**Department of Planning and Environment**

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# Lower Murrumbidgee Groundwater Sources

## Preliminary analysis of the influence of groundwater extraction on water quality

2005–2018

November 2023

# Acknowledgement of Country

The Department of Planning and Environment acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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# Preamble

The ‘*Water Sharing Plan for the Murrumbidgee Alluvial Groundwater Sources Order 2020*’ (the Plan) outlines a framework for the sustainable management of groundwater resources in the major alluvial groundwater systems of the Murrumbidgee Catchment. Sustainable management includes maintaining beneficial use. Beneficial use is how a water resource benefits the local environment, Aboriginal cultural values, communities, and businesses.

The Plan includes aims to keep groundwater salinity, also known as total dissolved solids, at levels than can maintain all beneficial uses. The minister responsible for water may prohibit or restrict the taking of water under Section 324 of the ‘NSW Water Management Act 2000’ to ‘maintain, protect or improve the quality of water in an aquifer’.

In this report the NSW Department of Planning and Environment investigated the potential impact of groundwater extraction on water quality within the Lower Murrumbidgee groundwater sources. The report considers both the requirements of the Plan, and earlier investigations into processes influencing water quality and beneficial use in the Lower Murrumbidgee groundwater sources.

This document outlines the department’s investigation. It focuses on an area at high risk of groundwater salinisation in the eastern part of the groundwater source.

# Introduction

## Scope

This document analyses water quality monitoring data to assess the potential impact of groundwater extraction activities on water quality within the Lower Murrumbidgee groundwater sources. The investigation focuses on 25 monitoring bores located within the Murrumbidgee Irrigation Area and the Coleambally Irrigation Area. These areas have areas of highly saline groundwater that threatens the benefit of groundwater to the local environment, Aboriginal cultural values, community uses, and businesses.

## Importance

Managing groundwater quality within the Lower Murrumbidgee groundwater sources will protect the future beneficial use of groundwater to support economic and social needs.

The *Water Sharing Plan for the Murrumbidgee Alluvial Groundwater Sources 2020* contains an objective to maintain groundwater salinity within water quality targets that support high–priority groundwater–dependent ecosystems. It also aims to keep salinity within ranges that allow groundwater-dependent businesses, Aboriginal people, and communities to make use of the water.

There are about 1,217 registered bores in the Lower Murrumbidgee Shallow Groundwater Source, the majority used for stock and domestic purposes. Groundwater is used less for irrigation than in the Lower Murrumbidgee Deep Groundwater source, with about 39 production bores, including spearpoint systems and shallow production bores. The majority occur in the east between Narrandera, Leeton, and Darlington Point. There are also groundwater production bores between Darlington Point, Coleambally, and Jerilderie.

There are about 1,376 registered bores in the underlying Lower Murrumbidgee Deep Groundwater Sources. The majority are for stock and domestic purposes. About 487 production bores are in the Lower Murrumbidgee Deep Groundwater Source. Most of the production bores occur between Griffith, Darlington Point, and Coleambally. There are 9 water utility bores located between Darlington Point and Hay.

Earlier investigations into groundwater quality of the Lower Murrumbidgee groundwater sources raised concerns about the impact of groundwater extraction on beneficial use. McDonald (2013) identified processes influencing groundwater salinisation in the Lower Murrumbidgee groundwater sources, and how groundwater extraction may mobilise saline groundwater into fresher groundwater occurrences. Parsons Brinckerhoff (2011) also identified areas of water quality concern west of the Coleambally Irrigation Area and Murrumbidgee Irrigation Area.

# Characterisation of the Lower Murrumbidgee Groundwater Sources

The Lower Murrumbidgee groundwater sources have been described in earlier studies (Parsons Brinckerhoff (2011), McDonald (2013), NSW DPIE (2019)). There have also been focused investigations that show how the alluvial deposits, aquitards, and paleochannels may be influencing groundwater chemistry (Prathapar et al., 1997, Timms, 2002, Khan et al., 2002, Timms and Acworth, 2002, Chen et al., 2012, and Papp et al., 2014).

## Topography and surface hydrology

The Lower Murrumbidgee groundwater sources occur in the Lower Murrumbidgee catchment, which sits in the riverine floodplain of the Murrumbidgee River west of Narrandera before the Murrumbidgee River joins the Murrumbidgee River near Balranald (Figure 1 and NSW DPIE, 2019). The Lower Murrumbidgee groundwater sources are bounded by Billabong Creek and the Edwards River in the south, the Lachlan River to the northwest, and exposed Palaeozoic bedrock to the east (Parsons Brinckerhoff, 2011). The ground surface is flat, and elevation gently declines from 175 m AHD near Narrandera to 40 m AHD near Balranald.

Locally, the Murrumbidgee River has various weirs and regulators that divert water along distributary channels. These include the Yanco Creek system, the main canals of the Murrumbidgee and Coleambally Irrigation Areas, and the Lowbidgee Flood Control and Irrigation District (NSW DPIE, 2019).

## Climate

The Lower Murrumbidgee catchment has a grasslands-type climate with hot dry summers and cold wet winters (BoM, 2020a).

The average daily minimum temperature ranges from 3 °C to 4 °C in winter and from 17 °C to 18 °C in summer. The average daily maximum temperature ranges from 14 °C to 15 °C in winter and from 33 °C to 35 °C in summer (Figure 2 and Figure 3).

Rainfall is uniform throughout the year, with a slight increase in mean monthly rainfall during winter and spring. Average annual rainfall decreases from east to west. Average annual rainfall at Narrandera is about 445 mm/year, about 360 mm/year at Hay, and about 325 mm/year at Balranald (Figure 4).

Evaporation data, using Class A pan evaporation, from sites close to the study area follow similar seasonal trends to temperature. Mean monthly evaporation ranges from a low of about 35 mm/month to 40 mm/month (Wagga Wagga AMO) in winter to a high of about 315 mm/month to

330 mm/month (Mildura Airport) in summer (Figure 5). Total annual evaporation is much higher than total annual rainfall, with total annual evaporation ranging from about 1,860 mm/month to 2,200 mm/year (BoM 2020b).

## Land use

The Barapa Barapa, Muthi Muthi, Nari Nari, Nyeri Nyeri, Wadi Wadi, Wamba Wamba, Weki Weki, Wolgalu, and Wiradjuri people are the traditional owners of the Murrumbidgee catchment. The land and waters of the Murrumbidgee catchment hold places of deep significance to Aboriginal people and are central to their spiritual and religious belief systems. These places are celebrated in ritual, ceremony, story, dance, and artwork. (MDBA, 2021).

European graziers began to establish pastoral runs in the Murrumbidgee catchment area in the 1820s, initially farming cattle, then sheep, and later growing grain crops. The introduction of river steamboats encouraged trade of timber, wool, and other goods from the 1860s until the early 20th century. The Murrumbidgee Irrigation Area was established in 1912, when a wide range of horticultural crops began to be produced. Further development of the area and the construction of more dams in the upper catchment helped establish rice production in the 1920s.

Most land use in the Murrumbidgee catchment is currently extensive agriculture. The largest industry is grazing, with much of the rest used for dryland cropping and horticulture. Irrigated crops are economically important for the catchment. Forests, conservation areas, and other native vegetation, defined as ‘minimal use’, also occur near tributaries throughout the catchment (Figure 6).

Irrigated cropping occurs within the Murrumbidgee Irrigation Area on the northern side of the Murrumbidgee River, in the Coleambally Irrigation Area on the southern side of the river, and along the Yanco Creek system. The prominent crops produced in the Murrumbidgee Irrigation Area are rice, corn, wheat, grapes, and citrus. In the Coleambally Irrigation Area rice, soybeans, and corn are grown in summer while wheat, oats, and barley are produced over winter. Irrigated pasture for grazing is grown throughout the year. The main irrigated crops along the Yanco Creek system are citrus, stone fruit, wine grapes, and rice.

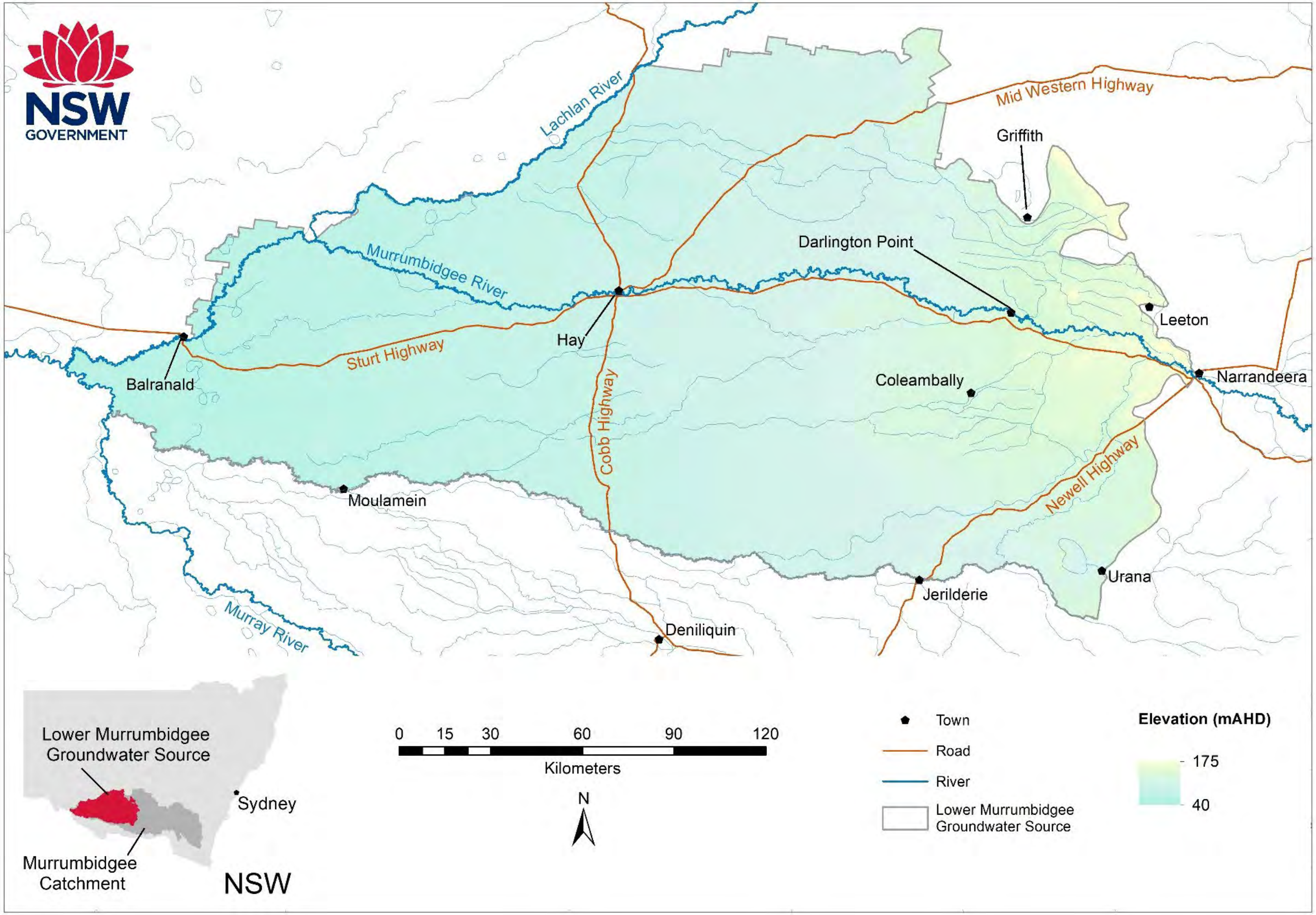


Figure 1. Topography and surface hydrology map of the Lower Murrumbidgee catchment (Gallant et al, 2009)

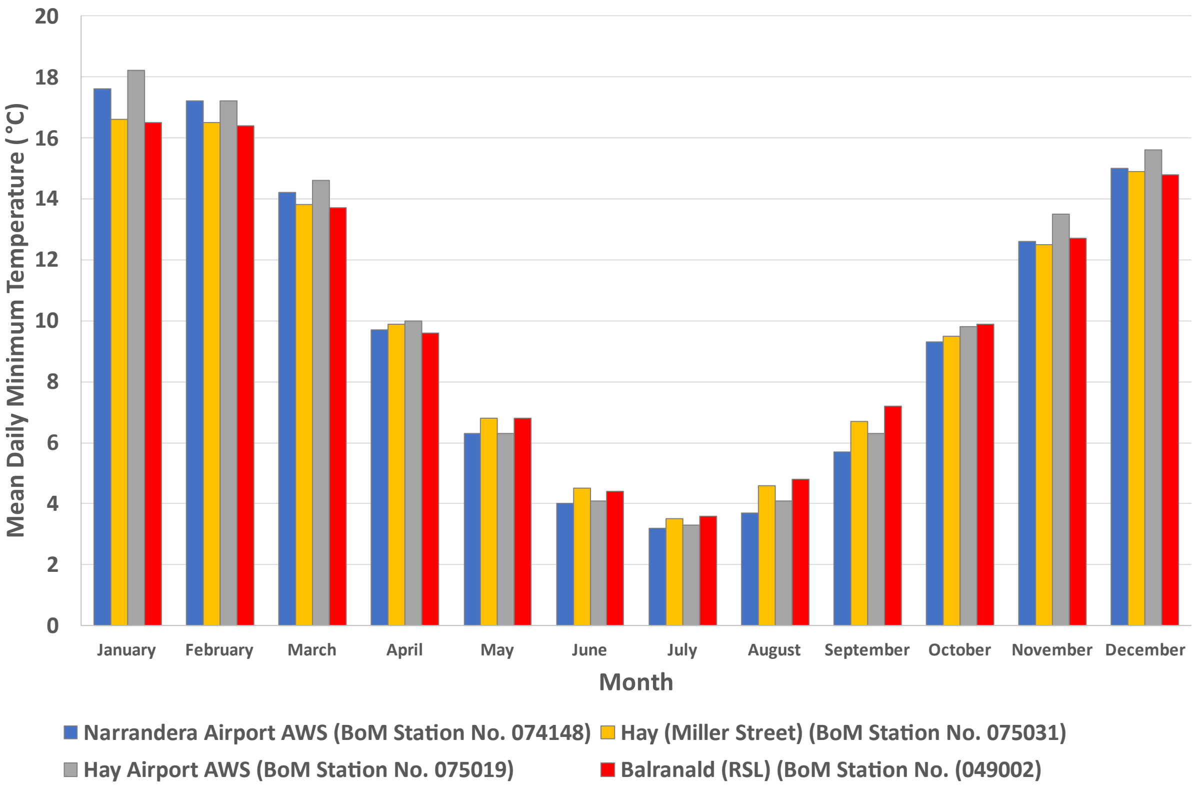


Figure 2. Mean daily minimum temperature at Narrandera Airport AWS (1970–2020), Hay (Miller Street) (1881–2015), Hay Airport AWS (2007–2020), and Balranald (RSL) (1907–2020) (BoM, 2020b)

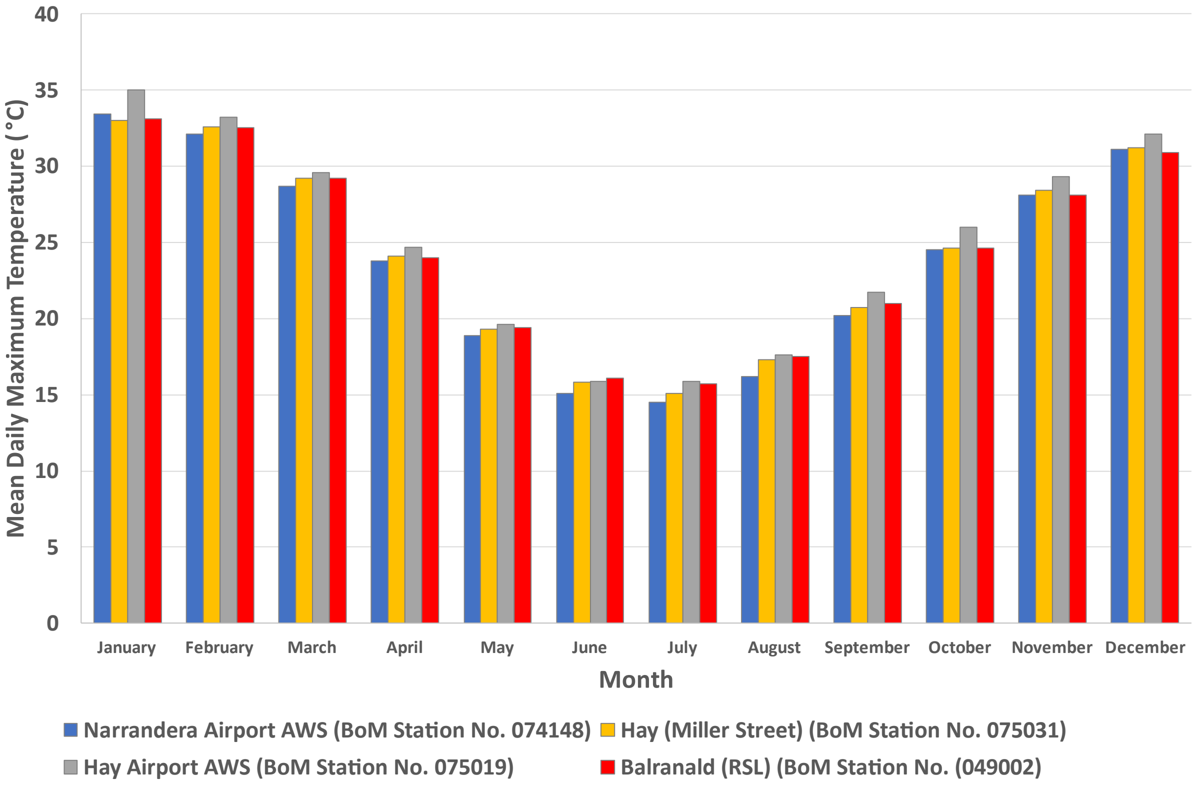


Figure 3. Mean daily maximum temperature at Narrandera Airport AWS (1970–2020), Hay (Miller Street) (1881–2015), Hay Airport AWS (2007–2020), and Balranald (RSL) (1907–2020) (BoM, 2020b)

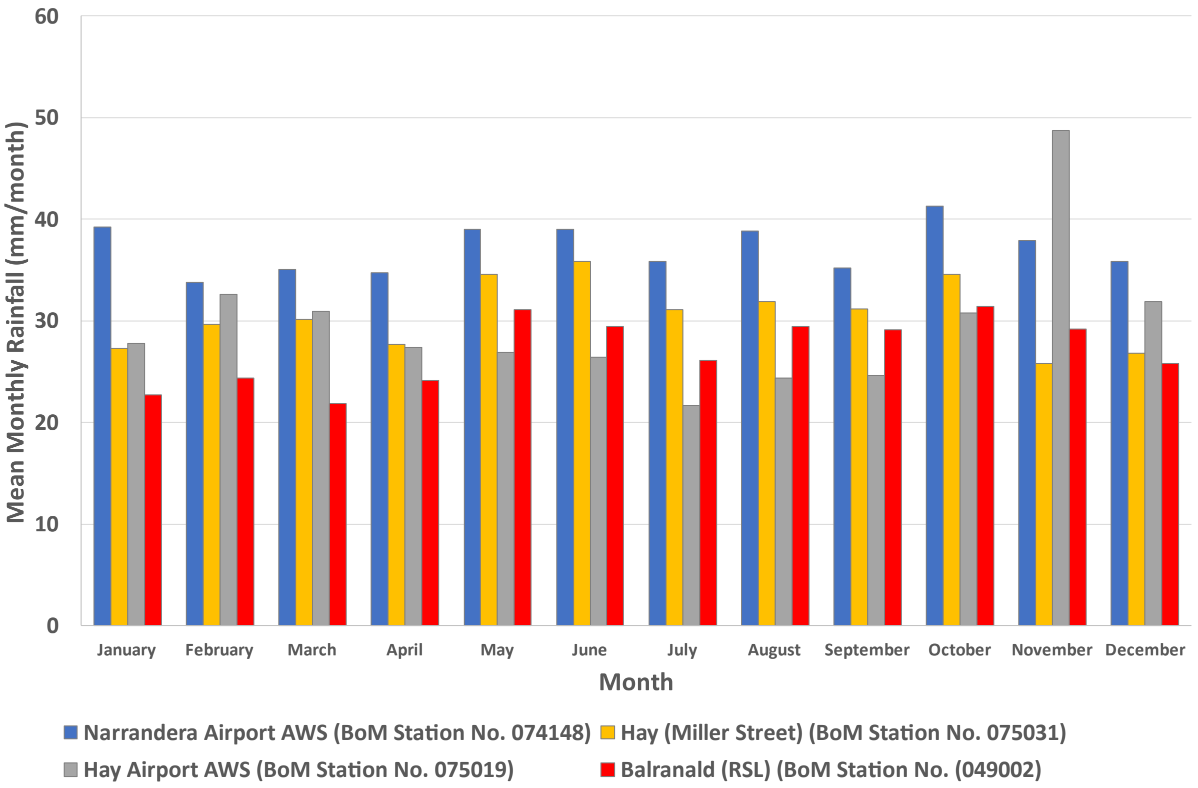


Figure 4. Mean monthly rainfall at Narrandera Airport AWS (1967–2020), Hay (Miller Street) (1877–2015), Hay Airport AWS (2007–2020), and Balranald (RSL) (1879–2020) (BoM, 2020b)

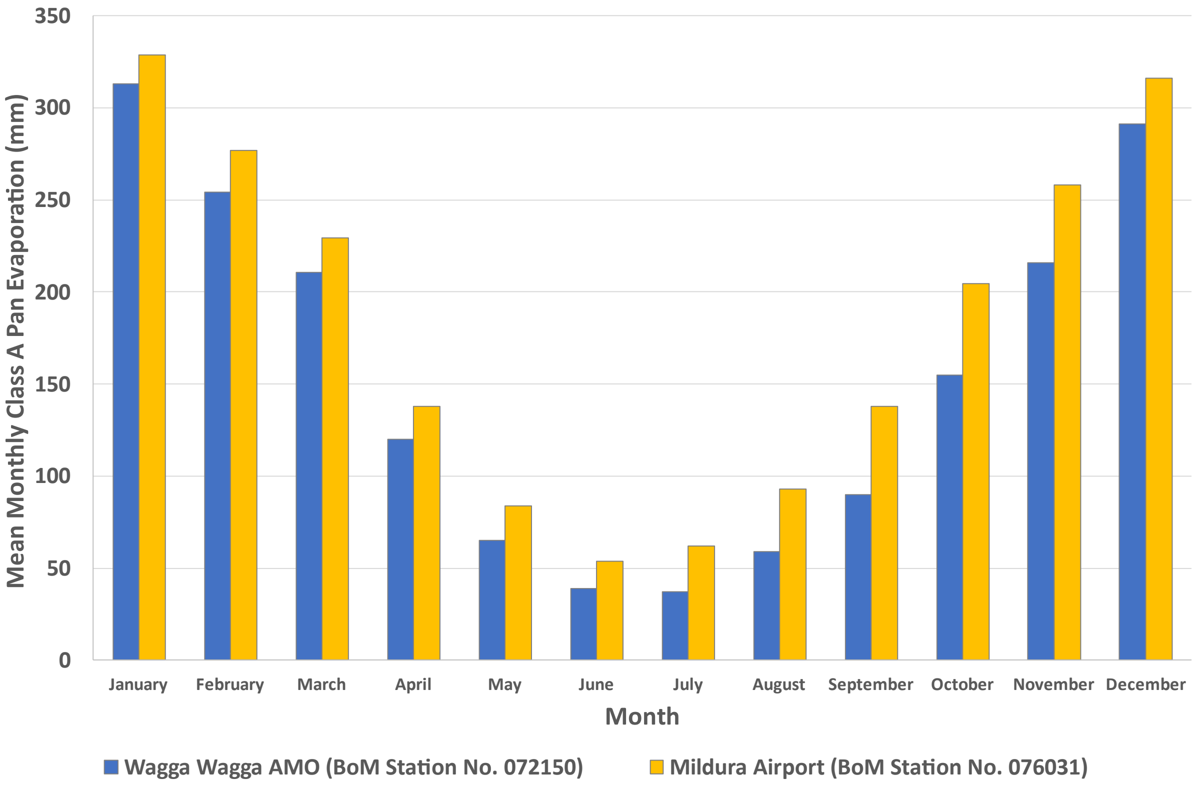


Figure 5. Mean monthly Class A pan evaporation at Wagga Wagga AMO (1966–2020) and Mildura Airport (1965–2016) (BoM, 2020b)

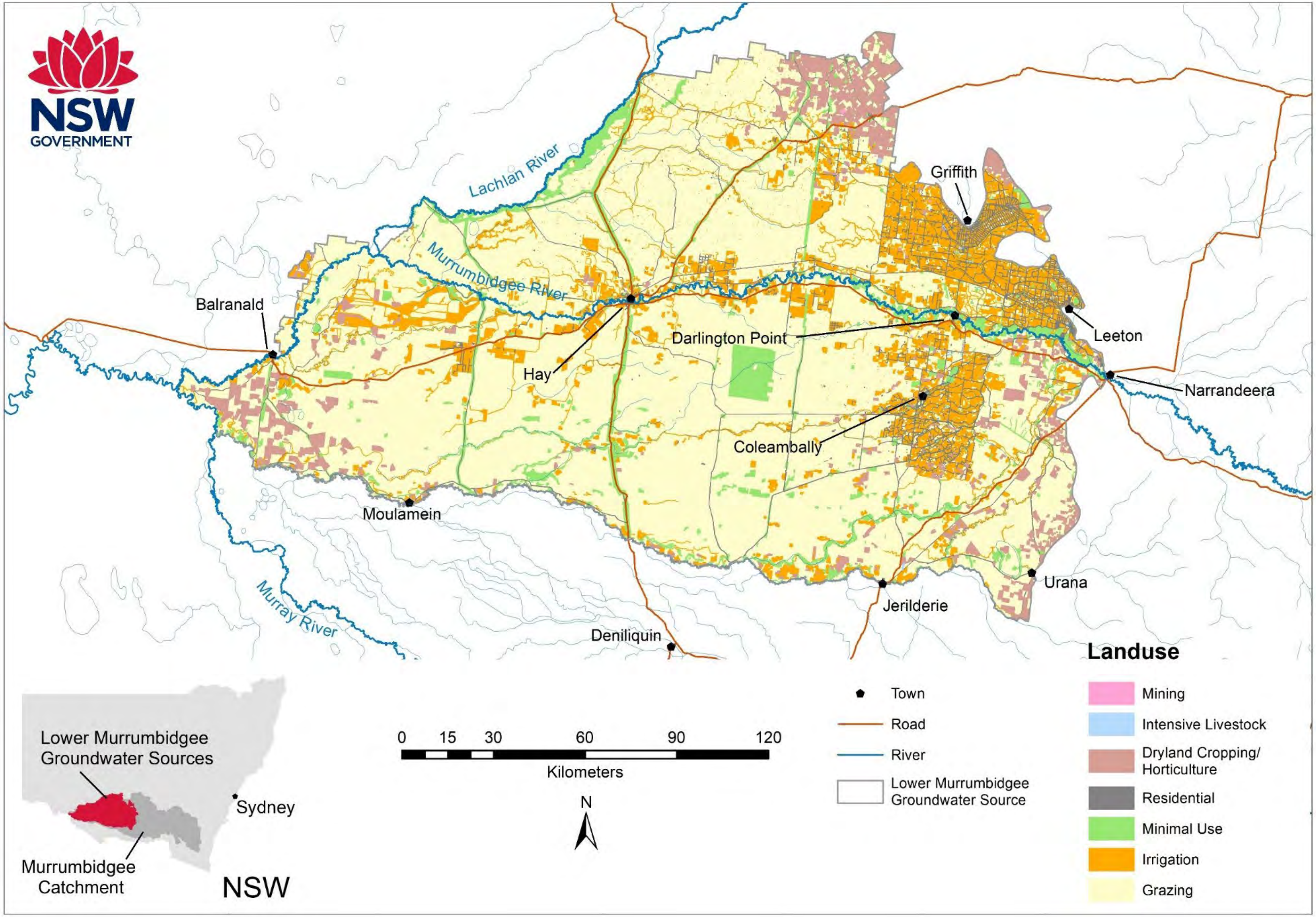


Figure 6. Land use of the Lower Murrumbidgee catchment (Smart, 2016)

# Alluvium geology

The Lower Murrumbidgee groundwater sources consists of unconsolidated and semi-consolidated Cenozoic sediments deposited within the Murrumbidgee Basin. These sediments are about 170 m thick where the Murrumbidgee River enters the Murrumbidgee Basin at Narrandera and are about 400 m thick near Balranald (NSW DPIE, 2019).

These deposits are subdivided into 3 main units. These units are not actually separate, distinct aquifers, but represent different time periods and types of sedimentary deposition. At any location within the study area, each unit could contain several aquifers. The 3 units, in order of youngest and uppermost to oldest and lowermost are the Shepparton Formation, the Calivil Formation, and the Renmark Group. Cross-sections and long sections showing the subterranean extent of the shallow and deep aquifer are shown in Figure 8 and Figure 9.

The Shepparton Formation, dating from the Late Pliocene to Holocene, is a complex assemblage of fluvio-lacustrine multicoloured clays, silts, and lenses of fine yellow and brown polymitic sands (Parsons Brinckerhoff, 2011). These sediments can be 50 m to 70 m thick and are laterally discontinuous. They form highly heterogeneous aquifer system both vertically and laterally.

The lower layers of the Shepparton Formation are sandier than the mid and upper layers, and in some areas are in hydraulic connection with the underlying Calivil Formation (Evans and Kellet, 1989, and Lawson and van der Lelij 1992). Thick clay units are found in the middle layers of the Shepparton Formation. They can form barriers, or aquitards, to vertical groundwater flow and partially confine the Calivil and Renmark aquifers. However, there are some regions of higher vertical hydraulic conductivity through these aquitards, which may allow downward movement of groundwater from the Shepparton Formation into underlying aquifers (Timms and Ackworth 2002).

The upper layers of the Shepparton Formation are a complex assemblage of sandy channel deposits from prior streams and rivers combined with floodplain clays (Page et al., 1996). The proportion of sand is highly variable but mostly between 10 % and 30 % (Lawson and van der Lelij 1992), and mainly restricted to the uppermost 30 m of the sequence. The Shepparton Formation is the shallowest aquifer of the Lower Murrumbidgee Shallow Groundwater Source, and conformably overlies the Calivil Formation.

The Calivil Formation, dating from the Late Miocene to Pliocene, contains paleo valley river deposits. The deposits form interbedded pale grey to white kaolinitic clay with thin bands of carbonaceous clay, silty clay, and silt. Subangular to subrounded fine to coarse-grained pale grey quartz sand, reef quartz, and fine grey metasediment gravel are also present (Brown and Stephenson, 1991). The formation ranges in thickness from 50 m to 70 m in the eastern part of the Lower Murrumbidgee groundwater sources to a maximum of 90 m to the west. The Calivil Formation conformably underlies the Shepparton Formation and unconformably overlies the upper Renmark Group.

The Renmark Group, dating from the Paleocene to Middle Miocene, forms the basal confined aquifer. It comprises fluvio-lacustrine deposits of gravel, grey medium-grained quartz sand, laterally discontinuous carbonaceous silts and clay. These unconsolidated to poorly consolidated deposits are pyritic and ferruginised. Minor seams of dark brown lignite (coal) occur.

The deepest, oldest deposits of the Renmark Group are in basement troughs and have a high proportion of coarse sand and gravel. The middle Renmark Group has finer sediments than the lower and upper layers, with a higher proportion of clays. Lignite and peat are abundant in the mid to upper Renmark Group. The upper Renmark Group contains about 50 % medium to fine sands (Evans and Kellet, 1989).

It can be difficult to distinguish the upper Renmark Group from the overlying Calivil Formation due to the erosion of the upper Renmark Group, and subsequent deposition of the Calivil Formation sediments, during the mid-Miocene marine recession (Evans and Kellet, 1989). This has resulted in areas of hydraulic connectivity between the upper deposits of the Renmark Group and the lower deposits of the Calivil Formation. The thickness of the Renmark Group is variable and peaks at 366 m within the investigation area.

The bedrock is predominately comprised of Ordovician sandstones, siltstones, mudstones, and shales along with Silurian-Devonian igneous intrusions of the Lachlan Fold Belt. The Devonian sandstones, conglomerates, siltstones, and shales of the Barka Basin occur in the northern area of the groundwater source near Hay, Griffith, and Narrandera. The coal-bearing Permian-Triassic Oaklands Basin occurs in the in the Jerilderie–Coleambally area. The bedrock outcrops at the eastern edge of the investigation area near Narrandera and dips down towards the western margin.

## Groundwater hydrology

Groundwater within the Lower Murrumbidgee sediments and within the boundary of the Lower Murrumbidgee groundwater sources is separated into 2 groundwater sources, based on depth, for management purposes. According to the Plan, the Lower Murrumbidgee Shallow Groundwater Source consists of all water contained within all unconsolidated alluvial sediments to a depth of 40 metres (below ground level, bgl) or to the bottom of the Shepparton Formation, whichever is deeper. The Lower Murrumbidgee Deep Groundwater Source consists of all water contained within the Calivil Formation and Renmark Group sediments at a depth greater than 40 mbgl.

Groundwater flow is generally westward (Figure 10 and Figure 11), with the highest bore yields occurring between Darlington Point and Carrathool. Groundwater age determinations using radiocarbon conducted by Drury et al. (1984) supports this, with groundwater age increasing from east to west and with increasing distance from the Murrumbidgee River. Drury et al. (1984) concluded that recharge to local aquifer systems is dominated by losses from the Murrumbidgee River via the Shepparton Formation between Narrandera and Gogeldrie Weir. Radiocarbon groundwater age determinations also identified local variations to the regional groundwater level trend occurring in areas of heavy pumping.

Bore yields decrease in the west and south of the Lower Murrumbidgee groundwater sources as the sediments become increasingly clay dominant. Potential recharge from the Murrumbidgee River also decreases in the west and south of the Lower Murrumbidgee groundwater sources (NSW DPIE, 2019). The groundwater potentiometric surface in both the shallow and deep groundwater sources rises in an area between Carrathool and Hay along the Murrumbidgee River, and may be an area where significant groundwater recharge is occurring away from the Murrumbidgee Basin eastern margin (Figure 10 and Figure 11).

The Shepparton Formation contain multiple aquifers. The shallowest aquifer is unconfined and is recharged by rainfall, flood, and irrigation. The horizontal hydraulic conductivity of the Shepparton Formation is highly variable because of the laterally discontinuous and poorly connected sand lenses, with the regional hydraulic conductivity being between 2 to 3 meters/day. Higher hydraulic conductivities occur in sandier lenses (Parsons Brinckerhoff, 2011 and Evans and Kellet, 1989).

The aquifers in the Calivil Formation are confined to semi-confined due to the overlying Shepparton Formation. It is the most productive aquifer within the Lower Murrumbidgee, with the highest yielding bores. There are yields greater than 350 litres/second located near Darlington Point (Parsons Brinckerhoff, 2011). Hydraulic conductivities in the Calivil Formation are up to 100 meters/day in the east near the Murrumbidgee River (van der Lelij et al., 1987, Evans and Kellett 1989, and McDonald, 2013). Groundwater recharge occurs by river leakage through coarse sediments near the eastern Murrumbidgee Basin margin near Narrandera (Drury et al., 1984). Groundwater leakage also occurs from the overlying Shepparton Formation.

The aquifers of the Renmark Group at the base of the alluvial sequence are confined to semi-confined, with horizontal hydraulic conductivity being 10 to 30 meters/day in the east and decreasing to 1 to 5 meters/day at the western margin. Hydraulic conductivity averages 3 meters/day on the regional scale (Evans and Kellet, 1989). Horizontal hydraulic conductivity can be up to 100 meters/day within the alluvial fans. This means that the Renmark Group is also a highly productive aquifer. Groundwater recharge occurs by river leakage through coarse sediments near the eastern Murrumbidgee Basin margin (Drury et al., 1984), with some groundwater movement occurring from the overlying Calivil Formation. Vertical hydraulic conductivities are poorly known but thought to be at least an order of magnitude lower than horizontal hydraulic conductivities due to the layered nature of the sediments (McDonald, 2013).

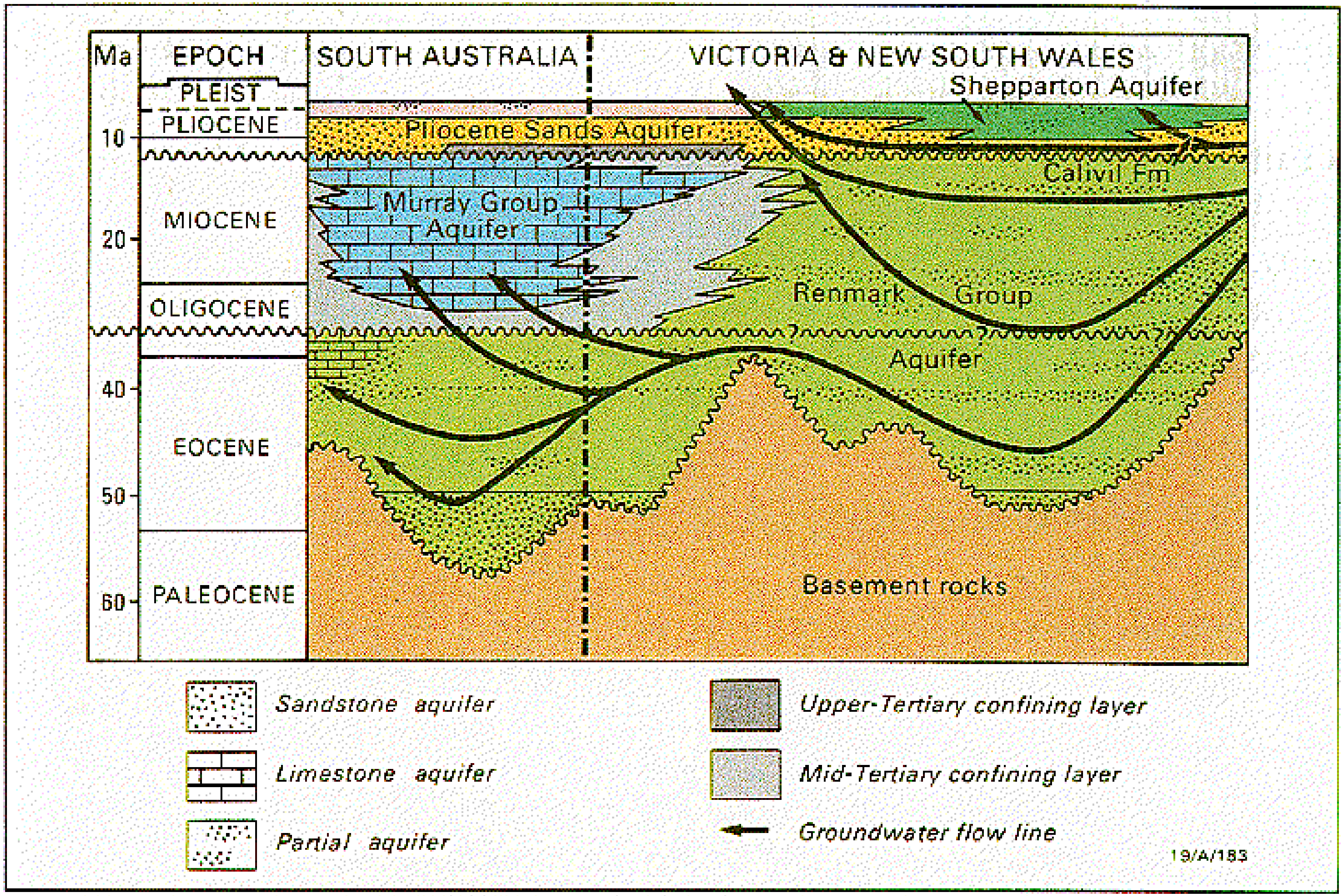
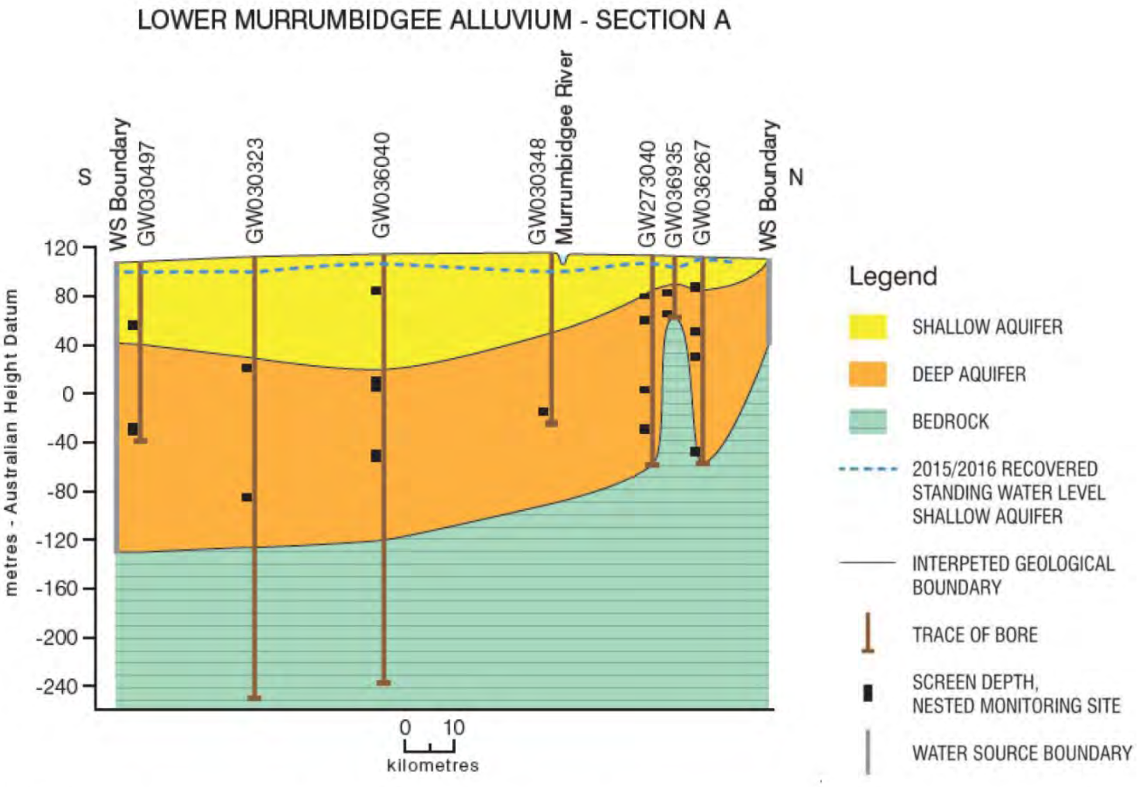
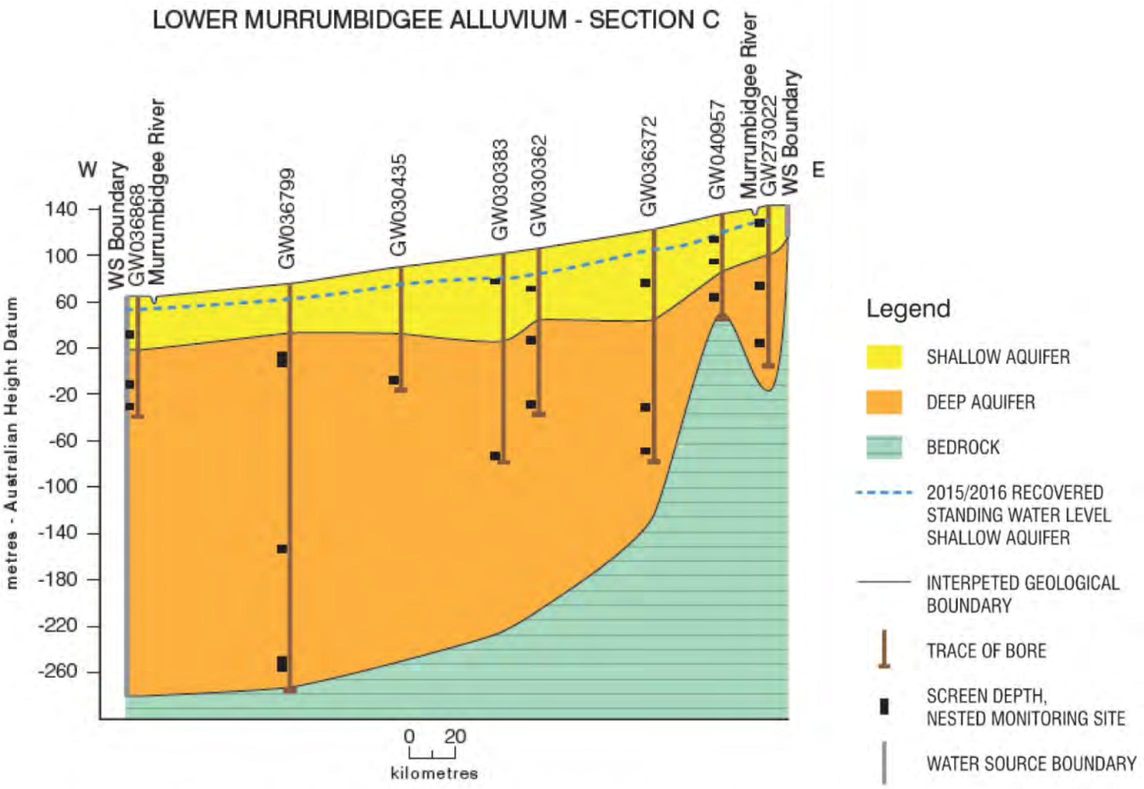


Figure 7. Schematic cross-section of the Murrumbidgee Basin Aquifers (taken from Brown & Stephenson, 1991)



*Note the boundary between the deep and shallow aquifers is interpreted based on limited information.*

Figure 8. North–south cross-section through the eastern Lower Murrumbidgee alluvium (taken from NSW DPIE, 2019)



*Note the boundary between the deep and shallow aquifers is interpreted based on limited information.*

Figure 9. East–west long section through the Lower Murrumbidgee alluvium (taken from NSW DPIE, 2019)

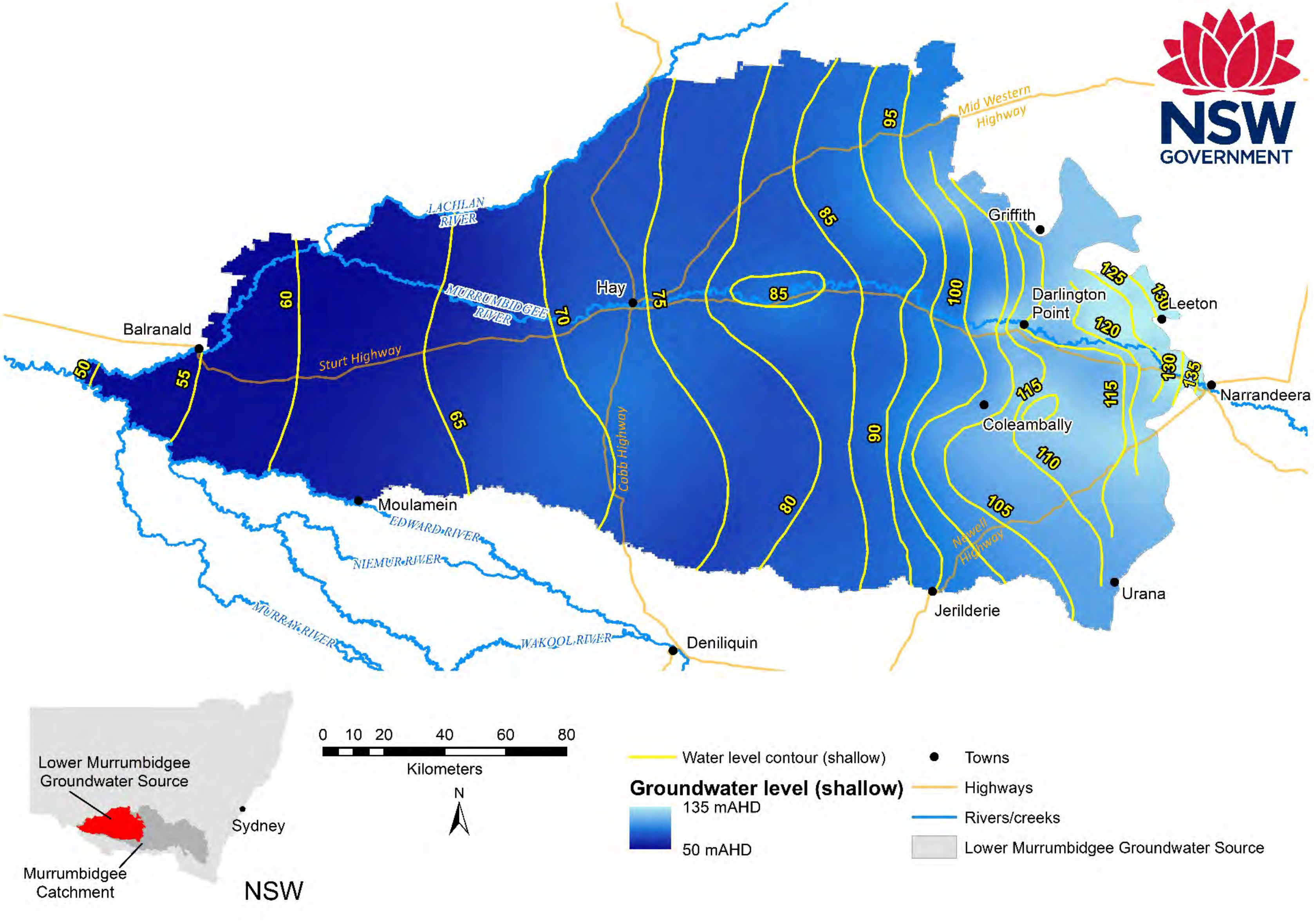


Figure 10. Groundwater flow direction in the Lower Murrumbidgee Shallow Groundwater Source (taken from NSW DPIE, 2019)

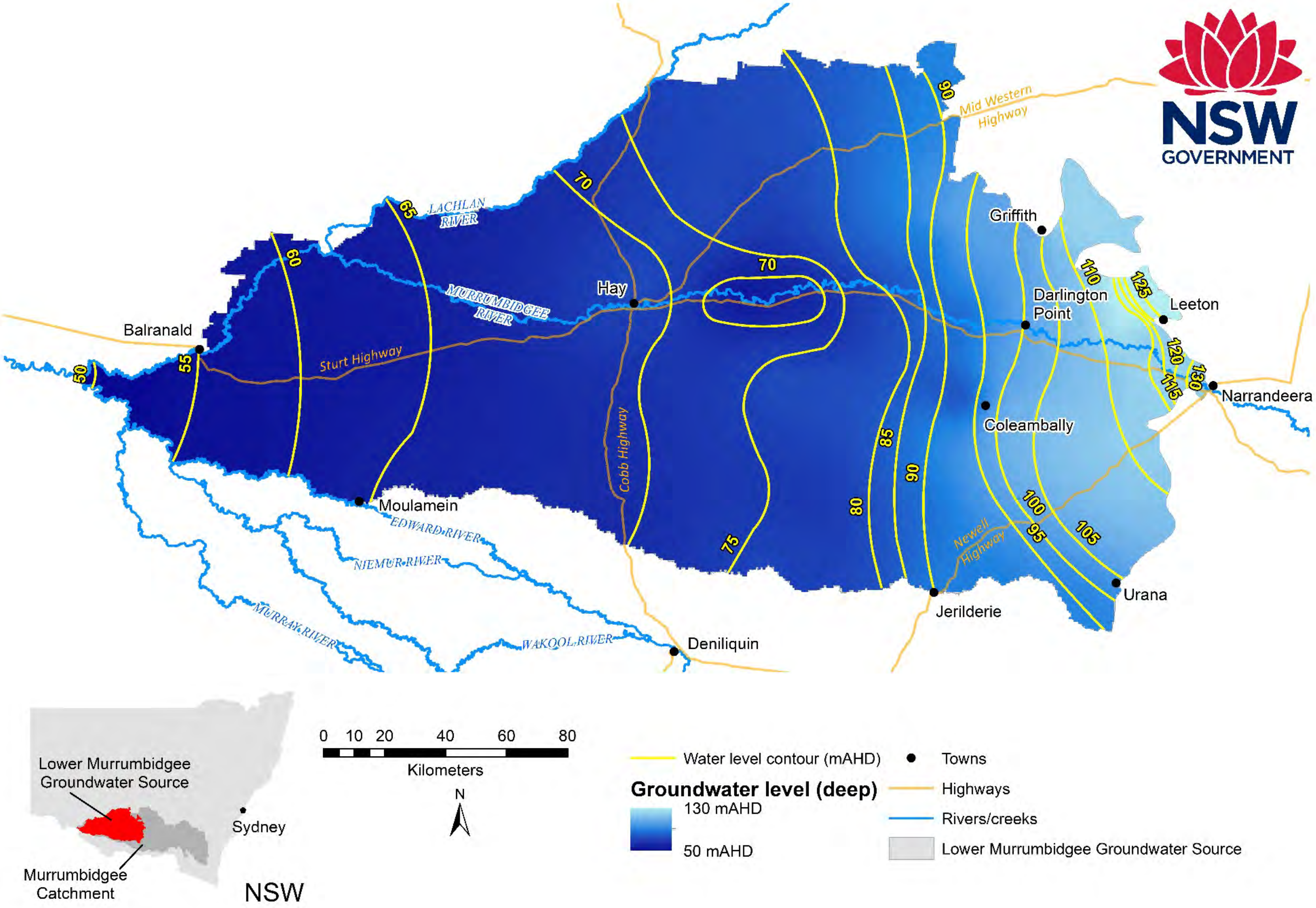


Figure 11. Groundwater flow direction in the Lower Murrumbidgee groundwater sources (taken from NSW DPIE, 2019)

# Groundwater salinity and geochemistry

Parsons Brinckerhoff (2011) and McDonald (2013) previously completed detailed hydrogeochemical analysis of the Lower Murrumbidgee groundwater sources.

The deeper Calivil and Renmark aquifers have lower salinity than the overlying Shepparton Formation. Within these 2 aquifers, groundwater electrical conductivity increases from less than 200 µS/cm in the east and near the Murrumbidgee River, to greater than 25,000 µS/cm in the west, with groundwater east of Hay generally less than 1,000 µS/cm.

Higher salinity groundwater also occurs in the northern part of the Lower Murrumbidgee groundwater sources between Leeton and Griffith. While the same regional trend is seen in the Shepparton Formation, higher groundwater electrical conductivity hotspots occur in the Murrumbidgee Irrigation Area and the Coleambally Irrigation Area, with groundwater electrical conductivities greater than 30,000 µS/cm (Parsons Brinckerhoff, 2011 and McDonald, 2013). The potential for deep aquifer salinisation due to vertical leakage and mixing from shallow groundwater was identified by Parsons Brinckerhoff (2011).

Processes influencing groundwater geochemistry in the Lower Murrumbidgee groundwater sources are described in more detail in the section 'Previous investigations'.

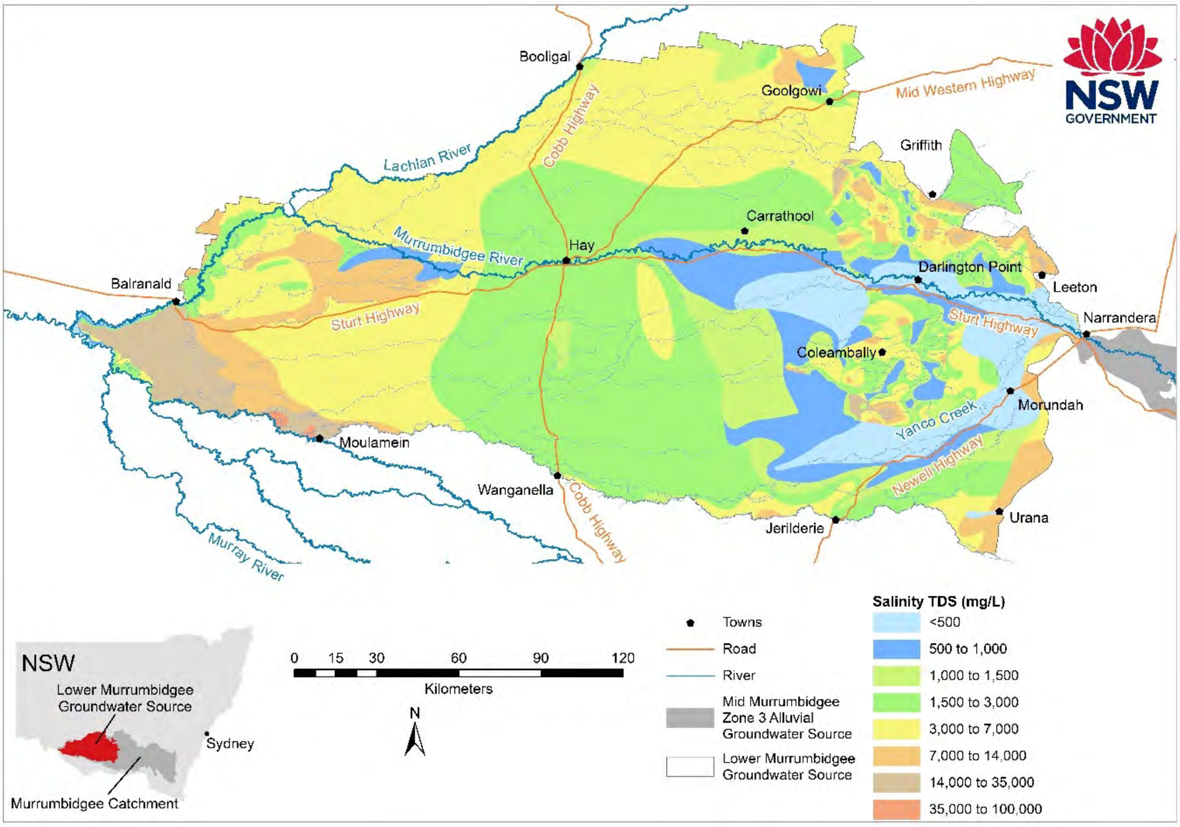


Figure 12. Groundwater salinity in the Shepparton Formation (Kellett, 1994; Woolley, 1991; Woolley, 1993a; Woolley, 1993b; Woolley, 1994)

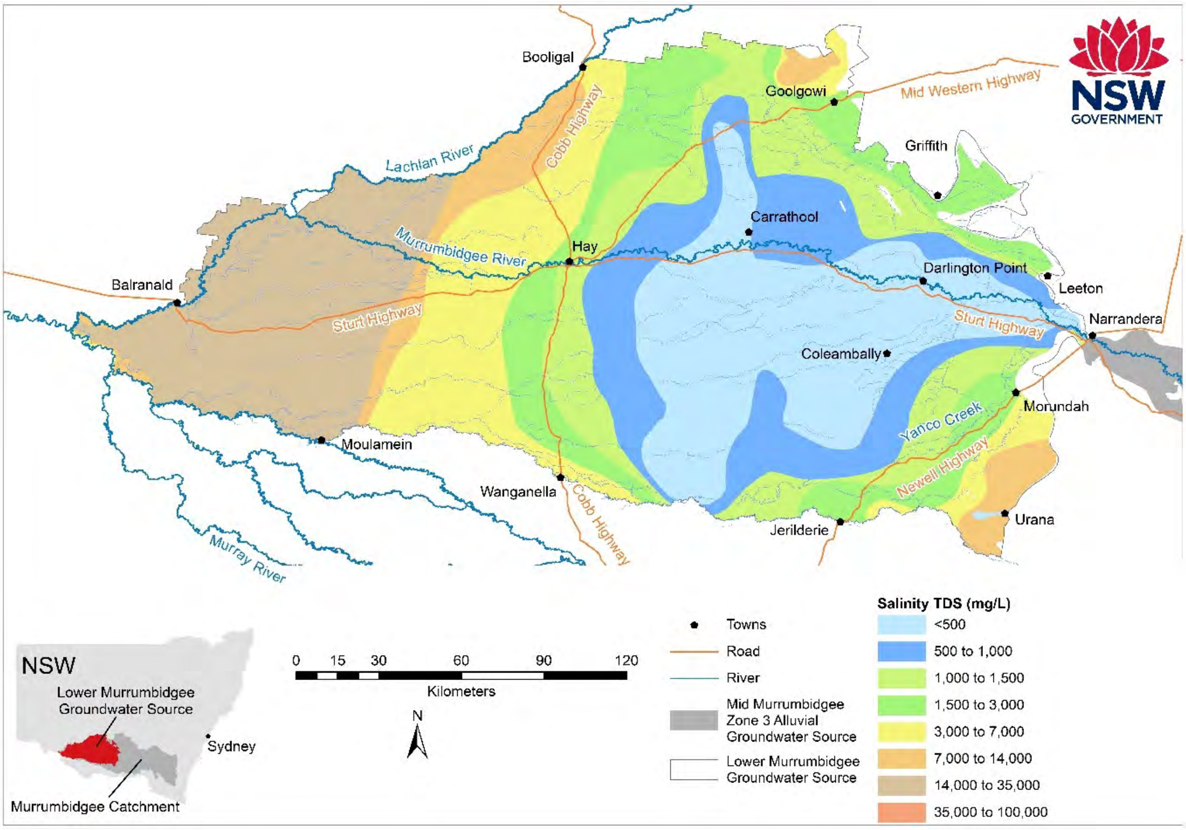


Figure 13. Groundwater salinity in the Calivil Formation (Kellett, 1994; Woolley, 1991; Woolley, 1993a; Woolley, 1993b; Woolley, 1994)

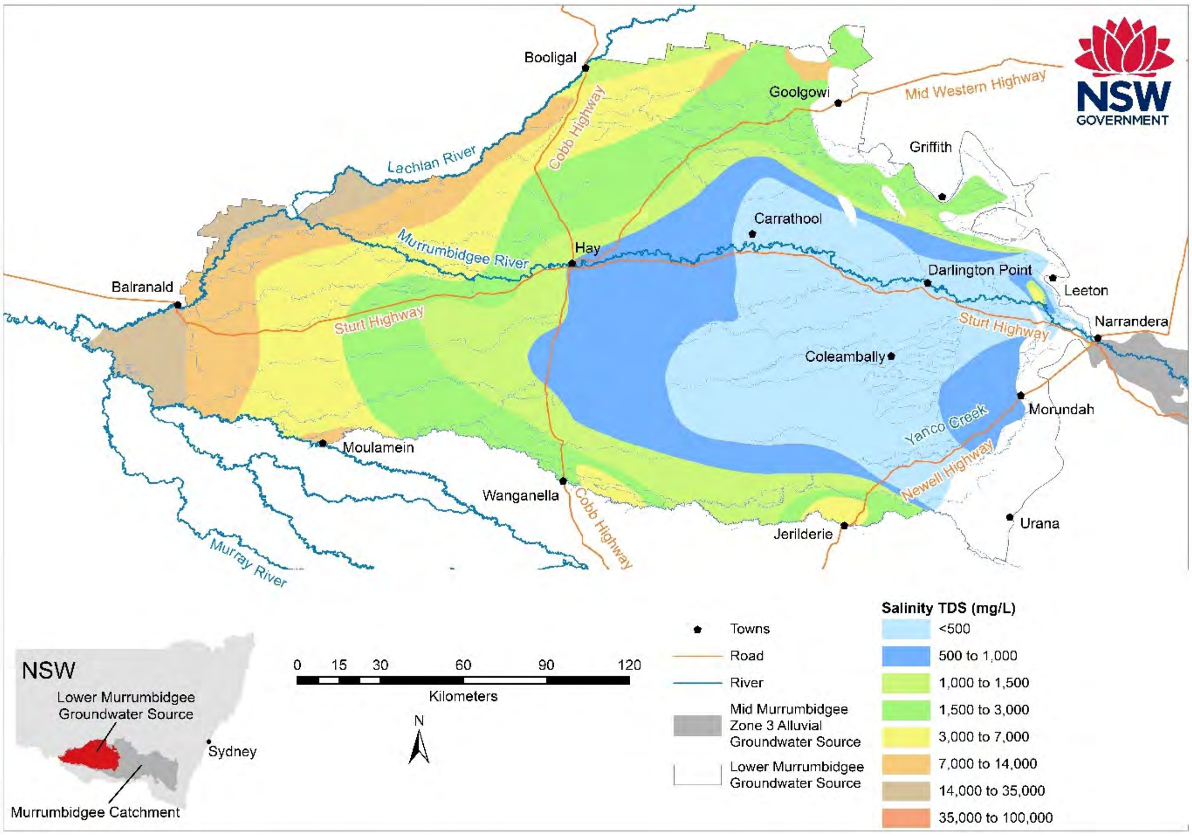


Figure 14. Groundwater salinity in the upper Renmark Group (Kellett, 1994; Woolley, 1991; Woolley, 1993a; Woolley, 1993b; Woolley, 1994)

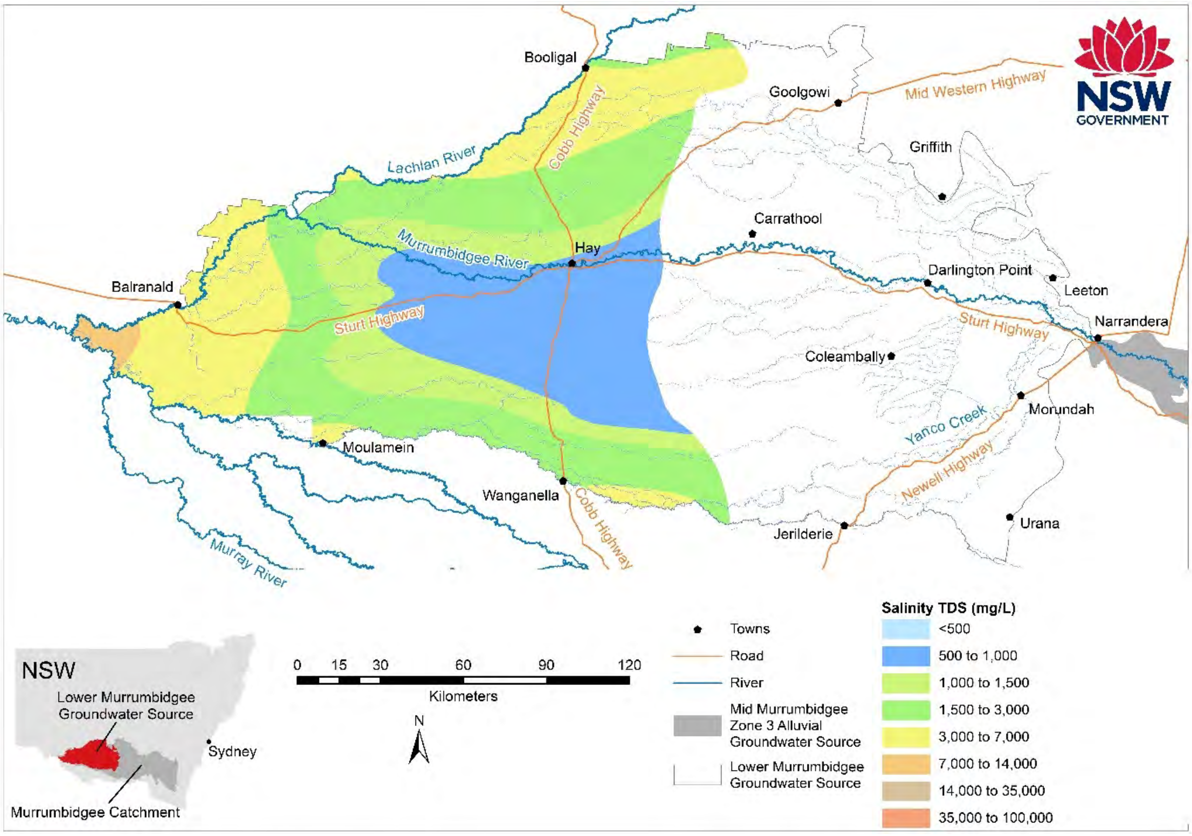


Figure 15. Groundwater salinity in the middle Renmark Group (Kellett, 1994; Woolley, 1991; Woolley, 1993a; Woolley, 1993b; Woolley, 1994)

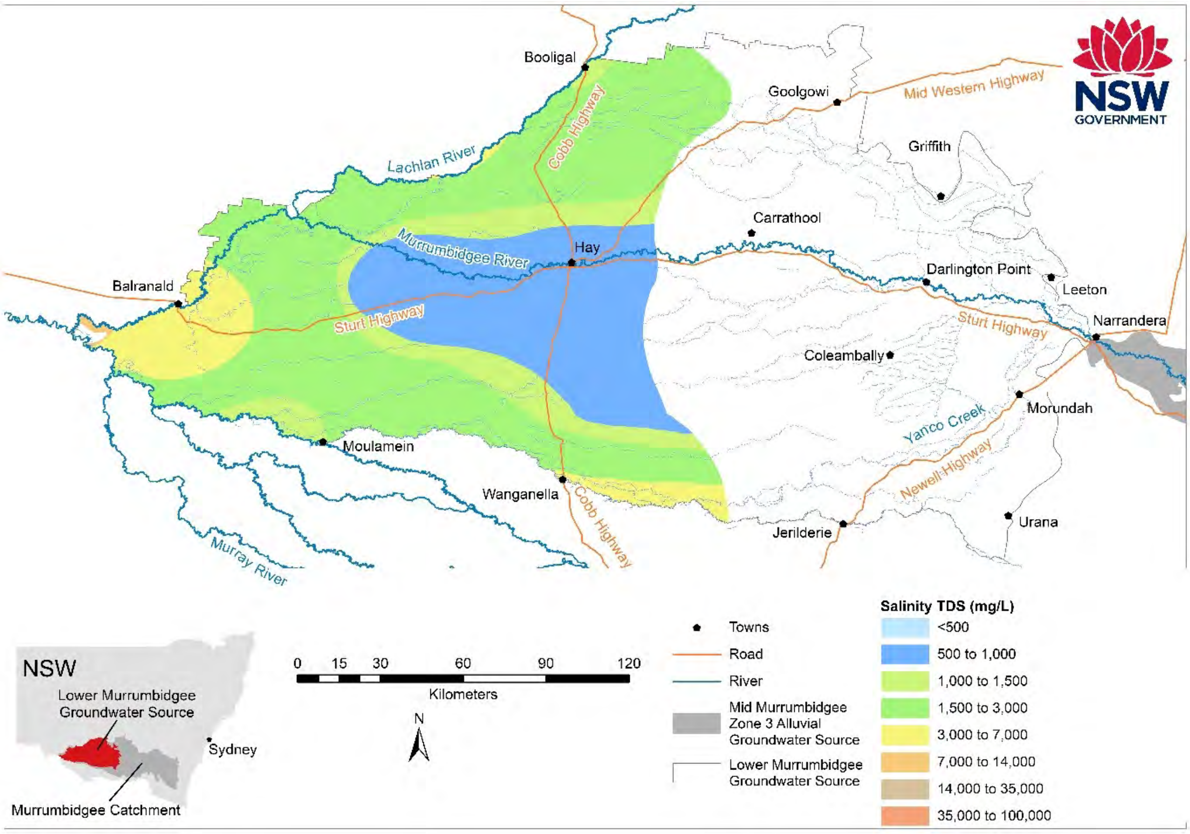


Figure 16. Groundwater salinity in the lower Renmark Group (Kellett, 1994; Woolley, 1991; Woolley, 1993a; Woolley, 1993b; Woolley, 1994)

# Groundwater use

Groundwater from the Lower Murrumbidgee groundwater sources supports many productive purposes. This includes irrigation and industry, water supply for local water utilities, and stock and domestic use. It is expected that groundwater use would increase during the irrigation season (October to March) and in low-rainfall years when access to surface water reduces.

There are about 2,577 registered bores in the Lower Murrumbidgee groundwater sources (NSW DPIE, 2021 and Figure 17). There are 2,045 bores used for stock and domestic purposes, with 1,199 bores screened in the shallow groundwater source and 846 screened in the deep groundwater source. There are 523 bores used for agricultural and industry production, with 39 bores screened in the shallow groundwater source and 484 screened in the deep groundwater source. There are 9 bores used for town water supply, all screened in the deep groundwater source, near Coleambally, Darlington Point, and Carrathool (Figure 18).

The current long-term average annual extraction limit (LTAAEL) for the Lower Murrumbidgee Shallow Groundwater Source is set at 26,875 ML/year with the LTAAEL for the Lower Murrumbidgee Deep Groundwater Source set to 273,625 ML/year (NSW DPIE, 2020 and The Plan). The LTAAEL for these groundwater sources equates to the long-term average sustainable diversion limits for the Lower Murrumbidgee Shallow Alluvium Groundwater SDL Resource Unit (GS28a) and the Lower Murrumbidgee Deep Alluvium Groundwater SDL Resource Unit (GS28b), specified in Schedule 4 to the Basin Plan. Under the water resource plans, NSW manages extractions to the LTAAEL, ensuring compliance with the Sustainable Diversion Limit (SDL).

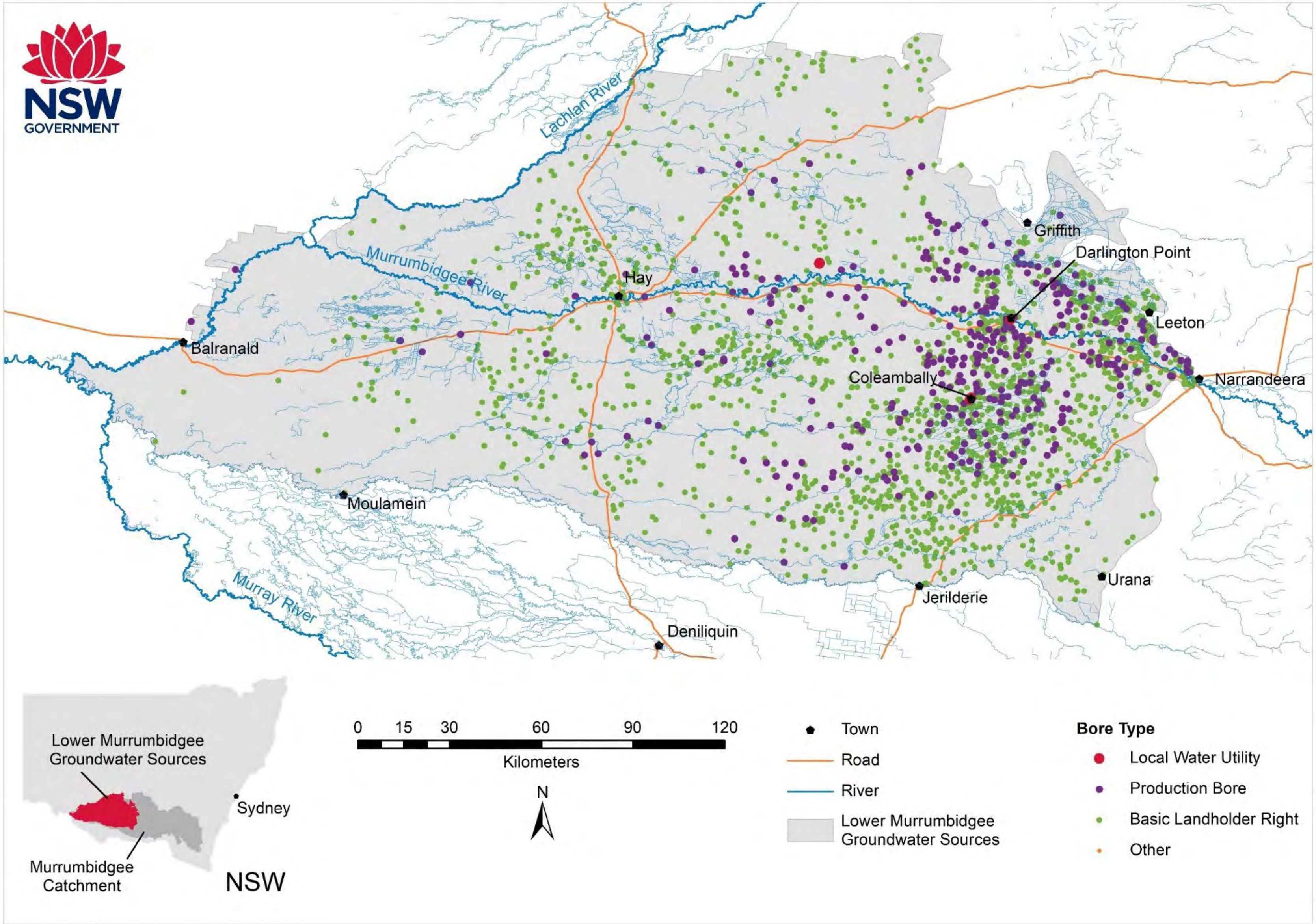


Figure 17. Registered bores in the Lower Murrumbidgee Groundwater Sources

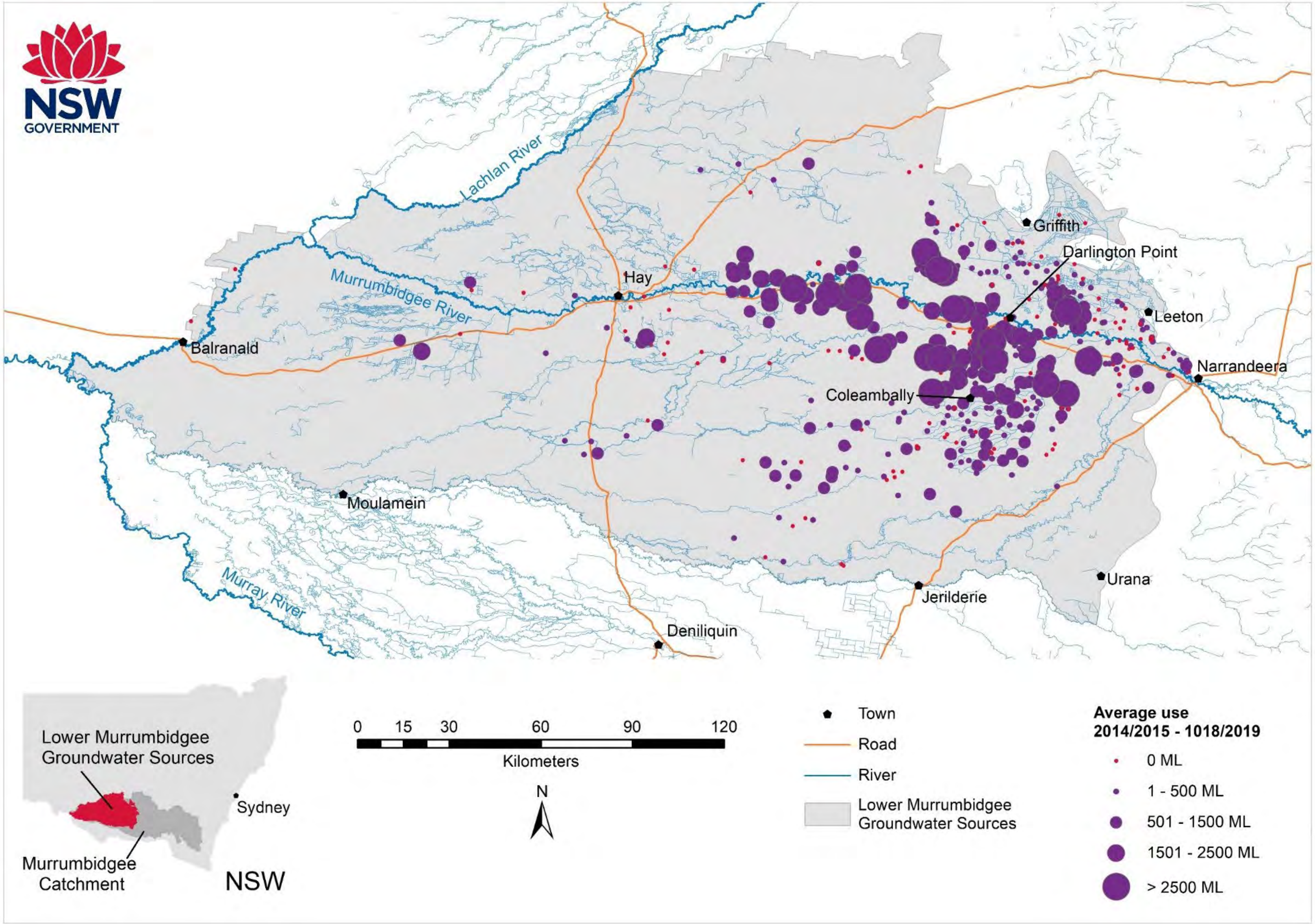


Figure 18. Lower Murrumbidgee groundwater sources distribution of extraction

# Risks to beneficial use

The main risks to groundwater quality within the Lower Murrumbidgee groundwater sources include:

- The rate of groundwater extraction resulting in aquifer depressurisation and, in some areas, reversal of hydraulic gradients
- mobilisation of salts from clay-rich bands in the alluvial deposits
- mobilisation of salts and salt stores formed by evapo-concentration and rising groundwater levels during the mid-1980s to mid-1990s.

Declining groundwater levels due to groundwater extraction can change hydraulic gradients on short and long-time scales. During a pumping season, where hydraulic heads decline near production bores, saline groundwater could be drawn towards landholder bores either from overlying saline aquifers, if hydraulic connectivity exists, or saline 'hot spots' within aquifers. This moves saline water 'plumes' into areas where fresher groundwater occurs. The movement of the plumes can stop once groundwater extraction ceases, and the pre-pumping hydraulic gradients recover. However, more saline groundwater can move through aquifers if groundwater drawdown and hydraulic heads declines are great enough in the next pumping season. Also, long-term water level declines can facilitate saline groundwater movement even when pumping ceases in between seasons (Pulido-Bosch et al., 2018).

Timms (2001) and Timms and Acworth (2002) identified stored salts within the clay-rich units of the Lower Murrumbidgee alluvium, with larger salt stores in shallower deposits than in deeper deposits. This was due to the lower deposits undergoing more leaching than the shallower deposits. Despite the leaching, stored salts within clay-rich units pose a risk to groundwater quality. Timms and Acworth (2002) found that about 91 % of the total subsurface aquitard salt storage occurs within 15 meters of the surface, with 37 % found within 3 meters of the surface. This can explain increasing groundwater salinity in the Shepparton Formation, along with evapo-concentration. This could migrate into the underlying Calivil Formation and Renmark Group if deep aquifer leakage occurs, either naturally or driven by stronger downward hydraulic gradients due to pumping.

Parsons Brinckerhoff (2011) had previously attributed groundwater salinity increases in the Calivil Formation to seasonal drawdowns inducing leakage of saline groundwater from the Shepparton Formation. Optimised mixing calculations performed by Parsons Brinckerhoff (2011) estimated that 20% of the dissolved ion composition at monitoring site GW036358.1.1 in the Calivil Formation could be from saline groundwater leakage from the Shepparton Formation. Increasing groundwater salinity in the Renmark Group was also attributed to vertical leakage, with optimised mixing calculations at monitoring site GW036358.3.3 in the Renmark Group estimating that 8% of the dissolved ion composition could be from saline groundwater leakage from the Calivil Formation. McDonald (2013) also identified vertical leakage as a dominant process contributing to the mobilisation of dissolved ions in the Lower Murrumbidgee groundwater sources.

Generalised beneficial use information is presented in Appendix 1–Beneficial use information.

# Method

## Site and time frame selection

Samples for geochemical analysis have been collected from 25 monitoring bores, located between Darlington Point and Hay, on a regular basis from August 2008 to the present time. This area has been monitored because there is a high-risk potential of groundwater pumping changing hydraulic gradients which could move saline groundwater into highly productive low-salinity groundwater areas (NSW DPIE, 2019).

This investigation focusses on data collected between 1 October 2005 and 1 October 2018. This matches when data is available and general pumping (October to March) and non-pumping (April to September) timeframes. A summary of geochemical data available from each monitoring site is in Table 1, with detailed work summaries of the monitoring bores in Appendix 2–Work summaries of monitoring bores. The location of these monitoring bores is in Figure 19.

## Data sources and parameter selection

Historical geochemical data was sourced from both the WaterNSW water quality database and the Kisters Water Quality Module database. Key geochemical parameters were selected for further investigation based on their ability to collectively identify and describe major geochemical processes occurring within groundwater systems. These parameters are outlined below.

- Physicochemical parameters:
    - Electrical conductivity (standardised to 25 °C)
    - pH.
- Major ions (dissolved):
    - cations: sodium ($Na^+$), potassium ($K^+$), calcium ($Ca^{2+}$), and magnesium ($Mg^{2+}$)
    - anions: chloride ($Cl^-$), sulfate ($SO_4^{2-}$), alkalinity represented by carbonate ($CO_3^{2-}$) and bicarbonate ($HCO_3^-$), and nitrate ($NO_3^-$).

