Simplified hydrostratigraphic 3-D models

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Government of South Australia
Department of Environment, Water and Natural Resources

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Contents

Contents ii

1 Introduction **4**
1.1 Objectives 4

2 Methodology **5**
2.1 Approach to develop simplified hydrostratigraphic layers 5
2.1.1 Eyre Peninsula and Northern and Yorke NRM Regions 5
2.1.2 SA MDB NRM Region 5
2.2 Interpolation process 6
2.2.1 Topo to Raster 6
2.2.2 Inverse Distance Weighted 6
2.3 Elevation surface construction 6
2.3.1 Extent of Simplified Hydrostratigraphic Units 6
2.3.2 Point Interpolation Data 6
2.3.3 Outcrop Features 6
2.3.4 Subsurface Features 6
2.3.5 Joining the Subsurface and Outcrop Extents 7
2.3.6 Validation and correction of generated stratigraphic elevation surfaces 7
2.3.6.1 Subsurface layer 'upwelling' 7
2.3.6.2 Errors in drillhole data 7
2.3.6.3 Low density of input data 7
2.4 GeoVolume construction 9
2.5 Generated water level surfaces 9
2.5.1 Validation and correction of generated water level surfaces 9
2.5.1.1 Spatial density of model input data and reducing model uncertainty 9
2.6 Generated groundwater salinity surfaces 9
2.7 Interpolation accuracy 10
2.8 Additional spatial data 10
2.9 PDF formatting 10

3 Results **12**
3.1 Calculation of groundwater storage 12

4 Outputs **14**
4.1 Final 3-D PDF products 14
4.2 Potential use of the model 21
4.3 Current modelling issues 22
4.4 Software used 23

5 Recommendations **24**
5.1 Data validation and improvement 24
5.2 Hydrostratigraphic refinement 24
5.3 Groundwater storage volumes 24
5.4 Groundwater assessment 24

6 References 25

List of figures

Figure 1. Example of negative thickness error on Eyre Peninsula 8
Figure 2. Example of negative thickness error in Northern and Yorke 8
Figure 3. Distribution of drillhole data points used in hydrostratigraphic surface interpolation 10
Figure 4. The PDF model interface (showing the Eyre Peninsula model start view) 15
Figure 5. Adobe PDF 3-D Toolbar demonstrating the range of navigation options and function available 16
Figure 6. EP hydrostratigraphic unit thickness (1:20 vertical exaggeration) 17
Figure 7. Salinity of EP Quaternary hydrostratigraphic unit (1:50 vertical exaggeration) 17
Figure 8. EP Tertiary RSWL water elevation surface (1:20 vertical exaggeration) 18
Figure 9. Cross Section displaying NY Permian hydrostratigraphic thickness (1:50 vertical exaggeration) 18
Figure 10. Salinity of NY Tertiary Hydrostratigraphic Units 19
Figure 11. NY Quaternary RSWL water elevation surface 19
Figure 12. SA MDB hydrostratigraphic unit thicknesses (1:50) 20
Figure 13. SA MDB salinity of Murray Group Limestone aquifer 21
Figure 14. Drilling depth to Tertiary sediments 22
Figure 15. Zones of fresh groundwater zones in the basement aquifer around Mt Remarkable 22

List of tables

Table 1. Eyre Peninsula - Estimated groundwater storage 13
Table 2. Northern & Yorke - Estimated groundwater storage 13
Table 3. Analysis of software packages 23

1 Introduction

The Non-Prescribed Regional Groundwater Assessments project aims to improve the understanding of the state's groundwater resources and their development potential outside the well-studied prescribed areas. An important component of this assessment is the delineation of the major aquifers (in both lateral and vertical extent) that will allow an estimation of the volume of groundwater stored in the aquifers and possible sustainable usage limits for future development.

As part of the non-prescribed project, 3-D surfaces were produced for the major hydrostratigraphic units in the sedimentary basins within the Eyre Peninsula (EP), Northern and Yorke (NY) and SA Murray-Darling Basin (SAMDB) Natural Resources Management (NRM) Regions, using existing geological and stratigraphic logs from the state drillhole database (SA Geodata). 3-D models of the simplified hydrostratigraphic units were produced for each of the three NRM Regions in the commonly available Adobe PDF file format to allow stakeholders and the general public to easily access the information products over the internet.

These 3-D models can potentially be used for decision making for water resource development and management at regional scales, by providing approximate drilling depths to various aquifers and expected groundwater levels and salinity ranges that may be encountered. Potential zones of recharge and discharge may also be identified. The constructed geovolumes were used to provide a first-order estimate of the total volume of groundwater held in storage in the major aquifers.

This report provides the methodology of the processes required to produce the 3-D surfaces of the major hydrostratigraphic units and the 3-D PDF simplified models. Recommendations are also made on how to improve data quality and refine the hydrostratigraphic units for future versions of the models. Further refinement of the groundwater storage volumes is recommended at smaller scales, with a better assessment of aquifer storage parameters required for the volume calculation. Further enhancement of this data is required to produce a regional groundwater assessment tool for the non-prescribed groundwater resources in SA.

1.1 Objectives

The objective of the project is to produce 3-D surfaces of the major hydrostratigraphic units in the sedimentary basins within the Eyre Peninsula (EP), Northern and Yorke (NY) and SA Murray-Darling Basin (SAMDB) Natural Resources Management (NRM) regions, using existing geological and stratigraphic logs from SA Geodata. When these surfaces have been constructed, groundwater storage volumes can be calculated. Another output is the production of simplified hydrostratigraphic 3-D models in the commonly available Adobe PDF file format to provide stakeholders with a generalised representation of the potential groundwater resources in their area, the thicknesses of each hydrostratigraphic unit and other information such as the groundwater level and salinities of various aquifers. These models would be available to key stakeholders and the general public through the DEWNR WaterConnect website (www.waterconnect.sa.gov.au).

2 Methodology

Several steps were involved in constructing the models of the various hydrostratigraphic layers, including:

- simplifying the stratigraphy of each NRM region into hydrostratigraphic units
- modelling surfaces of the hydrostratigraphic units by interpolating point data
- validation and correction of interpolated surfaces.

2.1 Approach to develop simplified hydrostratigraphic layers

2.1.1 Eyre Peninsula and Northern and Yorke NRM Regions

Because of the limited density of detailed stratigraphic information available in the EP and NY regions, the approach taken in modelling the simplified hydrostratigraphic units comprised of broadly grouping the stratigraphic formations by geological age. The units derived were:

- Quaternary
- Tertiary
- Jurassic
- Permo-carboniferous
- Basement.

The simplification process in the EP and NY regions results in all Quaternary formations being aggregated as one hydrostratigraphic unit without further subdivision (i.e. there has been no distinction between discrete formations, e.g. the St Kilda and Bridgewater Formations). Similarly, the Tertiary sedimentary units are presented as a single simplified hydrostratigraphic unit without distinction between the confining Tertiary clay aquitards (e.g. Uley or Poelpena Formations) or the Tertiary sand aquifers (e.g. Pidinga or Wanilla Formations).

Jurassic sediments that comprise the Polda Formation are limited in extent to the Polda Trough as defined by Drexel & Preiss (1995). Data indicating occurrences of the Polda Formation outside of the Polda Trough have been excluded from the model due to time constraints on further data validation.

Permo-carboniferous glacial sediments attributed to the Cape Jervis Formation are located in southern Yorke Peninsula where their extent has not been previously defined, except in the Troubridge Basin (Drexel & Preiss 1995). The modelled areal extent for these sediments was based on the approximate extent of the Troubridge Basin and interpretations of drillhole logs.

Crystalline and metamorphic rocks of the Archaean to early Palaeozoic era are aggregated and herein referred to as 'basement' (i.e. fractured rock aquifers).

2.1.2 SA MDB NRM Region

A wide coverage of drillhole data and better defined data of the thick sedimentary sequence enabled the definition of a greater number of aquifers and aquitards than in the EP and NY regions. The simplified hydrostratigraphic units comprised:

- Quaternary
  - Quaternary Limestone aquifer
  - Blanchetown Clay
- Tertiary
  - Pliocene Sands aquifer
  - Bookpurnong Beds aquitard
  - Murray Group Limestone aquifer
  - Winnambool Formation / Geera Clay aquitard
  - Ettrick Formation aquitard
  - Renmark Group confined aquifer
- Basement.

2.2 Interpolation process

2.2.1 Topo to Raster

The Topo to Raster interpolation algorithm visually produced the 'best fit' to the available surface elevation point data when compared to other interpolation algorithms available in ArcGIS 10.1 such as Inverse Distance Weighted (IDW), spline and kriging interpolation. Therefore the ArcGIS 10.1 Topo to Raster (TTR) interpolation algorithm was selected to interpolate elevation surfaces for the hydrostratigraphic units in the 3-D model. The TTR 'no enforcement of sinks' setting was used, meaning that the interpolation process would not attempt to fill in any depressions (no sinks filled) and would not create 'watercourse features' from the depressions in the interpolated surface.

2.2.2 Inverse Distance Weighted

A number of different interpolation methods where examined to see which method provided the most accurate reflection of the observed water level data. Difficulty was encountered with using the spline and kriging methods as the lack of data in many regions caused the interpolated surface to exceed the known or reasonable bounds of what would be expected in given areas. After experimenting with a number of different tools available in ArcGIS 10.1, the IDW tool was found to best fit the reduced standing water level (RSWL) elevation surface to the geometry of the appropriate hydrostratigraphic unit. The IDW interpolation method determines cell values using linearly weighted combination of a set of sample points. The weight is a function of inverse distance.

2.3 Elevation surface construction

Several methods were used to create the elevation surfaces for the tops of the various hydrostratigraphic units for the simplified 3-D models. These methods are discussed below.

2.3.1 Extent of Simplified Hydrostratigraphic Units

The extents of the units were developed from simplified geology geographic information system (GIS) layers that include the extent of surface outcrop. Subsurface extents were estimated from drillhole logs.

