DWLBC REPORT

Aquifer Storage and Recovery Potential of Fractured Rock Aquifers in the Golden Grove Embayment

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Government of South Australia
Department of Water, Land and Biodiversity Conservation

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Rob Freeman
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

This study has assessed the hydrogeological potential of the Fractured Rock Aquifer (FRA) for Aquifer Storage and Recovery (ASR) projects within a 147 km^2 Adelaide metropolitan area bounded by Dry Creek, Brown Hill Creek, Para Fault and the Hills Face Zone (HFZ). Within this area there are currently four operational ASR projects (Northgate, Regent Gardens, Torrens Valley Sportsfield and Scotch College) injecting a combined 135–250 ML/y. Other sites under recent or current investigation by, or with the assistance of, the Adelaide and Mount Lofty Ranges Natural Resource Management (NRM) Board include St Ignatius Senior School, Victoria Park Racecourse and the Botanic Gardens.

The study has been undertaken on a broad level as a desktop evaluation using the results of past geological, geophysical and hydrogeological investigations, and extensive review of the state drillhole and water well databases and archives. Over 4200 drillholes and wells occur in the study area; all those considered likely to intersect bedrock were identified and reviewed to establish and contour the:

- depth of overlying sediments
- thickness of weathered bedrock
- bedrock aquifer intervals, yields, salinities and groundwater levels.

Bedrock within the study area is largely concealed beneath a veneer of Quaternary and Tertiary sediments of the Golden Grove Embayment (GGE). Areas of outcropping bedrock are limited to the eastern margin of the study area and within the upper reaches of the Torrens River Valley (TRV). Drilling data indicate that the concealed basement is dominated by fine-grained metasiltstone, shale and slate of the Saddleworth Formation, Belair Subgroup and Tapley Hill Formation. The basement rocks have a variable palaeo-surface and are structurally complex as a result of extensive folding and faulting during the Delamerian Orogeny, which makes the identification of suitable aquifer zones difficult. The hydrogeology of the basement is quite variable, but can be summarised by:

- groundwater levels are often very shallow or artesian along the HFZ and TRV, but can be deeper than 30 m west of the Hope Valley Fault
- the depth to bedrock is controlled by current drainage patterns and the overall southeasterly dipping floor of the GGE; unfavourably high depths to bedrock in excess of 150 m occur in the southern and southeastern parts of the study area
- groundwater salinity is relatively good, being lowest (typically <3000 mg/L Total Dissolved Solids [TDS]) in eastern and northern parts of the study area, and highest (>5000 mg/L TDS) in the western and southwestern parts
- aquifer yields are highly variable as expected; of ~180 drillholes and water wells within the study area with yield information, ~50 have relatively high yields (>4 L/s).

Conceptually, the main aquifer targets are relatively high transmissivity, low storage fracture zone aquifers associated with discrete bedrock structures which, if developed for ASR, may be limited in size to below ~50 ML/y. The identification and quantification of such aquifer zones will rely on relatively high-risk site drilling investigations. The size and hydrogeological sustainability of ASR operations within such FRAs will be strongly influenced by the depth to (native) groundwater, aquifer transmissivity, storage, depth and orientation, and the proximity to existing users of the same FRA. In general terms, the study area has significant areas with favourable hydrogeologic conditions that include:

- ability to complete wells with open-hole production intervals
- ~60% of the study area has native groundwater salinities <3000 mg/L TDS
- much of area has <100 m of sedimentary cover above bedrock
- presence of at least three major fault and/or structural corridors.

The FRA ASR potential of the study area has been spatially mapped by definition and application of eight different zones based on native groundwater salinity, proximity to major structure zones, depth to bedrock and ground surface slope. Some of the less favourable categories (Type 5 and 6) are based on the assumption that the aquifer zone is relatively shallow but, if deeper confined aquifer zones occur in these areas, then conditions for FRA ASR may be more favourable.

Twenty-eight sites were identified as having high potential for FRA ASR development by qualitatively considering all landholdings within Type 1 zones that:

- are close to potential water supplies from creeks, drains or stormwater pipes of >0.5 m diameter
- have at least ~1 ha of open space for water capture and pre-treatment
- have a potential water demand based mainly on the presence of sports grounds or grassed public spaces.

Twelve existing FRA water wells with yields >4 L/s were identified that are considered suitable for further ASR investigation by undertaking aquifer tests. Seven of these wells coincide with, or are very close to, the 29 investigation sites and should be considered as priorities for testing.

Recommendations for furthering the development of new FRA ASR projects in the study area are:

1. Undertake a census of current groundwater use from the sedimentary T1 aquifer and FRA to identify potential FRA ASR proponents and determine the potential for adverse impacts from specific FRA ASR projects upon existing groundwater users.
2. Integrate the findings of the above with the potential ASR sites and existing water well shortlist from this study to define and prioritise the Adelaide and Mount Lofty Ranges Natural Resources Management (AMLR NRM) Board's future directions in promoting and supporting development of new FRA ASR operations within the study area.

1. INTRODUCTION

A study to evaluate the potential storage capacities of the major aquifers of the Adelaide region for ASR was recently concluded by the Department of Water, Land and Biodiversity Conservation (DWLBC; Hodgkin 2004). The study focused on the sedimentary aquifers as they have reasonably continuous extents that allow quantification of storage capacity. The storage capacities of the FRA were not estimated in the 2005 study as the bedrock aquifers are typically highly anisotropic and of variable extent. However, in many parts of the metropolitan area, the FRA forms the only significant aquifer for either groundwater supply or ASR projects.

The FRA is a significant aquifer within the northeastern, eastern and southern suburbs of the metropolitan area below the Adelaide Hills Face Zone (HFZ). The Torrens and Patawalonga Catchment Water Management Boards (now part of the AMLR NRM Board) commissioned DWLBC in late 2004 to investigate the potential for FRA ASR within this area. The study area is ~147 km^2 in size and forms a rectangular area bounded approximately by Dry Creek in the north, the Para Fault to the west , Brown Hill Creek to the south and the HFZ to the east (Fig. 1). The investigation was undertaken during 2005 as a desktop-based study using existing information. This report presents the results of the study and outlines favourable areas and existing well sites recommended for drilling and/or aquifer testing to establish potentially sustainable FRA ASR projects.

2. OBJECTIVES AND SCOPE

The objectives of the study comprise:

- Identify preferred areas and well sites for further (field) investigation of FRA ASR potential.
- Determine hydrogeological criteria for defining the potential sustainability of FRA ASR operations within the study area.
- Undertake aquifer testing at up to five existing favourable well sites to assist quantification of the potential ASR injection volumes.

The scope of work completed is:

- Review of previous relevant geological and hydrogeological reports.
- Review of past and current FRA ASR investigations within the study area.
- Collation and validation of existing drillhole and water well data.
- Interpretive mapping of various geological and hydrogeological surfaces and parameters.
- Establishment of hydrogeological criteria that can be spatially applied to delineate areas and sites where the potential for significantly sized operations (>10 ML/y) and sustainable FRA ASR operations is relatively high.
- Application of the above criteria to the developed datasets to delineate hydrogeologically favourable areas for FRA ASR.
- Preliminary mapping of potential ASR demand and source water availability to provide refined delineation of preferred areas and well sites for further FRA ASR investigation.

Aquifer testing of any preferred well sites is yet to be undertaken. The 12 wells listed in Section 7 should be considered by the AMLR NRM Board for aquifer testing.

3. BACKGROUND

3.1 PREVIOUS GEOLOGICAL AND HYDROGEOLOGICAL REPORTS

Most hydrogeological investigations to date within the study area have focused on the Quaternary and Tertiary-aged sediments that overlie Proterozoic bedrock within the GGE. Geological investigations of bedrock have been mainly by mapping of outcrop within drainage lines and areas east of the HFZ. Several geophysical surveys have been undertaken to delineate the location of major faults that form the eastern boundary of the GGE.

Previous reports used for this study comprise:

- Reed (1981)—a hydrogeological investigation of the Golden Grove – Hope Valley area.
- Selby and Lindsay (1982)—a synthesis of the geology and hydrogeology of the Adelaide Central Business District area.
- Hough (1986)—gravity surveys to locate the Eden–Burnside Fault in the Clapham and Panorama areas.
- Woods (1987)—a University of Adelaide Honours Degree project to locate possible fault structures in eastern suburban areas.
- Drexel, Preiss and Parker (1993)—South Australian Geological Survey Bulletin on the state's Precambrian geology.
- Gerges (1997)—overview of the hydrogeology of the Adelaide area.
- Rowett (1987)—preliminary mapping of Tertiary palaeo-drainages.
- Gerges (1999)—PhD thesis on the geology and hydrogeology of the Adelaide Metropolitan Area.
- Fairburn (2004)—a review of the shallow Cainozoic fluvial history of the GGE.
- Hodgkin (2004)—evaluation of the (sedimentary) aquifer storage capacities of the Adelaide region.

3.2 FRA ASR OPERATIONS AND INVESTIGATIONS

ASR investigations of the FRA to date within the study area have culminated in the establishment of four operating ASR projects that inject a combined volume of up to 250 ML/y. Summary details of these operations are presented in Table 1, and their location shown on Figure 1.

Table 1. Operating FRA ASR projects within the study area

Project	Year commenced operating	Typical injection volumes (ML/y)	Water source
Scotch College	1989	40	Brownhill Creek
Regent Gardens	1995	40–60	Urban runoff
Northgate	2001	40–110	Urban runoff
Torrens Valley Sportsfield	2003	15–40	Fifth Creek

Other past and current ASR investigations (Fig. 1) that have considered FRA targets within the study area include:

- Evaluation of ASR potential of the Tea Tree Gully Council area by Australian Groundwater Technologies (AGT) in 2001. This council area is largely to the north of the study area but does extend down within the study area in the vicinity of the Hope Valley Reservoir. The AGT study delineated three sites for further investigation:
    - Torrens River
    - Lyons Road Oval
    - Barracks Rd Hope Valley
- Preliminary investigations by St Ignatius Senior School for oval irrigation.
- FRA ASR potential of the Adelaide City Parkland areas by the AMLR NRM Board. Three sites (Victoria Park Racecourse, Botanic Gardens and North Parklands) were drilled during 2005 under the direction of AGT.

4. METHODOLOGY

The methodologies used for this study, in approximate order of completion, are:

- Capture of all drillhole and water well records within the study area held on the DWLBC-maintained SA_Geodata database. Approximately 4200 drillholes and wells, as at August 2005, are recorded within the study area, but most of these do not intersect bedrock.
- Analysis and review of the drillhole and well dataset using microfiche records and previous reports to establish data subsets of holes and wells that contain information on:
    - depth of sedimentary cover above bedrock
    - thickness of weathered bedrock
    - bedrock lithology
    - groundwater salinity of bedrock intervals
    - groundwater yield of bedrock intervals measured during drilling or pumping
    - groundwater levels of bedrock intervals measured during drilling or post-well construction.

For each of these data subsets, each record was assigned a qualitative confidence level rating (as a number between 1 to 3 or 1 to 4) to reflect the degree of uncertainty in the assigned value (1 being high-confidence data, a 3 or 4 being lower confidence data based on interpretation).

- Review of available pumping test information.
- Collation and review of known and interpreted fault locations from previous workers.
- Contouring and digitising of the base-of-sediments and top-of-fresh-bedrock surfaces (in absolute datum mAHD), groundwater salinity and groundwater level surfaces using the data subsets described above.
- Calculation, using Surfer 8 contouring software, of the following surfaces:
    - depth to base of sediments as metres below ground (mbgl)
    - depth to top of fresh bedrock (mbgl)
    - weathered rock isopach (thickness)
    - depth to groundwater (mbgl).

This work effectively involved the re-contouring of the hand-drawn contours by using a kriging interpolator on a 50x50 m cell size over a grid area between 275000 and 294000mE, and 6122000 to 6144000mN, and subsequent subtractions from a ground surface grid previously generated by Hodgkin (2004).

- Application of hydrogeological criteria to map the ASR aquifer potential of different zones within the study area.
- Refinement of hydrogeologically favourable areas by application of preliminary ASR demand and source water criteria.
- Delineation of potential FRA ASR sites by qualitatively considering potential water sources, water demand and open area within the most favourable ASR aquifer potential zones.
- Identification of high-yielding existing water wells within favourable ASR zones for possible aquifer testing.

5. BASEMENT GEOLOGY

5.1 LITHOSTRATIGRAPHY

The study area is underlain and bounded by various Proterozoic sedimentary rocks of the Adelaide Geosyncline, but predominantly by shale, slate, siltstone and quartzite of the Burra Group. A lithostratigraphic column of the Burra Group is shown in Figure 2. Figure 3 shows an outcrop plan of the major lithostratigraphic units of the study area and the main lithologies intersected near the base of ~200 drillholes and water wells.

A brief lithological description of the major stratigraphic rock units within and immediately surrounding the study area is provided below. More detailed descriptions are given in Preiss (1987).

5.1.1 CASTAMBUL FORMATION

Within the Torrens Gorge (near to the study area), this formation comprises a pale grey to white, finely crystalline, massive dolomite which occurs as a 50–100 m thick interbed within a dark grey and greenish, silty and phyllitic sequence overlying the Aldgate Sandstone (Preiss 1987). The dolomite is also sandy in the upper sections and grades up into ~30 m of coarse-grained quartzite (Preiss 1987).

5.1.2 MONTACUTE DOLOMITE

This unit comprises dominantly blue-grey fine-grained dolomite with interbeds of dolomitic sandstone, quartzite, magnesite conglomerate and minor dolomitic phyllite (Preiss 1987). It is ~130 m thick in the type section at Castambul, ~3 km east of Athelstone.

5.1.3 WOOLSHED FLAT SHALE

In the Montacute – Tea Tree Gully area, the Woolshed Flat Shale typically comprises an upper unit of laminated sandy or silty shale and phyllite, and a lower unit of dolomitic phyllite with thin dolomite lenses (Preiss 1987).

In the Mount Lofty – Lenswood – Balhannah area, the Burra Group is represented almost entirely by the Balhannah Shale Member, a carbonaceous black slate within the Woolshed Flat Shale (Preiss 1987).

5.1.4 STONYFELL QUARTZITE

This unit is responsible for much of the prominent relief of the Adelaide HFZ, especially north of the Black Hill – Athelstone area, where it is the main lithostratigraphic unit occurring immediately to the east of the major Eden–Burnside Fault (Fig. 3). Close to the study area, the Stonyfell Quartzite is ~250 m thick and comprised predominantly of feldspathic quartzite; it has been subdivided into three informal members (Preiss 1987):

- The basal Wattle Park Member is predominantly feldspathic quartzite with thin laminations of shale that transitions upwards into medium to coarse feldspathic sandstone, and then hard pink to white quartzite with minor thin shale laminations.
- The Slapes Gully Member is a feldspathic silty sandstone with shaly interbeds and thin quartzite bands. It is commonly schistose and calcareous.
- The uppermost Greenhill Member, which is a relatively clean, well-sorted quartzite and sandstone sequence.

5.1.5 SADDLEWORTH FORMATION

This unit is a relatively thick, fine-grained sequence that occurs as outcrop in Dry Creek and prominently within the HFZ between Black Hill and Glen Osmond (Fig. 3). Within and near the study area, the formation typically comprises dark green to grey dolomitic phyllite, slate and minor quartzite and dolomite (Preiss 1987). In the type section near Riverton, laminated shale is common.

5.1.6 BEAUMONT DOLOMITE

The Beaumont Dolomite is 110–140 m thick and consists of dark to medium grey, flaggy, laminated to medium-bedded dolomicrite with occasional black chert blebs (Preiss 1987).

5.1.7 GLEN OSMOND SLATE

This unit has some lithological similarities to the underlying Saddleworth Formation and has been mapped as outcrop within the Torrens Valley near Highbury. It characteristically occurs as laminated and fine sandy siltstone ~200 m thick at its type locality along the Mt Barker Road at Glen Osmond. Minor, very thin, fine dolomite lenses and slumped siltstone beds occur locally (Preiss 1987).

5.1.8 BELAIR SUBGROUP

This uppermost sequence of the Burra Group is known to crop out in the Torrens Valley near Highbury and immediately east of the Eden–Burnside Fault along the HFZ south of Glen Osmond (Fig. 3). The sequence comprises ~270 m of unnamed alternating laminated siltstone and fine sandstone above the 30 m thick, coarse to medium-grained highly feldspathic, cross-bedded Mitcham Quartzite (Preiss 1987).

5.1.9 STURT TILLITE

This unit occurs as part of the Umberatana Group, a major Neoproterozoic sequence that unconformably overlies the Burra Group. It consists of up to 360 m of boulder tillite with several 3–6 m thick interbeds of pale green and dark grey, carbonaceous, finely laminated shale and siltstone (Preiss 1987). It has not been definitively identified beneath the sediments of the GGE by this study but does crop out in the western Mount Lofty Ranges near the southern boundary of the study area.

5.1.10 TAPLEY HILL FORMATION

The dominant lithology of the thick (>1500 m) Tapley Hill Formation is a well-sorted, dark bluish grey, slightly calcareous or dolomitic, often pyritic siltstone, with grain size and carbonate content elevated in the upper parts of the unit (Preiss 1987). Very fine alternating pale and darker laminations are characteristic of the formation. It crops out in the HFZ to the south of the study area (below the Sturt River) and has been intersected by the Victoria Park Racecourse ASR investigation well and several other wells in the city area.

5.2 SUBCROP

Figure 3 displays the main rock types present at or near the base of over 200 drillholes and wells. Most of these intersections occur in the northern half of the study area where basement rocks are typically shallow and FRA have been historically utilised for such applications as market gardening in the River Torrens Valley upstream of Third Creek.

The dominant rock type recorded in the upper basement is slate with lesser occurrences of siltstone, shale, sandstone, quartzite and dolomite. Many of the slate intersections are based on field inspections of drill cuttings by drilling contractors — it is possible that a significant number of these intersections are actually fine-grained siltstone and shale.

Regardless of the slate definition, it is clear that the study area is underlain predominantly by fine-grained clastic sequences of the Burra Group, consistent with the outcropping basement sequences to the north and east of the study area. Slate and siltstone of the Tapley Hill Formation (Umberatana group) have been identified in several wells near the city of Adelaide, such as recent wells Adelaide University No.1 and N117b Botanic Gardens.

5.3 FAULTS

Post-orogenic faulting provided a strong control to initial development of the GGE. The Eden–Burnside Fault (Fig. 3) represents the eastern limit of Tertiary sedimentation, whilst the Para Fault is an Adelaidean fault that was reactivated in the Tertiary, causing post-depositional displacement of Tertiary sediments and which forms the boundary between the GGE and the Adelaide Plains Sub-basin.

