GHD Pty Ltd

Brief Hydrogeological Review
Threatened Ecological Community – Gaston Road Spring
Bullsbrook, Western Australia

FINAL

Project Number: GHD001
Report Date: July 2008

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1. INTRODUCTION

GHD Pty Ltd is assisting Main Roads Western Australia to select the alignment for the proposed Perth-Darwin National Highway. The current preferred alignment includes a section that was identified to be near a Threatened Ecological Community. The Threatened Ecological Community occurs on Gaston Road, Bullsbrook (*Figure 1, Appendix A*).

The Department of Environment and Conservation was consulted, and requested a hydrogeological assessment of the springs to provide guidance on the potential impacts of the preferred road alignment. This report documents the assessment.

Groundwater Consulting Services has investigated springs in the northern Perth region over a number of years. These previous investigations provided the basis of the conceptual hydrogeological model for this desktop assessment.

Figure 2 (Appendix A) shows the site with the proposed and alternative highway alignments.

1.1 PREVIOUS WORK

In 2002, Groundwater Consulting Services conducted a preliminary hydrogeological evaluation which assessed the location of the springs (Neaves, Egerton and Muchea) and associated threatened ecological communities, with reference to the hydrogeological environment, and offered possible explanations for their occurrence.

A site investigation was conducted in 2004, including installation of ten shallow groundwater monitoring wells, at the Neaves Road occurrence. Regular groundwater level and quality monitoring was commenced after installation, and was reported by Groundwater Consulting Services (2007). In 2007, three deep monitoring bores (about 20m depth) were installed by Parsons Brinckerhoff Pty Ltd to assess the vertical changes in groundwater pressure/flow and quality (refer DEC document number 07/380-1 223500). The data from the installation of the deep bores, and subsequent monitoring data to December 2007, were reviewed to provide additional background for this assessment.

A site investigation, which included installation, surveying, gauging and water sampling at ten shallow monitoring bores, was conducted at the Bingham Road Threatened Ecological Community, which adjoins the Gaston Road Threatened Ecological Community (Groundwater Consulting Service, 2008). No subsequent groundwater monitoring has been conducted. The detailed on-site information provides valuable local confirmation of the regional hydrogeological model.

1.2 PERCEIVED THREATS

The assessment of the hydrogeology of the springs at Gaston Road is based on the need for useable advice on the risk that the proposed highway may pose to the springs. Only groundwater-related threats are considered, and these comprise (for the purposes of this investigation):

- Changes in water level or spring flow (up or down) due to any changes in the water table elevation;

- Changes in the water quality, due to introduction of contaminants from the road.

As the road is likely to comprise a relatively shallow constructed pavement, it is unlikely to influence groundwater levels. Groundwater level impacts are not considered further.

Contaminants may comprise either spilt products being carried by road (from a catastrophic event such as a truck roll-over or crash) or incremental movement of materials such as residual fuel, oil, grease and metals from vehicle movement, which may be washed into the soil by rainfall and runoff. The ability of any such contaminants to enter and migrate with the groundwater clearly controls the level of risk.

It is important to understand that this study assesses the potential pathways for contaminants to migrate from a proposed alignment to the springs, but does not quantify the risk, and therefore does not recommend a particular alignment or safe buffer distance.

2. SCOPE OF WORK

The following scope of work was conducted.

- Review records of hydrogeological investigations at Neaves road and Bingham road springs, including records of deeper drilling at Neaves Road and water quality records that had not previously been reviewed.

- Receive any information from the DEC on the Gaston road spring, including description of the property and contact details for site access.

- Receive confirmation of proposed (and any alternative) alignments for the highway in the region of the Gaston road occurrence.

- Inspect the site and comment on local landuses, topography and surface drainage, groundwater use and any other pertinent observations.

- Assess the likely groundwater capture zone, based on field observations and review of hydrogeological investigations at other nearby sites.

- Provide a brief report outlining the findings, and providing advice on the land area that is likely to be contributing to groundwater discharge from the spring, including relevant figures and cross-sections.

3. SETTING

The site is located on the central/eastern part of the Swan Coastal Plain, approximately 50km north of Perth, and 4km north-west of Bullsbrook *(Figure 1, Appendix A).* Historical monthly average rainfall recorded for the RAAF base at Pearce Airport (located 3km south-east of the site) are provided in *Table 3.1.*

Table 3.1 Rainfall

Station	**Regional Rainfall Historical Averages (mm)**												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
RAAF Pearce (10568)	8.2	12.7	15.0	35.7	88.1	138.7	136.3	107.0	69.5	37.4	23.0	9.2	695.0

Data from Bureau of Meteorology http://www.bom.gov.au/climate/averages/tables downloaded on 8 May 2008

Soils to the west of the springs are pale grey quartz sand with high infiltration capacity and characterised by a lack of surface drainages. Soils beneath the low-lying land to the east comprise silt and clay of the Guildford Formation, with a thin cover of Bassendean Sand *(Figure 3, Appendix A).* Lithological records are only available for some of the recorded bores in the region, however the data support the existence of a sand aquifer to the west, which interfingers with clayey sediments to the east. The nearest detailed lithological log is for bore GN24, located on Bingham road, about 500m west of the site, which shows about 36m of sand from the surface.

Groundwater discharges from most of the vegetated area, both diffused and in some discrete locations. The discharged groundwater then flows overland and merges to form a single stream which flows easterly to the Ellen Brook and subsequently the Swan River. The spring area comprises a melaleuca over-storey with and understorey comprising reeds, sedges and grass. Cattle are free to graze in the spring area, however there is little evidence of damage. The remainder of the property is mostly cleared, and is used to graze cattle and other stock.

The following description of typical vegetation assemblages was taken from English (1999).

> Typical and common native vascular plant species associated with the tumulus springs are the trees *Banksia littoralis*, *Melaleuca preissiana* and *Eucalyptus rudis*, and the shrubs *Agonis linearifolia*, *Pteridium esculentum*, *Astartea fascicularis* and *Cyclosorus interruptus*. The following non-vascular plants have also been located on peat mounds associated with the community: *Lycopodium serpentium* (bog clubmoss), *Riccardia aequicellularis*, *Jungermannia inundata*, *Goebelobryum unguiculatum* and *Hyalolepidozia longiscypha*.

Several shallow soaks were excavated on the property, and they intersect the groundwater table near to the surface. A peat layer is exposed in the excavation, immediately below the natural surface.

3.1 GROUNDWATER USE

Local groundwater is used by many landholders for stock and domestic irrigation purposes. Larger scale irrigation of strawberries, vegetables and turf occurs in the region. Details of local groundwater use are provided in Groundwater Consulting Services (2008).

Most local properties are expected to have a shallow bore for domestic garden irrigation purposes, and annual abstraction of about 1,500kL is typically assigned to such bores.

3.2 SITE INSPECTION - SPRING MORPHOLOGY

The spring was inspected on 28 May with the land-owner, as well as an ecologist (Mia Podesta) and hydrogeologist (Ryan Vogwill) from the Department of Environment and Conservation.

The spring area covers approximately four hectares, and the surrounding remnant vegetation covers a total of about ten hectares (including the spring area). An elevated sand dune lies to the west and north of the site, and the ground surface falls easterly towards the springs. The area of the springs and surrounds is relatively flat, with a gentle fall to the east.

The spring area was mostly waterlogged, and peaty underfoot. A peat layer of over 0.3m was observed in an excavated soak nearby, and probing of the ground indicated peat to about 1m thickness. The soils surrounding the spring area were all sandy.

Several discrete springs (or zones of locally enhanced groundwater discharge) were observed indirectly. Discharged groundwater either lay on the surface in stagnant ponds, or drained easterly and formed a single stream that flows to the Ellen Brook. The vegetation is likely to be dependent on groundwater, and is clearly tolerant of seasonal to continuous waterlogging. The presence of saturated peat and standing surface water thoughout the spring area indicates that groundwater is discharging (albeit slowly) through the peat.

A soak, excavated through a peat layer and into the underlying saturated sand, was observed to be full, and water was slowly discharging and infiltrating into the unsaturated sand which overlies the peat.

Anecdotal information from the land-owner indicates that the spring area is saturated all year round, although the flow rate in the stream varies.

Animal and crop production on the adjacent agricultural land upgradient of the springs poses a threat from any inappropriate nutrient or pesticide/herbicide use. The land more distant in the upgradient direction comprises uncleared native vegetation and poses no threat to the groundwater quality.

Selected photographs of the springs and surrounds are provided in *Appendix B*.

3.3 HYDROGEOLOGY

A description of the hydrogeology at Neaves Nature Reserve and Bingham Road Threatened Ecological Community was provided in Groundwater Consulting Services (2002, 2007 and 2008), and a modified summary for the Gaston Road site is provided below.