2.3.2 Point Interpolation Data

Point elevation data was extracted from the National Groundwater Information System database (which is populated from SA Geodata) using Structured Query Language (SQL) queries in ArcGIS 10.1 to obtain the top elevation (in m AHD) of the simplified hydrostratigraphic units, e.g. Quaternary, Tertiary, Jurassic and basement. These simplified hydrostratigraphic units are identified in drillhole log data by a set of unique 'map symbols'.

2.3.3 Outcrop Features

The extents of outcropping hydrostratigraphic units were assigned an elevation by clipping them to the South Australian one-second Digital Elevation Model (SA 1 Sec. DEM). The slope of the outcrop surface was extended by a 150 m buffer beyond the mapped extent to facilitate the join with the corresponding subsurface layers.

2.3.4 Subsurface Features

Subsurface features are defined as a modelled hydrostratigraphic unit that lies beneath another modelled surface or ground level. For example, a modelled Tertiary unit is a subsurface feature if it lies beneath a modelled Quaternary outcrop surface.

The ArcGIS 10.1 TTR interpolation algorithm was used to interpolate an elevation surface from the extracted NGIS point data. In some areas, additional point data were created along boundaries of outcrop extents at 5 km intervals to assist the interpolation process. The height values for these points were obtained from the SA 1 Sec. DEM. The purpose of these additional points was to 'raise' the interpolated subsurface surface up to meet extents of outcrop and to force the generated surfaces to a more realistic representation in areas where data density was too low to enforce the geological variation.

The subsurface elevation rasters were extended by a 100 m buffer beyond the mapped extent to facilitate the join with the relevant outcropping surfaces.

2.3.5 Joining the Subsurface and Outcrop Extents

ArcGIS 10.1 was used to join the outcrop extents with the subsurface extents. Where the two extents overlapped due to the buffer zones as previously described, the average of the two surfaces was used to determine the surface elevation of the join.

2.3.6 Validation and correction of generated stratigraphic elevation surfaces

Validation of the generated elevation surfaces was undertaken to identify areas where generated subsurface features intersected or 'breached' an overlying generated elevation surface. Using the ArcGIS spatial analysis tool 'Raster Calculator', an 'error raster' is calculated by subtracting the generated subsurface elevation from the overlying generated surface elevation, thereby showing negative thicknesses. Overlaying the input point data on the 'error raster' suggested that the errors could be due to:

- the interpolation of the subsurface units breaching the ground surface where there is no known outcrop
- inaccuracies or errors in the interpretation of the original drillhole data, or data input errors in SA Geodata (which can be subject to erroneous data entry errors)
- a low density of model input point data.

2.3.6.1 Subsurface layer 'upwelling'

To limit the 'upwelling' of subsurface layers breaking through overlying layers, 'dummy point' data were used in areas where errors occurred to subdue the particular subsurface elevation raster. 'Upwelling' occurs due to insufficient point data that does not constrain the elevation surface to conform to a realistic representation of the sedimentary structure. This is particularly the case where subsurface units wedge out against rising basement but do not crop out. The 'dummy point' data was created at 2 km intervals where the subsurface unit intersected the basement and values were extracted from an interpolated elevation surface that was extended by 1.5 km (created using the TTR tool). Re-running the interpolation method with the additional 'dummy point' data demonstrated a satisfactory decrease in the 'error raster' around outcropping extents.

2.3.6.2 Errors in drillhole data

Analysis of the drillhole log information identified that misinterpretation and errors were present within the database. Additional validation of the borehole data resulted in data being either reinterpreted or excluded. A re-run of the interpolation method, once additional data cleansing was completed within the SA Geodata database, demonstrated that it decreased the amount of error associated with subsurface elevation rasters intersecting overlying elevation surfaces.

2.3.6.3 Low density of input data

Errors in the generated elevation surfaces (such as 'upwelling') that can be attributed to a lack of model input point data are edited by forcing the separation of the generated elevation surfaces using a conditional logic function in 'Raster Calculator'. After the 'error rasters' described previously are calculated, each generated raster that shows negative thickness is defined and the conditional logic function is then used to reduce the elevation of the spurious raster cell to an elevation below the overlying generated surface. The forced reduction in elevation is about 1–3 m below the overlying cell, scaled on the magnitude of the negative thickness.

For example in the EP model, negative thicknesses are shown where the generated Tertiary surface extends through the overlying generated Quaternary surface (Fig. 1). The green areas indicate a small negative thickness, while the red indicates greater negative thickness. The processes of data validation and data cleansing correct some of these errors. In NY, errors are shown where the generated basement extends through the overlying generated Permo-carboniferous, Tertiary and Quaternary surfaces. These 'upwelling' errors mostly occur around outcropping features and are corrected by the methods described in Section 2.3.6. In both these examples, any residual errors are corrected using the conditional logic function.