The major fault zones are complex, probably occurring as a series of close-spaced faults, and individual locations are not always well known, especially when they occur beneath sedimentary cover. Some of this complexity and uncertainty is displayed in Figure 3, which plots the major fault traces of Gerges (1999), Forbes (1980), and from the current DWLBC GIS dataset.

Given the inherently low permeability of the fine-grained bedrock beneath the GGE, fault zones are known to form significant structurally controlled aquifer zones within the Adelaidean basement. Their location and nature is therefore considered to be of great significance to the establishment of potential FRA ASR sites within the study area.

Major fault positions have been previously mapped by a combination of field mapping, aerial photography interpretation and drilling. Locally, land-based gravity surveys have been used, such as Hough (1986), who located a portion of the Eden–Burnside Fault zone in the Clapham–Panorama area, which occurs near the southern edge of the study area. Other geophysical surveys, such as more expansive land gravity surveys (Woods 1987) and the state-wide airborne gravity and magnetics datasets held by PIRSA, are not considered to be of sufficient resolution to delineate individual faults.

Smaller scale faults than those shown in Figure 3, that may suitable for development of small ASR projects (<10 ML), are likely to be present throughout the study area. Locating and mapping of such faults would rely on close-spaced drilling.

5.4 BASE OF SEDIMENTS

The most comprehensive work completed to date that defines the base of Quaternary and Tertiary sediments (or top of bedrock) in the GGE is that of Gerges (1999). This dataset and contouring was updated using drillholes and wells installed since the mid-1990s as well as a few older sites from microfiche records.

About 240 drillholes and wells were used to hand-contour the approximate base of sediments surface (mAHD) shown in Figure 4a. Confidence levels were assigned to each record based on the certainty and accuracy of the flagged sediment–bedrock boundary; low-confidence ratings were assigned to such situations where fine-grained sediments were considered to overly strongly weathered sedimentary rocks or where only inconclusive drilling logs were available. High-confidence flags were assigned to drillholes and wells where there were sharp contrasts between the sediment and bedrock mineralogies, or if detailed lithological logs by geologists were available. Many, but not all, of the low-confidence records were used for contouring, especially in areas where there was little or no other data.

Given the complexity of the major Eden–Burnside Fault zone and some uncertainties regarding exact fault locations, a singular fault trace considered to represent the westernmost position of the fault complex was chosen to simplify the contouring. The inferred position of this contouring constraint is shown as a dashed green line in Figure 4a. Conceptually, bedrock to the west of this line represents the down-thrown block of Adelaidean strata whilst, to the east of the line, bedrock occurs close to the ground surface, blanketed by relatively shallow alluvial and colluvial sediments.

The base of sediment contours are not considered highly accurate due to a lack of data in the southern and western parts of the study area, and because the Tertiary and Quaternary sediments were deposited unconformably over an undulating palaeotopography. They do, however, display the same southwesterly trending palaeosurface mapped by Gerges (1999).

The hand-drawn (mAHD) contours were re-gridded using Surfer and then subtracted from a Surfer grid of the current-day ground surface to generate a plot of the depth to weathered bedrock (Fig. 4b). These contours are shown over the top of several other datasets that have relevance to the thickness of sedimentary cover over bedrock:

- the state-wide airborne gravity dataset held by PIRSA
- inferred fault positions from the land-based gravity survey of Woods (1987)
- the approximate trace of the Golden Grove palaeochannel within the study area as mapped by Rowett (1997).

Key features of the depth of sediment contours (Fig. 4b) include:

- shallow depths to weathered bedrock within the Adelaide HFZ, along Dry Creek and along the upper reaches of the TRV

- relatively thick sequence of sedimentary cover south of the River Torrens and Fifth Creek that dips and thickens to the southeast towards the bounding Eden–Burnside Fault zone
- a southwest-trending palaeochannel beneath the Hope Valley Reservoir that shows a reasonable correlation between the contoured point data, the inferred fault position of Woods (1987) and the palaeochannel mapped by Rowett (1997)
- relatively shallow sedimentary cover in the northwestern parts of the study area.

The state-wide gravity dataset shows a subtle southwest-trending lineation along the TRV that extends from near the Hope Valley Reservoir down to the Adelaide Central Business District. Discussions with PIRSA geologists indicate that the reason(s) for the subtle lineation is unclear, but may reflect some form of structural control within the Adelaidean basement.

5.5 TOP OF FRESH BEDROCK

A similar process was followed for contouring the top of fresh bedrock; hand-drawn contours were developed using ~210 drillholes and wells, each assigned a confidence level, with some low-confidence records ignored during the contouring process. Figure 5a shows the top of fresh bedrock surface as an absolute datum (mAHD) whilst Figure 5b shows the surface as depth below ground that was calculated using Surfer software.

The top of fresh bedrock contours are not considered highly accurate due to:

- a lack of data in the southern and western parts of the study area
- the typically variable shape of the true base of weathering profile in structurally controlled sedimentary rock environments
- identification of the base of weathering in individual drillholes or exposures can be highly subjective, based on the visual assessment of a subtle boundary between slightly weathered and fresh rock.

Similar trends are noted for the top of fresh bedrock as for the base of sediments plots; the contoured surface is reasonably consistent with earlier contours of Gerges (1999).

An isopach map for the weathered rock interval (Fig. 6) was calculated by using Surfer to subtract the re-gridded base of sediment contours from the top of fresh bedrock contours. The weathered rock contours are considered less accurate than the two individual surfaces used to create it, as the accuracy errors are cumulative. The weathered rock isopachs are only considered representative of regional trends or accurate within localised areas where there are numerous close-spaced drillholes and wells.

Consideration of the weathered rock isopach map highlights some trends and observations consistent with what one would expect from the other contour maps and the general conceptualisation of the sediment–bedrock environment. These include:

- thin weathered rock intervals (typically <10 m) in the Adelaide HFZ, along the upper sections of the TRV and along Dry Creek, where bedrock crops out or is overlain by a relatively thin veneer of sediments
- relatively thin, weathered rock intervals (typically 5–20 m) in the area between the Hope Valley and Eden–Burnside Fault zones

- some elongation and thickening of the weathered rock interval in the Hope Valley Reservoir area, possibly as a result of enhanced weathering beneath a Tertiary palaeochannel
- large variations in weathered rock thickness (5–60 m) in the general vicinity of the River Torrens between Third and Fifth Creeks.

6. HYDROGEOLOGY

6.1 FRACTURED ROCK AQUIFER TYPES

In general terms, FRA can be subdivided into three types that reflect the process(es) responsible for development of enhanced aquifer storage and transmissivity.

6.1.1 TYPE 1 — BASE OF WEATHERING

In areas where significant weathering of bedrock has occurred, a considerable enhancement of aquifer properties can occur, particularly in the lower sections of the weathering profile. The upper portions of a highly weathered alumino-silicate rock profile may be dominated by clay minerals, which tends to development of aquitard zones. However, the lower zones that display only slight or moderate weathering often contain less clay minerals and have enhanced permeability as a result of weathering through primary porosity or along secondary features such as joint sets and other fracture sets. The lithology and texture of the bedrock is important to the development of significant permeability. The fine-grained base of Quaternary and Tertiary sediments, such as the shale, siltstone and slate present beneath much of the GGE, has limited primary permeability and would rely on extensively jointed and fractured zones within the weathering profile or weathering enhanced permeability for such to develop. Coarser grained rocks with higher silica contents, such as granite, quartz sandstone and calcarenite, can develop significantly enhanced permeability and porosity by weathering processes.

Base of weathering aquifer zones tend to be subhorizontal and have lateral extents that greatly exceed their vertical extent. Such zones typically exhibit low to moderate storativity and transmissivity. Given the high proportion of fine-grained alumino-silicate rocks beneath the study area and the degree of weathering observed, the base of weathering aquifer zones are considered overall to have relatively poor storativity and transmissivity, thus limiting their potential for ASR.

6.1.2 TYPE 2 — FRACTURE ZONES

This setting applies to bedrock where relatively narrow structural features such as faults, shear zones and close-spaced joint sets form a semi-planar aquifer. The aquifer geometry is typically limited in the direction perpendicular to the controlling structure(s) and relatively extensive along strike and down-dip of the controlling structure(s), with a highly variable orientation possible.

High-permeability zones associated with fracture sets can occur within the weathering profile or at great depths within fresh bedrock. Whilst only a generalisation, many FRA become less permeable or transmissive with increasing depth as the vertical and horizontal stresses associated with the increasing weight of the rock ‘column’ reduces the aperture of the individual fractures. Significant fracture zone aquifers below depths of the order of 150–200 m are relatively rare.

Within the fresh bedrock profile, there is a general tendency for fracture zone aquifers to display relatively high transmissivity (a result of very high permeability along individual fractures) but low storage as there is often very limited primary porosity and only the fracture porosity itself to store water.

6.1.3 TYPE 3 — KARSTIC AQUIFERS

Karstic aquifers represent a special version of Type 1 aquifers in which dissolution of significant portions of matrix material during weathering by percolating fluids results in the creation of significant (and often large in size) secondary porosity. Typical examples are karstic features formed by dissolution of carbonate within calcarenite or massive limestone, or the development of vuggy silcrete during extreme weathering of ultramafic igneous rocks.

Karstic aquifers can have very high transmissivities and storage, but often have limited extent and irregular distribution.

The three aquifer types outlined above do not always occur in isolation; two or more aquifer types are often well developed together. A common example of this is where near-vertical structures form preferential flow paths for weathering fluids, often resulting in deeper weathering and enhanced aquifer properties above the limit of weathering.

Within the study area, review of the individual drillhole and water well records and the overall regional geological setting indicates that FRA occurrences are dominated by the Type 2 (structural) aquifers with lesser occurrences of Type 1 and no obvious evidence of Type 3 aquifers.

6.2 GROUNDWATER LEVELS

There are relatively few FRA wells currently monitored with the study area as part of the DWLBC Obswell network, which prevents an accurate current-day potentiometric surface from being compiled. Instead, an approximation of the potentiometric surface has been created using current, recent and historic data (Fig. 7a). Consistent with earlier surfaces calculated by Gerges (1999) and with overlying aquifers, the regional groundwater flow direction is southwesterly to westerly. Current-day abstraction from the FRA is considered relatively minor, such that the contours drawn should be a reasonable representation of the natural groundwater flow regime.

Groundwater levels would be dominated by ground surface levels and drainage lines where the FRA is unconfined or semi-confined along the HFZ and northern parts of the study area. Elsewhere, under confined conditions, groundwater levels would be partly controlled by the orientation and extent of major structures and the connections these features have with overlying and adjoining (laterally) sedimentary aquifers.

The FRA potentiometric surface as depth below ground contours has been generated with Surfer 8 by subtracting the groundwater surface grid from a ground surface grid (previously developed by Hodgkin (2004) using the DWLBC 5 m contour GIS dataset). These contours (Fig. 7b) show that:

- Relatively shallow groundwater levels occur along elevated parts of the HFZ where the FRA is conceptually unconfined.

- The deepest groundwater levels occur between the Hope Valley and Eden–Burnside Faults where the ground surface gradually rises from the Adelaide Plains up to the HFZ.
- Relatively deep groundwater levels occur in the topographically high northwestern and northeastern parts of the study area.
- Shallower groundwater levels occur along the TRV and Dry Creek, which forms the northern boundary of the study area.
- Artesian groundwater levels have been observed in parts of the TRV and in parts of the HFZ, such as those observed recently in the ASR investigation well at the North Parklands site and at the University of Adelaide.
- An apparent discord between groundwater levels near the inferred western limit of the Eden–Burnside Fault system. Some of these differences may be artificial as groundwater levels were contoured as separate areas to the east and west of the Eden–Burnside Fault. To the west of the inferred fault line shown in Figure 7, groundwater levels represent the potentiometric surface of a confined aquifer system, while to the east, the groundwater contours conceptually represent water-table levels of an unconfined aquifer system.

The depth to groundwater is an important variable to ASR projects as shallow groundwater levels may limit the ultimate level of storage possible and also trigger the need to inject water under pressure at the well head instead of drainage by gravity. These and other hydrogeological criteria important to ASR development are discussed further in Section 7.

6.3 GROUDWATER SALINITY

As with groundwater levels, there is a general lack of current DWLBC Obswells that monitor basic water-quality parameters such as Electrical Conductivity (EC), salinity (mg/L TDS) and pH. Within the study area there are eight Obswells monitored infrequently (ADE 126, 168, 170, 184, and YAT 77, 106, 109, 110).

A recent monitoring program by the Torrens and Patawalonga Catchment Water Management Boards has undertaken detailed water-quality analyses from an additional 12 FRA wells within the study area. Salinity results from this program, and past results for other wells, have been used to generate the salinity contours displayed in Figure 8. The results are colour coded according to the confidence levels assigned to the salinity results. Recent salinity values from wells definitely screened and isolated within fractured rock intervals were assigned the highest confidence levels, while those drillholes or wells with old records, anomalous levels or with doubtful aquifer intervals were assigned the lowest confidence.

The contours were hand drawn and are both approximate and interpretive, although they are consistent with earlier work by Gerges (1999). Figure 8 shows that the freshest groundwater occurs in the eastern and northern parts of the study area, consistent with the conceptualisation of significant recharge of the FRA by rainfall and runoff from the western Mount Lofty Ranges. Salinity increases to >5000 mg/L TDS in the western and southwestern parts of the study area, partly as a result of reduced aquifer transmissivities.

6.4 GROUNDWATER YIELDS

About 220 drillholes and wells within and immediately adjacent to the study area were assigned yields after detailed review of the SA_Geodata database and microfiche records.

These yields (L/s) are plotted in Figure 9, with colour coding according to confidence levels. Highest confidence levels were assigned to those wells or drillholes with pumping values definitely recorded from fractured rock intervals, while lowest confidence levels were assigned to airlift yield data from uncertain aquifer intervals.

Yields were not contoured for several reasons:

- the lack of data over large portions of the study area
- limited accuracy and consistency of data, as many estimates may have been derived by visual estimation of airlift flows whereas some values are based on pumping rates from aquifer tests.
- the spatial distribution of yields would have a strong structural control with relatively discrete and limited continuity.

Wells with yields >4 L/s are highlighted in Figure 8. These were reviewed in detail to identify a preferred subset of wells that may potentially be aquifer-tested (see Section 7.3.1).

7. FRA ASR POTENTIAL

This section presents a broad discussion of the key issues likely to affect the development and sustainability of FRA ASR projects within the study area from a hydrogeological perspective (Section 7.1). Hydrogeological criteria are then applied to subdivide the study area into zones of differing ASR potential (Section 7.2). Within the hydrogeologically most favourable areas, potential FRA ASR sites for further investigation have been identified based on a qualitative assessment of existing high-yield wells, proximity of source water, open land availability and potential water demand (Section 7.3).

7.1 FRA ASR SUSTAINIBILITY AND SUITABILITY WITHIN THE STUDY AREA

Licensing and permitting issues associated with ASR establishment and operation are not discussed here, but are presented by Hodgkin (2004). Rather, issues that would influence the development and sustainability of FRA ASR operations in the study area from a hydrogeological perspective are presented below.

7.1.1 IMPACTS ON EXISTING GROUNDWATER USERS

Whilst the study area is not part of a Prescribed Well Area (PWA), which has Water Allocation Plans (WAPs) that provide documented guidelines and policies for abstraction and injection of groundwater, DWLBC would give consideration to the potential impacts of a proposed ASR project before issuing well and drainage permits.

The location of current groundwater users within the study area is not well known; the last detailed census was conducted in the mid-1980s (Edwards, Earl & Mathews 1987). The results of this census are summarily shown in Figure 10 and in detail as Appendix A. Both the T1 sedimentary aquifer and the FRA are shown, as the two aquifers may be in direct hydraulic connection (and hence injection into the FRA may impact upon the T1 aquifer) and because a T1 aquifer user may potentially be a future FRA ASR proponent.

The potential impacts of any FRA ASR in the study area on surrounding groundwater users could be highly variable if the aquifer displays a strong structural control with relatively high transmissivity and limited storage. If another FRA groundwater user is relatively close (say even tens of metres) to the proposed new ASR site, but is actually located on a separate structure system, then there may be little or no impacts. However, if an another groundwater user exists on the same structure for which the new ASR is proposed, then groundwater level changes impacts may be noticed at considerable distance from the ASR well (many hundreds of metres). Such cyclic groundwater level rises may not be adverse unless artesian groundwater levels are induced in a confined aquifer setting, which is probably only possible in wells located very close to the ASR project (tens of metres).

Exclusion zones of 500 m radius have been nominated in Figure 10 around existing FRA ASR operation wells. These zones would provide a buffer against possibly adverse interference of groundwater levels between two nearby ASR projects. The actual shape and size of any such buffer zone in FRAs could only be realistically defined by field investigations.

7.1.2 INCREASED WATER-TABLE LEVELS

As outlined by Hodgkin (2004) and earlier workers, ASR injection into unconfined aquifers with shallow water tables presents a risk of potential adverse impacts that include:

- water logging and salinisation of the shallow subsurface profile
- unwanted discharge of water at the ground surface
- damage to built infrastructure due to water-table rise affecting foundations and footings.

Unconfined, or semi-confined conditions for the FRA within the study area occur in several areas, notably along the HFZ, the upper reaches of the TRV, and northern parts of the study area where the overlying sediments are unsaturated, thin or absent. These areas are not automatically unsuitable for FRA ASR as it depends on the depth of the actual aquifer interval and the degree of confinement. Shallow aquifer intervals in these parts of the study area should be evaluated with a strong degree of caution to establish the nature of the aquifer and the true potential for adverse impacts from any significant rises induced upon a shallow water table. Deeper aquifer intervals in these parts of the study area will probably not be of a concern as they may be isolated from the shallow water table aquifer and be of a strongly confined nature.

7.1.3 SIZE OF FRA ASR PROJECTS

The potential size of individual FRA ASR projects in the study area may be relatively limited compared to other ASR projects in sedimentary aquifers within the Adelaide region. The four existing FRA ASR projects in the study area inject between 15 and 110 ML/y, typically of the order of 40–60 ML/y, compared to the typical injection volumes of 600–750 ML/y associated with some of the larger T1 and T2 ASR projects at Morphettville Racecourse and Edinburgh Park.

New FRA ASR projects within the study area are expected to be of a similar order of magnitude to the current FRA ASR operations, certainly not much larger. This expectation is based on the conceptualisation of most FRAs being of the fracture-zone subtype with relatively high transmissivity and low storativity. Such sites may permit relatively high injection rates but the effective injection volume may be limited by the low storage potential, causing large groundwater level rises within short timeframes. The combination of high transmissivity and low storativity may also enable significant migration of the injected freshwater plume during the dormant phase between injection and recovery, which would adversely impact the recovery efficiency of the project, especially if the required end-use water quality is high and the site has relatively high native salinities.