Table 1. Summary of monitoring sites

| Site ID | Pipe | Screen interval (mbgl) | Aquifer | Date range | Count |
|---|---|---|---|---|---|
| **GW030323** | 1.1 | 88.3–94.4 | Calivil Formation | 21 September 2009–17 April 2018 | 15 |
| **GW036211** | 1.1 | 131–143.2 | Renmark Group (upper) | 18 September 2009–11 April 2018 | 19 |
| **GW036211** | 2.2 | 196.6–202.6 | Renmark Group (middle) | 18 September 2009–11 April 2018 | 19 |
| **GW036211** | 3.3 | 256–262.1 | Renmark Group (lower) | 22 September 2009–10 April 2018 | 19 |
| **GW036396** | 1.1 | 139–145 | Renmark Group (middle) | 13 October 2009–17 April 2018 | 15 |
| **GW036773** | 1.1 | 57.3–62.8 | Shepparton Formation | 2 October 2009–3 May 2018 | 19 |
| **GW036773** | 2.2 | 122–128 | Calivil Formation | 2 October 2009–3 May 2018 | 19 |
| **GW036773** | 3.3 | 166–172 | Renmark Group (middle) | 2 October 2009–3 May 2018 | 19 |
| **GW036799** | 1.1 | 59–71 | Renmark Group (upper) | 16 September 2009–24 April 2018 | 11 |
| **GW036799** | 2.2 | 225–231 | Renmark Group (middle) | 16 September 2009–24 April 2018 | 11 |
| **GW036799** | 3.3 | 322–334 | Renmark Group (lower) | 16 September 2009–24 April 2018 | 11 |
| **GW041011** | 1.1 | 16–22 | Shepparton Formation | 14 December 2005–2 May 2018 | 20 |
| **GW041011** | 2.2 | 97–103 | Calivil Formation | 13 December 2005–2 May 2018 | 20 |
| **GW041011** | 3.3 | 178–184 | Renmark Group (middle) | 8 December 2005–2 May 2018 | 20 |
| **GW041012** | 1.1 | 30–34 | Shepparton Formation | 29 September 2009–2 May 2018 | 19 |
| **GW041012** | 2.2 | 71–77 | Calivil Formation | 29 September 2009–2 May 2018 | 20 |
| **GW041012** | 3.3 | 155–161 | Renmark Group (middle) | 29 September 2009–22 March 2006 | 21 |
| **GW273040** | 1.1 | 32–35 | Shepparton Formation | 1 October 2009–19 April 2018 | 16 |
| **GW273040** | 2.2 | 50–56 | Calivil Formation | 20 August 2008–19 April 2018 | 10 |
| **GW273040** | 3.3 | 107–113 | Renmark Group (upper) | 20 August 2008–19 April 2018 | 17 |
| **GW273040** | 4.4 | 140–146 | Renmark Group (lower) | 20 August 2008–19 April 2018 | 15 |
| **GW273041** | 1.1 | 19–22 | Shepparton Formation | 21 August 2008–18 April 2018 | 17 |
| **GW273041** | 2.2 | 77–83 | Calivil Formation | 20 August 2008–18 April 2018 | 9 |
| **GW273041** | 3.3 | 148–154 | Renmark Group (upper) | 20 August 2008–18 April 2018 | 17 |
| **GW273041** | 4.4 | 185–191 | Renmark Group (lower) | 20 August 2008–18 April 2018 | 17 |

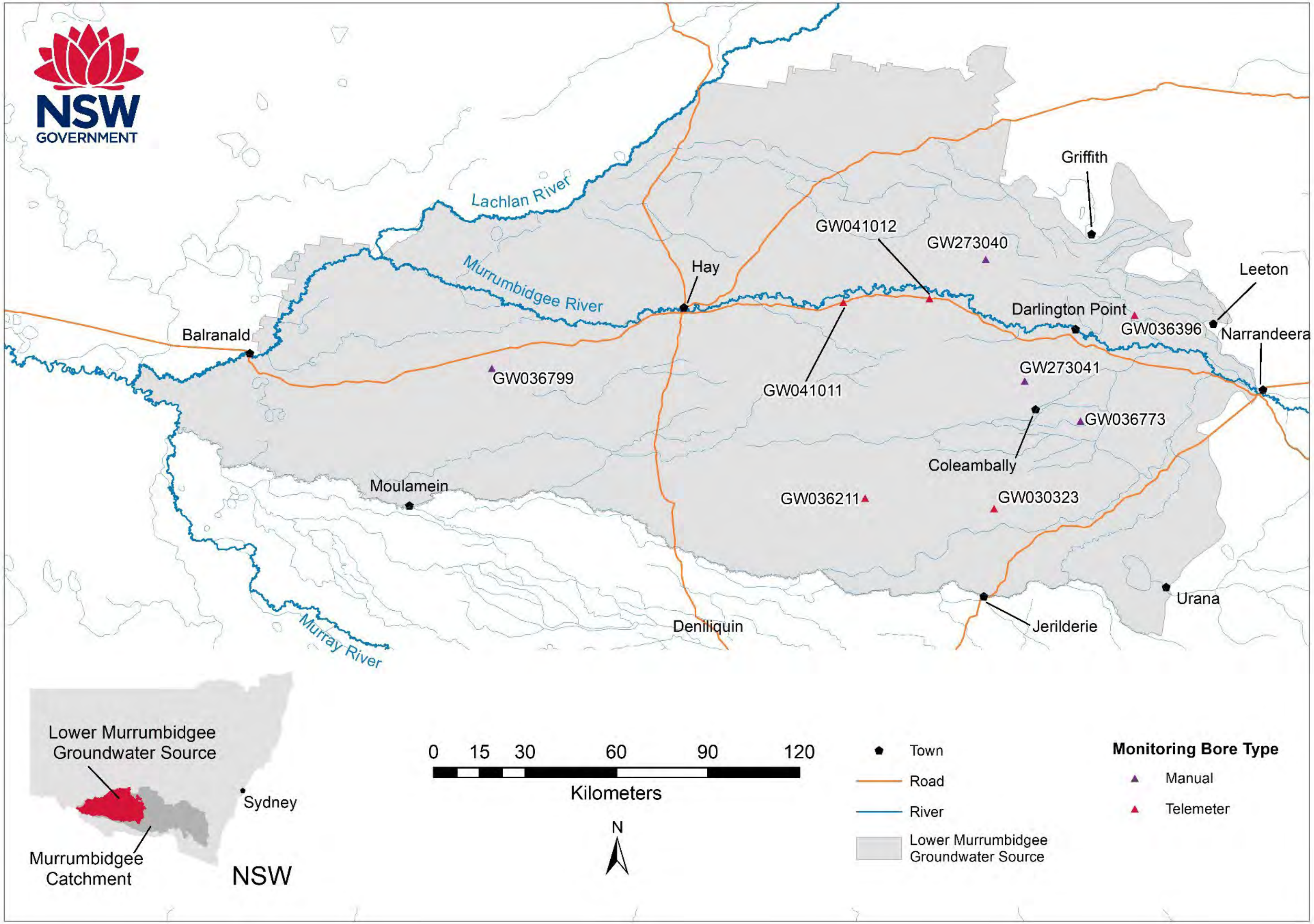


Figure 19. Monitoring bores utilised in this investigation in the Lower Murrumbidgee groundwater sources

# Data cleansing and preparation

## Data amalgamation

The same geochemical analyte can have different descriptors in different databases. A consistent descriptor framework is needed to simplify the amalgamated datasets, to ensure that geochemical analysis can be compared across the different source datasets, and to provide a longer timeline where geochemical data is available for a groundwater site. The descriptor framework used for this report is summarised in Table 2.

Table 2. Simplified geochemical analyte descriptor framework

| Analyte | Descriptor in source datasets | Descriptor in amalgamated datasets |
|---|---|---|
| **Electrical conductivity** | Conductivity–field (mS/cm)<br>Conductivity uS/cm<br>Electrical conductivity (uncompensated)<br>Electrical conductivity at 25 °C | Electrical conductivity at 25 °C (µS/cm) |
| **pH** | pH | pH (field) (pH units)<br>pH (field/lab) (pH units)[1] |
| **Metals/ metalloids** | (...)–soluble<br>(...) as ‘xx’–soluble<br>(...)–filtered<br>(...)–Sol | (...) as ‘xx’ (dissolved; *units*) |
| **Metals/ metalloids** | (...)–total<br>(...) as ‘xx’–total | (...) as ‘xx’ (total; *units*)[2] |
| **Hydroxide alkalinity** | Alkalinity (hydroxide) as $CaCO_3$<br>Hydroxide alkalinity as $CaCO_3$ | Hydroxide alkalinity as $CaCO_3$<br>Hydroxide alkalinity as $OH^-$ |
| **Carbonate alkalinity** | Alkalinity as carbonate<br>Alkalinity (carbonate) as $CaCO_3$<br>Carbonate alkalinity as $CaCO_3$ | Carbonate alkalinity as $CaCO_3$<br>Carbonate alkalinity as $CO_3^{2-}$ |
| **Bicarbonate alkalinity** | Alkalinity (bicarbonate) as $CO_3$<br>Bicarbonate alkalinity<br>Alkalinity as bicarbonate ($HCO_3$) | Bicarbonate alkalinity as $CaCO_3$<br>Bicarbonate alkalinity as $HCO_3^-$ |
| **Total alkalinity** | Alkalinity (total) as $CaCO_3$<br>Alkalinity (mg $CaCO_3$/L) | Total alkalinity as $CaCO_3$<br>Total alkalinity as $HCO_3^-$ |

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[1] Laboratory-based measurements for pH were utilised when field-based measurements were not available and are likely to be higher than field-based pH measurements due to $CO_2$ degassing.

[2] Total concentration was used when the dissolved concentration was not available, and the anion-cation balance passed QAQC criteria.

## ‘Zero’ data

Analyte concentrations have been reported as ‘0’ or ‘ND’ in the source databases. These values need to be changed so they can be used in geochemical interpretation methods. ‘Zero’ data was changed to the lowest ‘non-detect’ value for that analyte. A ‘non-detect’ value shows that the analyte concentration is below a certain level. This is typically the analytical method detection limit. ‘Zero’ data changes are summarised in Table 3. Reported values of ‘0’ for physicochemical parameters were removed if it could not be a realistic value.

Table 3. Replacement values in the amalgamated dataset for ‘zero’ data in source datasets

| Analyte | Count | Replacement value |
|---|---|---|
| **Alkalinity as carbonate** | 37 | <1 mg/L |
| **Sulfate as $SO_4$** | 8 | <0.5 mg/L |
| **Nitrate as N** | 19 | <0.2 mg/L |

## Censored data

Analyte concentrations reported as ‘non-detect’ values, meaning data that has a ‘<’ qualifier like the example <1 mg/L, cannot be used in some geochemical investigative techniques. Therefore, this data needs to change into an uncensored number, meaning a number that does not have a ‘<’ qualifier, to be used in data interpretation. This uncensored value should be between 0 and the ‘non-detect’ value since a ‘non-detect’ value does not show that an analyte is absent. Values of ‘0.5 × non-detect value’ (Farnham et al., 2002) and ‘0.55 × non-detect value’ (Sanford et al., 1993 and Güler et al., 2002) have been proposed. This investigation used the ‘0.55 × detection limit’ method to change ‘non-detect’ values into uncensored data. For example, a ‘non-detect’ value of <1 mg/L would change to 0.55 mg/L.

## Unit conversions

Some parameters required standardisation to ensure comparative continuity across the dataset.

Since the electrical conductivity of a solution can vary with temperature, all values were standardised to 25°C. The equations used to perform these standardisations are as follows (Hayashi 2004):

$$EC_{t_0} = \frac{EC_t}{1 + c(t - t_0)}$$

...Equation 1

where $EC_{t0}$ is the electrical conductivity (μS/cm) at a standard temperature $t_0$ (°C), where $EC_t$ is the electrical conductivity (μS/cm) at temperature $t$ (°C), and $c$ is a constant given by:

$$c = \frac{a}{[1 + a(t_0 - 25)]}$$

...Equation 2

where $a$ (°C$^{-1}$) is a temperature compensation constant set as 0.0187.

The temperature at which a field-measured electrical conductivity value was taken was assumed to be 25 °C when no temperature value was recorded in the database.

## Stoichiometric conversions

Some parameters are reported in different stoichiometric units, meaning as a concentration compared to a chemical element, and need to be changed for data QAQC and data comparison. These conversions used the following equation:

$$C_{analyte\ 2} \ = \ C_{analyte\ 1} \times \frac{mol_{analyte\ 2}}{mol_{analyte\ 1}} \times \frac{ma_{analyte\ 2}}{ma_{analyte\ 1}}$$

...Equation 3

where *C* is the analyte concentration, *mol* is the analyte molar concentrations in a balanced chemical equation, and *ma* is the analyte atomic mass.

An example conversion is that from sulfate as S to sulfate as $SO_4^{2-}$, which results in the following conversion equation:

$$C_{SO_4} \ = \ C_S \times \frac{mol_{SO_4}}{mol_S} \times \frac{ma_{SO_4}}{ma_S}$$

...Equation 4

Since 1 mole of S corresponds to 1 mole of $SO_4^{2-}$, the conversion equation is updated as follows:

$$C_{SO_4} \ = \ C_S \times \frac{1\ mol}{1\ mol} \times \frac{96.056\ g/mol}{32.06\ g/mol}$$

...Equation 5

Therefore, 1 mg/L of sulfate as S is about equivalent to 3 mg/L of sulfate as $SO_4^{2-}$.

# Data QAQC

Quality Assurance (QA) and Quality Control (QC) checks were performed to determine if the geochemistry data is representative of expected conditions for water samples. The QAQC checks utilised in this assessment include the anion-cation balance and comparing field-measured electrical conductivity with the ion sums (APHA *et al.,* 2017, Section 1030 pg. 8 to 9). Detailed results of the data QAQC is in Appendix 4–QAQC Results.

## Anion-Cation balance

The anion and cation sums, expressed as milliequivalents per litre or mEq/L, must balance because all waters are electrically neutral – that is, positively charged ions balance out the negatively charged ions. However, there can be a difference between these values since multiple analytical methods are used to determine analyte concentrations and there is an error associated with each of these methods. This error is calculated as follows:

$$\% \, difference = 100 \times \frac{\sum cations - \sum anions}{\sum cations + \sum anions}$$

...Equation 6

An accepted difference of ±5 % was used for this investigation. A total of 62 samples of 452 samples, or ~13.7 %, were excluded since the calculated anion-cation balance was outside the range of ±5 %.

## Comparison between electrical conductivity and ion sums

Comparing electrical conductivity and ion sums after the anion-cation balance check has occurred helps to find questionable field-measured electrical conductivity values.

Both the anion and cation sums are accepted to be 1/100th to 1/120th of the measured electrical conductivity when standardised to 25 °C. This depends on the dominant geochemical composition of the water, or the 'water-type' (Appelo and Postma, 2005).

Errors between the measured electrical conductivity and ion sums can occur due to field instrument calibration and use, along with analytical errors. The APHA *et al*. (2017) recommends an allowable error of ±10 %. Since most groundwaters included in this investigation were $Na^+$–$Cl^-$ dominated, the anion and cation sums are likely to be 1/120th of the measured electrical conductivity value (Appelo and Postma, 2005). Therefore, the acceptance criterion is:

$$120 \times anion\ (or\ cation) sum, mEq/L = (0.9\ to\ 1.1) \times\ electrical\ conductivity\ (\mu S/cm\ @\ 25\ °C)$$

...Equation 7

A total of 182 samples (of 390 samples, ~46.7 %) have questionable field-measured electrical conductivity values since they were not within the acceptance criterion. Since there are many factors that can influence the field-measured electrical conductivity values, these values are used with a warning that they are semi-quantitative values, meaning they approximate the accurate electrical conductivity result. This allows groundwater electrical conductivity trends to be found.

# Geochemical analysis methods

This investigation is a qualitative, meaning descriptive, analysis of geochemical trends in the Lower Murrumbidgee groundwater sources. Geochemical methods used to show major processes influencing groundwater chemistry are described below.

## Determination of water types

Identifying groundwater chemical types can help find processes influencing water quality. The groundwater chemical type is found using the Piper classification scheme (Piper, 1944). Groundwater chemical types are found based on the concentrations of major ions making up >20 % of the total anion or cation composition. If the concentration of a single ion makes up ≥50 % of the total cation or anion composition, this ion is 'dominant'. If no single ion concentration makes up ≥50 % of the cation or anion composition, then all ions that make up 20 to 50 % of the cation or anion composition are 'co-dominant'.

## Dissolved ion ratios

One key geochemical analysis method is calculating ion/$Cl^-$ ratios. Chloride ($Cl^-$) is a dissolved ion that is highly mobile and behaves in a conservative way. That is, $Cl^-$ has a similar mobility to water molecules and it is generally not removed from or added to groundwater by common hydrogeochemical reactions. This means that the dominant processes influencing $Cl^-$ concentrations in groundwater are dilution, concentration of salts along groundwater flow paths due to evapotranspiration, and mixing with other waters (Herczeg and Edmunds, 2000). Therefore, $Cl^-$ can be used as a tracer of salt movement in groundwater systems.

Calculating dissolved ion/$Cl^-$ ratios, with both concentrations in mEq/L, and finding changes to the ratios helps to find other processes that may be influencing dissolved ion concentrations. If other processes were not influencing dissolved ion concentrations, then the dissolved ion/$Cl^-$ ratios would be constant despite changing groundwater electrical conductivity. Dissolved ion/$Cl^-$ ratios are shown over time on biplots to find processes influencing groundwater geochemistry.

The ion ratios $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ are also shown over time on biplots to find broad changes in the cation and anion compositions, respectively.

## Beneficial use indicators

Some key beneficial use indicators were calculated and compared with time on biplots. These include total hardness, residual alkalinity, and the sodium absorption ratio.

Total hardness is a measure of multivalent cations in water, particularly $Ca^{2+}$ and $Mg^{2+}$. Irrigation water that has high hardness values can produce solid deposits on pumping and irrigation equipment, known as 'scale'. This is because by $Ca^{2+}$ and $Mg^{2+}$ ions react with $HCO_3^-$ ions to precipitate carbonate minerals when $CO_2$ is degassing or water is heated (equations 6 and 7, and 'Previous investigations').

Scale build-up can reduce equipment life and increase maintenance and running costs. Water hardness is calculated using the following equation:

$$Total\ hardness\ (mg/L\ as\ CaCO_3) = (2.497 \times [Ca^{2+}]) + (4.118 \times [Mg^{2+}])$$

...Equation 8

where $Ca^{2+}$ and $Mg^{2+}$ concentrations are in mg/L.

The sodium absorption ratio (SAR) is used in the management of sodium-affected soils. If irrigation water with high SAR is applied to soils for a long time, the dissolved $Na^+$ in the water can displace $Ca^{2+}$ and $Mg^{2+}$ adsorbed onto soil aggregates. This decreases soil aggregate stability, thereby decreasing soil structure and infiltration ability. The SAR is calculated using the following equation:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}([Ca^{2+}] + [Mg^{2+}])}}$$

...Equation 9

where $Na^{+}$, $Ca^{2+}$, and $Mg^{2+}$ concentrations are in mEq/L.

Residual alkalinity, or the residual sodium carbonate index (RSC), is an irrigation water quality parameter used to show the alkalinity hazard for soil. It is used to determine irrigation water suitability in clay soils that have a high cation exchange capacity. The RSC is calculated using the following equation:

$$RSC = \left(\left[HCO_3{}^{-}\right] + [CO_3{}^{2-}\ ]\right) - \left([Ca^{2+}] + [Mg^{2+}]\right)$$

...Equation 10

where $Ca^{2+}$, $Mg^{2+}$, $HCO_3^{-}$, and $CO_3^{2-}$ concentrations are in mEq/L.

# Hydrogeological trends and processes in the Lower Murrumbidgee Groundwater Sources

## Groundwater levels

### Trends within aquifers

Groundwater levels within the Shepparton Formation, Calivil Formation, and Renmark Group are higher in the east and lower in the west. Measured groundwater levels in the Shepparton Formation varying between monitoring sites by up to 25 meters, with measured groundwater levels in the Calivil Formation varying between monitoring sites by up to 55 meters. Measured groundwater levels in the Renmark Group vary between monitoring sites by up to 60 meters (Figure 10, Figure 11, Figure 20, Figure 21, and Figure 22). This suggests that most groundwater flow within aquifers is from east to west. This is consistent with groundwater potentiometric surface contours mapped for both the shallow and deep groundwater sources.

Groundwater levels within the Shepparton Formation, Calivil Formation, and Renmark Group also have seasonal water level fluctuations. Groundwater levels decline from October each year and increase from March the following year. In the Shepparton Formation, the difference between maximum drawdown and recovered water levels can be up to 15 meters, while in the Calivil Formation this difference can be up to 20 meters. The difference between maximum drawdown and recovered water levels in the Renmark Group can also be up to 20 meters.

These changes show the direct influence of pumping regimes on groundwater levels in the Calivil Formation and Renmark Group. Groundwater level drawdowns are higher in areas where production sites are more concentrated and where higher volumes are extracted. Lower groundwater level drawdown occurs further away from the main irrigation areas near Coleambally and Darlington Point. This suggests that the concentration of production sites and larger extraction volumes is likely the main influence on seasonal drawdown and recovered water levels.

Seasonal groundwater level changes at monitoring sites GW036773.1.1 and GW273040.1.1, screened in the Shepparton Formation, could show groundwater extraction from the Shepparton Formation (Figure 20), and/or could show induced drawdown from the underlying Calivil Formation where the 2 units have hydraulic connectivity. A subdued groundwater level response to groundwater extraction at site GW041012.1.1 could be influenced by the proximity of this site to the Murrumbidgee River and potential river leakage (Figure 19 and Figure 24).

Proximity to the Murrumbidgee River and river leakage could also explain the increasing groundwater levels in the Shepparton Formation at monitoring site GW041011.1.1

Groundwater levels at most monitoring sites appear to respond to extraction during drought periods. At monitoring sites with seasonal water level responses that are likely influenced by pumping, the recovered water levels decline from October 2005 to October 2009, increase from October 2009 to October 2012, and decline again from October 2012 to October 2019. This could show increased groundwater extraction during the Millennium drought and post-2013, with less groundwater extraction occurring when more rainfall and surface water was available between these 2 dryer periods.

Long-term groundwater levels trends vary across the aquifers. Long-term recovered groundwater levels in the Shepparton Formation have remained stable at monitoring sites GW273041.1.1, GW273040.1.1, and GW041012.1.1 (Figure 20). Recovered groundwater levels have increased at monitoring site GW041011.1.1 by up to 5 meters and declined at monitoring site GW036773.1.1 by up to 5 meters between October 2005 and October 2019.

Similar long-term groundwater level trends occur in the Calivil Formation and Renmark Group. Recovered groundwater levels in these aquifers have remained stable or declined over the investigation period. The initial and final recovered groundwater levels are generally within ±5 m of each other, and up to ±10 m at site GW036773.2.2 in the Calivil Formation, and sites GW036396 and GW041011 in the Renmark Group (Figure 19 and Figure 21, and Figure 22).

Groundwater levels in the Remark Group at monitoring site GW036799, where pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the middle-Renmark Group, and pipe 3.3 in the lower-Renmark Group show downstream impacts from groundwater extraction activities in the Lower Murrumbidgee groundwater sources (Figure 17 and Figure 25). Groundwater levels in the upper-Renmark Group downstream of the main groundwater extraction activities have remained steady throughout the investigation period, with groundwater levels in the middle-Renmark Group steadily declining by approximately 2 metres. Groundwater levels in the lower-Renmark Group have also steadily declined by up to 5 meters, with drawdown and recovery responses like those of monitoring bores closer to the irrigation districts. This could be due to localised extraction as opposed to a downstream impact from the irrigation districts.

## Hydrological connectivity between aquifers

Hydrological connectivity between the Shepparton Formation and underlying Calivil Formation changes across the groundwater source. Monitoring sites GW036773.1.1, GW273040.1.1, and GW041012.1.1 show seasonal water levels changes in the Shepparton Formation that are similar to nested monitoring bores screened within the underlying formations, including pipes 2.2 and 3.3 at sites GW036773, GW273040, and GW041012 (Figure 23 and Figure 24).

This similarity suggests that there is higher hydrogeological connectivity between aquifers in these areas. The hydraulic head differences between the Shepparton Formation and Calivil Formation at GW036773 is between 1 meter and 5 meters, with the hydraulic head difference at GW273040 generally less than 1 meter. Even though the hydraulic head difference between the Shepparton Formation and Calivil Formation is higher at GW041012 by between 10 and

15 meters, the similarity in when groundwater level drawdown and recovery occur suggests hydraulic connectivity is present at this location.

The Shepparton Formation groundwater levels at sites GW273041.1.1 and GW041011.1.1 remain stable or increase, and do not have the same seasonal fluctuations as nested monitoring sites screened in the underlying aquifers. This suggests there is minimal vertical hydrological connectivity between the Shepparton Formation and Calivil Formation in these areas. This is because there are areas of groundwater extraction nearby and there is a seasonal groundwater level drawdown and recovery response evident in the Calivil Formation monitoring sites (Figure 18 and Figure 19). Another explanation at monitoring site GW041011.1.1 could be river leakage from the Murrumbidgee River obscuring any connectivity signals in the water level record of the Shepparton Formation. Groundwater levels are higher in the Shepparton Formation than in the Calivil Formation, suggesting a potential for downward groundwater movement to occur.

Groundwater levels across the Calivil Formation and Renmark Group are very similar, along with responses to groundwater extraction (Figure 23 and Figure 24). This suggests that these aquifers are highly hydrologically connected. Groundwater levels are generally higher in the Calivil Formation than in the Renmark Group, which suggests there is the potential for downward groundwater movement to occur between the Calivil Formation and Renmark Group.

The vertical hydraulic gradients between the Calivil Formation and upper-Renmark Group are the lowest at monitoring site GW273041, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group (Figure 23). The vertical hydraulic gradients at this site range from approximately 50 centimetres to approximately 5 meters.

The vertical hydraulic gradients between the Calivil Formation and upper-Renmark Group are the highest at monitoring site GW273040, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group (Figure 24). The vertical hydraulic gradients at this site range from approximately 1 meter to approximately 20 meters. The vertical hydraulic gradients between the Calivil Formation and middle-Renmark Group generally range from approximately 1 meter to approximately 10 meters, such as at monitoring sites GW041011 and GW041012 (Figure 24).

Hydrological reversals, or groundwater levels in deeper aquifers that are higher than in the shallower aquifers, occur in the water level record at monitoring site GW036773, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the middle Renmark Group. The hydraulic gradients range from approximately 2 meters, with groundwater movement from the Calivil Formation into the Renmark Group, to −6 meters, with groundwater movement from the Renmark Group into the Calivil Formation. It is not clear if this occurs by different groundwater extraction regimes between the Calivil Formation and Renmark Group, different water level recovery rates between the aquifers, or water levels in the Renmark Group lagging in response to extraction in the Calivil Formation.

The hydrologic separation between the upper, middle, and lower Renmark Group varies across the groundwater source. Groundwater levels at monitoring site GW273040, with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group, are extremely similar, with the vertical hydraulic gradient less than 20 centimetres across the record of this investigation.

This indicates that there is minimal vertical movement of groundwater down through the Remark Group at this location (Figure 19 and Figure 24). At monitoring site GW273041, with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group, groundwater levels in the upper-Renmark Group are consistently higher than the lower-Renmark Group (Figure 19 and Figure 23). This difference is generally greater at the peak of groundwater level recovery, between 5 and 10 meters, and smallest when groundwater drawdown is at its lowest levels each pumping season, between 1 and 8 meters. This suggests that there is greater vertical groundwater movement throughout the Renmark Group at this monitoring site than at other monitoring sites screened within the Renmark Group. This could be explained by groundwater extraction at the nearby Coleambally Irrigation District.

Groundwater levels at monitoring site GW036211, with pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the mid-Renmark Group, and pipe 3.3 in the lower-Renmark Group, are unique amongst the monitoring sites within the Renmark Group. At this site, water levels in the middle and lower deposits are higher than those of the upper deposits, with the hydraulic gradient less than 20 centimetres. The water levels are more similar to each other across the 3 monitoring sites since 2010, suggesting that less groundwater movement is occurring across the deposit since water level recovery after 2009.

Surface elevation or water level measurement uncertainty could affect how the direction and intensity of the groundwater movements are interpreted in the water level record. The uncertainty associated with surface elevation and water level measurements needs to be quantified to confirm the direction and intensity of vertical hydraulic gradients across the Lower Murrumbidgee groundwater sources.

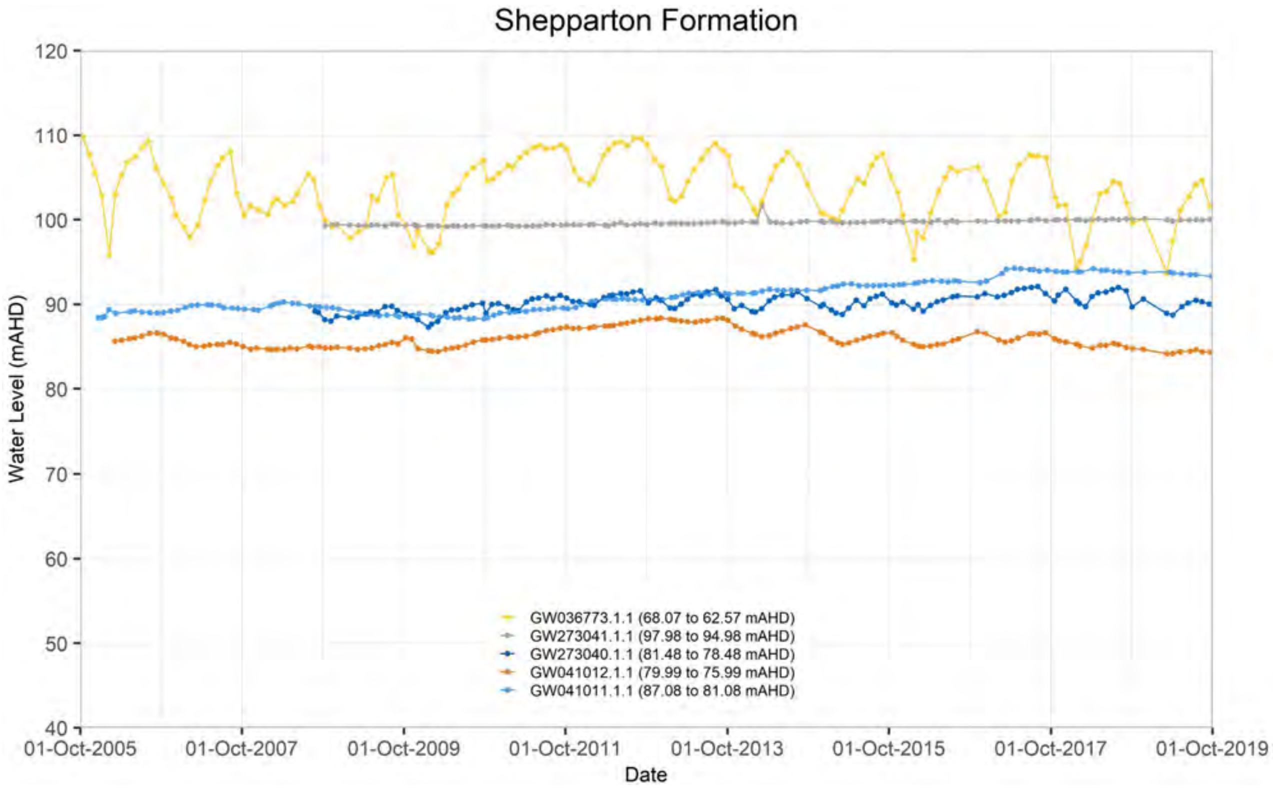


Figure 20. Groundwater levels in the Shepparton Formation of the Lower Murrumbidgee Groundwater Source

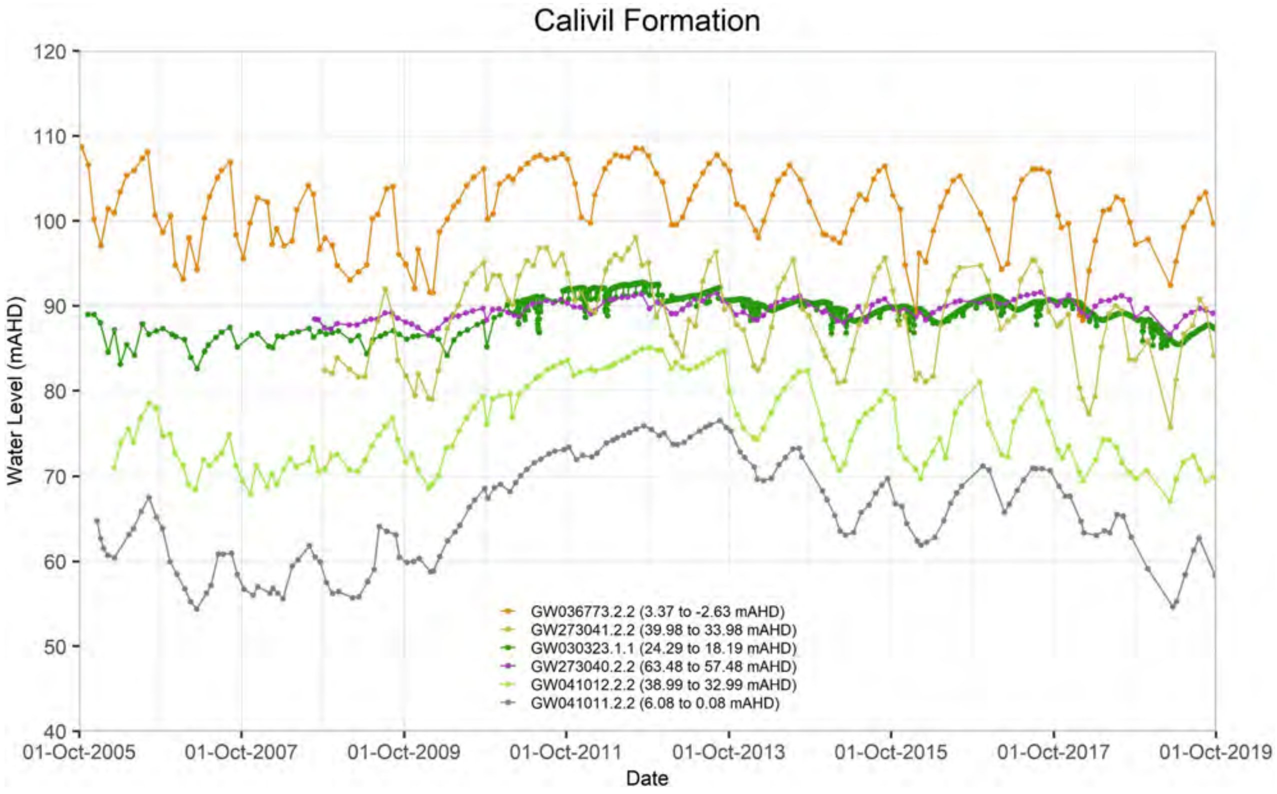


Figure 21. Groundwater levels in the Calivil Formation of the Lower Murrumbidgee Groundwater Source

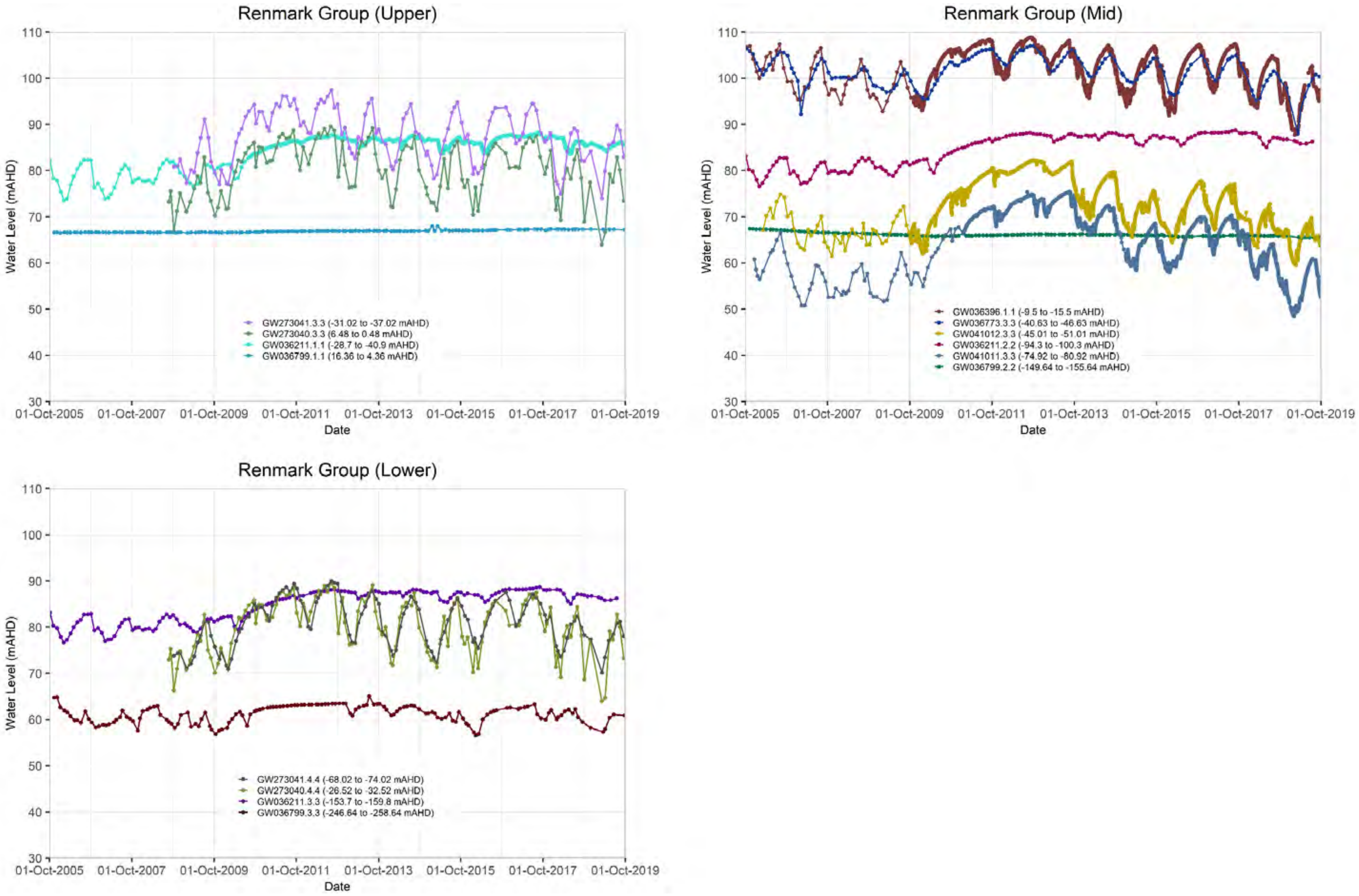


Figure 22. Groundwater levels in the Renmark Group of the Lower Murrumbidgee Groundwater Source

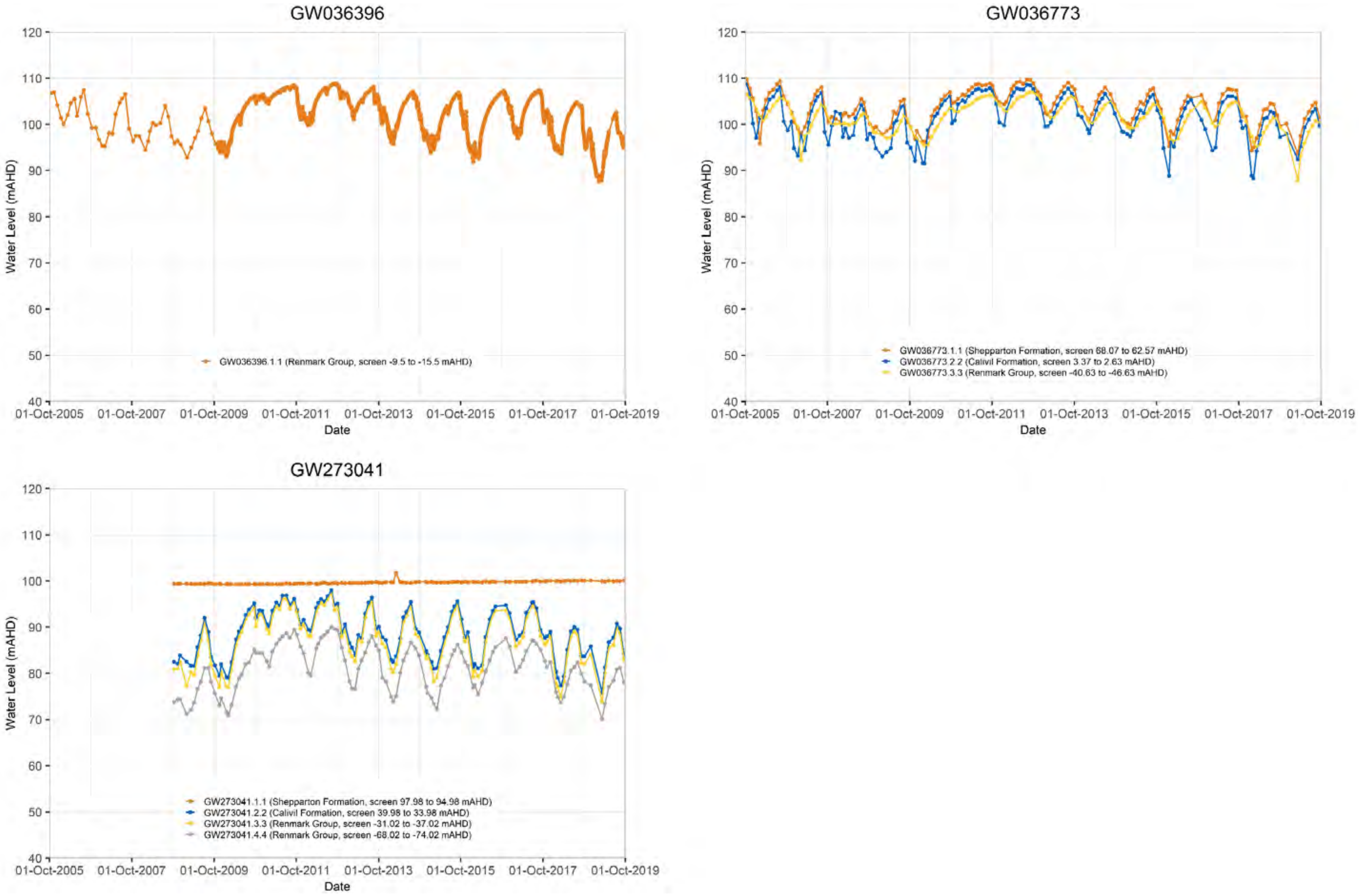


Figure 23. Groundwater levels in the cluster of monitoring sites screened in the upstream area of the Lower Murrumbidgee Groundwater Source

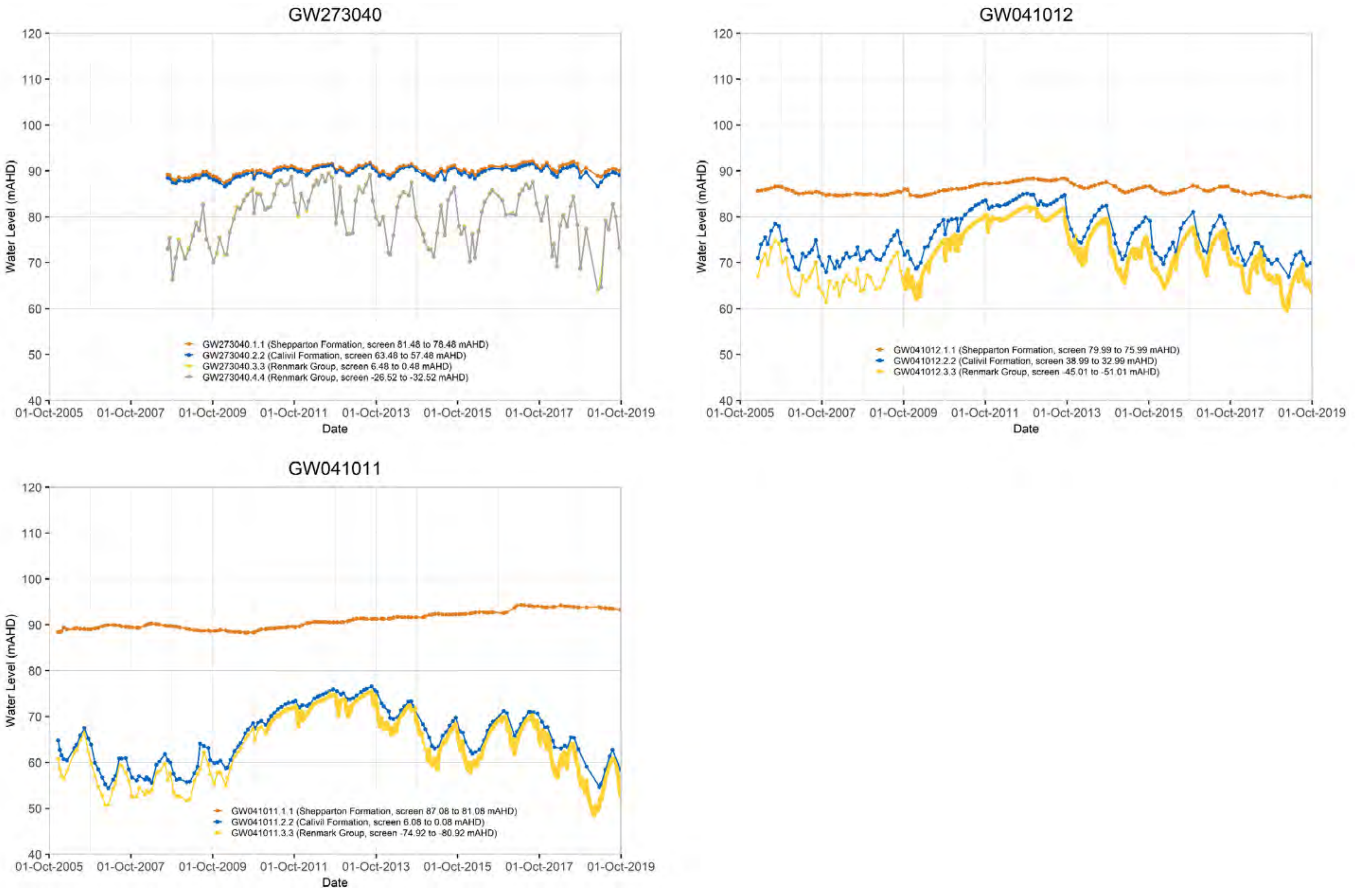


Figure 24. Groundwater levels in the cluster of monitoring sites screened north of and along the Murrumbidgee River in the Lower Murrumbidgee Groundwater Source

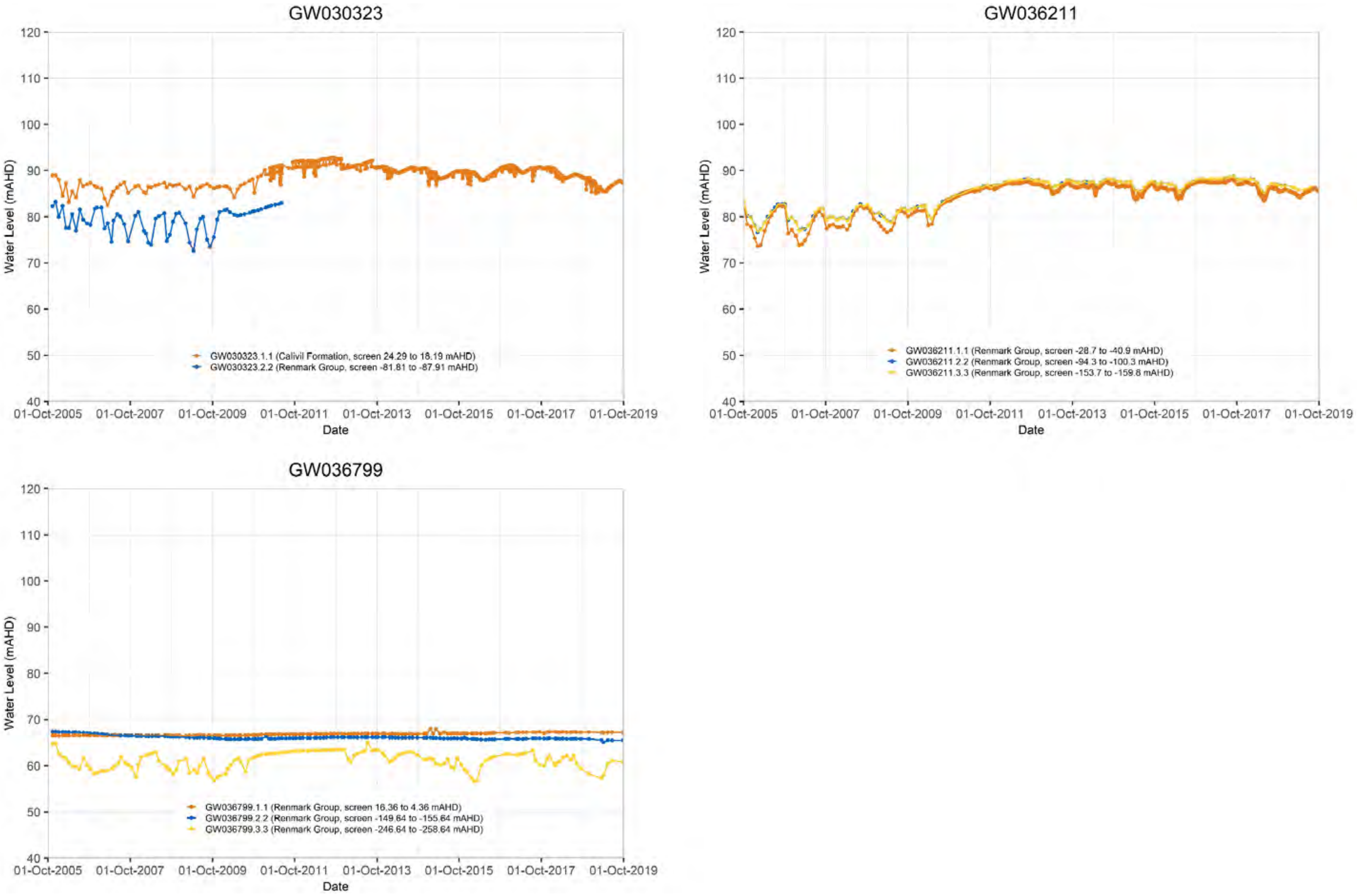


Figure 25. Groundwater levels in the cluster of monitoring sites screened south and downstream of the Murrumbidgee River in the Lower Murrumbidgee Groundwater Source

# Hydrogeochemistry

## Shepparton Formation

### Physicochemical parameters

Summary statistics for the Shepparton Formation groundwater electrical conductivity and pH are shown in Table 4. The raw data is in 'Appendix 3–Raw Data'.

Table 4. Summary statistics for physicochemical parameters in the Shepparton Formation

| Site | Parameter | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| All | Electrical conductivity (µS/cm) | 86 | 0 | 752 | 3,935 | 32,000 |
| All | pH (pH units) | 15 | 0 | 6.5 | 7.3 | 8.6 |
| GW036773.1.1 | Electrical conductivity (µS/cm) | 19 | 0 | 3,100 | 3,770 | 4,070 |
| GW036773.1.1 | pH (pH units) | 3 | 0 | 6.9 | 7.2 | 7.3 |
| GW041011.1.1 | Electrical conductivity (µS/cm) | 18 | 0 | 3,337 | 3,835 | 6,160 |
| GW041011.1.1 | pH (pH units) | 3 | 0 | 7.4 | 7.9 | 8.6 |
| GW041012.1.1 | Electrical conductivity (µS/cm) | 18 | 0 | 752 | 805 | 1,430 |
| GW041012.1.1 | pH (pH units) | 3 | 0 | 7.2 | 8.0 | 8.1 |
| GW273040.1.1 | Electrical conductivity (µS/cm) | 16 | 0 | 7,570 | 8,530 | 15,000 |
| GW273040.1.1 | pH (pH units) | 3 | 0 | 7.0 | 7.4 | 7.4 |
| GW273041.1.1 | Electrical conductivity (µS/cm) | 15 | 0 | 21,600 | 29,000 | 32,000 |
| GW273041.1.1 | pH (pH units) | 3 | 0 | 6.5 | 6.7 | 6.9 |

### Electrical conductivity

Groundwater electrical conductivity in the Shepparton Formation ranged from 752 µS/cm to 32,000 µS/cm. Electrical conductivity was highest at site GW273041.1.1, with values up to 40 times those of other Shepparton Formation monitoring sites (Table 4, Figure 19, and Figure 26).

Groundwater electrical conductivity in the Shepparton Formation increases from east to west, with an area of higher groundwater electrical conductivity at monitoring site GW273041.1.1 (Figure 19 and Figure 26). Groundwater electrical conductivity is lower at monitoring sites GW041012.1.1, GW041011.1.1, and GW036773.1.1. The lower groundwater electrical conductivity at monitoring sites GW041012.1.1 and GW041011.1.1 could be explained by their proximity to the Murrumbidgee River and river leakage (Figure 19 and Figure 26). Groundwater levels are higher than surrounding areas near monitoring site GW036773.1.1 despite it not being near a major river. This suggests that water from irrigation could be returning and contributing to the lower electrical conductivity.

Electrical conductivity trends vary across the Shepparton Formation but have generally remained steady or increased. Groundwater electrical conductivity decreased at monitoring site GW273040.1.1 between 2009–2013 before increasing until 2018 (Figure 19 and Figure 26). This follows water level trends, with groundwater level recovery occurring from 2009 to 2013 and groundwater level decline occurring from 2013 to 2018 (Figure 20). This suggests that long-term groundwater level decline could be inducing groundwater salinisation in this area. This could be from the mobilisation of saline groundwater occurring nearby.

Groundwater electrical conductivity has also increased at monitoring site GW041011.1.1 since 2014 (Figure 19 and Figure 26). This could be associated with groundwater level increases, although it is not clear what the source of the mobilised salt could be. It is possible that saline groundwater from surrounding areas is moving towards site GW041011.1.1. It is also possible that the rising groundwater levels are intercepting stored salts within the shallower alluvial deposits. Further investigations are needed to confirm how changing groundwater levels and hydraulic gradients are influencing the groundwater salinity in the area.

Groundwater electrical conductivity has declined at monitoring site GW273041.1.1 since 2010 (Figure 19 and Figure 26). Groundwater levels have remained stable during this time, so the groundwater electrical conductivity decline may represent the movement of fresher water into the area under ‘normal’ groundwater conditions. This is difficult to confirm when looking at electrical conductivity alone.

### pH

There is limited groundwater pH data available for the Shepparton Formation for this period. Groundwater pH in the Shepparton Formation ranges from 6.5 to 8.6, with groundwater pH values generally higher, meaning less acidic, at monitoring sites near the Murrumbidgee River such as GW041011.1.1 and GW041012.1.1 (Table 4, Figure 19, and Figure 26). Groundwater pH in the Shepparton Formation has declined during the study period (Figure 26).

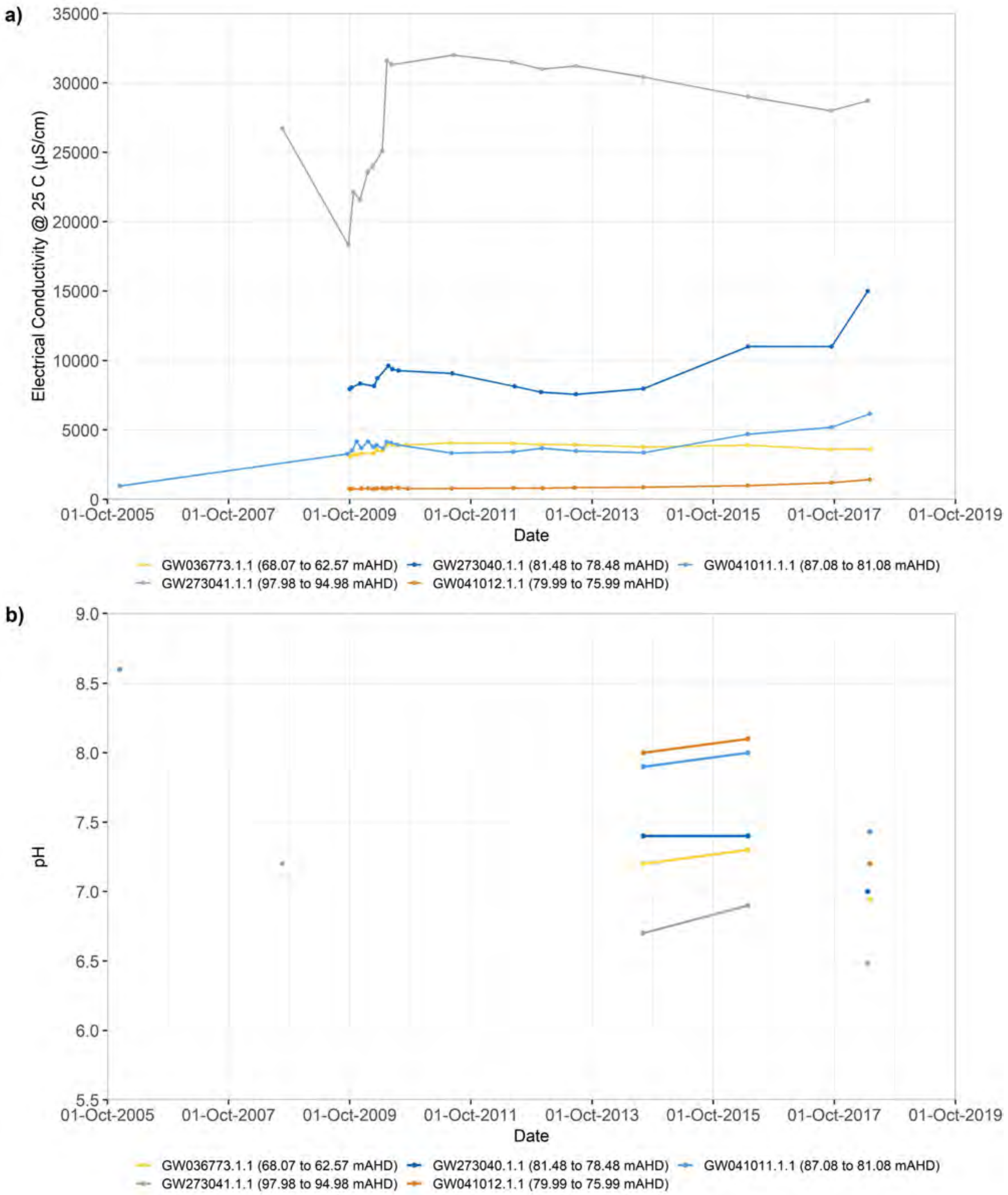


Figure 26. Groundwater (a) electrical conductivity (b) and pH in the Shepparton Formation

## Major ions

Summary statistics for groundwater major ions occurring throughout the Shepparton Formation and at individual monitoring sites is in Table 4 to Table 10, with the raw data in ‘Appendix 3–Raw Data‘.

Groundwater in the Shepparton Formation has variable geochemistry across the monitoring sites, reflecting the heterogenous nature of the alluvial deposits. The groundwater can be $Na^+$–$Cl^-$ dominated (GW273040.1.1 and GW041011.1.1), $Na^+$–$Cl^-$–$HCO_3^-$dominated (GW041012.1.1), $Na^+$–$Mg^{2+}$–$Ca^{2+}$–$Cl^-$ dominated (GW273041.1.1), or $Na^+$–$Cl^-$–$SO_4^{2-}$ dominated (GW036773.1.1) (Figure 19 and Appendix 4–QAQC Results).

The ion ratio trends of $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ in Shepparton Formation groundwater vary across the monitoring sites. The $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ ratios at monitoring sites GW273040.1.1, GW041012.1.1, and GW041011.1.1 have declined, with $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ ratios increasing. This suggest that the groundwater chemistry type at these sites is becoming more $(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})$ dominant. This contrasts with GW036773.1.1 and GW273041.1.1, in which the $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ remained relatively stable (Figure 27). This suggests that the groundwater chemistry type is stable at these monitoring sites. These geochemistry changes correlate with electrical conductivity, with increasing electrical conductivity occurring at monitoring sties GW273040.1.1, GW041012.1.1, and GW041011.1.1, and declining to stable electrical conductivity at monitoring sites GW036773.1.1 and GW273041.1.1 (Figure 26).

At monitoring sites GW273040.1.1 and GW041011.1.1, the groundwater electrical conductivity is increasing while the $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$ and $SO_4^{2-}/Cl^-$ are increasing (Figure 27, Figure 28, and Figure 29). The $Na^+/Cl^-$, $K^+/Cl^-$ and $(HCO_3^-+CO_3^{2-})/Cl^-$ are decreasing (Figure 27, Figure 28, and Figure 29). This suggests that reverse ion exchange could be associated with groundwater salinisation, with Na+ adsorbed onto clay sites while releasing $Ca^{2+}$ and $Mg^{2+}$. Increasing $SO_4^{2-}/Cl^-$ could occur due to mixing with a $SO_4^{2-}$-rich water and/or sulfate mineral dissolution. Declining $(HCO_3^-+CO_3^{2-})/Cl^-$ could be explained by carbonate mineral precipitation and/or mixing with $(HCO_3^-+CO_3^{2-})$-depleted water. Decreasing $(HCO_3^-+CO_3^{2-})/Cl^-$ could explain declining pH over time since the concentrations of $HCO_3^-+ CO_3^{2-}$ and $H^+$ (the ion that pH measures) influence each other through the reaction $Ca^{2+} + HCO_3^- \rightarrow CaCO_3 + H^+$ (Figure 26 and Figure 29).

At monitoring site GW041012.1.1 the groundwater electrical conductivity has remained stable while the $Na^+/Cl^-$, $K^+/Cl^-$, $(HCO_3^-+CO_3^{2-})/Cl^-$, and $SO_4^{2-}/Cl^-$ have declined. Only $(HCO_3^-+CO_3^{2-})/Cl^-$ declined at monitoring site GW036773.1.1, while groundwater electrical conductivity remained stable (Figure 27, Figure 28, and Figure 29). Given that the $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ is declining at GW041012.1.1, the changes in the cation/$Cl^-$ could be explained by mixing, with or without river leakage, and/or reverse cation exchange. River leakage cannot be confirmed since the geochemistry of the Murrumbidgee River is not known. More work will need to be performed to understand the $(HCO_3^-+CO_3^{2-})/Cl^-$ declines at GW036733.1.1 without other geochemistry changes, and this could be linked with declining pH (Figure 26 and Figure 29).

The $(HCO_3^-+CO_3^{2-})/Cl^-$ is also declining at monitoring site GW273041.1.1 while groundwater electrical conductivity is declining. All other ion/$Cl^-$ have remained stable. More work will be needed to understand the ($HCO_3^-$+$CO_3^{2-}$)/$Cl^-$ declines without other geochemistry changes, and this could be linked with declining pH (Figure 26 and Figure 29).

The $NO_3^-$/$Cl^-$ ratios at monitoring sites GW036773.1.1 and GW041012.1.1 generally decreased over the investigation period and could be explained by a combination of nitrate reduction and decreasing surface leakage (Figure 29). Generally increasing $NO_3^-$/$Cl^-$ ratios at monitoring sites GW273041.1.1, GW273040.1.1, and GW041011.1.1 indicate that increased surface leakage could be occurring (Figure 29). Further work is needed to confirm this.

## Irrigation parameters

Summary statistics for groundwater irrigation parameters occurring throughout the Shepparton Formation and at individual monitoring sites is in Table 11, with the raw data in 'Appendix 3–Raw Data'.

At monitoring sites GW273040.1.1 and GW041011.1.1, total hardness as $CaCO_3$ and the SAR have increased as residual alkalinity decreased (Figure 30). This reflects the geochemical changes that are occurring with increasing groundwater salinisation. The opposite has occurred at GW273041.1.1 and GW036733.1.1, with total hardness as $CaCO_3$ decreasing as residual alkalinity increasing with decreasing groundwater electrical conductivity. The SAR has remained stable at these sites.

The SAR has declined at GW041012.1.1 while total hardness as $CaCO_3$, residual alkalinity, and groundwater electrical has remained stable.

All irrigation parameters have remained stable at GW036773.1.1 and GW041012.1.1.

## Beneficial use

### Electrical conductivity and pH

Groundwater electrical conductivity changes at monitoring sites GW041011.1.1, GW041012.1.1, GW273040.1.1 have led to changes to beneficial use of groundwater.

Increased groundwater electrical conductivity at monitoring site GW041011.1.1 has led to a decline in livestock drinking and irrigation beneficial use. The groundwater near this site is no longer suitable for poultry drinking (Figure 26 and Table 43) and is now classed as 'very-high water salinity' that is 'suitable for very tolerant crops' (Figure 26 and Table 43). The groundwater salinity is too high to have a salinity hazard category (Table 45).

Increased groundwater electrical conductivity at monitoring site GW041012.1.1 has led to a decline in drinking water and irrigation beneficial use. The groundwater near this site has changed from 'good quality drinking water' to 'poor quality drinking water'. The groundwater is now classed as 'low water salinity suitable for moderately sensitive crops' (Figure 26 and Table 43).

Increased groundwater electrical conductivity at monitoring site GW273040.1.1 has led to a decline in livestock drinking beneficial use. The groundwater near this site is now not suitable for watering dairy and beef cattle, horses, or pigs (Figure 26 and Table 43).

Changes to groundwater pH have not led to changes to beneficial use categories. Declining pH has meant that the fouling potential has decreased. However, if pH continues to decline, the corrosion potential could increase.

### Irrigation parameters

Groundwater in the Shepparton Formation already has total hardness as $CaCO_3$ concentrations with an increased risk of fouling and severe scaling (Table 11, Figure 30, Table 44, and Table 50). This risk can increase further if total hardness as $CaCO_3$ concentrations continue to increase at sites GW041011.1.1 and GW273040.1.1. The SAR at all sites has not changed sodium hazard category, with most sites having an SAR that is in class S2 (Table 11, Figure 30, Table 44, and Table 46).

Table 5. Summary statistics for major ions for all monitoring sites in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| $Na^+$ | 75 | 0 | 160 | 640 | 3,800 |
| $K^+$ | 75 | 1 | 0.48 | 5.80 | 7.90 |
| $Ca^{2+}$ | 75 | 0 | 4.10 | 190 | 1,900 |
| $Mg^{2+}$ | 75 | 0 | 4.70 | 140 | 1,800 |
| $Cl^-$ | 75 | 0 | 77 | 1,200 | 12,000 |
| $SO_4^{2-}$ | 75 | 0 | 17.0 | 800 | 2,710 |
| $CO_3^{2-}$ | 75 | 72 | <1 | <1 | 19.0 |
| $HCO_3^-$ | 75 | 0 | 200 | 340 | 610 |
| $NO_3^-$ | 75 | 1 | <0.05 | 7.53 | 30 |

Table 6. Summary statistics for major ions for monitoring site GW036773.1.1 in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| $Na^+$ | 19 | 0 | 470 | 540 | 580 |
| $K^+$ | 19 | 0 | 5.00 | 6.40 | 6.80 |
| $Ca^{2+}$ | 19 | 0 | 140 | 190 | 200 |
| $Mg^{2+}$ | 19 | 0 | 110 | 140 | 150 |
| $Cl^-$ | 19 | 0 | 631 | 730 | 780 |
| $SO_4^{2-}$ | 19 | 0 | 778 | 860 | 950 |
| $CO_3^{2-}$ | 19 | 17 | <1 | <1 | 1.70 |
| $HCO_3^-$ | 19 | 0 | 160 | 350 | 360 |
| $NO_3^-$ | 19 | 0 | 2.35 | 12.8 | 14.2 |

Table 7. Summary statistics for major ions for monitoring site GW041011.1.1 in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| Na+ | 18 | 0 | 520 | 655 | 860 |
| K+ | 18 | 0 | 1.00 | 1.60 | 1.90 |
| Ca2+ | 18 | 0 | 61.0 | 98.5 | 156 |
| Mg2+ | 18 | 0 | 57.0 | 92.5 | 140 |
| $Cl^-$ | 18 | 0 | 880 | 1,200 | 1,430 |
| $SO_4^{2-}$ | 18 | 0 | 73.0 | 100 | 473 |
| $CO_3^{2-}$ | 18 | 14 | <1 | <1 | 14.0 |
| $HCO_3^-$ | 18 | 0 | 160 | 240 | 310 |
| $NO_3^-$ | 18 | 0 | 4.87 | 7.75 | 12.0 |

Table 8. Summary statistics for major ion for monitoring site GW041012.1.1 in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| $Na^+$ | 15 | 0 | 160 | 180 | 277 |
| $K^+$ | 15 | 1 | 0.48 | 0.59 | 0.81 |
| $Ca^{2+}$ | 15 | 0 | 4.10 | 4.50 | 14 |
| $Mg^{2+}$ | 15 | 0 | 4.70 | 5.10 | 18 |
| $Cl^-$ | 15 | 0 | 77 | 86 | 309 |
| $SO_4^{2-}$ | 15 | 0 | 17 | 21 | 24 |
| $CO_3^{2-}$ | 15 | 14 | <1 | <1 | 19.0 |
| $HCO_3^-$ | 15 | 0 | 258 | 300 | 320 |
| $NO_3^-$ | 15 | 0 | 0.53 | 1.06 | 1.59 |

Table 9. Summary statistics for major ions for monitoring site GW273040.1.1 in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| $Na^+$ | 16 | 0 | 1,200 | 1,600 | 2,100 |
| $K^+$ | 16 | 0 | 4.10 | 6.35 | 7.40 |
| $Ca^{2+}$ | 16 | 0 | 190 | 345 | 776 |
| $Mg^{2+}$ | 16 | 0 | 180 | 260 | 456 |
| $Cl^-$ | 16 | 0 | 1,900 | 2,500 | 4,020 |
| $SO_4^{2-}$ | 16 | 0 | 830 | 1,300 | 2,710 |
| $CO_3^{2-}$ | 16 | 14 | <1 | <1 | 1.70 |
| $HCO_3^-$ | 16 | 0 | 160 | 510 | 550 |
| $NO_3^-$ | 16 | 0 | 11.1 | 13.7 | 30.3 |

Table 10. Summary statistics for major ions for monitoring site GW273041.1.1 in the Shepparton Formation

| Parameter (mg/L) | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| $Na^+$ | 15 | 0 | 3,070 | 3,500 | 3,800 |
| $K^+$ | 15 | 0 | 5.00 | 7.10 | 7.90 |
| $Ca^{2+}$ | 15 | 0 | 1,300 | 1,800 | 1,900 |
| $Mg^{2+}$ | 15 | 0 | 1,200 | 1,500 | 1,800 |
| $Cl^-$ | 15 | 0 | 9,400 | 12,000 | 12,000 |
| $SO_4^{2-}$ | 15 | 0 | 690 | 800 | 870 |
| $CO_3^{2-}$ | 15 | 14 | <1 | <1 | 1.70 |
| $HCO_3^-$ | 15 | 0 | 160 | 590 | 610 |
| $NO_3^-$ | 15 | 1 | <0.05 | 1.64 | 75.3 |

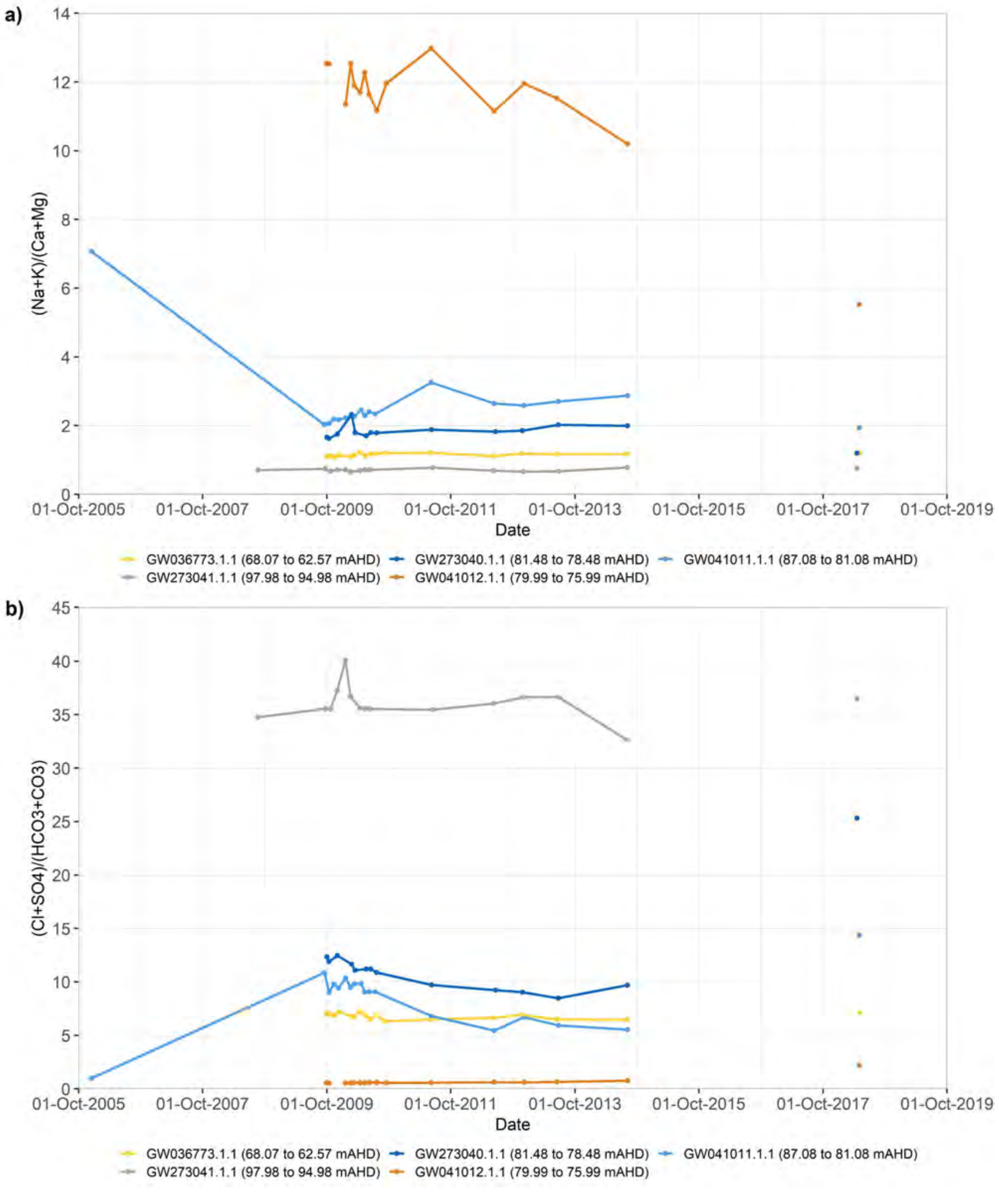


Figure 27. Groundwater (a) cation and (b) anion ratios in the Shepparton Formation

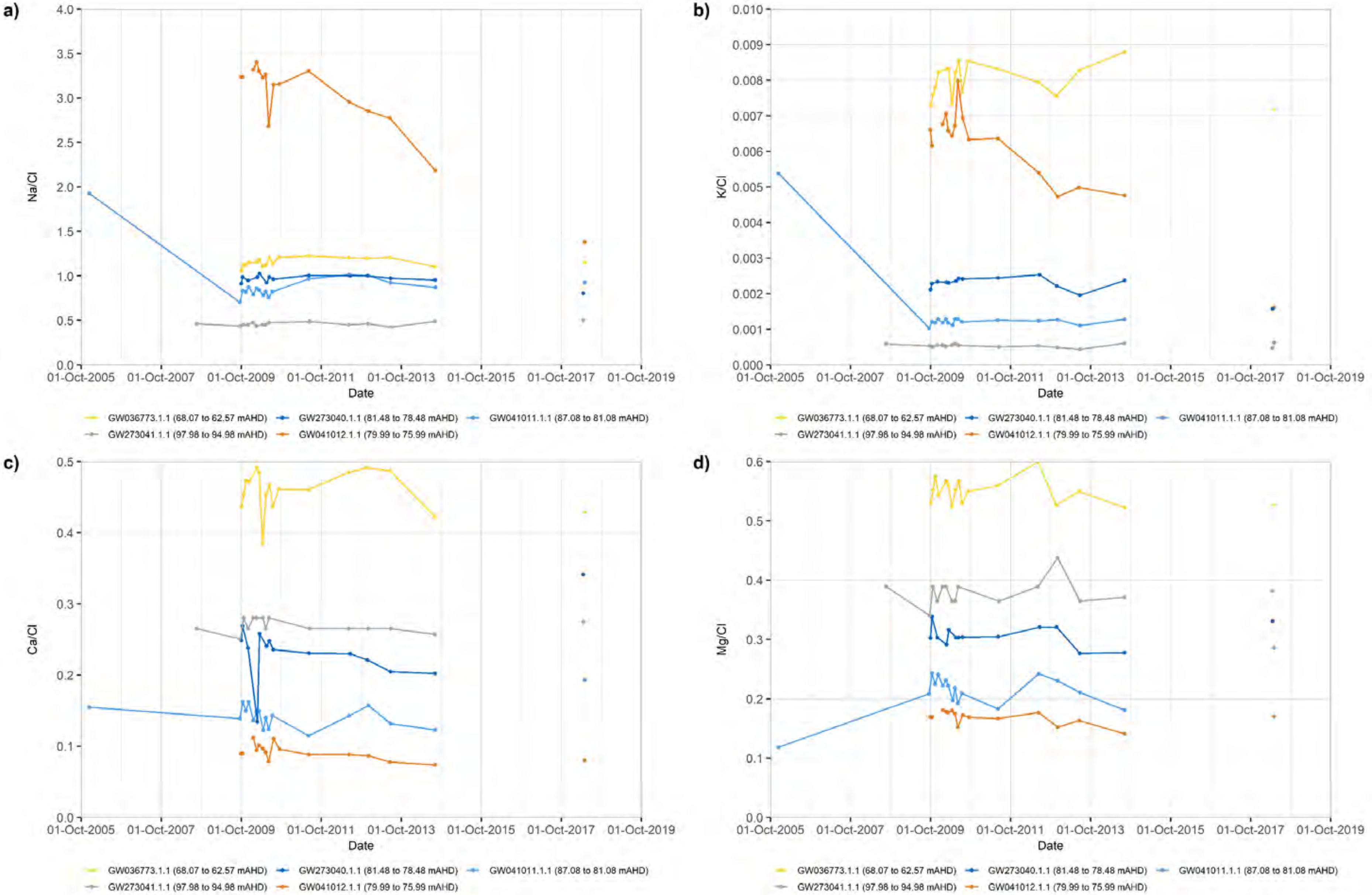


Figure 28. Detailed groundwater cation/chloride ratios in the Shepparton Formation, including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

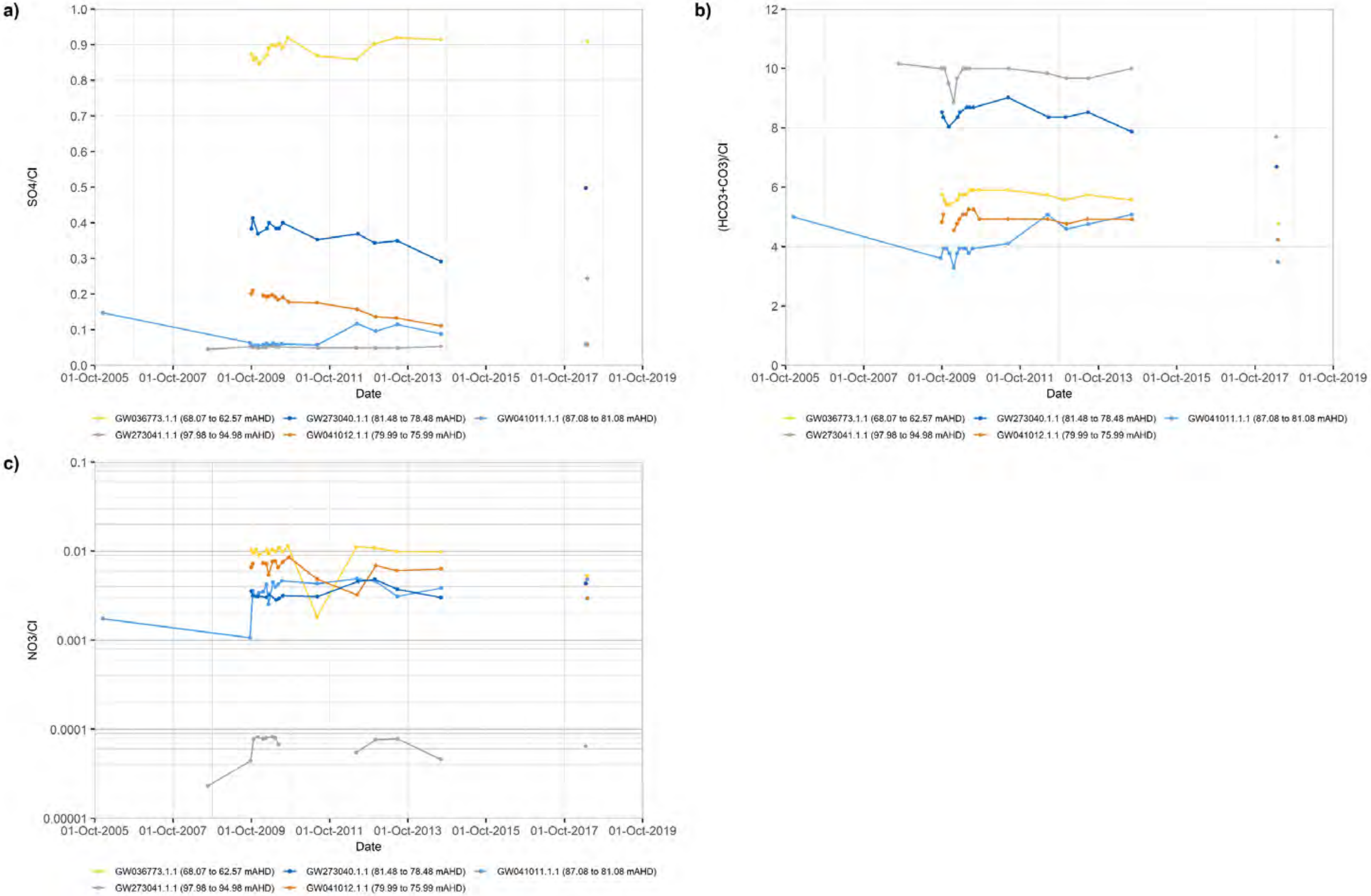


Figure 29. Detailed groundwater anion/chloride ratios in the Shepparton Formation, including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

Table 11. Summary statistics for irrigation parameters in the Shepparton Formation

| Site | Parameter | Count | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| All | Total hardness (mg/L as $CaCO_3$) | 75 | 29.6 | 1,051 | 11,907 |
| All | Residual alkalinity (mEq/L) | 75 | −228 | −15.1 | 4.66 |
| All | Sodium adsorption ratio | 75 | 6.98 | 13.2 | 18.0 |
| GW036773.1.1 | Total hardness (mg/L as $CaCO_3$) | 17 | 852 | 1,051 | 1,117 |
| GW036773.1.1 | Residual alkalinity (mEq/L) | 17 | −16.6 | −15.1 | −12.2 |
| GW036773.1.1 | Sodium adsorption ratio | 17 | 6.98 | 7.42 | 7.79 |
| GW041011.1.1 | Total hardness (mg/L as $CaCO_3$) | 16 | 395 | 602 | 966 |
| GW041011.1.1 | Residual alkalinity (mEq/L) | 16 | −15.8 | −8.08 | −2.78 |
| GW041011.1.1 | Sodium adsorption ratio | 16 | 10.8 | 11.4 | 12.9 |
| GW041012.1.1 | Total hardness (mg/L as $CaCO_3$) | 15 | 29.6 | 32.7 | 109 |
| GW041012.1.1 | Residual alkalinity (mEq/L) | 15 | 2.07 | 4.28 | 4.66 |
| GW041012.1.1 | Sodium adsorption ratio | 15 | 11.5 | 13.4 | 14.2 |
| GW273040.1.1 | Total hardness (mg/L as $CaCO_3$) | 14 | 1,291 | 1,874 | 3,816 |
| GW273040.1.1 | Residual alkalinity (mEq/L) | 14 | −69.5 | −28.7 | −17.2 |
| GW273040.1.1 | Sodium adsorption ratio | 14 | 14.3 | 15.1 | 18.0 |
| GW273041.1.1 | Total hardness (mg/L as $CaCO_3$) | 13 | 8,711 | 10,922 | 11,907 |
| GW273041.1.1 | Residual alkalinity (mEq/L) | 13 | −228 | −208 | −166 |
| GW273041.1.1 | Sodium adsorption ratio | 13 | 13.9 | 14.6 | 16.0 |

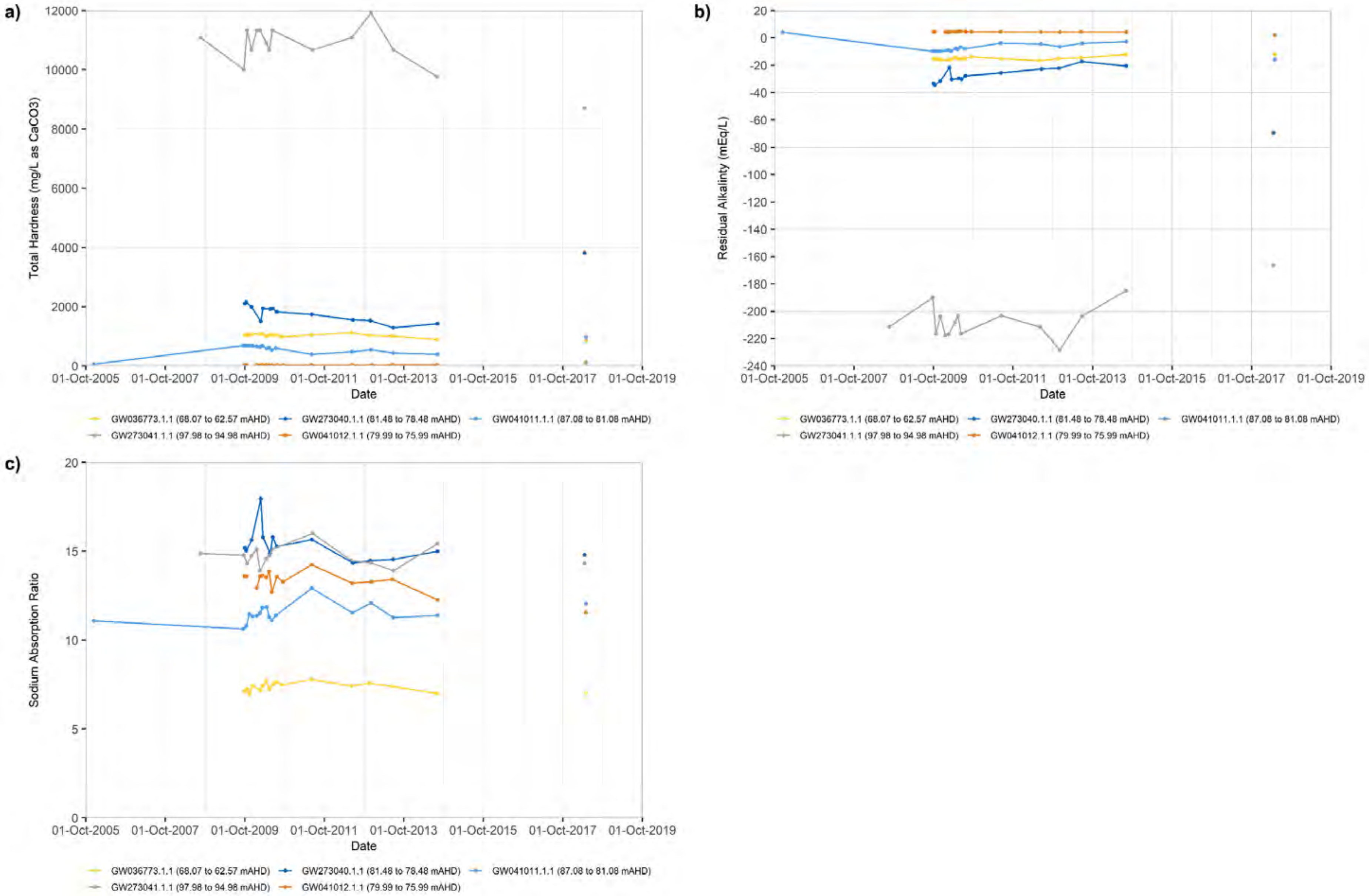


Figure 30. Irrigation parameters within the groundwater of the Shepparton Formation, including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

# Calivil Formation

## Physicochemical parameters

Summary statistics for the Calivil Formation groundwater electrical conductivity and pH are in Table 12. The raw data is in ‘Appendix 3–Raw Data‘.