The superficial aquifer locally comprises about 40m of saturated sand, which interfingers with increasingly clayey units to the east. The gradational change from sand of the Bassendean Sand and the Gnangara Sand to the west, to sand with silt and clay of the Guildford Formation to the east, occurs at about the locations of the springs *(Figure 3, Appendix A).*

Groundwater flows from the Gnangara Mound, which lies to the west and north-west, towards the east-south-east through the area *(Figure 3, Appendix A).* Depths to groundwater recorded in bores range from nil (water level at surface) to about 5m beneath the larger sand dunes. Groundwater levels vary seasonally by about 1m, and were nearest the lowest recorded (43 years of records) in superficial aquifer bore GN24, located on Bingham Road in autumn 2008 (refer Groundwater Consulting Services, 2008, for the hydrograph). The reduced groundwater levels since the mid 1980s reflect regional and/or local groundwater use and reduced rainfall.

Groundwater is very fresh, with salinities between 100 and 500mg/L total dissolved solids being common (50 to 290mg/L TDS at Bingham Road). Groundwater salinity up to or exceeding 1,000mg/L TDS can occur in the region, where evaporation from the shallow water table concentrates the dissolved salt. The groundwater pH at Bingham Road was recorded between 4.1 and 5.9.

The superficial aquifer is underlain by the Poison Hill Greensand, which is part of the Mirrabooka Aquifer. The upper aquifers are hydraulically isolated from the deeper Leederville Aquifer by the Kardinya Shale member of the Osborne Formation, a shale unit which effectively prevents groundwater flow.

The vulnerability of groundwater to contamination was mapped by Appleyard (1993). Appleyard ranked groundwater vulnerability to landuse impact by considering the depth to groundwater and the soil type. Sandy soils and shallow depths to water resulted in a higher degree of vulnerability being assigned. Appleyard ranks the areas of the springs “Very High Vulnerability”. The catchment areas (west of the springs) are ranked “High Vulnerability”, as they have a greater depth to groundwater.

Figure 3 (Appendix A) shows the location of the springs with respect to a regional hydrogeological dataset (including geology, aquifer thickness, groundwater level, and groundwater use).

4. GROUNDWATER INVESTIGATIONS

No on-site groundwater data were collected in relation to the Gaston Road site. The adjacent Bingham Road springs were investigated by installing ten shallow monitoring bores, and local groundwater flow directions, discharge patterns and water quality were observed.

By considering the results of the Bingham Road site investigation with reference to site observations at Gaston Road, a reasonable understanding of the likely hydrogeology was developed.

4.1 REVIEW OF NEAVES MONITORING DATA

Groundwater Consulting Services and others have installed and monitored groundwater levels and quality at the Neaves Nature Reserve (located approximately 2.5km to the south-west). Recently obtained data were reviewed as part of this project, and charts are provided in *Appendix C*, along with logs of the deeper bores and a site plan. Groundwater Consulting Services (2007) contains the logs of the shallow bores.

The data review shows the following pertinent points:

- The nested bores near the springs (NNR3D, I, S) show an upward hydraulic head which clearly supports the shallow groundwater level, and is likely to be responsible for maintaining groundwater pressures. Excessive pumping from the deeper superficial aquifer could reduce spring flows. The bore logs show the presence of clayey materials in NNR9D located further west, where there is less vertical hydraulic gradient. It would be expected that NNR3, with no recorded clay layers, would have a smaller vertical head gradient.
- Lower pH in bores located to the west, and no temporal trend in pH.
- Similar electrical conductivity across the site, and no overall trend.

The recent data support discharge of shallow groundwater from the springs, however it is also clear that the groundwater pressure in the deeper part of the aquifer plays a part in maintaining groundwater levels at the water table.

5. RESULTS

5.1 SPRING DEVELOPMENT AND DISCHARGE MECHANISM

The springs are inferred to result from the east-south-easterly flow of groundwater in the unconfined superficial aquifer. The downgradient flow is impeded by the eastward reduction in aquifer transmissivity, and the water table is exposed at the surface. The area of discharge likely caused erosion of the land surface (draining towards Ellen Brook), and the wetland vegetation thus supported has resulted in stabilisation of the land surface, and accumulation of decomposed vegetation as peat.

As the peat is forming at or below the groundwater level, it locally confines the shallow aquifer. Discharge of groundwater through the peat occurs both through discrete permeable zones, likely from decomposed tree roots and *en masse*, via smaller discontinuities or sandy zones.

5.2 GROUNDWATER QUALITY

The groundwater at the Bingham Road springs is fresh and acidic, and contains elevated nutrients. The implications for the highway alignment are:

- The groundwater has a greater capacity to mobilise and transport heavy metals (such as may be expected from road dust contamination) than neutral or alkaline groundwaters.
- The groundwater is sensitive to landuse impact and the pathway from surface application of fertilisers to the groundwater has been demonstrated locally.

5.3 CATCHMENT

The groundwater table has been mapped on a regional scale and nearby (but not at the site). The local and regional trends are consistent, and show a groundwater flow direction to the east-south-east. Local groundwater flows are likely to be diverted towards the discrete springs.

The unconfined nature of the aquifer upgradient of the springs means that the groundwater is vulnerable to surface contamination sources.

The notional groundwater catchment for the springs is shown in *Figure 4, Appendix A*.

5.3.1 Catchment Orientation

The upgradient direction has been assessed with a reasonable level of confidence. The groundwater flow direction is not considered likely to vary significantly on a seasonal basis. The local abstraction of groundwater from the superficial aquifer is not considered likely to induce any modification of groundwater flow patterns, however this is dependent on the pumping bore depth and pumping cycles. If pumping at the nursery or other groundwater users to the south did affect groundwater flow directions, it would tend to induce a greater southerly component, and would thus re-orient the catchment area for the springs. This phenomena is not considered to be significant and is ignored for the purposes of this study.

5.3.2 Catchment Width

The springs are about 300m wide, measured perpendicular the the inferred groundwater flow direction. Small-scale groundwater flow dynamics can lead to particle flows that are not aligned with the regional flow-field, and this would result in mixing of a body of water along the flow path, and thus a capture zone is likely to widen with distance from the spring. Some focussing of the groundwater flow towards the springs is likely to occur on a local scale (within 100m of the springs) but this is not likely to affect the overall catchment, as it has been considered in the estimation of the width of the springs.

5.3.3 Catchment Length

The groundwater flow path to the springs could be tracked back to the crest of the Gnangara Mound, is about 5km west of the springs. Any potential contaminants introduced into the groundwater will tend to reduce in concentration with distance downgradient along the flowpath, due to degradation and dispersion processes. The threat of a contaminant is therefore less for locations at a greater distance from the springs.

5.4 IMPLICATIONS ON PROPOSED ALIGNMENT

5.4.1 Upgradient Alignments

Any road alignment to the west of the springs has the potential to introduce contaminants to the local groundwater, through either catastrophic spills or movement of particulate contaminants and oil/grease from the road surface to the groundwater after rainfall. A large spill is the most likely threat to the springs. Increased separation between the springs and the road alignment would allow for not only natural degradation of any contaminants, but also greater time for recovery or remediation of contaminants before impacted groundwater could reach the springs.

An approximate catchment area is identified in *Figure 4 (Appendix A)* and represents the area in which contaminants that are introduced to the ground surface are considered to be a threat to groundwater quality at the springs.

5.4.2 Downgradient Alignments

The potential for impact on the spring from the downgradient direction (ie for road alignments east of the springs) is significantly reduced. As the groundwater flow is easterly, movement of any contaminants in groundwater would be easterly, and away from the spring.

There is potential for the highway to act as a barrier to surface drainage, and as such movement of water away from the springs may be impeded if surface water was impounded by insufficient surface drainage capacity through the road embankment.

Highway alignments east of the spring would need to consider an appropriate buffer distance in the event of, for example, a truck running off the road in the direction of the spring.

Highway alignments downgradient (east) of the springs would be preferred for protection of the groundwater quality at the springs.

This report does not provide advice on management of the risk of groundwater contamination. There may be viable methods such as surface water drainage control that would reduce the threat posed by a highway. If such controls were appropriately implemented, it is considered that the risk of impact on the springs from alignments to the west could be managed to an acceptable level.

The proposed alignment (east of the TEC, refer *Figure 2, Appendix A*) provides for approximately 150m separation in the downgradient direction of the boundary of the TEC, and a greater distance from the zone of groundwater discharge. The separation is considered to be sufficient to protect the TEC from typical water-borne impacts of potential contaminants from the highway use, although it is clear that a catastrophic event has the potential to cause an impact. Enhanced management of surface water and potential contaminants during construction should be considered for this location.

6. CONCLUSIONS

The superficial aquifer hosts the Gnangara Mound, a region of low salinity groundwater with an elevated water table. Groundwater in the superficial aquifer flows in an easterly to south-easterly direction at the site (radially outwards from the mound).