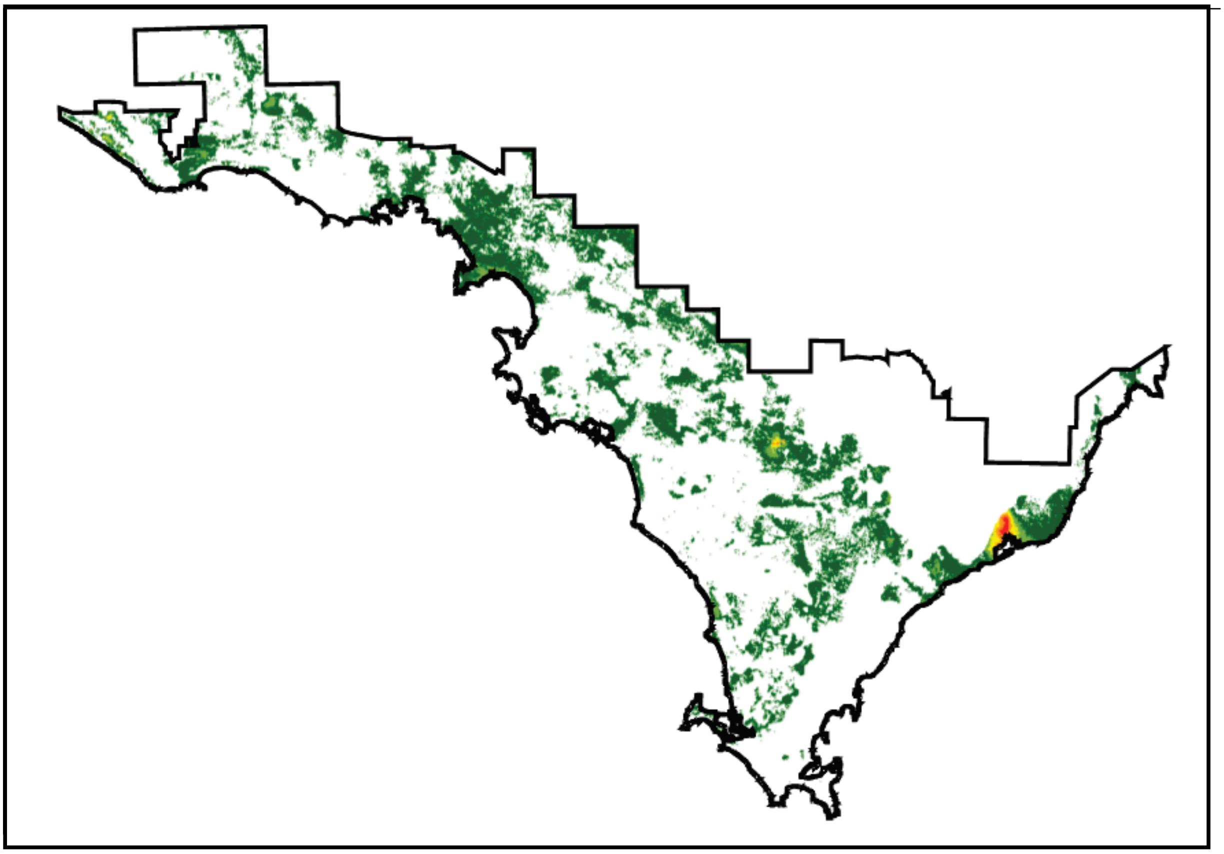

Figure 1. Example of negative thickness error on Eyre Peninsula

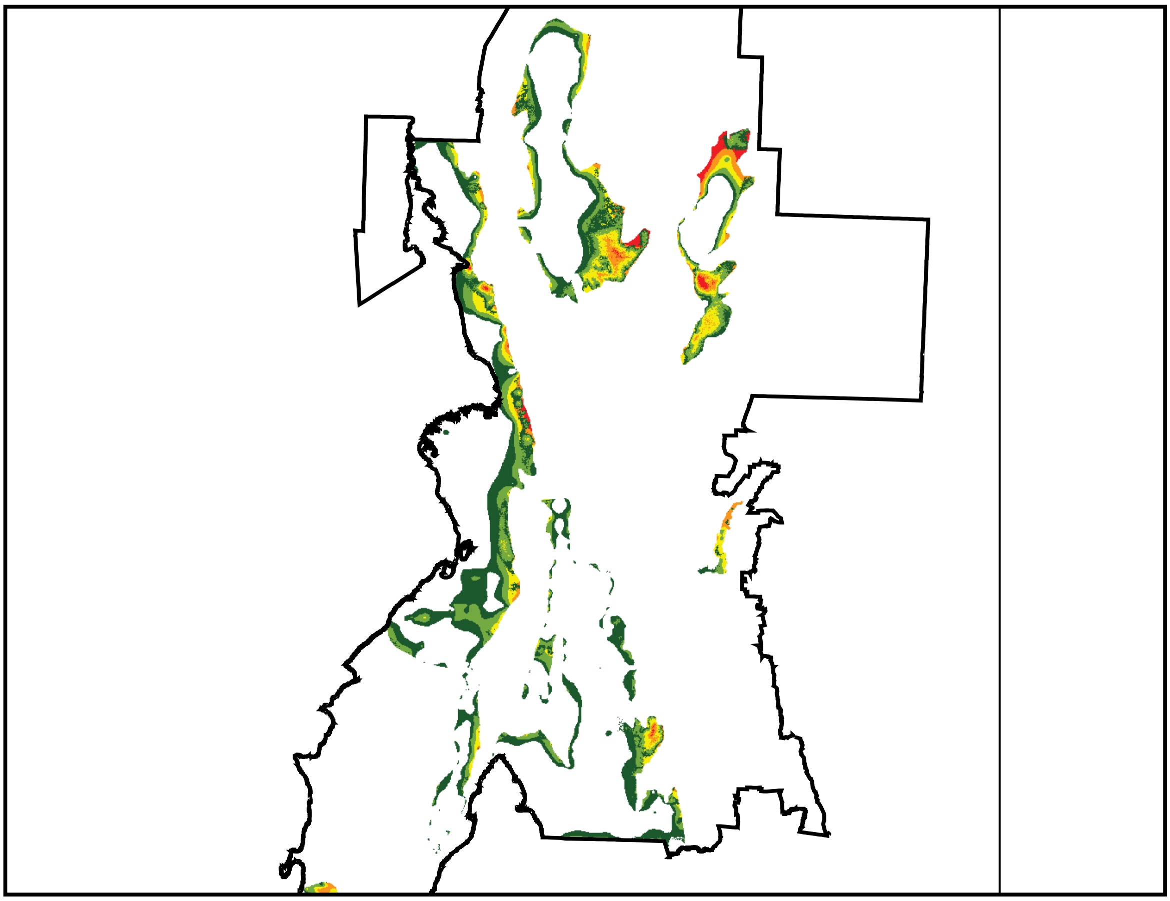

Figure 2. Example of negative thickness error in Northern and Yorke

2.4 GeoVolume construction

A geovolume represents the 'thickness' of a hydrostratigraphic unit in 3-D form and is created in ArcGIS 10.1 with the ArcHydro Groundwater tool that requires both an interpolated top surface elevation raster and a bottom raster, which typically uses the top of the underlying hydrostratigraphic unit. A vertical exaggeration factor of 10 (1:10) was applied to the geovolumes to accentuate the geovolume 'thickness' and enable better visualisation of the surfaces. Because of resource constraints, geovolumes were only calculated for the EP and NY regions.

2.5 Generated water level surfaces

Groundwater level elevation surfaces were developed for each major aquifer in the EP and NY regions using the spatial drillholes layer. Historical or current water level records were used from wells that have been identified as monitoring a particular aquifer. The well location data used in the model was referenced to the SA 1 Sec. DEM, allowing an elevation value to be assigned to each well with a standing water level (SWL) value and a new RSWL elevation value to be calculated. This was done using the ArcGIS 10.1 'Field Calculator' tool by subtracting the SWL value from the DEM value. This was necessary in order to keep the RSWL elevation surfaces consistent with other layers in the 3-D model.

In the SA MDB region, existing water level surfaces were extracted from the Murray Basin Hydrogeological Mapping GIS layers, as displayed on Barnett, 1991 (Murray Basin Hydrogeological Map Series).

2.5.1 Validation and correction of generated water level surfaces

In some areas of the EP and NY regions the generated water level surfaces project above the ground surface. In some areas, this may be reasonable, for example, where confined aquifers occur, groundwater is under pressure and the model may correctly indicate a water level (potentiometric) surface that is above ground level. However in areas where there is a paucity of data, generated water levels above ground level for unconfined aquifers may be an artefact of the interpolation, similar to the 'upwelling' of stratigraphic layers described previously. There are also several areas where the water level drops below the base elevation of its associated hydrostratigraphic unit and suggests that the base elevation of the aquifer may be too high, or the aquifer may be unsaturated in that area.

2.5.1.1 Spatial density of model input data and reducing model uncertainty

Preliminary modelling of water levels using only recent water level point data (the past 10 years) resulted in areas where the spatial density of data was very low and created a high uncertainty in the generated water level surface. Consequently, the final water level surfaces were generated using all available water level measurements, irrespective of the age of the record (many of which are greater than 50 years). This is unlikely to create large errors because water levels in the non-prescribed areas are likely to be relatively stable due to relatively low levels of extraction. Nonetheless, the generated water level surfaces are likely to reliably indicate current water levels only at the model's regional scale.

The areal extent of the generated water level surfaces is calculated beyond the boundary of the hydrostratigraphic unit because the uncertainty in the interpolation behaviour is greatest at the edge of the surface. The ArcGIS 'Extract by Mask' tool is subsequently used to clip the generated surface to the boundary of the aquifer (or hydrostratigraphic unit).

Following the initial production of water level rasters based on the above methodology, locations still existed where there was insufficient point data to have any confidence in the subsequent outputs, particularly for the Quaternary aquifers. To overcome this issue, the average thickness of the Quaternary sediments from the drillhole data was determined and it was assumed that all wells with a total depth not exceeding this thickness were completed in the Quaternary unit. Any of these wells with water level data that did not have their 'Aquifer monitored' attribute explicitly identified as Quaternary were included.

2.6 Generated groundwater salinity surfaces

Continuous surfaces showing the distribution of groundwater salinities have been generated and included in the model for each major aquifer areas in the EP, NY, and SA MDB regions, using the IDW interpolation technique. The salinity surfaces were clipped to the model boundary, or hydrostratigraphic unit, using the same approach outlined previously for the water level surface. Salinities in the basement aquifers of the NY region were not generated due to a paucity of salinity data.

Again in the SA MDB region, existing salinity surfaces were extracted from the Murray Basin Hydrogeological Mapping GIS layers as presented in the Murray Basin Hydrogeological Map Series (Barnett 1991).

2.7 Interpolation accuracy

Once interpolation of all the surfaces is completed (surface elevation, salinity and water level), examination of the spatial distribution of data points used is important when considering the accuracy of the surfaces. Where few or no data points exist there is a low confidence in the accuracy of the interpolated surface. In contrast, areas with numerous data points will be considered to have a higher confidence. As an example, Figure 3 displays data points used in surface elevation interpolation for hydrostratigraphic units on EP. Where more data points exist, the surface generally contains a higher resolution of detail. The areas where few to no data points exist result in a less detailed surface and are generally smoother (less variable) due to the large distance between data points. The exception to this is where the DEM has been used to represent the defined areas of outcrop.

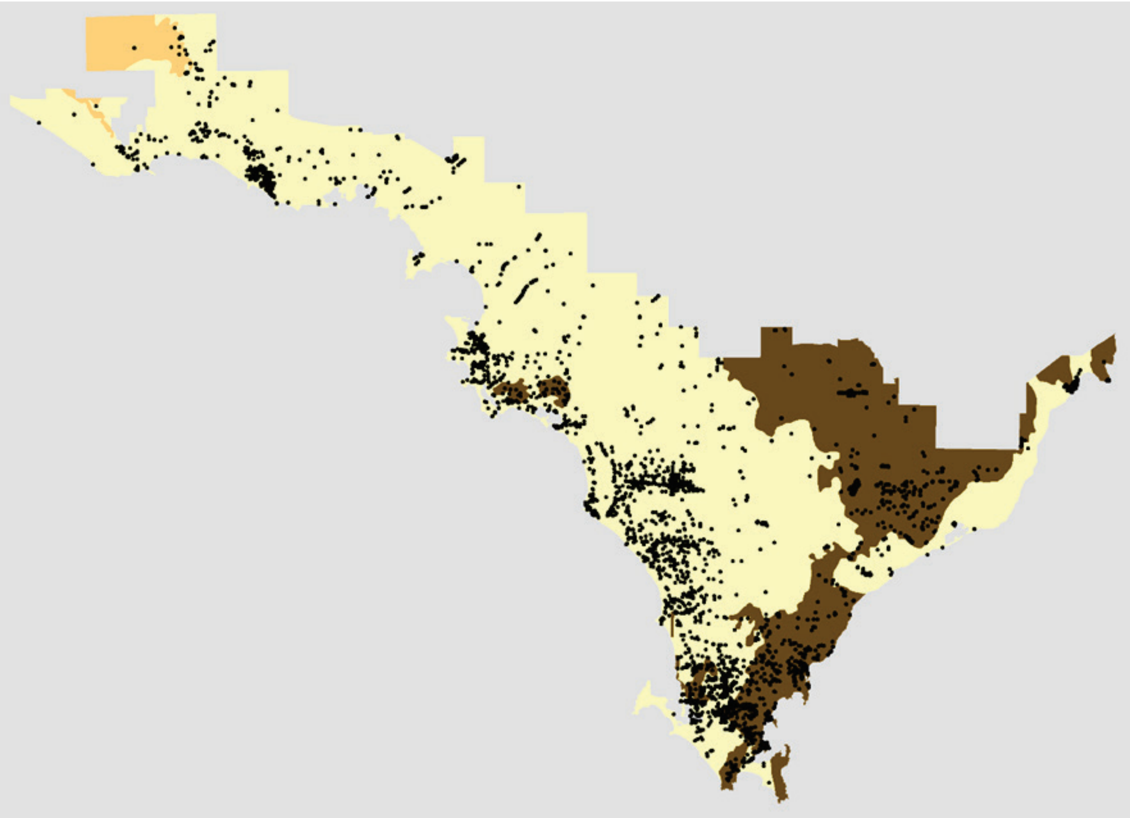

Figure 3. Distribution of drillhole data points used in hydrostratigraphic surface interpolation

2.8 Additional spatial data

Satellite imagery (25 m 2004 Landsat) and a basic roads layer were included in the 3-D model. This spatial information is intended to give users a reference point to help them find places of interest within the model.

