

An overview of the Mineral Resources Tasmania statewide groundwater monitoring network

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Abstract

Mineral Resources Tasmania (MRT) collects water chemistry and water level data from boreholes installed in various Tasmanian groundwater aquifers. Data from the boreholes have been used in salinity and groundwater mapping projects and for the publication of two groundwater catchment maps. This report documents the history of the boreholes and provides processed and checked water level and water quality data. New procedures are outlined and recommendations provided for the future management of the network.

Pressure and temperature data loggers indicate that the water level in most boreholes varies considerably with rainfall events. Of the monitored boreholes, 75% showed a net decline while 25% indicated a rise in the water level over the period of record (based on the linear regression technique). The linear regression of the total dissolved solids (TDS) data indicates that the TDS in the water from 60% of the boreholes is decreasing, while it is increasing in 40% of the boreholes. Such trends should be quoted in terms of past quality assurance issues and the lack of documented procedures.

Combined hydrographs of MRT groundwater level data and surface water stream-flow data (provided by DPIWE for the closest weirs) indicate a direct hydraulic link between surface and groundwater systems. A more detailed study of the existing hydrological datasets is required in order to provide some guidance about the value of long-term monitoring of surface and groundwater (as a single interactive resource).

The current statewide network requires on-going maintenance and is not sufficient for the sustainable management of Tasmania's water resources. Essential components of the water level monitoring program include a large array of observation wells, aquifer defined frequency water level measurements, quality assurance data, and data reporting.

Seven boreholes where data quality is questionable should be decommissioned and five others repaired. Seventeen boreholes require re-drilling and three cleaning out, or blockages removed.

Introduction

Monitoring of water level and groundwater quality began in the Devonport area in 1985 by the then Department of Mines. The Devonport network was installed to monitor the impact of groundwater extraction for irrigation purposes from the local/regional basalt aquifer.

In the period from 1990 to 1991 monitoring was expanded statewide by drilling new or using existing boreholes. This network has been slightly expanded in recent years.

A third network of boreholes was established in 2000 as part of a National Heritage Trust (NHT) funded salinity investigation. The NHT salinity network was intensively monitored between 2000 and 2002 for water quality and water level.

MRT has also been involved in the establishment of three other groundwater networks in recent years (DeLL, 2000; Ezzzy, 2002; Taylor, 2000). Because these boreholes are currently not monitored, only the Devonport, statewide and NHT salinity networks are discussed in this report.

The aim of this report is to provide an overview of past objectives of groundwater monitoring, types of data collected, data storage locations, identified strengths and limitations of the monitoring program, and provide recommendations for the future management of the borehole network.

As the term standing water level (SWL) is mainly applied to short-term trends (e.g. barometric pressure changes) and this report mainly refers to long-term static water levels, the term water level (WL) has been used instead of SWL.

The current monitored network of water level and groundwater quality boreholes in Tasmania consists of the remaining operational statewide and Devonport network boreholes (34 and 18 holes respectively) and a smaller subset of boreholes (9) from the National Heritage Trust salinity network.

Statewide groundwater level/ groundwater quality network

The statewide groundwater network initially consisted of 37 groundwater monitoring sites and one surface water monitoring site. At the time of drilling no formal agreement was made with the property owners. Consequently, no legal mandate exists for MRT to enter the properties and obtain water level measurements and collect water quality samples for chemical analysis.

In recent years, the network was expanded by using additional boreholes from the Devonport and NHT salinity networks. This expansion was brought about by the recognition of thirteen groundwater flow systems in Tasmania (Latinovic *et al.*, 2003). The objective of adding these boreholes to the network was to gain an understanding of the behaviour of these local, intermediate and regional groundwater flow systems. The expansion of the network included the monitoring of salt pans connected to near-surface saline water tables within agricultural areas (NHT salinity network), plus artificially-induced excessive drawdown as a result of high-density intensive extraction of groundwater for irrigation (Devonport network). The current expanded network provides a preliminary data source that supports/allows a sustainable approach to the management of the localised resources.

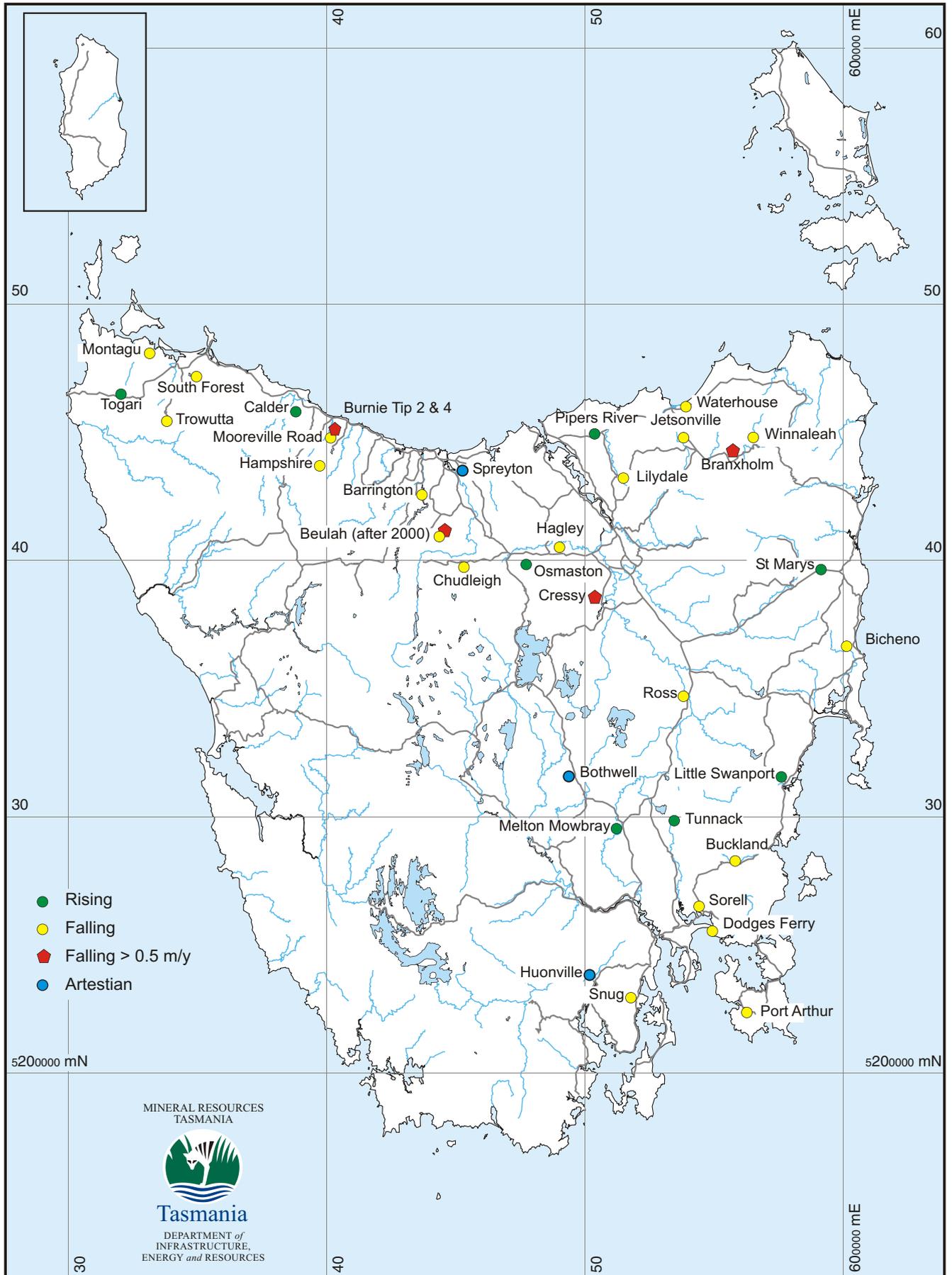


Figure 1
Location of currently monitored bores, statewide monitoring network

The reason for the siting of each of the boreholes has not always been well documented. Based on the depth and distribution of the boreholes, the sites appear to have been selected to assess natural temporal changes in the storage volumes and water quality of the particular aquifers. Monitoring data include time interval water quality parameters, manual water levels, and automatic pressure and temperature records.

The monitoring boreholes range in depth from 24 to 135 metres. Complete engineering logs do not exist for the boreholes. Many of the boreholes were not properly installed and this has resulted in silting and collapse of the borehole walls. As a result of the poor documentation of procedures and unsatisfactory storage and quality control of the data, the scientific integrity of some of the historical data is questionable.

A surface water monitoring site and three boreholes are located adjacent to the Burnie landfill. This monitoring was to detect any pollution that may result from a hydraulic connection of the groundwater with the fill material.

Figure 1 shows the location of the currently monitored boreholes. A general description and location map for each borehole in the statewide groundwater network is provided in Appendix 1. Appendix 2 contains drilling records from the MRT groundwater database for the statewide groundwater network boreholes.

To standardise the scientific integrity of the data, field procedure sheets were trialled in 2003. Appendix 3 contains a sample field procedure sheet for the Chudleigh monitoring borehole. Table 1 lists statewide groundwater network monitoring boreholes with respect to the groundwater flow systems (Latinovic *et al.*, 2003).

Water level readings and water quality samples have been collected during autumn and spring since 1990. Automatic pressure data have been recorded since 1995 from the statewide groundwater network. Basic maintenance on borehole collars was undertaken in 2002.

Two overview reports on the network were undertaken by the Hydro-Electric Commission (HEC) Water Resources Department, the first in 1994 (Buckland, 1994) and the second in 1995 (Buckland and Krohn, 1995). Buckland (1994) provided a detailed list of recommendations and Buckland and Krohn (1995) noted that none of the recommendations made by Buckland (1994) had been implemented. These recommendations have progressively been implemented since 2002.

Table 2 indicates what actions are currently required for the on-going management of individual boreholes in the statewide groundwater network. The cost of re-drilling, decommissioning and other required maintenance for the boreholes is estimated to be approximately \$300,000.

Devonport network

This network consists of two groups of boreholes. The first group was drilled close to existing irrigation boreholes and for some years the irrigation boreholes were monitored to record extraction volumes. The second group of boreholes was drilled away from existing private boreholes to monitor natural aquifer conditions and potential over extraction/induced drawdown on a regional scale. Results of the water level and quality monitoring for the period between 1984 and 1989 are available in Cromer (1993). One *Dataflow* data logger was installed to monitor natural aquifer conditions in 2001. This logger was decommissioned in March 2004 due to hardware failure.

The locations of the Devonport network boreholes are shown in Figure 2 and Appendix 1. The drilling records from the MRT groundwater database for the Devonport network boreholes are included in Appendix 2.

NHT salinity network

Between 2000 and 2003, MRT was involved in a joint State/Australian Government project to investigate hydrogeological and salinity processes in the Waterhouse, Tunbridge and Coal River areas (Coffey Geosciences, 2002). As part of this project MRT installed four *Dataflow* data loggers in each of the three field areas. Of the original twelve installed, only nine data loggers remain operational (three in each field area).

The locations of the NHT salinity network boreholes are shown in Figure 2. Engineering logs for the drilling and installation of the twelve currently monitored boreholes from the NHT salinity network are included in Appendix 2.

Water level information

Manual readings

The purpose of collecting manual water level readings is to calibrate data logger information and identify any times of aquifer stress during annual recharge and discharge.

