRANSIENT MOUND DISTRIBUTIONS
5 to 20 YEARS AFTER MINING

Figure 51a

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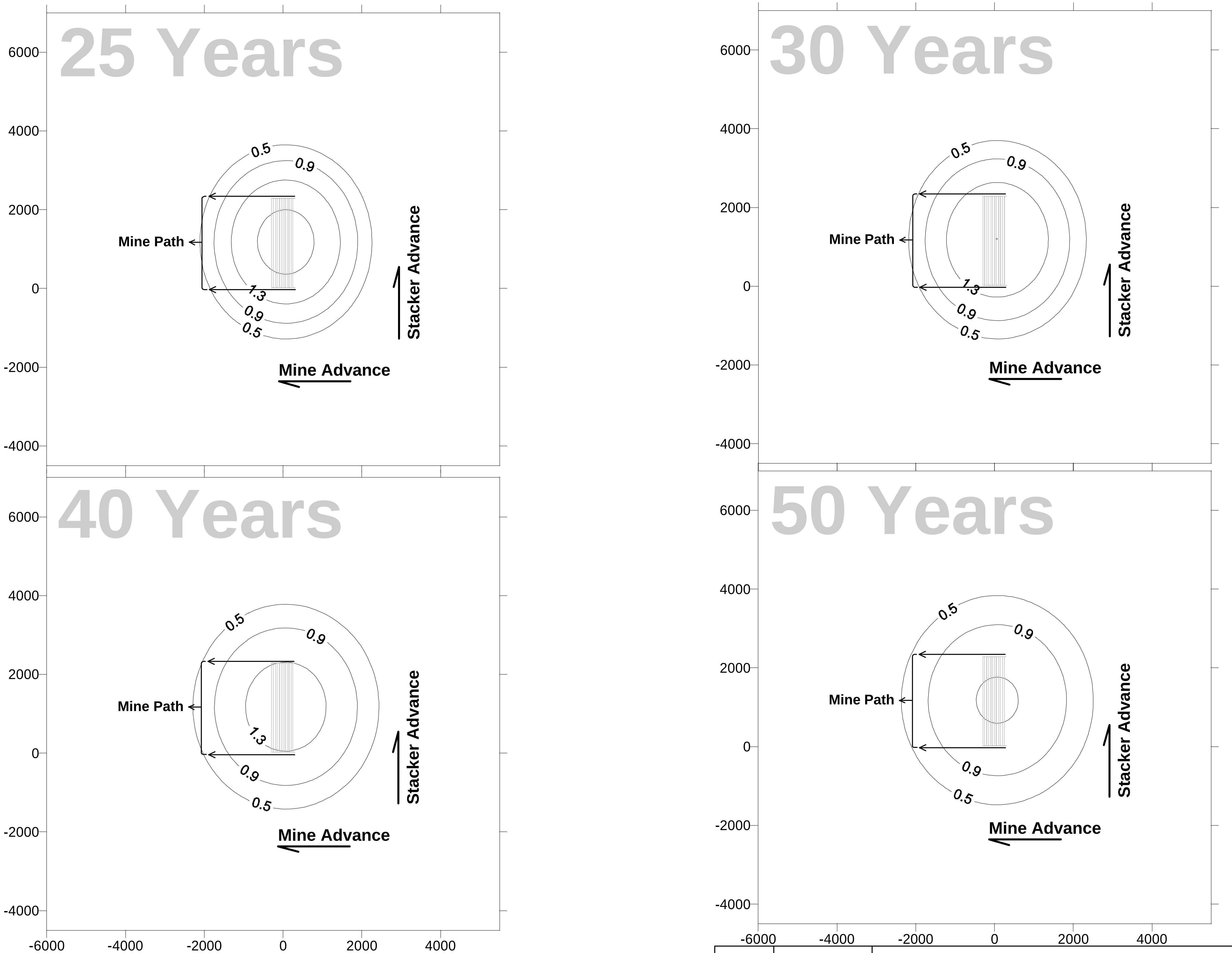
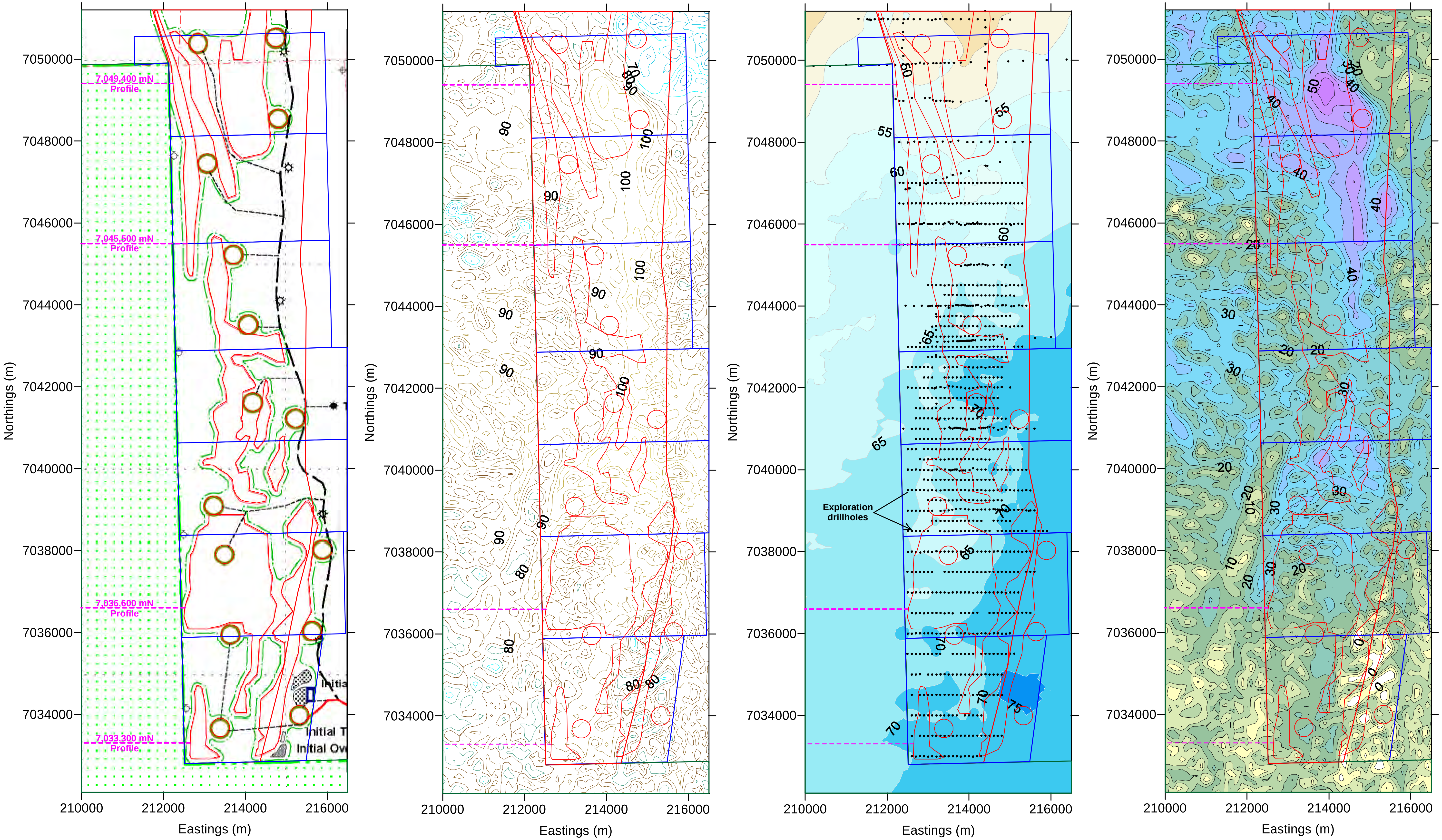
Conceptual Mounding Recovery 5-20yrs.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 51b
Prep. By	ECPL	21 Mar '05		
Chk'd By	RBW	21 Mar '05	**SIMULATED TRANSIENT MOUND DISTRIBUTIONS 25 to 50 YEARS AFTER MINING**	URS
Revision Indicator		0		



Planned Mine Layout and Profile Locations

Topography (m AHD)

Basement Contours (m AHD)

Superficial Formation Isopachs (m)

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 52a
Prep. By	ECPL	21 Mar '05		
Chk'd By	RBW	21 Mar '05	**DATA USED TO DEFINE PREDICTED MOUNDED WATER TABLE PROFILES BENEATH THE SHARK BAY WORLD HERITAGE AREA**	URS
Revision Indicator		0		

Note: Digital Terraine Model topographic elevations south of 7,040,000 mN may be between 3 and 6 m too low.

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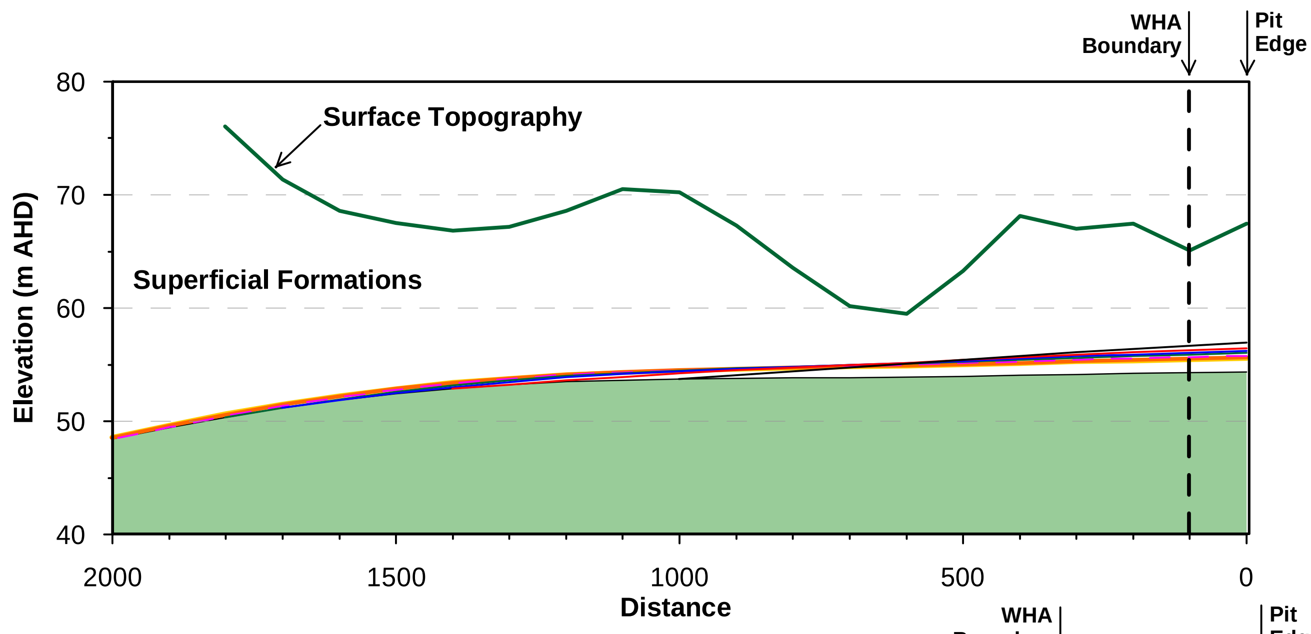
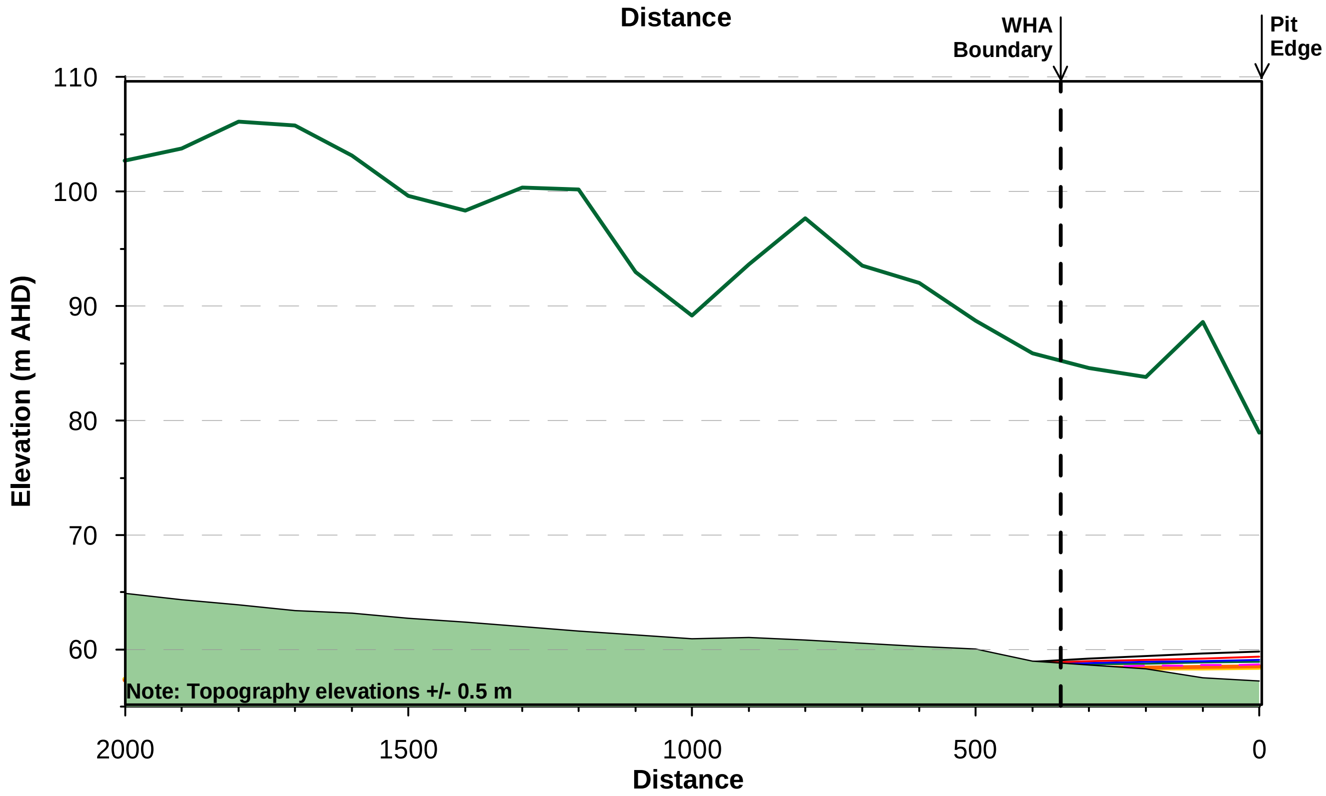
Southern WHA Boundary Mounding.srf

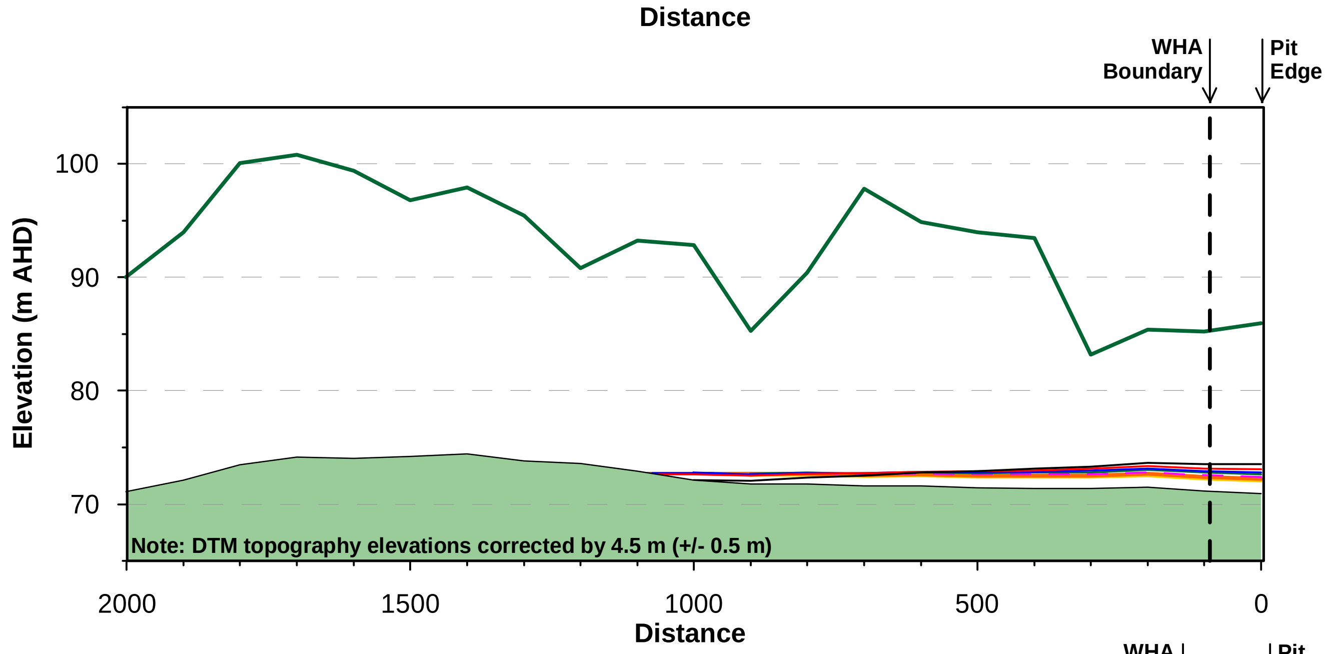
East-West Profile at 7,049,400 mN



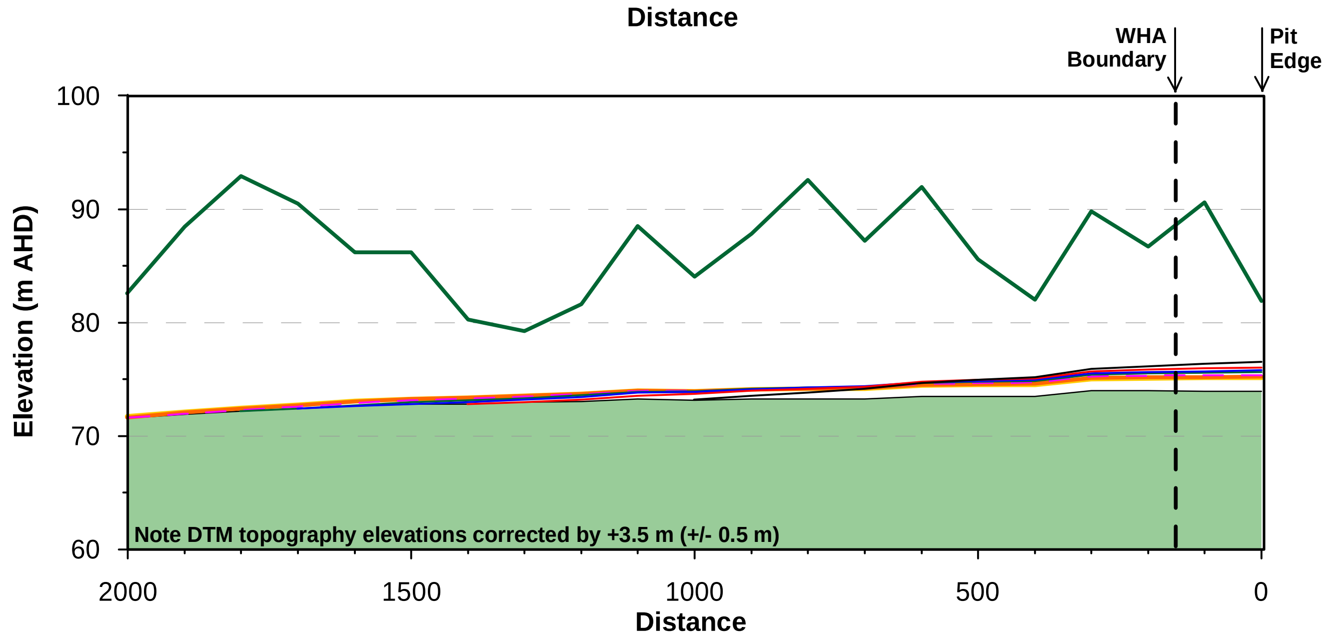
East-West Profile at 7,045,500 mN



East-West Profile at 7,036,600 mN



East-West Profile at 7,033,300 mN



LEGEND

- Predicted profile 5 years after mining
- Predicted profile 10 years after mining
- Predicted profile 15 years after mining
- Predicted profile 20 years after mining
- Predicted profile 30 years after mining
- Predicted profile 40 years after mining
- Predicted profile 50 years after mining

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	**Figure 52b**
Prep. By	RBW	18 Jan 05	**SECTION VIEWS OF PREDICTED MOUNDED WATER TABLE PROFILES BENEATH THE SHARK BAY WORLD HERITAGE PROPERTY**	URS
Chk'd By	RBW	18 Jan 05		
Revision No.		0		

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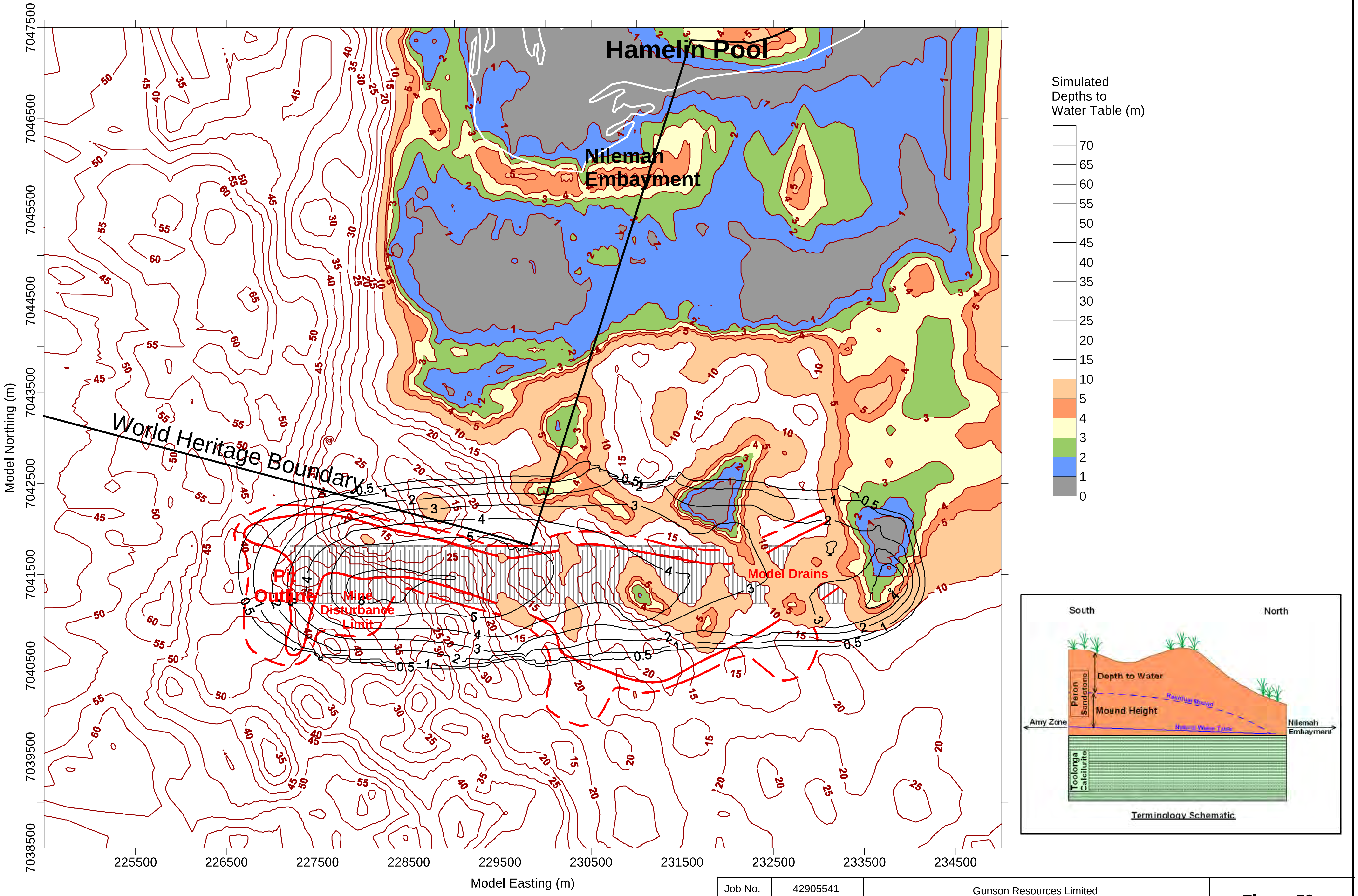
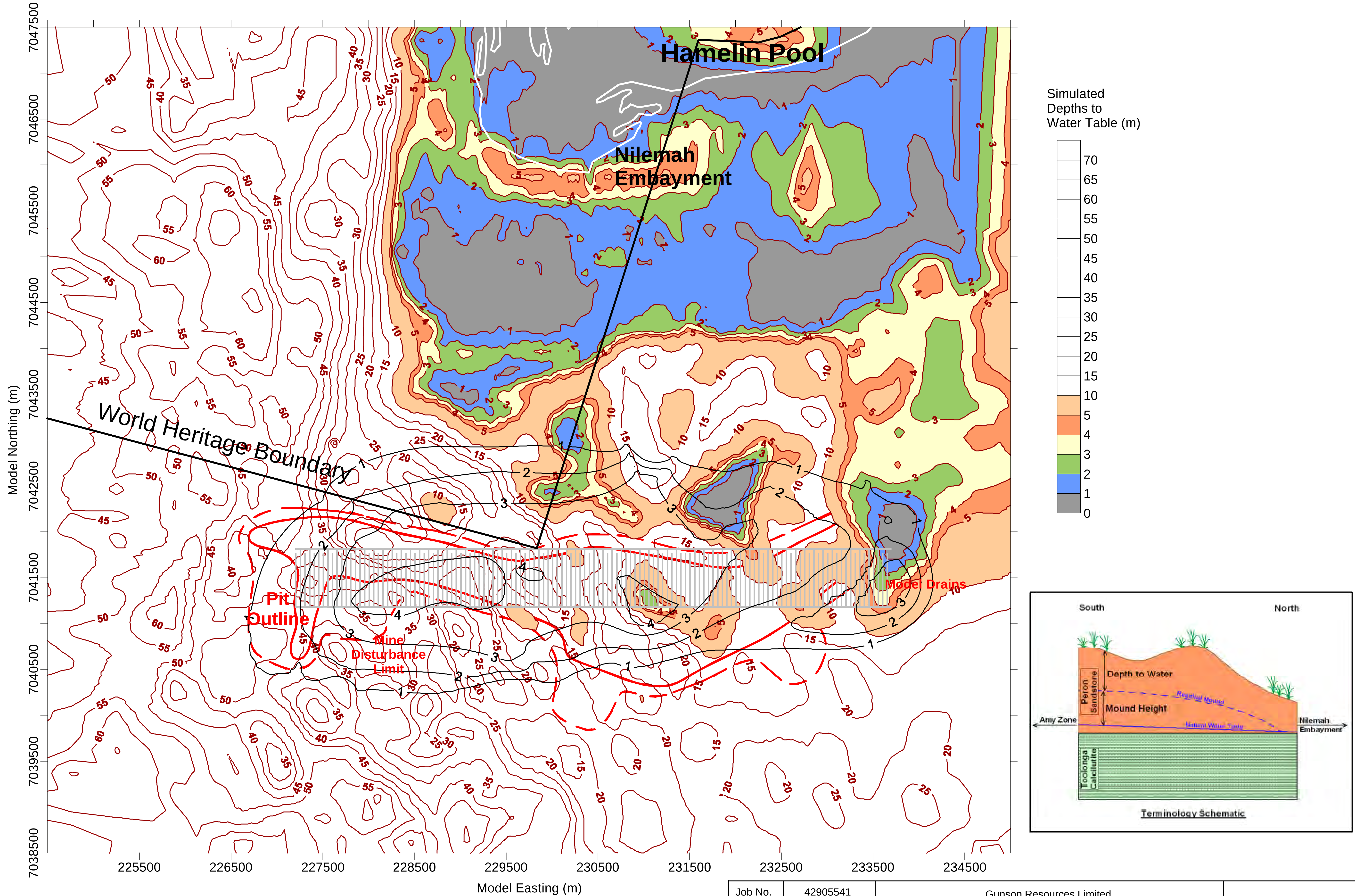
WHA Boundary Profiles.grf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 53a
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 1 YEAR AFTER MINING**	URS
Revision Indicator	0			

Fig53a.srf



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Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

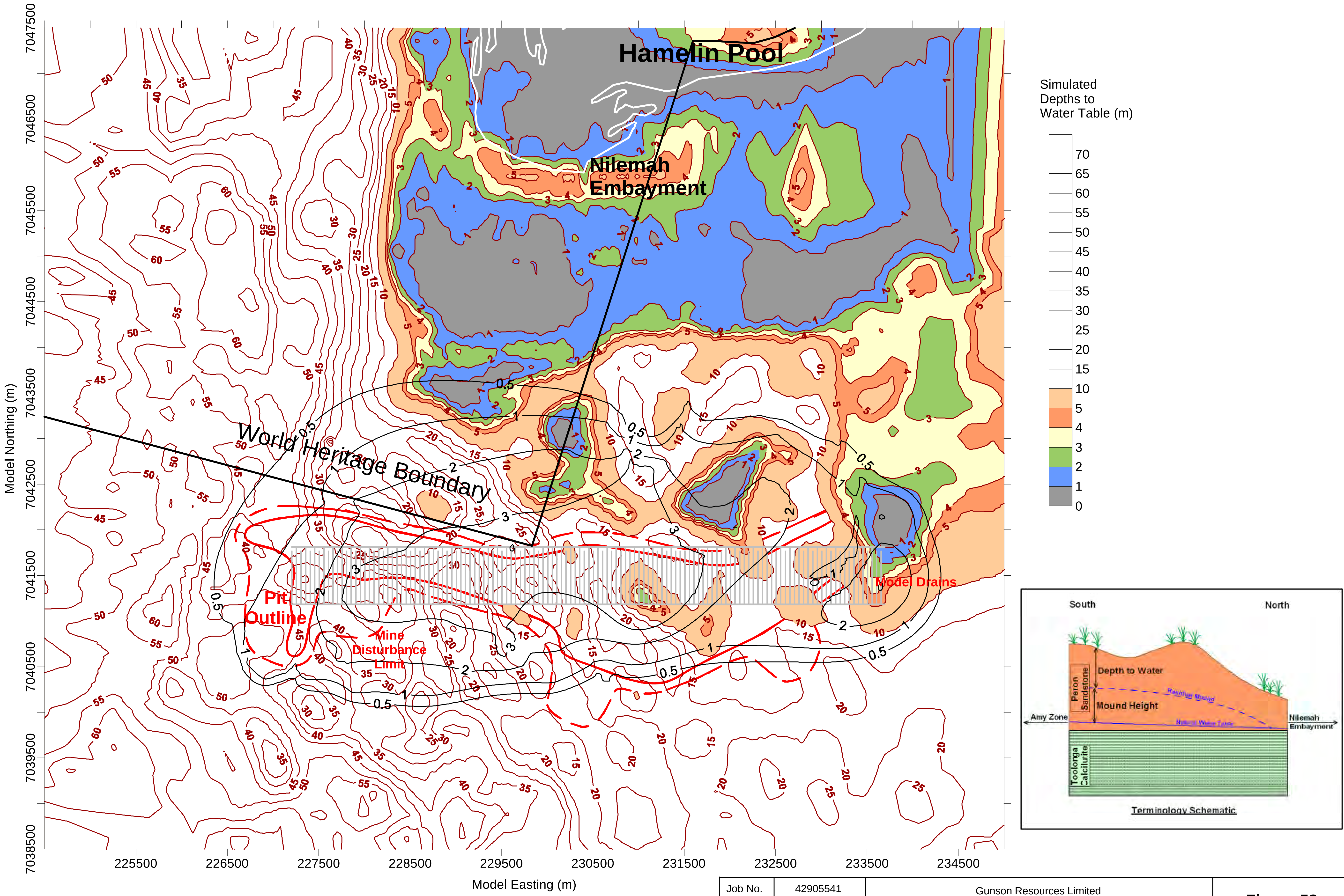
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 5 YEARS AFTER MINING

Figure 53b

URS

Fig53b.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 53c
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 10 YEARS AFTER MINING**	URS
Revision Indicator	0			

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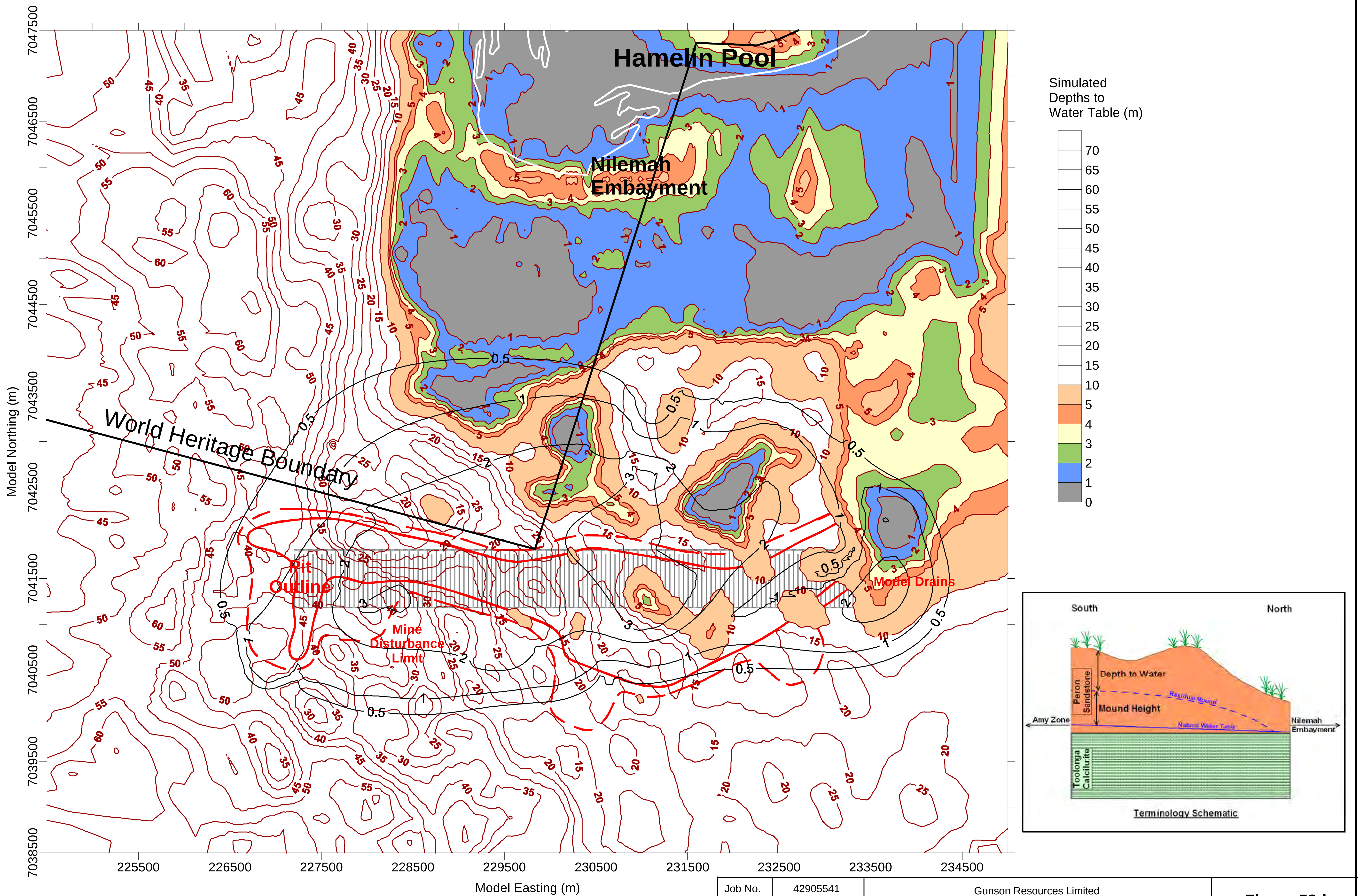
Fig53c.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 53d
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 15 YEARS AFTER MINING**	URS
Revision Indicator		0		

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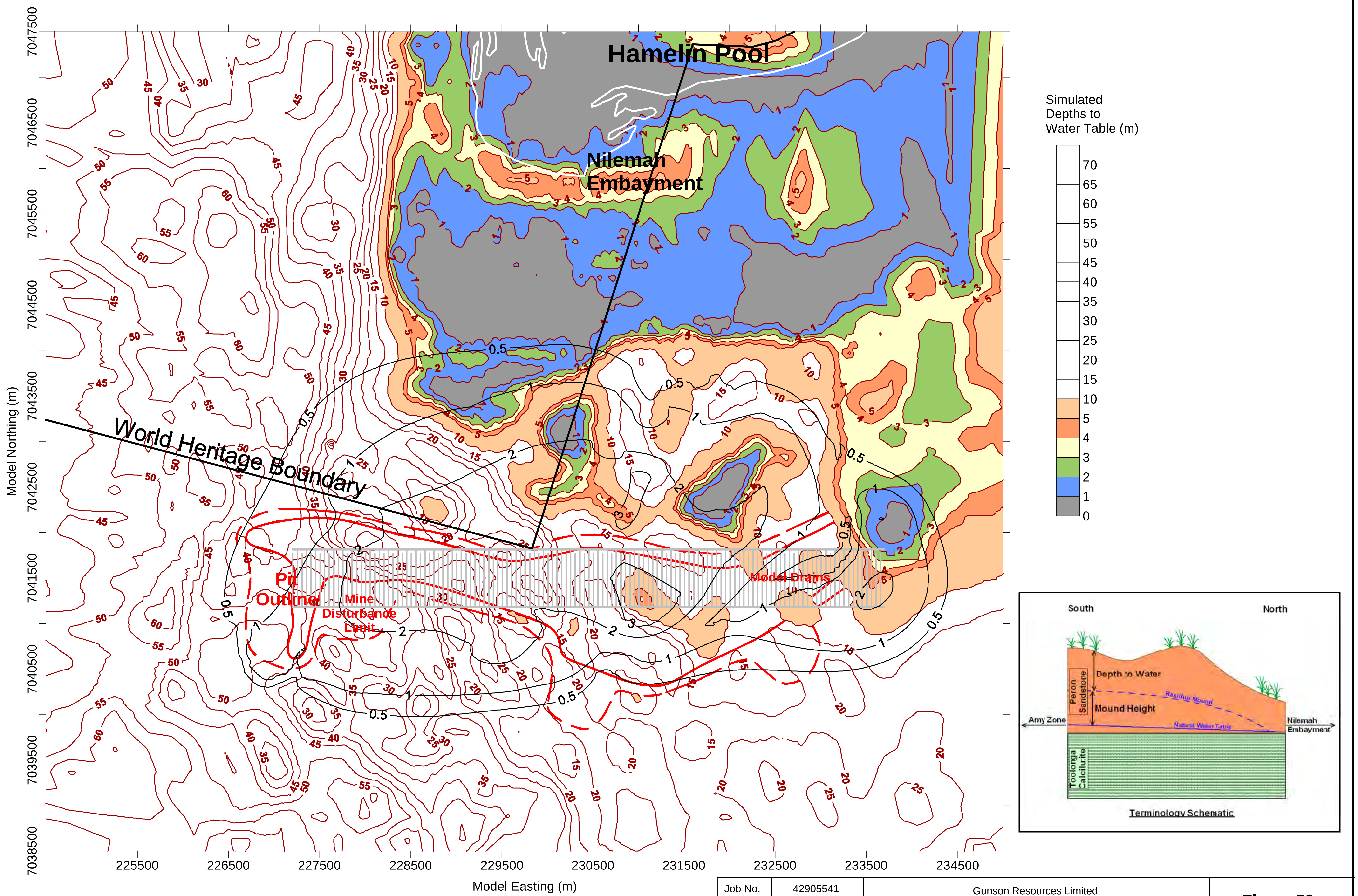
Fig53d.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

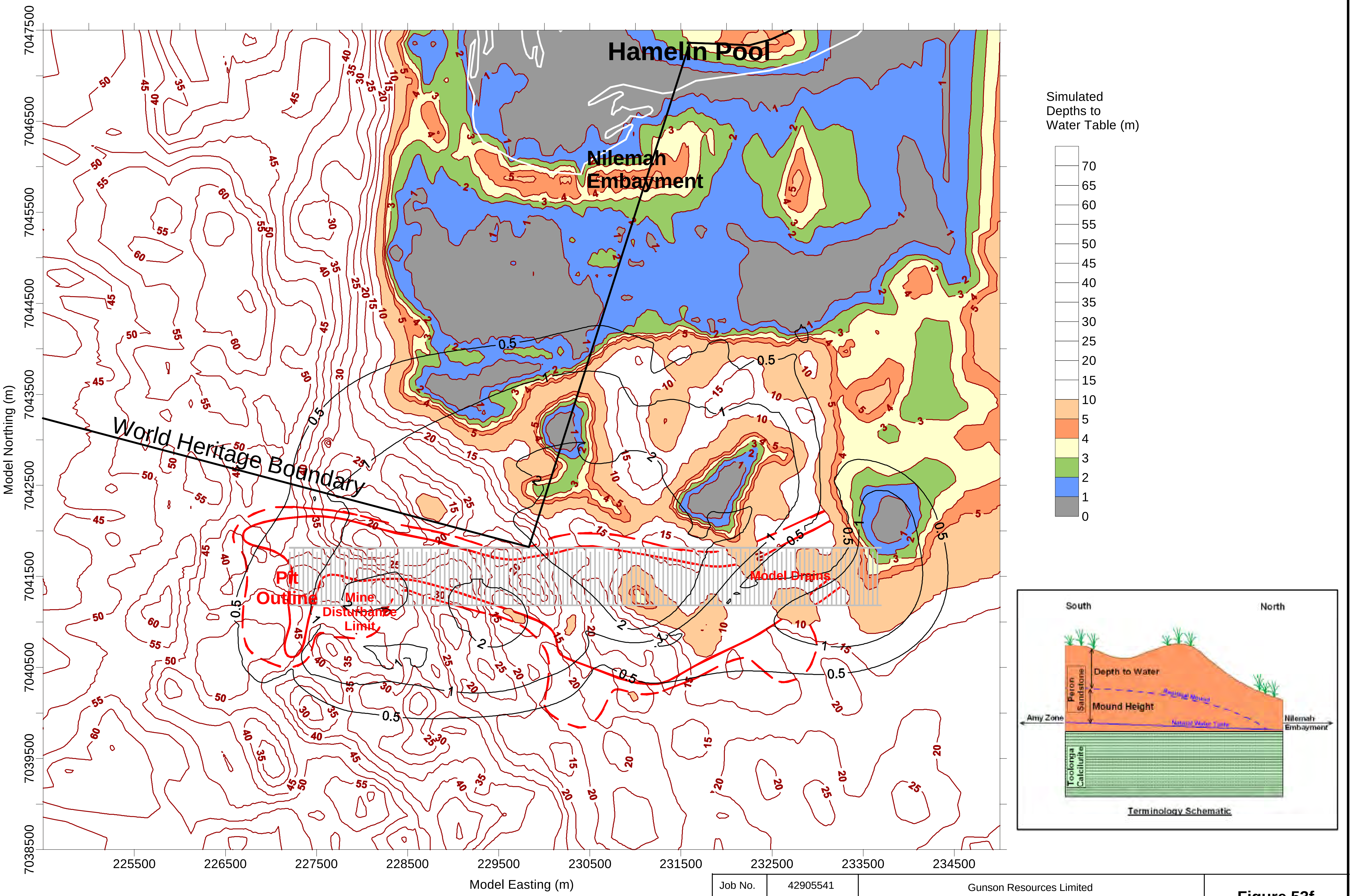
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 20 YEARS AFTER MINING

Figure 53e

URS

Fig53e.srf



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RBW	31 Mar 05
Revision Indicator	0	

Gunson Resources Limited

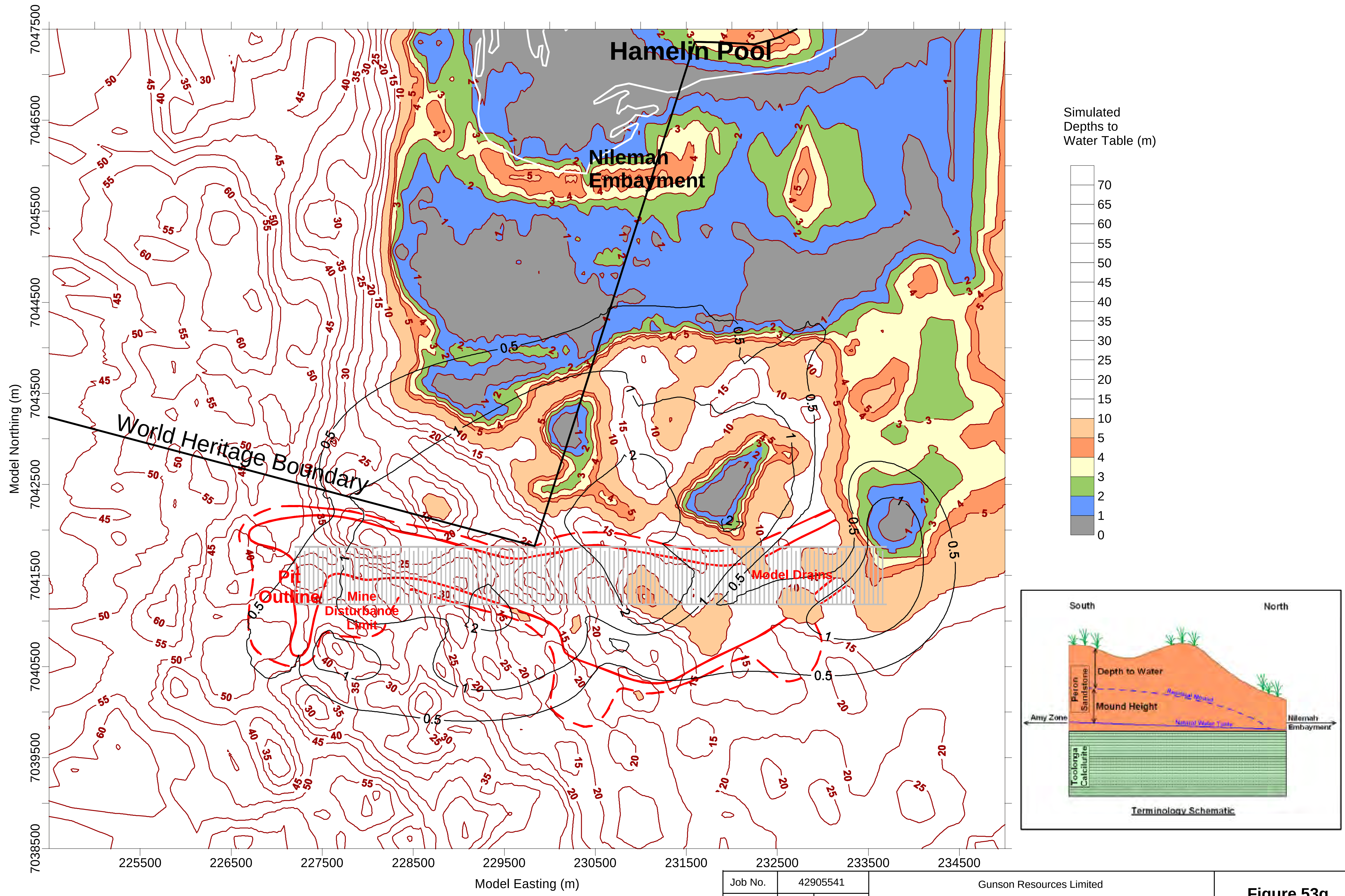
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 30 YEARS AFTER MINING

Figure 53f

URS

Fig53f.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 53g
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 40 YEARS AFTER MINING**	URS
Revision Indicator		0		

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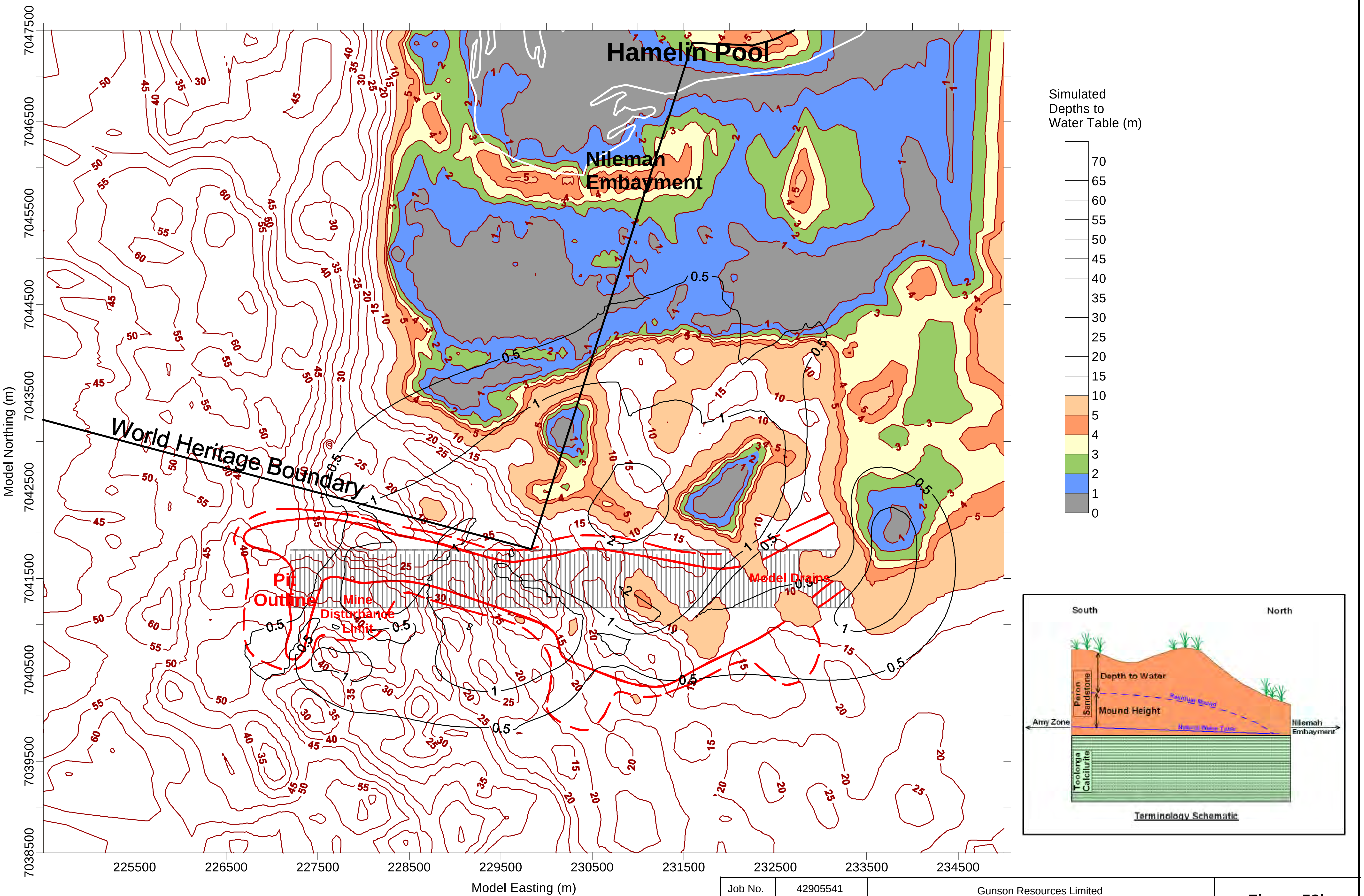
Fig53g.srf



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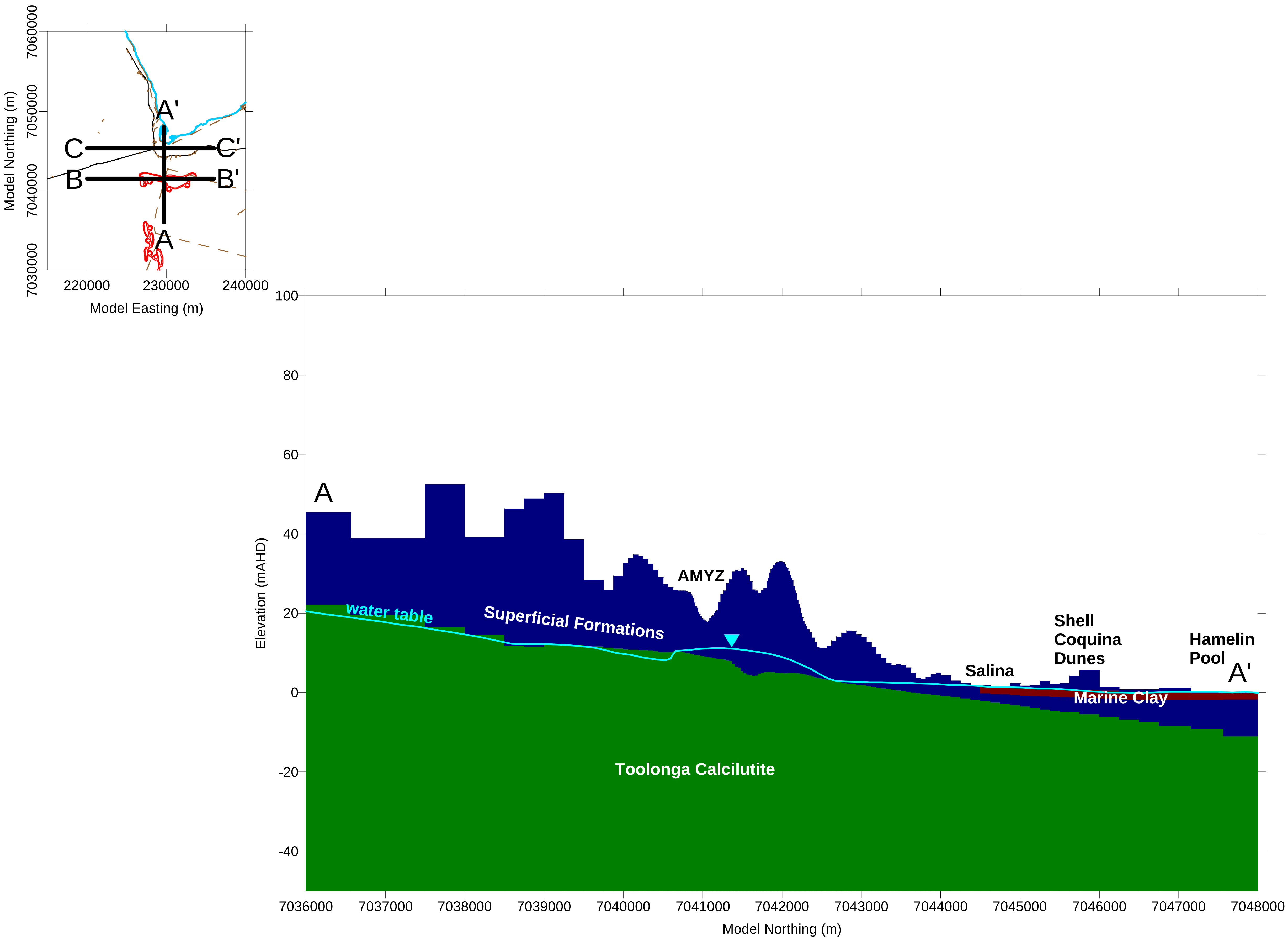
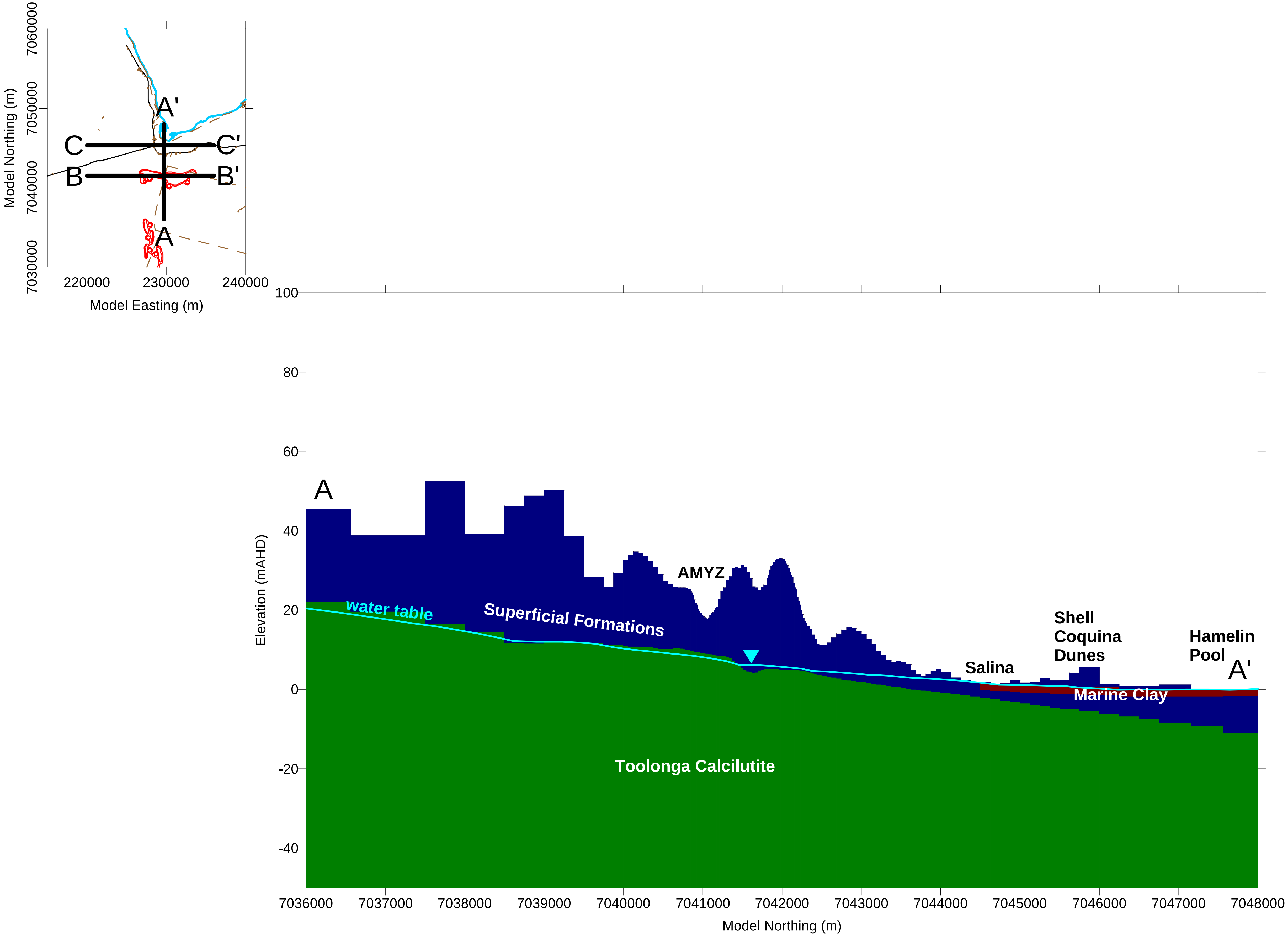
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 53h
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT RESIDUAL WATER TABLE MOUNDING - 50 YEARS AFTER MINING**	URS
Revision Indicator	0			

Fig53h.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 54a
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT WATER TABLE MOUNDING NORTH-SOUTH SECTION VIEW : A - A' 1 YEAR AFTER MINING**	URS
Revision Indicator		0		



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 54b
Prep. By	ECPL	31 Mar 05		
Chk'd By	RBW	31 Mar 05	**PREDICTED NORTHERN PIT WATER TABLE MOUNDING NORTH-SOUTH SECTION VIEW : A - A' 50 YEARS AFTER MINING**	URS
Revision Indicator		0		

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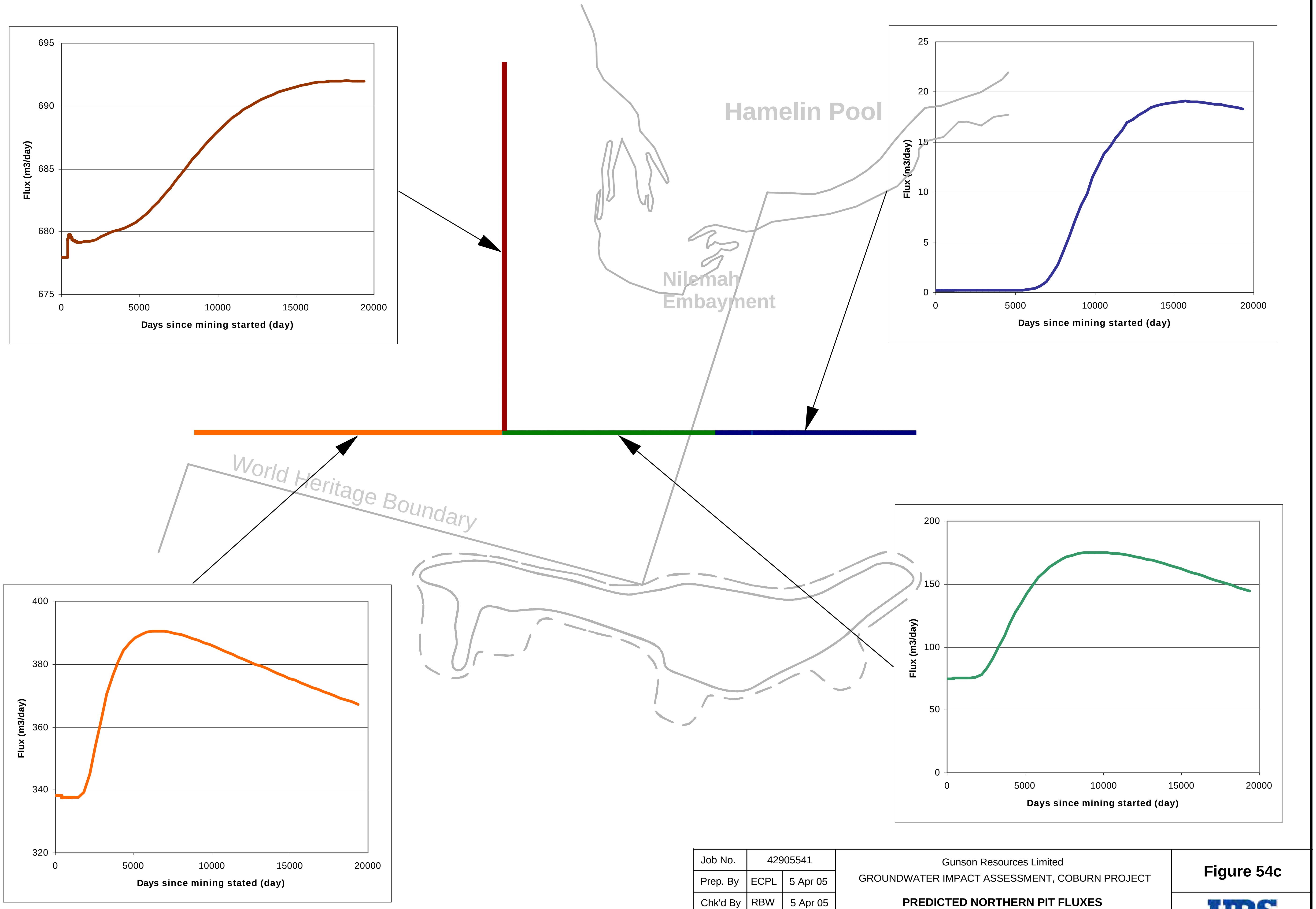
Fig54b.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 54c
Prep. By	ECPL	5 Apr 05		
Chk'd By	RBW	5 Apr 05	PREDICTED NORTHERN PIT FLUXES	URS
Revision Indicator		0		

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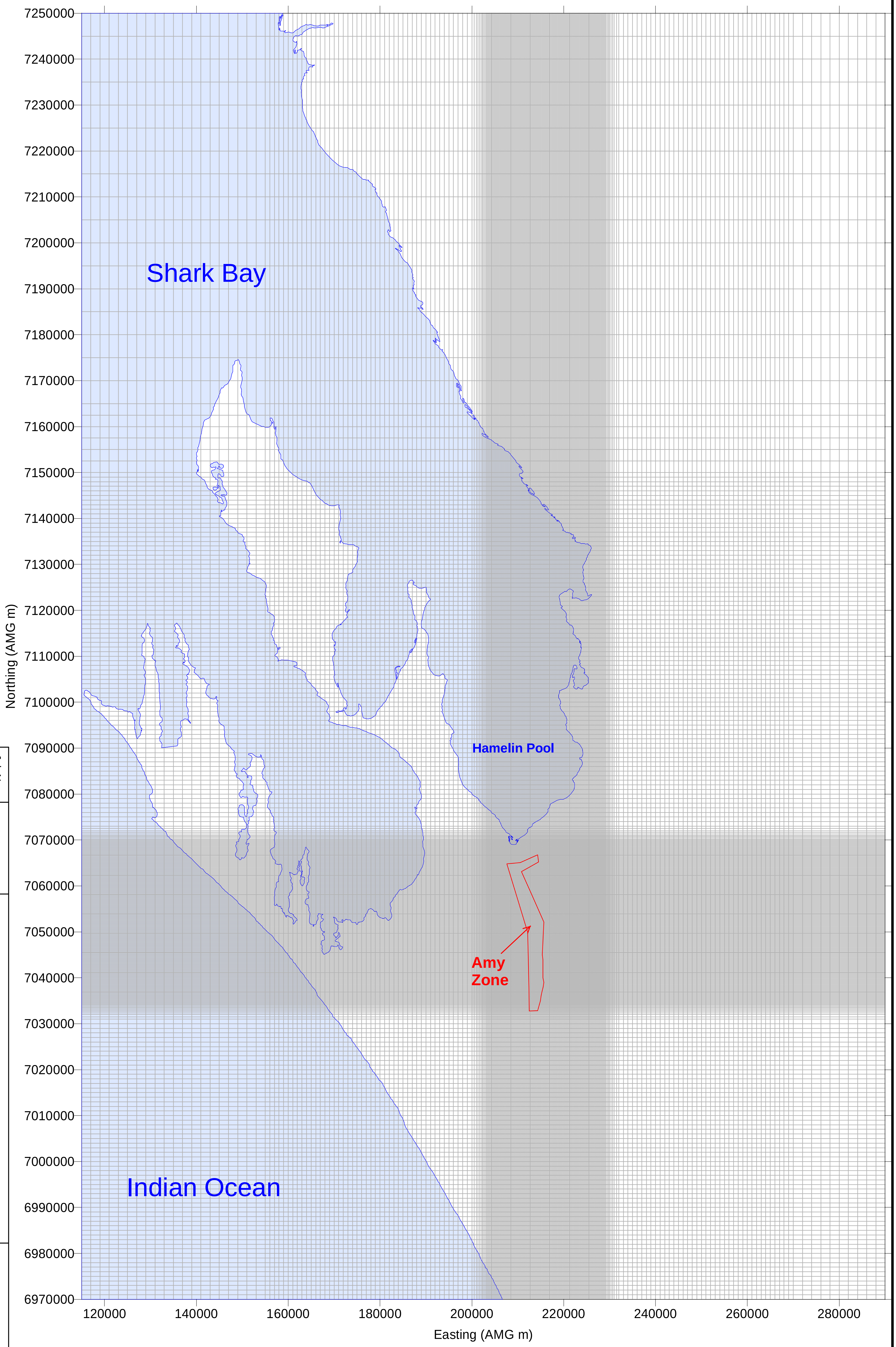
Fig54c.srf

figure55 Deep aquifer model domain.srf



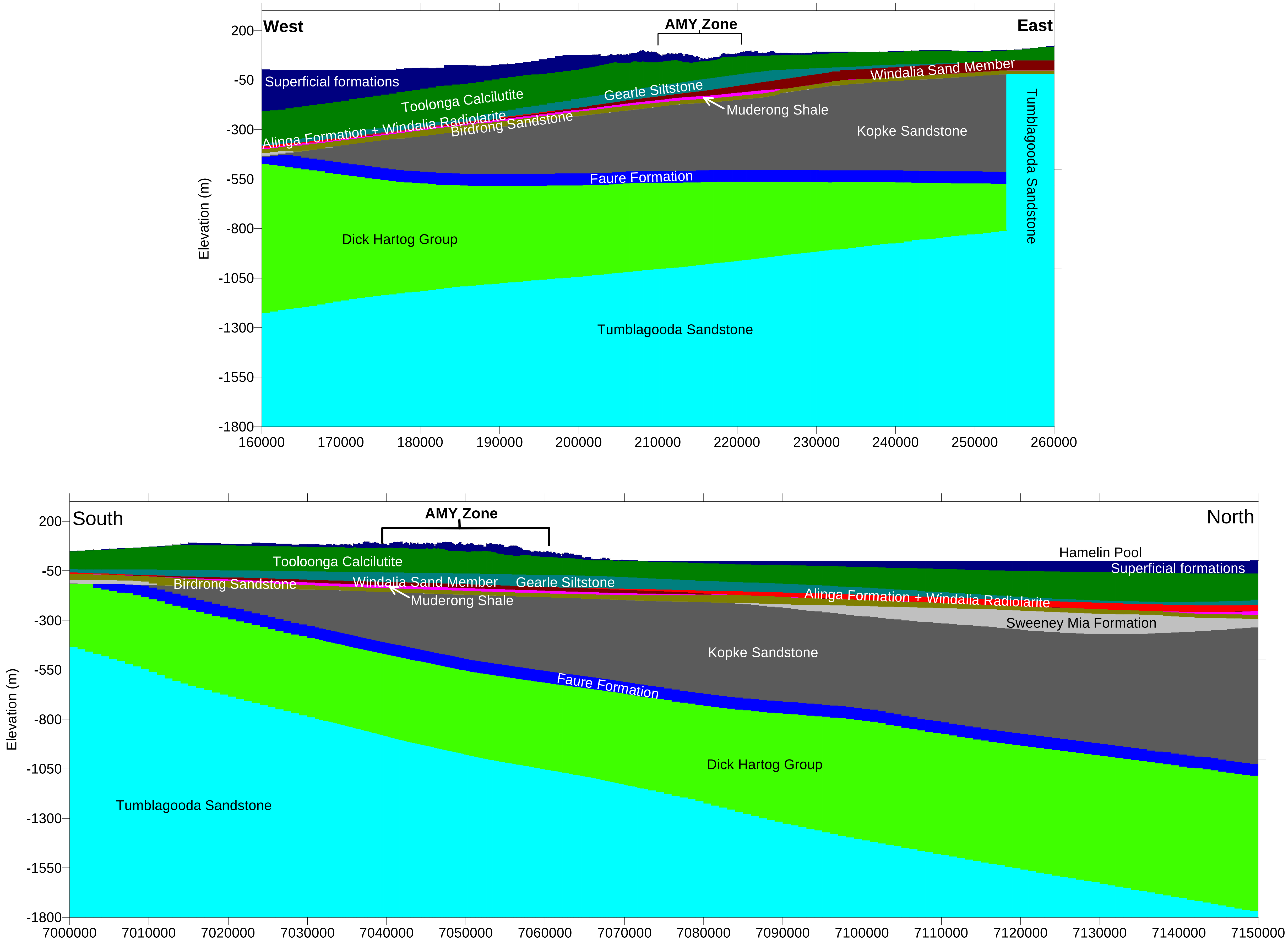
Job No.	42905541	
Prep. By	ECPL	3 Dec '04
Chk'd By	RBW	3 Dec '04
Revision Indicator	0	