2.9 PDF formatting

The final models were converted from Virtual Reality Modelling Language (VRML) format to 3-D PDF using Tetra 4D 3-D Converter software. Tetra 4D 3-D Reviewer was used to name model parts. The 3-D PDF model page formatting, layout and interactive buttons etc. were constructed in Adobe Pro XI. Javascripts were embedded into the interactive buttons used to control model elements such as controlling the vertical exaggeration animation (for example, when the 1:50 button is selected the model animation runs and will pause at the 1:50 key frame). Vertical exaggeration (z axis) was applied for all model elements in Adobe 3-D toolkit (Adobe 3-D 8). The vertical exaggerations were used in the creation of key frame model animation. Cross section tools for each 3-D PDF model are also controlled by javascript embedded into the interactive buttons. The starting cross section of each button is specified by coordinates and the axis the cross section is applied to.

3 Results

3.1 Calculation of groundwater storage

ArcHydro Groundwater was used to calculate the geovolumes of the 3-D hydrostratigraphic units in the EP and NY regions. The model for the SA MDB region did not undergo this process due to time limitations.

Whilst geovolumes are good for visually conceptualising the hydrostratigraphic units, there is no repeatable method for closing open geovolumes (a common problem and essential for volume calculation). Furthermore, the interpolated raster elevation surfaces have effectively been smoothed three times through the existing data processing procedures when they finally reach the geovolume stage. The three types of smoothing include: initial interpolation, resampling of cell sizes and geovolume conversion utilising coarse triangular-irregular-network (TIN) surfaces.

In smoothing the raster elevation surfaces, detail of the undulating surface is lost, which potentially reduces the accuracy of volume calculation. Therefore the volume calculation of the 'Cut Fill' tool available in ArcGIS 10.1 was applied to the 'raw' interpolated raster elevation surfaces before the smoothing of cell resampling and geovolume conversion was applied. The 'Cut Fill' tool uses the top and bottom elevation surfaces to calculate a volume for each corresponding cell and then sums the volume of each cell to give a total volume for the hydrostratigraphic unit. As the raster elevation surfaces created in this project have been 'snapped' to each other, every cell of every raster aligns horizontally thereby improving the accuracy of the 'Cut Fill' method.

The calculation of the total volume of water held in storage in unconfined aquifers requires the geovolumes to be multiplied by the specific yield (which is the volume in m^3 that an unconfined aquifer releases from storage for a one metre fall in the watertable over an area of one square metre). This parameter is difficult to measure and hence there are very few values available for the units in the non-prescribed areas. Typically, values vary from 0.01 to 0.3 (Freeze and Cherry 1979).

To obtain volumes that can be released from storage by confined aquifers, the geovolumes must be multiplied by the storativity value, which is much lower than the specific yield values because the confined aquifers yield water in response to changes in pressure, not actual draining of the pore spaces as occurs in unconfined aquifers. Typical values range from 0.005 to 0.00005 (Freeze and Cherry 1979).

For the purposes of this regional-scale exercise, it has been assumed that the Quaternary and basement units are unconfined, and that the Tertiary and Jurassic units are confined. Because an accurate estimate of the proportion of limestone, sands and clays for the units is not available, the mean values of the specific yield and storativity parameters from previous investigations and typical ranges were used. The following tables provide a first-order estimate of the total volume of groundwater held in storage, irrespective of the groundwater salinity. It should be noted that it would not be physically possible to extract this total volume of water from the aquifers.

Table 1. Eyre Peninsula - Estimated groundwater storage

Eyre Peninsula Hydrostratigraphic Unit	Cut Fill Calc. Volume (GL)	Specific yield (mean)	Storage (GL) (mean)
Basement (50m saturated thickness)	2 565 630	0.02	51 315
Jurassic	134 258	0.001	135
Tertiary	1 184 882	0.001	1185
Quaternary*	-	0.097	-

* Currently the available Quaternary point data are insufficient to provide an estimated volume and further work is required to produce meaningful values.

Table 2. Northern and Yorke - Estimated groundwater storage

Northern & Yorke Hydrostratigraphic Unit	Cut Fill Calc. Volume (GL)	Specific yield (mean)	Storage (GL) (mean)
Basement (50m saturated thickness)	1 720 705	0.02	34 414
Tertiary	6 543 679	0.001	6545
Quaternary*	-	0.097	-

* Currently the available Quaternary point data are insufficient to provide an estimated volume and further work is required to produce meaningful values.

4 Outputs

4.1 Final 3-D PDF products

The 3-D models are a useful visual representation of point data from the state's drillhole database, but it should be noted that these products do not automatically update as new point data is added to or updated in SA Geodata, i.e. it represents the information stored in the database at the time of model production. Users can navigate around the model (pan, zoom etc.) by dragging the mouse pointer across the model and rolling the mouse centre wheel. Users can also toggle layers of interest on and off using the control panel located on the right hand side of the model. The vertical exaggeration of the model can be altered and cross sections can be created (it is recommended that vertical exaggeration be applied when creating cross sections). A measurement tool can be used to measure horizontal and vertical distances, however, conversion of units is required depending on vertical exaggeration applied to the model (e.g. vertical exaggeration of 1:100 requires the measurement to be reduced by a factor of 100, i.e. a measurement of 5000 metres becomes 50 metres once reduced).

The 3-D models are provided in 3-D PDF format ensuring easy accessibility and viewing over the internet. They can be viewed using Adobe Reader 10.0 or later, or Abode Acrobat 10.0 or later.

A free download of the latest Acrobat Reader can be obtained from the Adobe website (http://www.adobe.com).

Note: The current version of Adobe Mobile Reader, for mobile devices, does not support 3-D PDF viewing. A 3-D PDF Reader for Apple iOS devices is available from the Apple Store. An Android version was not available at the time of writing.

Figure 4 displays the model interface as it appears in the PDF format, while Figure 5 presents the full version of the 3-D toolbar which can be extended (right-click the toolbar and select Extended).

Figures 6 to 13 present a series of 'screen grabs' demonstrating the range of information that can be accessed from the various 3-D PDF models.

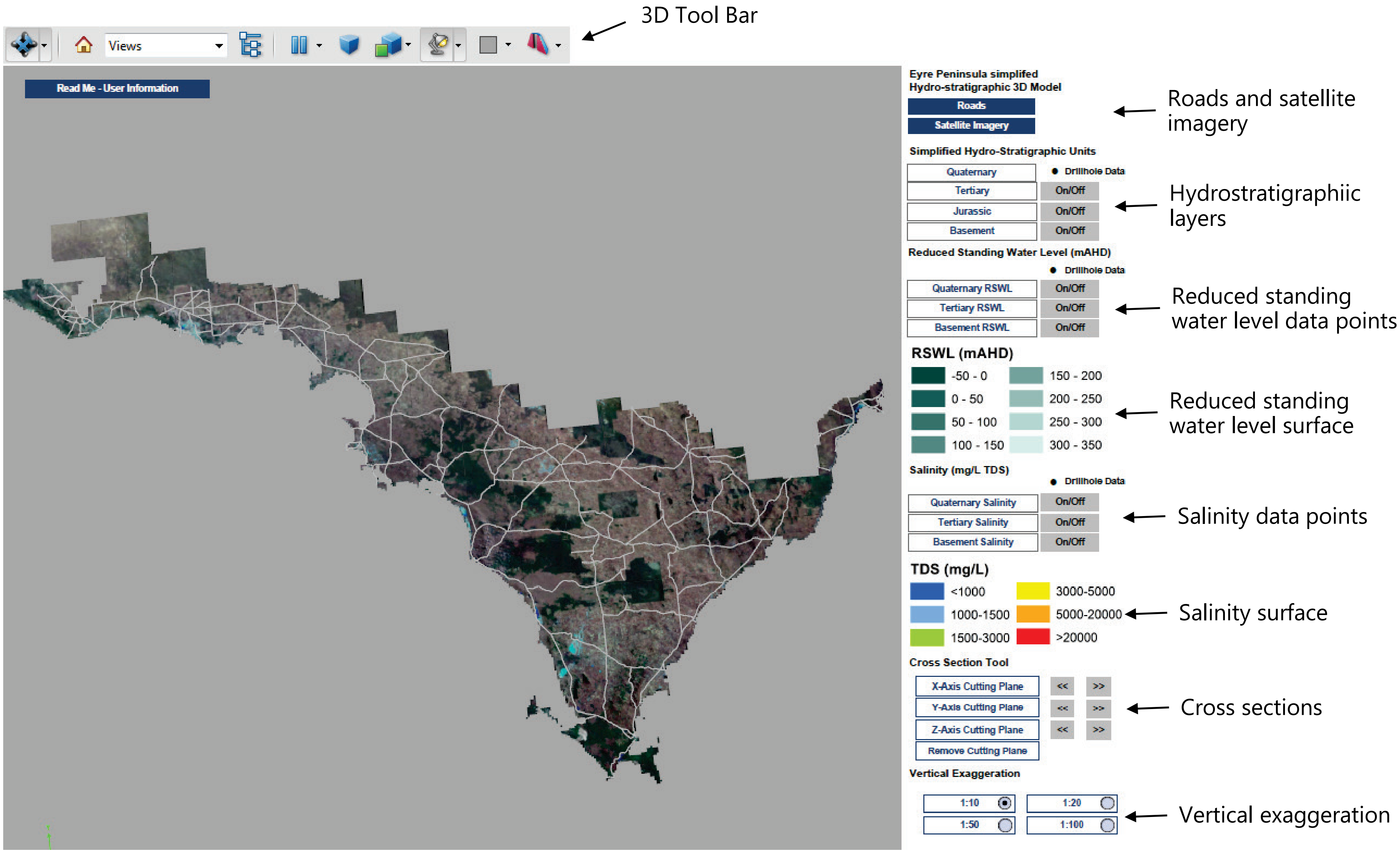

Figure 4. The PDF model interface (showing the Eyre Peninsula model start view)

