# Wheatstone Project

## BIRDRONG AQUIFER ASSESSMENT
## Groundwater Modelling of the Birdrong Aquifer (Four Options)



| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 0 | 30-July-2012 | Issued For Use | GOL | LCWS | DEIT |
| **REV** | **DATE** | **DESCRIPTION** | **ORIG** | **CHK** | **APPR** |

| | | | |
|---|---|---|---|
| **IP Security** | ☒ Company Confidential | **Total number of Pages (including Cover sheet):** | 22 |

| | | | |
|---|---|---|---|
| **For Contractor Documents** | **Contract No** | **Contractor Document No** | **Contractor Rev.** |
| | | **127646019-001-R** | 2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Company Document Control No.** | **Project** | **Area** | **Discipline** | **Type** | **Originator** | **Package** | **Sequence-Sht** | **Revision** |
| | WS0 | 9211 | HES | EVA | GOL | 000 | 00001-000 | 0 |

REPORT

July 2012

## BIRDRONG AQUIFER ASSESSMENT

# Groundwater Modelling of the Birdrong Aquifer (Four Options)

**Submitted to:**
Laurie Cooper
Chevron Australia Pty Ltd
216 St Georges Terrace
PERTH WA 6000

**Report Number.** 127646019-001-R-Rev2

**Distribution:**

1 Electronic Copy - Chevron Australia Pty Ltd
1 Electronic Copy - Golder Associates Pty Ltd

Golder Associates

# Table of Contents



**TABLES**



**FIGURES**

# 1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) has engaged Golder Associates Pty Ltd (Golder) to undertake an assessment of the Birdrong Aquifer as source water to the Town of Onslow (Figure 1). Specifically, Chevron asked Golder to assess potable supply options for 2 ML/day (i.e. 4 ML/day raw water supply) and for 4 ML/day (i.e. 8 ML/day raw water supply).

The objectives of the assessment are as follows:

- to provide Chevron with a clear and detailed understanding of the opportunities and constraints associated with developing the Birdrong Aquifer for the Onslow Township water supply
- to develop a simple numerical groundwater model to model the extent of depressurisation for a number of abstraction scenarios using the existing Macedon Deep Well (MDW4) and new conceptual wells
- to use the model results to facilitate discussions with the Department of Water, seeking to increase allocations within the northern Carnarvon Artesian Basin.

This report describes the work that was carried out to develop a simple 3D numerical groundwater flow model and simulate various wellfield configurations and production schedules for feed water requirements and potable supplies.

# 2.0 HYDROGEOLOGY

## 2.1 Geology

Recent surficial sediments close to the ocean (tidal flats, etc) comprise near-surface Quaternary beach and coastal dune systems (unconsolidated quartz to calcarenite), or intertidal flats and mangrove swamps (calcareous clay, silt and sand), underlain by claypan-dominant terrain clay, silt and minor sand. Away from the coast, colluvial sediments, clay, silt, sand and gravel generally overlie clay-pan deposits.

The site is located on the Onslow Terrace section of the Peedamullah Shelf. The Shelf is characterised by a sequence of gently west-dipping Tertiary to Cretaceous sediments unconformably overlying more steeply west-dipping strata of Palaeozoic through Triassic age (Carnarvon Petroleum NL, 1999). The generalised stratigraphy in the area surrounding Onslow is presented in Figure 2. The formation targeted for this assessment is the Early Cretaceous Birdrong Sandstone Formation (Birdrong). The Birdrong is underlain by the Flaccourt Formation (though the Flaccourt may be absent in places), and both the Birdrong and the Flaccourt overlie Early Cretaceous unconformities. The Mardie Greensand Member occurs stratigraphically between the Birdrong Sandstone Formation and overlying Muderong Shale. The Mardie Greensand is considered to be either an upper member of the Birdrong Sandstone (C&C Reservoirs, 2002) or a basal member of the overlying Muderong Shale (Bunt et al., 2001).

The Pre-Cretaceous geology (i.e. the sub-crop below the Cretaceous unconformities) is presented in Figure 3.

Precambrian basement outcrops approximately 70 km to the east of the site (Figures 3 and 4). Outcrops of undifferentiated Cretaceous sediments, which include the Birdrong Sandstone, have been mapped in the area immediately to the west of the Precambrian basement outcrop. The structural contour map for the top of the Birdrong Sandstone (Figure 4) indicates that at the site, the top of the Birdrong Sandstone is at an elevation of approximately 400 m below sea level (m bsl). At well MDW4, located close to the site, the Birdrong Sandstone was interpreted to have been intercepted from 368 m to approximately 375 m, giving a thickness of approximately 7 m. Brunt et al. (2001) interpreted the thickness of the Birdrong Sandstone as ranging between 4 m and 9 m.

The Birdrong Sandstone also outcrops adjacent to an E-W trending fault located to the south-west of the site (Figure 3). Upward displacement of the block to the west of the fault could have exposed the Birdrong Sandstone at the ground surface. The dip of the Birdrong Sandstone increases significantly to the west of the fault. The steeper dip of the Birdrong Formation has resulted in the top of the Birdrong Sandstone occurring at an elevation of approximately 1500 m bsl at Exmouth (Figure 4). The offshore extension of the

E-W trending fault is unknown. The fault could have also displaced the Birdrong sandstone to the west of the site.

## 2.2 Hydrogeological Setting

The Birdrong Sandstone is the most productive groundwater source within the Carnarvon Artesian Basin (CAB). It is known to host roll-front uranium mineralisation in places. The Birdrong Sandstone is primarily fine-grained and well sorted (Bunt et al., 2001). There are a number of additional artesian groundwater sources associated with geological units both above and below the Birdrong Sandstone in the CAB. Most of these units are considered to be in some degree of hydraulic connection with the Birdrong Sandstone.
The aquifers in hydraulic connection with the Birdrong Sandstone are considered to be part of the Birdrong Sandstone aquifer resource (collectively known as the Birdrong Aquifer). For this reason, and the fact that the screened interval for which we have hydraulic parameters in MDW4 is about 30 m, a thickness of 30 m was applied to the Birdrong Aquifer in this assessment. The eastern extent of the Birdrong Aquifer is thought to occur along the contact between Cretaceous outcrop and the Precambrian basement (Figure 4).
The groundwater recharge area to the Birdrong Aquifer has been assigned along the outcrop area of the Cretaceous sediments (Figure 4). Groundwater level equipotential lines for the Birdrong Aquifer decrease in a north-west direction across the site (Figure 4).

The geological units above the Birdrong Aquifer consist of interbedded claystones, siltstones, sandstones, limestones and dolomite (Figure 2) with a wide variability in permeability characteristics. The varying permeability characteristics of the interbedded geological units within the overlying layer have most likely resulted in an alternating sequence of aquifers and confining units.

# 3.0 CONCEPTUAL GROUNDWATER MODEL

The conceptual groundwater model developed for assessing the Birdrong Aquifer consists of the following elements.

- The Birdrong Aquifer was assigned a thickness of 30 m to include overlying and underlying aquifers in hydraulic connection with the Birdrong sandstone (Section 2.2).The hydraulic parameter values assigned to the Birdrong Aquifer are presented in Table 1. The hydraulic parameters assigned to the model for this layer are the same as those applied in MDW4 Supplementary H2 Level Assessment (Golder 2012).

- The sediments overlying the Birdrong Aquifer were grouped into a single hydrostratigraphic unit with a hydraulic conductivity of $1 \times 10^{-9}$ m/s. The overlying layer was assigned a relatively low hydraulic conductivity value to minimise vertical leakage to the underlying Birdrong Aquifer. The other hydraulic parameter values assigned to the overlying layer are presented in Table 1.

- The geological formations occurring below the Birdrong Sandstone were not included in the groundwater model. Setting an impermeable boundary at the base of the Birdrong Aquifer was done to prevent upward groundwater leakage into the Birdrong Aquifer during pumping. This modelling approach was considered to be conservative.

- The thickness of the overlying layer increases from south-east to north-west. The depth to the top of Birdrong Aquifer is based on the structural contours for the top of the Birdrong Sandstone (Figure 4).

- To the east of Onslow, the Birdrong Aquifer terminates along the contact with the Precambrian basement (Figure 4).