Table 12. Summary statistics for physicochemical parameters in the Calivil Formation

| Site | Parameter | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| **All** | Electrical conductivity (µS/cm) | 87 | 0 | 396 | 645 | 1,600 |
| **All** | pH (pH units) | 18 | 0 | 6.2 | 7.1 | 7.6 |
| **GW030323.1.1** | Electrical conductivity (µS/cm) | 14 | 0 | 982 | 1,044 | 1,110 |
| **GW030323.1.1** | pH (pH units) | 3 | 0 | 6.3 | 7.0 | 7.1 |
| **GW036773.2.2** | Electrical conductivity (µS/cm) | 19 | 0 | 889 | 1,200 | 1,500 |
| **GW036773.2.2** | pH (pH units) | 3 | 0 | 6.6 | 6.9 | 7.1 |
| **GW041011.2.2** | Electrical conductivity (µS/cm) | 18 | 0 | 552 | 578 | 680 |
| **GW041011.2.2** | pH (pH units) | 3 | 0 | 6.7 | 7.5 | 7.6 |
| **GW041012.2.2** | Electrical conductivity (µS/cm) | 19 | 0 | 396 | 410 | 427 |
| **GW041012.2.2** | pH (pH units) | 3 | 0 | 6.6 | 7.5 | 7.6 |
| **GW273040.2.2** | Electrical conductivity (µS/cm) | 9 | 0 | 1,140 | 1,500 | 1,600 |
| **GW273040.2.2** | pH (pH units) | 3 | 0 | 6.8 | 7.1 | 7.2 |
| **GW273041.2.2** | Electrical conductivity (µS/cm) | 8 | 0 | 406 | 434 | 560 |
| **GW273041.2.2** | pH (pH units) | 3 | 0 | 6.2 | 6.9 | 7.1 |

Groundwater electrical conductivity in the Calivil Formation ranged from 396 µS/cm to 1,600 µS/cm (Table 12 and Figure 31). The highest groundwater electrical conductivity was at monitoring site GW273040.2.2, with values generally between 2 to 4 times higher than other sites screened in the same aquifer (Table 12 and Figure 19). The lowest groundwater electrical conductivity occurs at monitoring site GW41012.2.2 (Table 12 and Figure 19).

There are 2 groupings of groundwater electrical conductivity in the Calivil Formation. One group includes monitoring sites along the north-eastern and south-eastern areas of the groundwater source, with electrical conductivity generally greater than 1,000 µS/cm, including sites GW036773.2.2, GW030323.1.1, and GW273040.2.2. The second group includes monitoring sites that are downstream of the more saline eastern sites and/or near the Murrumbidgee River, with electrical conductivity generally less than 600 µS/cm, including sites GW273041.2.2, GW041011.2.2, and GW041012.2.2 (Table 12, Figure 19, and Figure 31). Electrical conductivity values have generally remained steady or increased during the investigation period, with increases occurring after 2012 at monitoring sites GW273040.2.2, GW030323.1.1, and GW036773.2.2 (Figure 31). This means that sites with higher salinity are experiencing increasing salinisation while the sites that are fresher have stable salinity.

There is limited groundwater pH data available for the Calivil Formation during the investigation period. Groundwater pH in the Calivil Formation ranges from 6.2 to 7.6, with groundwater pH values generally declining over the investigation period (Table 12, Figure 19, and Figure 31).

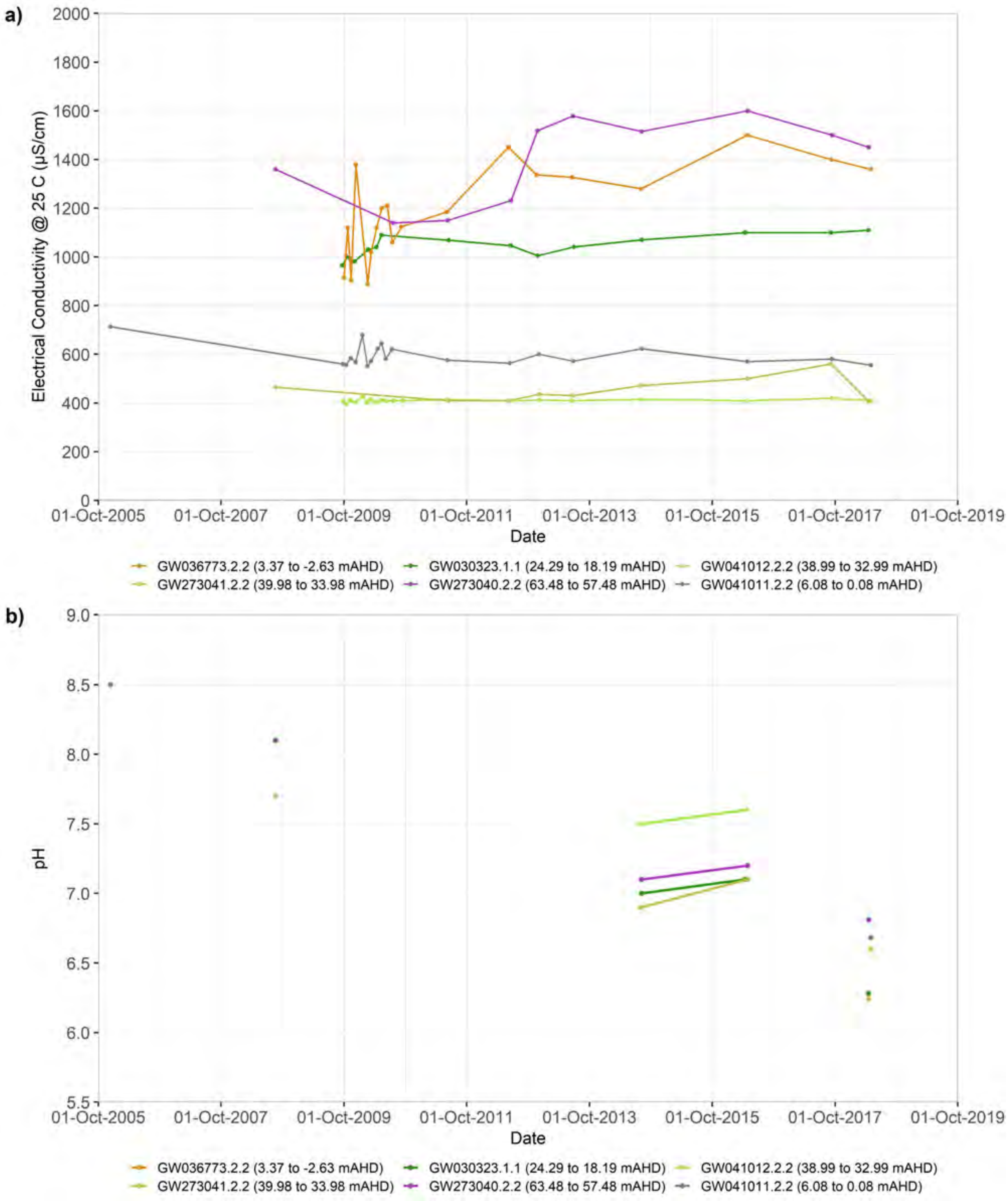


Figure 31. Groundwater (a) electrical conductivity (b) and pH in the Calivil Formation

## Major ions

Summary statistics for the Calivil Formation groundwater major ions are in Table 13 through Table 19. The raw data is in ‘Appendix 3–Raw Data‘.

Groundwater in the Calivil Formation is $Na^+$–$Cl^-$ dominated at monitoring sites GW036773.2.2, GW030323.1.1, and GW273040.2.2. Groundwater is $Na^+$–$HCO_3^-$ dominated at monitoring sites GW041012.2.2 and GW273041.1.1. Groundwater at monitoring site GW041011.2.2 is generally $Na^+$–$Cl^-$–$HCO_3^-$ dominated, with occurrences of $Na^+$–$HCO_3^-$–$Cl^-$ dominated groundwater during mid-2010 and $Na^+$–$Cl^-$ dominated groundwater since 2012 (Figure 19 and Appendix 4–QAQC Results).

The ion ratios of $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ in the Calivil Formation follow different trends at different sites. The $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ has remained stable at most monitoring sites. The $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ has increased at sites GW036773.2.2, GW030323.1.1, and GW273040.2.2 (Figure 32). This correlates with increasing salinisation.

Groundwater salinity increases at monitoring sites GW030323.1.1, GW036773.2.2, and GW273040.2.2 are generally correlated with declining $Na^+/Cl^-$, $K^+/Cl^-$, and $(HCO_3^-+CO_3^{2-})/Cl^-$. Increasing $Ca^+/Cl^-$ and $Mg^+/Cl^-$ also occurs (Figure 31, Figure 33, and Figure 34). This suggests salinisation is occurring and is possibly associated with reverse ion exchange and carbonate mineral precipitation. Increasing $SO_4^{2-}/Cl^-$ at site GW036773.2.2 could be due to mixing with a $SO_4^{2-}$-rich water or sulfate mineral dissolution. Increasing $NO_3^-/Cl^-$ at these sites suggests that groundwater from the overlying Shepparton Formation may be infiltrating into the Calivil Formation near these sites or being transported to these sites via lateral flow (Figure 31 and Figure 34).

Changes to the ion/$Cl^-$ ratios have also occurred at sites GW041012.2.2, and GW273041.2.2, which have relatively stable electrical conductivity values throughout the investigation period. Sites GW041012.2.2 and GW273041.2.2 have had declining $Na^+/Cl^-$ and $Mg^+/Cl^-$. Site GW273041.2.2 has also had declining $SO_4^{2-}/Cl^-$ and $(HCO_3^-+CO_3^{2-})/Cl^-$ (Figure 31, Figure 33, and Figure 34). Increasing $NO_3^-/Cl^-$ at site GW041012.2.2 suggests that these changes could be due to increased vertical leakage, possibly from the Murrumbidgee River. Decreasing $NO_3^-/Cl^-$ and increasing $K^+/Cl^-$ at site GW273041.2.2 suggests that these changes could also be due to increased vertical leakage. More work will need to be performed to confirm this since $K^+$ is usually quickly scavenged from groundwater and the geochemistry of the Murrumbidgee River water is unknown.

Declining $HCO_3^-/Cl^-$ at most sites within the Calivil Formation could explain declining pH via acidification or calcite precipitation (Figure 31 and Figure 34).

Table 13. Summary statistics for major ions for all monitoring sites screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 65 | 0 | 45 | 130 | 220 |
| $K^+$ | 65 | 0 | 1.30 | 2.40 | 3.70 |
| $Ca^{2+}$ | 65 | 0 | 6.40 | 25 | 46.0 |
| $Mg^{2+}$ | 65 | 0 | 6.30 | 23 | 42.0 |
| $Cl^-$ | 65 | 0 | 26 | 190 | 380 |
| $SO_4^{2-}$ | 65 | 0 | 11.0 | 32.0 | 200 |
| $CO_3^{2-}$ | 65 | 64 | <1 | <1 | 4.2 |
| $HCO_3^-$ | 65 | 0 | 106 | 140 | 190 |
| $NO_3^-$ | 65 | 19 | <0.05 | 0.09 | 1.86 |

Table 14. Summary statistics for major ions for monitoring site GW030323.1.1 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 12 | 0 | 120 | 130 | 150 |
| $K^+$ | 12 | 0 | 3 | 3.45 | 3.7 |
| $Ca^{2+}$ | 12 | 0 | 26 | 28 | 30 |
| $Mg^{2+}$ | 12 | 0 | 30 | 33 | 35 |
| $Cl^-$ | 12 | 0 | 230 | 250 | 292 |
| $SO_4^{2-}$ | 12 | 0 | 31 | 34 | 37 |
| $CO_3^{2-}$ | 12 | 12 | <1 | <1 | <1 |
| $HCO_3^-$ | 12 | 0 | 107 | 120 | 130 |
| $NO_3^-$ | 12 | 7 | <0.05 | 0.05 | 1.81 |

Table 15. Summary statistics for major ions for monitoring site GW036773.2.2 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 16 | 0 | 130 | 160 | 190 |
| $K^+$ | 16 | 0 | 2.6 | 2.85 | 3.1 |
| $Ca^{2+}$ | 16 | 0 | 24 | 33.5 | 46 |
| $Mg^{2+}$ | 16 | 0 | 23 | 28 | 41 |
| $Cl^-$ | 16 | 0 | 180 | 210 | 267 |
| $SO_4^{2-}$ | 16 | 0 | 77 | 130 | 200 |
| $CO_3^{2-}$ | 16 | 16 | <1 | <1 | <1 |
| $HCO_3^-$ | 16 | 0 | 110 | 130 | 150 |
| $NO_3^-$ | 16 | 0 | 0.35 | 0.86 | 1.86 |

Table 16. Summary statistics for major ions for monitoring site GW041011.2.2 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 13 | 0 | 94 | 100 | 110 |
| $K^+$ | 13 | 0 | 1.3 | 1.5 | 1.7 |
| $Ca^{2+}$ | 13 | 0 | 6.6 | 8.5 | 13 |
| $Mg^{2+}$ | 13 | 0 | 7.5 | 8 | 8.5 |
| $Cl^-$ | 13 | 0 | 91 | 93 | 95 |
| $SO_4^{2-}$ | 13 | 0 | 13 | 14 | 16 |
| $CO_3^{2-}$ | 13 | 12 | <1 | <1 | 4.2 |
| $HCO_3^-$ | 13 | 0 | 130 | 150 | 160 |
| $NO_3^-$ | 13 | 5 | <0.05 | 0.05 | 0.27 |

Table 17. Summary statistics for major ions for monitoring site GW041012.2.2 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 15 | 0 | 67 | 75 | 84 |
| $K^+$ | 15 | 0 | 1.3 | 1.4 | 1.5 |
| $Ca^{2+}$ | 15 | 0 | 6.4 | 6.8 | 7.9 |
| $Mg^{2+}$ | 15 | 0 | 6.3 | 6.7 | 7.2 |
| $Cl^-$ | 15 | 0 | 26 | 27 | 28 |
| $SO_4^{2-}$ | 15 | 0 | 11 | 12 | 13 |
| $CO_3^{2-}$ | 15 | 15 | <1 | <1 | <1 |
| $HCO_3^-$ | 15 | 0 | 180 | 180 | 190 |
| $NO_3^-$ | 15 | 4 | <0.05 | 0.09 | <0.9 |

Table 18. Summary statistics for major ions for monitoring site GW273040.2.2 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 6 | 0 | 150 | 188 | 220 |
| $K^+$ | 6 | 0 | 2.00 | 2.30 | 2.70 |
| $Ca^{2+}$ | 6 | 0 | 25.0 | 32.0 | 40.0 |
| $Mg^{2+}$ | 6 | 0 | 25.0 | 33.5 | 42.0 |
| $Cl^-$ | 6 | 0 | 210 | 315 | 380 |
| $SO_4^{2-}$ | 6 | 0 | 33 | 48.5 | 58.0 |
| $CO_3^{2-}$ | 6 | 6 | <1 | <1 | <1 |
| $HCO_3^-$ | 6 | 0 | 150 | 175 | 180 |
| $NO_3^-$ | 6 | 2 | <0.05 | 0.44 | 1.68 |

Table 19. Summary statistics for major ions for monitoring site GW273041.2.2 screened in the Calivil Formation

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 3 | 0 | 45.0 | 47.0 | 47.0 |
| $K^+$ | 3 | 0 | 2.00 | 2.40 | 2.40 |
| $Ca^{2+}$ | 3 | 0 | 14.0 | 15.0 | 15.0 |
| $Mg^{2+}$ | 3 | 0 | 12.0 | 14.0 | 14.0 |
| $Cl^-$ | 3 | 0 | 54.0 | 55.0 | 56.0 |
| $SO_4^{2-}$ | 3 | 0 | 15.0 | 16.0 | 17.0 |
| $CO_3^{2-}$ | 3 | 3 | <1 | <1 | <1 |
| $HCO_3^-$ | 3 | 0 | 106 | 120 | 120 |
| $NO_3^-$ | 3 | 1 | <0.05 | 0.13 | 0.27 |

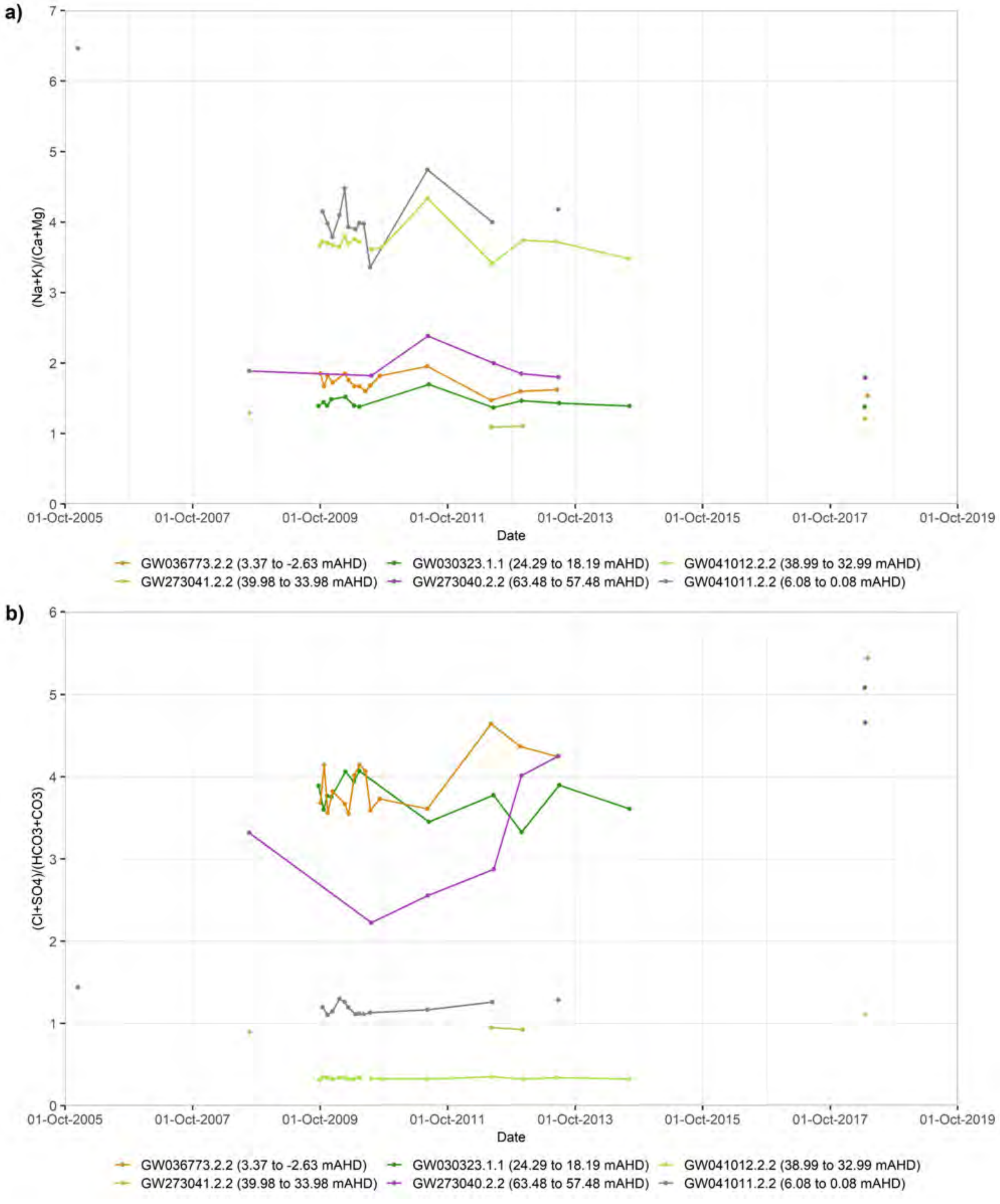


Figure 32. Groundwater (a) cation and (b) anion ratios in the Calivil Formation

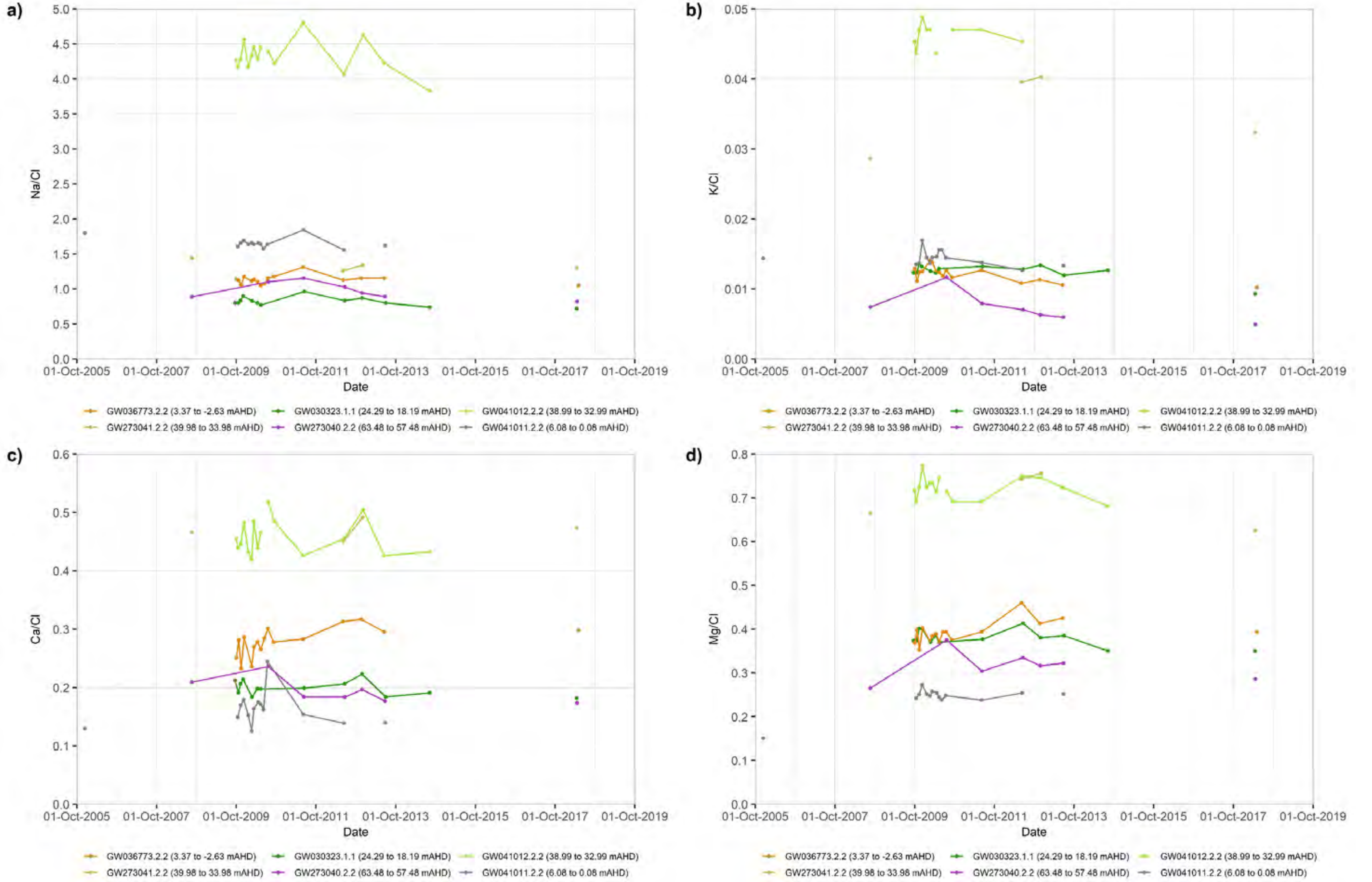


Figure 33. Detailed groundwater cation/chloride ratios in the Calivil Formation, including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

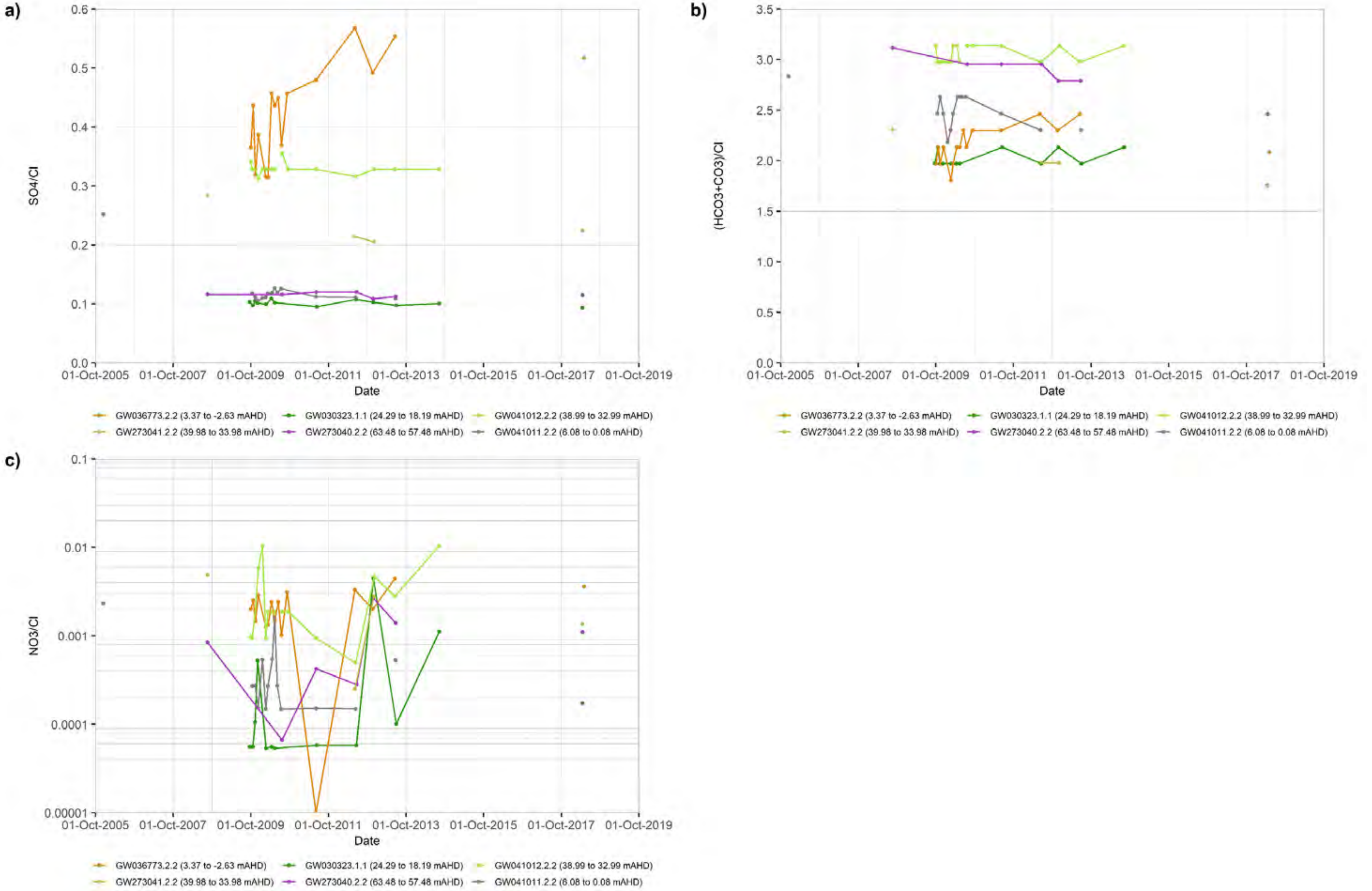


Figure 34. Detailed groundwater anion/chloride ratios in the Calivil Formation, including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

## Irrigation parameters

Summary statistics for groundwater irrigation parameters occurring throughout the Calivil Formation are in Table 20. The raw data is in ‘Appendix 3–Raw Data‘.

Total hardness as $CaCO_3$ has increased at monitoring sites GW0367733.2.2, GW273040.2.2, and GW030323.1.1. This is associated with increasing electrical conductivity along with declining residual alkalinity. The SAR increased or remained steady at these sites (Figure 31 and Figure 35).

Irrigation parameters generally remained steady at monitoring sites GW273041.2.2, GW041012.2.2, and GW041011.2.2. (Figure 35).

## Beneficial use

### Electrical conductivity and pH

Increased groundwater electrical conductivity at monitoring site GW036773.2.2 has led to changes in beneficial use of groundwater. Groundwater at this site now has ‘medium water salinity’ and has limited its suitability to the irrigation of ‘moderately tolerant crops’ (Table 12, Figure 31, and Table 43).

Increased groundwater electrical conductivity at monitoring sites GW273040.2.2 and GW030323.1.1 did not lead to changes in beneficial use during the investigation period. However, beneficial use could be limited in the future if the increasing trend continues.

Changes to groundwater pH have not led to changes in beneficial use categories. Declining pH has meant that the fouling potential has decreased. However, if pH continues to decline, the corrosion potential could increase.

### Irrigation parameters

The total hardness as $CaCO_3$ at monitoring sites GW041012.2.2 and GW041011.2.2 could result in increased corrosion potential (Table 20, Figure 35, and Table 49)

Increases in the total hardness as $CaCO_3$ at monitoring sites GW273040.2.2, GW030323.1.1, and GW036773.2.2 has led to an increased risk of scaling problems (Table 20, Figure 35, and Table 44). Further increases could lead to increased fouling potential (Table 50).

Table 20. Summary statistics for irrigation parameters in the groundwater of the Calivil Formation

| Site | Parameter | Count | Non-detects | Minimum | Median |
|---|---|---|---|---|---|
| All | Total hardness (mg/L as $CaCO_3$) | 65 | 42.4 | 157 | 284 |
| All | Residual alkalinity (mEq/L) | 65 | −3.19 | −0.65 | 2.29 |
| All | Sodium adsorption ratio | 65 | 2.03 | 4.89 | 6.71 |
| GW030323.1.1 | Total hardness (mg/L as $CaCO_3$) | 12 | 191 | 205 | 219 |
| GW030323.1.1 | Residual alkalinity (mEq/L) | 12 | −2.60 | −2.10 | −1.67 |
| GW030323.1.1 | Sodium adsorption ratio | 12 | 3.78 | 4.00 | 4.67 |
| GW036773.2.2 | Total hardness (mg/L as $CaCO_3$) | 16 | 155 | 198 | 284 |
| GW036773.2.2 | Residual alkalinity (mEq/L) | 16 | −3.19 | −1.80 | −1.15 |
| GW036773.2.2 | Sodium adsorption ratio | 16 | 4.51 | 4.76 | 5.35 |
| GW041011.2.2 | Total hardness (mg/L as $CaCO_3$) | 13 | 49.0 | 53.6 | 65.4 |
| GW041011.2.2 | Residual alkalinity (mEq/L) | 13 | 1.20 | 1.36 | 1.59 |
| GW041011.2.2 | Sodium adsorption ratio | 13 | 5.38 | 5.83 | 6.71 |
| GW041012.2.2 | Total hardness (mg/L as $CaCO_3$) | 15 | 42.4 | 44.6 | 47.6 |
| GW041012.2.2 | Residual alkalinity (mEq/L) | 15 | 2.02 | 2.11 | 2.29 |
| GW041012.2.2 | Sodium adsorption ratio | 15 | 4.48 | 4.89 | 5.60 |
| GW273040.2.2 | Total hardness (mg/L as $CaCO_3$) | 6 | 165 | 218 | 268 |
| GW273040.2.2 | Residual alkalinity (mEq/L) | 6 | −2.55 | −1.63 | −0.34 |
| GW273040.2.2 | Sodium adsorption ratio | 6 | 4.85 | 5.71 | 6.09 |
| GW273041.2.2 | Total hardness (mg/L as $CaCO_3$) | 3 | 86.9 | 92.6 | 95.1 |
| GW273041.2.2 | Residual alkalinity (mEq/L) | 3 | 0.02 | 0.08 | 0.13 |
| GW273041.2.2 | Sodium adsorption ratio | 3 | 2.03 | 2.10 | 2.19 |

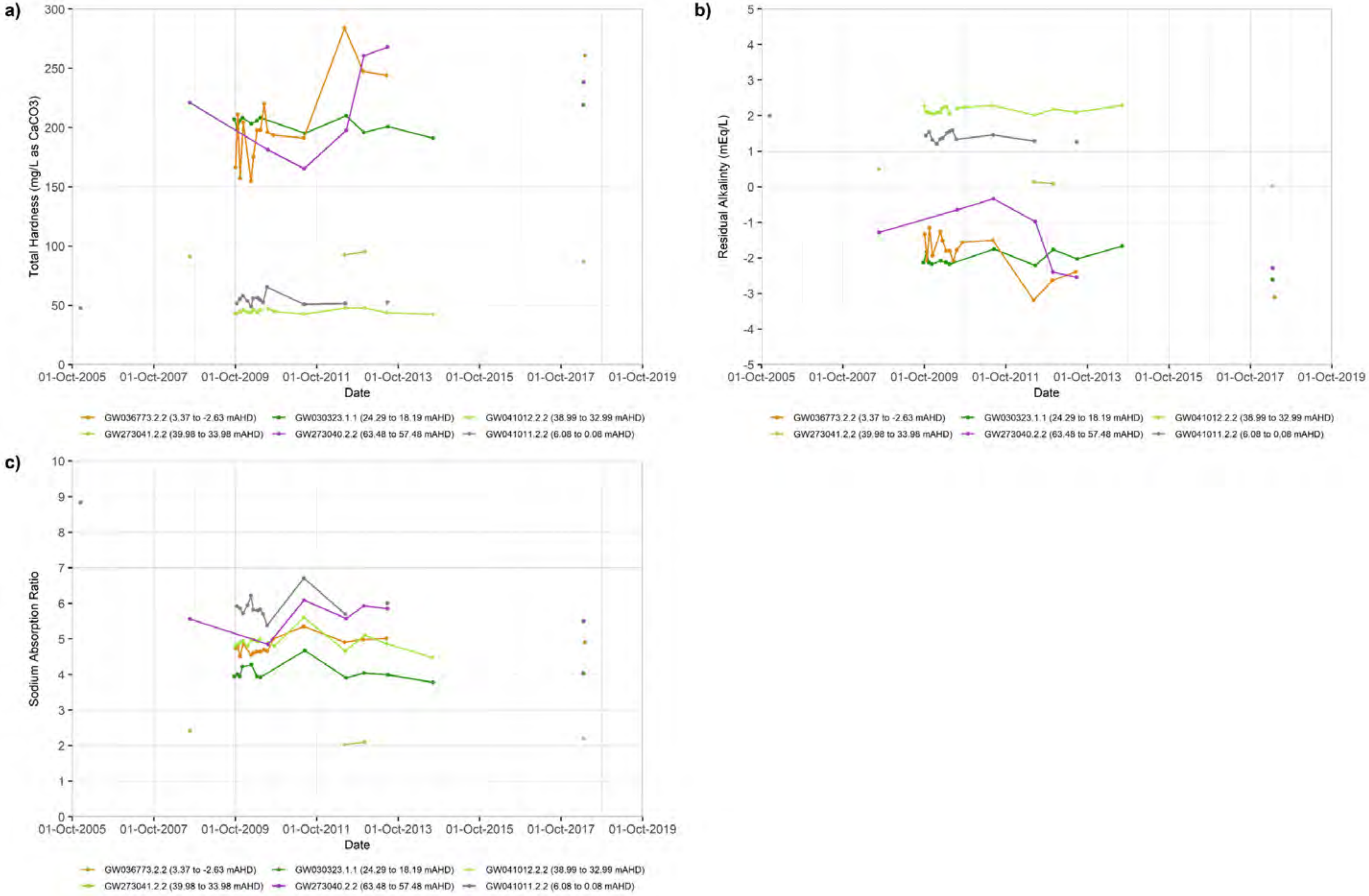


Figure 35. Irrigation parameters within the groundwater of the Calivil Formation, including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

## Renmark Group

### Physicochemical parameters

Summary statistics for the Renmark Group groundwater electrical conductivity and pH is shown in Table 21 to Table 23. The raw data is in ‘Appendix 3–Raw Data‘.

Groundwater electrical conductivity values in the upper-Renmark Group ranged from 404 µS/cm to 5,240 µS/cm (Table 21 and Figure 36) and ranged from 384 µS/cm to 2,320 µS/cm in the mid-Renmark Group (Table 22 and Figure 37). The groundwater in the lower-Renmark Group had electrical conductivity values ranging from 399 µS/cm to 4,530 µS/cm (Table 23 and Figure 38).

The highest groundwater electrical conductivity values occur at monitoring site GW036799 across all nested depths of the Renmark Group, with values between 1.1 to 13 times higher than other sites screened in the same aquifer. Higher groundwater electrical conductivity values also occur at monitoring site GW036396.1.1, screened in the mid-Renmark Group (Table 22 and Figure 37).

The electrical conductivity of the Renmark Group groundwater is higher on the margins of the groundwater source and fresher towards the centre (Figure 19, Figure 36, Figure 37, and Figure 38). The groundwater electrical conductivity also tends to be more saline in the upper Renmark Group and fresher in the lower Renmark Group (Table 21, Table 22, Table 23, Figure 36, Figure 37, and Figure 38).

Groundwater electrical conductivity values in the Renmark Group have remained steady at most monitoring sites. Increasing electrical conductivity occurred at monitoring sites GW036211.1.1 and GW036799.1.1 in the upper-Renmark Group, at monitoring sites GW036396.1.1 and GW036799.2.2 in the mid-Renmark Group, and at monitoring site GW036799.3.3 in the lower-Renmark Group (Figure 19, Figure 36, Figure 37, and Figure 38). As with the Calivil Formation, these sites are at the margins of the groundwater source and in areas where the groundwater salinity is higher than the fresher groundwater in the centre of the groundwater source. This means that relatively saline sites are becoming more saline, and the relatively fresher sites are remaining fresh.

There is limited groundwater pH data available for the Renmark Group during the investigation period. Groundwater pH in the Renmark Group ranges from 5.9 to 8.2, with groundwater pH values generally declining over the investigation period (Table 21, Table 22, Table 23, Figure 36, Figure 37, and Figure 38). Spatial trends in groundwater pH cannot be identified at this time.

Table 21. Summary statistics for physicochemical parameters in the upper Renmark Group

| Site | Parameter | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| All | Electrical conductivity (µS/cm) | 57 | 0 | 404 | 1,017 | 5,240 |
| All | pH (pH units) | 12 | 0 | 6.3 | 7.0 | 7.7 |
| GW036211.1.1 | Electrical conductivity (µS/cm) | 18 | 0 | 477 | 935 | 1,500 |
| GW036211.1.1 | pH (pH units) | 3 | 0 | 6.5 | 6.9 | 7.3 |
| GW036799.1.1 | Electrical conductivity (µS/cm) | 10 | 0 | 4,550 | 5,025 | 5,240 |
| GW036799.1.1 | pH (pH units) | 3 | 0 | 6.9 | 7.6 | 7.7 |
| GW273040.3.3 | Electrical conductivity (µS/cm) | 16 | 0 | 940 | 1,055 | 1,820 |
| GW273040.3.3 | pH (pH units) | 3 | 0 | 6.7 | 7.0 | 7.1 |
| GW273041.3.3 | Electrical conductivity (µS/cm) | 13 | 0 | 404 | 429 | 496 |
| GW273041.3.3 | pH (pH units) | 3 | 0 | 6.3 | 6.9 | 7.1 |

Table 22. Summary statistics for physicochemical parameters in the middle Renmark Group

| Site | Parameter | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| All | Electrical conductivity (µS/cm) | 99 | 0 | 384 | 662 | 2,320 |
| All | pH (pH units) | 18 | 0 | 6.0 | 7.0 | 7.6 |
| GW036211.2.2 | Electrical conductivity (µS/cm) | 18 | 0 | 459 | 470 | 725 |
| GW036211.2.2 | pH (pH units) | 3 | 0 | 5.9 | 6.6 | 7.0 |
| GW036396.1.1 | Electrical conductivity (µS/cm) | 15 | 0 | 1,570 | 1,799 | 2,060 |
| GW036396.1.1 | pH (pH units) | 3 | 0 | 6.8 | 7.0 | 7.1 |
| GW036773.3.3 | Electrical conductivity (µS/cm) | 19 | 0 | 577 | 631 | 674 |
| GW036773.3.3 | pH (pH units) | 3 | 0 | 6.0 | 6.5 | 6.6 |
| GW036799.2.2 | Electrical conductivity (µS/cm) | 10 | 0 | 1,898 | 2,083 | 2,320 |
| GW036799.2.2 | pH (pH units) | 3 | 0 | 7.1 | 7.4 | 7.6 |
| GW041011.3.3 | Electrical conductivity (µS/cm) | 18 | 0 | 648 | 664 | 728 |
| GW041011.3.3 | pH (pH units) | 3 | 0 | 6.1 | 7.0 | 7.6 |
| GW041012.3.3 | Electrical conductivity (µS/cm) | 19 | 0 | 384 | 409 | 430 |
| GW041012.3.3 | pH (pH units) | 3 | 0 | 6.4 | 7.2 | 7.4 |

Table 23. Summary statistics for physicochemical parameters in the lower Renmark Group

| Site | Parameter | Count | Non-detects | Minimum | Median | Maximum |
|---|---|---|---|---|---|---|
| All | Electrical conductivity (µS/cm) | 53 | 0 | 399 | 519 | 4,530 |
| All | pH (pH units) | 12 | 0 | 5.9 | 6.9 | 8.2 |
| GW036211.3.3 | Electrical conductivity (µS/cm) | 18 | 0 | 467 | 516 | 530 |
| GW036211.3.3 | pH (pH units) | 3 | 0 | 5.9 | 6.7 | 7.1 |
| GW036799.3.3 | Electrical conductivity (µS/cm) | 6 | 0 | 3,550 | 3,890 | 4,530 |
| GW036799.3.3 | pH (pH units) | 3 | 0 | 6.5 | 7.6 | 8.2 |
| GW273040.4.4 | Electrical conductivity (µS/cm) | 14 | 0 | 1,790 | 1,905 | 2,030 |
| GW273040.4.4 | pH (pH units) | 3 | 0 | 6.6 | 6.9 | 7.6 |
| GW273041.4.4 | Electrical conductivity (µS/cm) | 15 | 0 | 399 | 411 | 431 |
| GW273041.4.4 | pH (pH units) | 3 | 0 | 6.2 | 6.9 | 7.6 |

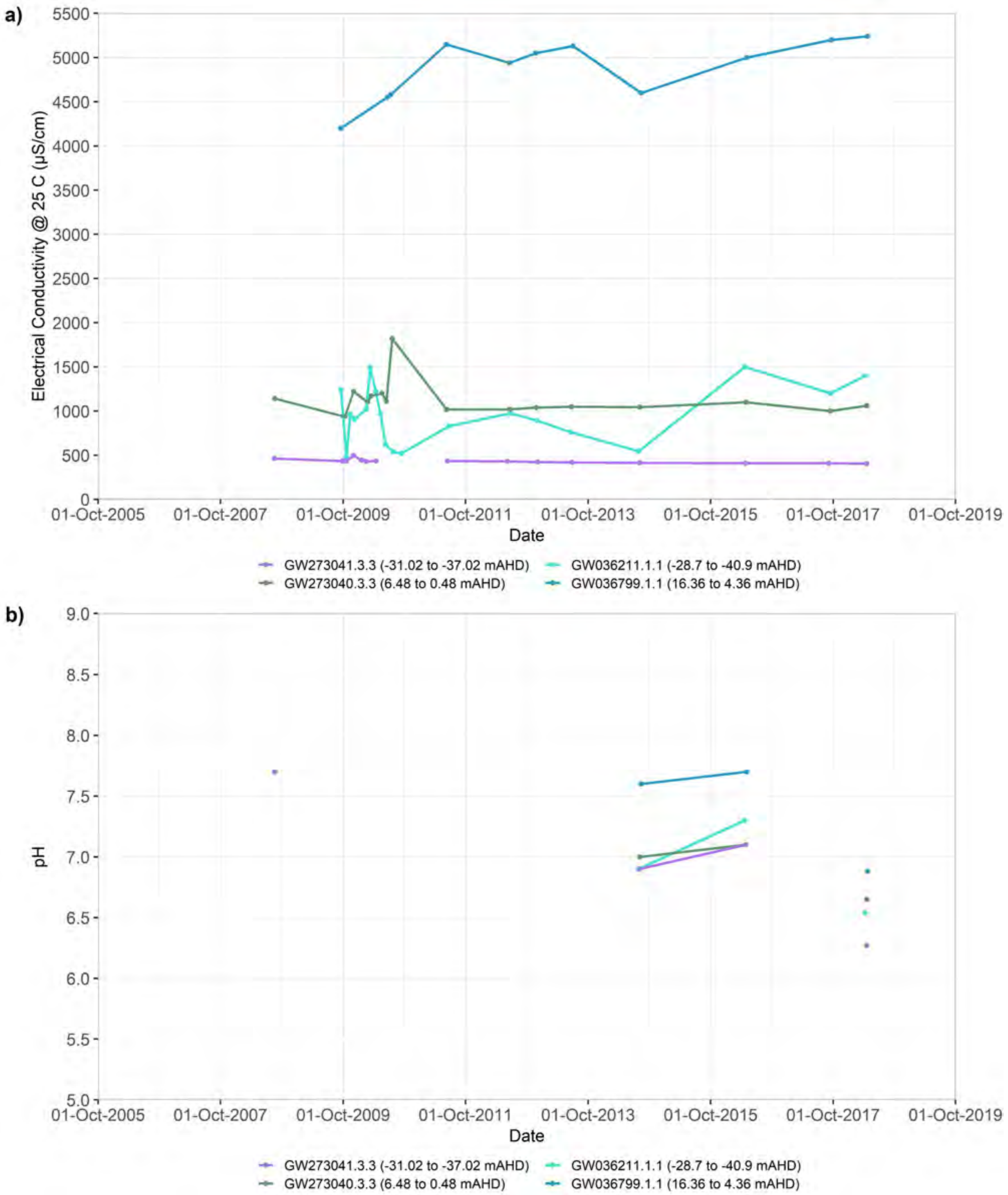


Figure 36. Groundwater (a) electrical conductivity (b) and pH within the upper Renmark Group

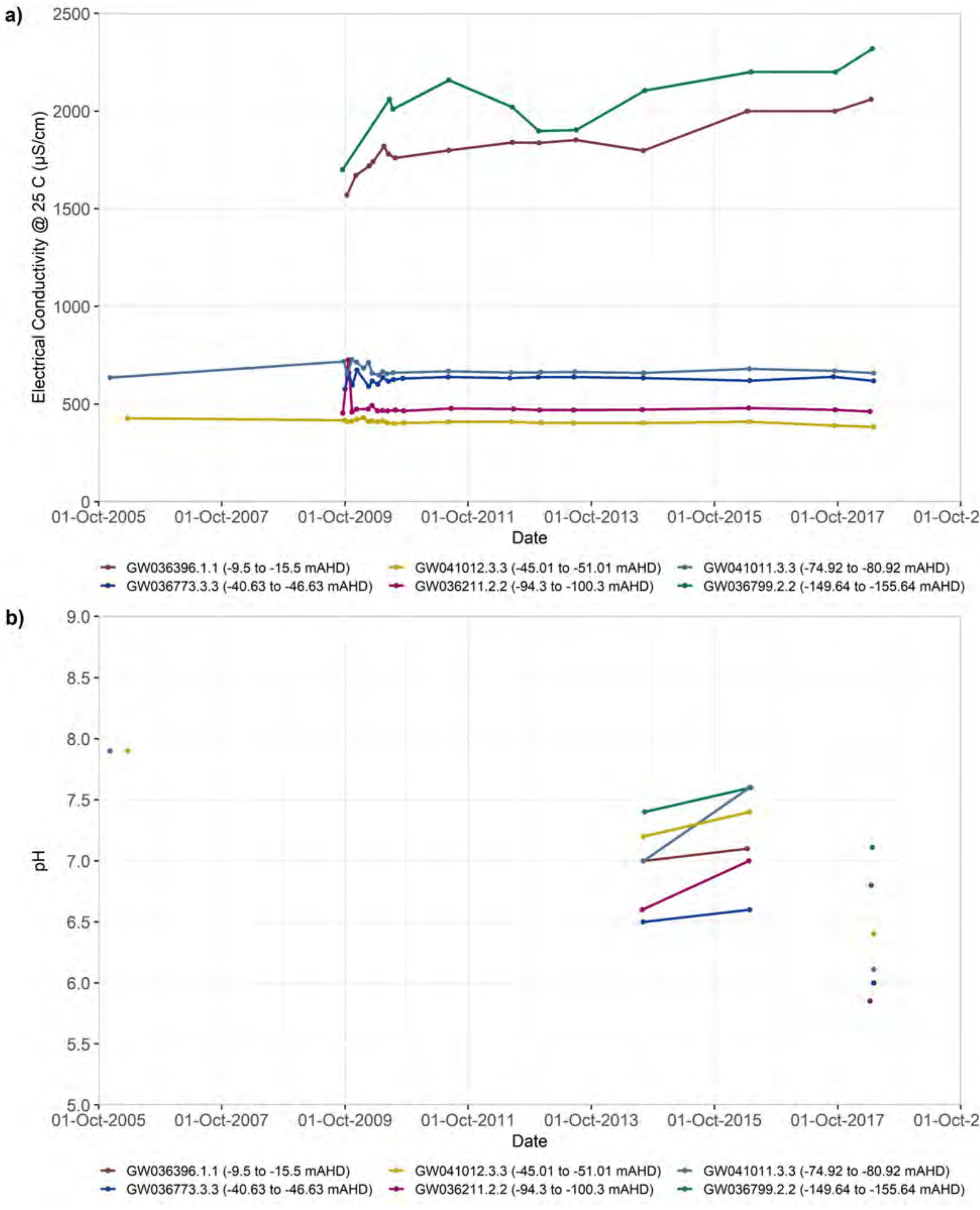


Figure 37. Groundwater (a) electrical conductivity (b) and pH within the middle Renmark Group

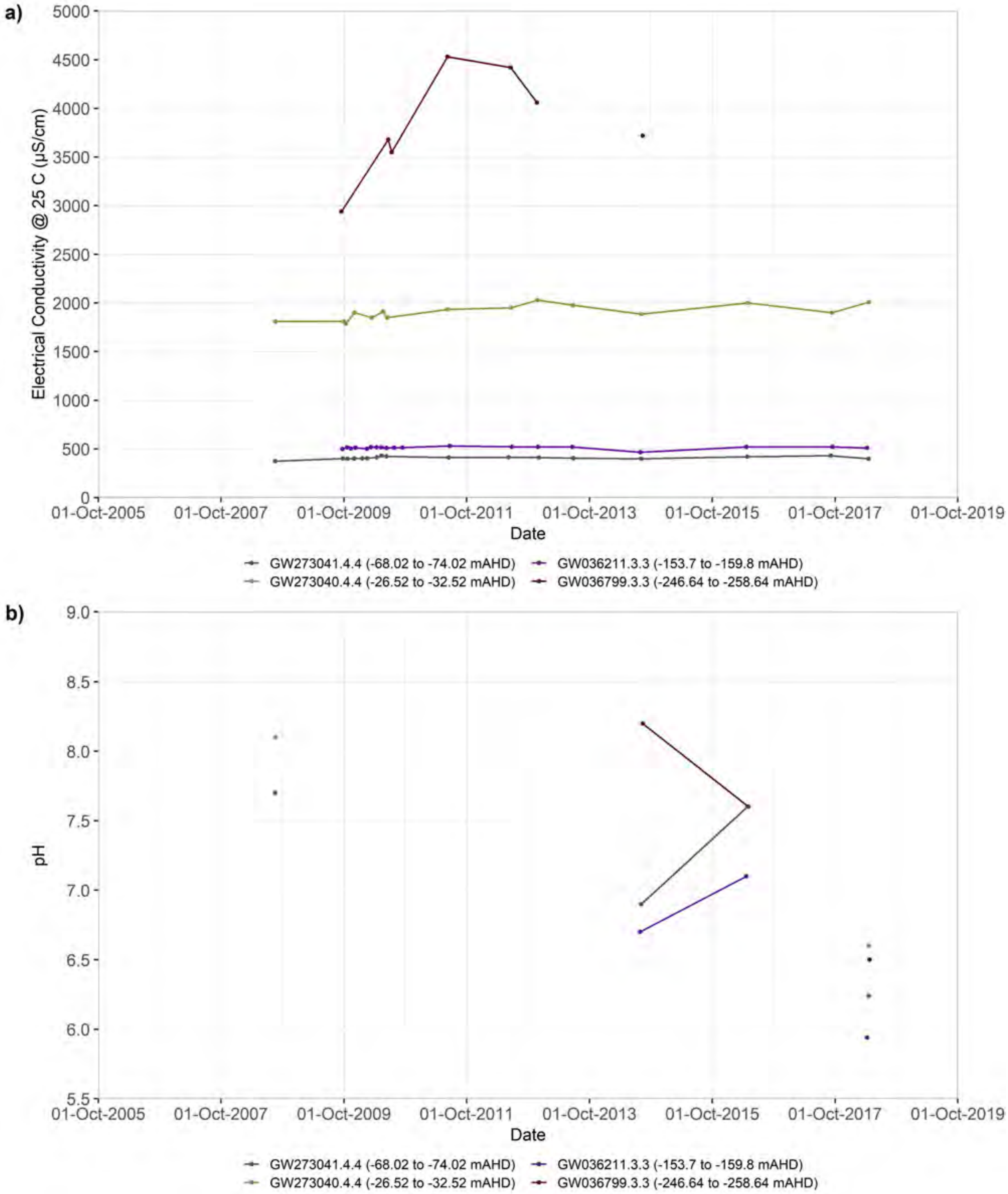


Figure 38. Groundwater (a) electrical conductivity (b) and pH within the lower Renmark Group

## Major ions

Summary statistics for groundwater major ions occurring throughout the upper, middle, and lower Renmark Group and at individual monitoring sites are in Table 28 to Table 39. The raw data is in ‘Appendix 3–Raw Data‘.

Groundwater in the Renmark Group is predominantly $Na^+$–$Cl^-$ dominated. Groundwater is $Na^+$–$HCO_3^-$ dominated at monitoring site GW273041.3.3 in the upper-Renmark Group, at monitoring site GW041012.3.3 in the mid-Renmark Group, and at monitoring site GW0273041.4.4 in the lower-Renmark Group (Appendix 4–QAQC Results). Sporadic occurrences of $Na^+$–$Mg^{2+}$–$HCO_3^-$, $Na^+$–$Cl^-$–$HCO_3^-$, $Na^+$–$Mg^{2+}$–$HCO_3^-$–$Cl^-$, and $Na^+$–$Mg^{2+}$–$Ca^{2+}$–$HCO_3^-$ are present at monitoring site GW273041.3.3 screened in the upper-Renmark Group. Sporadic occurrences of $Na^+$–$Cl^-$, $Na^+$–$Cl^-$–$HCO_3^-$, and $Na^+$–$HCO_3^-$–$Cl^-$ are present at monitoring site GW273041.4.4 screened in the lower-Renmark Group.

As with the overlying Calivil Formation, increasing electrical conductivity in the Renmark Group is correlated with increasing $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ and $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ (Figure 39, Figure 42, and Figure 45). This appears to be driven by increasing $Cl^-$ along with increasing $SO_4^{2-}/Cl^-$ at sites GW036211.1.1 in the upper-Renmark Group, and GW036396.1.1 in the mid-Renmark Group, which suggests that sulfate mineral dissolution or mixing with a $SO_4^{2-}$–rich water is occurring. This could also be driven by declining $(HCO_3^-+CO_3^{2-})/Cl^-$ at sites GW036396.1.1 and GW036799.2.2 in the mid-Renmark Group, and site GW036799.3.3 in the lower-Renmark Group (Figure 41, Figure 44, and Figure 47). Declining $(HCO_3^-+CO_3^{2-})/Cl^-$ suggests that carbonate mineral precipitation and/or mixing with a $(HCO_3^-+CO_3^{2-})$-poor water is occurring. Most of the cation/$Cl^-$ ratios are steady or declining (Figure 40, Figure 43, Figure 46). The mechanism for this change is not clear. It could be a combination of ion exchange, mineral precipitation, and mixing with other waters as groundwater salinisation occurs.

Geochemical changes are also occurring at monitoring sites where the groundwater electrical conductivity has remained steady. Increasing $Ca^{2+}/Cl^-$ and $Mg^{2+}/Cl^-$ occurs at monitoring site GW273041.3.3. The $SO_4^{2-}/Cl^-$ has declined at site GW041012.3.3 in the mid-Renmark Group, and sites GW273040.4.4 and GW273041.4.4 in the lower-Renmark Group. This suggests that mixing with a $SO_4^{2-}$-poor water could be occurring at these locations (Figure 44). Declining $(HCO_3^-+CO_3^{2-})/Cl^-$ at site GW273040.4.4 in the lower-Renmark Group suggests that either carbonate mineral precipitation is occurring or that mixing with a $(HCO_3^-+CO_3^{2-})$–poor water is occurring.

Increasing $NO_3^-/Cl^-$ ratios has occurred at monitoring sites GW273041.3.3 and GW273040.3.3 in the upper-Renmark Group. This also occurred at sites GW041012.3.3, GW041011.3.3 and GW036773.3.3 in the mid-Renmark Group (Figure 41 and Figure 44). This suggests that vertical leakage of $NO_3^-$–rich water may be occurring.

Table 24. Summary statistics for major ions for all monitoring sites in the upper Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 46 | 0 | 42.0 | 140 | 850 |
| $K^+$ | 46 | 0 | 2.00 | 2.95 | 13.0 |
| $Ca^{2+}$ | 46 | 0 | 5.30 | 16.5 | 87.0 |
| $Mg^{2+}$ | 46 | 0 | 12.0 | 23.0 | 110 |
| $Cl^-$ | 46 | 0 | 60.0 | 210 | 1,500 |
| $SO_4^{2-}$ | 45 | 1 | <0.5 | 16.0 | 77.0 |
| $CO_3^{2-}$ | 46 | 45 | <1 | <1 | 1.70 |
| $HCO_3^-$ | 46 | 0 | 110 | 140 | 380 |
| $NO_3^-$ | 46 | 30 | <0.02 | <0.05 | 2.04 |

Table 25. Summary statistics for Major ions for monitoring site GW036211.1.1 in the upper Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 16 | 0 | 77.0 | 140 | 205 |
| $K^+$ | 16 | 0 | 3.00 | 3.65 | 3.80 |
| $Ca^{2+}$ | 16 | 0 | 5.30 | 11.0 | 20.0 |
| $Mg^{2+}$ | 16 | 0 | 12.0 | 20.0 | 30.0 |
| $Cl^-$ | 16 | 0 | 94.0 | 205 | 376 |
| $SO_4^{2-}$ | 16 | 0 | 0.70 | 10.3 | 30.0 |
| $CO_3^{2-}$ | 16 | 16 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 16 | 0 | 110 | 135 | 140 |
| $NO_3^-$ | 16 | 12 | <0.02 | <0.05 | 0.53 |

Table 26. Summary statistics for Major ions for monitoring site GW036799.1.1 in the upper Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 6 | 0 | 770 | 790 | 850 |
| $K^+$ | 6 | 0 | 10.0 | 12.5 | 13.0 |
| $Ca^{2+}$ | 6 | 0 | 81.0 | 84.0 | 87.0 |
| $Mg^{2+}$ | 6 | 0 | 100 | 100 | 110 |
| $Cl^-$ | 6 | 0 | 1,300 | 1,400 | 1,500 |
| $SO_4^{2-}$ | 6 | 0 | 25.0 | 30.5 | 39.0 |
| $CO_3^{2-}$ | 6 | 6 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 6 | 0 | 370 | 380 | 380 |
| $NO_3^-$ | 6 | 4 | <0.05 | 0.09 | 2.04 |

Table 27. Summary statistics for Major ions for monitoring site GW273040.3.3 in the upper Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 13 | 0 | 130 | 150 | 300 |
| $K^+$ | 13 | 0 | 2.00 | 2.70 | 5.10 |
| $Ca^{2+}$ | 13 | 0 | 22.0 | 23.0 | 46.0 |
| $Mg^{2+}$ | 13 | 0 | 24.0 | 26.0 | 46.0 |
| $Cl^-$ | 13 | 0 | 200 | 220 | 460 |
| $SO_4^{2-}$ | 13 | 0 | 32.0 | 34.0 | 77.0 |
| $CO_3^{2-}$ | 13 | 13 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 13 | 0 | 148 | 170 | 190 |
| $NO_3^-$ | 13 | 8 | <0.05 | 0.09 | 0.89 |

Table 28. Summary statistics for Major ions for all monitoring sites in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 80 | 0 | 59.0 | 120 | 400 |
| $K^+$ | 80 | 0 | 1.50 | 3.80 | 14.0 |
| $Ca^{2+}$ | 80 | 0 | 4.90 | 13.0 | 45.0 |
| $Mg^{2+}$ | 80 | 0 | 5.80 | 14.0 | 49.0 |
| $Cl^-$ | 80 | 0 | 56.0 | 150 | 592 |
| $SO_4^{2-}$ | 80 | 50 | <0.5 | 1.20 | 111 |
| $CO_3^{2-}$ | 80 | 75 | <1 | <1 | 3.70 |
| $HCO_3^-$ | 80 | 0 | 65.0 | 140 | 390 |
| $NO_3^-$ | 78 | 44 | <0.02 | 0.02 | 3.28 |

Table 29. Summary statistics for Major ions for monitoring site GW036211.2.2 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 14 | 0 | 69.0 | 78.5 | 84.0 |
| $K^+$ | 14 | 0 | 3.40 | 3.85 | 4.30 |
| $Ca^{2+}$ | 14 | 0 | 4.00 | 4.55 | 5.70 |
| $Mg^{2+}$ | 14 | 0 | 7.20 | 7.90 | 8.40 |
| $Cl^-$ | 14 | 0 | 83.0 | 86.0 | 88.0 |
| $SO_4^{2-}$ | 14 | 14 | <0.5 | <0.5 | <0.5 |
| $CO_3^{2-}$ | 14 | 14 | <1 | <1 | <1 |
| $HCO_3^-$ | 14 | 0 | 110 | 110 | 140 |
| $NO_3^-$ | 14 | 8 | <0.02 | <0.05 | 0.75 |

Table 30. Summary statistics for Major ions for monitoring site GW036396.1.1 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 13 | 0 | 240 | 280 | 290 |
| $K^+$ | 13 | 0 | 3.80 | 4.10 | 4.40 |
| $Ca^{2+}$ | 13 | 0 | 34.0 | 39.0 | 45.0 |
| $Mg^{2+}$ | 13 | 0 | 39.0 | 45.0 | 49.0 |
| $Cl^-$ | 13 | 0 | 430 | 450 | 532 |
| $SO_4^{2-}$ | 13 | 0 | 79.0 | 85.0 | 111 |
| $CO_3^{2-}$ | 13 | 12 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 13 | 0 | 141 | 160 | 180 |
| $NO_3^-$ | 11 | 8 | <0.05 | <0.9 | 1.59 |

Table 31. Summary statistics for Major ions for monitoring site GW036773.3.3 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 15 | 0 | 71.0 | 75.0 | 82.0 |
| $K^+$ | 15 | 0 | 4.00 | 4.40 | 4.90 |
| $Ca^{2+}$ | 15 | 0 | 17.0 | 18.0 | 21.0 |
| $Mg^{2+}$ | 15 | 0 | 13.0 | 14.0 | 17.0 |
| $Cl^-$ | 15 | 0 | 140 | 150 | 166 |
| $SO_4^{2-}$ | 15 | 15 | <0.5 | <0.5 | <1 |
| $CO_3^{2-}$ | 15 | 15 | <1 | <1 | <1 |
| $HCO_3^-$ | 15 | 0 | 65.0 | 77.0 | 83.0 |
| $NO_3^-$ | 15 | 9 | <0.05 | <0.05 | 0.35 |

Table 32. Summary statistics for Major ions for monitoring site GW036799.2.2 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 7 | 0 | 340 | 380 | 400 |
| $K^+$ | 7 | 0 | 12.0 | 13.0 | 14.0 |
| $Ca^{2+}$ | 7 | 0 | 16.0 | 18.0 | 24.0 |
| $Mg^{2+}$ | 7 | 0 | 25.0 | 28.0 | 35.0 |
| $Cl^-$ | 7 | 0 | 440 | 470 | 592 |
| $SO_4^{2-}$ | 7 | 7 | <0.5 | <0.5 | 0.55 |
| $CO_3^{2-}$ | 7 | 7 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 7 | 0 | 315 | 360 | 390 |
| $NO_3^-$ | 7 | 3 | <0.05 | 0.09 | 3.28 |

Table 33. Summary statistics for Major ions for monitoring site GW041011.3.3 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 14 | 0 | 100 | 120 | 120 |
| $K^+$ | 14 | 0 | 2.00 | 2.50 | 2.90 |
| $Ca^{2+}$ | 14 | 0 | 4.90 | 5.30 | 6.90 |
| $Mg^{2+}$ | 14 | 0 | 9.00 | 11.0 | 12.0 |
| $Cl^-$ | 14 | 0 | 120 | 130 | 146 |
| $SO_4^{2-}$ | 14 | 14 | <0.5 | <0.5 | <1 |
| $CO_3^{2-}$ | 14 | 13 | <1 | <1 | 3.70 |
| $HCO_3^-$ | 14 | 0 | 123 | 150 | 160 |
| $NO_3^-$ | 14 | 8 | <0.05 | 0.03 | <0.9 |

Table 34. Summary statistics for Major ions for monitoring site GW041012.3.3 in the middle Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 15 | 0 | 59.0 | 67.0 | 73.0 |
| $K^+$ | 15 | 0 | 1.50 | 1.60 | 1.80 |
| $Ca^{2+}$ | 15 | 0 | 8.10 | 10.0 | 11.0 |
| $Mg^{2+}$ | 15 | 0 | 5.80 | 6.60 | 7.40 |
| $Cl^-$ | 15 | 0 | 56.0 | 58.0 | 60.0 |
| $SO_4^{2-}$ | 15 | 0 | 0.90 | 3.30 | 6.30 |
| $CO_3^{2-}$ | 15 | 14 | <1 | <1 | 3.50 |
| $HCO_3^-$ | 15 | 0 | 120 | 130 | 140 |
| $NO_3^-$ | 15 | 8 | <0.05 | <0.05 | 0.22 |

Table 35. Summary statistics for Major ions for all monitoring sites in the lower Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 44 | 0 | 51.0 | 94 | 3,810 |
| $K^+$ | 44 | 0 | 2.70 | 4.80 | 15.0 |
| $Ca^{2+}$ | 44 | 0 | 3.50 | 11.0 | 509 |
| $Mg^{2+}$ | 44 | 0 | 5.00 | 12.5 | 493 |
| $Cl^-$ | 44 | 0 | 64.0 | 98 | 7,600 |
| $SO_4^{2-}$ | 44 | 13 | <0.5 | 2.5 | 1,300 |
| $CO_3^{2-}$ | 44 | 44 | <1 | <1 | 1.30 |
| $HCO_3^-$ | 44 | 0 | 110 | 120 | 330 |
| $NO_3^-$ | 44 | 26 | <0.02 | <0.05 | 0.97 |

Table 36. Summary statistics for Major ions for all monitoring site GW036211.3.3 in the lower Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 42 | 0 | 51.0 | 93 | 800 |
| $K^+$ | 42 | 0 | 2.70 | 4.80 | 15.0 |
| $Ca^{2+}$ | 42 | 0 | 3.50 | 10.5 | 58 |
| $Mg^{2+}$ | 42 | 0 | 5.00 | 12.0 | 78 |
| $Cl^-$ | 42 | 0 | 64.0 | 98 | 1,200 |
| $SO_4^{2-}$ | 42 | 13 | <0.5 | 2.4 | 110 |
| $CO_3^{2-}$ | 42 | 44 | <1 | <1 | 1.30 |
| $HCO_3^-$ | 42 | 0 | 110 | 120 | 300 |
| $NO_3^-$ | 42 | 26 | <0.02 | <0.05 | 0.97 |

Table 37. Summary statistics for Major ions for all monitoring site GW036799.3.3 in the lower Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 13 | 0 | 78.0 | 90.0 | 94.0 |
| $K^+$ | 13 | 0 | 3.50 | 4.70 | 5.00 |
| $Ca^{2+}$ | 13 | 0 | 3.50 | 4.50 | 5.90 |
| $Mg^{2+}$ | 13 | 0 | 5.00 | 6.40 | 6.90 |
| $Cl^-$ | 13 | 0 | 87.0 | 97.0 | 98.0 |
| $SO_4^{2-}$ | 13 | 13 | <0.5 | <0.5 | <0.5 |
| $CO_3^{2-}$ | 13 | 13 | <1 | <1 | <1 |
| $HCO_3^-$ | 13 | 0 | 110 | 120 | 130 |
| $NO_3^-$ | 13 | 10 | <0.02 | <0.05 | 0.40 |

Table 38. Summary statistics for Major ions for all monitoring site GW273040.4.4 in the lower Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 6 | 0 | 590 | 700 | 800 |
| $K^+$ | 6 | 0 | 13.00 | 14.5 | 15.0 |
| $Ca^{2+}$ | 6 | 0 | 46.0 | 54.0 | 58 |
| $Mg^{2+}$ | 6 | 0 | 57.0 | 65.5 | 78 |
| $Cl^-$ | 6 | 0 | 1,000 | 1,150 | 1,200 |
| $SO_4^{2-}$ | 6 | 0 | 74.0 | 88 | 110 |
| $CO_3^{2-}$ | 6 | 8 | <1 | <1 | 0.55 |
| $HCO_3^-$ | 6 | 0 | 280 | 290 | 300 |
| $NO_3^-$ | 6 | 4 | <0.05 | <0.9 | <0.9 |

Table 39. Summary statistics for Major ions for all monitoring site GW273041.4.4 in the lower Renmark Group

| Parameter (mg/L) | No. points | No. non-detects | Min | Median | Max |
|---|---|---|---|---|---|
| $Na^+$ | 12 | 0 | 270 | 306 | 340 |
| $K^+$ | 12 | 0 | 4.00 | 5.45 | 6.40 |
| $Ca^{2+}$ | 12 | 0 | 36.0 | 39.0 | 44.0 |
| $Mg^{2+}$ | 12 | 0 | 39.0 | 42.5 | 45.0 |
| $Cl^-$ | 12 | 0 | 470 | 505 | 560 |
| $SO_4^{2-}$ | 12 | 0 | 38.0 | 51.0 | 71.0 |
| $CO_3^{2-}$ | 12 | 13 | <1 | <1 | <1 |
| $HCO_3^-$ | 12 | 0 | 184 | 205 | 240 |
| $NO_3^-$ | 12 | 5 | <0.05 | 0.09 | 0.97 |

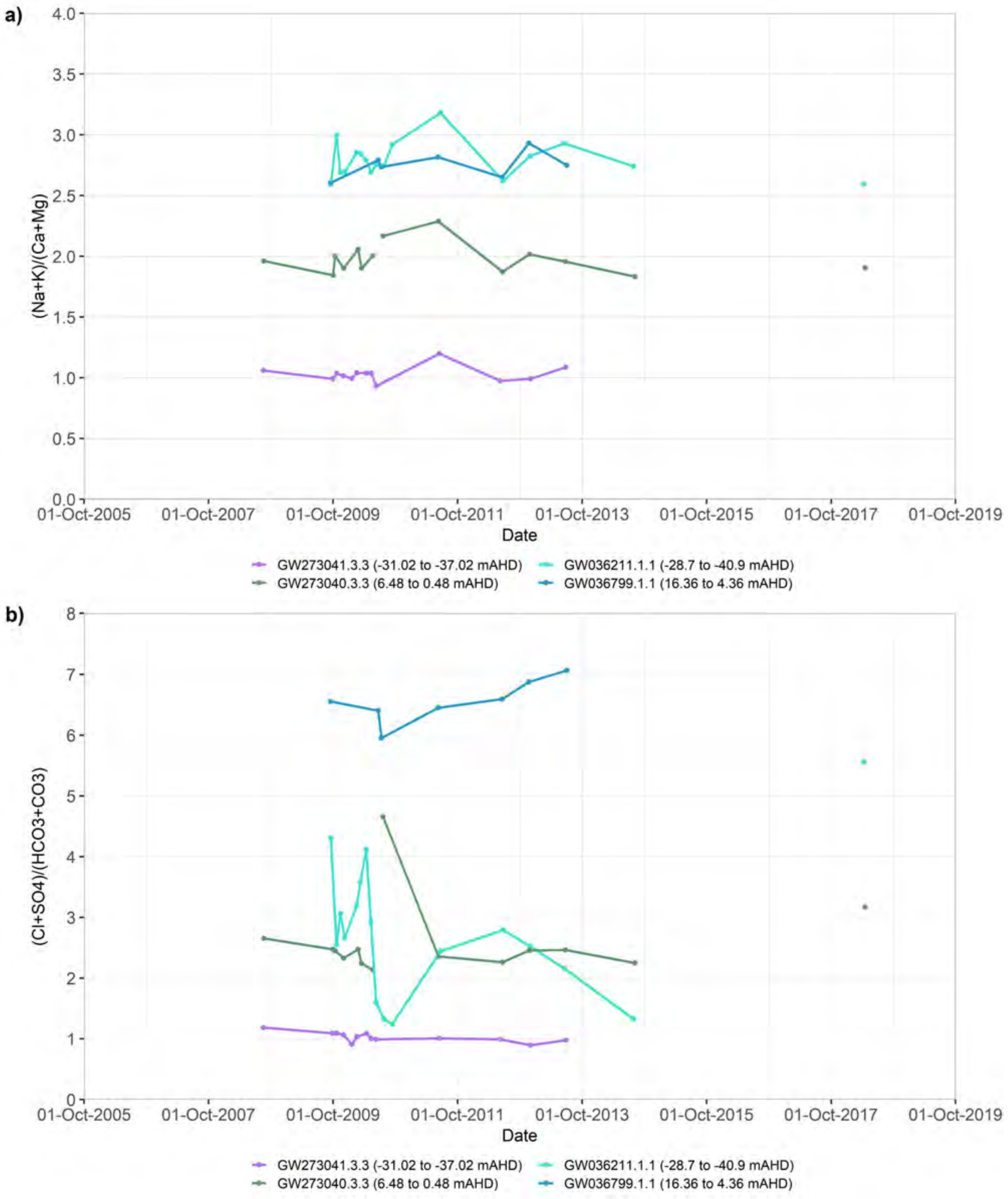


Figure 39. Groundwater (a) cation and (b) anion ratios in the upper Renmark Group

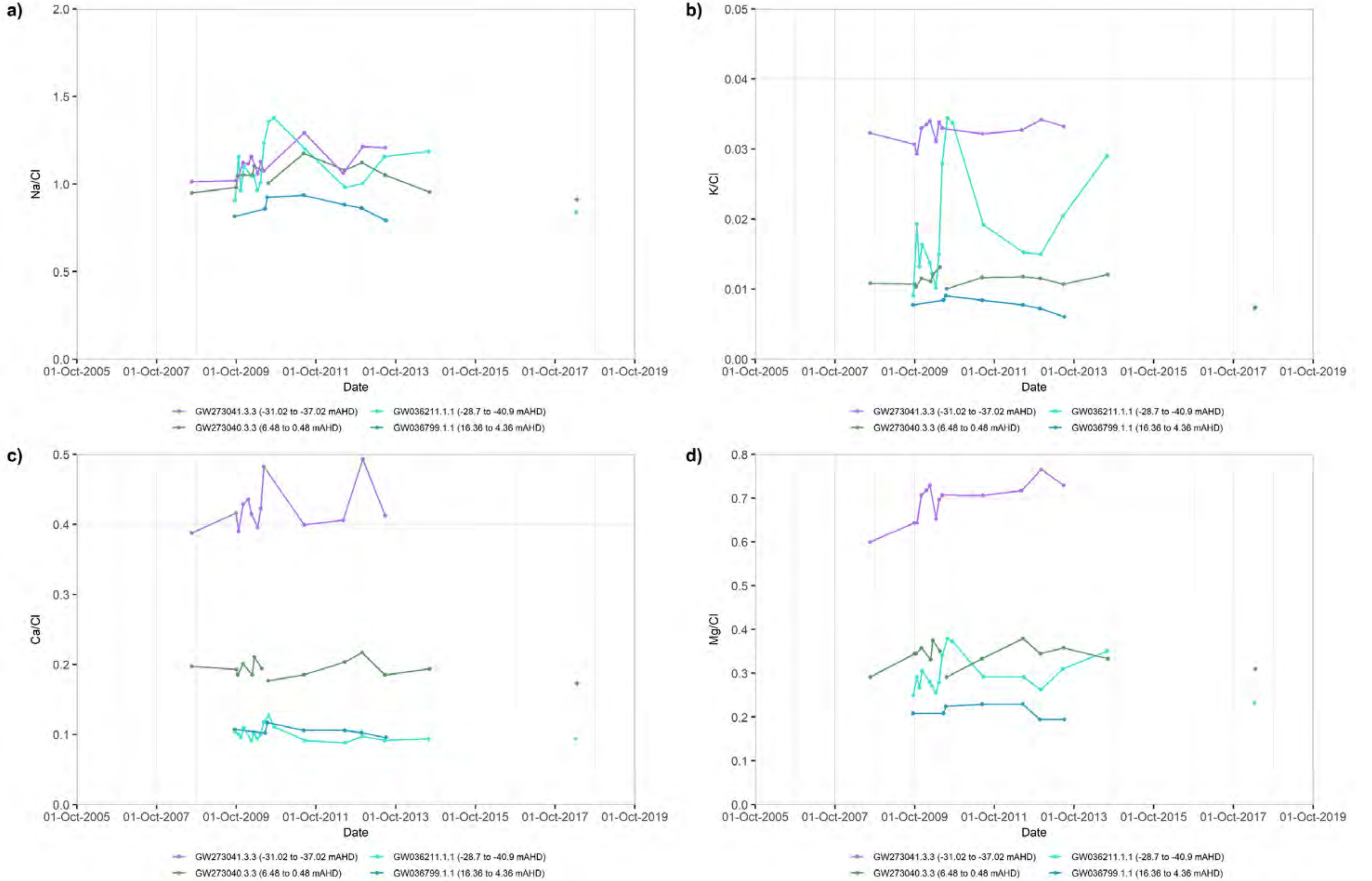


Figure 40. Detailed groundwater cation/chloride ratios in the upper Renmark Group, including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