7.1.4 WELL COMPLETION

Open-hole well completions in the aquifer interval are expected to be possible in virtually all potential FRA ASR projects in the study area as a result of the consolidated and competent nature of the bedrock types. Such well completions are preferred in general terms for ASR as it maximises the well efficiency, removes the potential for clogging of slotted casing or wire-wound screens, and reduces the potential time required for back-pumping or redevelopment of the injection well.

FRAs in the study area may also be suitable for enhancement of injection well efficiency by hydro-fracturing or acidification (if the bedrock has any significant carbonate content associated with the fracture zones). Such enhancements may reduce the amount of pre-treatment of source water needed, in turn potentially saving costs or land area.

7.1.5 NATIVE GROUNDWATER SALINITY

Much of the study area is suitable for ASR projects with low TDS requirements, as the native groundwater salinities are fresh or brackish. About 61% of the area is <3000 mg/L TDS, while only ~22% of the area is >5000 mg/L TDS. Much of the potentially unsuitable +5000 mg/L TDS groundwater occurs in an area of relatively thick sedimentary cover, which is itself a potential ASR negative.

Sub-3000 mg/L TDS is considered an important level (Hodgkin 2004), as it represents the approximate limit at which recovered water remains below 1000 mg/L TDS assuming that:

- injected water is required within the same irrigation season, with no significant build up of a freshwater plume to act as a buffer zone in subsequent recovery periods
- injected water salinity of ~300 mg/L TDS
- recovery efficiency of 75%
- the end uses for recovered water require potable TDS levels, such as turf irrigation or horticulture.

7.1.6 DEPTH TO AQUIFER

The depth of sedimentary cover above bedrock is only significantly high in the southern parts of the study area to the west of the Eden–Burnside Fault system, where it increases in a southeasterly direction to up to ~280 m near Torrens Park and Clapham (Fig. 4b).

Areas where the depth to bedrock exceeds ~150–200 m are considered to have reduced potential for FRA ASR in terms of aquifer transmissivity, storativity and salinity. In addition, deep wells may reduce the ASR potential as result of the increased cost of drilling and constructing injection and monitoring wells.

7.1.7 DEPTH TO GROUNDWATER

As outlined in Section 6.2, the depth to groundwater is quite variable throughout the study area, which would influence the effective injection volumes and choice of injection method (gravity or pressure injection).

In areas where the depth to the water table (unconfined aquifer) or potentiometric surface (confined aquifer) is high, the project may attain the required injection volume by gravity drainage of source water into the well alone (with the option of pressure injection also still available). Where groundwater levels are very shallow, the only option for attaining sufficient injection volumes will be by pressure injection.

7.1.8 STRUCTURAL GEOLOGY

The greatest potential for establishing FRA ASR projects in the study area is within the Fracture Zone aquifer types, predominantly below the limit of weathering. However, the accurate delineation of all such bedrock structures beneath sedimentary cover is not possible with the datasets available. That said, the major Eden–Burnside and Hope Valley Fault systems represent high-priority areas for further investigations, as does the potential structural corridor associated with the present-day TRV and the Tertiary Golden Grove palaeochannel.

The favourable structural corridors shown in Figure 10 are acknowledged as gross simplifications of what is expected to be a complex structural geological setting that would be influenced by the competency contrast between interbedded sedimentary rocks and pre-Tertiary folding and faulting associated with the Delamerian Orogeny. The complex distribution of rock types and fault structures within the western Mount Lofty Ranges is shown in Figure 3. A similar level of complex distribution is expected beneath sedimentary cover of the GGE.

7.1.9 INVESTIGATION TECHNIQUES

The identification of unmapped structures beneath sedimentary cover within the study area represents a costly challenge. The commitment to drill and construct water wells at sites where there is little or no supporting information is relatively high risk and high cost. However this approach may be preferred if the ASR proponent has a relatively limited land holding or search area available. If a large search area is involved, or if multiple potential ASR sites are to be investigated, then broader scale subsurface mapping should be considered prior to committing to installation of water wells.

Geophysical survey techniques may be useful in estimating the location and depth of buried geological structures. Advice should be sought from PIRSA staff to establish if any high-resolution land-based gravity or magnetic surveys may be useful. Another potential geophysical application is Controlled Source Audio-Frequency Magnetotellurics (CSAMT), which DWLBC is about to trial in a buried FRA water supply project at Nepabunna in the Northern Aboriginal Lands of South Australia in partnership with Zonge Engineering on behalf of SA Water. This technique has found application in the delineation of geological structures at depths ranging from 20–2000 m, largely for the mineral exploration industry. The technique uses large transmitter and receiver arrays which, along with the presence of significant electromagnetic sources in the urban environment, may not prevent or limit its application in the study area. However, it is recommended that the AMLR NRM Board keep in contact with DWLBC regarding the results of the Nepabunna project.

Reconnaissance drilling, either in conjunction with the results of geophysical surveys or as a stand-alone option before installation of water wells, should also be considered. The cheapest form of reconnaissance drilling is narrow-diameter (75–100 mm) air core or rotary-air-blast (RAB) holes. However, this drilling is generally confined to small drilling rigs that may not be able to drill much below 100 m, and have limited ability to penetrate significant hard bedrock intervals. RAB drilling by hammer is preferable for aquifer yield measurements and bedrock penetration but may not be feasible in areas where sedimentary cover is thick and/or unconsolidated. Such areas occur in large parts of the study area, in which the conventional drilling approach often involves use of a water well rig to drill and case the sedimentary cover using mud-rotary drilling, and then undertake RAB drilling below the casing, usually at a minimum of 150 mm hole diameter. This is relatively expensive and is basically the full cost of a water well. A compromised reconnaissance drilling method may be use of conventional mineral industry reverse circulation (RC) rigs, which would use rotary air drilling by hammer to produce representative drill cuttings from hole diameters of ~100–125 mm to depths beyond 200 m if required. Aquifer yields during drilling by this method are suppressed and often misleading; the identification of FRA intervals requires close consideration of the drill cuttings, drilling penetration rates and other drilling indicators.

7.2 FRA ASR ZONES

The study area has been subdivided into eight categories or zones of FRA ASR potential based on key hydrogeological criteria as outlined in Table 2. The spatial distribution of the ASR zones is shown in Figure 10.

Table 2. FRA ASR Zones

ASR potential	Zone number	Criteria
Higher ↑	1	Native groundwater salinity <3000 mg/L TDS and area within 500 m of major structure zone(s)
	2	Native groundwater salinity <3000 mg/L TDS and area beyond 500 m of major structure zone(s)
	3	Native groundwater salinity 3000–5000 mg/L TDS and area within 500 m of major structure zone(s)
	4	Native groundwater salinity 3000–5000 mg/L TDS and area beyond 500 m of major structure zone(s)
	5	<10 m of sedimentary cover and groundwater level <10 m below ground
	6	<10 m of sedimentary cover and ground surface slope steeper than 1:10
	7	Sedimentary cover >150 m
↓ Lower	8	Native groundwater salinity >5000 mg/L TDS

The ASR zones are relatively self-explanatory but require the following points of clarification if the spatial patterns are to be used further in future FRA ASR on-ground investigations:

- Not all possible combinations of the different hydrogeological criteria are used in defining the eight categories. For example, within the +5000 mg/L TDS area, there would be parts considered less suitable than others, i.e. those sub-areas where sedimentary cover is <150 m and within 500 m of a structure corridor would be preferable to those remaining areas where depths to sediment is >150 m and distance to a structure corridor >500 m where the potential for adverse impacts from ASR development in shallow FRAs are greater.
- Native groundwater salinity would not be as significant a variable to ASR projects that do not have low TDS end-use requirements.
- Structure corridors — an arbitrary 500 m buffer from a known or inferred fault zone trace has been used to define favourable target areas, which would have a variable accuracy. An example of this is the southern parts of the Eden–Burnside Fault system, where the 'displacement' of bedrock to the west of the true fault is significant. Thus, drilling in part of a favourable Type 1 zone may not intersect bedrock at the interpreted FRA depth. Selection of any future drilling targets should also consider the individual well and structural datasets shown in Figures 3–9.

- The Type 5 and 6 zones do not reflect areas that should be avoided from further consideration. Rather, they are intended to highlight areas where the potential for adverse impacts from ASR development in shallow FRAs are greater. However, these areas may also host deep confined aquifer intervals that may prove to be suitable ASR sites without risk of detrimental near-surface effects such as waterlogging and discharge, soil salinisation and damage to infrastructure.
- The boundaries of each zone are strongly influenced by the accuracy of the contouring of the individual datasets. As highlighted earlier, each contoured surface is only approximate so the zone boundaries shown in Figure 10 cannot be regarded as highly accurate.

7.3 SITES AND EXISTING WELLS RECOMMENDED FOR FURTHER INVESTIGATION

7.3.1 EXISTING WATER WELLS

Initially, all sites with yields >4 L/s were extracted from the dataset displayed in Figure 9. This produced 50 records within the study area, which were refined by eliminating sites that:

- occurred outside of Type 1 or 2 ASR zones
- have casing diameters <100 mm
- appear in SA_Geodata as abandoned or backfilled
- occur within 500 m of existing FRA ASR injection wells
- appear to be private or domestic wells based on visual examination of the recorded well position well against GIS coverages of aerial photography and land ownership.

As a result of applying the above criteria, 12 wells have been short-listed for possible aquifer testing; these are displayed in Figure 10. Summary details are presented in Table 3, and full details, including land ownership as indicated from a 2005 GIS coverage provided by the AMLR NRM Board, are included as Appendix B.

Well number 662812311, although listed with a yield of only 3 L/s, has been included, as it has other favourable ASR potential criteria. This well is part of the Cadbury Schweppes operations in Payneham, and occurs in a favourable ASR Zone (Type 2) very close to Third Creek. In the 1982–84 period, the average annual abstraction was ~160 000 kL, which suggests that the well may be capable of a yield higher than 3 L/s.

Well 662809072 was listed as a T1 well by Edwards, Earl and Mathews (1987). The original drilling log from 1972 could not be found; however, the well was deepened in 1994 from 64–73 m and intersected slate in this interval with an airlift yield at 73 m of 6 L/s. Cased below 21 m, the well is expected to be fully producing from the FRA.

The selection of any of these wells for aquifer testing should consider the ASR sites recommended in Section 7.3.2, as seven of the existing wells are within several hundred metres of sites considered suitable from the perspective of proximity to source water, land availability and potential water demand.

The SA_Geodata database indicates that none of these wells have previously been aquifer tested.

Table 3. Existing FRA Wells Recommended for Possible Aquifer Testing

Unit No.	Land owner	Date drilled	Production interval (mbgl)	Minimum casing diameter (mm)	Yield (L/s)	Approximate groundwater level (mbgl)	Salinity (mg/L TDS)
662809702	Corp. of the City of Campbelltown	12/14/72	21.3–73	127	8.8	12	1384
662810005	Christian Brothers Inc.	10/23/76	75.2–111	150	5.0	20	1468
662810007	Minister for Human Services	2/24/70	36.3–64	152	10.1	15	835
662812058	St Peters Collegiate Girls School	10/27/82	276.9–287	152	9.0	105	973
662812311	Cadbury Schweppes Pty Ltd	6/17/83	103–152	150	3.0	17	792
662813651	P & HJ Martino	4/30/86	54.8–98?	152	8.8	16	2409
662813652	SA Water Corp.	5/2/86	25.7–154	203	4.0	0	2278
662815256	CSR Ltd	11/16/90	39.1–146	155	10.0	31	3609
662815439	Corp. of the Town of Walkerville	11/15/90	60–90	203	25.0	11	860
662821610	Manresa Soc Inc.	1/28/04	52–140	158	12.5	38	2631
662822151	Corp. of the City of Adelaide	3/10/05	174–192	155	8.0	18	3110
662822152	Governors of the Botanic Garden	3/8/05	115–186	100	9.0	3	2700

Note: mbgl = metres below ground level
mm = millimetres
well unit numbers in italics correspond to known groundwater uses from the 1982–84 census.

7.3.2 POTENTIAL FRA ASR SITES

A qualitative assessment of all landholdings within Type 1 ASR zones was undertaken to generate a listing of sites where the potential for development of FRA ASR operations is considered relatively high.

Only Type 1 zones were assessed to maximise the hydrogeological suitability of derived targets. The landholdings or sites selected were all those considered to have the combined criteria of:

- proximity to a water source, as defined by a natural or modified water course or a stormwater pipe >0.5 m in diameter
- an open-land area of at least ~1 ha
- a potential irrigation water demand based mainly on the nearby presence of sports grounds and public reserves.

Twenty-eight sites were defined and are shown in Figure 10. Summary details are presented in Table 4 and additional details in Appendix C. The 28 sites are considered as a first-pass screening and not a rigid listing of all potential FRA ASR projects within the study area. Much of the development of future FRA ASR projects is expected be driven by the physical locations of the individual proponents, that may well be outside of the Type 1 ASR zones.

Table 4. Potential FRA ASR sites

Site number	Site name	Water source	Land owner
1	Mitcham Reserve	Stream	Unknown
2	Urrbrae Agricultural High School	Pipe	Minister for Education and Childrens Services
3	Waite Arboretum	Pipe	Distribution Lessor Corp.
4	Ridge Park Reserve	Stream or pipe	Corp. of the City of Unley
5	Langman Reserve	Stream	City of Burnside
6	Hazelwood Park	Stream	City of Burnside
7	Ferguson Park	Stream	Minister for Environment and Conservation
8	Penfolds Winery	Pipe	Southcorp Wines Pty Ltd
9	UniSA Magill Campus	Stream or pipe	Distribution Lessor Corp.
10	Gums Recreation Ground	Stream	Corp. of the City of Campelltown
11	Kensington Oval	Pipe	City of Burnside
12	Rostrevor College	Stream	Christian Brothers Inc.
13	Leabrook Drive Reserve	Stream	Corp. of the City of Campelltown
14	Market Garden	Pipe	Borrillo
15	Wadmore Park	Stream	Corp. of the City of Campelltown
16	River Torrens # 1	Stream	Minister for Transport and Urban Planning
17	CSR Quarry	Stream	CSR Ltd
18	Thorndon Park Reserve	Reservoir or pipe	Corp. of the City of Campelltown
19	River Torrens # 2	Stream	Unknown
20	River Torrens # 3	Stream	Corp. of the City of Campelltown
21	Botanic Gardens	Stream	Govenors of the Botanic Garden
22	St Peters River Park	Stream	Corp. of the City of Norwood Payneham and St Peters
23	River Torrens # 4	Stream	Minister for Infrastructure
24	Felixstow Reserve	Stream	Corp. of the City of Norwood Payneham and St Peters
25	Lochiel Park	Stream	SA Water Corp.
26	Campbell Memorial Oval	Stream	Corp. of the City of Campelltown
27	Lyons Road Reserve	Stream	City of Tea Tree Gully
28	Hope Valley Reservoir	Reservoir	SA Water Corp.

Land ownership at most of the 28 sites appears to be held by government agencies or private business, which may be preferable for ASR development.

8. CONCLUSIONS AND RECOMMENDATIONS

Key findings and conclusions from the desktop evaluation of the FRA ASR potential of the study comprise:

1. Currently there are four ASR operations within the study area (Northgate, Regent Gardens, Torrens Valley Sportsfield and Scotch College) injecting a combined volume of 135–250 ML/y into FRA.

2. The study area is underlain and adjoined by predominantly fine-grained metasedimentary rocks of the Adelaidean Burra and Umberatana Groups, notably shale, siltstone and slate of the Saddleworth Formation, Belair Subgroup and Tapley Hill Formation.

3. The structural geology of the Adelaidean basement beneath the GGE is likely to be quite complex, no less so than the outcropping areas in the western Mount Lofty Ranges, and cannot be highly resolved by this study.

4. Review of existing drillhole and water well records indicates that the most significant FRA settings in the study area are related to structurally discrete fracture zones, often within unweathered and quartz-veined slate. Such zones are considered most likely to occur within three major south-southwest-trending structural corridors; the Eden–Burnside and Hope Valley Fault systems and a corridor aligned with both the present-day TRV and the older Golden Grove palaeochannel.

5. The main FRA targets are considered likely to display relatively high aquifer transmissivities and low storativities, which may limit the ultimate injection volumes of individual projects to typically below 100 ML/y.

6. The potential impacts of developing FRA ASR schemes are quite variable and depend strongly on the orientation and continuity of the fracture zone(s), depth of the aquifer interval and depth to groundwater. Other groundwater users, even if close by, may not be affected if they are not 'co-located' on the same fracture zone(s). The knowledge of current groundwater use, from FRA or sedimentary aquifers, is poor — the last significant census of groundwater use concluded in 1984.

7. Caution should be applied in target areas where the aquifer interval and groundwater levels are shallow and the land surface is steep. Such combinations may result in soil salinisation, water discharge at surface or damage to the foundations of built infrastructure.

8. Much of the basement in the study area exhibits positive hydrogeological criteria for the development of FRA ASR, namely native groundwater salinities <3000 mg/L TDS, sediment cover of <150 m and depths to groundwater >10 m.