- For the purposes of this assessment it has been assumed that the offshore extent of the Birdrong Aquifer is up to 120 km to the west of the site. It has also been assumed that the Birdrong continues with the same dip and thickness to the model boundary. In reality, however, the Birdrong Aquifer could have been displaced along faults (Section 2.2). There is also a possibility that the Birdrong Aquifer thins out before reaching the assigned boundary located approximately 120 km offshore.

- Information on the permeability characteristics of the faults is poorly understood. For the purposes of this assessment, it has been assumed that the faults do not affect groundwater flow within the Birdrong Aquifer.
- Groundwater recharge to the Birdrong Aquifer occurs in the outcrop area of the Cretaceous sediments to the east of Onslow (Figure 4). An initial estimate for groundwater recharge rate of 5% of average annual rainfall ($4 \times 10^{-5}$ m/d) was applied to the model.
- No groundwater recharge was applied over the top of overlying layer.

**Table 1: Initial Hydraulic Parameter Values Assigned to Groundwater Model**

| Parameter | Birdrong Aquifer | Overlying Layer |
|---|---|---|
| Hydraulic conductivity (m/s) [(1)] | $3.0 \times 10^{-5}$ | $1 \times 10^{-9}$ |
| Specific yield | 0.35 | 0.10 |
| Specific storage (1/m) | $1 \times 10^{-5}$ | $1 \times 10^{-5}$ |
| Groundwater recharge rate (m/d) | $4 \times 10^{-5}$ [(2),(3)] | - |

Note: [(1)] The hydrogeologic layers are assumed to have isotropic hydraulic conductivity characteristics.
[(2)] Recharge is only applied over outcrop area.
[(3)] Initial recharge rate subject to adjustment during calibration.

# 4.0 NUMERICAL GROUNDWATER MODEL

## 4.1 Introduction

The 3D finite element numerical modelling software FEFLOW was used to develop the groundwater models. Initially a steady state groundwater model was developed to simulate the pre-pumping hydraulic heads within the Birdrong Aquifer and the overlying layer. The steady state groundwater model was also used to calibrate for the hydraulic parameter values assigned to the initial groundwater model. The hydraulic heads simulated from the steady state model were used as the initial heads in the predictive transient groundwater models that were used to calculate projected groundwater drawdown caused by pumping from the Birdrong Aquifer.

## 4.2 Model Structure

The model mesh used in the groundwater modelling is presented in Figure 5. The model mesh was refined in the area around the proposed pumping wells. The model consists of two layers representing the Birdrong Aquifer and the overlying layer. The Birdrong Aquifer has been assigned a constant thickness of 30 m. A model slice has been inserted through the middle of the Birdrong Aquifer (Figure 6).

The initial hydraulic parameter values assigned to the groundwater model are presented in Table 1. In FEFLOW every layer has the extents of the entire model domain. Therefore, to represent the outcrop of the Birdrong Aquifer, a hydraulic conductivity of $3 \times 10^{-5}$ m/s was assigned to the top model layer in the Birdrong Aquifer outcrop area (Figure 4). Groundwater recharge has been applied only to the Birdrong Aquifer outcrop area in Layer 1.

## 4.3 Model Boundaries

- The nodes along the offshore western boundary were assigned seepage face boundary conditions. A seepage face boundary is a special type of a hydraulic head boundary. Groundwater flows out of the model when the calculated head is above the topographic elevation of the seepage boundary node. However, groundwater inflow into the model cannot occur through seepage boundary nodes.
- Zero hydraulic head ($h = 0$ m) boundary conditions were assigned to the top of Layer 1 in the offshore region to represent the sea.
- A constant groundwater recharge rate of $4 \times 10^{-5}$ m/day (5% of mean annual rainfall) was applied over the outcrop area of the Birdrong aquifer.

- No flow conditions were assigned to the following model boundaries:
  - base of model, represented by the base of the Birdrong Aquifer
  - east of the model along the contact with the Precambrian basement
  - southern limit of the model. This boundary is very distant from the area of interest and the effects of the pumping are unlikely to propagate to this boundary
  - northern limit of the model. This boundary is very distant from the area of interest and the effects of the pumping are unlikely to propagate to this boundary.

## 4.4 Model Calibration

For the Birdrong Aquifer, the steady state model was calibrated against hydraulic heads measured in the Birdrong Sandstone (Figure 4). For the overlying layer, the simulated hydraulic heads were compared against hydraulic heads measured within the water table aquifer of the Carnarvon Basin.

In the initial calibration model run a groundwater recharge rate of approximately 5% of mean annual rainfall ($4 \times 10^{-5}$ m/day) was applied to the outcrop area of the Birdrong Aquifer. The simulated hydraulic heads for this initial model run, in the recharge area for both the Birdrong Aquifer and the overlying layer were higher than measured hydraulic heads by a factor of more than 3. Therefore, in subsequent calibration model runs the recharge rate was reduced to approximately 1% of mean annual rainfall ($1 \times 10^{-5}$ m/day).

A comparison of simulated and observed hydraulic heads with calibrated model parameters (Table 2) showed that within the site, the simulated hydraulic heads within the Birdrong Aquifer were within 10 m of the measured hydraulic heads. A similar level of calibration was obtained at the site for hydraulic heads within the overlying layer. However, in areas further to the south of the site, simulated hydraulic heads were still significantly higher than measured heads. Since the area with the lower level of calibration was outside the area of interest, the overall calibration level was considered to be acceptable.

The simulated steady state hydraulic gradient in the Birdrong Aquifer was approximately twice the measured hydraulic gradient for both the Birdrong Aquifer (Figure 6) and the overlying layer. The hydraulic gradient was not very sensitive to changes in K values applied to the Birdrong Aquifer and the overlying layer.

**Table 2: Hydraulic Parameter Values Assigned to Calibrated Groundwater Model**

| Parameter | Birdrong Aquifer | Overlying Layer |
|---|---|---|
| Hydraulic conductivity (m/s) (1) | $3.0 \times 10^{-5}$ | $1 \times 10^{-9}$ |
| Specific yield | 0.35 | 0.10 |
| Specific storage (1/m) | $1 \times 10^{-5}$ | $1 \times 10^{-5}$ |
| Groundwater recharge rate (m/d) | $1 \times 10^{-5}$ (2),(3) | - |

Note: (1) The hydrogeologic layers are assumed to have isotropic hydraulic conductivity characteristics.
(2) Recharge is only applied over outcrop area.
(3) Recharge rate reduced during calibration from initial recharge rate (Table 1).

## 4.5 Groundwater Drawdown Model Projections

### 4.5.1 Introduction

Transient groundwater models were used to calculate the projected groundwater drawdown caused by pumping simultaneously from selected wells. The locations of the existing and proposed pumping wells used in the assessment are presented in Figure 1, along with existing groundwater wells greater than 40 m deep, as recorded on Department of Water (DoW) databases.

Well MDW4 is an existing well authorised under Section 26D Licence CAW172426. The well was drilled to 401 m bgl between 16 February and 29 March 2011. The Birdrong Sandstone was intercepted at a depth of 368 m (Section 2.2).

Chevron provided two possible locations for the installation of new wells, CVX2 and CVX3, based upon access convenience (Figure 1). During preliminary modelling, however, it became apparent that the CXV3 location provided by Chevron was much too close to MDW4 and proposing to site a well there would be unlikely to receive authorisation from the regulators. Consequently, an alternative site was selected by Golder effectively at random for the purpose of simply illustrating the drawdown extents of another well in the Birdrong, but some distance away from other wells. In the groundwater model the Birdrong Sandstone upper surface elevations at the sites of wells CVX3 and CVX2 are 210 m and 440 m below ground level, respectively.

The specific yield and specific storage values assigned to the transient models are presented in Table 2. Each pumping well was simulated by assigning a well boundary condition to a node at the centre of Birdrong Aquifer.