Gunson Resources Limited
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

CONFINED AQUIFER MODEL DOMAIN

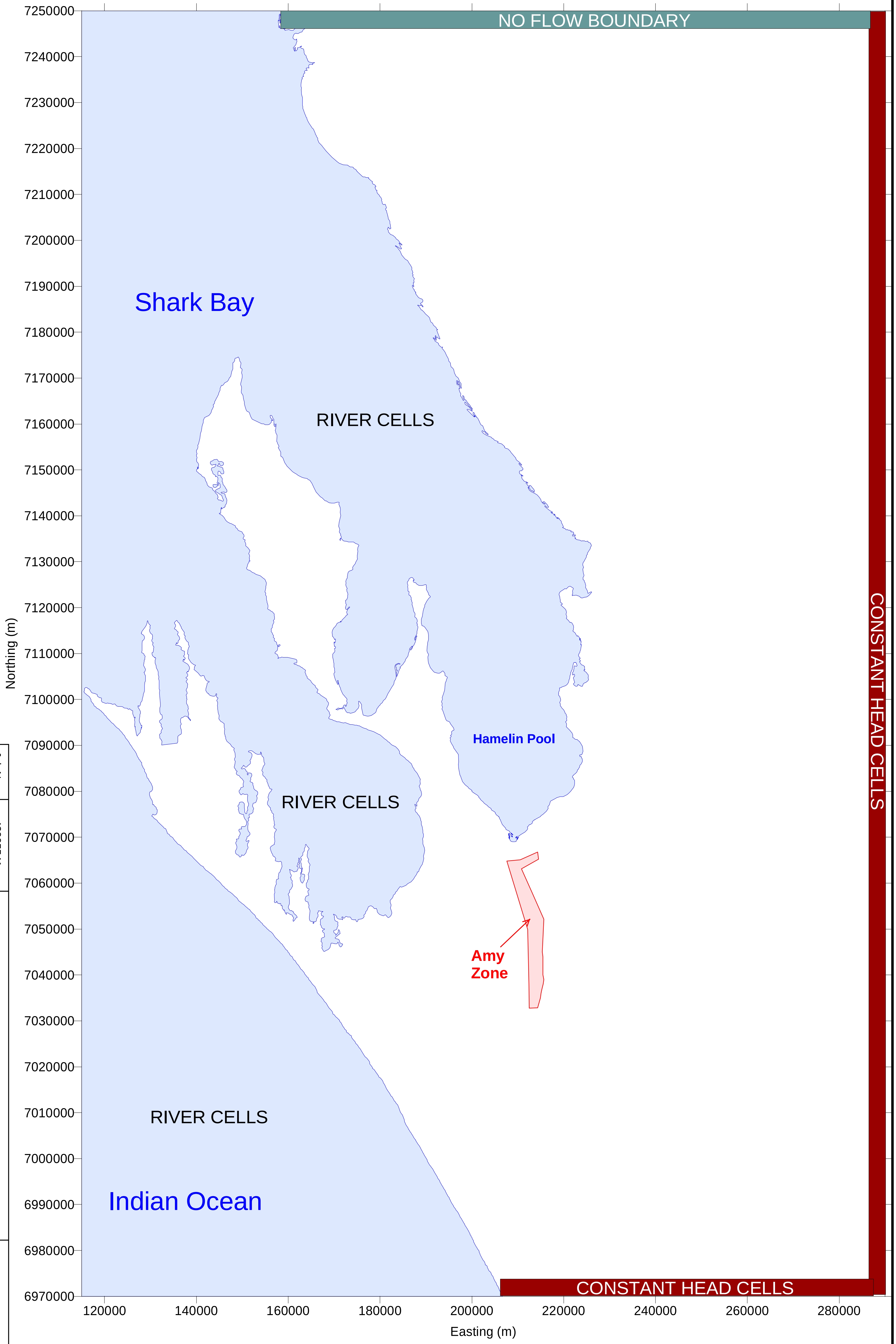
URS

Figure 55



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 56
Prep. By	RBW	3 Dec '04		
Chk'd By	RBW	3 Dec '04	FORM OF THE CONFINED AQUIFER MODEL	URS
Revision Indicator	0			

figure57 ConfinedAquiferModelBoundaryConditions.srf



Job No.	42905541	
Prep. By	ECPL	3 Dec '04
Chk'd By	RBW	3 Dec '04
Revision Indicator	0	

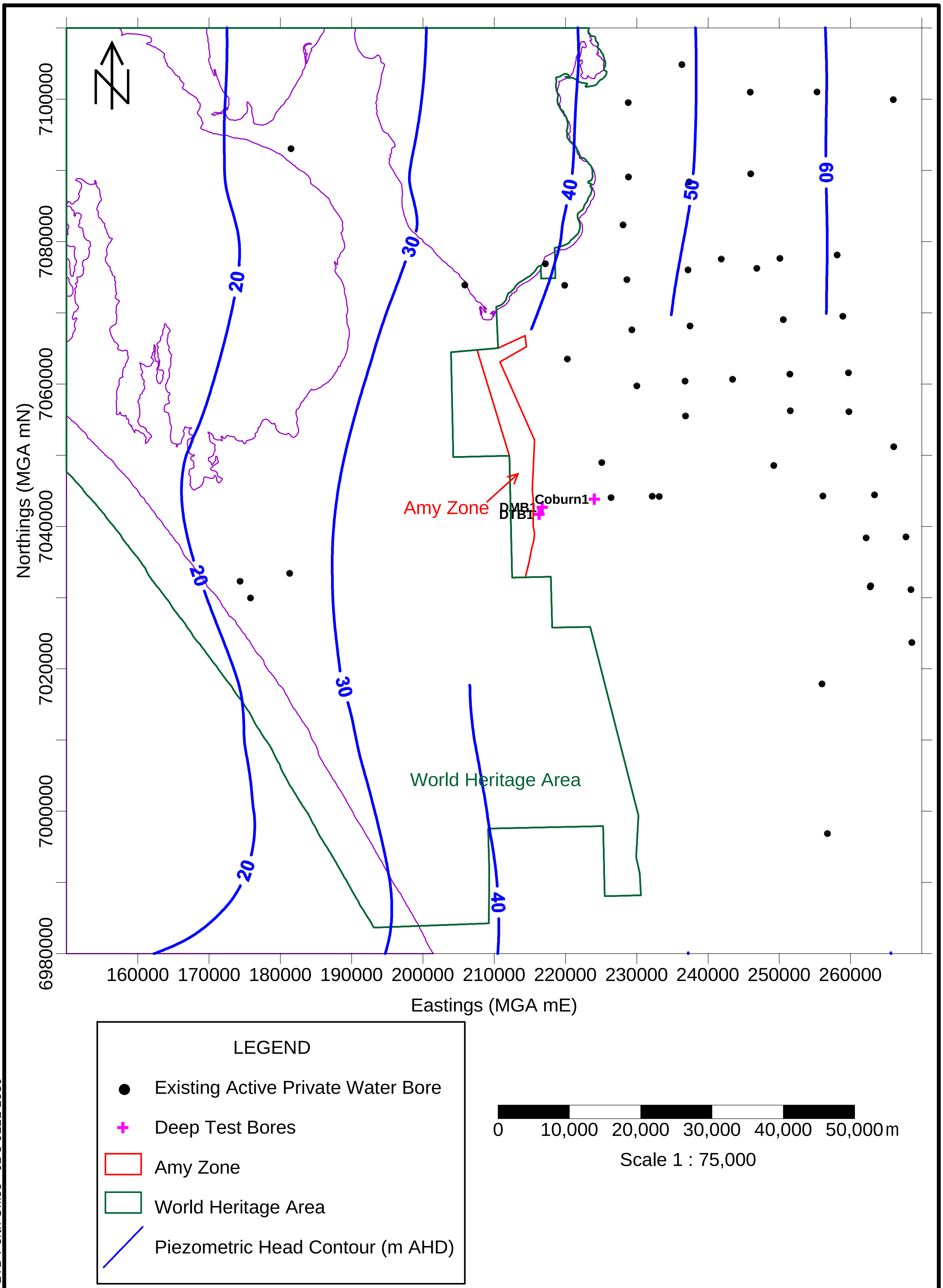
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

CONFINED AQUIFER MODEL BOUNDARY CONDITIONS

Figure 57

URS



Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RWC	31 Mar 05
Revision No.	0	

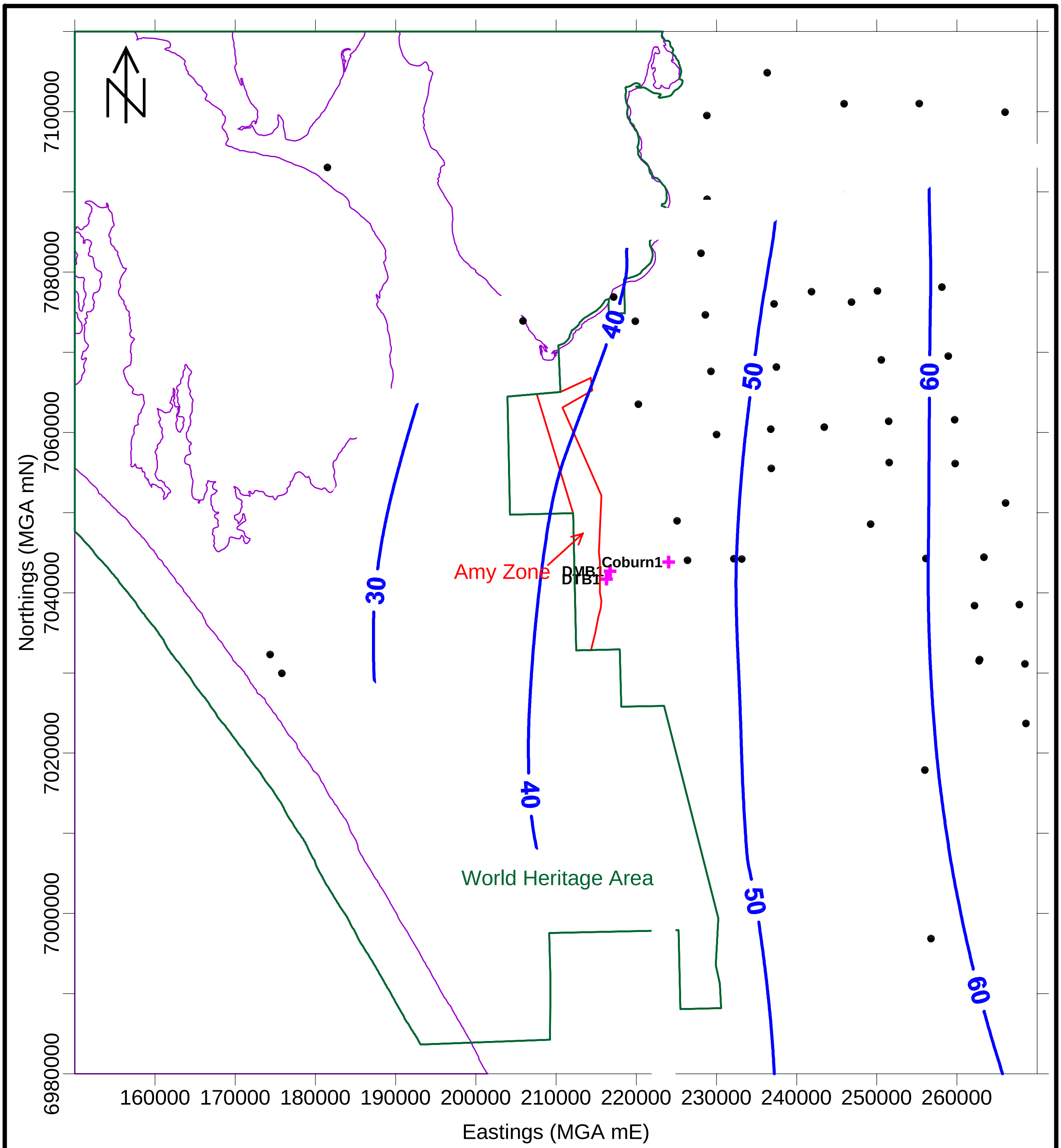
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED STEADY-STATE POTENTIOMETRIC LEVELS WINDALIA RADIOLARITE

Figure 58a

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Amy Zone
- World Heritage Area
- Piezometric Head Contour (m AHD)

0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

Job No.	42905541	
Prep. By	ECPL	31 Mar 05
Chk'd By	RWC	31 Mar 05
Revision No.	0	

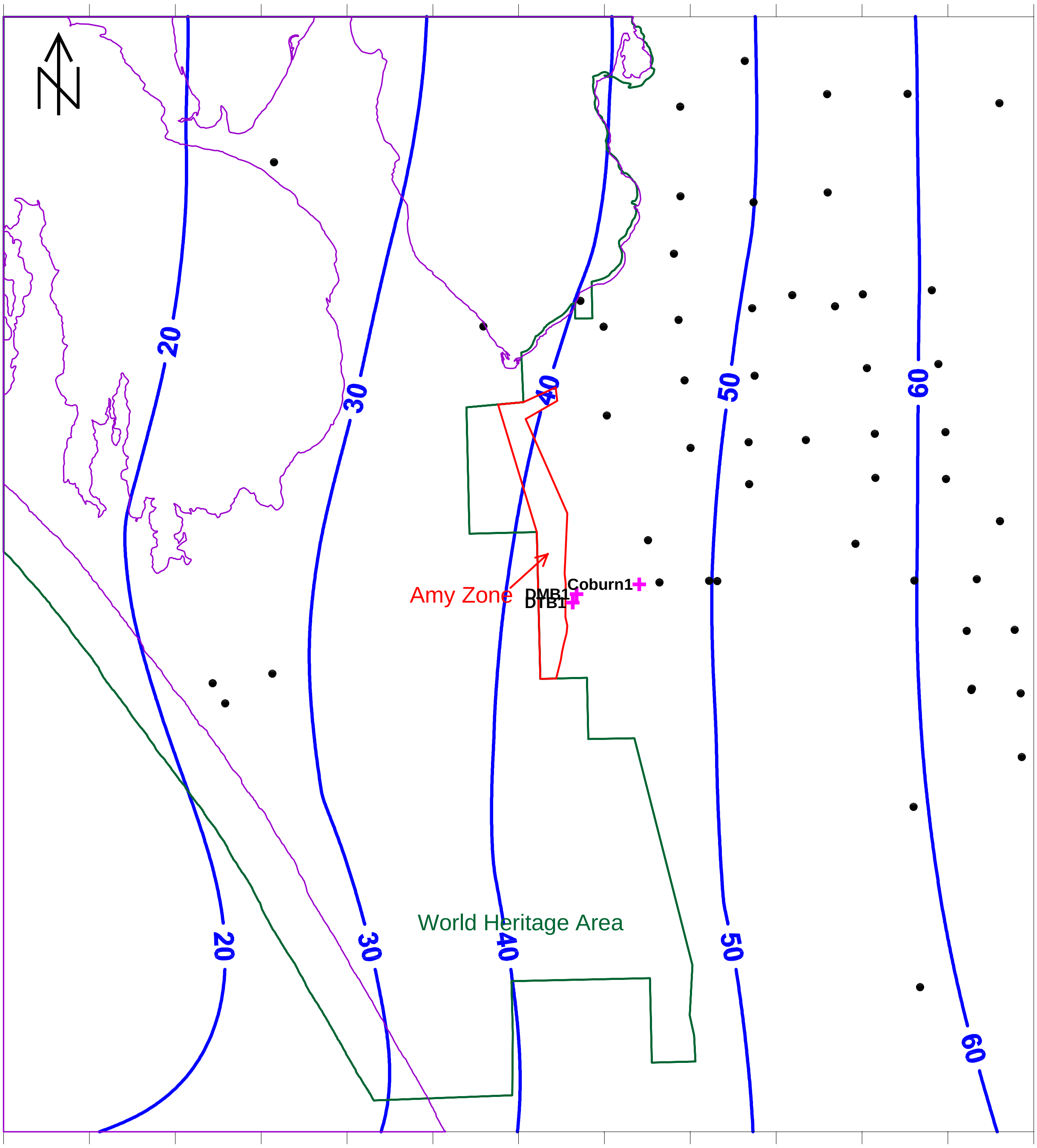
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED STEADY-STATE POTENTIOMETRIC LEVELS WINDALIA SAND MEMBER

Figure 58b

URS



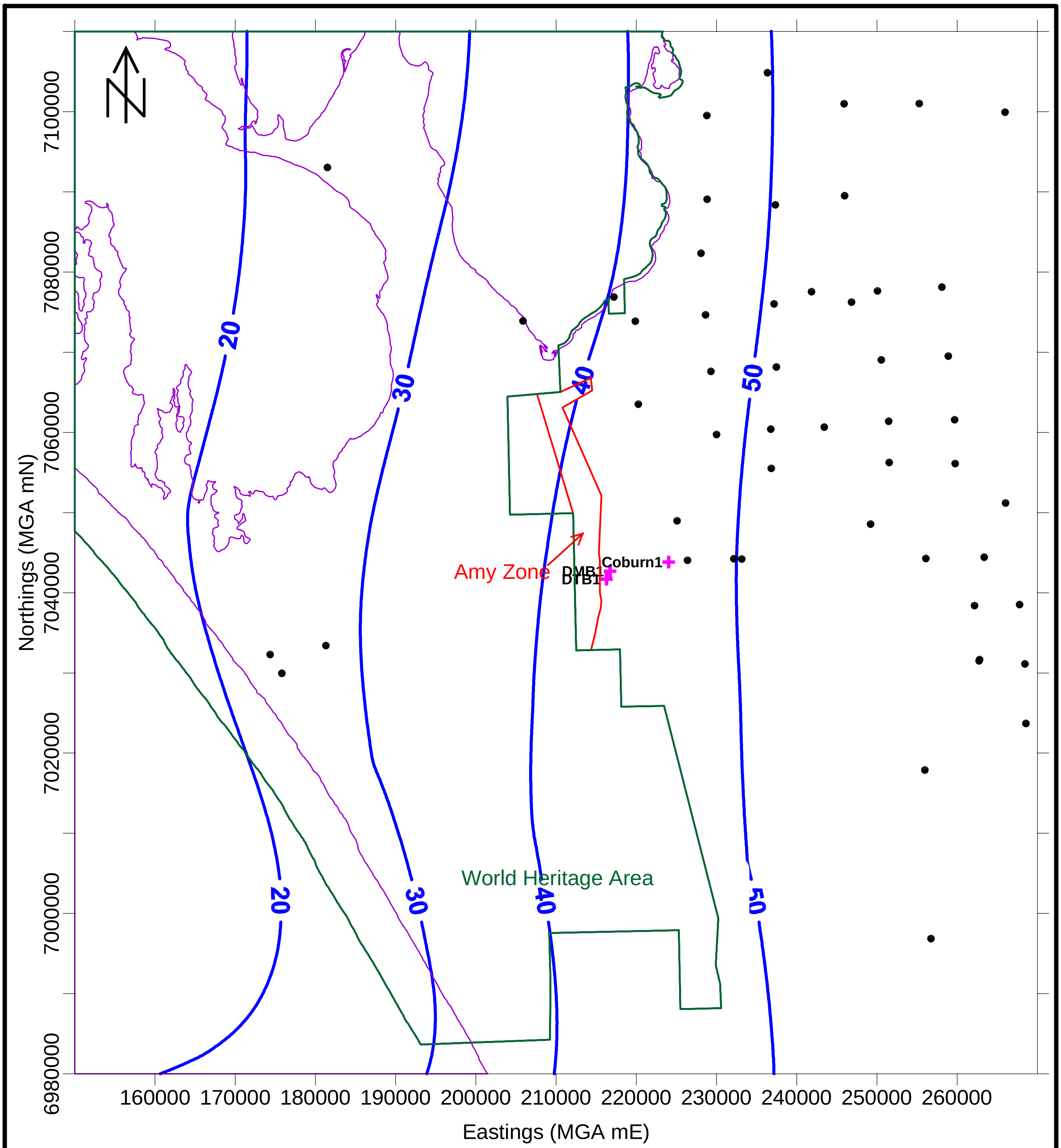
LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- Amy Zone
- World Heritage Area
- Piezometric Head Contour (m AHD)

0 10000 20000 30000 40000 50000m

Scale 1 : 75,000

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED STEADY-STATE POTENTIOMETRIC LEVELS BIRDRONG SANDSTONE**	**Figure 58c**
Prep. By	ECPL	31 Mar 05		URS
Chk'd By	RWC	31 Mar 05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Amy Zone
- World Heritage Area
- Piezometric Head Contour (m AHD)

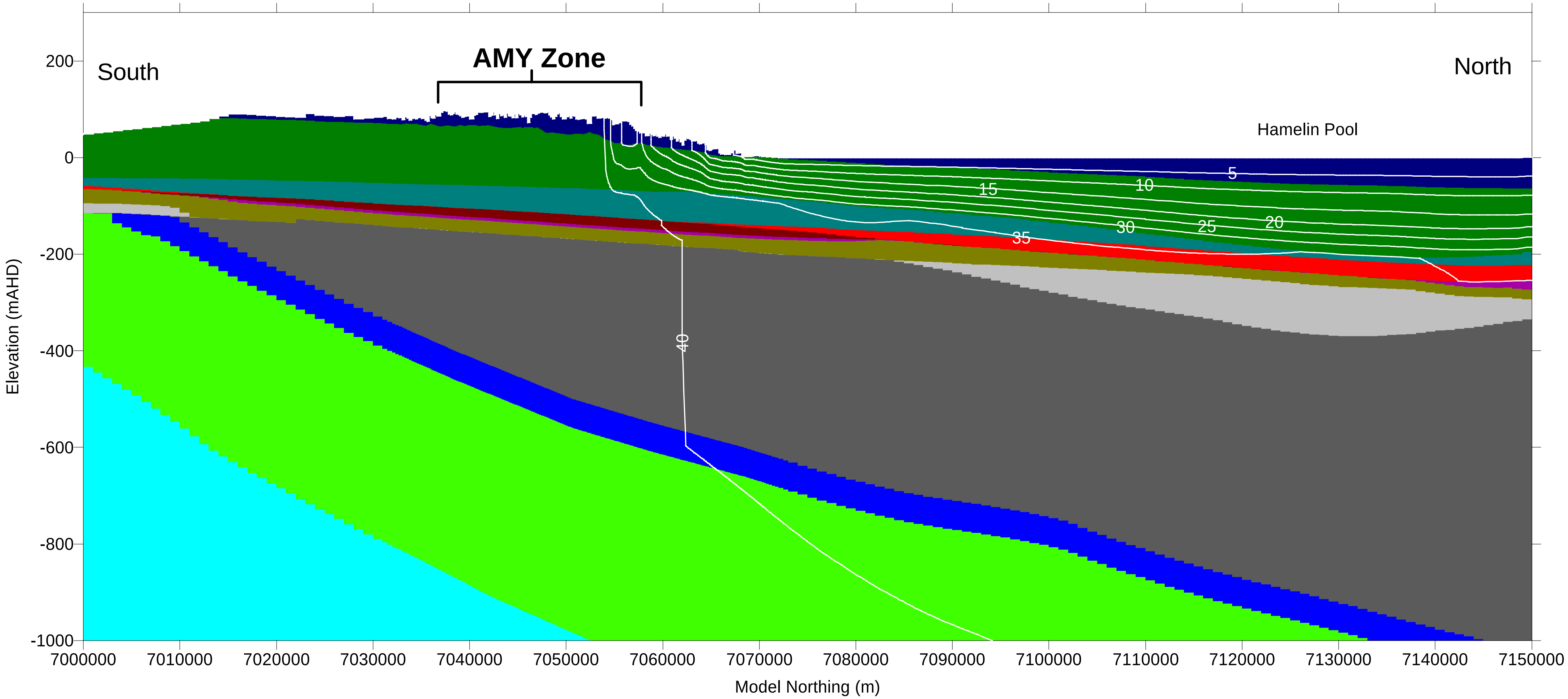
0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

Job No.	42905541		Gunson Resources Limited
Prep. By	ECPL	31 Mar 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT
Chk'd By	RWC	31 Mar 05	**SIMULATED STEADY-STATE POTENTIOMETRIC LEVELS KOPKE SANDSTONE**
Revision No.		0	

Figure 58d

URS



LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

Job No.	42905541	
Prep. By	ECPL	3 Apr '05
Chk'd By	RBW	3 Apr '05
Revision Indicator	0	

Gunson Resources Limited

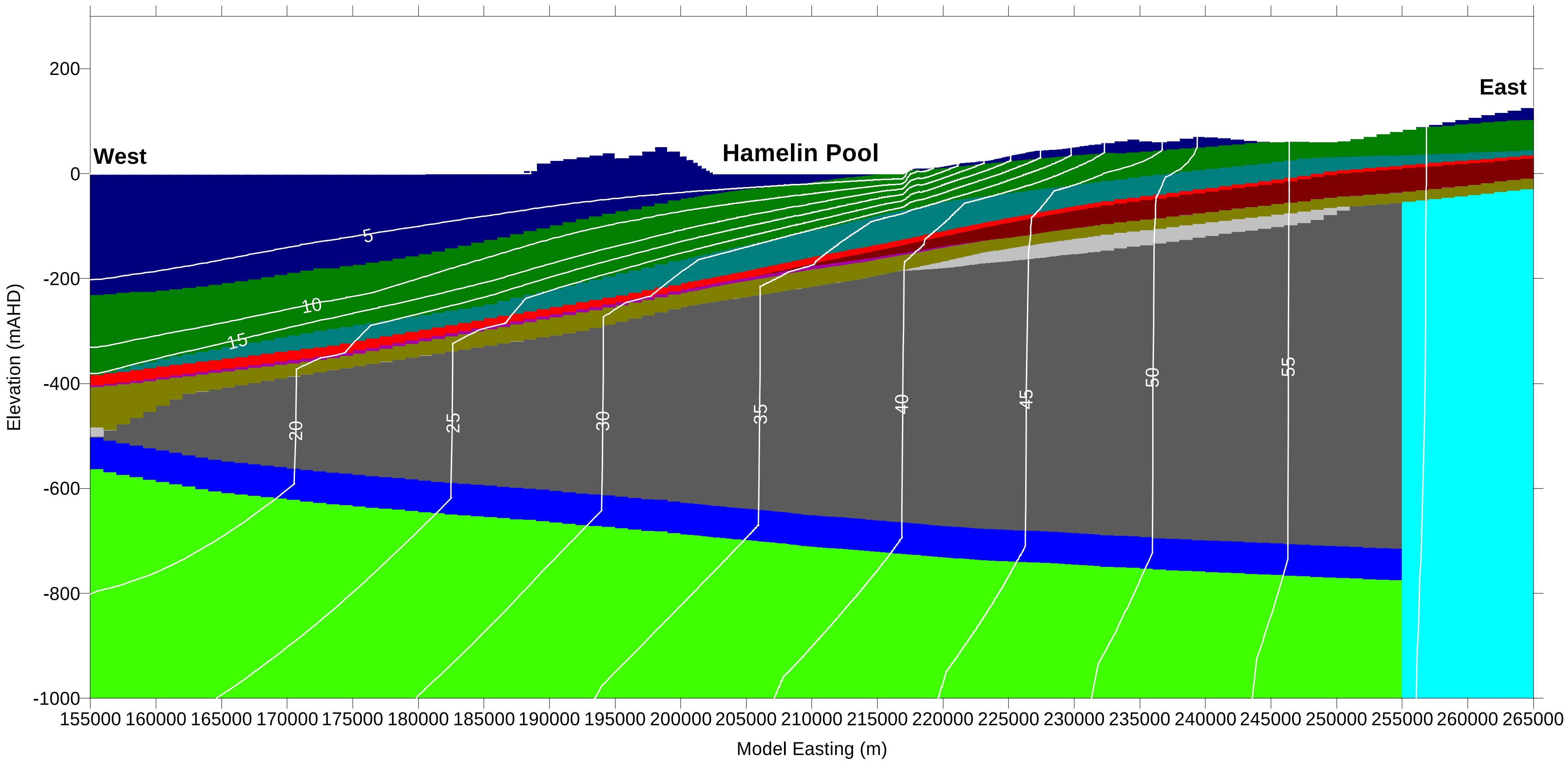
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED CONFINED AQUIFER NORTH TO SOUTH FLOW PATHS POTENTIOMETRIC LEVELS

Figure 59a

URS

Fig59a.srf

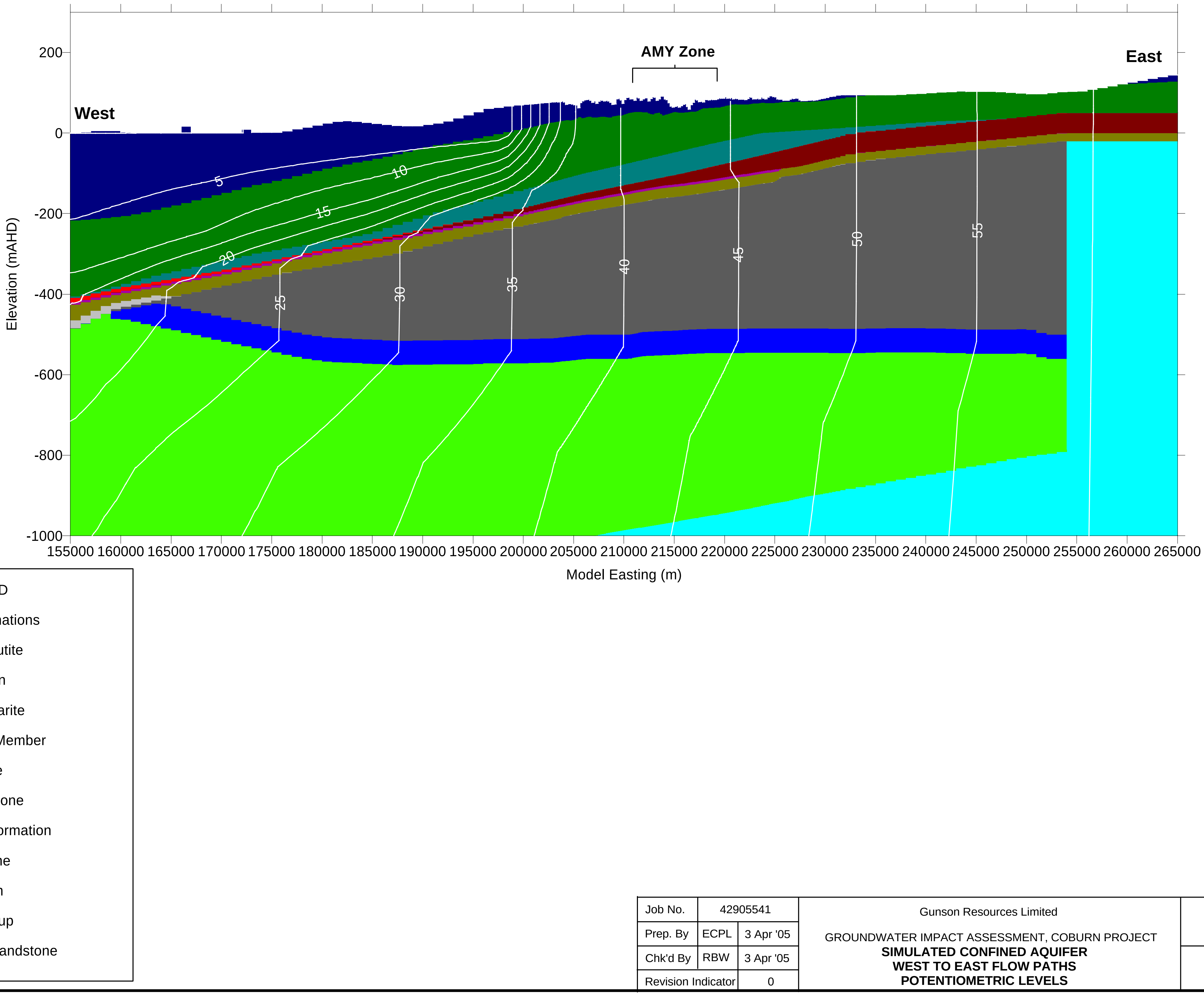


LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

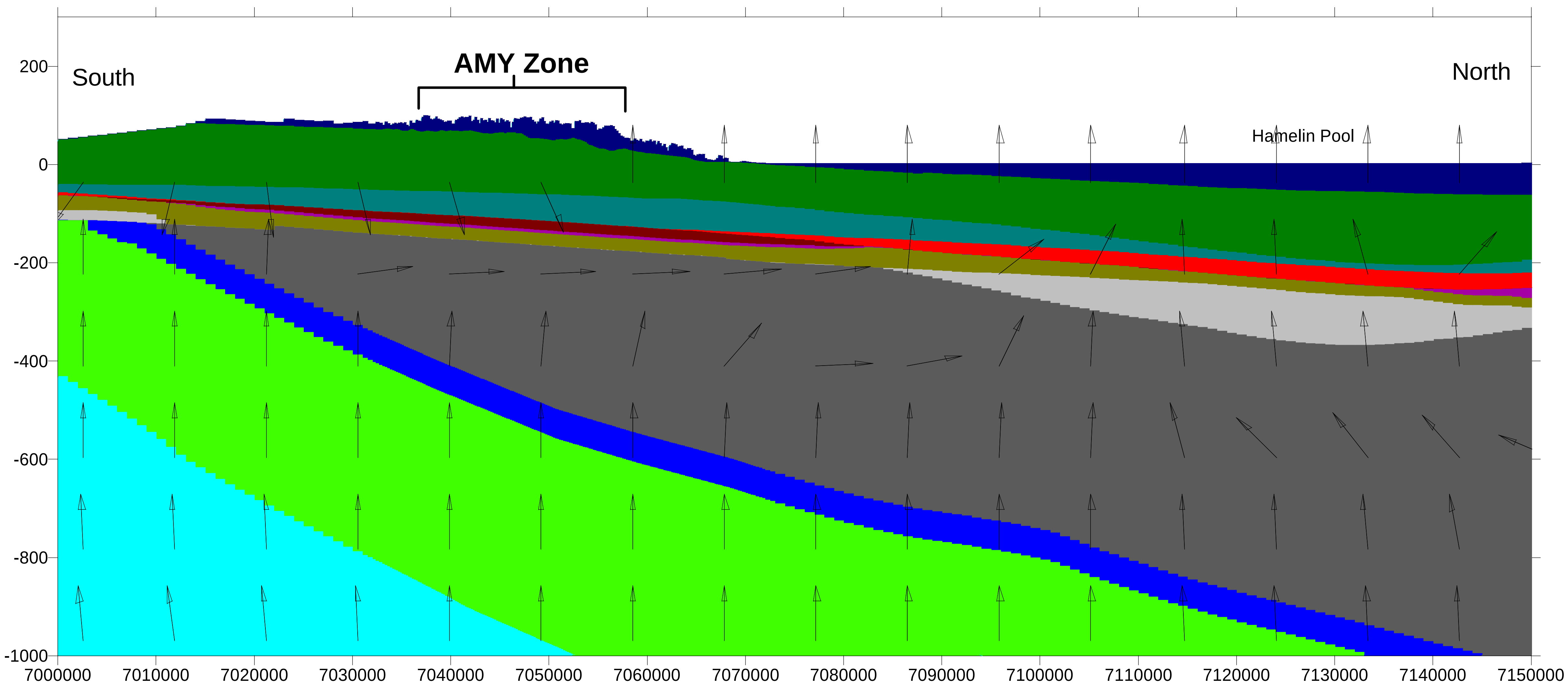
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED CONFINED AQUIFER** **WEST TO EAST FLOW PATHS** **POTENTIOMETRIC LEVELS**	**Figure 59b**
Prep. By	ECPL	3 Apr '05		URS
Chk'd By	RBW	3 Apr '05		
Revision Indicator		0		

Fig59b.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **SIMULATED CONFINED AQUIFER WEST TO EAST FLOW PATHS POTENTIOMETRIC LEVELS**	**Figure 59c**
Prep. By	ECPL	3 Apr '05		URS
Chk'd By	RBW	3 Apr '05		
Revision Indicator		0		

Fig59C.srf



LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

Job No.	42905541		Gunson Resources Limited
Prep. By	ECPL	3 Apr '05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT
Chk'd By	RBW	3 Apr '05	**SIMULATED CONFINED AQUIFER NORTH TO SOUTH FLOW PATHS FLOW VECTORS**
Revision Indicator		0	

Figure 60a

URS

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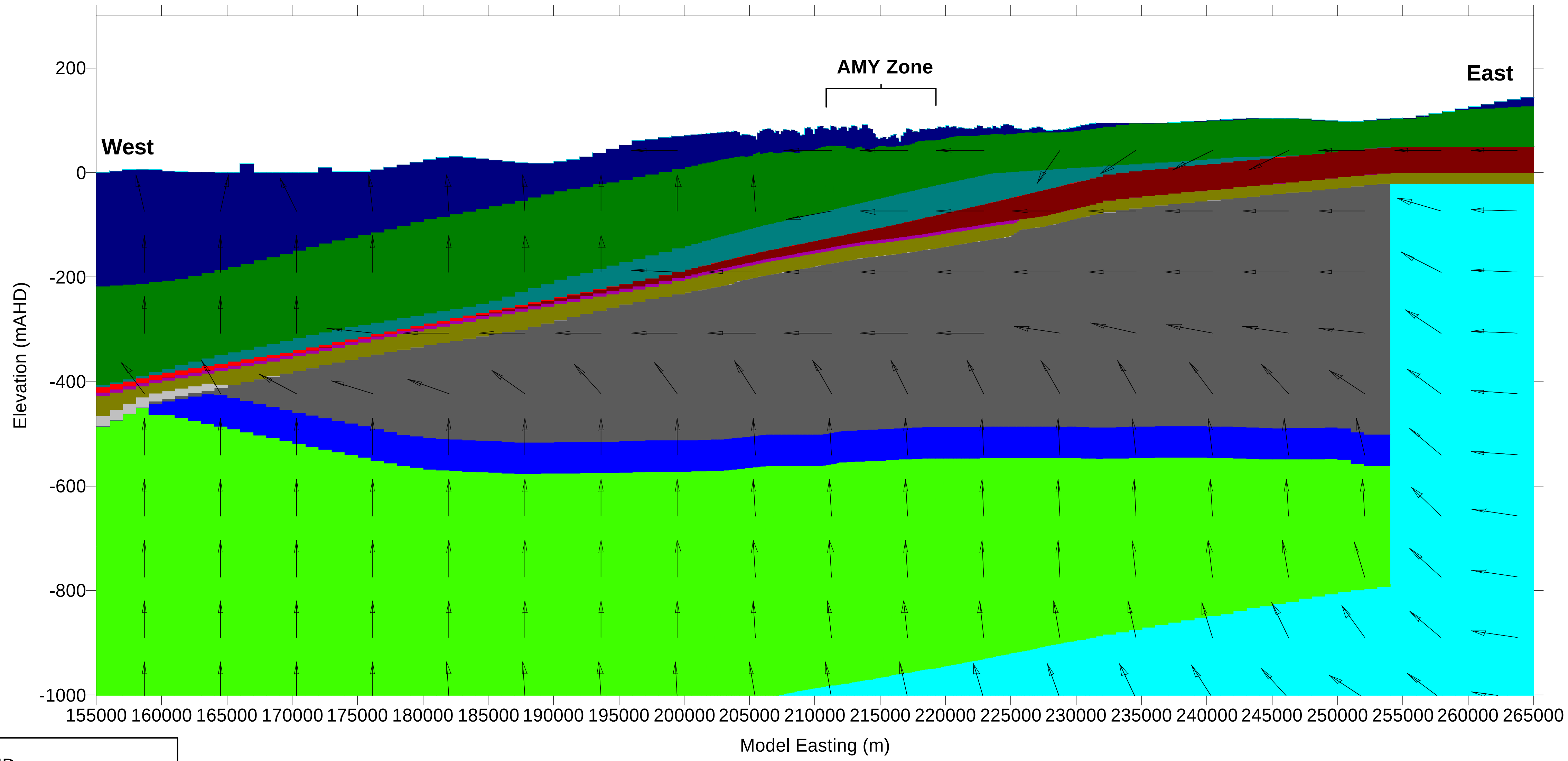


LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

Job No.	42905541	
Prep. By	ECPL	3 Apr '05
Chk'd By	RBW	3 Apr '05
Revision Indicator	0	

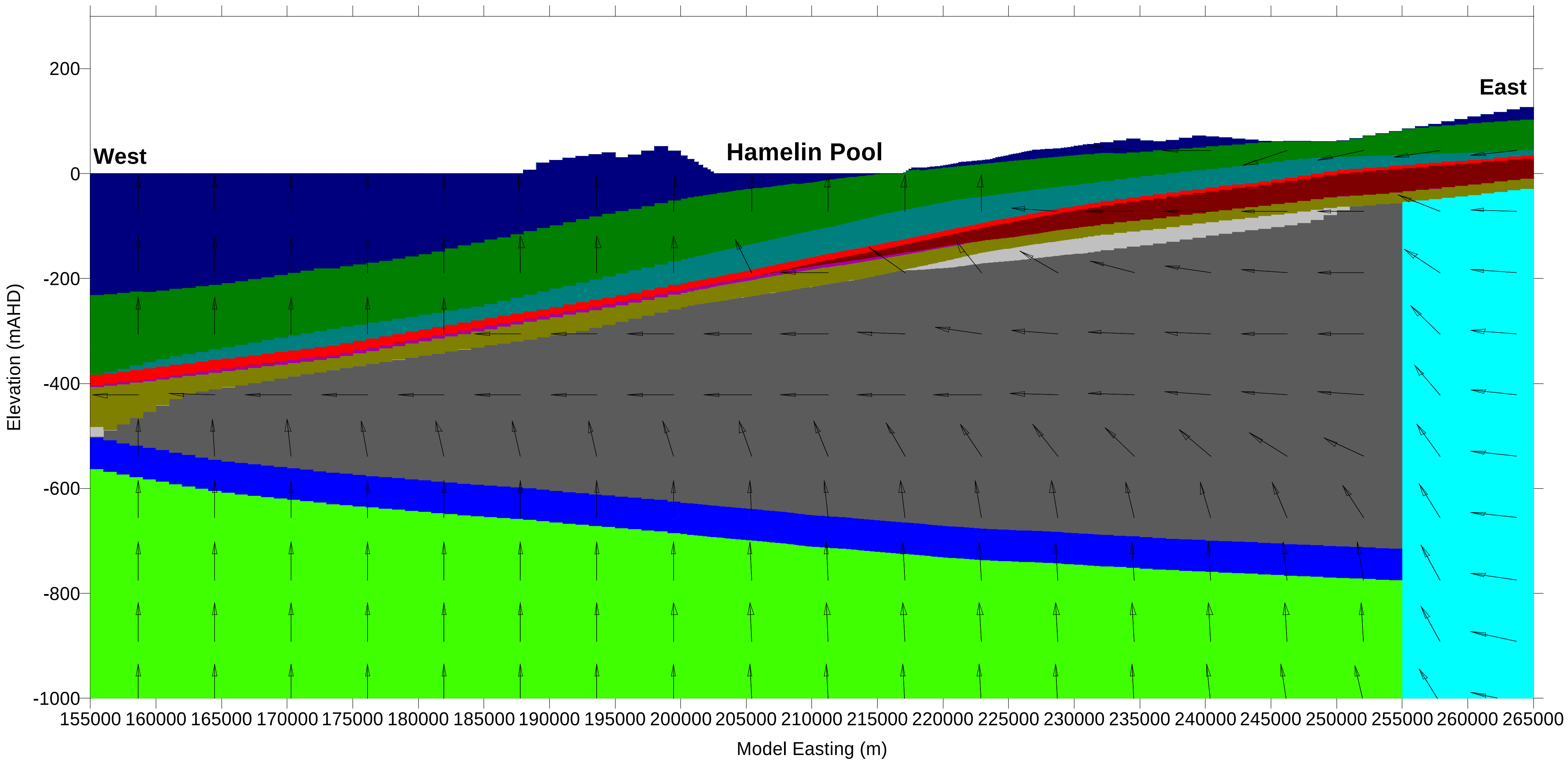
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED CONFINED AQUIFER
WEST TO EAST FLOW PATHS
FLOW VECTORS

Figure 60b

URS



LEGEND

- Superficial Formations
- Toolonga Calcilutite
- Alinga Formation
- Windalia Radiolarite
- Windalia Sand Member
- Muderong Shale
- Birdrong Sandstone
- Sweeney Mia Formation
- Kopke Sandstone
- Faure Formation
- Dirk Hartog Group
- Tumblagooda Sandstone

Job No.	42905541	
Prep. By	ECPL	3 Apr '05
Chk'd By	RBW	3 Apr '05
Revision Indicator	0	

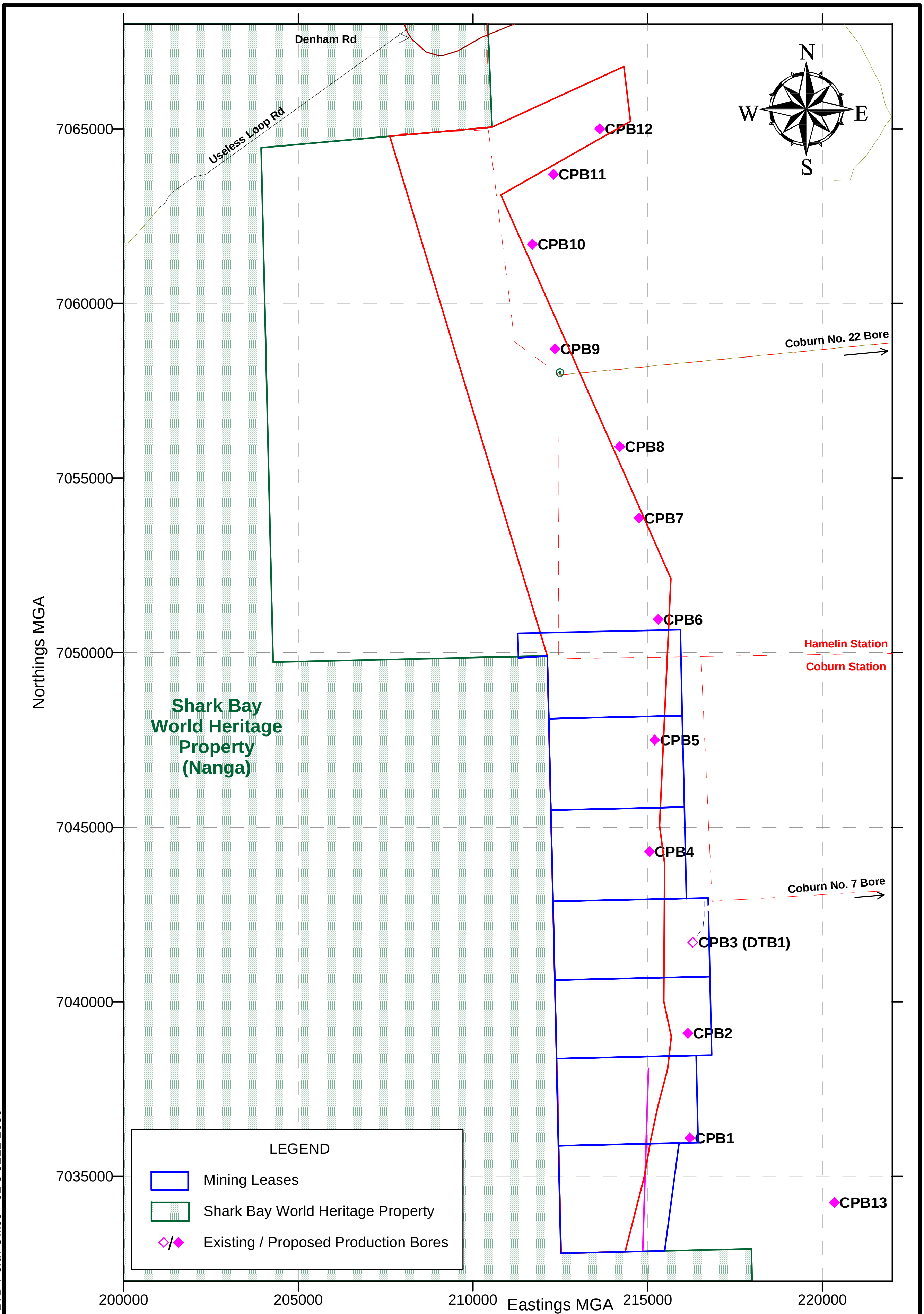
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

SIMULATED CONFINED AQUIFER
WEST TO EAST FLOW PATHS
FLOW VECTORS

Figure 60c

URS



Job No.	42905541	
Prep. By	RBW	1 Apr '05
Chk'd By	RBW	1 Apr '05
Revision No.	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Layout of Conceptual Process Water Borefield and Proposed Superficial Monitoring Bores

Figure 61

URS

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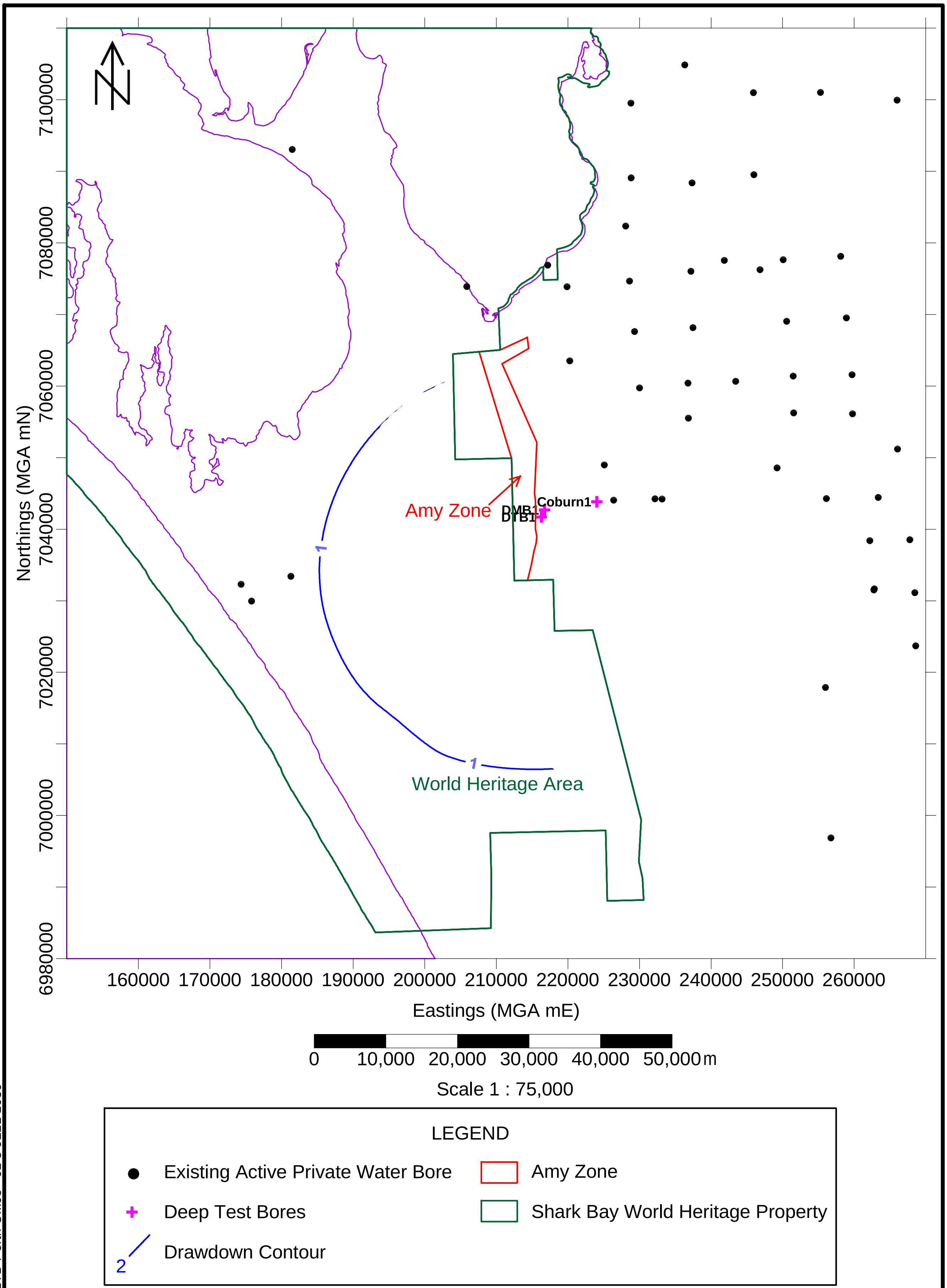
Conceptual Process Water Borefield Layout.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Windalia Radiolarite After 1 Year Of 11 GL/annum Abstraction**	**Figure 62a**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		

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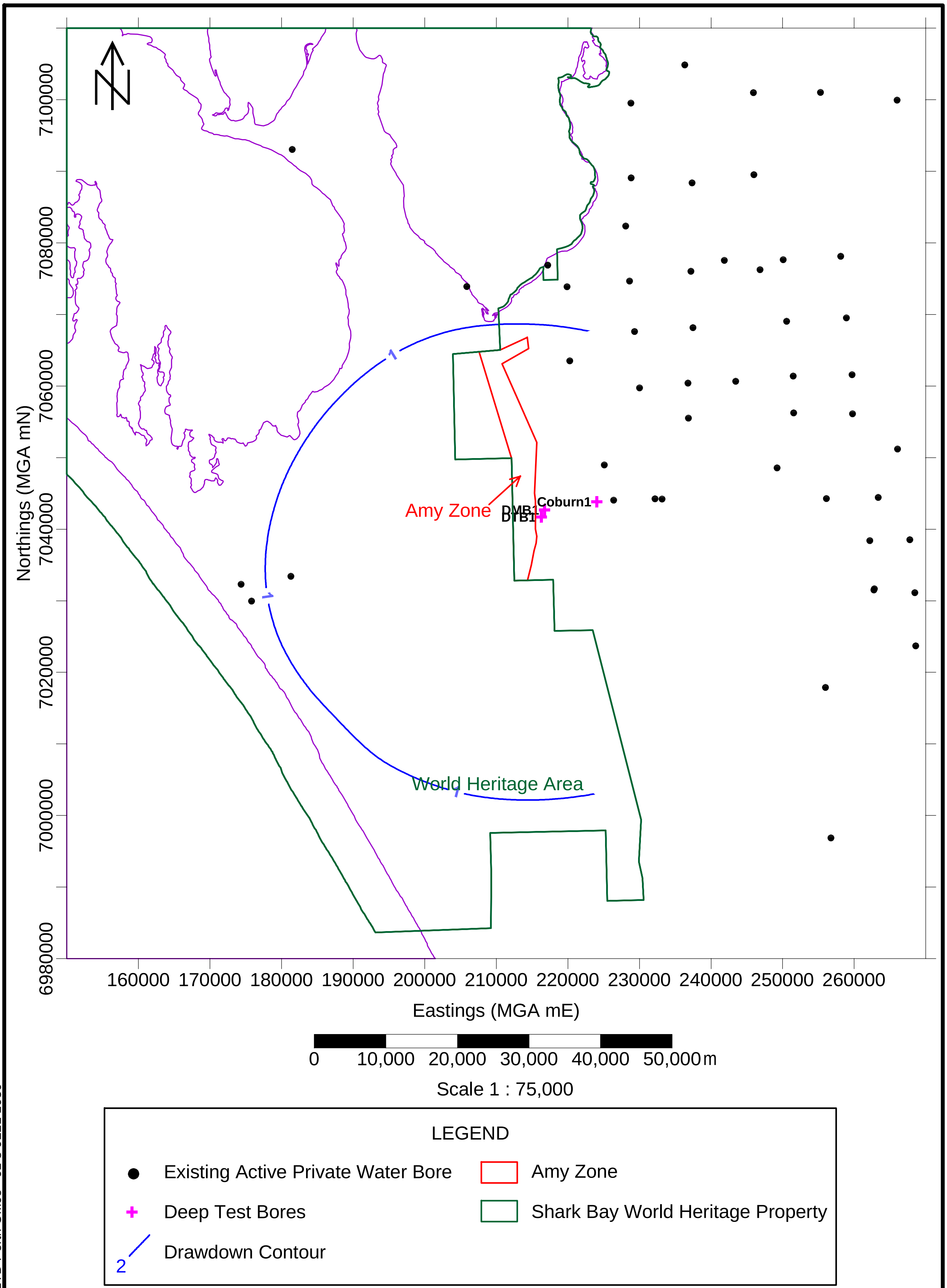

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Windalia Radiolarite After 2 Years Of 11 GL/annum Abstraction**	**Figure 62b**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		

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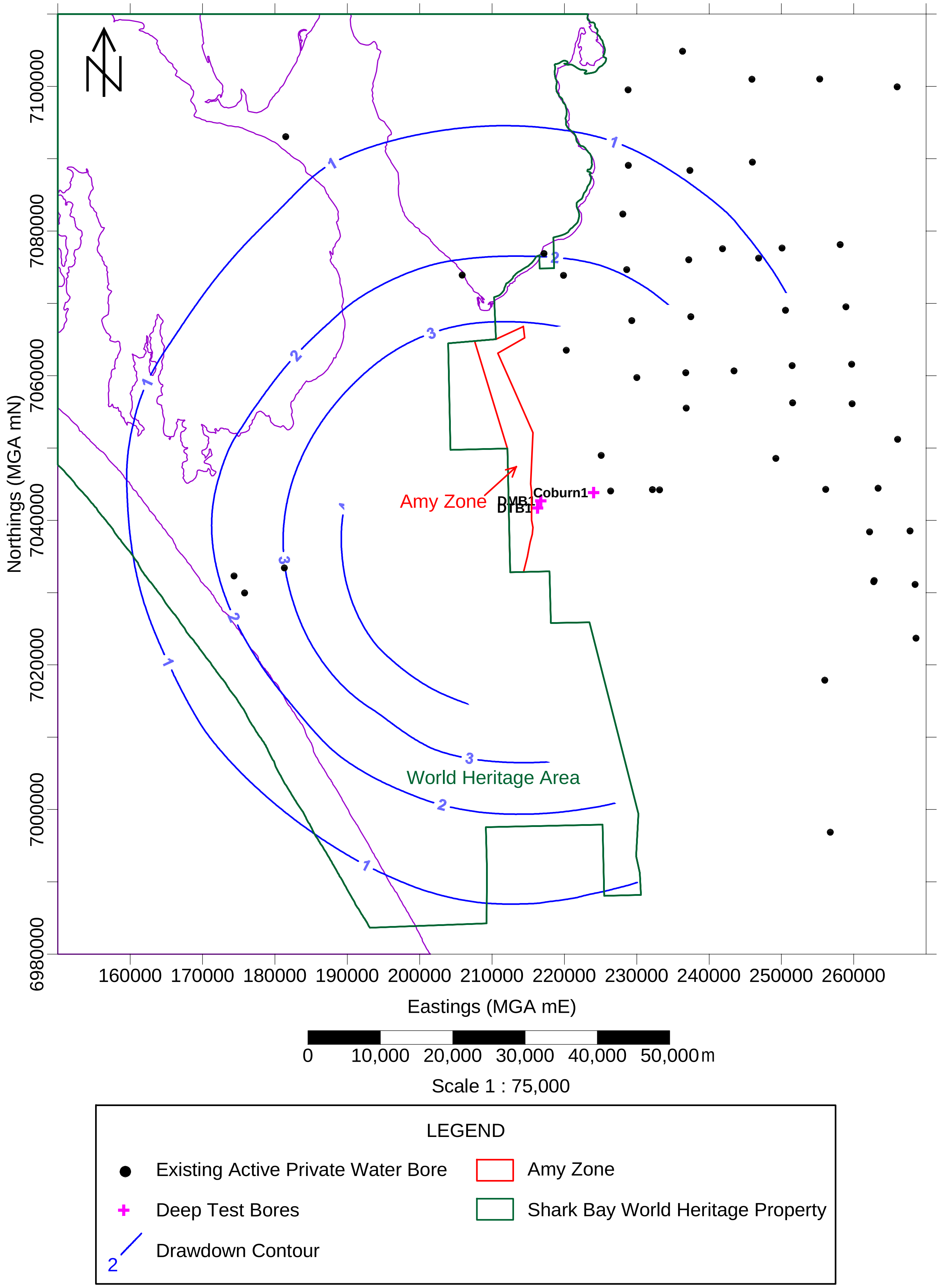


Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

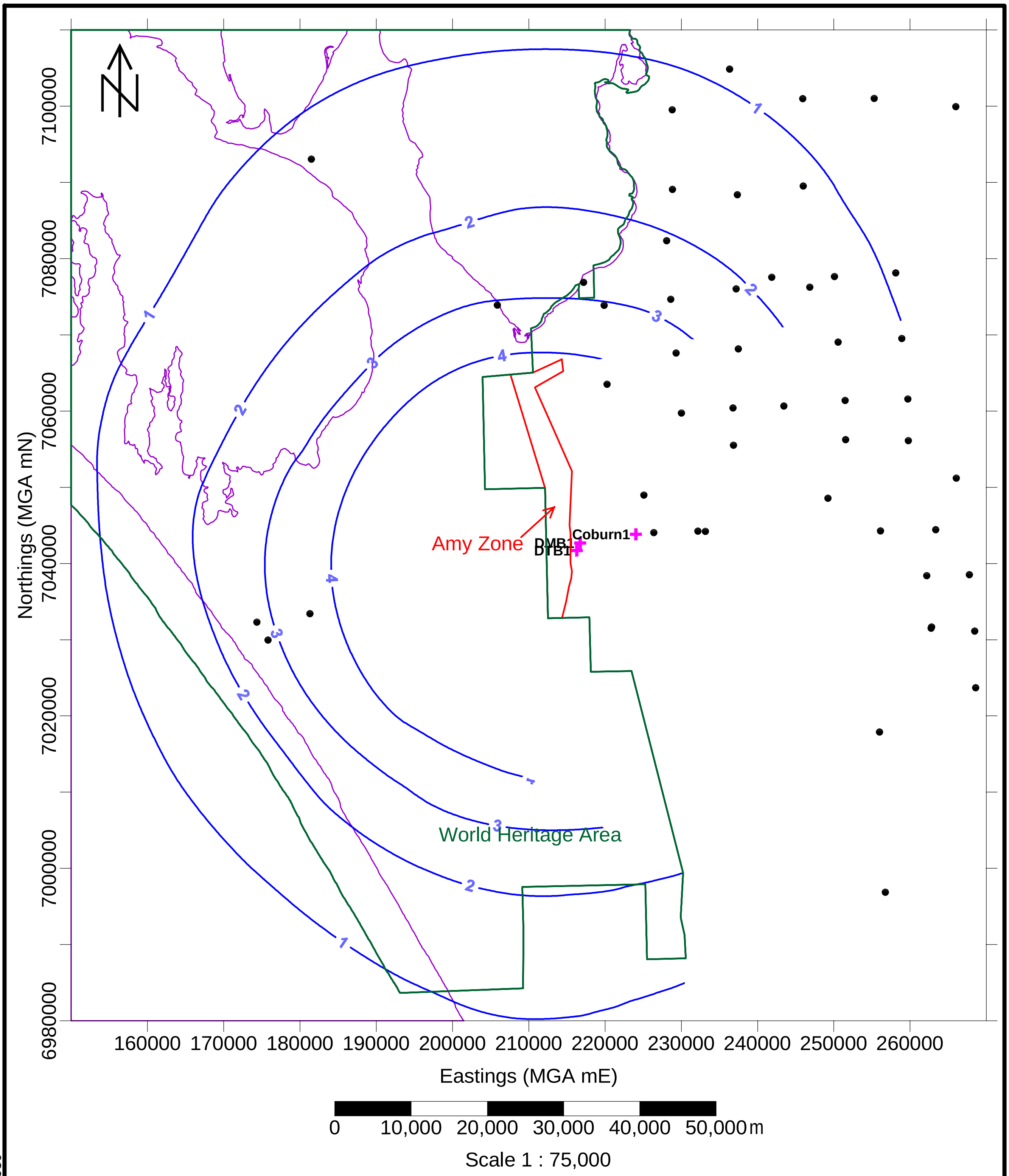
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Radiolarite After 5 Years Of 11 GL/annum Abstraction