Flow is impeded by lower permeability sediments (Guildford Formation) to the east of the Swan Coastal Plain, and the groundwater table is above ground in low-lying parts of the landscape. Such low-lying parts include the headwaters of the Ellen Brook and the subject springs.

The springs have formed where the water table is exposed at the incised land surface.

Peat has accumulated from the denser vegetation and now forms a partial confining layer. Groundwater discharges through the peat, especially where features like decomposed tree roots allow easier vertical flow.

A catchment zone approximately 300 to 500m wide (north-south) and extending 500-1000m to the west is considered to contribute most of the groundwater that discharges to the springs.

The groundwater is vulnerable to land-use impacts and is locally acidic, which would promote the movement of dissolved metals.

Surface spills or movement of contaminants in the groundwater from the catchment may result in reduced groundwater quality at the springs.

Road alignments will probably not affect groundwater levels, unless surface water movement from the site is impeded by an alignment to the east of the springs.

Road alignments downgradient (east) of the springs would be preferred for protection of the groundwater quality at the springs.

The proposed road alignment (east of the TEC) is considered to pose negligible threat to the groundwater quality at the TEC.

On behalf of Groundwater Consulting Services Pty Ltd,

Sam Burton
Director.

7. REFERENCES

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Groundwater Consulting Services 2002

“*Preliminary Hydrogeological Investigation, Northern Perth Springs, Muchea, Bullsbrook and Egerton”.* Consultants report to Department of Conservation and Land Management, Project No CALM004, December 2002.

Groundwater Consulting Services 2007

“*Shallow Groundwater Investigation and Monitoring, Northern Perth Springs, Neaves Nature Reserve”.* Consultants report to Department of Conservation and Land Management, Project No CALM008, June 2006.

Groundwater Consulting Services 2008

“*Shallow Hydrogeological Investigation, Bingham Road Threatened Ecological Community, Bullsbrook WA”.* Consultants report to Department of Environment and Conservation, Project No DEC001, June 2008.

8. LIMITATIONS

Groundwater Consulting Services Pty Ltd has prepared this report for the GHD Pty Ltd, in accordance with generally accepted consulting practice. The specific conditions of the contract and subsequent communications have had a bearing on the depth and breadth of the project and on the confidence in the findings. When client constraints, whether express or implied, have limited the scope of work, a lower than normal confidence may occur.

The confidence in the ability of a groundwater resource to support a nominated withdrawal of groundwater is subject to spatial and temporal variations in the aquifers, climate and landuse that may not be known or predictable. Conservative assumptions will have been used where-ever possible, however, estimates of bore yield or predicted impacts of pumping can be incorrect, especially where conditions on which predictions were made have been changed. Groundwater Consulting Services Pty Ltd's predictions are made on the basis that Groundwater Consulting Services Pty Ltd will be contracted to undertake regular reviews of operational data that may lead to groundwater availability or quality predictions being re-estimated.

Groundwater Consulting Services Pty Ltd does not provide advice on groundwater contaminants, crop water requirements, irrigation schedules, irrigation system design and other non-groundwater related areas. Groundwater Consulting Services Pty Ltd's advice on bore placement and operation must be considered by the proponent with reference to expert advice from other disciplines.

The project for which Groundwater Consulting Services Pty Ltd was contracted was undertaken for the client and its consulting advisers, and for review by regulatory agencies. The report should not be used by other parties without the consent of Groundwater Consulting Services Pty Ltd due to the potential for misunderstandings to occur.