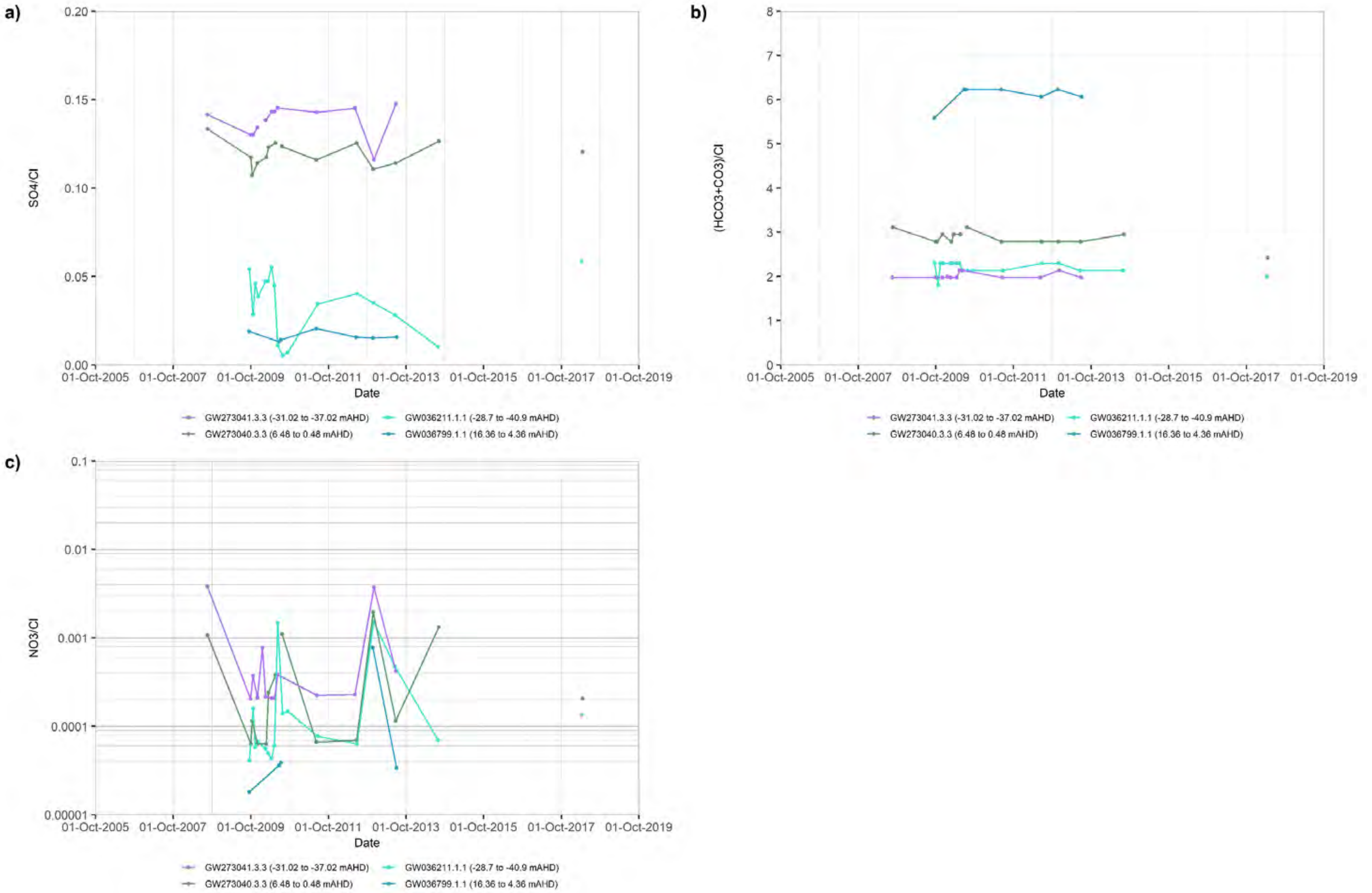


Figure 41. Detailed groundwater anion/chloride ratios in the upper Renmark Group, including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

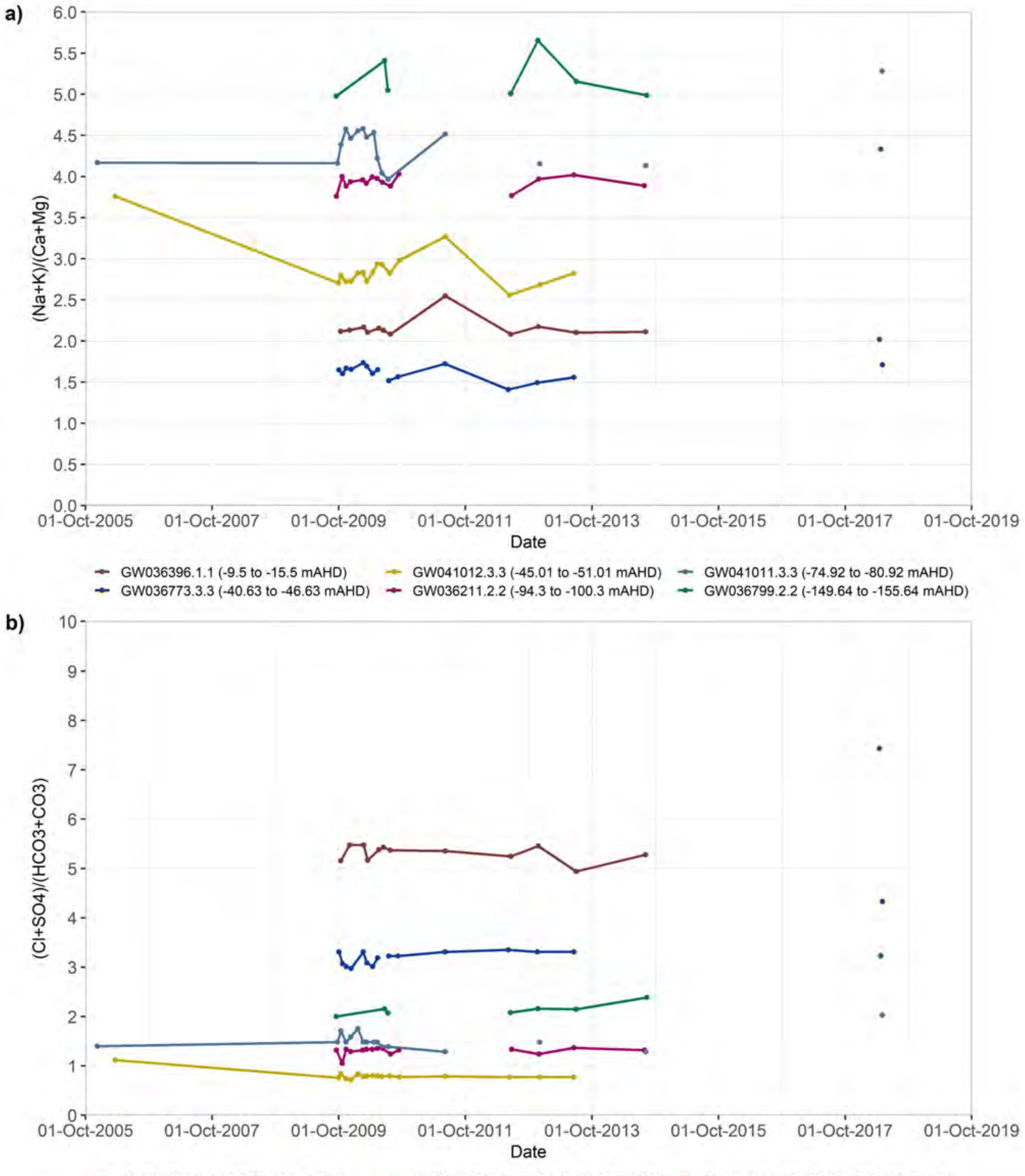


Figure 42. Groundwater (a) cation and (b) anion ratios in the mid Renmark Group

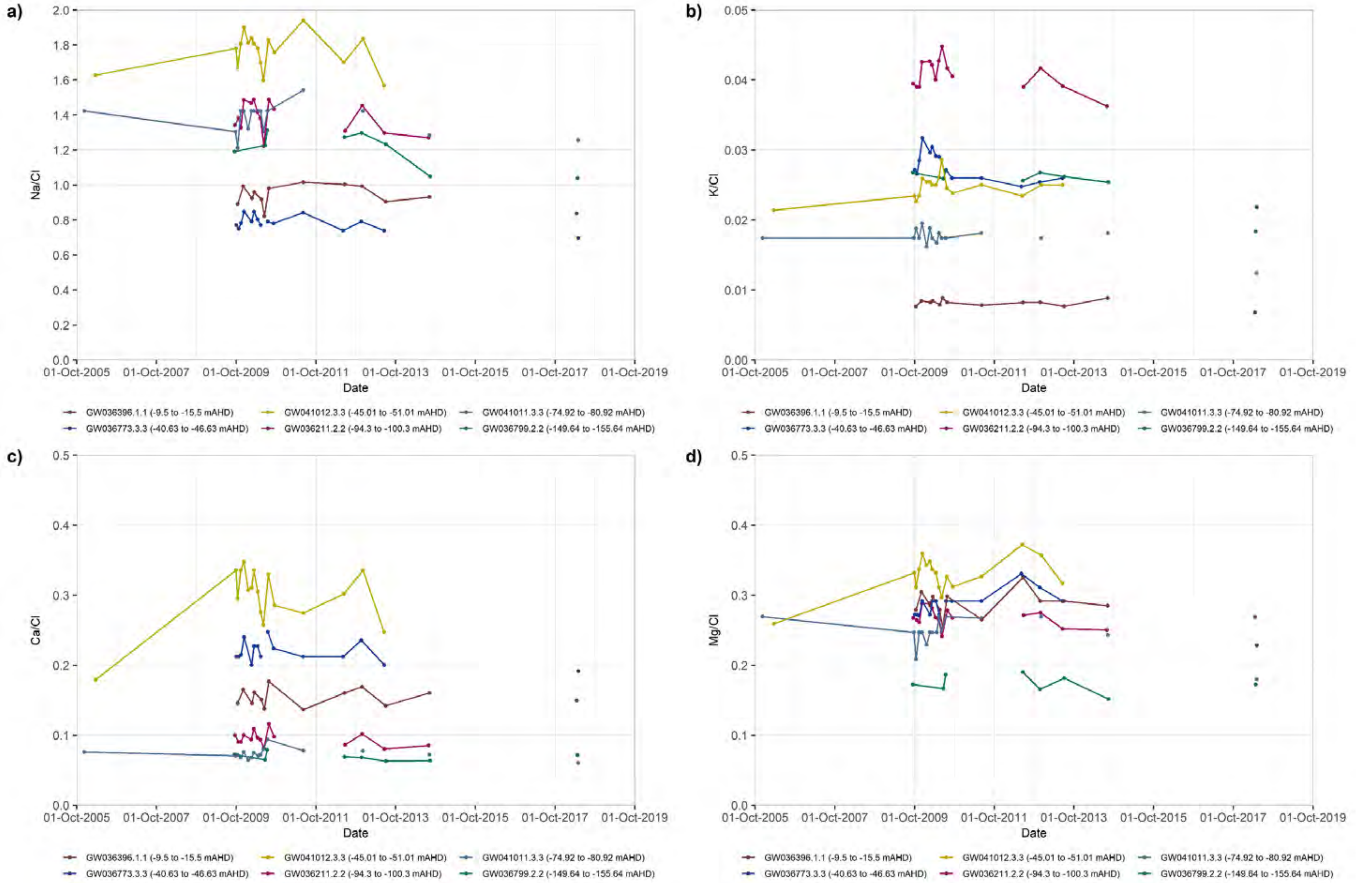


Figure 43. Detailed groundwater cation/chloride ratios in the mid Renmark Group, including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

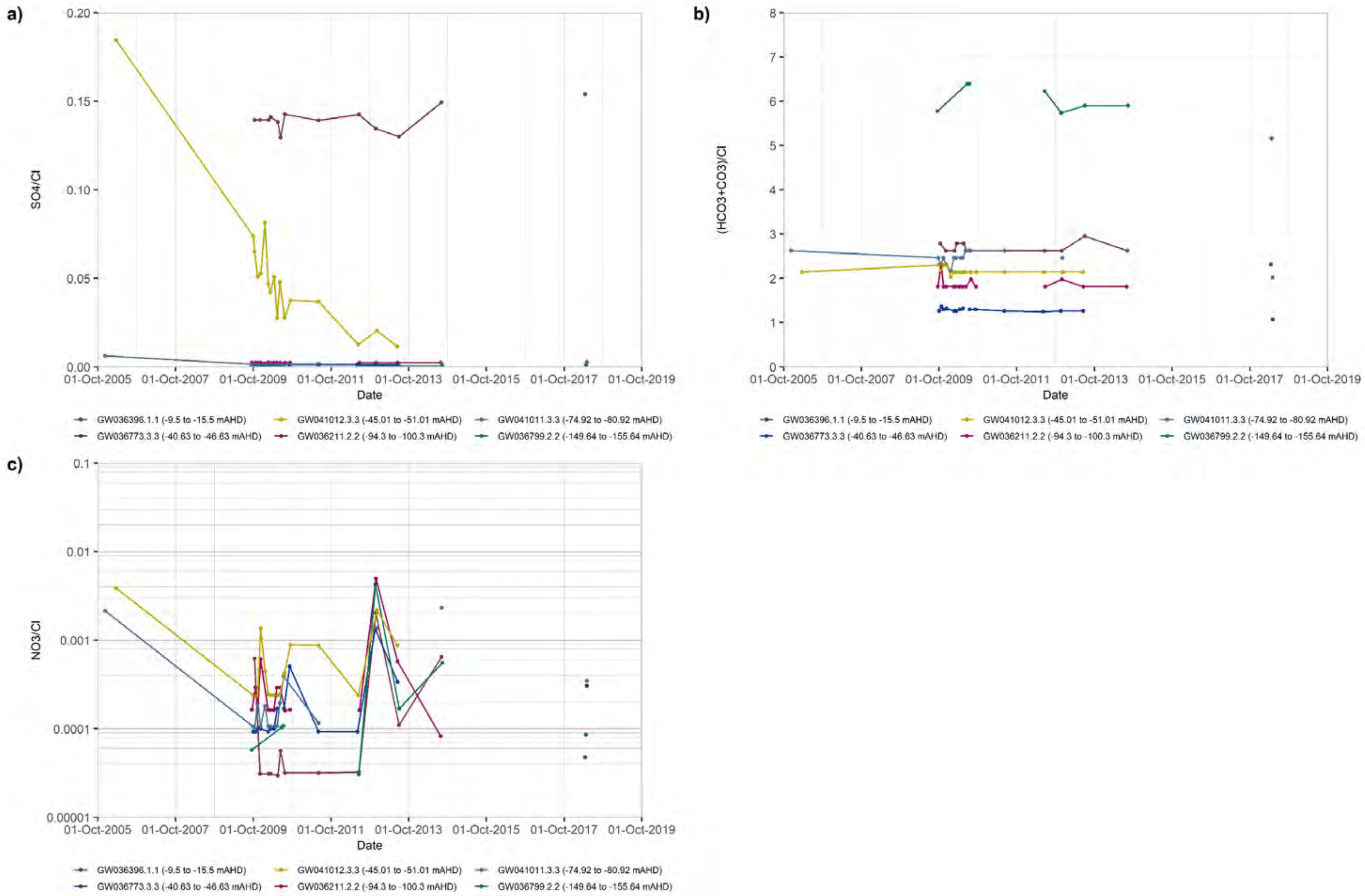
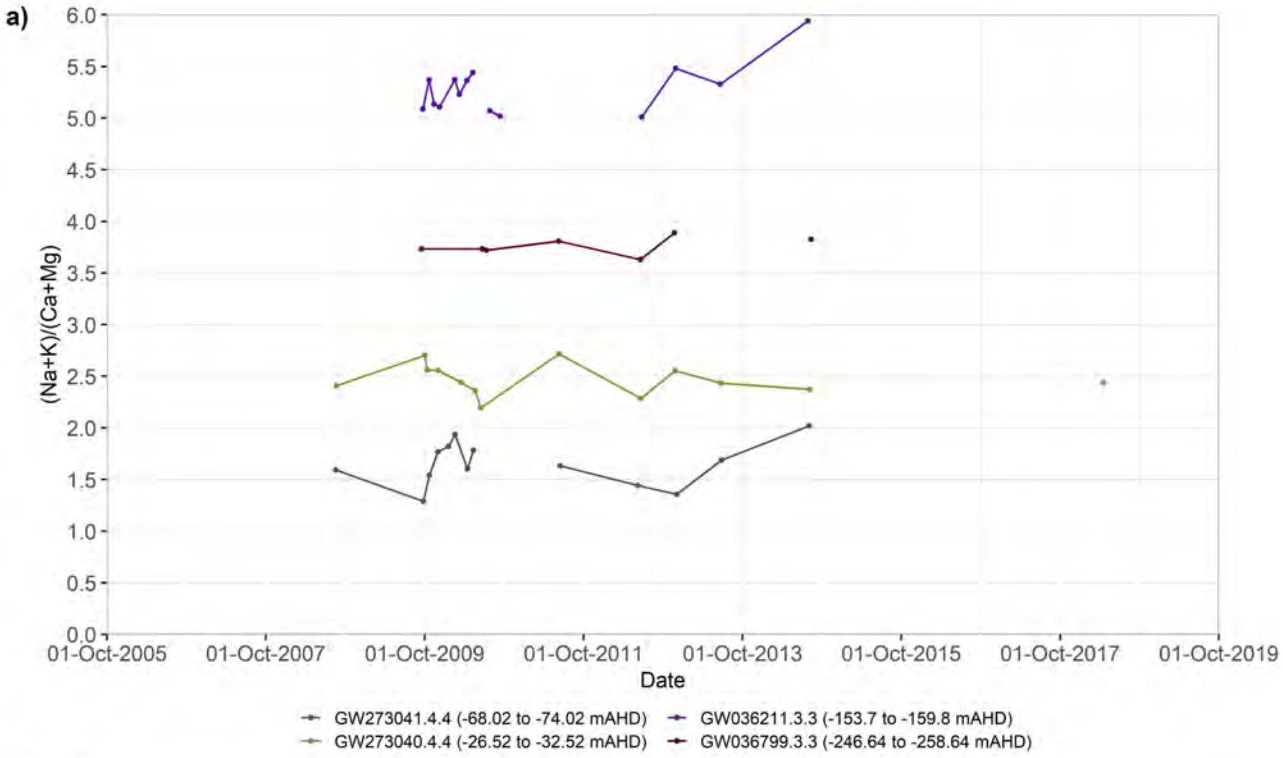


Figure 44. Detailed groundwater anion/chloride ratios in the mid Renmark Group, including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$



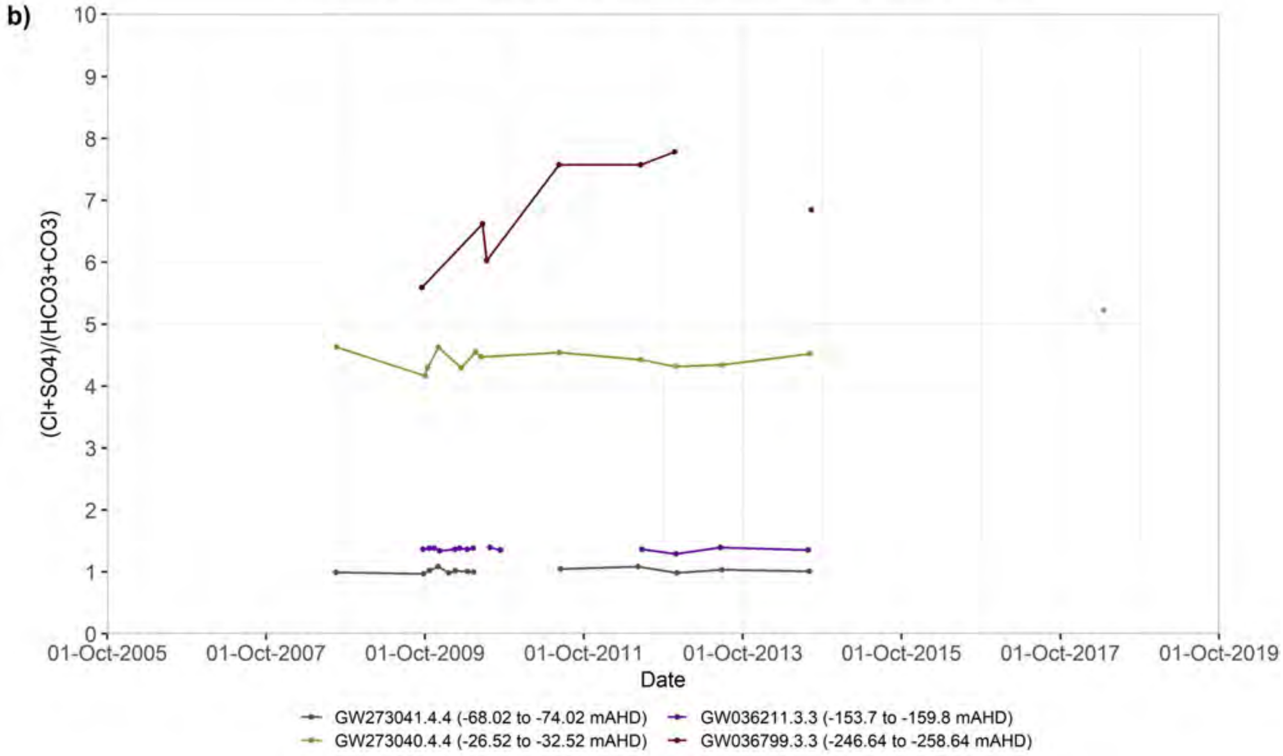


Figure 45. Groundwater (a) cation and (b) anion ratios in the lower Renmark Group

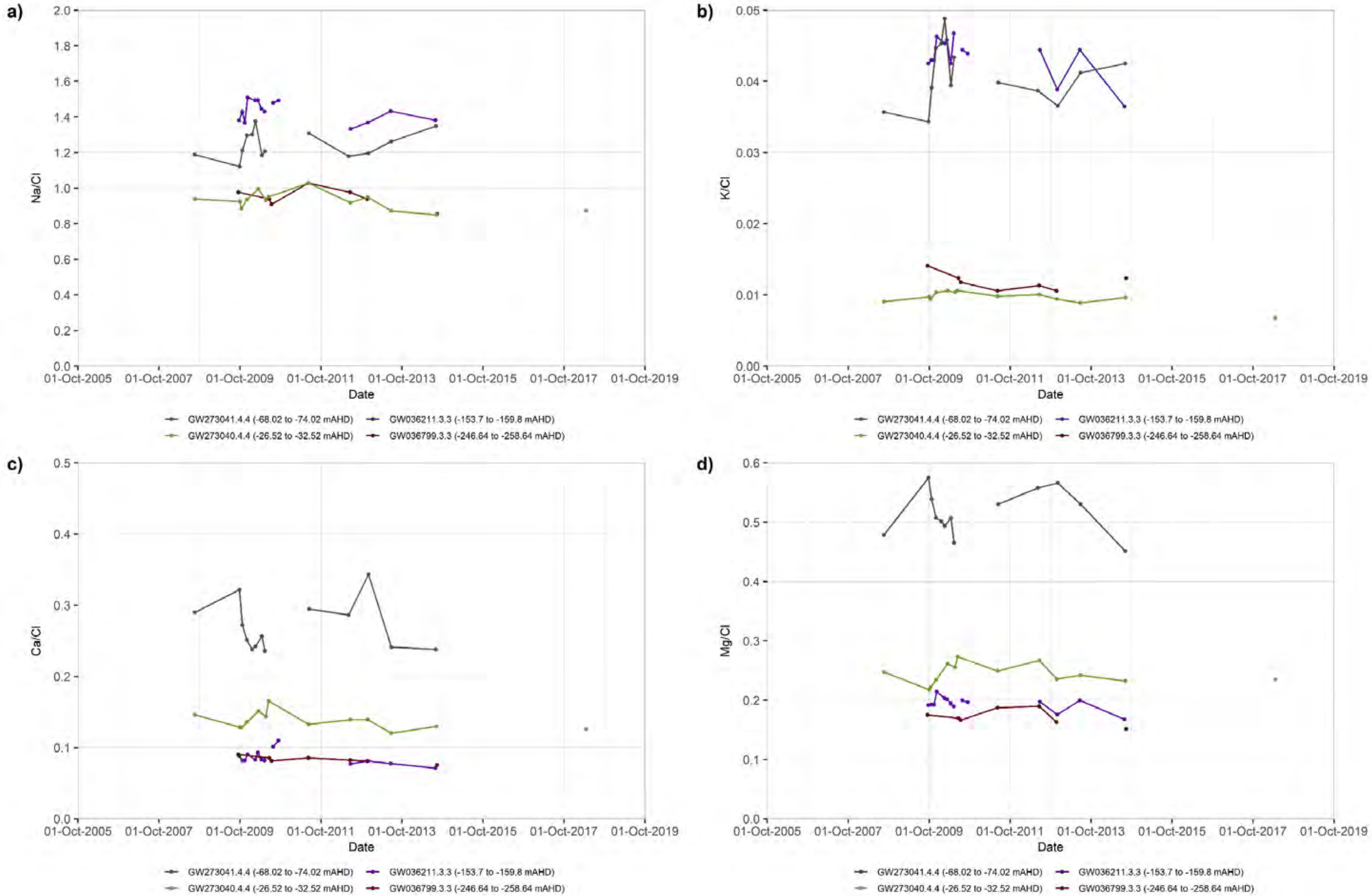


Figure 46. Detailed groundwater cation/chloride ratios in the lower Renmark Group, including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

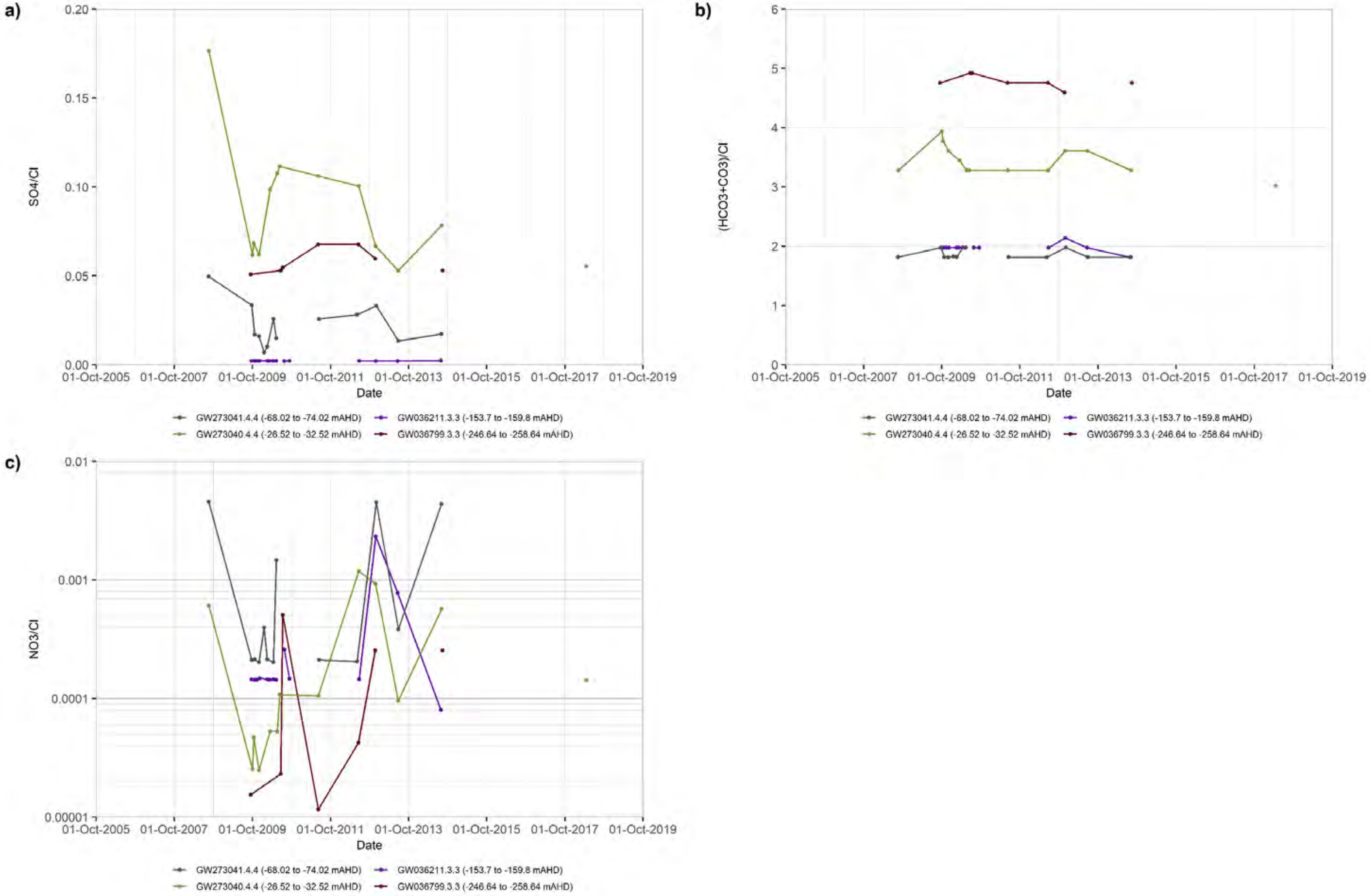


Figure 47. Detailed groundwater anion/chloride ratios in the lower Renmark Group, including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

## Irrigation parameters

Summary statistics for the Renmark Group groundwater irrigation parameters is in Table 40 to Table 42. The raw data is in ‘Appendix 3–Raw Data‘.

Total hardness as $CaCO_3$, residual alkalinity, and SAR have remained steady at most monitoring sites in the Renmark Group. Total hardness as $CaCO_3$, has increased at sites GW036396.1.1 and GW036799.2.2 in the mid-Renmark Group (Figure 49), with the SAR increasing at GW036799.1.1 in the upper-Renmark Group (Figure 48).

## Beneficial use

### Electrical conductivity and pH

Increased groundwater electrical conductivity in the Renmark Group has resulted in changes to beneficial use. Increase groundwater electrical conductivity at site GW036211.1.1 in the upper-Renmark Group has led to ‘poor quality’ drinking water, along with limiting irrigation to crops that are ‘moderately tolerant’ of salinity (Figure 36, Table 21, and Table 43). The salinity hazard category is at high risk of changing from a C3, high salinity water, to a C4 category, very-high salinity water (Table 45).

All other groundwater electrical conductivity increase has not led to changes in beneficial use during the investigation period. However, groundwater electrical conductivity should continue to be monitored in these areas to assess the risk to beneficial use in the future.

Changes to groundwater pH have not led to changes to beneficial use categories. Declining pH has meant that the fouling potential has decreased. However, if pH continues to decline, the corrosion potential could increase.

### Irrigation parameters

The total hardness as $CaCO_3$ at monitoring sites GW036799.1.1, in the upper-Renmark Group, and GW036799.3.3, lower-Renmark Group, have an increased fouling potential (Table 40, Table 42, Figure 48, Figure 50, and Table 50).

The increased total hardness as $CaCO_3$ at monitoring sites GW036396.1.1 and GW036799.2.2 in the mid-Renmark Group has not led to increased fouling or scaling potential (Figure 49, Table 41, Table 44, and Table 49). However, they could deteriorate in the future if the increasing trends continue.

The increased SAR at monitoring site GW036799.1.1 in the upper-Renmark Group has not changed the sodium hazard category of this groundwater. However, it could change in the future if the increasing trend continues.

Table 40. Summary statistics for irrigation parameters in the upper Renmark Group

| Site | Parameter | Count | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| **All** | Total hardness (mg/L as $CaCO_3$) | 46 | 62.7 | 127 | 663 |
| **All** | Residual alkalinity (mEq/L) | 46 | −7.16 | −0.15 | 0.90 |

| Site | Parameter | Count | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| All | Sodium adsorption ratio | 46 | 1.86 | 5.06 | 14.6 |
| GW036211.1.1 | Total hardness (mg/L as $CaCO_3$) | 16 | 62.7 | 110 | 173 |
| GW036211.1.1 | Residual alkalinity (mEq/L) | 16 | −1.45 | 0.00 | 0.90 |
| GW036211.1.1 | Sodium adsorption ratio | 16 | 4.23 | 5.75 | 6.93 |
| GW036799.1.1 | Total hardness (mg/L as $CaCO_3$) | 91 | 614 | 628 | 663 |
| GW036799.1.1 | Residual alkalinity (mEq/L) | 91 | −7.16 | −6.30 | −6.02 |
| GW036799.1.1 | Sodium adsorption ratio | 91 | 13.5 | 13.6 | 14.6 |
| GW273040.3.3 | Total hardness (mg/L as $CaCO_3$) | 13 | 154 | 167 | 304 |
| GW273040.3.3 | Residual alkalinity (mEq/L) | 13 | −2.95 | −0.50 | −0.10 |
| GW273040.3.3 | Sodium adsorption ratio | 13 | 4.53 | 4.95 | 7.48 |
| GW273041.3.3 | Total hardness (mg/L as $CaCO_3$) | 11 | 96.7 | 103 | 111 |
| GW273041.3.3 | Residual alkalinity (mEq/L) | 11 | −0.13 | 0.00 | 0.05 |
| GW273041.3.3 | Sodium adsorption ratio | 11 | 1.86 | 2.01 | 2.30 |

Table 41. Summary statistics for irrigation parameters in the middle Renmark Group

| Site | Parameter | Count | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| All | Total hardness (mg/L as $CaCO_3$) | 80 | 44.6 | 102 | 314 |
| All | Residual alkalinity (mEq/L) | 80 | −3.95 | 0.47 | 3.21 |
| All | Sodium adsorption ratio | 80 | 2.92 | 5.88 | 13.4 |
| GW036211.2.2 | Total hardness (mg/L as $CaCO_3$) | 14 | 39.6 | 43.9 | 48.4 |
| GW036211.2.2 | Residual alkalinity (mEq/L) | 14 | 0.87 | 0.96 | 1.45 |
| GW036211.2.2 | Sodium adsorption ratio | 14 | 4.77 | 5.14 | 5.25 |
| GW036396.1.1 | Total hardness (mg/L as $CaCO_3$) | 13 | 248 | 285 | 314 |
| GW036396.1.1 | Residual alkalinity (mEq/L) | 13 | −3.95 | −2.89 | −2.31 |
| GW036396.1.1 | Sodium adsorption ratio | 13 | 6.63 | 7.10 | 7.99 |
| GW036773.3.3 | Total hardness (mg/L as $CaCO_3$) | 15 | 96.0 | 103 | 116 |
| GW036773.3.3 | Residual alkalinity (mEq/L) | 15 | −1.03 | −0.77 | −0.60 |
| GW036773.3.3 | Sodium adsorption ratio | 15 | 2.92 | 3.16 | 3.45 |
| GW036799.2.2 | Total hardness (mg/L as $CaCO_3$) | 7 | 145 | 160 | 204 |
| GW036799.2.2 | Residual alkalinity (mEq/L) | 7 | 1.10 | 2.88 | 3.21 |
| GW036799.2.2 | Sodium adsorption ratio | 7 | 12.0 | 12.7 | 13.4 |
| GW041011.3.3 | Total hardness (mg/L as $CaCO_3$) | 14 | 49.5 | 58.4 | 66.6 |
| GW041011.3.3 | Residual alkalinity (mEq/L) | 14 | 1.04 | 1.30 | 1.57 |
| GW041011.3.3 | Sodium adsorption ratio | 14 | 5.95 | 6.79 | 7.36 |
| GW041012.3.3 | Total hardness (mg/L as $CaCO_3$) | 15 | 44.6 | 52.3 | 56.7 |
| GW041012.3.3 | Residual alkalinity (mEq/L) | 15 | 1.02 | 1.12 | 1.26 |
| GW041012.3.3 | Sodium adsorption ratio | 15 | 3.75 | 4.02 | 4.53 |

Table 42. Summary statistics for irrigation parameters in the lower Renmark Group

| Site | Parameter | Count | Minimum | Median | Maximum |
|---|---|---|---|---|---|
| All | Total hardness (mg/L as $CaCO_3$) | 42 | 29.3 | 76 | 462 |
| All | Residual alkalinity (mEq/L) | 42 | −4.5 | 0.31 | 1.44 |
| All | Sodium adsorption ratio | 42 | 2.44 | 6.41 | 16.2 |
| GW036211.3.3 | Total hardness (mg/L as $CaCO_3$) | 13 | 29.3 | 37.6 | 41.6 |
| GW036211.3.3 | Residual alkalinity (mEq/L) | 13 | 1.15 | 1.23 | 1.44 |
| GW036211.3.3 | Sodium adsorption ratio | 13 | 5.92 | 6.35 | 6.49 |
| GW036799.3.3 | Total hardness (mg/L as $CaCO_3$) | 6 | 350 | 405 | 462 |
| GW036799.3.3 | Residual alkalinity (mEq/L) | 6 | −4.5 | −3.31 | −2.05 |
| GW036799.3.3 | Sodium adsorption ratio | 6 | 13.7 | 15.0 | 16.2 |
| GW273040.4.4 | Total hardness (mg/L as $CaCO_3$) | 12 | 251 | 271 | 293 |
| GW273040.4.4 | Residual alkalinity (mEq/L) | 12 | −2.52 | −1.98 | −1.42 |
| GW273040.4.4 | Sodium adsorption ratio | 12 | 7.40 | 8.02 | 8.76 |
| GW273041.4.4 | Total hardness (mg/L as $CaCO_3$) | 11 | 62.2 | 73.9 | 86.0 |
| GW273041.4.4 | Residual alkalinity (mEq/L) | 11 | 0.20 | 0.38 | 0.62 |
| GW273041.4.4 | Sodium adsorption ratio | 11 | 2.44 | 2.78 | 3.09 |

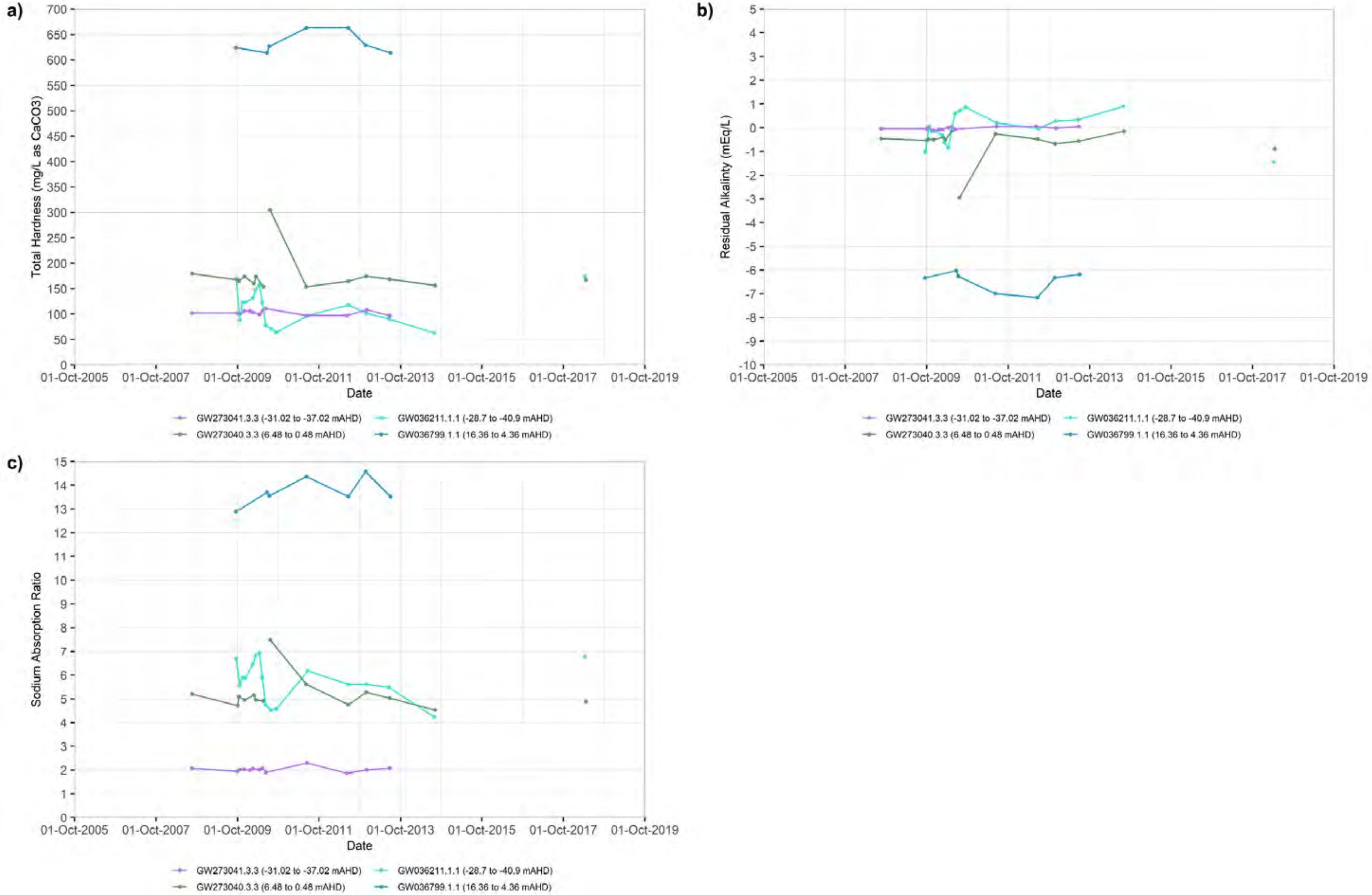


Figure 48. Irrigation parameters within the groundwater of the upper Renmark Group, including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

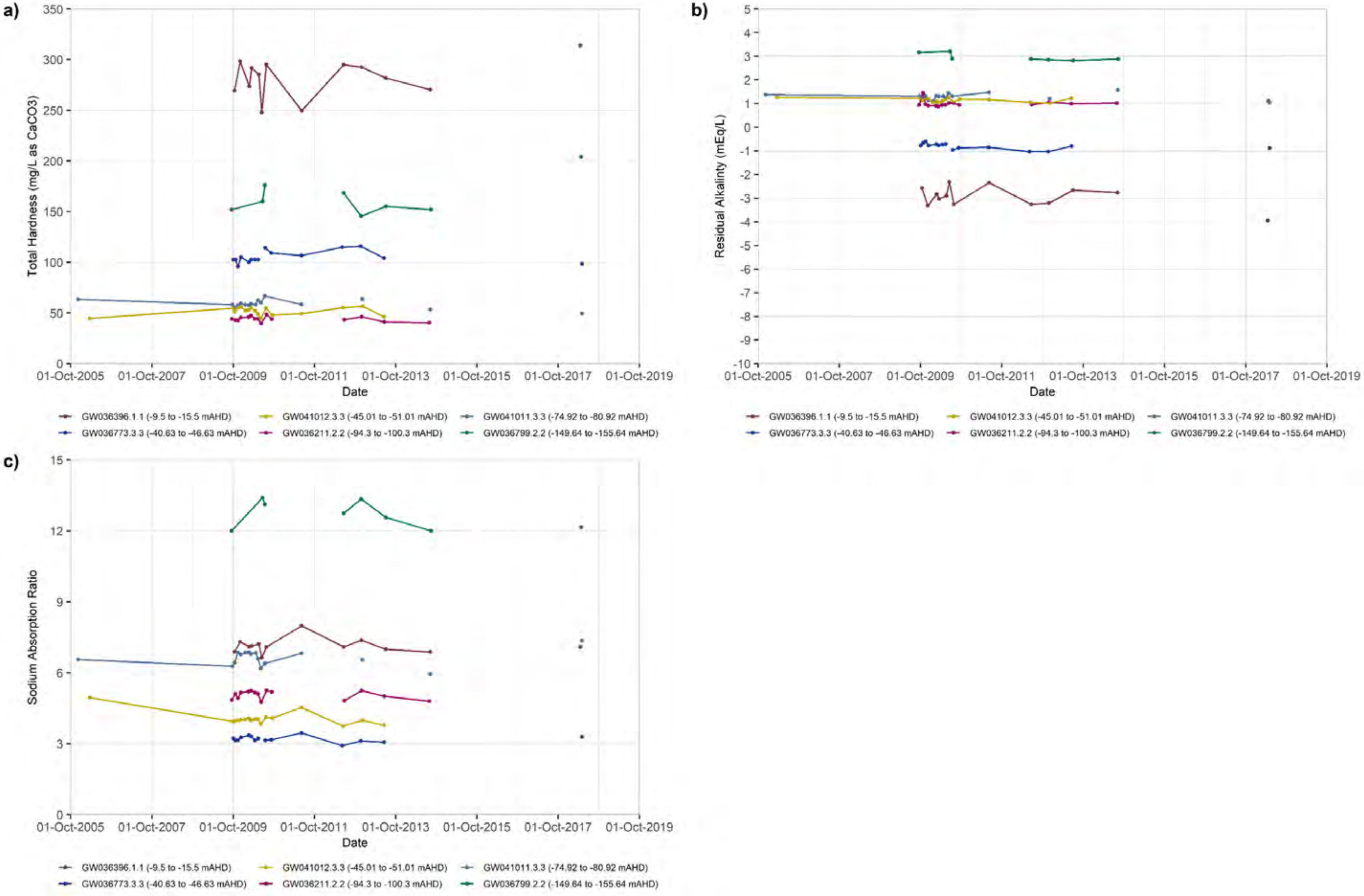


Figure 49. Irrigation parameters within the groundwater of the mid Renmark Group, including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

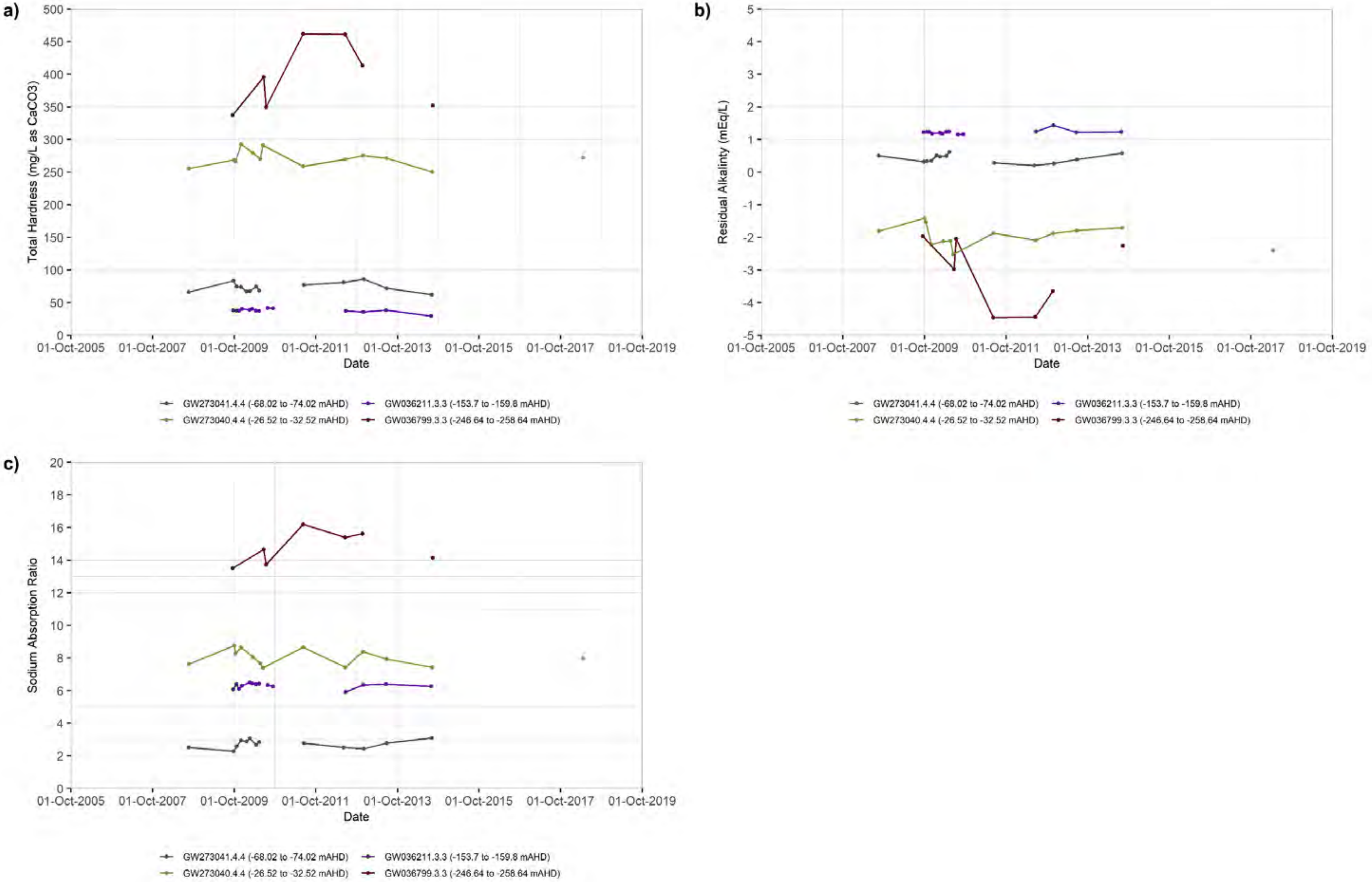


Figure 50. Irrigation parameters within the groundwater of the lower Renmark Group, including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

# Geochemical mixing between aquifers

## Shepparton Formation and Calivil Formation

There are 5 sites with nested monitoring bores screened within the Shepparton Formation and the Calivil Formation. These sites are:

- GW036773, with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation,
- GW273041 with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation,
- GW273040 with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation,
- GW041012 with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation, and
- GW041011 with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation.

The hydraulic connectivity between the Shepparton Formation and the Calivil Formation at monitoring sites GW036773, GW273040, and GW041012 is inferred due to similar hydrograph responses (Figure 19, Figure 23, Figure 24, and Figure 25). There are also indications in the geochemistry of vertical leakage from the Shepparton Formation into the Calivil Formation. Similar trends in $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$, $SO_4^{2-}/Cl^-$, $(HCO_3^-+CO_3^{2-})/Cl^-$, and $NO_3^-/Cl^-$ at monitoring site GW036773.1.1 in the Shepparton Formation and GW036773.2.2 in the Calivil Formation suggests a geochemical connection between the sites, with the trend in the Cavil Formation moving toward that of the Shepparton Formation (Figure 53 and Figure 54). This is also present in the $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ trend (Figure 52).

Despite the similar hydrograph responses between monitoring sites GW273040.1.1 in the Shepparton Formation and GW273040.2.2 in the Calivil Formation, there is little similarity between the geochemical trends nor convergence of geochemistry at these sites (Figure 52, Figure 53, and Figure 54). This suggests that lateral flow within the Calivil Formation may be influencing the groundwater chemistry at this site more than localised vertical leakage from the Shepparton Formation. This could explain the similar $(Na^++K^+)/(Ca^{2+}+Mg^{2+})$ and $(Cl^-+SO_4^{2-})/(HCO_3^-+CO_3^{2-})$ behaviour between monitoring sites GW036773.2.2 and GW273040.2.2 in the Calivil Formation (Figure 52), along with the similarity of $Na^+/Cl^-$, $(HCO_3^-+CO_3^{2-})/Cl^-$, and $NO_3^-/Cl^-$. The hydrochemistry at these monitoring sites should be monitored in the future to detect vertical groundwater flow from the Shepparton Formation into the Calivil Formation at this location.

Similar trends in $Na^+/Cl^-$, $(HCO_3^-+CO_3^{2-})/Cl^-$, and $NO_3^-/Cl^-$ between monitoring sites GW041012.1.1 in the Shepparton Formation and GW041012.2.2 in the Calivil Formation, along with ion trend convergence between these sites, suggests that localised vertical leakage from the Shepparton Formation is predominately influencing the geochemistry trends for $Na^+$, $HCO_3^-+CO_3^{2-}$, and $NO_3^-$ (Figure 53, Figure 54). This also suggests an influence of deep river leakage given the proximity of the Murrumbidgee River to this monitoring sites.

There appears to be little similarity between geochemical trends at monitoring sites GW273041, with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation, and GW041011, with pipe 1.1 in the Shepparton Formation and pipe 2.2 in the Calivil Formation, nor convergence of geochemistry at these sites (Figure 52, Figure 53, and Figure 54). This suggests that lateral flow within the Calivil Formation is influencing the groundwater chemistry at these sites more than localised vertical leakage from the Shepparton Formation. This is supported by the dissimilar hydrograph responses at these sites (Figure 21, Figure 23, Figure 24, and Figure 25).

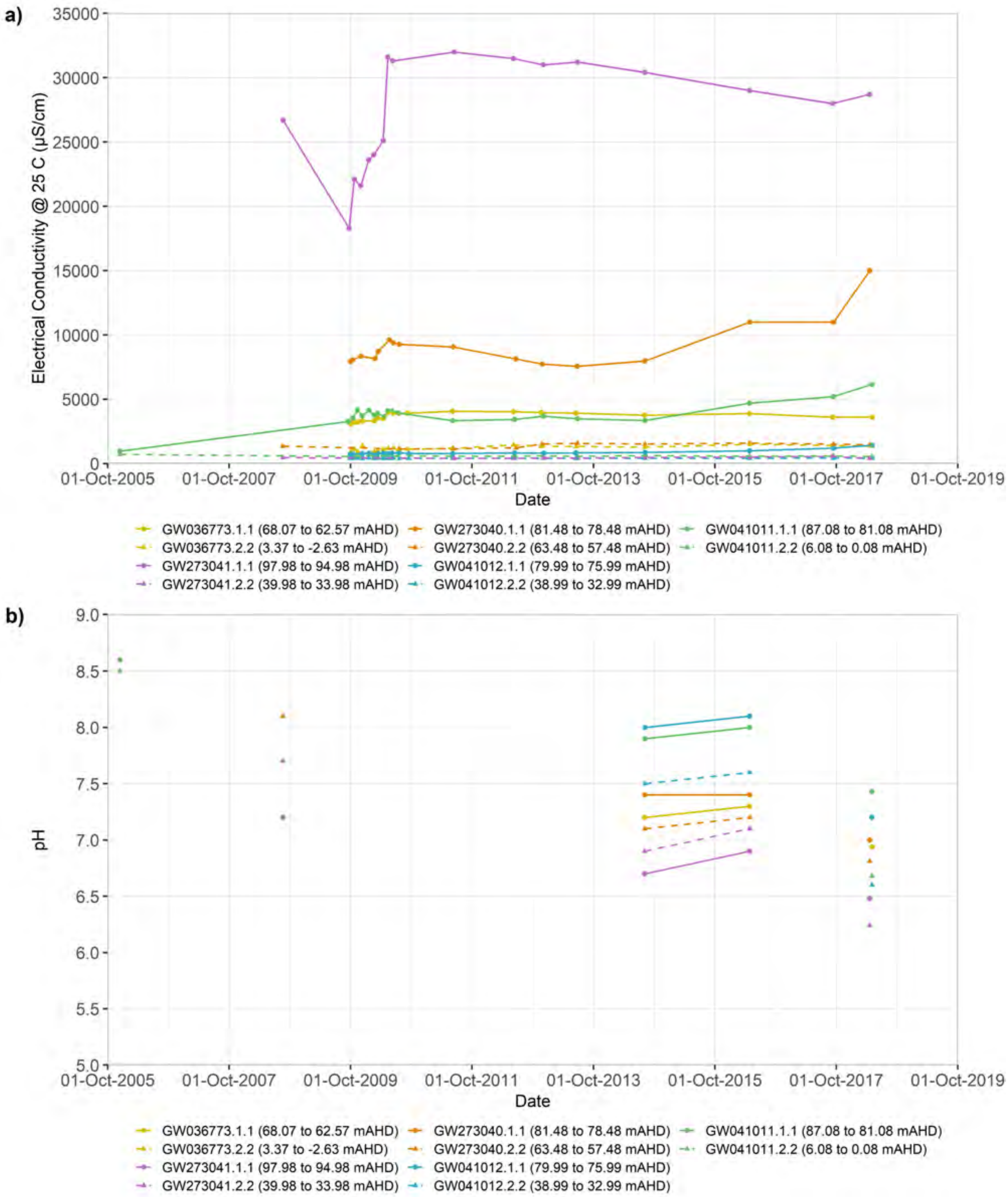


Figure 51. Groundwater (a) electrical conductivity (b) and pH at sites nested within the Shepparton Formation (solid line, circle marker) and Calivil Formation (dashed line, triangle marker)

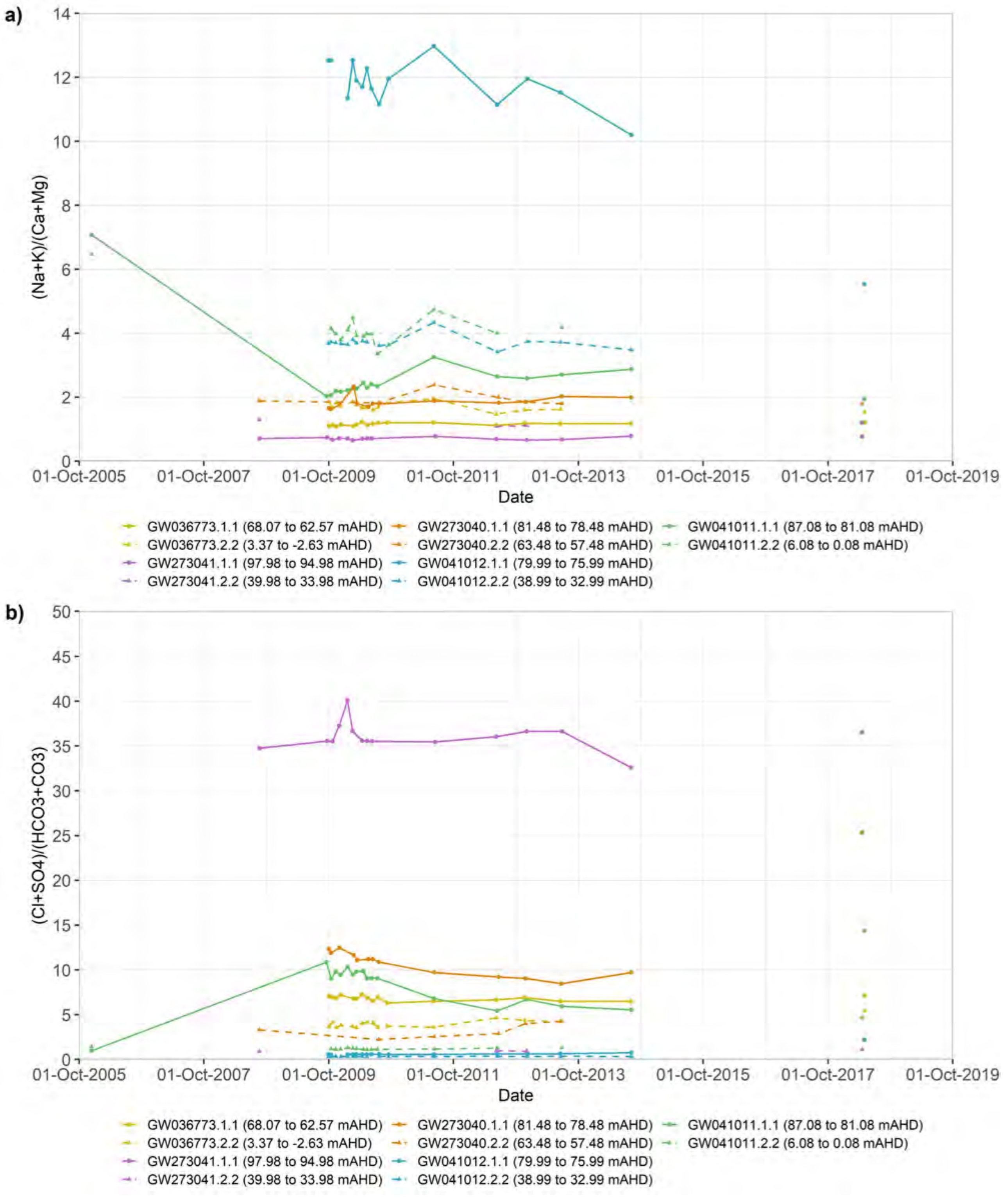


Figure 52. Groundwater (a) cation and (b) anion ratios at sites nested within the Shepparton Formation (solid line, circle marker) and Calivil Formation (dashed line, triangle marker)

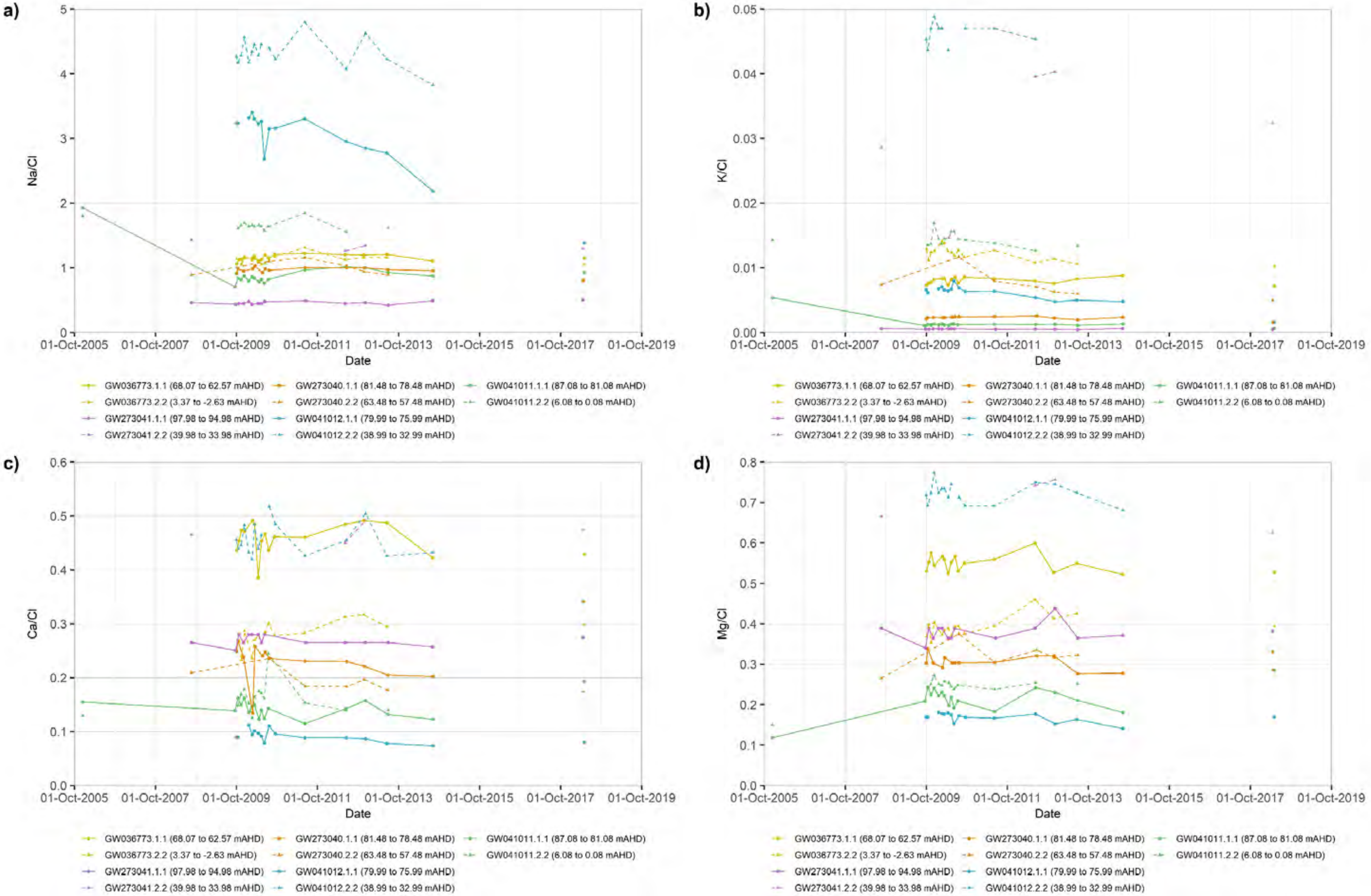


Figure 53. Detailed groundwater cation/chloride ratios at sites nested within the Shepparton Formation (solid line, circle marker) and Calivil Formation (dashed line, triangle marker), including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

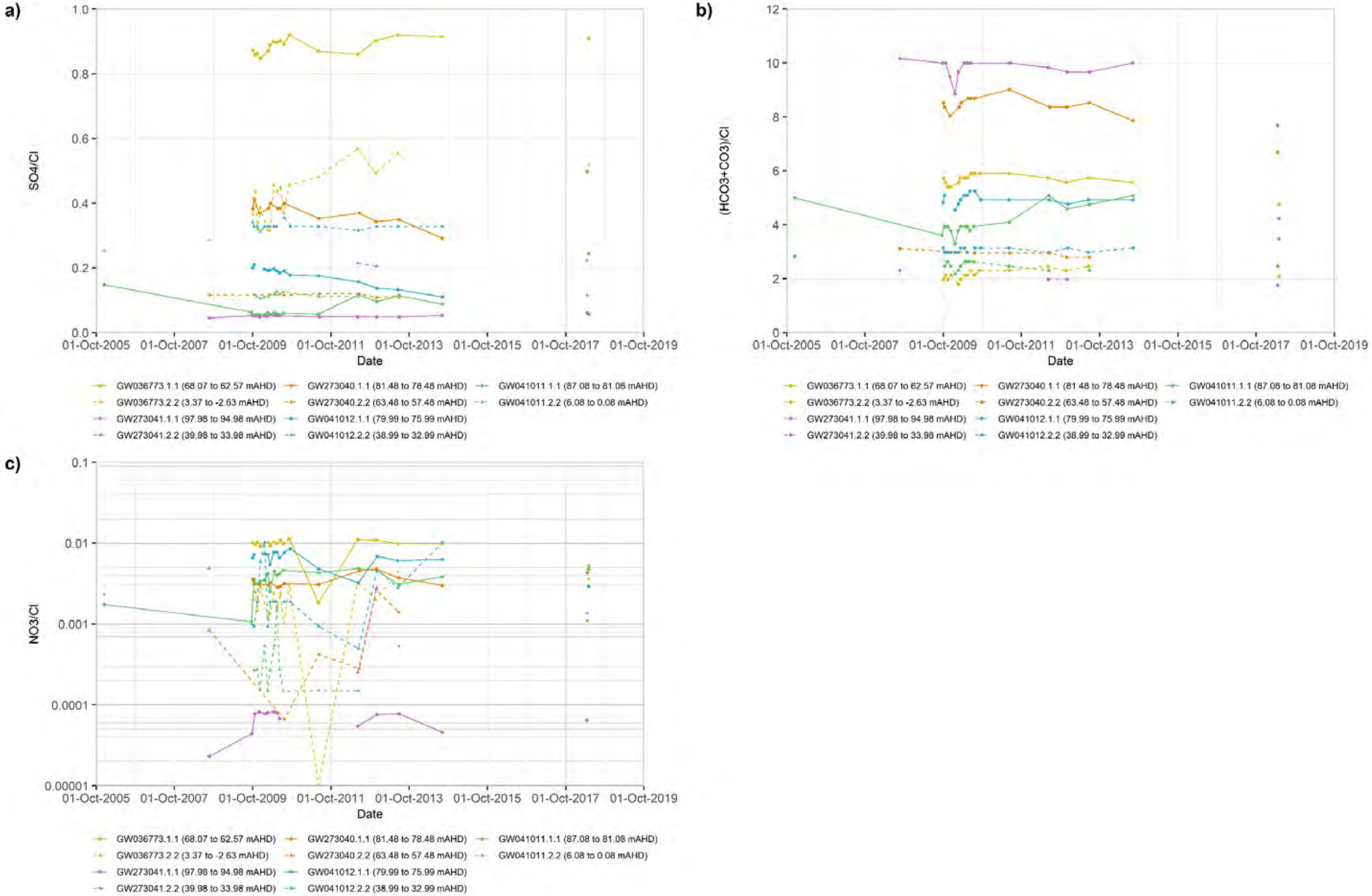


Figure 54. Detailed groundwater anion/chloride ratios in at sites nested within the Shepparton Formation (solid line, circle marker) and Calivil Formation (dashed line, triangle marker), including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

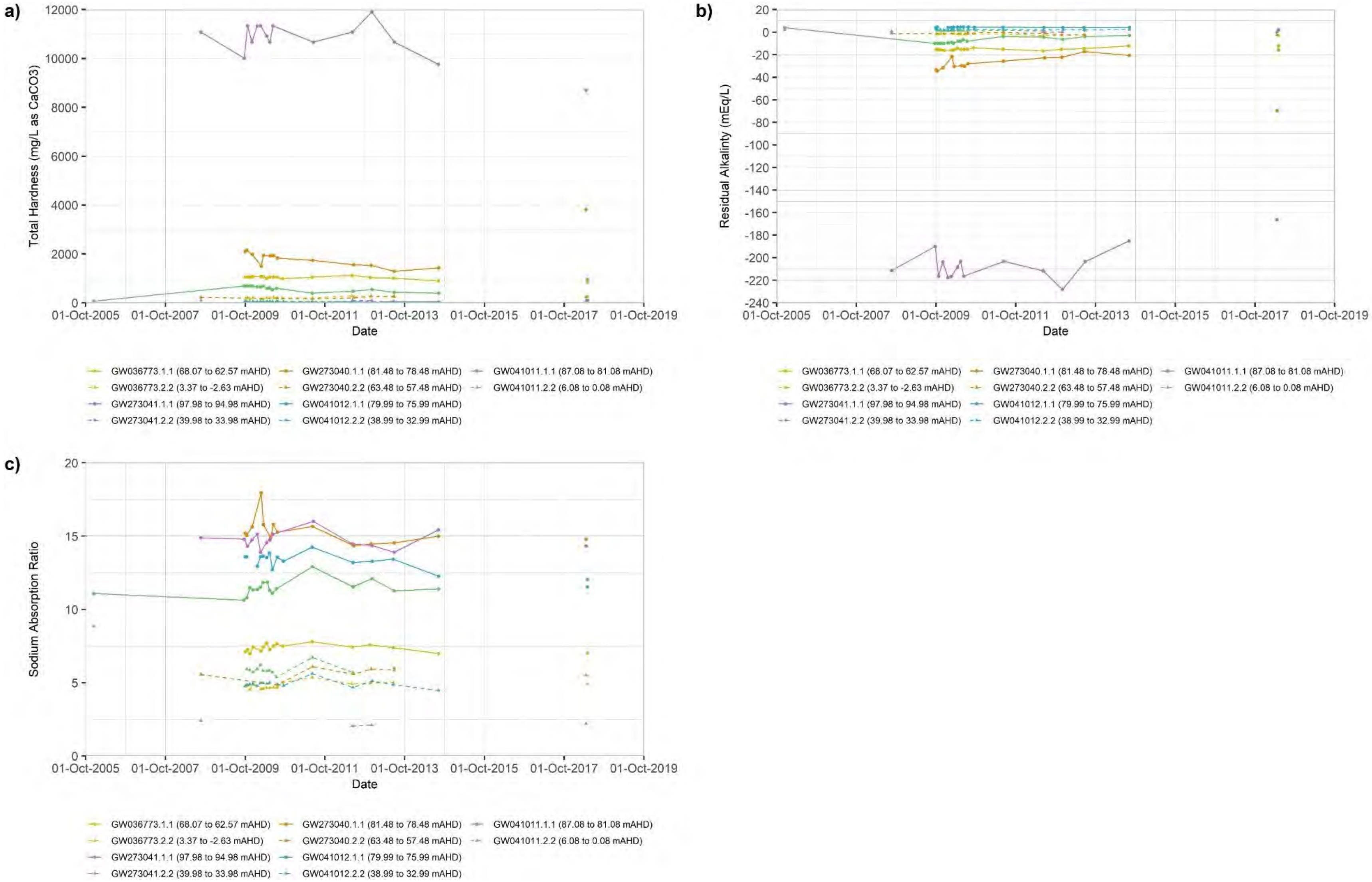


Figure 55. Irrigation parameters within the groundwater at sites nested within the Shepparton Formation (solid line, circle marker) and Calivil Formation (dashed line, triangle marker), including (a) total hardness (mg/L as $CaCO_3$), (b) residual alkalinity, and the (c) sodium absorption ratio

## Calivil Formation and Renmark Group

There are 5 sites with nested monitoring bores screened within the Calivil Formation and Renmark Group. These sites are:

- GW036773, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the mid-Renmark Group
- GW273041, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group
- GW273040, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group
- GW041012, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the mid-Renmark Group
- GW041011, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the mid-Renmark Group.

There are indications that hydraulic connectivity between the Calivil Formation and the Renmark Group occurs at all monitoring sites, with the Calivil Formation and Renmark Group hydrographs more similar at monitoring sites GW273041, GW041012, and GW041011 (Figure 23, Figure 24, and Figure 25). This could represent a higher degree of hydraulic interconnectivity when groundwater extraction occurs in either of the aquifers. For monitoring sites GW036773 and GW273040, the hydrographs can be explained better by a delayed hydraulic response. The hydrograph at GW036773 may represent a delayed response within the Renmark Group due to groundwater extraction in the Calivil Formation. Similarly, the hydrograph at GW273040 may represent a delayed response within the Calivil Formation and Shepparton Formation to ground extraction within the Renmark Group (Figure 23, Figure 24, and Figure 25).

However, at monitoring site GW273040, the hydrograph responses in the Calivil Formation and Shepparton Formation are very similar. This similarity suggests that vertical leakage from the overlying Shepparton Formation may be affecting the hydrograph response in the Calivil Formation more than groundwater extraction from the underlying Renmark Group (Figure 23, Figure 24, and Figure 25). A detailed assessment of the magnitude of vertical leakage between the monitoring sites would help to resolve this observation.

Despite the difference in hydrograph trends at monitoring site GW036773, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the mid-Renmark Group, dissolved geochemistry trends in $Na^+/Cl^-$, $K^+/Cl^-$, $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$, with $NO_3^-/Cl^-$ trend lines appearing to converge, suggest that there is geochemical mixing occurring between the 2 aquifers (Figure 58). However. the difference in groundwater electrical conductivity, $SO_4^{2-}/Cl^-$, and $(HCO_3^-+CO_3^{2-})/Cl^-$ suggests that lateral flow within the Renmark Formation is also occurring. Optimised mixing models could help to resolve the relative contribution of vertical leakage from the Calivil Formation and lateral flow from within the Renmark Group on groundwater geochemistry at this monitoring site.

Similar hydrograph responses between the Calivil Formation and upper-Renmark Group at monitoring site GW273041, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group, coupled with similar ion/$Cl^-$ trends and values, suggest that there is geochemical mixing occurring between the 2 aquifers (Figure 23, Figure 24, Figure 25, Figure 58, and Figure 59). The difference in $SO_4^{2-}/Cl^-$could indicate higher $SO_4^{2-}/Cl^-$ in the Calivil Formation at upstream sites including GW036773.2.2 and GW273041.2.2 and/or localised occurrence of sulfide minerals (Figure 59).

Despite a dissimilar hydrograph response between the Calivil Formation and Renmark Group at monitoring site GW273040, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the upper-Renmark Group, there are indications that geochemical mixing is occurring between the 2 aquifers. Similar trends and ranges of $Na^+/Cl^-$, $SO_4^{2-}/Cl^-$, and $NO_3^-/Cl^-$ suggest that localised vertical leakage from the Calivil Formation into the Renmark Group at monitoring site GW273040 is occurring. Less-similar trends in $K^+/Cl^-$, $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$ and $(HCO_3^-+CO_3^{2-})/Cl^-$ suggest that lateral flow within the aquifers is also a significant contributor to Renmark Group geochemistry (Figure 23, Figure 24, Figure 25, Figure 58, and Figure 59). Optimised mixing models could help to resolve the relative contribution of vertical leakage from the Calivil Formation and lateral flow from within the Renmark Group on groundwater geochemistry at this monitoring site.

For monitoring sites GW041012 and GW041011, with pipe 2.2 in the Calivil Formation and pipe 3.3 in the mid-Renmark Group, similar hydrograph trends along with similar dissolved geochemistry trends in $Na^+/Cl^-$, $K^+/Cl^-$, $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$, with $NO_3^-/Cl^-$ suggests that vertical leakage from the Calivil Formation into the Renmark Group is a significant contribution to dissolved cation and nitrate geochemistry (Figure 23, Figure 24, Figure 25, Figure 58, and Figure 59). The difference in groundwater electrical conductivity, $SO_4^{2-}/Cl^-$, and $(HCO_3^-+CO_3^{2-})/Cl^-$ suggests that lateral flow within the Renmark Formation influences the overall dissolved ion load and anion geochemistry more than vertical leakage from the Calivil Formation (Figure 56 and Figure 59). Optimised mixing models could help to resolve the relative contribution of vertical leakage from the Calivil Formation and lateral flow from within the Renmark Group on groundwater geochemistry at this monitoring site.