Figure 62c

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

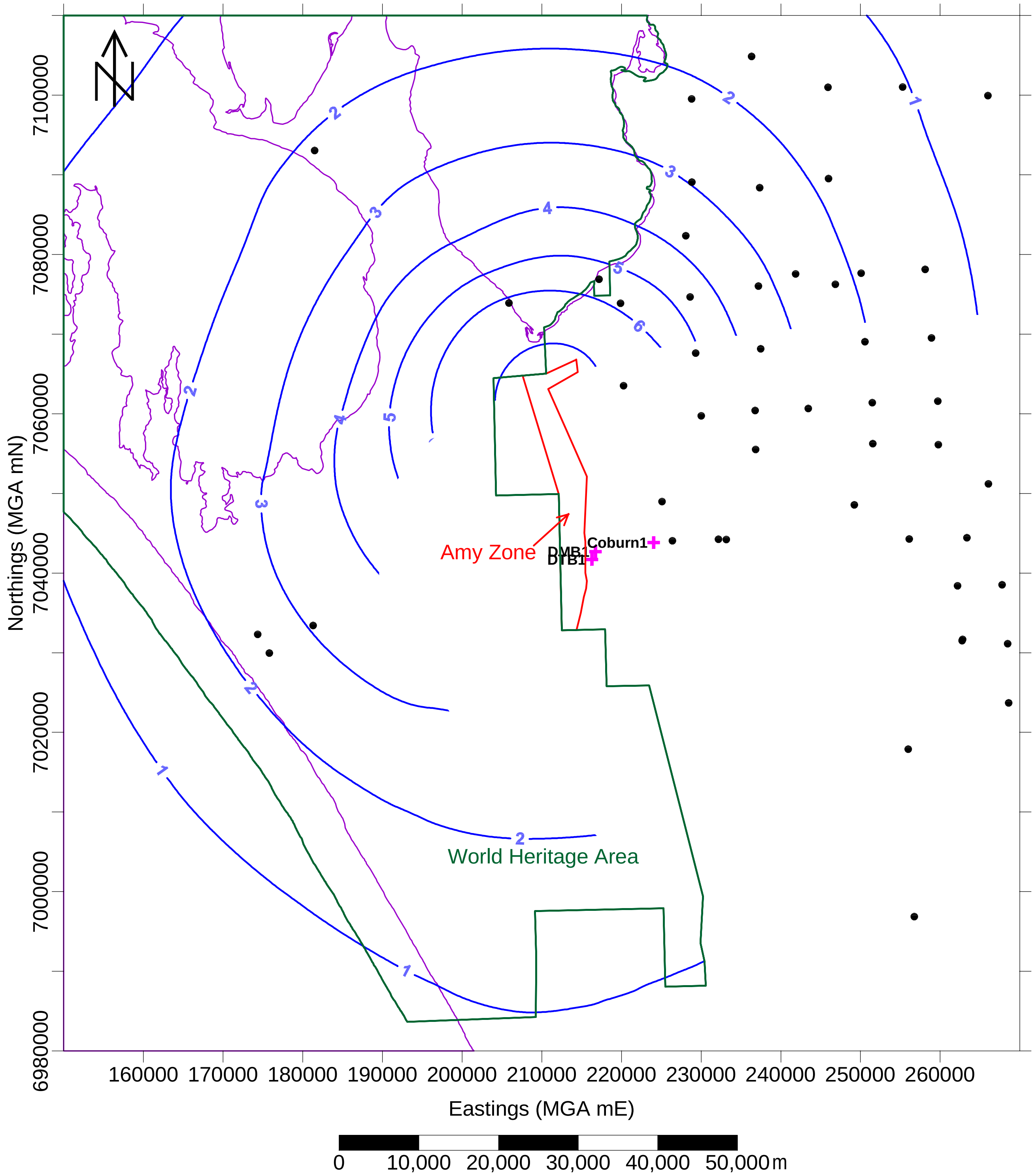
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Radiolarite After 10 Years Of 11 GL/annum Abstraction

Figure 62d

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited	Figure 62e
Prep. By	ECPL	1 Apr '05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Chk'd By	RWC	1 Apr '05	**Predicted Drawdowns in Windalia Radiolarite After 20 Years Of 11 GL/annum Abstraction**	
Revision No.		0		

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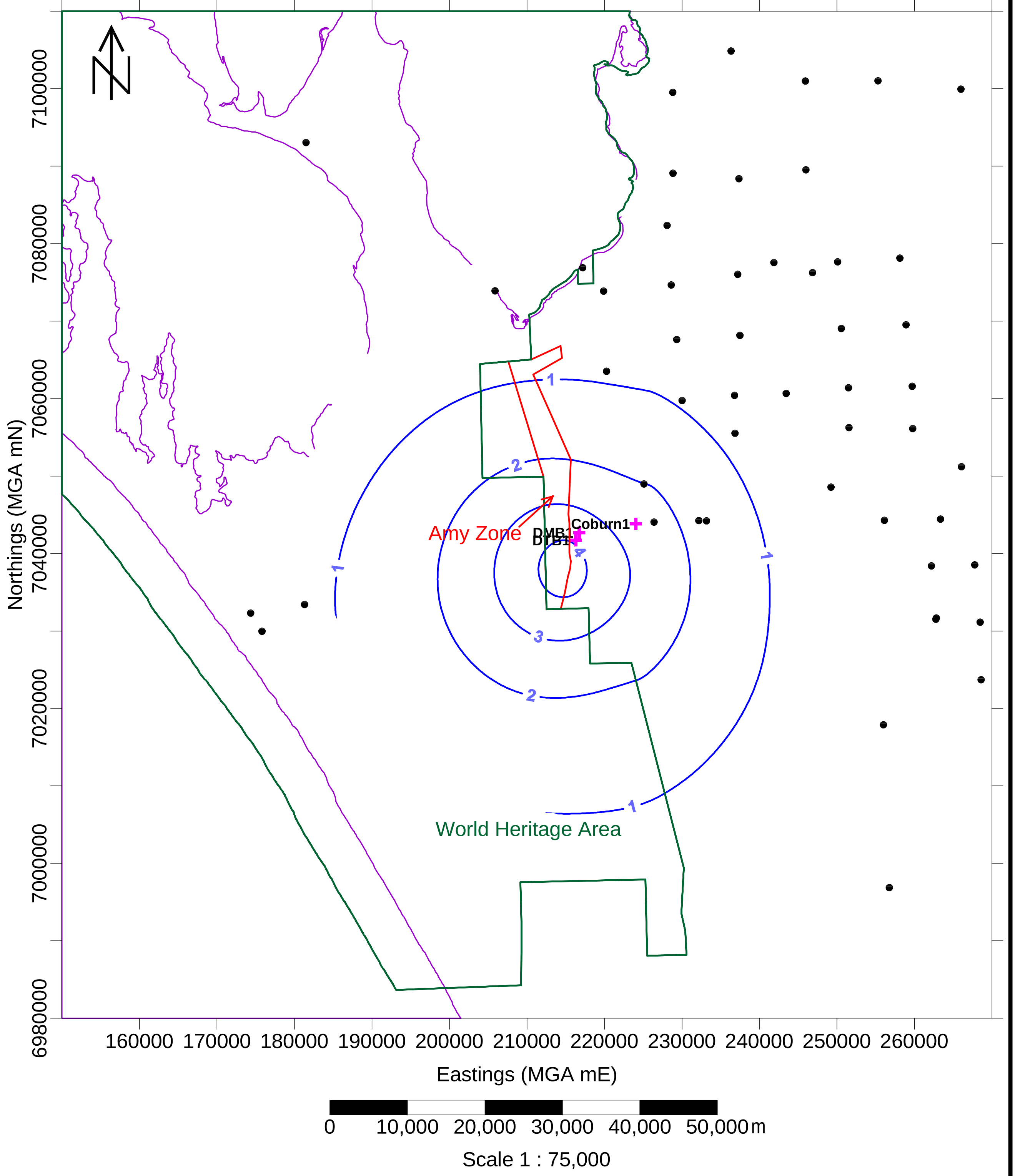
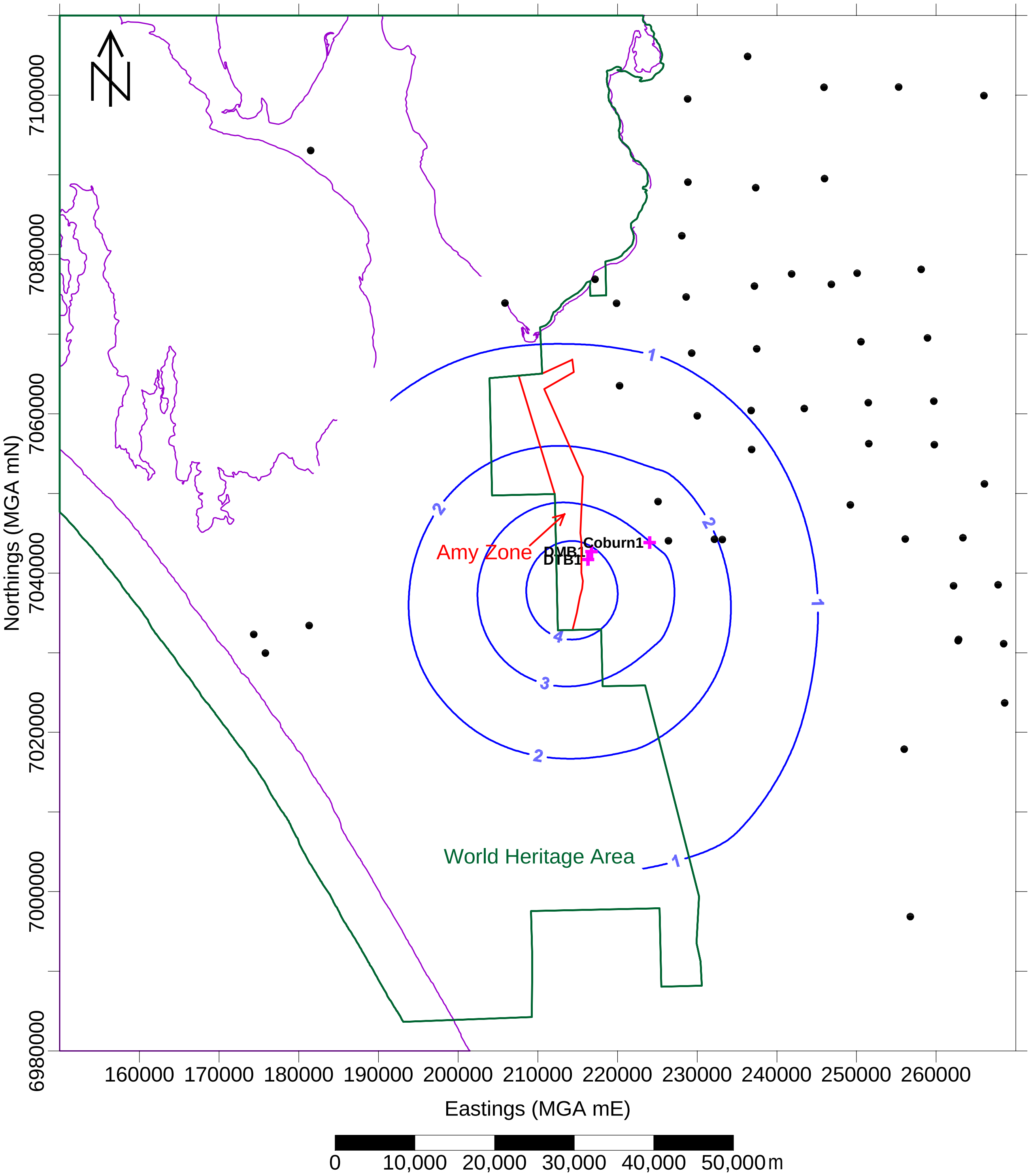


LEGEND

- ● Existing Active Private Water Bore
- + Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 63a
Prep. By	ECPL	1 Apr '05	**Predicted Drawdowns in Windalia Sand Member After 1 Year Of 11 GL/annum Abstraction**	URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

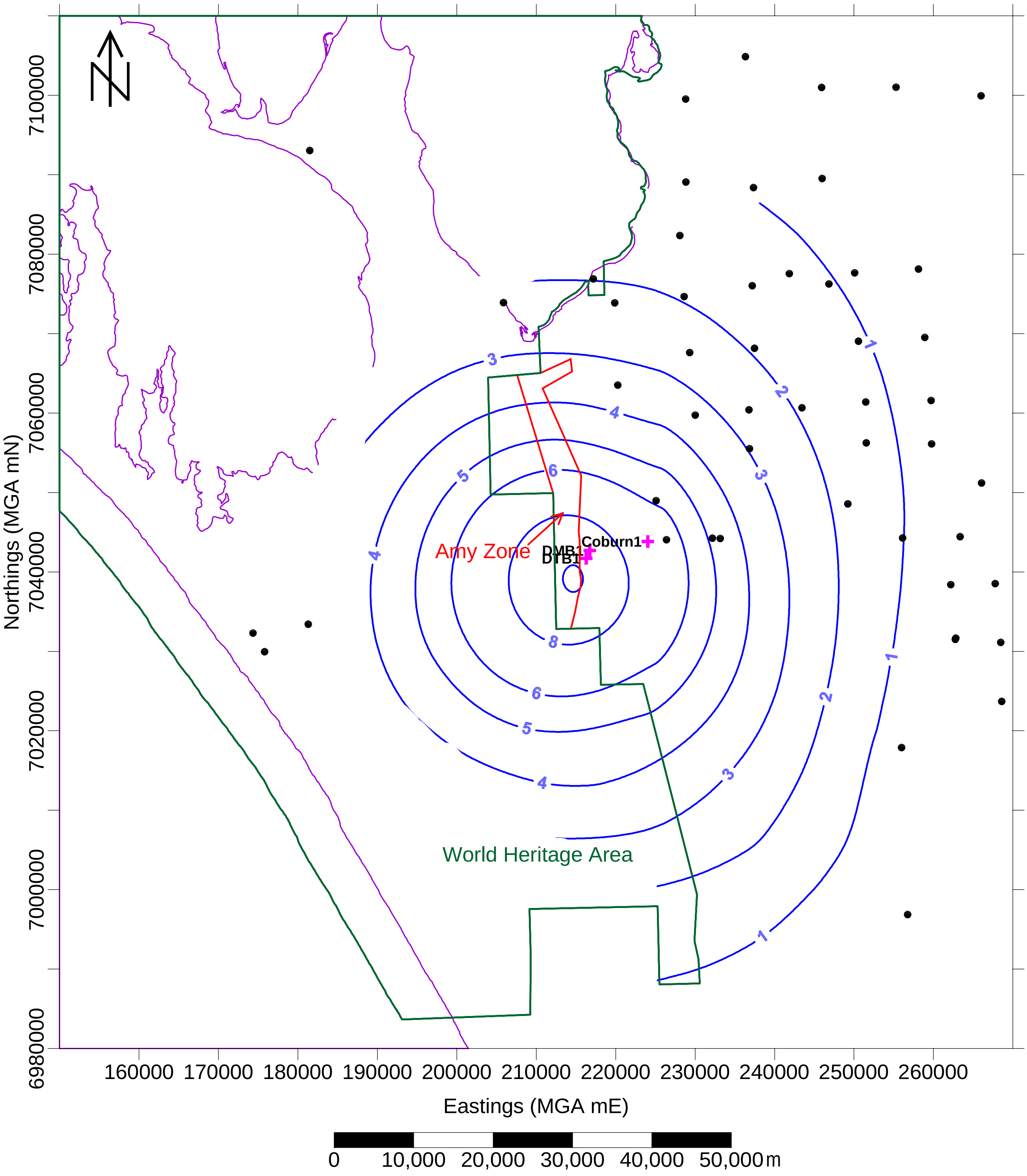
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 2 Years Of 11 GL/annum Abstraction

Figure 63b

URS

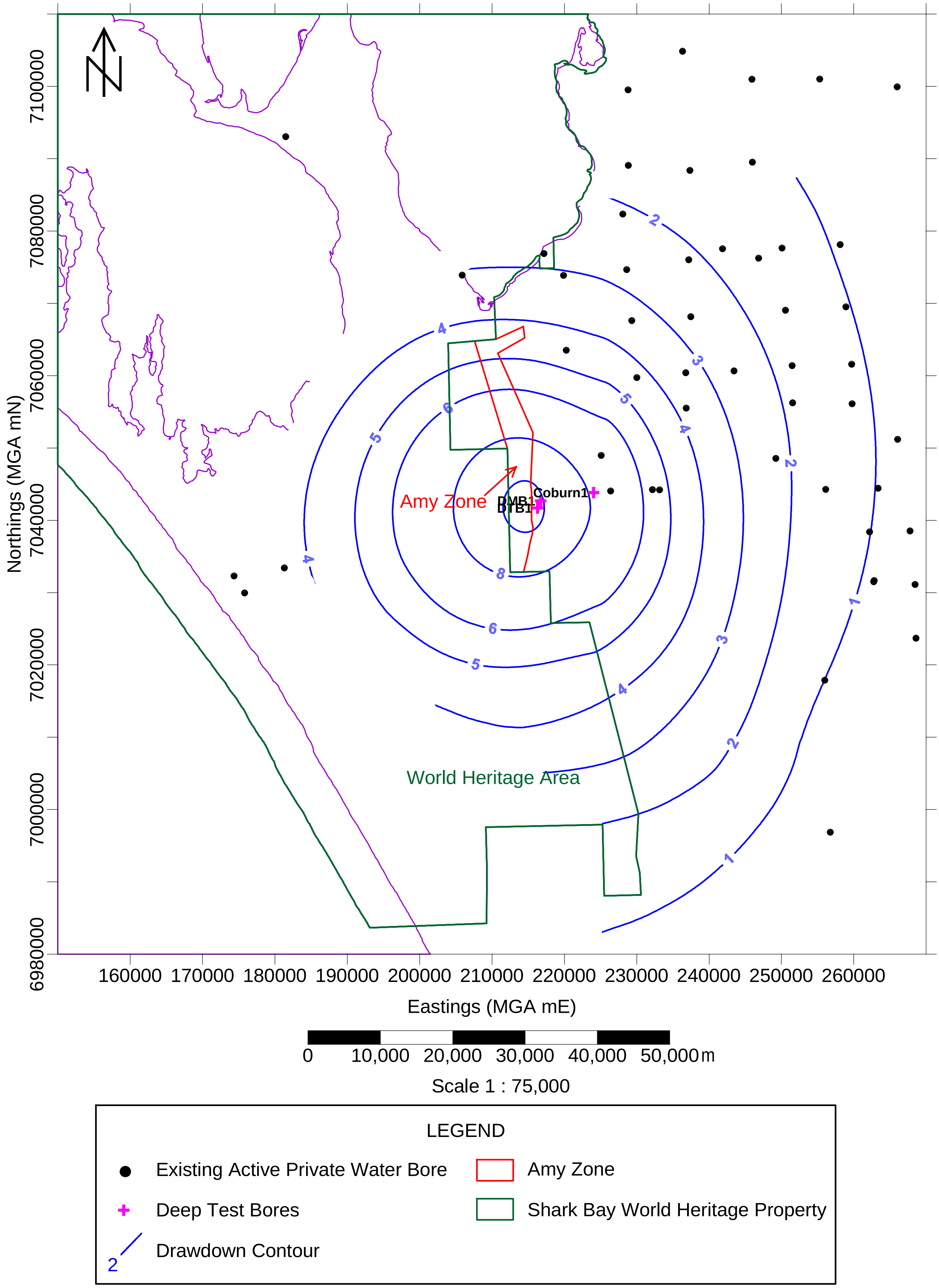


Scale 1 : 75,000

LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

			Gunson Resources Limited	Figure 63c
Job No.	42905541		GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Prep. By	ECPL	1 Apr '05	**Predicted Drawdowns in Windalia Sand Member After 5 Years Of 11 GL/annum Abstraction**	
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.		0

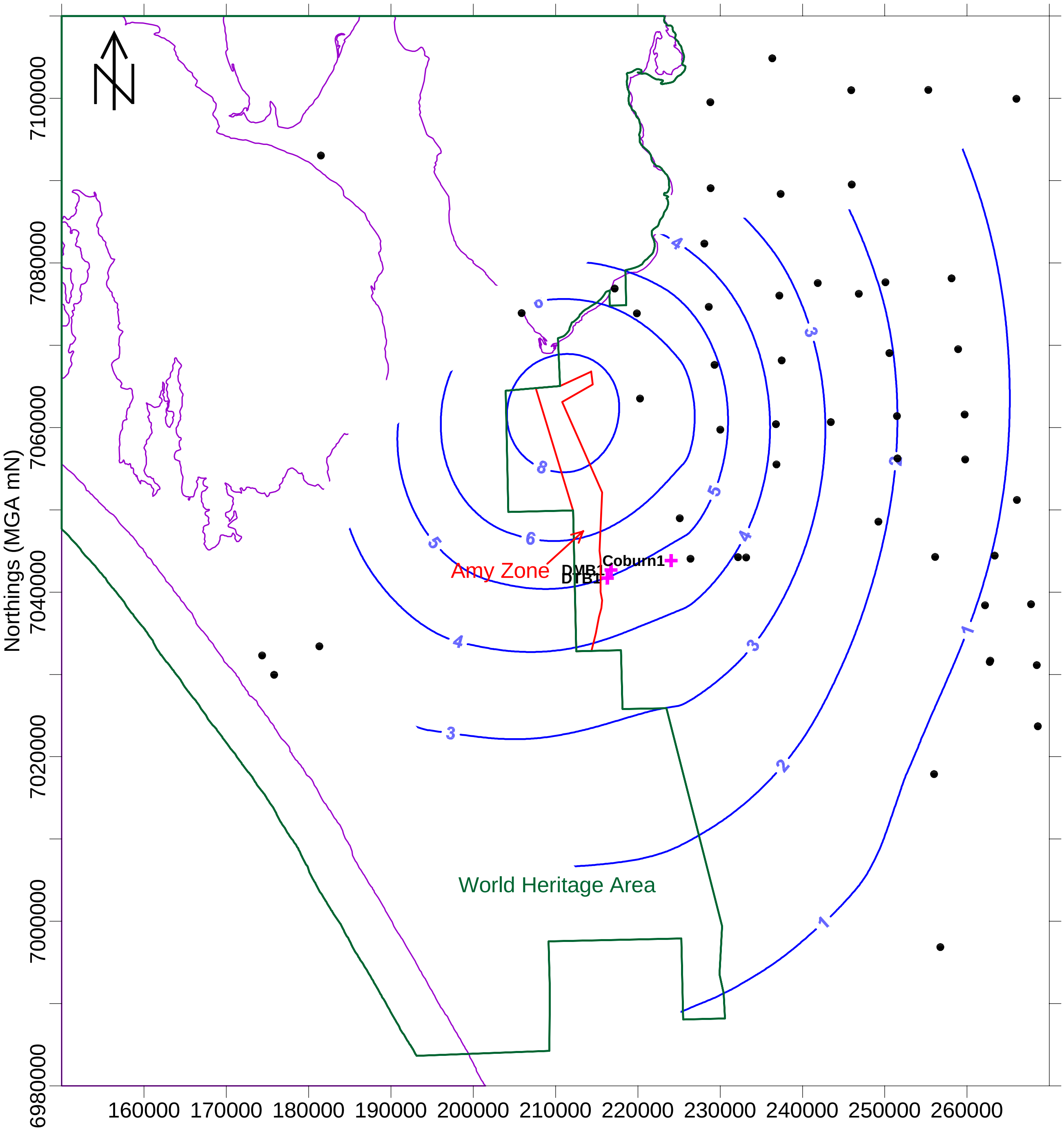
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 10 Years Of 11 GL/annum Abstraction

Figure 63d

URS



0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.		0

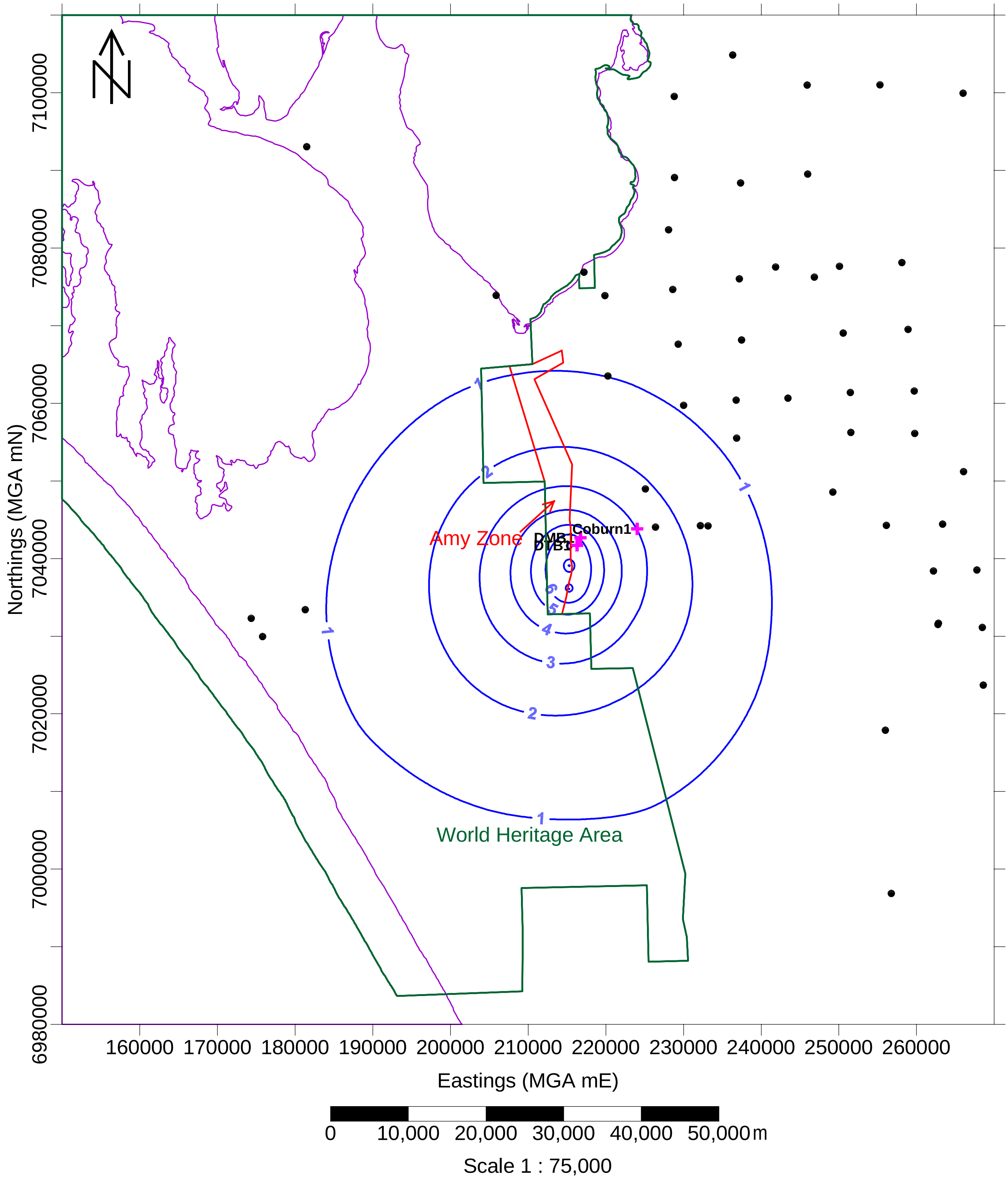
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 20 Years Of 11 GL/annum Abstraction

Figure 63e

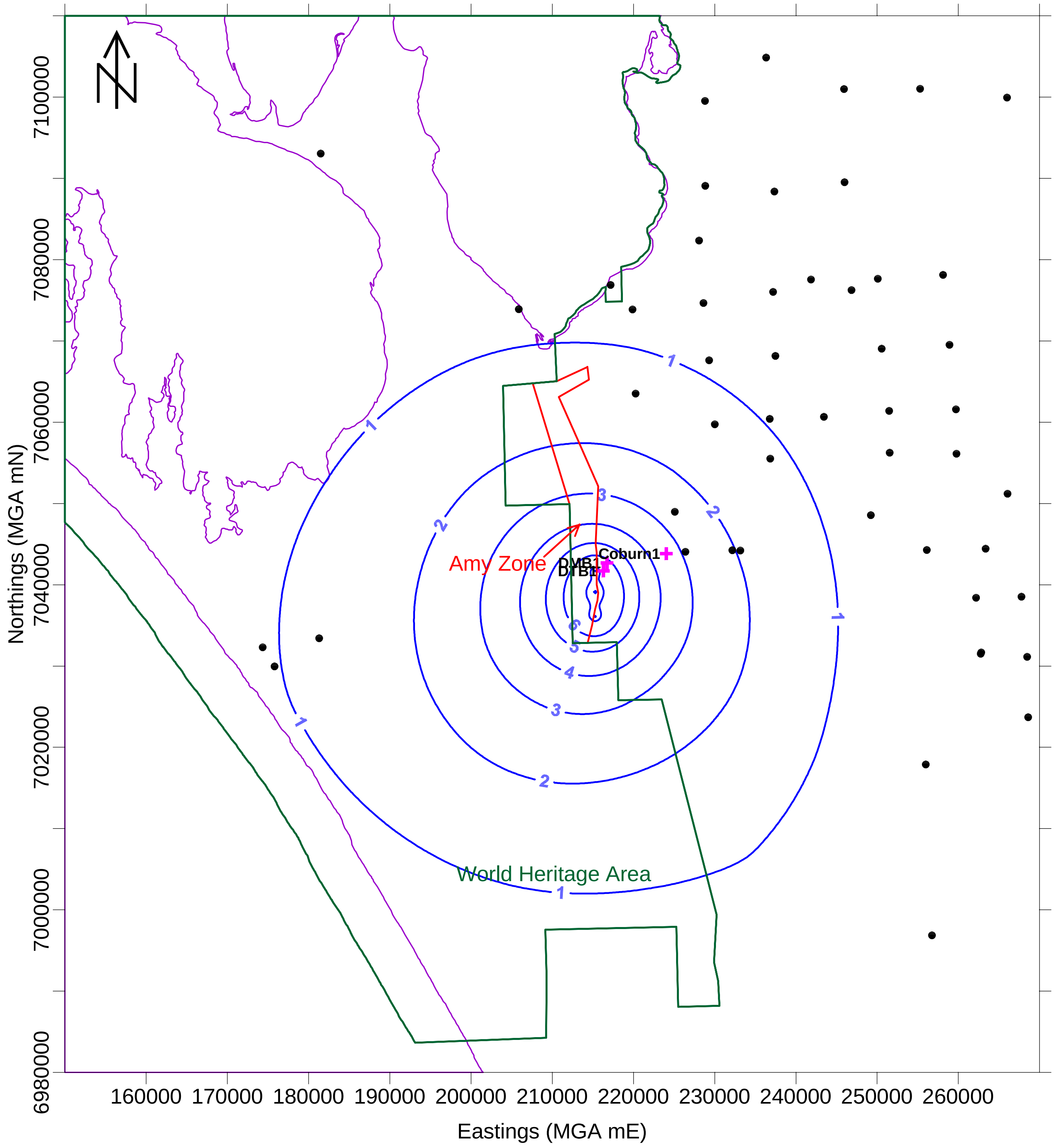
URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 64a
Prep. By	ECPL	1 Apr '05	**Predicted Drawdowns in Birdrong Sandstone After 1 Year Of 11 GL/annum Abstraction**	URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

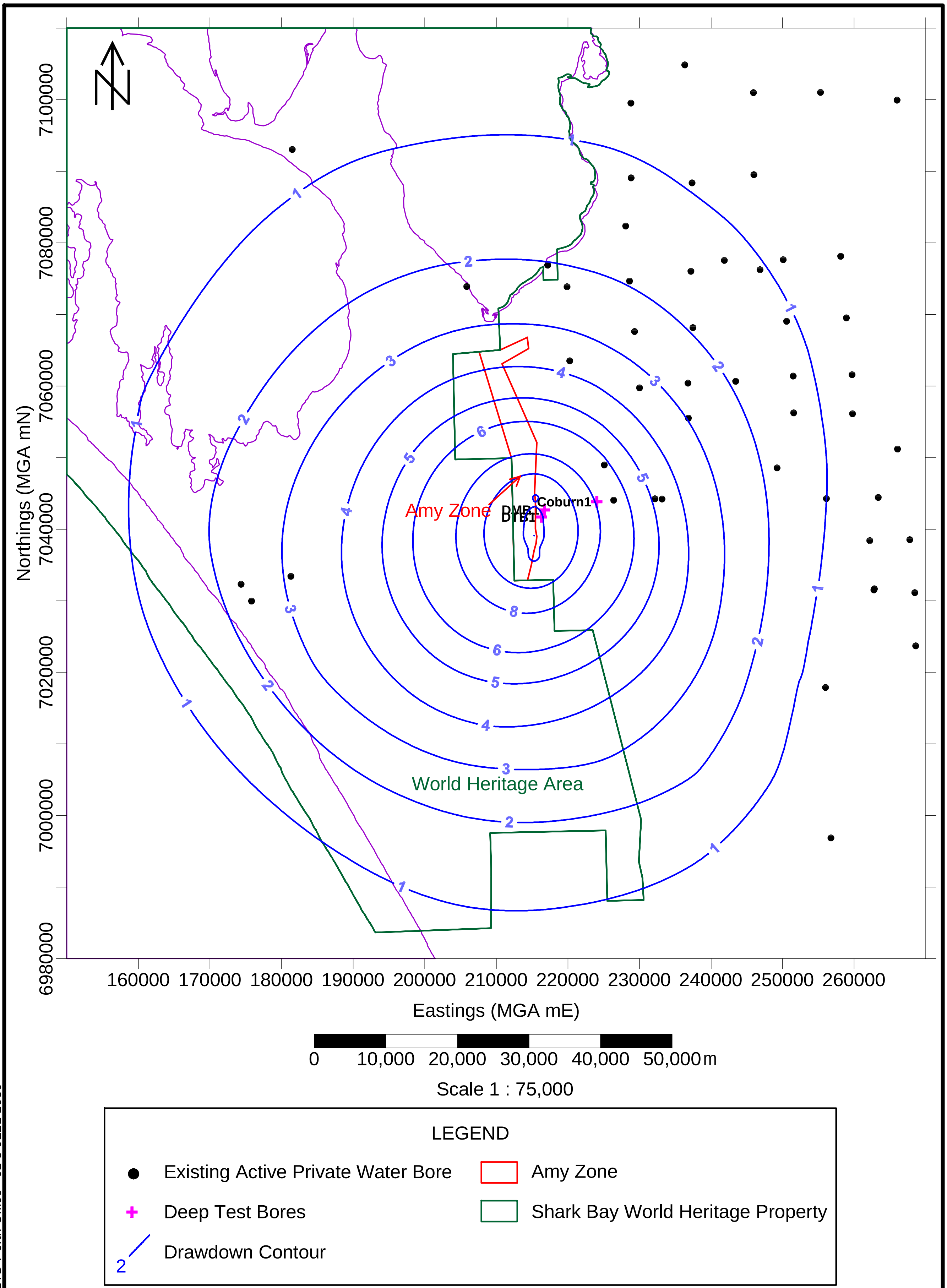
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

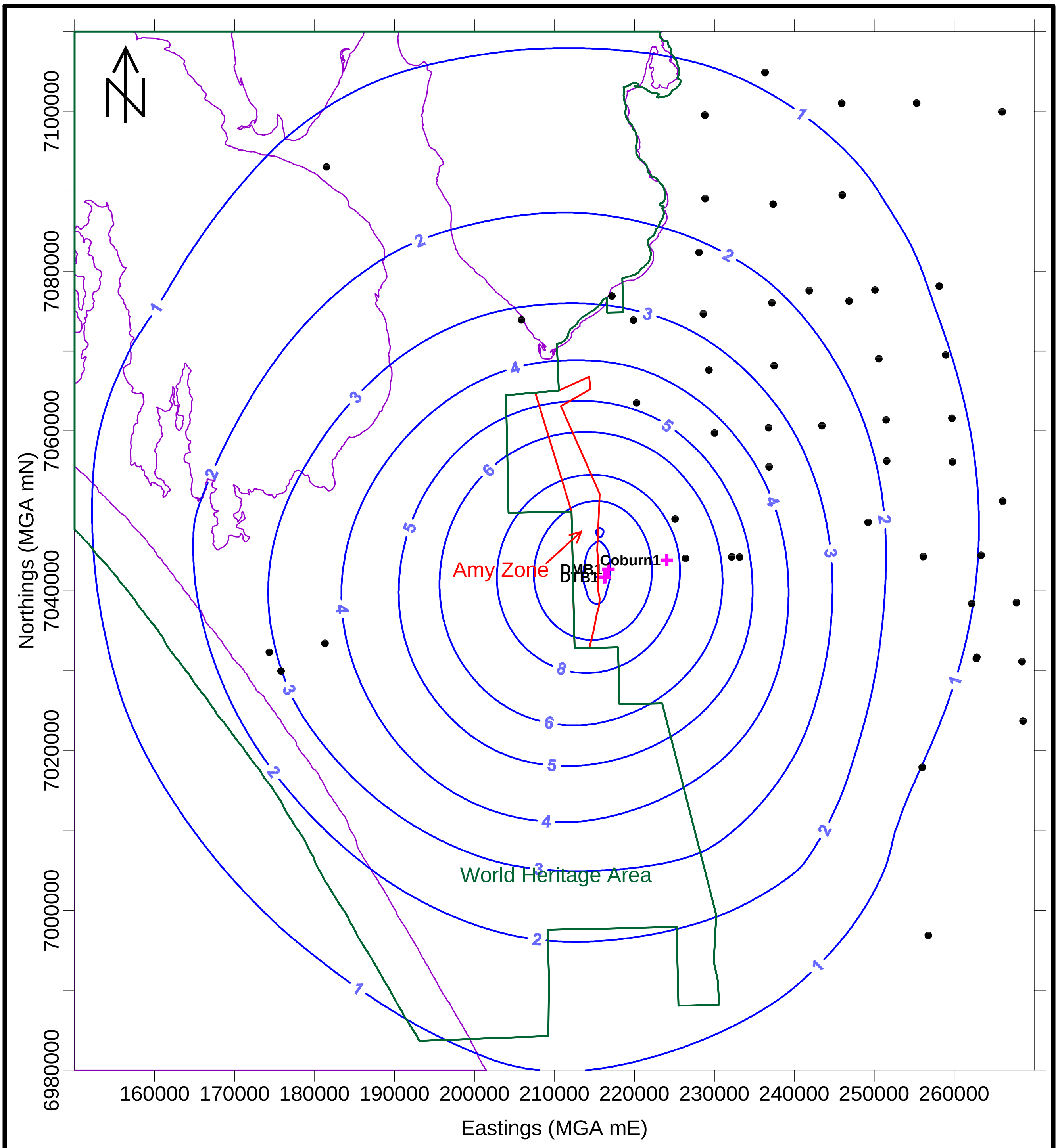
Predicted Drawdowns in Birdrong Sandstone After 2 Years Of 11 GL/annum Abstraction

Figure 64b

URS



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	Figure 64c
Prep. By	ECPL	1 Apr '05	**Predicted Drawdowns in Birdrong Sandstone After 5 Years Of 11 GL/annum Abstraction**	URS
Chk'd By	RWC	1 Apr '05		
Revision No.	0			



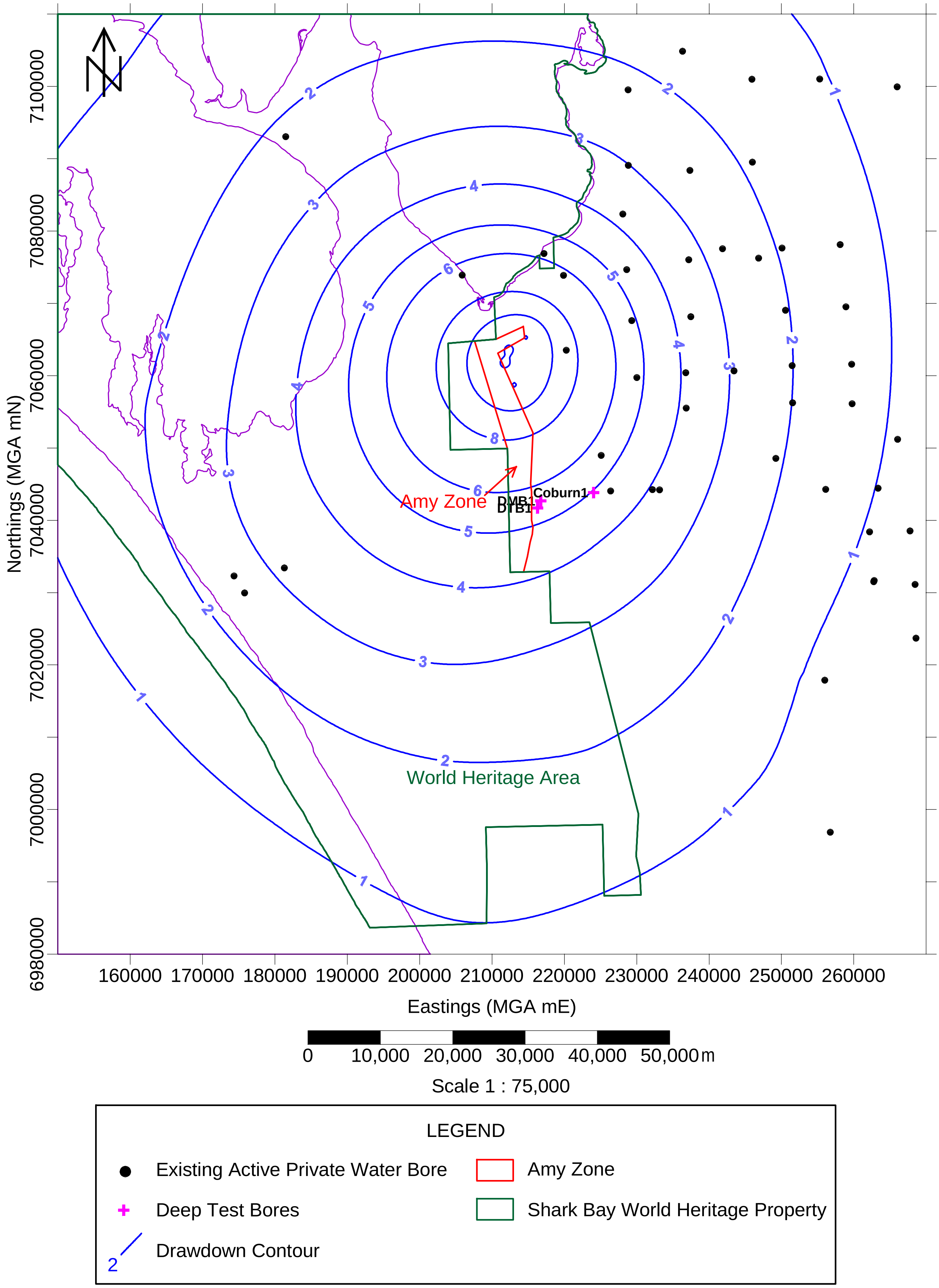
0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

LEGEND

● Existing Active Private Water Bore	Amy Zone
✚ Deep Test Bores	Shark Bay World Heritage Property
2 Drawdown Contour	

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Birdrong Sandstone After 10 Years Of 11 GL/annum Abstraction**	**Figure 64d**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

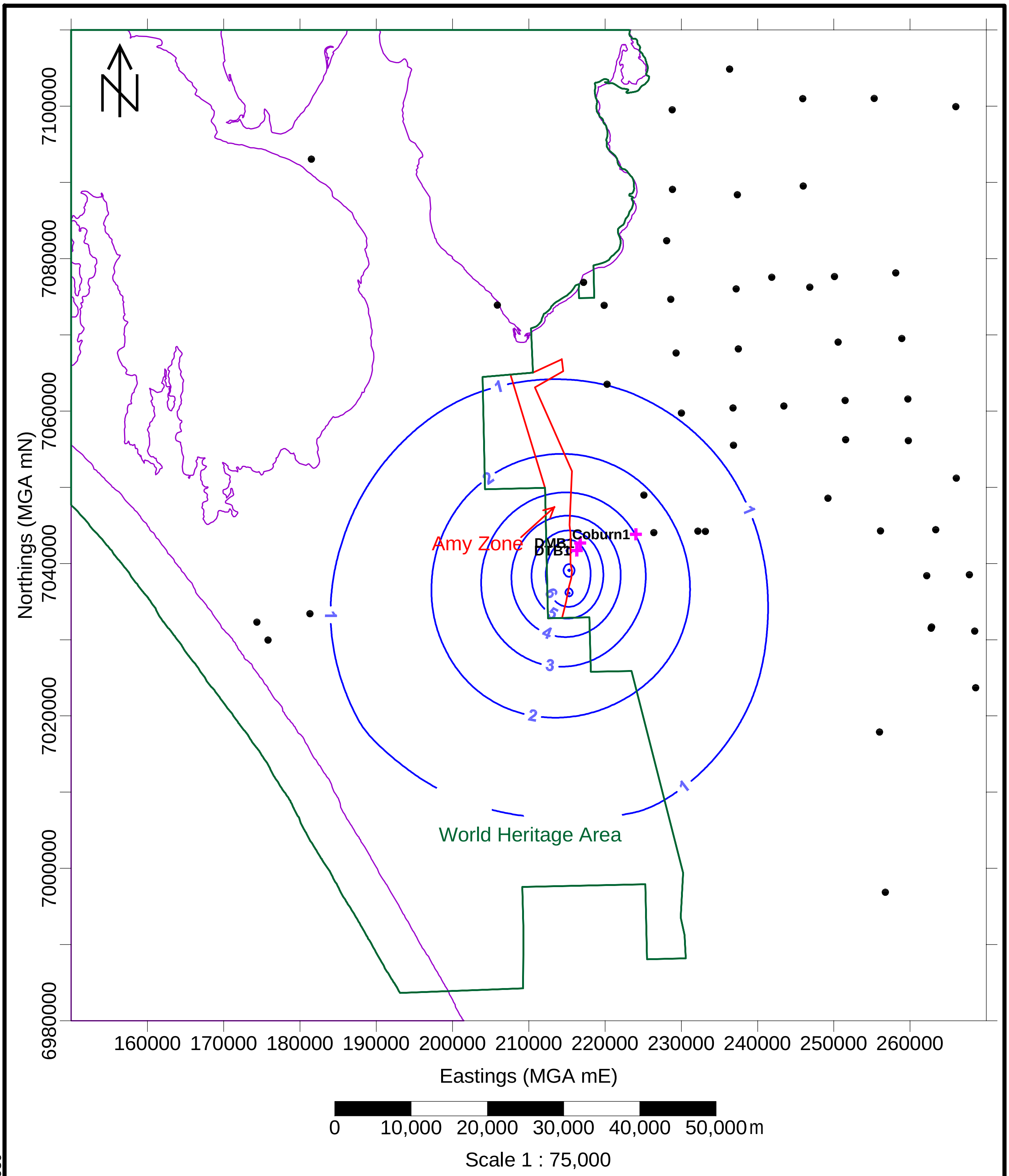
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Birdrong Sandstone After 20 Years Of 11 GL/annum Abstraction

Figure 64e

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Kopke Sandstone After 1 Year Of 11 GL/annum Abstraction

Figure 65a

URS

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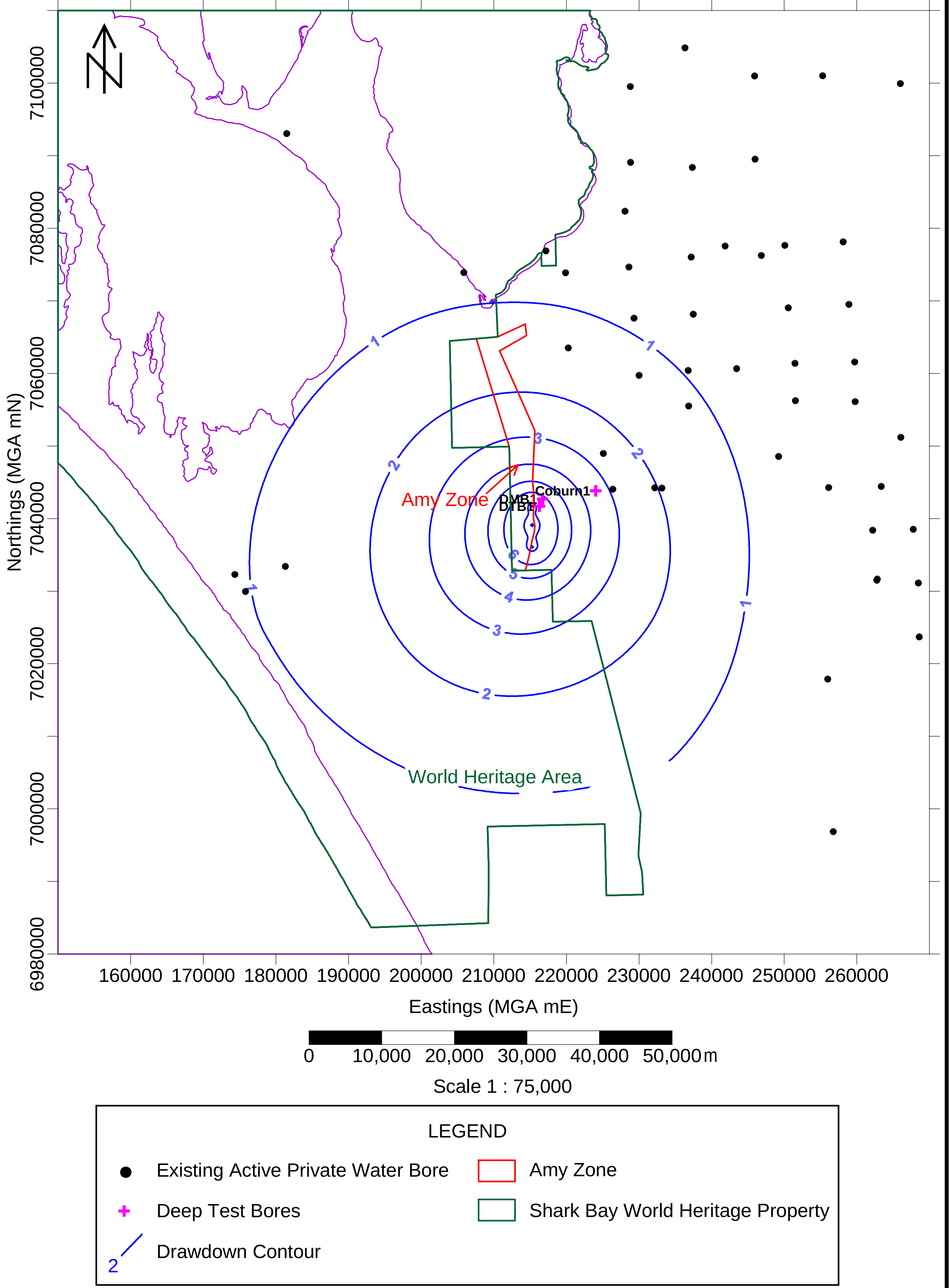
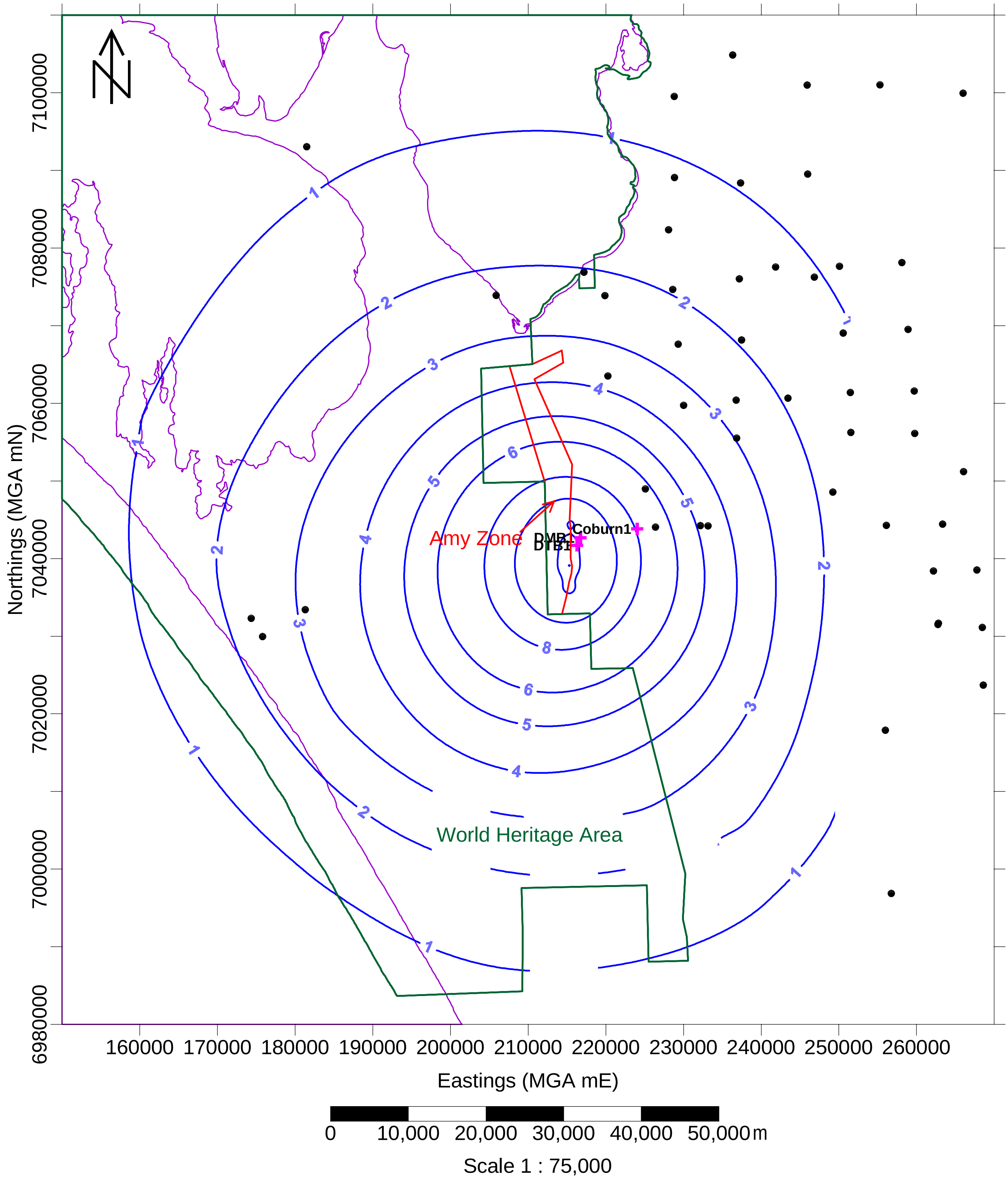


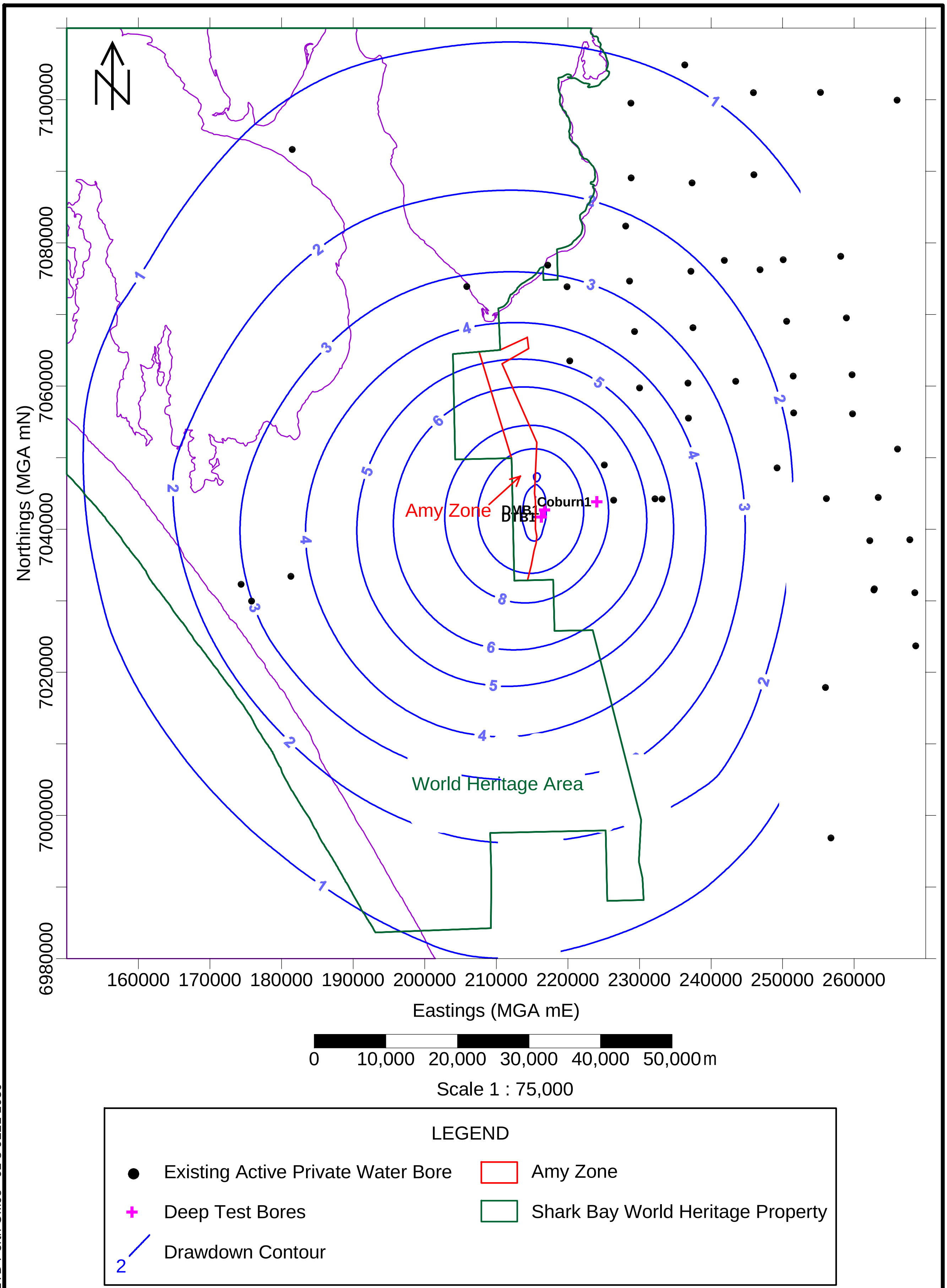
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 2 Years Of 11 GL/annum Abstraction**	**Figure 65b**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 5 Years Of 11 GL/annum Abstraction**	**Figure 65c**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.	0			



Job No.	42905541		Gunson Resources Limited	Figure 65d
Prep. By	ECPL	1 Apr '05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Chk'd By	RWC	1 Apr '05	**Predicted Drawdowns in Kopke Sandstone After 10 Years Of 11 GL/annum Abstraction**	
Revision No.	0			

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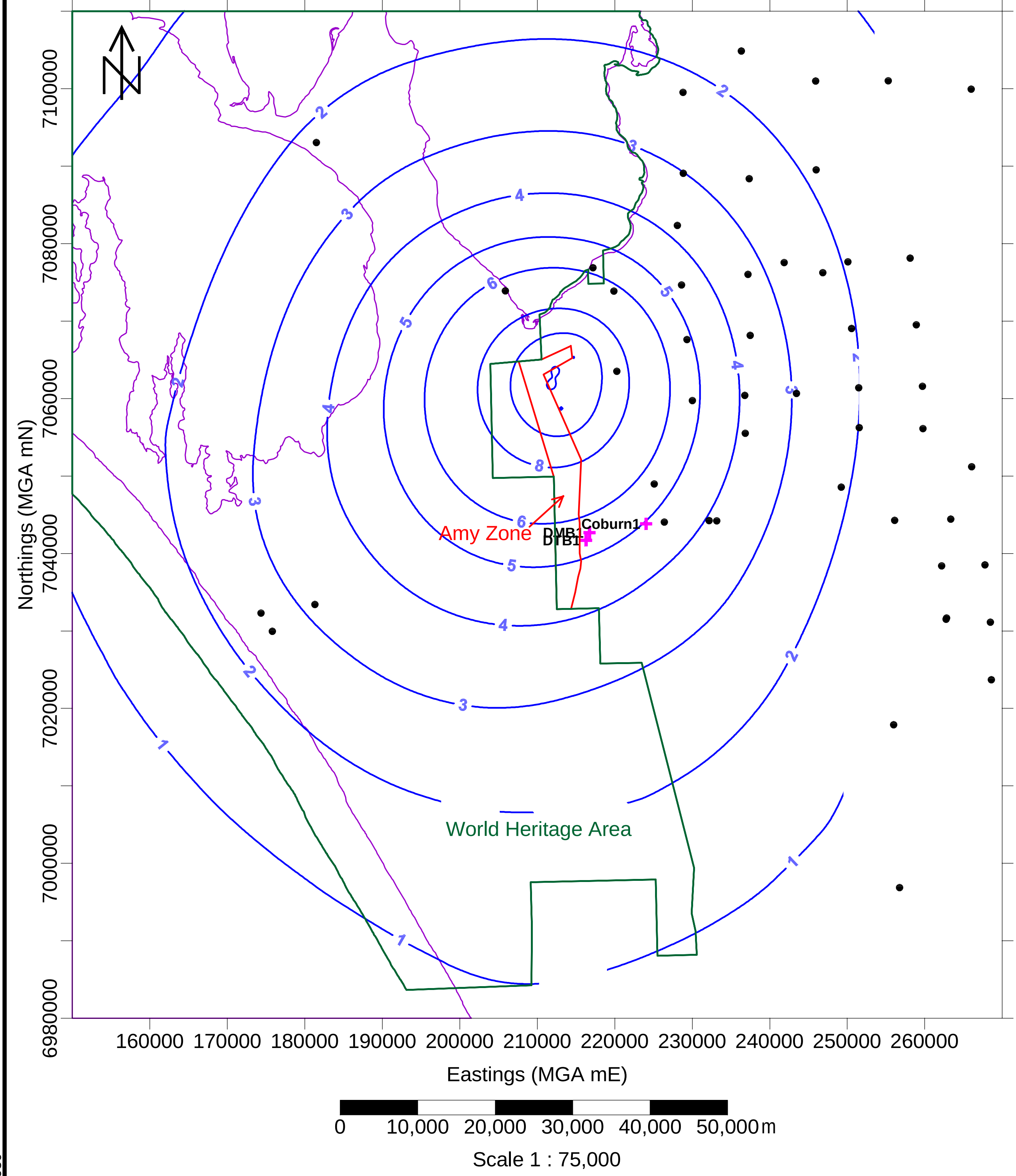


Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

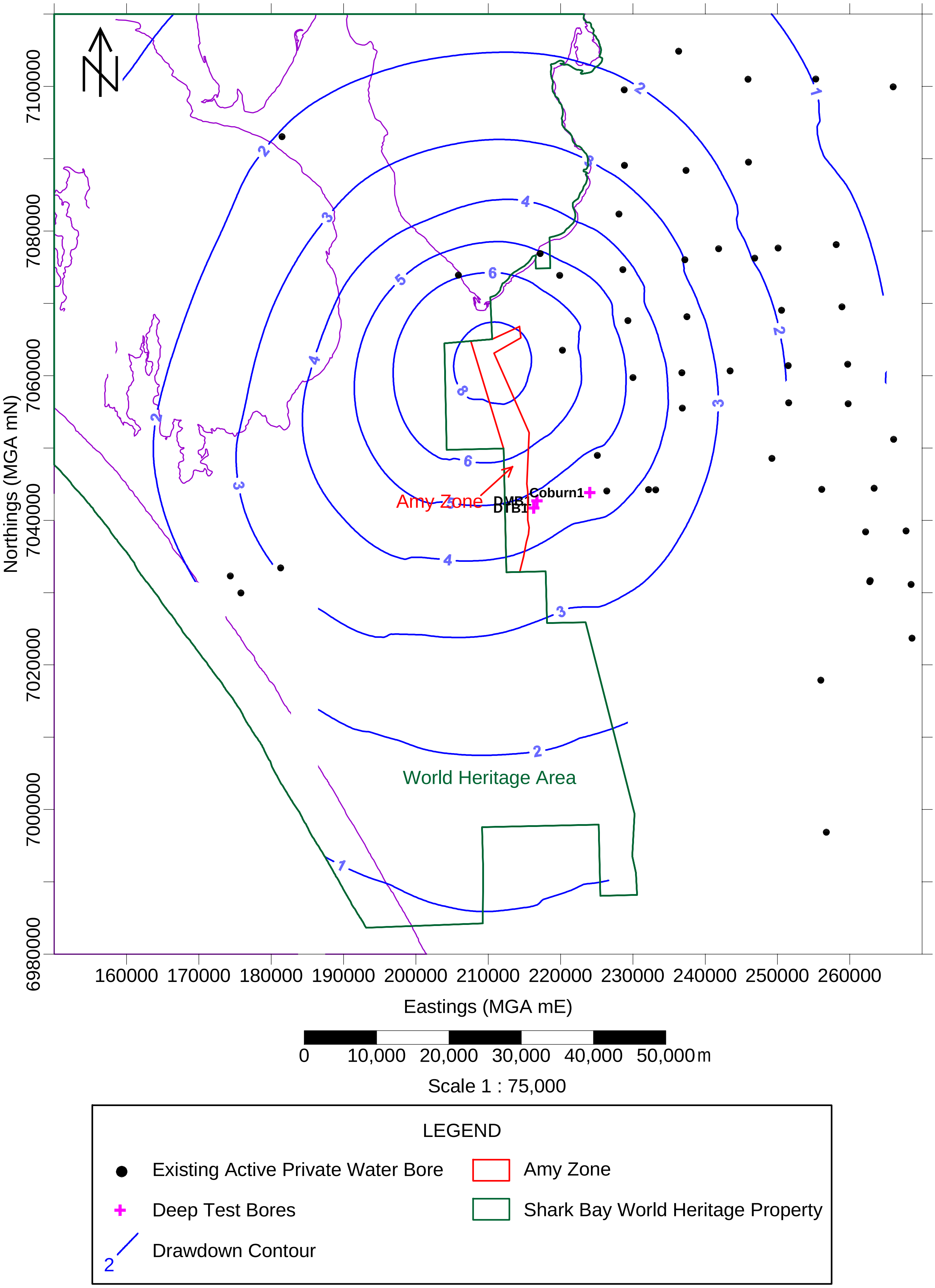
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Kopke Sandstone After 20 Years Of 11 GL/annum Abstraction

Figure 65e

URS



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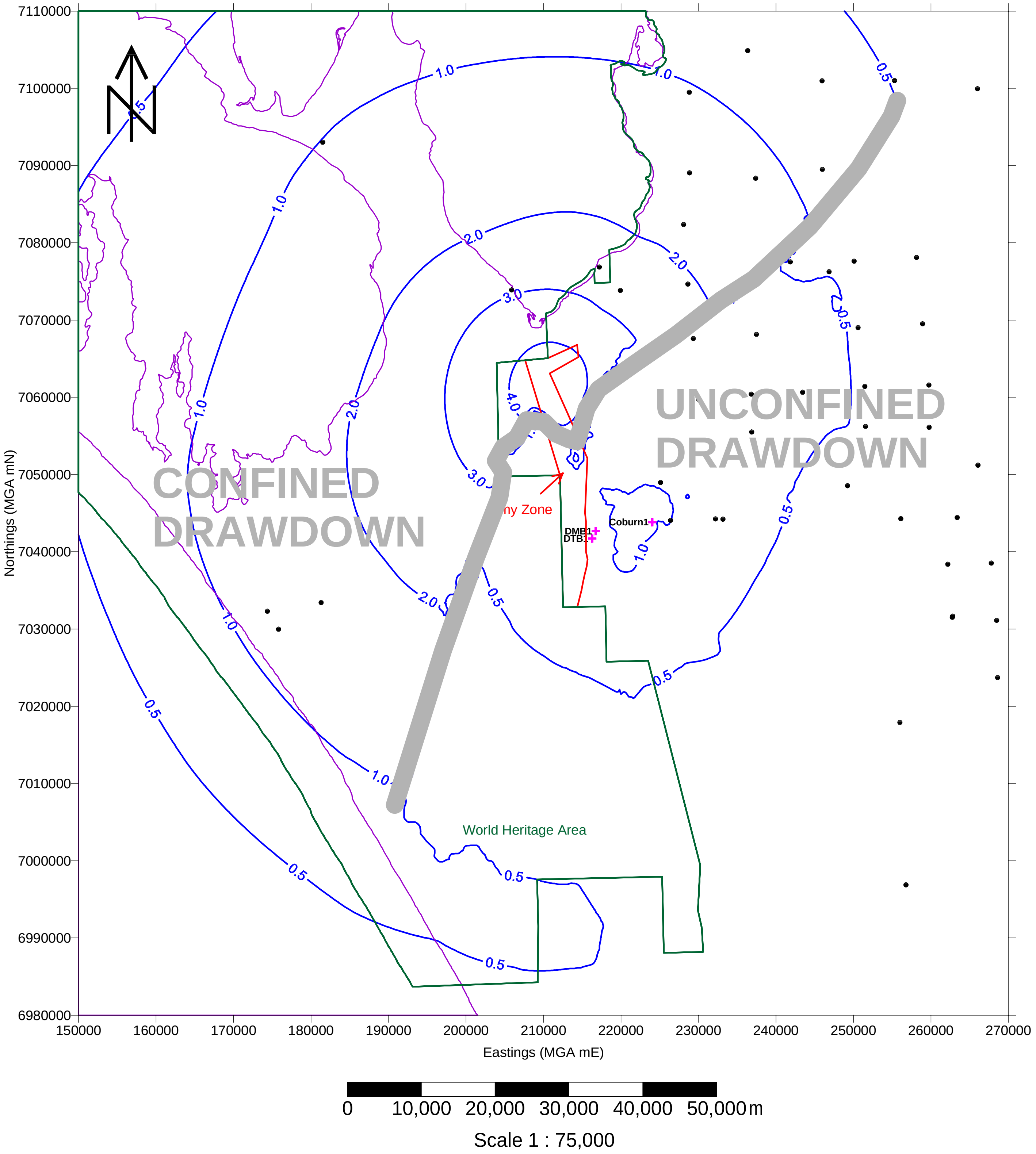
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Alinga Formation After 20 Years Of 11 GL/annum Abstraction**	**Figure 66a**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	RBW	7 Mar '05
Chk'd By	RBW	7 Mar '05
Revision Indicator	0	