9. APPENDICES

Appendix A – Figures

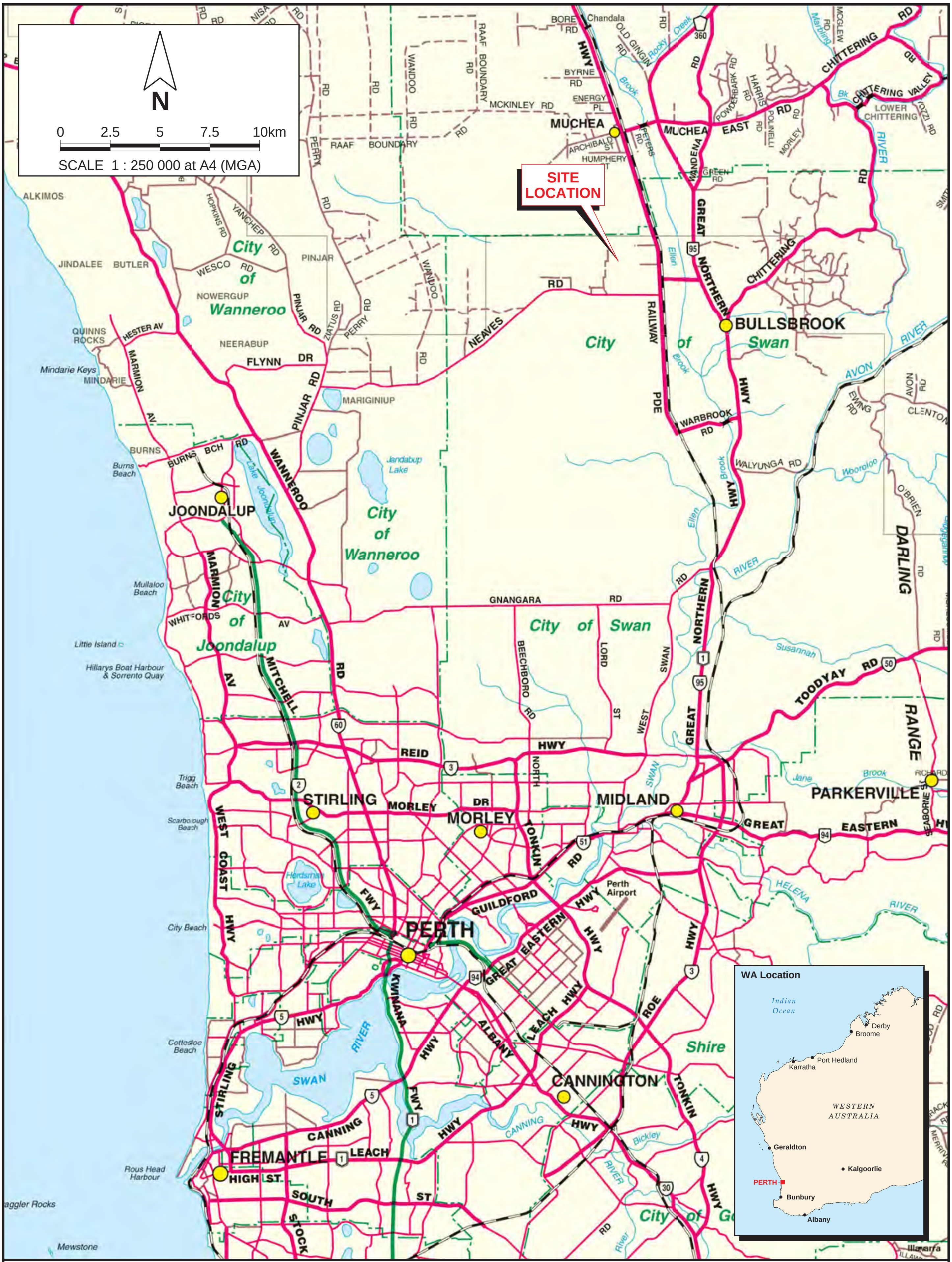
Appendix B – Plates

Appendix C – Neaves Road Data

Appendix A

Figures

Tue 20 May 08
GHD001-f01.dgn
PINPOINT CARTOGRAPHICS (08) 9277 7763



GCS Groundwater Consulting Services Pty Ltd

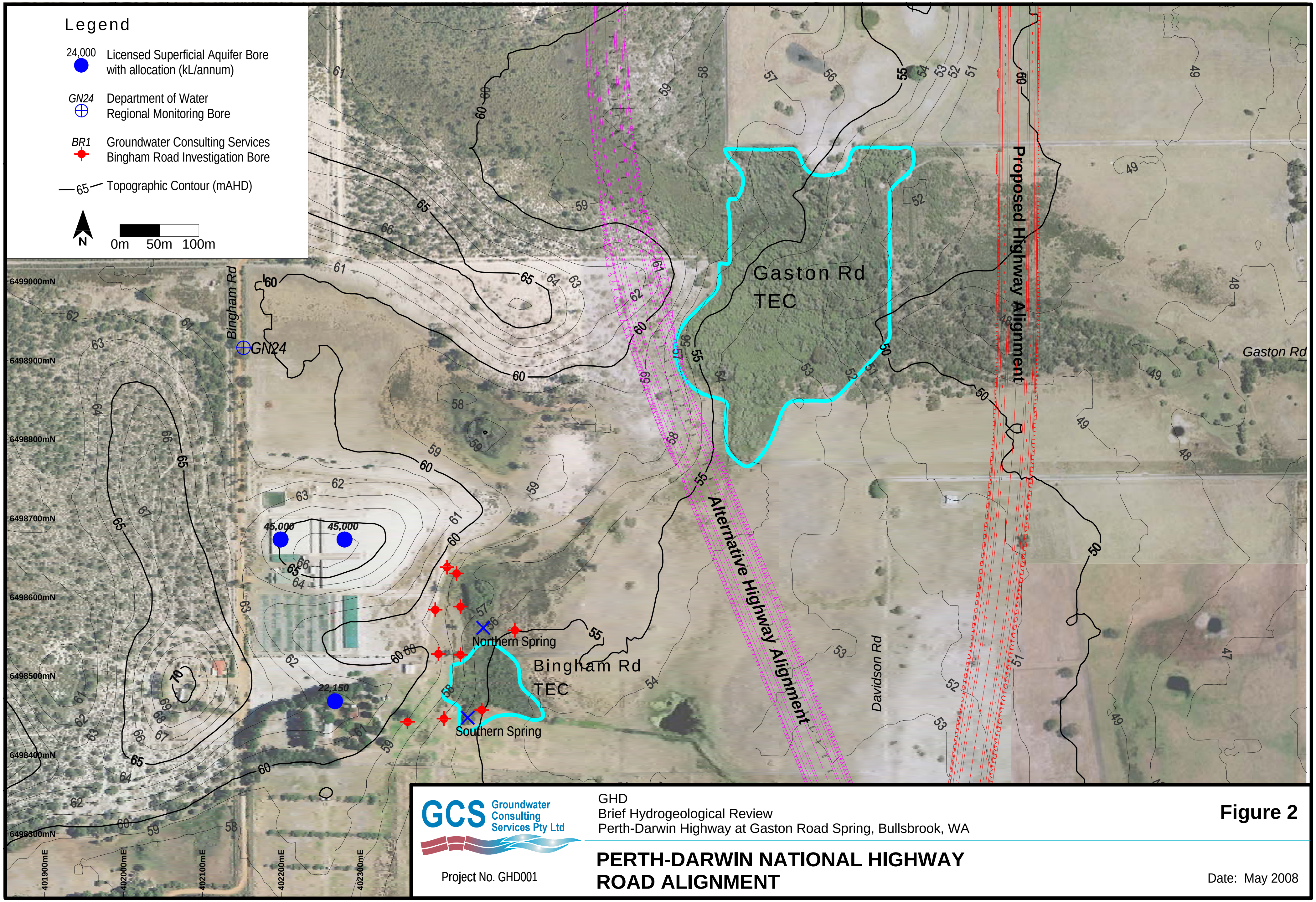
Project No. GHD001

GHD Pty Ltd
GASTON ROAD SPRINGS
HYDROGEOLOGICAL ASSESSMENT

Figure 1

SITE LOCATION

Drawn: S. Burton
Date: 20 May 2008



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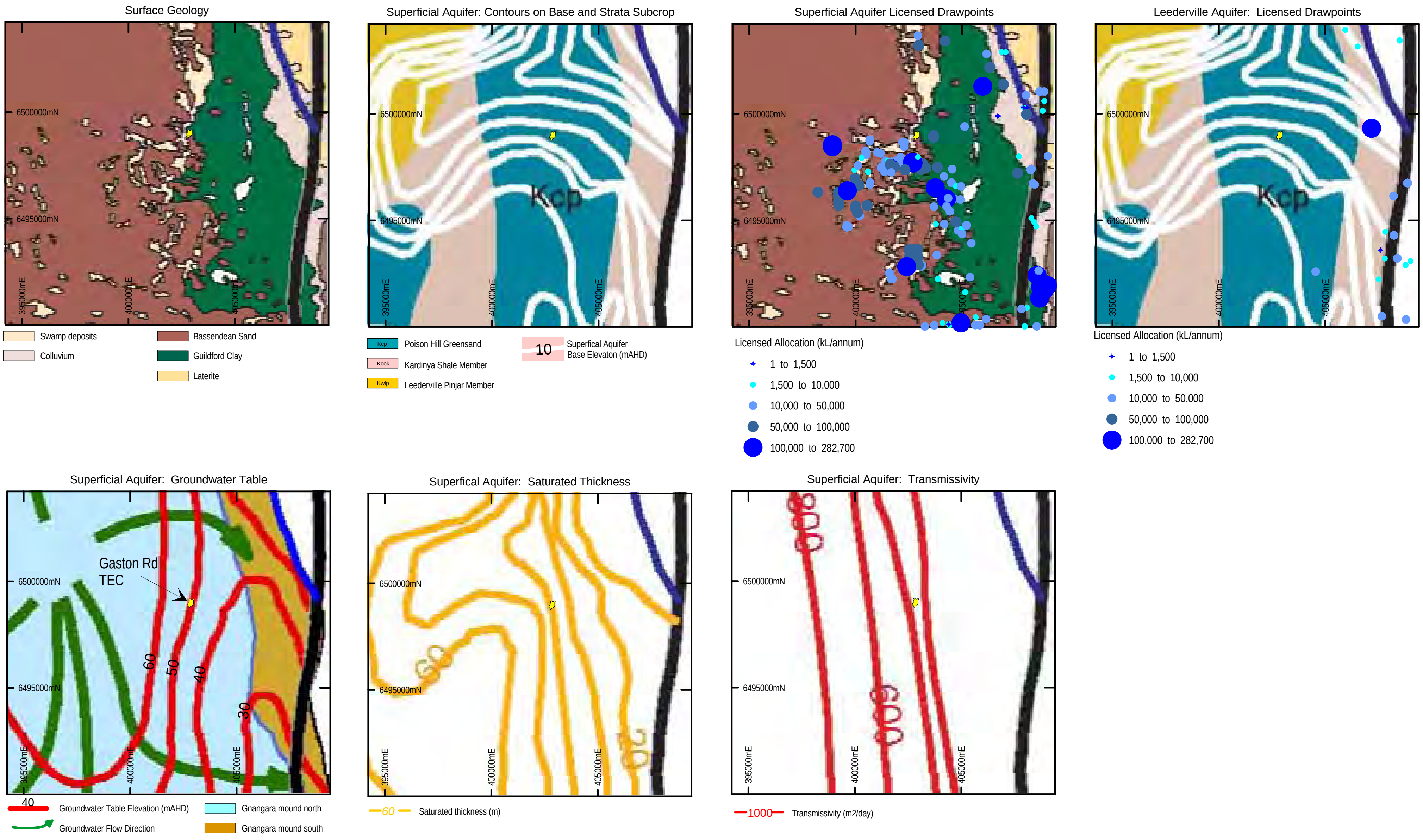
Project No. GHD001

GHD
Brief Hydrogeological Review
Perth-Darwin Highway at Gaston Road Spring, Bullsbrook, WA

Figure 2

PERTH-DARWIN NATIONAL HIGHWAY ROAD ALIGNMENT

Date: May 2008



Gaston Road
Threatened Ecological Community

Note: Hydrogeological base data (Davidson & Xu, 2006)