Manual readings of water level for the statewide groundwater network have been compiled from twice yearly readings and are summarised in Appendix 4. A ground level datum was not initially set and readings may have been affected by activity around the borehole collars. From this information, linear regression equations have been calculated for each borehole to determine the rate of change of water level, based on 13 years of measurement. The linear regression technique can only be regarded as an approximation of groundwater storage trends, as it is based on a small number of chance observations. Data loggers indicate that water level varies considerably with rainfall events for most boreholes, but 75% of all boreholes show a net decline and 25% indicate a rise in

Table 1*Currently monitored original network boreholes with respect to groundwater flow systems*

<i>Tasmanian groundwater flow system as defined by Latinovic et al. (2003)</i>	<i>MRT statewide groundwater network monitoring bores</i>	<i>Geology in which bore is located</i>
1. Regional and local flow systems in Tertiary sedimentary rocks	Cressy	Tertiary sedimentary rocks
2. Intermediate flow systems in Tertiary sedimentary rocks	Jetsonville	Tertiary sedimentary rocks
3. Intermediate flow systems in low relief Permian and Triassic sedimentary rocks	Calder Ross St Marys Bothwell Tunnack Melton Mowbray Huonville Buckland	Permian mudstone Triassic sandstone Triassic sandstone Permian mudstone Permian mudstone Triassic sandstone Permian mudstone Triassic sandstone
4. Intermediate flow systems in low relief folded and fractured Proterozoic and Palaeozoic rocks	Togari Trowutta Montagu South Forest Beulah Chudleigh Pipers River Branhholm	Precambrian dolomite Rocky Cape Group Precambrian slate Precambrian slate Precambrian slate Cambrian mudstone Ordovician limestone Mathinna Beds slate Mathinna Beds slate
5. Intermediate to local flow systems in Tertiary basalt	Hampshire Barrington Hagley Winnaleah Pawleena Road Burnie Tip 1 Burnie Tip 4	Tertiary basalt Tertiary basalt Tertiary basalt Tertiary basalt Tertiary basalt Tertiary basalt Tertiary basalt
6. Intermediate to local flow systems in Jurassic dolerite	Nil	N/A
7. Local flow systems in Quaternary sedimentary rocks (talus & till)	Nil	N/A
8. Local flow systems in high relief Jurassic dolerite	Little Swanport Port Arthur	Jurassic dolerite Jurassic dolerite
9. Local flow systems in high relief Permian and Triassic sedimentary rocks	Spreyton Osmaston Lilydale Bicheno Snug Dodges Ferry	Permian mudstone Permian slate Permian slate Triassic sandstone Triassic sandstone Triassic sandstone/mudstone
10. Local flow systems in high relief granitic rocks	Nil	N/A
11. Local flow systems in high relief folded and fractured Proterozoic and Palaeozoic rocks	Mooreville Road	Precambrian Burnie Formation slate
12. Local to Intermediate flow systems in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium)	Nil	N/A
13. Local to Intermediate flow systems in Quaternary to Tertiary sedimentary rocks (aeolian, coastal plains and alluvium)	Waterhouse	Quaternary sedimentary rocks

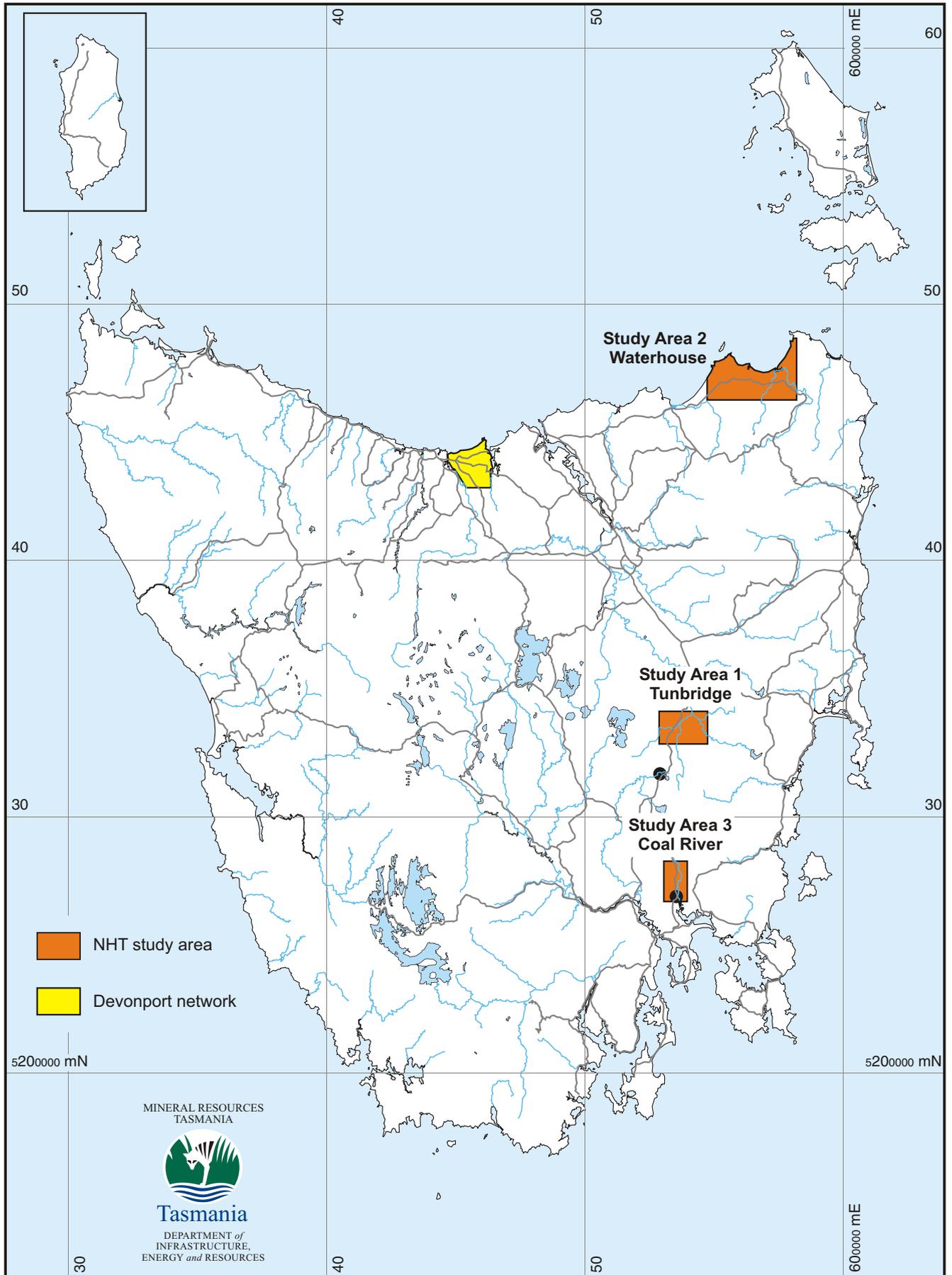


Figure 2
Location of the NHT salinity and Devonport network bores

Table 2*Actions required for the ongoing management of individual bores of the statewide groundwater network*

<i>Bore name</i>	<i>Re-drilling</i>	<i>Decommissioning</i>	<i>Cleaning of casing</i>	<i>Collar maintenance</i>
Barrington	x	x		
Branxholm	x	x		
Bothwell				x
Buckland				x
Calder	x			
Chudleigh	x			
Cressy	x			
Dodges Ferry	x	x		
Hampshire				x
Huonville				x
Jetsonville			x	
Lilydale	x			
Melton Mowbray	x	x		
Montagu	x			
Mooreville Road	x	x		
Osmaston	x	x		
Pipers River	x			
Port Arthur	x		x	
Snug	x	x		
St Marys	x			
Spreyton				x
Togari	x			
Tunnack	x			
Waterhouse			x	

water level. These trends should be quoted with caution due to past quality assurance issues and the lack of documented procedures.

Table 3 lists the common names of the boreholes, calculated linear regression equations, and related gradients of daily and annual movement based on November 2003 data. Because of the effect of drilling irrigation boreholes near the Montagu and Togari monitoring boreholes, data collected post 1999 has been ignored. Two of the four artesian boreholes (Spreyton and Huonville) stopped flowing from late 2001 to early 2003, and flow rates from the remaining two (Burnie Tip 1 and Bothwell) decreased significantly.

Automatic readings — time series data

Two types of digital time series pressure and temperature data collection devices have been installed in various boreholes in the network. The older *Dataflow* system has been in operation since 1995 for the statewide groundwater network and is being progressively decommissioned as individual devices become unserviceable. Large data gaps exist for many of the *Dataflow* monitored boreholes. Twenty-eight out of the 43 *Dataflow* devices installed across the three networks remain operational. As a result of these failures, the new *Odyssey* system was installed in 28 boreholes in December 2003. The co-installation of both types of hardware allows for cross checking of data integrity between the two systems. Table 4 is a summary of the current distribution of the two systems and the history of the progressive decommissioning of the *Dataflow* system.

***Dataflow* system**

This system consists of a data logger which is installed down the borehole above the maximum expected water table height. Two types of sensors can be attached to the logger. The older type of sensor consists of a 3.2 metre long PVC pipe with an external sensor wire which is lowered into the water table. The second type of sensor may be connected to the logger by a five or ten metre cable. The three probes have a respective range of measuring water table oscillations of three, five and ten metres. If a change in the water level exceeds the sensitivity of the installed sensor (i.e. 3, 5 or 10 metres), the recorded data cannot be calibrated.

The data loggers are programmed using MS-DOS software to record pressure and temperature readings every three hours. Based on hardware calibrations provided by *Dataflow* Systems Pty Ltd and in-field calibration equations generated at the time of download, the pressure readings can then be converted to water level values. Appendix 5 lists the calibration values provided by *Dataflow* Systems Pty Ltd and details of the status of each installation.

Even with the calibrations provided, field testing of the *Dataflow* devices has shown that data collected from this system must be field calibrated during each inspection. If the devices are not regularly field calibrated, any temporal drift in the data renders them useless.

Appendix 6 contains an internal MRT field operational procedure manual for the *Dataflow* system. The manual was developed to assist with data collection and processing, although site-specific conditions may

Table 3

Linear regression equations calculated in Microsoft Excel 2000 from 1990 to 2003 SWL data, statewide groundwater network monitoring boreholes. Negative values imply a declining water table.

Feature ID (MRT database)	Location	Linear regression equation	Gradient (metres/day)	Gradient (metres/year)
16531	TOGARI	y = -0.0002 +3.0124	0.0002	0.073
16527	SOUTH_FOREST	y = 0.0003 -6.0238	-0.0003	-0.1095
16532	MONTAGU	y = 0.00046 -2.185	-0.00046	-0.1679
16530	TROWUTTA	y = 0.0003 -0.8614	-0.0003	-0.1095
16533	CALDER	y = -0.0012 +64.293	0.0012	0.438
16534	HAMPSHIRE	y = 0.0002 +1.5954	-0.0002	-0.073
16535	MOOREVILLE_ROAD	y = 0.0005 -2.9986	-0.0005	-0.1825
16545	JETSONVILLE	y = 0.0009 -23.146	-0.0009	-0.3285
16543	PIPERS RIVER	y = -0.0009 +49.451	0.0009	0.3285
16544	WATERHOUSE	y = 0.000006 +3.2827	-0.000006	-0.00219
16547	WINNALEAH	y = 0.0002 +43.845	-0.0002	-0.073
16546	BRANXHOLM	y = 0.009 -7.6506	-0.009	-3.285
16526	ST_MARYS	y = -0.00005 +9.1411	0.00005	0.01825
16537	BEULAH	y = 0.0024 +11.705	-0.0024	-0.876
16536	BARRINGTON	y = 0.0004 -9.7605	-0.0004	-0.146
16542	LILYDALE	y = 0.0004 -7.3675	-0.0004	-0.146
16538	CHUDLEIGH	y = 0.0002 -0.1587	-0.0002	-0.073
16540	HAGLEY	y = 0.00008 -0.9297	-0.00008	-0.0292
16539	OSMASTON	y = -0.0002 +17.709	0.0002	0.073
16541	CRESSY	y = 0.0037 +9.3335	-0.0037	-1.3505
16548	BICHENO	y = 0.0005 -10.116	-0.0005	-0.1825
16553	ROSS	y = 0.00003 +0.3393	-0.00003	-0.01095
16550	TUNNACK	y = -0.003 +13.946	0.0003	0.1095
16529	MELTON_MOWBRAY	y = -0.0015 +2.991	0.0015	0.5475
16549	LITTLE_SWANPORT	y = -0.0001 +7.7528	0.0001	0.0365
16551	BUCKLAND	y = 0.0001 +2.243	-0.0001	-0.0365
16552	DODGES_FERRY	y = 0.0012 +10.582	-0.0012	-0.438
16554	PAWLEENA_ROAD	y = 0.0009 -21.89	-0.0009	-0.3285
16528	PORT_ARTHUR	y = 0.00005 +1.4679	-0.00005	-0.01825
17778	BURNIE_TIP_2	y = 0.0058 -0.4225	-0.0058	-2.117
17780	BURNIE_TIP_4	y = 0.0029 +0.5817	-0.0029	-1.0585
17773	SNUG	y = 0.00004 × +14.066	-0.00004	-0.0146