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Toolonga Calcilutite After 20 Years of 11 GL/annum Abstraction

Figure 66b

URS

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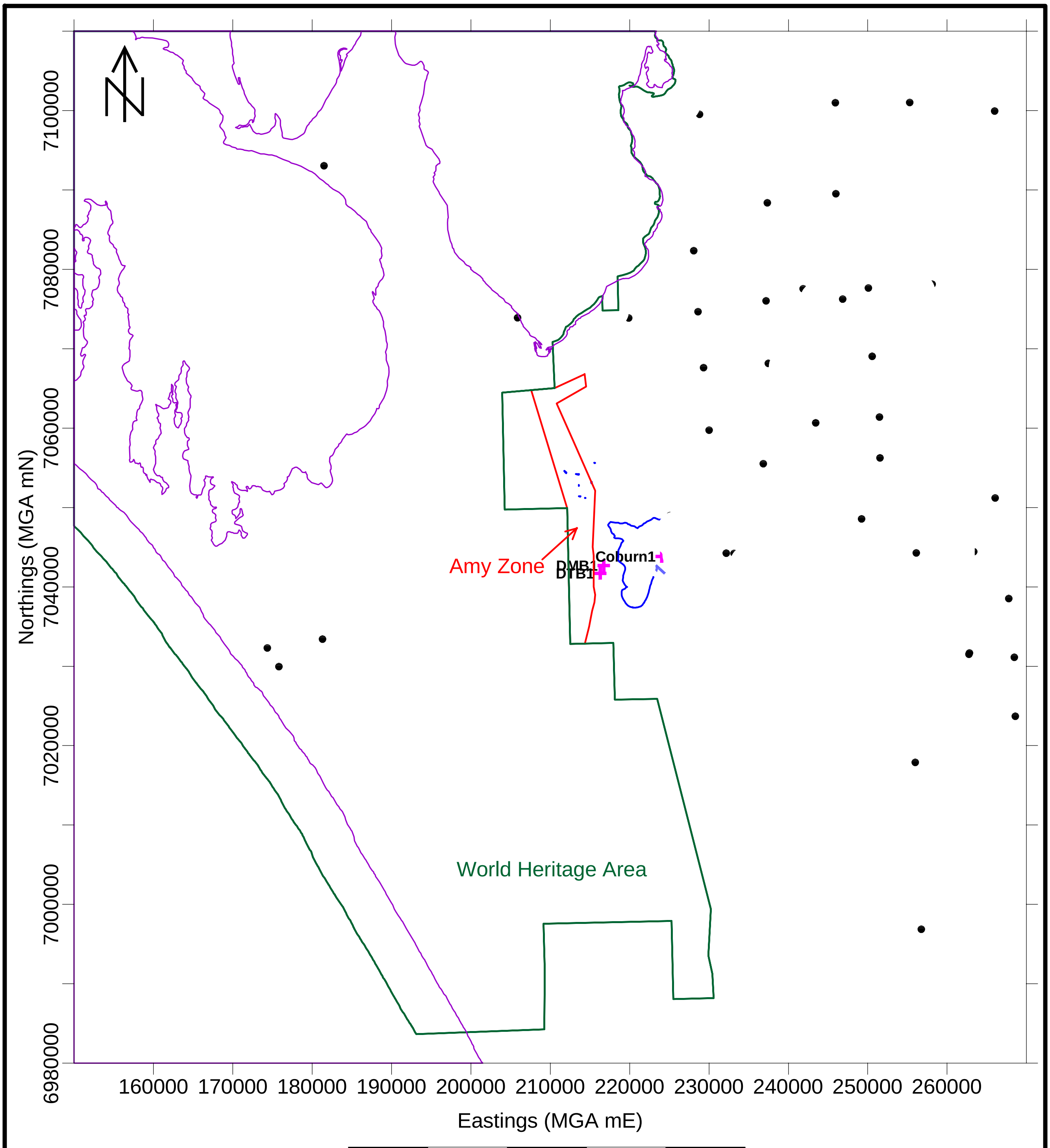


LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

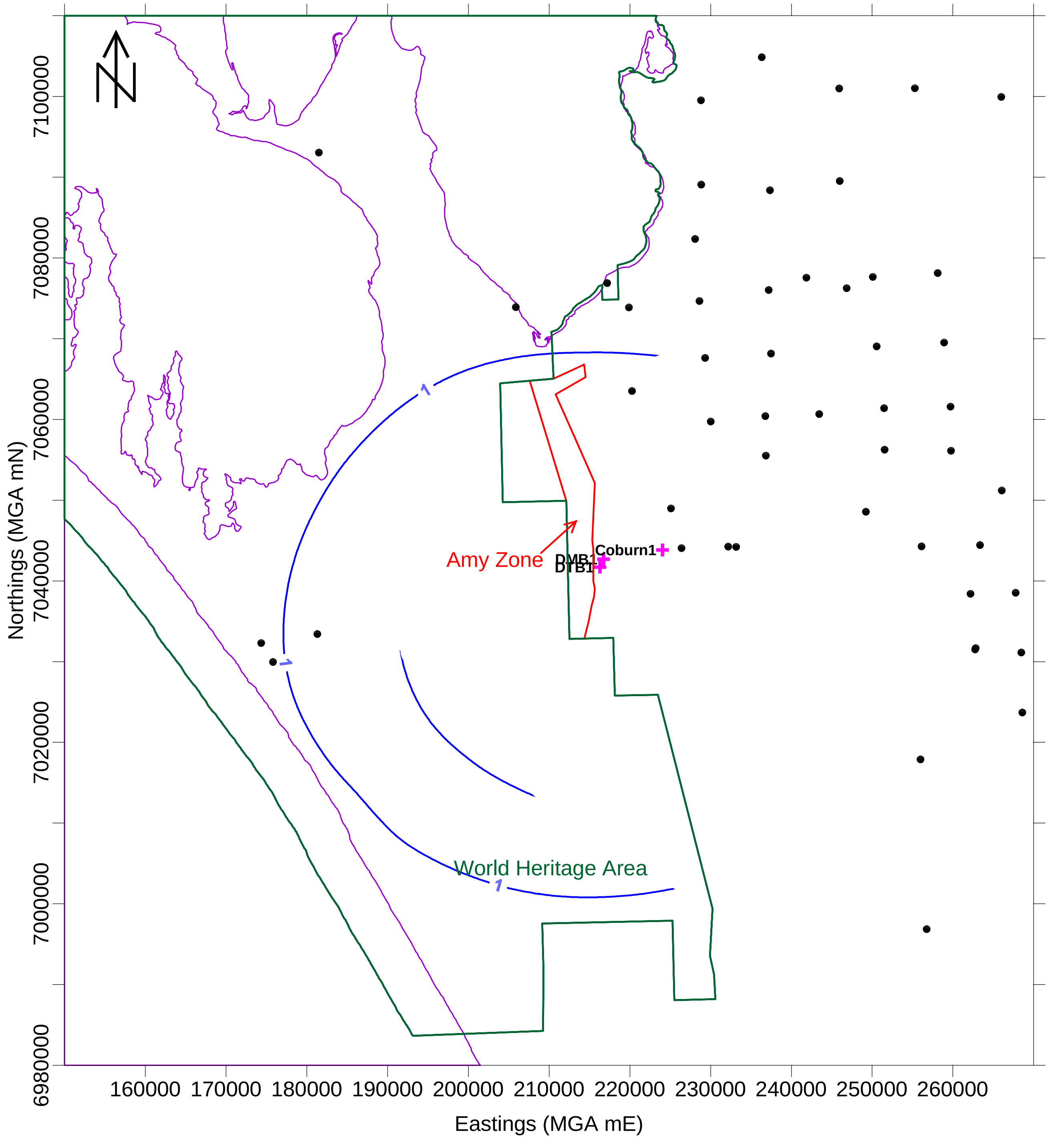
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in the Superficial Formations After 20 Years Of 11 GL/annum Abstraction

Figure 66c

URS



LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

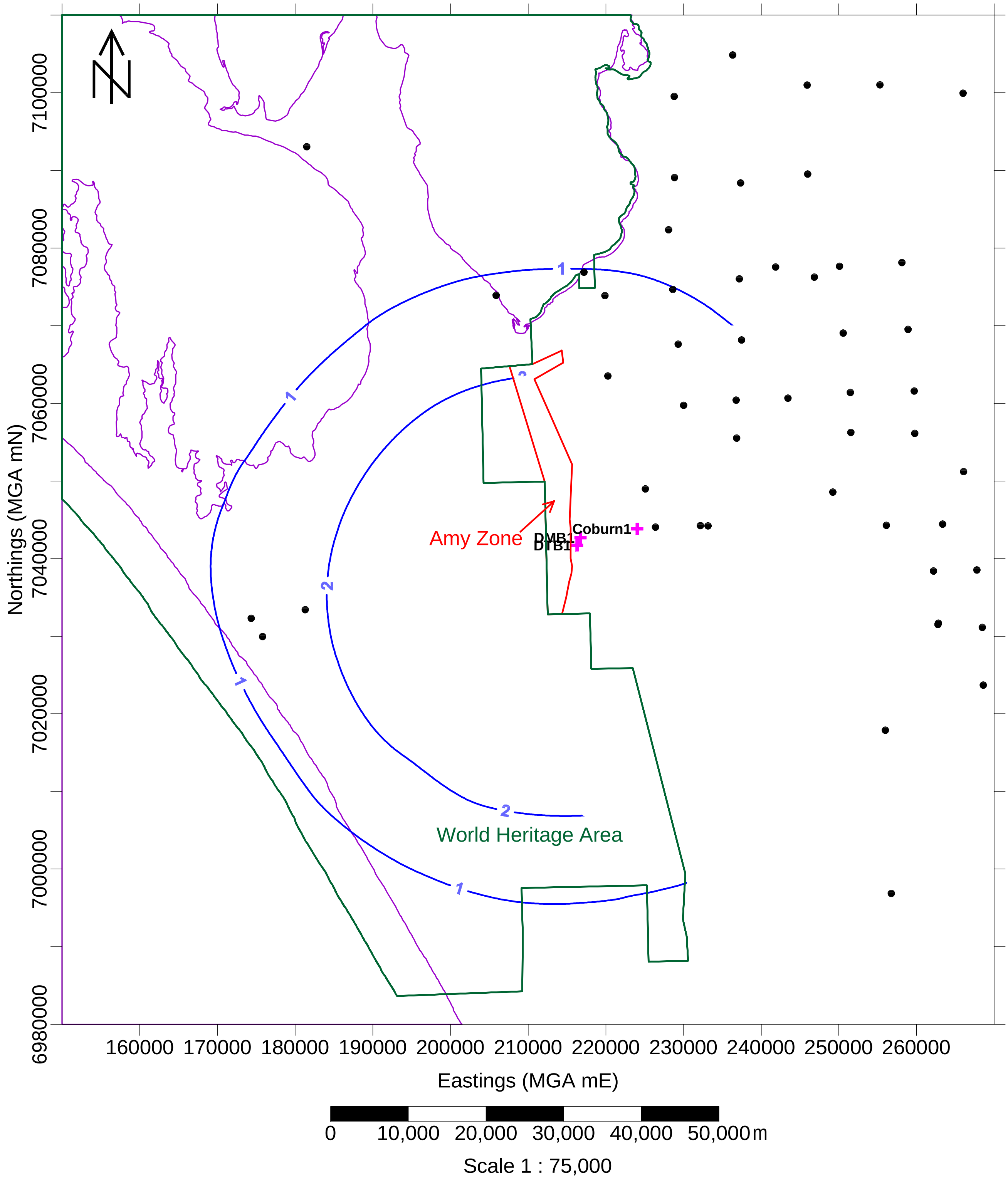
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Radiolarite After 1 Year Of 15 GL/annum Abstraction

Figure 67a

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

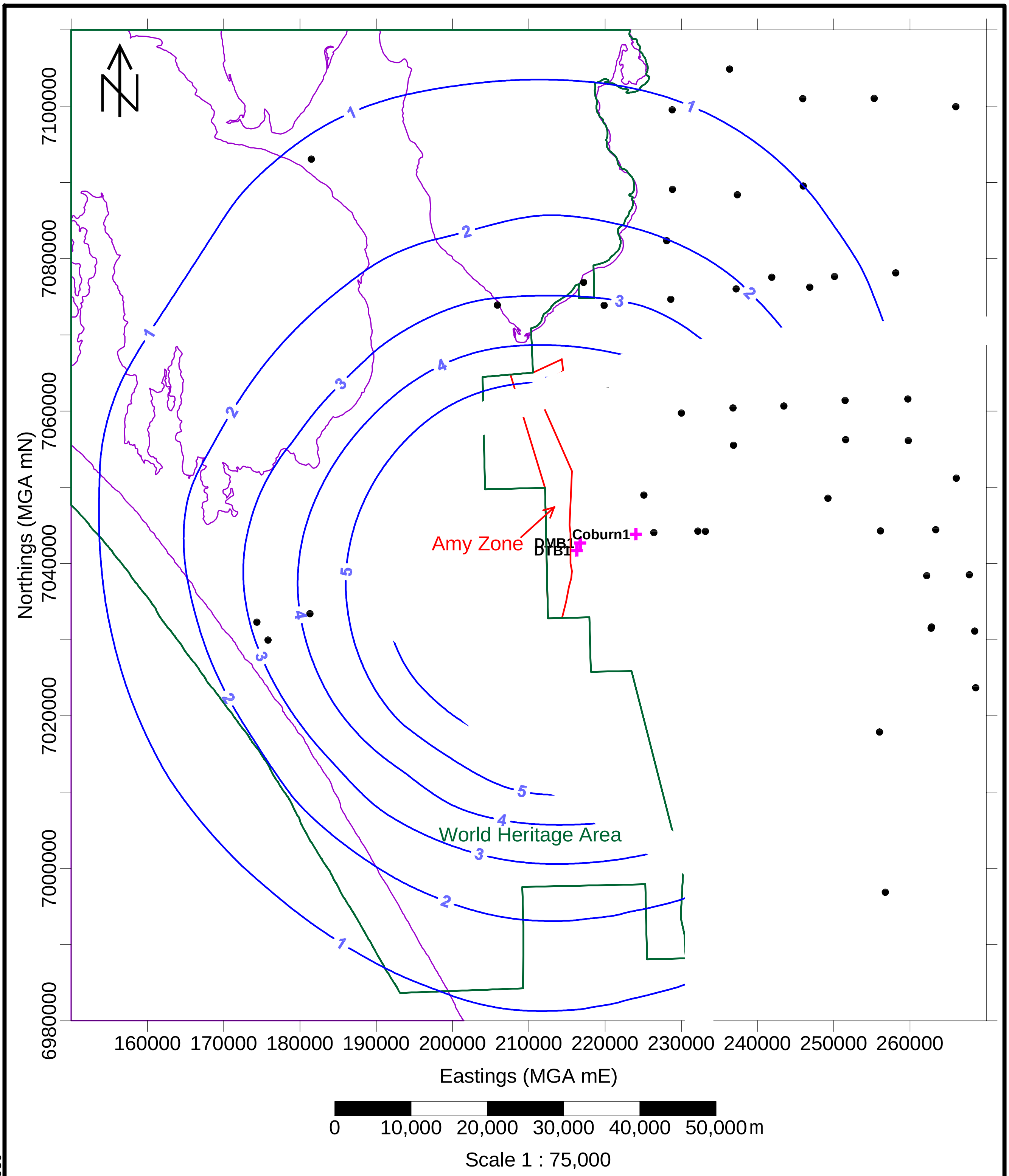
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Radiolarite After 2 Years Of 15 GL/annum Abstraction

Figure 67b

URS



LEGEND

- ● Existing Active Private Water Bore
- + Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

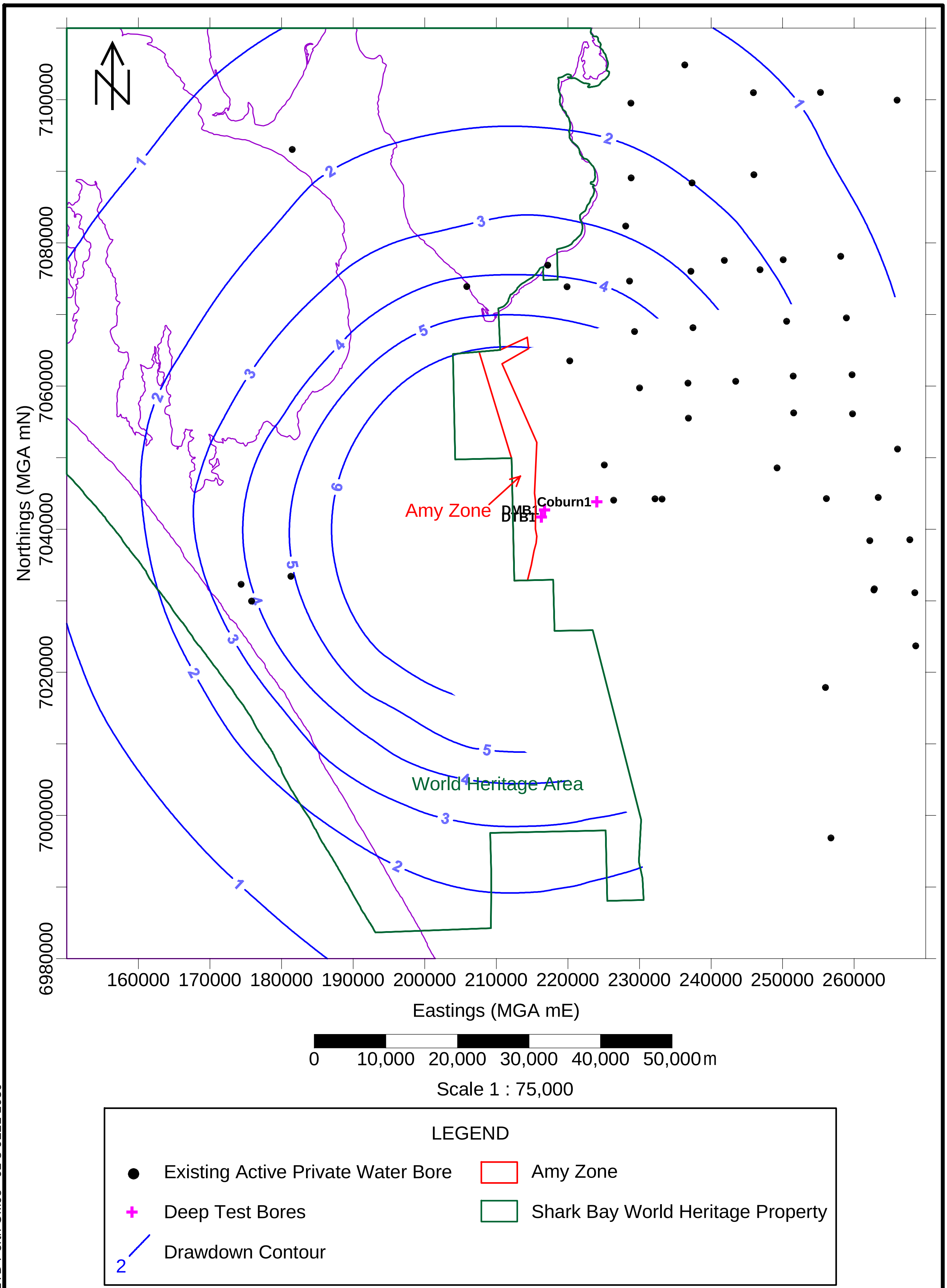
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

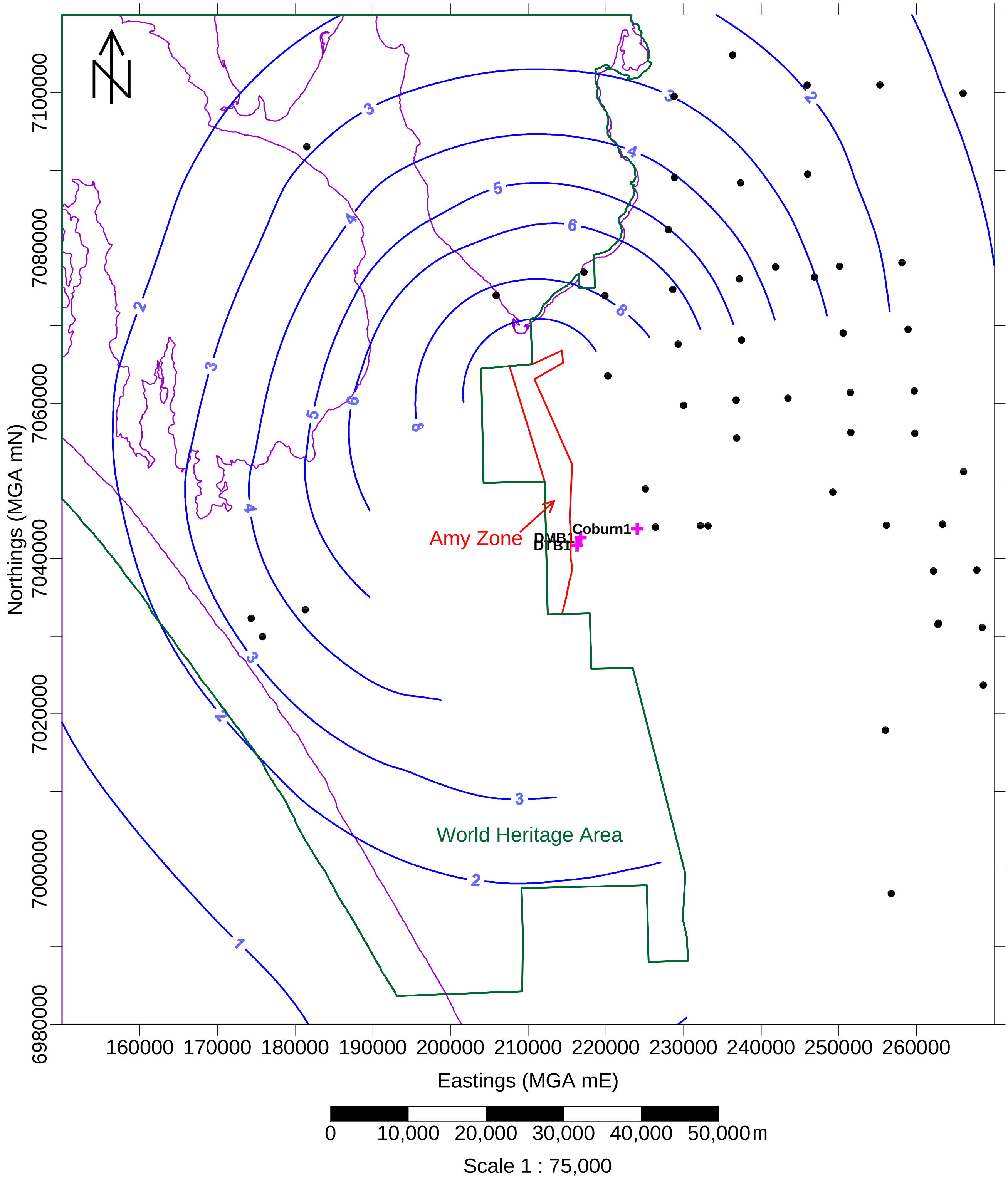
Predicted Drawdowns in Windalia Radiolarite After 5 Years Of 15 GL/annum Abstraction

Figure 67c

URS



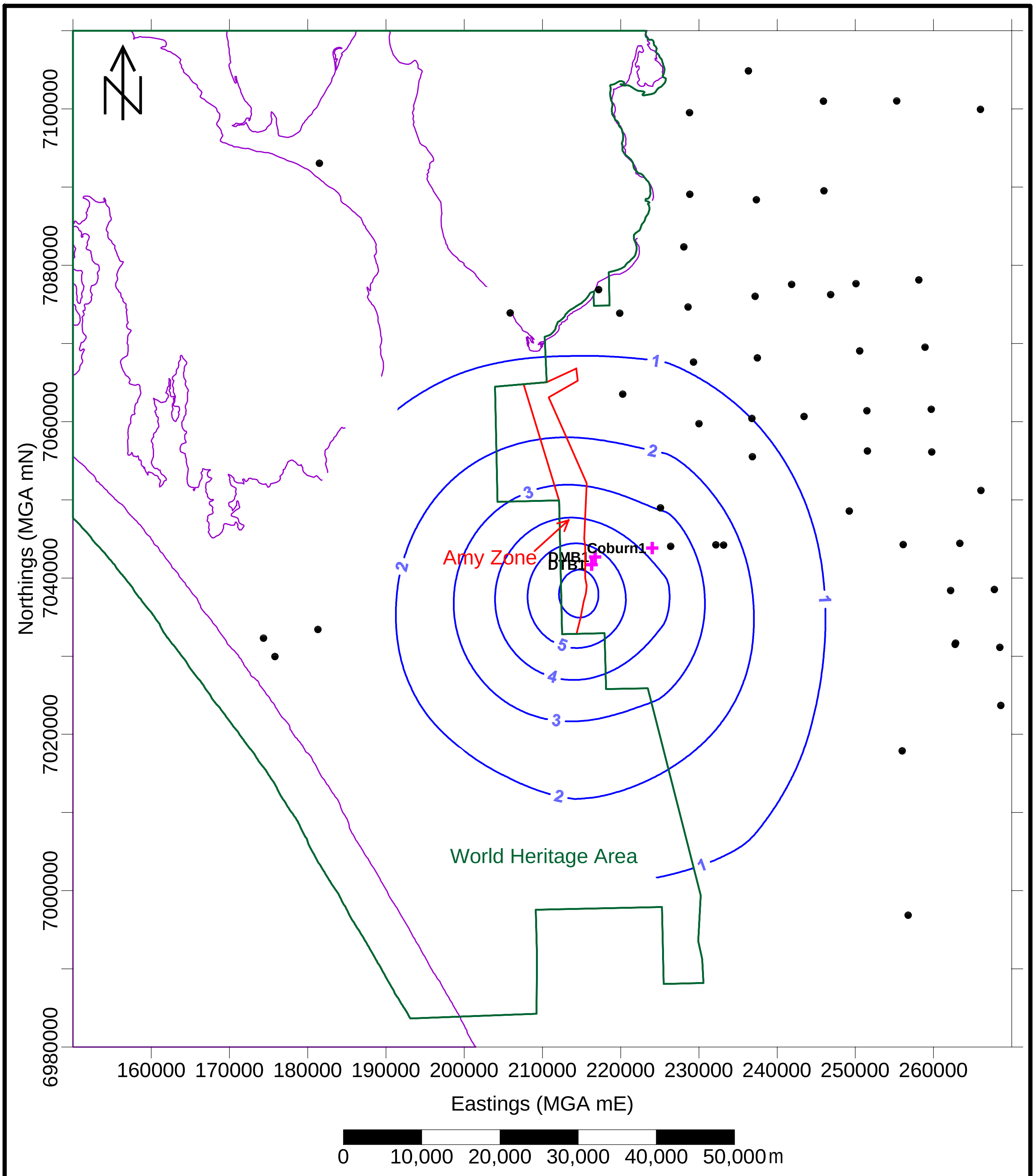
Job No.	42905541		Gunson Resources Limited	Figure 67d
Prep. By	ECPL	1 Apr '05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	URS
Chk'd By	RWC	1 Apr '05	**Predicted Drawdowns in Windalia Radiolarite After 10 Years Of 15 GL/annum Abstraction**	
Revision No.		0		



LEGEND

● Existing Active Private Water Bore	Amy Zone
Deep Test Bores	Shark Bay World Heritage Property
Drawdown Contour	

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	**Figure 67e**
Prep. By	ECPL	1 Apr '05	**Predicted Drawdowns in Windalia Radiolarite After 20 Years Of 15 GL/annum Abstraction**	URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Windalia Sand Member After 1 Year Of 15 GL/annum Abstraction**	**Figure 68a**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		

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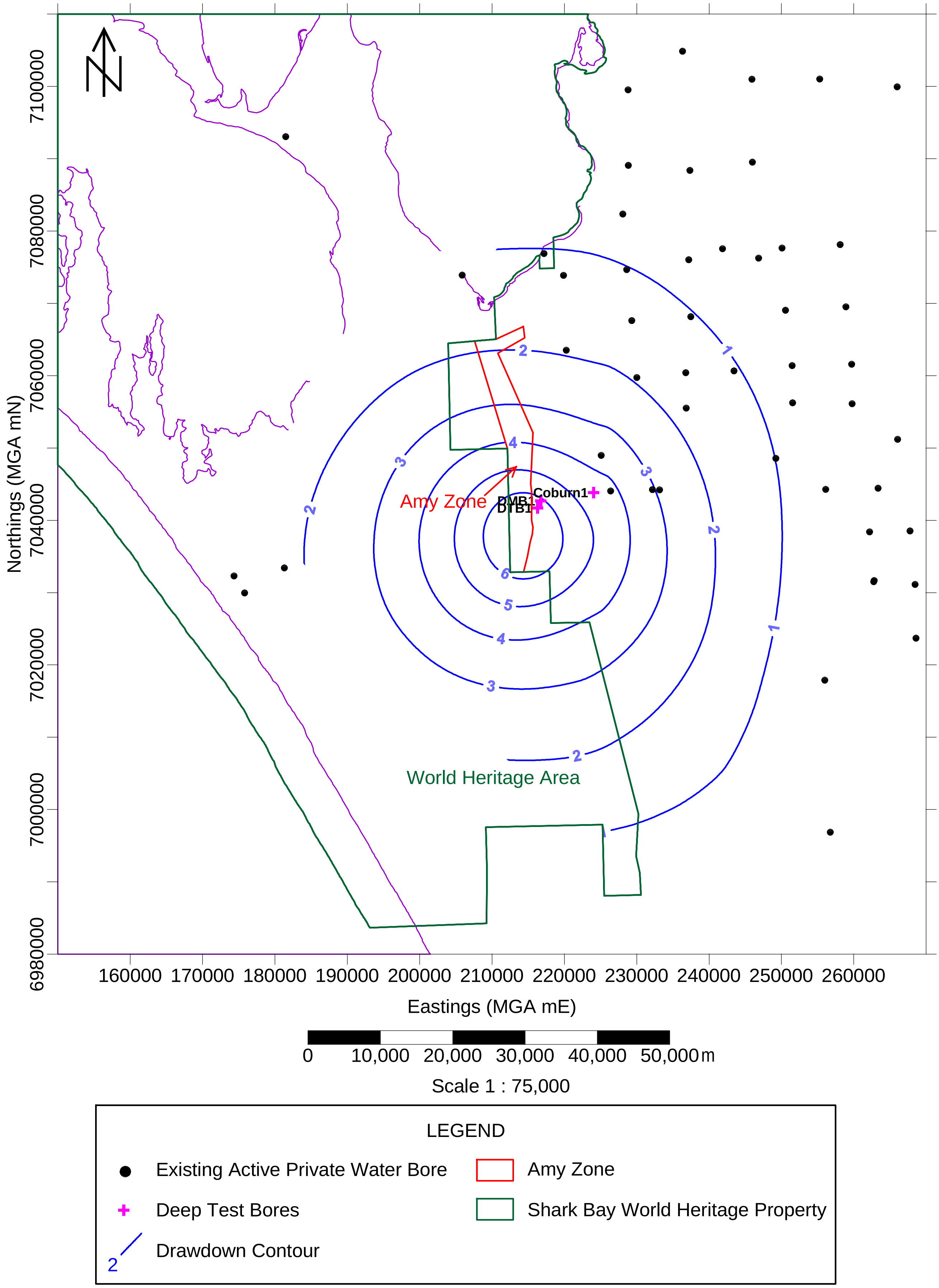


Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

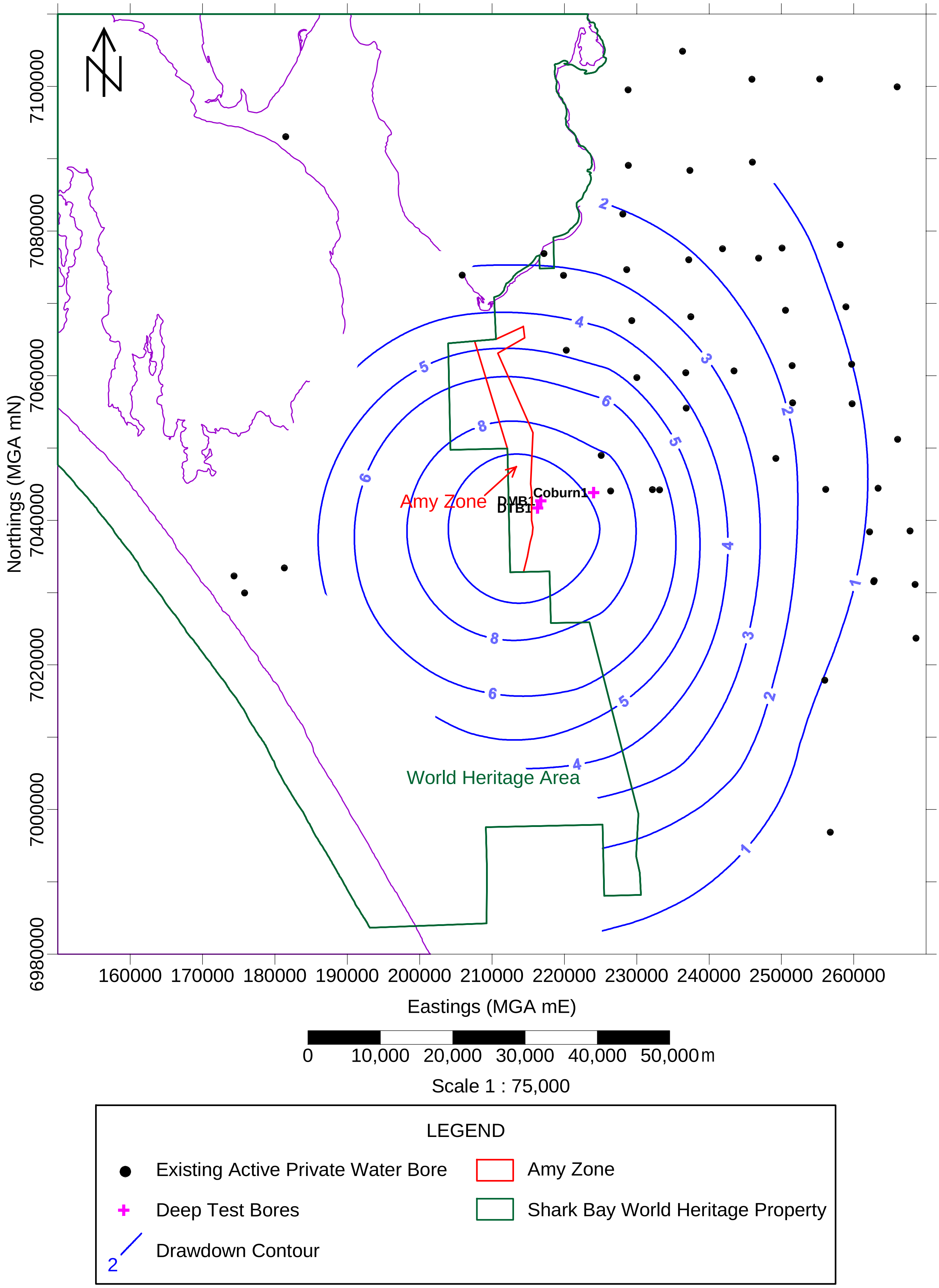
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 2 Years Of 15 GL/annum Abstraction

Figure 68b

URS



Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

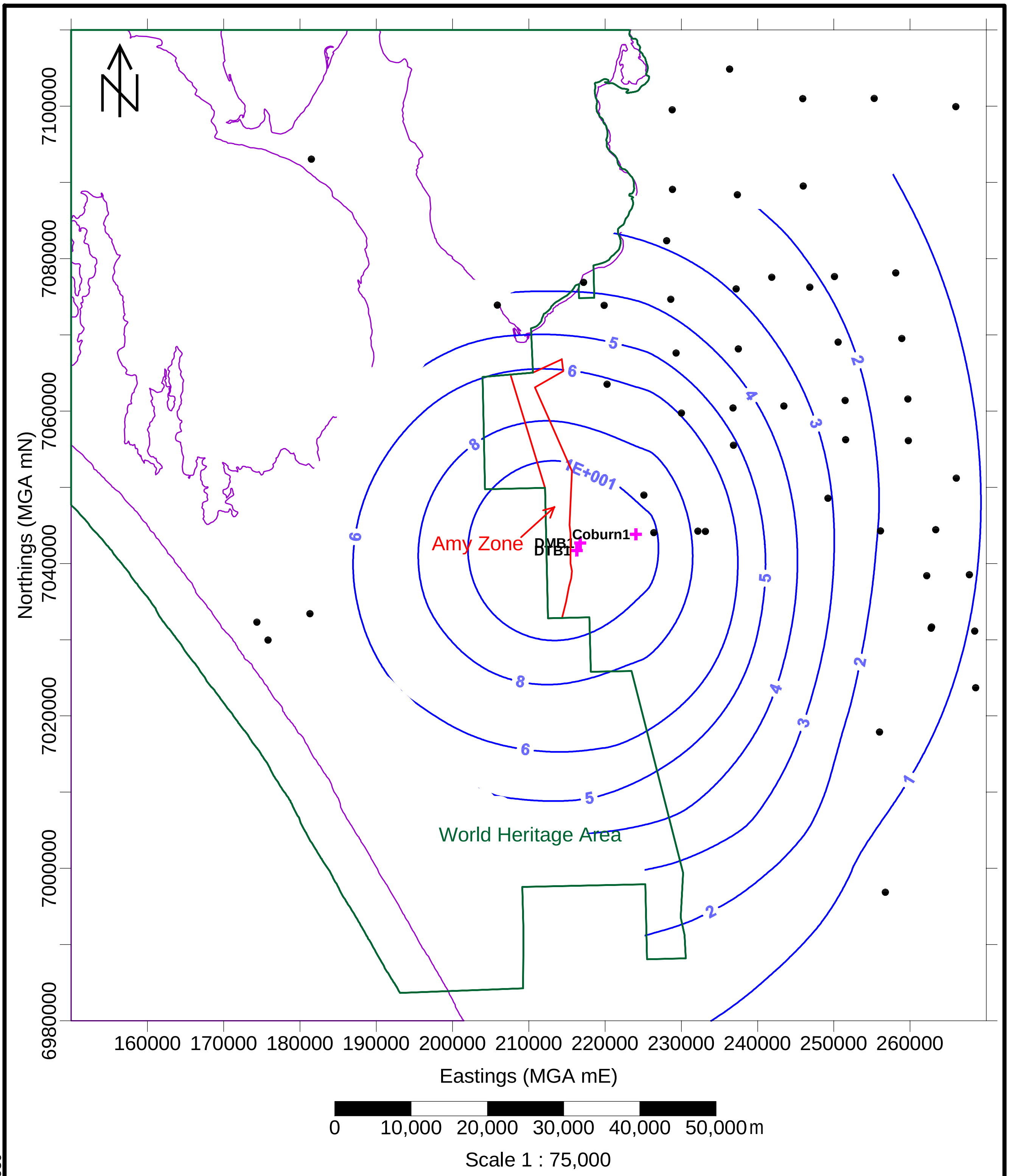
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 5 Years Of 15 GL/annum Abstraction

Figure 68c

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

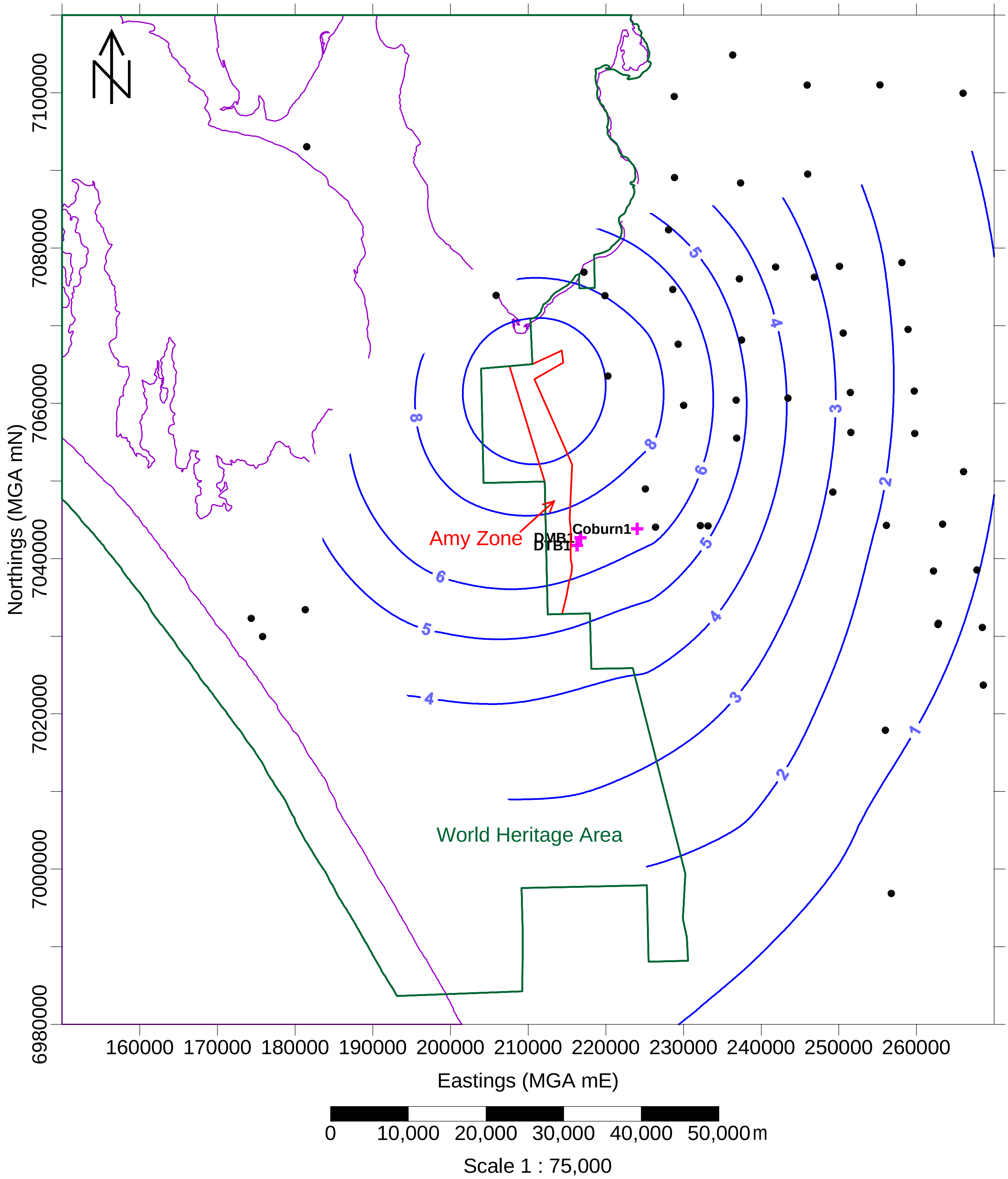
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Windalia Sand Member After 10 Years Of 15 GL/annum Abstraction

Figure 68d

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

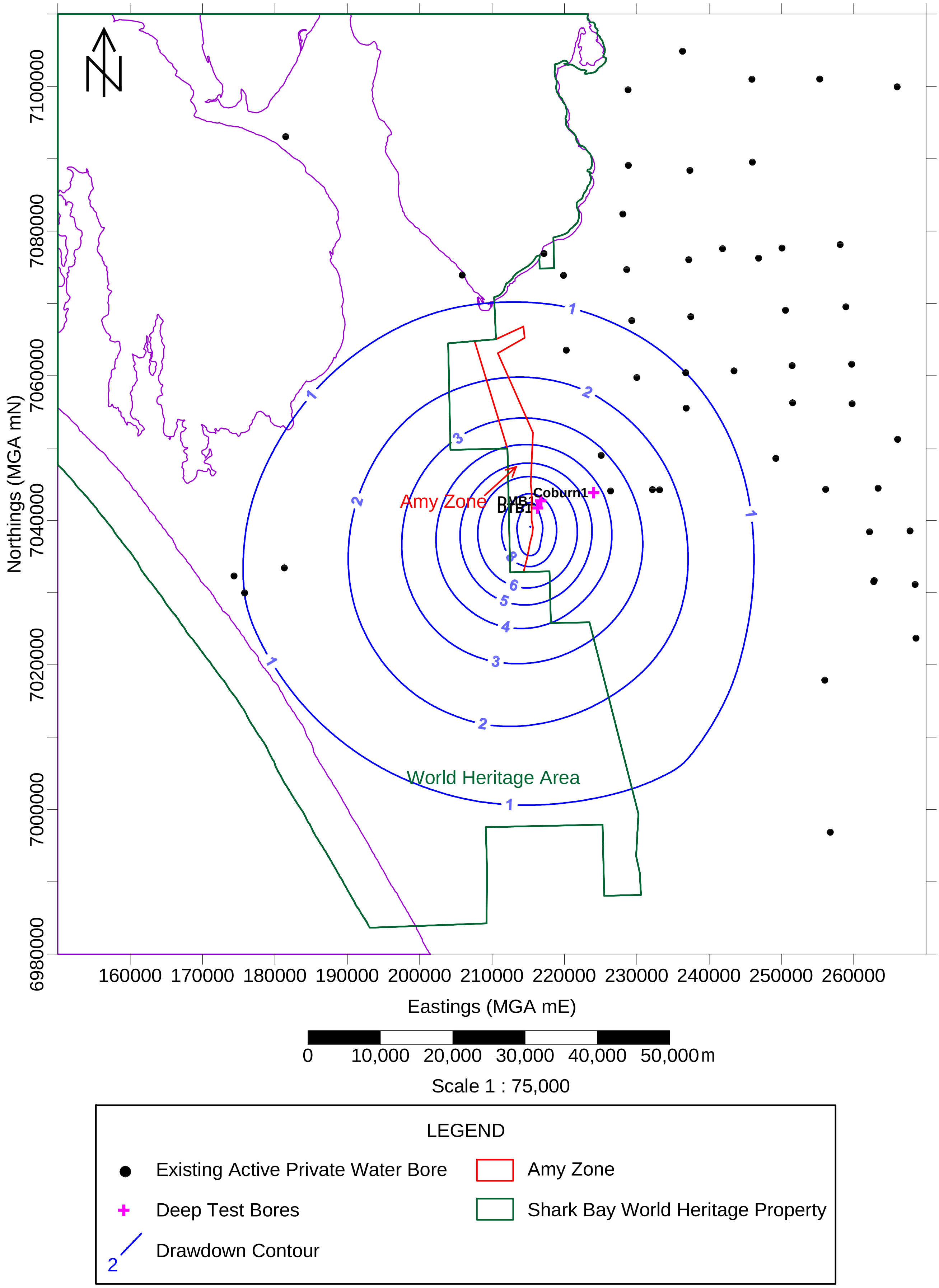
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

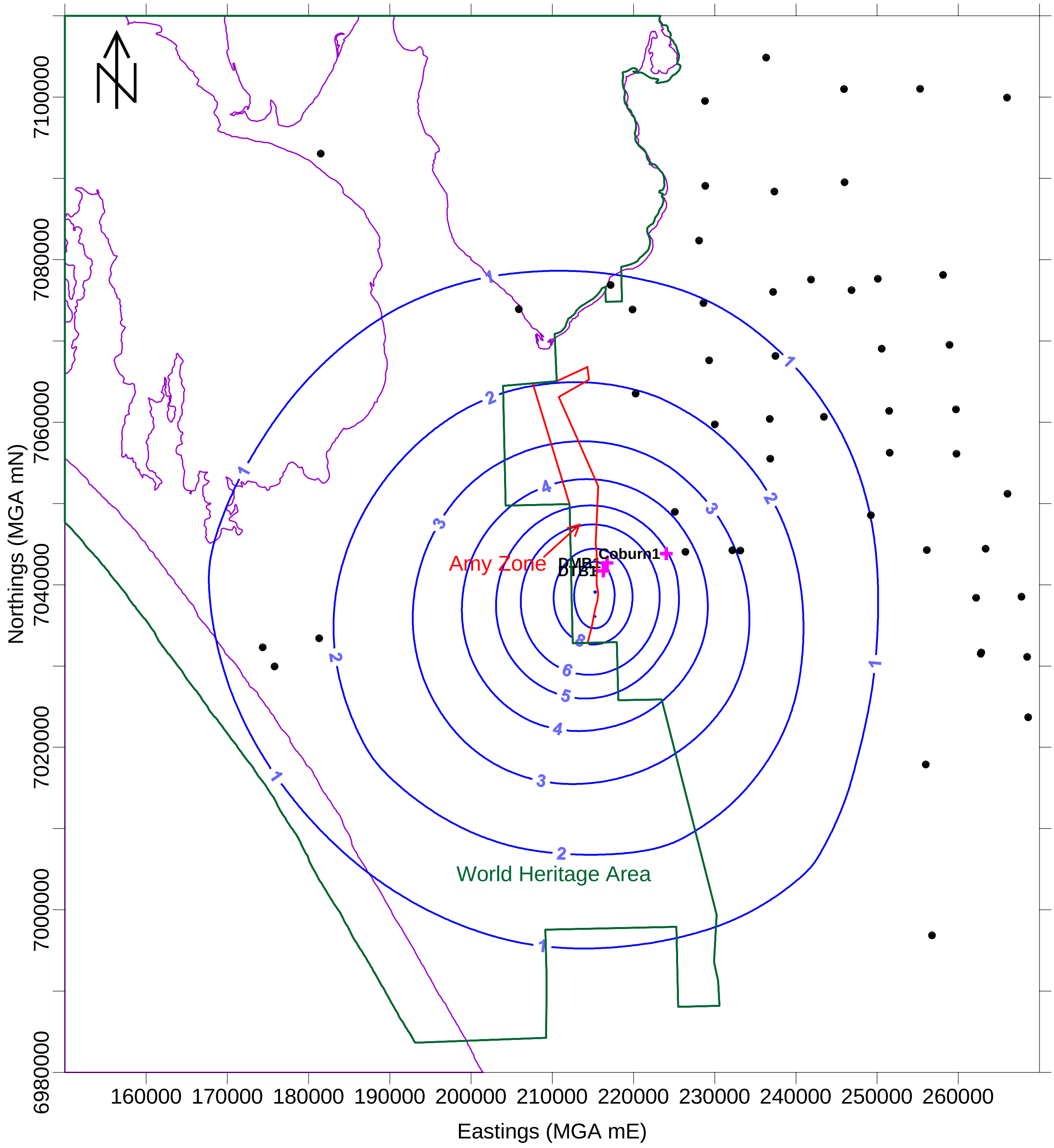
Predicted Drawdowns in Windalia Sand Member After 20 Years Of 15 GL/annum Abstraction

Figure 68e

URS



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Birdrong Sandstone After 1 Year Of 15 GL/annum Abstraction**	**Figure 69a**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

LEGEND

- ● Existing Active Private Water Bore
- + Deep Test Bores
- Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		
Prep. By	ECPL	1 Apr '05	
Chk'd By	RWC	1 Apr '05	
Revision No.		0	

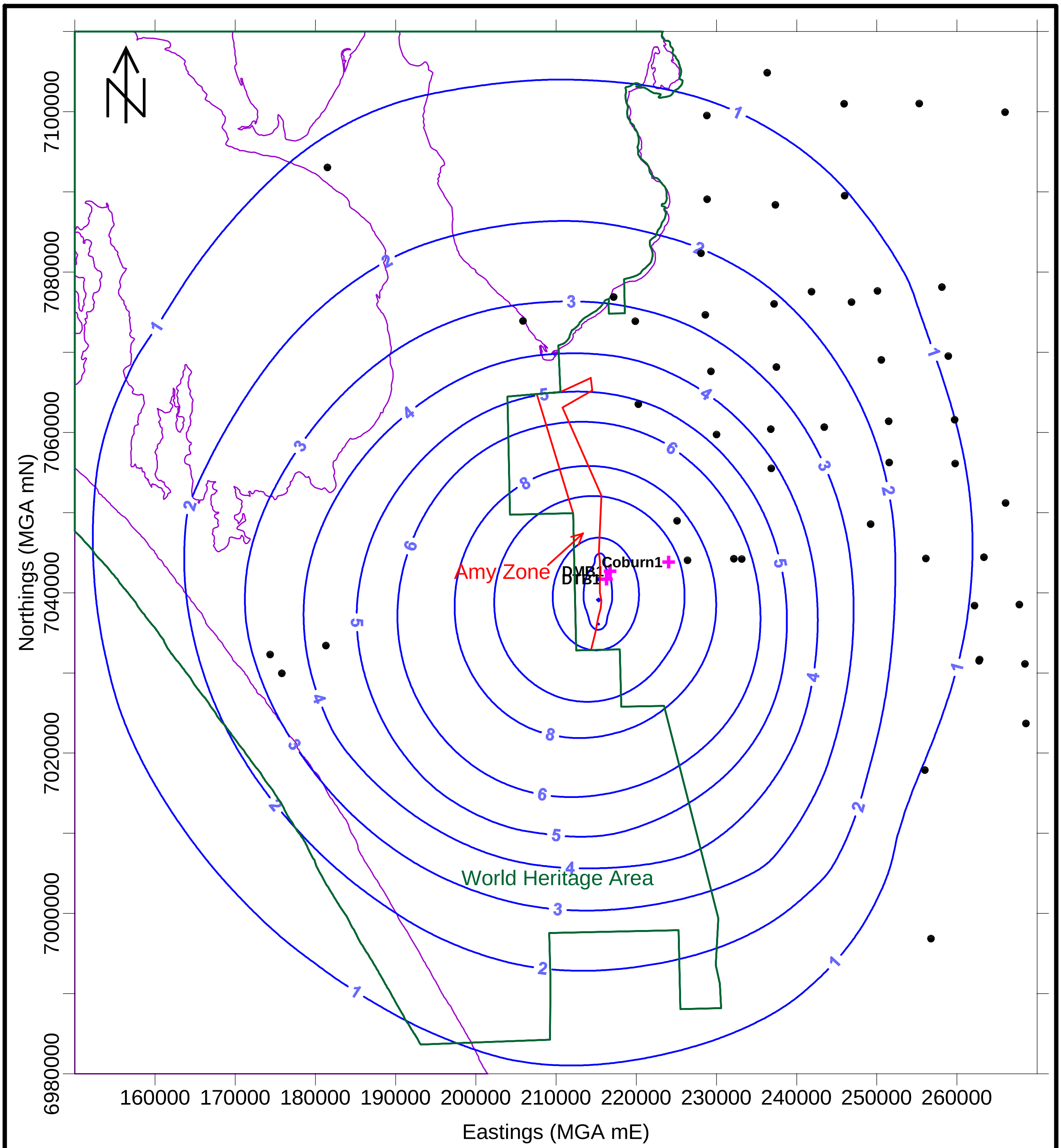
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Birdrong Sandstone After 2 Years Of 15 GL/annum Abstraction

Figure 69b

URS



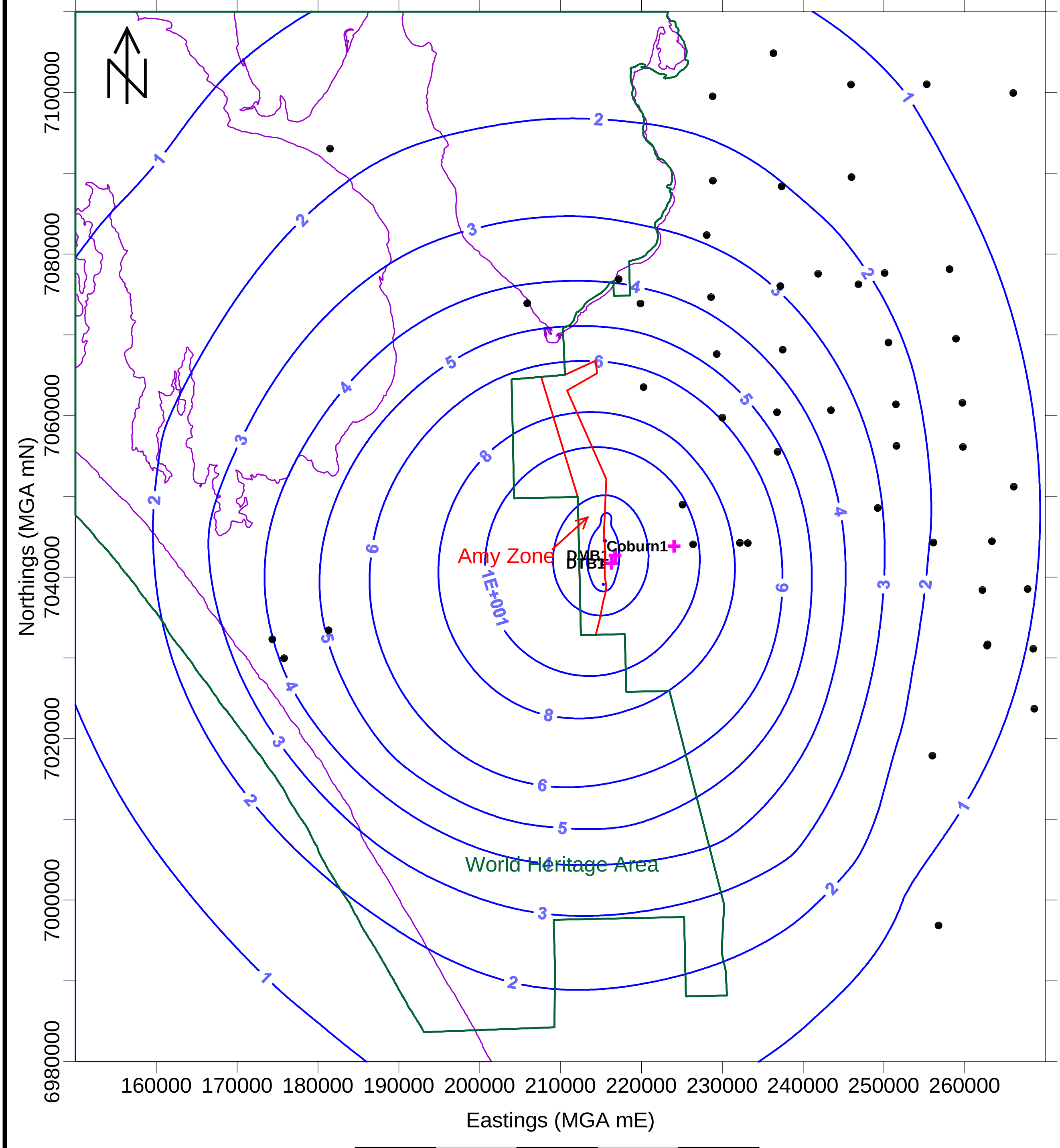
0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

LEGEND

● Existing Active Private Water Bore	Amy Zone
+ Deep Test Bores	Shark Bay World Heritage Property
2 Drawdown Contour	

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Birdrong Sandstone After 5 Years Of 15 GL/annum Abstraction**	**Figure 69c**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	0	

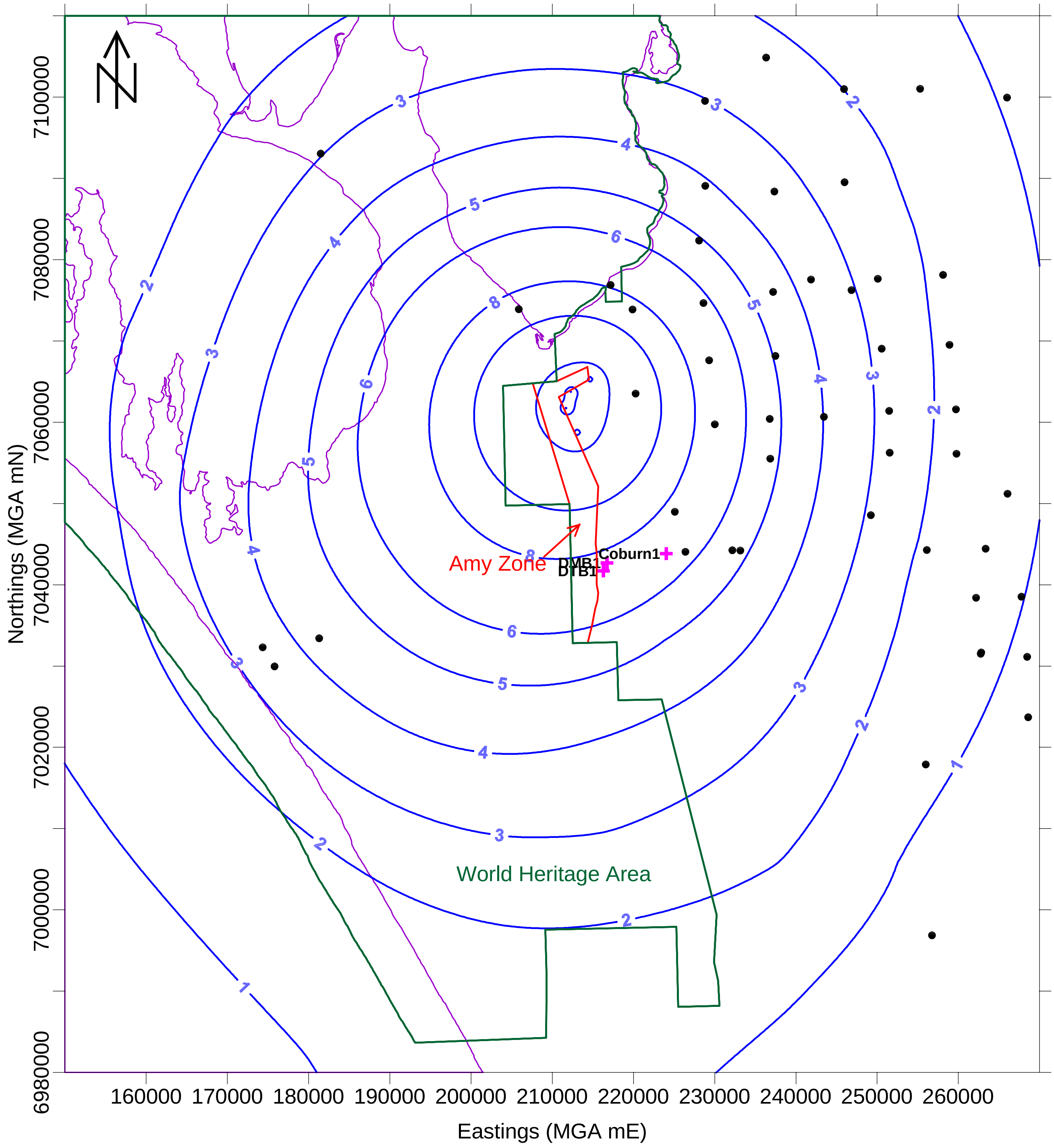
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Birdrong Sandstone After 10 Years Of 15 GL/annum Abstraction

Figure 69d

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.		0

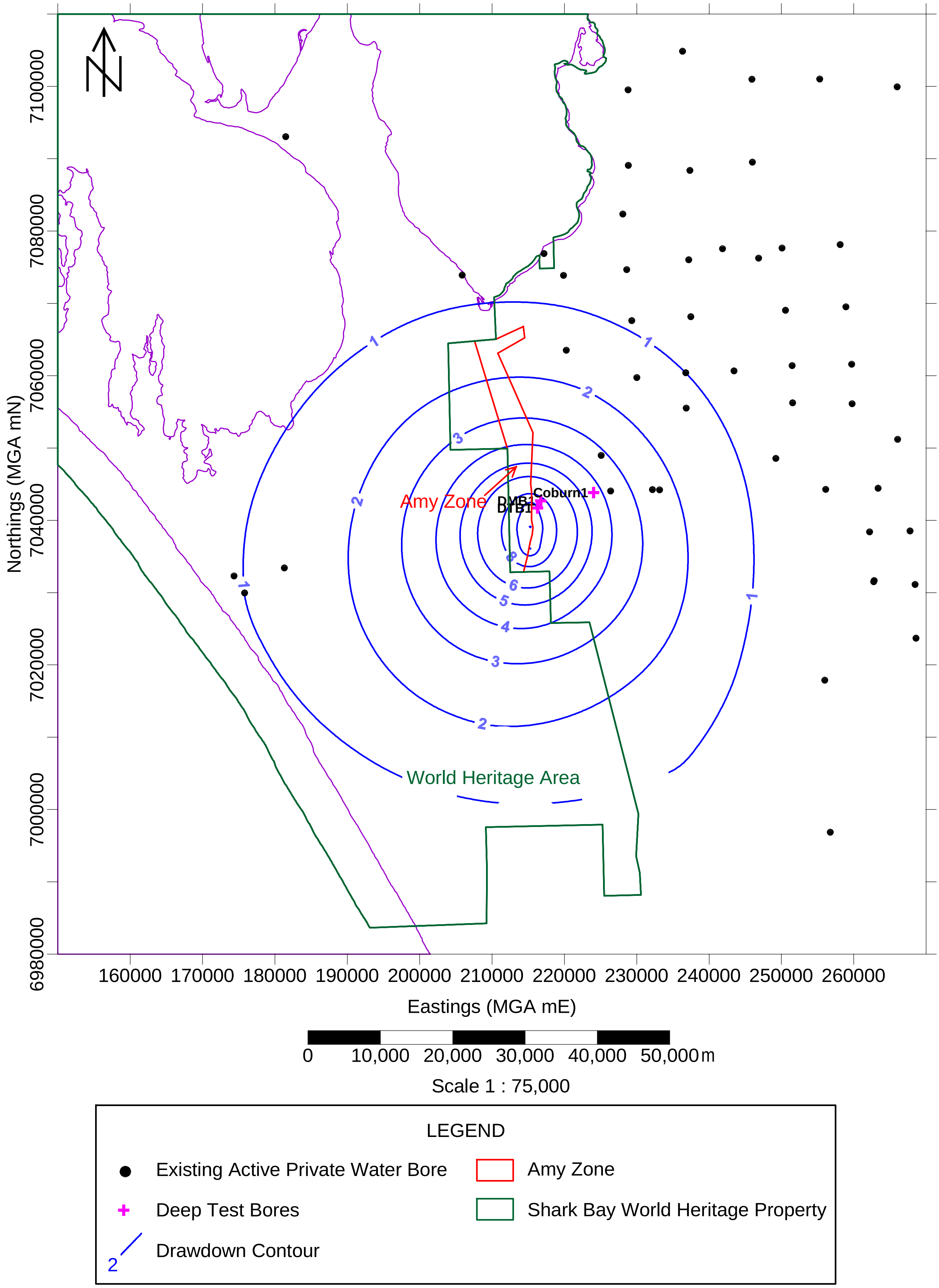
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