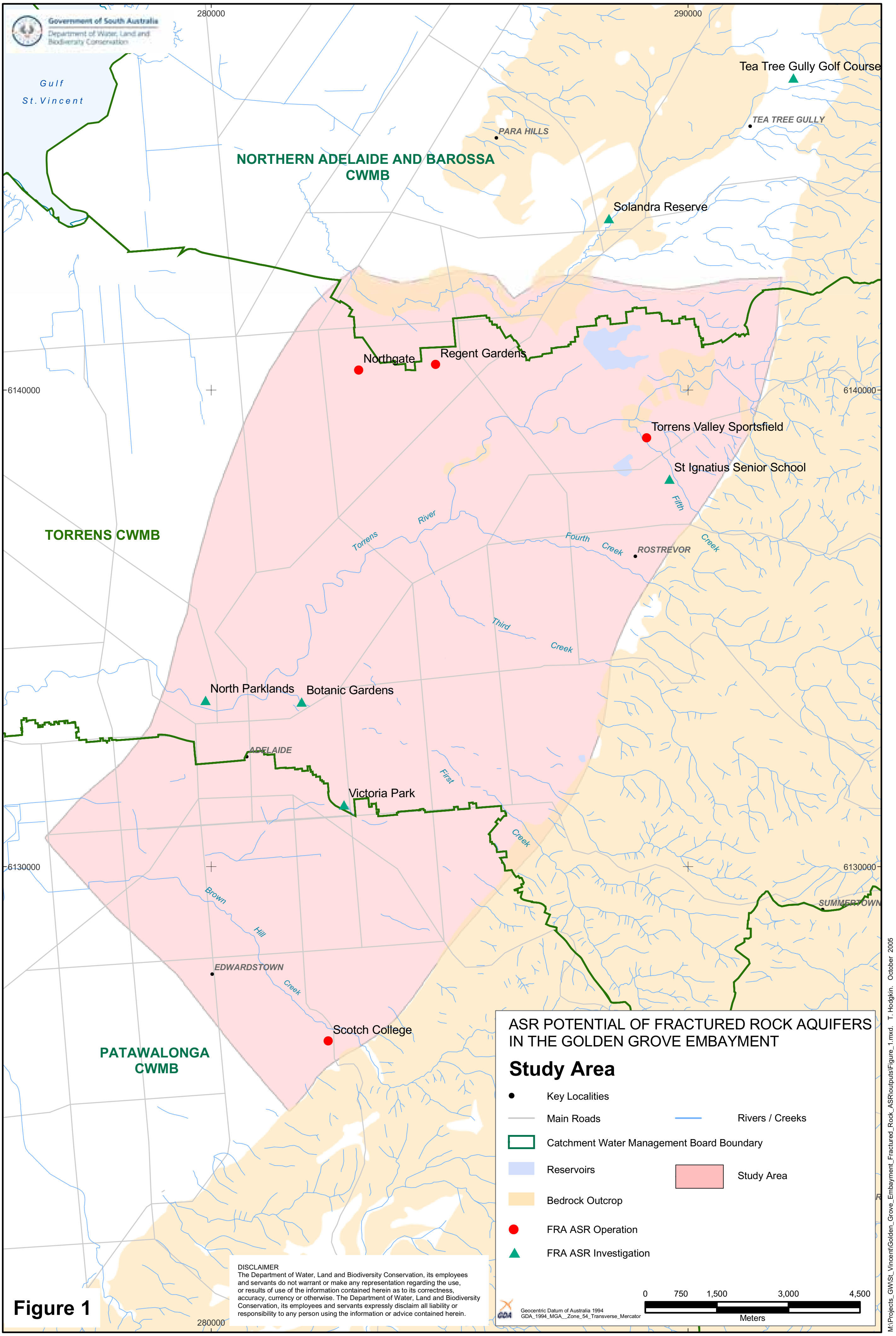
9. Eight categories of FRA ASR potential have been defined and spatially applied to the study area. The highest potential zone (Type 1) is defined as those areas located within 500 m of known or inferred major fracture zones that have groundwater salinities <3000 mg/L TDS.

10. Within Type 1 and 2 ASR zones, a detailed review of relatively high-yielding (>4 L/s) water wells has produced a shortlist of 12 wells considered suitable for further investigation and possible aquifer testing.

11. A qualitative assessment of all landholdings within Type 1 ASR Zones has identified 28 sites considered to have significant FRA ASR potential, based on proximity to source water (from natural streams, stormwater pipes and drains), presence of at least 1 ha of open land, and a likely irrigation water demand (principally based on the presence of sports grounds and public reserves).
12. Seven of the existing wells considered suitable for ASR aquifer testing are located within several hundred metres of the 28 potential ASR sites and could be integrated into any individual site evaluation.

Recommendations for furthering the development of new FRA ASR projects in the study area are:

1. Undertake a census of current groundwater use from the sedimentary T1 aquifer and FRA to identify potential FRA ASR proponents and determine the potential for adverse impacts from specific FRA ASR projects upon existing groundwater users.
2. Integrate the findings of the above with the potential ASR sites and existing water well shortlist from this study to define and prioritise the AMLR NRM Boards future directions in promoting and supporting development of new FRA ASR operations within the study area.


Government of South Australia
Department of Water, Land and Biodiversity Conservation
Gulf
St. Vincent
280000
290000
NORTHERN ADELAIDE AND BAROSSA
CWMB
Tea Tree Gully Golf Course
TEA TREE GULLY
PARA HILLS
Solandra Reserve
Northgate
Regent Gardens
6140000
Torrens Valley Sportsfield
St Ignatius Senior School
TORRENS CWMB
Torrens
River
Fifth
Fourth
Creek
ROSTREVOR
Third
North Parklands
Botanic Gardens
ADELAIDE
First
Victoria Park
Creek
6130000
Brown
Hill
EDWARDSTOWN
SUMMERTOWN
Scotch College
PATAWALONGA
CWMB
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS
IN THE GOLDEN GROVE EMBAYMENT
Study Area
Key Localities
Main Roads
Rivers / Creeks
Catchment Water Management Board Boundary
Reservoirs
Study Area
Bedrock Outcrop
FRA ASR Operation
FRA ASR Investigation
0
750
1,500
3,000
4,500
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Geocentric Datum of Australia 1994
GDA_1994_MGA__Zone_54_Transverse_Mercator
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M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_1.mxd. T. Hodgkin. October 2005

Figure 1

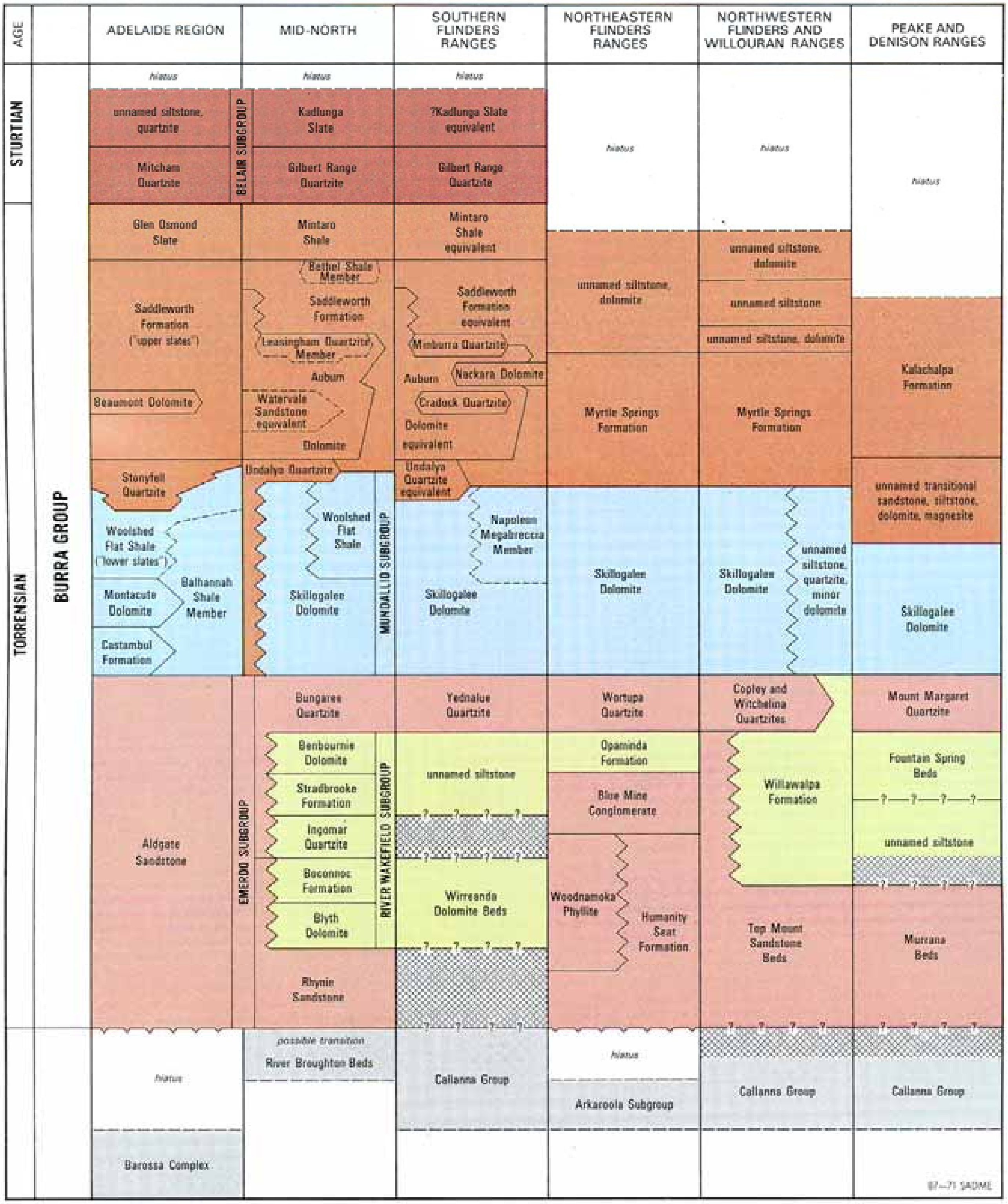
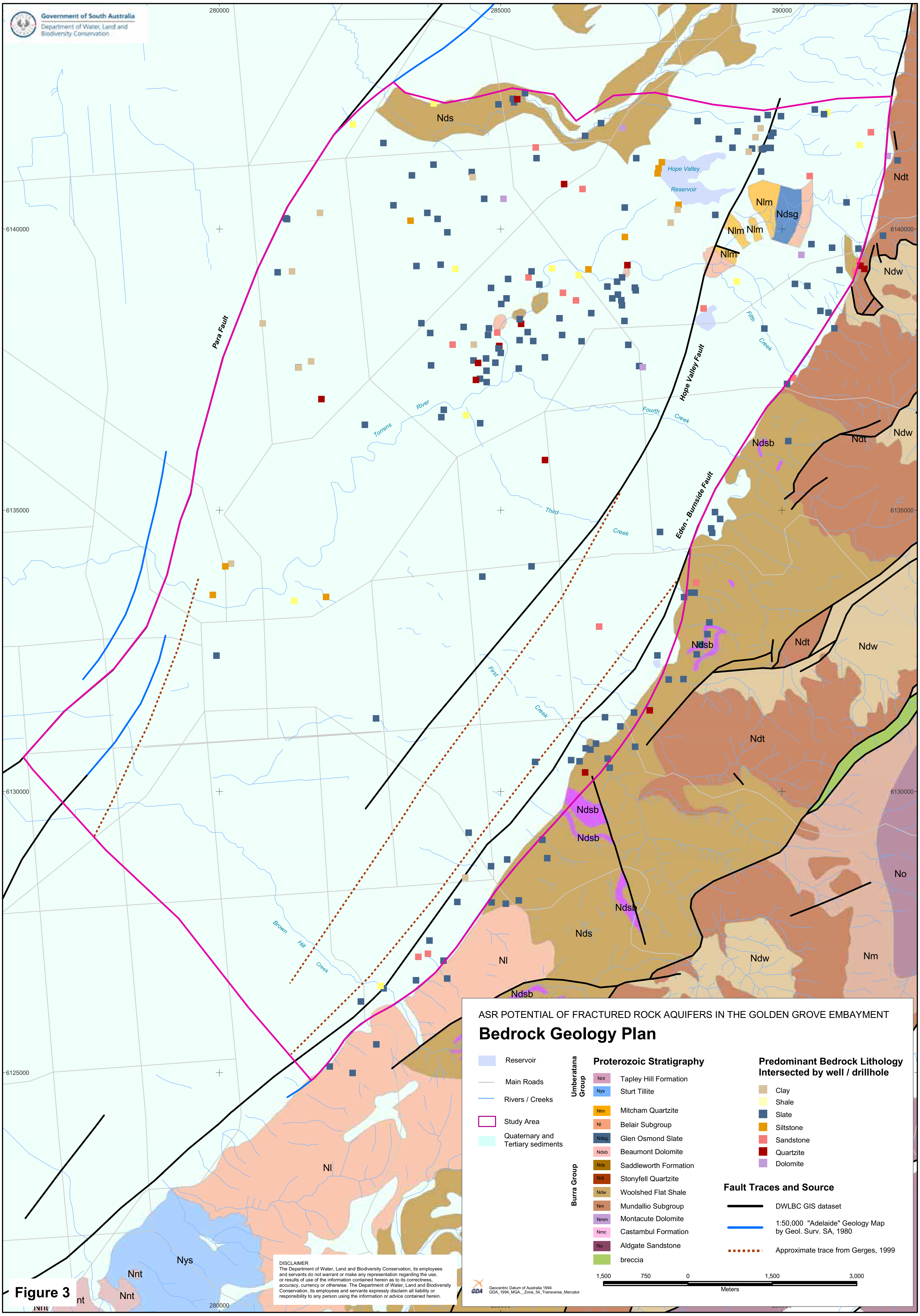


Figure 2. Burra Group stratigraphy of the Adelaide Geosyncline, after Priess 1987


Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Bedrock Geology Plan
Reservoir
Main Roads
Rivers / Creeks
Study Area
Quaternary and Tertiary sediments
Proterozoic Stratigraphy
Umberatana Group
Nnt Tapley Hill Formation
Nys Sturt Tillite
Burra Group
Nlm Mitcham Quartzite
Nl Belair Subgroup
Ndsg Glen Osmond Slate
Ndsb Beaumont Dolomite
Nds Saddleworth Formation
Ndt Stonyfell Quartzite
Ndw Woolshed Flat Shale
Nm Mundallio Subgroup
Nmm Montacute Dolomite
Nmc Castambul Formation
No Aldgate Sandstone
breccia
Predominant Bedrock Lithology Intersected by well / drillhole
Clay
Shale
Slate
Siltstone
Sandstone
Quartzite
Dolomite
Fault Traces and Source
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Approximate trace from Gerges, 1999
1,500 750 0 1,500 3,000
Meters
Geocentric Datum of Australia 1994
GDA_1994_MGA__Zone_54_Transverse_Mercator
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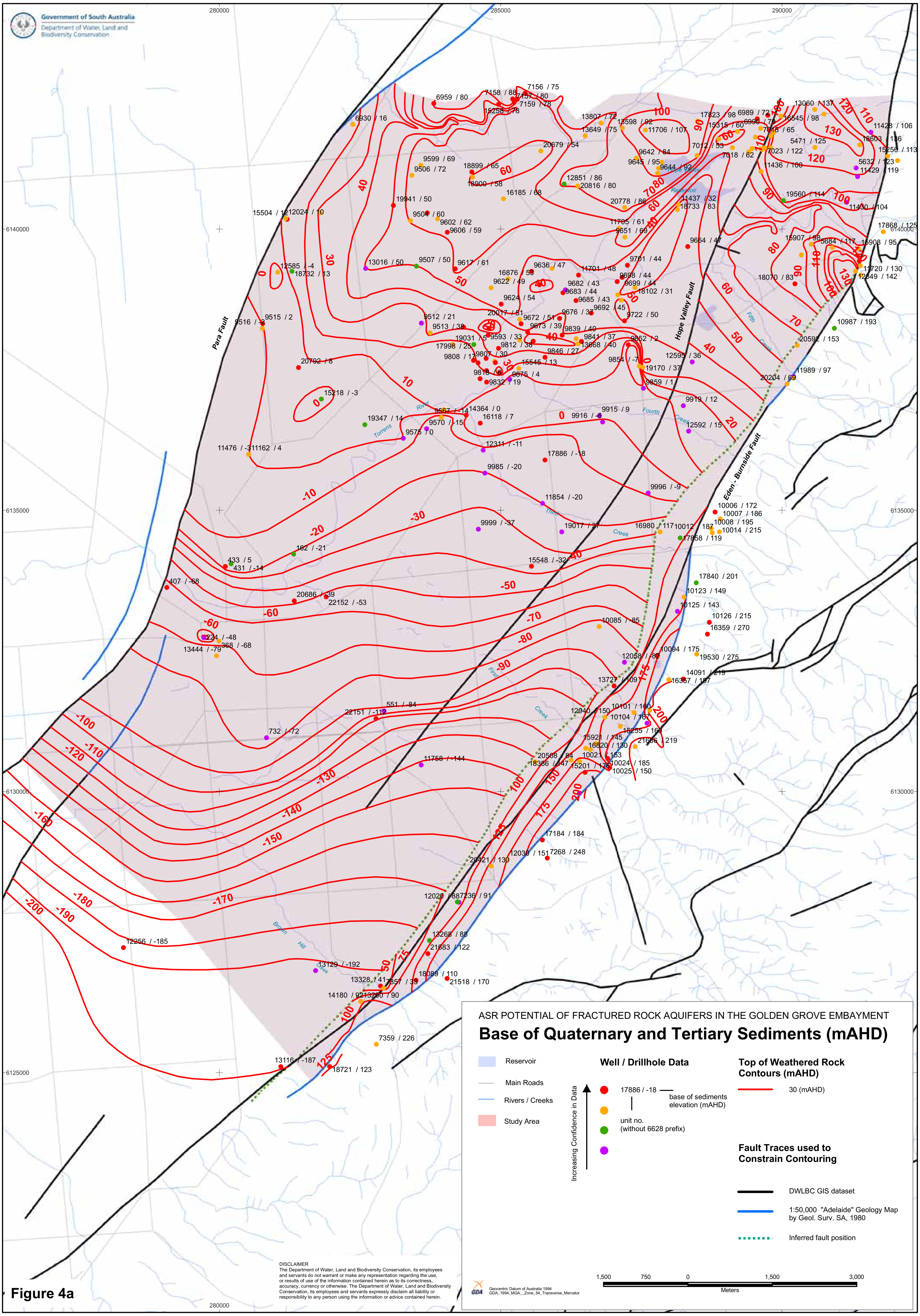
Para Fault
Hope Valley Fault
Eden - Burnside Fault
Hope Valley
Reservoir
Torrens
River
Fifth
Creek
Fourth
Creek
Third
Creek
First
Creek
Brown
Hill
Creek
280000
285000
290000
6140000
6135000
6130000
6125000
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_3.mxd   T. Hodgkin,   November 2005