Table 4*Current distribution of the two data systems and history of the progressive decommissioning of the Dataflow system*

<i>Feature ID (MRT database)</i>	<i>Borehole name</i>	<i>Status of Dataflow system installed 1995</i>	<i>Status of Odyssey system</i>
16536	Barrington	Operational	Installed 16/12/2003
4290	Beulah	Decommissioned 26/03/2003	Installed 16/12/2003
16548	Bicheno	Operational	Installed 15/12/2003
17772	Bothwell	No sensor ever installed	Installation not possible due to artesian flow
16546	Branxholm	Operational	Installed 15/12/2003
16551	Buckland	Decommissioned 02/04/2003	Installed 15/12/2003
17776	Burnie Tip 1	No sensor ever installed	Installation not possible due to artesian flow
17780	Burnie Tip 4	No sensor ever installed	No installation required
16533	Calder	Decommissioned 24/03/2003	Installed 17/12/2003
16538	Chudleigh	Operational	Installed 16/12/2003
16541	Cressy	Operational	Installed 11/12/2003
16552	Dodges Ferry	Decommissioned 1996	No installation required
807	Free's Bore	No sensor ever installed	No installation required
16540	Hagley	Operational	Installed 11/12/2003
16534	Hampshire	Decommissioned 28/11/2003	Installed 17/12/2003
16923	Huonville	No sensor ever installed	Installation not possible due to artesian flow
16545	Jetsonville	Operational	Installed 16/12/2003
16542	Lilydale	Decommissioned 18/03/2003	Installed 16/12/2003
16549	Little Swanport	Operational	Installed 15/12/2003
16529	Melton Mowbray	Operational	Installed 11/12/2003
16532	Montagu	Decommissioned 27/11/2003	Installed 17/12/2003
16535	Mooreville Road	Operational	Installed 17/12/2003
16539	Osmaston	Decommissioned 02/12/2003	Installed 16/12/2003
16554	Pawleena Road	Operational	Installed 12/12/2003
16543	Pipers River	Decommissioned 19/03/2003	Installed 16/12/2003
16528	Port Arthur	Operational	Installed 12/12/2003
16553	Ross	Operational	Installed 11/12/2003
17773	Snug	Operational	Installed 12/12/2003
16527	South Forest	Decommissioned 25/2003/2003	Installed 17/12/2003
18606	Spreyton	No sensor ever installed	Installation not possible due to artesian flow
16526	St Marys	Operational	Installed 15/12/2003
16531	Togari	Operational	Installed 17/12/2003
16530	Trowutta	Decommissioned 25/03/2003	Installed 17/12/2003
16550	Tunnack	Decommissioned 02/04/2003	Installed 15/12/2003
16544	Waterhouse	Operational	Installed 16/12/2003
16547	Winnaleah	Operational	Not installed
1497	Devonport	Operational	Not installed
Not entered	CRMB03	Operational	Not installed
Not entered	CRMB05	Operational	Not installed
Not entered	CRMB16	Operational	Not installed
Not entered	CRMB20	Decommissioned 09/12/2003	Not installed
Not entered	TMB06	Operational	Not installed
Not entered	TMB09	Operational	Not installed
Not entered	TMB16	Decommissioned December 2002	Not installed
Not entered	TMB18	Operational	Not installed
Not entered	WHMB02	Operational	Not installed
Not entered	WHMB05	Decommissioned December 2002	Not installed
Not entered	WHMB17	Operational	Not installed
Not entered	WHMB22	Operational	Not installed

still require additional procedures to produce reliable hydrographs. Raw data exported from the *Dataflow* software can be processed in Microsoft Excel.

Two distinct groups of processed data exist for the *Dataflow* system. Data collected between 1995 and 1999 were compiled into a continuous data stream of calibrated values held as a single text file. Calibration files and the method for processing the raw data were not documented and no record of the raw data is known to exist. The continuous data stream was broken into chronological data blocks for each unique key identifier. Based on water level values and data sequencing, borehole identities were assigned to the unique key identifiers.

The second group of *Dataflow* data was collected between 1999 and 2004. Field calibrated and raw data exists with additional important metadata (e.g. changes in probe depths). The nature of the second dataset indicates that the older *Dataflow* data was 'smoothed' (to some degree) at the time of processing.

Microsoft Excel files containing all combined existing raw and processed *Dataflow* calibrated data from 1995 to 2004 are held by MRT. Hydrographs based on the *Dataflow* data of this duration are included in Appendix 7. The hydrographs demonstrate drift in the data (e.g. Snug statewide monitoring borehole), hardware failure (e.g. Mooreville Road statewide monitoring borehole) and the sensitivity of the data to the calibration equations used for processing the raw data (e.g. Osmaston statewide monitoring borehole, where no field calibration existed; the Jetsonville equation was used to convert pressure data to water level).

To investigate surface and subsurface interactive processes, surface water flow data were provided by the Department of Primary Industries, Water and Environment (DPIWE) for the closest weirs to the monitoring boreholes. Combined hydrographs are included in Appendix 8. Some direct relationships within the hydrological system can be seen in the two datasets. Where good datasets exist, events of groundwater rises match increased surface water flow in the DPIWE weir data (e.g. Chudleigh statewide network monitoring borehole). Combined with some assumptions relating to properties of the aquifers, further processing of these data may indicate the potential magnitude of groundwater recharge from rainfall and the related expression of surface water basal flow.

Odyssey system

The *Odyssey* temperature and pressure data recorder consists of a single unit located within the water column beneath the water table and which is suspended by an air line. All *Odyssey* data recorders installed in the network have a specified range of ten metres of variation in SWL. A recording interval of one hour has been selected.

Initial trials of the *Odyssey* data records indicate that field calibration is not required. This will be reassessed once the second complete downloading of this system is completed in 2004. Appendix 9 contains an internal MRT field operational procedure manual for the *Odyssey* system. The *Odyssey* software allows data graphing in the field. Figure 3 is a comparison of the *Odyssey* and *Dataflow* hydrographs generated for the Chudleigh statewide monitoring borehole, from data recorded between December 2003 and March 2004. Hydrographs from a range of boreholes for both systems indicate that the *Odyssey* system is operating to specifications with long-term reliability still to be proven. Future hydrographs could include rainfall, surface water (stream flow), *Dataflow* and *Odyssey* datasets.

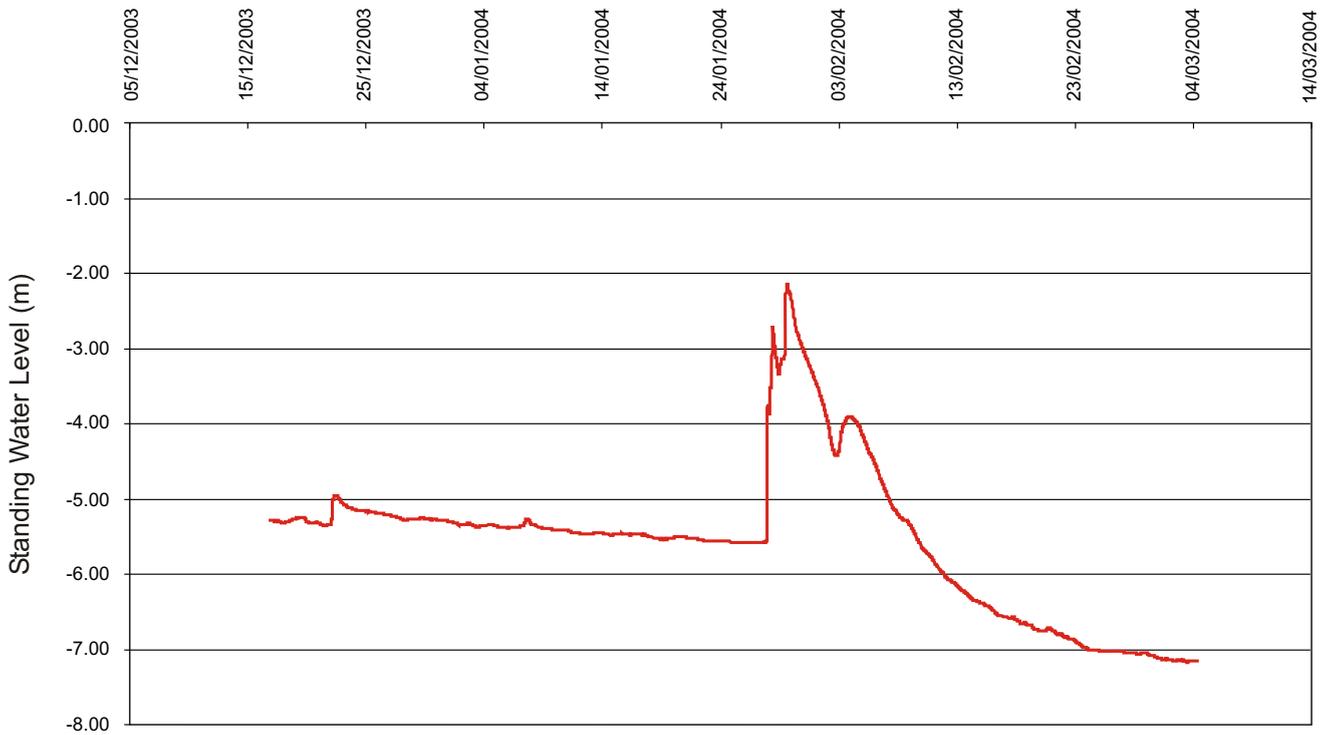
Groundwater sampling and chemistry

Groundwater sampling procedures and the effect on water quality

Sampling procedures for the network were not formally documented prior to February 2003. Sampling was apparently based on the 'cleaning up' of discolouration of water pumped from the boreholes. From February 2003 onwards groundwater sampling has been in accordance with Australian/New Zealand Standard AS/NZS 5667:11:1998: *Water quality – Sampling: Part 11: Guidance on sampling of groundwaters*. This standard involves removing three times the volume of the water column within the borehole before collecting samples. Representative Elementary Volumes (REV's) required for removal are listed in Table 5. If a borehole has constant artesian flow to the surface, the REV may not be required for sampling.

Two samples were collected and analysed from each statewide network groundwater quality monitored borehole during the November 2003. One sample was collected by the 'cleaning up' method and the other as close as possible to the REV. Piper plots of the laboratory results (Appendix 10) indicate that water types are not strongly affected by the two sampling methods, although the concentration of the ionic species in some cases varies significantly. Table 6 lists the analytical results for total dissolved solids (TDS) between the two methods and demonstrates that the future sampling approach should be the REV method. The results indicate that groundwater chemistry analyses before February 2003 for the Togari, Montagu, Barrington, Lilydale, Osmaston, Cressy, Bicheno, Ross and Little Swanport boreholes should be treated with some caution. The TDS values for groundwater at these nine monitoring sites may have been higher than the collected data indicate. These nine boreholes range in yield between 0.10 to 3.78 l/s; the lower TDS values may relate to well design and its impact on potential flow.