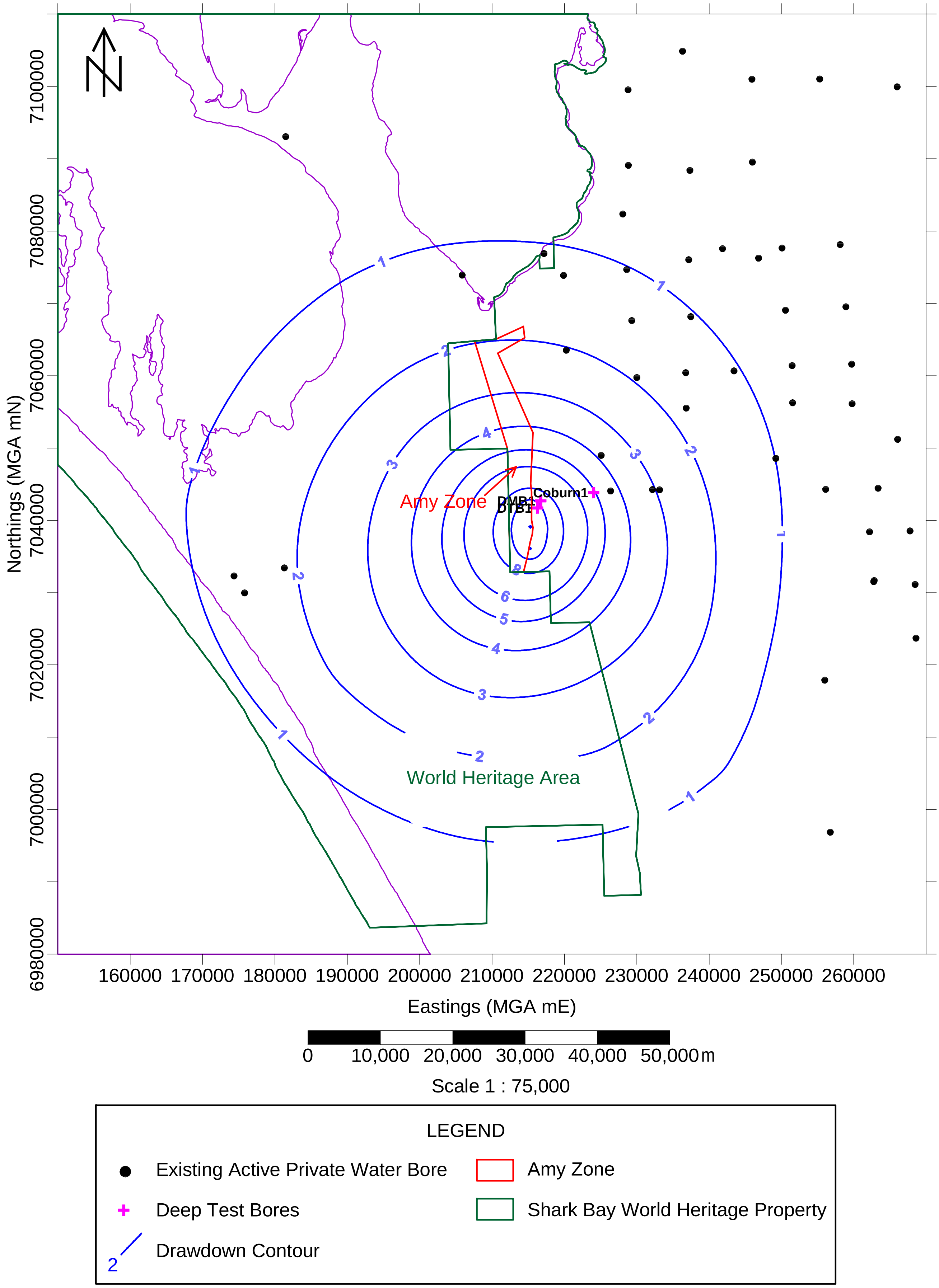
Predicted Drawdowns in Birdrong Sandstone After 20 Years Of 15 GL/annum Abstraction

Figure 69e

URS



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 1 Year Of 15 GL/annum Abstraction**	**Figure 70a**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



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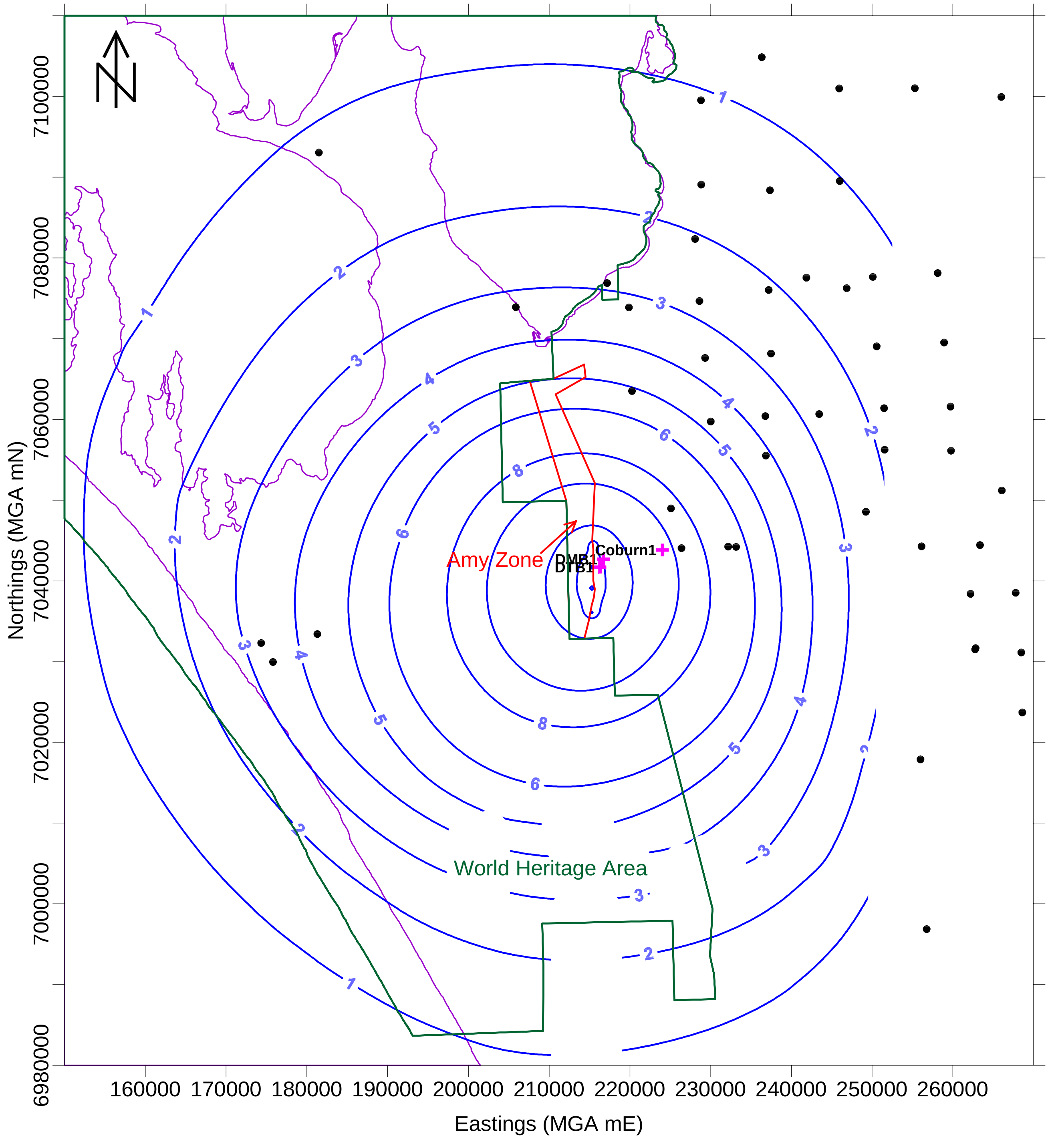
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 2 Years Of 15 GL/annum Abstraction**	**Figure 70b**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		
Prep. By	ECPL	1 Apr '05	
Chk'd By	RWC	1 Apr '05	
Revision No.	0		

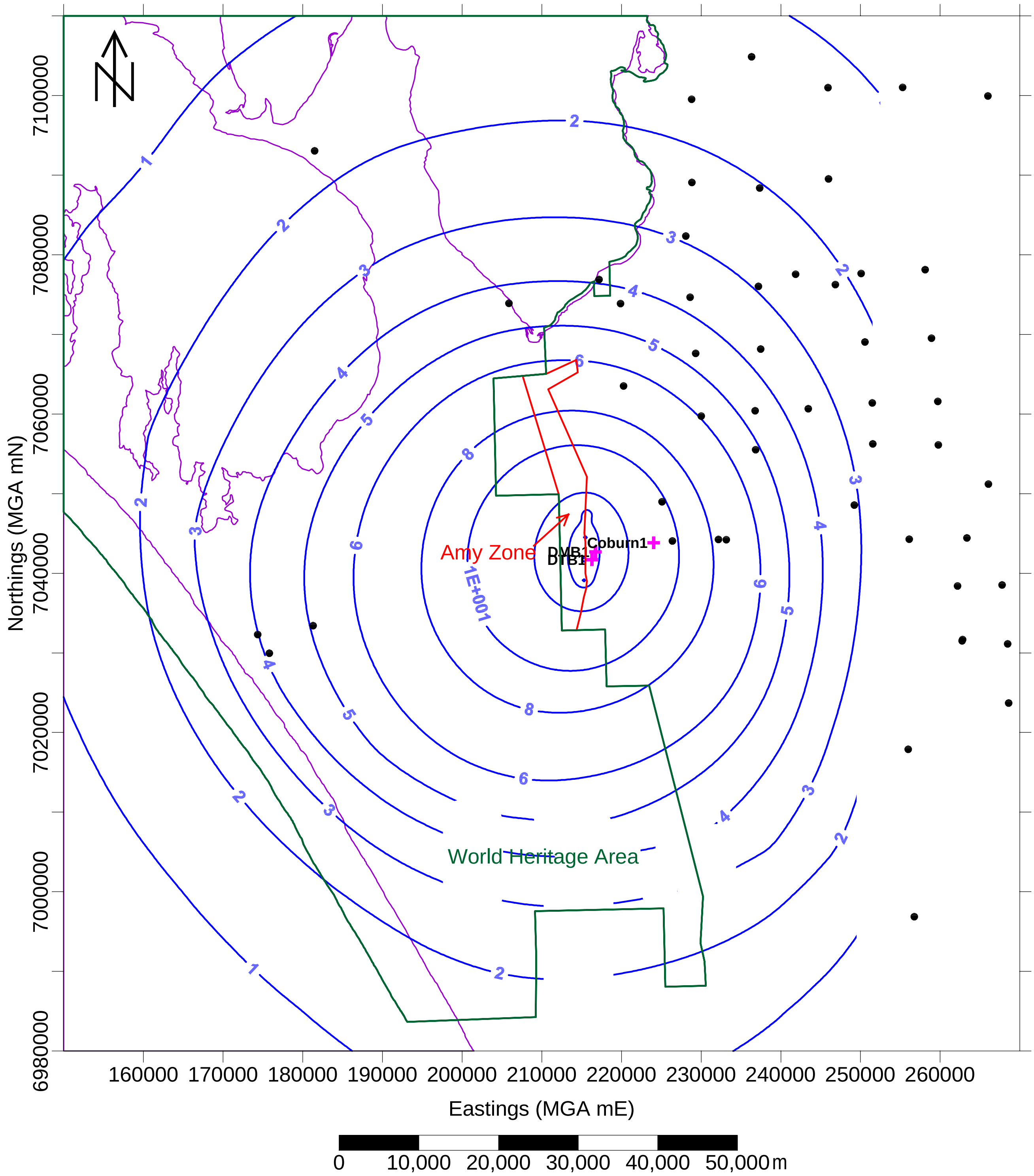
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Drawdowns in Kopke Sandstone After 5 Years Of 15 GL/annum Abstraction

Figure 70c

URS



Scale 1 : 75,000

LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 10 Years Of 15 GL/annum Abstraction**	**Figure 70d**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		

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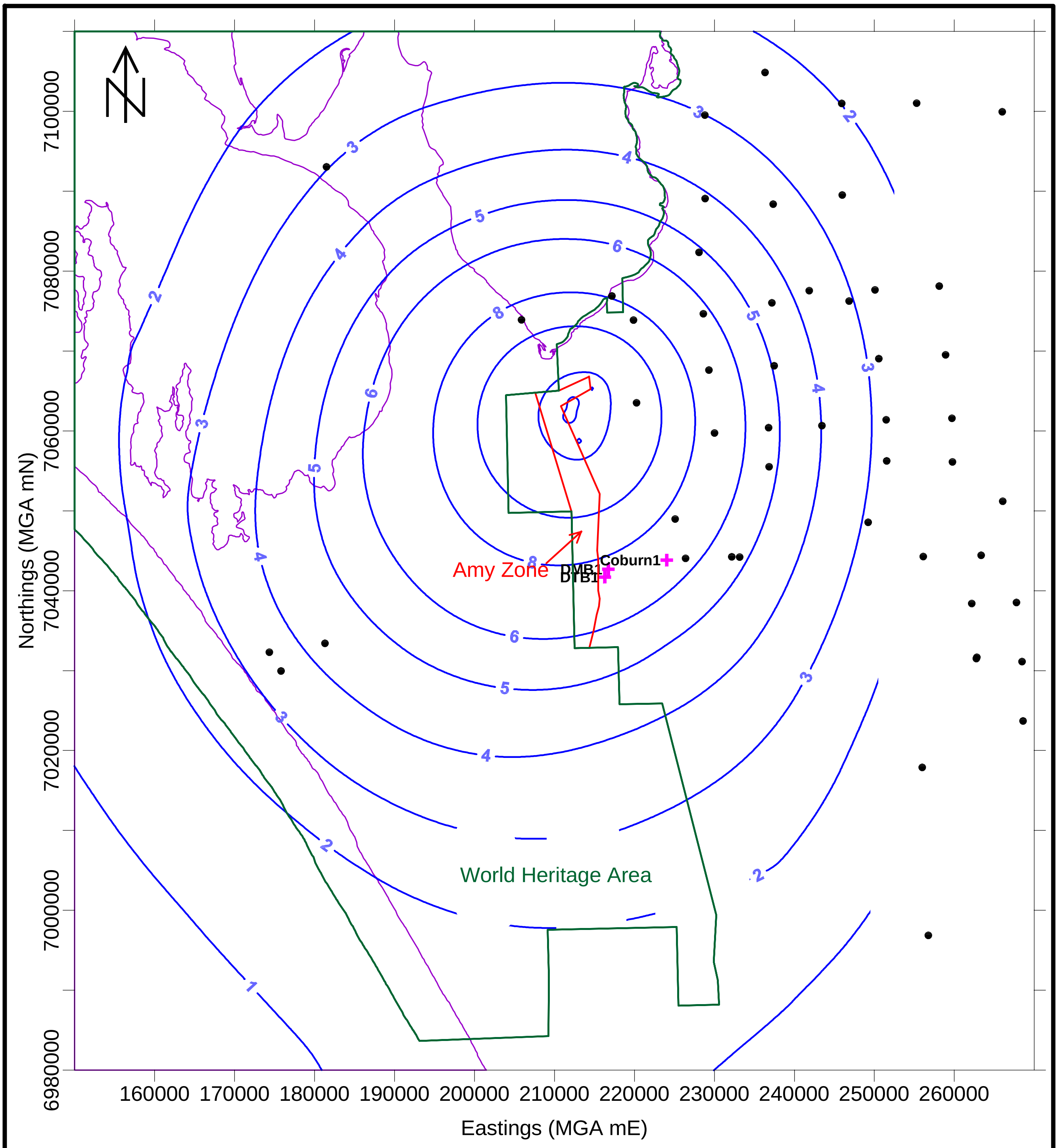

0 10,000 20,000 30,000 40,000 50,000 m

Scale 1 : 75,000

LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

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Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Drawdowns in Kopke Sandstone After 20 Years Of 15 GL/annum Abstraction**	**Figure 70e**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		0		

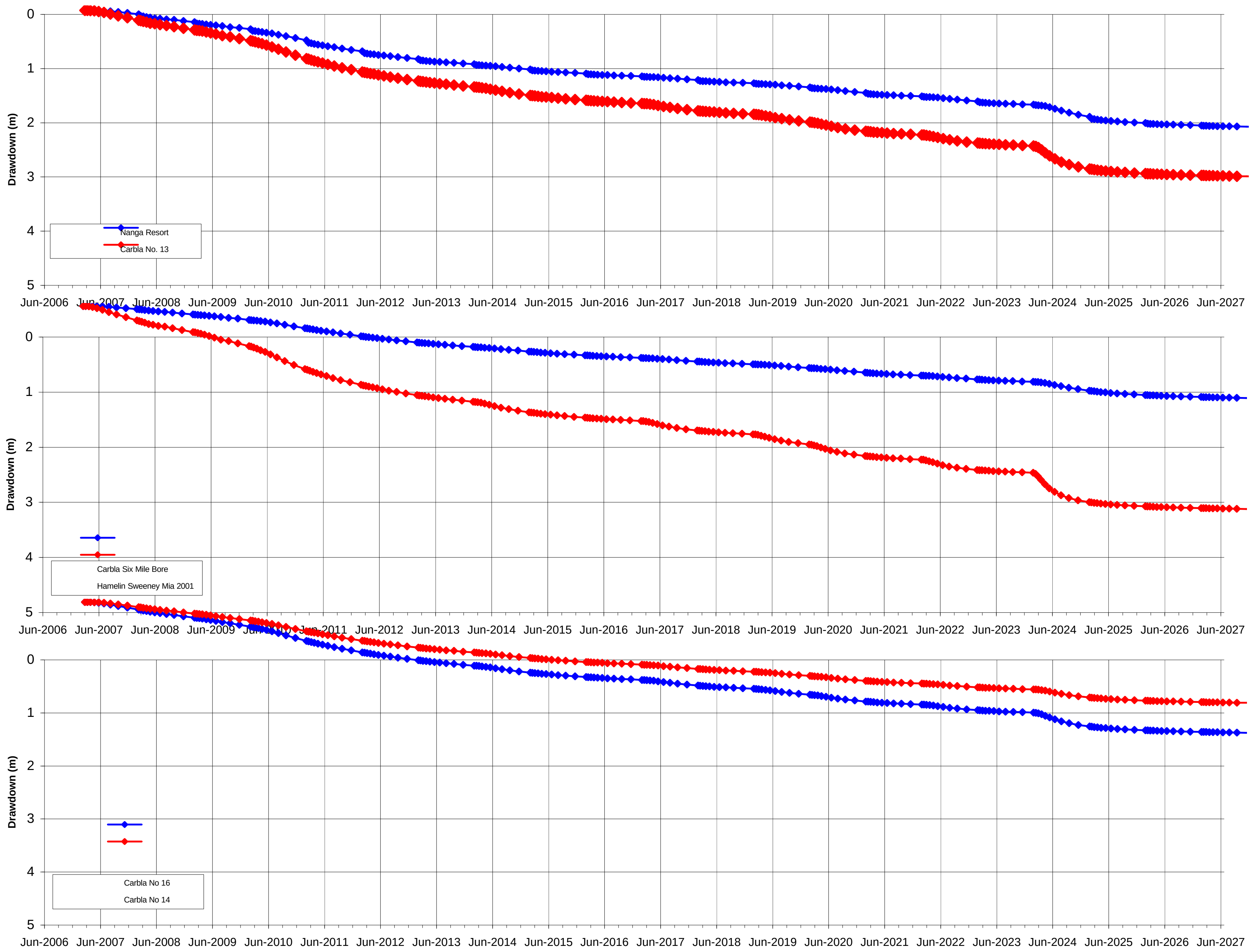
Job No.	42905541
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED DRAWDOWN IMPACTS OF 11GL/ANNUM ABSTRACTION ON NANGA RESORT, CARBLA STATION AND SWEENY MIA 2001 BORES

Figure 71a



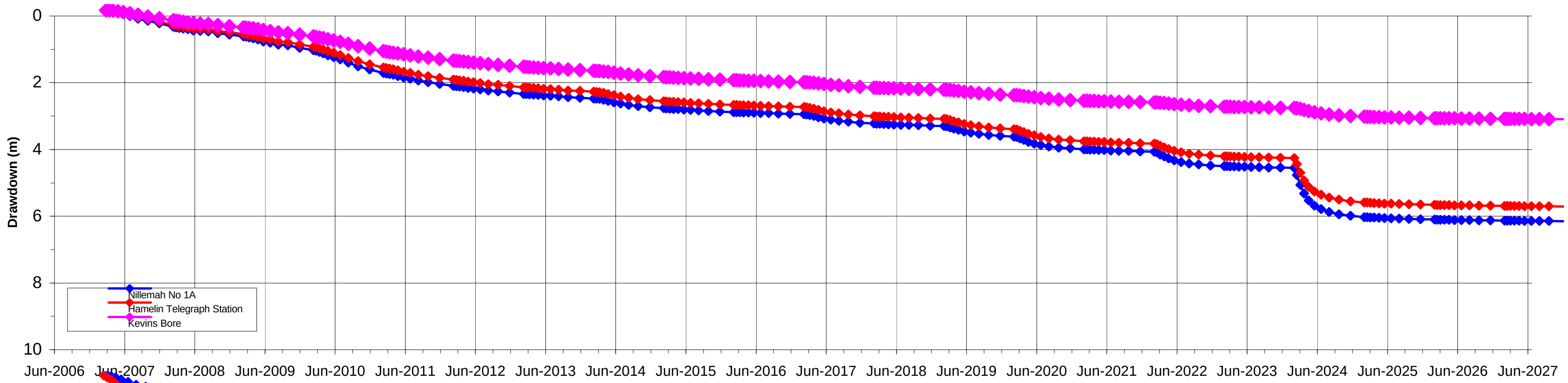
Job No.	42905541
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

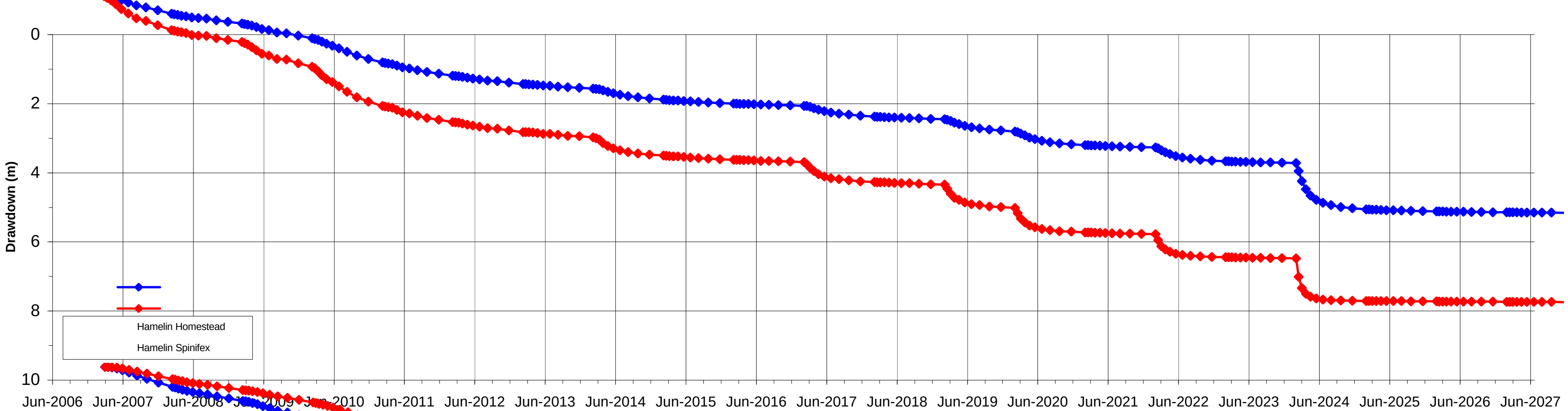
Gunson Resources Limited

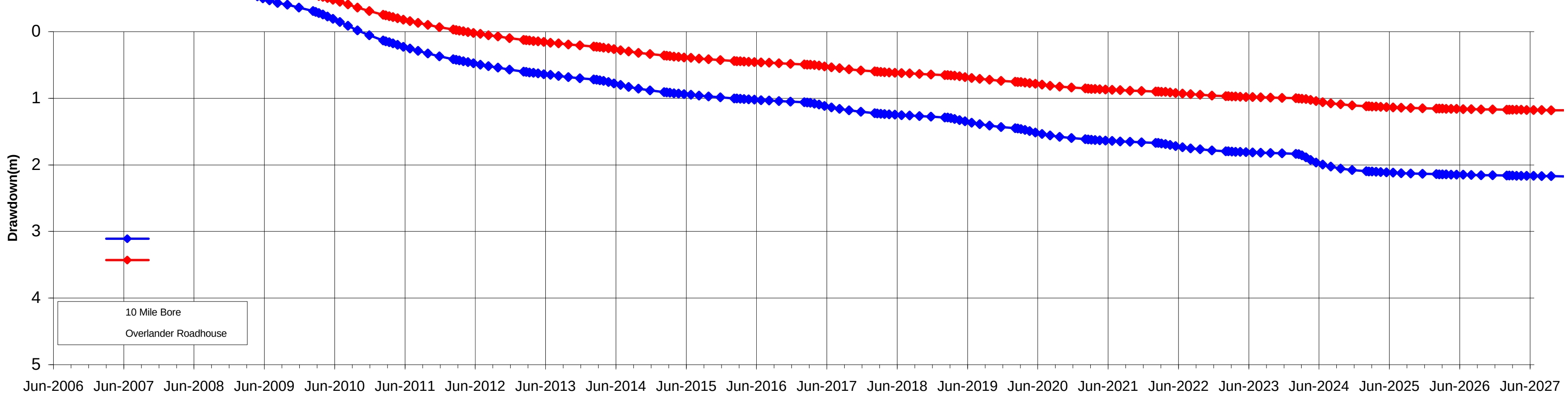
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED DRAWDOWN IMPACTS OF 11GL/ANNUM ABSTRACTION ON NORTHERN HAMELIN STATION, TELEGRAPH STATION AND OVERLANDER ROADHOUSE BORES

Figure 71b







Job No.	42905541
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

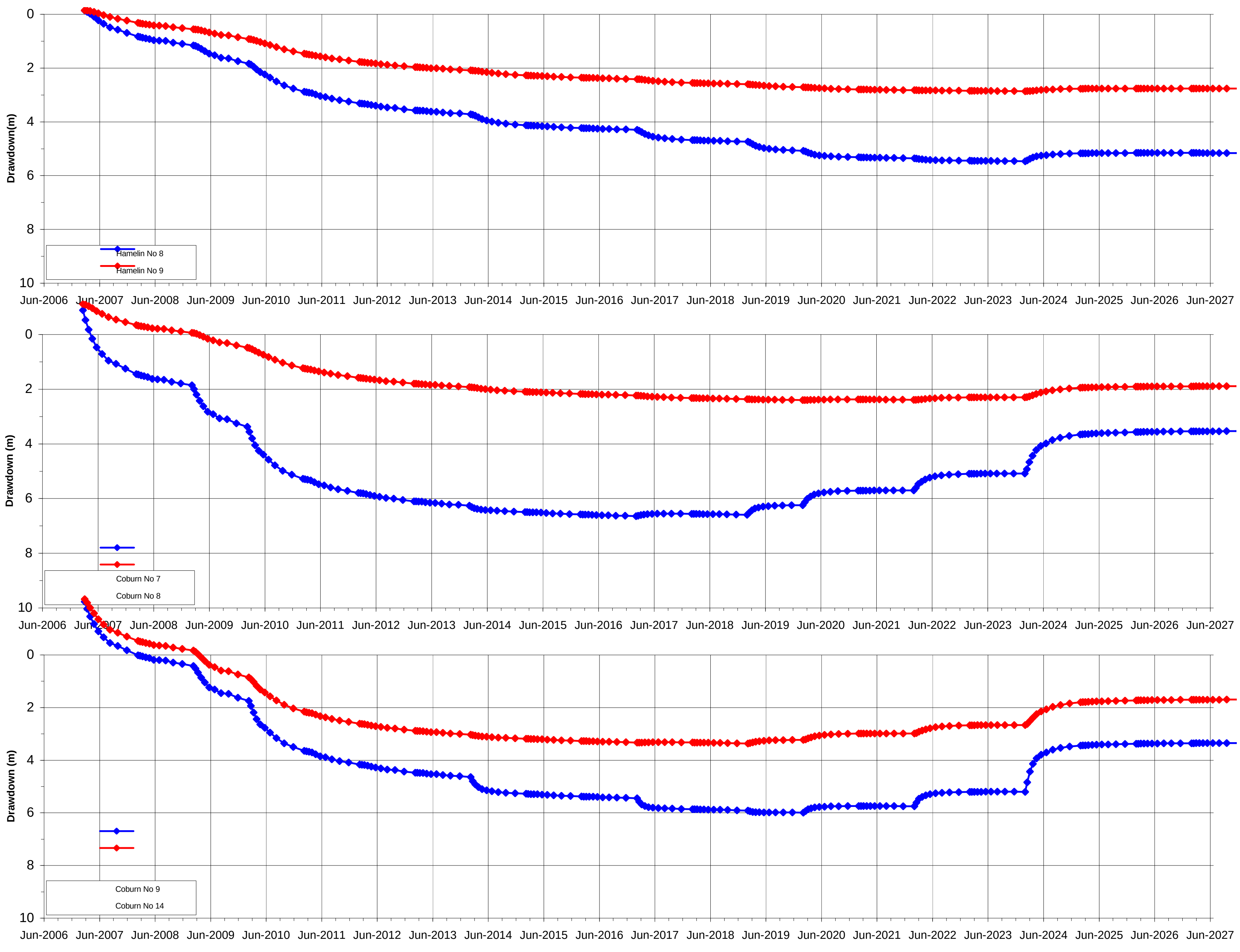
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED DRAWDOWN IMPACTS OF 11GL/ANNUM ABSTRACTION ON SOUTHERN HAMELIN AND COBURN STATIONS BORES

Figure 71c

URS



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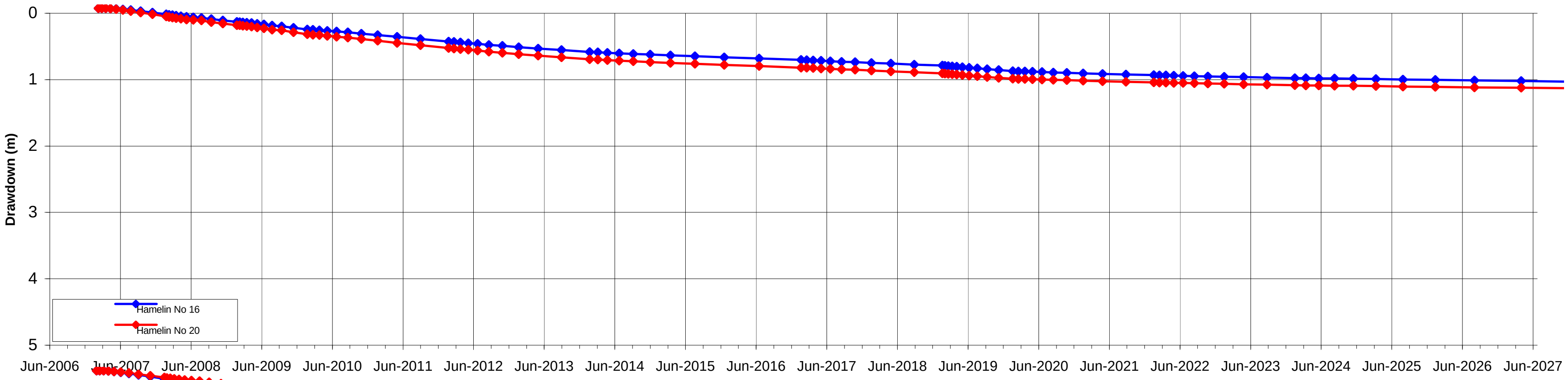
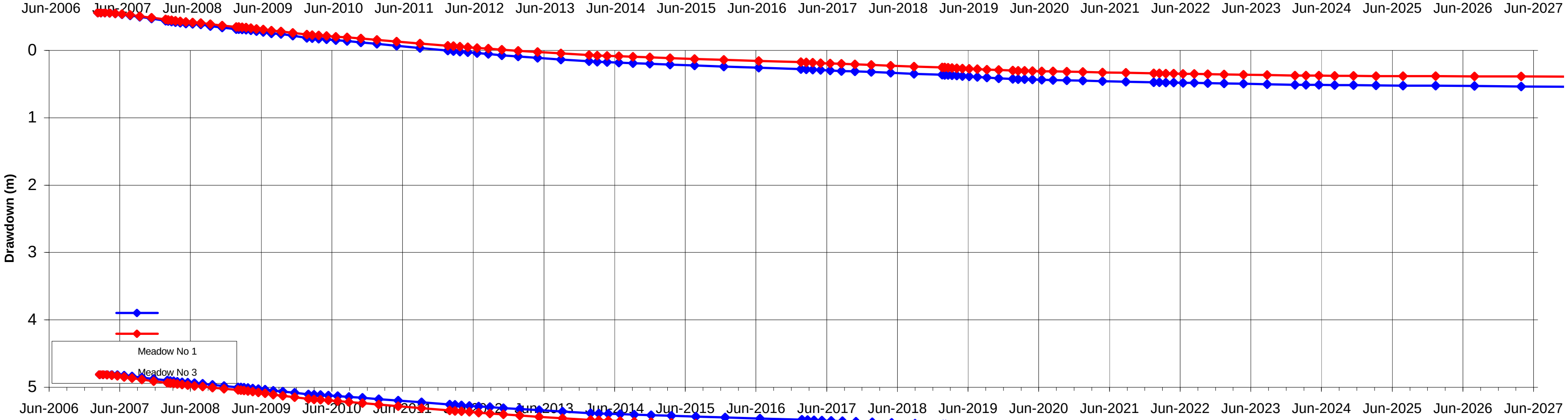
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

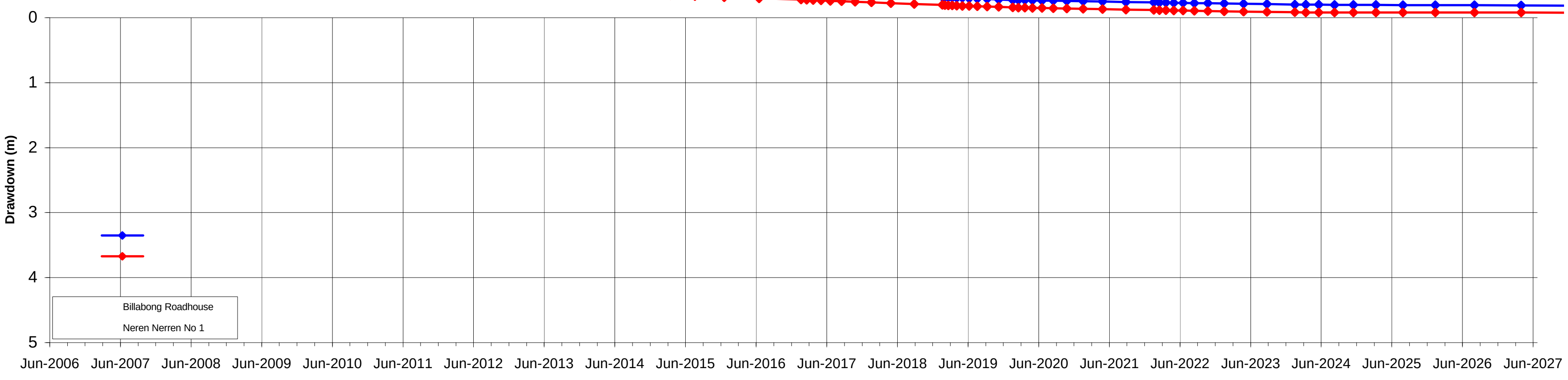
PREDICTED DRAWDOWN IMPACTS OF 11GL/ANNUM ABSTRACTION ON EASTERN HAMELIN, MEADOW AND NERREN NERREN STATIONS AND BILLABONG ROADHOUSE BORES

Job No.	42905541
Prep. By	BM	28-Feb-05
Chk'd By	RBW	28-Feb-05
Revision No.	0

Figure 71d







Job No. 42905541

Prep. By BM 28-Feb-05

Chk'd By RBW 28-Feb-05

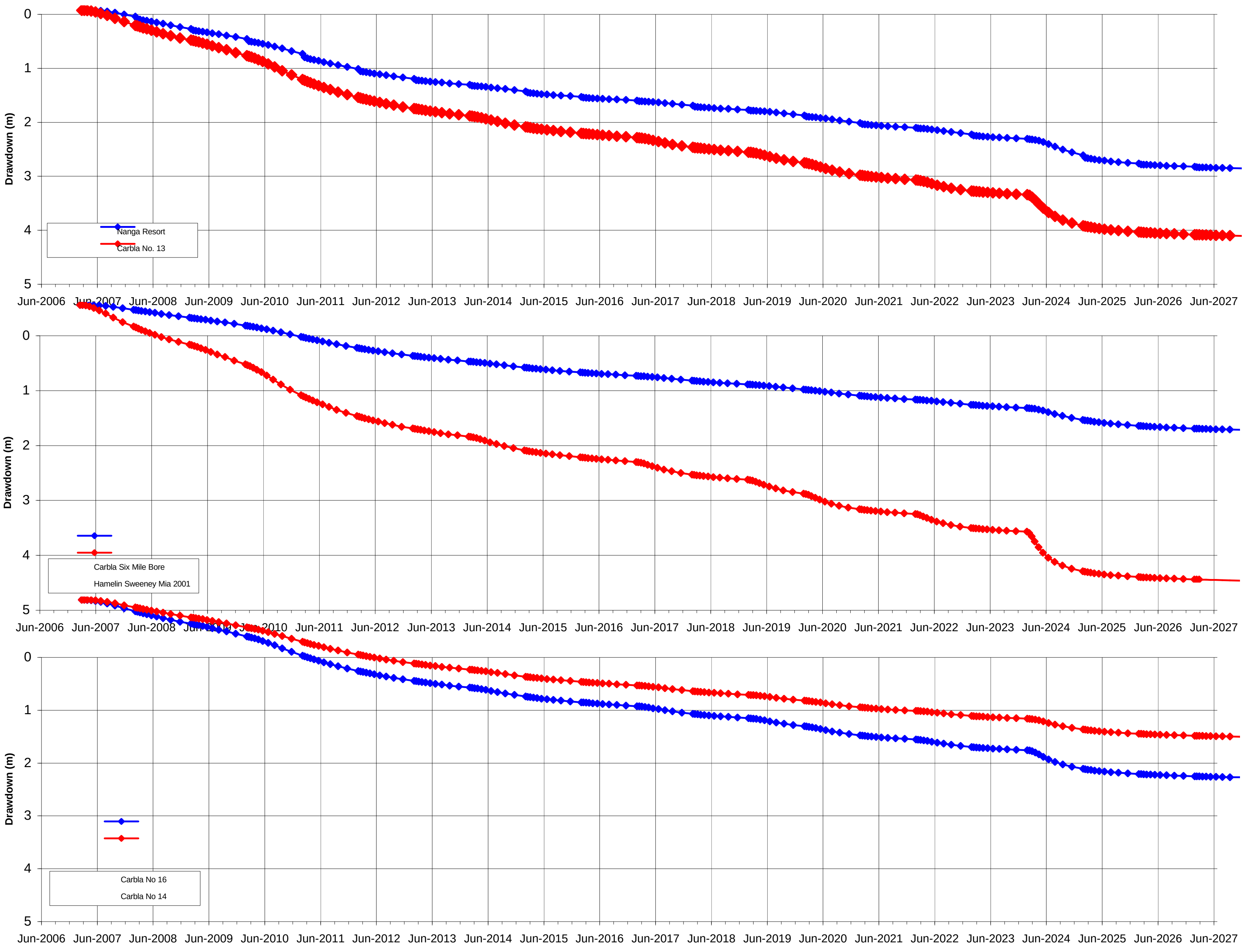
Revision No. 0

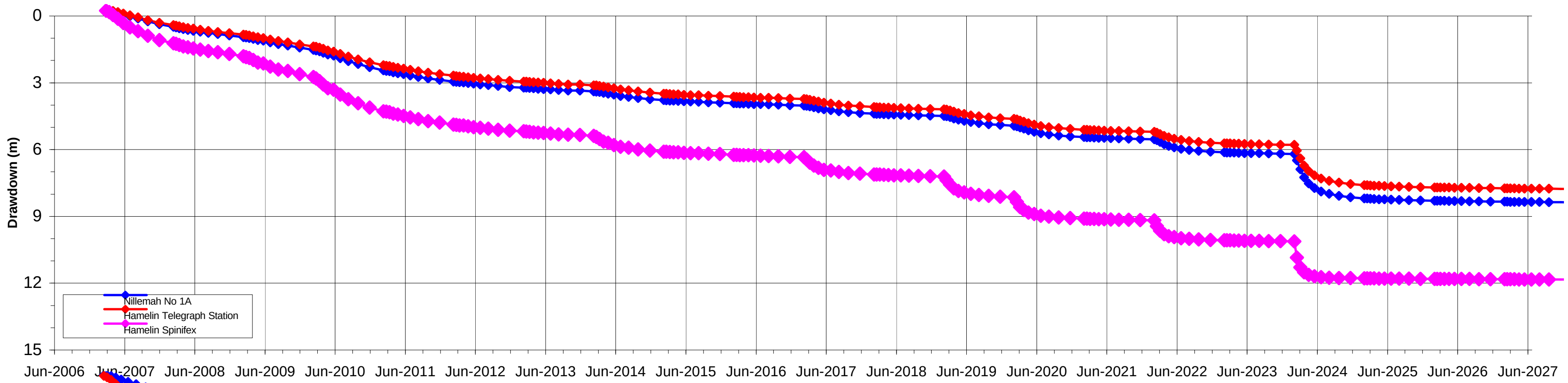
Gunson Resources Limited

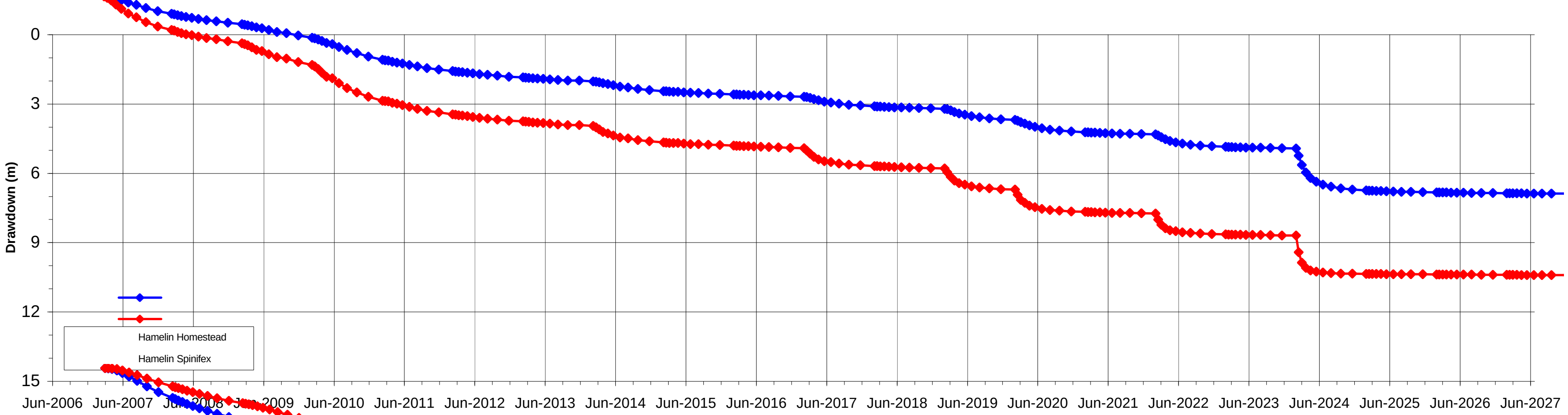
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

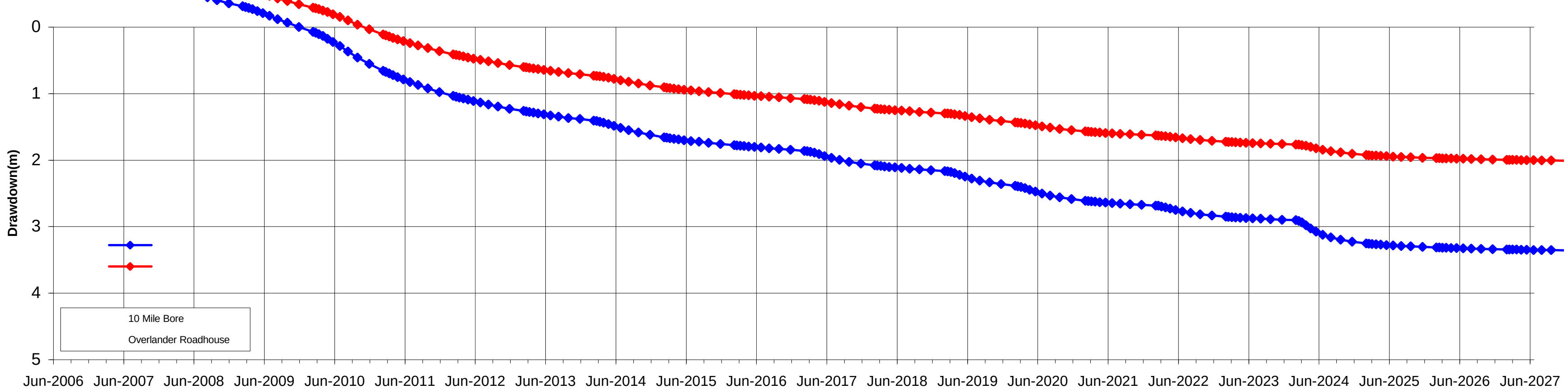
PREDICTED DRAWDOWN IMPACTS OF 15GL/ANNUM ABSTRACTION ON NANGA RESORT, CARBLA STATION AND SWEENY MIA 2001 BORES

Figure 72a









Job No.	42905541
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED DRAWDOWN IMPACTS OF 15 GL/ANNUM ABSTRACTION ON NORTHERN HAMELIN STATION, TELEGRAPH STATION AND OVERLANDER ROADHOUSE BORES

Figure 72b

Job No. 42905541

Prep. By BM 28-Feb-05

Chk'd By RBW 28-Feb-05

Revision No. 0

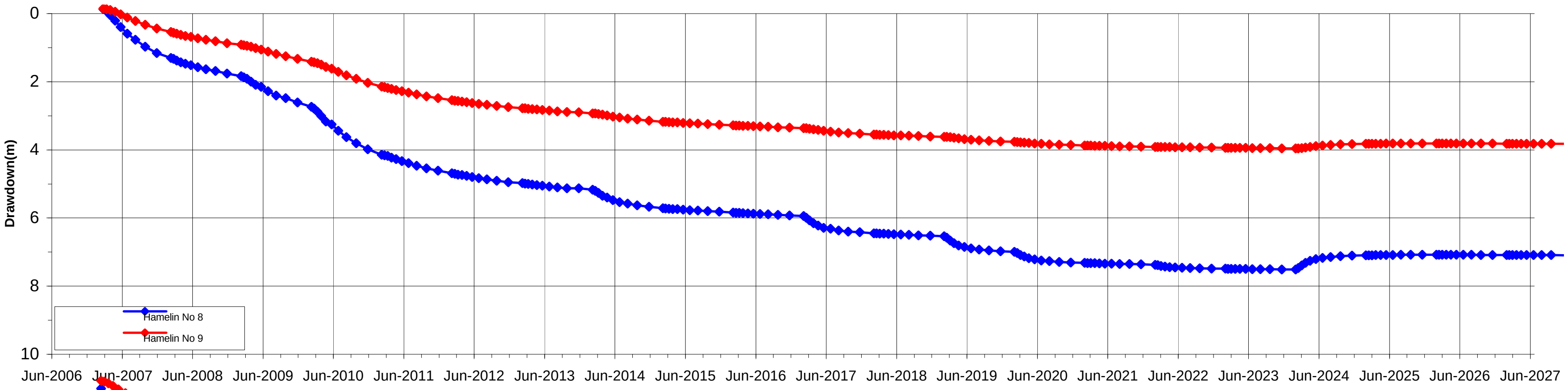
Gunson Resources Limited

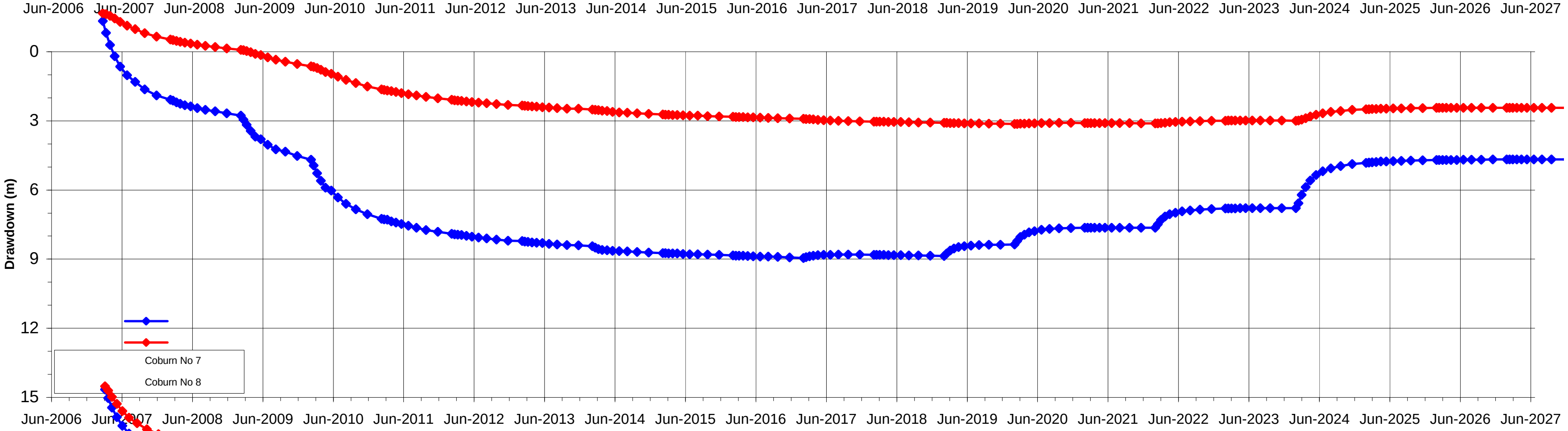
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

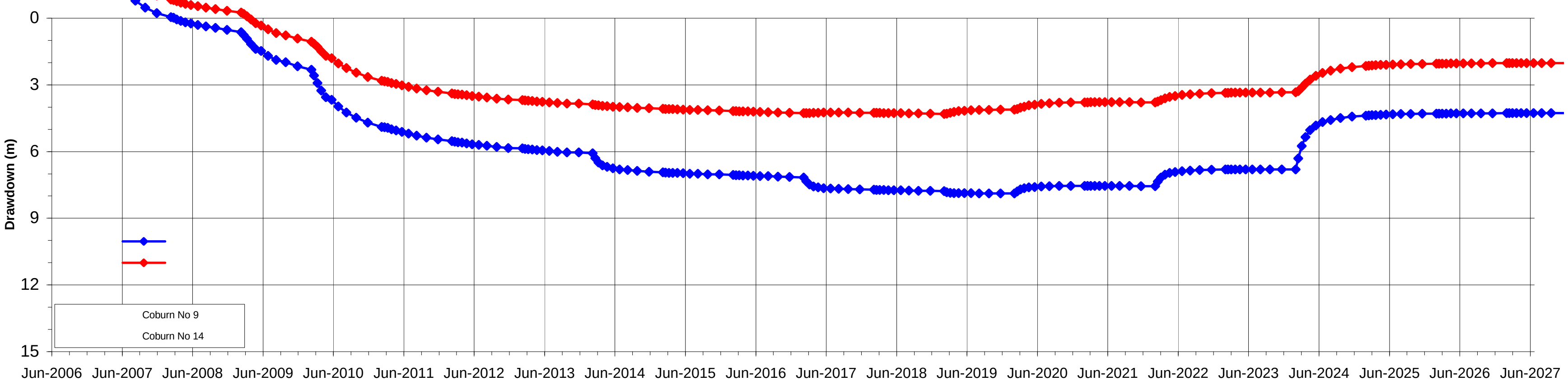
PREDICTED DRAWDOWN IMPACTS OF 15GL/ANNUM ABSTRACTION ON SOUTHERN HAMELIN AND COBURN STATIONS BORES

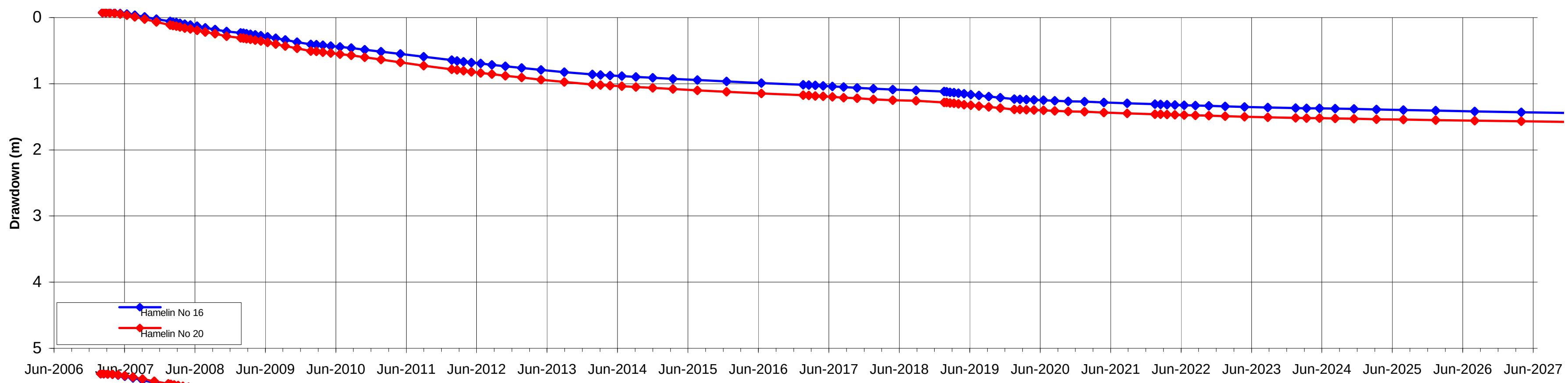
URS

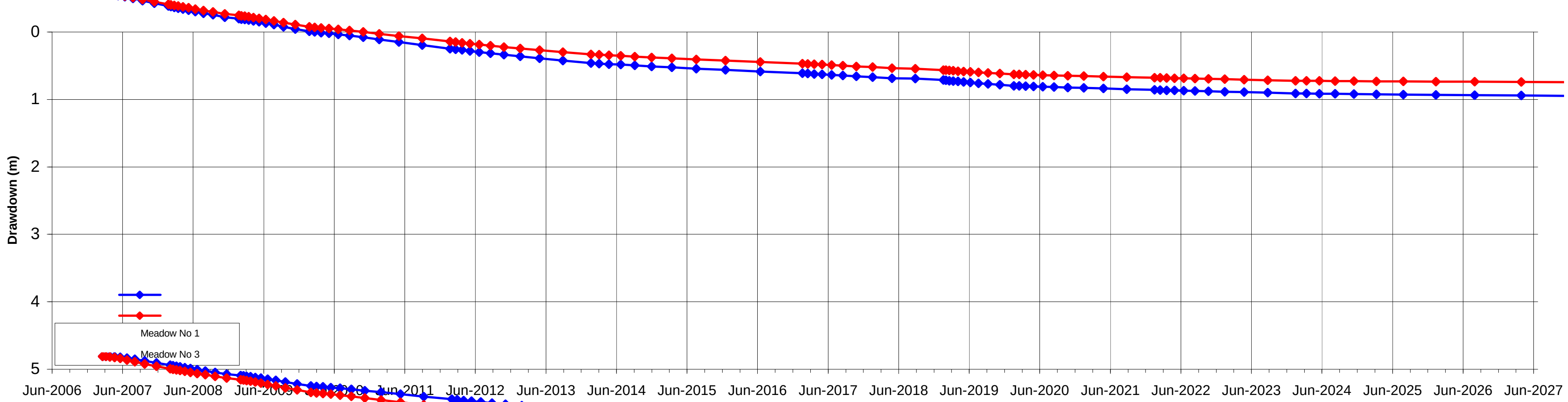
Figure 72c

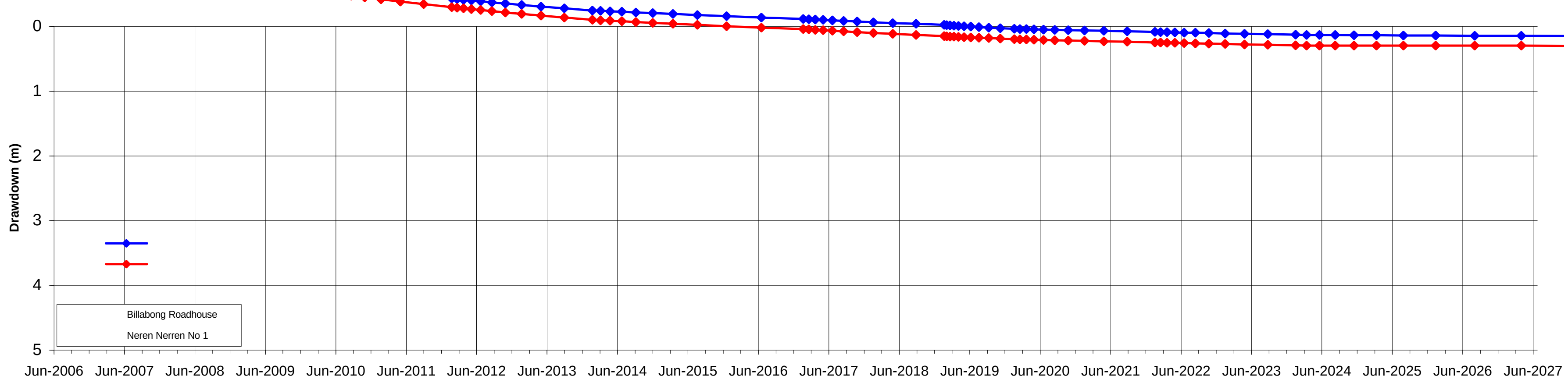












Job No.	42905541.1895
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

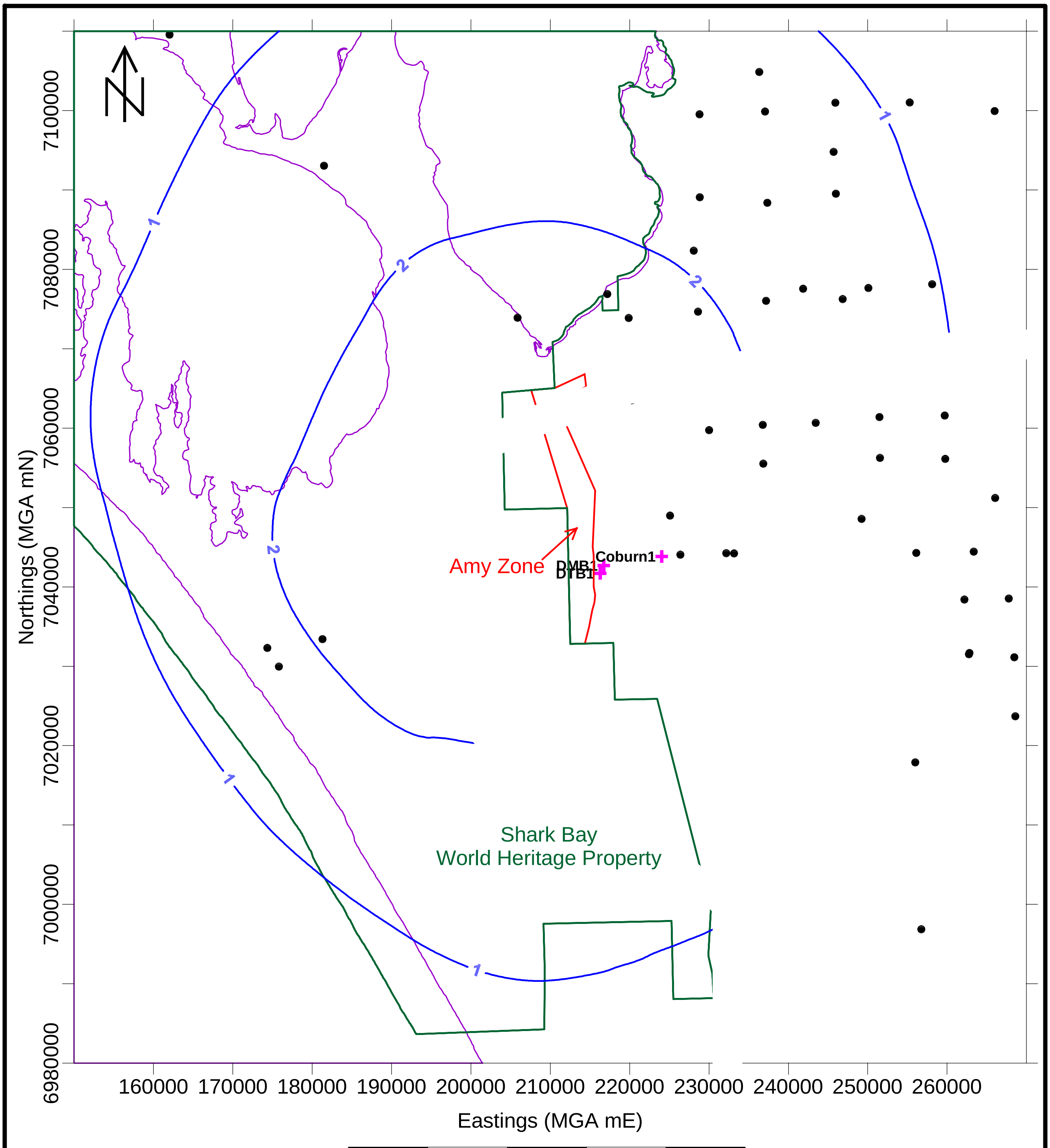
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED DRAWDOWN IMPACTS OF 15GL/ANNUM ABSTRACTION ON EASTERN HAMELIN, MEADOW AND NERREN NERREN STATIONS AND BILLABONG ROADHOUSE BORES

Figure 72d

URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	1	

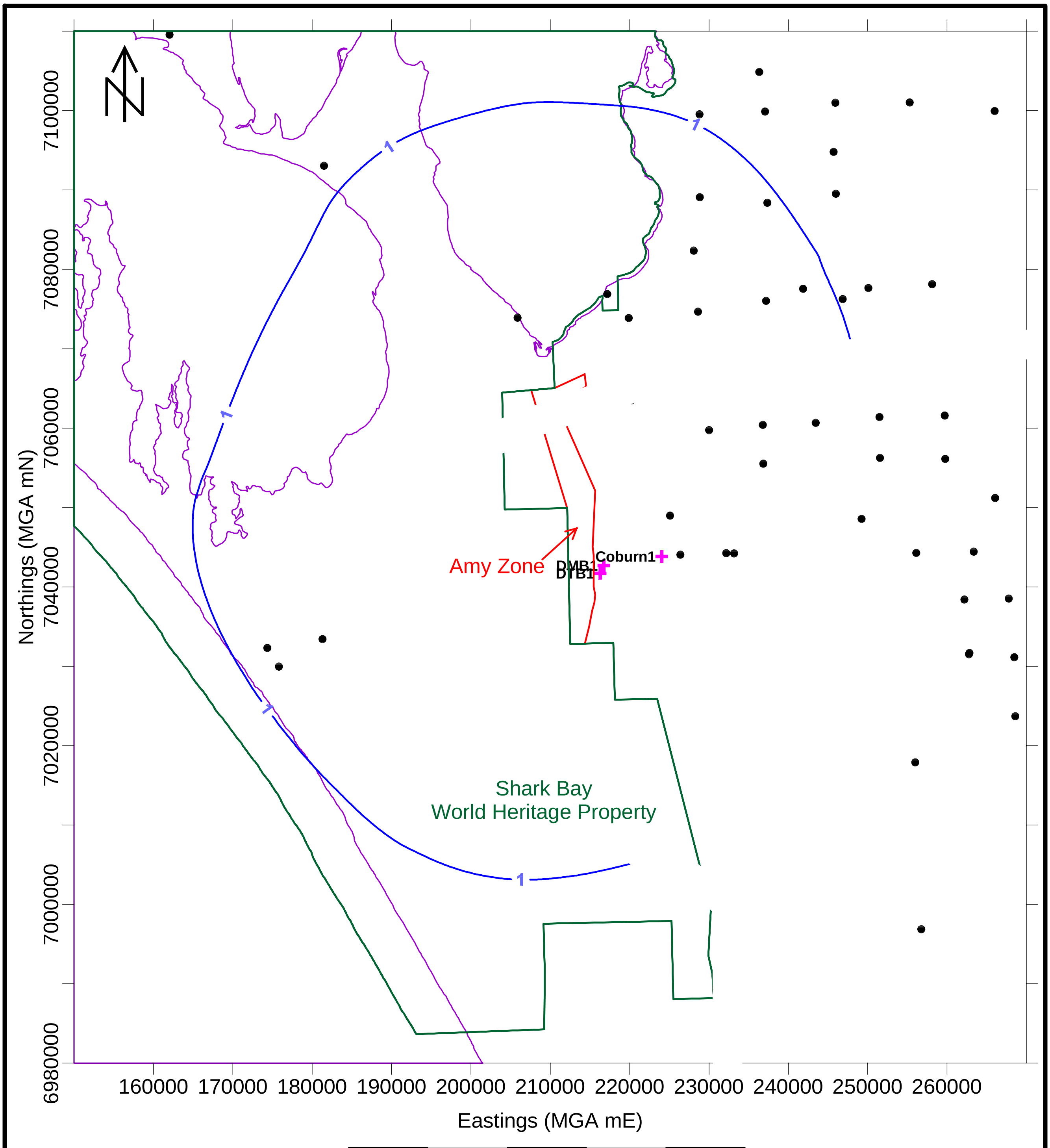
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Windalia Radiolarite, 1 Year After Abstraction of 11 Gl/annum Has Stopped

Figure 73a

URS



Scale 1 : 75,000

LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

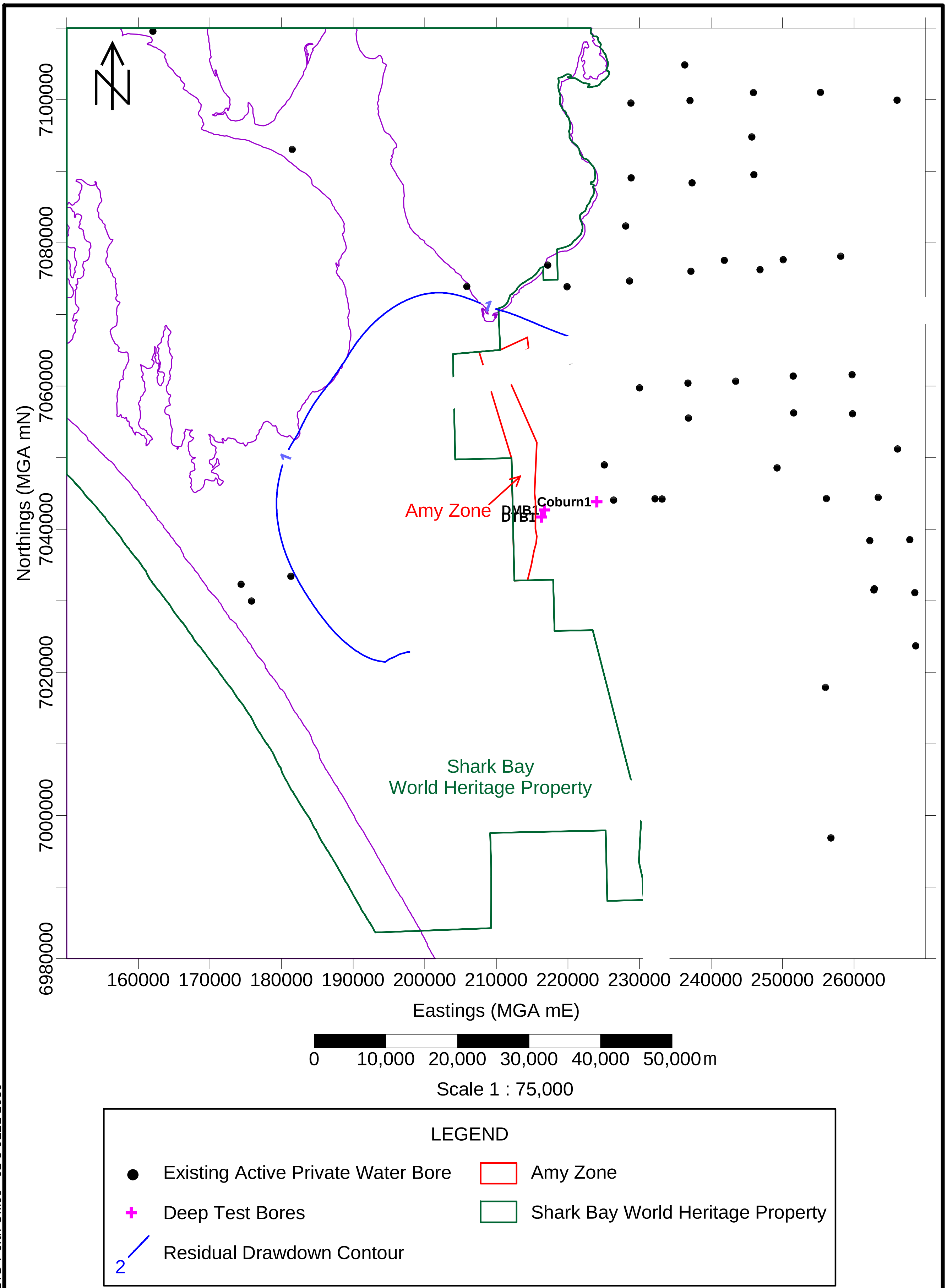
Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.		1