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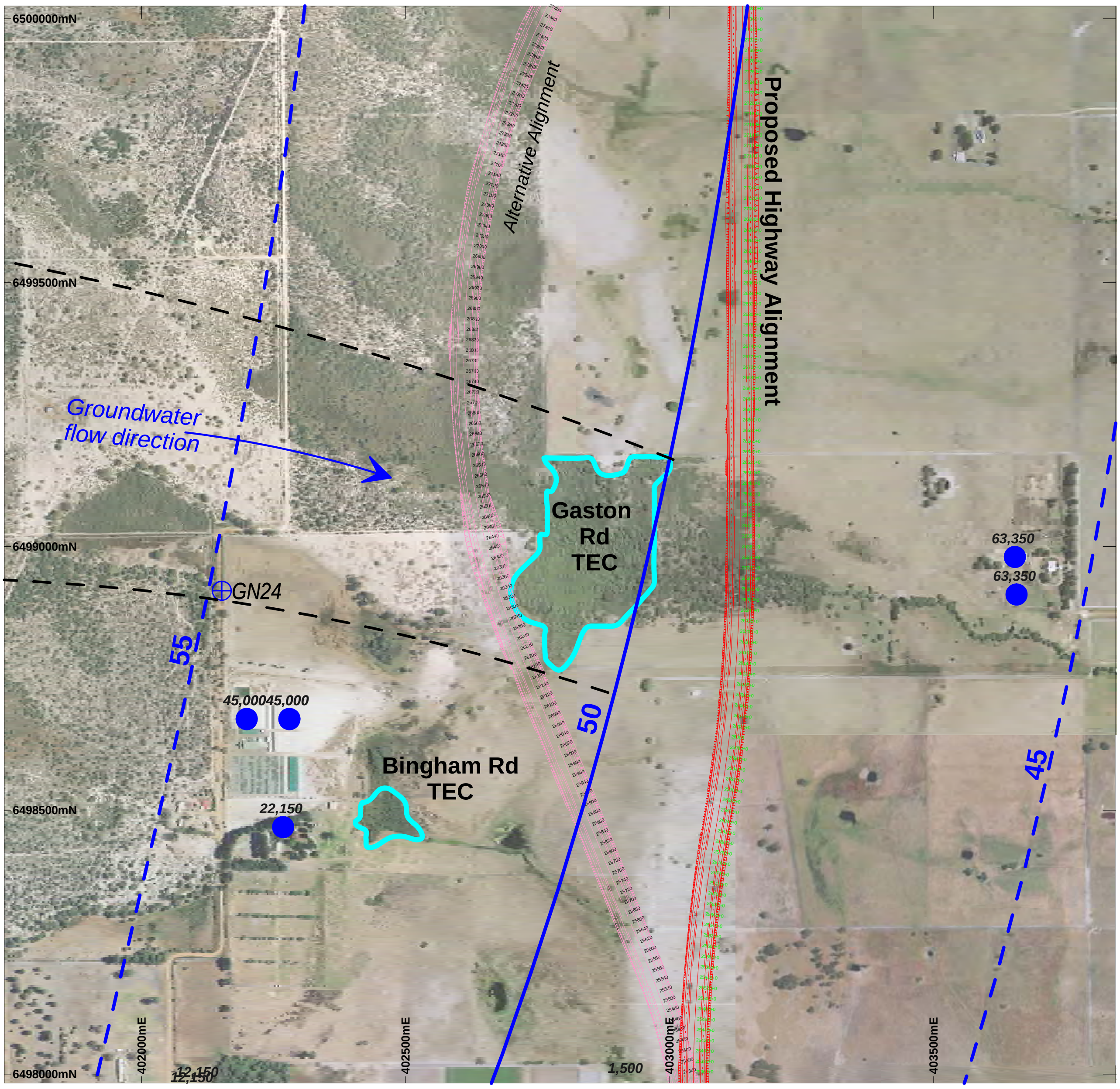
Project No. DEC001

GHD
Brief Hydrogeological Review
Perth-Darwin Highway at Gaston Road Spring, Bullsbrook, WA

Figure 3

REGIONAL HYDROGEOLOGICAL SETTING

Date: May 2008



Legend

24,000 ● Licensed Superficial Aquifer Bore with allocation (kL/annum)

GN24 ⊕ Department of Water Regional Monitoring Bore

- - - Approximate Groundwater Catchment for Gaston Rd TEC

— Groundwater Level Contour (mAHD) Superficial Aquifer

- - - (Interpolated)

N

0m 250m 500m

Note: Groundwater contours adapted from Davidson & Xu (2006).

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Project No. GHD001

GHD
Brief Hydrogeological Review
Perth-Darwin Highway at Gaston Road Spring, Bullsbrook, WA

Figure 4

CATCHMENT AREA

Date: July 2008

Appendix B

Plates

Plate 1a: Typical view of spring area.

Plate 1b: Typical view of spring area.

Plate 3:

Excavated soak showing peat layer.

Plate 4:

Excavated soak showing elevated water level.

Plate 5:

Excavated soak east of springs showing peat layer and water level below ground.

Appendix C

Neaves Road Data

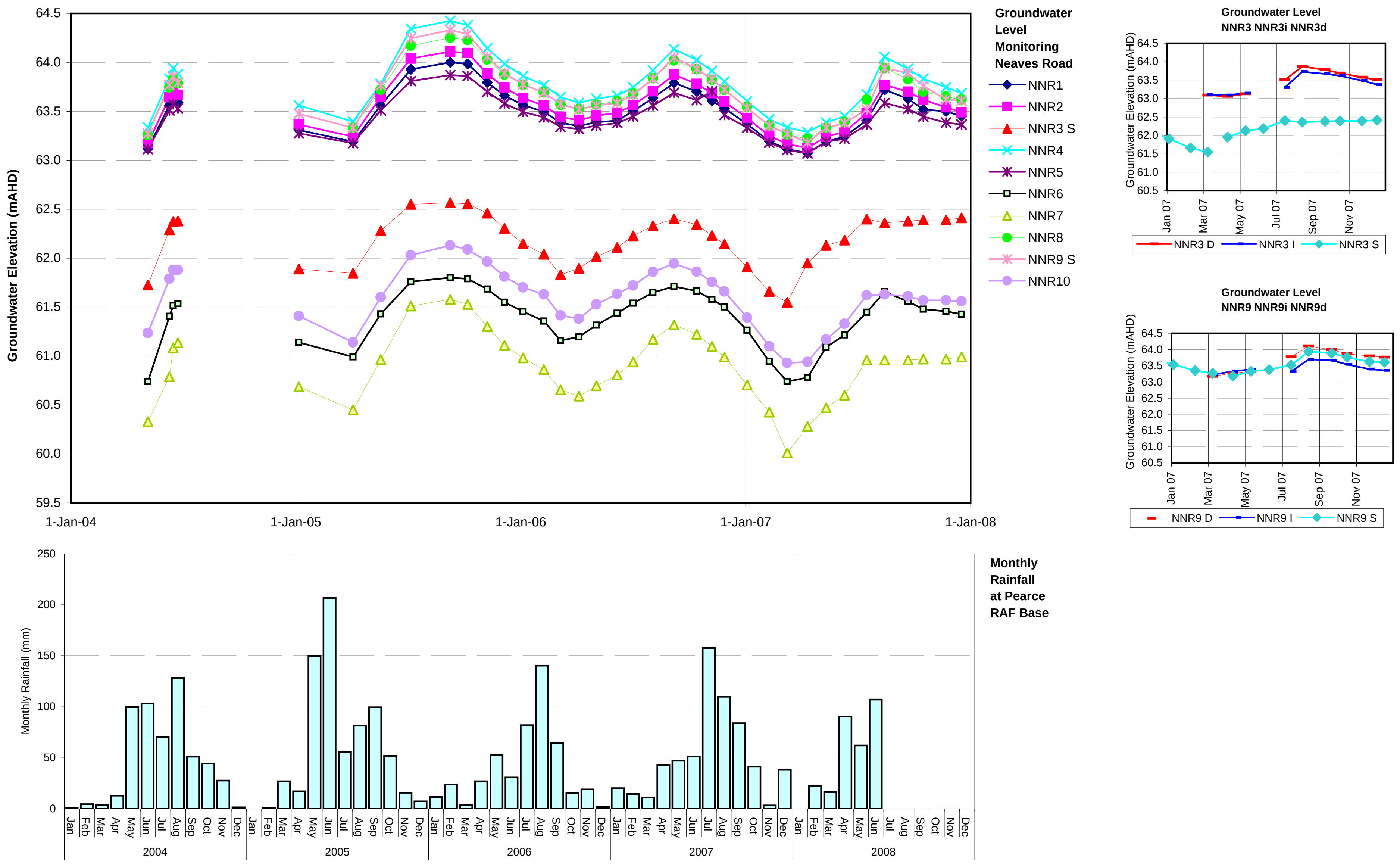

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Figure 2	***Groundwater Monitoring***
Project:	*Neaves Road, Bullsbrook*
Client:	*Department of Environment and Conservation*
Project Number:	*GHD001 July 2007*