Chudleigh Hydrograph (Odyssey) post 2003



Chudleigh Hydrograph (Dataflow) 12/2003 to 03/2004

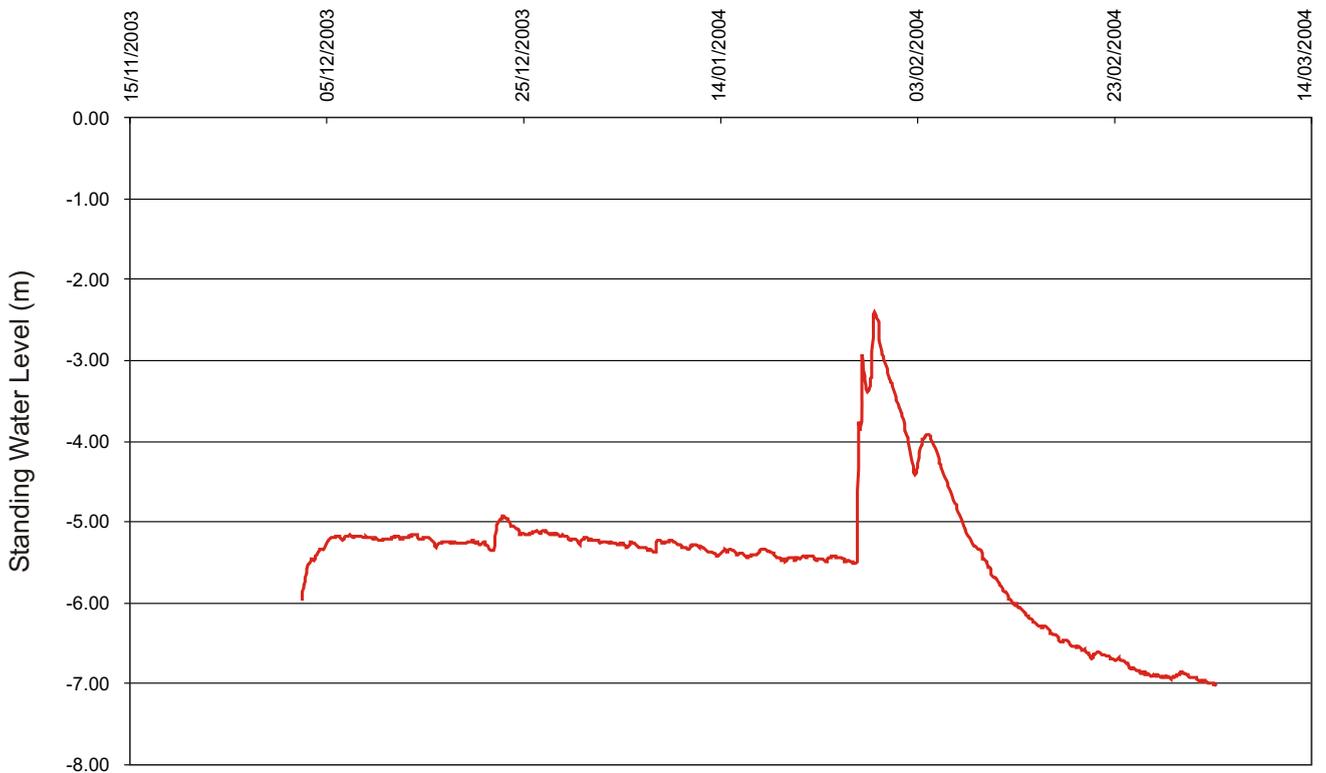


Figure 3

A comparison of the Odyssey and Dataflow hydrographs generated from data collected between December 2003 and March 2004 for the Chudleigh statewide monitoring borehole.

Table 5*Representative elementary volumes for groundwater samples collected post February 2003 from the original network*

<i>Feature ID</i>	<i>Common borehole name</i>	<i>REV* (litres)</i>	<i>Feature ID</i>	<i>Common borehole name</i>	<i>REV (litres)</i>
16531	TOGARI	1770	16527	SOUTH FOREST	1520
16532	MONTAGU	480	16530	TROWUTTA	1560
16533	CALDER	1367	16534	HAMPSHIRE	1180
16535	MOOREVILLE ROAD	1640	16545	JETSONVILLE	340
16543	PIPERS RIVER	390	16544	WATERHOUSE	110
16547	WINNALEAH	320	16546	BRANXHOLM	1160
16526	ST MARYS	40	4290	BEULAH	2120
16536	BARRINGTON	1000	16542	LILYDALE	545
16538	CHUDLEIGH	320	16540	HAGLEY	735
16539	OSMASTON	1055	16541	CRESSY	270
16548	BICHENO	1590	16553	ROSS	1485
16550	TUNNACK	1570	16529	MELTON MOWBRAY	2090
16549	LITTLE SWANPORT	445	16551	BUCKLAND	990
16554	PAWLEENA ROAD	560	16528	PORT ARTHUR	131
17772	BOTHWELL	1525	807	FREE'S BORE	50
17776	BURNIE TIP 1	50	17780	BURNIE TIP 4	480
18606	SPREYTON	5273	16923	HUONVILLE	1070
17773	SNUG	760			

* Representative Elementary Volume for sampling

Table 6

*Analytical results for Total Dissolved Solids (TDS) between the 'cleaning up' and AS/NZS 5667:11:1998 REV sampling methods. * indicates that due to slow recovery the REV was not totally removed before sampling. Italicised records identify bores with variation between the sampling methods.*

<i>Feature ID</i>	<i>Common borehole name</i>	<i>'Cleaning up' sampling method TDS (mg/L)</i>	<i>AS/NZS 5667:11:1998 REV sampling method TDS (mg/L)</i>
16531	TOGARI	555	706
16527	SOUTH FOREST	74	127
16532	MONTAGU	387	690
16530	TROWUTTA	127	166
16534	HAMPSHIRE	98	116
16535	MOOREVILLE ROAD	33	50
16545	JETSONVILLE	71	71
16543	PIPERS RIVER	228	283*
16544	WATERHOUSE	303	336
16546	BRANXHOLM	60	71
16526	ST MARYS	767	797
4290	BEULAH	56	83
16536	BARRINGTON	110	149
16542	LILYDALE	482	287
16538	CHUDLEIGH	35	54
16540	HAGLEY	318	331
16539	OSMASTON	369	596
16541	CRESSY	1610	1950
16548	BICHENO	1940	4430
16553	ROSS	1670	2300
16550	TUNNACK	968	993*
16529	MELTON MOWBRAY	1190	1230
16549	LITTLE SWANPORT	1390	2210
16551	BUCKLAND	810	966
16554	PAWLEENA ROAD	1480	1470
16528	PORT ARTHUR	272	313
17772	BOTHWELL	851	840
17773	SNUG	1140	1170

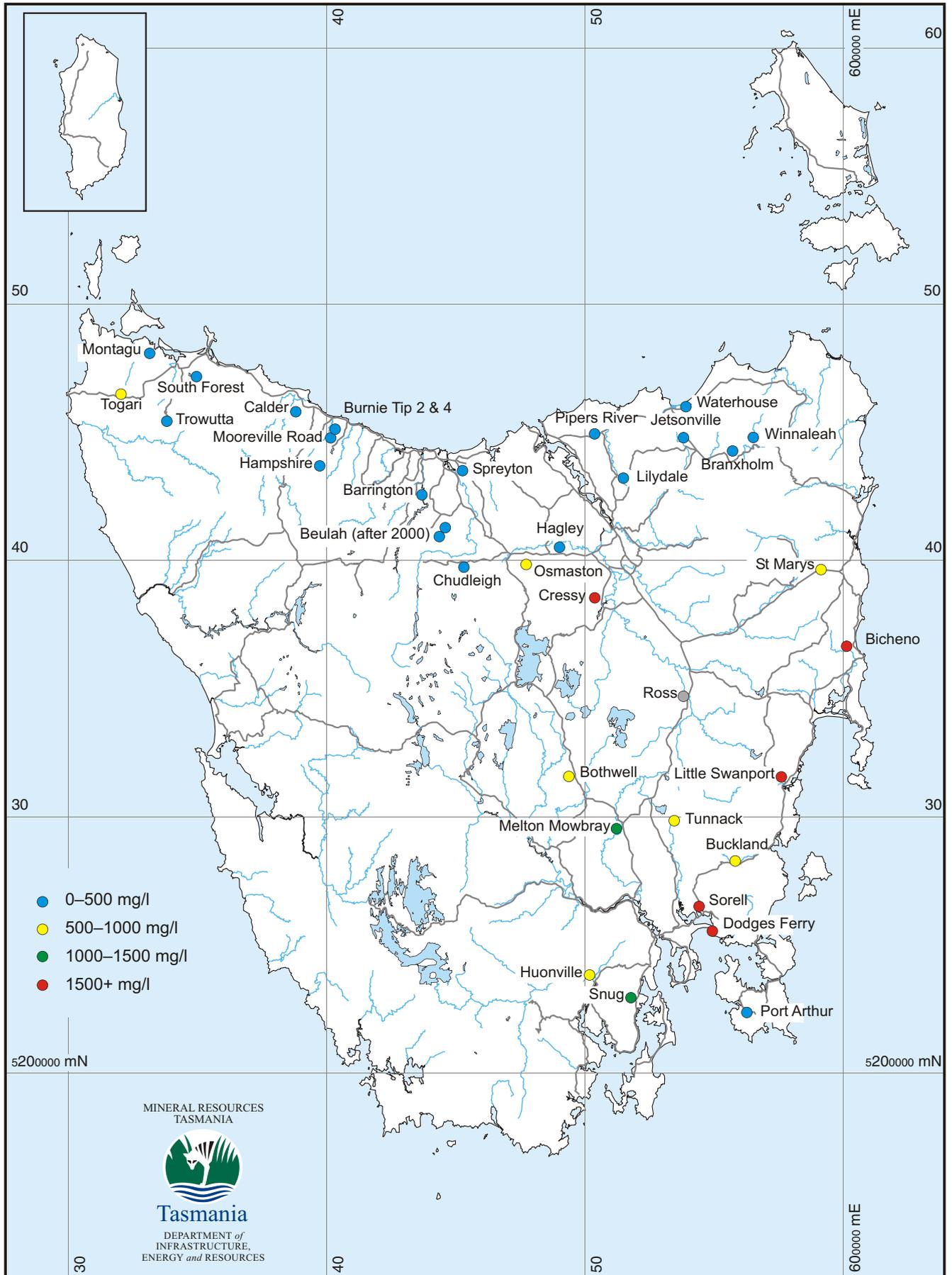


Figure 4

Classification of the statewide network bores based on the ten year average TDS value for each bore.

Groundwater quality

At the time of sampling, primary water quality parameters including pH, conductivity and temperature are recorded. The MRT laboratory undertakes analyses to determine water quality and the concentration of various dominant groundwater ions, including: Ca²⁺; Mg²⁺; Fe²⁺⁽⁺⁾; Al³⁺; Na⁺; K⁺; Cl⁻; F⁻; SO₄²⁻; NO₃⁻; CO₃²⁻; HCO₃⁻; total dissolved solids (TDS); permanent hardness; temporary hardness; and alkalinity. Table 7 contains data sourced from the November 2003 monitoring round used to illustrate groundwater types, Sodium Absorption Ratio (SAR) and Na⁺ percentage for each borehole. Sodium chloride water types are the most common within the statewide network. Appendix 11 contains Piper plots of boreholes that are located in the same type of Tasmanian groundwater flow system. This is a limited dataset and no major trends can be identified. Figure 4 is a classification of the statewide network boreholes based on the ten year average TDS value for each borehole.