1. **Rotate:** (default) Applies Rotate mode to the pointer, in the model view. Drag the pointer in the direction that you want; the model rotates and tilts on the central axis.
2. **Spin:** Applies Spin mode to the pointer, in the model view.
3. **Pan:** Applies Pan to the pointer, in the model view.
4. **Zoom:** Applies Zoom mode to the pointer, in the model view. In the model view, click and drag the pointer up (zoom in) or down (zoom out).
5. **Fly:** Activates fly over mode. Best used when viewing the model horizontally. Click the model and move the mouse forward to start the 'fly over' animation. Release the mouse button to stop.
6. **Camera Properties:** adjust camera view properties - camera presets, alignment, position target, parameters. Allows the user to input precise camera view angles and positioning.
7. **3D Measure Tool:** Enables you to measure tool, in meters. Point switches to a cross-hair and a red dot appears. On the model, click the starting point, then double-click at the end point. See **Measuring layer thickness** below.
8. **Add 3D Comment:** Add a comment to a selected location on the model.
9. **Default View:** Return to the default view, i.e. scale and orientation of the model when first opened. Useful for clearing comments or measurements.
10. **View selection:** Select a view of the model, e.g. top or bottom. If you have used the measure tool, each measurement is added to the selection.
11. **Toggle Model Tree:** Opens the Model Tree panel showing the list of layers that make up the model. Enables you to refine layer selections. See **Using the map layers** below.
12. **Pause Animation:** Not applicable for these models.
13. **Use Perspective Projection:** switch between perspective projection (realistic view of the 3D image) & orthographic projection (unrealistic view that enhances 3D image depth. The scale is only true at centre of the 3D image).
14. **Model Render Mode:** Enables you to apply different renders to the model.
15. **Enable Extra Lighting:** Enables you to apply different light effects to the model.
16. **Background Color:** Enables you to select a different background colour.
17. **Toggle Cross Section:** Enables you to select cross section properties. See also Cross Section Tool below.

Figure 5. Adobe PDF 3-D Toolbar demonstrating the range of navigation options and function available

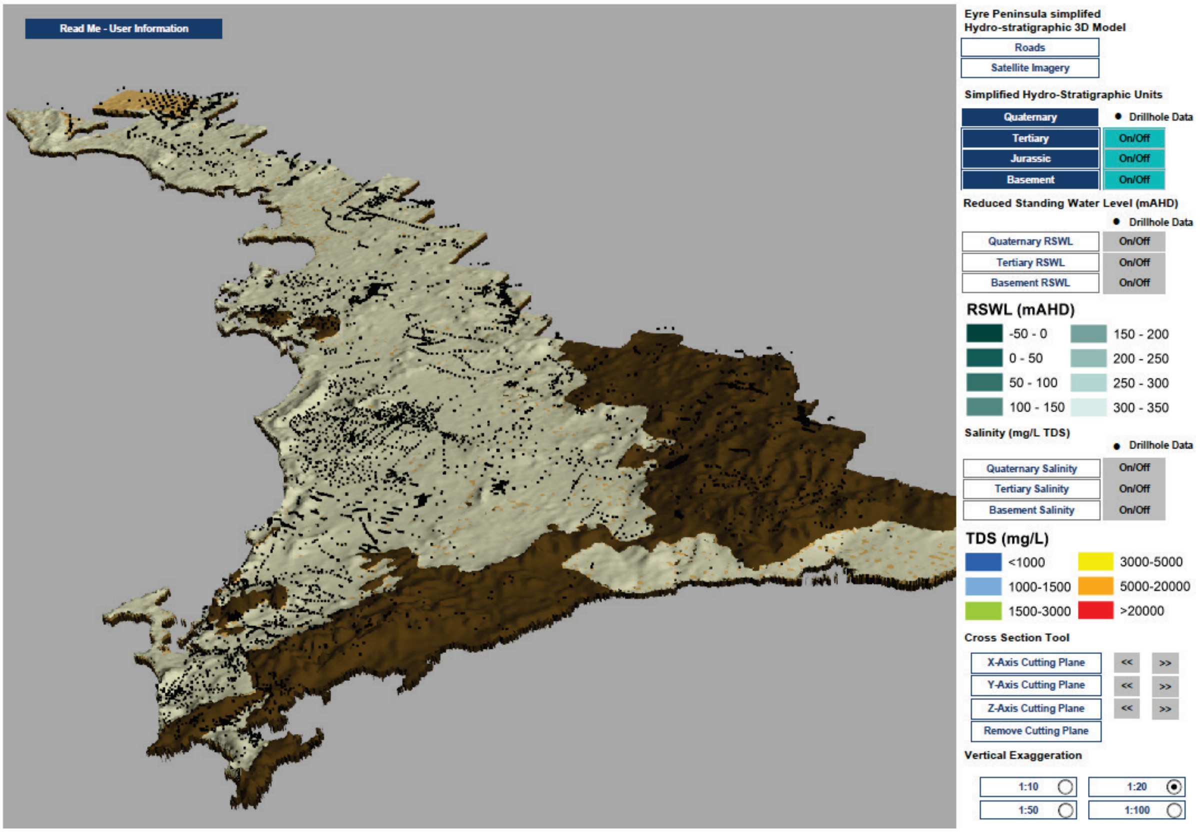

Figure 6. EP hydrostratigraphic unit thickness (1:20 vertical exaggeration)

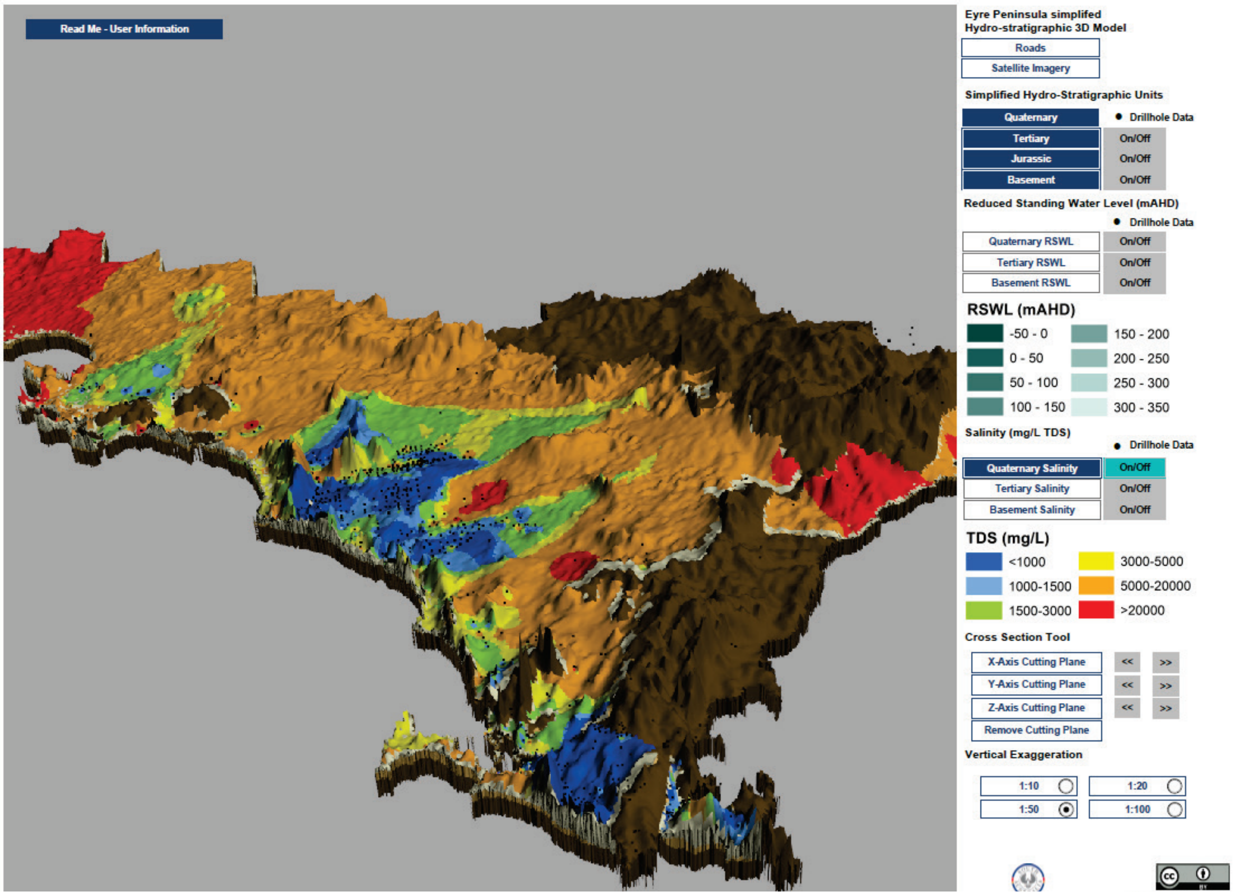

Figure 7. Salinity of EP Quaternary hydrostratigraphic unit (1:50 vertical exaggeration)