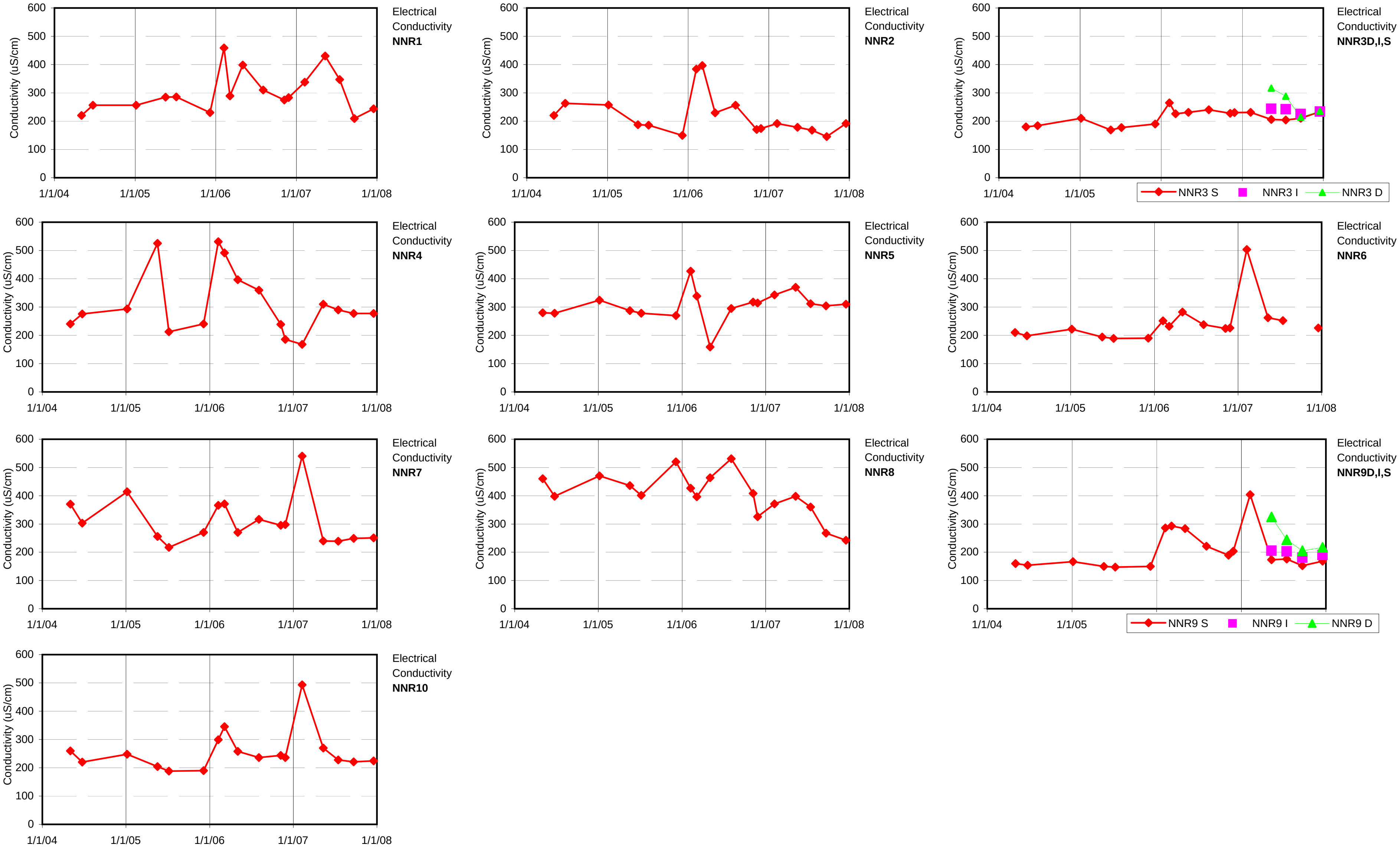

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Figure 3 ***Electrical Conductivity Monitoring***

Project: *Neaves Road, Bullsbrook*

Client: *Department of Environment and Conservation*

Project Number: *GHD001 July 2007*

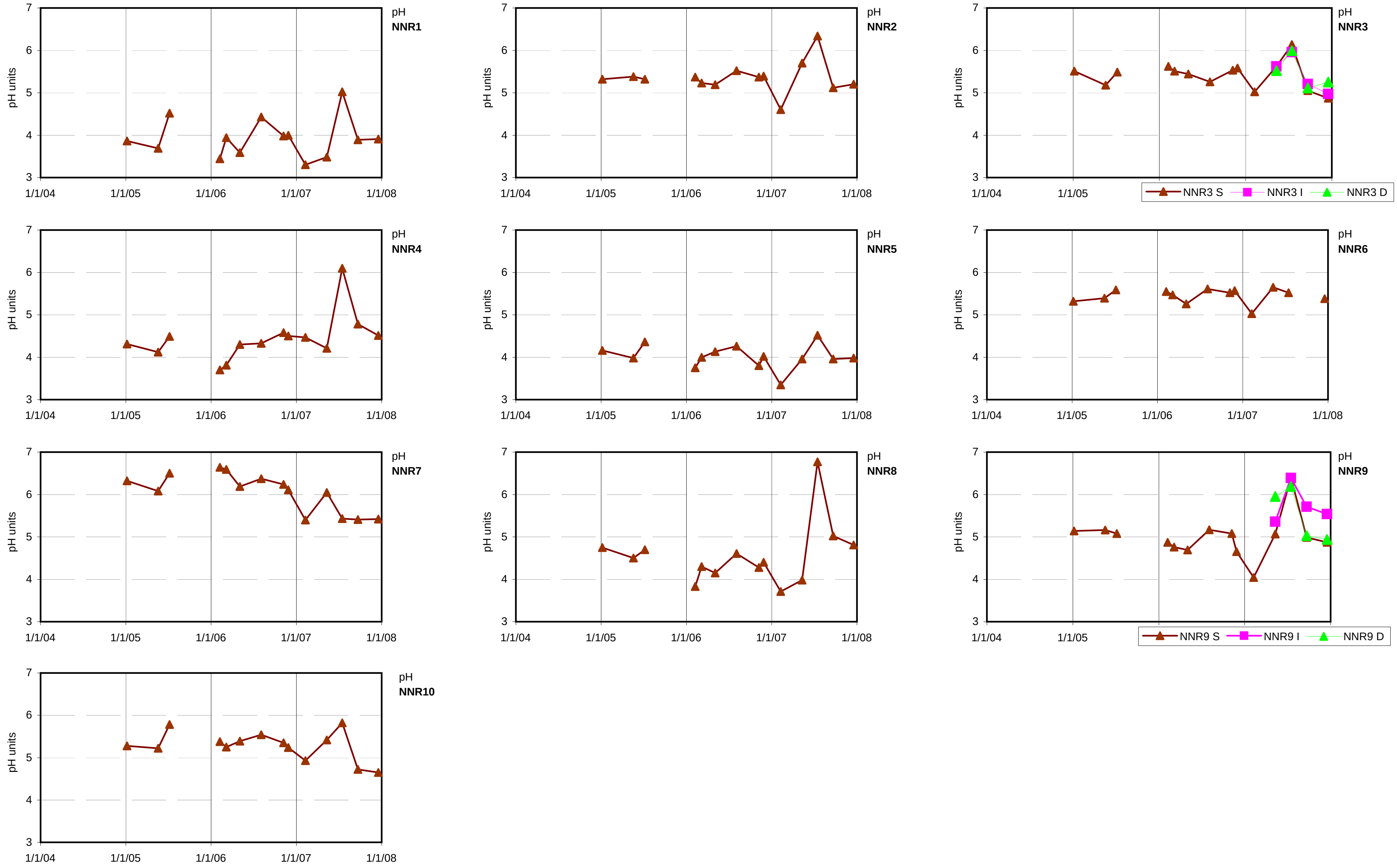

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Figure 4 ***pH Monitoring***