Appendix 12 contains individual graphs of TDS for each borehole of the statewide network. Figure 5 is a combined graph of all long-term TDS results for all boreholes in the statewide network and demonstrates that the network is focussed on groundwater resources of multiple beneficial uses.

The linear regression of the TDS data indicates that 60% of the boreholes of the statewide network are decreasing and 40% increasing in TDS. Again, the linear regression technique can only be regarded as an approximation of groundwater quality trends. The results for the Cressy borehole indicate that the method of sampling with respect to multiple aquifer levels requires consideration for future sampling procedures. Figure 6 contains graphs of chemical trends for the Cressy and Bothwell statewide network monitoring boreholes. A major change in the Cressy water chemistry during 1998 may have been related to the construction of a house next to the borehole.

Table 8 contains average and standard deviation values for the entire laboratory results between 1990

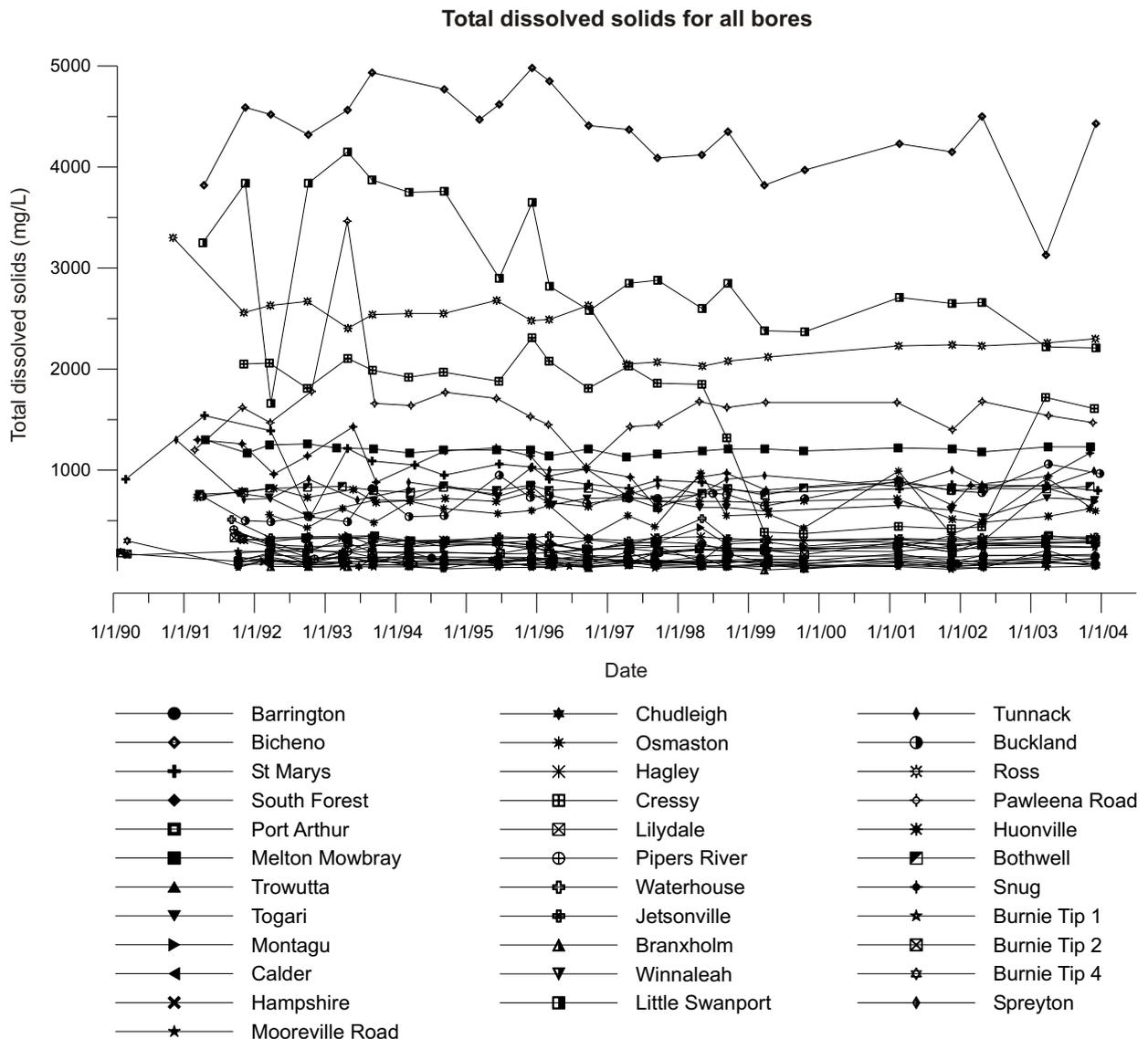
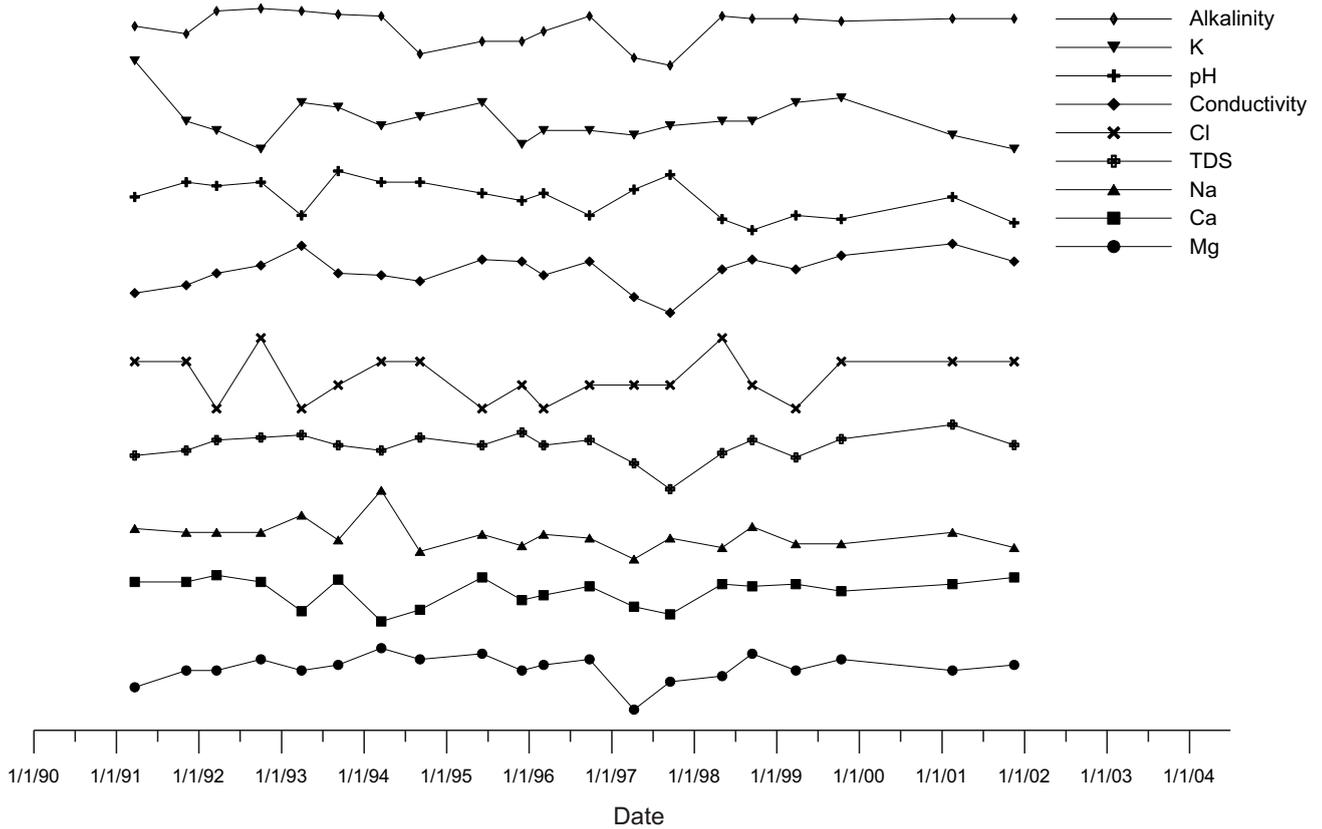


Figure 5

Graph of long-term TDS analyses for all bores in the statewide network

BOTHWELL MONITORING BOREHOLE — CHEMICAL TRENDS 1991 TO 2001



CRESSY MONITORING BOREHOLE — CHEMICAL TRENDS 1991 TO 2001

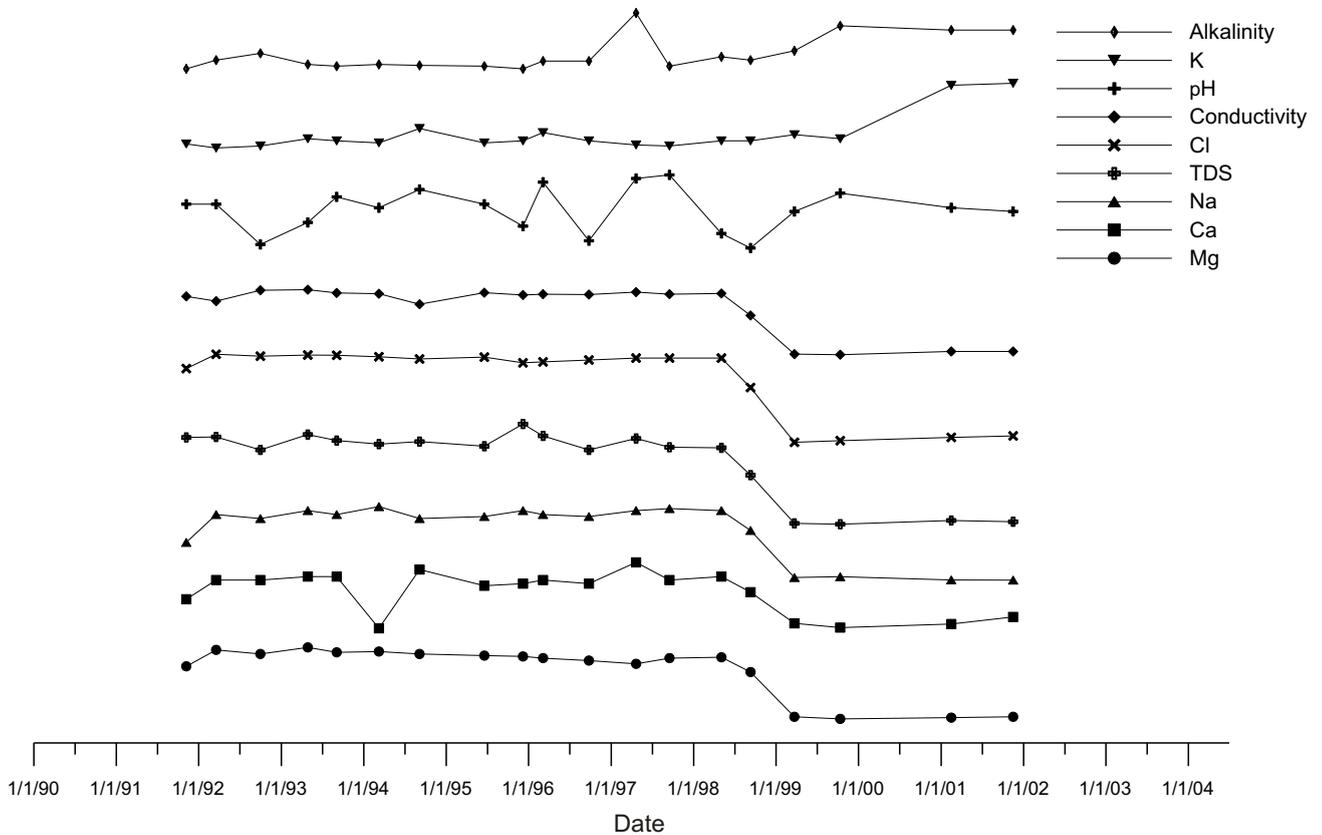


Figure 6

Graphs of chemical trends for the Cressy and Bothwell statewide network monitoring boreholes