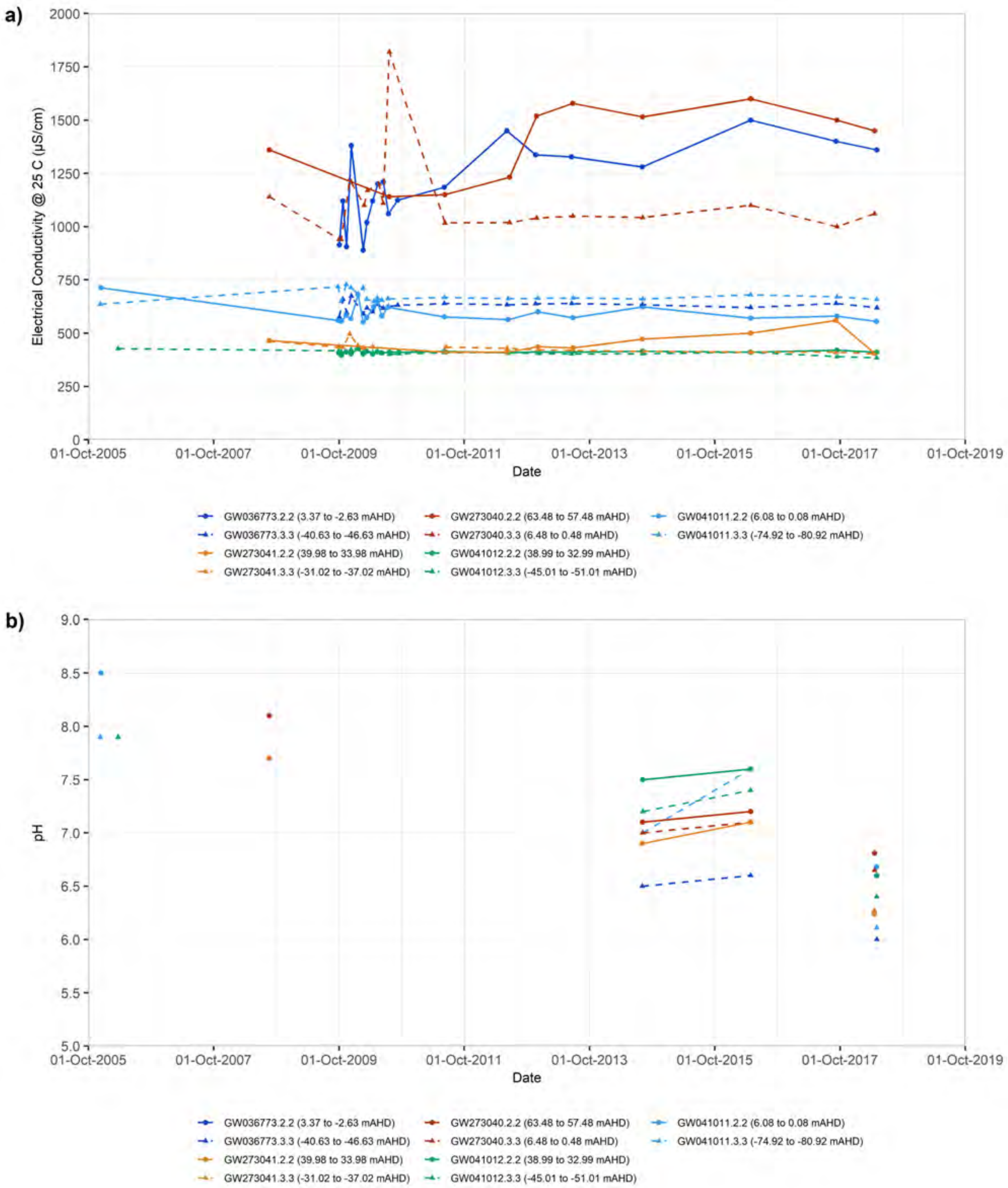


Figure 56. Groundwater (a) electrical conductivity (b) and pH at sites nested within Calivil Formation (solid line, circle marker) and Renmark Group (dashed line, triangle marker)

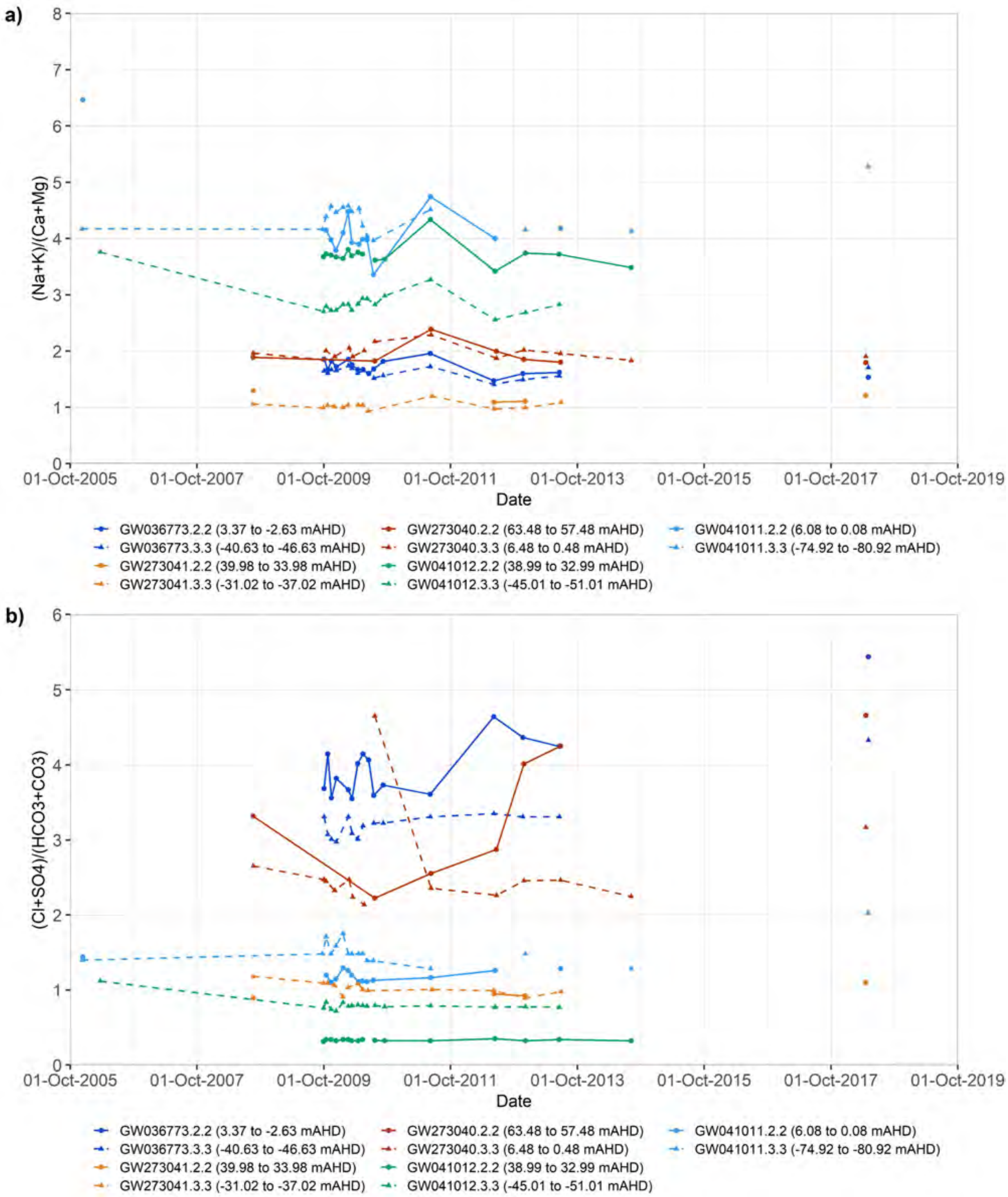


Figure 57. Groundwater (a) cation and (b) anion ratios at sites nested within the Calivil Formation (solid line, circle marker) and Renmark Group (dashed line, triangle marker)

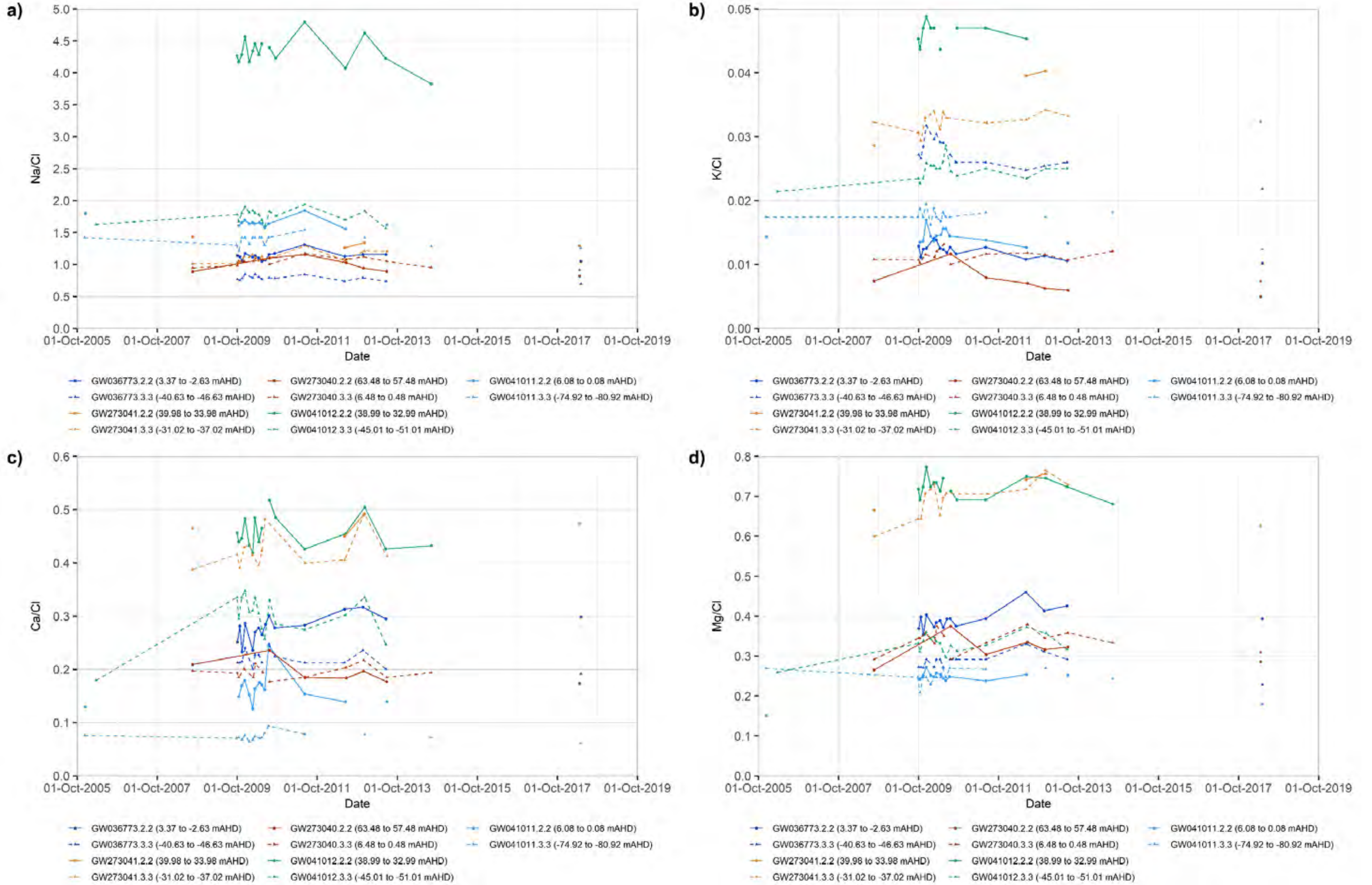


Figure 58. Detailed groundwater cation/chloride ratios at sites nested within the Calivil Formation (solid line, circle marker) and Renmark Group (dashed line, triangle marker), including (a) Na$^+$/Cl$^-$, (b) K$^+$/Cl$^-$, (c) Ca$^{2+}$/Cl$^-$, and (d) Mg$^{2+}$/Cl$^-$

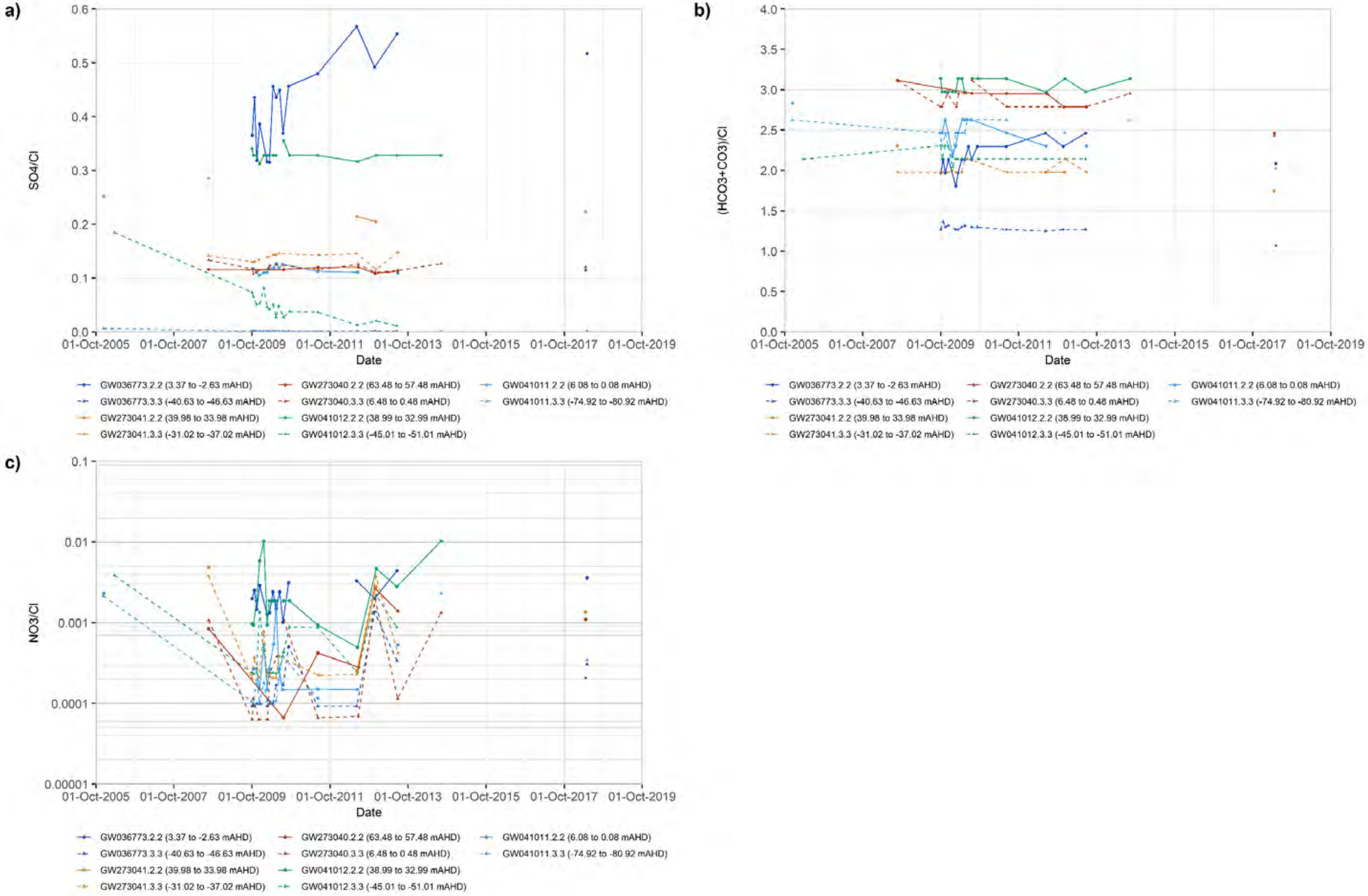


Figure 59. Detailed groundwater anion/chloride ratios in at sites nested within the Calivil Formation (solid line, circle marker) and Renmark Group (dashed line, triangle marker), including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

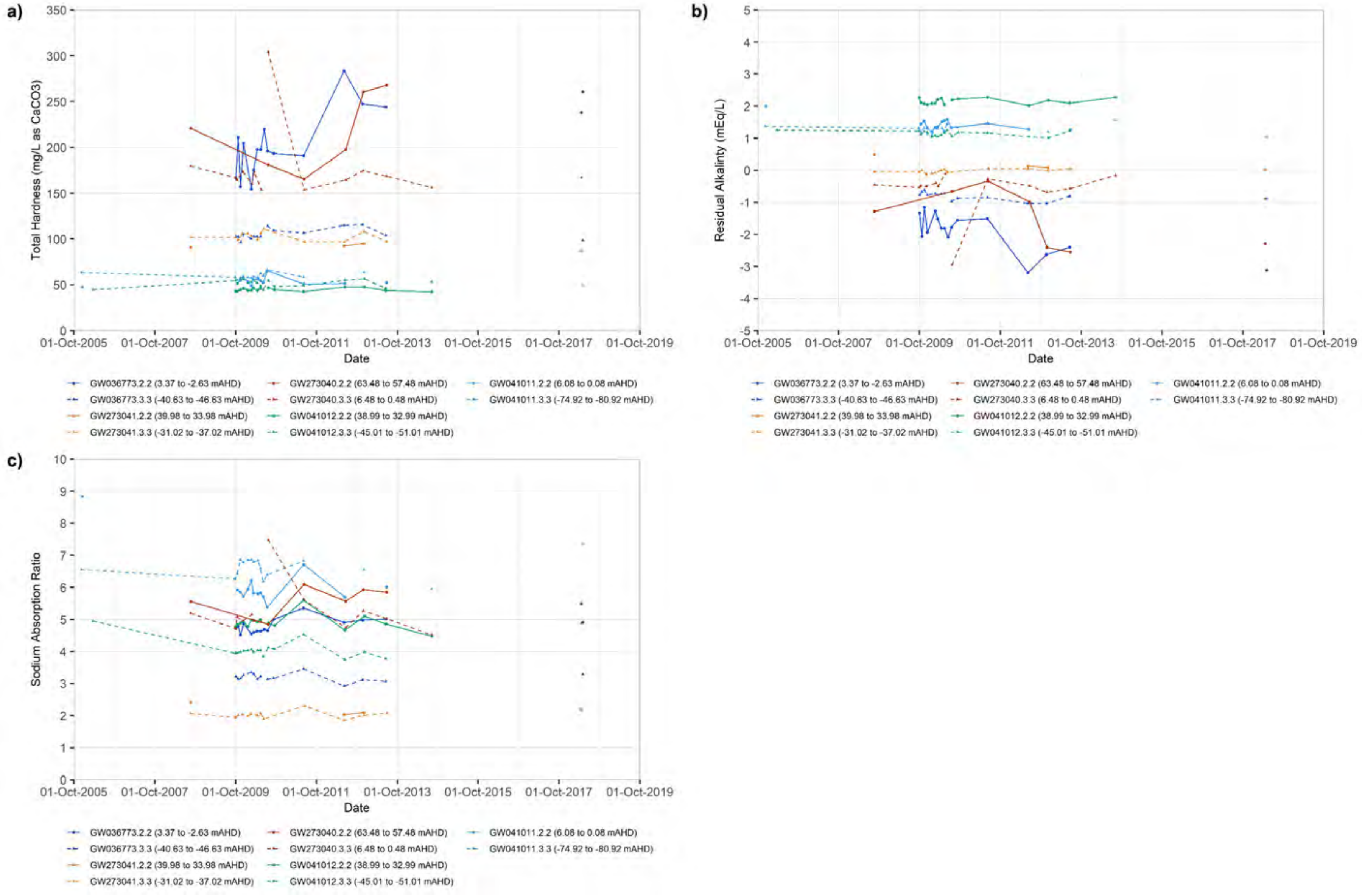


Figure 60. Detailed groundwater Irrigation parameters at sites nested within the Calivil Formation (solid line, circle marker) and Renmark Group (dashed line, triangle marker), including (a) total hardness, (b) residual alkalinity, and (c) sodium absorption ratio

## Renmark Group (upper, middle, and lower)

There are 4 monitoring sites screened across the Renmark Group. These include:

- GW273041, with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group
- GW273040, with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group
- GW036211, with pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the mid-Renmark Group, and pipe 3.3 in the lower-Renmark Group
- GW036799, with pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the mid-Renmark Group, and pipe 3.3 in the lower-Renmark Group

Hydrograph responses to drawdown and recovery across the upper, middle, and lower Renmark Group are extremely similar to each other at monitoring sites GW273041, with pipe 3.3 in the upper Renmark Group and pipe 4.4 in the lower-Renmark Group, GW273040 with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group, and GW063211 with pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the mid-Renmark Group, and pipe 3.3 in the lower-Renmark Group. This indicates high hydraulic connectivity throughout the Renmark Group (Figure 22, Figure 23, Figure 24, and Figure 25).

Differing hydrograph responses at monitoring site GW036799, with pipe 1.1 in the upper-Renmark Group, pipe 2.2 in the mid-Renmark Group, and pipe 3.3 in the lower-Renmark Group, (Figure 22, Figure 23, Figure 24, and Figure 25) may reflect the geographical separation of this monitoring site from the main irrigation areas in the Lower Murrumbidgee groundwater sources. It may also reflect broader processes influencing groundwater in different areas of the Renmark Group in the distal area of the groundwater source. Groundwater depressurisation in the mid-Renmark Group upstream of monitoring site GW036799, plus localised groundwater extraction in the lower-Renmark Group, could explain hydrograph trends and behaviours.

The similar hydrograph responses along with similar groundwater electrical conductivity and dissolved geochemistry trends and ranges at monitoring site GW273041, with pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group, indicate a degree of geochemical homogenisation throughout the Renmark Group at this site (Figure 23, Figure 24, Figure 25, Figure 61, Figure 63, and Figure 64). Differences in $K^+/Cl^-$, $Ca^{2+}/Cl^-$, $Mg^{2+}/Cl^-$ and $SO_4^{2-}/Cl^-$ ranges can be attributed to vertical leakage and mixing from the overlying Calivil Formation (Figure 63 and Figure 64). Hydrograph levels and behaviour in the upper-Renmark Group (GW273041.3.3) are also more similar to the Calivil Formation (GW273041.2.2) than the lower-Renmark Group (GW273041.4.4) (Figure 23, Figure 24, and Figure 25), suggesting a higher degree of hydraulic connectivity between the upper-Renmark Group with the Calivil Formation than with the lower-Renmark Group.

Geochemistry trends observed at monitoring site GW273041 are also observed at monitoring site GW273040, in pipe 3.3 in the upper-Renmark Group and pipe 4.4 in the lower-Renmark Group. However, the range of ion/$Cl^-$ values are more similar between the upper-Renmark Group and lower-Renmark Group at monitoring site GW273040 than at monitoring site

GW273041 (Figure 63 and Figure 64). This can be explained by the hydrograph response in the upper-Renmark Group (GW273040.3.3) being more similar to the lower-Renmark Group (GW273040.4.4) than the Calivil Formation (GW273040.2.2) (Figure 23, Figure 24, and Figure 25). This suggests that groundwater in the upper-Renmark Group is interacting more with groundwater in the lower-Renmark Group than it is with groundwater in the Calivil Formation.

The ion/$Cl^-$ ratios and trends in the upper-Renmark Group at monitoring site GW036211 pipe 1.1 are significantly different to those in the mid-Renmark Group and lower-Renmark Group, GW036211.2.2 and GW036211.3.3, respectively, despite similar hydrograph levels and trends across the Renmark Group at this monitoring site (Figure 23, Figure 24, Figure 25, Figure 63, and Figure 64). This can be explained by possible vertical leakage from the Calivil Formation into the upper-Renmark Group at GW036211.1.1, with this leakage not extending down into the mid-and lower-Renmark Group. There are no monitoring sites screen within the Calivil Formation or Shepparton Formation nearby to confirm this process.

As with most of the Renmark Group, geochemistry ratio trends are similar to each other throughout the Renmark Group at monitoring site GW036799 (Figure 63 and Figure 64). However, this monitoring site is unique in that groundwater electrical conductivity values are lowest in the mid-Renmark Group and are higher in both the upper- and lower-Renmark Group (Figure 61). Further, the electrical conductivities in the upper- and lower-Renmark Group at this monitoring site are the highest reported (Table 21, Table 22, Table 23, and Figure 61).

This trend is also seen in the ion/$Cl^-$ data, where trends and ranges in the ion/$Cl^-$ ratios is in one direction from upper- to mid-Renmark Group, and then reverses going from middle- to lower-Renmark Group (Figure 63 and Figure 64). A possible explanation for this occurrence could be a plume of relatively fresh groundwater is moving laterally through the mid-Renmark Group, induced by the depressurisation and resultant water level drop that is occurring at this monitoring site. Higher groundwater salinisation in the upper-Renmark Group at GW036799.1.1 could result from vertical leakage from the overlying Shepparton and Calivil Formation. Higher groundwater salinisation in the lower-Renmark Group at GW036799.3.3 may occur due to the lateral flow of saline groundwater within the lower-Renmark Group.

There are no monitoring sites screened within the Calivil Formation or Shepparton Formation nearby to confirm if vertical leakage is a contributing factor. There are no neighbouring monitoring sites in proximity to confirm how lateral flow could influence the distribution of groundwater salinity observed at this monitoring site.

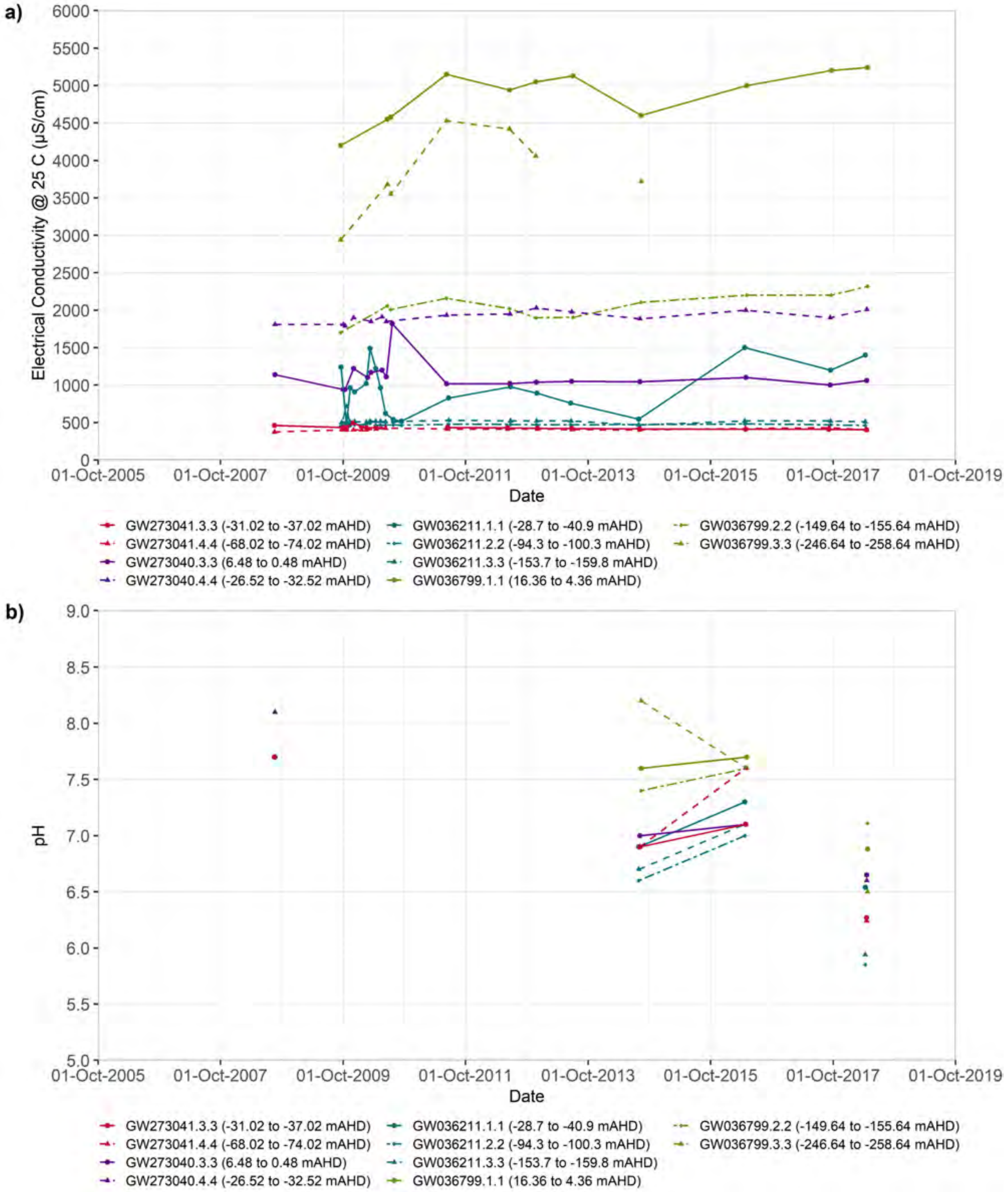


Figure 61. Groundwater (a) electrical conductivity (b) and pH at sites nested within the upper Renmark Group (solid line, circle marker), middle Renmark Group (-dash line, diamond marker), and lower Renmark Group (dashed line, triangle marker)

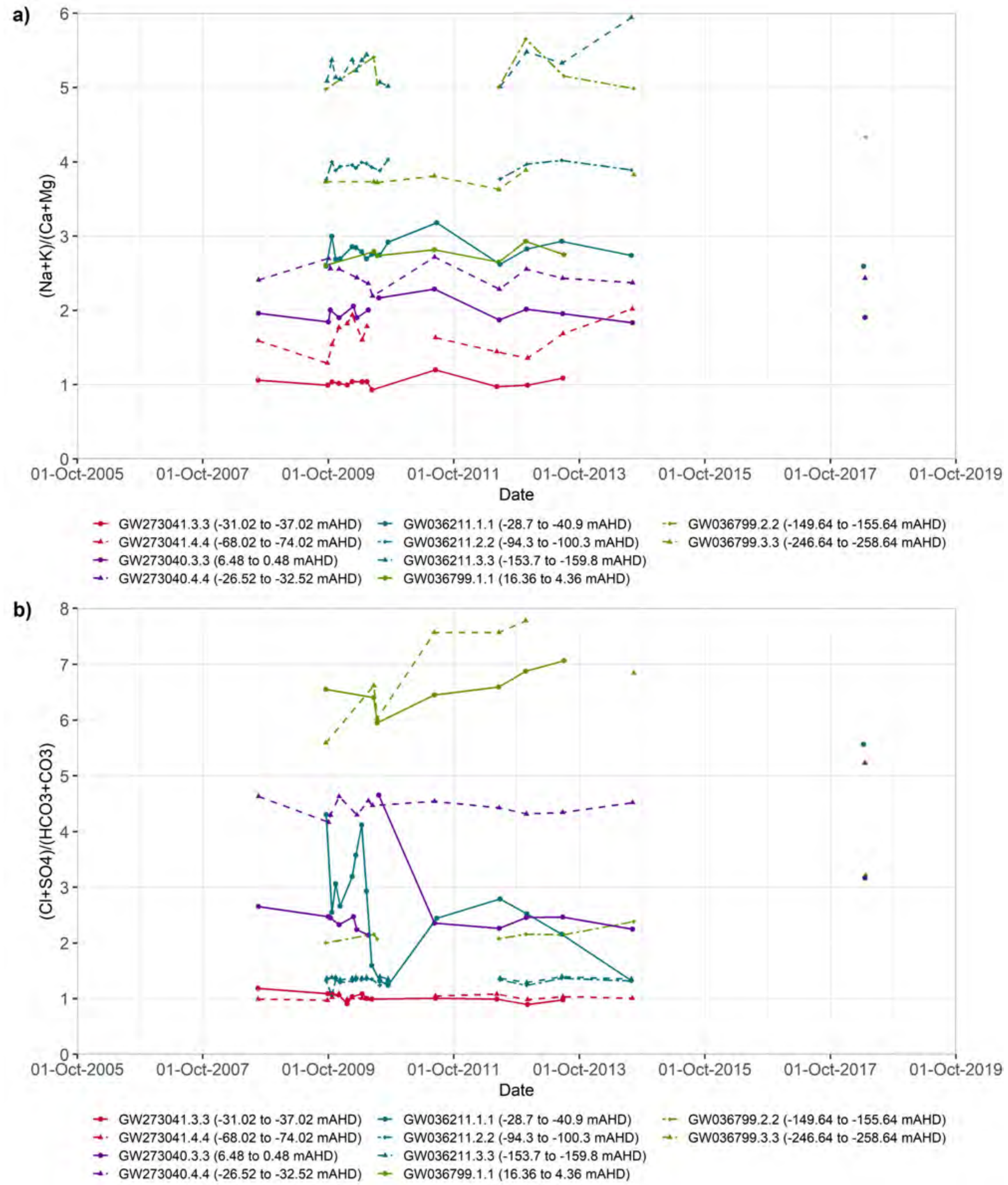


Figure 62. Groundwater (a) cation and (b) anion ratios at sites nested within the upper Renmark Group (solid line, circle marker), middle Renmark Group (2-dash line, diamond marker), and lower Renmark Group (dashed line, triangle marker)

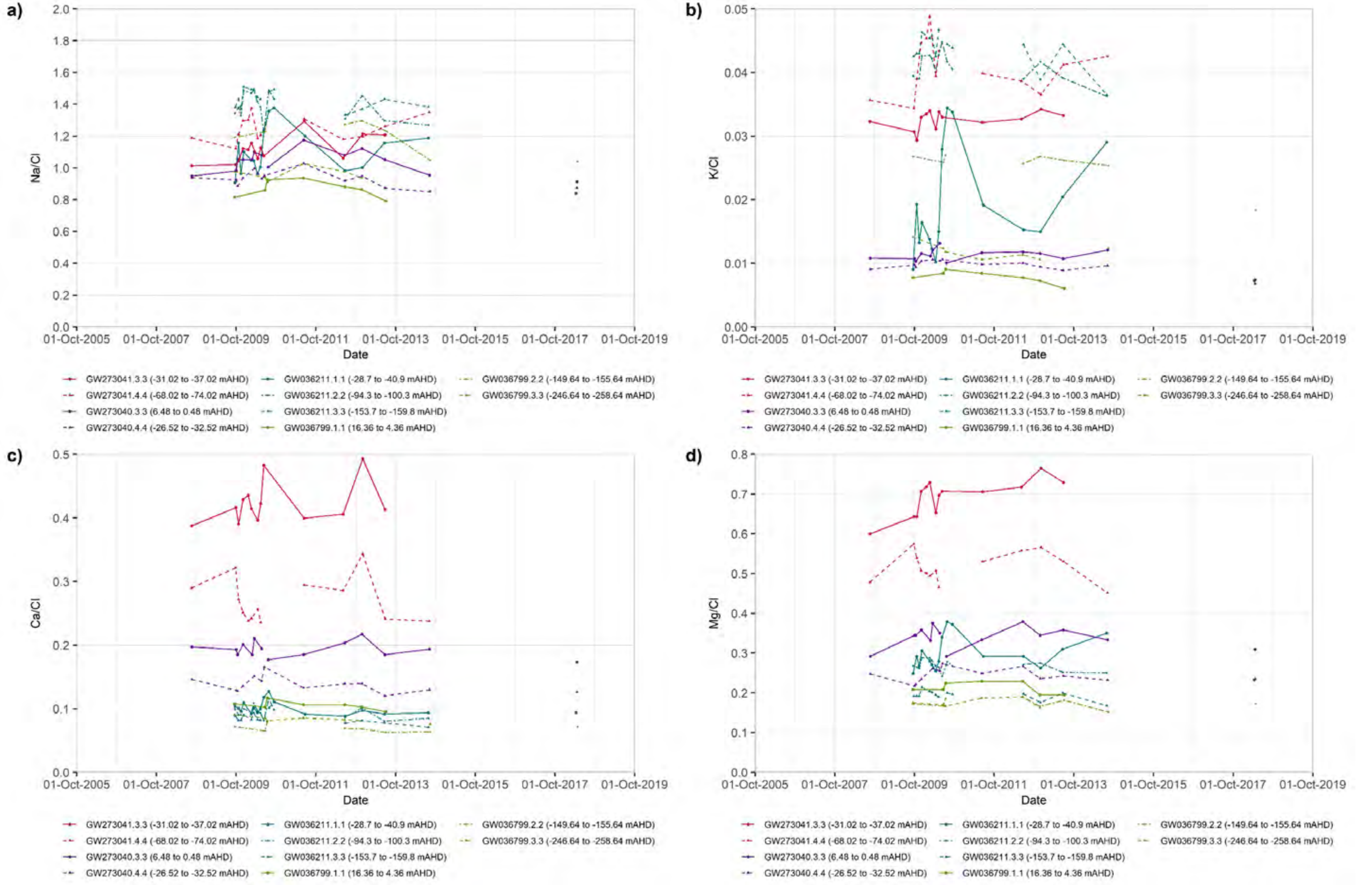


Figure 63. Detailed groundwater cation/chloride ratios at sites nested within the upper Renmark Group (solid line, circle marker), middle Renmark Group (2-dash line, diamond marker), and lower Renmark Group (dashed line, triangle marker), including (a) $Na^+/Cl^-$, (b) $K^+/Cl^-$, (c) $Ca^{2+}/Cl^-$, and (d) $Mg^{2+}/Cl^-$

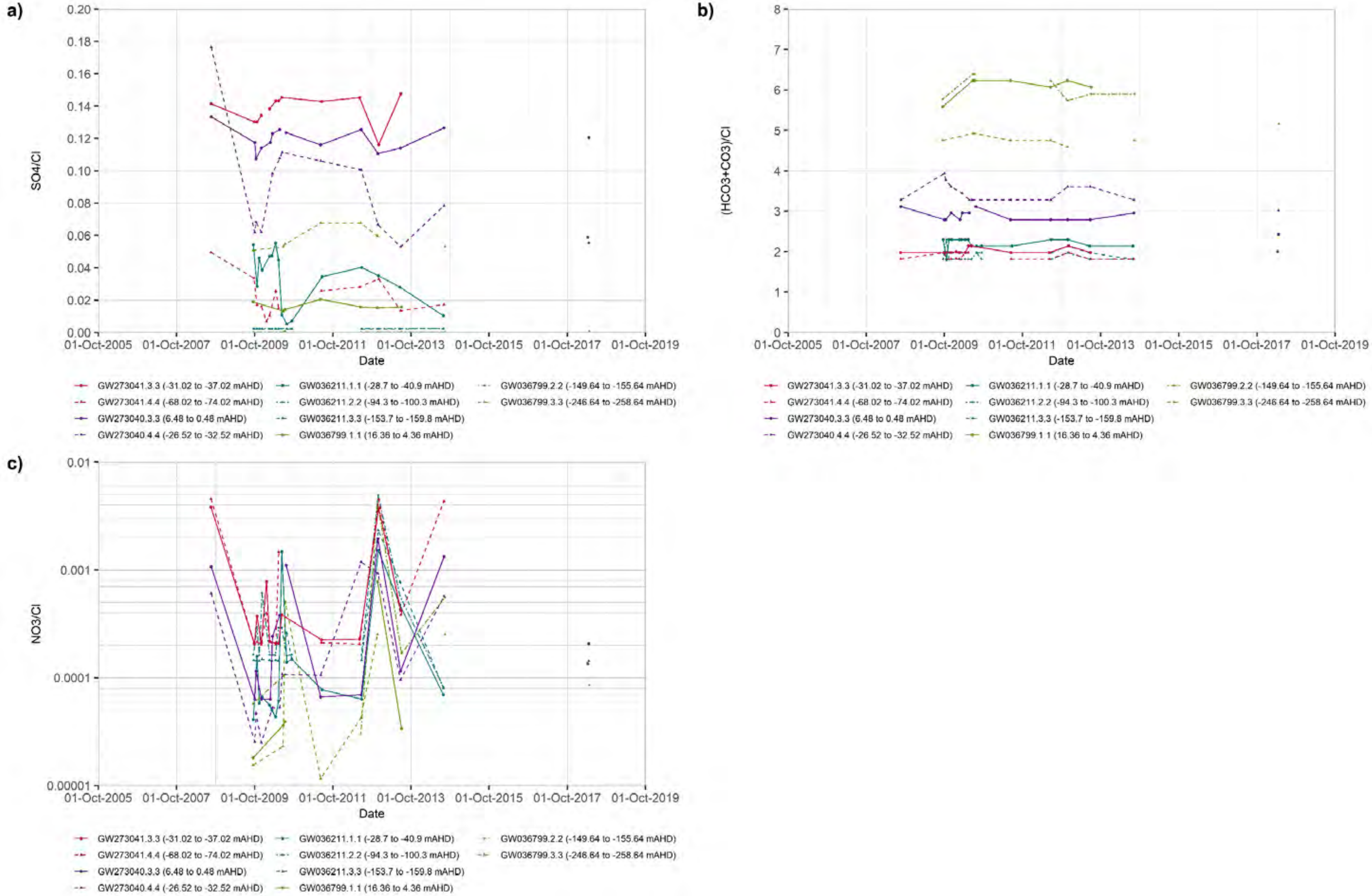


Figure 64. Detailed groundwater anion/chloride ratios in at sites nested within the upper Renmark Group (solid line, circle marker), middle Renmark Group (2-dash line, diamond marker), and lower Renmark Group (dashed line, triangle marker), including (a) $SO_4^{2-}/Cl^-$, (b) $(HCO_3^-+CO_3^{2-})/Cl^-$, and (c) $NO_3^-/Cl^-$

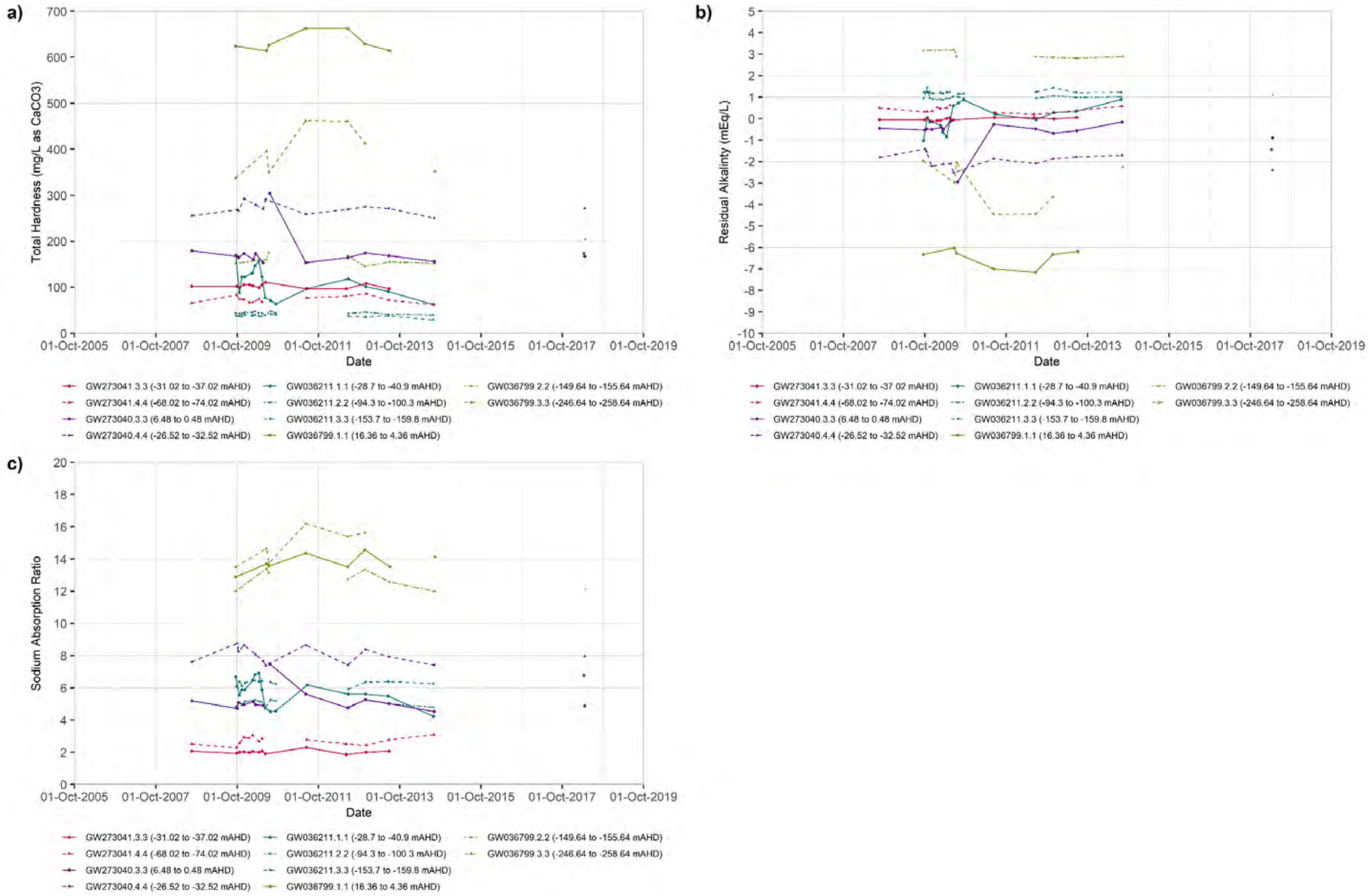


Figure 65. Detailed groundwater Irrigation parameters at sites nested within the upper Renmark Group (solid line, circle marker), middle Renmark Group (2-dash line, diamond marker), and lower Renmark Group (dashed line, triangle marker), including (a) total hardness, (b) residual alkalinity, and (c) sodium absorption ratio

# Interpretation of geochemical processes–influence of pumping on groundwater chemistry

## Previous investigations

Previous investigations identified the main processes influencing groundwater geochemistry in the eastern part of the Lower Murrumbidgee Groundwater Source. These include:

- **Clay content of alluvial deposits:** higher clay content in alluvial deposits is associated with higher groundwater electrical conductivity values. Higher clay content in alluvial deposits can slow water flow velocities, allowing the water to interact more with the aquifer matrix and increase the total dissolved ion load. The Shepparton Formation has the highest clay content of the 3 layers. This, along with the higher exposure to evapotranspiration, results in the highest salinities in the alluvial system.
- **Presence of paleodrainages:** paleodrainages can act as conduits to groundwater movement if the deposits are relatively gravel- or sand-rich or could act as an aquitard if the deposits are relatively clay-rich. Papp et al. (2014) demonstrated how the presence of a paleodrainage could influence groundwater mounding within the Coleambally Irrigation Area.
- **Salt leaching from clay-rich deposits**: Timms (2001) and Timms and Acworth (2002) identified significant storage of dissolved salts and saline porewaters in clay-rich bands on the Lower Murrumbidgee alluvium. The stored salts are more likely to occur closer to the groundwater surface, and it is estimated that 91% of the total subsurface aquitard salt storage occurs within 15 m of the groundwater surface, with 37% found within 3 m of the surface. This could explain increasing groundwater salinity in the Shepparton Formation.
- **River leakage from the Murrumbidgee River:** McDonald (2013) identified that low salinity groundwater with similar geochemical compositions to river water occurs around the Murrumbidgee River in the Narrandera to Darlington Point region. The groundwater becomes more saline with increasing distance to the west on the south side of the river. This not only occurs in the shallow groundwater source, the Shepparton Formation, but could also account for low salinity groundwater in the deep groundwater source, including the Calivil Formation and Renmark Group. This would be via river leakage from the Murrumbidgee River where the river enters the Murrumbidgee Basin at Narrandera.
- **Cation Exchange:** this involves the removal of dissolved Ca2+ and Mg2+ from groundwater via adsorption onto clay minerals, releasing Na+ in the process via the following equation:

$$(Ca^{2+}, Mg^{2+})_{(aq)} + (2Na^{+})\boxed{CLAY}_{(s)} \rightarrow 2Na^{+}{}_{(aq)} + (Ca^{2+}, Mg^{2+})\boxed{CLAY}_{(s)}$$

...Equation 11

- **Reverse Ion Exchange: this** involves the removal of dissolved Na+ ions from groundwater via adsorption onto clay minerals, releasing Ca2+ and Mg2+ in the process via the following equation:

$$2Na^+{}_{(aq)} + (Ca^{2+}, Mg^{2+})\boxed{CLAY}_{(s)} \leftrightarrow (Ca^{2+}, Mg^{2+})_{(aq)} + (2Na^+)\boxed{CLAY}_{(s)}$$

...Equation 12

- **Dissolution of halite:** the dissolution of halite adds dissolved Na+ and Cl–to groundwater via the below equation:

  $$NaCl_{(s)\,(halite)} \leftrightarrow Na^+{}_{(aq)} + Cl^-{}_{(aq)}$$

  ...Equation 13

  McDonald (2013) determined that up to 30% of Cl⁻in shallow saline groundwater could be attributed to halite dissolution.

- **Dissolution of carbonate minerals:** the dissolution of calcite and dolomite adds dissolved Ca2+, Mg2+, and HCO3– to groundwater via the below equations:

$$CaCO_{3(s)\,(calcite)} + H_2O_{(l)} + CO_{2(aq)} \leftrightarrow Ca^{2+}{}_{(aq)} + 2HCO_3{}^-{}_{(aq)}$$

...Equation 14

$$CaMg(CO_3)_{2(s)\,(dolomite)} + 2H_2O_{(l)} + 2CO_{2(aq)} \leftrightarrow Ca^{2+}{}_{(aq)} + Mg^{2+}{}_{(aq)} + 4HCO_3{}^-{}_{(aq)}$$

...Equation 15

- **Precipitation of carbonate minerals:** the precipitation of calcite and dolomite removes dissolved Ca2+, Mg2+, and HCO3– from groundwater via the below equations:

$$Ca^{2+}{}_{(aq)} + 2HCO_3{}^-{}_{(aq)} \leftrightarrow CaCO_{3(s)\,(calcite)} + H_2O_{(l)} + CO_{2(aq)}$$

...Equation 16

$$Ca^{2+}{}_{(aq)} + Mg^{2+}{}_{(aq)} + 4HCO_3{}^-{}_{(aq)} \leftrightarrow CaMg(CO_3)_{2(s)\,(dolomite)} + 2H_2O_{(l)} + 2CO_{2(aq)}$$

...Equation 17

- **Precipitation of sulfate minerals:** the precipitation of gypsum removes dissolved Ca2+, and SO42– from shallow groundwater with high Eh values, meaning oxidising environments, via the below equation:

$$Ca^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} + 2H_2O_{(l)} \leftrightarrow CaSO_4 \bullet 2H_2O_{(s)\,(gypsum)}$$

...Equation 18

- **Sulfate reduction:** the reduction of $SO4_2^-$ to H2S in deep groundwater could occur when groundwater encounters reducing conditions induced by the presence of organic carbon, particularly with lignite within the Renmark Group (Brown, 1991). Bacteria generally mediate these reactions. The generalised equation as follows:

$$SO_4{}^{2-}{}_{(aq)} + 2CH_2O_{(s)\,(organic\ material)} \rightarrow H_2S_{(aq)} + 2HCO_3{}^-{}_{(aq)}$$

...Equation 19

- **Silicate mineral weathering:** a kinetically controlled, and therefore slow, process where plagioclase undergoes incongruent dissolution into kaolinite via the below generalised equation:

$$Na_{0.62}Ca_{0.38}Al_{1.38}Si_{2.62}O_{8(s)\,(plagioclase)} + 1.38CO_{2(aq)} + 4.55H_2O_{(aq)}$$
$$\rightarrow 0.69Al_2Si_2O_5(OH)_{4(s)\,(kaolinite)} + 0.62Na^+{}_{(aq)} + 0.38Ca^{2+}{}_{(aq)} + 1.38HCO_3{}^-{}_{(aq)}$$
$$+ 1.24H_4SiO_{4(aq)}$$

…Equation 20

- **Mixing of fresh and saline groundwater:** McDonald (2013) identified that mixing between low salinity deep-recharge groundwater and more saline shallow groundwater was occurring in the Lower Murrumbidgee Groundwater Source. They determined that low salinity deep groundwater could form via the mixing of at least 92% surface water, introduced by river leakage, with up to 8% shallow saline groundwater.

The way some of these processes influence groundwater geochemical evolution and salinity is shown below in Figure 66.

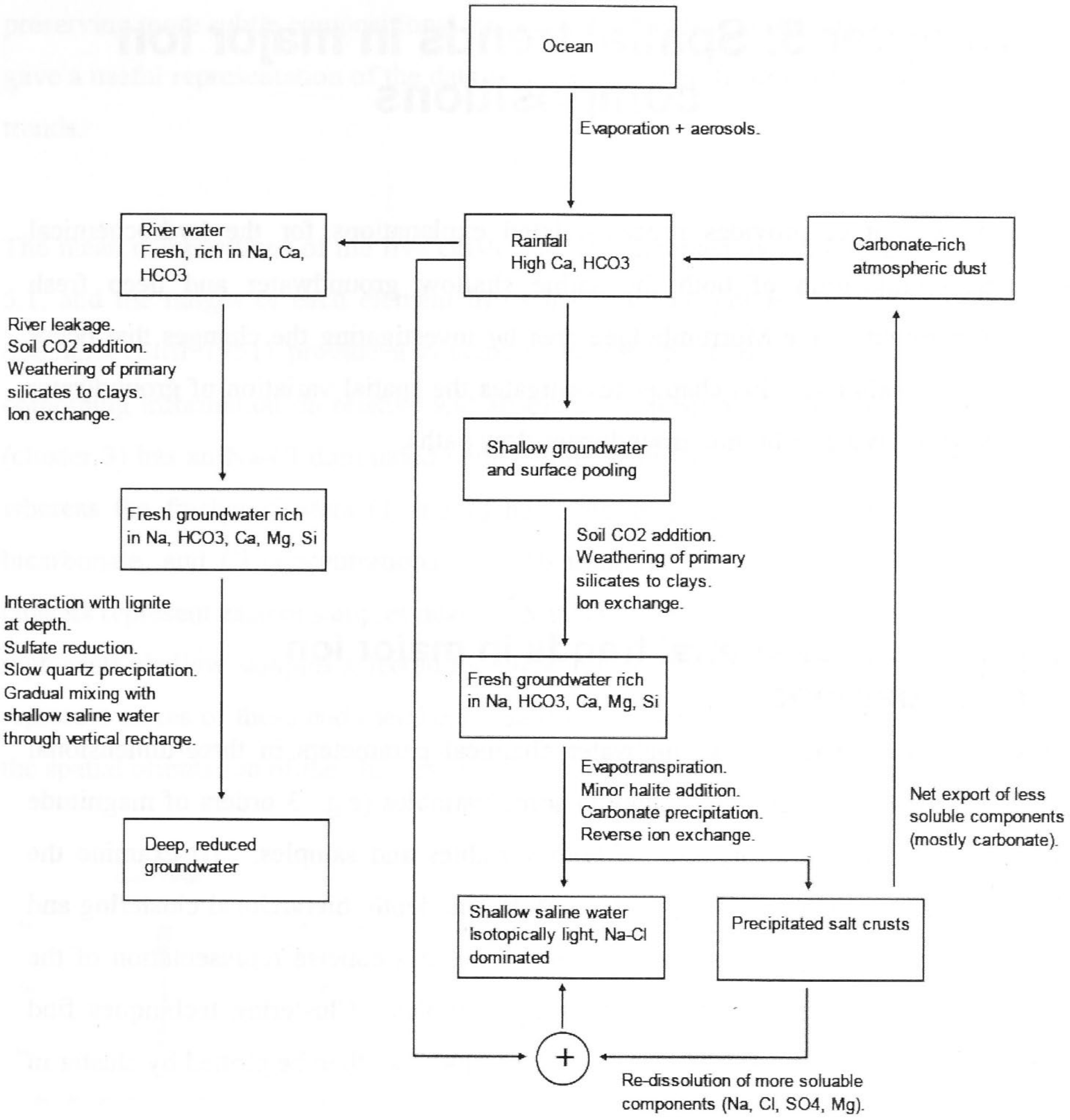


Figure 66. Block diagram of processes influencing the geochemical evolution of fresh and saline groundwaters in the Murrumbidgee Groundwater Source (taken from McDonald, 2013)

# Geochemistry data (2005–2018)

There is evidence to suggest that extraction of groundwater from the Lower Murrumbidgee groundwater sources is affecting groundwater quality. This is occurring on the margins of the groundwater source where relatively more saline groundwater is encroaching on fresher groundwater.

Effects on groundwater may be occurring both within a pumping season and over successive pumping seasons. The steps driving these potential impacts are interpreted to be as follows:

1. Drawdown by groundwater pumping decreases the groundwater levels at production bores, moving groundwater towards them. The change in groundwater levels and flow directions moves groundwater from overlying aquifers through vertical flow and from within the same aquifer through lateral flow, where there is hydraulic connectivity. Groundwater upwelling from lower alluvial deposits may occur throughout the Calivil Formation and Renmark Group.

2. Groundwater drawdown leads to groundwater salinisation near the margins by moving saline groundwater into an area where fresher groundwater occurs. This may occur between aquifers through vertical leakage or upwelling, and within the same aquifer through lateral flow.

3. When groundwater pumping ceases and groundwater levels and flow directions begin to recover, the movement of groundwater salinity plumes begins to slow. This can be very slow with ambient water level gradients, meaning when there is no pumping.

4. The groundwater salinity plumes within the Lower Murrumbidgee groundwater sources do not return to a pre-drawdown condition, changing the geochemistry over time at individual monitoring sites. This is mainly observed at monitoring sites located near the margins of the groundwater source. This also occurs in the Shepparton Formation where groundwater salinity continues to increase despite stabilised groundwater levels.

5. The inducement of flow between and within aquifers may mobilise $NO_3^-$ from the outcropping Shepparton Formation into the underlying Calivil Formation and Renmark Group, resulting in increasing $NO_3^-/Cl^-$ over time.

6. Changes in the groundwater geochemistry type at monitoring sites GW041011 and GW273041 could be an early indicator that saline groundwater is encroaching on these areas. More monitoring is needed to confirm if saline groundwater encroachment is happening.

# Potential implications for beneficial uses and aquifer environments

The changing groundwater geochemistry within the Lower Murrumbidgee groundwater sources has consequences for the beneficial use of groundwater in this area. This is due to increasing groundwater salinity limiting how groundwater can be used for irrigation and stock watering purposes. This is also through changes in irrigation quality parameters, which could increase the risk of changing soil structure and permeability, and damage to irrigation infrastructure. This has implications for how groundwater beneficial use is maintained under the '*Water Sharing Plan for the Murrumbidgee Alluvial Groundwater Sources Order 2020*'.

Further information relating to beneficial use categories is in Section 'Appendix 1– Beneficial use information'.

## Risks to groundwater salinity

The groundwater salinity of the Lower Murrumbidgee groundwater sources has changed in certain areas. Changes to groundwater salinity can mean the groundwater is no longer suitable for certain beneficial uses. This risk to beneficial use could increase further if the changes also affect other parameters such as sodium hazard categories, corrosion potential, fouling potential, and supporting human and livestock health.

Changes in groundwater salinity in the Shepparton Formation at monitoring sites GW273040.1.1, GW041012.1.1, and GW041011.1.1 have affected beneficial use of groundwater. Groundwater salinity increases at monitoring site GW273040.1.1 has limited its use for stock watering as it is no longer suitable for dairy cattle, and made it unsuitable for irrigation (Table 4, Table 43, and Figure 26). Groundwater salinity increases at monitoring site GW041012.1.1 have lowered the quality of human drinking water from 'fair' to 'poor' quality. They have also limited irrigation use to moderately sensitivity crops to moderately tolerant crops, and shifted the salinity hazard category to medium salinity water to high salinity water (Table 4, Table 43, and Figure 26). Groundwater salinity increases at monitoring site GW041001.1.1 has limited use for stock watering, as it is no longer suitable for poultry, limited crops watered by irrigation, as it is now only suitable for very salinity tolerant crops and made groundwater unsuitable for human drinking water. The salinity hazard categories could not be applied to groundwater from monitoring site GW041011.1.1 for the 2017 and 2018 sampling rounds (Table 4, Table 43, and Figure 26).

Increased groundwater salinity in the Calivil Formation has limited beneficial use at monitoring sites GW036773.2.2, GW030323.1.1, and GW273040.2.2. Groundwater salinity increases at GW030323.1.1 and GW273040.2.2 have changed human drinking water quality from 'fair' to 'poor', with irrigation limited to 'moderately' tolerant crops at GW273040.2.2. This reduction in irrigation beneficial use could also occur at monitoring site GW030323.1.1 if current salinity trends continue. Groundwater at monitoring site GW036773.2.2 has also had irrigation beneficial use limited to ‘moderately’ tolerant crops, with human drinking water quality and salinity hazard potentially affected if current salinity trends continue (Table 4, Table 43, and Figure 31).

Groundwater salinity changes at monitoring site GW036211.1.1 in the upper-Renmark Group have changed human drinking water quality throughout the monitoring period between ‘good’, ‘fair’, and ‘poor. Irrigation water classification also changed between ‘very low’, ‘low’, and ‘medium’ water salinity, with the salinity hazard changing from ‘medium salinity water’ to ‘high salinity water’. Salinity changes at monitoring site GW036799.1.1, also in the upper-Renmark Group, resulted in salinity unable to be classified under the salinity hazard criteria for irrigation. If increased salinity trends continue, beneficial use could be further limited (Table 21. Summary statistics for physicochemical parameters in the upper Renmark Group, Table 43, and Figure 36).

In the mid-Renmark Group, marginal changes in irrigation beneficial use occurred at monitoring sites GW036773.3.3 and GW041011.3.3, with beneficial use limited to ‘moderately sensitive’ crops. Salinity changes at monitoring sites GW036396.1.1 and GW036799.2.2 limited human drinking water from ‘poor’ to ‘unacceptable’ quality, with irrigation beneficial use limited to ‘moderately tolerant’ crops and salinity hazard category changed from ‘high salinity’ to ‘very-high salinity’ if salinity continues to increase (Table 22Table 4, Table 43, and Figure 37).

Increased groundwater salinity at monitoring site GW036799.3.3 in the lower-Renmark Group changed irrigation beneficial use from ‘moderately tolerant’ crops to ‘tolerant’ crops, with the salinity hazard changing from ‘high salinity water’ to ‘very-high salinity water’. Even though there were no changes to beneficial use at monitoring site GW273040.4.4 during the investigation period, there could be limitations to irrigation and salinity hazard beneficial use if salinity trends continue into the future (Table 23, Table 43, and Figure 38).

Changes to beneficial use caused by groundwater salinity are not expected to occur where groundwater salinity has stabilised. However, changes to beneficial use could occur in areas where groundwater salinity is continuing to increase (GW036743.2.2 and GW036742.3.3). Beneficial use could also be affected by future groundwater salinity changes. Groundwater salinity should be assessed regularly to capture these changes. This will enable monitoring of the suitability of irrigation water for watering different crop types and application on different soils, as well as the suitability of groundwater for livestock and human drinking water.

## Risks to sodium absorption ratio (SAR)

The groundwater sodium absorption ratio (SAR) has changed in some areas of the Lower Murrumbidgee groundwater sources. Increases in the SAR increases the risk of foliar injury, crop toxicity, and degrading soil structure. This also increases the risks associated with agricultural productivity and economic viability.

Changes to sodium hazard categories occurred within in the Shepparton Formation. The sodium hazard category changed from S1 (SAR 0–10) to S2 (SAR 10–18) at monitoring site GW036743.1.1. The SAR at sites GW036587.2.2 and GW036876.1.1 is approaching the threshold of sodium hazard category changes (Figure 30 and Table 46).

Changes to groundwater SAR at monitoring sites GW036587.2.2 in the upper parts of the Calivil Formation and GW036585.3.3 in the lower parts of the Calivil Formation have changed the classification from S1 to S2 class between October 2003 and October 2015(Table 20, Figure 35, and Table 46).This also occurred at monitoring site GW036742.3.3 in the Renmark Group (Figure 48, Figure 49, Figure 50, and Table 46).

The SAR at monitoring sites GW036786.2.2 and GW036742.2.2 in the lower parts of the Calivil Formation) is approaching the boundary between sodium hazard categories. Further changes could occur if SAR trends continue in the future.

The SAR of irrigation water should regularly be assessed to determine the suitability of irrigation water for watering different crop types and application on different soils.

## Risks to irrigation infrastructure

Increases in total hardness as $CaCO_3$ could affect groundwater pumping infrastructure and irrigation equipment through increased wear and tear.

There were no changes in total hardness as $CaCO_3$ for most monitoring sites used for this investigation that changed the risk of increased corrosion or fouling potential (Table 49, Table 50, Figure 30, Figure 35, Figure 48, Figure 49, and Figure 50).

Total hardness as $CaCO_3$ trends at 2 monitoring sites in the lower-Renmark Group, GW273041.4.4 and GW036799.3.3, changed the risk of increased corrosion or fouling potential. The decreasing trend at monitoring site GW273041.4.4 increased the corrosion potential and the increasing trend at monitoring site GW036799.3.3 increased the fouling potential (Table 49, Table 50, and Figure 50). Despite most monitoring sites not changing the risk of increased corrosion or fouling potential due to changes in total hardness as $CaCO_3$ concentrations, there is the potential to increased risk to occur if concentrations continue to trend upwards or downwards at some sites.

Declining pH trends at most monitoring sites has not currently resulted in an increased risk of corrosion potential. However, if the declining pH trends continue, there could be an increased risk of corrosion potential in the future (Table 49, Table 50, Figure 26, Figure 31, Figure 36, Figure 37, and Figure 38).

Groundwater pH and total hardness as $CaCO_3$ should be assessed to determine the risks to groundwater pumping infrastructure and how these risks could be mitigated if groundwater geochemistry continues to change in the Lower Murrumbidgee alluvium.

# Recommendations for Lower Murrumbidgee resource management

The '*Water Sharing Plan for the Murrumbidgee Alluvial Groundwater Sources Order 2020*' (the Plan) includes aims to keep groundwater salinity, also known as total dissolved solids, at levels than can maintain all beneficial uses. Groundwater monitoring has been conducted by the NSW Department of Planning and Environment to meet this aim. This report interpreted the monitoring data to assess groundwater salinisation and its influence on beneficial use. There have been limitations to the assessment method and available data that need to be addressed to improve future monitoring programs.

## Program data acquisition

### Improve data quality management

Data quality issues were a limiting factor in what geochemical analysis methods could be used. The data quality issues included:

- **Missing data:** there were several times where the expected geochemistry data, based on the monitoring and analytical schedule set for this program, was missing from the WaterNSW water quality database. This limited both the data available for analysis and the geochemical methods used. This was an issue when analysing $SO_4^{2-}$/$Cl^-$and $NO_3^-$/$Cl^-$ trends. Redox reactions can affect their concentrations. However, redox potential and dissolved oxygen values to figure out what redox reactions could be occurring were not in the databases for many samples. Another example of missing data was when analysis for 'total' cations, meaning unfiltered sample, was present, not 'dissolved', meaning filtered sample. It is difficult to use total cation data to figure out what processes may be changing groundwater geochemistry when no related dissolved cation data is available.
- **Incorrect data:** there were several times where incorrect data was recorded for a monitoring site. This happened when samples were assigned the wrong pipe at a monitoring site or when data was not linked with the correct monitoring site in the WaterNSW water quality database. This also happened when data from a sample was duplicated across multiple samples and across multiple sites. Finding and fixing these data issues was the biggest limiting factor in what data analysis occurred due to time limitations. Fixing data input errors is easier when they are found early. In addition,

finding errors long after entering the data into the database increases the likelihood of the original data being irretrievably lost.

- **Data not meeting QAQC requirements**: there were several times where dissolved ion data did not meet the anion-cation balance requirements. There were also times where field-measured electrical conductivity did not meet the requirements for electrical conductivity vs. ion sums checks. These parameters should be calculated when the laboratory reports are received so that issues can be investigated and fixed by analytical laboratories. This becomes increasingly difficult as time passes.
- **Potentially accurate data not used in analysis:** there were several times where dissolved ion data did not meet the anion-cation balance requirements, and the whole analysis for that sample was not used. This was due to time and resource constraints on using other data checks to find which specific ions may be anomalous or within historic variation. Data quality checks such as statistical range and trend analysis, along with calculating mineral saturation indices, should be used in the future if time and resource are available.

These issues could be resolved by applying the below management methods:

- Ensure all field-measured data is entered and stored in the WaterNSW water quality database within a reasonable timeframe after the monitoring round has finished. This should happen before receiving analytical results.
- Keep records of field probe calibrations as these can influence field-measured results.
- Conduct data QAQC checks quickly after receiving analytical data to find any anomalous results. This will allow the analytical laboratories to conduct any investigations while they still have the water samples. Such checks could include:
    - cation-anion balance checks, electrical conductivity vs. total dissolved solid checks, and electrical conductivity vs. ion sum checks to assess the accuracy of field-based and analytical results
    - calculate mineral saturation indices to find potential concerns with the analysis. This can be done using a geochemical program such as PHREEQC
    - use descriptive statistical techniques to figure out the ‘natural’ variability of geochemical concentrations, for example, control charting, and any long-term trends in geochemical data, for example, Mann-Kendall Trend Test. This can help to find any statistically significant trends
    - compare geochemical data with water quality guideline values
    - perform regular data quality audits on data within Power BI database to confirm that data is transcribed and stored accurately.

WaterNSW and the NSW Department of Planning and Environment are currently working to improve data quality management processes for ongoing data collection and storage.

## Increase sampling program delivery compliance

Increasing sampling program compliance will increase the amount of data available for water quality investigations and will allow a wider range of analysis techniques to be used in the future. There are indications that redox reactions could explain variability in pH, $SO_4^{2-}$ and $NO_3^-$ within the Lower Murrumbidgee groundwater sources. However, the lack of recorded redox potential information, along with dissolved oxygen, means that the influence of redox reactions on these parameters cannot be assessed.

Iron (Fe) and manganese (Mn) can be useful in understanding redox processes but were also not routinely analysed. Also, the irregular timing of sampling events during the last few years of the dataset means that a comparison between pumping versus non-pumping conditions cannot happen. This could hide the influence of groundwater extraction on water quality.

## Expand the geochemical suite

Ion exchange and carbonate mineral dissolution/precipitation could be important processes influencing geochemical changes in groundwater within the Lower Murrumbidgee groundwater sources. Unfortunately, there is limited information available on how much $Ca^{2+}$, $Mg^{2+}$, and $Na^+$ moves between groundwater and the aquifer matrix during ion exchange processes. Analysing for the total concentrations of major cations could improve knowledge in this area. Sediment sampling and analysis combined with geochemical modelling could also help in figuring out how cation exchange capacity and ion exchange effects groundwater geochemistry.

If pH continues to fluctuate within the Lower Murrumbidgee groundwater sources, there is the risk of mobilising trace metals and metalloids into the groundwater. Changing pH can also affect how toxic these metals and metalloids are to crops, stock, and humans. Parsons Brinckerhoff (2011) also noted that some trace metal and metalloid concentrations occasionally exceeded certain water quality guidelines in the Lower Murrumbidgee Groundwater Source. Including key trace metals and metalloids to the analysis suite will help inform our understanding of water quality and toxicity risks.

The addition of dissolved organic carbon (DOC), ammonium ($NH_4^+$), and water stable isotopes to the routine analysis suite could help assess fast deep-recharge due to irrigation returns and river recharge in the Lower Murrumbidgee groundwater sources. In addition, increasing groundwater DOC over time could increase the risk of higher dissolved iron and arsenic concentrations in groundwater. This could change future beneficial use. Therefore, adding DOC to the routine analysis suite could aid in longer-term water quality monitoring and management. Adding ammonium could also help in defining redox processes that may be occurring.

As groundwater salinity continues to rise in some areas of the Lower Murrumbidgee groundwater sources, the chemical stability of clays within the alluvial deposits could also change. This could lead to incongruent dissolution of clays within the aquifer matrix and could change the ion change capacity. Parsons Brinckerhoff (2011) also named incongruent dissolution as a process that could be occurring in the Lower Murrumbidgee groundwater sources. While incongruent dissolution is a kinetically slow process and may not be influenced by groundwater salinisation in the short term, the longer-term changes could have implications for geochemical processes in the future. Mineral stability could not be analysed since reactive silica data is needed to assess this. Adding reactive silica to the analysis suite could improve our understanding on how mineral stability changes over time and how this may affect ion exchange capacity.

It is recommended that the following analytes are added to the sampling and analytical suite

- Total major cations: $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$
- Minor ions–reactive silica, $F^-$, $Br^-$, $NH_3/NH_4^+$
- Trace metals and metalloids: Al, Fe, Mn, Ba, B, Be, Sr, As, Cd, Cr, Co, Cu, Pb, Hg, Ni, Se, Zn, U
- Dissolved organic carbon (DOC)
- Water stable isotopes ($^{16}O/^{18}O$, $^1H/^2H$)

Using major ion trends and hydrograph data found that both lateral flow within aquifers and vertical flow between aquifers are potential flow paths for saline groundwater. However, it was difficult to separate the effect of lateral flow and vertical flow over time. Since these dissolved ions moved by groundwater, utilising the stable isotope pairings of $^{16}O/^{18}O$ and $^1H/^2H$ could help to trace water movement throughout the groundwater source. This could help explain mixing contributions over time. Stable isotope sampling could occur yearly, ideally when recovered water levels are at their highest, to assess if sources of groundwater are changing over time.

Lastly, it should be considered how radiotracers such as carbon-14, with carbon-13 corrections, and tritium could be used to figure out groundwater residence times, meaning how long it takes groundwater to flow to a certain point after recharge. This information could help in understanding how geochemical processes occur within this groundwater source. Radiotracer data from the 2020/2021 state-wide groundwater quality program could be used. If more information is needed, then a sampling plan should be developed which describes which monitoring sites should be sampled for radiotracer analysis, what radiotracer analysis should occur, and at which time during the pumping and non-pumping cycles sampling should happen. This will mean that future sampling opportunities could be used to collect this information.

# Program assessment and analysis

## Quantifying the uncertainty in water level measurement.

This investigation identified nested monitoring sites where groundwater levels were slightly higher in one aquifer than in another. In some cases, it was the deeper aquifers that had higher groundwater levels than shallower aquifers. This means that groundwater has the potential to upwell from the deeper aquifers into shallower aquifers.

However, in these cases, the groundwater levels in shallower and deeper aquifers were within a few centimetres of each other. it is possible that error and uncertainty associated with water level measurements could significantly impact how groundwater levels and associated groundwater movement are tracked at these sites. This error and uncertainty could not be quantified in this investigation since a detailed measurement method was not available.

Further work needs to be performed to confirm the water level measurement method, what the error is on the water level measurement, and how this applies to the water level record and interpretations of groundwater movement throughout the groundwater source.

## Adopt statistical methods to describe geochemical variability and groundwater level trends

This investigation qualitatively analysed major ion and groundwater level trends in the Lower Murrumbidgee groundwater sources and the impact of groundwater pumping on water levels and quality. Therefore, descriptors associated with the intensity and direction of trends are highly influenced by how the investigator interpreted them. To remove this potential influence on interpreted results, it is recommended that statistical analysis of geochemical data is adopted so that quantitative trends descriptors can be used instead.

Applying statistical methods to describe geochemical variability and water level changes will also assist in describing the relative intensity of changes between different monitoring sites. This is difficult to currently perform. Also, using statistical methods could help in linking changes in groundwater levels and quality to groundwater extraction rates.

### Investigate how groundwater level changes are linked to groundwater extraction and how they influence vertical hydraulic conductivity

This investigation described groundwater level changes within aquifers and across nested sites, with some geochemical changes linked to changing water levels. It also identified that a lag effect in water level changes could occur between hydrologically linked aquifers where one aquifer is directly impacted by groundwater extracted while the other is not.

This means that persistent groundwater level declines during the Millennium Drought (2001 to 2009) could be attributed to higher groundwater extraction while the water level recovery between 2009 and 2013 could be attributed to lower groundwater extraction. Furthermore, seasonal groundwater level changed could be attributed to the influence of groundwater pumping within and between irrigation seasons. However, there is not enough evidence currently to confirm these relationships.

Detailed analysis is needed to link groundwater level changes with groundwater extraction regimes within irrigation seasons and between water years. Additionally, an analysis of how the vertical hydraulic head changes over time in response to pumping and recharge, and how this relates to pumping and geochemistry changes, could provide new insights into the conditions needed for saline groundwater to move into underlying aquifers.

## Use more complex graphical methods and geochemical ion ratio comparisons to aid geochemical process identification

This investigation used ion/$Cl^-$ratios presented as a time-series graph to identify groundwater geochemical changes over time. There are other graphical methods available that can complement and enhance the interpretation of this data which include Scholler Plots, Piper Plots, and Durov Plots. There are also other geochemical parameters that can be compared with each other and include comparison of ion ratios with the seawater dilution line, comparison of ion ratios other than with $Cl^-$, and calculating mineral saturation indices.

## Quantify the stored salt load in the Lower Murrumbidgee Alluvial deposits

Timms (2001) and Timms and Acworth (2002) identified that leaching of stored salts within clay-rich deposits of the Lower Murrumbidgee aquifers could be contributing to increased groundwater salinisation in shallow aquifers and could pose a risk to groundwater quality in the deeper aquifers if this salt were mobilised. Their investigations focused on a site near Tubbo, located between the Coleambally Irrigation Area and the Murrumbidgee Irrigation Area.

While it could be informative for the quantified stored salt load to be extrapolated from this site across the Lower Murrumbidgee groundwater sources, it would be more prudent to conduct similar investigations across these groundwater sources. This is because of the heterogenous nature of alluvial deposits, which could make extrapolated values inaccurate.

Further investigations are needed to determine the extent of clay-rich bands throughout the alluvial deposits, quantify the salt loads within the clay-rich bands, and determine how much more leaching is required to remove these salts. The investigation should then assess how this could affect water quality and beneficial use if this salt is mobilised. This could include further geochemical analysis coupled with drill core analysis.

## Determine nitrate sources for the Calivil Formation and Renmark Group

Increasing trends in $NO_3^-/Cl^-$ ratios were observed in both the Calivil Formation and Renmark Group over the investigation period. The most likely pathway for $NO_3^-$ to mobilise into the deeper confined aquifers was vertical leakage.

The $NO_3^-/Cl^-$ generally increased in the Calivil Formation and Renmark Group as it was decreasing in the Shepparton Formation. This suggests there could be a delayed accumulation in the deeper aquifers that could also be influenced by lateral flow within aquifers. Further investigations should be performed to determine (1) if vertical leakage is transporting elevated $NO_3^-$ at certain locations or if this is occurring across the investigation area and (2) what role lateral flow is playing in the mobilisation and concentration of $NO_3^-$ within the deeper aquifers.

### Develop 3D geological, numerical flow, and reactive transport models to inform future management practices

Geological, numerical flow, and reactive transport modelling are increasingly being used to understand groundwater flow, hydrogeochemical processes, and the impacts of management and agricultural practises on groundwater resources. Updating the current regional model or developing a numerical flow with reactive transport capabilities could assist in understanding:

- how aquifer heterogeneity influences groundwater flow and water quality
- how salinity hot spots develop and where they could develop next
- how the distribution and timing of groundwater extraction influences groundwater level drawdown and recovery, how this influences salt movement through the alluvium, and what this means for future groundwater quality and beneficial use
- how both short-term and long-term groundwater level drawdown and recovery influence salt movement throughout the alluvium, and what this means for future groundwater quality and beneficial use
- what impact management decisions such as restricting pumping and managed aquifer recharge have on groundwater availability and quality.

## Groundwater management issues to address

### Investigate how hydraulic head changes during and between irrigation seasons and how this influences saline groundwater movement

The first step in the movement of saline groundwater from shallow aquifers into the deeper aquifers is an increase in the vertical hydraulic head between the shallow and deeper aquifers. Current understanding is that the increase in vertical hydraulic head occurs when deeper aquifers are depressurised by groundwater extraction, with the vertical hydraulic head decreasing as water level recovery occurs when groundwater extraction ceases. This facilitates the movement of shallow saline groundwater into deeper fresher groundwater.

Once saline groundwater has moved from shallow aquifers into deeper aquifers, lateral groundwater flow within the deeper aquifer can spread the saline groundwater throughout the deeper aquifer. Lateral groundwater flow can increase with increasing horizontal hydraulic head.

It is not currently understood how the vertical hydraulic head between shallow and deeper aquifers and horizontal hydraulic head within aquifers change during and between pumping seasons. It is also not understood how this can influence the movement of saline groundwater throughout the groundwater source. Further investigations into how vertical and horizontal hydraulic heads change spatially and temporally, with links to groundwater extraction regimes and changing groundwater chemistry, could establish these relationships.

## Understand declining groundwater salinity

Groundwater salinity is declining at multiple monitoring sites in the Lower Murrumbidgee groundwater sources. This could be affected by river leakage, or the movement of fresher groundwater within or between aquifers.

If declining groundwater salinity is due to river leakage, it is important to know the mixing ratios and water volumes. This is to ensure that both surface water and groundwater allocations are accounted for in the future. Also, river leakage can increase the dissolved organic carbon content of groundwater. This could lead to increased dissolved iron and arsenic in groundwater, which could affect future beneficial use.

If declining groundwater salinity results from mixing from fresher groundwater, it is important to understand:

- the groundwater flow pathways that formed the fresher groundwater,
- the spatial extent of the fresher groundwater is
- how the spatial extent varies with groundwater extraction regimes

Using environmental radiogenic tracers such as carbon-14 ($^{14}C$) or tritium ($^{3}H$) could show whether the groundwater is modern, meaning less than 50 years old, or older. This could help in figuring out groundwater flow pathways. This data may be available from the 2020/2021 state-wide groundwater quality acquisition program. Otherwise, samples for environmental radiogenic tracers could be collected during a future monitoring round.

## Redefine the distribution of saline and fresh groundwater in the Calivil Formation and Renmark Group

Salinisation is increasing in the Calivil Formation and Renmark Group on the groundwater source margins. The groundwater in these areas is already more saline relative to the fresher groundwater occurring throughout the central part of the groundwater source east of Hay. What is not clear is if and how the distribution of this saline groundwater has changed.

The sporadic changes to the dominant groundwater geochemistry type at monitoring sites GW273041.3.3 and GW273041.4.4 in the Renmark Group could indicate that saline groundwater is encroaching on the area. More work should be done to update the salinity distribution maps of the groundwater sources and to show how these have changed with time. This may include collecting an updated electrical conductivity reading, along with other physicochemical parameters, at the screen interval of all monitoring bores within the Lower Murrumbidgee groundwater sources.

## Determine how bicarbonate and carbonate declines occur

Declining $(HCO_3^- + CO_3^{2-})/Cl^-$ has occurred throughout the Lower Murrumbidgee Groundwater Source. It is currently difficult to identify what process or processes are influencing this change. Declining $(HCO_3^- + CO_3^{2-})/Cl^-$ is likely linked with declining pH, but it is not clear which declined first and influenced the other. Also, declining $(HCO_3^- + CO_3^{2-})/Cl^-$ could occur through increasing $Cl^-$ without a proportionate increase in $(HCO_3^- + CO_3^{2-})$. Future work should seek to better understand the ($HCO_3^-$+$CO_3^{2-}$) dynamics in this groundwater source and how they interplay with pH.

## Consider adding more sampling sites to understand increasing groundwater salinity in the Renmark Group

There were several monitoring sites within the Renmark Group that showed increasing salinity trends throughout the investigation period. In most cases this can be explained by vertical leakage from the overlying Calivil Formation.

However, monitoring sites GW036211 and GW036799 do not have either a nested or neighbouring monitoring bore screened within the Calivil Formation (Table 1 and Figure 19). This makes it difficult to confirm if vertical leakage is a significant source of increased groundwater salinity or if lateral flow with increased water-rock interaction better explains the geochemical trends. Commissioning more monitoring sites should be considered to better understand vertical leakage in the distal parts of the investigation area.

## Understanding how a fresh water 'wedge' has formed in the Renmark Group

There is a unique observation in the downstream monitoring site GW036799 in the Renmark Group. Monitoring site GW036799 has elevated groundwater salinity within the upper-and lower-Renmark Group at GW036799.1.1 and GW036799.3.3, respectively, with a band of fresher groundwater occurring in the mid-Renmark Group (Table 21, Table 22, Figure 19, and Figure 61).

Processes that could contribute to this includes increased vertical leakage from the overlying Calivil Formation forming a 'perched' saline groundwater occurrence in the upper-Renmark Group and/or lateral movement of saline groundwater in the lower-Renmark Group. The contribution of these processes cannot be quantified since there are no neighbouring monitoring sites within the Renmark Group to confirm the extent of this occurrence. There are also no neighbouring monitoring sites screened within the Calivil Formation or Shepparton Formation to determine the influence of vertical leakage. Commissioning more monitoring sites should be considered to better understand the dynamics between fresher and more saline groundwater in this area of the Renmark Group.

### Determine the extent of saline groundwater interactions between the Calivil Formation and Renmark Group

Groundwater in the Calivil Formation and Renmark Group is managed as a single deep groundwater source. However, this investigation has identified that complex groundwater interactions between the 2 aquifers have resulted in salinity 'hotspots' forming in the aquifers.

In some areas there are indications of greater interactions between the Shepparton Formation and Calivil Formation, while in other areas there are indications of greater interactions between the Renmark Group and Calivil Formation. These could indicate preferential flow paths throughout the alluvial deposit and therefore pathways in which saline groundwater could be quickly mobilised. Understanding saline groundwater interactions between the Calivil Formation and Renmark Group and the sources of the dissolved ions will help limit the movement of these salts through the most productive aquifer in the Lower Murrumbidgee Groundwater Source.

## Minimising irreversible changes to irrigation water composition

Changes in groundwater geochemistry within the Lower Murrumbidgee groundwater sources are increasing the risk of widespread groundwater salinisation and changes in beneficial use. Increasing groundwater salinisation could mean that active water management strategies need to be used to limit further water quality decline. Otherwise, remediation strategies might need to be used to improve water quality and to reduce the risk of irreversible water quality changes.

Planning of remediation and management strategies to minimise the impact of groundwater salinisation on beneficial use would be improved with better understanding of:

- How river leakage might be contributing to groundwater freshening and how this affects groundwater salinisation processes.
- How river leakage may influence groundwater geochemistry and impact on beneficial use. A particular concern is how dissolved organic carbon could influence redox potential, and how this could release dissolved iron and arsenic from aquifer minerals.
- If upwelling of deep saline groundwater into productive aquifers is occurring and how this might be contributing to groundwater salinisation.
- The end point of groundwater salinisation within the Lower Murrumbidgee alluvium at locations where groundwater salinisation trends were found and what the geochemical composition might be.
- The active management strategies that could be used to reduce the risk of further groundwater salinisation and related geochemical changes.
- The active management strategies, including remediation, that could be used to reverse groundwater salinisation.