### 4.5.2 Model Scenarios

Groundwater drawdown projections were assessed for the following pumping options:

- Option 1: Assessment of the effects of pumping from Well CVX2 only at a constant rate of 4000 $m^3$/day for periods of 5, 10 15 and 20 years.
- Option 2: Assessment of pumping from Well MDW4 only at a constant rate of 8000 $m^3$/day for a period of 20 years.
- Option 3: Assessment of pumping from Well MDW4 only at a constant rate of 4000 $m^3$/day for a period of 20 years.
- Option 4: Assessment of the effects of pumping simultaneously from Wells CVX2 and MDW4 at 4000 $m^3$/day for a period of 20 years.

### 4.5.3 Results

The drawdown projections for the different model options are as follows:

- Option 1: The simulated groundwater drawdown cone after pumping at well CVX2 only for 20 years is projected to extend to a radial distance of approximately 16 km (Figure 7).
- Option 2: After 20 years of pumping, the drawdown at pumping well MDW4 is projected to be approximately 69.6 m (Figure 8). Note that the physical ability of MDW4 to be pumped at 8000 $m^3$/day (92.6 L/second) has not been demonstrated to date.
- Option 3: After 20 years of pumping, the drawdown at pumping well MDW4 is projected to be approximately 33.2 m (Figure 9).
- Option 4: After 20 years of pumping, the drawdowns at pumping wells CVX2 and MDW4 are projected to be 37.5 m and 36.3 m respectively (Figure 10).

## 5.0 CONCLUSIONS

The key findings from the modelling are as follows:

- The original position of the CVX3 site is likely to be too close to MDW4 to obtain regulatory approval to drill a new well. Note that if such a well was installed, the cumulative drawdown would be equivalent to the Option 2 scenario where MDW4 is pumped continuously at 8000 $m^3$/day.
- The largest areal extents of drawdown impacts for the various modelled scenarios occurs in Option 2 (Figure 8). No existing operating groundwater users are affected by this worst case pumping scenario. Note that the only wells deep enough to intersect the Birdrong Aquifer are petroleum exploration wells that have been abandoned or have no current owners.

## 6.0 RECOMMENDATIONS

Golder recommends that this report be used as the basis for discussions with the Department of Water, seeking to increase allocations in the Northern Carnarvon Artesian Basin, and to attain consensus on the best means for utilising the groundwater resources in the Basin.

## 7.0 REFERENCES

Bunt, R. J. W., Powell, W. D., & Scholefield, T., 2001. The Tubridgi Gas Field Rejuvenated. APPEA Journal 2001, pp 429-447.

C&C Reservoirs, 2002. Reservoir Evaluation Report, Tubridgi Field, Carnarvon Basin, Australia. Western Australia - Lower Cretaceous & Triassic Reservoirs, Far East.

Crostella, A., Iasky, R.P., Blundell, K.A., Yasin, A.R., and Ghori, K.A.R., 2000, Petroleum Geology of the Peedamullah Shelf and Onslow Terrace, Northern Carnarvon Basin, Western Australia.

Carnarvon Petroleum NL, 1999. Final Report, Amethyst Seismic Survey, EP110.

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

Golder 2012. Macedon Deep Well. Supplementary H2 Level Assessment Report. Report prepared for BHP Billiton Petroleum by Golder Associates Pty Ltd. January 2012

# Report Signature Page

**GOLDER ASSOCIATES PTY LTD**

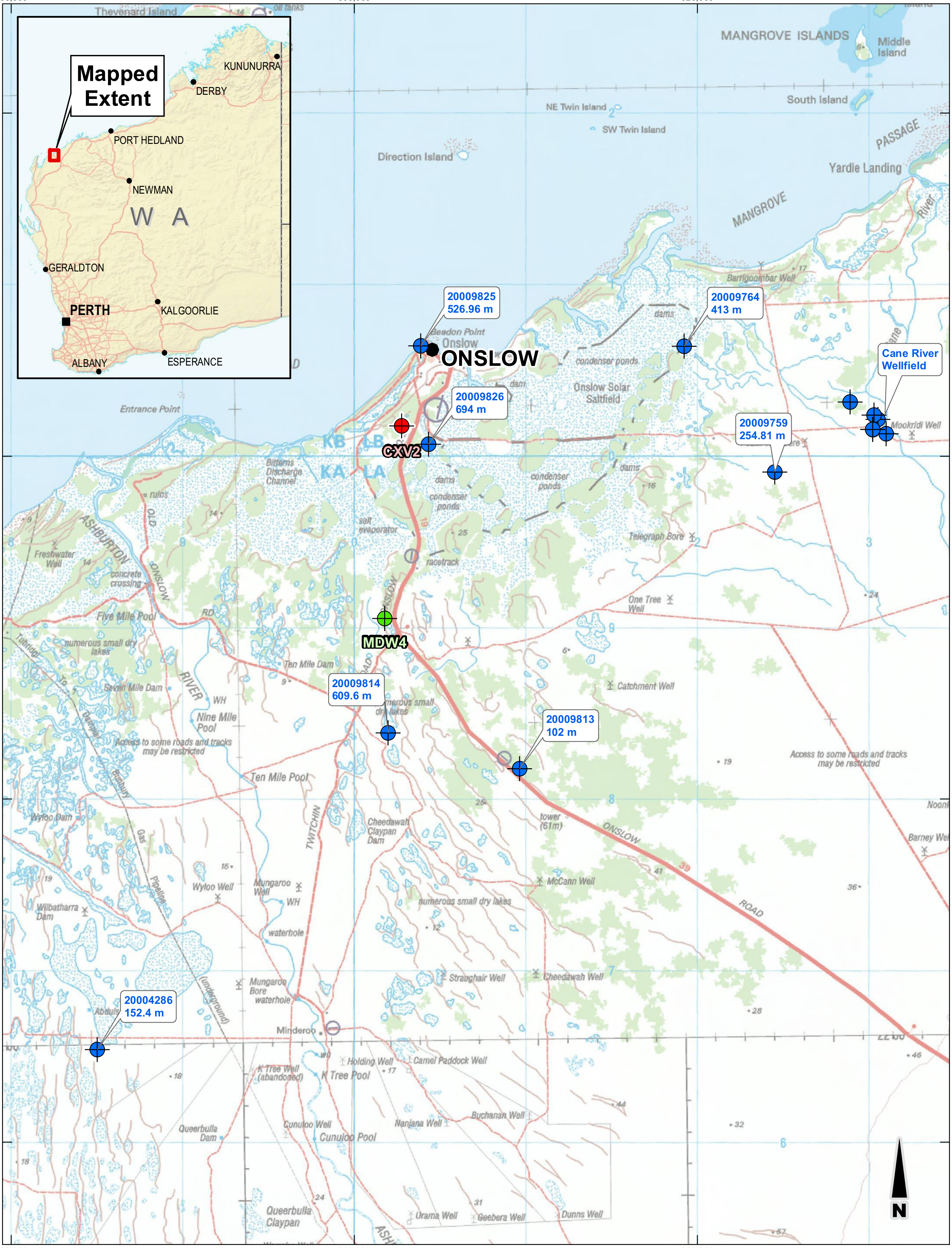
David Thomson
Principal Hydrogeologist

PM/DMT/slj

A.B.N. 64 006 107 857



j:\hydro\2012\127646019_chevron onslow water\correspondence out (including reports)\127646019-001-r-rev2.docx






Golder Associates

| | |
|---|---|
| CLIENT | Chevron Australia Pty Ltd |
| DOCUMENT | 127646019-001-R-Rev2 |
| DATE | 12 Nov 2012 |
| COMPILED | GGW |
| APPROVED | DMT |