Average water chemistry and standard deviation for TDS, Na and Cl

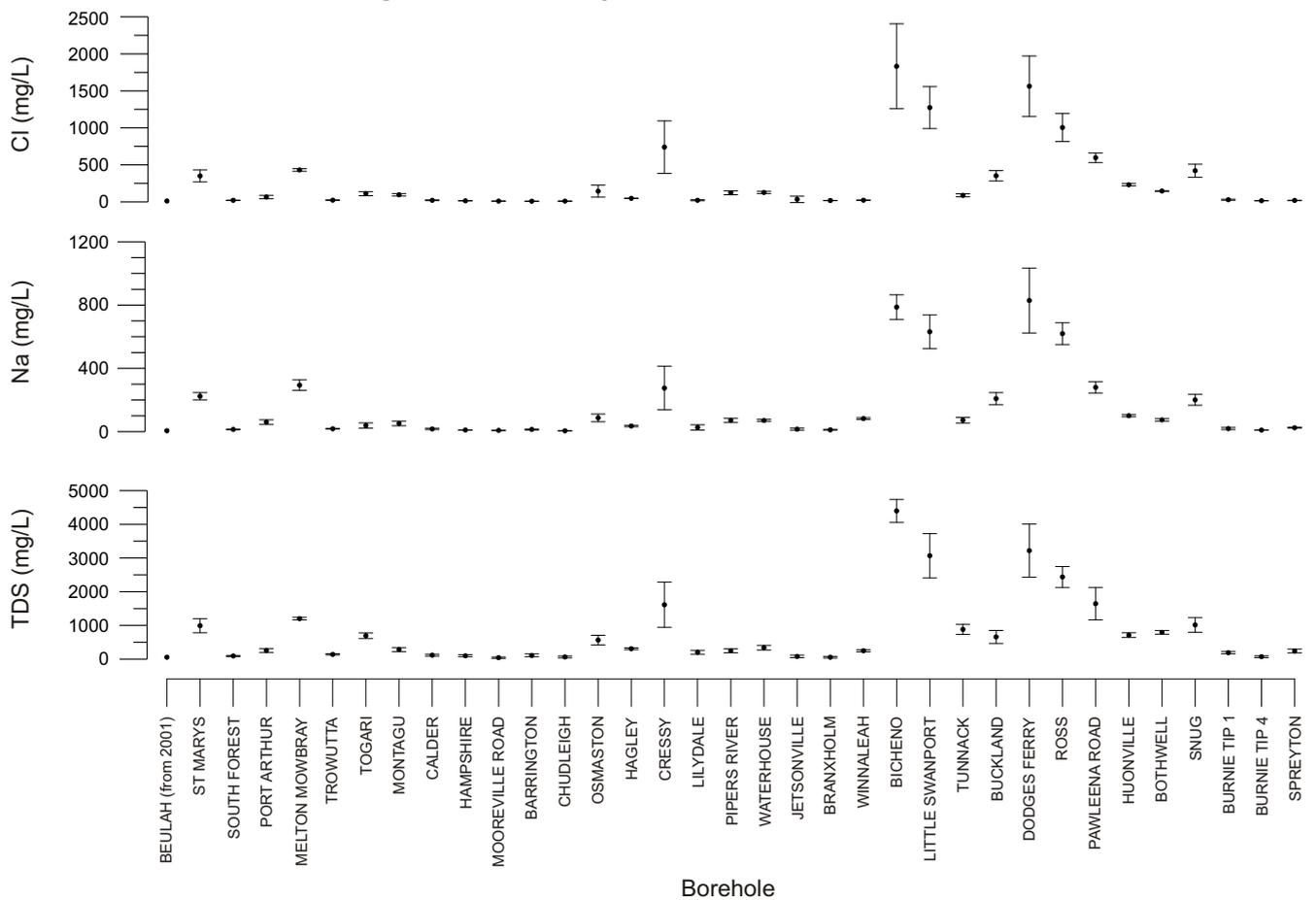


Figure 7

Graphical presentation of the TDS, Na and Cl average and standard deviation values between 1990 and 2001 for each statewide network borehole

and 2001 for each borehole. Figure 7 is a graphical presentation of the TDS, Na and Cl data of Table 7. The standard deviation values of these data indicate that the most appropriate boreholes to undertake a linear regression analyses on for TDS would be Cressy, Bicheno, Little Swanport, Ross and Pawleena Road (Dodges Ferry is excluded because of hydrocarbon contamination).

Data storage

Past procedures for the storage of data varied significantly for each dataset and required a major reorganisation in a logical manner. All laboratory analysis results to the end of 2001 have been entered into the MRT groundwater module. Because of a previous lack of formal data reporting procedures, all the *Dataflow* water level data are still to be entered into the MRT groundwater module. The current data structure on the MRT server is complex and contains some duplication for particular subsets of data (e.g. *Dataflow* processing calibration and related summary files).

A streamlining of the data storage structure is required. At present, no time series data can be stored within the existing MRT groundwater module. Time

series data could be stored in a Time Studio/ Hydstra-style software package.

Strengths and limitations of networks

Statewide groundwater network

Strengths

- The manually-measured water level data shows if a long-term trend exists that indicates depletion, increase or no change in aquifer recharge (e.g. low recharge due to extended low rainfall). The minimum and maximum water level values provide a range to indicate if the aquifer is under stress.
- Water chemistry data may indicate changes in the aquifer as a result of seasonal conditions and/or human activities.
- Digital time series data of temperature and pressure readings can be used to examine recharge and discharge events in some detail. The installation of the new *Odyssey* system in December 2003 should provide more accurate and precise six-monthly hydrographs for the boreholes.

Limitations

- The method of processing the *Dataflow* time series data collected before February 2002 is not documented.
- All data collected after February 2002 is stored in a complex data structure of directories which contain a range of file types and multiple spreadsheets.
- Not all data are stored in a central database.
- Procedures for the collection of field data, water analyses and processing of the time series data require significant automation.
- With the implementation of the *Water Management Act 1999*, MRT no longer has a mandate to undertake the monitoring of groundwater systems.
- Monitoring undertaken around the Burnie landfill site does not appear to fulfil the surmised original aim of the network.

The network only covers nine of the thirteen identified groundwater flow systems in Tasmania (and related aquifer systems). The intermediate to local flow systems in Jurassic dolerite, local flow systems in Quaternary sedimentary rocks (talus and till), local flow systems in high relief granitic rocks, and local to intermediate flow systems in Quaternary sedimentary rocks (aeolian, coastal plains and alluvium) are currently not monitored. The coverage of monitoring points in some cases only represents localised conditions and provides very limited information about the greater hydrological system.

Devonport network

Strengths

- Water level data collected between 1984 and 2001 (see fig. 8).
- This is the only network in Tasmania used to monitor groundwater resources in an area of high agricultural extraction.

Limitations

- No complete engineering logs exist for the drilling and installation of the boreholes. Drillers log do exist.
- Several holes have been destroyed and no formal agreement was entered into with the property owners at the time of drilling.
- Water levels were taken on a random basis post 2000.
- Data collected next to irrigation boreholes is strongly influenced by pumping extraction rates which are not presently recorded by meters.
- Data collected before 2000 has not yet been converted into a digital format.
- Procedures for collecting and storing this historical data were not documented.

- Data collected after 2000 is stored in spreadsheets but is not in a central database.

The spatial distribution of the monitoring points and frequency of data collection indicates that the data could be used to identify periods of heavy use of the groundwater resources.

NHT salinity network

Strengths

- At the time of drilling, access for future monitoring was discussed with local property owners.
- Detailed engineering and hydrogeological maps exist for all three field areas.
- Hydrographs have been produced from data recorded in 2003.
- Hydrograph data has scientific integrity and could be used to publish at least one scientific paper.

MRT is the custodian of this data and holds digital copies of *Groundwater Modelling Systems 4.0* hydrogeological models which were produced as part of the three-year salinity study. These models may be calibrated using future data collected from this network. Since completion of the project, the Land Management Division of DPIWE has continued to collect water level data from all boreholes in the network (including those installed with data loggers).

Limitations

- Not all data has been entered into a central database. Much of it is stored in a range of directories containing time series data and spreadsheets.
- MRT does not hold a copy of all DPIWE data collected during the NHT project, nor of additional data collected subsequently.

Recommendations

Statewide groundwater network

- Remove the Burnie tip monitoring points (groundwater and surface water) from the network. These monitoring points are located in an area of significant land disturbance and the boreholes are also monitored by the Burnie City Council. MRT should request all future data be collected by Burnie City Council.
- Undertake a survey datum height for all boreholes (from the top of casing and ground level).
- Undertake an inspection of all boreholes known to exist within one kilometre of the monitoring boreholes.
- Install additional pressure and salinity probes in all statewide network boreholes to collect time series water quality data.
- For one year, undertake monthly manual water level readings from selected boreholes across

Tasmania to verify the integrity of the *Odyssey* system and monitor local use of the aquifers.

- Progressively decommission the *Dataflow* system.
- Automate data processing and storage into the MRT groundwater module.
- Upgrade the existing network by a process of repairs to boreholes and decommissioning holes that have limited scientific value (Appendix 13 outlines short and long-term management options for each borehole).
- Drill, log and install additional boreholes to appropriate standards in critical hydrological data gap areas. This may include locations in areas covered by catchment water management plans or newly proposed groundwater areas with a mandate under the *Water Management Act 1999* and the National Land and Water Audit (Sinclair Knight Merz, 2000). Under this same mandate, establish legal agreements with property owners.
- More interpretation of the existing data relationships could aid in the future management of Tasmanian groundwater resources.

Devonport network

- Collect data at regular intervals.
- Continue to collect data from boreholes that were installed to monitor natural aquifer conditions or possible over extraction/induced drawdown on a regional scale (and where feasible install pressure sensors).
- Automate data processing and storage into the MRT groundwater module.
- Review and interpret the data annually.

NHT salinity network

- Continue to collect data from the remaining *Dataflow* data loggers as part of the statewide groundwater monitoring network.
- Automate data processing and storage into the MRT groundwater module.
- Clarify with DPIWE the objectives for this component of monitoring (within the greater government approach to salinity investigations) and alter procedures or upgrade infrastructure to ensure the aims are met.

Future work

- Current and future National Action Plan (NAP) salinity groundwater investigation projects should consider the location of current monitoring boreholes and weirs that measure stream flow and rainfall stations when siting future long-term monitoring boreholes.
- Any future studies on individual groundwater flow systems should consider pump tests (undertaken to Australian Standards) to obtain hydraulic property

data (transmissivity, hydraulic conductivity and storativity/specific yield). The hydraulic properties will be valuable for the sustainable management of the resource.

- All future groundwater level, pump test and water quality data should be stored in a central groundwater database together with other borehole information.

Acknowledgements

The author acknowledges the support of John McDougall in matching datasets to boreholes and sourcing water quality data from the MRT groundwater module. Field assistant Shane Heawood collected a significant quantity of the MRT data presented in this report and without these data, this overview report would not have been possible. The assistance of DPIWE officers Dr Shivaraj Gurung, Ms Jenny Deakin and Alistair Brooks in compiling and providing stream-flow data significantly helped with the interpretation of groundwater data presented in this report.