Figure 3



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ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Base of Quaternary and Tertiary Sediments (mAHD)
Reservoir
Main Roads
Rivers / Creeks
Study Area
Well / Drillhole Data
17886 / -18
base of sediments elevation (mAHD)
unit no. (without 6628 prefix)
Increasing Confidence in Data
Top of Weathered Rock Contours (mAHD)
30 (mAHD)
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
1,500
750
0
1,500
3,000
Meters
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
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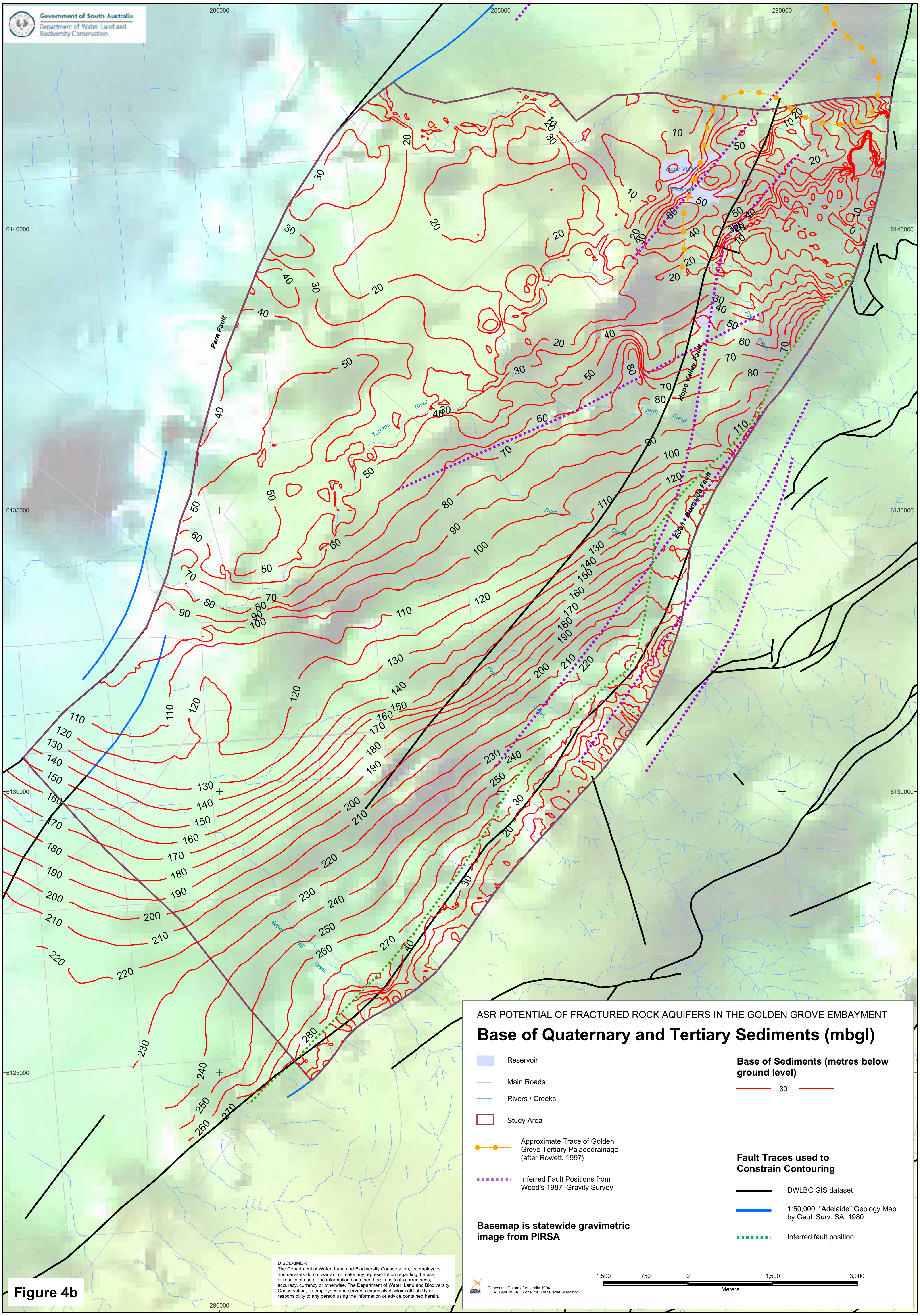
Para Fault
Hope Valley Fault
Eden - Burnside Fault
River Torrens
Third Creek
Fourth Creek
Fifth Creek
First Creek
Brown Hill Creek
280000
285000
290000
6140000
6135000
6130000
6125000
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_4a.mxd T. Hodgkin December 2005

Figure 4a


Government of South Australia
Department of Water, Land and Biodiversity Conservation
280000
285000
290000
6140000
6135000
6130000
6125000
Para Fault
Hope Valley Fault
Eden Burnside Fault
Hope Valley Reservoir
Torrens River
Fourth Creek
Third Creek
First Creek
Brown Hill Creek
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Base of Quaternary and Tertiary Sediments (mbgl)
Reservoir
Main Roads
Rivers / Creeks
Study Area
Approximate Trace of Golden Grove Tertiary Palaeodrainage (after Rowett, 1997)
Inferred Fault Positions from Wood's 1987 Gravity Survey
Basemap is statewide gravimetric image from PIRSA
Base of Sediments (metres below ground level)
30
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
Geocentric Datum of Australia 1994
GDA_1994_MGA__Zone_54_Transverse_Mercator
1,500 750 0 1,500 3,000
Meters
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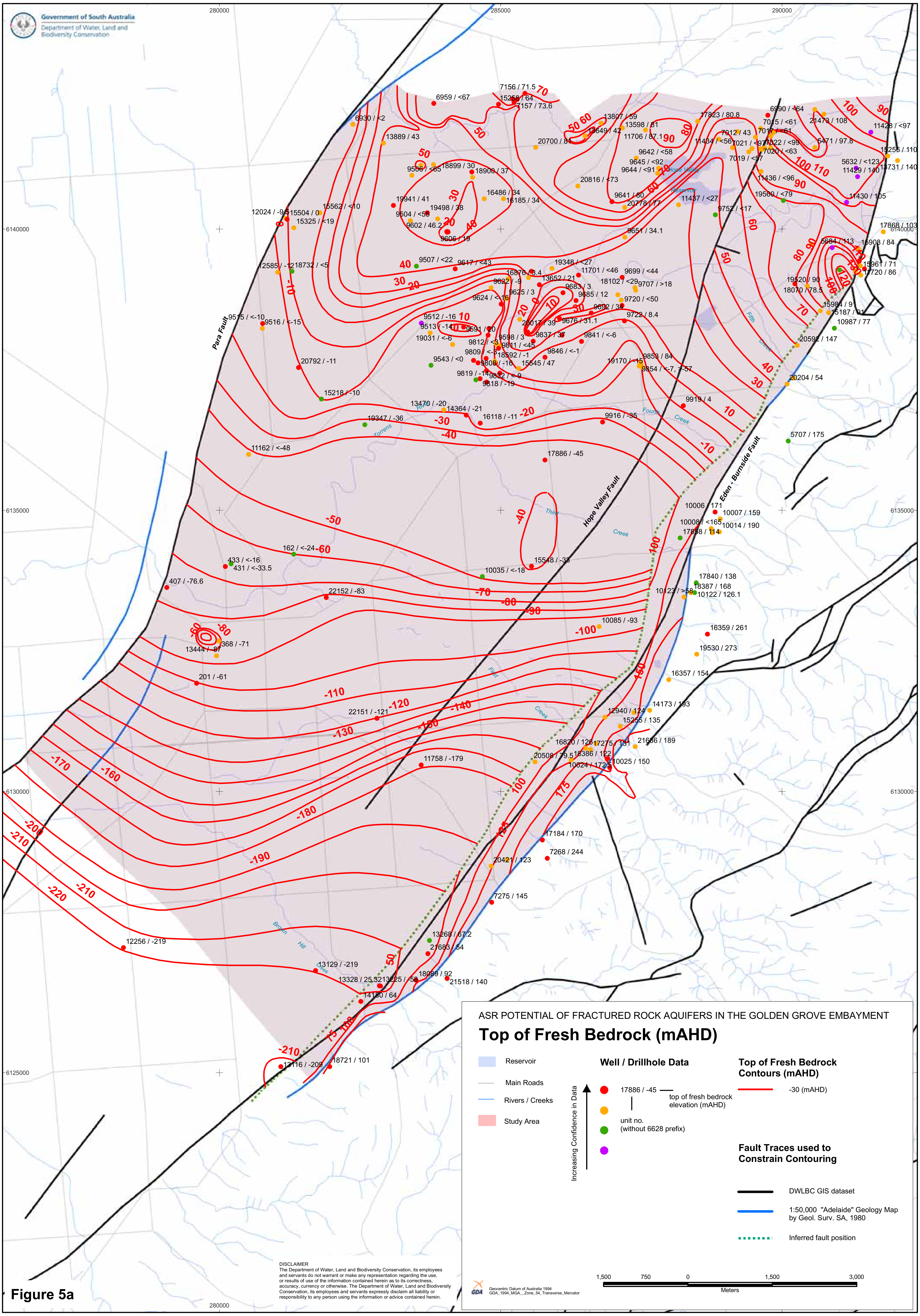
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_4b.mxd. T. Hodgkin. December 2005

Figure 4b


Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Top of Fresh Bedrock (mAHD)
Reservoir
Main Roads
Rivers / Creeks
Study Area
Well / Drillhole Data
17886 / -45
top of fresh bedrock elevation (mAHD)
unit no. (without 6628 prefix)
Increasing Confidence in Data
Top of Fresh Bedrock Contours (mAHD)
-30 (mAHD)
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
1,500
750
0
1,500
3,000
Meters
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
Para Fault
Hope Valley Fault
Eden - Burnside Fault
280000
285000
290000
6140000
6135000
6130000
6125000
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M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_5a.mxd. T. Hodgkin. December 2005

Figure 5a

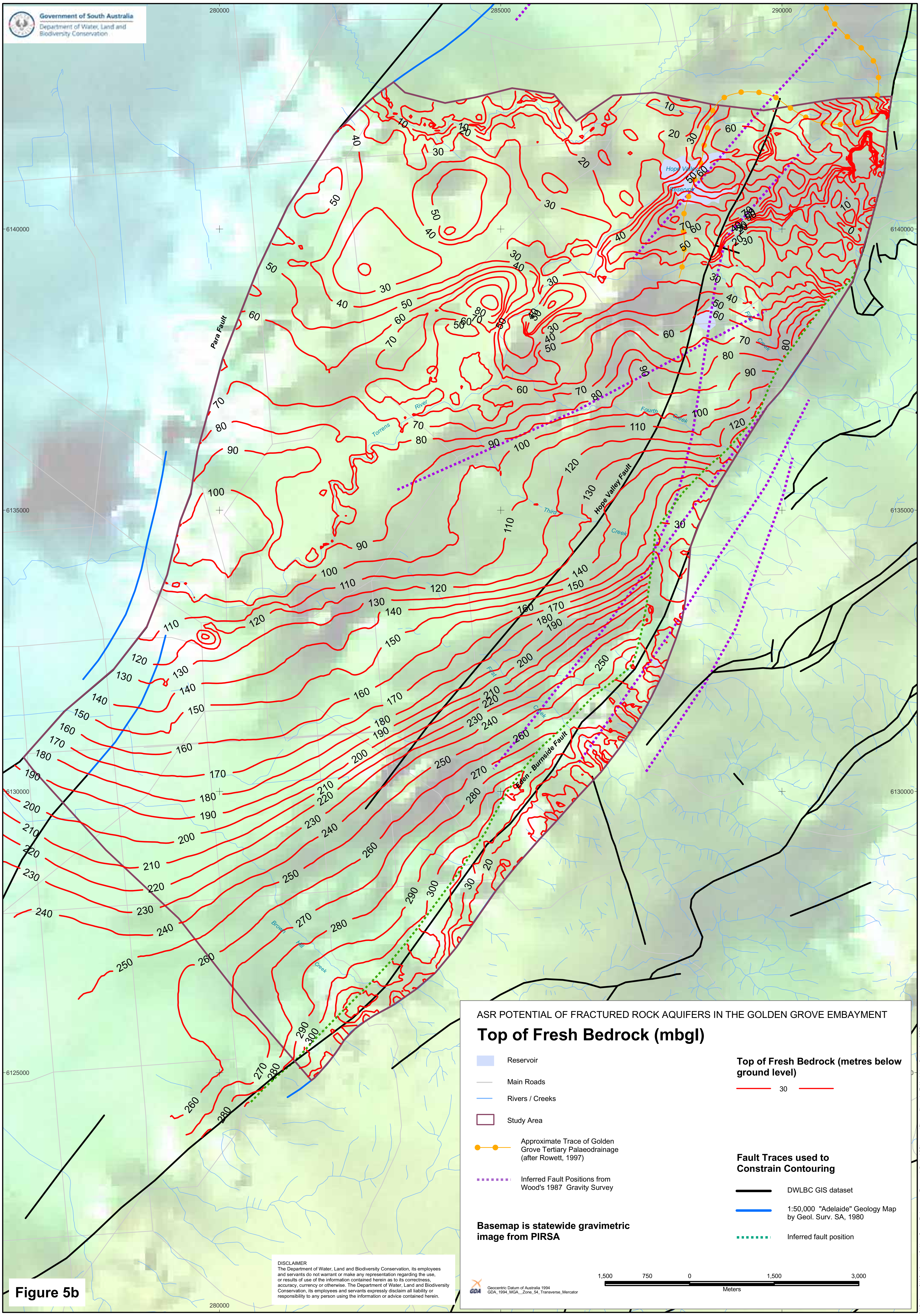

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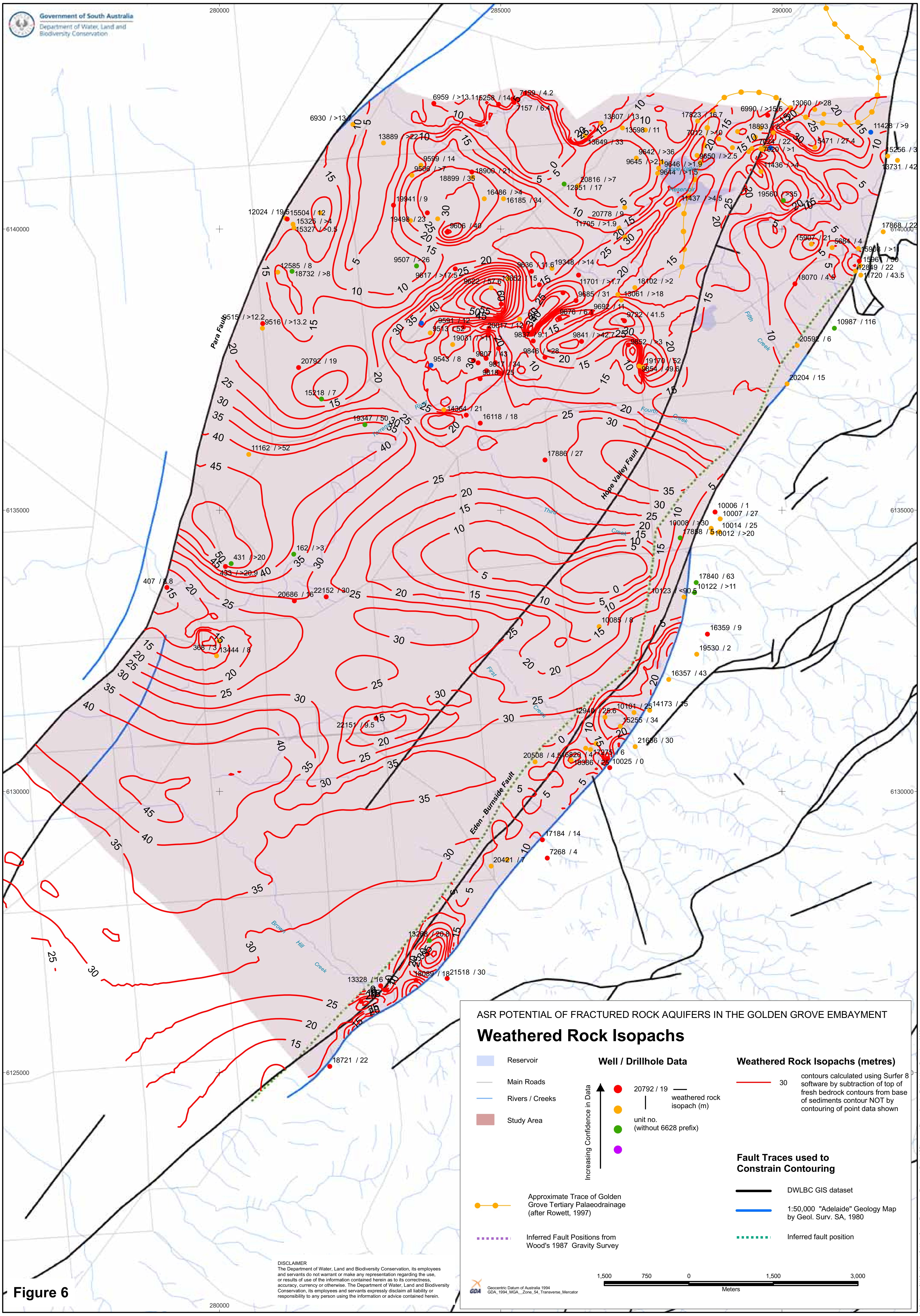
Figure 5b

M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_5b.mxd. T. Hodgkin. December 2005


Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Weathered Rock Isopachs
Reservoir
Main Roads
Rivers / Creeks
Study Area
Well / Drillhole Data
20792 / 19
weathered rock isopach (m)
unit no. (without 6628 prefix)
Increasing Confidence in Data
Weathered Rock Isopachs (metres)
30
contours calculated using Surfer 8 software by subtraction of top of fresh bedrock contours from base of sediments contour NOT by contouring of point data shown
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
Approximate Trace of Golden Grove Tertiary Palaeodrainage (after Rowett, 1997)
Inferred Fault Positions from Wood's 1987 Gravity Survey
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
1,500 750 0 1,500 3,000
Meters
Para Fault
Hope Valley Fault
Eden - Burnside Fault
Fifth Creek
Fourth Creek
Third Creek
First Creek
Brown Hill Creek
280000
285000
290000
6140000
6135000
6130000
6125000
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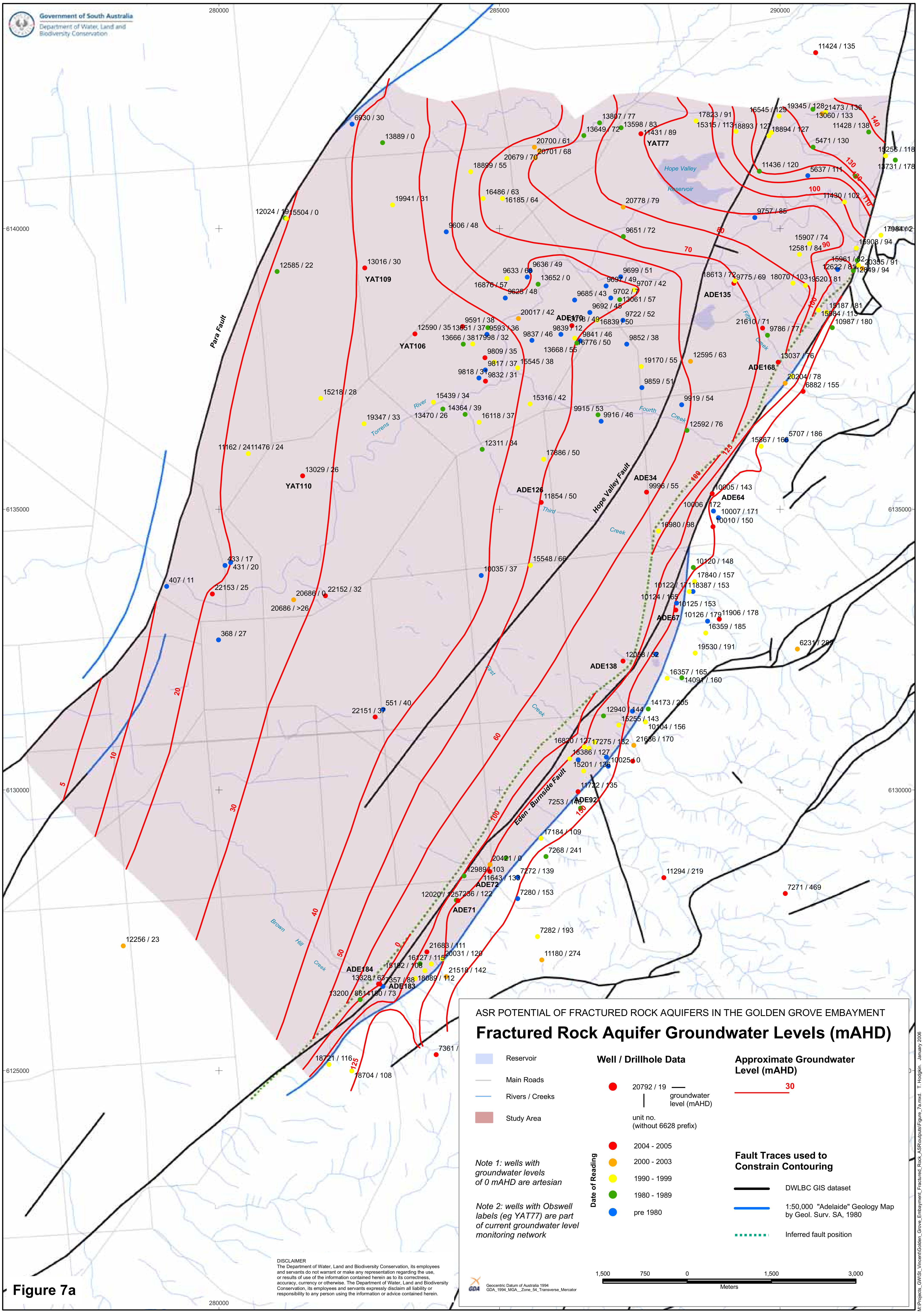
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_6.mxd T. Hodgkin December 2005

Figure 6



Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Fractured Rock Aquifer Groundwater Levels (mAHD)
Reservoir
Main Roads
Rivers / Creeks
Study Area
Well / Drillhole Data
20792 / 19
groundwater level (mAHD)
unit no. (without 6628 prefix)
Date of Reading
2004 - 2005
2000 - 2003
1990 - 1999
1980 - 1989
pre 1980
Approximate Groundwater Level (mAHD)
30
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
Note 1: wells with groundwater levels of 0 mAHD are artesian
Note 2: wells with Obswell labels (eg YAT77) are part of current groundwater level monitoring network
1,500 750 0 1,500 3,000
Meters
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
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Para Fault
Hope Valley Fault
Eden - Burnside Fault
Hope Valley Reservoir
Torrens River
First Creek
Third Creek
Fourth Creek
Fifth Creek
Brown Hill Creek
280000
285000
290000
6140000
6135000
6130000
6125000
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_7a.mxd T. Hodgkin. January 2006

Figure 7a

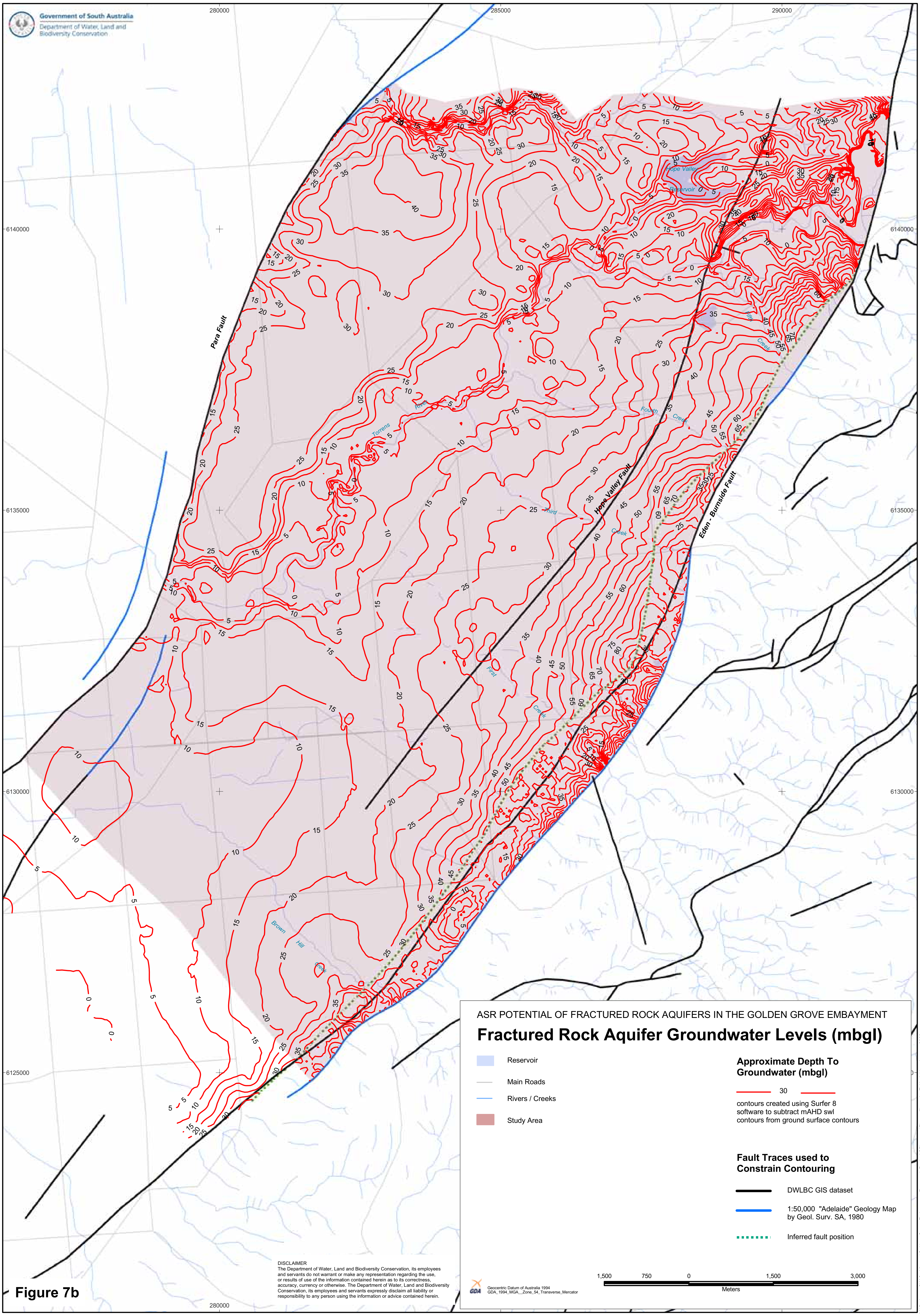
Government of South Australia
Department of Water, Land and Biodiversity Conservation
280000
285000
290000
6140000
6135000
6130000
6125000
Para Fault
Hope Valley Fault
Eden - Burnside Fault
Hope Valley Reservoir
Torrens River
Fourth Creek
Third Creek
First Creek
Fifth Creek
Brown Hill Creek
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Fractured Rock Aquifer Groundwater Levels (mbgl)
Reservoir
Main Roads
Rivers / Creeks
Study Area
Approximate Depth To Groundwater (mbgl)
30
contours created using Surfer 8 software to subtract mAHD swl contours from ground surface contours
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
Geocentric Datum of Australia 1994
GDA_1994_MGA__Zone_54_Transverse_Mercator
1,500 750 0 1,500 3,000
Meters
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Figure 7b

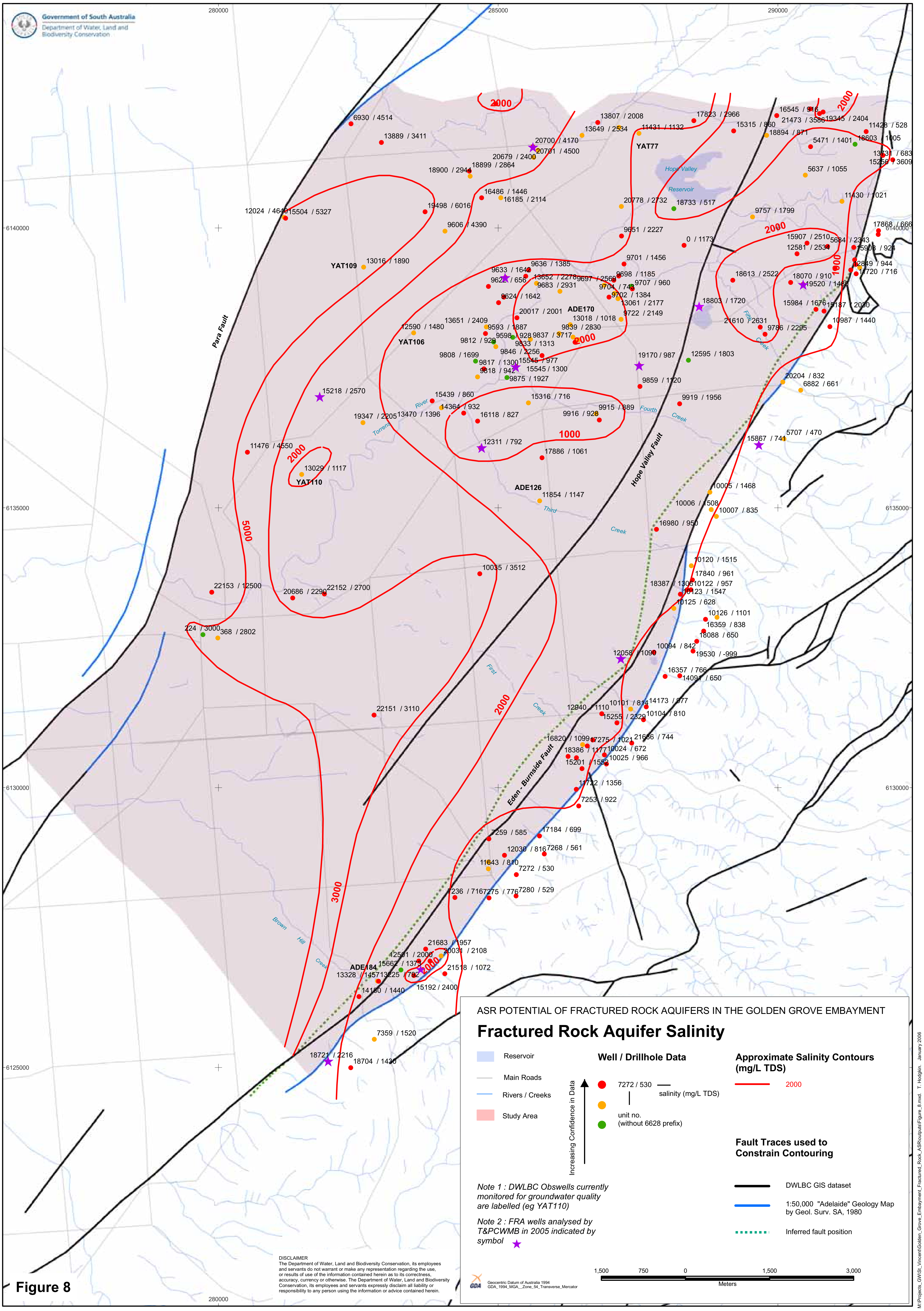
Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
Fractured Rock Aquifer Salinity
Reservoir
Main Roads
Rivers / Creeks
Study Area
Well / Drillhole Data
Increasing Confidence in Data
7272 / 530
salinity (mg/L TDS)
unit no. (without 6628 prefix)
Approximate Salinity Contours (mg/L TDS)
2000
Fault Traces used to Constrain Contouring
DWLBC GIS dataset
1:50,000 "Adelaide" Geology Map by Geol. Surv. SA, 1980
Inferred fault position
Note 1 : DWLBC Obswells currently monitored for groundwater quality are labelled (eg YAT110)
Note 2 : FRA wells analysed by T&PCWMB in 2005 indicated by symbol
Para Fault
Hope Valley Fault
Eden - Burnside Fault
Hope Valley Reservoir
Torrens River
First Creek
Third Creek
Fourth Creek
Fifth Creek
Brown Hill Creek
YAT77
YAT109
YAT106
YAT110
ADE170
ADE126
ADE184
1000
2000
3000
5000
280000
285000
290000
6140000
6135000
6130000
6125000
1,500
750
0
1,500
3,000
Meters
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
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Figure 8

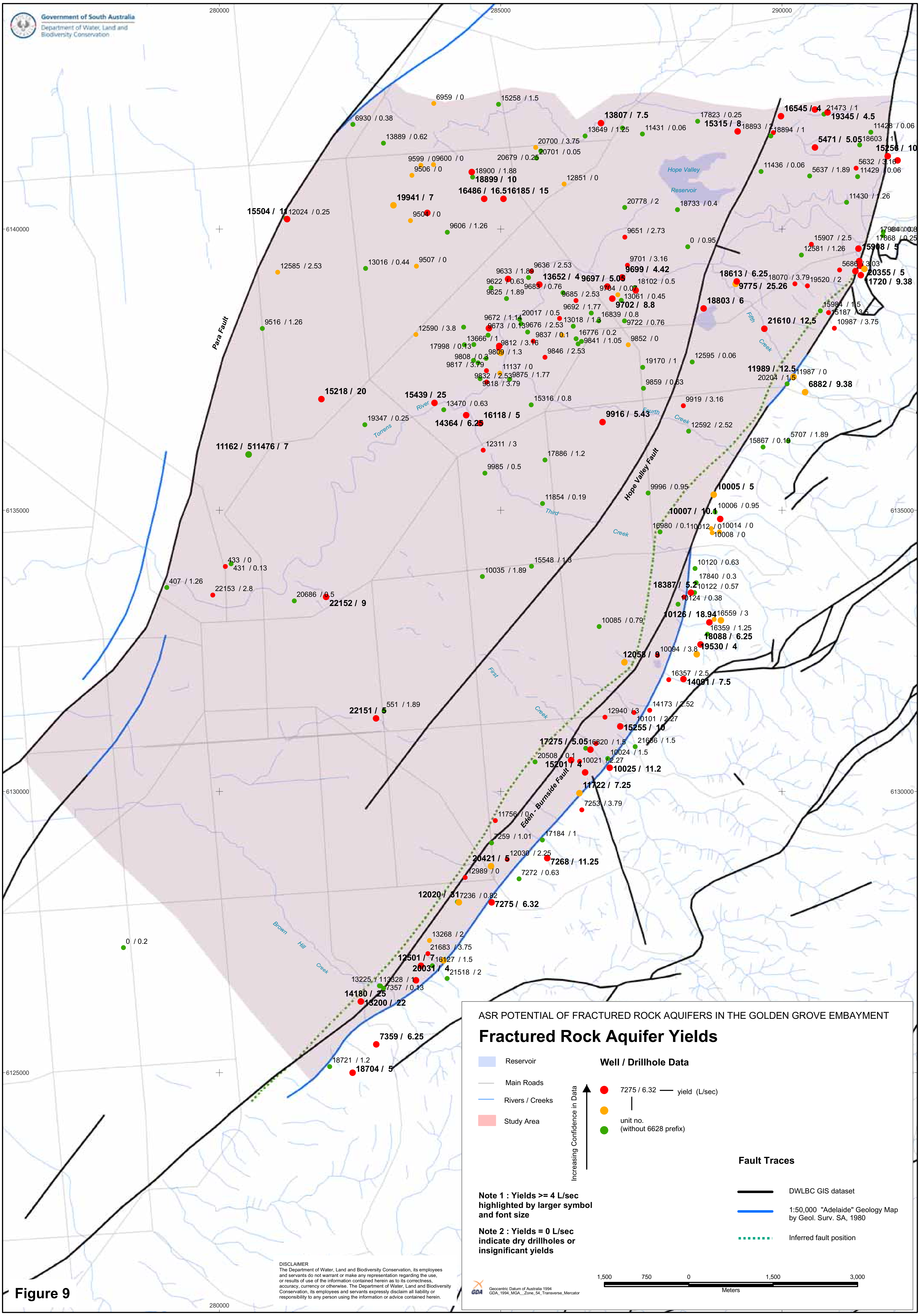

Figure 9

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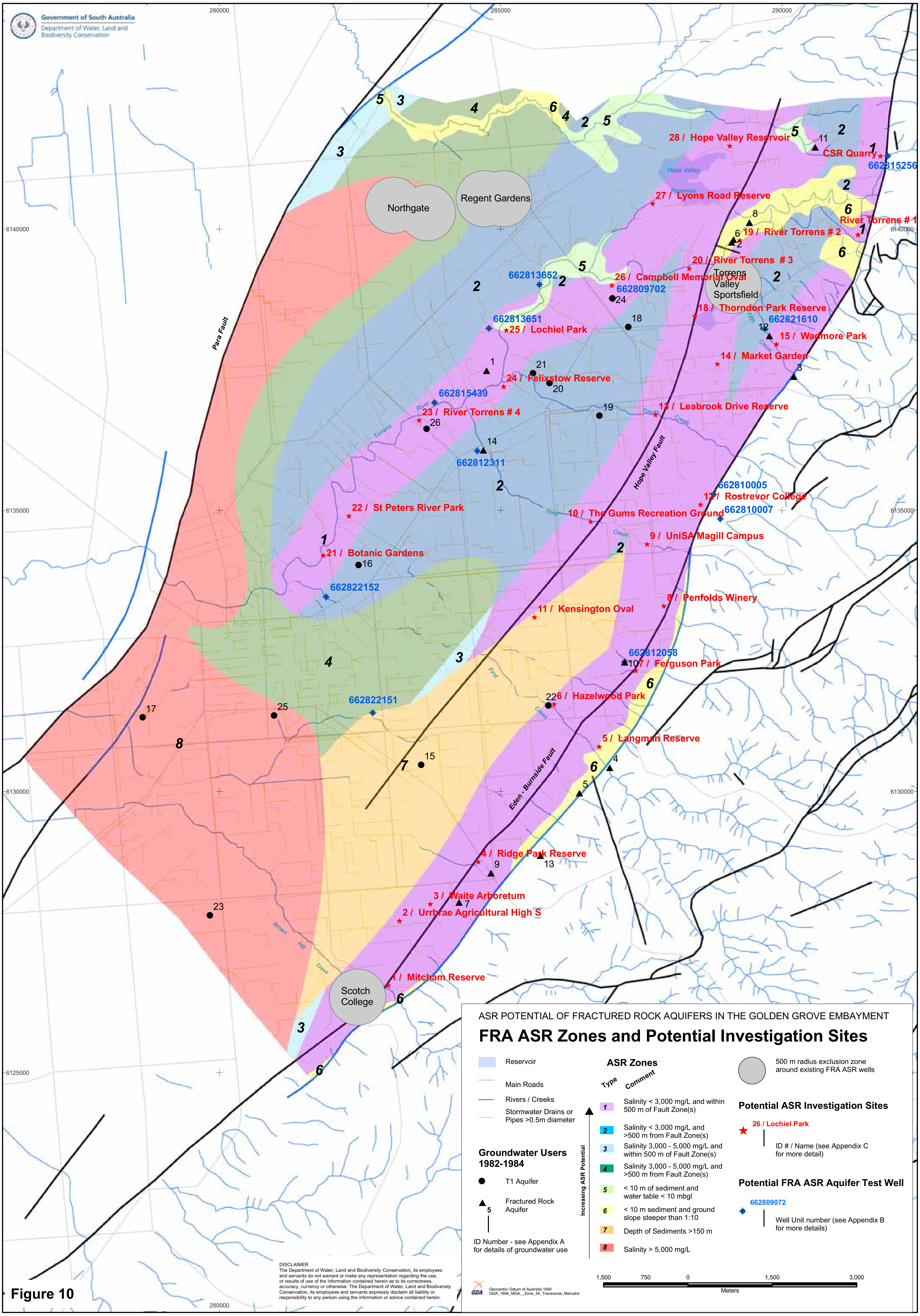