0 3 6 9 12
km

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

COPYRIGHT
Topographical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

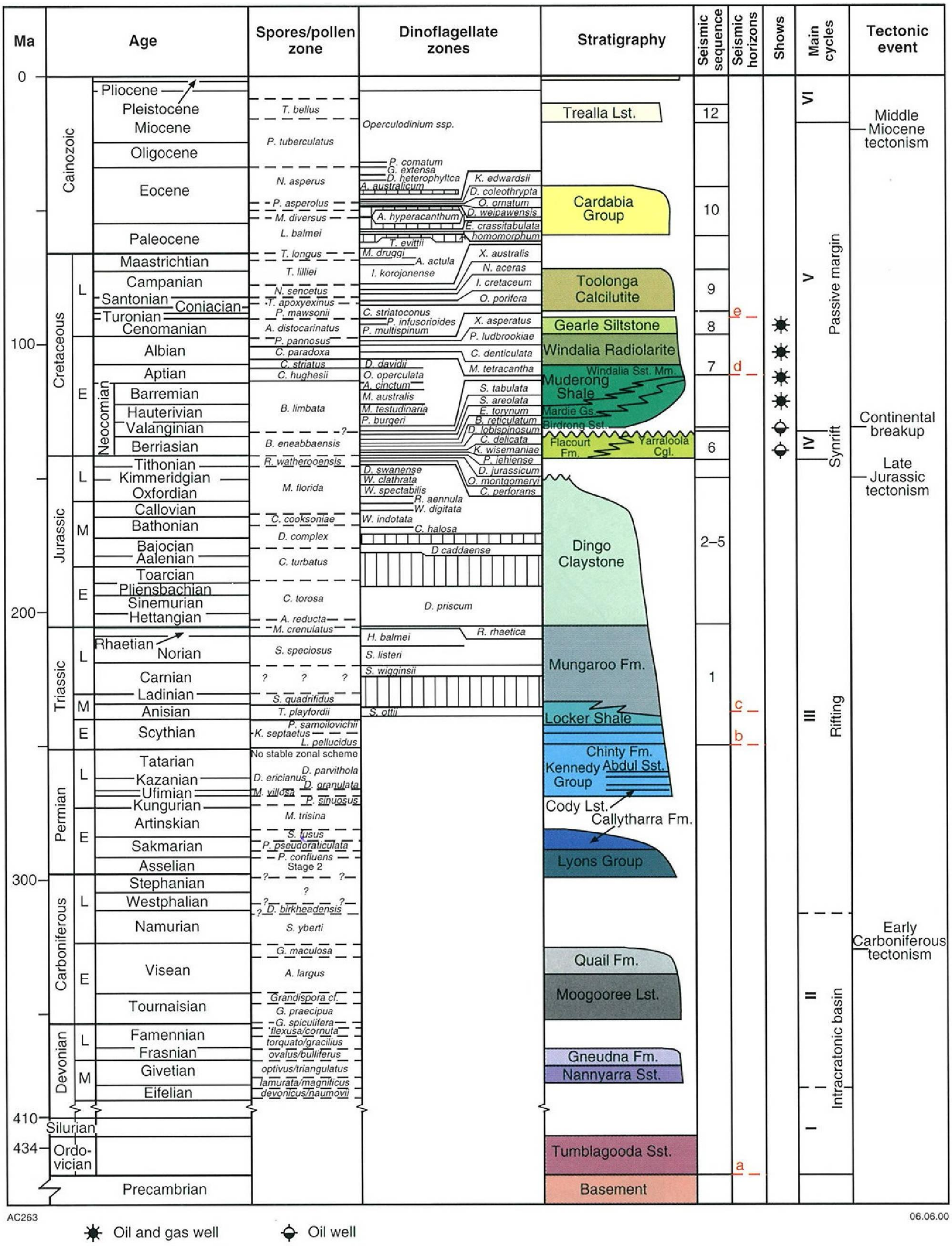
LEGEND
- Macedon Deep Well
- Proposed Well Location
- WIN Site

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**SITE LOCATION AND WELL LOCATIONS**

**FIGURE 1**

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F001-Rev2.mxd




**Stratigraphy of the Peedamullah Shelf and Onslow Terrace modified after Hocking et al. (1987). Seismic sequences are from Westphal and Aigner (1997), interpreted seismic horizons (Figs 17–21, Plates 4–8) are: a = basement, b = top Kennedy Group, c = top Locker Shale, d = top Muderong Shale, and e = top Gearle Siltstone**



Golder Associates

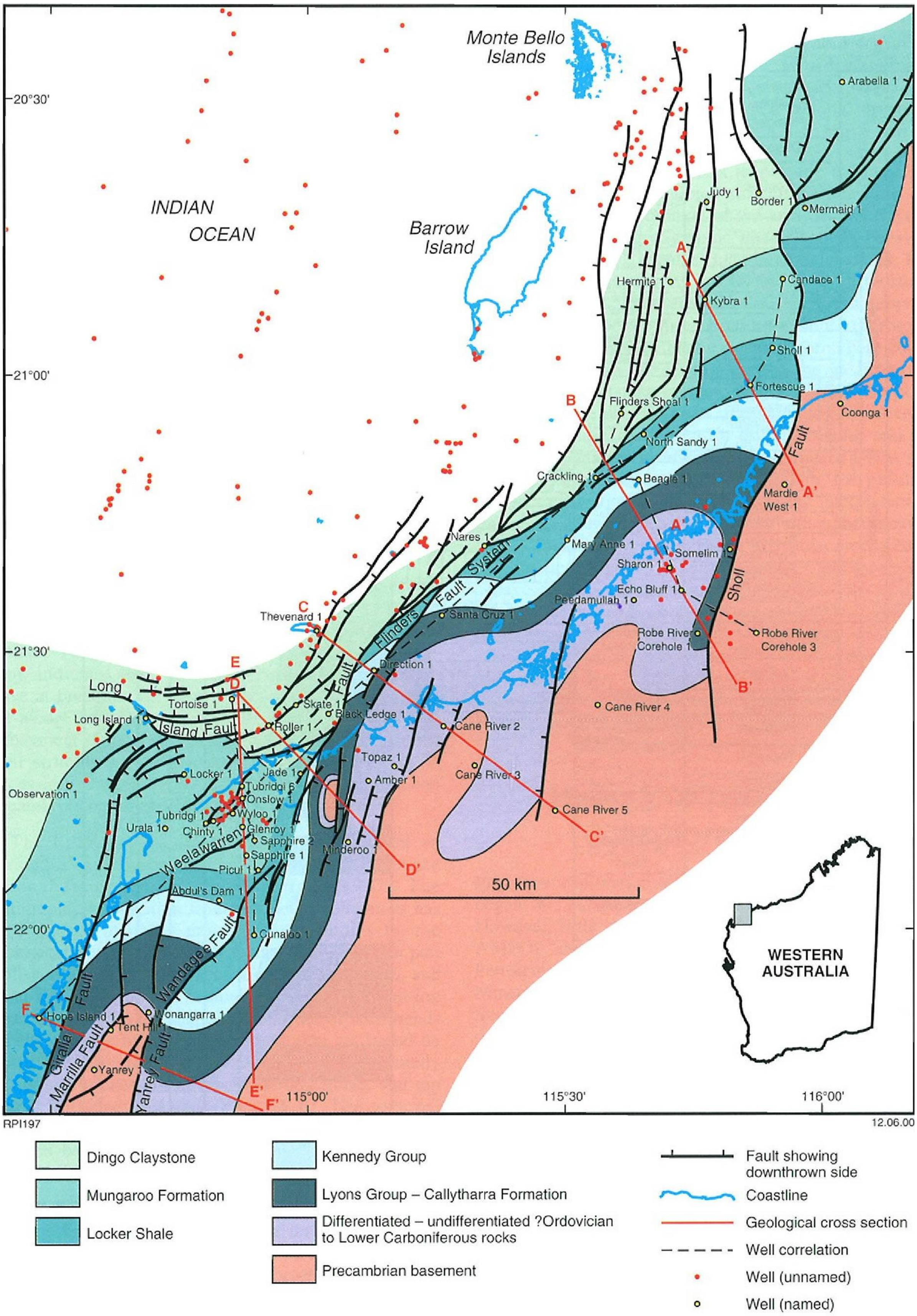
| | |
|---|---|
| CLIENT | Chevron Australia Pty Ltd |
| DOCUMENT | 127646019-001-R-Rev2 |
| DATE | 12 Nov 2012 |
| COMPILED | GGW |
| APPROVED | DMT |

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**GENERALISED STRATIGRAPHY IN THE ONLSLOW AREA (after Crostella et al., 2000).**

**FIGURE 2**

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F002-Rev2.mxd




Pre-Cretaceous geology of the Peedamullah Shelf and Onslow Terrace with the location of geological cross sections and well-log correlations. All well locations are shown, but only those with a yellow symbol are named.

Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

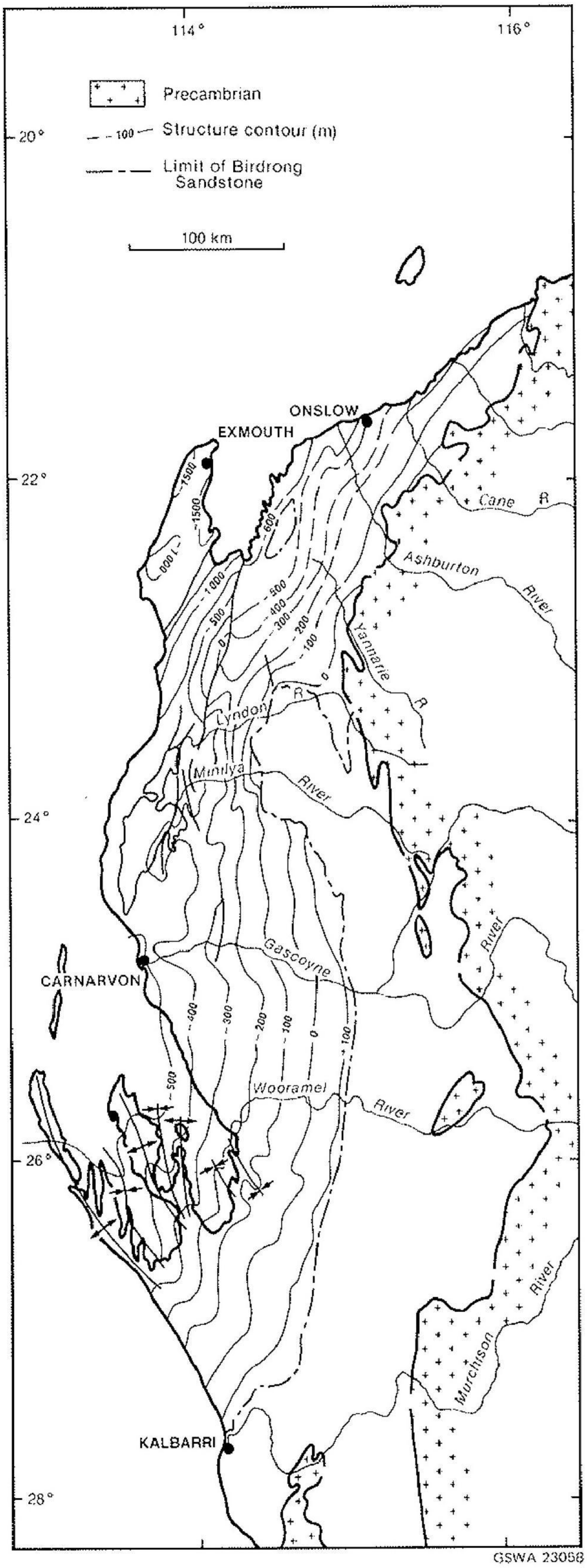
**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**PRE-CRETACEOUS GEOLOGY OF THE PEEDAMULLAH SHELF AND ONLSOW TERRACE**
**(after Crostella et al., 2000)**

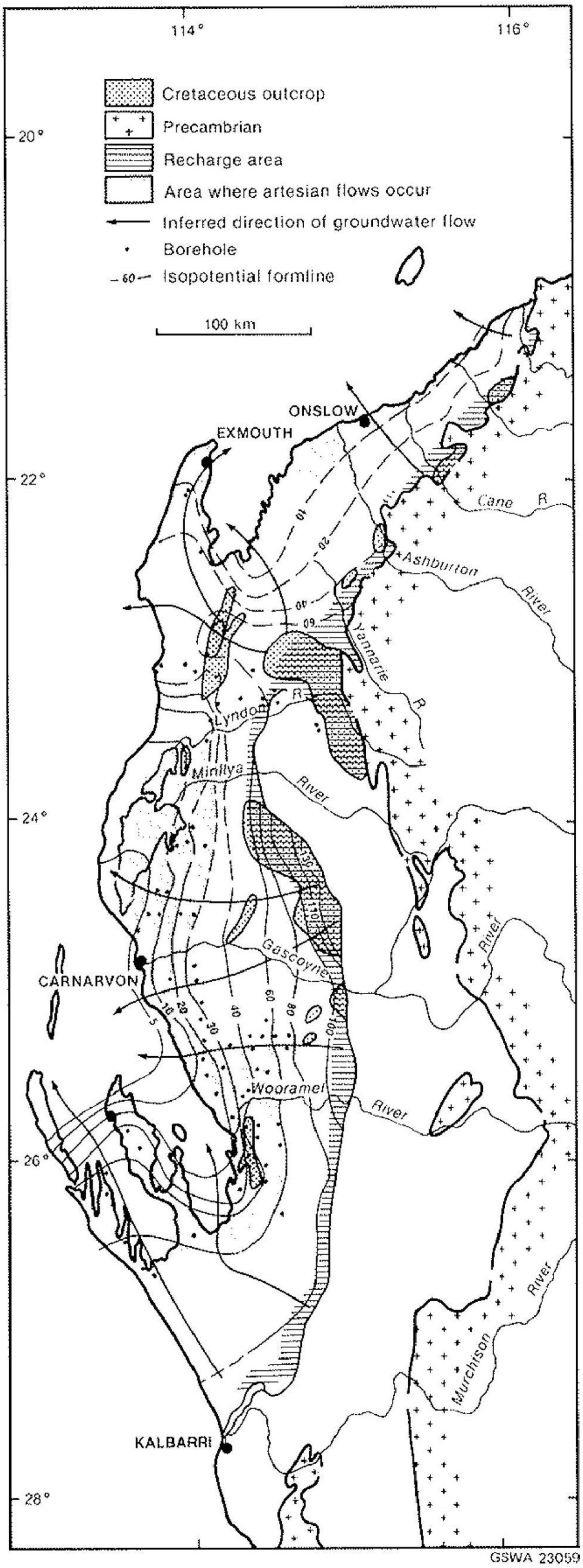
**FIGURE 3**



File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F003-Rev2.mxd




Depth to Birdrong Sandstone, relative to sea level.




Isopotential formlines of groundwater in the Birdrong Sandstone.