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[6 September 2004]

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Table 7
Groundwater chemistry types, SAR and Na percentage for individual boreholes

<i>Borehole name</i>	<i>Feature ID</i>	<i>Groundwater type – principal ions</i>	<i>Sodium Absorption Ratio (SAR)</i>	<i>Na percentage</i>
Barrington	16536	Na, Mg, HCO ₃	1.028	40.002
Beulah	4290	Mg, HCO ₃ , Cl	0.394	21.770
Bicheno	16548	Na, Mg, Cl	8.657	52.652
Bothwell	17772	Ca, Mg, HCO ₃ , Cl	1.453	24.565
Branxholm	16546	Mg, Na, Cl, HCO ₃	0.937	48.240
Buckland	16551	Na, Cl	11.265	84.520
Burnie tip 1	17776	Mg, Ca, HCO ₃ , Cl	0.758	26.467
Burnie tip 4	17780	Na, Mg, Cl	1.019	57.224
Calder	16533	Na, Cl	1.692	70.053
Chudleigh	16538	Na, Ca, Mg, Cl	0.593	46.954
Cressy	16541	Na, Mg, Cl	5.765	54.735
Hagley	16540	Mg, Ca, Na, HCO ₃ , Cl	1.136	29.535
Hampshire	16534	Ca, Na, Mg, HCO ₃ , Cl	0.735	36.205
Huonville	16923	Na, Ca, Cl	2.977	51.651
Jetsonville	16545	Na, Cl	2.201	75.816
Lilydale	16542	Na, SO ₄	3.183	69.818
Little Swanport	16549	Na, Cl, HCO ₃	8.958	62.426
Melton Mowbray	16529	Na, Cl, HCO ₃	5.796	57.296
Montagu	16532	Na, Ca, Cl	3.007	49.351
Mooreville Road	16535	Na, Cl	1.605	77.563
Osmaston	16539	Na, Mg, Cl	3.290	64.835
Pawleena Road	16554	Na, Mg, Cl, HCO ₃	4.553	47.948
Pipers River	16543	Na, Cl	5.407	84.515
Port Arthur	16528	Na, Cl, HCO ₃	2.649	61.921
Ross	16553	Na, Mg, Cl, HCO ₃	9.547	63.698
Snug	17773	Na, Cl	7.589	70.599
South Forest	16527	Na, Mg, Cl	1.153	55.958
Spreyton	18606	Ca, Mg, HCO ₃	0.810	27.323
St Marys	16526	Na, Cl, HCO ₃	6.646	69.817
Togari	16531	Ca, Mg, HCO ₃ , Cl	0.981	20.444
Trowutta	16530	Na, Ca, Mg, HCO ₃ , Cl	0.989	38.695
Tunnack	16550	Mg, Na, Ca, SO ₄	1.883	31.826
Waterhouse	16544	Na, Cl	3.253	62.045
Winnaleah	16547	Na, HCO ₃	11.663	95.278

Table 8. Average and standard deviation values for laboratory analyses between 1990 and 2001 for each statewide groundwater network monitoring borehole

Feature ID	Name	No. samples	pH Average	pH Std Dev	EC Average	EC Std Dev	Ca Average	Ca Std Dev	Mg Average	Mg Std Dev	Fe Average	Fe Std Dev	Al Average	Al Std Dev
4290	BEULAH (from 2001)	1	5.8		127		6.5		9.6		0.05		0.1	
16526	ST MARYS	18	7.72	0.59	1543.89	189.62	63.44	28.87	48.67	10.15	0.09	0.09	0.1	0.01
16527	SOUTH FOREST	18	5.95	0.99	148.28	27.91	4.16	4.08	4.47	0.37	0.05	0	0.12	0.09
16528	PORT ARTHUR	18	7.27	0.98	379.06	99.71	9.79	2.23	12.61	19.93	0.45	0.43	0.6	0.9
16529	MELTON MOWBRAY	20	7.69	0.35	1975.5	102.67	71.6	22.64	64.15	3.69	0.07	0.06	0.11	0.02
16530	TROWUTTA	18	7.51	0.82	205.78	25.72	14.33	4.48	6.85	1.3	0.05	0.01	0.1	0.01
16531	TOGARI	17	7.79	0.62	898.06	95.94	97.53	15.25	40.82	4.97	0.52	0.39	0.16	0.15
16532	MONTAGU	19	5.97	0.97	404.79	74.82	9.27	9.21	10.75	2.01	0.68	0.79	0.25	0.18
16533	CALDER	19	5.96	1.05	135.53	42.95	6.03	4.81	3.05	1.27	0.74	0.87	0.14	0.12
16534	HAMPSHIRE	19	6.95	1.1	207.37	322.22	9.65	4.91	4.55	0.93	0.09	0.15	0.13	0.08
16535	MOOREVILLE ROAD	19	5.45	0.89	66.16	27.28	2.63	6.08	1.15	0.09	0.05	0	0.13	0.11
16536	BARRINGTON	19	7.16	0.97	163	45.1	10.07	4.95	7.04	1.39	0.31	0.93	0.11	0.02
16538	CHUDLEIGH	19	6.33	1.22	105.05	99.64	8.85	9.44	1.2	0.4	0.06	0.02	0.15	0.12
16539	OSMASTON	16	6.46	1.09	732.5	310.69	26.71	22.37	20.06	6.09	0.05	0	0.1	0
16540	HAGLEY	16	7.9	0.69	458.19	52.4	32.41	5.82	23.41	2.81	0.05	0	0.1	0
16541	CRESSY	19	7.15	0.59	2260.84	926.72	88.32	29.95	70.66	31.57	0.15	0.18	0.12	0.09
16542	LILYDALE	15	5.79	1.69	255.8	112.54	10.16	8.59	5.32	1.96	0.1	0.17	0.15	0.16
16543	PIPERS RIVER	18	5.58	1.12	442.94	101.22	4.04	5.66	7.72	2.17	0.05	0.01	0.13	0.1
16544	WATERHOUSE	18	7.03	0.85	528.28	50.61	14.42	7.52	13.75	1.42	0.05	0	0.15	0.15
16545	JETSONVILLE	17	6.33	1.08	129.47	59.34	5.34	11.36	2.56	0.66	0.33	0.45	0.36	0.72
16546	BRANXHOLM	18	6.34	1.24	96.83	25.53	2.3	4.26	3.39	2.3	0.08	0.13	0.11	0.05
16547	WINNALEAH	17	8.64	0.79	342.41	66.19	0.96	1.3	0.76	2.2	1.67	6.27	6.18	21.05
16548	BICHENO	20	7.22	0.51	6011	446.91	199.7	43.48	243.95	29.2	0.23	0.77	0.1	0.01
16549	LITTLE SWANPORT	20	7.49	0.31	4317.5	783.85	147.25	49.28	152.2	42.48	0.07	0.06	0.1	0.01
16550	TUNNACK	18	6.66	1.07	979.44	235.11	73.67	20.53	49.11	12.93	0.09	0.11	0.36	0.99
16551	BUCKLAND	20	5.98	1.06	1153	214.6	7.04	10.95	13.85	5.79	0.11	0.17	0.11	0.07
16552	DODGES FERRY	16	7.12	0.7	4764.38	1139.92	75	20.36	142.31	37.83	0.32	0.57	0.1	0
16553	ROSS	19	8.06	0.3	3816.84	355.9	45.51	31.87	156.84	18.95	0.05	0	0.1	0
16554	PAWLEENA ROAD	19	7.86	0.52	2334.74	317.23	99.47	39.2	100	11.88	0.05	0	0.1	0
16923	HUONVILLE	19	7.3	0.83	981.58	77.05	67.23	19.91	19.92	2.29	0.11	0.2	0.1	0
17772	BOTHWELL	20	7.56	0.48	1102	85.88	98.3	31.66	48.4	2.44	0.05	0	0.1	0
17773	SNUG	18	7.25	1.19	1611.11	547.42	40.56	28.63	44.83	14.49	0.06	0.04	0.11	0.02
17776	BURNIE TIP 1	16	7.98	1.14	265.56	54.26	19.75	5.01	12.59	3.57	0.06	0.05	0.1	0
17780	BURNIE TIP 4	18	6.48	1.54	101.11	41.52	5.74	7.45	2.78	0.75	0.05	0	0.11	0.02
18606	SPREYTON	16	7.81	0.36	420.06	74.31	43.5	20.38	15.13	1.3	0.07	0.06	0.09	0.02

Table 8 (continued)

Feature ID	Name	No. samples	Na Average	Na Std Dev	K Average	K Std Dev	Cl Average	Cl Std Dev	F Average	F Std Dev	SO ₄ Average	SO ₄ Std Dev	NO ₃ Average	NO ₃ Std Dev
4290	BEULAH (from 2001)	1	5.9		1.1		12.5		0.15		2.5		5	
16526	ST MARYS	18	223.89	22.27	2.13	2.85	350.67	80.75	0.15	0	73.83	8.76	3.47	2.23
16527	SOUTH FOREST	18	13.86	2.11	4.19	0.6	22.03	2.92	0.15	0	8.95	4.29	21.39	19.31
16528	PORT ARTHUR	18	59.83	15.06	0.54	0.48	65.89	23.62	0.15	0	15.12	6.05	4.06	2.52
16529	MELTON MOWBRAY	20	293.75	33.04	3.78	1.23	431.15	16.83	0.16	0.03	59	2.75	3.58	2.23
16530	TROWUTTA	18	18.14	1.6	1.66	1.01	23.42	3.52	0.15	0	12.78	5.72	4.85	3.1
16531	TOGARI	17	38.65	16.8	12.91	8.88	111.35	27.29	0.15	0	69.29	21.88	8.82	5.74
16532	MONTAGU	19	51.74	14.82	3.83	0.6	96.05	16.27	0.15	0	30.79	5.34	4.46	2.19
16533	CALDER	19	16.92	3.7	1.28	0.37	21.57	5.37	0.15	0	6.73	4.01	3.59	2.14
16534	HAMPSHIRE	19	10.1	1.54	1.36	0.27	15.42	3.13	0.16	0.03	3.47	4.1	16.84	11.21
16535	MOOREVILLE ROAD	19	7.88	1.05	0.29	0.1	11.22	1.65	0.15	0	2.49	1.29	4.2	1.64
16536	BARRINGTON	19	13.63	4.05	1.59	3.32	9.25	2.29	0.15	0	3.3	1.54	4.72	2.97
16538	CHUDLEIGH	19	5.29	0.68	0.3	0.26	10.95	2.65	0.17	0.08	3.78	4.28	5.85	1.93
16539	OSMASTON	16	86.88	23.99	17.97	2.96	145.31	80.13	0.15	0	26.19	9.72	151.56	60.87
16540	HAGLEY	16	35.19	3.56	1.02	0.14	48.31	3.59	0.15	0	2.91	1.65	16.56	7.9
16541	CRESSY	19	275.32	137.58	22.95	8.96	739.74	354.85	0.15	0	8.66	18.09	24.41	56.66
16542	LILYDALE	15	26.49	16.78	4.37	4.74	22.13	7.02	0.18	0.1	45.68	29.14	14.78	15.04
16543	PIPERS RIVER	18	71.28	14.01	1.66	2.47	122.83	25.69	0.15	0	12.44	7.63	3.74	2.1
16544	WATERHOUSE	18	70.61	6.59	2.97	0.47	127.78	14.37	0.15	0	33.11	4.3	3.42	2.3
16545	JETSONVILLE	17	15.32	6.78	2.36	3.53	34.76	43.39	0.15	0	3.61	2.67	7.29	6.48
16546	BRANXHOLM	18	11.41	2.49	1.55	0.51	18.78	2.47	0.15	0	3.31	2.37	4.11	1.77
16547	WINNALEAH	17	82.53	5.25	13.31	19.78	23.06	2.16	0.15	0	6.89	8.3	7.72	5.49
16548	BICHENO	20	787.35	77.48	9.21	1.77	1831.48	573.72	0.15	0	120.65	45.66	3.81	2.11
16549	LITTLE SWANPORT	20	631.45	105.79	7.17	1.37	1273.9	282.87	0.22	0.11	102.75	16.49	3.43	2.23
16550	TUNNACK	18	72.67	17.59	6.41	5.18	89.22	19.95	0.38	0.28	384.11	89.05	3.15	2.38
16551	BUCKLAND	20	208.75	37.55	3.78	1.02	353.2	69.34	0.15	0	16.3	4.85	4.09	1.72
16552	DODGES FERRY	16	829.25	205.43	17.78	5.13	1562.75	409.73	0.32	0.13	144.56	47.27	5.36	5.57
16553	ROSS	19	619.47	68.35	5.94	2.5	1004.89	189.03	0.5	0.12	83.79	12.15	46.84	17.58
16554	PAWLEENA ROAD	19	279.84	35.07	2.16	0.85	597.42	64.99	0.52	0.09	16.76	4.35	18.95	12.65
16923	HUONVILLE	19	100.42	6.59	7.68	3.57	232.42	15.5	0.15	0	46	4.98	3.75	2.15
17772	BOTHWELL	20	74.25	7.6	2.62	0.45	146.5	4.89	0.19	0.07	114.1	12.35	3.58	2.23
17773	SNUG	18	201.06	34.29	6.81	7.36	421.72	87.33	0.17	0.07	82.31	26.26	3.44	2.84
17776	BURNIE TIP 1	16	19.13	6.5	2.76	0.43	29.31	7.44	0.15	0	2.5	0	6.54	3.93
17780	BURNIE TIP 4	18	9.84	1.39	0.77	0.41	15.69	1.78	0.15	0	8.75	26.52	9.33	4.51
18606	SPREYTON	16	24.72	2.82	8.42	1	19.81	2.36	0.15	0	2.66	0.95	3.53	2.9