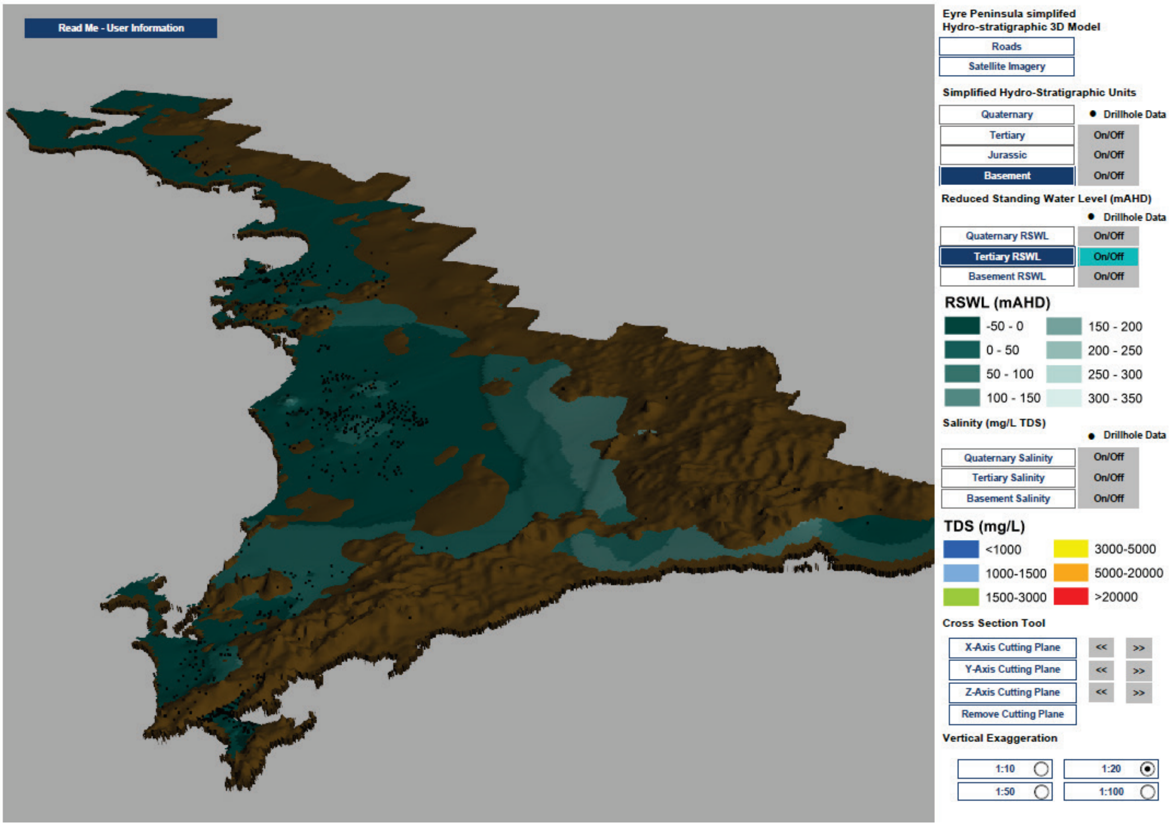

Figure 8. **EP Tertiary RSWL water elevation surface (1:20 vertical exaggeration)**

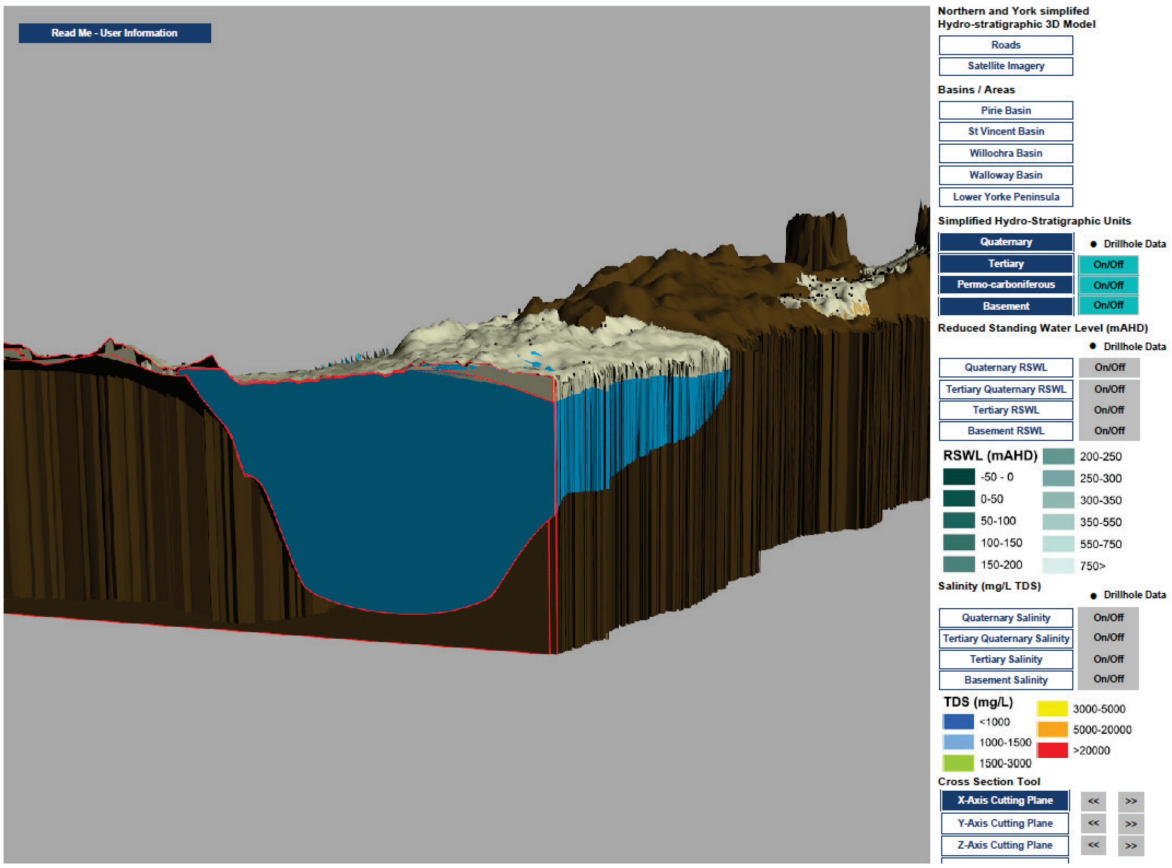

Figure 9. **Cross Section displaying NY Permian hydrostratigraphic thickness (1:50 vertical exaggeration)**