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# Glossary

| Word | Definition |
|---|---|
| Acidity | Base neutralising capacity.<br>The level of acid in substances such as water or soil. |
| Alkalinity | Acid neutralising capacity<br>The capacity of water to resist changes in pH that would make the water more acidic. |
| Alluvial aquifer | A groundwater system whose geological matrix is composed of unconsolidated sediments consisting of gravel, sand, silt and clay transported and deposited by rivers and streams. |
| Alluvium | Unconsolidated sediments deposited by rivers or streams consisting of gravel, sand, silt and clay, and found in terraces, valleys, alluvial fans and floodplains. |
| Analyte | A substance whose chemical constituents are being identified and measured |
| Anion | An ion with a negative charge–usually non-metal ions when disassociated and dissolved in water. |
| Aquifer | Under the Water Management Act 2000 an aquifer is a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water. More generally, the term aquifer is commonly understood to mean a groundwater system that can yield useful volumes of groundwater. For the purposes of groundwater management in NSW the term ‘aquifer’ has the same meaning as ‘groundwater system’ and includes low yielding and saline systems. |
| Artesian | Groundwater which rises above the surface of the ground under its own pressure by way of a spring or when accessed by a bore. |
| Atomic mass | The mass of an atom of a chemical element expressed in atomic mass units. It is about equivalent to the number of protons and neutrons in the atom (the mass number) or rot he average number allowing for the relative abundances of different isotopes. |
| Australian Height Datum (AHD) | The reference point (very close to mean sea level) for all elevation measurements and used for correlating depths of aquifers and water levels in bores. |

| Word | Definition |
|---|---|
| Basement (rock) | See Bedrock |
| Bedding | Discrete sedimentary layers that were deposited one on top of another. |
| Bedrock | A general term used for solid rock that underlies aquifers, soils or other unconsolidated material. |
| Beneficial use (category) | A general categorisation of groundwater uses based on water quality and the presence or absence of contaminants. Beneficial use is the equivalent to the 'environmental value' of water. |
| Bore (or well) | A hole or shaft drilled or dug into the ground. |
| Cainozoic | Is the most recent geological era and covers the period from 65.5 million years ago to the present. |
| Carbonate | A salt or ester of carbonic acid containing the ion $CO_3^{2-}$. |
| Cation | An ion with a positive charge–usually metal/metalloid ions when disassociated and dissolved in water. |
| Cation exchange | Ion exchange in which one cation (as sodium or hydrogen) is substituted for one or more other cations (as calcium or magnesium) |
| Cenozoic | The Cenozoic Era spanned from 66 million years ago to present |
| Concentration | The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample). |
| Confined aquifer | An aquifer which is bounded above and below by impermeable layers causing it to be under pressure so that when the aquifer is penetrated by a bore, the groundwater will rise above the top of the aquifer. |
| Contamination | The presence of an undesirable compound that makes unfit or inferior a natural environment (that is water, soil) |
| Detection limit | The lowest quantity of a substance that can be distinguished from the absence of that substance (that is a blank value) with a high degree of certainty. |
| Development (of a groundwater resource) | The commencement of extraction of significant volumes of water from a water source. |
| Dissolution | Process of dissolving a substance into a liquid. |
| Drawdown | The difference between groundwater level/pressure before extraction and that during extraction. |

| Word | Definition |
|---|---|
| Electrical conductivity (EC) | Ability of a substance to conduct an electrical current. Used as a measure of the concentration of dissolved ions (salts) in water (that is water salinity). Measured in micro-Siemens per centimetre (µS/cm) or deci-Siemens per metre (dS/m) at 25o C. 1 dS/m = 1000 µS/cm |
| Equilibrium (chemical) | The state in which both reactants and products are present in concentrations which have no further tendency to change with time, so that there is no observable change in the properties of the system. |
| Equivalent (concentration) | A measure of the concentration equal to the gram equivalent weight per litre of solution. The gram equivalent weight is the measure of the reactive capacity of a molecule, and accounts for both the amount of an ion/atom/molecule and its charge. |
| Fouling potential | The potential for unwanted material to accumulate on solid surfaces |
| Geochemical<br>Hydrogeochemical | Relating to the chemical composition of the earth and its rocks and minerals. When relating to water, how its interaction with rocks and minerals influences its water quality. |
| Geological sequence | A sequence of rocks or sediments occurring in chronological order. |
| Groundwater | Water that occurs beneath the ground surface in the saturated zone. |
| Groundwater flow | The movement of water through openings in sediment and rock within the zone of saturation. |
| Geological formation | A fundamental lithostratigraphic unit used in the local classification of strata and classified by the distinctive physical and chemical features of the rocks that distinguish it from other formations. |
| Groundwater system | Any type of saturated sequence of rocks or sediments that is in hydraulic connection. The characteristics can range from low yielding and high salinity water to high yielding and low salinity water. |
| Hydraulic conductivity | The capacity of a porous medium to transmit water. Measured in meters/day. |
| Hydraulic connection | A path or conduit allowing fluids to be connected. The degree to which a groundwater system can respond hydraulically to changes in hydraulic head. |
| Hydraulic gradient | The change in total hydraulic head with a change in distance in a particular direction. |

| Word | Definition |
|---|---|
| Hydraulic head | The height of a water column above a defined point, usually expressed in metres. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between 2 or more points. |
| Hydrochemistry / Hydrogeochemistry | Chemical characteristics of surface waters and groundwaters. Particularly, the relationship between the chemical characteristics and quality of waters and the surrounding aerial and geological environments. |
| Hydrogeology | The branch of geology that relates to the occurrence, distribution and processes of groundwater. |
| Infiltration | The movement of water from the land surface into the ground. |
| Isotope | One of multiple forms of an element that has a different number of neutrons than other atoms of that element. Some elements have isotopes that are unstable or radioactive, while others have 'stable isotopes'. |
| Ion | Mineral species dissolved in water.<br>An atom or molecule that has the total number of electrons not equal to the total number of protons, giving it a net positive or negative electrical charge. |
| Lithic | Pertaining to or consisting of stone/rocks. For example, lithic sand describes pieces of other rocks that have been eroded down to sand size. |
| Major ions | Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate. |
| Metalloid | Metalloid refers to a subset of elements, which are neither metals nor non-metals, as they contain characteristics of both. Boron, silicon, germanium, arsenic, antimony, tellurium and polonium are generally classified as metalloids. |
| Miocene | A geological epoch extending from 23.03 to 5.33 million years ago. |
| Mole | A unit of measurement for a substance defined as exactly $6.02214076 \times 10^{23}$ particles, which may be atoms, molecules, ions, or electrons. |
| Monitoring bore | A specially constructed bore used to measure groundwater level or pressure and groundwater quality at a specific depth. Not intended to supply water. |

| Word | Definition |
|---|---|
| Oxidation | The loss of electrons during a chemical reaction by a molecule, atom, or ion. This may or may not involve the addition of oxygen and/or the loss of hydrogen to a compound. |
| Piezometric or Potentiometric head | The pressure or hydraulic head of the groundwater at a particular depth in the ground. In unconfined aquifers this is the same as the water table. |
| Paleochannel | A remnant of an inactive river or stream channel that has been filled or buried by younger sediment. |
| Permeability | The capacity of earth materials to transmit a fluid. |
| pH | Potential of Hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline, and less than 7 is acidic). |
| Pleistocene | The Pleistocene is the geological epoch from 2,588,000 to 12,000 years ago. |
| Pliocene | The Pliocene is the geological epoch that extends from 5.332 million to 2.588 million years ago. |
| Polymictic | When describing sedimentary rock: composed of several minerals or rock types containing fragments of differing composition. In the case of polymictic gravel, different minerals or rock types weathered down to the size of gravel. |
| Porous rock | Consolidated sedimentary rock containing voids, pores or other openings in the rock (such as joints, cleats and/or fractures. |
| Precipitation | The formation of a suspension of an insoluble compound by mixing 2 solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral. |
| Quality assurance | Part of data quality management focussed on providing confidence that quality requirements are fulfilled |
| Quality control | Part of data quality management focussed on fulfilling quality requirements within specified control parameters |
| Recharge | The addition of water into a groundwater system by infiltration, flow or injection from sources such as rainfall, overland flow, adjacent groundwater sources, irrigation, or surface water sources. |

| Word | Definition |
|---|---|
| Recharge area | A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or deeper aquifer zones. |
| Recovery | The rise of groundwater levels or pressures after groundwater take has ceased. Where water is being added, recovery will be a fall. |
| Reduction | The gain of electrons during a chemical reaction by a molecule, atom, or ion. This may or may not involve the removal of oxygen and/or the addition of hydrogen to a compound. |
| Redox potential (ORP or Eh) | The redox potential is a measure (in volts) of the affinity of a substance for electrons — its electronegativity — compared with hydrogen (which is set at 0). Substances more strongly electronegative than (that is capable of oxidising) hydrogen have positive redox potentials. Substances less electronegative than (that is capable of reducing) hydrogen have negative redox potentials. Also known as oxidation-reduction potential and Eh. |
| Residual alkalinity | An irrigation water quality parameter used to indicate the alkalinity hazard for soil and is used to determine irrigation water suitability in clay soils with have a high cation exchange capacity. Also see Residual Sodium Carbonate index (RSC). |
| Reverse ion exchange | Ion exchange in which one cation (as calcium or magnesium) is substituted for one or more other cations (as sodium or hydrogen) |
| Salinisation | Increasing the salt content of water or soil. |
| Salinity | The concentration of dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre. |
| Salt | A mineral which in a liquid will readily dissociate into its component ionic species for example NaCl into Na+ and $Cl^-$ ions. |
| Saturated zone<br>Zone of saturation | Area below the water table where all soil spaces, pores, fractures and voids are filled with water. |
| Screen | A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material. |
| Sedimentary rock | A rock formed by consolidation of sediments deposited in layers, for example sandstone, siltstone and limestone. |

| Word | Definition |
|---|---|
| Semi-confined aquifer | An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the confining layer — also known as a leaky artesian or leaky confined aquifer. |
| Sodium Absorption Ratio (SAR) | SAR is the ratio of sodium to calcium and magnesium in relation to known effects on soil used to measure the suitability of water for use in agricultural irrigation. |
| Stable isotope | Stable isotopes are not radioactive, and do not decay over time. For example, most oxygen atoms have 16 neutrons, while a very small percentage of naturally occurring oxygen atoms have 18 neutrons. The $^{18}O$ atoms are referred to as stable isotopes. |
| Stratigraphy | The depositional order of sedimentary rocks in layers. |
| Toxicity | The degree to which a substance is able to damage an animal or plant life form. |
| Total Dissolved Solids (TDS) | A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). This can be determined by evaporating a known volume of sample and weighing the left-over precipitate/salts, calculating from the measured dissolved ion concentrations, or calculating from the measured Electrical conductivity. |
| Total Hardness | A measurement of the mineral content in a water sample and is largely made up of calcium and magnesium carbonates, bicarbonates, and sulfates. |
| Trace element | An element found in only minor amounts (concentrations less than 10 milligram per litre) in water or sediment; includes heavy metals arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. |
| Transmissivity | The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media. |
| Trigger value | Trigger values are conservative water quality assessment levels based mainly on statistical distributions. They are concentrations of key indicators, above or below, which there is a risk of adverse biological or environmental effects. |
| Unconfined aquifer | A groundwater system usually near the ground surface, which there are no confining begs between the zone of saturation and is in connection with atmospheric pressure and whose upper level is represented by the water table. Also known as a water table or phreatic aquifer. |

| Word | Definition |
|---|---|
| Unconsolidated sediment | Particles of gravel, sand, silt or clay that are not bound or hardened by mineral cement, pressure, or thermal alteration of the grains. |
| Water quality | Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose. |
| Water quality data | Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and wastewater and of the immediate environment in which the water exists. |
| Water resource plan | A plan made under the Commonwealth Water Act 2007 that outlines how an area of the Murray–Darling Basin's water resources will be managed to be consistent with the Murray–Darling Basin Plan. These plans set out the water sharing rules and arrangements relating to issues such as annual limits on water take, environmental water, managing water during extreme events and strategies to achieve water quality standards and manage risks. |
| Water sharing plan | A plan made under the *Water Management Act 2000* which set out the rules for sharing water between the environment and water users within whole or part of a water management area or water source. |
| Water source | Defined under the *Water Management Act 2000* as 'The whole or any part of one or more rivers, lakes or estuaries, or one or more places where water occurs naturally on or below the surface of the ground and includes the coastal waters of the State. Individual water sources are more specifically defined in water sharing plans. |
| Water table | Upper surface of groundwater in an unconfined aquifer or confining bed which is at atmospheric pressure, below which the ground is saturated. It can be measured by installing shallow bores extending a few metres into the zone of saturation and then measuring the water level in those bores. |
| Yield | The amount of water that can be supplied over a specific period. |

# List of abbreviations

| Abbreviation | Description |
|---|---|
| BoM | Bureau of Meteorology |
| EC | Electrical conductivity |
| DPE | Department of Planning and Environment |
| NSW | New South Wales |
| RSC | Residual Sodium Carbonate index |
| SAR | Sodium absorption ratio |
| TDS | Total Dissolved Solids |

# List of units

| Unit | Description |
|---|---|
| °C | Degrees Celsius |
| L/s | Litres per second |
| m | Metres |
| mAHD | Metres Australian height datum |
| mbgl | Metres below ground level |
| mEq/L | Milliequivalents per litre |
| mm | Millimetres |
| µS/cm | microSiemens per centimetre |
| mg/L | Milligrams per litre |
| mol | Mole |

# Appendix 1– Beneficial use information

Table 43. Salinity criteria for beneficial use[3,4,5]

| Beneficial use | Range | Category TDS (mg/L) | Category EC (µS/cm)[3] | Category comment |
|---|---|---|---|---|
| Human drinking water | 0–1,800 | 0–600 | 0–900 | Good quality drinking water |
| Human drinking water | 0–1,800 | 600–900 | 900–1,350 | Fair quality drinking water |
| Human drinking water | 0–1,800 | 900–1,200 | 1,350–1,800 | Poor quality drinking water |
| Human drinking water | 0–1,800 | >1,200 | >1,800 | Unacceptable/unpalatable quality drink water |
| Livestock drinking water | 0–19,400 | 3,000–4,000 | 4,480–5,970 | Loss of production and decline in condition and health of poultry |
| Livestock drinking water | 0–19,400 | 4,000–7,000 | 5,970–10,450 | Loss of production and decline in condition and health of dairy cattle |
| Livestock drinking water | 0–19,400 | 5,000–10,000 | 7,460–14,920 | Loss of production and decline in condition and health of beef cattle |
| Livestock drinking water | 0–19,400 | 6,000–7,000 | 8,955–10,450 | Loss of production and decline in condition and health of horses |
| Livestock drinking water | 0–19,400 | 6,000–8,000 | 8,955–11,940 | Loss of production and decline in condition and health of pigs |
| Livestock drinking water | 0–19,400 | 10,000–13,000 | 14,920–19,400 | Loss of production and decline in condition and health of sheep |
| Irrigation | 0–8,100 | n/a | 0–650 | Very low water salinity: suitable for sensitive crops |
| Irrigation | 0–8,100 | n/a | 650–1,300 | Low water salinity: suitable for moderately sensitive crops |

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[3] ‘Human drinking water’ information taken from the *Australian Drinking Water Guidelines* (2011)

[4] ‘Livestock drinking water’ and ‘Irrigation’ information taken from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2018)

[5] Electrical Conductivity (EC) values calculated from Total Dissolved Solids (TDS) concentration using the equation EC (µS/cm) = TDS (mg/L) / 0.67. This excludes ‘Irrigation’, which has been classified based on Electrical Conductivity values.

| Beneficial use | Range | Category TDS (mg/L) | Category EC (µS/cm)[3] | Category comment |
|---|---|---|---|---|
| **Irrigation** | 0–8,100 | n/a | 1,300–2,900 | Medium water salinity: suitable for moderately tolerant crops |
| **Irrigation** | 0–8,100 | n/a | 2,900–5,200 | High water salinity: suitable for tolerant crops |
| **Irrigation** | 0–8,100 | n/a | 5,200–8,100 | Very-high water salinity: suitable for very tolerant crops |
| **Irrigation** | 0–8,100 | n/a | >8,100 | Extreme water salinity: generally too saline for irrigation |

Table 44. Australian Drinking Water Guideline (2011) values

| Analyte | Health guideline value | Aesthetic guideline value | Comments |
|---|---|---|---|
| **pH (pH units)** | n/a | 6.5–8.5 | Based on minimising corrosion and encrustation of plumbing fittings and pipes. |
| **Total dissolved solids (mg/L)** | n/a | 600 | Based on palatability:<br>0–600 mg/L: good<br>600–900 mg/L: fair<br>900–1,200 mg/L: poor<br>>1,200 mg/L: unacceptable (unpalatable) |
| **Sodium (mg/L)** | n/a | 180 | |
| **Potassium (mg/L)** | n/a | n/a | No guideline values reported |
| **Calcium (mg/L)** | n/a | n/a | No guideline values reported |
| **Magnesium (mg/L)** | n/a | n/a | No guideline values reported |
| **Chloride (mg/L)** | n/a | 250 | |
| **Sulfate (mg/L)** | 500 | 250 | |
| **Bicarbonate (mg/L)** | n/a | n/a | No guideline values reported |
| **Nitrate (as $NO_3^-$) (mg/L)** | 50 (infants under 3 months old)<br>100 (adults and children over 3 months old) | n/a | Guideline value for infants under 3 months old to minimise risk of methaemoglobinaemia. Water must also be known to be microbiologically safe. |
| **Hardness as $CaCO_3$ (mg/L)** | n/a | 200 | Based on minimising undesirable build-up of scale in hot water systems<br>< 60 mg/L $CaCO_3$: soft but possibly corrosive<br>60–200 mg/L $CaCO_3$: good quality<br>200–500 mg/L $CaCO_3$: increasing scaling problems<br>> 500 mg/L $CaCO_3$: severe scaling |

Table 45. Salinity hazard categories

| TDS (mg/L) | EC (µS/cm) | Class | Remarks |
|---|---|---|---|
| <200 | <250 | C1 | Low salinity water–can be used for most irrigation with most crops on most soils with little likelihood that a salinity problem will develop. Some leaching is required but this occurs under normal irrigation practices except in soils of extremely low permeability. |
| 200–250 | 250–750 | C2 | Medium salinity water–can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices for salinity control. |
| 500–1,500 | 750–2,250 | C3 | High salinity water–cannot be used on soils with restricted drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. |
| 1,500–3,000 | 2,250–5,000 | C4 | Very-high salinity water–is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and very salt tolerant crops should be used. |

Table 46. Sodium hazard categories

| SAR | Class | Remarks |
|---|---|---|
| 0–10 | S1 | Low sodium water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.<br>However, sodium sensitive crops such as stone fruit trees and avocado may accumulate injurious concentrations of sodium. |
| 10–18 | S2 | Medium sodium water will present an appreciable sodium hazard in fine-textured soils having a high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil. |
| 18–26 | S3 | High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management–good drainage, high leaching and organic matter additions. |
| >26 | S4 | Very-high sodium water is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the dissolving of calcium from the soil or the use of gypsum or other additives may make the use of these waters feasible. |

Table 47. Chloride and sodium concentrations (mg/L) causing foliar injury in crops of varying sensitivity (adapted from ANZECC & ARMZANZ; 2018)

| Sensitive<br><175 mg/L (chloride)<br><115 mg/L (sodium) | Moderately sensitive<br>175–350 mg/L (chloride)<br>115–230 mg/L (sodium) | Moderately tolerant<br>350–700 mg/L (chloride)<br>230–460 mg/L (sodium) | Tolerant<br>>700 mg/L (chloride)<br>>460 mg/L (sodium) |
|---|---|---|---|
| Almond | Pepper | Barley | Cauliflower |
| Apricot | Potato | Maize | Cotton |
| Citrus | Tomato | Cucumber | Sugar beet |
| Plum |  | Lucerne | Sunflower |
| Grape |  | Safflower |  |
|  |  | Sorghum |  |

Table 48. Risks of increasing cadmium concentrations in drops due to chloride in irrigation waters (adapted from ANZECC & ARMZANZ; 2018)

| Irrigation water chloride concentration (mg/L) | Risk of increasing crop cadmium concentrations |
|---|---|
| 0–350 | Low |
| 350–750 | Medium |
| >750 | High |

Table 49. Corrosion potential of waters on metal surfaces as indicated by pH and hardness (adapted from ANZECC & ARMZANZ; 2018)

| Parameter | Value | Comments |
|---|---|---|
| pH | <5 | High corrosion potential |
|  | 5–6 | Likelihood of corrosion |
|  | >6 | Limited corrosion potential |
| Hardness | <60 mg/L $CaCO_3$ | Increased corrosion potential |

Table 50. Fouling potential of waters as indicated by pH and hardness (adapted from ANZECC & ARMZANZ; 2018)

| Parameter | Value | Comments |
|---|---|---|
| pH | <7 | Limited fouling potential |
|  | 7–8.5 | Moderate fouling potential |
|  | >8.5 | Increased fouling potential |
| Hardness | >350 mg/L $CaCO_3$ | Increased fouling potential |

Table 51. ANZECC & ARMZANZ (2018) guidelines for livestock drinking[6]

| Analyte | Guideline value (mg/L) | Comments |
|---|---|---|
| **Calcium** | 1,000 | In the presence of high concentrations of magnesium and sodium, or if calcium is added to feed as a dietary supplement, the level of calcium in drinking water may be less |
| **Magnesium** | n/a | Insufficient information available to set trigger value |
| **Sulfate** | 1,000 | n/a |
| **Nitrate (as $NO_3^-$)** | 1,500 | n/a |

---

[6] n/a denotes that no water quality guideline value has been reported for this analyte

# Appendix 2– Work summaries of monitoring bores

# WaterNSW
## Work Summary

**GW030323**

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (2)
**Work Status:** Instrumented
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 01/09/1975
**Final Depth:** 362.70 m
**Drilled Depth:** 362.70 m

**Contractor Name:** (None)
**Driller:**
**Assistant Driller:**

**Property:**
**Standing Water Level (m):**
**GWMA:**
**GW Zone:**
**Salinity Description:**
**Yield (L/s):**

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | URANA | BROOME | 127//756396 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**CMA Map:** 8027-N
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:** 45
**Grid Zone:**
**Scale:**

**Elevation:** 112.59 m (A.H.D.)
**Elevation Source:** R.L. at W.L.M.Pt.
**Northing:** 6115343.000
**Easting:** 386918.000
**Latitude:** 35°05'53.7"S
**Longitude:** 145°45'33.6"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** GD.,PR. MAP

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Backfill | Backfill | 102.10 | 275.80 | 200 | | | |
| 1 | | Backfill | Backfill | 275.80 | 362.70 | 171 | | | |
| 1 | | Casing | Casing Protector | -1.23 | 0.00 | | | | |
| 1 | 1 | Casing | P.V.C. | -0.90 | 102.10 | 64 | | | |
| 1 | 1 | Casing | Other | 0.00 | 182.80 | 102 | | | |
| 1 | 1 | Casing | Withdrawn | 0.00 | 245.00 | 150 | | | |
| 1 | 1 | Opening | Slots | 88.30 | 94.40 | 64 | | 1 | Plastic |
| 1 | 1 | Opening | Slots | 88.50 | 100.20 | 152 | | 0 | |
| 1 | 1 | Opening | Slots | 117.90 | 129.60 | 152 | | 0 | |
| 1 | 1 | Opening | Slots | 134.60 | 146.30 | 152 | | 0 | |
| 1 | 1 | Opening | Slots | 174.60 | 186.30 | 152 | | 0 | |
| 1 | 1 | Opening | Slots | 192.70 | 204.40 | 152 | | 0 | |
| 1 | 1 | Opening | Slots | 229.30 | 241.00 | 152 | | 0 | |
| 2 | | Backfill | Backfill | 206.70 | 213.30 | 200 | | | |
| 2 | | Casing | Casing Protector | -0.67 | 1.70 | 203 | | | |
| 2 | 2 | Casing | P.V.C. | -0.60 | 206.70 | 102 | | | |
| 2 | 2 | Opening | Slots | 194.40 | 200.50 | 102 | | 2 | Plastic |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 68.00 | 71.00 | 3.00 | Unconsolidated | | | | | | |
| 76.00 | 81.00 | 5.00 | Unconsolidated | | | | | | |
| 85.00 | 97.00 | 12.00 | Unconsolidated | 20.00 | | 0.10 | | | |
| 108.00 | 125.00 | 17.00 | Unconsolidated | 19.40 | | 10.00 | | | |
| 137.00 | 143.00 | 6.00 | Unconsolidated | 19.50 | | 1.20 | | | |
| 175.00 | 181.00 | 6.00 | Unconsolidated | 24.90 | | 0.30 | | | |
| 194.50 | 202.70 | 8.20 | Unconsolidated | 22.50 | | 15.00 | | | |
| 241.00 | 247.00 | 6.00 | Unconsolidated | 22.50 | | 1.80 | | | |

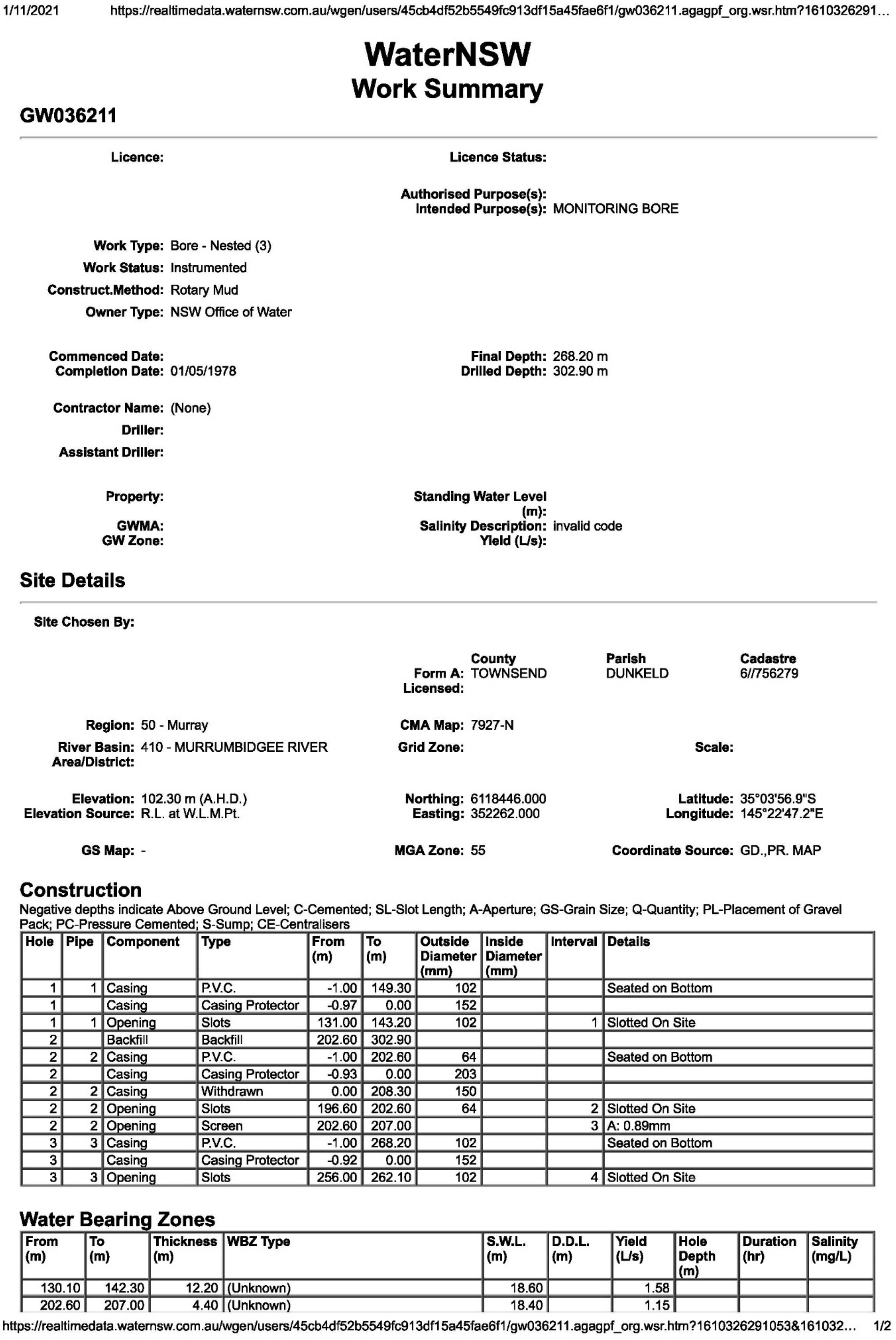
## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 3.00 | 3.00 | Clay Geologist | Clay | |
| 3.00 | 4.25 | 1.25 | Clay Sandy Geologist | Clay | |
| 4.25 | 12.00 | 7.75 | Clay Grey Geologist | Clay | |
| 12.00 | 13.50 | 1.50 | Clay Very Sandy Geologist | Clay | |
| 13.50 | 14.50 | 1.00 | Clay Sandy Geologist | Clay | |
| 14.50 | 16.00 | 1.50 | Sand Geologist | Sand | |
| 16.00 | 20.00 | 4.00 | Clay Geologist | Clay | |
| 20.00 | 23.00 | 3.00 | Clay Sandy Geologist | Clay | |
| 23.00 | 26.00 | 3.00 | Clay Geologist | Clay | |
| 26.00 | 27.50 | 1.50 | Clay Sandy Geologist | Clay | |
| 27.50 | 35.00 | 7.50 | Clay Geologist | Clay | |
| 35.00 | 38.00 | 3.00 | Clay Silty Geologist | Clay | |
| 38.00 | 42.70 | 4.70 | Clay Sandy Geologist | Clay | |
| 42.70 | 47.30 | 4.60 | Clay Geologist | Clay | |
| 47.30 | 48.70 | 1.40 | Sand Clayey Geologist | Sand | |
| 48.70 | 50.30 | 1.60 | Clay Sandy Geologist | Clay | |
| 50.30 | 65.20 | 14.90 | Clay Geologist | Clay | |
| 65.20 | 67.00 | 1.80 | Clay Sandy Geologist | Clay | |
| 67.00 | 71.00 | 4.00 | Sand Geologist | Sand | |
| 71.00 | 73.00 | 2.00 | Clay Geologist | Clay | |
| 73.00 | 100.50 | 27.50 | Sand Gravel Geologist | Sand | |
| 100.50 | 108.00 | 7.50 | Clay Sandy Geologist | Clay | |
| 108.00 | 125.00 | 17.00 | Sand Geologist | Sand | |
| 125.00 | 126.50 | 1.50 | Clay Sandy Geologist | Clay | |
| 126.50 | 137.00 | 10.50 | Carbonaceous Geologist, Clay Black Some Sand Geologist | Clay | |
| 137.00 | 140.00 | 3.00 | Clay Dark Sandy Geologist | Clay | |
| 140.00 | 141.50 | 1.50 | Sand Dark Clayey Geologist | Sand | |
| 141.50 | 144.50 | 3.00 | Clay Carbonaceous Sandy Geologist | Clay | |
| 144.50 | 149.20 | 4.70 | Sand Geologist, Clay Black Geologist | Sand | |
| 149.20 | 152.20 | 3.00 | Clay Black Geologist | Clay | |
| 152.20 | 165.80 | 13.60 | Carbonaceous Geologist, Clay Some Silt Geologist | Clay | |
| 165.80 | 167.30 | 1.50 | Clay Sandy Geologist | Clay | |
| 167.30 | 193.40 | 26.10 | Carbonaceous Geologist | Unknown | |
| 193.40 | 201.00 | 7.60 | Sand Geologist | Sand | |
| 201.00 | 205.50 | 4.50 | Gravel Clayey Geologist | Gravel | |
| 205.50 | 211.80 | 6.30 | Lignite Geologist | Lignite | |
| 211.80 | 225.50 | 13.70 | Clay Carbonaceous Geologist | Clay | |
| 225.50 | 230.00 | 4.50 | Carbonised Wood Geologist | Unknown | |
| 230.00 | 234.70 | 4.70 | Sand Some Wood Geologist | Sand | |
| 234.70 | 239.00 | 4.30 | Carbonised Wood Geologist | Unknown | |
| 239.00 | 248.00 | 9.00 | Sand Geologist | Sand | |
| 248.00 | 312.20 | 64.20 | Sandstone Siltstone Geologist | Sandstone | |
| 312.20 | 329.00 | 16.80 | Sand Geologist | Sand | |
| 329.00 | 331.00 | 2.00 | Coal Geologist | Coal | |
| 331.00 | 337.00 | 6.00 | Siltstone Geologist | Siltstone | |
| 337.00 | 340.00 | 3.00 | Coal Geologist | Coal | |
| 340.00 | 344.00 | 4.00 | Coal Soft Geologist | Coal | |
| 344.00 | 353.50 | 9.50 | Coal Some Soft Some Hard Geologist | Coal | |
| 353.50 | 358.00 | 4.50 | Coal Clay Geologist | Coal | |
| 358.00 | 362.70 | 4.70 | Sand Some Coal Geologist | Sand | |

## Remarks

14/04/1976: HOLE 1 102M CASLN 1-4 SCNLN 1-7.
14/04/1976: HOLE 2 206.7M CASLN 6-9 SCNLN 8.
14/04/1976: CASLN 8 LOST IN HOLE.
14/04/1976: PUMPING TESTS BY CABLE TOOL RIG.
05/10/2001: GPS COORDS TAKEN 3/9/01 - OLD COORDS 386860/6115260.
09/12/2008: Nat Carling, 9-Dec-2008: Updated RL's (no date found), cadastre (was entered as '127') & casing protector details, based in info provided in State Water Survey database, provided by Jim Salmon.
28/10/2009: Entered Geologist log remarks were as follows: "the log for the interval 800-1190 ft (244 - 362.95 m) was obtained by interpreting the drill cuttings in conjunction with the two cored intervals. No sandstone chips were obtained in the cuttings, so heavy reliance was placed on the cores". Monica McColl
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW030323 *****



1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036211.agagpf_org.wsr.htm?1610326291…

# WaterNSW
## Work Summary

**GW036211**

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (3)
**Work Status:** Instrumented
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 01/05/1978
**Final Depth:** 268.20 m
**Drilled Depth:** 302.90 m

**Contractor Name:** (None)
**Driller:**
**Assistant Driller:**

**Property:**
**GWMA:**
**GW Zone:**
**Standing Water Level (m):**
**Salinity Description:** invalid code
**Yield (L/s):**

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | TOWNSEND | DUNKELD | 6//756279 |
| **Licensed:** | | | |

**Region:** 50 - Murray
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:**
**CMA Map:** 7927-N
**Grid Zone:**
**Scale:**

**Elevation:** 102.30 m (A.H.D.)
**Elevation Source:** R.L. at W.L.M.Pt.
**Northing:** 6118446.000
**Easting:** 352262.000
**Latitude:** 35°03'56.9"S
**Longitude:** 145°22'47.2"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** GD.,PR. MAP

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Casing | P.V.C. | -1.00 | 149.30 | 102 | | | Seated on Bottom |
| 1 | | Casing | Casing Protector | -0.97 | 0.00 | 152 | | | |
| 1 | 1 | Opening | Slots | 131.00 | 143.20 | 102 | | 1 | Slotted On Site |
| 2 | | Backfill | Backfill | 202.60 | 302.90 | | | | |
| 2 | 2 | Casing | P.V.C. | -1.00 | 202.60 | 64 | | | Seated on Bottom |
| 2 | | Casing | Casing Protector | -0.93 | 0.00 | 203 | | | |
| 2 | 2 | Casing | Withdrawn | 0.00 | 208.30 | 150 | | | |
| 2 | 2 | Opening | Slots | 196.60 | 202.60 | 64 | | 2 | Slotted On Site |
| 2 | 2 | Opening | Screen | 202.60 | 207.00 | | | 3 | A: 0.89mm |
| 3 | 3 | Casing | P.V.C. | -1.00 | 268.20 | 102 | | | Seated on Bottom |
| 3 | | Casing | Casing Protector | -0.92 | 0.00 | 152 | | | |
| 3 | 3 | Opening | Slots | 256.00 | 262.10 | 102 | | 4 | Slotted On Site |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 130.10 | 142.30 | 12.20 | (Unknown) | 18.60 | | 1.58 | | | |
| 202.60 | 207.00 | 4.40 | (Unknown) | 18.40 | | 1.15 | | | |

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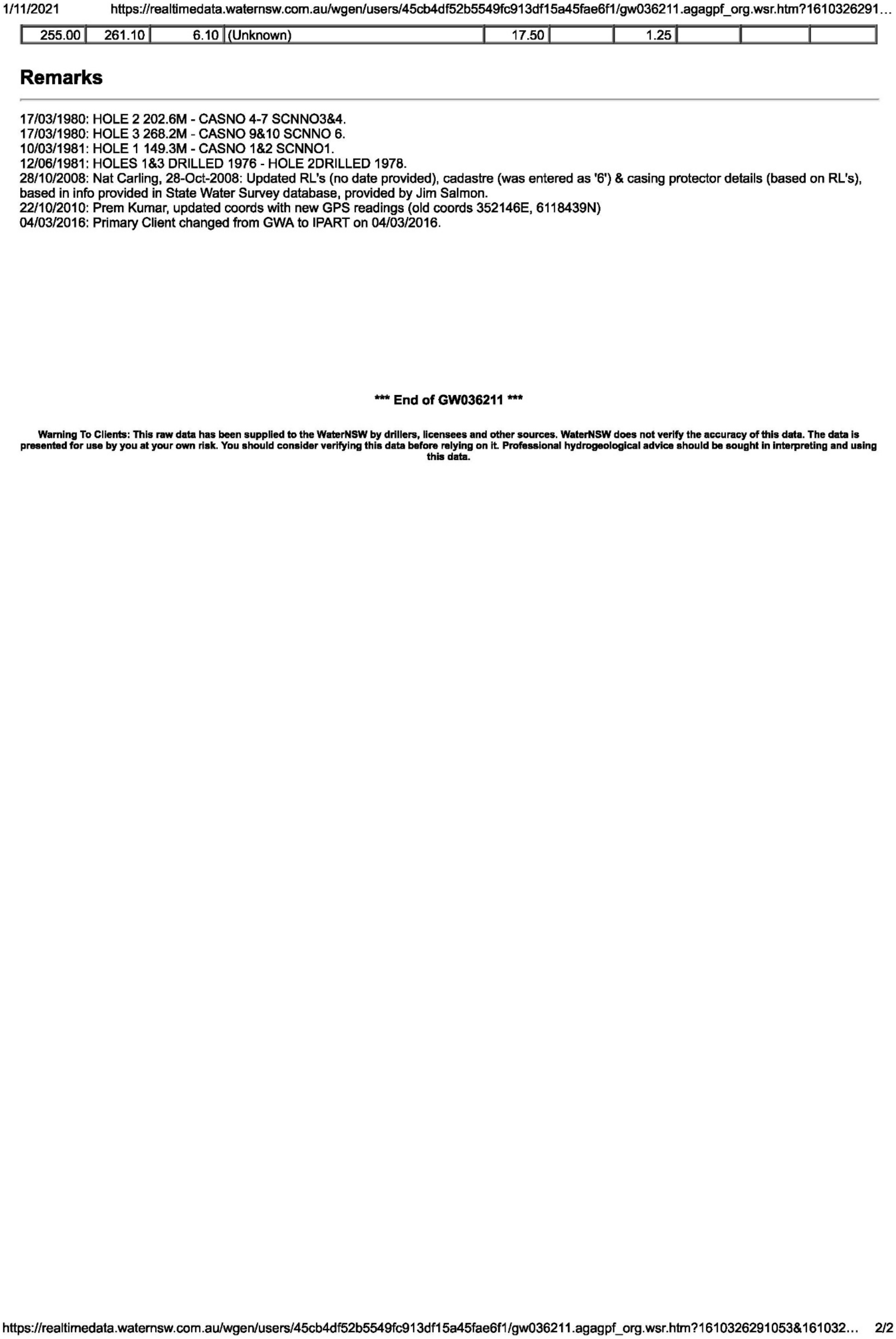
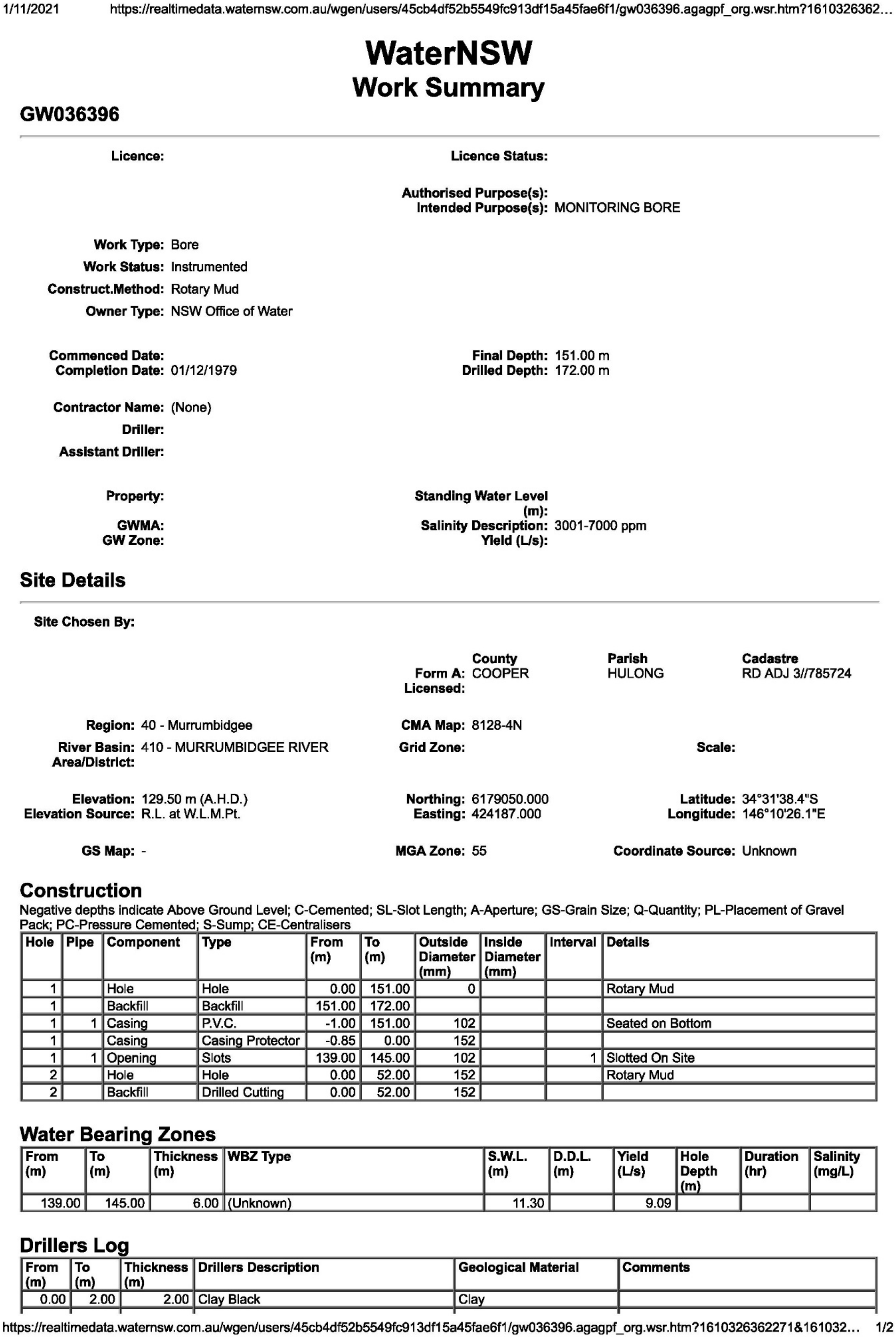


| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 255.00 | 261.10 | 6.10 | (Unknown) | 17.50 | | 1.25 | | | |

## Remarks

17/03/1980: HOLE 2 202.6M - CASNO 4-7 SCNNO3&4.
17/03/1980: HOLE 3 268.2M - CASNO 9&10 SCNNO 6.
10/03/1981: HOLE 1 149.3M - CASNO 1&2 SCNNO1.
12/06/1981: HOLES 1&3 DRILLED 1976 - HOLE 2DRILLED 1978.
28/10/2008: Nat Carling, 28-Oct-2008: Updated RL's (no date provided), cadastre (was entered as '6') & casing protector details (based on RL's), based in info provided in State Water Survey database, provided by Jim Salmon.
22/10/2010: Prem Kumar, updated coords with new GPS readings (old coords 352146E, 6118439N)
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW036211 *****



1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036396.agagpf_org.wsr.htm?1610326362…

# WaterNSW

## Work Summary

### GW036396

**Licence:**

**Licence Status:**

**Authorised Purpose(s):** 
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore
**Work Status:** Instrumented
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:** 
**Completion Date:** 01/12/1979

**Final Depth:** 151.00 m
**Drilled Depth:** 172.00 m

**Contractor Name:** (None)
**Driller:** 
**Assistant Driller:**

**Property:** 
**GWMA:** 
**GW Zone:**

**Standing Water Level (m):** 
**Salinity Description:** 3001-7000 ppm
**Yield (L/s):**

### Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | COOPER | HULONG | RD ADJ 3//785724 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:**

**CMA Map:** 8128-4N
**Grid Zone:** 
**Scale:**

**Elevation:** 129.50 m (A.H.D.)
**Elevation Source:** R.L. at W.L.M.Pt.

**Northing:** 6179050.000
**Easting:** 424187.000

**Latitude:** 34°31'38.4"S
**Longitude:** 146°10'26.1"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** Unknown

### Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Hole | Hole | 0.00 | 151.00 | 0 | | | Rotary Mud |
| 1 | | Backfill | Backfill | 151.00 | 172.00 | | | | |
| 1 | 1 | Casing | P.V.C. | -1.00 | 151.00 | 102 | | | Seated on Bottom |
| 1 | | Casing | Casing Protector | -0.85 | 0.00 | 152 | | | |
| 1 | 1 | Opening | Slots | 139.00 | 145.00 | 102 | | 1 | Slotted On Site |
| 2 | | Hole | Hole | 0.00 | 52.00 | 152 | | | Rotary Mud |
| 2 | | Backfill | Drilled Cutting | 0.00 | 52.00 | 152 | | | |

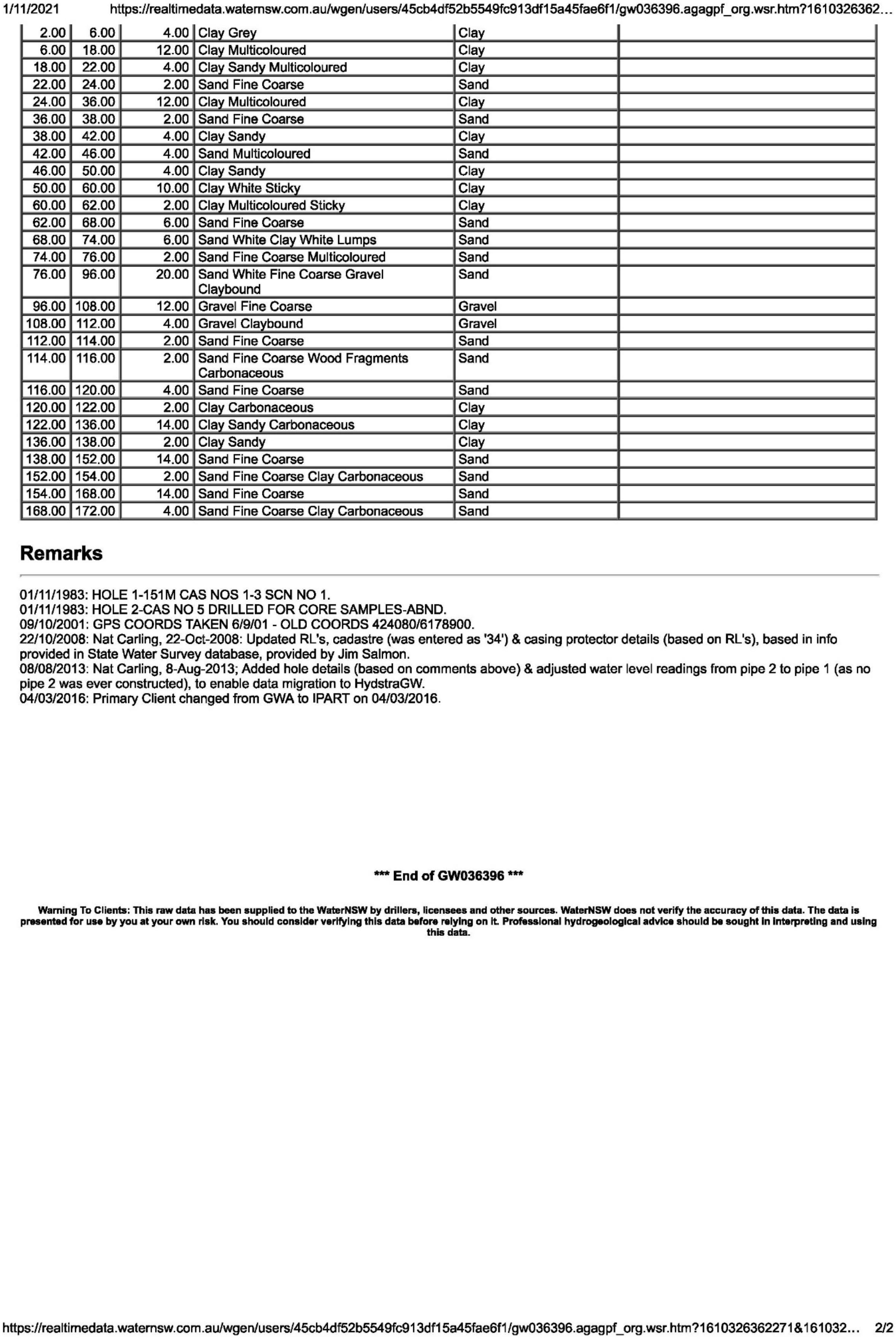
### Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 139.00 | 145.00 | 6.00 | (Unknown) | 11.30 | | 9.09 | | | |

### Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 2.00 | 2.00 | Clay Black | Clay | |

https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036396.agagpf_org.wsr.htm?1610326362271&161032… 1/2

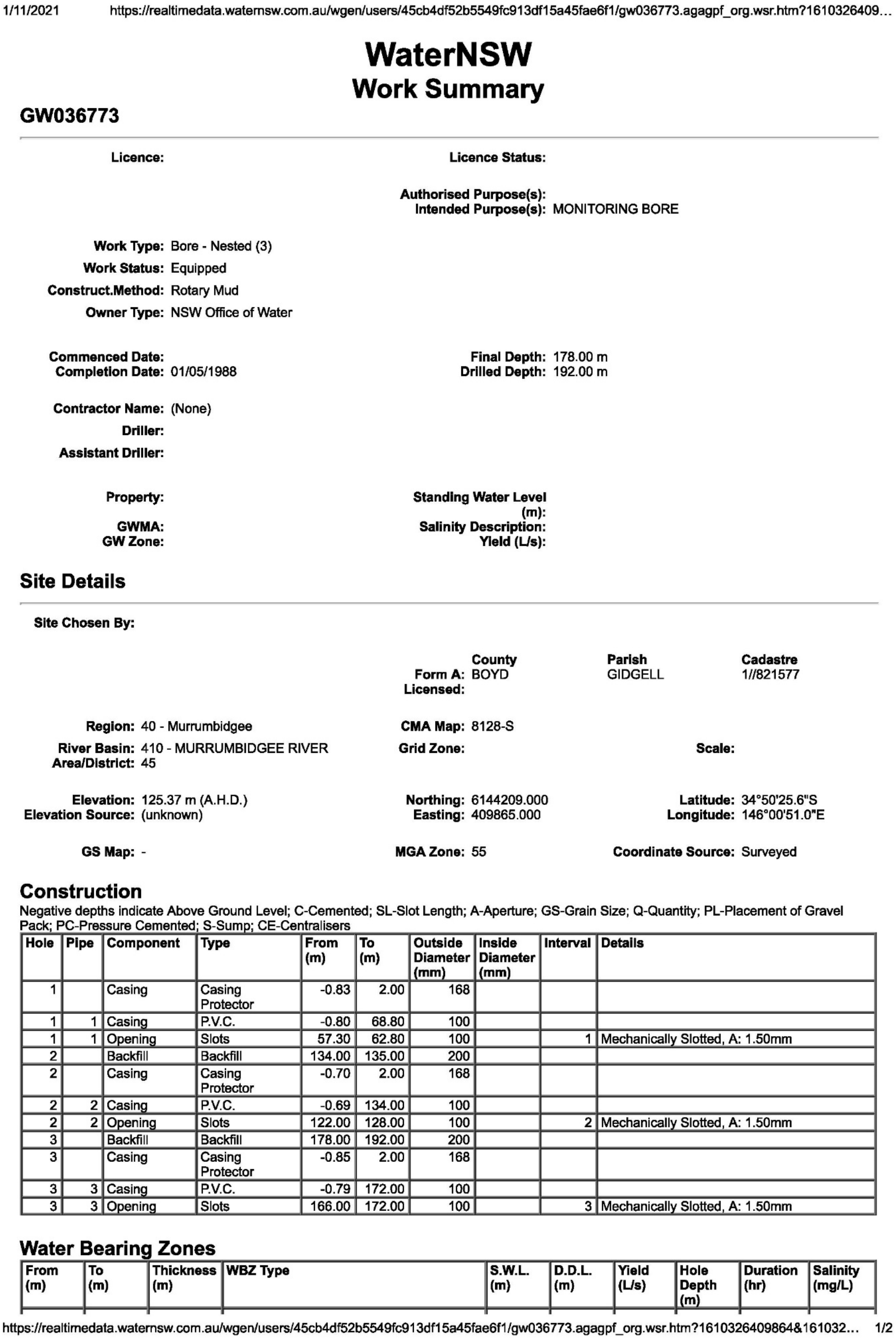


| | | | | | |
|---|---|---|---|---|---|
| 2.00 | 6.00 | 4.00 | Clay Grey | Clay | |
| 6.00 | 18.00 | 12.00 | Clay Multicoloured | Clay | |
| 18.00 | 22.00 | 4.00 | Clay Sandy Multicoloured | Clay | |
| 22.00 | 24.00 | 2.00 | Sand Fine Coarse | Sand | |
| 24.00 | 36.00 | 12.00 | Clay Multicoloured | Clay | |
| 36.00 | 38.00 | 2.00 | Sand Fine Coarse | Sand | |
| 38.00 | 42.00 | 4.00 | Clay Sandy | Clay | |
| 42.00 | 46.00 | 4.00 | Sand Multicoloured | Sand | |
| 46.00 | 50.00 | 4.00 | Clay Sandy | Clay | |
| 50.00 | 60.00 | 10.00 | Clay White Sticky | Clay | |
| 60.00 | 62.00 | 2.00 | Clay Multicoloured Sticky | Clay | |
| 62.00 | 68.00 | 6.00 | Sand Fine Coarse | Sand | |
| 68.00 | 74.00 | 6.00 | Sand White Clay White Lumps | Sand | |
| 74.00 | 76.00 | 2.00 | Sand Fine Coarse Multicoloured | Sand | |
| 76.00 | 96.00 | 20.00 | Sand White Fine Coarse Gravel Claybound | Sand | |
| 96.00 | 108.00 | 12.00 | Gravel Fine Coarse | Gravel | |
| 108.00 | 112.00 | 4.00 | Gravel Claybound | Gravel | |
| 112.00 | 114.00 | 2.00 | Sand Fine Coarse | Sand | |
| 114.00 | 116.00 | 2.00 | Sand Fine Coarse Wood Fragments Carbonaceous | Sand | |
| 116.00 | 120.00 | 4.00 | Sand Fine Coarse | Sand | |
| 120.00 | 122.00 | 2.00 | Clay Carbonaceous | Clay | |
| 122.00 | 136.00 | 14.00 | Clay Sandy Carbonaceous | Clay | |
| 136.00 | 138.00 | 2.00 | Clay Sandy | Clay | |
| 138.00 | 152.00 | 14.00 | Sand Fine Coarse | Sand | |
| 152.00 | 154.00 | 2.00 | Sand Fine Coarse Clay Carbonaceous | Sand | |
| 154.00 | 168.00 | 14.00 | Sand Fine Coarse | Sand | |
| 168.00 | 172.00 | 4.00 | Sand Fine Coarse Clay Carbonaceous | Sand | |

## Remarks

01/11/1983: HOLE 1-151M CAS NOS 1-3 SCN NO 1.
01/11/1983: HOLE 2-CAS NO 5 DRILLED FOR CORE SAMPLES-ABND.
09/10/2001: GPS COORDS TAKEN 6/9/01 - OLD COORDS 424080/6178900.
22/10/2008: Nat Carling, 22-Oct-2008: Updated RL's, cadastre (was entered as '34') & casing protector details (based on RL's), based in info provided in State Water Survey database, provided by Jim Salmon.
08/08/2013: Nat Carling, 8-Aug-2013; Added hole details (based on comments above) & adjusted water level readings from pipe 2 to pipe 1 (as no pipe 2 was ever constructed), to enable data migration to HydstraGW.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW036396 *****



1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036773.agagpf_org.wsr.htm?1610326409…

# WaterNSW

## Work Summary

**GW036773**

**Licence:**

**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (3)
**Work Status:** Equipped
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 01/05/1988

**Final Depth:** 178.00 m
**Drilled Depth:** 192.00 m

**Contractor Name:** (None)
**Driller:**
**Assistant Driller:**

**Property:**
**GWMA:**
**GW Zone:**

**Standing Water Level (m):**
**Salinity Description:**
**Yield (L/s):**

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | BOYD | GIDGELL | 1//821577 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:** 45

**CMA Map:** 8128-S
**Grid Zone:**
**Scale:**

**Elevation:** 125.37 m (A.H.D.)
**Elevation Source:** (unknown)

**Northing:** 6144209.000
**Easting:** 409865.000

**Latitude:** 34°50'25.6"S
**Longitude:** 146°00'51.0"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** Surveyed

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Casing | Casing Protector | -0.83 | 2.00 | 168 | | | |
| 1 | 1 | Casing | P.V.C. | -0.80 | 68.80 | 100 | | | |
| 1 | 1 | Opening | Slots | 57.30 | 62.80 | 100 | | 1 | Mechanically Slotted, A: 1.50mm |
| 2 | | Backfill | Backfill | 134.00 | 135.00 | 200 | | | |
| 2 | | Casing | Casing Protector | -0.70 | 2.00 | 168 | | | |
| 2 | 2 | Casing | P.V.C. | -0.69 | 134.00 | 100 | | | |
| 2 | 2 | Opening | Slots | 122.00 | 128.00 | 100 | | 2 | Mechanically Slotted, A: 1.50mm |
| 3 | | Backfill | Backfill | 178.00 | 192.00 | 200 | | | |
| 3 | | Casing | Casing Protector | -0.85 | 2.00 | 168 | | | |
| 3 | 3 | Casing | P.V.C. | -0.79 | 172.00 | 100 | | | |
| 3 | 3 | Opening | Slots | 166.00 | 172.00 | 100 | | 3 | Mechanically Slotted, A: 1.50mm |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|

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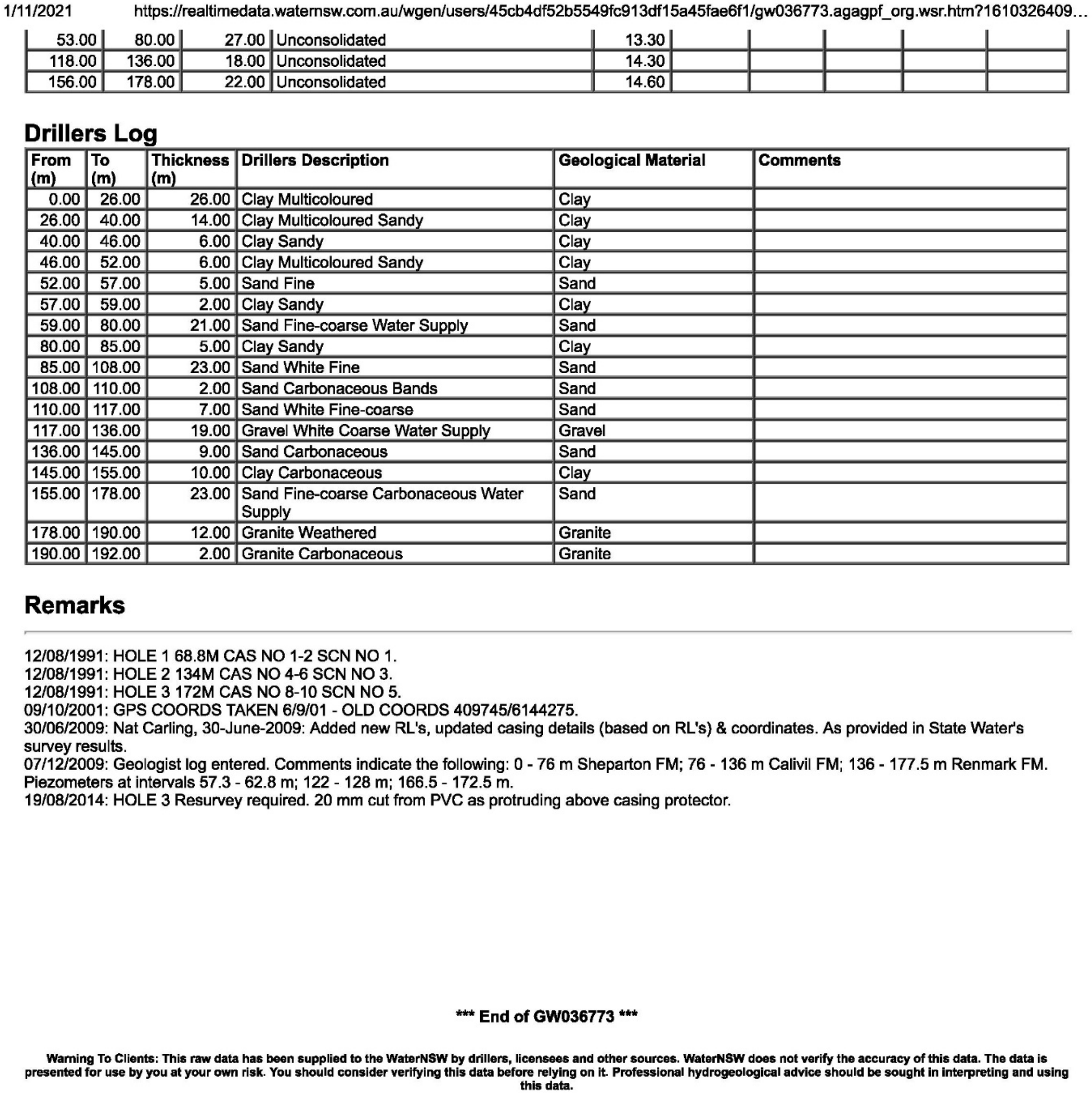

1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036773.agagpf_org.wsr.htm?1610326409…

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53.00 | 80.00 | 27.00 | Unconsolidated | 13.30 | | | | | |
| 118.00 | 136.00 | 18.00 | Unconsolidated | 14.30 | | | | | |
| 156.00 | 178.00 | 22.00 | Unconsolidated | 14.60 | | | | | |

## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 26.00 | 26.00 | Clay Multicoloured | Clay | |
| 26.00 | 40.00 | 14.00 | Clay Multicoloured Sandy | Clay | |
| 40.00 | 46.00 | 6.00 | Clay Sandy | Clay | |
| 46.00 | 52.00 | 6.00 | Clay Multicoloured Sandy | Clay | |
| 52.00 | 57.00 | 5.00 | Sand Fine | Sand | |
| 57.00 | 59.00 | 2.00 | Clay Sandy | Clay | |
| 59.00 | 80.00 | 21.00 | Sand Fine-coarse Water Supply | Sand | |
| 80.00 | 85.00 | 5.00 | Clay Sandy | Clay | |
| 85.00 | 108.00 | 23.00 | Sand White Fine | Sand | |
| 108.00 | 110.00 | 2.00 | Sand Carbonaceous Bands | Sand | |
| 110.00 | 117.00 | 7.00 | Sand White Fine-coarse | Sand | |
| 117.00 | 136.00 | 19.00 | Gravel White Coarse Water Supply | Gravel | |
| 136.00 | 145.00 | 9.00 | Sand Carbonaceous | Sand | |
| 145.00 | 155.00 | 10.00 | Clay Carbonaceous | Clay | |
| 155.00 | 178.00 | 23.00 | Sand Fine-coarse Carbonaceous Water Supply | Sand | |
| 178.00 | 190.00 | 12.00 | Granite Weathered | Granite | |
| 190.00 | 192.00 | 2.00 | Granite Carbonaceous | Granite | |

## Remarks

12/08/1991: HOLE 1 68.8M CAS NO 1-2 SCN NO 1.
12/08/1991: HOLE 2 134M CAS NO 4-6 SCN NO 3.
12/08/1991: HOLE 3 172M CAS NO 8-10 SCN NO 5.
09/10/2001: GPS COORDS TAKEN 6/9/01 - OLD COORDS 409745/6144275.
30/06/2009: Nat Carling, 30-June-2009: Added new RL's, updated casing details (based on RL's) & coordinates. As provided in State Water's survey results.
07/12/2009: Geologist log entered. Comments indicate the following: 0 - 76 m Sheparton FM; 76 - 136 m Calivil FM; 136 - 177.5 m Renmark FM. Piezometers at intervals 57.3 - 62.8 m; 122 - 128 m; 166.5 - 172.5 m.
19/08/2014: HOLE 3 Resurvey required. 20 mm cut from PVC as protruding above casing protector.

***** End of GW036773 *****

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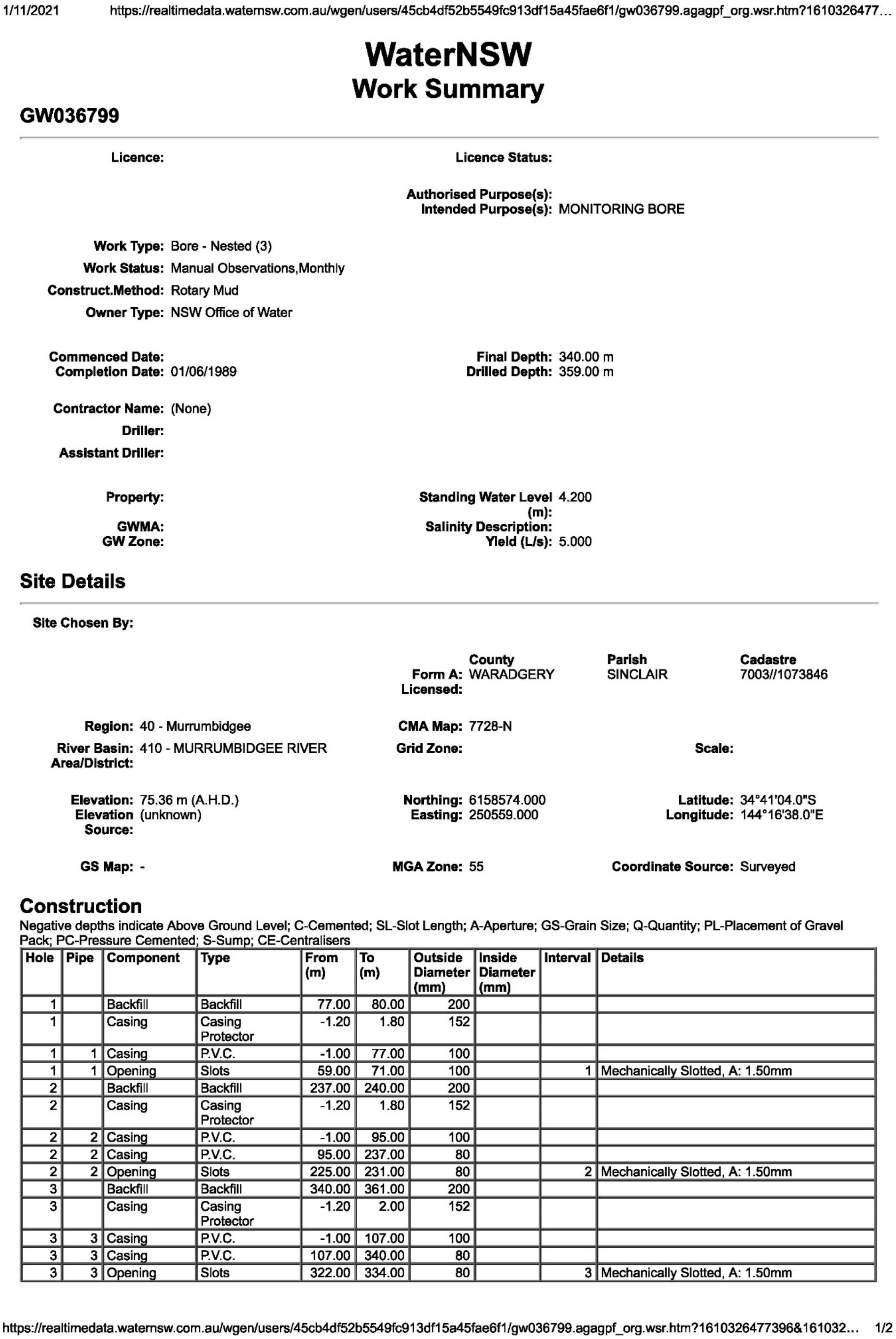

1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036799.agagpf_org.wsr.htm?1610326477…

# WaterNSW

## Work Summary

**GW036799**

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (3)
**Work Status:** Manual Observations,Monthly
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 01/06/1989
**Final Depth:** 340.00 m
**Drilled Depth:** 359.00 m

**Contractor Name:** (None)
**Driller:**
**Assistant Driller:**

**Property:**
**Standing Water Level (m):** 4.200
**GWMA:**
**Salinity Description:**
**GW Zone:**
**Yield (L/s):** 5.000

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | WARADGERY | SINCLAIR | 7003//1073846 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**CMA Map:** 7728-N
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Grid Zone:**
**Scale:**
**Area/District:**

**Elevation:** 75.36 m (A.H.D.)
**Elevation Source:** (unknown)
**Northing:** 6158574.000
**Easting:** 250559.000
**Latitude:** 34°41'04.0"S
**Longitude:** 144°16'38.0"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** Surveyed

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Backfill | Backfill | 77.00 | 80.00 | 200 | | | |
| 1 | | Casing | Casing Protector | -1.20 | 1.80 | 152 | | | |
| 1 | 1 | Casing | P.V.C. | -1.00 | 77.00 | 100 | | | |
| 1 | 1 | Opening | Slots | 59.00 | 71.00 | 100 | | 1 | Mechanically Slotted, A: 1.50mm |
| 2 | | Backfill | Backfill | 237.00 | 240.00 | 200 | | | |
| 2 | | Casing | Casing Protector | -1.20 | 1.80 | 152 | | | |
| 2 | 2 | Casing | P.V.C. | -1.00 | 95.00 | 100 | | | |
| 2 | 2 | Casing | P.V.C. | 95.00 | 237.00 | 80 | | | |
| 2 | 2 | Opening | Slots | 225.00 | 231.00 | 80 | | 2 | Mechanically Slotted, A: 1.50mm |
| 3 | | Backfill | Backfill | 340.00 | 361.00 | 200 | | | |
| 3 | | Casing | Casing Protector | -1.20 | 2.00 | 152 | | | |
| 3 | 3 | Casing | P.V.C. | -1.00 | 107.00 | 100 | | | |
| 3 | 3 | Casing | P.V.C. | 107.00 | 340.00 | 80 | | | |
| 3 | 3 | Opening | Slots | 322.00 | 334.00 | 80 | | 3 | Mechanically Slotted, A: 1.50mm |

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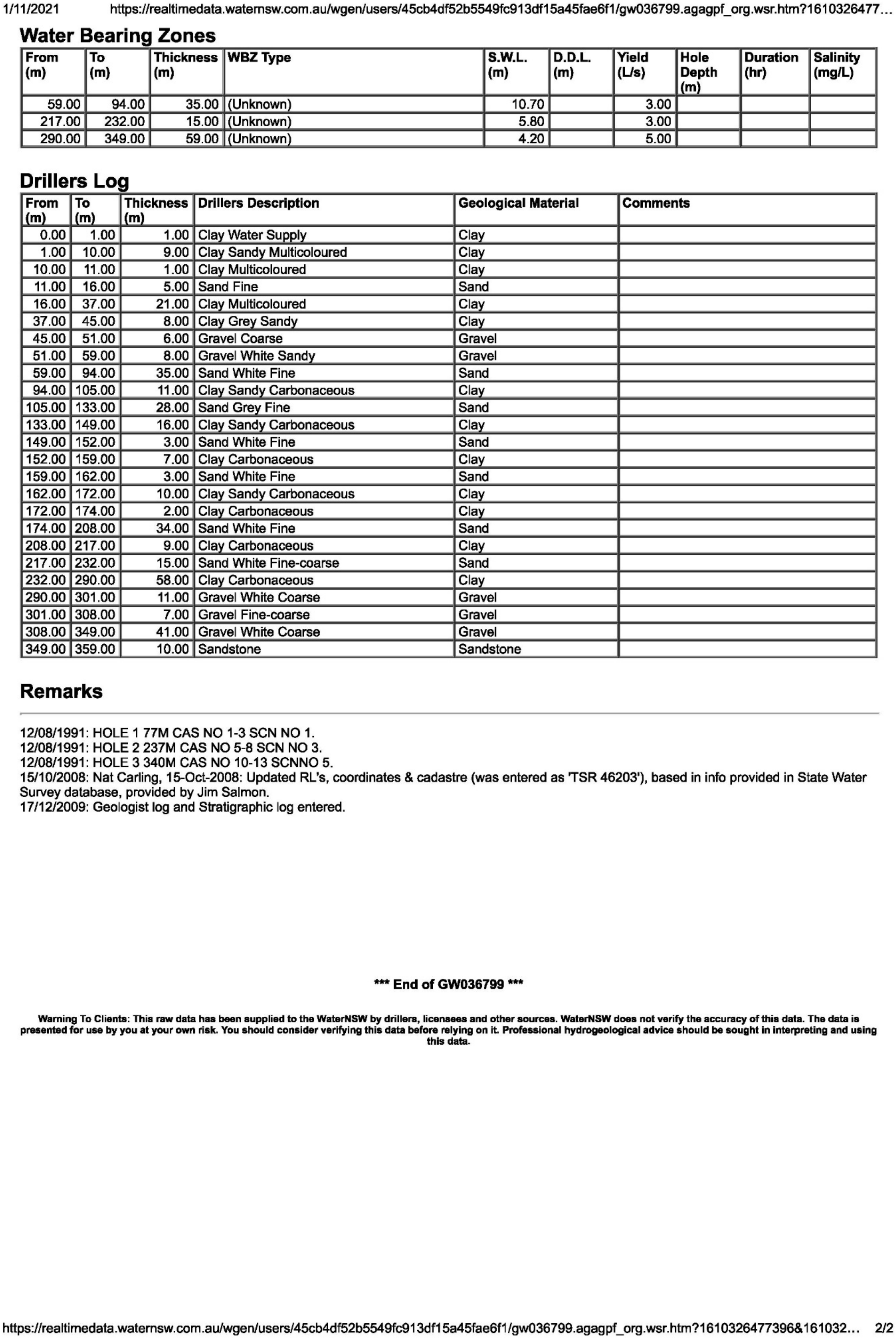

1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw036799.agagpf_org.wsr.htm?1610326477…

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 59.00 | 94.00 | 35.00 | (Unknown) | 10.70 | | 3.00 | | | |
| 217.00 | 232.00 | 15.00 | (Unknown) | 5.80 | | 3.00 | | | |
| 290.00 | 349.00 | 59.00 | (Unknown) | 4.20 | | 5.00 | | | |

## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 1.00 | 1.00 | Clay Water Supply | Clay | |
| 1.00 | 10.00 | 9.00 | Clay Sandy Multicoloured | Clay | |
| 10.00 | 11.00 | 1.00 | Clay Multicoloured | Clay | |
| 11.00 | 16.00 | 5.00 | Sand Fine | Sand | |
| 16.00 | 37.00 | 21.00 | Clay Multicoloured | Clay | |
| 37.00 | 45.00 | 8.00 | Clay Grey Sandy | Clay | |
| 45.00 | 51.00 | 6.00 | Gravel Coarse | Gravel | |
| 51.00 | 59.00 | 8.00 | Gravel White Sandy | Gravel | |
| 59.00 | 94.00 | 35.00 | Sand White Fine | Sand | |
| 94.00 | 105.00 | 11.00 | Clay Sandy Carbonaceous | Clay | |
| 105.00 | 133.00 | 28.00 | Sand Grey Fine | Sand | |
| 133.00 | 149.00 | 16.00 | Clay Sandy Carbonaceous | Clay | |
| 149.00 | 152.00 | 3.00 | Sand White Fine | Sand | |
| 152.00 | 159.00 | 7.00 | Clay Carbonaceous | Clay | |
| 159.00 | 162.00 | 3.00 | Sand White Fine | Sand | |
| 162.00 | 172.00 | 10.00 | Clay Sandy Carbonaceous | Clay | |
| 172.00 | 174.00 | 2.00 | Clay Carbonaceous | Clay | |
| 174.00 | 208.00 | 34.00 | Sand White Fine | Sand | |
| 208.00 | 217.00 | 9.00 | Clay Carbonaceous | Clay | |
| 217.00 | 232.00 | 15.00 | Sand White Fine-coarse | Sand | |
| 232.00 | 290.00 | 58.00 | Clay Carbonaceous | Clay | |
| 290.00 | 301.00 | 11.00 | Gravel White Coarse | Gravel | |
| 301.00 | 308.00 | 7.00 | Gravel Fine-coarse | Gravel | |
| 308.00 | 349.00 | 41.00 | Gravel White Coarse | Gravel | |
| 349.00 | 359.00 | 10.00 | Sandstone | Sandstone | |

## Remarks

12/08/1991: HOLE 1 77M CAS NO 1-3 SCN NO 1.
12/08/1991: HOLE 2 237M CAS NO 5-8 SCN NO 3.
12/08/1991: HOLE 3 340M CAS NO 10-13 SCNNO 5.
15/10/2008: Nat Carling, 15-Oct-2008: Updated RL's, coordinates & cadastre (was entered as 'TSR 46203'), based in info provided in State Water Survey database, provided by Jim Salmon.
17/12/2009: Geologist log and Stratigraphic log entered.

***** End of GW036799 *****

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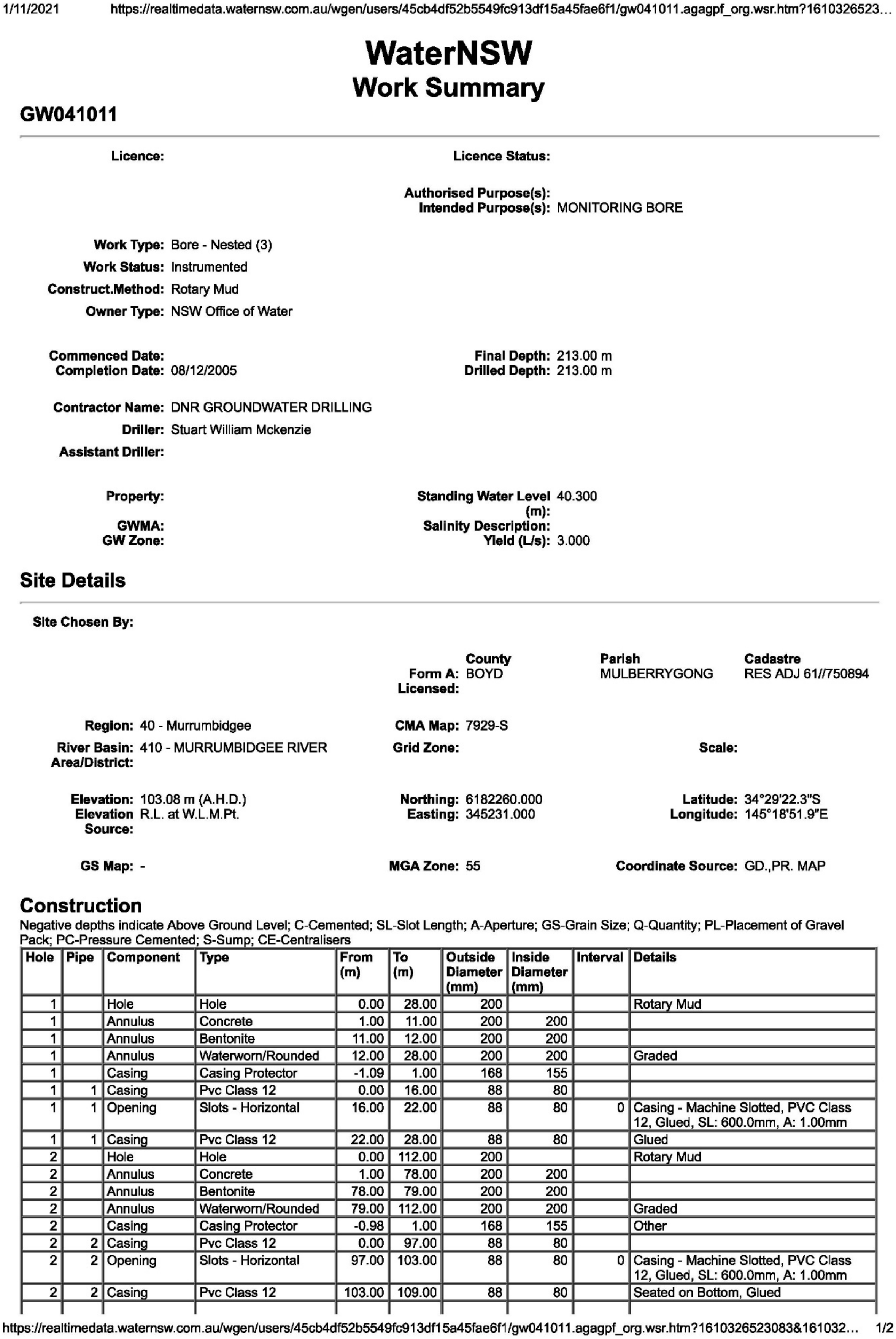

1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw041011.agagpf_org.wsr.htm?1610326523…

# WaterNSW

## Work Summary

### GW041011

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (3)
**Work Status:** Instrumented
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 08/12/2005
**Final Depth:** 213.00 m
**Drilled Depth:** 213.00 m

**Contractor Name:** DNR GROUNDWATER DRILLING
**Driller:** Stuart William Mckenzie
**Assistant Driller:**

**Property:**
**Standing Water Level (m):** 40.300
**GWMA:**
**Salinity Description:**
**GW Zone:**
**Yield (L/s):** 3.000

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | BOYD | MULBERRYGONG | RES ADJ 61//750894 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**CMA Map:** 7929-S
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Grid Zone:**
**Scale:**
**Area/District:**

**Elevation:** 103.08 m (A.H.D.)
**Elevation Source:** R.L. at W.L.M.Pt.
**Northing:** 6182260.000
**Easting:** 345231.000
**Latitude:** 34°29'22.3"S
**Longitude:** 145°18'51.9"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** GD.,PR. MAP

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Hole | Hole | 0.00 | 28.00 | 200 | | | Rotary Mud |
| 1 | | Annulus | Concrete | 1.00 | 11.00 | 200 | 200 | | |
| 1 | | Annulus | Bentonite | 11.00 | 12.00 | 200 | 200 | | |
| 1 | | Annulus | Waterworn/Rounded | 12.00 | 28.00 | 200 | 200 | | Graded |
| 1 | | Casing | Casing Protector | -1.09 | 1.00 | 168 | 155 | | |
| 1 | 1 | Casing | Pvc Class 12 | 0.00 | 16.00 | 88 | 80 | | |
| 1 | 1 | Opening | Slots - Horizontal | 16.00 | 22.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 1.00mm |
| 1 | 1 | Casing | Pvc Class 12 | 22.00 | 28.00 | 88 | 80 | | Glued |
| 2 | | Hole | Hole | 0.00 | 112.00 | 200 | | | Rotary Mud |
| 2 | | Annulus | Concrete | 1.00 | 78.00 | 200 | 200 | | |
| 2 | | Annulus | Bentonite | 78.00 | 79.00 | 200 | 200 | | |
| 2 | | Annulus | Waterworn/Rounded | 79.00 | 112.00 | 200 | 200 | | Graded |
| 2 | | Casing | Casing Protector | -0.98 | 1.00 | 168 | 155 | | Other |
| 2 | 2 | Casing | Pvc Class 12 | 0.00 | 97.00 | 88 | 80 | | |
| 2 | 2 | Opening | Slots - Horizontal | 97.00 | 103.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 1.00mm |
| 2 | 2 | Casing | Pvc Class 12 | 103.00 | 109.00 | 88 | 80 | | Seated on Bottom, Glued |

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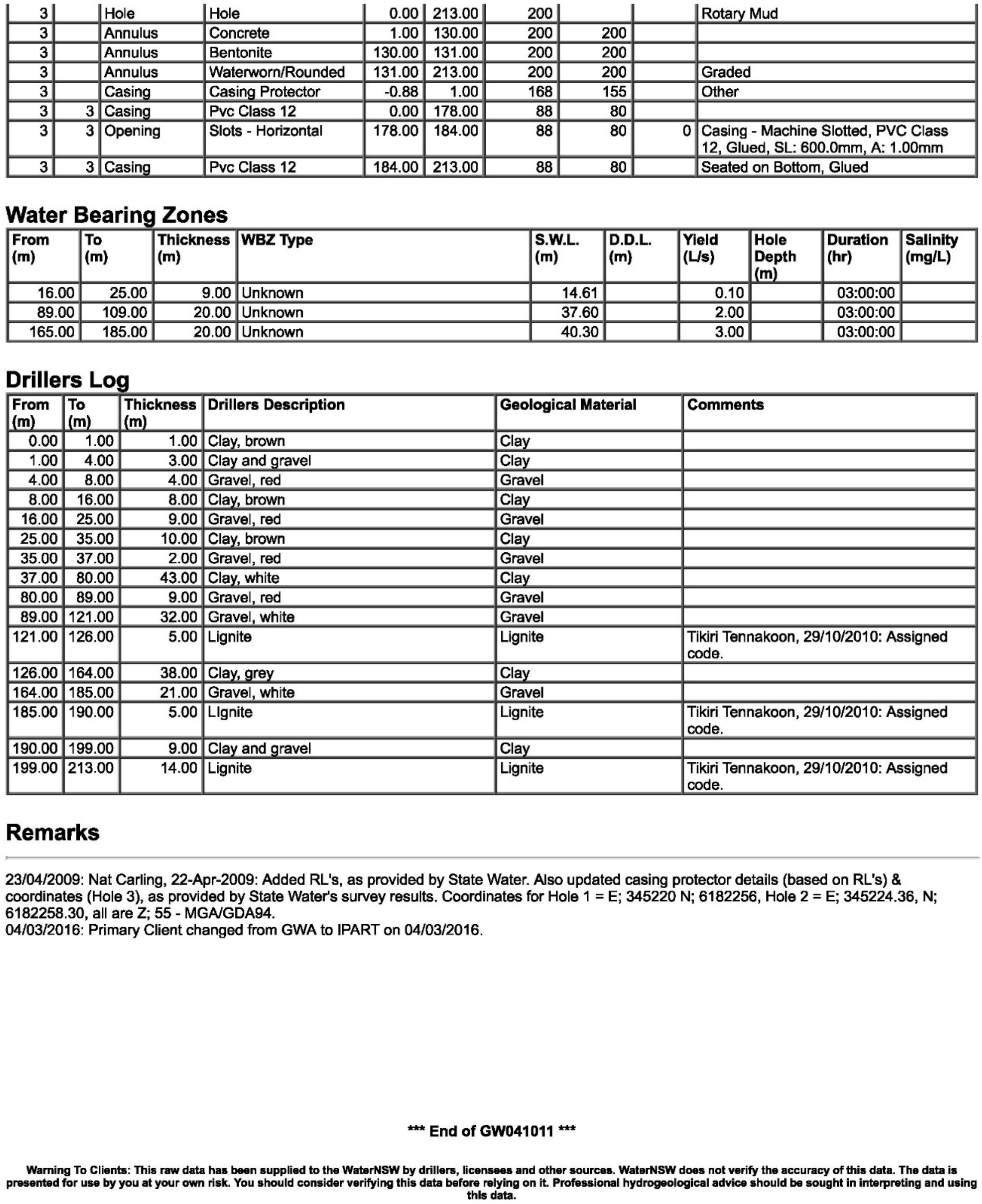


| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | Hole | Hole | 0.00 | 213.00 | 200 | | | Rotary Mud |
| 3 | | Annulus | Concrete | 1.00 | 130.00 | 200 | 200 | | |
| 3 | | Annulus | Bentonite | 130.00 | 131.00 | 200 | 200 | | |
| 3 | | Annulus | Waterworn/Rounded | 131.00 | 213.00 | 200 | 200 | | Graded |
| 3 | | Casing | Casing Protector | -0.88 | 1.00 | 168 | 155 | | Other |
| 3 | 3 | Casing | Pvc Class 12 | 0.00 | 178.00 | 88 | 80 | | |
| 3 | 3 | Opening | Slots - Horizontal | 178.00 | 184.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 1.00mm |
| 3 | 3 | Casing | Pvc Class 12 | 184.00 | 213.00 | 88 | 80 | | Seated on Bottom, Glued |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 16.00 | 25.00 | 9.00 | Unknown | 14.61 | | 0.10 | | 03:00:00 | |
| 89.00 | 109.00 | 20.00 | Unknown | 37.60 | | 2.00 | | 03:00:00 | |
| 165.00 | 185.00 | 20.00 | Unknown | 40.30 | | 3.00 | | 03:00:00 | |