Table 8 (continued)

Feature ID	Name	No. samples	CO ₃ Average	CO ₃ Std Dev	HCO ₃ Average	HCO ₃ Std Dev	TDS Average	TDS Std Dev	Perm. Hard. Average	Perm. Hard. Std Dev	Temp. Hard. Average	Temp. Hard. Std Dev	Alkalinity Average	Alkalinity Std Dev
4290	BEULAH (from 2001)	1	0		56		58		10		46		46	
16526	ST MARYS	18	3.25	3.58	303.56	41.92	992.39	208.61	107.44	90.66	249.44	35.93	249.44	35.93
16527	SOUTH FOREST	18	1.67	1.21	6.97	13.17	95	15.94	23.8	4.87	6.27	11.83	6.27	11.83
16528	PORT ARTHUR	18	3.14	4.77	87.06	22.81	257.67	56.45	1.68	1.8	60.72	13.4	74.72	15.67
16529	MELTON MOWBRAY	20	2.9	6.03	492	54.25	1202.5	39.32	47.35	39.68	396.2	48.17	405.7	46.81
16530	TROWUTTA	18	2.86	5.41	61.56	17.57	140.83	17.64	11.47	6.22	52.89	14.2	53.5	14.75
16531	TOGARI	17	4.72	5.69	327.65	46.17	694.47	82.07	141.29	55.65	275.41	36.48	275.41	36.48
16532	MONTAGU	19	1.54	1.22	19.47	31.5	283.53	58.59	53.79	9	16.25	25.68	16.25	25.68
16533	CALDER	19	1.58	1.24	20.67	25.46	118.21	30.2	13.42	6.3	16.66	19.19	16.98	20.34
16534	HAMPSHIRE	19	2.08	2.69	33.26	22.17	99.68	29.15	14.46	6.04	28.43	18.76	28.43	18.76
16535	MOOREVILLE ROAD	19	1.58	1.24	7.86	19.15	43.21	19.67	5.55	3.21	6.69	15.6	6.69	15.6
16536	BARRINGTON	19	2.16	2.47	74.42	28.77	110.48	43.18	3.42	5.12	52.53	16.5	62.53	23.9
16538	CHUDLEIGH	19	1.58	1.24	20.07	24.59	64.74	29.6	11.94	8.94	17.19	19.75	17.29	19.89
16539	OSMASTON	16	2.21	1.86	29.06	39.7	565.56	143.76	113.25	35.56	25.37	32.92	25.37	32.92
16540	HAGLEY	16	4.81	7.01	204.06	28.36	310.81	24.92	6.78	8	168.75	17.84	172.81	13.78
16541	CRESSY	19	1.58	1.24	82.63	24.65	1614	669.47	437.32	202.91	71.79	19.49	71.79	19.49
16542	LILYDALE	15	1.5	1.27	29	49.18	204.27	56.65	29.33	17.75	19.74	29.3	24.61	40.96
16543	PIPERS RIVER	18	1.67	1.21	11.13	19.24	250.22	61.08	31.31	12.3	9.34	15.67	9.34	15.67
16544	WATERHOUSE	18	1.83	1.49	40.53	27.61	339.44	68.82	59.44	10.13	33.67	22.22	33.67	22.22
16545	JETSONVILLE	17	1.62	1.23	16.53	41.52	80.88	35.83	12.99	7.17	13.7	32.88	13.7	32.88
16546	BRANXHOLM	18	1.53	1.25	15.01	17.08	57.61	24.09	7.47	1.97	12.87	14.8	12.98	15.16
16547	WINNALEAH	17	14.24	19.22	150.15	48.22	249.47	30.8	1.62	1.23	10.21	23.07	144.29	15.81
16548	BICHENO	20	1.5	1.26	310.1	80.23	4397.4	342.21	1237.3	152.58	264.15	36.51	264.15	36.51
16549	LITTLE SWANPORT	20	1.63	1.22	592.1	108.22	3068.05	658.79	506.65	210.34	485.45	87.21	485.45	87.21
16550	TUNNACK	18	1.53	1.25	61.47	47.65	882.17	150.77	360.06	68.88	51.28	40.35	51.28	40.35
16551	BUCKLAND	20	2.13	2.72	13.6	32.06	659.25	193.43	60.95	25.62	12.07	26.12	12.07	26.12
16552	DODGES FERRY	16	2.19	3.64	229.25	98.68	3219	786.25	581.88	191.3	189.56	84.18	189.56	84.18
16553	ROSS	19	15.18	33.91	654.05	114.7	2437.05	311.75	214.08	178.93	545.05	95.47	546.11	96.45
16554	PAWLEENA ROAD	19	4.66	7.02	434.84	113.14	1644.42	480.35	299.89	68.05	362.26	89.64	362.26	89.64
16923	HUONVILLE	19	1.73	1.93	141	37.47	712.21	69.98	139.58	21.85	119.95	23.64	119.95	23.64
17772	BOTHWELL	20	1.5	1.26	360.25	79.38	795.9	52.84	151.23	62.53	292.85	64.13	296.85	66.16
17773	SNUG	18	2.82	4.24	82.56	158.61	1014.94	218.75	248.17	121.29	41.58	35.58	41.58	35.58
17776	BURNIE TIP 1	16	8.81	10.97	93.72	44.01	192.44	34.13	11.59	7.17	89.69	22.25	89.81	22.3
17780	BURNIE TIP 4	18	2.39	2.88	14.48	23.93	72.5	26.64	12.75	4.86	13.72	20.13	13.72	20.13
18606	SPREYTON	16	1.88	1.12	239.25	55.48	240.38	58.43	24.69	52.58	134.55	81.69	181.68	63.46

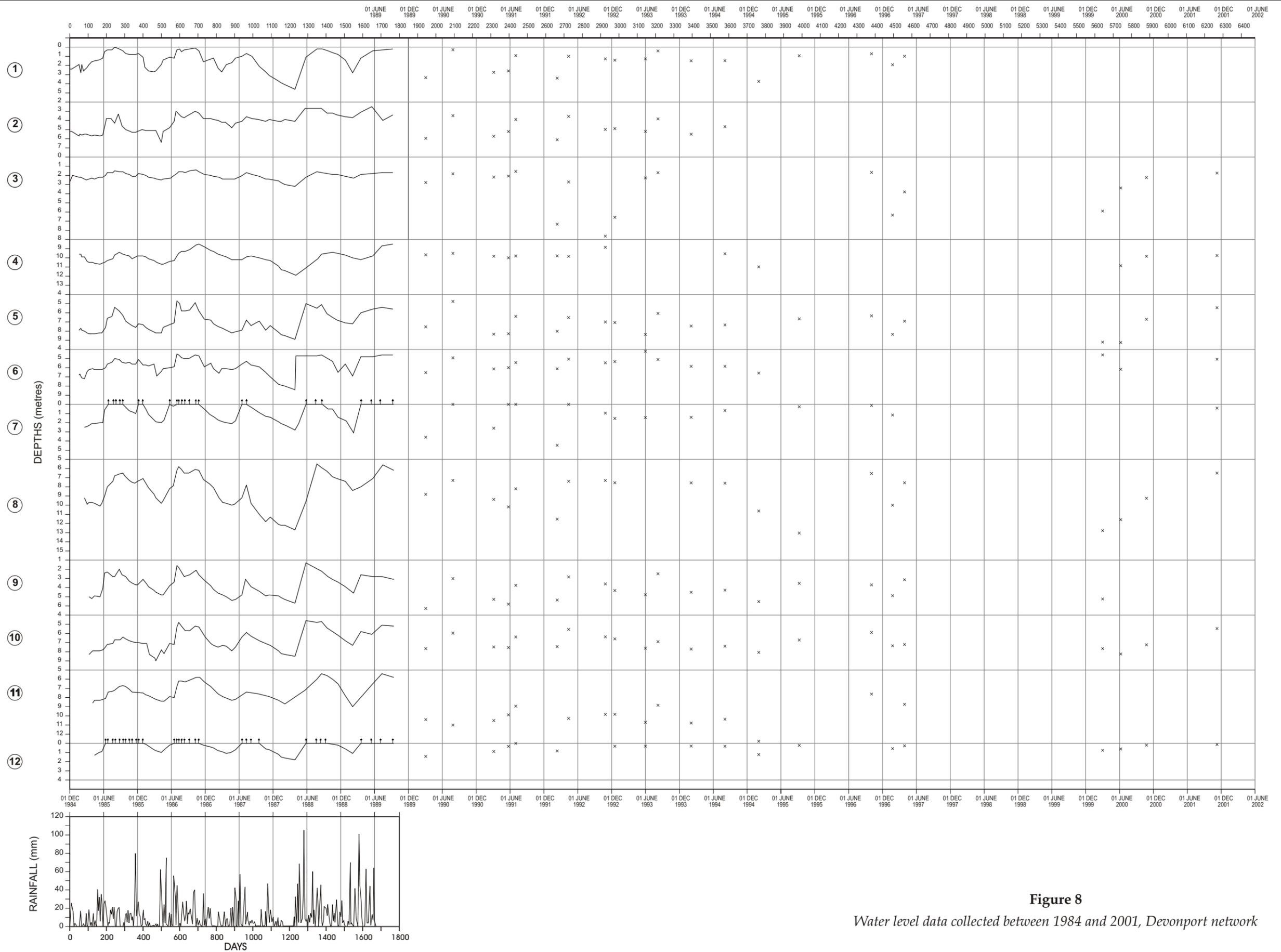


Figure 8
Water level data collected between 1984 and 2001, Devonport network