Project: *Neaves Road, Bullsbrook*

Client: *Department of Environment and Conservation*

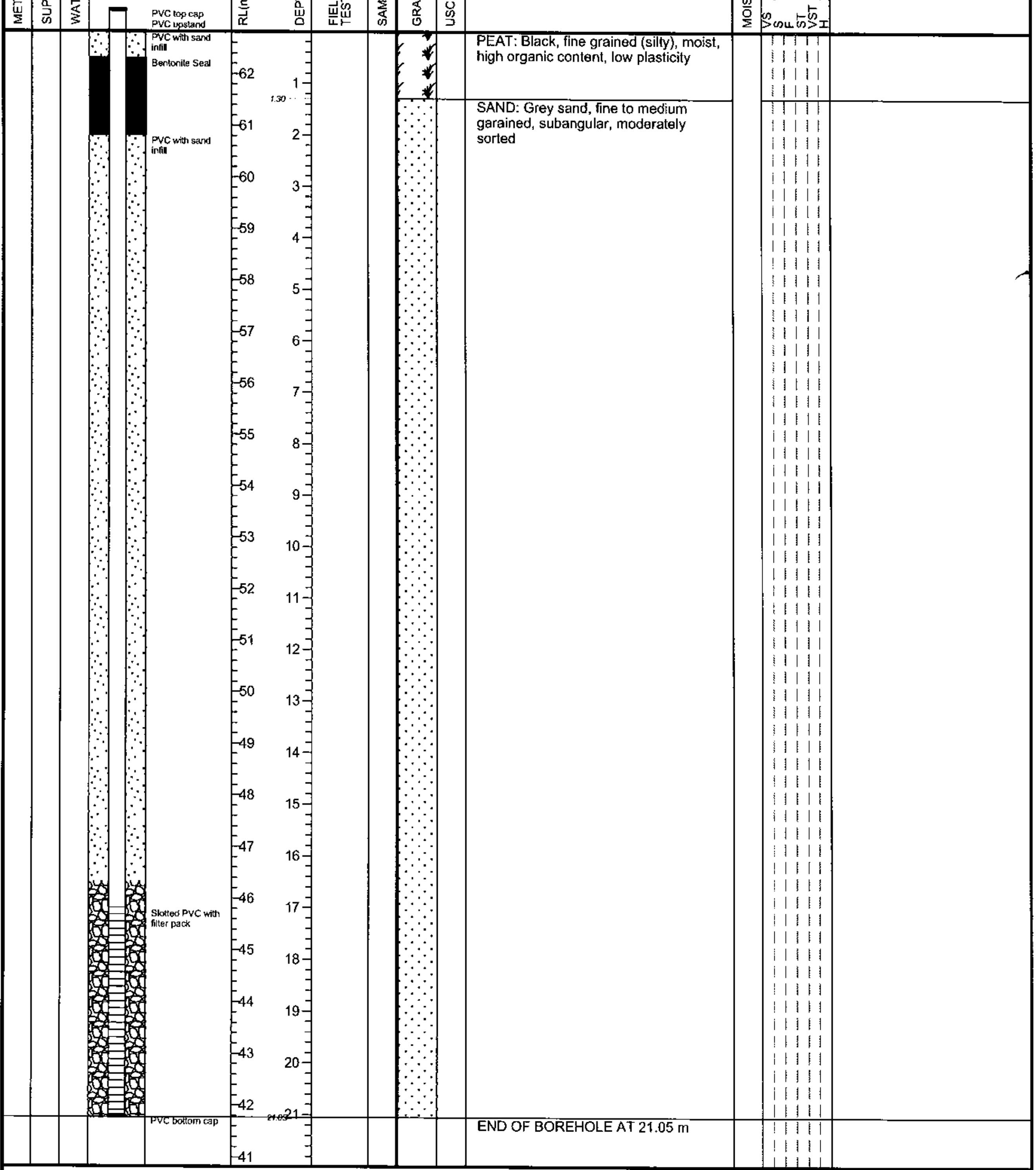
Project Number: *GHD001 July 2007*

BOREHOLE ENVIRONMENTAL LOG

BOREHOLE NO.
NNR3D
SHEET 1 OF 1

Client:	**CALM**	Date Commenced:	**29/3/07**
Project:	**Bore installation at Neaves Nature Reserve**	Date Completed:	**29/3/07**
Borehole Location:	**Bullsbrook**	Recorded By:	**JS**
Project Number:	**2146393A**	Log Checked By:	**EB**

Drill Model/Mounting:	**Hollow Stem**	Driller:	**GS Drilling**	Surface RL:	**62.82 m**
Borehole Diameter:	**150 mm**	Driller Lic No:		Co-ords:	**E 400742.34 N 6497802.31**



Borehole Information							Field Material Description					
1	2	3	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	WELL CONSTRUCTION	RL(m) DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS FB VL S L F MD ST VST D VD H	STRUCTURE AND ADDITIONAL OBSERVATIONS
			PVC with sand infill Bentonite Seal	1.30					PEAT: Black, fine grained (silty), moist, high organic content, low plasticity			
			PVC with sand infill Slotted PVC with filter pack	21.05					SAND: Grey sand, fine to medium garained, subangular, moderately sorted			
			PVC bottom cap						END OF BOREHOLE AT 21.05 m			

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENVIRONMENTAL LOG

BOREHOLE NO.
NNR3I
SHEET 1 OF 1

Client:	**CALM**	Date Commenced:	**29/3/07**
Project:	**Bore installation at Neaves Nature Reserve**	Date Completed:	**29/3/07**
Borehole Location:	**Bullsbrook**	Recorded By:	**JS**
Project Number:	**2146393A**	Log Checked By:	**EB**

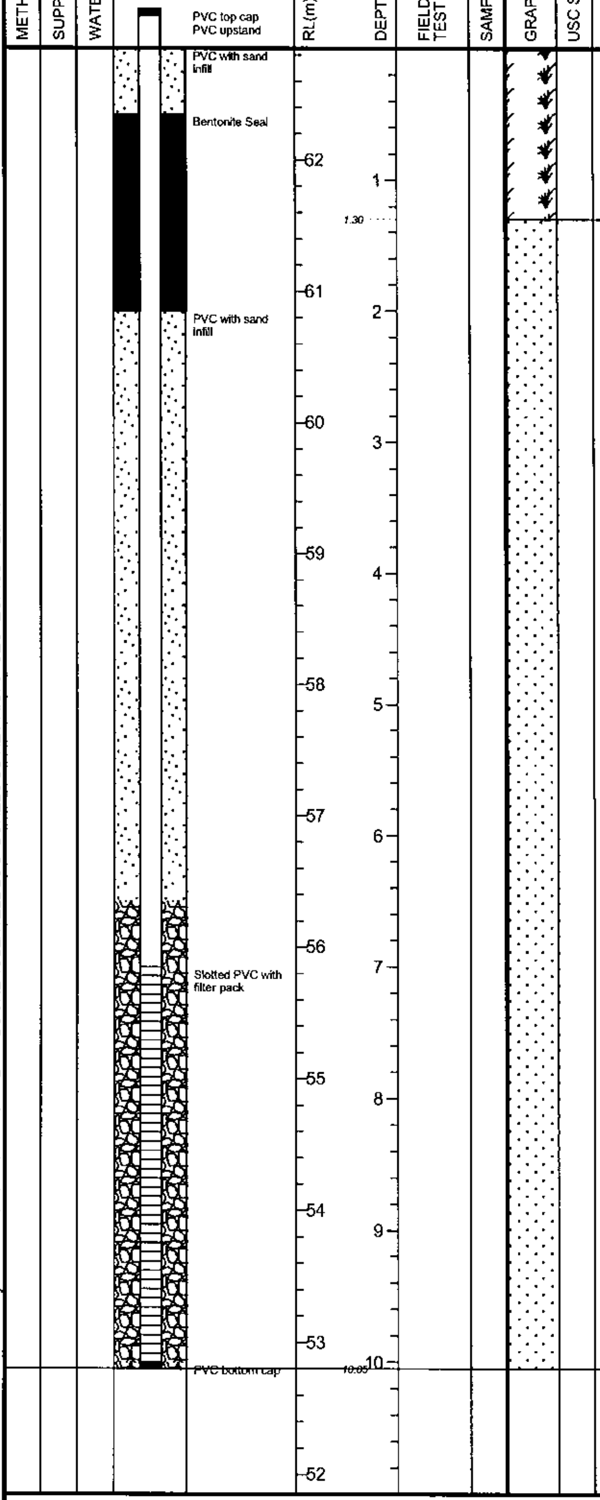
Drill Model/Mounting:	**Hollow Stem**	Driller:	**GS Drilling**	Surface RL:	**62.85 m**
Borehole Diameter:	**150 mm**	Driller Lic No:		Co-ords:	**E 400743.65 N 6497800.28**

Borehole Information

1	2	3	4	5		6	7
METHOD	SUPPORT	WATER	WELL CONSTRUCTION	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE

Field Material Description

8	9
GRAPHIC LOG	USC SYMBOL



10 SOIL/ROCK MATERIAL FIELD DESCRIPTION	11 MOISTURE	12 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H FB VL L MD D VD	13 STRUCTURE AND ADDITIONAL OBSERVATIONS
PEAT: Black, fine grained (silty), moist, high organic content, low plasticity			
SAND: Grey sand, fine to medium garained, subangular, moderately sorted			
END OF BOREHOLE AT 10.05 m			

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENVIRONMENTAL LOG

BOREHOLE NO.

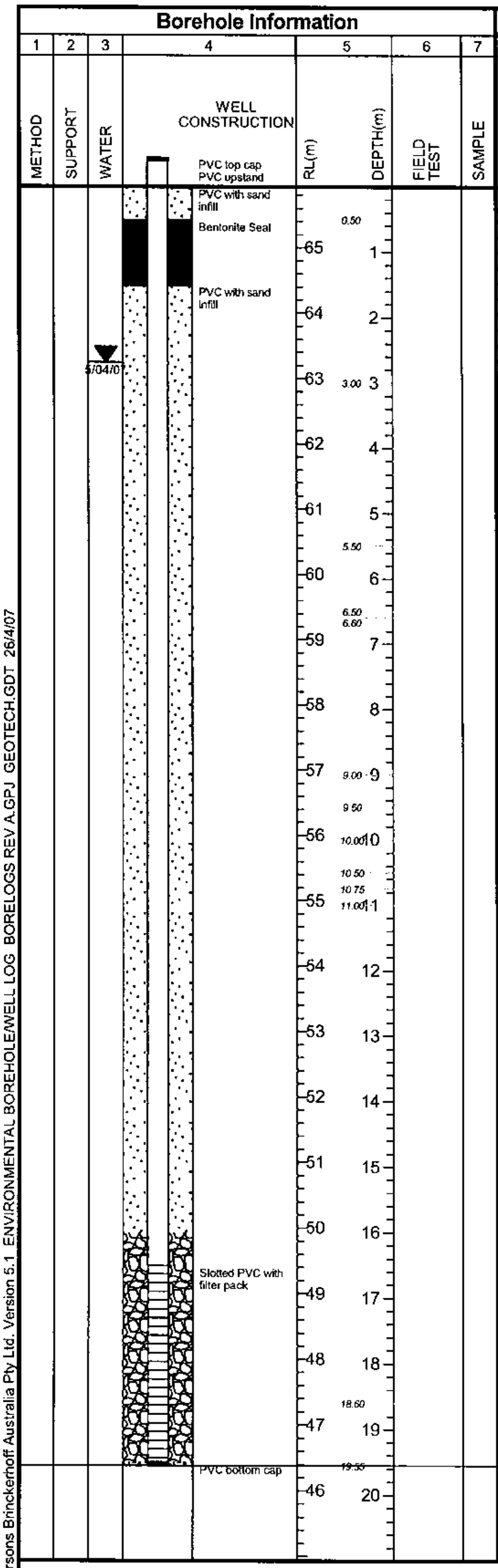
NNR9D

SHEET 1 OF 1

Client:	**CALM**	Date Commenced:	**30/3/07**
Project:	**Bore installation at Neaves Nature Reserve**	Date Completed:	**30/3/07**
Borehole Location:	**Bullsbrook**	Recorded By:	**JS**
Project Number:	**2146393A**	Log Checked By:	**EB**