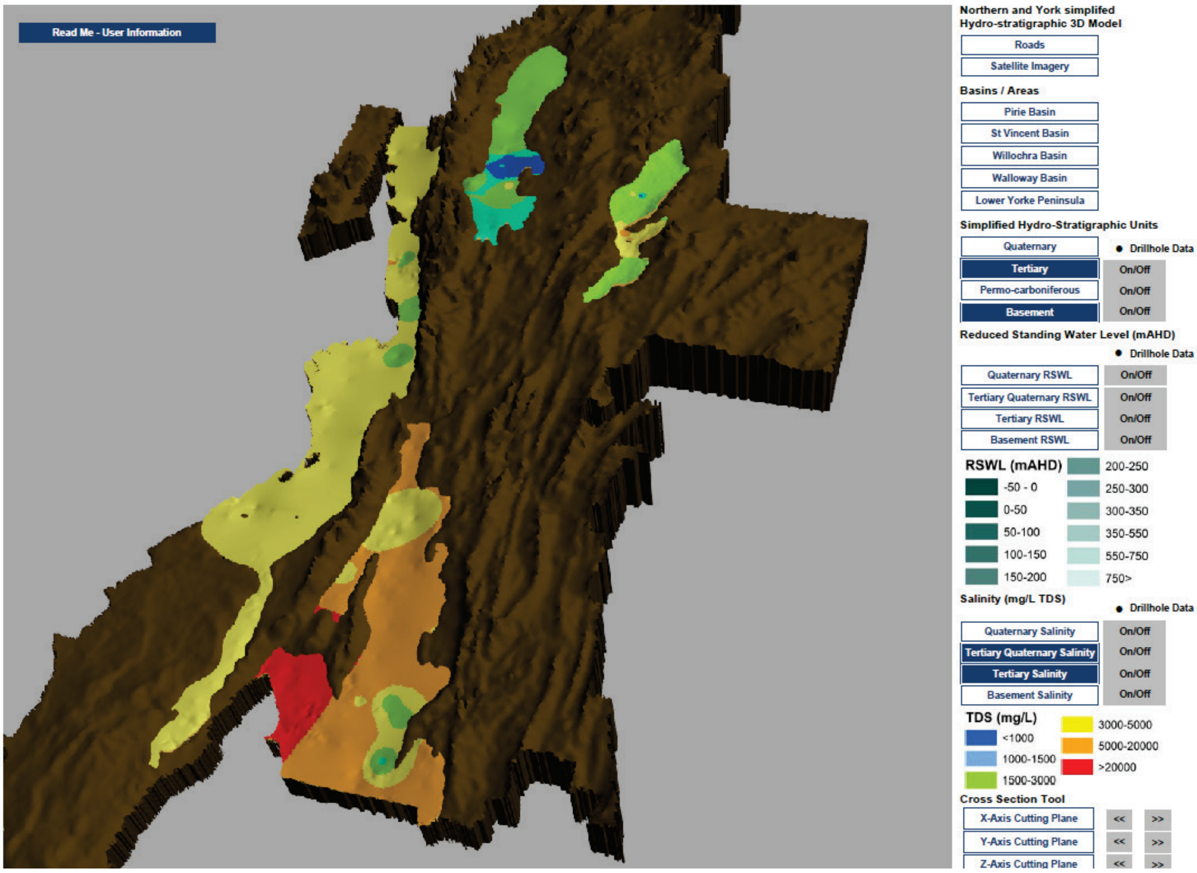

Figure 10. Salinity of NY Tertiary Hydrostratigraphic Units

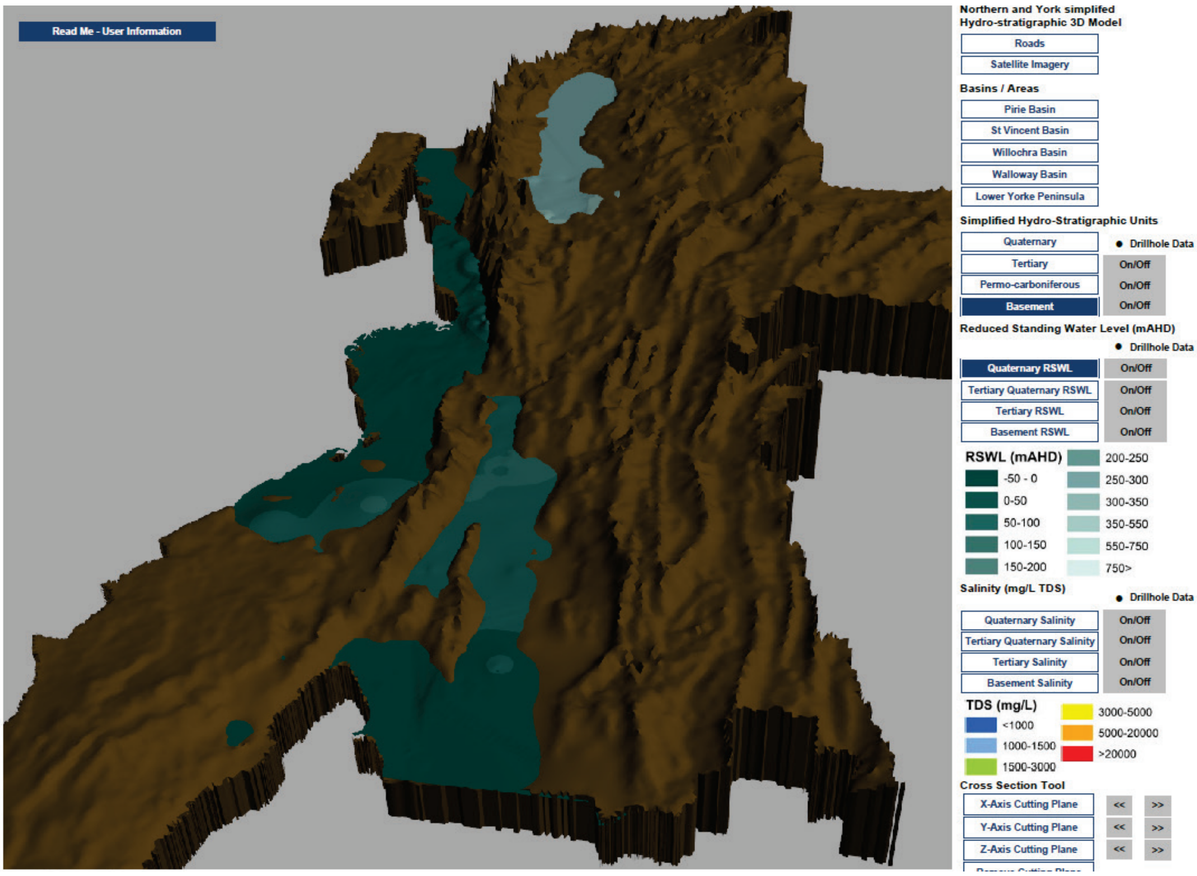

Figure 11. NY Quaternary RSWL water elevation surface

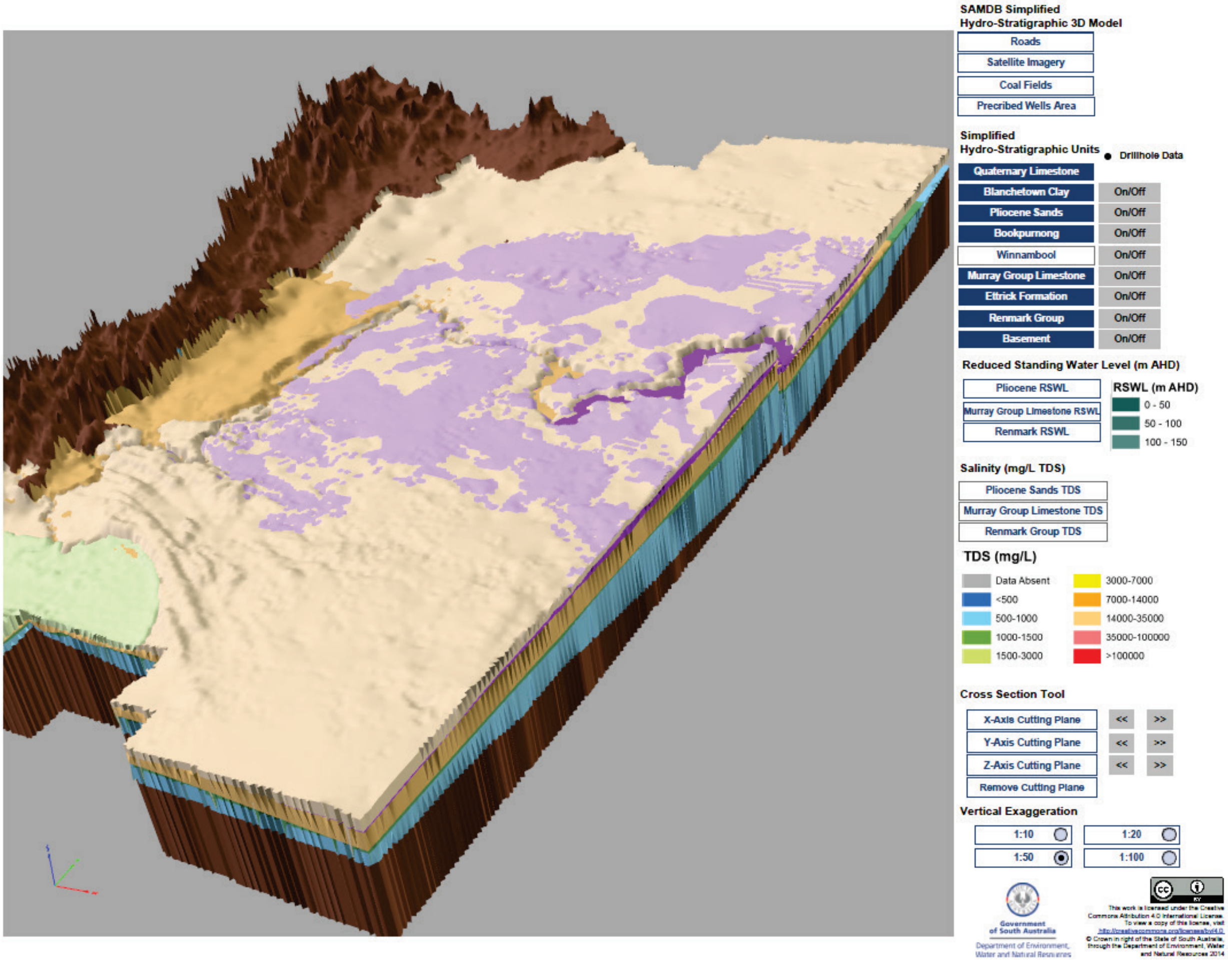

Figure 12. SA MDB hydrostratigraphic unit thicknesses (1:50)

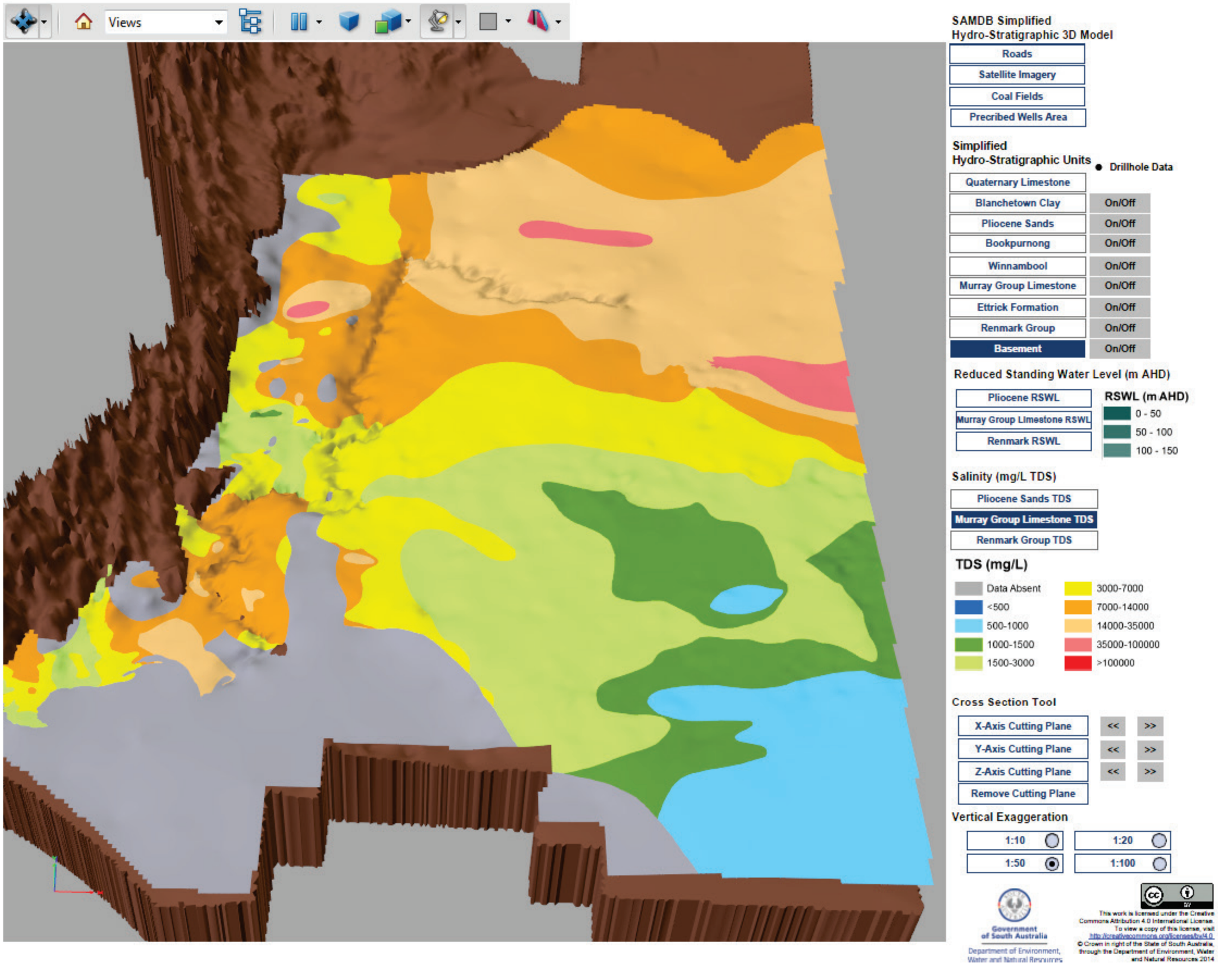

Figure 13. SA MDB salinity of Murray Group Limestone aquifer

4.2 Potential use of the model

The models have the potential to be used for decision making to support groundwater management and development at regional scales. For example, the approximate drilling depths to various aquifers can be determined by using the measurement tool to measure depth to hydrostratigraphic units. Figure 14 provides an example of the depth to Tertiary sediments below the ground surface. In this example, the model's vertical exaggeration is set at 1:10, therefore the measurement shown is reduced by a factor of 10 to convert the model to the actual measurement, i.e. 89.4 m. The models can also be used for conceptualising the geology of the region.