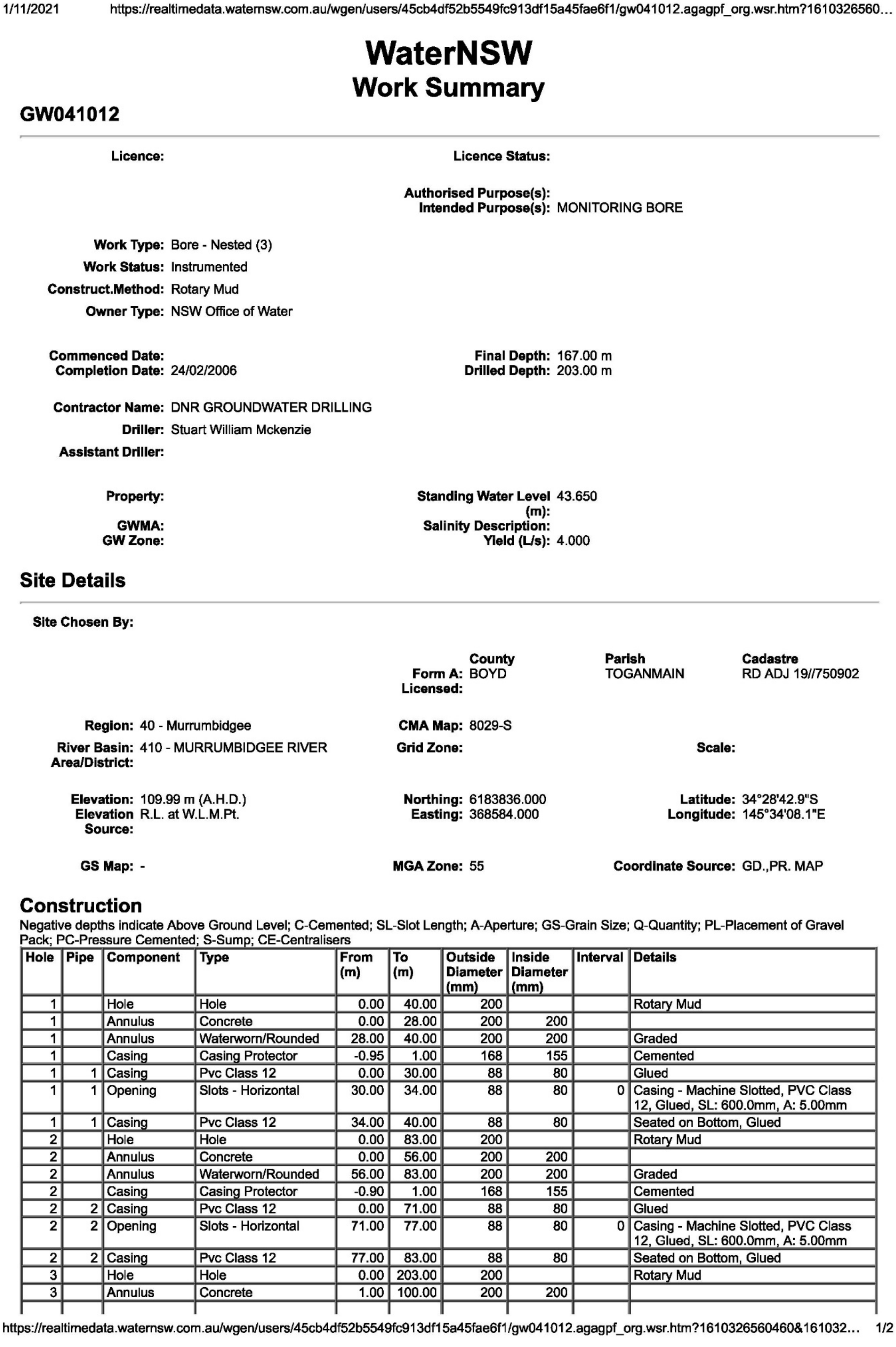
## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 1.00 | 1.00 | Clay, brown | Clay | |
| 1.00 | 4.00 | 3.00 | Clay and gravel | Clay | |
| 4.00 | 8.00 | 4.00 | Gravel, red | Gravel | |
| 8.00 | 16.00 | 8.00 | Clay, brown | Clay | |
| 16.00 | 25.00 | 9.00 | Gravel, red | Gravel | |
| 25.00 | 35.00 | 10.00 | Clay, brown | Clay | |
| 35.00 | 37.00 | 2.00 | Gravel, red | Gravel | |
| 37.00 | 80.00 | 43.00 | Clay, white | Clay | |
| 80.00 | 89.00 | 9.00 | Gravel, red | Gravel | |
| 89.00 | 121.00 | 32.00 | Gravel, white | Gravel | |
| 121.00 | 126.00 | 5.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 126.00 | 164.00 | 38.00 | Clay, grey | Clay | |
| 164.00 | 185.00 | 21.00 | Gravel, white | Gravel | |
| 185.00 | 190.00 | 5.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 190.00 | 199.00 | 9.00 | Clay and gravel | Clay | |
| 199.00 | 213.00 | 14.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |

## Remarks

23/04/2009: Nat Carling, 22-Apr-2009: Added RL's, as provided by State Water. Also updated casing protector details (based on RL's) & coordinates (Hole 3), as provided by State Water's survey results. Coordinates for Hole 1 = E; 345220 N; 6182256, Hole 2 = E; 345224.36, N; 6182258.30, all are Z; 55 - MGA/GDA94.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW041011 *****



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# WaterNSW

## Work Summary

**GW041012**

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (3)
**Work Status:** Instrumented
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 24/02/2006
**Final Depth:** 167.00 m
**Drilled Depth:** 203.00 m

**Contractor Name:** DNR GROUNDWATER DRILLING
**Driller:** Stuart William Mckenzie
**Assistant Driller:**

**Property:**
**GWMA:**
**GW Zone:**
**Standing Water Level (m):** 43.650
**Salinity Description:**
**Yield (L/s):** 4.000

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | BOYD | TOGANMAIN | RD ADJ 19//750902 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**CMA Map:** 8029-S
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:**
**Grid Zone:**
**Scale:**

**Elevation:** 109.99 m (A.H.D.)
**Elevation Source:** R.L. at W.L.M.Pt.
**Northing:** 6183836.000
**Easting:** 368584.000
**Latitude:** 34°28'42.9"S
**Longitude:** 145°34'08.1"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** GD.,PR. MAP

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Hole | Hole | 0.00 | 40.00 | 200 | | | Rotary Mud |
| 1 | | Annulus | Concrete | 0.00 | 28.00 | 200 | 200 | | |
| 1 | | Annulus | Waterworn/Rounded | 28.00 | 40.00 | 200 | 200 | | Graded |
| 1 | | Casing | Casing Protector | -0.95 | 1.00 | 168 | 155 | | Cemented |
| 1 | 1 | Casing | Pvc Class 12 | 0.00 | 30.00 | 88 | 80 | | Glued |
| 1 | 1 | Opening | Slots - Horizontal | 30.00 | 34.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 5.00mm |
| 1 | 1 | Casing | Pvc Class 12 | 34.00 | 40.00 | 88 | 80 | | Seated on Bottom, Glued |
| 2 | | Hole | Hole | 0.00 | 83.00 | 200 | | | Rotary Mud |
| 2 | | Annulus | Concrete | 0.00 | 56.00 | 200 | 200 | | |
| 2 | | Annulus | Waterworn/Rounded | 56.00 | 83.00 | 200 | 200 | | Graded |
| 2 | | Casing | Casing Protector | -0.90 | 1.00 | 168 | 155 | | Cemented |
| 2 | 2 | Casing | Pvc Class 12 | 0.00 | 71.00 | 88 | 80 | | Glued |
| 2 | 2 | Opening | Slots - Horizontal | 71.00 | 77.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 5.00mm |
| 2 | 2 | Casing | Pvc Class 12 | 77.00 | 83.00 | 88 | 80 | | Seated on Bottom, Glued |
| 3 | | Hole | Hole | 0.00 | 203.00 | 200 | | | Rotary Mud |
| 3 | | Annulus | Concrete | 1.00 | 100.00 | 200 | 200 | | |

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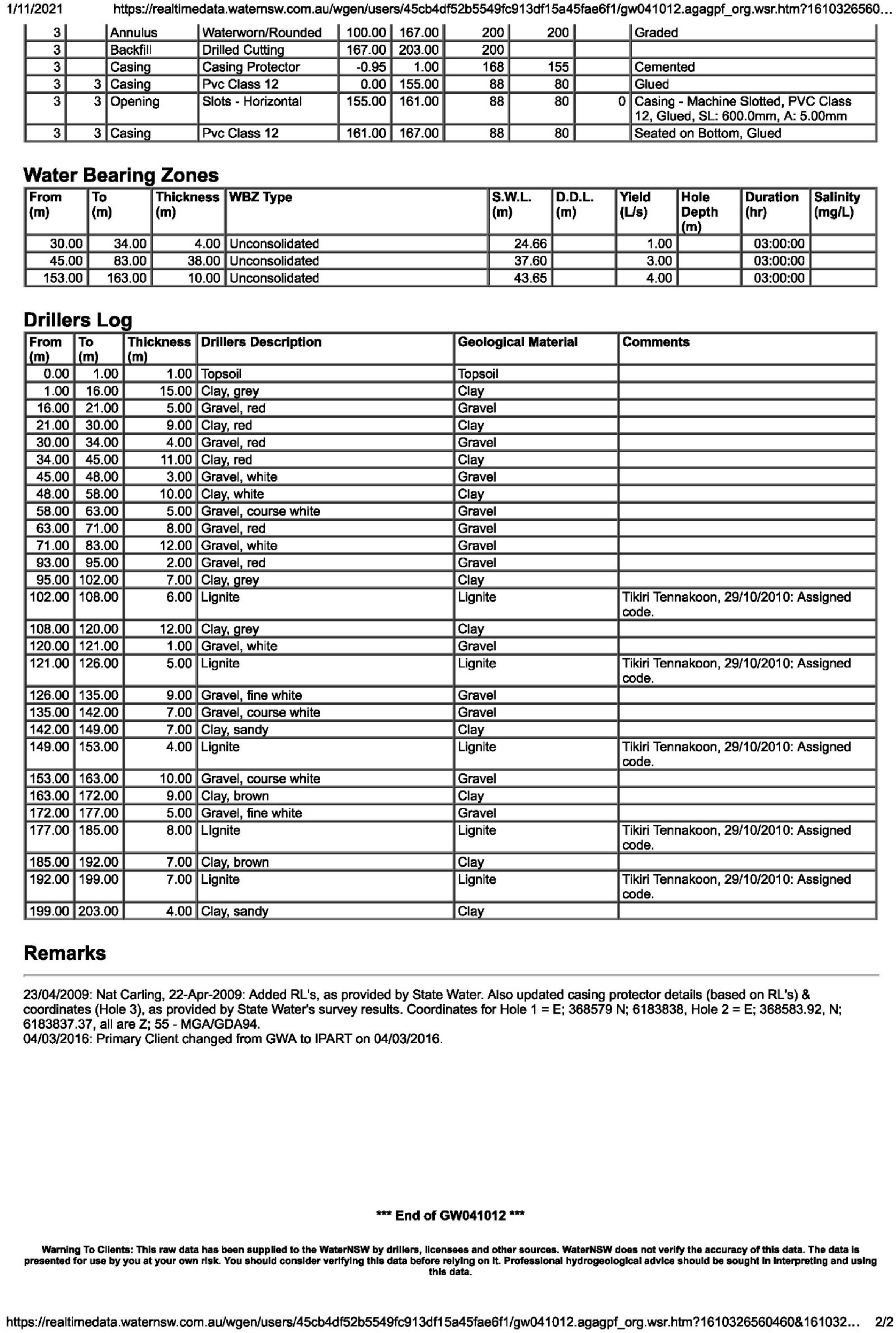


| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | Annulus | Waterworn/Rounded | 100.00 | 167.00 | 200 | 200 | | Graded |
| 3 | | Backfill | Drilled Cutting | 167.00 | 203.00 | 200 | | | |
| 3 | | Casing | Casing Protector | -0.95 | 1.00 | 168 | 155 | | Cemented |
| 3 | 3 | Casing | Pvc Class 12 | 0.00 | 155.00 | 88 | 80 | | Glued |
| 3 | 3 | Opening | Slots - Horizontal | 155.00 | 161.00 | 88 | 80 | 0 | Casing - Machine Slotted, PVC Class 12, Glued, SL: 600.0mm, A: 5.00mm |
| 3 | 3 | Casing | Pvc Class 12 | 161.00 | 167.00 | 88 | 80 | | Seated on Bottom, Glued |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 30.00 | 34.00 | 4.00 | Unconsolidated | 24.66 | | 1.00 | | 03:00:00 | |
| 45.00 | 83.00 | 38.00 | Unconsolidated | 37.60 | | 3.00 | | 03:00:00 | |
| 153.00 | 163.00 | 10.00 | Unconsolidated | 43.65 | | 4.00 | | 03:00:00 | |

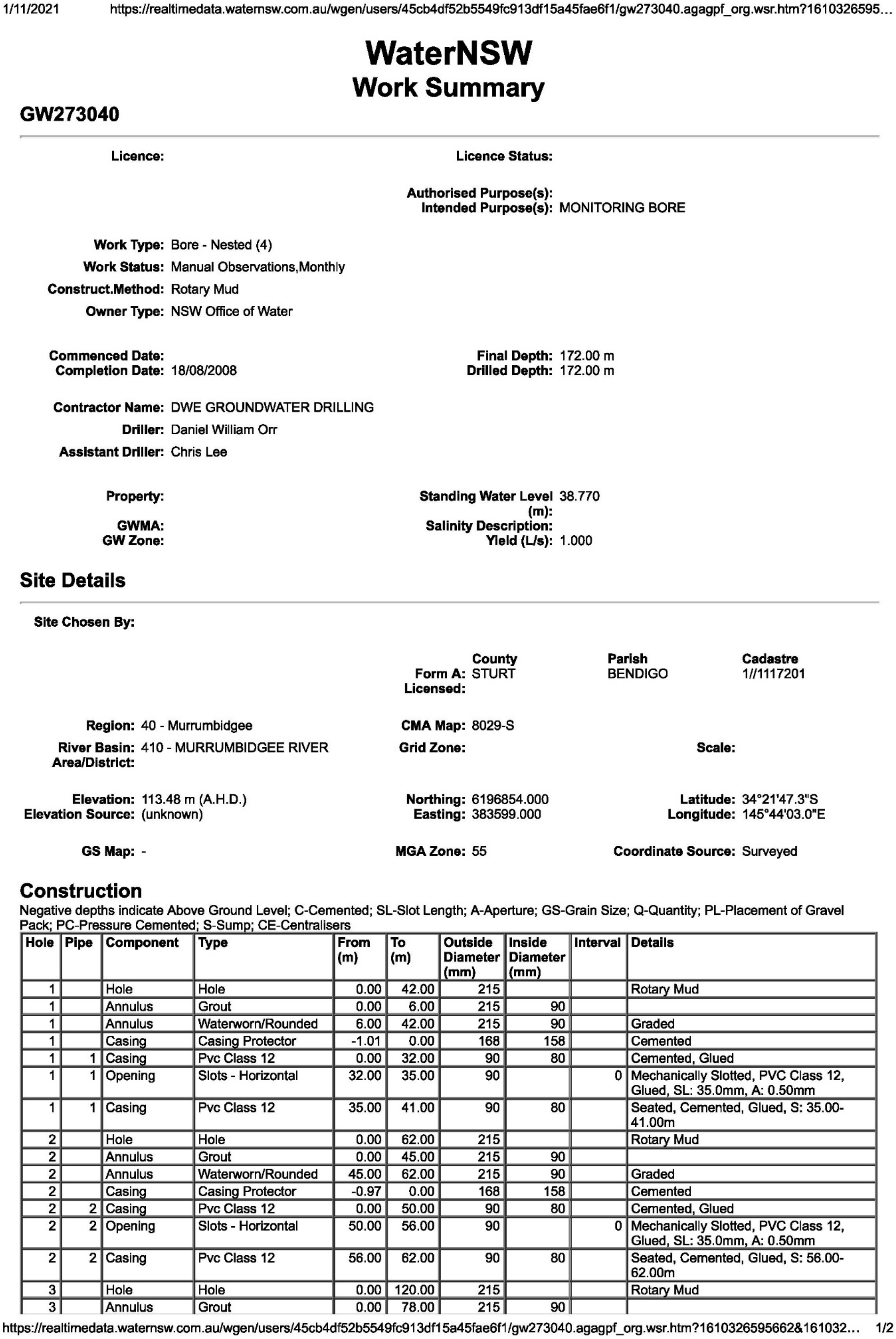
## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 1.00 | 1.00 | Topsoil | Topsoil | |
| 1.00 | 16.00 | 15.00 | Clay, grey | Clay | |
| 16.00 | 21.00 | 5.00 | Gravel, red | Gravel | |
| 21.00 | 30.00 | 9.00 | Clay, red | Clay | |
| 30.00 | 34.00 | 4.00 | Gravel, red | Gravel | |
| 34.00 | 45.00 | 11.00 | Clay, red | Clay | |
| 45.00 | 48.00 | 3.00 | Gravel, white | Gravel | |
| 48.00 | 58.00 | 10.00 | Clay, white | Clay | |
| 58.00 | 63.00 | 5.00 | Gravel, course white | Gravel | |
| 63.00 | 71.00 | 8.00 | Gravel, red | Gravel | |
| 71.00 | 83.00 | 12.00 | Gravel, white | Gravel | |
| 93.00 | 95.00 | 2.00 | Gravel, red | Gravel | |
| 95.00 | 102.00 | 7.00 | Clay, grey | Clay | |
| 102.00 | 108.00 | 6.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 108.00 | 120.00 | 12.00 | Clay, grey | Clay | |
| 120.00 | 121.00 | 1.00 | Gravel, white | Gravel | |
| 121.00 | 126.00 | 5.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 126.00 | 135.00 | 9.00 | Gravel, fine white | Gravel | |
| 135.00 | 142.00 | 7.00 | Gravel, course white | Gravel | |
| 142.00 | 149.00 | 7.00 | Clay, sandy | Clay | |
| 149.00 | 153.00 | 4.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 153.00 | 163.00 | 10.00 | Gravel, course white | Gravel | |
| 163.00 | 172.00 | 9.00 | Clay, brown | Clay | |
| 172.00 | 177.00 | 5.00 | Gravel, fine white | Gravel | |
| 177.00 | 185.00 | 8.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 185.00 | 192.00 | 7.00 | Clay, brown | Clay | |
| 192.00 | 199.00 | 7.00 | Lignite | Lignite | Tikiri Tennakoon, 29/10/2010: Assigned code. |
| 199.00 | 203.00 | 4.00 | Clay, sandy | Clay | |

## Remarks

23/04/2009: Nat Carling, 22-Apr-2009: Added RL's, as provided by State Water. Also updated casing protector details (based on RL's) & coordinates (Hole 3), as provided by State Water's survey results. Coordinates for Hole 1 = E; 368579 N; 6183838, Hole 2 = E; 368583.92, N; 6183837.37, all are Z; 55 - MGA/GDA94.
04/03/2016: Primary Client changed from GWA to IPART on 04/03/2016.

***** End of GW041012 *****



# WaterNSW
## Work Summary

## GW273040

**Licence:**
**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (4)
**Work Status:** Manual Observations,Monthly
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 18/08/2008
**Final Depth:** 172.00 m
**Drilled Depth:** 172.00 m

**Contractor Name:** DWE GROUNDWATER DRILLING
**Driller:** Daniel William Orr
**Assistant Driller:** Chris Lee

**Property:**
**Standing Water Level (m):** 38.770
**GWMA:**
**Salinity Description:**
**GW Zone:**
**Yield (L/s):** 1.000

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | STURT | BENDIGO | 1//1117201 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**CMA Map:** 8029-S
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Grid Zone:**
**Scale:**
**Area/District:**

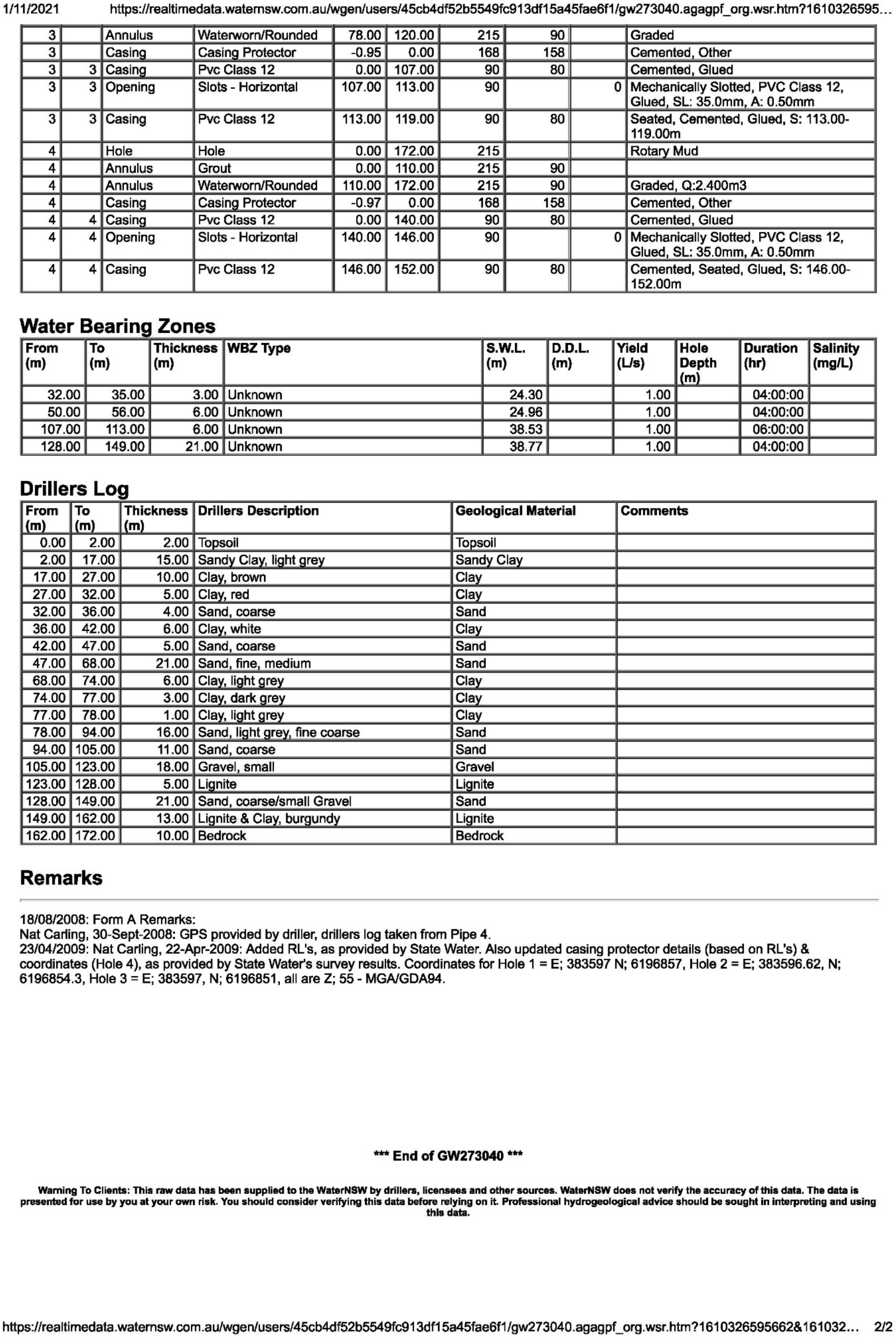
**Elevation:** 113.48 m (A.H.D.)
**Elevation Source:** (unknown)
**Northing:** 6196854.000
**Easting:** 383599.000
**Latitude:** 34°21'47.3"S
**Longitude:** 145°44'03.0"E

**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** Surveyed

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Hole | Hole | 0.00 | 42.00 | 215 | | | Rotary Mud |
| 1 | | Annulus | Grout | 0.00 | 6.00 | 215 | 90 | | |
| 1 | | Annulus | Waterworn/Rounded | 6.00 | 42.00 | 215 | 90 | | Graded |
| 1 | | Casing | Casing Protector | -1.01 | 0.00 | 168 | 158 | | Cemented |
| 1 | 1 | Casing | Pvc Class 12 | 0.00 | 32.00 | 90 | 80 | | Cemented, Glued |
| 1 | 1 | Opening | Slots - Horizontal | 32.00 | 35.00 | 90 | | 0 | Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 0.50mm |
| 1 | 1 | Casing | Pvc Class 12 | 35.00 | 41.00 | 90 | 80 | | Seated, Cemented, Glued, S: 35.00-41.00m |
| 2 | | Hole | Hole | 0.00 | 62.00 | 215 | | | Rotary Mud |
| 2 | | Annulus | Grout | 0.00 | 45.00 | 215 | 90 | | |
| 2 | | Annulus | Waterworn/Rounded | 45.00 | 62.00 | 215 | 90 | | Graded |
| 2 | | Casing | Casing Protector | -0.97 | 0.00 | 168 | 158 | | Cemented |
| 2 | 2 | Casing | Pvc Class 12 | 0.00 | 50.00 | 90 | 80 | | Cemented, Glued |
| 2 | 2 | Opening | Slots - Horizontal | 50.00 | 56.00 | 90 | | 0 | Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 0.50mm |
| 2 | 2 | Casing | Pvc Class 12 | 56.00 | 62.00 | 90 | 80 | | Seated, Cemented, Glued, S: 56.00-62.00m |
| 3 | | Hole | Hole | 0.00 | 120.00 | 215 | | | Rotary Mud |
| 3 | | Annulus | Grout | 0.00 | 78.00 | 215 | 90 | | |



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | Annulus | Waterworn/Rounded | 78.00 | 120.00 | 215 | 90 | | Graded |
| 3 | | Casing | Casing Protector | -0.95 | 0.00 | 168 | 158 | | Cemented, Other |
| 3 | 3 | Casing | Pvc Class 12 | 0.00 | 107.00 | 90 | 80 | | Cemented, Glued |
| 3 | 3 | Opening | Slots - Horizontal | 107.00 | 113.00 | 90 | | 0 | Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 0.50mm |
| 3 | 3 | Casing | Pvc Class 12 | 113.00 | 119.00 | 90 | 80 | | Seated, Cemented, Glued, S: 113.00-119.00m |
| 4 | | Hole | Hole | 0.00 | 172.00 | 215 | | | Rotary Mud |
| 4 | | Annulus | Grout | 0.00 | 110.00 | 215 | 90 | | |
| 4 | | Annulus | Waterworn/Rounded | 110.00 | 172.00 | 215 | 90 | | Graded, Q:2.400m3 |
| 4 | | Casing | Casing Protector | -0.97 | 0.00 | 168 | 158 | | Cemented, Other |
| 4 | 4 | Casing | Pvc Class 12 | 0.00 | 140.00 | 90 | 80 | | Cemented, Glued |
| 4 | 4 | Opening | Slots - Horizontal | 140.00 | 146.00 | 90 | | 0 | Mechanically Slotted, PVC Class 12, Glued, SL: 35.0mm, A: 0.50mm |
| 4 | 4 | Casing | Pvc Class 12 | 146.00 | 152.00 | 90 | 80 | | Cemented, Seated, Glued, S: 146.00-152.00m |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 32.00 | 35.00 | 3.00 | Unknown | 24.30 | | 1.00 | | 04:00:00 | |
| 50.00 | 56.00 | 6.00 | Unknown | 24.96 | | 1.00 | | 04:00:00 | |
| 107.00 | 113.00 | 6.00 | Unknown | 38.53 | | 1.00 | | 06:00:00 | |
| 128.00 | 149.00 | 21.00 | Unknown | 38.77 | | 1.00 | | 04:00:00 | |

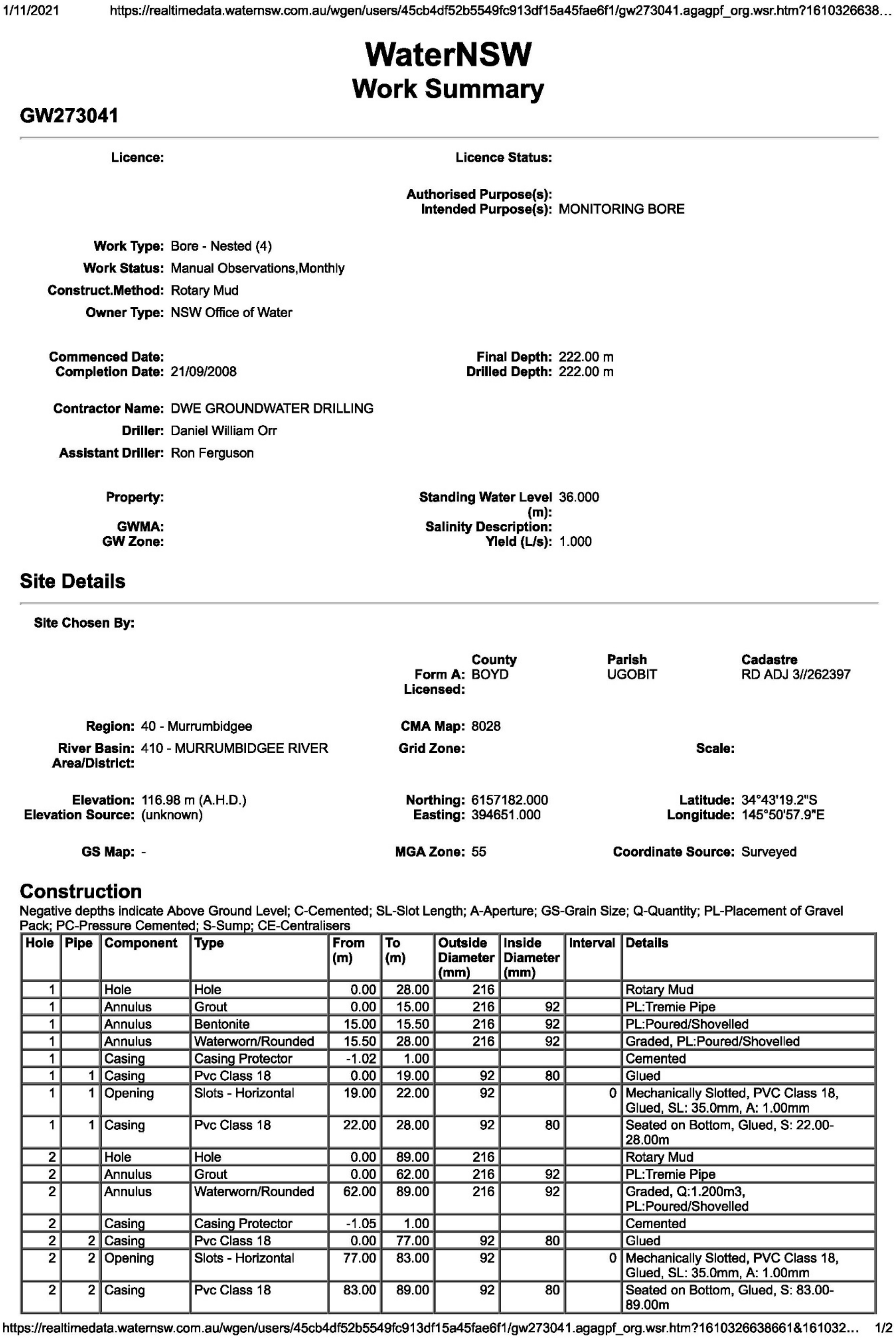
## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 2.00 | 2.00 | Topsoil | Topsoil | |
| 2.00 | 17.00 | 15.00 | Sandy Clay, light grey | Sandy Clay | |
| 17.00 | 27.00 | 10.00 | Clay, brown | Clay | |
| 27.00 | 32.00 | 5.00 | Clay, red | Clay | |
| 32.00 | 36.00 | 4.00 | Sand, coarse | Sand | |
| 36.00 | 42.00 | 6.00 | Clay, white | Clay | |
| 42.00 | 47.00 | 5.00 | Sand, coarse | Sand | |
| 47.00 | 68.00 | 21.00 | Sand, fine, medium | Sand | |
| 68.00 | 74.00 | 6.00 | Clay, light grey | Clay | |
| 74.00 | 77.00 | 3.00 | Clay, dark grey | Clay | |
| 77.00 | 78.00 | 1.00 | Clay, light grey | Clay | |
| 78.00 | 94.00 | 16.00 | Sand, light grey, fine coarse | Sand | |
| 94.00 | 105.00 | 11.00 | Sand, coarse | Sand | |
| 105.00 | 123.00 | 18.00 | Gravel, small | Gravel | |
| 123.00 | 128.00 | 5.00 | Lignite | Lignite | |
| 128.00 | 149.00 | 21.00 | Sand, coarse/small Gravel | Sand | |
| 149.00 | 162.00 | 13.00 | Lignite & Clay, burgundy | Lignite | |
| 162.00 | 172.00 | 10.00 | Bedrock | Bedrock | |

## Remarks

18/08/2008: Form A Remarks:
Nat Carling, 30-Sept-2008: GPS provided by driller, drillers log taken from Pipe 4.
23/04/2009: Nat Carling, 22-Apr-2009: Added RL's, as provided by State Water. Also updated casing protector details (based on RL's) & coordinates (Hole 4), as provided by State Water's survey results. Coordinates for Hole 1 = E; 383597 N; 6196857, Hole 2 = E; 383596.62, N; 6196854.3, Hole 3 = E; 383597, N; 6196851, all are Z; 55 - MGA/GDA94.

***** End of GW273040 *****



1/11/2021 https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw273041.agagpf_org.wsr.htm?1610326638…

# WaterNSW

## Work Summary

### GW273041

**Licence:**

**Licence Status:**

**Authorised Purpose(s):**
**Intended Purpose(s):** MONITORING BORE

**Work Type:** Bore - Nested (4)
**Work Status:** Manual Observations,Monthly
**Construct.Method:** Rotary Mud
**Owner Type:** NSW Office of Water

**Commenced Date:**
**Completion Date:** 21/09/2008

**Final Depth:** 222.00 m
**Drilled Depth:** 222.00 m

**Contractor Name:** DWE GROUNDWATER DRILLING
**Driller:** Daniel William Orr
**Assistant Driller:** Ron Ferguson

**Property:**
**GWMA:**
**GW Zone:**

**Standing Water Level (m):** 36.000
**Salinity Description:**
**Yield (L/s):** 1.000

## Site Details

**Site Chosen By:**

| | County | Parish | Cadastre |
|---|---|---|---|
| **Form A:** | BOYD | UGOBIT | RD ADJ 3//262397 |
| **Licensed:** | | | |

**Region:** 40 - Murrumbidgee
**River Basin:** 410 - MURRUMBIDGEE RIVER
**Area/District:**

**CMA Map:** 8028
**Grid Zone:**
**Scale:**

**Elevation:** 116.98 m (A.H.D.)
**Elevation Source:** (unknown)

**Northing:** 6157182.000
**Easting:** 394651.000

**Latitude:** 34°43'19.2"S
**Longitude:** 145°50'57.9"E

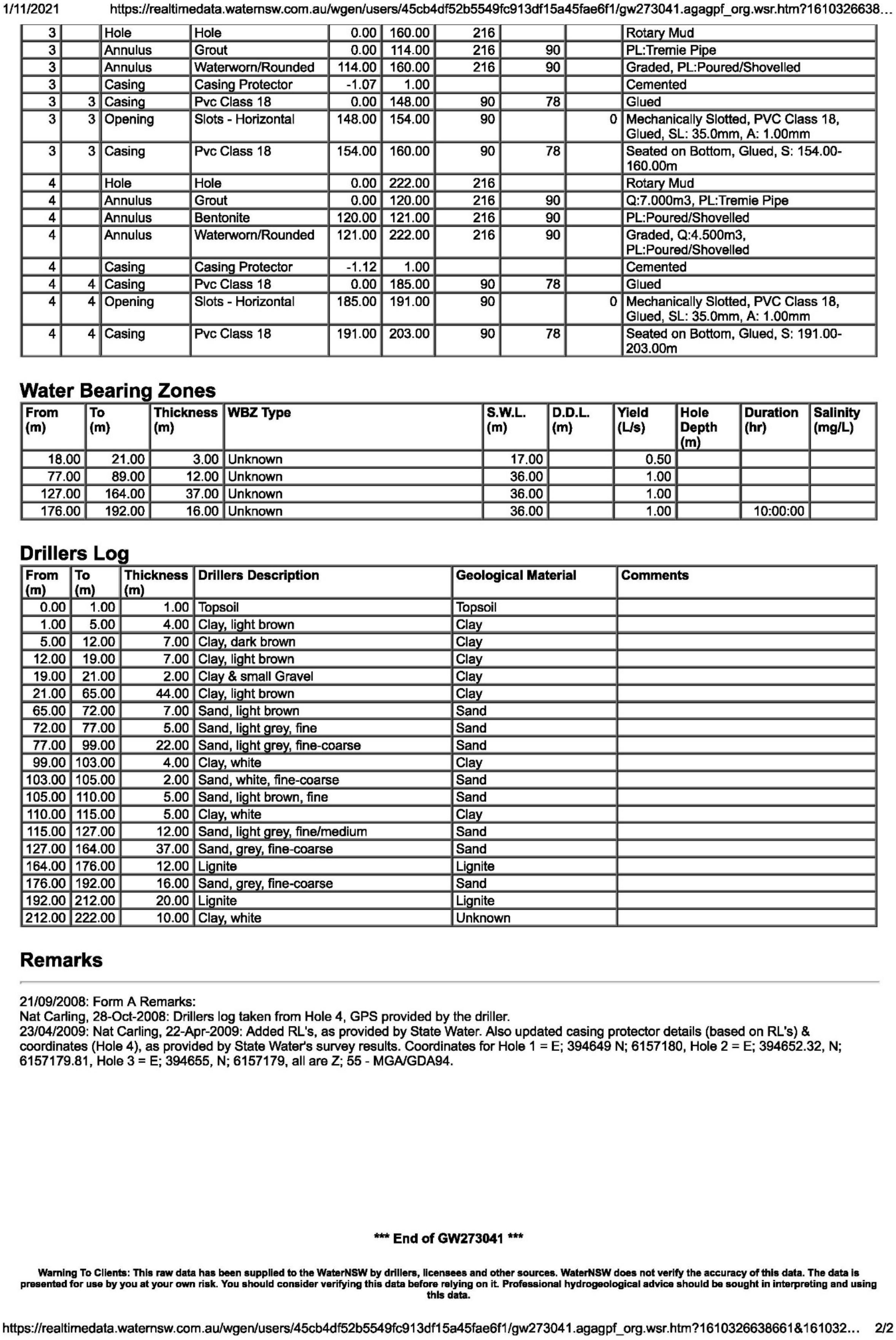
**GS Map:** -
**MGA Zone:** 55
**Coordinate Source:** Surveyed

## Construction

Negative depths indicate Above Ground Level; C-Cemented; SL-Slot Length; A-Aperture; GS-Grain Size; Q-Quantity; PL-Placement of Gravel Pack; PC-Pressure Cemented; S-Sump; CE-Centralisers

| Hole | Pipe | Component | Type | From (m) | To (m) | Outside Diameter (mm) | Inside Diameter (mm) | Interval | Details |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Hole | Hole | 0.00 | 28.00 | 216 | | | Rotary Mud |
| 1 | | Annulus | Grout | 0.00 | 15.00 | 216 | 92 | | PL:Tremie Pipe |
| 1 | | Annulus | Bentonite | 15.00 | 15.50 | 216 | 92 | | PL:Poured/Shovelled |
| 1 | | Annulus | Waterworn/Rounded | 15.50 | 28.00 | 216 | 92 | | Graded, PL:Poured/Shovelled |
| 1 | | Casing | Casing Protector | -1.02 | 1.00 | | | | Cemented |
| 1 | 1 | Casing | Pvc Class 18 | 0.00 | 19.00 | 92 | 80 | | Glued |
| 1 | 1 | Opening | Slots - Horizontal | 19.00 | 22.00 | 92 | | 0 | Mechanically Slotted, PVC Class 18, Glued, SL: 35.0mm, A: 1.00mm |
| 1 | 1 | Casing | Pvc Class 18 | 22.00 | 28.00 | 92 | 80 | | Seated on Bottom, Glued, S: 22.00-28.00m |
| 2 | | Hole | Hole | 0.00 | 89.00 | 216 | | | Rotary Mud |
| 2 | | Annulus | Grout | 0.00 | 62.00 | 216 | 92 | | PL:Tremie Pipe |
| 2 | | Annulus | Waterworn/Rounded | 62.00 | 89.00 | 216 | 92 | | Graded, Q:1.200m3, PL:Poured/Shovelled |
| 2 | | Casing | Casing Protector | -1.05 | 1.00 | | | | Cemented |
| 2 | 2 | Casing | Pvc Class 18 | 0.00 | 77.00 | 92 | 80 | | Glued |
| 2 | 2 | Opening | Slots - Horizontal | 77.00 | 83.00 | 92 | | 0 | Mechanically Slotted, PVC Class 18, Glued, SL: 35.0mm, A: 1.00mm |
| 2 | 2 | Casing | Pvc Class 18 | 83.00 | 89.00 | 92 | 80 | | Seated on Bottom, Glued, S: 83.00-89.00m |

https://realtimedata.waternsw.com.au/wgen/users/45cb4df52b5549fc913df15a45fae6f1/gw273041.agagpf_org.wsr.htm?1610326638661&161032… 1/2



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | | Hole | Hole | 0.00 | 160.00 | 216 | | | Rotary Mud |
| 3 | | Annulus | Grout | 0.00 | 114.00 | 216 | 90 | | PL:Tremie Pipe |
| 3 | | Annulus | Waterworn/Rounded | 114.00 | 160.00 | 216 | 90 | | Graded, PL:Poured/Shovelled |
| 3 | | Casing | Casing Protector | -1.07 | 1.00 | | | | Cemented |
| 3 | 3 | Casing | Pvc Class 18 | 0.00 | 148.00 | 90 | 78 | | Glued |
| 3 | 3 | Opening | Slots - Horizontal | 148.00 | 154.00 | 90 | | 0 | Mechanically Slotted, PVC Class 18, Glued, SL: 35.0mm, A: 1.00mm |
| 3 | 3 | Casing | Pvc Class 18 | 154.00 | 160.00 | 90 | 78 | | Seated on Bottom, Glued, S: 154.00-160.00m |
| 4 | | Hole | Hole | 0.00 | 222.00 | 216 | | | Rotary Mud |
| 4 | | Annulus | Grout | 0.00 | 120.00 | 216 | 90 | | Q:7.000m3, PL:Tremie Pipe |
| 4 | | Annulus | Bentonite | 120.00 | 121.00 | 216 | 90 | | PL:Poured/Shovelled |
| 4 | | Annulus | Waterworn/Rounded | 121.00 | 222.00 | 216 | 90 | | Graded, Q:4.500m3, PL:Poured/Shovelled |
| 4 | | Casing | Casing Protector | -1.12 | 1.00 | | | | Cemented |
| 4 | 4 | Casing | Pvc Class 18 | 0.00 | 185.00 | 90 | 78 | | Glued |
| 4 | 4 | Opening | Slots - Horizontal | 185.00 | 191.00 | 90 | | 0 | Mechanically Slotted, PVC Class 18, Glued, SL: 35.0mm, A: 1.00mm |
| 4 | 4 | Casing | Pvc Class 18 | 191.00 | 203.00 | 90 | 78 | | Seated on Bottom, Glued, S: 191.00-203.00m |

## Water Bearing Zones

| From (m) | To (m) | Thickness (m) | WBZ Type | S.W.L. (m) | D.D.L. (m) | Yield (L/s) | Hole Depth (m) | Duration (hr) | Salinity (mg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 18.00 | 21.00 | 3.00 | Unknown | 17.00 | | 0.50 | | | |
| 77.00 | 89.00 | 12.00 | Unknown | 36.00 | | 1.00 | | | |
| 127.00 | 164.00 | 37.00 | Unknown | 36.00 | | 1.00 | | | |
| 176.00 | 192.00 | 16.00 | Unknown | 36.00 | | 1.00 | | 10:00:00 | |

## Drillers Log

| From (m) | To (m) | Thickness (m) | Drillers Description | Geological Material | Comments |
|---|---|---|---|---|---|
| 0.00 | 1.00 | 1.00 | Topsoil | Topsoil | |
| 1.00 | 5.00 | 4.00 | Clay, light brown | Clay | |
| 5.00 | 12.00 | 7.00 | Clay, dark brown | Clay | |
| 12.00 | 19.00 | 7.00 | Clay, light brown | Clay | |
| 19.00 | 21.00 | 2.00 | Clay & small Gravel | Clay | |
| 21.00 | 65.00 | 44.00 | Clay, light brown | Clay | |
| 65.00 | 72.00 | 7.00 | Sand, light brown | Sand | |
| 72.00 | 77.00 | 5.00 | Sand, light grey, fine | Sand | |
| 77.00 | 99.00 | 22.00 | Sand, light grey, fine-coarse | Sand | |
| 99.00 | 103.00 | 4.00 | Clay, white | Clay | |
| 103.00 | 105.00 | 2.00 | Sand, white, fine-coarse | Sand | |
| 105.00 | 110.00 | 5.00 | Sand, light brown, fine | Sand | |
| 110.00 | 115.00 | 5.00 | Clay, white | Clay | |
| 115.00 | 127.00 | 12.00 | Sand, light grey, fine/medium | Sand | |
| 127.00 | 164.00 | 37.00 | Sand, grey, fine-coarse | Sand | |
| 164.00 | 176.00 | 12.00 | Lignite | Lignite | |
| 176.00 | 192.00 | 16.00 | Sand, grey, fine-coarse | Sand | |
| 192.00 | 212.00 | 20.00 | Lignite | Lignite | |
| 212.00 | 222.00 | 10.00 | Clay, white | Unknown | |

## Remarks

21/09/2008: Form A Remarks:
Nat Carling, 28-Oct-2008: Drillers log taken from Hole 4, GPS provided by the driller.
23/04/2009: Nat Carling, 22-Apr-2009: Added RL's, as provided by State Water. Also updated casing protector details (based on RL's) & coordinates (Hole 4), as provided by State Water's survey results. Coordinates for Hole 1 = E; 394649 N; 6157180, Hole 2 = E; 394652.32, N; 6157179.81, Hole 3 = E; 394655, N; 6157179, all are Z; 55 - MGA/GDA94.