Golder Associates

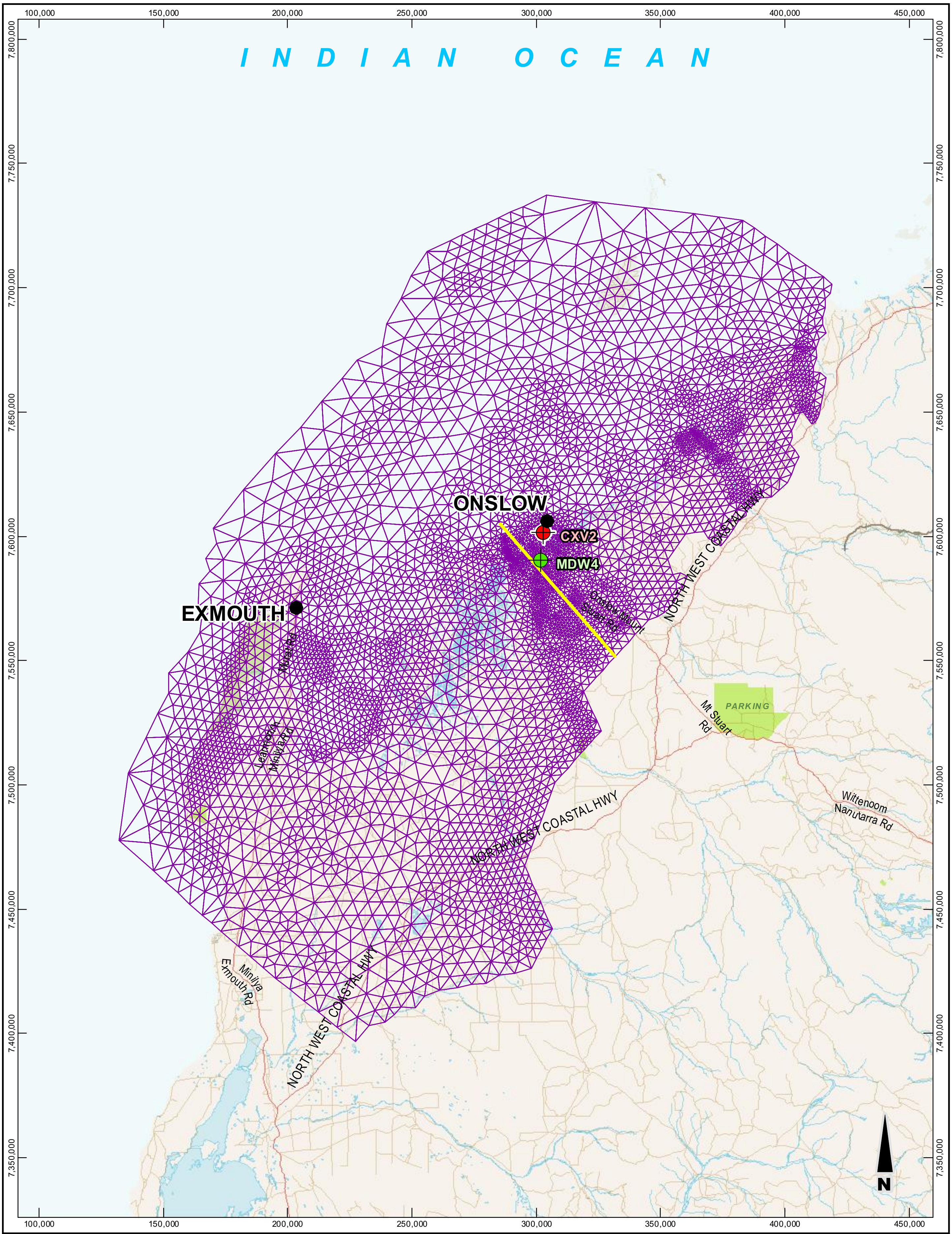
| | |
|---|---|
| CLIENT | Chevron Australia Pty Ltd |
| DOCUMENT | 127646019-001-R-Rev2 |
| DATE | 12 Nov 2012 |
| COMPILED | GGW |
| APPROVED | DMT |

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**BIRDRONG SANDSTONE STRUCTURE CONTOURS AND ISOPOTENTIALS, RELATIVE TO SEA LEVEL PRE-CRETACEOUS GEOLOGY OF THE PEEDAMULLAH SHELF AND ONSLOW TERRACE (after Hocking et al.,1987)**

**FIGURE 4**

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F004-Rev2.mxd






Golder Associates

| | |
|---|---|
| CLIENT | Chevron Australia Pty Ltd |
| DOCUMENT | 127646019-001-R-Rev2 |
| DATE | 19 Nov 2012 |
| COMPILED | GGW |
| APPROVED | DMT |

0 10 20 30 40 50 km

SCALE (at A4) 1:2,000,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.

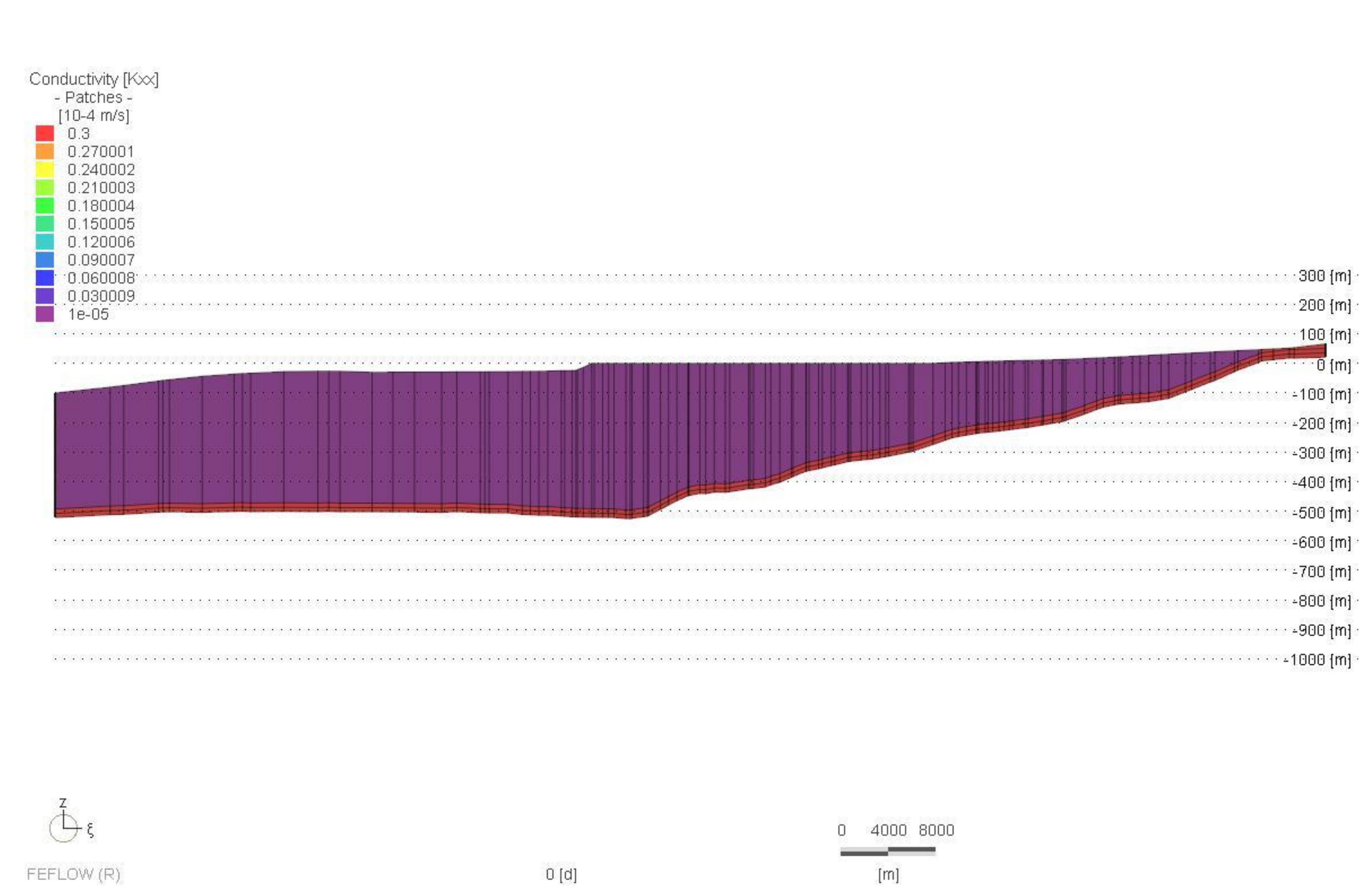
LEGEND
- Model Mesh
- Proposed Well Location
- Macedon Deep Well
- Cross Section (refer to Figure 8)

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**MODEL MESH STRUCTURE**

**FIGURE 5**

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F005-Rev2.mxd




NOTES

Cross section location shown on Figure 7.

Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

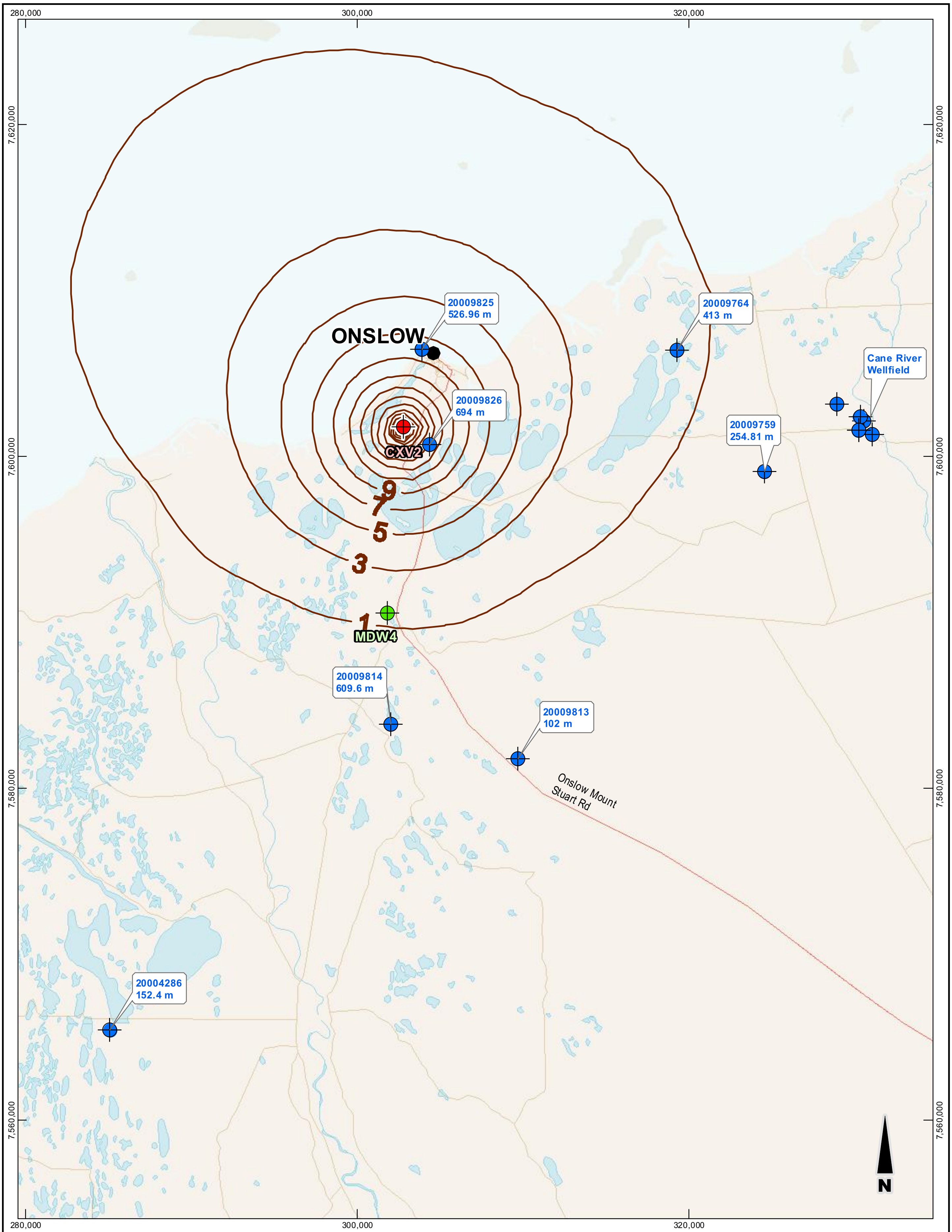
**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**MODEL CROSS SECTION THROUGH SITE**

**FIGURE 6**



File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F006-Rev2.mxd




Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

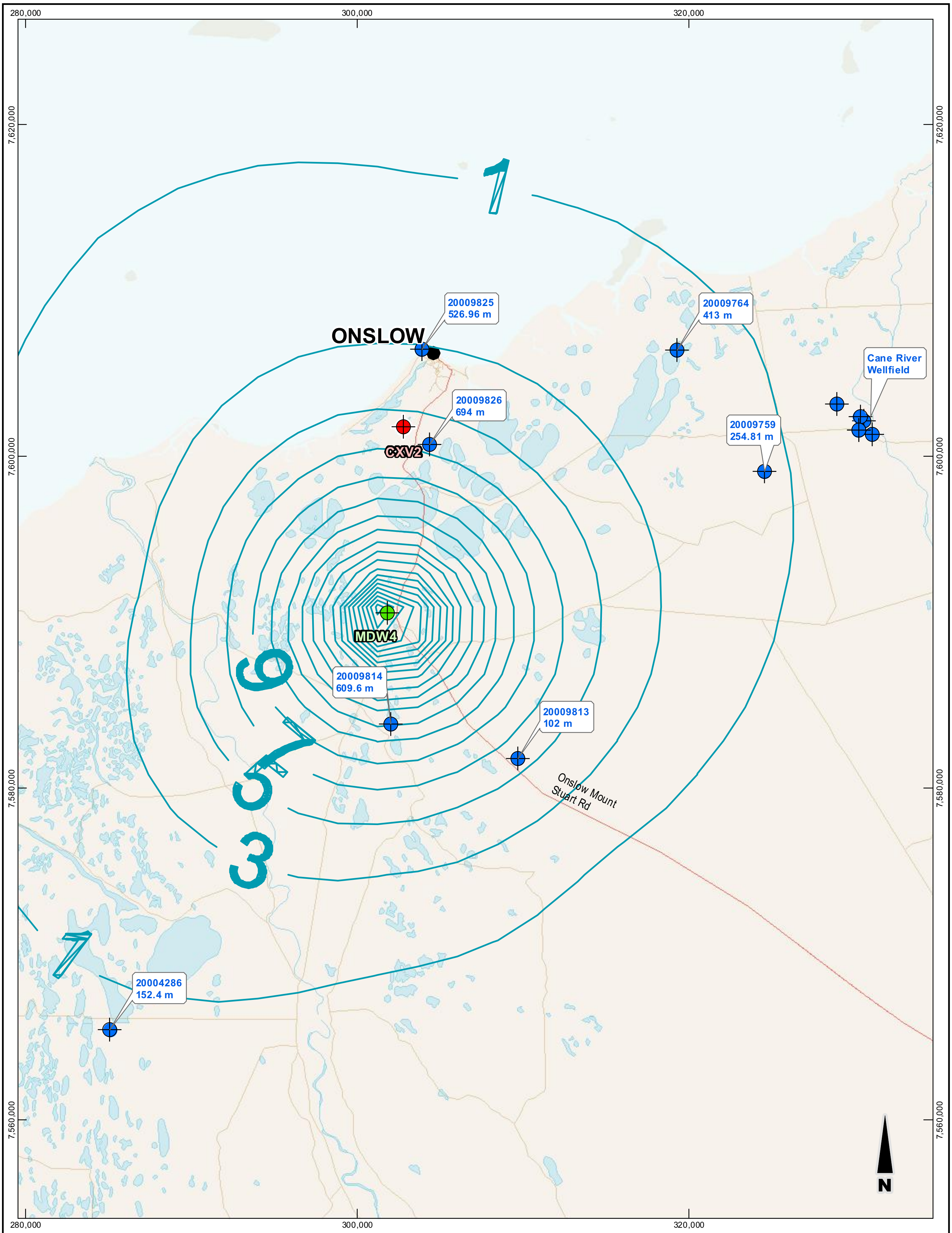
COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Macedon Deep Well
- Proposed Well Location
- WIN Site