Additionally, the expected groundwater levels and salinity ranges may be determined, as well as areas at risk to dryland salinity impacts (where shallow watertables are less than 2 m below ground). Potential zones of recharge may be identified where salinities are low (Fig. 15) and water level elevations are high. Conversely, discharge zones may be delineated by high salinities and shallow water level elevations.

In addition to the potential uses described above, the constructed geovolumes can be used to calculate a first-order estimate of the total volume of groundwater held in storage (see Section 3.1; Note: this does not represent the total volume of water that can be physically extracted from the aquifer).

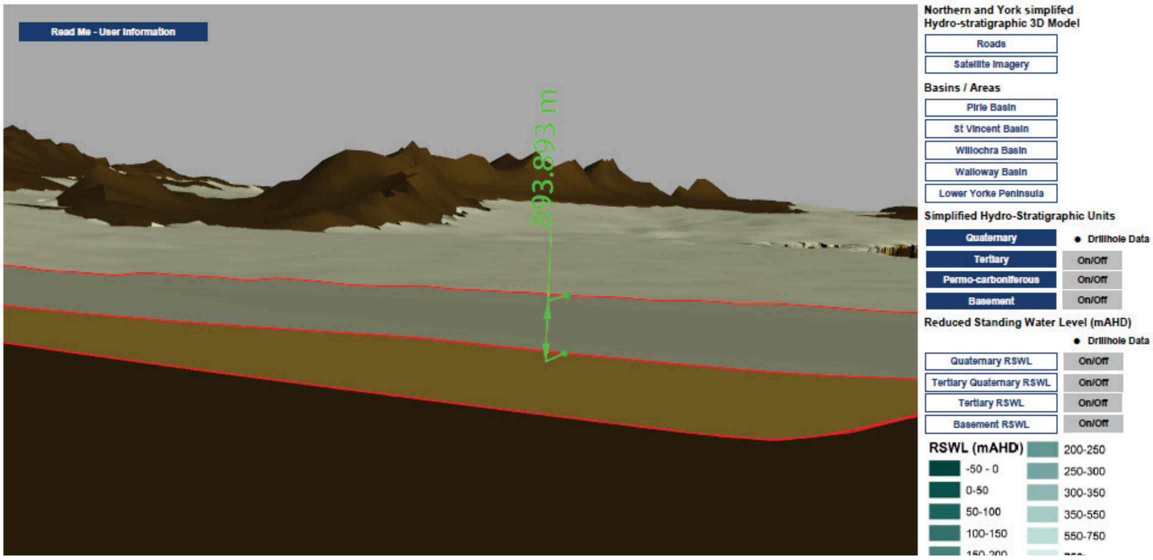

Figure 14. Drilling depth to Tertiary sediments

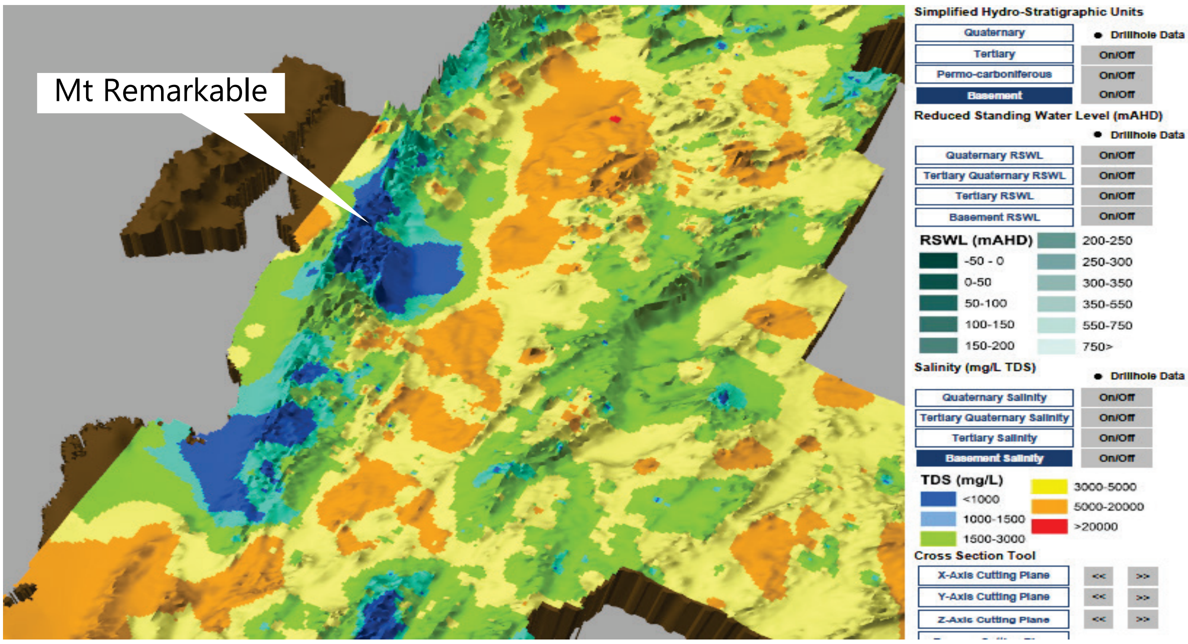

Figure 15. Zones of fresh groundwater zones in the basement aquifer around Mt Remarkable

4.3 Current modelling issues

It has not been possible to fully resolve several issues with the 3-D PDF models. These include:

- Processing Power – the construction of GeoVolumes is limited to around a 500–1000 m sized TIN at the regional scale that these models are produced
- ArcScene 10.1 is very unstable with GeoVolumes and large 3-D 'Scenes', particularly in Windows XP. The Windows 7 operating system has rectified these issues
- Roads (line features) appear as Default Grey colour when the model is edited/animated in Adobe 3-D Toolkit. This is a known issue with Universal 3-D (.u3D) files (this issue does not occur with PRC files, however, they do not support animation). Work is underway on a potential javascript to change the colour of lines in 3-D PDFs.

4.4 Software used

Other software has been investigated for the 3-D modelling process. Several other software packages have been tested internally or have been recommended by industry experts. The following lists the potential benefits and disadvantages of each software package.

Table 3. Analysis of software packages

Package	Advantages	Disadvantages
3-D Modelling		
GOCAD	Industry standard, very powerful visualisation software	Higher cost (>$50 000), many components and add-ons that increase cost
Leapfrog	Similar to GOCAD but has fewer features (such as data confidence etc.) and lower cost (around $5000)	
3-D Editing & Animation		
Right Hemisphere Deep Exploration	Powerful editing and animation software, lots of features and tools	Costly (~$10 000)
Corel Designer Technical Suite x4/x5	Contains Right Hemisphere CSE, inexpensive (~$1000)	Not the current version, difficult to acquire and version x6 does not contain the required right hemisphere
Blender	Free, Open Source Community	Cannot replicate results obtained using Adobe 3-D 8, as it doesn't seem to handle large models such as NRM regions; further testing required

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5 Recommendations

5.1 Data validation and improvement

Investment in upgrading the SA Geodata database is recommended, particularly with respect to inputting both lithologic and hydrostratigraphic logs from microfiche records (this was not within the scope of this initial project). More extensive completion of the 'Aquifer Monitored' field in SA Geodata would create more data points for the water level elevation surfaces. This could be achieved by comparing the well construction details against the known hydrostratigraphic surfaces. Where drillhole data and geological interpretations are clearly incorrect, further cleansing of existing data should be undertaken to improve the accuracy and credibility of the surfaces before any further versions of the models are produced.

5.2 Hydrostratigraphic refinement

A more detailed subdivision of the regional hydrostratigraphic units could be carried out if adequate data are available. A reinterpretation of some existing logs would also be required. It is also recommended that a review of the extent of subsurface features such as the Polda Formation be undertaken. In this case, drillhole logs recorded the existence of the Polda Formation outside of the generalised boundary used in the current Eyre Peninsula model.

5.3 Groundwater storage volumes

A data cleanse and improvement of the Quaternary water level data is required to be able to produce an elevation surface required for the estimations of aquifer storage volumes in the Quaternary aquifers. Refinement of storage estimations will be possible at a sub-regional scale (e.g. Willochra Basin in NY or Cummins Basin on EP) if there is sufficient stratigraphic data to enable a better understanding of the spatial distribution of the dominant lithologies (limestone, sand and clay), and will allow a more accurate attribution of the specific yield and storativity values.

5.4 Groundwater assessment

Estimation of groundwater storage volumes is the first stage of developing data sets to enable broad assessments of the non-prescribed groundwater resources. The storage volumes data can be enhanced by presenting it on a one square kilometre grid (e.g. 2.3 ML/km^2) so that the footprint of any development can be estimated (in the above example, an annual demand of 5 ML/y would have a minimum footprint of about 2 km^2). Another data set would be average well yield on a one square kilometre grid (a yield of 0.2 ML/y from a well would mean 25 wells being required to supply the above demand).

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