Drill Model/Mounting:	**Hollow Stem**	Driller:	**GS Drilling**	Surface RL:	**65.93 m**
Borehole Diameter:	**150 mm**	Driller Lic No:		Co-ords:	**E 400615.43 N 6497801.09**

Borehole Information



Field Material Description

Depth (m)	10 SOIL/ROCK MATERIAL FIELD DESCRIPTION	11 MOISTURE	12 RELATIVE DENSITY /CONSISTENCY	13 STRUCTURE AND ADDITIONAL OBSERVATIONS
0.00–0.50	TOPSOIL: Grey/brown, silty, fine to medium grained, subangular, poorly sorted			
0.50–3.00	SAND: Light grey, fine to medium grained, subangular, poorly sorted			
3.00–5.50	SAND: Dark Brown, fine to medium grained, subrounded, moderately sorted			
5.50–6.50	As above - fine grained, well sorted			
6.50–6.60	SILTY SAND: Dark brown, silty, fine grained, non plasticity			
6.60–9.00	SAND: Dark brown, fine to medium grained, subangular, moderately sorted			
9.00–9.50	SAND: Off white, fine to medium, moderate to well sorted			
9.50–10.00	CLAYEY SAND: Off white, fine to medium grained, non plasticity, subrounded			
10.00–10.50	As above - low plasticity			
10.50–10.75	SAND: Orange/brown with white mottling, fine to medium grained, subrounded, non pllasticity			
10.75–11.00	SAND: Orange/brown, medium grained, well sorted, subrounded, wet			
11.00–18.60	SAND: Orange/dark brown, subrounded, fine to medium grained, moderately sorted, wet			
18.60–19.55	CLAYEY SAND: Offwhite, fine to medium grained, moderately sorted, subangular			
19.55	END OF BOREHOLE AT 19.55 m			

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE NO.

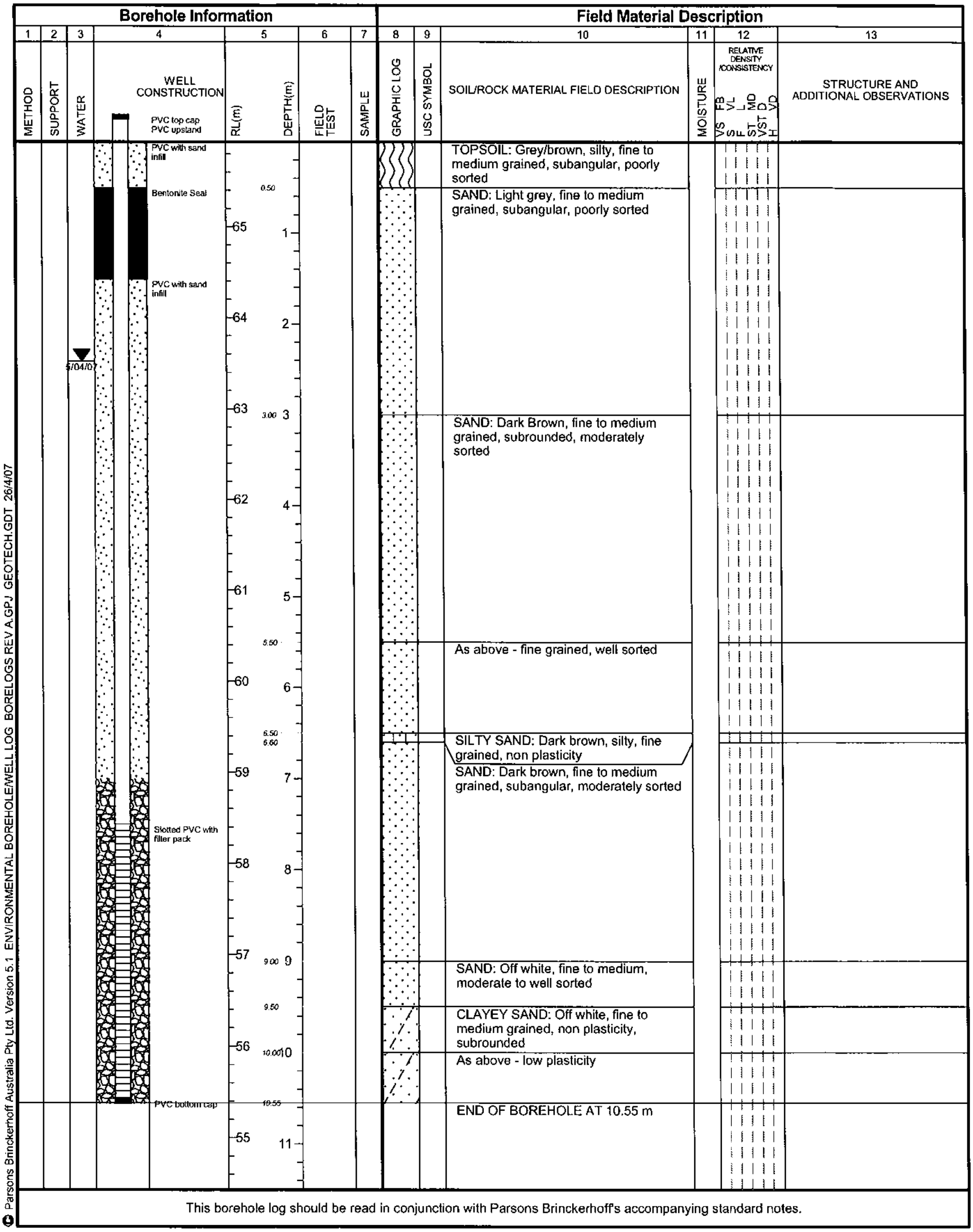
NNR9I

SHEET 1 OF 1

BOREHOLE ENVIRONMENTAL LOG

Client:	**CALM**	Date Commenced:	**30/3/07**
Project:	**Bore installation at Neaves Nature Reserve**	Date Completed:	**30/3/07**
Borehole Location:	**Bullsbrook**	Recorded By:	**JS**
Project Number:	**2146393A**	Log Checked By:	**EB**

Drill Model/Mounting:	**Hollow Stem**	Driller:	**GS Drilling**	Surface RL:	**65.93 m**
Borehole Diameter:	**150 mm**	Driller Lic No:		Co-ords:	**E 400616.38 N 6497801.52**



DEPTH(m)	SOIL/ROCK MATERIAL FIELD DESCRIPTION
0.00 – 0.50	TOPSOIL: Grey/brown, silty, fine to medium grained, subangular, poorly sorted
0.50 – 3.00	SAND: Light grey, fine to medium grained, subangular, poorly sorted
3.00 – 5.50	SAND: Dark Brown, fine to medium grained, subrounded, moderately sorted
5.50 – 6.50	As above - fine grained, well sorted
6.50 – 6.60	SILTY SAND: Dark brown, silty, fine grained, non plasticity
6.60 – 9.00	SAND: Dark brown, fine to medium grained, subangular, moderately sorted
9.00 – 9.50	SAND: Off white, fine to medium, moderate to well sorted
9.50 – 10.00	CLAYEY SAND: Off white, fine to medium grained, non plasticity, subrounded
10.00 – 10.55	As above - low plasticity
10.55	END OF BOREHOLE AT 10.55 m

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Parsons Brinckerhoff Australia Pty Ltd. Version 5.1 ENVIRONMENTAL BOREHOLE/WELL LOG BORELOGS REV A.GPJ GEOTECH.GDT 26/4/07

PINPOINT CARTOGRAPHICS (08) 9277 7763 CALM008-f02.dgn Thu 06 Jul 06

GCS Groundwater Consulting Services Pty Ltd

Project No. CALM008

Conservation and Land Management
NORTHERN PERTH SPRINGS

MONITORING BORES (2004)

Figure 2

Drawn: S. Burton
Date: 23 May 2006