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Windalia Radiolarite, 2 Years After Abstraction of 11 Gl/annum Has Stopped

Figure 73b



Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.		1

Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Windalia Radiolarite, 5 Years After Abstraction of 11 Gl/annum Has Stopped

Figure 73c

URS

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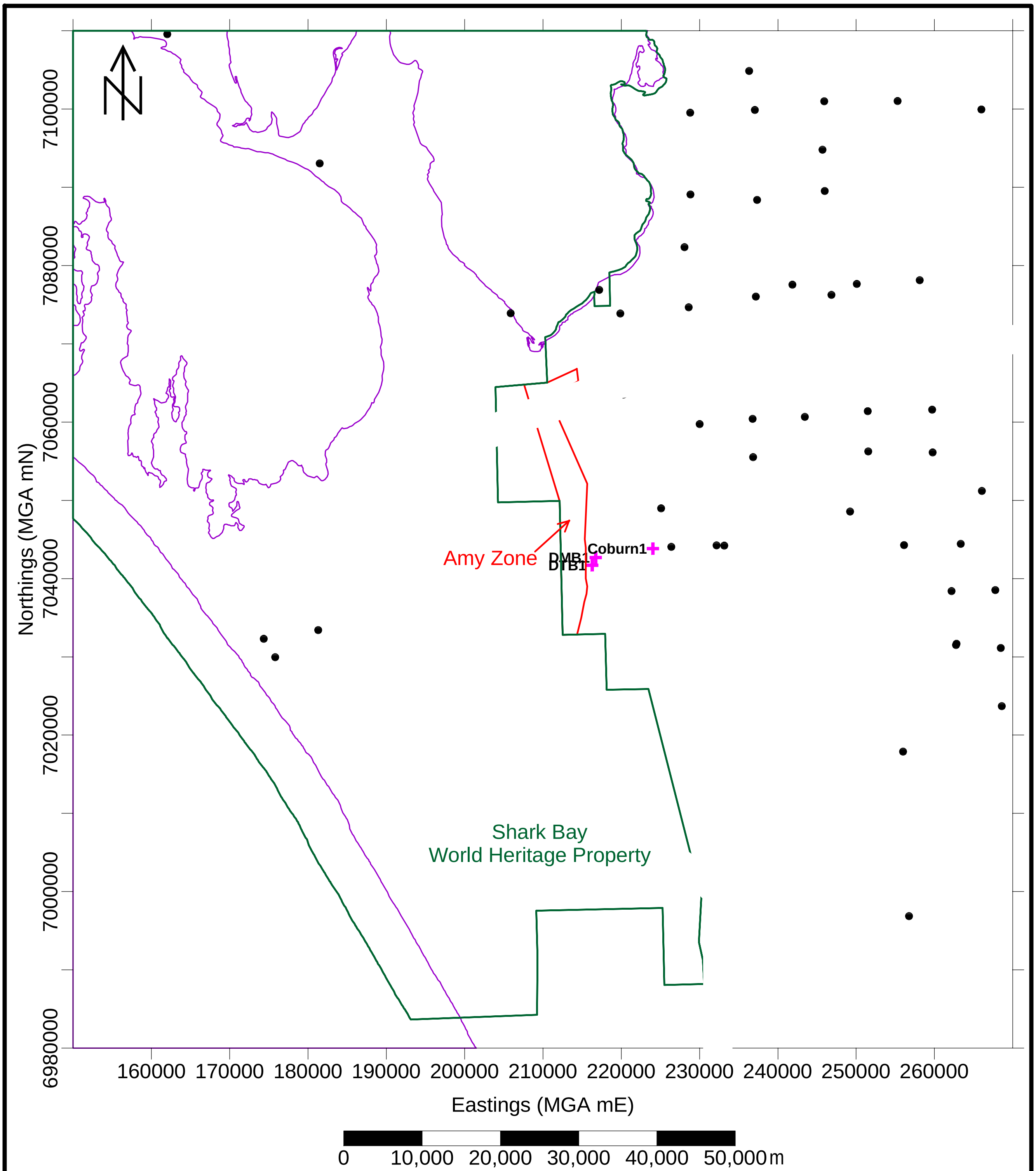


LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	1	

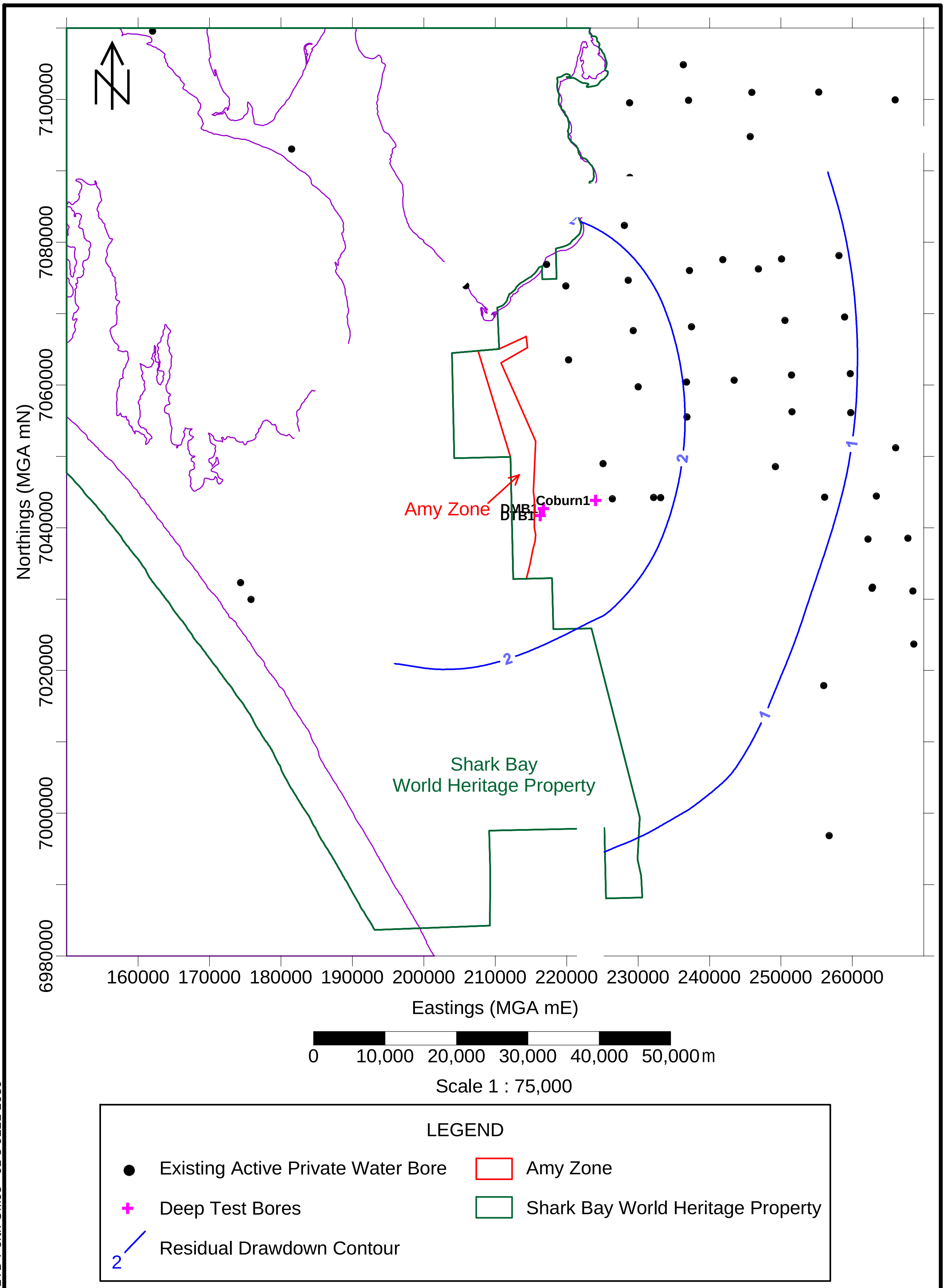
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Windalia Radiolarite, 10 Years After Abstraction of 11 Gl/annum Has Stopped

Figure 73d

URS



Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	1	

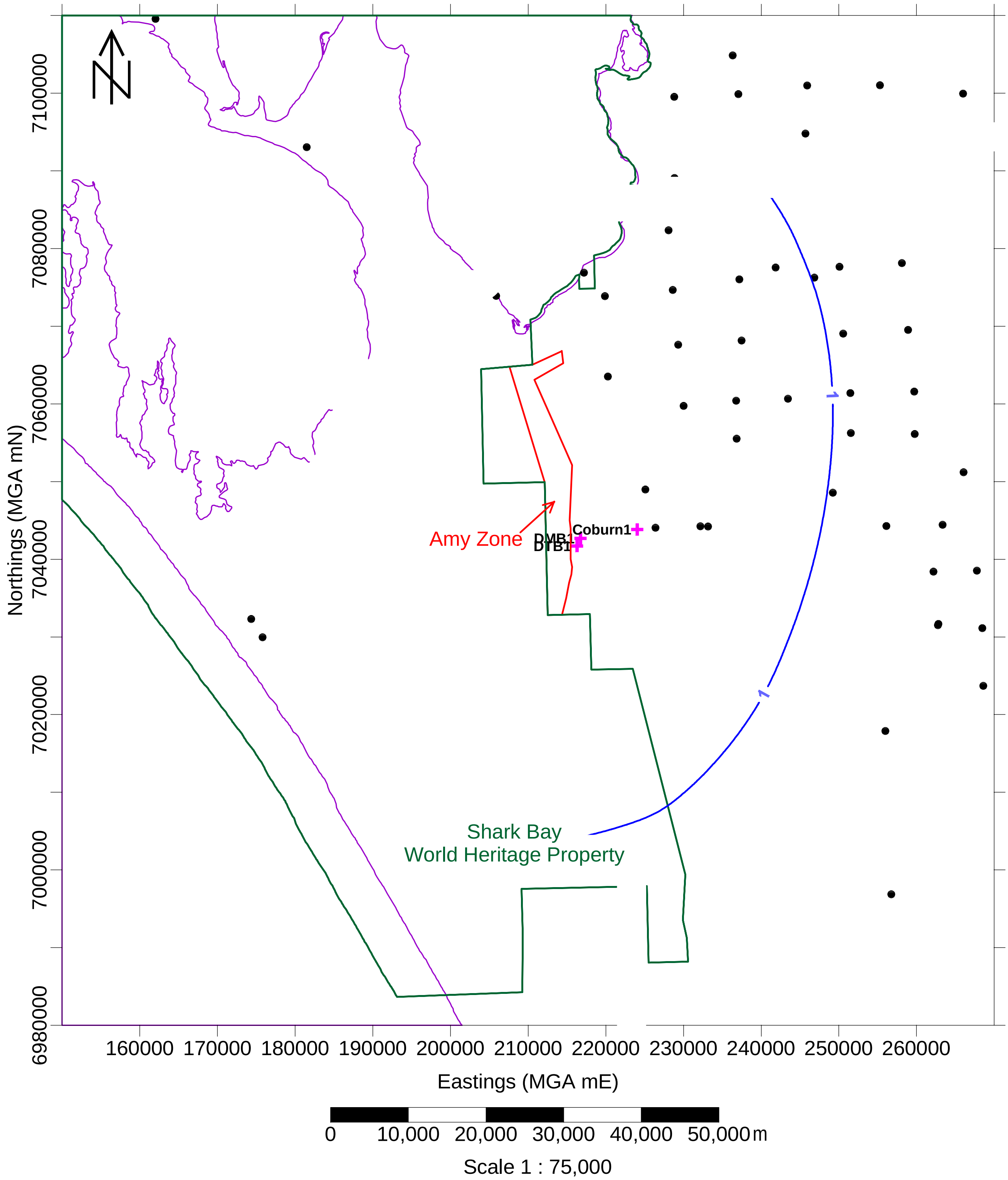
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Windalia Sand Member, 1 Year After Abstraction of 11 Gl/annum Has Stopped

Figure 74a

URS



LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- 2 Residual Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Windalia Sand Member, 2 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 74b**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.	1			

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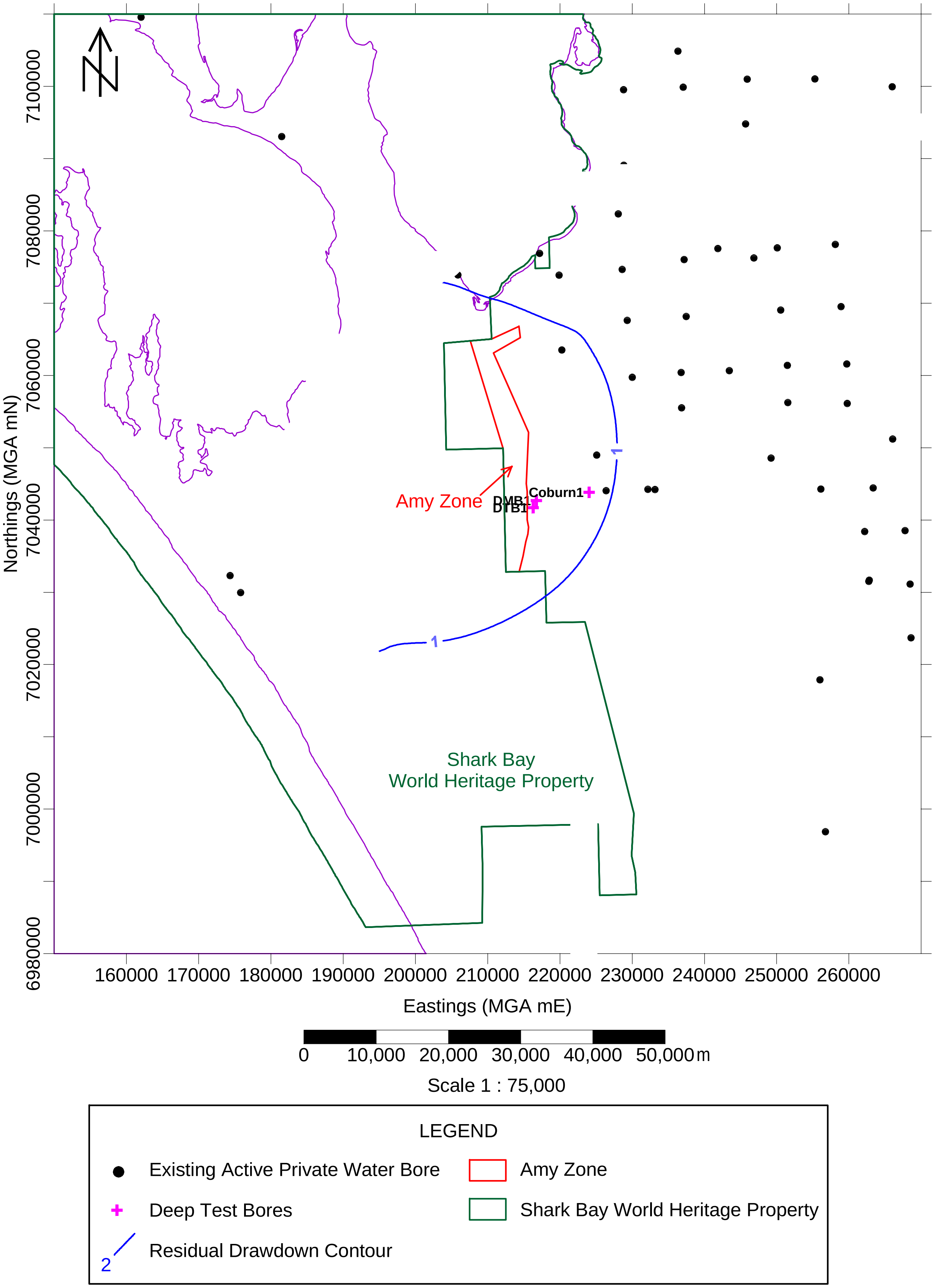
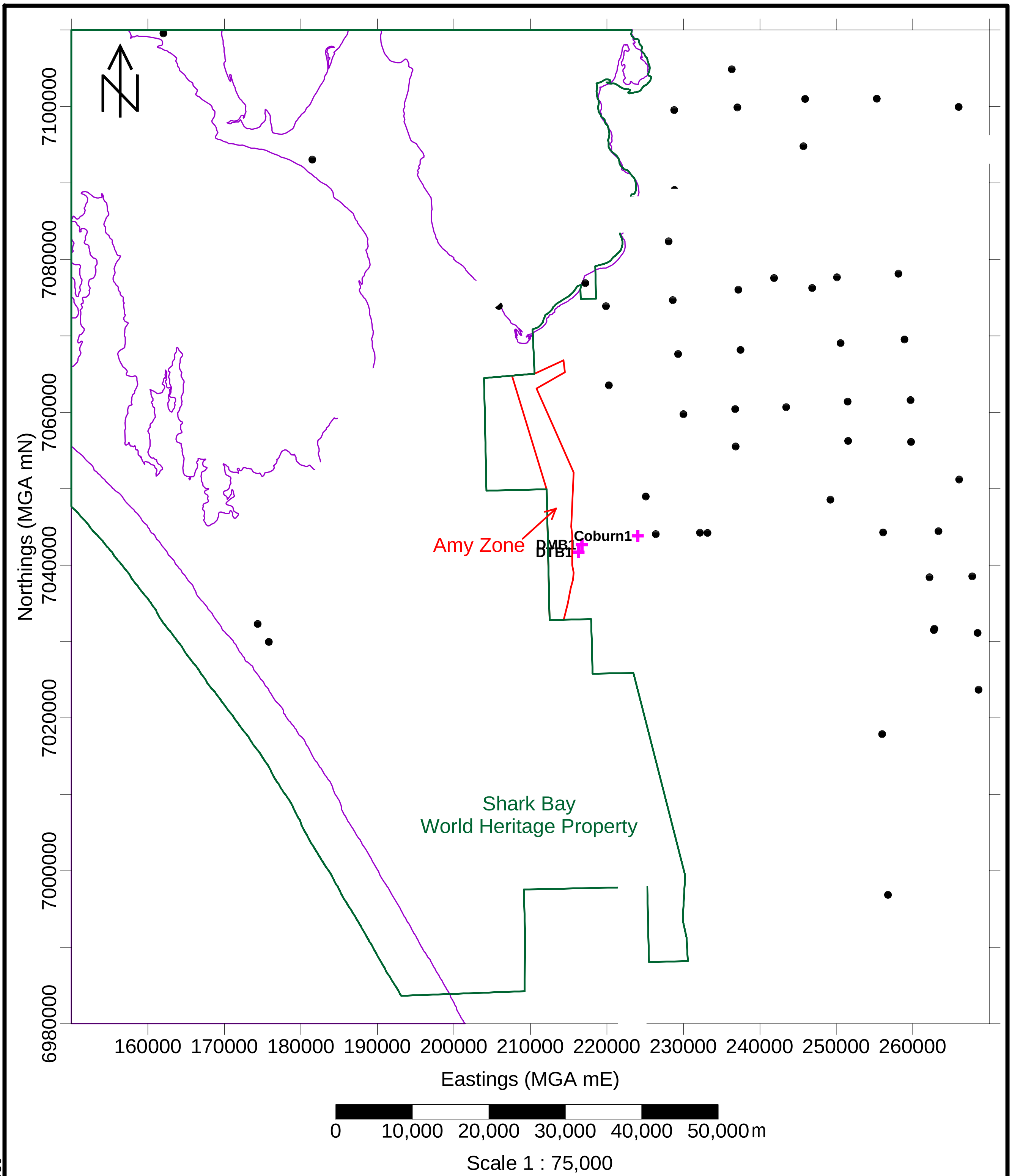


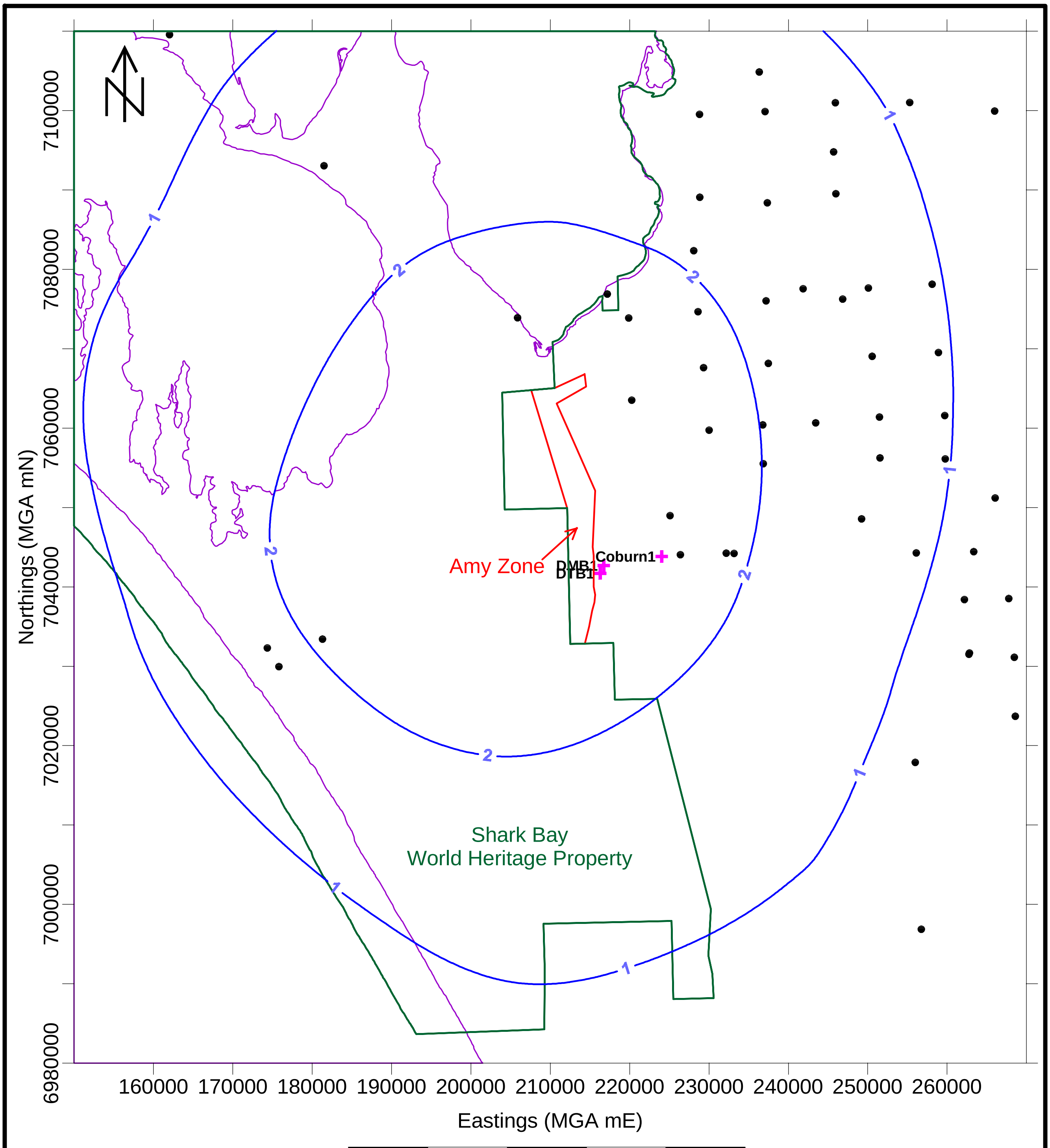
Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Windalia Sand Member, 5 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 74c**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Windalia Sand Member, 10 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 74d**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour
- Amy Zone
- Shark Bay World Heritage Property

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Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	1	

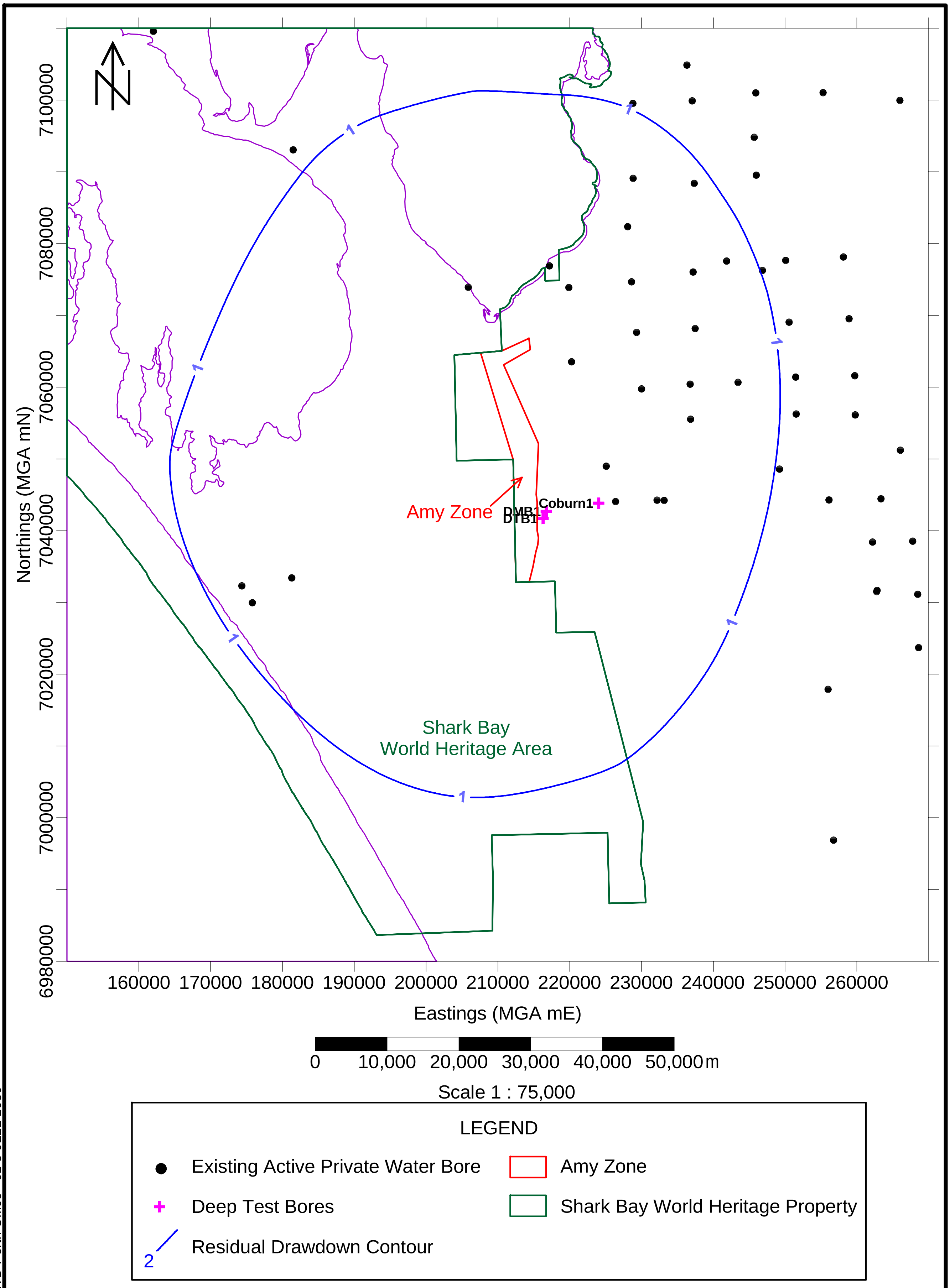
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Birdrong Sandstone, 1 Year After Abstraction of 11 Gl/annum Has Stopped

Figure 75a

URS



Job No.	42905541		
Prep. By	ECPL	1 Apr '05	
Chk'd By	RWC	1 Apr '05	
Revision No.		1	

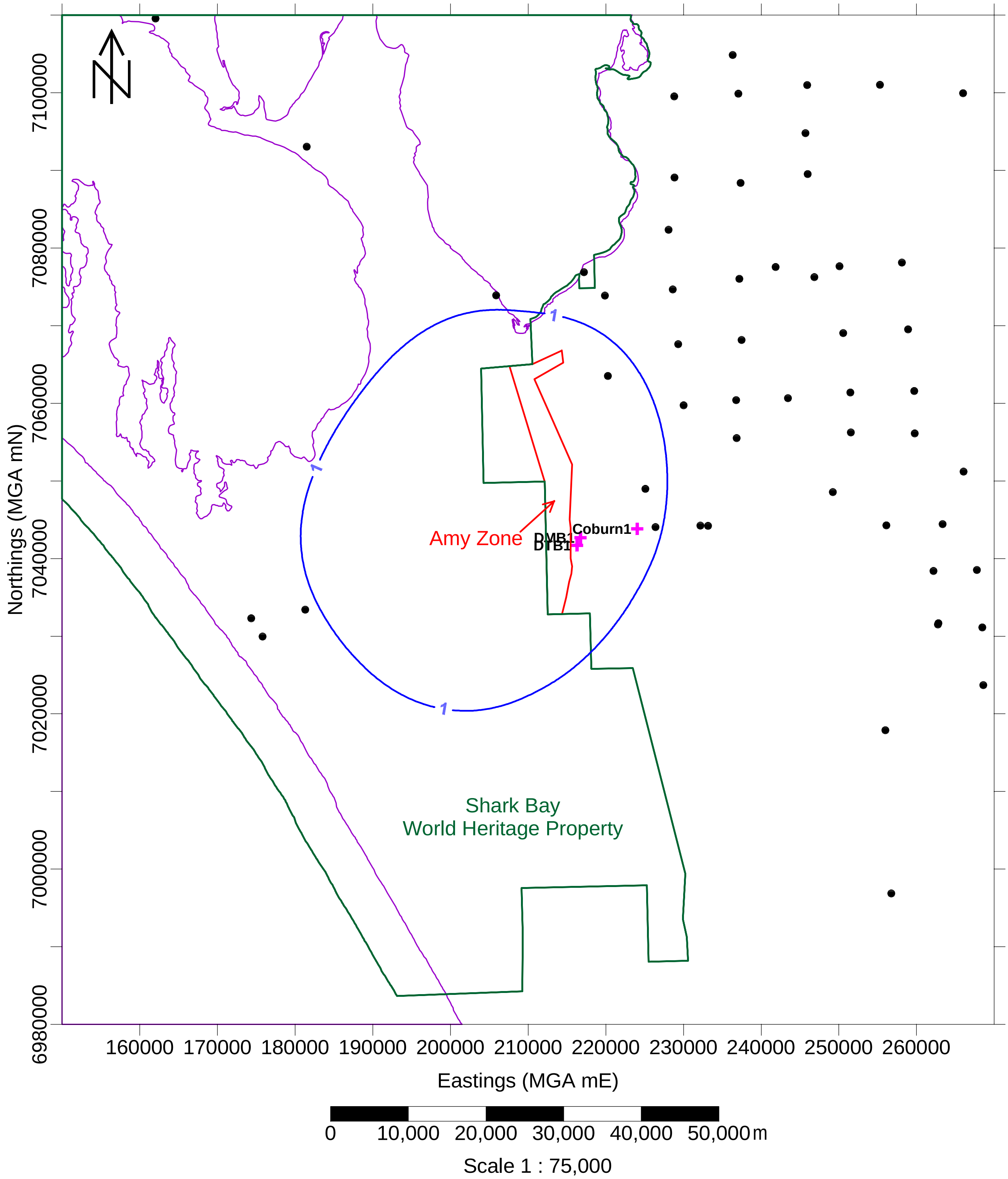
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Birdrong Sandstone, 2 Year After Abstraction of 11 Gl/annum Has Stopped

Figure 75b

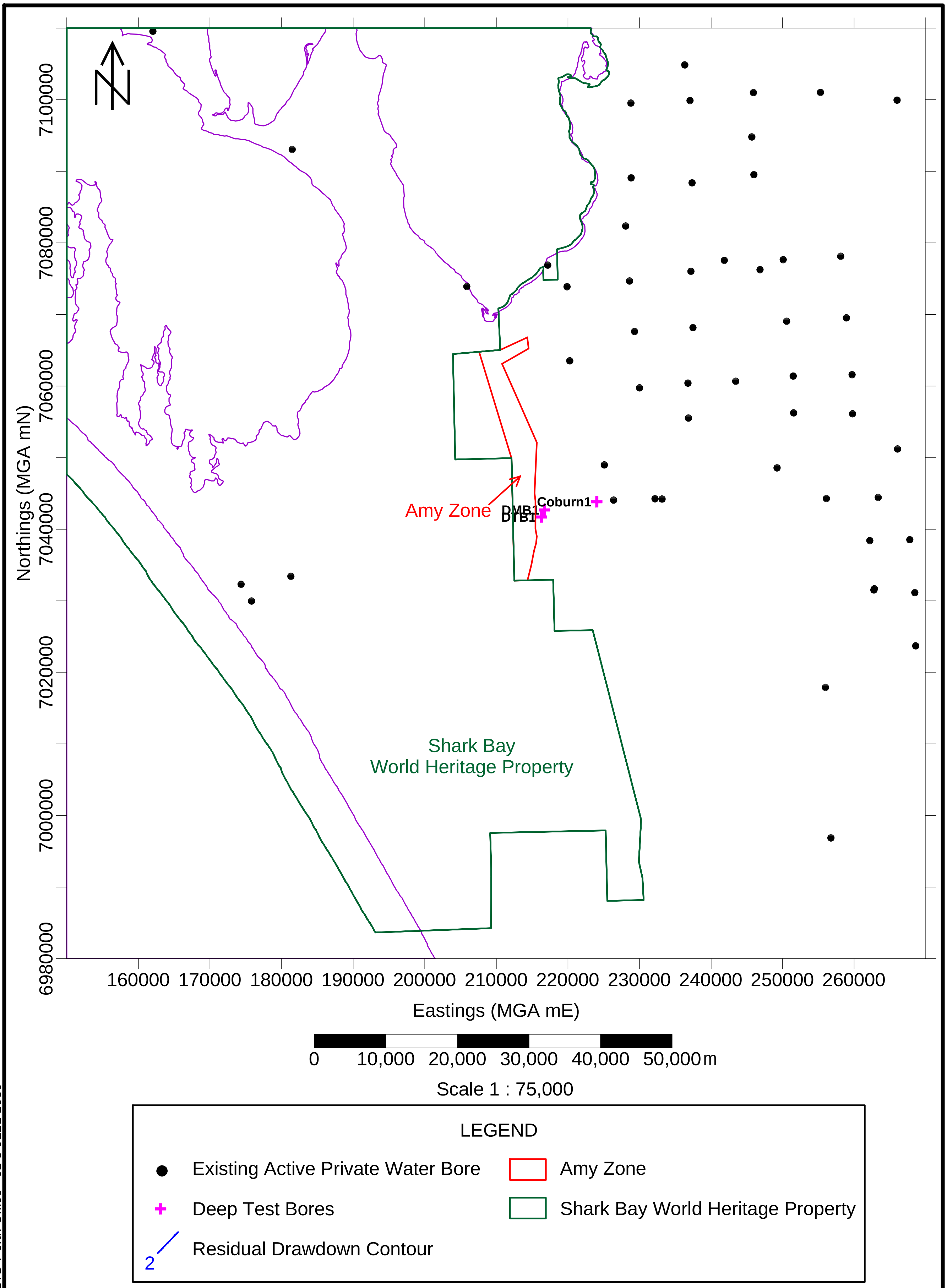
URS



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Birdrong Sandstone, 5 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 75c**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Birdrong Sandstone, 10 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 75d**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		

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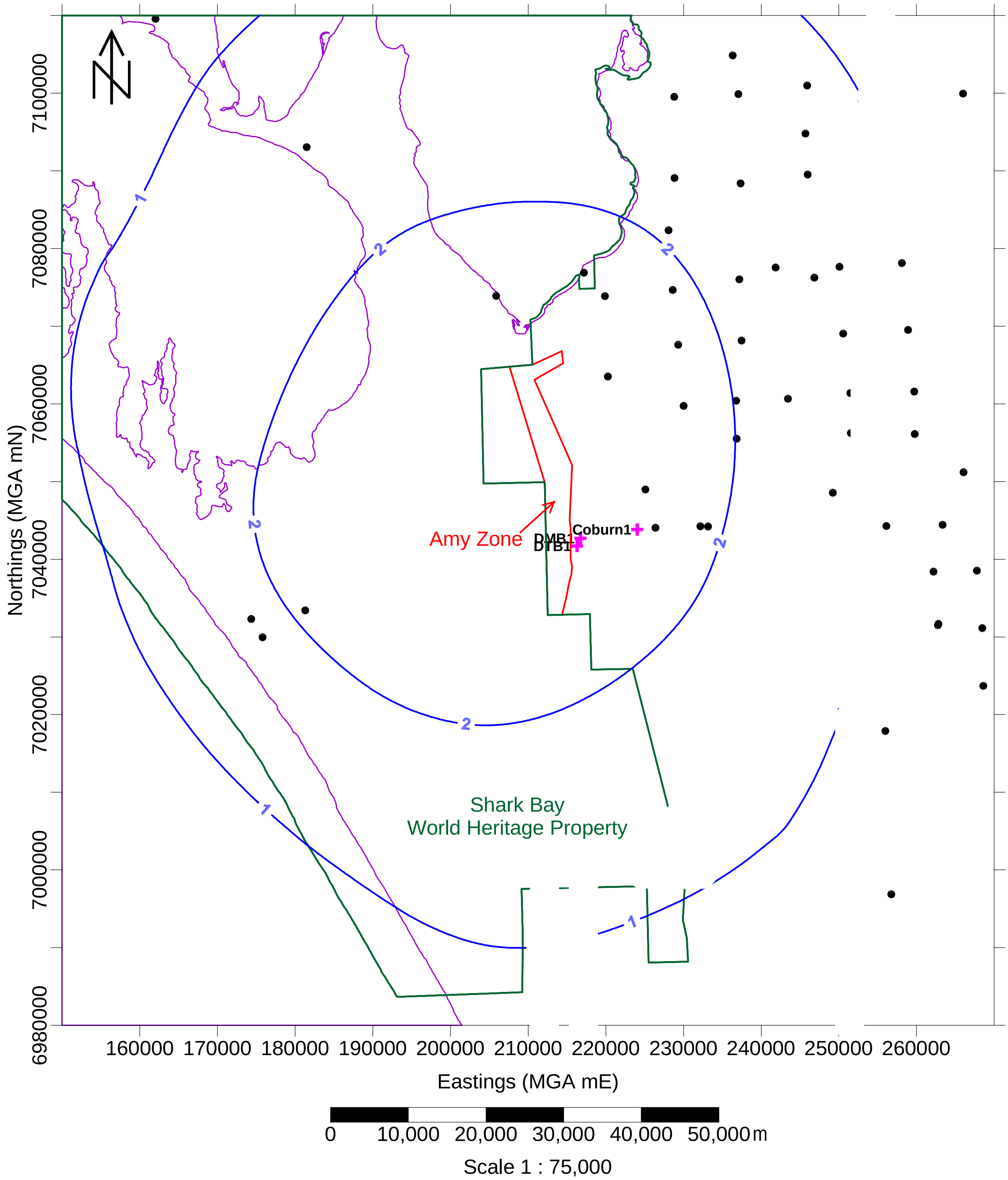


Job No.	42905541	
Prep. By	ECPL	1 Apr '05
Chk'd By	RWC	1 Apr '05
Revision No.	1	

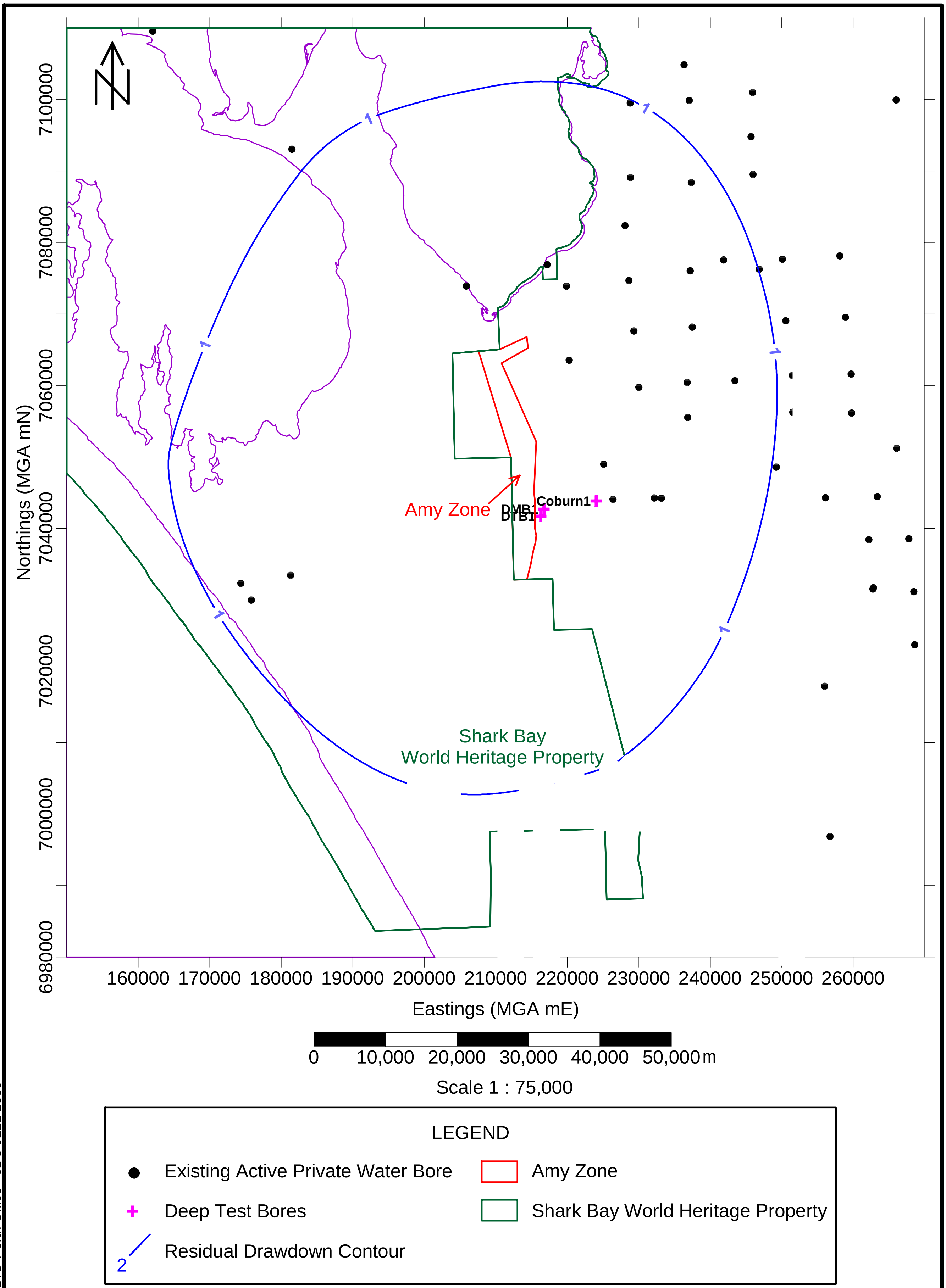
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

Predicted Residual Drawdown in Kopke Sandstone, 1 Year After Abstraction of 11 Gl/annum Has Stopped

Figure 76a

URS



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Kopke Sandstone, 2 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 76b**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		

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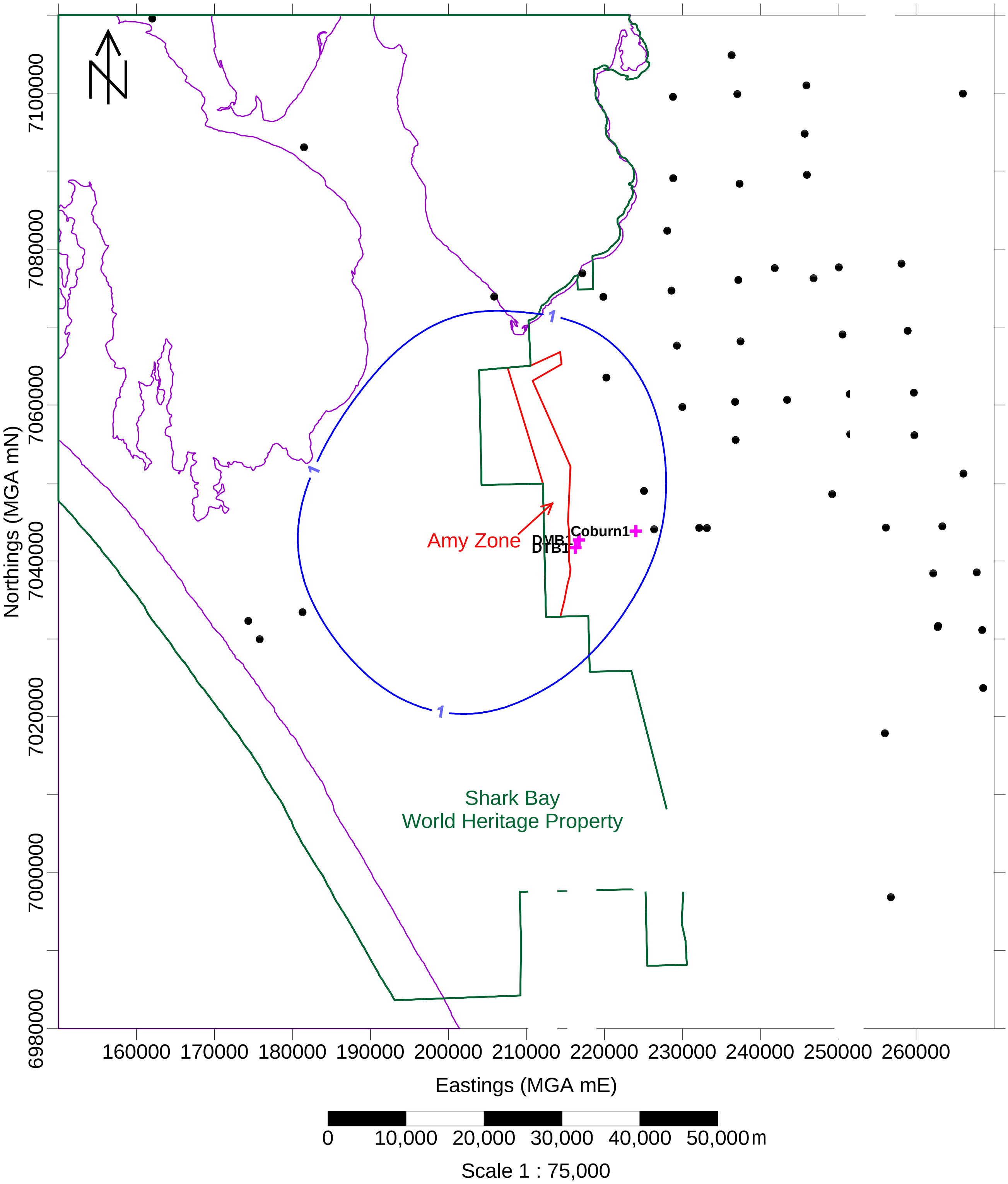
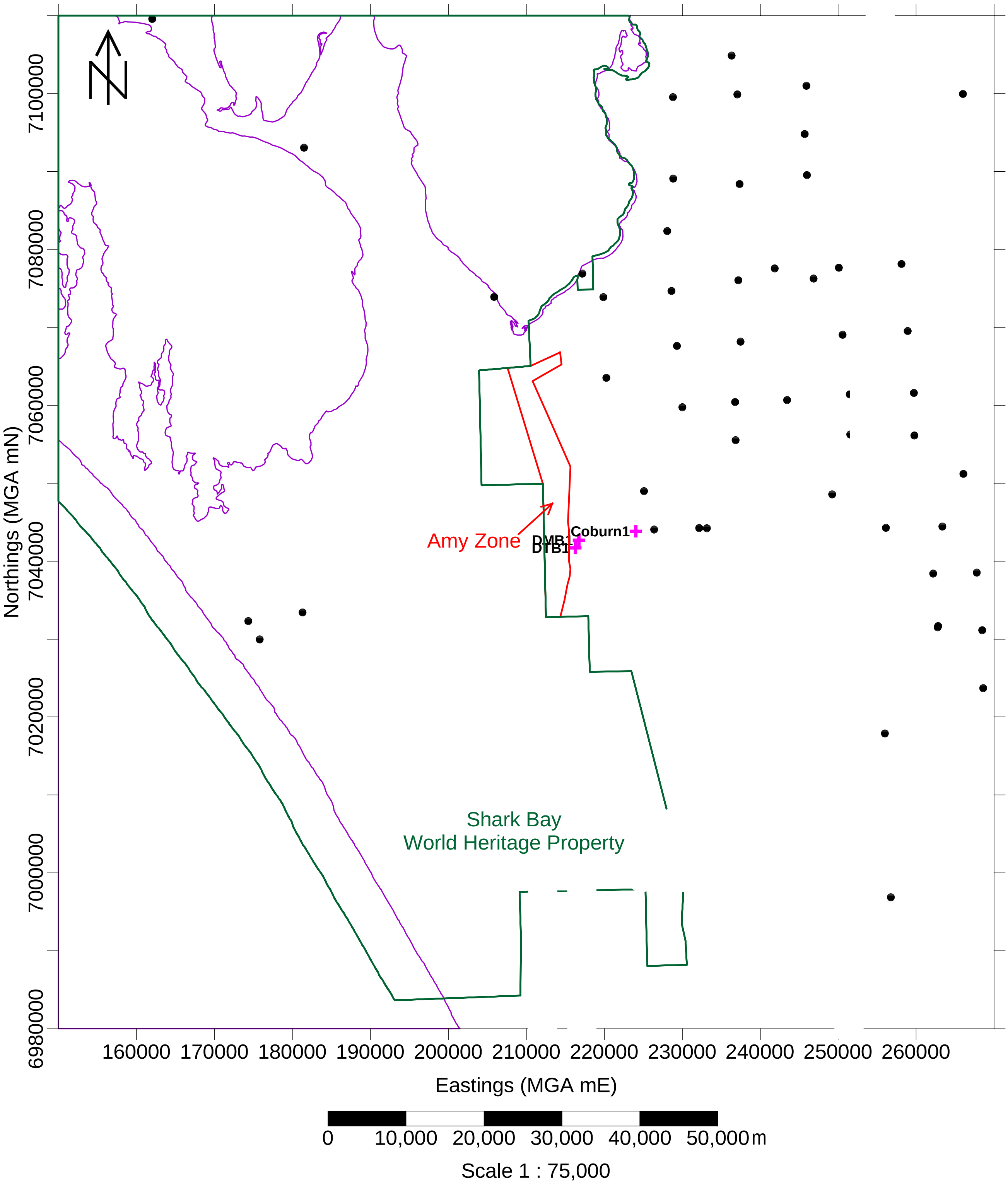


LEGEND

- ● Existing Active Private Water Bore
- ✚ Deep Test Bores
- Residual Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Kopke Sandstone, 5 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 76c**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		



LEGEND

- Existing Active Private Water Bore
- Deep Test Bores
- Residual Drawdown Contour (2)
- Amy Zone
- Shark Bay World Heritage Property

Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **Predicted Residual Drawdown in Kopke Sandstone, 10 Years After Abstraction of 11 Gl/annum Has Stopped**	**Figure 76d**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		

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Job No. 42905541

Prep. By BM 28-Feb-05

Chk'd By RBW 28-Feb-05

Revision No. 0

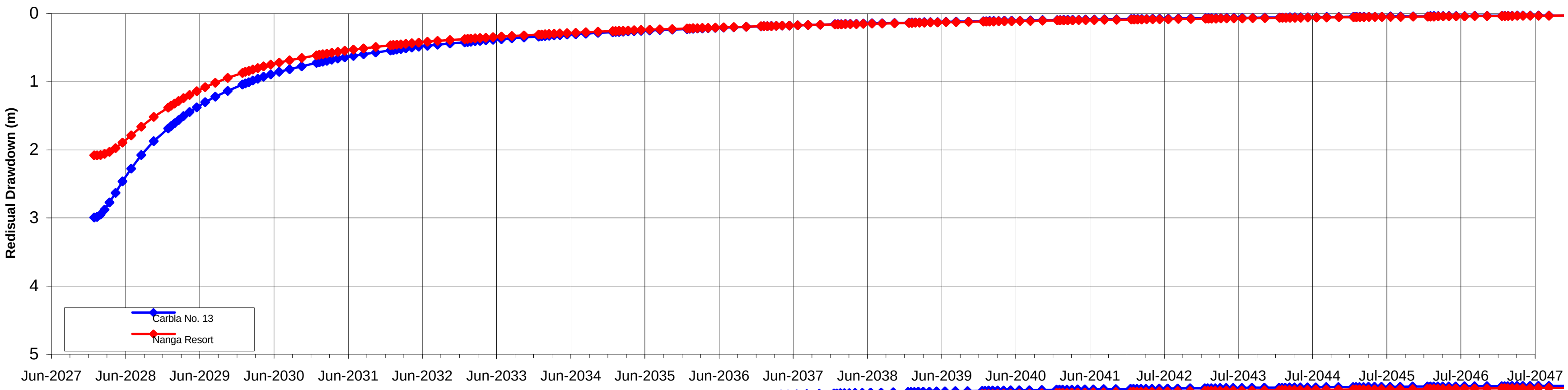
Gunson Resources Limited

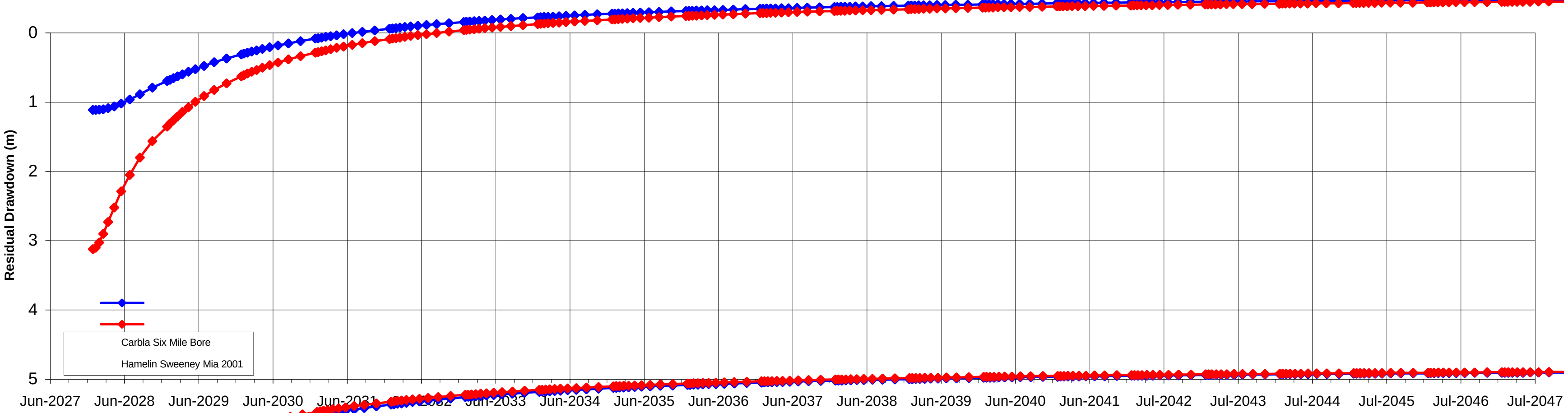
GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED TRANSIENT RESIDUAL DRAWDOWNS AFTER ABSTRACTION OF 11GL/ANNUM - NANGA RESORT, CARBLA STATION AND SWEENY MIA 2001 BORES

URS

Figure 77a





Job No. 42905541

Prep. By BM 28-Feb-05

Chk'd By RBW 28-Feb-05

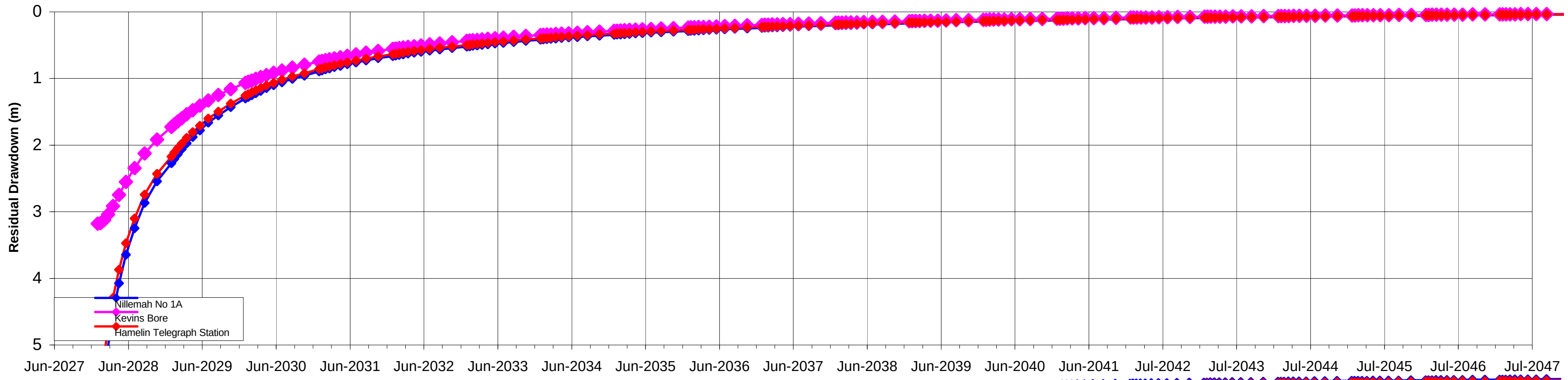
Revision No. 0

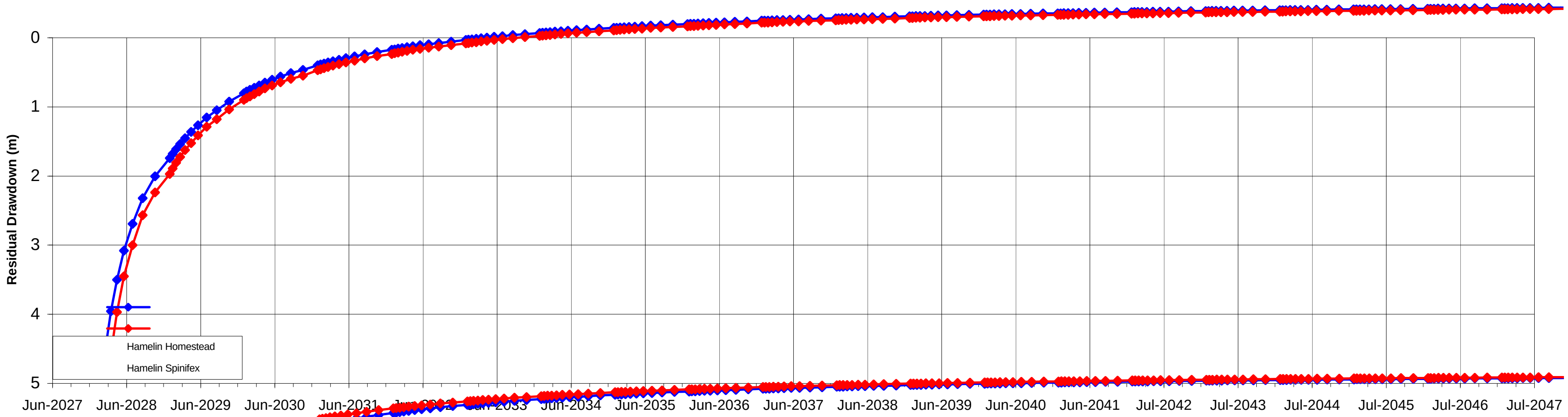
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED TRANSIENT RESIDUAL DRAWDOWNS AFTER ABSTRACTION OF 11GL/ANNUM - NORTHERN HAMELIN STATION, TELEGRAPH STATION AND OVERLANDER ROADHOUSE BORES

Figure 77b





Job No.	42905541
Prep. By	BM
	28-Feb-05
Chk'd By	RBW
	28-Feb-05
Revision No.	0

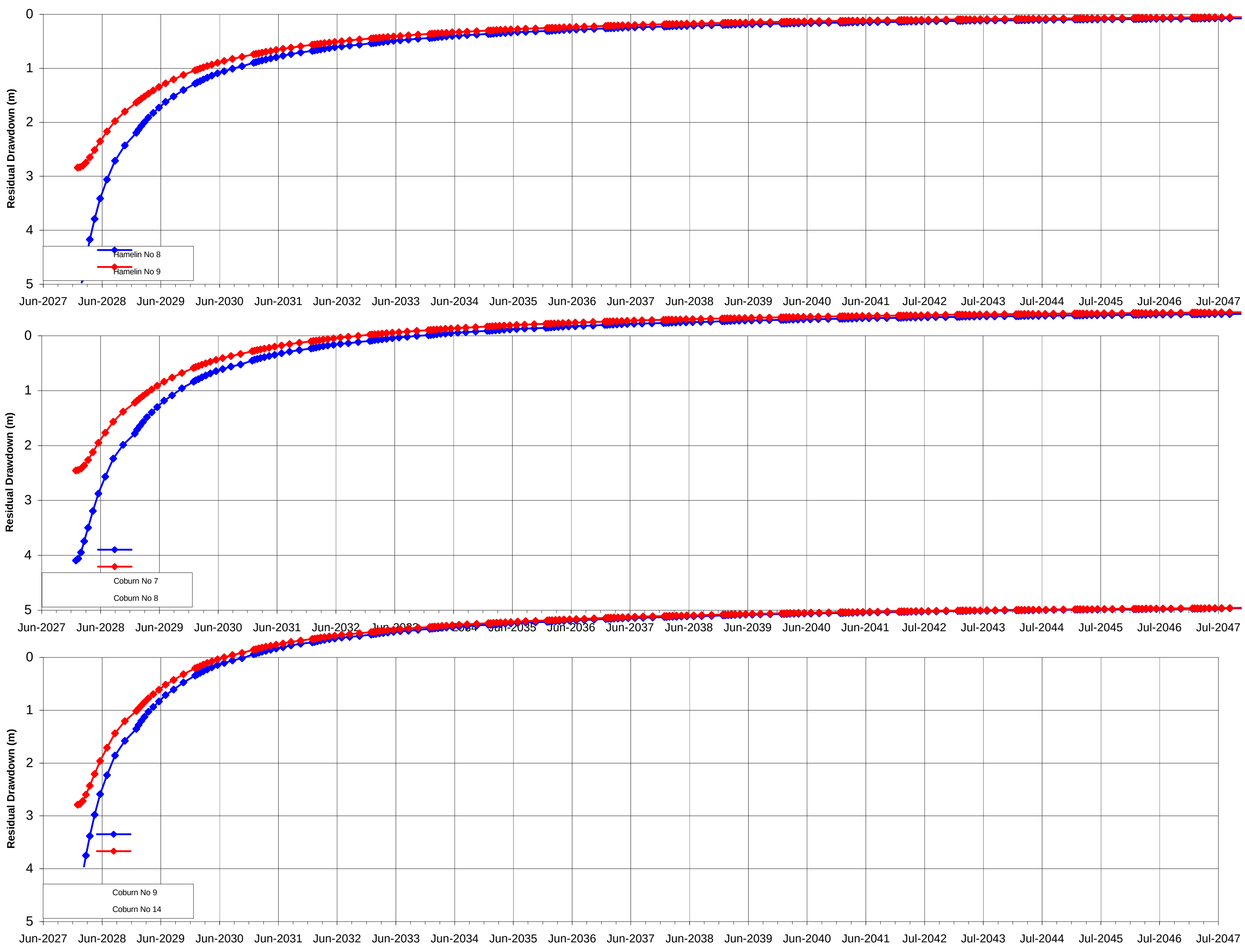
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED TRANSIENT RESIDUAL DRAWDOWNS AFTER ABSTRACTION OF 11GL/ANNUM - SOUTHERN HAMELIN AND COBURN STATIONS BORES

URS

Figure 77c



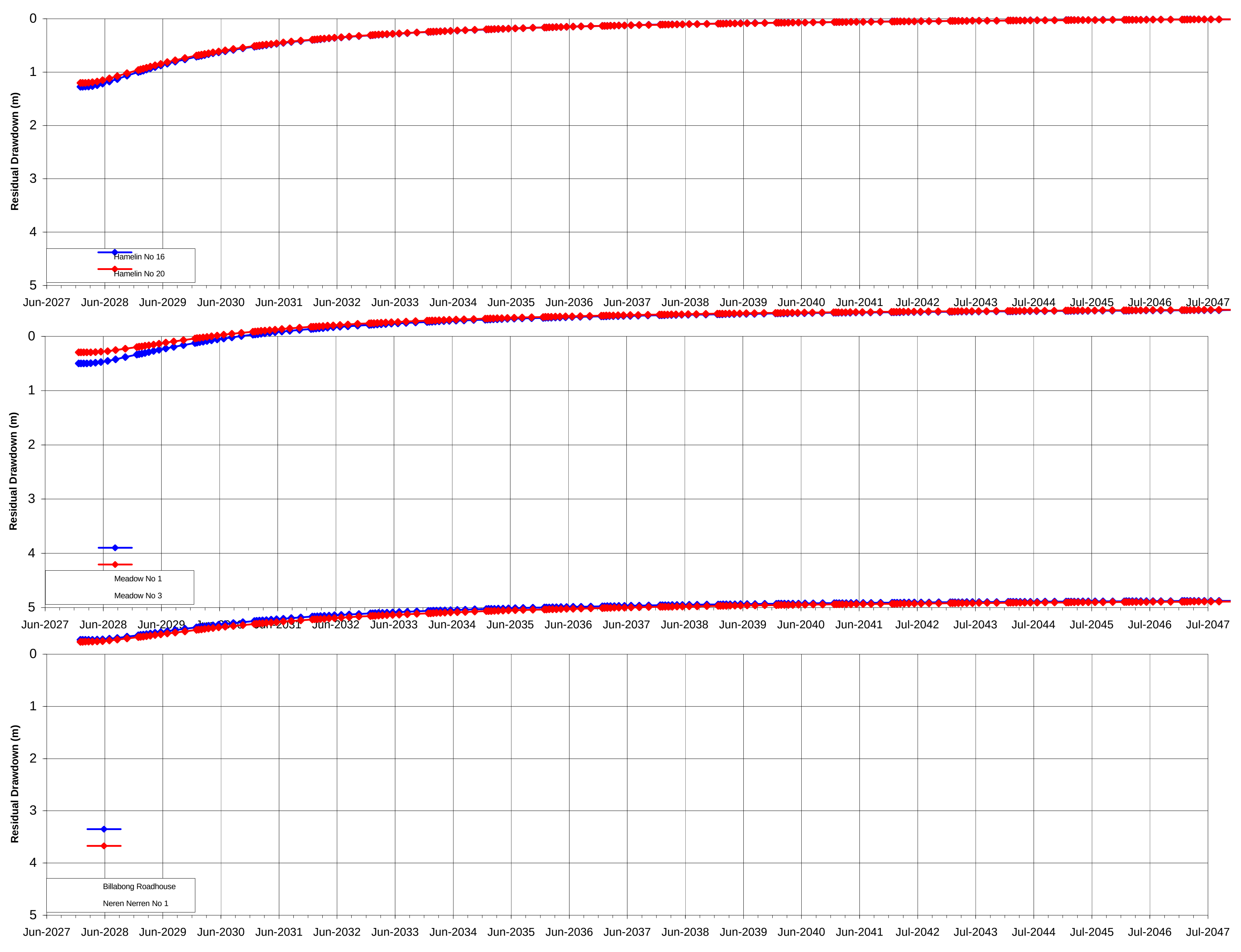
Job No.	42905541
Prep. By	BM 28-Feb-05
Chk'd By	RBW 28-Feb-05
Revision No.	0