Government of South Australia
Department of Water, Land and Biodiversity Conservation
ASR POTENTIAL OF FRACTURED ROCK AQUIFERS IN THE GOLDEN GROVE EMBAYMENT
FRA ASR Zones and Potential Investigation Sites
Reservoir
Main Roads
Rivers / Creeks
Stormwater Drains or Pipes >0.5m diameter
Groundwater Users 1982-1984
T1 Aquifer
Fractured Rock Aquifer
ID Number - see Appendix A for details of groundwater use
ASR Zones
Type
Comment
Increasing ASR Potential
1 Salinity < 3,000 mg/L and within 500 m of Fault Zone(s)
2 Salinity < 3,000 mg/L and >500 m from Fault Zone(s)
3 Salinity 3,000 - 5,000 mg/L and within 500 m of Fault Zone(s)
4 Salinity 3,000 - 5,000 mg/L and >500 m from Fault Zone(s)
5 < 10 m of sediment and water table < 10 mbgl
6 < 10 m sediment and ground slope steeper than 1:10
7 Depth of Sediments >150 m
8 Salinity > 5,000 mg/L
500 m radius exclusion zone around existing FRA ASR wells
Potential ASR Investigation Sites
26 / Lochiel Park
ID # / Name (see Appendix C for more detail)
Potential FRA ASR Aquifer Test Well
662809072
Well Unit number (see Appendix B for more details)
Geocentric Datum of Australia 1994
GDA_1994_MGA_Zone_54_Transverse_Mercator
1,500 750 0 1,500 3,000
Meters
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Para Fault
Hope Valley Fault
Eden - Burnside Fault
Northgate
Regent Gardens
Torrens Valley Sportsfield
Scotch College
Hope Valley Reservoir
River Torrens
Third Creek
Fourth Creek
Fifth Creek
First Creek
Brown Hill Creek
28 / Hope Valley Reservoir
CSR Quarry
27 / Lyons Road Reserve
River Torrens # 1
19 / River Torrens # 2
20 / River Torrens # 3
26 / Campbell Memorial Oval
18 / Thorndon Park Reserve
25 / Lochiel Park
15 / Wadmore Park
14 / Market Garden
24 / Felixstow Reserve
23 / River Torrens # 4
13 / Leabrook Drive Reserve
12 / Rostrevor College
22 / St Peters River Park
10 / The Gums Recreation Ground
9 / UniSA Magill Campus
21 / Botanic Gardens
8 / Penfolds Winery
11 / Kensington Oval
7 / Ferguson Park
6 / Hazelwood Park
5 / Langman Reserve
4 / Ridge Park Reserve
3 / Waite Arboretum
2 / Urrbrae Agricultural High S
1 / Mitcham Reserve
662815256
662813652
662809702
662813651
662821610
662815439
662812311
662810005
662810007
662822152
662812058
662822151
280000
285000
290000
6140000
6135000
6130000
6125000
M:\Projects_GW\St_Vincent\Golden_Grove_Embayment_Fractured_Rock_ASR\outputs\Figure_10.mxd T. Hodgkin February 2006

Figure 10

APPENDICES

A. 1982–83 AND 1983–84 AVERAGE ANNUAL GROUNDWATER ABSTRACTIONS (AFTER EDWARDS ET AL, 1987)

ID	Well Unit Number	MGA Easting	MGA Northing	Aquifer	Well Depth (m)	Average Annual Abstraction (kL)	Operator
1	662809817	284748	6137482	Fractured rock	73.2	730	Mr L Heading, Klemzig (agricultural)
2	662811721	289137	6139813	Fractured rock	31.6	2180	NV Emergy, Athelstone (agricultural)
3	662811989	290207	6137376	Fractured rock	114.0	2270	Black Hill Conservation Park
4	662810025	286938	6130422	Fractured rock	22.0	2270	RG Pank, Burnside
5	662811722	286399	6129971	Fractured rock	90.0	5455	Beaumont House (National Trust)
6	662809762	289104	6139764	Fractured rock	93.0	5455	P Mercorella, Athelstone (agricultural)
7	662812020	284259	6128027	Fractured rock	62.0	6240	Waite Research Unit
8	662809756	289419	6140114	Fractured rock	24.4	6545	Mr Fry (agricultural)
9	662811643	284828	6128548	Fractured rock	21.3	8180	Carmellite Cement
10	662812058	287201	6132297	Fractured rock	287.0	11 820	St Peters Girl School, Wattle Park
11	662805471	290588	6141454	Fractured rock	75.6	15 840	Highbury Primary School PBD
12	662809786	289775	6138101	Fractured rock	140.0	50 455	St Ignatius College
13	662807267	285705	6128861	Fractured rock	121.9	98 180	Mt Osmond Golf Club, total from 2? wells
14	662812311	284691	6136068	Fractured rock	152.0	159 105	Cadbury Schweppes Pty Ltd
15	662811758	283586	6130473	T1	250.0	301	Glenside Hospital
16	662800104	282475	6134025	T1	47.5	590	St Peters Boys College, Hackney
17	662807759	278635	6131316	T1	103.0	680	SA Cold Stores
18	662809723	287268	6138258	T1	90.8	7000	Campbelltown Primary School
19	662809915	286756	6136681	T1	89.9	10 780	Newton Primary School PBD
20	662809874	285869	6137263	T1	48.0	10 910	St Bernards Recreation Centre
21	662809872	285573	6137436	T1	45.7	13 370	East Marden Primary School PBD
22	662811160	285847	6131529	T1	133.3	13 640	Hazelwood Park Reserve
23	662808010	279832	6127798	T1	61.0	21 820	Cabra Convent
24	662809702	286985	6138766	T1	63.1	22 730	Campbelltown Oval, Daly Rd
25	662800555	280973	6131351	T1	29.3	36 000	Pulteney Grammar School
26	662809570	283684	6136448	T1	50.3	39 900	Marden High School PBD

B. EXISTING WELLS SUITABLE FOR FRA ASR AQUIFER TESTING

Well Unit Number	Date completed	MGA Easting	MGA Northing	Approximate ground level	Obswell	Production interval (mbgl)	Minimum casing diameter (mm)	Assigned yield (L/s)	Approximate groundwater level (mbgl)	Salinity (mg/L TDS)	Depth To weathered bedrock (mbgl)
662809702	14/12/1972	286984	6138766	63	-	21.3–73	127	8.8	12	1384	*18*
662810005	23/10/1976	288788	6135280	168	ADE64	75.2–111 ?	150	5.0	20	1468	
662810007	24/02/1970	288901	6134846	186	-	36.3–64	152	10.1	15	835	0.0
662812058	27/10/1982	287200	6132297	158	ADE138	276.9–287	152	9.0	105	973	
662812311	17/06/1983	284691	6136068	51	-	103–152	150	3.0	17	792	62
662813651	30/04/1986	284792	6138235	53	-	54.8–98?	152	8.8	16	2409	0.0
662813652	02/05/1986	285687	6139011	53	-	25.7–154	203	4.0	0	2278	17.0
662815256	16/11/1990	291879	6141299	149	-	39.1–146	155	10.0	31	3609	36
662815439	15/11/1990	283823	6136911	40	-	60–90	203	25.0	11	860	51.0
662821610	28/01/2004	289688	6138228	109	-	52–140	158	12.5	38	2631	*42*
662822151	10/03/2005	282785	6131298	55	-	174–192	155	5.0	18	3110	166
662822152	08/03/2005	281897	6133460	35	-	115–186	100	9.0	3	2700	88.0

Well Unit Number	Depth to fresh bedrock	DCDB_ID	TITLE_ID	Owner	Owner address
662809702	*42*	F126935 A1	CT5878/611	Corp. of the City of Campbelltown	PO Box 1 CAMPBELLTOWN 5074
662810005		F134182 A31	CT5506/173	Christian Brothers Inc.	214 Wakefield St ADELAIDE 5000
662810007	27.0	D47275 A501	CT5440/636	Minister for Human Services	GPO Box 2555 ADELAIDE 5001
662812058		F141797 A36	CT5803/930	St Peters Collegiate Girls School Inc.	Stonyfell Rd STONYFELL 5066
662812311	*92*	F135526 A75	CT5791/806	Cadbury Schweppes Pty Ltd	323 - 351 Canterbury Rd RINGWOOD VIC 3134
662813651	70.0	D6708 A15	CT5633/272	Martino	42 Fourth Ave KLEMZIG 5087
662813652	32.0	F131993 A3	CT5870/424	SA Water Corp.	Attn F.Alexander Level 15/77 Grenfell St ADELAIDE 5000
662815256	39.0	D55490 A55	CT5890/10	CSR Ltd	Level 1/9 Help St CHATSWOOD N S W 2067
662815439	51.0	F127638 A4	CT5749/386	Corp. of the Town of Walkerville	PO Box 55 WALKERVILLE 5081
662821610	*52*	F146367 A4	CT5565/126	Manresa Soc. Inc.	"MANRESA" 137 William St NORWOOD 5067
662822151	176	H105100 S6016	CR5707/712	Corp. of the City of Adelaide	PO Box 43 NORTH ADELAIDE 5006
662822152	118.0	H105100 S571	CR5715/226	Governors of the Botanic Garden	Goodman Building Hackney Rd ADELAIDE 5000

C. POTENTIAL FRA ASR INVESTIGATION SITES

Site no.	Approx. MGA Easting	Approx. MGA Northing	Site name	Water source	DCDB ID	PLAN ID	PARCEL ID	TITLE ID	Land owner	Land Owners Address
1	283000	6126550	Mitcham Reserve	Stream	D15858 A52					
2	283200	6127700	Urrbrae Agricultural High School	Pipe	D39536 A10	D39536	A10	CT5540/952	Minister for Education and Children's Services	C/- PROPERTY MANAGER LEVEL 7/31 FLINDERS ST ADELAIDE 5000
3	283750	6128000	Waite Arboretum	Pipe	F16164 A101	F16164	A101	CT5299/270	Distribution Lessor Corp.	GPO BOX 1045 ADELAIDE 5001
4	284600	6128750	Ridge Park Reserve	Stream or pipe	F15596 A128	F15596	A128	CT5605/707	Corp. of the City of Unley	PO BOX 1 UNLEY 5061
5	286750	6130800	Langman Reserve	Stream	F18762 A354	F18762	A354	CT5889/786	City of Burnside	PO BOX 9 GLENSIDE 5065
6	285950	6131550	Hazelwood Park	Stream	F138218 A38	F138218	A38	CT5804/323	City of Burnside	PO BOX 9 GLENSIDE 5065
7	287400	6132150	Ferguson Park	Stream	H105100 S687	H105100	S687	CR5772/813	Minister for Environment and Conservation	ADELAIDE 5000
8	287900	6133300	Penfolds Winery	Pipe	F20538 A1	F20538	A1	CT5161/394	Southcorp Wines Pty Ltd	403 PACIFIC HIGHWAY ARTARMON N S W 2064
9	287600	6134400	UniSA Magill Campus	Stream or pipe	F146354 A11	F146354	A11	CT5420/630	Distribution Lessor Corp.	GPO BOX 1045 ADELAIDE 5001
10	286600	6134800	Gums Recreation Ground	Stream	F133886 A35	F133886	A35	CT5616/56	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
11	285600	6133100	Kensington Oval	Pipe	F141164 A4	F141164	A4	CT5557/100	City of Burnside	PO BOX 9 GLENSIDE 5065
12	288550	6135100	Rostrevor College	Stream	D47275 A500	D47275	A500	CR5440/635	Christian Brothers Inc.	PO BOX 1129 BENTLEY DC WA 6983
13	287750	6136700	Leabrook Drive Reserve	Stream	F133131 A41	F133131	A41	CT5876/870	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
14	288850	6137600	Market Garden	Pipe	F9233 A19	F9233	A19	CT5381/392	Borrillo	12 GORDON AVE ROSTREVOR 5073
15	289900	6137950	Wadmore Park	Stream	D35275 A2	D35275	A2	CR5752/729	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
16	291350	6139900	River Torrens # 1	Stream	D55138 A2312	D55138	A2312	CT5828/302	Minister for Transport and Urban Planning	PO BOX 1 WALKERVILLE 5081

Site no.	Approx. MGA Easting	Approx. MGA Northing	Site name	Water source	DCDB ID	PLAN ID	PARCEL ID	TITLE ID	Land owner	Land Owners Address
17	291750	6141300	CSR Quarry	Stream	D55490 A55	D55490	A55	CT5890/10	CSR Ltd	LEVEL 1/9 HELP STREET CHATSWOOD N S W 2067
18	288450	6138450	Thorndon Park Reserve	Reservoir or pipe	H105100 S726	H105100	S726	CR5759/864	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
19	289250	6139800	River Torrens # 2	Stream	D9801 A46					
20	288350	6139301	River Torrens # 3	Stream	F11032 A2	F11032	A2	CT5528/955	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
21	281850	6134200	Botanic Gardens	Stream	H105100 S574	H105100	S574	CR5756/651	Govenors of the Botanic Garden	GOODMAN BUILDING HACKNEY RD ADELAIDE 5000
22	282300	6134900	St Peters River Park	Stream	F136682 A31	F136682	A31	CT5853/87	Corp of the City of Norwood Payneham and St Peters	PO BOX 204 KENT TOWN 5071
23	283550	6136600	River Torrens # 4	Stream	D19035 A24	D19035	A24	CT5471/360	Minister for Infrastructure	LEVEL 11 TERRACE TOWERS 178 NORTH TCE ADELAIDE 5000
24	285050	6137200	Felixstow Reserve	Stream	F128129 A95	F128129	A95	CT5805/49	Corp. of the City of Norwood Payneham and St Peters	PO BOX 204 KENT TOWN 5071
25	285100	6138200	Lochiel Park	Stream	D57618 A302	D57618	A302	CT5873/761	SA Water Corp.	ATTN F.ALEXANDER LEVEL 15/77 GRENFELL ST ADELAIDE 5000
26	286975	6139000	Campbell Memorial Oval	Stream	F126935 A1	F126935	A1	CT5878/611	Corp. of the City of Campbelltown	PO BOX 1 CAMPBELLTOWN 5074
27	287700	6140450	Lyons Road Reserve	Stream	D28047 A611	D28047	A611	CT5408/478	City of Tea Tree Gully	PO BOX 571 MODBURY 5092
28	289070	6141480	Hope Valley Reservoir	Reservoir	D33371 A1	D33371	A1	CT5066/56	SA Water Corp.	ATTN F.ALEXANDER LEVEL 15/77 GRENFELL ST ADELAIDE 5000

UNITS AND MEASUREMENTS

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
day	d	24 h	time interval
gigalitre	GL	10^6 m^3	volume
gram	g	10^{-3} kg	mass
hectare	ha	10^4 m^2	area
hour	h	60 min	time interval
kilogram	kg	base unit	mass
kilolitre	kL	1 m^3	volume
kilometre	km	10^3 m	length
litre	L	10^{-3} m^3	volume
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
microgram	µg	10^{-6} g	mass
microlitre	µL	10^{-9} m^3	volume
milligram	mg	10^{-3} g	mass
millilitre	mL	10^{-6} m^3	volume
millimetre	mm	10^{-3} m	length
minute	min	60 s	time interval
second	s	base unit	time interval
tonne	t	1000 kg	mass
year	y	356 or 366 days	time interval

δD	hydrogen isotope composition
$\delta^{18}O$	oxygen isotope composition
^{14}C	carbon-14 isotope (percent modern carbon)
CFC	chlorofluorocarbon (parts per trillion volume)
EC	electrical conductivity (µS/cm)
pH	acidity
ppm	parts per million
ppb	parts per billion
TDS	total dissolved solids (mg/L)

GLOSSARY

Act (the). In this document, refers to The *Natural Resources Management Act* (South Australia) 2004.

Adaptive management. A management approach, often used in natural resource management, where there is little information and/or a lot of complexity and there is a need to implement some management changes sooner rather than later. The approach is to use the best available information for the first actions, implement the changes, monitor the outcomes, investigate the assumptions and regularly evaluate and review the actions required. Consideration must be given to the temporal and spatial scale of monitoring and the evaluation processes appropriate to the ecosystem being managed.

Algal bloom. A rapid accumulation of algal biomass (living organic matter) which can result in deterioration in water quality when the algae die and break down consuming the dissolved oxygen and releasing toxins.

Ambient. The background level of an environmental parameter (e.g. a background water quality like salinity).

Anabranch. A branch of a river that leaves the main stream.

Annual adjusted catchment yield. Annual catchment yield with the impact of dams removed.

Aquifer. An underground layer of rock or sediment which holds water and allows water to percolate through.

Aquifer, confined. Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure. Water in a penetrating well will rise above the surface of the aquifer.