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**PROJECTED DRAWDOWN FOR OPTION 1 AFTER 20 YEARS OF PUMPING**

**FIGURE 7**






Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

0 3 6 9 12 km

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

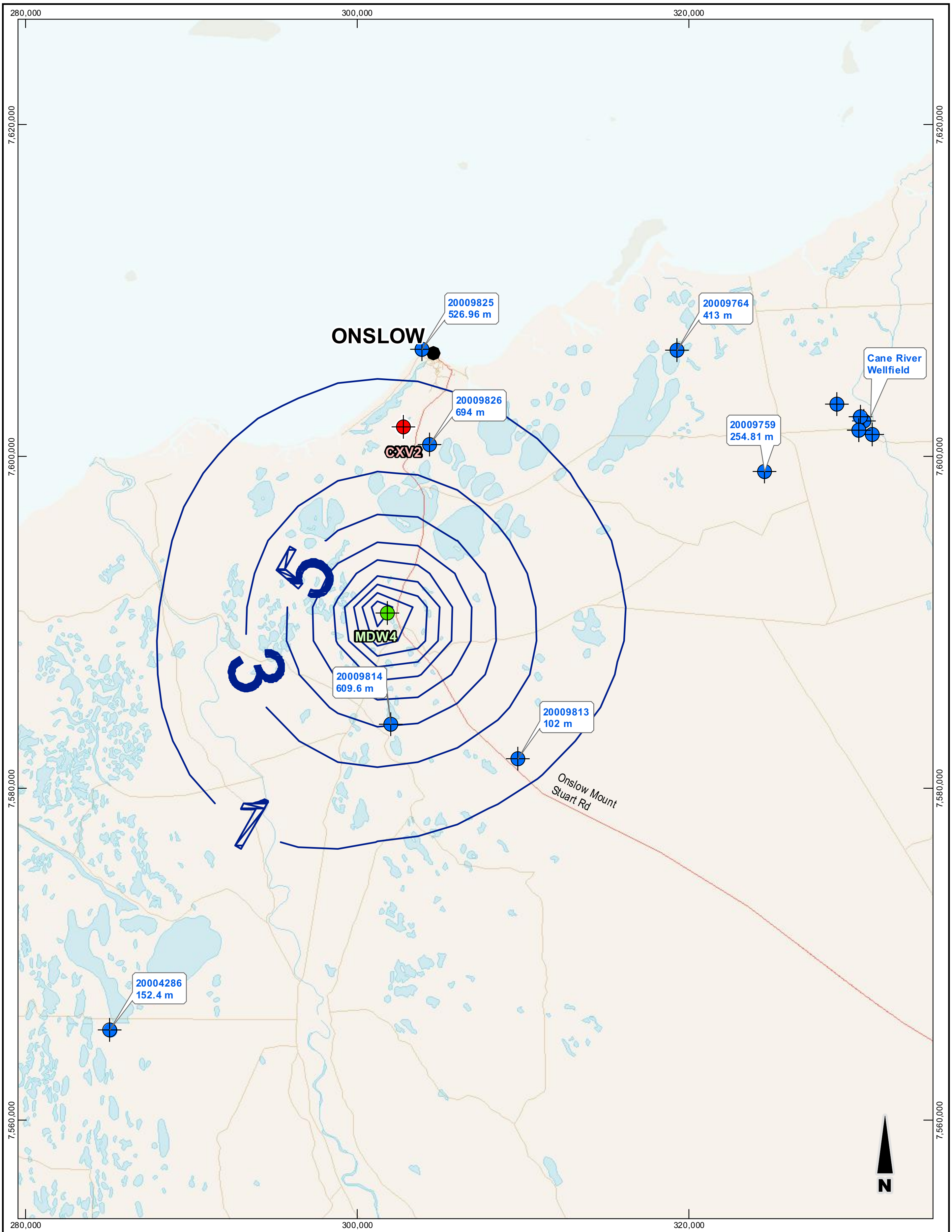
LEGEND
- Macedon Deep Well
- Proposed Well Location
- WIN Site

**Wheatstone Social Infrastructure**
**Onslow Water Supply**

**PROJECTED DRAWDOWN FOR OPTION 2 AFTER 20 YEARS OF PUMPING**

**FIGURE 8**

File Location: G:\Spatial_Information_Group\GIS_WORKSPACE_AUSTRALIA\01_WA\SF5005_ONSLOW\127646019\Projects\R001\Rev2\127646019-001-R-F008-Rev2.mxd




Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

0 3 6 9 12
km

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

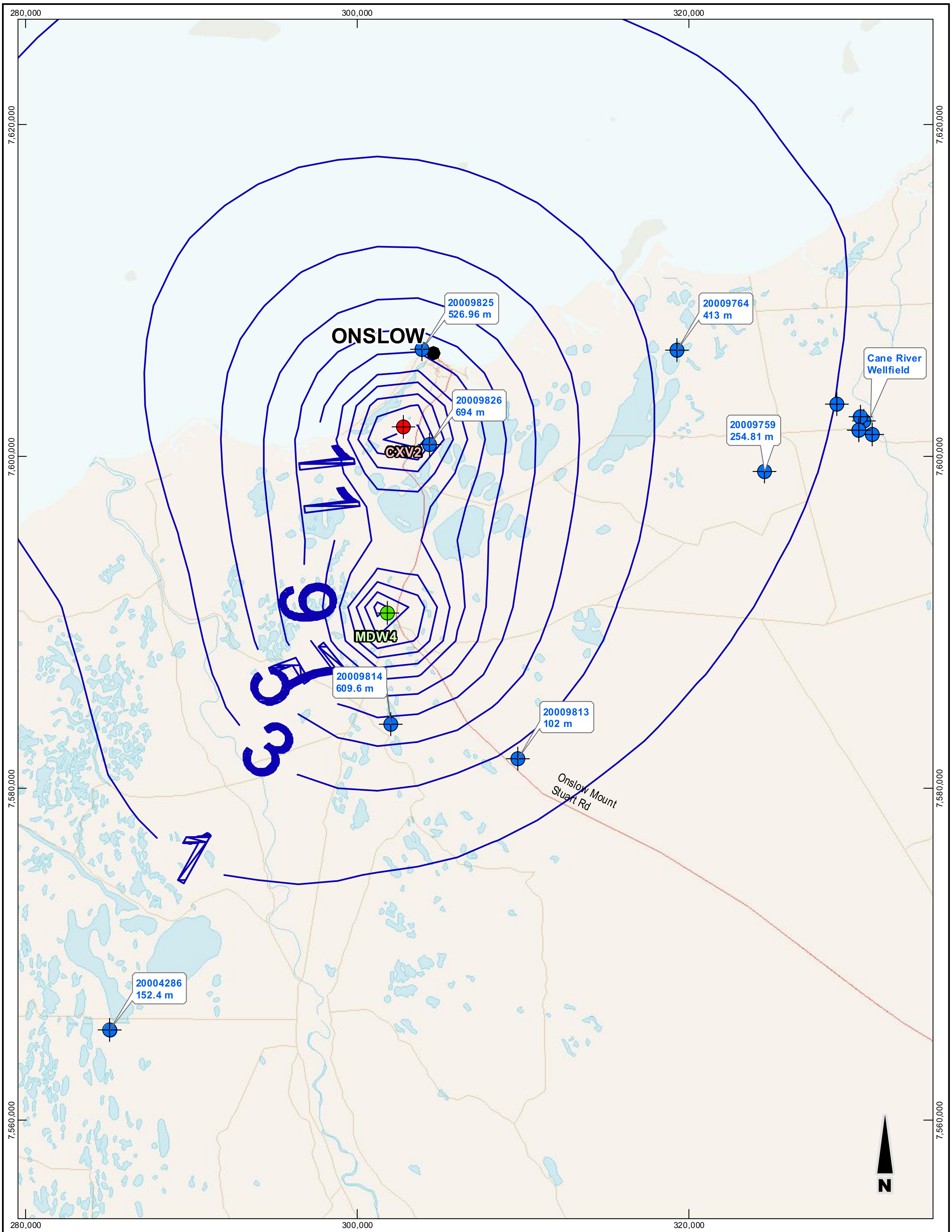
COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Macedon Deep Well
- Proposed Well Location
- WIN Site

Wheatstone Social Infrastructure
Onslow Water Supply

PROJECTED DRAWDOWN FOR OPTION 3 AFTER 20 YEARS OF PUMPING

FIGURE 9




Golder Associates

CLIENT Chevron Australia Pty Ltd
DOCUMENT 127646019-001-R-Rev2
DATE 19 Nov 2012
COMPILED GGW
APPROVED DMT

0 3 6 9 12
km

SCALE (at A4) 1:300,000

NOTES
Coordinate System: GDA 1994 MGA Zone 50

COPYRIGHT
Topgraphical data sourced from StreetPro Display 2009.
WIN Sites sourced from DoW 2012.

LEGEND
- Macedon Deep Well
- Proposed Well Location
- WIN Site

Wheatstone Social Infrastructure
Onslow Water Supply

**PROJECTED DRAWDOWN FOR OPTION 4 AFTER 20 YEARS OF PUMPING**

**FIGURE 10**

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.


| | |
|---|---|
| Africa | + 27 11 254 4800 |
| Asia | + 86 21 6258 5522 |
| Australasia | + 61 3 8862 3500 |
| Europe | + 356 21 42 30 20 |
| North America | + 1 800 275 3281 |
| South America | + 55 21 3095 9500 |

solutions@golder.com
www.golder.com

**Golder Associates Pty Ltd**
**Level 3, 1 Havelock Street**
**West Perth, Western Australia 6005**
**Australia**
**T: +61 8 9213 7600**

## - Changemarks ( 1

No changemarks applied