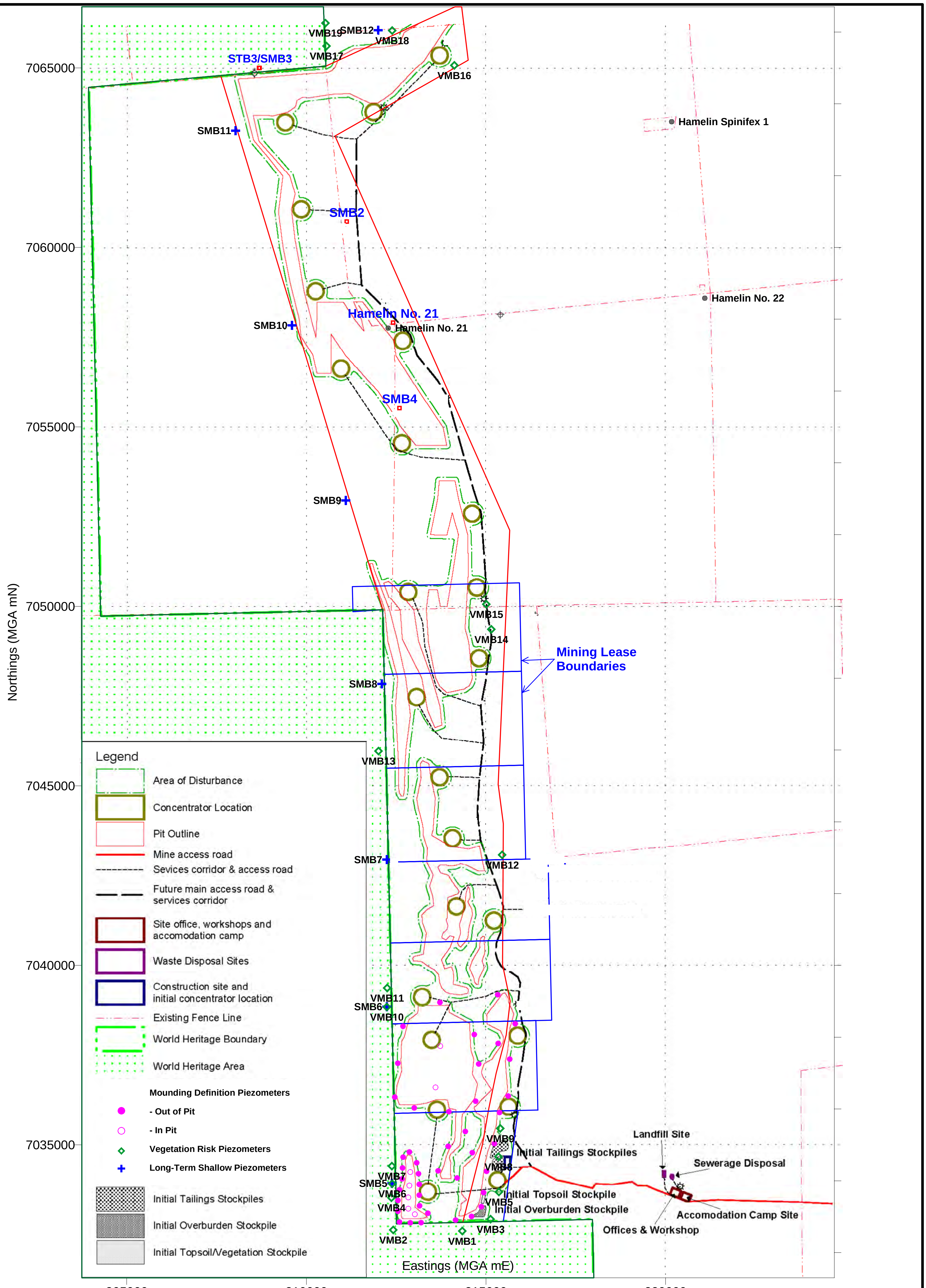
Gunson Resources Limited

GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT

PREDICTED TRANSIENT RESIDUAL DRAWDOWNS AFTER ABSTRACTION OF 11GL/ANNUM - EASTERN HAMELIN STATION, MEADOW AND NERREN NERREN STATIONS AND BILLABONG ROADHOUSE BORES

Figure 77d





Job No.	42905541		Gunson Resources Limited	Figure 78a
Prep. By	RBW	27 Feb 05	GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT	
Chk'd By	RBW	27 Feb 05	**LOCATIONS OF ADDITIONAL SUPERFICIAL FORMATIONS MONITORING BORES**	URS
Revision Indicator	1			

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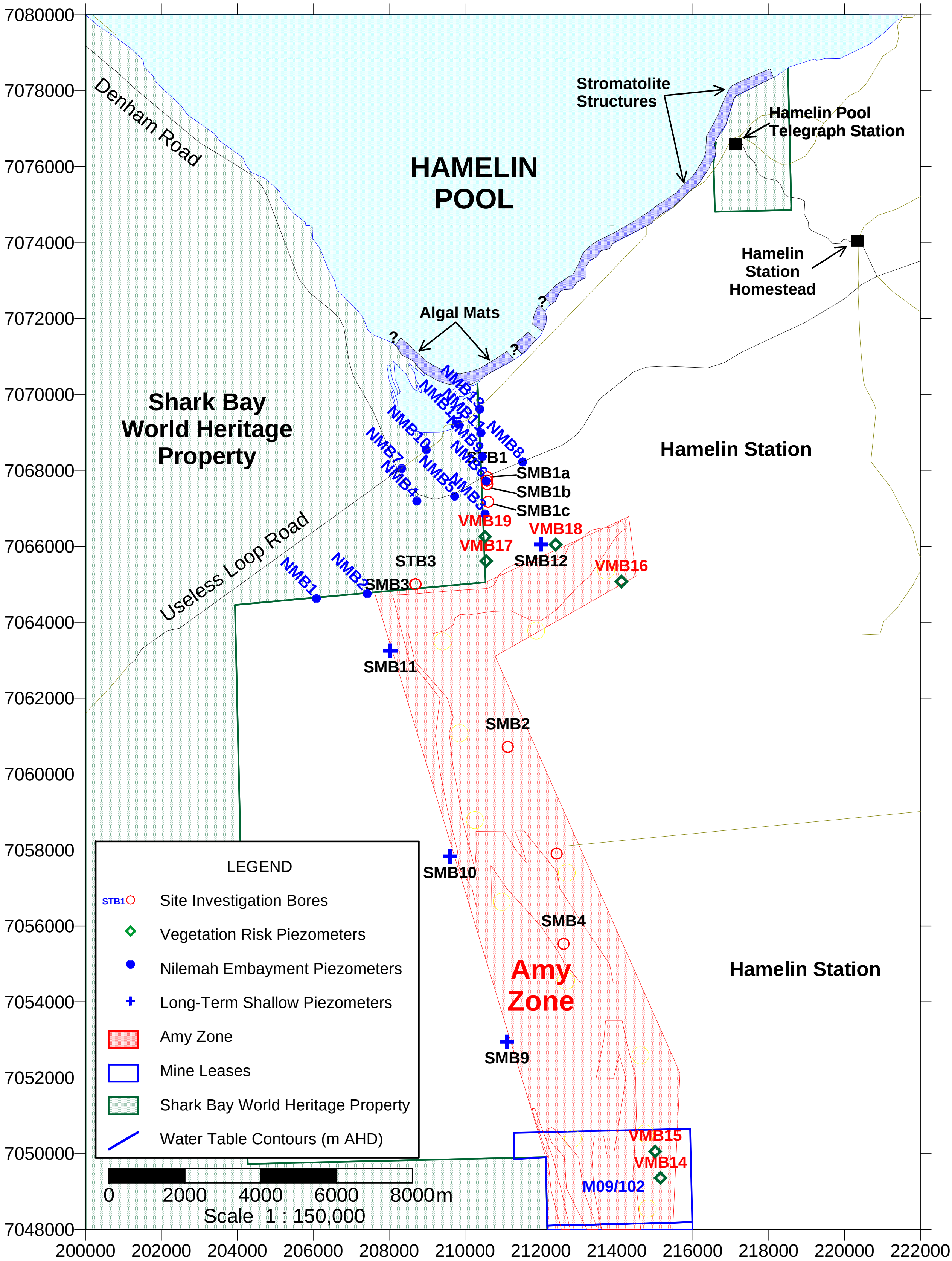
Additional Shallow Mon Bore Locations - Regional.srf



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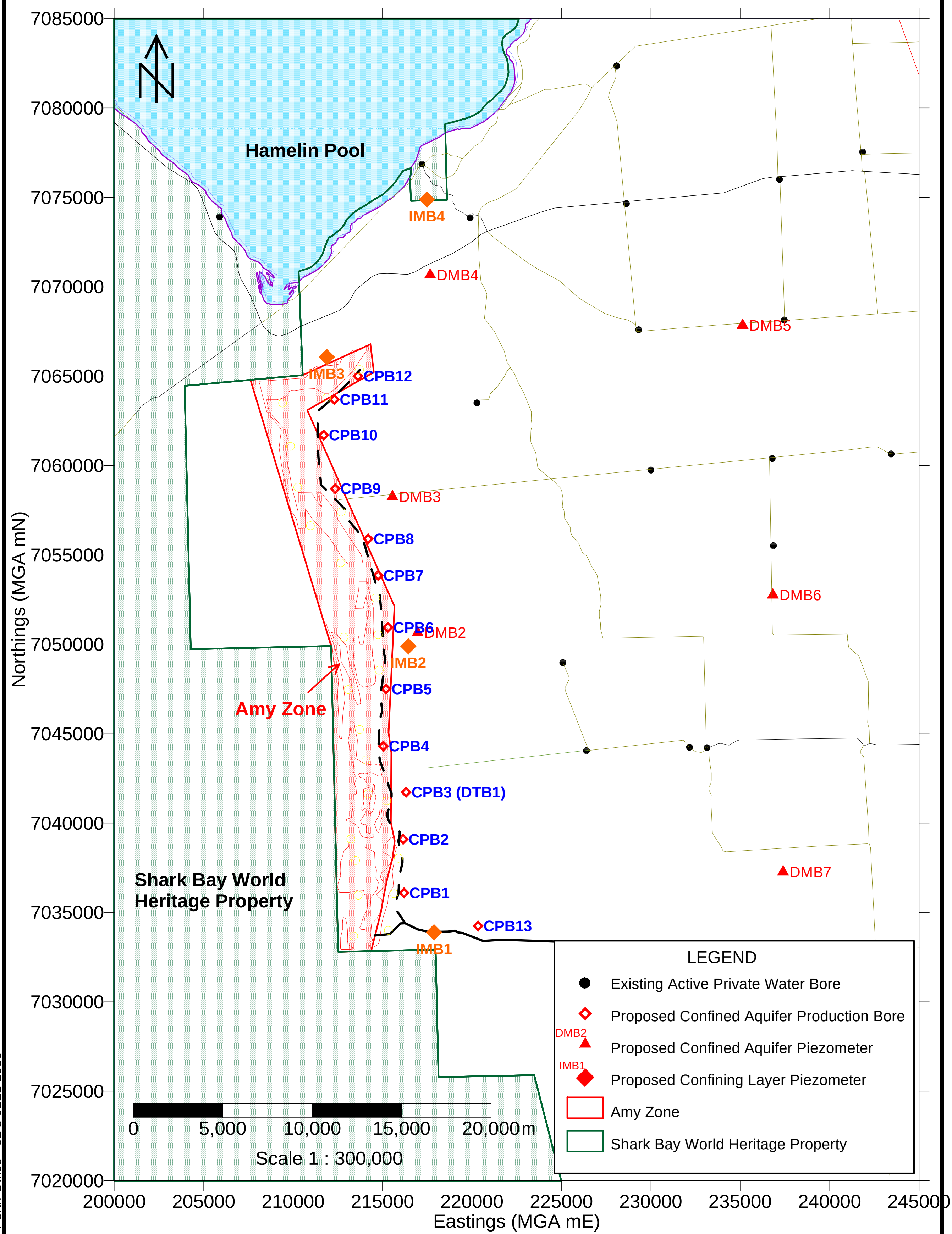
Job No.	42905541		Gunson Resources Limited	**Figure 78b**
Prep. By	RBW	15 Oct '04	GROUNDWATER IMPACT ASSESSMENT, CORURN PROJECT	URS
Chk'd By	RBW	15 Oct '04	**LOCATIONS OF ADDITIONAL SUPERFICIAL FORMATIONS PIEZOMETERS IN THE NORTHERN MINE AND NILEMAH EMBAYMENT AREA**	
Revision No.		1		

Proposed Shallow Monitoring Bore Layout - North.srf



Job No.	42905541		Gunson Resources Limited GROUNDWATER IMPACT ASSESSMENT, COBURN PROJECT **LOCATIONS OF CONFINED AQUIFER MULTIPIEZOMETERS**	**Figure 79**
Prep. By	ECPL	1 Apr '05		URS
Chk'd By	RWC	1 Apr '05		
Revision No.		1		

Proposed Regional Confined Mon Bore Locs.srf

Appendix A
Copy of Licence to Construct or Alter Well Nos. CAW155919(1) & CAW155924(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Commission under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Gunson Resources Ltd	
Description of Water Resource	Gascoyne Carnarvon - Superficial	
Location of Well(s)	E9/939 E9/940, E9/941 & E9/996	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 4 exploratory well(s).	E9/939 E9/940, E9/941 & E9/996
Duration of Licence	From 14 June 2004 to 14 June 2005	

This Licence is subject to the following terms, conditions and restrictions:

1 The well must be constructed by a driller having a current class 1 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or other certification approved by the Water and Rivers Commission as equivalent.

2 That no well shall be sunk within 200 metres of an existing well without the written permission of the owner of that well.

3 That the depth of the bore/s shall be limited to the superficial aquifer.

4 That the licensee install a monitoring device, approved by the Water and Rivers Commission,on the bore for the measurement of water levels.

5 The licensee is required to provide to the Water and Rivers Commission a geophysical log of the bore.

6 The licensee is required to provide to the Water and Rivers Commission a completed ' Particulars of Completed Bore Hole Form' on completion of the approved drilling programme.

7 That on completion of the exploratory drilling programme the licensee shall submit two copies of a hydrogeological assessment of the groundwater source, prepared by a competent hydrogeologist.

8 The Hydrological and Monitoring report should be compiled in accordance with the Water and Rivers Commission publication "Guidelines for Hydrogeological and Monitoring Reports Associated with Groundwater Licensing".

9 That prior to a production bore licence being issued the licensee demonstrates that the required groundwater will be available for abstraction without causing harmful effects on the aquifer or other users.

10 The water drawn from the bore shall be limited to well development, test pumping and sampling

11 That water discharged during the pump test, is to be disposed of in such a manner as to cause no undesirable environmental impact

12 That a plan is provided showing the exact locations of all wells or shafts and indicating those designated as production, monitoring or abandoned.

13 Approval by the Water and Rivers Commission is to be obtained prior to the construction of additional and replacement wells and the modification or refurbishment of existing wells.

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

Water and Rivers Commission
Government of Western Australia

Instrument No. CAW155919(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Commission under section 26D of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

14 That the licensee shall allow access, in an agreed manner, by Water And Rivers Commission personnel for the purposes of inspection at any time.

15 This licence is not renewable.

End of terms, conditions and restrictions

Water and Rivers Commission
Government of Western Australia

Instrument No. CAW155924(1)

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Commission under section 26D of the Rights in Water and Irrigation Act 1914

Licensee(s)	Gunson Resources Ltd	
Description of Water Resource	Gascoyne Carnarvon - Birdrong.	
Location of Well(s)	E9/939 E9/940, E9/941 & E9/996	
Authorised Activities	**Activity**	**Location of Activity**
	Construct 2 exploratory well(s).	E9/939 E9/940, E9/941 & E9/996
Duration of Licence	From 14 June 2004 to 14 June 2005	

This Licence is subject to the following terms, conditions and restrictions:

1 The well must be constructed by a driller having a current class 3 water well drillers certificate issued by the Western Australian branch of the Australian Drilling Industry Association or other certification approved by the Water and Rivers Commission as equivalent.

2 That no well shall be sunk within 1000 metres of an existing well without the written permission of the owner of that well.

3 That bore construction is limited to the screening of one discrete aquifer interval per bore.

4 That the casing or casings are equipped with centralisers not less than one per casing length and are inserted in a hole providing an annulus of not less than 30mm and that the annulus is pressure cement grouted from the top of the screen to the surface.

5 That the bore is adequately capped and if it flows at the surface, equipped with a valve to control the flow.

6 The licensee is required to provide to the Water and Rivers Commission a geophysical log of the bore.

7 The licensee is required to provide to the Water and Rivers Commission a completed 'Particulars of Completed Bore Hole Form' on completion of the approved drilling programme.

8 That on completion of the exploratory drilling programme the licensee shall submit two copies of a hydrogeological assessment of the groundwater source, prepared by a competent hydrogeologist.

9 The Hydrological and Monitoring report should be compiled in accordance with the Water and Rivers Commission publication "Guidelines for Hydrogeological and Monitoring Reports Associated with Groundwater Licensing".

10 That prior to a production bore licence being issued the licensee demonstrates that the required groundwater will be available for abstraction without causing harmful effects on the aquifer or other users.

11 The water drawn from the bore shall be limited to well development, test pumping and sampling

12 That the bore is not permitted to run to waste.

13 That should the bore/s be abandoned it/they shall be sealed off to the satisfaction of the Water and Rivers Commission.

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

LICENCE TO CONSTRUCT OR ALTER WELL

Granted by the Commission under section 26D of the Rights in Water and Irrigation Act 1914

This Licence is subject to the following terms, conditions and restrictions:

14 That water discharged during the pump test, is to be disposed of in such a manner as to cause no undesirable environmental impact

15 That a plan is provided showing the exact locations of all wells or shafts and indicating those designated as production, monitoring or abandoned.

16 Approval by the Water and Rivers Commission is to be obtained prior to the construction of additional and replacement wells and the modification or refurbishment of existing wells.

17 That the licensee shall allow access, in an agreed manner, by Water And Rivers Commission personnel for the purposes of inspection at any time.

18 This licence is not renewable.

End of terms, conditions and restrictions

This Licence is granted subject to the Rights in Water and Irrigation Regulations 2000.

Appendix B
Summary of Aquifer Testing and Calculated Parameters

APPENDIX B. Summary of Aquifer Paramaters - Shallow Bores

Bore No.	Ref. Point	SWL		Depth	Saturated Thickness	Slotted Interval		Pumping Rate	Inflow rate	Const. Head	Hydraulic Conductivity (m/d)				Storage Coeff.
	(m agl)	(m brp)	(m bgl)	(m bgl)	(m)	From (m bgl)	To (m bgl)	(kL/d)	(kL/d)	(m)	Jacob	Bower & Rice	Summerville	Hvorslev	Jacob
SMB2s	0.51	23.74	23.23	24	0.77	18	24	N/A	>360	abt. 23.5	-	-	>13	>2.5	-
SMB2d	0.51	23.76	23.25	40	16.75	34	40	13.8	13	23.8	-	0.13	-	0.08	-
STB3	0.41	30.63	30.22	43	12.78	16	43	7.5	-	-	0.2	-	-	-	-
SMB3s	0.49	>30.2	>29.7	30	0	24	30	N/A	~440	25.0	-	-	5.6	2.6	-
SMB3d	0.49	30.2	29.71	43	13.29	37	43	N/A	35	30.2	0.4	0.1	-	0.17	2.2E-05
SMB4s	0.54	>30.0	>30.0	30	0	24	30	N/A	>345	30.0	-	-	>5.3	-	-
SMB4d	0.54	37.63	37.09	42	4.91	36	42	2.4	>410	30.0	0.05	0.5*	-	>2.0*	-

APPENDIX B. Derivation of Formation Yields Based on Salinities and Formation Resistivities

Groundwater				Formation			
Salinity (mg/L) TDS	EC (mS/m)	EC (mho/m)	Resistivity (ohm m)	Resistivity (ohm m)	Formation Factor	Depth Interval (m bgl)	Material Type
Windalia Sand Member							
9,100	1,400	1.4	0.714	3.0	4.2	170 - 195	Sand(stone)
Birdrong Sandstone							
7,750	1,100	1.1	0.909	3.5	3.9	205 - 230	Sand(stone)
Kopke Sandstone							
12,000	1,700	1.7	0.588	4.5	7.7	380 - 387	Sandstone

Kopke Sandstone Salinities from DTB1 Geophysical Log

Interval Details				Formation		Groundwater			
Depth From (m)	Depth To (m)	Interval Thickness	Cumulative Thickness	Resistivity (ohm m)	Formation Factor	Resistivity (ohm m)	EC (mS/m)	Interval Salinity * (mg/L TDS)	Average Salinity (mg/L TDS)
228	240	12	12	3.5	7.7	0.455	2,200	14,300	14300
240	245	5	17	4	7.7	0.519	1,925	12,513	13774
245	280	35	52	5.5	7.7	0.714	1,400	9,100	10628
280	285	5	57	5	7.7	0.649	1,540	10,010	10574
285	317	32	89	4.5	7.7	0.584	1,711	11,122	10771
317	370	53	142	6	7.7	0.779	1,283	8,342	9864
370	415	45	187	5	7.7	0.649	1,540	10,010	9899

Note: * - EC to TDS conversion based on an average of four Kopke groundwater samples to arrive at a ratio of 0.65. 0.65

DTB1 Salinity =	8900	mg/L TDS
Kopke Proportion =	54%	
Birdrong Proportion =	46%	
Derived Combined Salinity =	8911	mg/L TDS

Appendix C
Laboratory Certificates and Chemical Analyses of Regional (Private) Bores

LABORATORY REPORT COVERSHEET

DATE:	3 September 2004
TO:	URS Corporation Level 3, The Hyatt Centre 20 Terrace Road EAST PERTH WA 6004
ATTENTION:	Mr Rob Wallis
YOUR REFERENCE:	52830-005-562 0108
OUR REFERENCE:	83127
SAMPLES RECEIVED:	16/08/04
SAMPLES/QUANTITY:	5 Waters

The above samples were received intact and analysed according to your written instructions. Unless otherwise stated, solid samples are reported on a dry weight basis and liquid samples as received.

JANICE VENNING
Manager, Perth

LIEN TANG
Manager Reporting Systems

This report supersedes preliminary results that were reported by E-Mail.
This report must not be reproduced except in full.

SGS Australia Pty Ltd ABN 44 000 964 278 | Environmental Services t +61 (0)8 9458 7278 | 52 Murray Road f +61 (0)8 9451 3505 | Welshpool 6106 | Western Australia | www.au.sgs.com
Member of the SGS Group

CLIENT: URS Corporation

PROJECT: 52830-005-562 0108

OUR REFERENCE: 83127

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of Sample	Units	SMB 2 (shall) 83127-1 13/08/2004 Water	SMB 2 (deep) 83127-2 12/08/2004 Water	STB 3 83127-3 12/08/2004 Water	SMB 4 (deep) 83127-4 12/08/2004 Water	STB 1 83127-5 13/08/2004 Water
pH	pH Units	6.3	6.7	6.2	6.2	6.6
Electrical Conductivity @ 25 oC	µS/cm	18,000	34,000	47,000	17,000	92,000
Total Dissolved Solids (grav) @ 180°C	mg/L	14,000	25,000	34,000	11,000	68,000
Total Alkalinity as $CaCO_3$	mg/L	750	260	130	280	230
True Colour	PCU	60	10	10	35	10
Hardness (equivalent $CaCO_3$)	mg/L	430	4,300	6,000	880	12,000
Iron (Total), Fe	mg/L	8.6	0.25	0.15	10	<0.5
Sodium, Na	mg/L	4,200	8,100	10,000	3,700	21,000
Potassium, K	mg/L	72	210	280	99	560
Calcium, Ca	mg/L	56	420	590	88	1,200
Magnesium, Mg	mg/L	72	780	1,100	160	2,200
Chloride, Cl	mg/L	5,100	13,000	17,000	4,900	37,000
Carbonate, CO_3	mg/L	<1	<1	<1	<1	<1
Bicarbonate, HCO_3	mg/L	920	320	160	350	280
Sulphate, SO_4	mg/L	1,100	2,200	1,400	1,000	4,800
Nitrate, NO_3	mg/L	1.0	6.9	15	<0.2	34
Nitrite, NO_2	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride, F	mg/L	0.5	0.6	1.0	0.1	0.6
Manganese, Mn	mg/L	0.50	0.85	0.10	1.1	<0.5
Silica, SiO_2	mg/L	190	41	60	140	21
Sum of Ions (calc.)	mg/L	11,521	25,041	30,543	10,295	67,072
Cation/Anion balance	%	3.04	2.89	4.71	4.71	0.86

SGS

CLIENT: URS Corporation

PROJECT: 52830-005-562 0108

OUR REFERENCE: 83127

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of Sample	Units	SMB 2 (shall) 83127-1 13/08/2004 Water	SMB 2 (deep) 83127-2 12/08/2004 Water	STB 3 83127-3 12/08/2004 Water	SMB 4 (deep) 83127-4 12/08/2004 Water	STB 1 83127-5 13/08/2004 Water
Aluminium, Al	mg/L	12	<0.1	0.2	4.4	<1
Arsenic, As	mg/L	0.090	0.005	0.010	0.065	<0.005
Cadmium, Cd	mg/L	<0.001	<0.001	<0.001	<0.001	<0.01
Copper, Cu	mg/L	<0.05	<0.05	0.05	<0.05	<0.5
Mercury, Hg	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lead, Pb	mg/L	<0.005	<0.005	<0.005	<0.005	<0.05
Selenium, Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc, Zn	mg/L	0.10	0.05	0.10	0.05	<0.5

TEST PARAMETERS	UNITS	LOR	METHOD
Standard 2			
pH	pH Units	0.1	PEI-001
Electrical Conductivity @ 25°C	µS/cm	1	PEI-032
Total Dissolved Solids (grav) @ 180°C	mg/L	10	PEI-002
Total Alkalinity as $CaCO_3$	mg/L	5	PEI-006
True Colour	PCU	5	PEI-004
Hardness (equivalent $CaCO_3$)	mg/L	5	PEI-043
Iron (Total), Fe	mg/L	0.05	PEP-060/ PEM001
Sodium, Na	mg/L	0.5	PEM-001
Potassium, K	mg/L	0.5	PEM-001
Calcium, Ca	mg/L	0.5	PEM-002
Magnesium, Mg	mg/L	0.5	PEM-002
Chloride, Cl	mg/L	1	PEI-020
Carbonate, CO_3	mg/L	1	PEI-006
Bicarbonate, HCO_3	mg/L	5	PEI-006

SGS

CLIENT: URS Corporation

PROJECT: 52830-005-562 0108

OUR REFERENCE: 83127

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
Sulphate, SO_4	mg/L	1	PEI-020
Nitrate, NO_3	mg/L	0.2	PEI-020
Nitrite, NO_2	mg/L	0.05	PEI-013
Fluoride, F	mg/L	0.1	PEI-027
Manganese, Mn	mg/L	0.05	PEM-001
Silica, SiO_2	mg/L	2	PEM-002
Sum of Ions (calc.)	mg/L		Calc.
Cation/Anion balance	%		Calc.
Drinking Water Metals			
Aluminium, Al	mg/L	0.1	PEM-002
Arsenic, As	mg/L	0.005	PEM-004
Cadmium, Cd	mg/L	0.001	PEM-003
Copper, Cu	mg/L	0.05	PEM-001
Mercury, Hg	mg/L	0.0005	PEM-005
Lead, Pb	mg/L	0.005	PEM-003
Selenium, Se	mg/L	0.01	PEM-004
Zinc, Zn	mg/L	0.05	PEM-001

CLIENT: URS Corporation

PROJECT: 52830-005-562 0108

OUR REFERENCE: 83127

LABORATORY REPORT

QUALTY CONTROL	UNITS	Blank	Replicate Sm#	Replicate Sample||Replicate	Spike Sm#	Matrix Spike
pH	pH Units	-	[NT]	[NT]	Water	-
Electrical Conductivity @ 25°C	µS/cm	-	[NT]	[NT]	Water	-
Total Dissolved Solids (grav) @ 180°C	mg/L	<10	[NT]	[NT]	Water	129%
Total Alkalinity as $CaCO_3$	mg/L	<5	[NT]	[NT]	Water	107%
True Colour	PCU	<5	[NT]	[NT]	Water	-
Hardness (equivalent $CaCO_3$)	mg/L	<5	[NT]	[NT]	Water	-
Iron (Total), Fe	mg/L	<0.05	[NT]	[NT]	Water	105%
Sodium, Na	mg/L	<0.5	[NT]	[NT]	Water	102%
Potassium, K	mg/L	<0.5	[NT]	[NT]	Water	102%
Calcium, Ca	mg/L	<0.5	[NT]	[NT]	Water	110%
Magnesium, Mg	mg/L	<0.5	[NT]	[NT]	Water	104%
Chloride, Cl	mg/L	<1	[NT]	[NT]	Water	94%
Carbonate, CO_3	mg/L	<1	[NT]	[NT]	Water	-
Bicarbonate, HCO_3	mg/L	<5	[NT]	[NT]	Water	-
Sulphate, SO_4	mg/L	<1	[NT]	[NT]	Water	106%
Nitrate, NO_3	mg/L	<0.2	[NT]	[NT]	Water	96%
Nitrite, NO_2	mg/L	<0.05	[NT]	[NT]	Water	103%
Fluoride, F	mg/L	<0.1	[NT]	[NT]	Water	88%
Manganese, Mn	mg/L	<0.05	[NT]	[NT]	Water	107%
Silica, SiO_2	mg/L	<2	[NT]	[NT]	Water	-
Sum of Ions (calc.)	mg/L	-	[NT]	[NT]	Water	-
Cation/Anion balance	%	-	[NT]	[NT]	Water	-

CLIENT: URS Corporation

OUR REFERENCE: 83127

PROJECT: 52830-005-562 0108

LABORATORY REPORT

QUALTY CONTROL	UNITS	Blank	Replicate Sm#	Replicate Sample‖Replicate	Spike Sm#	Matrix Spike
Aluminium, Al	mg/L	<0.1	[NT]	[NT]	Water	-
Arsenic, As	mg/L	<0.005	[NT]	[NT]	Water	105%
Cadmium, Cd	mg/L	<0.001	[NT]	[NT]	Water	123%
Copper, Cu	mg/L	<0.05	[NT]	[NT]	Water	99%
Mercury, Hg	mg/L	<0. 0005	[NT]	[NT]	Water	105%
Lead, Pb	mg/L	<0.005	[NT]	[NT]	Water	114%
Selenium, Se	mg/L	<0.01	[NT]	[NT]	Water	105%
Zinc, Zn	mg/L	<0.05	[NT]	[NT]	Water	101%

NOTES:
LOR - Limit of Reporting.

CHAIN OF CUSTODY and ANALYSIS REQUEST

FAXED

SGS Environmental Services
52 Murray Road, Welshpool, WA 6106
Phone: 08 9458 7278
Facsimile: 08 9451 3505

SGS

LAB. QUOTE:
PURCHASE ORDER:

CLIENT: URS
PROJECT NAME: Coburn Mineral Sands
COLLECTOR'S NAME: Rob Wallis
PROJECT #: 52830-005 & -562 0108
LAB. REF: 83127

REPORTS
PRELIMINARY BY: / /
FINAL REPORT BY: / /
EMAIL REPORT (YES/NO) — YES circled

ANALYSIS REQUIRED: Refer to attached schedule

SAMPLE ID	LAB #	MATRIX: WATER	SOIL	AIR	OTHER	PRESERVATION: ICE	ACIDIFIED	~~ALKALINE~~ Acidified/Pot Permanganate	NONE	SAMPLING DATE	No of CONTAINERS	REMARKS
SMB2 (shall)	1	X				✓	✓	✓	✓	13/8/04	3	
SMB2 (deep)	2	X				✓	✓	✓	✓	12/8/04	3	
STB3	3	X				✓	✓	✓	✓	12/8/04	3	
SMB4 (deep)	4	X				✓	✓	✓	✓	12/8/04	3	
STB1	5	X				✓	✓	✓	✓	13/8/04	3	

Relinquished by:	Date:	Time:	Received by:	Date:	Time:	Condition of cooler:
R B Wallis	13/8/04	1730	Tamara	16/8		Sealed: Yes / No (Yes circled)
Relinquished by:	Date:	Time:	Received by:	Date:	Time:	Temperature: Ambient / Chilled (Chilled circled) (Please circle as appropriate)

SGS

Water Quality Report

Report Number : 00053071
Job Number : JP042570

Report Comprising:	This Cover Page Pages 1 to 1	Date Received: Date Reported:	21/12/04 30/12/04
		No. of Samples:	3

To: Chris MacHunter
URS (Australia)

Please note assay results for the above samples, as received.

Samples were analysed in accordance with the following test methods (MOAP):

QPW-010	Alkalinity
QPW-075	Conductivity
QPW-090	Fluoride
QPW-013	ICP Spectroscopy
QPW-145	Nitrogen - Nitrate and Nitrite
QPW-165	pH
QPW-225	Total Dissolved Solids
QPW-053	Anions Total

REG No 162005-20.
DATE 31-1-05

NAME	INFO	ACTION	Complete Sign	DATE
R. Wallace				

FILE No

NATA

This laboratory is accredited by the National Association of Testing Authorities, accreditation No: 2562(898). The tests reported herein have been performed in accordance with the terms of accreditation. This report shall not be reproduced except in full.

SGS

30/12/04

Water Quality Report

Report Number : 00053071
Job Number : JP042570

Samples Received : 21/12/04

Lab No.	Sample Description	Date Sampled
P0408761	DMB1_392m-398m	06/12/04
P0408762	DMB1_206m-212m	07/12/04
P0408763	DMB1_184m-190m	08/12/04

	P0408761	P0408762	P0408763
Total Alkalinity as CaCO3	300	350	300
Chloride	5540	3210	4080
Alkalinity as HCO3	371	425	371
Conductivity at 25°C (mS/m)	1700	1100	1400
Fluoride	0.60	0.80	0.70
Calcium ICP	360	220	200
Hardness as CaCO3	2200	1280	1420
Potassium ICP	135	99	105
Magnesium ICP	320	180	220
Sodium ICP	3280	1960	2480
Sulfate ICP	1270	765	895
Nitrate as Nitrogen	0.095	<0.05	<0.05
pH Lab (units)	7.30	7.70	7.90
Total Filt. Solids (by evap)	12000	7750	9100

All units in mg/L (equivalent to g/m³) unless otherwise stated.

Approved Signatory ....
Arash Shafizadeh
Senior Chemist

NATA

Job No: **032230B**
Client: GUNSON RESOURCES
Address: LEVEL 2
33 RICHARDSON ST WEST PERTH
WA 6005

Client Reference: Paid VISA
Date Received: 2/09/2003
Date Sampled: 21/08/2003
Test Method: Water samples submitted by clients are analysed on an as received basis. Metals analysis on acidified samples as received. Analysis performed in accordance with MPL Laboratories WILAB 5, 6 and 8.

Sampled By: CLIENT

IDENT	**External ident**	**EC**	**TDS**	**pH**	**CO3**	**HCO3**	**OH**	**Na**	**K**	**Ca**	**Mg**
UNITS		**uS/cm**	**mg/L**		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
		+	**+**	**+**	**+**	**+**	**+**				
M001	CP-Site1	11000	7300	7.15	<1	230	<1	2100	92	160	210
M002	CP-Site3	15000	10000	8.00	<1	310	<1	2900	120	200	340
M003	CP-Base1	630	400	7.95	<1	140	<1	70	5	38	12
M004	CP-Base2	170	110	6.50	<1	3	<1	25	2	3	4
M001 Lab Dup	CP-Site1	11000	7000	--	--	--	--	2100	93	160	200
LQL		**1**	**1**	**0.05**	**1**	**1**	**1**	**5**	**1**	**1**	**1**

IDENT	**External ident**	**Hard**	**Fe**	**Si**	**Mn**	**Cl**	**SO4**	**NO3**	**NO2**
UNITS		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
								+	**+**
M001	CP-Site1	1200	<0.01	8	<0.01	3600	880	0.8	<0.1
M002	CP-Site3	1900	<0.01	6	0.12	5200	1100	<0.1	<0.1
M003	CP-Base1	140	<0.01	8	<0.01	130	19	3.3	<0.1
M004	CP-Base2	25	0.15	2	<0.01	50	5	9.2	<0.1
M001 Lab Dup	CP-Site1	1200	<0.01	8	<0.01	3800	890	0.6	<0.1
LQL		**5**	**0.01**	**2**	**0.01**	**1**	**1**	**0.1**	**0.1**

+ indicates sample received outside holding time recommended by AS/NZ 5667.1:1998

Checked:________________________ Approved Signatory:_____________________________ Date: 4/02/2005

CLIENT: URS Corporation

PROJECT: 42905541

OUR REFERENCE: 86464

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of Sample	Units	DTB1_45hrs 86464-1 17/01/2005 Water
pH	pH Units	7.3
Electrical Conductivity @ 25 oC	µS/cm	15,000
Total Dissolved Solids (grav) @ 180°C	mg/L	8,900
Total Alkalinity as $CaCO_3$	mg/L	140
True Colour	PCU	<5
Hardness (equivalent $CaCO_3$)	mg/L	2,300
Iron (Total), Fe	mg/L	3.0
Sodium, Na	mg/L	3,000
Potassium, K	mg/L	120
Calcium, Ca	mg/L	330
Magnesium, Mg	mg/L	350
Chloride, Cl	mg/L	4,900
Carbonate, CO_3	mg/L	<1
Bicarbonate, HCO_3	mg/L	160
Sulphate, SO_4	mg/L	1,100
Nitrate, NO_3	mg/L	0.2
Nitrite, NO_2	mg/L	<0.2
Fluoride, F	mg/L	0.5
Manganese, Mn	mg/L	0.30
Silica, SiO_2	mg/L	17
Sum of Ions (calc.)	mg/L	9,885
Cation/Anion balance	%	4.96

SGS

CLIENT: URS Corporation

PROJECT: 42905541

OUR REFERENCE: 86464

LABORATORY REPORT

Your Reference Our Reference Date Sampled Type of Sample	Units	DTB1_45hrs 86464-1 17/01/2005 Water
Aluminium, Al	mg/L	<0.1
Arsenic, As	mg/L	<0.005
Cadmium, Cd	mg/L	<0.005
Copper, Cu	mg/L	<0.05
Lead, Pb	mg/L	<0.05
Zinc, Zn	mg/L	0.05
Mercury, Hg	mg/L	<0.0005
Selenium, Se	mg/L	<0.005

TEST PARAMETERS	UNITS	LOR	METHOD
Standard 2			
pH	pH Units	0.1	PEI-001
Electrical Conductivity @ 25^{o}C	µS/cm	1	PEI-032
Total Dissolved Solids (grav) @ 180^{o}C	mg/L	10	PEI-002
Total Alkalinity as $CaCO_3$	mg/L	5	PEI-006
True Colour	PCU	5	PEI-004
Hardness (equivalent $CaCO_3$)	mg/L	5	PEI-043
Iron (Total), Fe	mg/L	0.05	PEP-060/ PEM001
Sodium, Na	mg/L	0.5	PEM-001
Potassium, K	mg/L	0.5	PEM-001
Calcium, Ca	mg/L	0.5	PEM-002
Magnesium, Mg	mg/L	0.5	PEM-002
Chloride, Cl	mg/L	1	PEI-020
Carbonate, CO_3	mg/L	1	PEI-006
Bicarbonate, HCO_3	mg/L	5	PEI-006

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CLIENT: URS Corporation

PROJECT: 42905541

OUR REFERENCE: 86464

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
Sulphate, SO_4	mg/L	1	PEI-020
Nitrate, NO_3	mg/L	0.2	PEI-020
Nitrite, NO_2	mg/L	0.2	PEI-020
Fluoride, F	mg/L	0.1	PEI-027
Manganese, Mn	mg/L	0.05	PEM-001
Silica, SiO_2	mg/L	2	PEM-002
Sum of Ions (calc.)	mg/L		Calc.
Cation/Anion balance	%		Calc.
Metals in water			
Aluminium, Al	mg/L	0.1	PEM-002
Arsenic, As	mg/L	0.005	PEM-004
Cadmium, Cd	mg/L	0.005	PEM-001
Copper, Cu	mg/L	0.05	PEM-001
Lead, Pb	mg/L	0.05	PEM-001
Zinc, Zn	mg/L	0.05	PEM-001
Mercury, Hg	mg/L	0.0005	PEM-005
Selenium, Se	mg/L	0.005	PEM-004

CLIENT: URS Corporation

PROJECT: 42905541

OUR REFERENCE: 86464

LABORATORY REPORT

QUALTY CONTROL	UNITS	Blank	Replicate Sm#	Replicate Sample||Replicate	Spike Sm#	Matrix Spike
pH	pH Units	-	[NT]	[NT]	Water	-
Electrical Conductivity @ 25°C	µS/cm	-	[NT]	[NT]	Water	-
Total Dissolved Solids (grav) @ 180°C	mg/L	<10	[NT]	[NT]	Water	97%
Total Alkalinity as $CaCO_3$	mg/L	<5	[NT]	[NT]	Water	109%
True Colour	PCU	<5	[NT]	[NT]	Water	-
Hardness (equivalent CaCO 3)	mg/L	<5	[NT]	[NT]	Water	-
Iron (Total), Fe	mg/L	<0.05	[NT]	[NT]	Water	78%
Sodium, Na	mg/L	<0.5	[NT]	[NT]	Water	106%
Potassium, K	mg/L	<0.5	[NT]	[NT]	Water	106%
Calcium, Ca	mg/L	<0.5	[NT]	[NT]	Water	101%
Magnesium, Mg	mg/L	<0.5	[NT]	[NT]	Water	101%
Chloride, Cl	mg/L	<1	[NT]	[NT]	Water	93%
Carbonate, CO_3	mg/L	<1	[NT]	[NT]	Water	-
Bicarbonate, HCO_3	mg/L	<5	[NT]	[NT]	Water	-
Sulphate, SO_4	mg/L	<1	[NT]	[NT]	Water	98%
Nitrate, NO_3	mg/L	<0.2	[NT]	[NT]	Water	98%
Nitrite, NO_2	mg/L	<0.2	[NT]	[NT]	Water	95%
Fluoride, F	mg/L	<0.1	[NT]	[NT]	Water	74%
Manganese, Mn	mg/L	<0.05	[NT]	[NT]	Water	107%
Silica, SiO_2	mg/L	<2	[NT]	[NT]	Water	85%
Sum of Ions (calc.)	mg/L	-	[NT]	[NT]	Water	-
Cation/Anion balance	%	-	[NT]	[NT]	Water	-

CLIENT: URS Corporation

PROJECT: 42905541

OUR REFERENCE: 86464

LABORATORY REPORT

QUALTY CONTROL	UNITS	Blank	Replicate Sm#	Replicate Sample‖Replicate	Spike Sm#	Matrix Spike
Aluminium, Al	mg/L	<0.1	[NT]	[NT]	Water	-
Arsenic, As	mg/L	<0.005	[NT]	[NT]	Water	105%
Cadmium, Cd	mg/L	<0.005	[NT]	[NT]	Water	95%
Copper, Cu	mg/L	<0.05	[NT]	[NT]	Water	116%
Lead, Pb	mg/L	<0.05	[NT]	[NT]	Water	115%
Zinc, Zn	mg/L	<0.05	[NT]	[NT]	Water	101%
Mercury, Hg	mg/L	<0. 0005	[NT]	[NT]	Water	-
Selenium, Se	mg/L	<0.005	[NT]	[NT]	Water	84%

NOTES:

LOR - Limit of Reporting.

faxed

CHAIN OF CUSTODY FORM

Sheet of

THIS COLUMN FOR LAB USE ONLY	FROM:	DATE: 18/1/05	TO: SGS Environmental 52 Murray Rd, Welshpool, WA, 6106 ph: 08 9458 7278
Job Code:	URS (AUSTRALIA) ACN 000 691 690 ~~Insert your office address here~~ 20 Terrace Rd, East Perth 6004		
Due Date:	Ph:	Fax:	
	Project No: 42905541 Project Manager: Rob Wallis Agreement No: —	Sampler(s): Rob Wallis Signature(s): Checked:	
Custody seal intact? YES / NO Sample cold? YES / NO	Released for URS by: Bob Willis-Jones Date: 18/1/05 Time:	Received for Laboratory by: Tamara. Date: 18/1/05 Time: 1:20pm	

Container Size, Type, Preservative and Analysis

Container Identification	1	2	3	4			
Size	500ml	500ml	250ml	100ml			
Type*	P	P	N	*			
Preservative Code	Non-Filtered	Non-Filtered	0.45µm Filtered	0.45µm Filtered			
Analytes	pH, EC, TDS(grav), Alkalinity, Colour, hardness	Na, Ca, K, Mg, Cl, SO4, HCO3, CO3, NO3, NO2, F	Al, As, Cd, Cu, Pb, Mn, Se, Total Fe, Zn, Si	Hg			

Lab identification	Date	Time	Matrix	Sample Number	Comments	Total no	Tick required analytes						
~~DTB1 – 45hrs~~	~~17/1/05~~		~~water~~										
	17/1/05		water	DTB 1 – 45hrs	Job Nº 86464-1	3 bottles	✓	✓	✓	✓			
						TOTAL							

Remarks: * Potassium permanganate preservation / nitric preservation

* Container Type and Preservative Codes: P = Neutral Plastic; N = Nitric Acid Preserved; C = Sodium Hydroxide Preserved; J = Solvent Washed Acid Rinsed Jar; S = Solvent Washed Acid Rinsed Glass Bottle; VC = Hydrochloric Acid Preserved Vial; VS = Sulfuric Acid Preserved Vial; BS = Sulfuric Acid Preserved Glass Bottle; Z = Zinc Acetate Preserved Bottle; E = EDTA Preserved Bottles; ST = Sterile Bottle

Courier Job No:

Specify Turnaround Time:

NOTE: SAMPLES MAY CONTAIN DANGEROUS AND HAZARDOUS SUBSTANCES

SGS

LABORATORY REPORT COVERSHEET

DATE:	3 February 2005
TO:	URS Corporation Level 3, The Hyatt Centre 20 Terrace Road EAST PERTH WA 6004
ATTENTION:	Mr Rob Wallis
YOUR REFERENCE:	42905541
OUR REFERENCE:	86464
SAMPLES RECEIVED:	18/01/05
SAMPLES/QUANTITY:	1 Water

The above samples were received intact and analysed according to your written instructions. Unless otherwise stated, solid samples are reported on a dry weight basis and liquid samples as received.

JANICE VENNING
Manager, Perth

LIEN TANG
Manager Reporting Systems

This report supersedes our preliminary results that were reported by facsimile.
This report must not be reproduced except in full.

SGS Australia Pty Ltd ABN 44 000 964 278 | Environmental Services t +61 (0)8 9458 7278 | 52 Murray Road f +61 (0)8 9451 3505 | Welshpool 6106 | Western Australia | www.au.sgs.com

APPENDIX D. Chemical Analyses from Regional (Private) Bores

Bore Name		Nanga Homestead	Spinifex Bore	Hamelin Old Homestead Bore	Meadow No. 1		Coburn 7	Carbla New Homestead Bore	Homestead Tamala No. 1		Sweeney Mia 2001	Yaringa No. 6	Brickhouse Stn Boodalia Bore	Wooramel Woora Bore	Marron Stn New Homestead Bore
WIN ID No.		**20000069**	**20000916**	**20000958**	**20003960**		**20000919**	**23002263**	**20000058**		**23000421**	**20000970**	**20000096**	**6907**	**23000382**
Sampled Date		**1999***	**21-Aug-2003**	**1999***	**18-May-1977**	**30-May-1977**	**21-Aug-2003**	**1999***	**8-Jul-1966**	**20-Sep-1967**	**8-Aug-2001**	**1999***	**1999***	**1999***	**1999***
pH		7.4	7.15	7.1	6.1	7.2	8.0	7.2	7.3	7.8	6.9	7.0	7.6	7.2	7.4
EC	uS/cm	7,200	11,000	10,000	20,300	9,400	15,000	6,400	3,449	6,656		7,600	5,200	6,800	2,700
TDS	mg/L	4,490	7,300	6,410	13,500	5,720	10,000	3,880	2,150	4,540	6,930	4,510	3,460	4,260	1,590
Na	mg/L	1,300	2,100	1,700	3,800	1,730	2,900	1,200	478	1,100	1,600	1,100	860	1,200	320
K	mg/L	68	92	85	177	84	120	63	29	49	61	65	44	59	31
Ca	mg/L	140	160	170	240	150	200	68	144	210	160	140	100	120	92
Mg	mg/L	92	210	140	465	147	340	62	86	158	140	100	72	100	65
Cl	mg/L	1,800	3,600	2,700	6,610	2,760	5,200	1,700	753	1,940	2,400	2,100	<1	1,700	550
CO_3	mg/L	<1	<1	<1			<1	<1				<1		<1	<1
HCO_3	mg/L	250	230	230			310	200				180	210	210	230
OH	mg/L		<1				<1								
SO_4	mg/L	540	880	690	1,590	732	1,100	360	398	558	650	450	540	480	320
NO_3	mg/L		0.8		3	5	<0.1		77	88					
NO_2	mg/L		<0.1				<0.1								
F (sol)	mg/L	0.6		0.8	0.2	0.8		0.7			0.032	0.8	0.7	0.8	0.5
Fe	mg/L	<0.1	<0.01	<0.1			<0.01	<0.01	0.1	0.1	0.8	<0.1	<0.1	<0.1	<0.1
Si	mg/L	28	8	16	13	29	6	12	8	15	7.8	8.1	11	8	8.9
Mn	mg/L		<0.01				0.12				0.18				
Colour	(TCU)					5									
Hardness	mg/L	730	1,200	1,000	2,509	979	1,900	430	713	1,174		790	540	710	500
Alkalinity (HCO3-HCO3)	mg/L				27	238			305	302					
Alkalinity (total) (CaCO3)	mg/L				22	195			250	248	160				
Aquifer Sampled		Windalia	Windalia	Windalia	Windalia		Windalia/Birdrong	Birdrong	Birdrong		Birdrong	Birdrong	Kopke	Kopke	Kopke

Data Sources: Gunson Resources Ltd, (2003)

WIN Database - Department of Environment (2004)

Wills and Dogramaci, Water & Rivers Commission Hydrogeology Report No. 170, (2000) - These results have a sampled date of 1999.

Appendix D
Results of Bore Census

Census of Bores within 50 km of the Coburn Project

Name / No.	Also Known As	WIN ID No.	Station / Loc	Completion Date	Status	Easting	Northing	Datum Elevation	Depth	Screened	Aquifer	Formation(s)	Equipped With	Original Flow Rate		Current Flow Rate		Original SWL			Current SWL				Original Water Quality			Current Water Quality			
						m MGA (Z50)	m MGA	m AHD	m bgl	m bgl	m bgl			m^3/d	date	m^3/d	date	m brp*	mAHD	date	m brp*	Collar height	mAHD	date	mg/L	pH	date	mg/L	E.C. mS/cm	pH	date
Hamelin Station																															
Hamelin Homestead No.3	Hamelin Homestead No.1c	20000962	Hamelin	3/09/1990	Active	219,899	7,073,849	21.94	115	open	112-115	?Birdrong	Artesian Headworks	N.D.	N.D.	~1000	Aug-04	-24.1	46.04	3-Sep-1990	-22.06	0.65	44.00	3-Jun-2004	5,260	N.D.	Nov-1999	6,930	N.D.	N.D.	3/08/2001
Hamelin MRD Bore		N.D.	Hamelin	N.D.	Decomm.	253,842	7,056,239	N.D.	N.D.	N.D.	N.D.	N.D.	Not Equipped	S/A	-	S/A	-	N.D.	N.D.	N.D	45.89	0.20	N.D.	15-Dec-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	15-Dec-2004
Hamelin No. 4	Boolagoorda No. 4	20000944	Hamelin	1928	Active	250,068	7,077,631	61.45	67.36	N.D.	60.6 - 67.4	Alinga	Windmill	S/A	-	S/A	-	11.6	49.9	N.D.	N.D.	N.D.	N.D.	18-Dec-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	18-Dec-2004
Hamelin No. 5	Boolagoorda No. 5, or Stone Tank	20000951	Hamelin	1928	Active	229,315	7,067,593	74.79	128.02	N.D.	122.5 - 127.7	?Birdrong	Windmill	S/A	-	S/A	-	25.5	49.3	30-Jun-1921	25.84	0.28	48.95	11-Aug-2004	6,063	6.9	N.D.	8,380	13.20	6.8	11-Aug-2004
Outcamp Bore	Hamelin No.7, or 23 Mile Bore	20000946	Hamelin	N.D.	Active	250,564	7,069,042	67.95	137.46	N.D.	N.D.	Windalia Radiolarite /?Birdrong	Windmill	S/A	-	S/A	-	18.2	49.75	1967	21.1(P)	0.30	46.85	18-Dec-2004	N.D.	N.D.	N.D.	9,450	14.77	6.7	18-Dec-2004
Hamelin No. 8		20000901	Hamelin	13/05/1926	Active	230,010	7,059,746	84.52	117.65	N.D.	112.5 - 117.3	Windalia Sand Mbr	Windmill	S/A	-	32.91m	1926	32.8	51.7	1967	34.12	0.40	50.40	11-Aug-2004	6,564	7.0	1926	12,350	19.00	6.6	11-Aug-2004
Hamelin No 9		20003952	Hamelin	9/07/1926	Active	243,443	7,060,644	76.45	65.53	ND	215.0 - 218.0	?Windalia Sand Mbr	Windmill	S/A	-	22.5m	1926	30.4	46.05	1967	25.60	0.31	50.85	11-Aug-2004	ND	ND	ND	8,250	13.00	6.6	11/08/2004
Hamelin No. 11		20000952	Hamelin	26/03/1927	Active	237,465	7,068,143	80.09	105.46	N.D.	102.1 - 105.1	Windalia Sand Mbr	Windmill	S/A	-	28.95m	1927.0	29.0	51.1	1927	30.60	0.18	50.30	11-Aug-2004	5,000	ND	1985	5,970	9.60	7.1	11-Aug-2004
Hamelin No. 13			Hamelin	N.D.	Active	258,120	7,078,104	68.20	46.9	open	37.8-46.9	Windalia Radiolarite	Windmill	S/A	-	S/A	-	12.8	55.4	N.D.	19.40(P)	0.25	N.D.	15-Dec-2004	ND	ND	ND	7,420	11.77	6.5	15-Dec-2004
Hamelin No. 14		20003954	Hamelin	4/08/1928	Active	251,468	7,061,391	78.92	67.36	N.D.	67.5 - 79.0	?Birdrong	Windmill	S/A	-	S/A	-	25.5	53.4	1967	27.70(P)	0.35	51.22	15-Dec-2004	12,200	7.1	N.D.	11,900	18.34	6.7	15-Dec-2004
Hamelin No. 16		20003976	Hamelin	1959	Active	258,894	7,069,508	68.99	35.97	N.D.	30.8 - 36.0	Windalia Radiolarite	Windmill	S/A	-	S/A	-	13.7	55.3	10-Nov-1928	15.50	0.20	53.49	15-Dec-2004	N.D.	N.D.	N.D.	7,650	12.12	6.5	15-Dec-2004
Hamelin No. 17 New		20000900(old)	Hamelin	5/09/1953	Not yet comm.	236,848	7,055,518	86.87	93.57	90-93	88.7-93.6	Windalia Sand Mbr	Not Equipped	S/A	-	S/A	-	36.3	50.6	Sep-2003	36.45	0.36	50.42	11-Aug-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	11-Aug-2004
Hamelin No. 18		20003955	Hamelin	Aug-35	Active	251,540	7,056,232	91.94	65.53	N.D.	58.7 - 65.4	?Windalia Sand Mbr	Windmill	S/A	-	S/A	-	38.6	53.3	1967	41.75(P)	0.45	50.19	15/12/2004	10,480	8.3	Jun-35	9,420	1473.00	6.9	15-Dec-2004
Hamelin No. 20B		20003956	Hamelin	Nov-20	Active	259,755	7,056,124	122.92	76.5	N.D.	76.0 - 76.3	?Windalia / ?Alinga	Windmill	S/A	-	S/A	-	68.7	54.2	February 1950	63.60	0.30	59.32	15/12/2004	15,115	N.D.	Jan-50	10,550	16.38	6.5	15-Dec-2004
Hamelin No. 23	Hamelin No. 19 (replaced)	N.D.	Hamelin	1959	Active	236,790	7,060,395	83.90	90.83	N.D.	68.1 - 90.6	Windalia Sand Mbr	Windmill	S/A	-	S/A	-	71.4	12.5	1967	33.00	0.26	50.90	11/08/2004	6,000	N.D.	1985	5,970	9.60	7.1	11-Aug-2004
Hamelin No. 24	North Bore	N.D.	Hamelin	1962	U/S	259,263	7,089,876	N.D.	89.3	N.D.	N.D.	N.D.	Not Equiped	S/A	-	S/A	-	45.7	N.D.	1967	Blocked	0.47	N.D.	18/12/2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	18-Dec-2004
Hamelin No 26	SB1	20003959	Hamelin	N.D.	Decomm	266,050	7,051,196	138.20	184	80.1-184.0	80-184	?Windalia Sand Mbr	Not Equiped	S/A	-	S/A	-	80.8	57.40	11-Nov-1987	81.63	0.26	56.57	14-Dec-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	14-Dec-2004
Hamelin Spinifex 1	Hamelin No. 6	20000916	Hamelin	1921	Flowing	220,276	7,063,497	46.63	158.49	153.1 - 158.1	128 - 158	Windalia Sand Mbr	Flowing	378.54	1921	~10	11/08/2004	N.D.	>46.6	1921	Flowing	None	>46	11/08/2004	7,659	N.D.	4/11/1997	N.D.	N.D.	N.D.	11-Aug-2004
Hamelin Spinifex 2	South Bore	20000917		1964	Flowing	220,278	7,063,508	~46.6	159.71	No Screen	N.D.	Windalia Sand Mbr	Flowing	11.35	1967	~10	11/08/2004	N.D.	N.D.	N.D.	Flowing	0.65	>46.6	11/08/2004	6,786	N.D.	4/11/1997	5,840	9.40	7.1	11-Aug-2004
Hamelin Kevins Bore	Hamelin No. 25	20000955	Hamelin	1965	Active	241,846	7,077,532	71.42	116.4	N.D.	101.8 - 116.4	?Birdrong	Windmill	S/A	-	S/A	-	32.0	39.42	10-May-1965	22.35	0.28	49.07	15-Dec-2004	8,000	N.D.	1985	8,480	13.35	7.3	15-Dec-2004
Hamelin Five Mile Bore	Hamelin No. 12 (1928)	20000947	Hamelin	1965	Active	228,633	7,074,650	59.78	127.1	N.D.	122.5-126.7	?Windalia Sand Mbr	Windmill	S/A	-	S/A	-	6.4	53.4	1967	13.50	0.16	46.28	11-Aug-2004	6,000	N.D.	1985	6,100	9.80	6.8	11-Aug-2004
Hamelin Ten Mile Bore	Hamelin No. 6, or Boolagoorda No. 3	20000954	Hamelin	N.D.	Active	237,198	7,076,015	71.96	184.7	N.D.	137.1-184.7	?Birdrong	Windmill	S/A	-	S/A	-	23.2	48.4	1967	N.D.	0.40	N.D.	11-Aug-2004	7,000	N.D.	1985	8,180	12.90	N.D.	11-Aug-2004
Sweeney Mia Bore 2001		23000421	Hamelin	15-Jun-01	Active	236,347	7,104,862	25.60	177.5	147-159 165-171	137.0-177.5	Birdrong	Nil - Artesian Headworks	733	37091	N.D.	-	-24.1	49.1	19-Jul-2001	Artesian	N.D.	N.D.	15-Dec-2004	5,000	N.D.	7/06/1905	5,430	8.78	6.8	15-Dec-2004

Census of Bores within 50 km of the Coburn Project

Name / No.	Also Known As	WIN ID No.	Station / Loc	Completion Date	Status	Easting	Northing	Datum Elevation	Depth	Screened	Aquifer	Formation(s)	Equipped With	Original Flow Rate		Current Flow Rate		Original SWL			Current SWL				Original Water Quality			Current Water Quality			
						m MGA (Z50)	m MGA	m AHD	m bgl	m bgl	m bgl			m^3/d	date	m^3/d	date	m brp*	mAHD	date	m brp*	Collar height	mAHD	date	mg/L	pH	date	mg/L	E.C. mS/cm	pH	date
Coburn Station																															
Coburn No. 4		20000904	Coburn	1926 (Deepened 1935)	Decomm	249,216	7,045,002	110.89	116.43	110 - 116	>60	Windalia Sand Mbr	Not Equipped	S/A	-	S/A	-	56.1	54.809	30-Jun-1920	56.90	0.14	53.99	11-Aug-2004	8,610 - 11,690	N.D.	1926	N.D.	N.D.	N.D.	11-Aug-2004
Coburn No. 7		20000919	Coburn	N.D.	Active	226,396	7,044,054	79.50	184.1	Open below 98.8 m	107.0 - 164.7	Windalia / Birdrong	Mono Pump 54.8m	S/A	-	S/A	-	42.7?	36.83?	N.D.	N.D.	N.D.	N.D.	11-Aug-2004	8,660	7	30/06/1936	8,250	13.00	6.5	16-Dec-2004
Coburn No. 8		N.D.	Coburn	N.D.	Active	241,162	7,049,691	99.45	79.9	N.D.	N.D.	N.D.	Mono Pump 60.96m	S/A	-	S/A	-	N.D.	N.D.	N.D.	N.D.	0.35	N.D.	11-Aug-2004	N.D.	N.D.	N.D	7,240	11.50	7.5	11-Aug-2004
Coburn No. 9 B		N.D.	Coburn	16/07/1988	Active	225,080	7,048,971	84.69	129	117-129	117-129	Windalia Sand Mbr	Mono Pump 60.96m	S/A	-	S/A	-	36.0	48.7	1-Jul-1988	N.D.	0.45	N.D.	11-Aug-2004	9,415	N.D.	Jul-88	6,240	10.00	7.5	11-Aug-2004
Coburn No. 11 B		20000905	Coburn	6/08/1988	Active	249,224	7,048,552	103.06	69	57-69	54-69	Windalia Sand Mbr	Mono Pump 60.96m	S/A	-	S/A	-	50.0	53.06	1-Aug-1988	N.D.	0.40	N.D.	11-Aug-2004	10,750	N.D.	N.D	7,170	11.40	7.8	11-Aug-2004
Coburn No. 14		20000907	Coburn	N.D.	Active	232,169	7,044,243	87.82	91.44	N.D.	N.D.	N.D.	Mono Pump 60.96m	S/A/	-	S/A	-	39.6	48.22	N.D.	N.D.	0.25	N.D.	11-Aug-2004	9,200	N.D.	N.D	7,910	12.50	7.1	11-Aug-2004
Overlander Roadhouse (Main Roads Bore)																															
Overlander Roadhouse	MRD Overlander	20000945	Hamelin	Jan-80	Active	246,846	7,076,254	63.59	150	114-149	85 - 149	Windalia Sand Mbr	Electric Submersible	S/A	-	S/A	-	21.35	48.7	11-Nov-1997	N.D.	N.D.	N.D.	12-Dec-2004	9,510	N.D.	Jan-80	8,740	13.73	6.7	12-Dec-2004
Billabong Roadhouse																															
Billabong Roadhouse		20003946	Meadow	N.D.	Active	262,732	7,031,518	130.44	N.D.	N.D.	N.D.	?Windalia Sand Mbr	Electric Submersible	S/A	-	S/A	-	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	14-Dec-2004	11,680	N.D.	N.D.	11,520	17.80	6.0	14-Dec-2004
Hamelin Telegraph Station & Caravan park																															
Hamelin Telegraph Station	Hamelin Caravan Park	20000961	Lot 161, Hamelin	18-Nov-88	Active	217,201	7,076,870	4.14	106	N.D.	N.D.	Windalia Radiolarite	Artesian Headworks	N.D.	-	N.D.	N.D.	-42	46.14	18-Nov-1998	N.D.	0.35	N.D	11-Aug-2004	5,970	N.D.	N.D.	4,890	7.95	6.9	11-Aug-2004