Aquifer, storage and recovery (ASR). The process of recharging water into an aquifer for the purpose of storage and subsequent withdrawal.

Aquifer test. A hydrological test performed on a well, aimed to increase the understanding of the aquifer properties, including any interference between wells, and to more accurately estimate the sustainable use of the water resource available for development from the well.

Aquifer, unconfined. Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure.

Aquitard. A layer in the geological profile that separates two aquifers and restricts the flow between them.

Arid lands. In South Australia arid lands are usually considered to be areas with an average rainfall of less than 250 mm and support pastoral activities instead of broad acre cropping.

Artesian. Under pressure such that when wells penetrate the aquifer water will rise to the ground surface without the need for pumping.

Artificial recharge. The process of artificially diverting water from the surface to an aquifer. Artificial recharge can reduce evaporation losses and increase aquifer yield. *(See recharge, natural recharge, aquifer.)*

Barrage. Specifically any of the five low weirs at the mouth of the River Murray constructed to exclude seawater from the Lower Lakes.

Baseflow. The water in a stream that results from groundwater discharge to the stream. (This discharge often maintains flows during seasonal dry periods and has important ecological functions.)

Basin. The area drained by a major river and its tributaries.

Benchmark condition. Points of reference from which change can be measured.

Biological diversity (biodiversity). The variety of life forms: the different life forms including plants, animals and micro-organisms, the genes they contain and the *ecosystems (see below)* they form. It is usually considered at three levels — genetic diversity, species diversity and ecosystem diversity.

Biota. All of the organisms at a particular locality.

Bore. *See well.*

Buffer zone. A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (e.g. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses).

Catchment. A catchment is that area of land determined by topographic features within which rainfall will contribute to runoff at a particular point.

Catchment water management board. A statutory body established under Part 6, Division 3, s. 53 of the Act whose prime function under Division 2, s. 61 is to implement a catchment water management plan for its area.

Catchment water management plan. The plan prepared by a CWMB and adopted by the Minister in accordance with Part 7, Division 2 of the Water Resources Act 1997.

Codes of practice. Standards of management developed by industry and government, promoting techniques or methods of environmental management by which environmental objectives may be achieved.

Cone of depression. An inverted cone-shaped space within an aquifer caused by a rate of groundwater extraction which exceeds the rate of recharge. Continuing extraction of water can extend the area and may affect the viability of adjacent wells, due to declining water levels or water quality.

Conjunctive use. The utilisation of more than one source of water to satisfy a single demand.

Council of Australian Governments (COAG). A council of the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association which exists to set national policy directions for Australia.

CWMB. Catchment Water Management Board.

Dams, off-stream dam. A dam, wall or other structure that is not constructed across a watercourse or drainage path and is designed to hold water diverted, or pumped, from a watercourse, a drainage path, an aquifer or from another source. Off-stream dams may capture a limited volume of surface water from the catchment above the dam.

Dams, on-stream dam. A dam, wall or other structure placed or constructed on, in or across a watercourse or drainage path for the purpose of holding and storing the natural flow of that watercourse or the surface water.

Dams, turkey nest dam. An off-stream dam that does not capture any surface water from the catchment above the dam.

Diffuse source pollution. Pollution from sources such as an eroding paddock, urban or suburban lands and forests; spread out, and often not easily identified or managed.

District Plan. (District Soil Conservation Plan) An approved soil conservation plan under the repealed *Soil Conservation Act 1989*. These plans are taken to form part of the relevant regional NRM plans under the transitional provisions of the *Natural Resources Management Act 2004* (Schedule 4 – subclause 53[4] until regional NRM plans are prepared under Chapter 4, Part 2 of the Act.

Domestic purpose. The taking of water for ordinary household purposes and includes the watering of land in conjunction with a dwelling not exceeding 0.4 hectares.

Domestic wastewater. Water used in the disposal of human waste, for personal washing, washing clothes or dishes, and swimming pools.

DSS (decision support system). A system of logic or a set of rules derived from experts, to assist decision making. Typically they are constructed as computer programs.

DSS. Dissolved suspended solids.

DWLBC. Department of Water, Land and Biodiversity Conservation. Government of South Australia.

EC. Abbreviation for electrical conductivity. 1 EC unit = 1 micro-Siemen per centimetre (µS/cm) measured at 25 degrees Celsius. Commonly used to indicate the salinity of water.

Ecological processes. All biological, physical or chemical processes that maintain an ecosystem.

Ecological values. The habitats, the natural ecological processes and the biodiversity of ecosystems.

Ecologically sustainable development (ESD). Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased.

Ecology. The study of the relationships between living organisms and their environment.

Ecosystem. Any system in which there is an interdependence upon and interaction between living organisms and their immediate physical, chemical and biological environment.

Ecosystem Services. All biological, physical or chemical processes that maintain ecosystems and biodiversity and provide inputs and waste treatment services that support human activities.

Effluent. Domestic wastewater and industrial wastewater.

EIP. Environment improvement program.

EMLR. Eastern Mount Lofty Ranges.

Entitlement flows. Minimum monthly River Murray flows to South Australia agreed in the Murray-Darling Basin Agreement 1992.

Environmental values. The uses of the environment that are recognised as of value to the community. This concept is used in setting water quality objectives under the Environment Protection (Water Quality) Policy, which recognises five environmental values — protection of aquatic ecosystems, recreational water use and aesthetics, potable (drinking water) use, agricultural and aquaculture use, and industrial use. It is not the same as ecological values, which are about the elements and functions of ecosystems.

Environmental water provisions. Those parts of environmental water requirements that can be met, at any given time. This is what can be provided at that time with consideration of existing users' rights, social and economic impacts.

Environmental water requirements. The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk.

EP. Eyre Peninsula.

EPA. Environment Protection Agency.

Ephemeral streams / wetlands. Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Erosion. Natural breakdown and movement of soil and rock by water, wind or ice. The process may be accelerated by human activities.

ESD. Ecologically sustainable development *(see above for definition)*.

Estuaries. Semi-enclosed waterbodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences and experience periodic fluctuations and gradients in salinity.

Eutrophication. Degradation of water quality due to enrichment by nutrients (primarily nitrogen and phosphorus), causing excessive plant growth and decay. *(See algal bloom).*

Evapotranspiration. The total loss of water as a result of transpiration from plants and evaporation from land, and surface waterbodies.

Fishway. A generic term describing all mechanisms that allow the passage of fish along a waterway. Specific structures include fish ladders (gentle sloping channels with baffles that reduce the velocity of water and provide resting places for fish as they 'climb' over a weir) and fishlifts (chambers, rather like lift-wells, that are flooded and emptied to enable fish to move across a barrier).

Floodplain. Of a watercourse means: (a) the floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under Part 7 of the Water Resources Act 1997; or (b) where paragraph (a) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the Development Act 1993, or (c) where neither paragraph (a) nor paragraph (b) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse.

Flow bands. Flows of different frequency, volume and duration.

GAB. Great Artesian Basin.

Gigalitre (GL). One thousand million litres (1 000 000 000).

GIS (geographic information system). Computer software allows for the linking of geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

GL. *See gigalitre.*

Greenhouse effect. The balance of incoming and outgoing solar radiation which regulates our climate. Changes to the composition of the atmosphere such as the addition of carbon dioxide through human activities, have the potential to alter the radiation balance and to effect changes to the climate. Scientists suggest that changes would include global warming, a rise in sea level and shifts in rainfall patterns.

Geological features. Include geological monuments, landscape amenity and the substrate of land systems and ecosystems.

Greywater. Household wastewater excluding sewage effluent. Wastewater from kitchen, laundry and bathroom.

Groundwater. *See underground water.*

Habitat. The natural place or type of site in which an animal or plant, or communities of plants and animals, lives.

Heavy metal. Any metal with a high atomic weight (usually, although not exclusively, greater than 100), for example mercury, lead and chromium. Heavy metals have a widespread industrial use, and many are released into the biosphere via air, water and solids pollution. Usually these metals are toxic at low concentrations to most plant and animal life.

Hydrogeology. The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers. *(See hydrology.)*

Hydrography. The discipline related to the measurement and recording of parameters associated with the hydrological cycle, both historic and real time.

Hydrology. The study of the characteristics, occurrence, movement and utilisation of water on and below the earth's surface and within its atmosphere. *(See hydrogeology.)*

Hyporheic zone. The wetted zone among sediments below and alongside rivers. It is a refuge for some aquatic fauna.

Indigenous species. A species that occurs naturally in a region.

Industrial wastewater. Water (not being domestic wastewater) that has been used in the course of carrying on a business (including water used in the watering of irrigation of plants) that has been allowed to run to waste or has been disposed of or has been collected for disposal.

Infrastructure. Artificial lakes; or dams or reservoirs; or embankments, walls, channels or other works; or buildings or structures; or pipes, machinery or other equipment.

Integrated catchment management. Natural resources management that considers in an integrated manner the total long-term effect of land and water management practices on a catchment basis, from production and environmental viewpoints.

Intensive farming. A method of keeping animals in the course of carrying on the business of primary production in which the animals are confined to a small space or area and are usually fed by hand or by mechanical means.

Irrigation. Watering land by any means for the purpose of growing plants.

Irrigation season. The period in which major irrigation diversions occur, usually starting in August–September and ending in April–May.

Lake. A natural lake, pond, lagoon, wetland or spring (whether modified or not) and includes: part of a lake; and a body of water declared by regulation to be a lake; a reference to a lake is a reference to either the bed, banks and shores of the lake or the water for the time being held by the bed, banks and shores of the lake, or both, depending on the context.

Land. Whether under water or not and includes an interest in land and any building or structure fixed to the land.

Land capability. The ability of the land to accept a type and intensity of use without sustaining long-term damage.

Leaching. Removal of material in solution such as minerals, nutrients and salts through soil.

Licence. A licence to take water in accordance with the Water Resources Act 1997. *(See water licence.)*

Licensee. A person who holds a water licence.

Local water management plan. A plan prepared by a council and adopted by the Minister in accordance with Part 7, Division 4 of the Act.

Macro-invertebrates. Animals without backbones that are typically of a size that is visible to the naked eye. They are a major component of aquatic ecosystem biodiversity and fundamental in food webs.

MDBC. Murray-Darling Basin Commission.

Megalitre (ML). One million litres (1 000 000).

ML. *See megalitre.*

MLR. Mount Lofty Ranges.

Model. A conceptual or mathematical means of understanding elements of the real world which allows for predictions of outcomes given certain conditions. Examples include estimating storm runoff, assessing the impacts of dams or predicting ecological response to environmental change.

Mount Lofty Ranges Watershed. The area prescribed by Schedule 1 of the regulations.

Natural recharge. The infiltration of water into an aquifer from the surface (rainfall, streamflow, irrigation etc.) *(See recharge area, artificial recharge.)*

NHMRC. National Health and Medical Research Council.

NHT. Natural Heritage Trust.

Natural Resources. Soil; water resources; geological features and landscapes; native vegetation, native animals and other native organisms; ecosystems.

Natural Resources Management (NRM). All activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

Occupier of land. A person who has, or is entitled to, possession or control of the land.

Owner of land. In relation to land alienated from the Crown by grant in fee simple — the holder of the fee simple; in relation to dedicated land within the meaning of the *Crown Lands Act 1929* that has not been granted in fee simple but which is under the care, control and management of a Minister, body or other person — the Minister, body or other person; in relation to land held under Crown lease or licence — the lessee or licensee; in relation to land held under an agreement to purchase from the Crown — the person entitled to the benefit of the agreement; in relation to any other land — the Minister who is responsible for the care, control and management of the land or, if no Minister is responsible for the land, the Minister for Environment and Heritage.

Palaeochannels. Ancient buried river channels in arid areas of the state. Aquifers in palaeochannels can yield useful quantities of groundwater or be suitable for ASR.

Pasture. Grassland used for the production of grazing animals such as sheep and cattle.

Percentile. A way of describing sets of data by ranking the data set and establishing the value for each percentage of the total number of data records. The 90th percentile of the distribution is the value such that 90% of the observations fall at or below it.

Permeability. A measure of the ease with which water flows through an aquifer or aquitard.

Personal property. All forms of property other than real property. For example, shares or a water licence.

Phreaphytic vegetation. Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater.

Phytoplankton. The plant constituent of organisms inhabiting the surface layer of a lake; mainly single-cell algae.

PIRSA. (Department of) Primary Industries and Resources South Australia.

Pollution, diffuse source. Pollution from sources that are spread out and not easily identified or managed (e.g. an eroding paddock, urban or suburban lands and forests).

Pollution, point source. A localised source of pollution.

Potable water. Water suitable for human consumption.

Potentiometric head. The potentiometric head or surface is the level to which water rises in a well due to water pressure in the aquifer.

Precautionary principle. Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

Prescribed area, surface water. Part of the State declared to be a surface water prescribed area under the Water Resources Act 1997.

Prescribed lake. A lake declared to be a prescribed lake under the Water Resources Act 1997.

Prescribed water resource. A water resource declared by the Governor to be prescribed under the Act, and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed watercourse. A watercourse declared to be a prescribed watercourse under the Water Resources Act 1997.

Prescribed well. A well declared to be a prescribed well under the Water Resources Act 1997.

Property right. A right of ownership or some other right to property, whether real property or personal property.

Proponent. The person or persons (who may be a body corporate) seeking approval to take water from prescribed water.

PWA. Prescribed Wells Area.

PWCA. Prescribed Watercourse Area.

PWRA. Prescribed Water Resources Area.

Ramsar Convention. This is an international treaty on wetlands titled The Convention on Wetlands of International Importance Especially as Waterfowl Habitat. It is administered by the International Union for Conservation of Nature and Natural Resources. It was signed in the town of Ramsar, Iran in 1971, hence its common name. The Convention includes a list of wetlands of international importance and protocols regarding the management of these wetlands. Australia became a signatory in 1974.

Recharge area. The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. *(See artificial recharge, natural recharge.)*

Reclaimed water. Treated effluent of a quality suitable for the designated purpose.

Rehabilitation (of waterbodies). Actions that improve the ecological health of a waterbody by reinstating important elements of the environment that existed prior to European settlement.

Remediation (of waterbodies). Actions that improve the ecological condition of a waterbody without necessarily reinstating elements of the environment that existed prior to European settlement.

Restoration (of waterbodies). Actions that reinstate the pre-European condition of a waterbody.

Reticulated water. Water supplied through a piped distribution system.

Riffles. Shallow stream section with fast and turbulent flow.

Riparian landholder. A person whose property abuts a watercourse or through whose property a watercourse runs.

Riparian rights. These were old common law rights of access to, and use of water. These common law rights were abolished with the enactment of the Water Resources Act 1997, which now includes similar rights under s. 7. Riparian rights are therefore now statutory rights under the Act. Where the resource is not prescribed (Water Resources Act 1997, s. 8) or subject to restrictions (Water Resources Act 1997, s. 16), riparian landholders may take any amount of water from watercourses, lakes or wells without consideration to downstream landholders, if it is to be used for stock or domestic purposes. If the capture of water from watercourses and groundwater is to be used for any other purpose then the right of downstream landholders must be protected. Landholders may take any amount of surface water for any purpose without regard to other landholders, unless the surface water is prescribed or subject to restrictions.

Riparian zone. That part of the landscape adjacent to a water body, that influences and is influenced by watercourse processes. This can include landform, hydrological or vegetation definitions. It is commonly used to include the in-stream habitats, bed, banks and sometimes floodplains of watercourses.

Seasonal watercourses or wetlands. Those watercourses and wetlands that contain water on a seasonal basis, usually over the winter/spring period, although there may be some flow or standing water at other times.

State water plan. The plan prepared by the Minister under Part 7, Division 1, s. 90 of the Act.

Stock Use. The taking of water to provide drinking water for stock other than stock subject to intensive farming (as defined by the Act).

Stormwater. Runoff in an urban area.

Surface water. (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir.

Taxa. General term for a group identified by taxonomy — which is the science of describing, naming and classifying organisms.

To take water. From a water resource includes (a) to take water by pumping or syphoning the water; (b) to stop, impede or divert the flow of water over land (whether in a watercourse or not) for the purpose of collecting the water; (c) to divert the flow of water in a watercourse from the watercourse; (d) to release water from a lake; (e) to permit water to flow under natural pressure from a well; (f) to permit stock to drink from a watercourse, a natural or artificial lake, a dam or reservoir.

Total kjeldhal nitrogen (TKN). The sum of aqueous ammonia and organic nitrogen. Used as a measure of probable sewage pollution.

Transfer. A transfer of a licence (including its water allocation) to another person, or the whole or part of the water allocation of a licence to another licensee or the Minister under Part 5, Division 3, s. 38 of the Act. The transfer may be absolute or for a limited period.

Underground water (groundwater). Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground.

Volumetric allocation. An allocation of water expressed on a water licence as a volume (e.g. kilolitres) to be used over a specified period of time, usually per water use year (as distinct from any other sort of allocation).

Wastewater. *See domestic wastewater, industrial wastewater.*

Water affecting activities. Activities referred to in Part 4, Division 1, s. 9 of the Act.

Water allocation. (a) in respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence; (b) in respect of water taken pursuant to an authorisation under s. 11 means the maximum quantity of water that can be taken and used pursuant to the authorisation.

Water allocation, area based. An allocation of water that entitles the licensee to irrigate a specified area of land for a specified period of time usually per water use year.

Water allocation plan (WAP). A plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with Division 3 of Part 7 of the Act.

Water licence. A licence granted under the Act entitling the holder to take water from a prescribed watercourse, lake or well or to take surface water from a surface water prescribed area. This grants the licensee a right to take an allocation of water specified on the licence, which may also include conditions on the taking and use of that water. A water licence confers a property right on the holder of the licence and this right is separate from land title.

Water plans. The State Water Plan, catchment water management plans, water allocation plans and local water management plans prepared under Part 7 of the Act.

Water service provider. A person or corporate body that supplies water for domestic, industrial or irrigation purposes or manages wastewater.

Waterbody. Waterbodies include watercourses, riparian zones, floodplains, wetlands, estuaries, lakes and groundwater aquifers.

Watercourse. A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; and a lake through which water flows; and a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse.

Water-dependent ecosystems. Those parts of the environment, the species composition and natural ecological processes, which are determined by the permanent or temporary presence of flowing or standing water, above or below ground. The in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems.

Water-use year. The period between 1 July in any given calendar year and 30 June the following calendar year. This is also called a licensing year.

Well. (a) an opening in the ground excavated for the purpose of obtaining access to underground water; (b) an opening in the ground excavated for some other purpose but that gives access to underground water; (c) a natural opening in the ground that gives access to underground water.

Wetlands. Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic/intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six metres.

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