Census of Bores within 50 km of the Coburn Project

Name / No.	Also Known As	WIN ID No.	Station / Loc	Completion Date	Status	Easting	Northing	Datum Elevation	Depth	Screened	Aquifer	Formation(s)	Equipped With	Original Flow Rate		Current Flow Rate		Original SWL			Current SWL				Original Water Quality			Current Water Quality			
						m MGA (Z50)	m MGA	m AHD	m bgl	m bgl	m bgl			m^3/d	date	m^3/d	date	m brp*	mAHD	date	m brp*	Collar height	mAHD	date	mg/L	pH	date	mg/L	E.C. mS/cm	pH	date
Meadow Station																															
Meadow No. 1		20003960	Meadow	1988	Active	263,366	7,044,424	135.46	87.8	86.2-87.8	76.6 - 87.6	Windalia Sand Mbr	Mono Pump	S/A	-	S/A	-	76.6	58.9	May 1951	N.D.	N.D.	N.D.	16-Dec-2004	16,913	5.4	May-51	N.D.	N.D.	N.D.	16-Dec-2004
Meadow No. 3	Billabong Hotel	20003947	Meadow	1980	Active	262,798	7,031,657	130.35	78.6	75.6-78.6	74.4 - 78.6	?Windalia Sand Mbr	Electric Submersible	S/A	-	S/A	-	74.4	56.0	1950	N.D.	N.D.	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	11,390	17.61	5.7	14-Dec-2004
Meadow No. 4		20003944	Meadow	Abt 1951-52	Active	268,465	7,031,136	139.29	88.2	N.D.	82.3-88.2	Tumblagooda Sandstone	Windmill	S/A	-	S/A	-	Est 76	Est 63	1951-52	N.D.	0.30	N.D.	15-Dec-2004	9,928	7.6	1951-52	8,900	13.98	9.2	14-Dec-2004
Meadow No. 5		20003945	Meadow	1990-91	Active	267,779	7,038,527	134.87	106.7	100.7-106.7	78.3-106.7	Windalia Sand? Tumblagooda Sandstone	Windmill	S/A	-	S/A	-	77.4	57.5	1952-53	78.12	0.38	56.75	15/12/2004 (old bore)	11,000	N.D.	18/05/1977	12,000	18.53	4.5	15-Dec-2004
Meadow No. 6	Relined 1988	20003949	Meadow	1950	Pump U/S	268,580	7,023,695	141.67	95.1	N.D.	86.3-95.1	?Tumblagooda Sandstone	Mono Pump	S/A	-	S/A	-	Est 86.3	N.D.	1950	N.D.	N.D.	N.D.	16-Dec-2004	8,800	7.1	1950	N.D.	N.D.	N.D.	16-Dec-2004
Meadow No. 7		20003948	Meadow	1946	Active	262,288	7,038,384	128.07	86.6	N.D.	57.9 - 86.6	Windalia Sand Mbr / ?Birdrong / ?Tumblagooda	Windmill	S/A	-	S/A	-	72.4	55.7	1946	N.D.	N.D.	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	13,460	20.60	4.0	14-Dec-2004
Meadow No. 8 (New)		N.D.	Meadow	2000	Not Equiped	256,460	7,044,452	118.90	109.7	103.7-109.7	75.6-109.7	?Windalia Sand Mbr	Not Equiped	S/A	-	S/A	-	N.D.	N.D.	N.D.	72.96	0.53	45.94	14-Dec-2004	13,330	6.4	Jun 1950 (old bore)	N.D.	N.D.	N.D.	14-Dec-2004
Nerren Nerren Station																															
Nerren Nerren 1A	Cooloomia	20000913	Nerren Nerren	N.D.	Active	255,991	7,017,901	147.07	109.7	103.7-109.7	N.D.	?Tumblagooda Sandstone	Mono Pump	S/A	-	S/A	-	92.0	55.07	N.D.	N.D.	N.D.	N.D.	18-Dec-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	16-Dec-2004
Nerren Nerren 5A	Nerren Nerren 5	20003942	Nerren Nerren	N.D.	Active	256,752	6,996,877	172.39	167.6	pen 152.4-167	152.4-167.6	?Tumblagooda Sandstone	Mono Pump	S/A	-	S/A	-	109.7	62.69	N.D.	N.D.	N.D.	N.D.	18-Dec-2004	N.D.	N.D.	N.D.	14,570	22.20	6.8	18-Dec-2004
Carbla Station																															
Carbla Homestead	Replaced Milylia No. 11 / Carbla 11	23002263	Carbla	22/08/2001	Active	228,800	7,099,500	Abt. 32	156.59	138.3 - 150.3	140.0 - 156.6	Birdrong	Artesian Headworks	N.D.	-	N.D	N.D	17.56	49.56	22-Aug-2001	N.D.	0.60	N.D.	17-Dec-04	4,739	N.D.	Jun-68	4,740	7.73	6.5	17-Dec-2004
Carbla No. 12		N.D.	Carbla	N.D.	Active	245,705	7,094,785	N.D.	N.D.	N.D.	N.D.	N.D.	Windmill	S/A	-	S/A	-	N.D.	N.D.	N.D.	16.19	0.25	N.D.	17-Dec-2004	N.D.	N.D.	N.D.	5,210	8.45	N.D.	17-Dec-2004
Carbla No. 13		20000936	Carbla	1935	Active	228,838	7,089,056	13.32	113.39	107 - 113.1	N.D.	?Windalia Radiolarite	Windmill	Sml flow	-	S/A	N.D	9.14	10.98	30-Jun-1935	5.15	0.45	8.17	17-Dec-2004	N.D.	N.D.	N.D.	6,160	9.89	6.9	17-Dec-2004
Carbla No. 14		20000934	Carbla	1935	Active	245,973	7,089,500	57.09	101.5	N.D.	N.D.	?Birdrong	Windmill	S/A	-	S/A	N.D	1.83	71.32	30-Jun-1935	10.25	0.32	46.84	17-Dec-2004	N.D.	N.D.	N.D.	5,680	9.16	6.5	17-Dec-2004
Carbla No. 16		20000941	Carbla	N.D.	Active	237,358	7,088,357	50.91	N.D.	N.D.	N.D.	?Windalia Radiolarite	Windmill	S/A	-	S/A	-	N.D.	N.D.	N.D.	7.03	0.32	43.88	17-Dec-2004	N.D.	N.D.	N.D.	5,260	8.52	6.9	17-Dec-2004
Carbla No. 17		N.D.	Carbla	N.D.	Active	237,073	7,099,858	N.D.	N.D.	N.D.	N.D.	N.D.	Windmill	N.D.	N.D.	S/A	-	N.D.	N.D.	N.D.	N.D.	0.10	N.D.	17-Dec-2004	N.D.	N.D.	N.D.	5,460	8.33	6.5	17-Dec-2004
Six Mile Well	Hamelin Pool No.2	20000931	Carbla	Jun-68	Active	236,347	7,104,862	25.60	130.4	127.4 - 130.4	127.4 - 130.4	Nannyarra Sandstone	Leaking Artesian Headworks	3182	Jun-68	N.D.	17/12/2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	17-Dec-2004	3,968	N.D.	6-Nov-1997	3,760	6.21	6.4	17-Dec-2004
SEC Bore		N.D.	Carbla	N.D.	Active	245,926	7,100,986	N.D.	N.D.	N.D.	N.D.	N.D.	Windmill	S/A	-	S/A	-	N.D.	N.D.	N.D.	4.07	0.29	N.D.	17-Dec-2004	N.D.	N.D.	N.D.	5,640	9.09	6.5	17-Dec-2004
Nanga Station																															
Nanga Homestead	Nanga No.2 Homestead Nanga View Homestead	20000069	Nanga	12-Aug-90	Active	*181,513*	7,093,023	N.D.	349.5	312-349.5	330-349.5	Windalia Radiolarite	Artesian Headworks	N.D.	12-Aug-90	N.D.	13/12/2004	>-20	>30	12-Aug-1990	>20	0.45	>30	13-Dec-2004	N.D.	N.D.	12/08/1990	4,680	7.64	7.1	Dec-04
Nilemah Artesian No. 1A		20000963	Nanga	26/11/1992	Active	205,888	7,073,900	5.37	164	161-164	154-164	Birdrong	Artesian Headworks	5,680	1921	N.D	12-Aug-2004	N.D.	>30.5	1955	-40.00	0.46	45.37	12-Aug-2004	6,829	N.D.	1921 (old bore)	6,300	10.10	6.9	12-Aug-2004
Tamala Station																															
Cape Well Bore	Cape Camp Bore	20000050	Tamala	Bef. 1972	Active	*175,645*	7,029,550	N.D	100.0	N.D.	N.D.	?Tamala Limestone	Mono Pump	S/A	-	S/A	-	N.D	N.D	N.D	N.D	N.D	N.D	12-Dec-2004	688	N.D.	12/03/1993	N.D	N.D	N.D	12-Dec-2004
Beethen Outcamp Well	Beethan Well (South)	20000051	Tamala	Bef 1977	Active	*174,195*	7,031,900	N.D	9.0	N.D.	N.D.	?Tamala Limestone	Mono Pump & Windmill	S/A	-	S/A	-	N.D	N.D	N.D	N.D	N.D	N.D	12-Dec-2004	2,943	N.D.	12/03/1993	N.D	N.D	N.D	12-Dec-2004
Natta Outcamp Bore		20000048	Tamala	N.D.	Active	*181,145*	7,033,000	N.D	30	N.D.	N.D.	?Tamala Limestone	Windmill & Electric Submersible	S/A	-	S/A	-	N.D	N.D	N.D	N.D	N.D	N.D	12-Dec-2004	1,694	N.D.	12/03/1993	N.D	N.D	N.D	12-Dec-2004
Woodleigh Station																															
Woodleigh No 10C			Woodleigh	N.D.	Active	265,980	7,099,940	N.D.	N.D.	N.D.	N.D.	N.D.	Electric Submersible	S/A	-	S/A	-	N.D	N.D	N.D	60.92	0.19	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	11,000	17.05	N.D.	14-Dec-2004
Woodleigh No 11			Woodleigh	N.D.	Active	255,281	7,101,004	N.D.	N.D.	N.D.	N.D.	N.D.	Windmill	S/A	-	S/A	-	5.49	N.D.	N.D.	N.D.	N.D.	N.D.	17-Dec-2004	8,812	7.2	1948	5,790	9.32	N.D.	18-Dec-2004
Woodleigh No 22			Woodleigh	N.D.	Active	273,765	7,092,651	N.D.	N.D.	N.D.	N.D.	N.D.	Electric Submersible	S/A	-	S/A	-	N.D	N.D	N.D	N.D.	0.05	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	4,330	7.09	N.D.	14-Dec-2004
Woodleigh No 25	BHP Camp Bore		Woodleigh	N.D.	Active	270,223	7,078,696	N.D.	N.D.	N.D.	N.D.	N.D.	Electric Submersible	S/A	-	S/A	-	N.D	N.D	N.D	N.D.	0.20	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	8,280	13.05	6.5	14-Dec-2004
Toolonga Station																															
SB2		20003943	Toolonga	N.D.	Not in use	294,721	7,044,156	201.34	190	87.3-190	87-190	?Tumblagooda Sandstone	Not Equiped	S/A	-	S/A	-	110.7	90.64	16-Nov-1981	N.D.	0.13	N.D.	14-Dec-2004	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	14-Dec-2004

Data Sources:
McWhae, Hydrodynamic and Salinity Study of the Chief Aquifers of the Carnarvon Basin, (1958)
Playford & Chase, Carnarvon Basin Water Bores: West Australian Petroleum Dept. (1955)
WIN Database - Department of Environment (2004)
Wills and Dogramaci, Water & Rivers Commission Hydrogeology Report No. 170, (2000)

Abbreviations:
m AHD - metres above the Autralian Height Datum
m bgl - metres below ground level
m brp - metres below the reference point (usually top of bore casing)
N.D. - Not Determined
mg/L TDS - milligrams per litre Total Dissolved Solids
m^3/d - cubic metres (or kilolitres)
S/A - Sub artesian water level, i.e. not flowing

Appendix E
Mine Water Balance Detail

Appendix E. Summary Calculations for Life-of-Mine Water Balance

Year	Inputs	Outputs*	Period Balance Required from Bores	Annual Bore Water Requirement
	kL	kL	kL	kL
1	10,595	5,942,564	5,931,969	5,931,969
2	10,595	5,942,564	5,931,969	5,931,969
3	10,595	9,917,228	9,906,633	9,906,633
4	10,595	9,917,228	9,906,633	9,906,633
5	10,595	11,267,228	11,256,633	11,256,633
5 - 10	52,975	53,185,085	53,132,110	10,626,422
10 - 15	52,975	52,285,085	52,232,110	10,446,422
15 - 20	52,975	51,385,085	51,332,110	10,266,422
Average Water Requirement (1 plant)				5,931,969
Average Water Requirement (2 plants)				10,401,528

APPENDIX E. Annual Water Balance Calculations

			Water In	Water Out												Balance	
Source			Direct Rainfall Recharge	Process Wate Dams	Evaporation Losses			Evapora-tion Losses Total	Dust Suppress-ion	Concen-trate Water Losses	Process Bores	Seepage Losses			Seepage Losses (Total)	Total Make-up Process Water Pumpage Required	Estimated Annual Licenced Water Requirement
Location			Water Dams	Initial Plant Start-ups	Process Water Dam	Slimes Settling Area	Stacker Areas				Camp Supply	Tailings Not Recovered	Process Water Dams	Slimes Settling Areas			
Notes			1	2	3	4	5	3 - 5	6	7	8	9	10	11	9 - 11	12	13
Year No.	Operating time (yrs)	Plants Operating	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL
1	0.81	1	10,595	900,000	224,458	26,935	11,223	262,616	182,500	170,400	131,400	2,662,784	0	1,632,864	4,295,648	5,931,969	5,931,969
2	0.81	1	10,595	900,000	224,458	26,935	11,223	262,616	182,500	170,400	131,400	2,662,784	0	1,632,864	4,295,648	5,931,969	5,931,969
3	0.81	2	10,595	0	448,916	53,870	22,446	525,232	365,000	340,800	94,900	5,325,568	0	3,265,728	8,591,296	9,906,633	9,906,633
4	0.81	2	10,595	0	448,916	53,870	22,446	525,232	365,000	340,800	94,900	5,325,568	0	3,265,728	8,591,296	9,906,633	9,906,633
5	0.81	2	10,595	1,350,000	448,916	53,870	22,446	525,232	365,000	340,800	94,900	5,325,568	0	3,265,728	8,591,296	11,256,633	11,256,633
10	4.05	2	52,975	3,600,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	26,627,840	0	16,328,640	42,956,480	53,132,110	10,626,422
15	4.05	2	52,975	2,700,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	26,627,840	0	16,328,640	42,956,480	52,232,110	10,446,422
20	4.05	2	52,975	1,800,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	26,627,840	0	16,328,640	42,956,480	51,332,110	10,266,422
Project Lifetime Totals			211,900	11,250,000	8,529,412	1,023,529	426,471	9,979,412	6,935,000	6,472,032	1,971,000	101,185,792	0	62,048,832	163,234,624	199,630,168	

Key Assumptions:

- Tailings discharge cyclones recover 47% of water used for each 2,000 tonnes/hr of ore processed reaching an average solids content of 65%.
- On average, 68% of the tailings water is recovered
- Process water bores each yield 3.1 Gl/annum (100 L/sec) but only pumped at an average of 75 L.sec (75% up-time) for 2.37 GL/year
- Processing occurs for 7,100 hrs/year

Notes:

1 Based on the annual mean rainfall data for Hamelin Pool (BoM Stn. No. 006025, Jan 1886-Jul 2004) and annual evaporation data from Hamelin pool (BoM Stn. No. 006025, May 1978-Apr 1980), Nanga Stn. (BoM Stn. No. 006080, May 1980-Apr 1988) and Brickhouse Stn (BoM Stn. No. 6087, Sep 1966-Mar 1977).
Dam surface areas based on there being 1 Ha of water in the process water dam and 4 Ha in the slimes settling area.

2 This value based on filling process water dams (450 ML each) for each plant site move. (Does not include plant recommissioning requirements)

3 Surface area of the process water dams are based on 320 x 320 m dams for each plant. One new dam is allowed for for each new plant site.
Evaporation calculated as 0.72 x pan evaporation figures from BoM as per Ag. Dpet tech Report 65, 1988.

4 Surface area of the slimes dams are based on 2 dams (1 active and 1 inactive) of average size of 200 x 30 m dams for each plant. Two for years 1 and 2, and four dams for years 3 onwards.
Evaporation calculated as 0.72 x pan evaporation figures from BoM as per Ag. Dpet tech Report 65, 1988.

5 It is assumed that the active stacker site will be approx. 50 x 100 m per plant.

6 Dust suppression losses based on half the nominated area of 30,000 m^2 of watered roads (mine access and internal roads) being constantly wet and subjected to evaporative losses.
An additional average of 500 kL/d has been allowed for dust suppression that is assumed as a total loss.

7 Losses are expected from the system via the concentrate stockpiles at a rate of 24 kL/hr.

8 Camp supply based on nominated number of people as 100 construction personnel, 80 mining personnel in years 1-2 and 130 in years 3 onwards. An average consumption is calculated on the basis of 0.75 kL perperson per day of potable water and that 1.5 kL of raw water required to produce this.

9 Non-recovered tailings seepage is the difference between the hydrocyclone underflow discharge and calculated seepage recovery.
This value calculated from modelling water recovery from the re-deposited and/or underlying Superficial sand for the tailings water.
It is assumed that processing occurs for 7,100 hrs per year and that only 20% of the slimes water is recovered..

10 All process water dams are nominated to be lined.

11 Assume that all slimes water is not recovered, and that which is not evaporated is retained or lost to seepage. Quantity of water discharged based on the consumption of 233 kL/hr of water per plant and that 20 % of this is recovered by decant, and no seepage water is recovered.

12 Difference between the water in (or recovered) and losses from the system.

13 Water requirements for the make-up supply re-calculated on an annual basis to include a 20% factor of safety for hydrogeological and operational uncertainties.

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Optimal Drain Configuration

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,033,000	**0.11**	2,006.91	2,007.41	182.5	72.3	700	0	0.7												
7,033,125	0.18	2,006.98	2,007.48	26.4	69.0	70	0	4.7	2.6	93%	520,434	484,004	36,430	1,378	36,430					
7,033,250	0.21	2,007.01	2,007.51	10.3	69.5	750	0	12.1	72.6	59%	203,350	120,221	83,129	8,045	119,559					
7,033,375	0.26	2,007.06	2,007.56	20.8	69.0	750	0	6.0	36.0	65%	410,313	268,637	141,676	6,795	261,235					
7,033,500	0.31	2,007.11	2,007.61	18.5	69.5	800	0	6.8	43.3	65%	363,970	238,296	125,674	6,795	386,909					
7,033,625	0.37	2,007.17	2,007.67	22.0	67.0	800	0	5.7	36.4	65%	432,446	283,128	149,318	6,795	536,227					
7,033,750	0.37	2,007.17	2,007.67	0.0											536,227					
7,033,875	0.37	2,007.17	2,007.67	0.0											536,227					
7,034,000	0.41	2,007.21	2,007.71	11.6	75.0	1,100	0	10.8	94.8	59%	228,464	135,068	93,396	8,045	629,623					
7,034,125	0.49	2,007.29	2,007.79	31.6	70.7	1,000	0	4.0	31.6	73%	622,154	454,456	167,698	5,305	797,321					
7,034,250	0.55	2,007.35	2,007.85	19.8	71.5	900	0	6.3	45.5	65%	388,903	254,620	134,283	6,795	931,604					
7,034,375	0.63	2,007.43	2,007.93	29.0	70.0	800	0	4.3	27.6	73%	570,662	416,843	153,819	5,305	1,085,423					
7,034,500	0.71	2,007.51	2,008.01	31.9	71.3	600	0	3.9	18.8	73%	627,575	458,416	169,159	5,305	1,254,582					
7,034,625	0.76	2,007.56	2,008.06	16.5	71.3	550	0	7.6	33.3	73%	325,034	237,423	87,611	5,305	1,342,193					
7,034,750	0.76	2,007.56	2,008.06	0.0											1,342,193					
7,034,875	0.82	2,007.62	2,008.12	23.7	67.0	450	1	5.3	19.0	70%	465,509	325,142	140,367	5,934	1,482,561					
7,035,000	0.86	2,007.66	2,008.16	14.5	71.3	450	1	8.6	31.1	70%	285,015	199,073	85,942	5,934	1,568,502					
7,035,125	0.90	2,007.70	2,008.20	14.9	68.5	450	1	8.4	30.2	70%	293,416	204,941	88,475	5,934	1,656,978					
7,035,250	0.92	2,007.72	2,008.22	7.2	69.0	450	1	17.2	62.1	53%	142,643	74,895	67,748	9,347	1,724,726					
7,035,375	0.95	2,007.75	2,008.25	8.1	72.0	450	1	15.4	55.6	53%	159,265	83,622	75,643	9,347	1,800,369					
7,035,500	0.99	2,007.79	2,008.29	17.2	71.3	450	1	7.3	26.2	70%	338,495	236,427	102,068	5,934	1,902,437					
7,035,625	**1.03**	2,007.83	2,008.33	12.9	70.5	500	1	9.7	38.8	61%	253,577	153,995	99,582	7,728	2,002,019	67%	2,002,019	2,002,019	67%	2,002,019
7,035,750	1.06	2,007.86	2,008.36	12.4	72.0	700	1	10.1	56.6	53%	243,279	127,734	115,545	9,347	115,545					
7,035,875	1.10	2,007.90	2,008.40	12.8	75.0	900	1	9.7	70.1	53%	252,493	132,572	119,922	9,347	235,467					
7,036,000	1.17	2,007.97	2,008.47	26.6	71.5	1,100	1	4.7	41.4	61%	522,602	317,372	205,230	7,728	440,697					
7,036,125	1.24	2,008.04	2,008.54	26.0	74.3	2,400	1	4.8	92.5	53%	510,768	268,179	242,589	9,347	683,287					
7,036,250	1.57	2,008.37	2,008.87	119.3	68.5	2,500	1	1.0	20.9	70%	2,348,594	1,640,411	708,184	5,934	1,391,470					
7,036,375	**2.01**	2,008.81	2,009.31	162.1	70.0	2,600	1	0.8	16.0	70%	3,190,811	2,228,669	962,141	5,934	2,353,612	60%	2,353,612	4,355,631	63%	2,177,815
7,036,500	2.28	2,009.08	2,009.58	98.7	69.0	2,650	1	1.3	13.4	84%	3,886,256	3,253,178	633,078	6,412	633,078					
7,036,625	2.53	2,009.33	2,009.83	91.3	69.5	2,650	1	1.4	14.5	84%	3,591,638	3,006,554	585,084	6,412	1,218,162					
7,036,750	2.74	2,009.54	2,010.04	76.9	69.3	2,700	1	1.6	17.6	70%	3,027,481	2,114,589	912,892	11,868	2,131,054					
7,036,875	2.88	2,009.68	2,010.18	48.4	72.0	2,700	1	2.6	27.9	70%	1,904,405	1,330,160	574,245	11,868	2,705,299					
7,037,000	**3.08**	2,009.88	2,010.38	75.9	71.3	2,700	1	1.6	17.8	70%	2,985,745	2,085,438	900,307	11,868	3,605,606	75%	3,605,606	7,961,236	67%	2,653,745
7,037,125	3.25	2,010.05	2,010.55	58.7	71.5	2,600	1	2.1	22.1	70%	2,311,646	1,614,604	697,042	11,868	697,042					
7,037,250	3.42	2,010.22	2,010.72	64.2	71.8	2,500	1	1.9	19.5	70%	2,527,914	1,765,659	762,255	11,868	1,459,297					
7,037,375	3.60	2,010.40	2,010.90	64.8	66.0	2,400	1	1.9	18.5	70%	2,549,866	1,780,992	768,874	11,868	2,228,172					
7,037,500	3.75	2,010.55	2,011.05	56.2	67.3	2,300	1	2.2	20.4	70%	2,213,901	1,546,332	667,569	11,868	2,895,740					
7,037,625	3.91	2,010.71	2,011.21	56.3	66.7	2,200	2	2.2	19.5	67%	2,216,069	1,476,953	739,117	13,128	3,634,857					
7,037,750	**3.98**	2,010.78	2,011.28	26.0	65.5	2,100	2	4.8	40.5	56%	1,021,627	571,979	449,648	17,323	4,084,505	67%	4,084,505	12,045,741	67%	3,011,435
7,037,875	4.12	2,010.92	2,011.42	51.6	65.0	2,000	3	2.4	19.4	62%	2,029,974	1,250,347	779,627	15,117	779,627					
7,038,000	4.16	2,010.96	2,011.46	15.9	61.0	1,950	3	7.9	61.3	37%	626,129	230,643	395,486	24,861	1,175,113					
7,038,125	4.21	2,011.01	2,011.51	16.8	69.0	2,000	3	7.4	59.4	37%	662,987	244,220	418,767	24,861	1,593,880					
7,038,250	4.28	2,011.08	2,011.58	25.6	69.3	2,100	3	4.9	41.0	49%	1,008,167	491,826	516,341	20,159	2,110,220					
7,038,375	4.39	2,011.19	2,011.69	40.5	67.3	2,200	2	3.1	27.2	67%	1,592,921	1,061,641	531,281	13,128	2,641,501					
7,038,500	4.52	2,011.32	2,011.82	45.7	66.3	2,250	2	2.7	24.6	67%	1,796,813	1,197,529	599,284	13,128	3,240,785					
7,038,625	4.57	2,011.37	2,011.87	19.0	67.5	2,100	2	6.6	55.1	46%	749,711	344,041	405,670	21,298	3,646,454					
7,038,750	4.62	2,011.42	2,011.92	20.7	65.0	2,000	1	6.0	48.4	61%	813,760	494,190	319,570	15,457	3,966,025					
7,038,875	4.67	2,011.47	2,011.97	16.3	66.5	1,900	1	7.7	58.4	53%	640,403	336,243	304,159	18,694	4,270,184					
7,039,000	4.67	2,011.47	2,011.97	0.0											4,270,184					
7,039,125	4.68	2,011.48	2,011.98	3.7	71.0	350	0	33.6	47.0	65%	146,527	95,933	50,594	13,591	4,320,778					
7,039,250	4.75	2,011.55	2,012.05	24.5	64.0	400	0	5.1	8.2	89%	965,527	859,328	106,199	4,329	4,426,977					
7,039,375	4.85	2,011.65	2,012.15	38.2	64.0	400	0	3.3	5.2	89%	1,503,035	1,337,715	165,320	4,329	4,592,297					
7,039,500	4.92	2,011.72	2,012.22	24.5	67.0	450	0	5.1	9.2	89%	963,991	857,961	106,030	4,329	4,698,327					
7,039,625	**5.00**	2,011.80	2,012.30	31.6	67.7	500	0	4.0	7.9	89%	1,241,870	1,105,275	136,594	4,329	4,834,922	64%	4,834,922	16,880,663	67%	3,376,133
7,039,750	5.12	2,011.92	2,012.42	41.9	64.0	600	0	3.0	7.2	89%	1,647,937	1,466,679	181,258	4,329	181,258					
7,039,875	5.23	2,012.03	2,012.53	40.8	70.5	700	0	3.1	8.6	89%	1,604,755	1,428,247	176,509	4,329	357,767					
7,040,000	5.35	2,012.15	2,012.65	42.8	66.7	850	0	2.9	9.9	89%	1,685,517	1,500,126	185,392	4,329	543,158					
7,040,125	5.52	2,012.32	2,012.82	61.8	65.7	850	2	2.0	6.9	87%	2,432,337	2,107,976	324,362	5,249	867,520					
7,040,250	5.61	2,012.41	2,012.91	33.8	66.0	850	4	3.7	12.6	77%	1,331,755	1,025,845	305,910	9,041	1,173,430					
7,040,375	5.70	2,012.50	2,013.00	33.7	76.0	850	6	3.7	12.6	74%	1,326,245	987,867	338,377	10,042	1,511,807					
7,040,500	5.80	2,012.60	2,013.10	35.8	76.5	850	8	3.5	11.9	74%	1,410,168	1,050,379	359,790	10,042	1,871,597					
7,040,625	5.89	2,012.69	2,013.19	32.8	85.3	840	8	3.8	12.8	66%	1,291,013	850,430	440,583	13,432	2,312,181					
7,040,750	5.95	2,012.75	2,013.25	20.9	85.8	830	8	6.0	19.9	38%	821,620	308,710	512,910	24,571	2,825,090					
7,040,875	**6.00**	2,012.80	2,013.30	20.3	77.0	820	8	6.1	20.2	38%	800,661	300,835	499,826	24,571	3,324,916	72%	3,324,916	20205579	68%	3,367,597

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Optimal Drain Configuration

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,041,000	6.05	2,012.85	2,013.35	17.8	79.0	810	8	7.0	22.8	51%	699,032	359,916	339,115	19,094	339,115					
7,041,125	6.11	2,012.91	2,013.41	21.1	80.0	780	8	5.9	18.5	38%	831,286	312,342	518,944	24,571	858,059					
7,041,250	6.18	2,012.98	2,013.48	26.4	69.7	750	8	4.7	14.2	66%	1,038,610	684,164	354,446	13,432	1,212,505					
7,041,375	6.25	2,013.05	2,013.55	25.9	73.7	700	9	4.8	13.5	63%	1,019,188	642,109	377,079	14,562	1,589,583					
7,041,500	6.30	2,013.10	2,013.60	16.3	75.3	650	9	7.7	20.0	38%	640,854	240,790	400,064	24,571	1,989,647					
7,041,625	6.33	2,013.13	2,013.63	11.2	81.5	700	9	11.2	31.2	33%	440,847	145,194	295,653	26,397	2,285,300					
7,041,750	6.35	2,013.15	2,013.65	9.0	79.0	750	9	14.0	41.9	14%	352,678	51,046	301,631	33,663	2,586,932					
7,041,875	6.39	2,013.19	2,013.69	15.1	82.0	800	9	8.3	26.5	33%	593,788	195,565	398,223	26,397	2,985,155					
7,042,000	6.46	2,013.26	2,013.76	24.0	79.5	850	9	5.2	17.7	38%	945,382	355,212	590,170	24,571	3,575,325					
7,042,125	6.50	2,013.30	2,013.80	15.7	78.5	650	7	8.0	20.8	51%	616,373	317,357	299,016	19,094	3,874,341					
7,042,250	6.53	2,013.33	2,013.83	9.9	72.7	450	5	12.7	22.8	51%	388,722	200,145	188,577	19,094	4,062,918					
7,042,375	6.55	2,013.35	2,013.85	7.2	72.0	300	4	17.4	20.9	57%	282,847	159,924	122,922	17,105	4,185,840					
7,042,500	6.59	2,013.39	2,013.89	13.2	65.0	250	4	9.5	9.5	83%	518,537	429,642	88,895	6,748	4,274,736					
7,042,625	6.62	2,013.42	2,013.92	10.9	73.3	300	4	11.5	13.8	77%	427,838	329,562	98,276	9,041	4,373,012					
7,042,750	6.71	2,013.51	2,014.01	35.6	69.6	500	4	3.5	7.0	83%	1,401,044	1,160,856	240,188	6,748	4,613,200					
7,042,875	6.83	2,013.63	2,014.13	42.0	69.3	1,500	3	3.0	17.9	62%	1,653,447	1,018,428	635,019	15,117	5,248,220					
7,043,000	**6.94**	2,013.74	2,014.24	42.0	68.3	1,500	3	3.0	17.9	62%	1,651,460	1,017,204	634,256	15,117	5,882,476	53%	5,882,476	26,088,055	65%	3,726,865
7,043,125	7.09	2,013.89	2,014.39	55.0	68.7	1,500	3	2.3	13.6	80%	2,165,209	1,722,923	442,286	8,040	442,286					
7,043,250	7.17	2,013.97	2,014.47	28.8	71.8	500	2	4.3	8.7	87%	1,134,549	983,252	151,296	5,249	593,583					
7,043,375	7.22	2,014.02	2,014.52	15.6	74.0	300	1	8.0	9.6	88%	615,650	540,742	74,908	4,789	668,490					
7,043,500	7.22	2,014.02	2,014.52	0.0											668,490					
7,043,625	7.22	2,014.02	2,014.52	0.0											668,490					
7,043,750	7.25	2,014.05	2,014.55	12.6	75.0	300	0	9.9	11.9	85%	495,682	422,832	72,850	5,785	741,340					
7,043,875	7.25	2,014.05	2,014.55	0.0											741,340					
7,044,000	7.30	2,014.10	2,014.60	16.3	71.3	350	0	7.7	10.7	85%	642,390	547,978	94,412	5,785	835,752					
7,044,125	7.33	2,014.13	2,014.63	13.3	72.3	400	0	9.4	15.0	85%	525,042	447,877	77,165	5,785	912,917					
7,044,250	7.35	2,014.15	2,014.65	8.1	73.5	450	0	15.4	27.7	73%	319,253	233,200	86,053	10,609	998,969					
7,044,375	7.39	2,014.19	2,014.69	12.8	61.0	500	1	9.8	19.6	70%	502,457	350,949	151,508	11,868	1,150,478					
7,044,500	7.40	2,014.20	2,014.70	3.1	70.0	500	1	40.9	81.9	53%	120,149	63,084	57,065	18,694	1,207,542					
7,044,625	7.46	2,014.26	2,014.76	23.1	64.0	500	1	5.4	10.8	84%	908,253	760,297	147,956	6,412	1,355,499					
7,044,750	7.50	2,014.30	2,014.80	13.0	62.0	500	1	9.6	19.2	70%	511,220	357,069	154,151	11,868	1,509,649					
7,044,875	7.52	2,014.32	2,014.82	8.4	75.0	550	1	14.8	32.6	70%	331,629	231,631	99,998	11,868	1,609,647					
7,045,000	7.55	2,014.35	2,014.85	9.6	81.3	550	1	13.0	28.6	73%	378,604	276,554	102,051	10,609	1,711,698					
7,045,125	7.56	2,014.36	2,014.86	7.0	81.3	550	1	17.8	39.1	61%	276,794	168,095	108,699	15,457	1,820,397					
7,045,250	7.62	2,014.42	2,014.92	20.7	69.5	500	1	6.0	12.1	84%	816,380	683,390	132,990	6,412	1,953,387					
7,045,375	7.68	2,014.48	2,014.98	22.9	69.5	450	0	5.5	9.8	89%	900,033	801,037	98,995	4,329	2,052,382					
7,045,500	7.76	2,014.56	2,015.06	26.0	68.3	400	0	4.8	7.7	89%	1,022,982	910,463	112,519	4,329	2,164,901					
7,045,625	7.83	2,014.63	2,015.13	26.1	68.0	350	0	4.8	6.7	89%	1,026,415	913,518	112,896	4,329	2,277,797					
7,045,750	7.83	2,014.63	2,015.13	0.0											2,277,797					
7,045,875	7.83	2,014.63	2,015.13	0.0											2,277,797					
7,046,000	7.88	2,014.68	2,015.18	18.6	65.1	200	1	6.7	5.4	88%	731,734	642,702	89,032	4,789	2,366,829					
7,046,125	7.88	2,014.68	2,015.18	0.0											2,366,829					
7,046,250	7.88	2,014.68	2,015.18	0.0											2,366,829					
7,046,375	7.88	2,014.68	2,015.18	0.0											2,366,829					
7,046,500	7.92	2,014.72	2,015.22	16.5	62.2	300	0	7.6	9.1	89%	650,430	578,889	71,541	4,329	2,438,370					
7,046,625	7.92	2,014.72	2,015.22	0.0											2,438,370					
7,046,750	7.92	2,014.72	2,015.22	0.0											2,438,370					
7,046,875	7.92	2,014.72	2,015.22	0.0											2,438,370					
7,047,000	7.96	2,014.76	2,015.26	14.7	59.1	700	0	8.5	23.8	73%	578,160	422,320	155,840	10,609	2,594,210					
7,047,125	7.96	2,014.76	2,015.26	0.0											2,594,210					
7,047,250	7.96	2,014.76	2,015.26	0.0											2,594,210					
7,047,375	7.96	2,014.76	2,015.26	0.0											2,594,210					
7,047,500	7.99	2,014.79	2,015.29	10.3	56.2	650	0	12.1	31.5	73%	406,519	296,944	109,575	10,609	2,703,785					
7,047,625	7.99	2,014.79	2,015.29	0.0											2,703,785					
7,047,750	7.99	2,014.79	2,015.29	0.0											2,703,785					
7,047,875	7.99	2,014.79	2,015.29	0.0											2,703,785					
7,048,000	**8.03**	2,014.83	2,015.33	12.4	64.8	1,550	3	10.1	62.5	37%	487,823	179,696	308,126	24,861	3,011,911	77%	3,011,911	29,099,966	67%	3,637,496

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Optimal Drain Configuration

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,048,125	8.03	2,014.83	2,015.33	0.0											0					
7,048,250	8.03	2,014.83	2,015.33	0.0											0					
7,048,375	8.03	2,014.83	2,015.33	0.0											0					
7,048,500	8.07	2,014.87	2,015.37	15.6	64.0	1,650	4	8.0	52.9	42%	614,295	255,432	358,863	22,994	358,863					
7,048,625	8.07	2,014.87	2,015.37	0.0											358,863					
7,048,750	8.07	2,014.87	2,015.37	0.0											358,863					
7,048,875	8.07	2,014.87	2,015.37	0.0											358,863					
7,049,000	8.07	2,014.87	2,015.37	0.0											358,863					
7,049,125	8.07	2,014.87	2,015.37	0.0											358,863					
7,049,250	**9.01**	2,015.81	2,016.31	344.6	66.0	1,700	5	0.4	2.5	88%	13,563,761	11,898,690	1,665,071	4,832	2,023,934	65%	2,023,934	31,123,900	67%	3,458,211
7,049,375	9.01	2,015.81	2,016.31	0.0											0					
7,049,500	9.01	2,015.81	2,016.31	0.0											0					
7,049,625	9.01	2,015.81	2,016.31	0.0											0					
7,049,750	9.75	2,016.55	2,017.05	269.4	64.9	1,650	5	0.5	3.1	88%	10,601,867	9,300,395	1,301,473	4,832	1,301,473					
7,049,875	9.75	2,016.55	2,017.05	0.0											1,301,473					
7,050,000	9.75	2,016.55	2,017.05	0.0											1,301,473					
7,050,125	9.75	2,016.55	2,017.05	0.0											1,301,473					
7,050,250	**10.16**	2,016.96	2,017.46	151.0	54.6	1,300	4	0.8	4.3	89%	5,943,168	5,288,815	654,353	4,334	1,955,826	78%	1,955,826	33,079,726	68%	3,307,973
Max					85.8	2,700	9	40.9	94.8	93%				33,663		78%	5,882,476			
Min					54.6	70	0	0.4	2.5	14%				1,378		53%	1,955,826			
Average					70.1	1,052	2	6.9	26.5	67%				11,236		68%	3,307,973			

Notes: The recovery rates were derived from the numerical modelling using an underflow rate of 1,172 kL/hr.
The floor sand thicknesses were derived directly from the Gunson geological and mine database as at 11 Jan 2005 at 500 or 1,000 m centres. Data for line spacings between have been interpolated from the database or planned mine layout maps.

Appendix E. Summary Calculations for Life-of-Mine Water Balance, 2-Drains Scenario

Year	Inputs	Outputs*	Period Balance Required from Bores	Annual Bore Water Require-ment
	kL	kL	kL	kL
1	10,595	7,939,652	7,929,057	7,929,057
2	10,595	7,939,652	7,929,057	7,929,057
3	10,595	13,911,404	13,900,809	13,900,809
4	10,595	13,911,404	13,900,809	13,900,809
5	10,595	15,261,404	15,250,809	15,250,809
5 - 10	52,975	73,155,965	73,102,990	14,620,598
10 - 15	52,975	72,255,965	72,202,990	14,440,598
15 - 20	52,975	71,355,965	71,302,990	14,260,598
Average Water Requirement (1 plant)				7,929,057
Average Water Requirement (2 plants)				14,395,704

APPENDIX E. Annual Water Balance Calculations, 2-Drains Scenario

			Water In	Water Out												Balance	
Source			Direct Rainfall Recharge	Process Wate Dams	Evaporation Losses			Evapora-tion Losses Total	Dust Suppress-ion	Concen-trate Water Losses	Process Bores	Seepage Losses			Seepage Losses (Total)	Total Make-up Process Water Pumpage Required	Estimated Annual Licenced Water Requirement
Location			Water Dams	Initial Plant Start-ups	Process Water Dam	Slimes Settling Area	Stacker Areas				Camp Supply	Tailings Not Recovered	Process Water Dams	Slimes Settling Areas			
Notes			1	2	3	4	5	3 - 5	6	7	8	9	10	11	9 - 11	12	13
Year No.	Operating time (yrs)	Plants Operating	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL	kL
1	0.81	1	10,595	900,000	224,458	26,935	11,223	262,616	182,500	170,400	131,400	4,659,872	0	1,632,864	6,292,736	7,929,057	7,929,057
2	0.81	1	10,595	900,000	224,458	26,935	11,223	262,616	182,500	170,400	131,400	4,659,872	0	1,632,864	6,292,736	7,929,057	7,929,057
3	0.81	2	10,595	0	448,916	53,870	22,446	525,232	365,000	340,800	94,900	9,319,744	0	3,265,728	12,585,472	13,900,809	13,900,809
4	0.81	2	10,595	0	448,916	53,870	22,446	525,232	365,000	340,800	94,900	9,319,744	0	3,265,728	12,585,472	13,900,809	13,900,809
5	0.81	2	10,595	1,350,000	448,916	53,870	22,446	525,232	365,000	340,800	94,900	9,319,744	0	3,265,728	12,585,472	15,250,809	15,250,809
10	4.05	2	52,975	3,600,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	46,598,720	0	16,328,640	62,927,360	73,102,990	14,620,598
15	4.05	2	52,975	2,700,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	46,598,720	0	16,328,640	62,927,360	72,202,990	14,440,598
20	4.05	2	52,975	1,800,000	2,244,582	269,350	112,229	2,626,161	1,825,000	1,702,944	474,500	46,598,720	0	16,328,640	62,927,360	71,302,990	14,260,598
Project Lifetime Totals			211,900	11,250,000	8,529,412	1,023,529	426,471	9,979,412	6,935,000	6,472,032	1,971,000	177,075,136	0	62,048,832	239,123,968	275,519,512	

Key Assumptions:
- Tailings discharge cyclones recover 47% of water used for each 2,000 tonnes/hr of ore processed reaching an average solids content of 65%.
- On average, 44% of the tailings water is recovered
- Process water bores each yield 3.1 Gl/annum (100 L/sec) but only pumped at an average of 75 L.sec (75% up-time) for 2.37 GL/year
- Processing occurs for 7,100 hrs/year

Notes:

1 Based on the annual mean rainfall data for Hamelin Pool (BoM Stn. No. 006025, Jan 1886-Jul 2004) and annual evaporation data from Hamelin pool (BoM Stn. No. 006025, May 1978-Apr 1980), Nanga Stn. (BoM Stn. No. 006080, May 1980-Apr 1988) and Brickhouse Stn (BoM Stn. No. 6087, Sep 1966-Mar 1977).
Dam surface areas based on there being 1 Ha of water in the process water dam and 4 Ha in the slimes settling area.

2 This value based on filling process water dams (450 ML each) for each plant site move. (Does not include plant recommissioning requirements)

3 Surface area of the process water dams are based on 320 x 320 m dams for each plant. One new dam is allowed for for each new plant site.
Evaporation calculated as 0.72 x pan evaporation figures from BoM as per Ag. Dpet tech Report 65, 1988.

4 Surface area of the slimes dams are based on 2 dams (1 active and 1 inactive) of average size of 200 x 30 m dams for each plant. Two for years 1 and 2, and four dams for years 3 onwards.
Evaporation calculated as 0.72 x pan evaporation figures from BoM as per Ag. Dpet tech Report 65, 1988.

5 It is assumed that the active stacker site will be approx. 50 x 100 m per plant.

6 Dust suppression losses based on half the nominated area of 30,000 m^2 of watered roads (mine access and internal roads) being constantly wet and subjected to evaporative losses.
An additional average of 500 kL/d has been allowed for dust suppression that is assumed as a total loss.

7 Losses are expected from the system via the concentrate stockpiles at a rate of 24 kL/hr.

8 Camp supply based on nominated number of people as 100 construction personnel, 80 mining personnel in years 1-2 and 130 in years 3 onwards. An average consumption is calculated on the basis of 0.75 kL perperson per day of potable water and that 1.5 kL of raw water required to produce this.

9 Non-recovered tailings seepage is the difference between the hydrocyclone underflow discharge and calculated seepage recovery.
This value calculated from modelling water recovery from the re-deposited and/or underlying Superficial sand for the tailings water.
It is assumed that processing occurs for 7,100 hrs per year and that only 20% of the slimes water is recovered..

10 All process water dams are nominated to be lined.

11 Assume that all slimes water is not recovered, and that which is not evaporated is retained or lost to seepage. Quantity of water discharged based on the consumption of 233 kL/hr of water per plant and that 20 % of this is recovered by decant, and no seepage water is recovered.

12 Difference between the water in (or recovered) and losses from the system.

13 Water requirements for the make-up supply re-calculated on an annual basis to include a 20% factor of safety for hydrogeological and operational uncertainties.

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Only 2 Active Drains

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,033,000	**0.11**	2,006.91	2,007.41	182.5	72.3	700	0	0.7												
7,033,125	0.18	2,006.98	2,007.48	26.4	69.0	70	0	4.7	2.6	81%	520,434	421,552	98,883	3,739	98,883					
7,033,250	0.21	2,007.01	2,007.51	10.3	69.5	750	0	12.1	72.6	30%	203,350	61,005	142,345	13,776	241,227					
7,033,375	0.26	2,007.06	2,007.56	20.8	69.0	750	0	6.0	36.0	33%	410,313	135,403	274,910	13,186	516,137					
7,033,500	0.31	2,007.11	2,007.61	18.5	69.5	800	0	6.8	43.3	33%	363,970	120,110	243,860	13,186	759,997					
7,033,625	0.37	2,007.17	2,007.67	22.0	67.0	800	0	5.7	36.4	33%	432,446	142,707	289,739	13,186	1,049,735					
7,033,750	0.37	2,007.17	2,007.67	0.0											1,049,735					
7,033,875	0.37	2,007.17	2,007.67	0.0											1,049,735					
7,034,000	0.41	2,007.21	2,007.71	11.6	75.0	1,100	0	10.8	94.8	30%	228,464	68,539	159,924	13,776	1,209,660					
7,034,125	0.49	2,007.29	2,007.79	31.6	70.7	1,000	0	4.0	31.6	42%	622,154	261,305	360,850	11,414	1,570,509					
7,034,250	0.55	2,007.35	2,007.85	19.8	71.5	900	0	6.3	45.5	33%	388,903	128,338	260,565	13,186	1,831,074					
7,034,375	0.63	2,007.43	2,007.93	29.0	70.0	800	0	4.3	27.6	42%	570,662	239,678	330,984	11,414	2,162,058					
7,034,500	0.71	2,007.51	2,008.01	31.9	71.3	600	0	3.9	18.8	42%	627,575	263,581	363,993	11,414	2,526,052					
7,034,625	0.76	2,007.56	2,008.06	16.5	71.3	550	0	7.6	33.3	42%	325,034	136,514	188,520	11,414	2,714,571					
7,034,750	0.76	2,007.56	2,008.06	0.0											2,714,571					
7,034,875	0.82	2,007.62	2,008.12	23.7	67.0	450	1	5.3	19.0	40%	465,509	183,876	281,633	11,906	2,996,204					
7,035,000	0.86	2,007.66	2,008.16	14.5	71.3	450	1	8.6	31.1	40%	285,015	112,581	172,434	11,906	3,168,638					
7,035,125	0.90	2,007.70	2,008.20	14.9	68.5	450	1	8.4	30.2	40%	293,416	115,899	177,517	11,906	3,346,155					
7,035,250	0.92	2,007.72	2,008.22	7.2	69.0	450	1	17.2	62.1	26%	142,643	36,374	106,269	14,662	3,452,424					
7,035,375	0.95	2,007.75	2,008.25	8.1	72.0	450	1	15.4	55.6	26%	159,265	40,613	118,652	14,662	3,571,077					
7,035,500	0.99	2,007.79	2,008.29	17.2	71.3	450	1	7.3	26.2	40%	338,495	133,705	204,789	11,906	3,775,866					
7,035,625	**1.03**	2,007.83	2,008.33	12.9	70.5	500	1	9.7	38.8	30%	253,577	74,805	178,772	13,874	3,954,638	38%	3,954,638	3,954,638	38%	3,954,638
7,035,750	1.06	2,007.86	2,008.36	12.4	72.0	700	1	10.1	56.6	26%	243,279	62,036	181,243	14,662	181,243					
7,035,875	1.10	2,007.90	2,008.40	12.8	75.0	900	1	9.7	70.1	26%	252,493	64,386	188,108	14,662	369,350					
7,036,000	1.17	2,007.97	2,008.47	26.6	71.5	1,100	1	4.7	41.4	30%	522,602	154,168	368,435	13,874	737,785					
7,036,125	1.24	2,008.04	2,008.54	26.0	74.3	2,400	1	4.8	92.5	26%	510,768	130,246	380,522	14,662	1,118,307					
7,036,250	1.57	2,008.37	2,008.87	119.3	68.5	2,500	1	1.0	20.9	40%	2,348,594	927,695	1,420,900	11,906	2,539,207					
7,036,375	**2.01**	2,008.81	2,009.31	162.1	70.0	2,600	1	0.8	16.0	40%	3,190,811	1,260,370	1,930,441	11,906	4,469,647	31%	4,469,647	8,424,285	34%	4,212,143
7,036,500	2.28	2,009.08	2,009.58	98.7	69.0	2,650	1	1.3	13.4	64%	3,886,256	2,487,204	1,399,052	14,170	1,399,052					
7,036,625	2.53	2,009.33	2,009.83	91.3	69.5	2,650	1	1.4	14.5	64%	3,591,638	2,298,649	1,292,990	14,170	2,692,042					
7,036,750	2.74	2,009.54	2,010.04	76.9	69.3	2,700	1	1.6	17.6	40%	3,027,481	1,195,855	1,831,626	23,813	4,523,668					
7,036,875	2.88	2,009.68	2,010.18	48.4	72.0	2,700	1	2.6	27.9	40%	1,904,405	752,240	1,152,165	23,813	5,675,833					
7,037,000	**3.08**	2,009.88	2,010.38	75.9	71.3	2,700	1	1.6	17.8	40%	2,985,745	1,179,369	1,806,376	23,813	7,482,208	49%	7,482,208	15,906,494	39%	5,302,165
7,037,125	3.25	2,010.05	2,010.55	58.7	71.5	2,600	1	2.1	22.1	40%	2,311,646	913,100	1,398,546	23,813	1,398,546					
7,037,250	3.42	2,010.22	2,010.72	64.2	71.8	2,500	1	1.9	19.5	40%	2,527,914	998,526	1,529,388	23,813	2,927,934					
7,037,375	3.60	2,010.40	2,010.90	64.8	66.0	2,400	1	1.9	18.5	40%	2,549,866	1,007,197	1,542,669	23,813	4,470,603					
7,037,500	3.75	2,010.55	2,011.05	56.2	67.3	2,300	1	2.2	20.4	40%	2,213,901	874,491	1,339,410	23,813	5,810,013					
7,037,625	3.91	2,010.71	2,011.21	56.3	66.7	2,200	2	2.2	19.5	37%	2,216,069	819,946	1,396,124	24,797	7,206,137					
7,037,750	**3.98**	2,010.78	2,011.28	26.0	65.5	2,100	2	4.8	40.5	26%	1,021,627	265,623	756,004	29,126	7,962,141	37%	7,962,141	23,868,634	39%	5,967,159
7,037,875	4.12	2,010.92	2,011.42	51.6	65.0	2,000	3	2.4	19.4	34%	2,029,974	683,425	1,346,549	26,109	1,346,549					
7,038,000	4.16	2,010.96	2,011.46	15.9	61.0	1,950	3	7.9	61.3	16%	626,129	100,181	525,949	33,062	1,872,498					
7,038,125	4.21	2,011.01	2,011.51	16.8	69.0	2,000	3	7.4	59.4	16%	662,987	106,078	556,909	33,062	2,429,407					
7,038,250	4.28	2,011.08	2,011.58	25.6	69.3	2,100	3	4.9	41.0	22%	1,008,167	218,436	789,730	30,832	3,219,137					
7,038,375	4.39	2,011.19	2,011.69	40.5	67.3	2,200	2	3.1	27.2	37%	1,592,921	589,381	1,003,540	24,797	4,222,678					
7,038,500	4.52	2,011.32	2,011.82	45.7	66.3	2,250	2	2.7	24.6	37%	1,796,813	664,821	1,131,992	24,797	5,354,670					
7,038,625	4.57	2,011.37	2,011.87	19.0	67.5	2,100	2	6.6	55.1	21%	749,711	157,439	592,272	31,094	5,946,941					
7,038,750	4.62	2,011.42	2,011.92	20.7	65.0	2,000	1	6.0	48.4	30%	813,760	240,059	573,701	27,749	6,520,642					
7,038,875	4.67	2,011.47	2,011.97	16.3	66.5	1,900	1	7.7	58.4	26%	640,403	163,303	477,100	29,323	6,997,742					
7,039,000	4.67	2,011.47	2,011.97	0.0											6,997,742					
7,039,125	4.68	2,011.48	2,011.98	3.7	71.0	350	0	33.6	47.0	33%	146,527	48,354	98,173	26,371	7,095,916					
7,039,250	4.75	2,011.55	2,012.05	24.5	64.0	400	0	5.1	8.2	73%	965,527	704,835	260,692	10,627	7,356,608					
7,039,375	4.85	2,011.65	2,012.15	38.2	64.0	400	0	3.3	5.2	73%	1,503,035	1,097,216	405,820	10,627	7,762,428					
7,039,500	4.92	2,011.72	2,012.22	24.5	67.0	450	0	5.1	9.2	73%	963,991	703,714	260,278	10,627	8,022,705					
7,039,625	**5.00**	2,011.80	2,012.30	31.6	67.7	500	0	4.0	7.9	73%	1,241,870	906,565	335,305	10,627	8,358,010	40%	8,358,010	32,226,644	39%	6,445,329
7,039,750	5.12	2,011.92	2,012.42	41.9	64.0	600	0	3.0	7.2	73%	1,647,937	1,202,994	444,943	10,627	444,943					
7,039,875	5.23	2,012.03	2,012.53	40.8	70.5	700	0	3.1	8.6	73%	1,604,755	1,171,471	433,284	10,627	878,227					
7,040,000	5.35	2,012.15	2,012.65	42.8	66.7	850	0	2.9	9.9	73%	1,685,517	1,230,427	455,090	10,627	1,333,316					
7,040,125	5.52	2,012.32	2,012.82	61.8	65.7	850	2	2.0	6.9	71%	2,432,337	1,726,959	705,378	11,414	2,038,694					
7,040,250	5.61	2,012.41	2,012.91	33.8	66.0	850	4	3.7	12.6	60%	1,331,755	794,614	537,141	15,875	2,575,836					
7,040,375	5.70	2,012.50	2,013.00	33.7	76.0	850	6	3.7	12.6	58%	1,326,245	769,222	557,023	16,531	3,132,858					
7,040,500	5.80	2,012.60	2,013.10	35.8	76.5	850	8	3.5	11.9	58%	1,410,168	817,898	592,271	16,531	3,725,129					
7,040,625	5.89	2,012.69	2,013.19	32.8	85.3	840	8	3.8	12.8	52%	1,291,013	671,327	619,686	18,893	4,344,815					
7,040,750	5.95	2,012.75	2,013.25	20.9	85.8	830	8	6.0	19.9	18%	821,620	147,892	673,728	32,275	5,018,544					
7,040,875	**6.00**	2,012.80	2,013.30	20.3	77.0	820	8	6.1	20.2	18%	800,661	144,119	656,542	32,275	5,675,086	55%	5,675,086	37901730	42%	6,316,955

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Only 2 Active Drains

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,041,000	6.05	2,012.85	2,013.35	17.8	79.0	810	8	7.0	22.8	27%	699,032	188,739	510,293	28,733	510,293					
7,041,125	6.11	2,012.91	2,013.41	21.1	80.0	780	8	5.9	18.5	18%	831,286	149,631	681,654	32,275	1,191,947					
7,041,250	6.18	2,012.98	2,013.48	26.4	69.7	750	8	4.7	14.2	52%	1,038,610	540,077	498,533	18,893	1,690,480					
7,041,375	6.25	2,013.05	2,013.55	25.9	73.7	700	9	4.8	13.5	50%	1,019,188	509,594	509,594	19,680	2,200,074					
7,041,500	6.30	2,013.10	2,013.60	16.3	75.3	650	9	7.7	20.0	18%	640,854	115,354	525,500	32,275	2,725,575					
7,041,625	6.33	2,013.13	2,013.63	11.2	81.5	700	9	11.2	31.2	15%	440,847	66,127	374,720	33,456	3,100,294					
7,041,750	6.35	2,013.15	2,013.65	9.0	79.0	750	9	14.0	41.9	3%	352,678	11,991	340,687	38,022	3,440,981					
7,041,875	6.39	2,013.19	2,013.69	15.1	82.0	800	9	8.3	26.5	15%	593,788	89,068	504,720	33,456	3,945,701					
7,042,000	6.46	2,013.26	2,013.76	24.0	79.5	850	9	5.2	17.7	18%	945,382	170,169	775,213	32,275	4,720,914					
7,042,125	6.50	2,013.30	2,013.80	15.7	78.5	650	7	8.0	20.8	27%	616,373	166,421	449,952	28,733	5,170,866					
7,042,250	6.53	2,013.33	2,013.83	9.9	72.7	450	5	12.7	22.8	27%	388,722	104,955	283,767	28,733	5,454,634					
7,042,375	6.55	2,013.35	2,013.85	7.2	72.0	300	4	17.4	20.9	30%	282,847	85,797	197,050	27,421	5,651,684					
7,042,500	6.59	2,013.39	2,013.89	13.2	65.0	250	4	9.5	9.5	69%	518,537	357,791	160,747	12,202	5,812,430					
7,042,625	6.62	2,013.42	2,013.92	10.9	73.3	300	4	11.5	13.8	60%	427,838	255,277	172,561	15,875	5,984,992					
7,042,750	6.71	2,013.51	2,014.01	35.6	69.6	500	4	3.5	7.0	69%	1,401,044	966,721	434,324	12,202	6,419,315					
7,042,875	6.83	2,013.63	2,014.13	42.0	69.3	1,500	3	3.0	17.9	34%	1,653,447	556,661	1,096,787	26,109	7,516,102					
7,043,000	**6.94**	2,013.74	2,014.24	42.0	68.3	1,500	3	3.0	17.9	34%	1,651,460	555,991	1,095,468	26,109	8,611,570	33%	8,611,570	46,513,301	41%	6,644,757
7,043,125	7.09	2,013.89	2,014.39	55.0	68.7	1,500	3	2.3	13.6	61%	2,165,209	1,327,995	837,214	15,219	837,214					
7,043,250	7.17	2,013.97	2,014.47	28.8	71.8	500	2	4.3	8.7	71%	1,134,549	805,530	329,019	11,414	1,166,233					
7,043,375	7.22	2,014.02	2,014.52	15.6	74.0	300	1	8.0	9.6	72%	615,650	443,268	172,382	11,021	1,338,615					
7,043,500	7.22	2,014.02	2,014.52	0.0											1,338,615					
7,043,625	7.22	2,014.02	2,014.52	0.0											1,338,615					
7,043,750	7.25	2,014.05	2,014.55	12.6	75.0	300	0	9.9	11.9	65%	495,682	322,193	173,489	13,776	1,512,104					
7,043,875	7.25	2,014.05	2,014.55	0.0											1,512,104					
7,044,000	7.30	2,014.10	2,014.60	16.3	71.3	350	0	7.7	10.7	65%	642,390	417,553	224,836	13,776	1,736,940					
7,044,125	7.33	2,014.13	2,014.63	13.3	72.3	400	0	9.4	15.0	65%	525,042	341,277	183,765	13,776	1,920,705					
7,044,250	7.35	2,014.15	2,014.65	8.1	73.5	450	0	15.4	27.7	42%	319,253	134,086	185,167	22,829	2,105,872					
7,044,375	7.39	2,014.19	2,014.69	12.8	61.0	500	1	9.8	19.6	40%	502,457	198,471	303,987	23,813	2,409,858					
7,044,500	7.40	2,014.20	2,014.70	3.1	70.0	500	1	40.9	81.9	26%	120,149	30,638	89,511	29,323	2,499,369					
7,044,625	7.46	2,014.26	2,014.76	23.1	64.0	500	1	5.4	10.8	64%	908,253	581,282	326,971	14,170	2,826,340					
7,044,750	7.50	2,014.30	2,014.80	13.0	62.0	500	1	9.6	19.2	40%	511,220	201,932	309,288	23,813	3,135,628					
7,044,875	7.52	2,014.32	2,014.82	8.4	75.0	550	1	14.8	32.6	40%	331,629	130,993	200,636	23,813	3,336,264					
7,045,000	7.55	2,014.35	2,014.85	9.6	81.3	550	1	13.0	28.6	42%	378,604	159,014	219,591	22,829	3,555,854					
7,045,125	7.56	2,014.36	2,014.86	7.0	81.3	550	1	17.8	39.1	30%	276,794	81,654	195,140	27,749	3,750,994					
7,045,250	7.62	2,014.42	2,014.92	20.7	69.5	500	1	6.0	12.1	64%	816,380	522,483	293,897	14,170	4,044,891					
7,045,375	7.68	2,014.48	2,014.98	22.9	69.5	450	0	5.5	9.8	73%	900,033	657,024	243,009	10,627	4,287,900					
7,045,500	7.76	2,014.56	2,015.06	26.0	68.3	400	0	4.8	7.7	73%	1,022,982	746,777	276,205	10,627	4,564,105					
7,045,625	7.83	2,014.63	2,015.13	26.1	68.0	350	0	4.8	6.7	73%	1,026,415	749,283	277,132	10,627	4,841,237					
7,045,750	7.83	2,014.63	2,015.13	0.0											4,841,237					
7,045,875	7.83	2,014.63	2,015.13	0.0											4,841,237					
7,046,000	7.88	2,014.68	2,015.18	18.6	65.1	200	1	6.7	5.4	72%	731,734	526,848	204,885	11,021	5,046,122					
7,046,125	7.88	2,014.68	2,015.18	0.0											5,046,122					
7,046,250	7.88	2,014.68	2,015.18	0.0											5,046,122					
7,046,375	7.88	2,014.68	2,015.18	0.0											5,046,122					
7,046,500	7.92	2,014.72	2,015.22	16.5	62.2	300	0	7.6	9.1	73%	650,430	474,814	175,616	10,627	5,221,738					
7,046,625	7.92	2,014.72	2,015.22	0.0											5,221,738					
7,046,750	7.92	2,014.72	2,015.22	0.0											5,221,738					
7,046,875	7.92	2,014.72	2,015.22	0.0											5,221,738					
7,047,000	7.96	2,014.76	2,015.26	14.7	59.1	700	0	8.5	23.8	42%	578,160	242,827	335,333	22,829	5,557,071					
7,047,125	7.96	2,014.76	2,015.26	0.0											5,557,071					
7,047,250	7.96	2,014.76	2,015.26	0.0											5,557,071					
7,047,375	7.96	2,014.76	2,015.26	0.0											5,557,071					
7,047,500	7.99	2,014.79	2,015.29	10.3	56.2	650	0	12.1	31.5	42%	406,519	170,738	235,781	22,829	5,792,852					
7,047,625	7.99	2,014.79	2,015.29	0.0											5,792,852					
7,047,750	7.99	2,014.79	2,015.29	0.0											5,792,852					
7,047,875	7.99	2,014.79	2,015.29	0.0											5,792,852					
7,048,000	**8.03**	2,014.83	2,015.33	12.4	64.8	1,550	3	10.1	62.5	16%	487,823	78,052	409,771	33,062	6,202,623	54%	6,202,623	52,715,924	42%	6,589,490

APPENDIX E. Detailed Mine Water Balance Calculations, 1,172 kL/hr With Only 2 Active Drains

Mine Northing	Mining Year	Mining Year	Tails Year (approx.)	Duration	Pit Base	Pit Width (or sum)	Floor Sand Thickness	Overall Mine Advance Rate	Tailing Rate	Recovery Rate	Cyclone Underflow	Mine Water Recovered	Make-up Water Lost	Average Make-up Rate	Cumulative Annual Requirements	Average Recovery Rate	Annual Losses	Cumulative Annual Losses	Cumulative Average Annual Recovery	Cumulative Average Annual Losses
	(years)	(calendar)	(years)	Days	(av. m RL)	(m)	(m)	(m/d)	(m/d)	%	(kL/d)	(kL)	(kL)	(kL/d)	(kL)	%	(kL)	(kL)	%	(kL)
A	Formulae:	B	C	D	E	F	G	H = diff A / D	I = F / D	J = (modelled)	K = D x 19,680	L = J x K	M = K - L	N = M / D	O = sum N	P = ann. average				
7,048,125	8.03	2,014.83	2,015.33	0.0											0					
7,048,250	8.03	2,014.83	2,015.33	0.0											0					
7,048,375	8.03	2,014.83	2,015.33	0.0											0					
7,048,500	8.07	2,014.87	2,015.37	15.6	64.0	1,650	4	8.0	52.9	17%	614,295	106,478	507,817	32,538	507,817					
7,048,625	8.07	2,014.87	2,015.37	0.0											507,817					
7,048,750	8.07	2,014.87	2,015.37	0.0											507,817					
7,048,875	8.07	2,014.87	2,015.37	0.0											507,817					
7,049,000	8.07	2,014.87	2,015.37	0.0											507,817					
7,049,125	8.07	2,014.87	2,015.37	0.0											507,817					
7,049,250	**9.01**	2,015.81	2,016.31	344.6	66.0	1,700	5	0.4	2.5	77%	13,563,761	10,444,096	3,119,665	9,053	3,627,482	47%	3,627,482	56,343,406	43%	6,260,378
7,049,375	9.01	2,015.81	2,016.31	0.0											0					
7,049,500	9.01	2,015.81	2,016.31	0.0											0					
7,049,625	9.01	2,015.81	2,016.31	0.0											0					
7,049,750	9.75	2,016.55	2,017.05	269.4	64.9	1,650	5	0.5	3.1	77%	10,601,867	8,163,438	2,438,429	9,053	2,438,429					
7,049,875	9.75	2,016.55	2,017.05	0.0											2,438,429					
7,050,000	9.75	2,016.55	2,017.05	0.0											2,438,429					
7,050,125	9.75	2,016.55	2,017.05	0.0											2,438,429					
7,050,250	**10.16**	2,016.96	2,017.46	151.0	54.6	1,300	4	0.8	4.3	78%	5,943,168	4,635,671	1,307,497	8,659	3,745,926	59%	3,745,926	60,089,332	44%	6,008,933
Max					85.8	2,700	9	40.9	94.8	81%				38,022		59%	8,611,570			
Min					54.6	70	0	0.4	2.5	3%				3,739		31%	3,627,482			
Average					70.1	1,052	2	6.9	26.5	44%				19,185		44%	6,008,933			

Notes: The recovery rates were derived from the numerical modelling using an underflow rate of 1,172 kL/hr.
The floor sand thicknesses were derived directly from the Gunson geological and mine database as at 11 Jan 2005 at 500 or 1,000 m centres. Data for line spacings between have been interpolated from the database or planned mine layout maps.

APPENDIX E. Derived Sand Thicknesses and Pit Widths from Mine Database for First 10 Years of Mining

Northing (m AMG)	Year(s)	Pit 1* Sand Thickness	Adopted Thickness (m)	Pit 1 Width (m)	Pit 2 Sand Thickness	Adopted Thickness (m)	Pit 2 Width (m)	Pit 3 Sand Thickness	Adopted Thickness (m)	Pit 3 Width (m)	Pit 4 Sand Thickness	Adopted Thickness (m)	Pit 4 Width (m)	Pit 5 Sand Thickness	Adopted Thickness (m)	Pit 5 Width (m)	Pit 6 Sand Thickness	Adopted Thickness (m)	Pit 6 Width (m)	Pit 7 Sand Thickness	Adopted Thickness (m)	Pit 7 Width (m)	Pit 8 sand Thickness	Adopted Thickness (m)	Pit 8 Width (m)	Pit 9 Sand Thickness	Adopted Thickness (m)	Pit 9 Width (m)	Average Sand Thickness (m)	Combined Pit Width (m)	No. of Pits
7,033,000	2007.41	0	0	700																									0	700	1
7,033,500	2007.61	0	0	400	0	0	400																						0	800	2
7,034,000	2007.71	0	0	300	0	0	500	0	0	300																			0	1100	3
7,034,500	2008.01	0	0	200	0 - 1	1	300	0	0	100																			0	600	3
7,035,000	2008.16				1	1	250	0	0	200																			1	450	2
7,035,500	2008.29				1	1	300	1	1	150																			1	450	2
7,036,000	2008.47				1	1	650	0	0	450																			1	1100	2
7,036,500	2009.58				1	1	450	0	0	2200																			1	2650	2
7,037,000	2010.38				0	0	700	Av 1 - 2	2	2000																			1	2700	2
7,037,500	2011.05				0	0	350	Av 1 - 2	2	1950																			1	2300	2
7,038,000	2011.46				2	2	150	Av 3 - 4	4	1800																			3	1950	2
7,038,500	2011.82				0	0	750	Av 4	4	1500																			2	2250	2
7,039,000	2011.97				0	0	350																						0	350	1
7,039,500	2012.22										0	0	350	0	0	100													0	450	2
7,040,000	2012.65										0	0	450	0	0	400													0	850	2
7,040,500	2013.10										(N.D)	0	700	15	15	150													8	850	2
7,041,000	2013.35										0	0	560				10 - 15	15	250										8	810	2
7,041,500	2013.60										Av 2	2	400				10 - 15	15	250										9	650	2
7,042,000	2013.76										1 - 2	2	750				15	15	100										9	850	2
7,042,500	2013.89										4	4	250																4	250	1
7,043,000	2014.24										3	3	1500																3	1500	1
7,043,500	2014.52										1	1	250																1	250	1
7,044,000	2014.60										0	0	350																0	350	1
7,044,500	2014.70										Av 1	1	500																1	500	1
7,045,000	2014.85										1	1	400							0	0	150							1	550	2
7,045,500	2015.06										0	0	250							0	0	150							0	400	2
7,046,000	2015.18																			1	1	200							1	200	1
7,046,500	2015.22																			0	0	300							0	300	1
7,047,000	2015.26																			0	0	400	0	0	300				0	700	2
7,047,500	2015.29																			(N.D)	0	350	(N.D)	0	300				0	650	2
7,048,000	2015.33																			0	0	250	0	0	300	$^1/_2$ = 0; $^1/_2$ - Av 15	10	1000	3	1550	3
7,048,500	2015.37																			(N.D)	2	250	(N.D)	2	350	(N.D)	9	1050	4	1650	3
7,049,000	2015.37																			Av 4	4	250	Av 4	4	400	$^1/_2$ = 0; $^1/_2$ - Av 10	7	1100	5	1750	3
7,049,500	2016.31																			(N.D)	4	200	(N.D)	4	400	(N.D)	6	1100	5	1700	3
7,050,000	2017.05																			Av 4	4	100	Av 4	4	350	$^1/_2$ = 0; $^1/_2$ - Av 4	4	1100	4	1550	3

Notes: * - Pit numbers nominal from South and West to North and East
Av - Average thickness visually averaged off cross sections with 100 m spacced drillholes
(N.D.) - Not determined. No drillhole data available.