***** End of GW273041 *****

# Appendix 3–Raw Data

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW030323 | 1.1 | 17 Apr 2018 12:00:00 pm | 1,110 | 6.3 | 137 | 3.00 | 30.0 | 35.0 | 292 | 37.0 | <1 | 107 | 0.09 |
| GW030323 | 1.1 | 06 Sep 2017 12:00:00 am | 1,100 | n/a | 120 | 1.80 | 25.0 | 15.0 | 250 | 2.10 | 1.70 | 160 | <0.9 |
| GW030323 | 1.1 | 14 Apr 2016 12:00:00 am | 1,100 | 7.1 | 130 | 1.80 | 26.0 | 15.0 | 290 | 2.10 | 1.70 | 160 | <0.9 |
| GW030323 | 1.1 | 08 Aug 2014 12:00:00 am | 1,070 | 7.0 | 120 | 3.50 | 27.0 | 30.0 | 250 | 34.0 | <1 | 130 | <0.9 |
| GW030323 | 1.1 | 01 Jul 2013 01:55:00 pm | 1,041 | n/a | 130 | 3.30 | 26.0 | 33.0 | 250 | 33.0 | <1 | 120 | 0.04 |
| GW030323 | 1.1 | 27 Nov 2012 10:40:00 am | 1,005 | n/a | 130 | 3.40 | 29.0 | 30.0 | 230 | 32.0 | <1 | 130 | 1.81 |
| GW030323 | 1.1 | 20 Jun 2012 10:35:00 am | 1,046 | n/a | 130 | 3.40 | 28.0 | 34.0 | 240 | 35.0 | <1 | 120 | <0.05 |
| GW030323 | 1.1 | 16 Jun 2011 03:10:00 pm | 1,069 | n/a | 150 | 3.50 | 27.0 | 31.0 | 240 | 31.0 | <1 | 130 | <0.05 |
| GW030323 | 1.1 | 13 May 2010 01:35:00 pm | 1,090 | n/a | 130 | 3.70 | 29.0 | 33.0 | 260 | 36.0 | <1 | 120 | <0.05 |
| GW030323 | 1.1 | 12 Apr 2010 10:30:00 am | 1,040 | n/a | 130 | 3.40 | 28.0 | 33.0 | 250 | 37.0 | <1 | 120 | <0.05 |
| GW030323 | 1.1 | 22 Feb 2010 10:55:00 am | 1,030 | n/a | 140 | 3.60 | 27.0 | 33.0 | 260 | 35.0 | <1 | 120 | <0.05 |
| GW030323 | 1.1 | 04 Dec 2009 12:00:00 am | 982 | n/a | 140 | 3.50 | 29.0 | 33.0 | 240 | 33.0 | <1 | 120 | 0.22 |
| GW030323 | 1.1 | 09 Nov 2009 03:45:00 pm | 991 | n/a | 130 | 3.60 | 28.0 | 33.0 | 240 | 34.0 | <1 | 120 | 0.04 |
| GW030323 | 1.1 | 20 Oct 2009 12:15:00 pm | 1,000 | n/a | 130 | 3.40 | 27.0 | 32.0 | 250 | 33.0 | <1 | 130 | <0.05 |
| GW030323 | 1.1 | 21 Sep 2009 04:20:00 pm | 965 | n/a | 130 | 3.40 | 30.0 | 32.0 | 250 | 35.0 | 1.00 | 120 | <0.05 |
| GW030323 | 1.1 | 16 Dec 1986 12:00:00 pm | 646 | 6.9 | 88.4 | 2.63 | 15.3 | 21.0 | 131 | 3.20 | <1 | 81.0 | 0.58 |
| GW030323 | 1.1 | 14 Jul 1978 12:01:00 pm | 660 | 7.0 | 105 | 3.13 | 6.21 | 18.0 | 128 | 19.2 | <1 | 164 | n/a |
| GW030323 | 1.1 | 19 Aug 1977 12:00:00 pm | 1,100 | 7.4 | 161 | 3.13 | 32.1 | 29.9 | 246 | 21.1 | <1 | 254 | n/a |
| GW030323 | 1.1 | 27 Jul 1977 12:01:00 pm | 696 | 7.3 | 97.0 | 2.35 | 40.1 | 10.8 | 133 | 10.1 | <1 | 210 | n/a |
| GW030323 | 1.1 | 01 May 1976 12:00:00 pm | 680 | 6.8 | 103 | 3.13 | 13.0 | 17.7 | 132 | 4.32 | <1 | 162 | <0.9 |
| GW030323 | 1.1 | 18 Sep 1975 12:00:00 pm | 880 | 7.2 | 130 | 3.13 | 19.8 | 20.8 | 195 | 24.0 | n/a | 159 | <0.9 |
| GW030323 | 1.1 | 15 Sep 1975 01:00:00 pm | 800 | 7.0 | 103 | 2.74 | 21.2 | 23.3 | 183 | 26.4 | n/a | 97.6 | <0.9 |
| GW030323 | 1.1 | 08 Sep 1975 12:00:00 pm | 660 | 6.8 | 103 | 3.13 | 15.8 | 15.6 | 128 | 9.61 | n/a | 171 | 3.10 |
| GW030323 | 1.1 | 25 Aug 1975 12:00:00 pm | 650 | 7.0 | 138 | 5.08 | 10.6 | 18.7 | n/a | 12.0 | n/a | n/a | n/a |
| GW030323 | 1.1 | 15 Jul 1975 12:01:00 pm | 646 | 7.1 | 94.0 | 3.13 | 5.01 | 21.9 | 136 | <0.5 | n/a | 145 | n/a |
| GW030323 | 1.1 | 06 Dec 1974 08:00:00 am | 605 | 6.7 | 85.1 | 2.74 | 8.02 | 20.1 | 144 | <0.5 | n/a | 91.5 | 0.62 |
| GW030323 | 1.1 | 22 Nov 1974 10:00:00 am | 760 | 7.1 | 106 | 2.74 | 15.0 | 20.1 | 156 | 2.40 | n/a | 140 | 3.72 |
| GW030323 | 1.1 | 27 Sep 1974 03:00:00 pm | 620 | 7.5 | 90.8 | 2.74 | 7.01 | 15.8 | 145 | <0.5 | n/a | 104 | 0.62 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036211 | 1.1 | 11 Apr 2018 12:00:00 pm | 1,400 | 6.5 | 205 | 3.00 | 20.0 | 30.0 | 376 | 30.0 | <1 | 122 | 0.09 |
| GW036211 | 1.1 | 15 Sep 2017 12:00:00 am | 1,200 | n/a | 170 | 3.90 | 14.0 | 24.0 | 300 | 20.0 | 1.70 | 160 | <0.9 |
| GW036211 | 1.1 | 22 Apr 2016 12:00:00 am | 1,500 | 7.3 | 220 | 3.70 | 21.0 | 33.0 | 390 | 30.0 | 1.70 | 160 | <0.9 |
| GW036211 | 1.1 | 29 Jul 2014 12:00:00 am | 546 | 6.9 | 77.0 | 3.20 | 5.30 | 12.0 | 100 | 1.40 | <1 | 130 | <0.02 |
| GW036211 | 1.1 | 19 Jun 2013 01:00:00 pm | 760 | n/a | 120 | 3.60 | 8.30 | 17.0 | 160 | 6.10 | <1 | 130 | 0.13 |
| GW036211 | 1.1 | 29 Nov 2012 11:45:00 am | 892 | n/a | 130 | 3.30 | 11.0 | 18.0 | 200 | 9.50 | <1 | 140 | 0.53 |
| GW036211 | 1.1 | 25 Jun 2012 11:30:00 am | 976 | n/a | 140 | 3.70 | 11.0 | 22.0 | 220 | 12.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 23 Jun 2011 10:45:00 am | 828 | n/a | 140 | 3.80 | 9.30 | 18.0 | 180 | 8.40 | <1 | 130 | <0.05 |
| GW036211 | 1.1 | 13 Sep 2010 12:00:00 pm | 519 | n/a | 84.0 | 3.50 | 5.90 | 12.0 | 94.0 | 0.90 | <1 | 130 | <0.05 |
| GW036211 | 1.1 | 27 Jul 2010 11:00:00 am | 541 | n/a | 88.0 | 3.80 | 7.20 | 13.0 | 100 | 0.70 | <1 | 130 | <0.05 |
| GW036211 | 1.1 | 10 Jun 2010 11:20:00 am | 620 | n/a | 96.0 | 3.70 | 8.00 | 14.0 | 120 | 1.80 | <1 | 130 | 0.31 |
| GW036211 | 1.1 | 11 May 2010 02:30:00 pm | 964 | n/a | 150 | 3.80 | 13.0 | 22.0 | 230 | 14.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 13 Apr 2010 11:30:00 am | 1,220 | n/a | 200 | 3.60 | 17.0 | 28.0 | 320 | 24.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 10 Mar 2010 02:40:00 pm | 1,490 | n/a | 190 | 3.80 | 16.0 | 26.0 | 280 | 18.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 16 Feb 2010 03:20:00 pm | 1,020 | n/a | 170 | 3.80 | 13.0 | 24.0 | 250 | 16.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 08 Dec 2009 01:00:00 pm | 908 | n/a | 150 | 3.80 | 13.0 | 22.0 | 210 | 11.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 12 Nov 2009 01:00:00 pm | 962 | n/a | 150 | 3.50 | 13.0 | 22.0 | 240 | 15.0 | <1 | 140 | <0.05 |
| GW036211 | 1.1 | 21 Oct 2009 11:40:00 am | 477 | n/a | 120 | 3.40 | 9.10 | 16.0 | 160 | 6.20 | <1 | 110 | 0.04 |
| GW036211 | 1.1 | 18 Sep 2009 02:15:00 pm | 1,240 | n/a | 200 | 3.40 | 20.0 | 29.0 | 340 | 25.0 | 1.60 | 140 | <0.05 |
| GW036211 | 1.1 | 18 Sep 1986 12:00:00 pm | 456 | 6.8 | 63.5 | 3.52 | 4.21 | 11.4 | 75.2 | 1.44 | <1 | 123 | <0.9 |
| GW036211 | 1.1 | 03 Apr 1978 06:00:00 am | 500 | 7.0 | 73.6 | 4.30 | 6.41 | 12.9 | 83.3 | 7.20 | n/a | 143 | 2.48 |
| GW036211 | 1.1 | 26 Jul 1977 12:01:00 pm | 1,834 | 7.2 | 268 | 3.91 | 43.1 | 44.0 | 490 | 35.1 | <1 | 209 | n/a |
| GW036211 | 2.2 | 11 Apr 2018 12:00:00 pm | 462 | 5.9 | 78.0 | 3.00 | 4.00 | 7.00 | 72.0 | <1 | <1 | 96.0 | 0.09 |
| GW036211 | 2.2 | 15 Sep 2017 12:00:00 am | 470 | n/a | 75.0 | 4.00 | 3.80 | 7.20 | 89.0 | <0.5 | 1.70 | 160 | <0.9 |
| GW036211 | 2.2 | 22 Apr 2016 12:00:00 am | 480 | 7.0 | 75.0 | 3.90 | 4.60 | 8.10 | 91.0 | <0.5 | 1.70 | 160 | <0.9 |
| GW036211 | 2.2 | 30 Jul 2014 12:00:00 am | 471 | 6.6 | 70.0 | 3.40 | 4.10 | 7.30 | 85.0 | <0.5 | <1 | 110 | <0.02 |
| GW036211 | 2.2 | 19 Jun 2013 02:25:00 pm | 469 | n/a | 74.0 | 3.80 | 4.00 | 7.60 | 88.0 | <0.5 | <1 | 110 | 0.09 |
| GW036211 | 2.2 | 28 Nov 2012 10:00:00 am | 469 | n/a | 82.0 | 4.00 | 5.00 | 8.20 | 87.0 | <0.5 | <1 | 120 | 0.75 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036211 | 2.2 | 25 Jun 2012 11:25:00 am | 475 | n/a | 73.0 | 3.70 | 4.20 | 8.00 | 86.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 23 Jun 2011 02:55:00 pm | 478 | n/a | 87.0 | 3.90 | 4.70 | 7.80 | 84.0 | <0.5 | <1 | 110 | 0.04 |
| GW036211 | 2.2 | 13 Sep 2010 01:55:00 pm | 465 | n/a | 79.0 | 3.80 | 4.70 | 7.80 | 85.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 27 Jul 2010 12:45:00 pm | 469 | n/a | 84.0 | 4.00 | 5.70 | 8.30 | 87.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 2.2 | 10 Jun 2010 01:15:00 pm | 465 | n/a | 69.0 | 4.30 | 4.00 | 7.20 | 87.0 | <0.5 | <1 | 110 | 0.04 |
| GW036211 | 2.2 | 11 May 2010 10:40:00 am | 467 | n/a | 78.0 | 4.10 | 4.60 | 7.90 | 87.0 | <0.5 | <1 | 110 | 0.04 |
| GW036211 | 2.2 | 12 Apr 2010 02:30:00 pm | 464 | n/a | 79.0 | 3.80 | 4.70 | 7.90 | 86.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 10 Mar 2010 10:35:00 am | 492 | n/a | 83.0 | 4.00 | 5.30 | 8.30 | 86.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 16 Feb 2010 04:45:00 pm | 474 | n/a | 81.0 | 4.00 | 4.50 | 8.40 | 85.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 08 Dec 2009 02:30:00 pm | 473 | n/a | 80.0 | 3.90 | 4.70 | 8.20 | 83.0 | <0.5 | <1 | 110 | 0.09 |
| GW036211 | 2.2 | 12 Nov 2009 09:30:00 am | 459 | n/a | 74.0 | 3.70 | 4.40 | 7.70 | 86.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 21 Oct 2009 02:30:00 pm | 725 | n/a | 77.0 | 3.70 | 4.40 | 7.80 | 86.0 | <0.5 | <1 | 140 | 0.04 |
| GW036211 | 2.2 | 18 Sep 2009 10:35:00 am | 454 | n/a | 74.0 | 3.70 | 4.80 | 7.80 | 85.0 | <0.5 | <1 | 110 | <0.05 |
| GW036211 | 2.2 | 18 Sep 1986 02:00:00 pm | 466 | 6.7 | 69.2 | 3.91 | 4.41 | 7.66 | 84.0 | 1.44 | <1 | 117 | 0.62 |
| GW036211 | 2.2 | 19 Apr 1978 08:00:00 am | 450 | 6.9 | 79.5 | 3.52 | 5.01 | 7.53 | 86.9 | <0.5 | n/a | 119 | 1.24 |
| GW036211 | 3.3 | 10 Apr 2018 12:00:00 pm | 510 | 5.9 | 89.0 | 4.00 | 5.00 | 6.00 | 80.0 | <1 | <1 | 103 | 0.09 |
| GW036211 | 3.3 | 15 Sep 2017 12:00:00 am | 520 | n/a | 86.0 | 4.90 | 3.90 | 5.90 | 100 | <0.5 | 1.70 | 160 | <0.9 |
| GW036211 | 3.3 | 21 Apr 2016 12:00:00 am | 520 | 7.1 | 87.0 | 4.70 | 4.70 | 6.60 | 100 | <0.5 | 1.70 | 160 | <0.9 |
| GW036211 | 3.3 | 29 Jul 2014 12:00:00 am | 467 | 6.7 | 78.0 | 3.50 | 3.50 | 5.00 | 87.0 | <0.5 | <1 | 110 | <0.02 |
| GW036211 | 3.3 | 21 Jun 2013 01:20:00 pm | 521 | n/a | 91.0 | 4.80 | 4.30 | 6.70 | 98.0 | <0.5 | <1 | 120 | 0.13 |
| GW036211 | 3.3 | 28 Nov 2012 02:30:00 pm | 520 | n/a | 87.0 | 4.20 | 4.50 | 5.90 | 98.0 | <0.5 | <1 | 130 | 0.40 |
| GW036211 | 3.3 | 25 Jun 2012 03:10:00 pm | 522 | n/a | 83.0 | 4.70 | 4.20 | 6.50 | 96.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 23 Jun 2011 02:00:00 pm | 530 | n/a | 100 | 4.90 | 5.00 | 6.20 | 95.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 13 Sep 2010 02:15:00 pm | 514 | n/a | 92.0 | 4.60 | 5.90 | 6.40 | 95.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 27 Jul 2010 03:20:00 pm | 513 | n/a | 94.0 | 4.80 | 5.60 | 6.70 | 98.0 | <0.5 | <1 | 120 | 0.04 |
| GW036211 | 3.3 | 10 Jun 2010 01:05:00 pm | 511 | n/a | 80.0 | 5.10 | 4.00 | 5.80 | 98.0 | <0.5 | <1 | 120 | 0.27 |
| GW036211 | 3.3 | 11 May 2010 02:25:00 pm | 517 | n/a | 90.0 | 5.00 | 4.50 | 6.30 | 97.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 13 Apr 2010 03:30:00 pm | 516 | n/a | 90.0 | 4.50 | 4.50 | 6.40 | 96.0 | <0.5 | <1 | 120 | <0.05 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036211 | 3.3 | 10 Mar 2010 01:55:00 pm | 519 | n/a | 94.0 | 4.90 | 5.10 | 6.70 | 97.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 16 Feb 2010 12:10:00 pm | 501 | n/a | 93.0 | 4.80 | 4.50 | 6.70 | 96.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 08 Dec 2009 10:20:00 am | 513 | n/a | 92.0 | 4.80 | 4.80 | 6.90 | 94.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 12 Nov 2009 11:40:00 am | 503 | n/a | 86.0 | 4.60 | 4.50 | 6.40 | 97.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 21 Oct 2009 02:00:00 pm | 516 | n/a | 90.0 | 4.60 | 4.50 | 6.40 | 97.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 22 Sep 2009 01:40:00 pm | 499 | n/a | 86.0 | 4.50 | 4.80 | 6.30 | 96.0 | <0.5 | <1 | 120 | <0.05 |
| GW036211 | 3.3 | 03 May 1978 12:01:00 pm | 520 | 6.8 | 93.3 | 4.69 | 5.21 | 7.05 | 103 | <0.5 | n/a | 134 | <0.9 |
| GW036211 | 3.3 | 26 Jul 1977 12:00:00 pm | 2,283 | 7.2 | 347 | 3.91 | 45.1 | 47.6 | 635 | 37.9 | <1 | 216 | n/a |
| GW036396 | 1.1 | 17 Apr 2018 12:00:00 pm | 2,060 | 6.8 | 289 | 4.00 | 45.0 | 49.0 | 532 | 111 | <1 | 141 | 0.04 |
| GW036396 | 1.1 | 14 Sep 2017 12:00:00 am | 2,000 | n/a | 270 | 4.30 | 41.0 | 46.0 | 510 | 100 | 1.70 | 160 | <0.9 |
| GW036396 | 1.1 | 12 Apr 2016 12:00:00 am | 2,000 | 7.1 | 280 | 4.20 | 43.0 | 50.0 | 520 | 110 | 1.70 | 160 | <0.9 |
| GW036396 | 1.1 | 06 Aug 2014 12:00:00 am | 1,798 | 7.0 | 260 | 4.20 | 39.0 | 42.0 | 430 | 87.0 | <1 | 160 | <0.9 |
| GW036396 | 1.1 | 02 Jul 2013 03:35:00 pm | 1,852 | n/a | 270 | 3.90 | 37.0 | 46.0 | 460 | 81.0 | <1 | 180 | 0.09 |
| GW036396 | 1.1 | 26 Nov 2012 03:15:00 pm | 1,838 | n/a | 290 | 4.10 | 43.0 | 45.0 | 450 | 82.0 | <1 | 160 | 1.59 |
| GW036396 | 1.1 | 20 Jun 2012 03:00:00 pm | 1,840 | n/a | 280 | 3.90 | 39.0 | 48.0 | 430 | 83.0 | <1 | 160 | <0.05 |
| GW036396 | 1.1 | 08 Jun 2011 02:20:00 pm | 1,799 | n/a | 290 | 3.80 | 34.0 | 40.0 | 440 | 83.0 | <1 | 160 | <0.05 |
| GW036396 | 1.1 | 26 Jul 2010 01:20:00 pm | 1,760 | n/a | 280 | 4.00 | 44.0 | 45.0 | 440 | 85.0 | <1 | 160 | <0.05 |
| GW036396 | 1.1 | 15 Jun 2010 03:10:00 pm | 1,780 | n/a | 240 | 4.40 | 35.0 | 39.0 | 450 | 79.0 | <1 | 160 | 0.04 |
| GW036396 | 1.1 | 20 May 2010 04:05:00 pm | 1,820 | n/a | 280 | 4.10 | 40.0 | 45.0 | 470 | 88.0 | <1 | 170 | 0.04 |
| GW036396 | 1.1 | 16 Mar 2010 03:55:00 pm | 1,740 | n/a | 280 | 4.20 | 41.0 | 46.0 | 450 | 86.0 | <1 | 170 | <0.05 |
| GW036396 | 1.1 | 22 Feb 2010 03:40:00 pm | 1,720 | n/a | 270 | 4.10 | 37.0 | 44.0 | 450 | 85.0 | <1 | 160 | <0.05 |
| GW036396 | 1.1 | 03 Dec 2009 12:00:00 am | 1,670 | n/a | 290 | 4.20 | 42.0 | 47.0 | 450 | 85.0 | <1 | 160 | <0.05 |
| GW036396 | 1.1 | 13 Oct 2009 09:35:00 am | 1,570 | n/a | 260 | 3.80 | 37.0 | 43.0 | 450 | 85.0 | <1 | 170 | 0.09 |
| GW036396 | 1.1 | 05 Mar 1981 12:00:00 pm | 1,200 | 7.2 | 176 | 3.13 | 27.1 | 28.6 | 264 | 77.3 | <1 | 154 | <0.9 |
| GW036396 | 1.1 | 29 Nov 1979 05:00:00 pm | 5,500 | 8.1 | 931 | 1.95 | 93.6 | 127 | 1,515 | 366 | <1 | 381 | <0.9 |
| GW036773 | 1.1 | 03 May 2018 12:00:00 pm | 3,610 | 6.9 | 470 | 5.00 | 153 | 114 | 631 | 778 | <1 | 290 | 5.84 |
| GW036773 | 1.1 | 07 Sep 2017 12:00:00 am | 3,600 | n/a | 470 | 6.20 | 140 | 110 | 660 | 780 | 1.70 | 160 | 10.2 |
| GW036773 | 1.1 | 27 Apr 2016 12:00:00 am | 3,900 | 7.3 | 500 | 6.20 | 180 | 130 | 750 | 840 | 1.70 | 160 | 11.5 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036773 | 1.1 | 04 Aug 2014 12:00:00 am | 3,770 | 7.2 | 480 | 6.50 | 160 | 120 | 670 | 830 | <1 | 340 | 11.5 |
| GW036773 | 1.1 | 18 Jun 2013 02:00:00 pm | 3,930 | n/a | 540 | 6.30 | 190 | 130 | 690 | 860 | <1 | 350 | 12.0 |
| GW036773 | 1.1 | 20 Nov 2012 01:15:00 pm | 3,970 | n/a | 560 | 6.00 | 200 | 130 | 720 | 880 | <1 | 340 | 13.7 |
| GW036773 | 1.1 | 06 Jun 2012 01:00:00 pm | 4,040 | n/a | 570 | 6.40 | 200 | 150 | 730 | 850 | <1 | 350 | 14.2 |
| GW036773 | 1.1 | 06 Jun 2011 02:40:00 pm | 4,070 | n/a | 580 | 6.70 | 190 | 140 | 730 | 860 | <1 | 360 | 2.35 |
| GW036773 | 1.1 | 08 Sep 2010 01:25:00 pm | 3,920 | n/a | 540 | 6.50 | 180 | 130 | 690 | 860 | <1 | 360 | 13.7 |
| GW036773 | 1.1 | 16 Jul 2010 10:20:00 am | 3,910 | n/a | 570 | 6.50 | 190 | 140 | 770 | 930 | <1 | 360 | 13.3 |
| GW036773 | 1.1 | 16 Jun 2010 01:10:00 pm | 3,920 | n/a | 560 | 6.80 | 190 | 140 | 720 | 880 | <1 | 360 | 13.7 |
| GW036773 | 1.1 | 14 May 2010 09:15:00 am | 3,990 | n/a | 540 | 6.70 | 190 | 140 | 740 | 900 | <1 | 350 | 12.8 |
| GW036773 | 1.1 | 14 Apr 2010 01:40:00 pm | 3,500 | n/a | 560 | 6.30 | 170 | 140 | 780 | 950 | <1 | 350 | 14.2 |
| GW036773 | 1.1 | 12 Mar 2010 11:20:00 am | 3,550 | n/a | 560 | 6.70 | 200 | 140 | 730 | 880 | <1 | 350 | 12.0 |
| GW036773 | 1.1 | 22 Feb 2010 04:35:00 pm | 3,320 | n/a | 540 | 6.60 | 200 | 140 | 720 | 850 | <1 | 340 | 12.8 |
| GW036773 | 1.1 | 11 Dec 2009 09:00:00 am | 3,310 | n/a | 560 | 6.80 | 200 | 140 | 750 | 860 | <1 | 330 | 12.0 |
| GW036773 | 1.1 | 13 Nov 2009 11:15:00 am | 3,220 | n/a | 520 | 6.10 | 190 | 140 | 710 | 830 | <1 | 330 | 12.8 |
| GW036773 | 1.1 | 23 Oct 2009 12:35:00 pm | 3,200 | n/a | 540 | 6.20 | 190 | 140 | 740 | 860 | <1 | 340 | 12.4 |
| GW036773 | 1.1 | 02 Oct 2009 12:00:00 pm | 3,100 | n/a | 530 | 6.20 | 190 | 140 | 770 | 910 | <1 | 350 | 13.7 |
| GW036773 | 2.2 | 03 May 2018 12:00:00 pm | 1,360 | 6.6 | 182 | 3.00 | 45.0 | 36.0 | 267 | 187 | <1 | 127 | 1.68 |
| GW036773 | 2.2 | 07 Sep 2017 12:00:00 am | 1,400 | n/a | 180 | 3.30 | 38.0 | 32.0 | 250 | 180 | 1.70 | 160 | 1.77 |
| GW036773 | 2.2 | 27 Apr 2016 12:00:00 am | 1,500 | 7.1 | 190 | 3.20 | 50.0 | 41.0 | 290 | 210 | 1.70 | 160 | 2.21 |
| GW036773 | 2.2 | 04 Aug 2014 12:00:00 am | 1,280 | 6.9 | 150 | 3.10 | 37.0 | 29.0 | 230 | 160 | <1 | 150 | 1.33 |
| GW036773 | 2.2 | 18 Jun 2013 04:10:00 pm | 1,327 | n/a | 180 | 2.80 | 40.0 | 35.0 | 240 | 180 | <1 | 150 | 1.86 |
| GW036773 | 2.2 | 20 Nov 2012 02:30:00 pm | 1,337 | n/a | 180 | 3.00 | 43.0 | 34.0 | 240 | 160 | <1 | 140 | 0.84 |
| GW036773 | 2.2 | 06 Jun 2012 01:15:00 pm | 1,450 | n/a | 190 | 3.10 | 46.0 | 41.0 | 260 | 200 | <1 | 150 | 1.51 |
| GW036773 | 2.2 | 06 Jun 2011 01:40:00 pm | 1,185 | n/a | 170 | 2.80 | 32.0 | 27.0 | 200 | 130 | <1 | 140 | 0.53 |
| GW036773 | 2.2 | 08 Sep 2010 02:25:00 pm | 1,124 | n/a | 160 | 2.70 | 33.0 | 27.0 | 210 | 130 | <1 | 140 | 1.15 |
| GW036773 | 2.2 | 16 Jul 2010 11:25:00 am | 1,060 | n/a | 150 | 2.80 | 34.0 | 27.0 | 200 | 100 | <1 | 130 | 0.35 |
| GW036773 | 2.2 | 16 Jun 2010 01:50:00 pm | 1,210 | n/a | 160 | 3.00 | 37.0 | 31.0 | 230 | 140 | <1 | 140 | 0.97 |
| GW036773 | 2.2 | 14 May 2010 11:45:00 am | 1,200 | n/a | 150 | 3.00 | 33.0 | 28.0 | 220 | 130 | <1 | 130 | 0.58 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036773 | 2.2 | 14 Apr 2010 03:15:00 pm | 1,120 | n/a | 150 | 2.90 | 33.0 | 28.0 | 210 | 130 | <1 | 130 | 0.89 |
| GW036773 | 2.2 | 12 Mar 2010 11:00:00 am | 1,020 | n/a | 140 | 2.90 | 29.0 | 25.0 | 190 | 81.0 | <1 | 120 | 0.44 |
| GW036773 | 2.2 | 19 Feb 2010 03:25:00 pm | 889 | n/a | 130 | 2.80 | 24.0 | 23.0 | 180 | 77.0 | <1 | 110 | 0.40 |
| GW036773 | 2.2 | 11 Dec 2009 11:55:00 am | 1,380 | n/a | 160 | 2.90 | 34.0 | 29.0 | 210 | 110 | <1 | 130 | 1.06 |
| GW036773 | 2.2 | 13 Nov 2009 09:35:00 am | 905 | n/a | 130 | 2.60 | 25.0 | 23.0 | 190 | 82.0 | <1 | 120 | 0.49 |
| GW036773 | 2.2 | 23 Oct 2009 11:05:00 am | 1,120 | n/a | 160 | 2.70 | 35.0 | 30.0 | 220 | 130 | <1 | 130 | 0.97 |
| GW036773 | 2.2 | 02 Oct 2009 11:45:00 am | 914 | n/a | 140 | 2.70 | 27.0 | 24.0 | 190 | 94.0 | <1 | 120 | 0.66 |
| GW036773 | 3.3 | 03 May 2018 12:00:00 pm | 619 | 6.0 | 75.0 | 4.00 | 18.0 | 13.0 | 166 | <1 | <1 | 65.0 | 0.09 |
| GW036773 | 3.3 | 07 Sep 2017 12:00:00 am | 640 | n/a | 74.0 | 4.50 | 17.0 | 14.0 | 160 | <0.5 | 1.70 | 160 | <0.9 |
| GW036773 | 3.3 | 27 Apr 2016 12:00:00 am | 620 | 6.6 | 70.0 | 4.60 | 18.0 | 14.0 | 150 | <0.5 | 1.70 | 160 | <0.9 |
| GW036773 | 3.3 | 04 Aug 2014 12:00:00 am | 633 | 6.5 | 65.0 | 4.20 | 17.0 | 14.0 | 150 | <0.5 | <1 | 78.0 | <0.9 |
| GW036773 | 3.3 | 18 Jun 2013 12:40:00 pm | 639 | n/a | 72.0 | 4.30 | 17.0 | 15.0 | 150 | <0.5 | <1 | 77.0 | 0.09 |
| GW036773 | 3.3 | 20 Nov 2012 12:10:00 pm | 638 | n/a | 77.0 | 4.20 | 20.0 | 16.0 | 150 | <0.5 | <1 | 77.0 | 0.35 |
| GW036773 | 3.3 | 06 Jun 2012 11:30:00 am | 633 | n/a | 72.0 | 4.10 | 18.0 | 17.0 | 150 | <0.5 | <1 | 76.0 | <0.05 |
| GW036773 | 3.3 | 06 Jun 2011 11:20:00 am | 639 | n/a | 82.0 | 4.30 | 18.0 | 15.0 | 150 | <0.5 | <1 | 77.0 | <0.05 |
| GW036773 | 3.3 | 08 Sep 2010 11:45:00 am | 631 | n/a | 76.0 | 4.30 | 19.0 | 15.0 | 150 | <0.5 | <1 | 79.0 | 0.13 |
| GW036773 | 3.3 | 16 Jul 2010 11:40:00 am | 625 | n/a | 77.0 | 4.50 | 21.0 | 15.0 | 150 | <0.5 | <1 | 79.0 | 0.04 |
| GW036773 | 3.3 | 16 Jun 2010 10:55:00 am | 617 | n/a | 67.0 | 4.90 | 18.0 | 13.0 | 150 | <0.5 | <1 | 79.0 | 0.04 |
| GW036773 | 3.3 | 14 May 2010 10:10:00 am | 635 | n/a | 75.0 | 4.80 | 18.0 | 14.0 | 150 | <0.5 | <1 | 80.0 | 0.04 |
| GW036773 | 3.3 | 14 Apr 2010 10:30:00 am | 601 | n/a | 73.0 | 4.50 | 18.0 | 14.0 | 140 | <0.5 | <1 | 79.0 | <0.05 |
| GW036773 | 3.3 | 12 Mar 2010 09:55:00 am | 618 | n/a | 77.0 | 4.70 | 18.0 | 14.0 | 140 | <0.5 | <1 | 77.0 | <0.05 |
| GW036773 | 3.3 | 19 Feb 2010 10:10:00 am | 590 | n/a | 77.0 | 4.90 | 17.0 | 14.0 | 150 | <0.5 | <1 | 77.0 | <0.05 |
| GW036773 | 3.3 | 11 Dec 2009 09:45:00 am | 674 | n/a | 77.0 | 4.90 | 19.0 | 14.0 | 140 | <0.5 | <1 | 80.0 | <0.05 |
| GW036773 | 3.3 | 13 Nov 2009 10:35:00 am | 597 | n/a | 71.0 | 4.40 | 17.0 | 13.0 | 140 | <0.5 | <1 | 79.0 | <0.05 |
| GW036773 | 3.3 | 23 Oct 2009 09:00:00 am | 659 | n/a | 73.0 | 4.40 | 18.0 | 14.0 | 150 | <0.5 | <1 | 83.0 | <0.05 |
| GW036773 | 3.3 | 02 Oct 2009 11:10:00 am | 577 | n/a | 75.0 | 4.50 | 18.0 | 14.0 | 150 | <0.5 | <1 | 77.0 | <0.05 |
| GW036799 | 1.1 | 24 Apr 2018 12:00:00 pm | 5,240 | 6.9 | 800 | 10.0 | 94.0 | 114 | 1,330 | 44.0 | <1 | 320 | 0.09 |
| GW036799 | 1.1 | 19 Sep 2017 12:00:00 am | 5,200 | n/a | 810 | 13.0 | 77.0 | 100 | 1,600 | 42.0 | 1.70 | 160 | <0.9 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036799 | 1.1 | 03 May 2016 12:00:00 am | 5,000 | 7.7 | 740 | 13.0 | 87.0 | 100 | 1,500 | 36.0 | 1.70 | 160 | <0.9 |
| GW036799 | 1.1 | 13 Aug 2014 12:00:00 am | 4,600 | 7.6 | 700 | 12.0 | 72.0 | 89.0 | 1,400 | 28.0 | <1 | 380 | <0.9 |
| GW036799 | 1.1 | 03 Jul 2013 12:20:00 pm | 5,130 | n/a | 770 | 10.0 | 81.0 | 100 | 1,500 | 32.0 | <1 | 370 | 0.09 |
| GW036799 | 1.1 | 22 Nov 2012 02:00:00 pm | 5,050 | n/a | 840 | 12.0 | 87.0 | 100 | 1,500 | 31.0 | <1 | 380 | 2.04 |
| GW036799 | 1.1 | 19 Jun 2012 11:10:00 am | 4,940 | n/a | 800 | 12.0 | 84.0 | 110 | 1,400 | 30.0 | <1 | 370 | <0.05 |
| GW036799 | 1.1 | 09 Jun 2011 02:50:00 pm | 5,150 | n/a | 850 | 13.0 | 84.0 | 110 | 1,400 | 39.0 | <1 | 380 | <0.05 |
| GW036799 | 1.1 | 12 Jul 2010 12:15:00 pm | 4,580 | n/a | 780 | 13.0 | 86.0 | 100 | 1,300 | 25.0 | <1 | 380 | 0.09 |
| GW036799 | 1.1 | 22 Jun 2010 10:55:00 am | 4,550 | n/a | 780 | 13.0 | 81.0 | 100 | 1,400 | 25.0 | <1 | 380 | 0.09 |
| GW036799 | 1.1 | 16 Sep 2009 05:40:00 pm | 4,200 | n/a | 740 | 12.0 | 85.0 | 100 | 1,400 | 36.0 | 17.0 | 340 | 0.04 |
| GW036799 | 2.2 | 03 Jun 1989 12:00:00 pm | n/a | n/a | n/a | n/a | 14.7 | 24.6 | n/a | n/a | n/a | n/a | n/a |
| GW036799 | 2.2 | 24 Apr 2018 12:00:00 pm | 2,320 | 7.1 | 399 | 12.0 | 24.0 | 35.0 | 592 | <1 | <1 | 315 | 0.09 |
| GW036799 | 2.2 | 19 Sep 2017 12:00:00 am | 2,200 | n/a | 380 | 14.0 | 18.0 | 29.0 | 560 | <0.5 | 1.70 | 160 | <0.9 |
| GW036799 | 2.2 | 03 May 2016 12:00:00 am | 2,200 | 7.6 | 380 | 14.0 | 22.0 | 34.0 | 560 | <0.5 | 1.70 | 160 | <0.9 |
| GW036799 | 2.2 | 13 Aug 2014 12:00:00 am | 2,105 | 7.4 | 340 | 14.0 | 18.0 | 26.0 | 500 | <0.5 | <1 | 360 | <0.9 |
| GW036799 | 2.2 | 03 Jul 2013 11:10:00 am | 1,903 | n/a | 360 | 13.0 | 16.0 | 28.0 | 450 | <0.5 | <1 | 360 | 0.13 |
| GW036799 | 2.2 | 23 Nov 2012 12:30:00 pm | 1,898 | n/a | 370 | 13.0 | 17.0 | 25.0 | 440 | <0.5 | <1 | 350 | 3.28 |
| GW036799 | 2.2 | 19 Jun 2012 03:40:00 pm | 2,021 | n/a | 380 | 13.0 | 18.0 | 30.0 | 460 | <0.5 | <1 | 380 | <0.05 |
| GW036799 | 2.2 | 09 Jun 2011 01:50:00 pm | 2,159 | n/a | 440 | 14.0 | 19.0 | 30.0 | 490 | 0.60 | <1 | 400 | <0.05 |
| GW036799 | 2.2 | 12 Jul 2010 03:15:00 pm | 2,010 | n/a | 400 | 14.0 | 21.0 | 30.0 | 470 | 0.50 | <1 | 390 | 0.09 |
| GW036799 | 2.2 | 22 Jun 2010 01:50:00 pm | 2,060 | n/a | 390 | 14.0 | 18.0 | 28.0 | 490 | <0.5 | <1 | 390 | 0.09 |
| GW036799 | 2.2 | 16 Sep 2009 04:03:00 pm | 1,700 | n/a | 340 | 13.0 | 18.0 | 26.0 | 440 | <0.5 | 14.0 | 350 | 0.04 |
| GW036799 | 2.2 | 19 Jun 1996 12:01:00 am | 1,670 | 7.3 | 290 | 14.0 | 13.0 | 20.0 | 400 | 1.10 | <1 | 350 | <2.5 |
| GW036799 | 3.3 | 24 Apr 2018 12:00:00 pm | 22,800 | 6.5 | 3,810 | 6.00 | 509 | 493 | 7,110 | 1,300 | <1 | 275 | 0.04 |
| GW036799 | 3.3 | 19 Sep 2017 12:00:00 am | 23,000 | n/a | 3,900 | 7.10 | 480 | 580 | 8,400 | 1,200 | 1.70 | 160 | <0.9 |
| GW036799 | 3.3 | 03 May 2016 12:00:00 am | 22,000 | 7.6 | 4,000 | 7.30 | 440 | 550 | 8,100 | 1,200 | 1.70 | 160 | <0.9 |
| GW036799 | 3.3 | 13 Aug 2014 12:00:00 am | 3,720 | 8.2 | 610 | 15.0 | 47.0 | 57.0 | 1,100 | 79.0 | <1 | 290 | <0.9 |
| GW036799 | 3.3 | 03 Jul 2013 02:25:00 pm | 21,460 | n/a | 3,700 | 6.00 | 370 | 470 | 7,600 | 850 | <1 | 330 | 0.09 |
| GW036799 | 3.3 | 22 Nov 2012 12:35:00 pm | 4,060 | n/a | 730 | 14.0 | 55.0 | 67.0 | 1,200 | 97.0 | <1 | 280 | 0.53 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW036799 | 3.3 | 19 Jun 2012 12:30:00 pm | 4,420 | n/a | 760 | 15.0 | 56.0 | 78.0 | 1,200 | 110 | <1 | 290 | 0.09 |
| GW036799 | 3.3 | 09 Jun 2011 12:00:00 pm | 4,530 | n/a | 800 | 14.0 | 58.0 | 77.0 | 1,200 | 110 | <1 | 290 | <0.05 |
| GW036799 | 3.3 | 12 Jul 2010 03:30:00 pm | 3,550 | n/a | 590 | 13.0 | 46.0 | 57.0 | 1,000 | 74.0 | <1 | 300 | 0.89 |
| GW036799 | 3.3 | 22 Jun 2010 02:30:00 pm | 3,680 | n/a | 670 | 15.0 | 53.0 | 64.0 | 1,100 | 79.0 | <1 | 300 | 0.04 |
| GW036799 | 3.3 | 16 Sep 2009 05:50:00 pm | 2,940 | n/a | 570 | 14.0 | 46.0 | 54.0 | 900 | 62.0 | <1 | 290 | <0.05 |
| GW036799 | 3.3 | 19 Jun 1996 12:00:00 am | 1,950 | 7.3 | 320 | 14.0 | 17.0 | 23.0 | 480 | 1.30 | <1 | 290 | <2.5 |
| GW041011 | 1.1 | 02 May 2018 12:00:00 pm | 6,160 | 7.4 | 860 | 1.00 | 156 | 140 | 1,430 | 473 | <1 | 212 | 12.0 |
| GW041011 | 1.1 | 12 Sep 2017 12:00:00 am | 5,200 | n/a | 780 | 1.90 | 110 | 110 | 1,400 | 370 | 1.70 | 160 | 10.2 |
| GW041011 | 1.1 | 26 Apr 2016 12:00:00 am | 4,700 | 8.0 | 720 | 1.60 | 110 | 95.0 | 1,400 | 190 | 1.70 | 160 | 7.53 |
| GW041011 | 1.1 | 07 Aug 2014 12:00:00 am | 3,358 | 7.9 | 520 | 1.30 | 64.0 | 57.0 | 920 | 110 | <1 | 310 | 6.20 |
| GW041011 | 1.1 | 26 Jun 2013 02:05:00 pm | 3,480 | n/a | 540 | 1.10 | 67.0 | 65.0 | 900 | 140 | <1 | 290 | 4.87 |
| GW041011 | 1.1 | 04 Dec 2012 01:05:00 pm | 3,690 | n/a | 650 | 1.40 | 89.0 | 79.0 | 1,000 | 130 | <1 | 280 | 7.97 |
| GW041011 | 1.1 | 13 Jun 2012 12:05:00 pm | 3,430 | n/a | 580 | 1.20 | 71.0 | 73.0 | 880 | 140 | <1 | 310 | 7.53 |
| GW041011 | 1.1 | 08 Jun 2011 10:35:00 am | 3,337 | n/a | 590 | 1.30 | 61.0 | 59.0 | 940 | 73.0 | <1 | 250 | 7.08 |
| GW041011 | 1.1 | 13 Jul 2010 08:15:00 am | 3,940 | n/a | 640 | 1.60 | 97.0 | 86.0 | 1,200 | 97.0 | <1 | 240 | 9.74 |
| GW041011 | 1.1 | 07 Jun 2010 11:45:00 am | 4,070 | n/a | 590 | 1.70 | 84.0 | 79.0 | 1,200 | 92.0 | 5.10 | 230 | 8.85 |
| GW041011 | 1.1 | 12 May 2010 09:50:00 am | 4,120 | n/a | 640 | 1.70 | 95.0 | 90.0 | 1,200 | 95.0 | <1 | 240 | 8.41 |
| GW041011 | 1.1 | 21 Apr 2010 07:45:00 am | 3,660 | n/a | 660 | 1.60 | 90.0 | 88.0 | 1,300 | 110 | <1 | 240 | 10.2 |
| GW041011 | 1.1 | 11 Mar 2010 10:55:00 am | 3,900 | n/a | 710 | 1.70 | 110 | 99.0 | 1,300 | 100 | <1 | 240 | 5.75 |
| GW041011 | 1.1 | 18 Feb 2010 08:50:00 am | 3,770 | n/a | 670 | 1.70 | 100 | 95.0 | 1,200 | 100 | <1 | 230 | 8.85 |
| GW041011 | 1.1 | 19 Jan 2010 08:55:00 am | 4,150 | n/a | 670 | 1.70 | 100 | 99.0 | 1,300 | 100 | 14.0 | 200 | 7.97 |
| GW041011 | 1.1 | 09 Dec 2009 11:30:00 am | 3,700 | n/a | 680 | 1.70 | 110 | 99.0 | 1,200 | 90.0 | <1 | 230 | 7.08 |
| GW041011 | 1.1 | 11 Nov 2009 10:50:00 am | 4,170 | n/a | 690 | 1.70 | 110 | 100 | 1,300 | 98.0 | <1 | 240 | 7.08 |
| GW041011 | 1.1 | 14 Oct 2009 05:05:00 pm | 3,530 | n/a | 650 | 1.60 | 110 | 100 | 1,200 | 89.0 | <1 | 240 | 7.53 |
| GW041011 | 1.1 | 17 Sep 2009 01:35:00 pm | 3,280 | n/a | 640 | 1.60 | 110 | 100 | 1,400 | 120 | 7.70 | 220 | 2.61 |
| GW041011 | 1.1 | 14 Dec 2005 12:00:00 am | 963 | 8.6 | 200 | 0.95 | 14.0 | 6.50 | 160 | 32.0 | 11.0 | 300 | <0.9 |
| GW041011 | 2.2 | 02 May 2018 12:00:00 pm | 555 | 6.7 | 97.0 | 1.00 | 6.00 | 7.00 | 79.0 | 14.0 | <1 | 126 | 0.13 |
| GW041011 | 2.2 | 12 Sep 2017 12:00:00 am | 580 | n/a | 97.0 | 1.50 | 5.80 | 7.30 | 96.0 | 15.0 | 1.70 | 160 | <0.9 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW041011 | 2.2 | 26 Apr 2016 12:00:00 am | 570 | 7.6 | 94.0 | 1.40 | 6.40 | 7.80 | 99.0 | 15.0 | 1.70 | 160 | <0.9 |
| GW041011 | 2.2 | 07 Aug 2014 12:00:00 am | 623 | 7.5 | 89.0 | 1.40 | 6.70 | 7.40 | 94.0 | 14.0 | <1 | 150 | <0.9 |
| GW041011 | 2.2 | 26 Jun 2013 01:30:00 pm | 572 | n/a | 100 | 1.40 | 7.50 | 8.20 | 95.0 | 14.0 | <1 | 140 | 0.09 |
| GW041011 | 2.2 | 04 Dec 2012 12:30:00 pm | 600 | n/a | 110 | 1.50 | 9.40 | 8.50 | 95.0 | 14.0 | <1 | 140 | 0.35 |
| GW041011 | 2.2 | 13 Jun 2012 12:30:00 pm | 564 | n/a | 94.0 | 1.30 | 7.30 | 8.10 | 93.0 | 14.0 | <1 | 140 | <0.05 |
| GW041011 | 2.2 | 08 Jun 2011 10:10:00 am | 576 | n/a | 110 | 1.40 | 8.00 | 7.50 | 92.0 | 14.0 | <1 | 150 | <0.05 |
| GW041011 | 2.2 | 13 Jul 2010 09:45:00 am | 621 | n/a | 100 | 1.50 | 13.0 | 8.00 | 94.0 | 16.0 | <1 | 160 | <0.05 |
| GW041011 | 2.2 | 07 Jun 2010 12:30:00 pm | 581 | n/a | 95.0 | 1.60 | 8.50 | 7.60 | 93.0 | 15.0 | <1 | 160 | 0.04 |
| GW041011 | 2.2 | 12 May 2010 10:56:00 am | 645 | n/a | 99.0 | 1.60 | 9.00 | 7.80 | 93.0 | 16.0 | <1 | 160 | 0.27 |
| GW041011 | 2.2 | 21 Apr 2010 10:41:00 am | 623 | n/a | 100 | 1.50 | 9.20 | 8.10 | 93.0 | 15.0 | <1 | 160 | 0.09 |
| GW041011 | 2.2 | 11 Mar 2010 10:05:00 am | 572 | n/a | 100 | 1.50 | 8.70 | 8.30 | 94.0 | 15.0 | <1 | 150 | 0.04 |
| GW041011 | 2.2 | 18 Feb 2010 11:35:00 am | 552 | n/a | 100 | 1.40 | 6.60 | 7.90 | 93.0 | 14.0 | <1 | 140 | <0.05 |
| GW041011 | 2.2 | 19 Jan 2010 09:15:00 am | 680 | n/a | 100 | 1.50 | 8.10 | 8.10 | 94.0 | 14.0 | 4.20 | 130 | 0.09 |
| GW041011 | 2.2 | 09 Dec 2009 02:10:00 pm | 568 | n/a | 100 | 1.70 | 9.20 | 8.50 | 91.0 | 13.0 | <1 | 150 | <0.05 |
| GW041011 | 2.2 | 11 Nov 2009 08:30:00 am | 584 | n/a | 100 | 1.40 | 8.90 | 8.00 | 93.0 | 14.0 | <1 | 160 | 0.04 |
| GW041011 | 2.2 | 14 Oct 2009 04:45:00 pm | 556 | n/a | 98.0 | 1.40 | 7.90 | 7.80 | 94.0 | 15.0 | <1 | 150 | 0.04 |
| GW041011 | 2.2 | 24 Sep 2009 02:30:00 pm | 560 | n/a | 43.0 | 0.62 | 3.70 | 3.40 | 92.0 | 15.0 | <1 | 150 | <0.05 |
| GW041011 | 2.2 | 13 Dec 2005 12:00:00 am | 713 | 8.5 | 140 | 1.90 | 8.80 | 6.20 | 120 | 41.0 | 4.80 | 170 | <0.9 |
| GW041011 | 3.3 | 02 May 2018 12:00:00 pm | 658 | 6.1 | 119 | 2.00 | 5.00 | 9.00 | 146 | <1 | <1 | 123 | 0.09 |
| GW041011 | 3.3 | 12 Sep 2017 12:00:00 am | 670 | n/a | 110 | 2.70 | 4.90 | 10.0 | 140 | <0.5 | 1.70 | 160 | <0.9 |
| GW041011 | 3.3 | 26 Apr 2016 12:00:00 am | 680 | 7.6 | 110 | 2.70 | 5.50 | 10.0 | 140 | 0.80 | 1.70 | 160 | <0.9 |
| GW041011 | 3.3 | 07 Aug 2014 12:00:00 am | 660 | 7.0 | 100 | 2.40 | 4.90 | 10.0 | 120 | <0.5 | <1 | 160 | <0.9 |
| GW041011 | 3.3 | 26 Jun 2013 12:05:00 pm | 665 | n/a | 100 | 2.30 | 4.50 | 10.0 | 130 | <0.5 | <1 | 150 | 0.09 |
| GW041011 | 3.3 | 04 Dec 2012 10:50:00 am | 663 | n/a | 120 | 2.50 | 5.70 | 12.0 | 130 | <0.5 | <1 | 150 | 0.31 |
| GW041011 | 3.3 | 13 Jun 2012 11:25:00 am | 662 | n/a | 120 | 2.20 | 5.70 | 12.0 | 120 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 07 Jun 2011 01:20:00 pm | 668 | n/a | 120 | 2.40 | 5.30 | 11.0 | 120 | <0.5 | <1 | 160 | <0.05 |
| GW041011 | 3.3 | 13 Jul 2010 10:50:00 am | 661 | n/a | 120 | 2.50 | 6.90 | 12.0 | 130 | <0.5 | <1 | 160 | 0.09 |
| GW041011 | 3.3 | 07 Jun 2010 11:00:00 am | 655 | n/a | 110 | 2.50 | 5.90 | 11.0 | 130 | <0.5 | <1 | 160 | 0.04 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW041011 | 3.3 | 12 May 2010 11:05:00 am | 665 | n/a | 120 | 2.60 | 5.30 | 12.0 | 130 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 21 Apr 2010 08:35:00 am | 648 | n/a | 120 | 2.40 | 5.20 | 11.0 | 130 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 11 Mar 2010 11:06:00 am | 659 | n/a | 120 | 2.50 | 5.50 | 11.0 | 130 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 18 Feb 2010 09:50:00 am | 713 | n/a | 120 | 2.70 | 5.00 | 11.0 | 130 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 19 Jan 2010 12:05:00 pm | 684 | n/a | 120 | 2.50 | 5.10 | 11.0 | 140 | <0.5 | 3.70 | 130 | 0.04 |
| GW041011 | 3.3 | 09 Dec 2009 12:30:00 pm | 714 | n/a | 120 | 2.80 | 5.60 | 11.0 | 130 | <0.5 | <1 | 140 | <0.05 |
| GW041011 | 3.3 | 11 Nov 2009 10:20:00 am | 728 | n/a | 120 | 2.50 | 5.00 | 11.0 | 130 | <0.5 | <1 | 150 | 0.04 |
| GW041011 | 3.3 | 14 Oct 2009 03:45:00 pm | 650 | n/a | 110 | 2.90 | 5.70 | 10.0 | 140 | <0.5 | <1 | 140 | <0.05 |
| GW041011 | 3.3 | 24 Sep 2009 12:30:00 pm | 718 | n/a | 110 | 2.50 | 5.20 | 11.0 | 130 | <0.5 | <1 | 150 | <0.05 |
| GW041011 | 3.3 | 08 Dec 2005 12:00:00 am | 636 | 7.9 | 120 | 2.50 | 5.60 | 12.0 | 130 | 1.10 | <1 | 160 | <0.9 |
| GW041012 | 1.1 | 02 May 2018 12:00:00 pm | 1,430 | 7.2 | 277 | <1 | 14.0 | 18.0 | 309 | 24.0 | <1 | 258 | 1.59 |
| GW041012 | 1.1 | 12 Sep 2017 12:00:00 am | 1,200 | n/a | 230 | 0.77 | 8.60 | 12.0 | 230 | 20.0 | 1.70 | 160 | 1.33 |
| GW041012 | 1.1 | 26 Apr 2016 12:00:00 am | 1,000 | 8.1 | 200 | 0.64 | 6.90 | 8.60 | 170 | 20.0 | 1.70 | 160 | 1.33 |
| GW041012 | 1.1 | 07 Aug 2014 12:00:00 am | 875 | 8.0 | 170 | 0.63 | 5.00 | 5.80 | 120 | 18.0 | <1 | 300 | 1.33 |
| GW041012 | 1.1 | 17 Jun 2013 03:15:00 pm | 845 | n/a | 180 | 0.55 | 4.40 | 5.60 | 100 | 18.0 | <1 | 300 | 1.06 |
| GW041012 | 1.1 | 06 Dec 2012 11:15:00 am | 804 | n/a | 170 | 0.48 | 4.50 | 4.80 | 92.0 | 17.0 | <1 | 290 | 1.11 |
| GW041012 | 1.1 | 13 Jun 2012 03:35:00 pm | 821 | n/a | 180 | 0.56 | 4.70 | 5.70 | 94.0 | 20.0 | <1 | 300 | 0.53 |
| GW041012 | 1.1 | 07 Jun 2011 11:00:00 am | 790 | n/a | 180 | 0.59 | 4.20 | 4.80 | 84.0 | 20.0 | <1 | 300 | 0.71 |
| GW041012 | 1.1 | 16 Sep 2010 10:05:00 am | 781 | n/a | 170 | 0.58 | 4.50 | 4.80 | 83.0 | 20.0 | <1 | 300 | 1.24 |
| GW041012 | 1.1 | 22 Jul 2010 12:05:00 pm | 839 | n/a | 190 | 0.71 | 5.80 | 5.50 | 93.0 | 24.0 | <1 | 320 | 1.24 |
| GW041012 | 1.1 | 07 Jun 2010 03:40:00 pm | 826 | n/a | 160 | 0.81 | 4.10 | 4.80 | 92.0 | 23.0 | <1 | 320 | 1.06 |
| GW041012 | 1.1 | 12 May 2010 12:55:00 pm | 781 | n/a | 180 | 0.63 | 4.40 | 5.10 | 85.0 | 22.0 | <1 | 310 | 1.15 |
| GW041012 | 1.1 | 15 Apr 2010 01:40:00 pm | 798 | n/a | 180 | 0.61 | 4.70 | 5.30 | 86.0 | 23.0 | <1 | 310 | 1.15 |
| GW041012 | 1.1 | 11 Mar 2010 01:35:00 pm | 790 | n/a | 180 | 0.61 | 4.80 | 5.10 | 84.0 | 22.0 | <1 | 300 | 0.80 |
| GW041012 | 1.1 | 18 Feb 2010 03:25:00 pm | 752 | n/a | 170 | 0.60 | 4.10 | 4.70 | 77.0 | 20.0 | <1 | 290 | 0.97 |
| GW041012 | 1.1 | 19 Jan 2010 02:30:00 pm | 805 | n/a | 170 | 0.59 | 5.00 | 4.90 | 79.0 | 21.0 | 19.0 | 260 | 1.02 |
| GW041012 | 1.1 | 10 Dec 2009 08:25:00 am | 778 | n/a | 180 | 0.64 | 4.60 | 5.10 | 79.0 | 19.0 | <1 | 300 | 1.33 |
| GW041012 | 1.1 | 14 Oct 2009 11:50:00 am | 762 | n/a | 170 | 0.55 | 4.10 | 4.70 | 81.0 | 23.0 | <1 | 310 | 1.02 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW041012 | 1.1 | 29 Sep 2009 12:00:00 pm | 743 | n/a | 170 | 0.59 | 4.10 | 4.70 | 81.0 | 22.0 | 5.10 | 290 | 0.93 |
| GW041012 | 2.2 | 02 May 2018 12:00:00 pm | 410 | 6.6 | 76.0 | 1.00 | 7.00 | 6.00 | 29.0 | 12.0 | <1 | 161 | 0.09 |
| GW041012 | 2.2 | 12 Sep 2017 12:00:00 am | 420 | n/a | 73.0 | 1.50 | 6.10 | 6.80 | 29.0 | 11.0 | 1.70 | 160 | <0.9 |
| GW041012 | 2.2 | 26 Apr 2016 12:00:00 am | 410 | 7.6 | 71.0 | 1.40 | 7.00 | 7.40 | 20.0 | 7.50 | 1.70 | 160 | <0.9 |
| GW041012 | 2.2 | 07 Aug 2014 12:00:00 am | 415 | 7.5 | 67.0 | 1.50 | 6.60 | 6.30 | 27.0 | 12.0 | <1 | 190 | <0.9 |
| GW041012 | 2.2 | 17 Jun 2013 02:40:00 pm | 410 | n/a | 74.0 | 1.50 | 6.50 | 6.70 | 27.0 | 12.0 | <1 | 180 | 0.13 |
| GW041012 | 2.2 | 06 Dec 2012 10:30:00 am | 412 | n/a | 81.0 | 1.50 | 7.70 | 6.90 | 27.0 | 12.0 | <1 | 190 | 0.22 |
| GW041012 | 2.2 | 13 Jun 2012 03:45:00 pm | 409 | n/a | 74.0 | 1.40 | 7.20 | 7.20 | 28.0 | 12.0 | <1 | 180 | <0.05 |
| GW041012 | 2.2 | 07 Jun 2011 10:20:00 am | 414 | n/a | 84.0 | 1.40 | 6.50 | 6.40 | 27.0 | 12.0 | <1 | 190 | 0.04 |
| GW041012 | 2.2 | 16 Sep 2010 10:25:00 am | 410 | n/a | 74.0 | 1.40 | 7.40 | 6.40 | 27.0 | 12.0 | <1 | 190 | 0.09 |
| GW041012 | 2.2 | 22 Jul 2010 12:25:00 pm | 410 | n/a | 77.0 | 1.50 | 7.90 | 6.60 | 27.0 | 13.0 | <1 | 190 | 0.09 |
| GW041012 | 2.2 | 07 Jun 2010 04:05:00 pm | 408 | n/a | 66.0 | 1.60 | 5.90 | 6.00 | 27.0 | 12.0 | <1 | 190 | 0.04 |
| GW041012 | 2.2 | 12 May 2010 01:36:00 pm | 412 | n/a | 78.0 | 1.50 | 7.10 | 6.90 | 27.0 | 12.0 | <1 | 180 | 0.09 |
| GW041012 | 2.2 | 16 Apr 2010 07:45:00 am | 402 | n/a | 75.0 | 1.30 | 6.70 | 6.60 | 27.0 | 12.0 | <1 | 190 | 0.09 |
| GW041012 | 2.2 | 11 Mar 2010 01:25:00 pm | 414 | n/a | 78.0 | 1.50 | 7.40 | 6.80 | 27.0 | 12.0 | <1 | 190 | 0.09 |
| GW041012 | 2.2 | 18 Feb 2010 04:35:00 pm | 402 | n/a | 76.0 | 1.40 | 6.40 | 6.80 | 27.0 | 12.0 | <1 | 180 | 0.04 |
| GW041012 | 2.2 | 19 Jan 2010 03:45:00 pm | 427 | n/a | 73.0 | 1.40 | 6.60 | 6.70 | 27.0 | 12.0 | <1 | 180 | <0.9 |
| GW041012 | 2.2 | 10 Dec 2009 11:20:00 am | 403 | n/a | 77.0 | 1.40 | 7.10 | 6.90 | 26.0 | 11.0 | <1 | 180 | 0.27 |
| GW041012 | 2.2 | 11 Nov 2009 12:40:00 pm | 411 | n/a | 75.0 | 1.40 | 6.80 | 6.70 | 27.0 | 12.0 | <1 | 180 | 0.09 |
| GW041012 | 2.2 | 14 Oct 2009 10:40:00 am | 396 | n/a | 73.0 | 1.30 | 6.70 | 6.40 | 27.0 | 12.0 | <1 | 180 | 0.04 |
| GW041012 | 2.2 | 29 Sep 2009 10:15:00 am | 408 | n/a | 72.0 | 1.30 | 6.70 | 6.40 | 26.0 | 12.0 | <1 | 190 | 0.04 |
| GW041012 | 3.3 | 02 May 2018 12:00:00 pm | 384 | 6.4 | 64.0 | 1.00 | 8.00 | 6.00 | 52.0 | 2.00 | <1 | 104 | 0.18 |
| GW041012 | 3.3 | 12 Sep 2017 12:00:00 am | 390 | n/a | 64.0 | 1.80 | 7.40 | 6.00 | 59.0 | 1.10 | 1.70 | 160 | <0.9 |
| GW041012 | 3.3 | 26 Apr 2016 12:00:00 am | 410 | 7.4 | 61.0 | 1.60 | 9.10 | 6.80 | 62.0 | 1.30 | 1.70 | 160 | <0.9 |
| GW041012 | 3.3 | 07 Aug 2014 12:00:00 am | 403 | 7.2 | 54.0 | 1.60 | 9.00 | 6.10 | 58.0 | 1.70 | <1 | 130 | <0.9 |
| GW041012 | 3.3 | 17 Jun 2013 01:30:00 pm | 402 | n/a | 59.0 | 1.60 | 8.10 | 6.30 | 58.0 | 0.90 | <1 | 130 | 0.09 |
| GW041012 | 3.3 | 06 Dec 2012 01:30:00 pm | 405 | n/a | 69.0 | 1.60 | 11.0 | 7.10 | 58.0 | 1.60 | <1 | 130 | 0.22 |
| GW041012 | 3.3 | 13 Jun 2012 02:50:00 pm | 409 | n/a | 64.0 | 1.50 | 9.90 | 7.40 | 58.0 | 1.00 | <1 | 130 | <0.05 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW041012 | 3.3 | 07 Jun 2011 09:20:00 am | 409 | n/a | 73.0 | 1.60 | 9.00 | 6.50 | 58.0 | 2.90 | <1 | 130 | 0.09 |
| GW041012 | 3.3 | 16 Sep 2010 10:50:00 am | 403 | n/a | 65.0 | 1.50 | 9.20 | 6.10 | 57.0 | 2.90 | <1 | 130 | 0.09 |
| GW041012 | 3.3 | 22 Jul 2010 11:00:00 am | 400 | n/a | 70.0 | 1.60 | 11.0 | 6.60 | 59.0 | 2.20 | <1 | 130 | 0.04 |
| GW041012 | 3.3 | 07 Jun 2010 02:50:00 pm | 404 | n/a | 59.0 | 1.80 | 8.30 | 5.80 | 57.0 | 3.70 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 12 May 2010 02:40:00 pm | 414 | n/a | 65.0 | 1.70 | 9.20 | 6.30 | 59.0 | 2.20 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 15 Apr 2010 03:10:00 pm | 409 | n/a | 67.0 | 1.60 | 10.0 | 6.60 | 58.0 | 4.00 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 11 Mar 2010 02:10:00 pm | 414 | n/a | 68.0 | 1.60 | 11.0 | 6.70 | 58.0 | 3.30 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 18 Feb 2010 03:40:00 pm | 410 | n/a | 68.0 | 1.60 | 10.0 | 6.80 | 57.0 | 3.60 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 19 Jan 2010 02:45:00 pm | 430 | n/a | 67.0 | 1.60 | 9.90 | 6.70 | 57.0 | 6.30 | 3.50 | 120 | 0.04 |
| GW041012 | 3.3 | 10 Dec 2009 09:25:00 am | 422 | n/a | 69.0 | 1.60 | 11.0 | 6.90 | 56.0 | 4.00 | <1 | 140 | 0.13 |
| GW041012 | 3.3 | 11 Nov 2009 01:40:00 pm | 412 | n/a | 68.0 | 1.50 | 11.0 | 6.70 | 58.0 | 4.00 | <1 | 140 | <0.05 |
| GW041012 | 3.3 | 14 Oct 2009 11:30:00 am | 410 | n/a | 65.0 | 1.50 | 10.0 | 6.40 | 60.0 | 5.30 | <1 | 130 | <0.05 |
| GW041012 | 3.3 | 29 Sep 2009 12:30:00 pm | 417 | n/a | 67.0 | 1.50 | 11.0 | 6.60 | 58.0 | 5.80 | <1 | 140 | <0.05 |
| GW041012 | 3.3 | 22 Mar 2006 12:00:00 am | 427 | 7.9 | 76.0 | 1.70 | 7.30 | 6.40 | 72.0 | 18.0 | <1 | 130 | <0.9 |
| GW273040 | 1.1 | 19 Apr 2018 12:00:00 pm | 15,000 | 7.0 | 2,100 | 7.00 | 776 | 456 | 4,020 | 2,710 | <1 | 408 | 30.3 |
| GW273040 | 1.1 | 13 Sep 2017 12:00:00 am | 11,000 | n/a | 1,700 | 7.40 | 390 | 300 | 2,900 | 1,600 | 1.70 | 160 | 18.6 |
| GW273040 | 1.1 | 28 Apr 2016 12:00:00 am | 11,000 | 7.4 | 1,700 | 6.60 | 460 | 350 | 3,200 | 1,700 | 1.70 | 160 | 18.1 |
| GW273040 | 1.1 | 06 Aug 2014 12:00:00 am | 7,970 | 7.4 | 1,300 | 5.50 | 240 | 200 | 2,100 | 830 | <1 | 480 | 11.1 |
| GW273040 | 1.1 | 25 Jun 2013 01:15:00 pm | 7,570 | n/a | 1,200 | 4.10 | 220 | 180 | 1,900 | 900 | <1 | 520 | 12.4 |
| GW273040 | 1.1 | 26 Nov 2012 11:45:00 am | 7,730 | n/a | 1,300 | 4.90 | 250 | 220 | 2,000 | 930 | <1 | 510 | 16.8 |
| GW273040 | 1.1 | 21 Jun 2012 10:55:00 am | 8,130 | n/a | 1,300 | 5.60 | 260 | 220 | 2,000 | 1,000 | <1 | 510 | 15.9 |
| GW273040 | 1.1 | 10 Jun 2011 12:25:00 pm | 9,070 | n/a | 1,500 | 6.20 | 300 | 240 | 2,300 | 1,100 | <1 | 550 | 12.4 |
| GW273040 | 1.1 | 21 Jul 2010 10:30:00 am | 9,280 | n/a | 1,500 | 6.40 | 320 | 250 | 2,400 | 1,300 | <1 | 530 | 13.3 |
| GW273040 | 1.1 | 15 Jun 2010 10:15:00 am | 9,380 | n/a | 1,600 | 6.70 | 350 | 260 | 2,500 | 1,300 | <1 | 530 | 12.8 |
| GW273040 | 1.1 | 21 May 2010 09:25:00 am | 9,620 | n/a | 1,500 | 6.50 | 340 | 260 | 2,500 | 1,300 | <1 | 530 | 12.4 |
| GW273040 | 1.1 | 16 Mar 2010 09:50:00 am | 8,720 | n/a | 1,600 | 6.10 | 350 | 260 | 2,400 | 1,300 | <1 | 520 | 13.7 |
| GW273040 | 1.1 | 24 Feb 2010 10:40:00 am | 8,160 | n/a | 1,600 | 6.40 | 190 | 250 | 2,500 | 1,300 | <1 | 510 | 13.3 |
| GW273040 | 1.1 | 02 Dec 2009 12:02:00 am | 8,340 | n/a | 1,600 | 6.70 | 350 | 270 | 2,600 | 1,300 | <1 | 490 | 14.2 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GW273040** | 1.1 | 13 Oct 2009 03:35:00 pm | 8,060 | n/a | 1,600 | 6.30 | 380 | 290 | 2,500 | 1,400 | <1 | 510 | 13.7 |
| **GW273040** | 1.1 | 01 Oct 2009 09:35:00 am | 7,940 | n/a | 1,600 | 6.30 | 380 | 280 | 2,700 | 1,400 | <1 | 520 | 16.8 |
| **GW273040** | 2.2 | 19 Apr 2018 12:00:00 pm | 1,450 | 6.8 | 195 | 2.00 | 36.0 | 36.0 | 367 | 57.0 | <1 | 150 | 0.71 |
| **GW273040** | 2.2 | 13 Sep 2017 12:00:00 am | 1,500 | n/a | 190 | 2.50 | 34.0 | 35.0 | 350 | 51.0 | 1.70 | 160 | <0.9 |
| **GW273040** | 2.2 | 28 Apr 2016 12:00:00 am | 1,600 | 7.2 | 210 | 2.50 | 40.0 | 41.0 | 380 | 66.0 | 1.70 | 160 | 0.89 |
| **GW273040** | 2.2 | 06 Aug 2014 12:00:00 am | 1,515 | 7.1 | 170 | 2.40 | 33.0 | 32.0 | 320 | 49.0 | <1 | 180 | <0.9 |
| **GW273040** | 2.2 | 25 Jun 2013 12:30:00 pm | 1,579 | n/a | 220 | 2.50 | 38.0 | 42.0 | 380 | 58.0 | <1 | 170 | 0.93 |
| **GW273040** | 2.2 | 26 Nov 2012 11:00:00 am | 1,519 | n/a | 220 | 2.50 | 40.0 | 39.0 | 360 | 53.0 | <1 | 170 | 1.68 |
| **GW273040** | 2.2 | 21 Jun 2012 10:25:00 am | 1,232 | n/a | 180 | 2.10 | 28.0 | 31.0 | 270 | 44.0 | <1 | 180 | 0.13 |
| **GW273040** | 2.2 | 10 Jun 2011 11:45:00 am | 1,150 | n/a | 180 | 2.10 | 25.0 | 25.0 | 240 | 39.0 | <1 | 180 | 0.18 |
| **GW273040** | 2.2 | 21 Jul 2010 11:40:00 am | 1,140 | n/a | 150 | 2.70 | 28.0 | 27.0 | 210 | 33.0 | <1 | 180 | <0.05 |
| **GW273040** | 2.2 | 20 Aug 2008 12:05:00 am | 1,360 | 8.1 | 190 | 2.70 | 39.0 | 30.0 | 330 | 52.0 | <1 | 190 | <0.9 |
| **GW273040** | 3.3 | 19 Apr 2018 12:00:00 pm | 1,060 | 6.7 | 145 | 2.00 | 24.0 | 26.0 | 245 | 40.0 | <1 | 148 | 0.09 |
| **GW273040** | 3.3 | 13 Sep 2017 12:00:00 am | 1,000 | n/a | 140 | 2.80 | 23.0 | 24.0 | 220 | 36.0 | 1.70 | 160 | <0.9 |
| **GW273040** | 3.3 | 28 Apr 2016 12:00:00 am | 1,100 | 7.1 | 140 | 2.70 | 24.0 | 27.0 | 220 | 39.0 | 1.70 | 160 | <0.9 |
| **GW273040** | 3.3 | 06 Aug 2014 12:00:00 am | 1,043 | 7.0 | 130 | 2.80 | 23.0 | 24.0 | 210 | 36.0 | <1 | 180 | <0.9 |
| **GW273040** | 3.3 | 25 Jun 2013 11:20:00 am | 1,049 | n/a | 150 | 2.60 | 23.0 | 27.0 | 220 | 34.0 | <1 | 170 | 0.04 |
| **GW273040** | 3.3 | 26 Nov 2012 10:10:00 am | 1,040 | n/a | 160 | 2.80 | 27.0 | 26.0 | 220 | 33.0 | <1 | 170 | 0.75 |
| **GW273040** | 3.3 | 21 Jun 2012 09:20:00 am | 1,019 | n/a | 140 | 2.60 | 23.0 | 26.0 | 200 | 34.0 | <1 | 170 | <0.05 |
| **GW273040** | 3.3 | 10 Jun 2011 11:05:00 am | 1,017 | n/a | 160 | 2.70 | 22.0 | 24.0 | 210 | 33.0 | <1 | 170 | <0.05 |
| **GW273040** | 3.3 | 21 Jul 2010 01:10:00 pm | 1,820 | n/a | 300 | 5.10 | 46.0 | 46.0 | 460 | 77.0 | <1 | 190 | 0.89 |
| **GW273040** | 3.3 | 15 Jun 2010 11:20:00 am | 1,110 | n/a | 130 | 2.90 | 21.0 | 22.0 | 210 | 31.0 | <1 | 180 | 0.04 |
| **GW273040** | 3.3 | 21 May 2010 10:35:00 am | 1,200 | n/a | 140 | 2.90 | 22.0 | 24.0 | 200 | 34.0 | <1 | 180 | 0.13 |
| **GW273040** | 3.3 | 16 Mar 2010 10:40:00 am | 1,170 | n/a | 150 | 2.80 | 25.0 | 27.0 | 210 | 35.0 | <1 | 180 | 0.09 |
| **GW273040** | 3.3 | 24 Feb 2010 11:20:00 am | 1,100 | n/a | 150 | 2.70 | 23.0 | 25.0 | 220 | 35.0 | <1 | 170 | <0.05 |
| **GW273040** | 3.3 | 02 Dec 2009 12:01:00 am | 1,220 | n/a | 150 | 2.80 | 25.0 | 27.0 | 220 | 34.0 | <1 | 180 | <0.05 |
| **GW273040** | 3.3 | 13 Oct 2009 02:20:00 pm | 940 | n/a | 150 | 2.50 | 23.0 | 26.0 | 220 | 32.0 | <1 | 170 | 0.04 |
| **GW273040** | 3.3 | 01 Oct 2009 11:20:00 am | 941 | n/a | 140 | 2.60 | 24.0 | 26.0 | 220 | 35.0 | <1 | 170 | <0.05 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW273040 | 3.3 | 20 Aug 2008 12:04:00 am | 1,140 | 7.7 | 160 | 3.10 | 29.0 | 26.0 | 260 | 47.0 | <1 | 190 | <0.9 |
| GW273040 | 4.4 | 19 Apr 2018 12:00:00 pm | 2,010 | 6.6 | 302 | 4.00 | 38.0 | 43.0 | 533 | 40.0 | <1 | 184 | 0.13 |
| GW273040 | 4.4 | 13 Sep 2017 12:00:00 am | 1,900 | n/a | 270 | 5.20 | 35.0 | 40.0 | 490 | 60.0 | 1.70 | 160 | <0.9 |
| GW273040 | 4.4 | 28 Apr 2016 12:00:00 am | 2,000 | 7.6 | 290 | 5.50 | 38.0 | 44.0 | 540 | 33.0 | 1.70 | 160 | <0.9 |
| GW273040 | 4.4 | 06 Aug 2014 12:00:00 am | 1,886 | 6.9 | 270 | 5.20 | 36.0 | 39.0 | 490 | 52.0 | <1 | 200 | <0.9 |
| GW273040 | 4.4 | 25 Jun 2013 09:50:00 am | 1,977 | n/a | 300 | 5.20 | 36.0 | 44.0 | 530 | 38.0 | <1 | 220 | 0.09 |
| GW273040 | 4.4 | 26 Nov 2012 11:15:00 am | 2,030 | n/a | 320 | 5.40 | 41.0 | 42.0 | 520 | 47.0 | <1 | 220 | 0.84 |
| GW273040 | 4.4 | 21 Jun 2012 10:45:00 am | 1,950 | n/a | 280 | 5.20 | 37.0 | 43.0 | 470 | 64.0 | <1 | 200 | 0.97 |
| GW273040 | 4.4 | 10 Jun 2011 09:55:00 am | 1,934 | n/a | 320 | 5.20 | 36.0 | 41.0 | 480 | 69.0 | <1 | 200 | 0.09 |
| GW273040 | 4.4 | 15 Jun 2010 11:30:00 am | 1,850 | n/a | 290 | 5.50 | 44.0 | 44.0 | 470 | 71.0 | <1 | 200 | 0.09 |
| GW273040 | 4.4 | 21 May 2010 11:00:00 am | 1,910 | n/a | 290 | 5.50 | 39.0 | 42.0 | 480 | 70.0 | <1 | 200 | 0.04 |
| GW273040 | 4.4 | 16 Mar 2010 11:45:00 am | 1,850 | n/a | 310 | 5.60 | 41.0 | 43.0 | 480 | 64.0 | <1 | 210 | 0.04 |
| GW273040 | 4.4 | 02 Dec 2009 12:00:00 am | 1,900 | n/a | 340 | 6.40 | 43.0 | 45.0 | 560 | 47.0 | <1 | 220 | <0.05 |
| GW273040 | 4.4 | 13 Oct 2009 04:00:00 pm | 1,790 | n/a | 310 | 5.60 | 39.0 | 41.0 | 540 | 50.0 | <1 | 230 | 0.04 |
| GW273040 | 4.4 | 01 Oct 2009 10:30:00 am | 1,810 | n/a | 330 | 5.90 | 40.0 | 41.0 | 550 | 46.0 | <1 | 240 | <0.05 |
| GW273040 | 4.4 | 20 Aug 2008 12:03:00 am | 1,810 | 8.1 | 280 | 4.60 | 38.0 | 39.0 | 460 | 110 | <1 | 200 | <0.9 |
| GW273041 | 1.1 | 18 Apr 2018 12:00:00 pm | 28,700 | 6.5 | 3,070 | 5.00 | 1,460 | 1,230 | 9,400 | 778 | <1 | 469 | 1.06 |
| GW273041 | 1.1 | 06 Sep 2017 12:00:00 am | 28,000 | n/a | 3,200 | 7.20 | 1,300 | 1,200 | 11,000 | 690 | 1.70 | 160 | 75.3 |
| GW273041 | 1.1 | 27 Apr 2016 12:00:00 am | 29,000 | 6.9 | 3,300 | 6.80 | 1,700 | 1,400 | 11,000 | 800 | 1.70 | 160 | 4.87 |
| GW273041 | 1.1 | 04 Aug 2014 12:00:00 am | 30,420 | 6.7 | 3,500 | 7.40 | 1,600 | 1,400 | 11,000 | 790 | <1 | 610 | 0.89 |
| GW273041 | 1.1 | 27 Jun 2013 01:45:00 pm | 31,220 | n/a | 3,300 | 5.80 | 1,800 | 1,500 | 12,000 | 790 | <1 | 590 | 1.64 |
| GW273041 | 1.1 | 03 Dec 2012 01:20:00 pm | 31,000 | n/a | 3,600 | 6.50 | 1,800 | 1,800 | 12,000 | 790 | <1 | 590 | 1.59 |
| GW273041 | 1.1 | 07 Jun 2012 01:20:00 pm | 31,500 | n/a | 3,500 | 7.10 | 1,800 | 1,600 | 12,000 | 800 | <1 | 600 | 1.15 |
| GW273041 | 1.1 | 16 Jun 2011 01:00:00 pm | 32,000 | n/a | 3,800 | 6.80 | 1,800 | 1,500 | 12,000 | 800 | <1 | 610 | <0.05 |
| GW273041 | 1.1 | 11 Jun 2010 08:55:00 am | 31,300 | n/a | 3,700 | 7.30 | 1,900 | 1,600 | 12,000 | 840 | <1 | 610 | 1.42 |
| GW273041 | 1.1 | 13 May 2010 08:55:00 am | 31,600 | n/a | 3,500 | 7.90 | 1,800 | 1,500 | 12,000 | 850 | <1 | 610 | 1.68 |
| GW273041 | 1.1 | 15 Apr 2010 08:15:00 am | 25,100 | n/a | 3,500 | 7.40 | 1,900 | 1,500 | 12,000 | 870 | <1 | 610 | 1.73 |
| GW273041 | 1.1 | 17 Feb 2010 09:15:00 am | 24,000 | n/a | 3,400 | 6.90 | 1,900 | 1,600 | 12,000 | 820 | <1 | 590 | 1.68 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as $Na^+$ (filtered; mg/L) | Potassium as $K^+$ (filtered; mg/L) | Calcium as $Ca^{2+}$ (filtered; mg/L) | Magnesium as $Mg^{2+}$ (filtered; mg/L) | Chloride as $Cl^-$ (mg/L) | Sulfate as $SO_4^{2-}$ (mg/L) | Carbonate alkalinity as $CO_3^{2-}$ (mg/L) | Bicarbonate alkalinity as $HCO_3^-$ (mg/L) | Nitrate as $NO_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW273041 | 1.1 | 18 Jan 2010 01:40:00 pm | 23,600 | n/a | 3,700 | 7.30 | 1,900 | 1,600 | 12,000 | 820 | <1 | 540 | 1.64 |
| GW273041 | 1.1 | 01 Dec 2009 12:02:00 am | 21,600 | n/a | 3,500 | 7.30 | 1,800 | 1,500 | 12,000 | 790 | <1 | 580 | 1.73 |
| GW273041 | 1.1 | 22 Oct 2009 01:30:00 pm | 22,100 | n/a | 3,500 | 6.80 | 1,900 | 1,600 | 12,000 | 830 | <1 | 610 | 1.64 |
| GW273041 | 1.1 | 22 Sep 2009 04:15:00 pm | 18,300 | n/a | 3,400 | 7.10 | 1,700 | 1,400 | 12,000 | 850 | <1 | 610 | 0.93 |
| GW273041 | 1.1 | 21 Aug 2008 12:00:00 am | 26,700 | 7.2 | 3,600 | 7.80 | 1,800 | 1,600 | 12,000 | 740 | <1 | 620 | <0.9 |
| GW273041 | 2.2 | 18 Apr 2018 12:00:00 pm | 406 | 6.2 | 47.0 | 2.00 | 15.0 | 12.0 | 56.0 | 17.0 | <1 | 106 | 0.13 |
| GW273041 | 2.2 | 06 Sep 2017 12:00:00 am | 560 | n/a | 50.0 | 2.40 | 14.0 | 13.0 | 57.0 | 16.0 | 1.70 | 160 | <0.9 |
| GW273041 | 2.2 | 27 Apr 2016 12:00:00 am | 500 | 7.1 | 44.0 | 1.90 | 15.0 | 14.0 | 59.0 | 16.0 | 1.70 | 160 | <0.9 |
| GW273041 | 2.2 | 04 Aug 2014 12:00:00 am | 472 | 6.9 | 39.0 | 2.00 | 13.0 | 11.0 | 54.0 | 15.0 | <1 | 120 | <0.9 |
| GW273041 | 2.2 | 27 Jun 2013 01:20:00 pm | 431 | n/a | 41.0 | 1.90 | 12.0 | 12.0 | 54.0 | 15.0 | <1 | 120 | 0.04 |
| GW273041 | 2.2 | 03 Dec 2012 12:40:00 pm | 436 | n/a | 47.0 | 2.40 | 15.0 | 14.0 | 54.0 | 15.0 | <1 | 120 | 0.27 |
| GW273041 | 2.2 | 07 Jun 2012 02:00:00 pm | 410 | n/a | 45.0 | 2.40 | 14.0 | 14.0 | 55.0 | 16.0 | <1 | 120 | <0.05 |
| GW273041 | 2.2 | 16 Jun 2011 12:30:00 pm | 410 | n/a | 41.0 | 2.80 | 10.0 | 9.20 | 53.0 | 15.0 | <1 | 120 | <0.05 |
| GW273041 | 2.2 | 20 Aug 2008 12:00:00 am | 465 | 7.7 | 53.0 | 1.80 | 15.0 | 13.0 | 57.0 | 22.0 | <1 | 140 | <0.9 |
| GW273041 | 3.3 | 18 Apr 2018 12:00:00 pm | 404 | 6.3 | 48.0 | 2.00 | 15.0 | 15.0 | 51.0 | 13.0 | <1 | 106 | 0.13 |
| GW273041 | 3.3 | 06 Sep 2017 12:00:00 am | 410 | n/a | 45.0 | 2.10 | 15.0 | 15.0 | 58.0 | 12.0 | 1.70 | 160 | <0.9 |
| GW273041 | 3.3 | 27 Apr 2016 12:00:00 am | 410 | 7.1 | 42.0 | 2.20 | 14.0 | 15.0 | 61.0 | 10.0 | 1.70 | 160 | <0.9 |
| GW273041 | 3.3 | 04 Aug 2014 12:00:00 am | 414 | 6.9 | 39.0 | 2.20 | 14.0 | 13.0 | 58.0 | 12.0 | <1 | 130 | <0.9 |
| GW273041 | 3.3 | 27 Jun 2013 12:20:00 pm | 419 | n/a | 47.0 | 2.20 | 14.0 | 15.0 | 60.0 | 12.0 | <1 | 120 | 0.04 |
| GW273041 | 3.3 | 03 Dec 2012 11:30:00 am | 422 | n/a | 48.0 | 2.30 | 17.0 | 16.0 | 61.0 | 9.60 | <1 | 130 | 0.40 |
| GW273041 | 3.3 | 07 Jun 2012 12:30:00 pm | 429 | n/a | 42.0 | 2.20 | 14.0 | 15.0 | 61.0 | 12.0 | <1 | 120 | <0.05 |
| GW273041 | 3.3 | 16 Jun 2011 11:40:00 am | 435 | n/a | 52.0 | 2.20 | 14.0 | 15.0 | 62.0 | 12.0 | <1 | 120 | <0.05 |
| GW273041 | 3.3 | 11 Jun 2010 10:10:00 am | 966 | n/a | 46.0 | 2.40 | 18.0 | 16.0 | 66.0 | 13.0 | <1 | 130 | 0.04 |
| GW273041 | 3.3 | 13 May 2010 10:15:00 am | 1,200 | n/a | 49.0 | 2.50 | 16.0 | 16.0 | 67.0 | 13.0 | <1 | 130 | <0.05 |
| GW273041 | 3.3 | 15 Apr 2010 11:30:00 am | 435 | n/a | 46.0 | 2.30 | 15.0 | 15.0 | 67.0 | 13.0 | <1 | 120 | <0.05 |
| GW273041 | 3.3 | 17 Feb 2010 03:15:00 pm | 429 | n/a | 48.0 | 2.40 | 15.0 | 16.0 | 64.0 | 12.0 | <1 | 120 | <0.05 |
| GW273041 | 3.3 | 18 Jan 2010 02:45:00 pm | 443 | n/a | 47.0 | 2.40 | 16.0 | 16.0 | 65.0 | <0.5 | 1.70 | 120 | 0.09 |
| GW273041 | 3.3 | 01 Dec 2009 12:00:00 am | 496 | n/a | 48.0 | 2.40 | 16.0 | 16.0 | 66.0 | 12.0 | <1 | 120 | <0.05 |

| Station | Pipe | Sample collection (date and time) | Electrical conductivity @ 25°C (µS/cm) | pH (field; pH units) | Sodium as Na$^+$ (filtered; mg/L) | Potassium as K$^+$ (filtered; mg/L) | Calcium as Ca$^{2+}$ (filtered; mg/L) | Magnesium as Mg$^{2+}$ (filtered; mg/L) | Chloride as Cl$^-$ (mg/L) | Sulfate as SO$_4^{2-}$ (mg/L) | Carbonate alkalinity as CO$_3^{2-}$ (mg/L) | Bicarbonate alkalinity as HCO$_3^-$ (mg/L) | Nitrate as NO$_3^-$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW273041 | 3.3 | 22 Oct 2009 12:45:00 pm | 434 | n/a | 46.0 | 2.20 | 15.0 | 15.0 | 68.0 | 12.0 | <1 | 120 | 0.04 |
| GW273041 | 3.3 | 28 Sep 2009 05:00:00 pm | 435 | n/a | 45.0 | 2.30 | 16.0 | 15.0 | 68.0 | 12.0 | <1 | 120 | <0.05 |
| GW273041 | 3.3 | 18 Aug 2008 12:01:00 am | 462 | 7.7 | 48.0 | 2.60 | 16.0 | 15.0 | 73.0 | 14.0 | <1 | 120 | <0.9 |
| GW273041 | 4.4 | 18 Apr 2018 12:00:00 pm | 400 | 6.2 | 56.0 | 3.00 | 8.00 | 9.00 | 56.0 | <1 | <1 | 97.0 | 0.09 |
| GW273041 | 4.4 | 06 Sep 2017 12:00:00 am | 430 | n/a | 47.0 | 2.40 | 13.0 | 14.0 | 68.0 | 9.20 | 1.70 | 160 | <0.9 |
| GW273041 | 4.4 | 27 Apr 2016 12:00:00 am | 420 | 7.6 | 47.0 | 2.70 | 12.0 | 13.0 | 70.0 | 3.10 | 1.70 | 160 | <0.9 |
| GW273041 | 4.4 | 04 Aug 2014 12:00:00 am | 400 | 6.9 | 56.0 | 3.00 | 8.60 | 9.90 | 64.0 | 1.50 | <1 | 110 | <0.9 |
| GW273041 | 4.4 | 27 Jun 2013 10:40:00 am | 405 | n/a | 54.0 | 3.00 | 9.00 | 12.0 | 66.0 | 1.20 | <1 | 110 | 0.04 |
| GW273041 | 4.4 | 03 Dec 2012 10:30:00 am | 411 | n/a | 52.0 | 2.70 | 13.0 | 13.0 | 67.0 | 3.00 | <1 | 120 | 0.53 |
| GW273041 | 4.4 | 07 Jun 2012 11:00:00 am | 413 | n/a | 52.0 | 2.90 | 11.0 | 13.0 | 68.0 | 2.60 | <1 | 110 | <0.05 |
| GW273041 | 4.4 | 16 Jun 2011 10:20:00 am | 412 | n/a | 56.0 | 2.90 | 11.0 | 12.0 | 66.0 | 2.30 | <1 | 110 | <0.05 |
| GW273041 | 4.4 | 11 Jun 2010 10:50:00 am | 425 | n/a | 50.0 | 3.50 | 8.70 | 10.0 | 67.0 | 1.20 | <1 | 120 | 0.04 |
| GW273041 | 4.4 | 13 May 2010 10:35:00 am | 431 | n/a | 54.0 | 3.30 | 9.20 | 11.0 | 69.0 | 1.40 | <1 | 120 | 0.18 |
| GW273041 | 4.4 | 15 Apr 2010 09:40:00 am | 414 | n/a | 53.0 | 3.00 | 10.0 | 12.0 | 69.0 | 2.40 | <1 | 120 | <0.05 |
| GW273041 | 4.4 | 17 Feb 2010 12:20:00 pm | 403 | n/a | 58.0 | 3.50 | 8.90 | 11.0 | 65.0 | 0.90 | <1 | 110 | <0.05 |
| GW273041 | 4.4 | 18 Jan 2010 11:53:00 am | 403 | n/a | 54.0 | 3.20 | 8.60 | 11.0 | 64.0 | 0.60 | 1.30 | 110 | 0.04 |
| GW273041 | 4.4 | 01 Dec 2009 12:01:00 am | 402 | n/a | 58.0 | 3.40 | 9.80 | 12.0 | 69.0 | 1.50 | <1 | 110 | <0.05 |
| GW273041 | 4.4 | 22 Oct 2009 09:30:00 am | 399 | n/a | 51.0 | 2.80 | 10.0 | 12.0 | 65.0 | 1.50 | <1 | 110 | <0.05 |
| GW273041 | 4.4 | 25 Sep 2009 12:00:00 pm | 402 | n/a | 48.0 | 2.50 | 12.0 | 13.0 | 66.0 | 3.00 | <1 | 120 | <0.05 |
| GW273041 | 4.4 | 18 Aug 2008 12:00:00 am | 374 | 7.7 | 47.0 | 2.40 | 10.0 | 10.0 | 61.0 | 4.10 | <1 | 110 | <0.9[7] |

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n/a denotes that data was not available for physicochemical parameter or analyte for a sample[7]

# Appendix 4–QAQC Results

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW030323 | 1.1 | 17 Apr 2018 12:00:00 pm | 10.4 | 10.8 | −1.74 | 0.94 | 0.97 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 06 Sep 2017 12:00:00 am | 7.75 | 9.78 | −11.6 | n/a | n/a | n/a |
| GW030323 | 1.1 | 14 Apr 2016 12:00:00 am | 8.23 | 10.9 | −14.0 | n/a | n/a | n/a |
| GW030323 | 1.1 | 08 Aug 2014 12:00:00 am | 9.13 | 9.92 | −4.16 | 0.85 | 0.93 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 01 Jul 2013 01:55:00 pm | 9.75 | 9.73 | 0.14 | 0.94 | 0.93 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 27 Nov 2012 10:40:00 am | 9.66 | 9.33 | 1.71 | 0.96 | 0.93 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 20 Jun 2012 10:35:00 am | 9.94 | 9.48 | 2.33 | 0.95 | 0.91 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 16 Jun 2011 03:10:00 pm | 10.5 | 9.57 | 4.72 | 0.98 | 0.89 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 13 May 2010 01:35:00 pm | 9.91 | 10.1 | −0.79 | 0.91 | 0.92 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 12 Apr 2010 10:30:00 am | 9.85 | 9.81 | 0.23 | 0.95 | 0.94 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 22 Feb 2010 10:55:00 am | 10.2 | 10.0 | 0.97 | 0.99 | 0.98 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 04 Dec 2009 12:00:00 am | 10.3 | 9.45 | 4.53 | 1.05 | 0.96 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 09 Nov 2009 03:45:00 pm | 9.86 | 9.46 | 2.05 | 0.99 | 0.96 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 20 Oct 2009 12:15:00 pm | 9.72 | 9.89 | −0.85 | 0.97 | 0.99 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 21 Sep 2009 04:20:00 pm | 9.87 | 9.78 | 0.46 | 1.02 | 1.01 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 16 Dec 1986 12:00:00 pm | 6.40 | 5.11 | 11.2 | n/a | n/a | n/a |
| GW030323 | 1.1 | 14 Jul 1978 12:01:00 pm | 6.44 | 6.71 | −2.05 | 0.98 | 1.02 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 19 Aug 1977 12:00:00 pm | 11.1 | 11.6 | −1.85 | 1.01 | 1.05 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 27 Jul 1977 12:01:00 pm | 7.17 | 7.42 | −1.71 | 1.03 | 1.07 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 01 May 1976 12:00:00 pm | 6.67 | 6.50 | 1.31 | 0.98 | 0.96 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 18 Sep 1975 12:00:00 pm | 8.42 | 8.61 | −1.11 | 0.96 | 0.98 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 15 Sep 1975 01:00:00 pm | 7.55 | 7.31 | 1.63 | 0.94 | 0.91 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 08 Sep 1975 12:00:00 pm | 6.65 | 6.65 | −0.01 | 1.01 | 1.01 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 25 Aug 1975 12:00:00 pm | 8.20 | 0.25 | 94.1 | n/a | n/a | n/a |
| GW030323 | 1.1 | 15 Jul 1975 12:01:00 pm | 6.22 | 6.23 | −0.05 | 0.96 | 0.96 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 06 Dec 1974 08:00:00 am | 5.82 | 5.57 | 2.23 | 0.96 | 0.92 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 22 Nov 1974 10:00:00 am | 7.07 | 6.81 | 1.87 | 0.93 | 0.90 | $Na^+$–$Cl^-$ |
| GW030323 | 1.1 | 27 Sep 1974 03:00:00 pm | 5.67 | 5.82 | −1.27 | 0.91 | 0.94 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 11 Apr 2018 12:00:00 pm | 12.5 | 13.3 | −3.07 | 0.89 | 0.95 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 29 Jul 2014 12:00:00 am | 4.68 | 5.00 | −3.27 | 0.86 | 0.92 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 19 Jun 2013 01:00:00 pm | 7.12 | 6.79 | 2.39 | 0.94 | 0.89 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 29 Nov 2012 11:45:00 am | 7.77 | 8.16 | −2.46 | 0.87 | 0.91 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 25 Jun 2012 11:30:00 am | 8.54 | 8.77 | −1.30 | 0.88 | 0.90 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 23 Jun 2011 10:45:00 am | 8.13 | 7.40 | 4.70 | 0.98 | 0.89 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 13 Sep 2010 12:00:00 pm | 5.03 | 4.82 | 2.08 | 0.97 | 0.93 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 27 Jul 2010 11:00:00 am | 5.35 | 4.99 | 3.57 | 0.99 | 0.92 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 10 Jun 2010 11:20:00 am | 5.82 | 5.58 | 2.15 | 0.94 | 0.90 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 11 May 2010 02:30:00 pm | 9.08 | 9.09 | −0.07 | 0.94 | 0.94 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 13 Apr 2010 11:30:00 am | 11.9 | 11.8 | 0.44 | 0.98 | 0.97 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 10 Mar 2010 02:40:00 pm | 11.3 | 10.6 | 3.26 | 0.76 | 0.71 | $Na^+$–$Cl^-$ |
| GW036211 | 1.1 | 16 Feb 2010 03:20:00 pm | 10.1 | 9.70 | 2.10 | 0.99 | 0.95 | $Na^+$–$Cl^-$ |

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[8] n/a denotes that a QAQC calculation and water type determination was not performed since the anion-cation balance for a sample was not within the ±5 % acceptance level

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW036211 | 1.1 | 08 Dec 2009 01:00:00 pm | 9.08 | 8.47 | 3.50 | 1.00 | 0.93 | $Na^+-Cl^-$ |
| GW036211 | 1.1 | 12 Nov 2009 01:00:00 pm | 9.07 | 9.40 | −1.75 | 0.94 | 0.98 | $Na^+-Cl^-$ |
| GW036211 | 1.1 | 21 Oct 2009 11:40:00 am | 7.08 | 6.46 | 4.52 | 1.48 | 1.36 | $Na^+-Cl^-$ |
| GW036211 | 1.1 | 18 Sep 2009 02:15:00 pm | 12.2 | 12.5 | −1.17 | 0.98 | 1.00 | $Na^+-Cl^-$ |
| GW036211 | 1.1 | 18 Sep 1986 12:00:00 pm | 4.00 | 4.19 | −2.28 | 0.88 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 1.1 | 03 Apr 1978 06:00:00 am | 4.69 | 4.89 | −2.09 | 0.94 | 0.98 | $Na^+-(HCO_3^- - Cl^-)$ |
| GW036211 | 1.1 | 26 Jul 1977 12:01:00 pm | 17.5 | 18.0 | −1.30 | 0.96 | 0.98 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 11 Apr 2018 12:00:00 pm | 4.25 | 3.64 | 7.73 | n/a | n/a | n/a |
| GW036211 | 2.2 | 15 Sep 2017 12:00:00 am | 4.15 | 5.20 | −11.3 | n/a | n/a | n/a |
| GW036211 | 2.2 | 22 Apr 2016 12:00:00 am | 4.26 | 5.26 | −10.5 | n/a | n/a | n/a |
| GW036211 | 2.2 | 30 Jul 2014 12:00:00 am | 3.94 | 4.23 | −3.53 | 0.84 | 0.90 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 19 Jun 2013 02:25:00 pm | 4.14 | 4.31 | −2.01 | 0.88 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 28 Nov 2012 10:00:00 am | 4.59 | 4.46 | 1.50 | 0.98 | 0.95 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 25 Jun 2012 11:25:00 am | 4.14 | 4.25 | −1.38 | 0.87 | 0.90 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 23 Jun 2011 02:55:00 pm | 4.76 | 4.20 | 6.29 | n/a | n/a | n/a |
| GW036211 | 2.2 | 13 Sep 2010 01:55:00 pm | 4.41 | 4.23 | 2.14 | 0.95 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 27 Jul 2010 12:45:00 pm | 4.72 | 4.45 | 3.03 | 1.01 | 0.95 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 10 Jun 2010 01:15:00 pm | 3.90 | 4.28 | −4.63 | 0.84 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 11 May 2010 10:40:00 am | 4.38 | 4.28 | 1.10 | 0.94 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 12 Apr 2010 02:30:00 pm | 4.42 | 4.25 | 1.90 | 0.95 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 10 Mar 2010 10:35:00 am | 4.66 | 4.25 | 4.56 | 0.95 | 0.86 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 16 Feb 2010 04:45:00 pm | 4.54 | 4.23 | 3.61 | 0.96 | 0.89 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 08 Dec 2009 02:30:00 pm | 4.49 | 4.17 | 3.68 | 0.95 | 0.88 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 12 Nov 2009 09:30:00 am | 4.17 | 4.25 | −1.03 | 0.91 | 0.93 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 21 Oct 2009 02:30:00 pm | 4.31 | 4.75 | −4.86 | 0.59 | 0.65 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 18 Sep 2009 10:35:00 am | 4.19 | 4.23 | −0.36 | 0.92 | 0.93 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 18 Sep 1986 02:00:00 pm | 3.96 | 4.35 | −4.68 | 0.85 | 0.93 | $Na^+-Cl^-$ |
| GW036211 | 2.2 | 19 Apr 1978 08:00:00 am | 4.42 | 4.43 | −0.07 | 0.98 | 0.98 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 10 Apr 2018 12:00:00 pm | 4.72 | 3.98 | 8.52 | n/a | n/a | n/a |
| GW036211 | 3.3 | 15 Sep 2017 12:00:00 am | 4.55 | 5.51 | −9.62 | n/a | n/a | n/a |
| GW036211 | 3.3 | 21 Apr 2016 12:00:00 am | 4.68 | 5.51 | −8.16 | n/a | n/a | n/a |
| GW036211 | 3.3 | 29 Jul 2014 12:00:00 am | 4.07 | 4.28 | −2.55 | 0.87 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 21 Jun 2013 01:20:00 pm | 4.85 | 4.76 | 0.93 | 0.93 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 28 Nov 2012 02:30:00 pm | 4.60 | 4.93 | −3.40 | 0.88 | 0.95 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 25 Jun 2012 03:10:00 pm | 4.47 | 4.70 | −2.45 | 0.86 | 0.90 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 23 Jun 2011 02:00:00 pm | 5.23 | 4.67 | 5.69 | n/a | n/a | n/a |
| GW036211 | 3.3 | 13 Sep 2010 02:15:00 pm | 4.94 | 4.67 | 2.80 | 0.96 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 27 Jul 2010 03:20:00 pm | 5.04 | 4.76 | 2.92 | 0.98 | 0.93 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 10 Jun 2010 01:05:00 pm | 4.29 | 4.76 | −5.22 | n/a | n/a | n/a |
| GW036211 | 3.3 | 11 May 2010 02:25:00 pm | 4.79 | 4.73 | 0.61 | 0.93 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 13 Apr 2010 03:30:00 pm | 4.78 | 4.70 | 0.86 | 0.93 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 10 Mar 2010 01:55:00 pm | 5.02 | 4.73 | 3.00 | 0.97 | 0.91 | $Na^+-Cl^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW036211 | 3.3 | 16 Feb 2010 12:10:00 pm | 4.94 | 4.70 | 2.53 | 0.99 | 0.94 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 08 Dec 2009 10:20:00 am | 4.93 | 4.64 | 3.02 | 0.96 | 0.91 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 12 Nov 2009 11:40:00 am | 4.61 | 4.73 | −1.26 | 0.92 | 0.94 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 21 Oct 2009 02:00:00 pm | 4.78 | 4.73 | 0.59 | 0.93 | 0.92 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 22 Sep 2009 01:40:00 pm | 4.61 | 4.70 | −0.92 | 0.92 | 0.94 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 03 May 1978 12:01:00 pm | 5.02 | 5.11 | −0.93 | 0.97 | 0.98 | $Na^+-Cl^-$ |
| GW036211 | 3.3 | 26 Jul 1977 12:00:00 pm | 21.4 | 22.3 | −2.06 | 0.94 | 0.98 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 17 Apr 2018 12:00:00 pm | 19.0 | 19.6 | −1.81 | 0.92 | 0.95 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 06 Aug 2014 12:00:00 am | 16.8 | 16.6 | 0.69 | 0.94 | 0.92 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 02 Jul 2013 03:35:00 pm | 17.5 | 17.6 | −0.45 | 0.94 | 0.95 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 26 Nov 2012 03:15:00 pm | 18.6 | 17.1 | 4.21 | 1.01 | 0.93 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 20 Jun 2012 03:00:00 pm | 18.2 | 16.5 | 4.83 | 0.99 | 0.90 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 08 Jun 2011 02:20:00 pm | 17.7 | 16.8 | 2.66 | 0.98 | 0.93 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 26 Jul 2010 01:20:00 pm | 18.2 | 16.8 | 3.88 | 1.03 | 0.96 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 15 Jun 2010 03:10:00 pm | 15.5 | 17.0 | −4.53 | 0.87 | 0.95 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 20 May 2010 04:05:00 pm | 18.0 | 17.9 | 0.24 | 0.99 | 0.98 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 16 Mar 2010 03:55:00 pm | 18.1 | 17.3 | 2.34 | 1.04 | 0.99 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 22 Feb 2010 03:40:00 pm | 17.3 | 17.1 | 0.61 | 1.01 | 0.99 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 03 Dec 2009 12:00:00 am | 18.7 | 17.1 | 4.41 | 1.12 | 1.02 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 13 Oct 2009 09:35:00 am | 16.8 | 17.3 | −1.41 | 1.07 | 1.10 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 05 Mar 1981 12:00:00 pm | 11.4 | 11.6 | −0.81 | 0.95 | 0.97 | $Na^+-Cl^-$ |
| GW036396 | 1.1 | 29 Nov 1979 05:00:00 pm | 55.7 | 56.6 | −0.83 | 1.01 | 1.03 | $Na^+-Cl^-$ |
| GW036773 | 1.1 | 03 May 2018 12:00:00 pm | 37.6 | 38.9 | −1.67 | 1.04 | 1.08 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 04 Aug 2014 12:00:00 am | 38.9 | 42.0 | −3.78 | 1.03 | 1.11 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 18 Jun 2013 02:00:00 pm | 43.8 | 43.3 | 0.59 | 1.12 | 1.10 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 20 Nov 2012 01:15:00 pm | 45.2 | 44.4 | 0.83 | 1.14 | 1.12 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 06 Jun 2012 01:00:00 pm | 47.3 | 44.3 | 3.28 | 1.17 | 1.10 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 06 Jun 2011 02:40:00 pm | 46.4 | 44.5 | 2.14 | 1.14 | 1.09 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 08 Sep 2010 01:25:00 pm | 43.3 | 43.5 | −0.20 | 1.11 | 1.11 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 16 Jul 2010 10:20:00 am | 46.0 | 47.2 | −1.35 | 1.18 | 1.21 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 16 Jun 2010 01:10:00 pm | 45.5 | 44.8 | 0.84 | 1.16 | 1.14 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 14 May 2010 09:15:00 am | 44.7 | 45.6 | −1.01 | 1.12 | 1.14 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 14 Apr 2010 01:40:00 pm | 44.5 | 47.8 | −3.51 | 1.27 | 1.36 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 12 Mar 2010 11:20:00 am | 46.0 | 44.9 | 1.29 | 1.30 | 1.26 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 22 Feb 2010 04:35:00 pm | 45.2 | 43.8 | 1.52 | 1.36 | 1.32 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 11 Dec 2009 09:00:00 am | 46.0 | 44.7 | 1.49 | 1.39 | 1.35 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 13 Nov 2009 11:15:00 am | 43.8 | 42.9 | 0.96 | 1.36 | 1.33 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 23 Oct 2009 12:35:00 pm | 44.6 | 44.6 | 0.09 | 1.40 | 1.39 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 1.1 | 02 Oct 2009 12:00:00 pm | 44.2 | 46.6 | −2.67 | 1.43 | 1.50 | $Na^+-(Cl^--SO_4^{2-})$ |
| GW036773 | 2.2 | 03 May 2018 12:00:00 pm | 13.2 | 13.6 | −1.31 | 0.97 | 1.00 | $Na^+-Cl^-$ |
| GW036773 | 2.2 | 04 Aug 2014 12:00:00 am | 10.8 | 12.3 | −6.40 | n/a | n/a | n/a |
| GW036773 | 2.2 | 18 Jun 2013 04:10:00 pm | 12.8 | 13.0 | −0.96 | 0.96 | 0.98 | $Na^+-Cl^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW036773 | 2.2 | 20 Nov 2012 02:30:00 pm | 12.8 | 12.4 | 1.67 | 0.96 | 0.93 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 06 Jun 2012 01:15:00 pm | 14.0 | 14.0 | 0.05 | 0.97 | 0.97 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 06 Jun 2011 01:40:00 pm | 11.3 | 10.7 | 2.80 | 0.95 | 0.90 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 08 Sep 2010 02:25:00 pm | 10.9 | 11.0 | −0.30 | 0.97 | 0.98 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 16 Jul 2010 11:25:00 am | 10.5 | 9.88 | 3.12 | 0.99 | 0.93 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 16 Jun 2010 01:50:00 pm | 11.4 | 11.7 | −1.29 | 0.94 | 0.97 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 14 May 2010 11:45:00 am | 10.6 | 11.1 | −2.40 | 0.88 | 0.92 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 14 Apr 2010 03:15:00 pm | 10.5 | 10.8 | −1.15 | 0.94 | 0.96 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 12 Mar 2010 11:00:00 am | 9.67 | 9.04 | 3.37 | 0.95 | 0.89 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 19 Feb 2010 03:25:00 pm | 8.82 | 8.51 | 1.78 | 0.99 | 0.96 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 11 Dec 2009 11:55:00 am | 11.1 | 10.4 | 3.43 | 0.81 | 0.75 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 13 Nov 2009 09:35:00 am | 8.86 | 9.06 | −1.11 | 0.98 | 1.00 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 23 Oct 2009 11:05:00 am | 11.2 | 11.1 | 0.75 | 1.00 | 0.99 | $Na^+$–$Cl^-$ |
| GW036773 | 2.2 | 02 Oct 2009 11:45:00 am | 9.48 | 9.31 | 0.89 | 1.04 | 1.02 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 03 May 2018 12:00:00 pm | 5.33 | 5.78 | −4.02 | 0.86 | 0.93 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 07 Sep 2017 12:00:00 am | 5.33 | 7.21 | −14.9 | n/a | n/a | n/a |
| GW036773 | 3.3 | 27 Apr 2016 12:00:00 am | 5.21 | 6.92 | −14.1 | n/a | n/a | n/a |
| GW036773 | 3.3 | 04 Aug 2014 12:00:00 am | 4.94 | 5.54 | −5.79 | n/a | n/a | n/a |
| GW036773 | 3.3 | 18 Jun 2013 12:40:00 pm | 5.32 | 5.52 | −1.79 | 0.83 | 0.86 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 20 Nov 2012 12:10:00 pm | 5.77 | 5.52 | 2.20 | 0.90 | 0.87 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 06 Jun 2012 11:30:00 am | 5.53 | 5.50 | 0.29 | 0.87 | 0.87 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 06 Jun 2011 11:20:00 am | 5.81 | 5.52 | 2.57 | 0.91 | 0.86 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 08 Sep 2010 11:45:00 am | 5.60 | 5.55 | 0.41 | 0.89 | 0.88 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 16 Jul 2010 11:40:00 am | 5.75 | 5.55 | 1.73 | 0.92 | 0.89 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 16 Jun 2010 10:55:00 am | 5.01 | 5.55 | −5.15 | n/a | n/a | n/a |
| GW036773 | 3.3 | 14 May 2010 10:10:00 am | 5.44 | 5.57 | −1.20 | 0.86 | 0.88 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 14 Apr 2010 10:30:00 am | 5.34 | 5.27 | 0.68 | 0.89 | 0.88 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 12 Mar 2010 09:55:00 am | 5.52 | 5.24 | 2.64 | 0.89 | 0.85 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 19 Feb 2010 10:10:00 am | 5.48 | 5.52 | −0.39 | 0.93 | 0.94 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 11 Dec 2009 09:45:00 am | 5.57 | 5.29 | 2.67 | 0.83 | 0.78 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 13 Nov 2009 10:35:00 am | 5.12 | 5.27 | −1.44 | 0.86 | 0.88 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 23 Oct 2009 09:00:00 am | 5.34 | 5.62 | −2.54 | 0.81 | 0.85 | $Na^+$–$Cl^-$ |
| GW036773 | 3.3 | 02 Oct 2009 11:10:00 am | 5.43 | 5.52 | −0.82 | 0.94 | 0.96 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 24 Apr 2018 12:00:00 pm | 49.1 | 43.7 | 5.85 | n/a | n/a | n/a |
| GW036799 | 1.1 | 13 Aug 2014 12:00:00 am | 41.7 | 46.3 | −5.29 | n/a | n/a | n/a |
| GW036799 | 1.1 | 03 Jul 2013 12:20:00 pm | 46.0 | 49.1 | −3.20 | 0.90 | 0.96 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 22 Nov 2012 02:00:00 pm | 49.4 | 49.2 | 0.18 | 0.98 | 0.98 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 19 Jun 2012 11:10:00 am | 48.3 | 46.2 | 2.27 | 0.98 | 0.94 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 09 Jun 2011 02:50:00 pm | 50.5 | 46.6 | 4.12 | 0.98 | 0.90 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 12 Jul 2010 12:15:00 pm | 46.8 | 43.4 | 3.70 | 1.02 | 0.95 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 22 Jun 2010 10:55:00 am | 46.5 | 46.3 | 0.29 | 1.02 | 1.02 | $Na^+$–$Cl^-$ |
| GW036799 | 1.1 | 16 Sep 2009 05:40:00 pm | 45.0 | 46.4 | −1.55 | 1.07 | 1.10 | $Na^+$–$Cl^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| **GW036799** | 1.1 | 03 Jun 1989 12:00:00 pm | 2.76 | 0.00 | 100 | n/a | n/a | n/a |
| **GW036799** | 2.2 | 24 Apr 2018 12:00:00 pm | 21.7 | 21.9 | −0.35 | 0.94 | 0.94 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 13 Aug 2014 12:00:00 am | 18.2 | 20.0 | −4.85 | 0.86 | 0.95 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 03 Jul 2013 11:10:00 am | 19.1 | 18.6 | 1.25 | 1.00 | 0.98 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 23 Nov 2012 12:30:00 pm | 19.3 | 18.2 | 2.95 | 1.02 | 0.96 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 19 Jun 2012 03:40:00 pm | 20.2 | 19.2 | 2.53 | 1.00 | 0.95 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 09 Jun 2011 01:50:00 pm | 22.9 | 20.4 | 5.78 | n/a | n/a | n/a |
| **GW036799** | 2.2 | 12 Jul 2010 03:15:00 pm | 21.3 | 19.7 | 3.89 | 1.06 | 0.98 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 22 Jun 2010 01:50:00 pm | 20.5 | 20.2 | 0.70 | 1.00 | 0.98 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 16 Sep 2009 04:03:00 pm | 18.2 | 18.6 | −1.26 | 1.07 | 1.10 | $Na^+$–$Cl^-$ |
| **GW036799** | 2.2 | 19 Jun 1996 12:01:00 am | 15.3 | 17.1 | −5.61 | n/a | n/a | n/a |
| **GW036799** | 3.3 | 13 Aug 2014 12:00:00 am | 34.0 | 37.5 | −4.90 | 0.91 | 1.01 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 22 Nov 2012 12:35:00 pm | 40.4 | 40.5 | −0.15 | 0.99 | 1.00 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 19 Jun 2012 12:30:00 pm | 42.7 | 40.9 | 2.08 | 0.97 | 0.93 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 09 Jun 2011 12:00:00 pm | 44.4 | 40.9 | 4.07 | 0.98 | 0.90 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 12 Jul 2010 03:30:00 pm | 33.0 | 34.7 | −2.54 | 0.93 | 0.98 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 22 Jun 2010 02:30:00 pm | 37.4 | 37.6 | −0.23 | 1.02 | 1.02 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 16 Sep 2009 05:50:00 pm | 31.9 | 31.5 | 0.69 | 1.08 | 1.07 | $Na^+$–$Cl^-$ |
| **GW036799** | 3.3 | 19 Jun 1996 12:00:00 am | 17.0 | 18.4 | −3.79 | 0.87 | 0.94 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 02 May 2018 12:00:00 pm | 56.7 | 53.9 | 2.59 | 0.92 | 0.87 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 07 Aug 2014 12:00:00 am | 30.5 | 33.4 | −4.54 | 0.91 | 1.00 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 26 Jun 2013 02:05:00 pm | 32.2 | 33.2 | −1.44 | 0.93 | 0.95 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 04 Dec 2012 01:05:00 pm | 39.3 | 35.7 | 4.81 | 1.06 | 0.97 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 13 Jun 2012 12:05:00 pm | 34.8 | 33.0 | 2.73 | 1.01 | 0.96 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 08 Jun 2011 10:35:00 am | 33.6 | 32.3 | 2.02 | 1.01 | 0.97 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 13 Jul 2010 08:15:00 am | 39.8 | 40.0 | −0.23 | 1.01 | 1.01 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 07 Jun 2010 11:45:00 am | 36.4 | 39.8 | −4.52 | 0.89 | 0.98 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 12 May 2010 09:50:00 am | 40.0 | 39.9 | 0.14 | 0.97 | 0.97 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 21 Apr 2010 07:45:00 am | 40.5 | 43.1 | −3.11 | 1.11 | 1.18 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 11 Mar 2010 10:55:00 am | 44.6 | 42.8 | 2.02 | 1.14 | 1.10 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 18 Feb 2010 08:50:00 am | 42.0 | 39.9 | 2.60 | 1.11 | 1.06 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 19 Jan 2010 08:55:00 am | 42.3 | 42.6 | −0.36 | 1.02 | 1.03 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 09 Dec 2009 11:30:00 am | 43.3 | 39.6 | 4.38 | 1.17 | 1.07 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 11 Nov 2009 10:50:00 am | 43.8 | 42.8 | 1.15 | 1.05 | 1.03 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 14 Oct 2009 05:05:00 pm | 42.0 | 39.8 | 2.76 | 1.19 | 1.13 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 17 Sep 2009 01:35:00 pm | 41.6 | 45.9 | −4.91 | 1.27 | 1.40 | $Na^+$–$Cl^-$ |
| GW041011 | 1.1 | 14 Dec 2005 12:00:00 am | 9.96 | 10.5 | −2.52 | 1.03 | 1.09 | $Na^+$–$HCO_3^-$ |
| GW041011 | 2.2 | 02 May 2018 12:00:00 pm | 5.12 | 4.61 | 5.29 | n/a | n/a | n/a |
| GW041011 | 2.2 | 12 Sep 2017 12:00:00 am | 5.15 | 5.71 | −5.16 | n/a | n/a | n/a |
| GW041011 | 2.2 | 26 Apr 2016 12:00:00 am | 5.09 | 5.79 | −6.49 | n/a | n/a | n/a |
| GW041011 | 2.2 | 07 Aug 2014 12:00:00 am | 4.85 | 5.43 | −5.62 | n/a | n/a | n/a |
| GW041011 | 2.2 | 26 Jun 2013 01:30:00 pm | 5.43 | 5.29 | 1.39 | 0.95 | 0.92 | $Na^+$–$Cl^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW041011 | 2.2 | 04 Dec 2012 12:30:00 pm | 5.99 | 5.29 | 6.22 | n/a | n/a | n/a |
| GW041011 | 2.2 | 13 Jun 2012 12:30:00 pm | 5.15 | 5.23 | −0.73 | 0.91 | 0.93 | $Na^+$–$Cl^-$ |
| GW041011 | 2.2 | 08 Jun 2011 10:10:00 am | 5.84 | 5.36 | 4.22 | 1.01 | 0.93 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 2.2 | 13 Jul 2010 09:45:00 am | 5.70 | 5.63 | 0.61 | 0.92 | 0.91 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 2.2 | 07 Jun 2010 12:30:00 pm | 5.22 | 5.58 | −3.28 | 0.90 | 0.96 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| GW041011 | 2.2 | 12 May 2010 10:56:00 am | 5.44 | 5.60 | −1.48 | 0.84 | 0.87 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| GW041011 | 2.2 | 21 Apr 2010 10:41:00 am | 5.51 | 5.58 | −0.58 | 0.89 | 0.90 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| GW041011 | 2.2 | 11 Mar 2010 10:05:00 am | 5.51 | 5.44 | 0.58 | 0.96 | 0.95 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 2.2 | 18 Feb 2010 11:35:00 am | 5.36 | 5.23 | 1.29 | 0.97 | 0.95 | $Na^+$–$Cl^-$ |
| GW041011 | 2.2 | 19 Jan 2010 09:15:00 am | 5.46 | 5.22 | 2.28 | 0.80 | 0.77 | $Na^+$–$Cl^-$ |
| GW041011 | 2.2 | 09 Dec 2009 02:10:00 pm | 5.55 | 5.32 | 2.18 | 0.98 | 0.94 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 2.2 | 11 Nov 2009 08:30:00 am | 5.49 | 5.56 | −0.62 | 0.94 | 0.95 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| GW041011 | 2.2 | 14 Oct 2009 04:45:00 pm | 5.33 | 5.44 | −0.99 | 0.96 | 0.98 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 2.2 | 24 Sep 2009 02:30:00 pm | 2.35 | 5.39 | −39.2 | n/a | n/a | n/a |
| GW041011 | 2.2 | 13 Dec 2005 12:00:00 am | 7.09 | 7.19 | −0.74 | 0.99 | 1.01 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| GW041011 | 3.3 | 02 May 2018 12:00:00 pm | 6.22 | 6.17 | 0.42 | 0.94 | 0.94 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 12 Sep 2017 12:00:00 am | 5.92 | 6.64 | −5.74 | n/a | n/a | n/a |
| GW041011 | 3.3 | 26 Apr 2016 12:00:00 am | 5.95 | 6.65 | −5.57 | n/a | n/a | n/a |
| GW041011 | 3.3 | 07 Aug 2014 12:00:00 am | 5.48 | 6.04 | −4.87 | 0.83 | 0.92 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 26 Jun 2013 12:05:00 pm | 5.46 | 6.15 | −5.99 | n/a | n/a | n/a |
| GW041011 | 3.3 | 04 Dec 2012 10:50:00 am | 6.56 | 6.15 | 3.15 | 0.99 | 0.93 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 13 Jun 2012 11:25:00 am | 6.55 | 5.87 | 5.47 | n/a | n/a | n/a |
| GW041011 | 3.3 | 07 Jun 2011 01:20:00 pm | 6.45 | 6.03 | 3.35 | 0.97 | 0.90 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 13 Jul 2010 10:50:00 am | 6.62 | 6.32 | 2.32 | 1.00 | 0.96 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 07 Jun 2010 11:00:00 am | 6.05 | 6.31 | −2.15 | 0.92 | 0.96 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 12 May 2010 11:05:00 am | 6.54 | 6.15 | 3.06 | 0.98 | 0.92 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 21 Apr 2010 08:35:00 am | 6.45 | 6.15 | 2.35 | 0.99 | 0.95 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 11 Mar 2010 11:06:00 am | 6.46 | 6.15 | 2.48 | 0.98 | 0.93 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 18 Feb 2010 09:50:00 am | 6.44 | 6.15 | 2.33 | 0.90 | 0.86 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 19 Jan 2010 12:05:00 pm | 6.44 | 6.21 | 1.84 | 0.94 | 0.91 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 09 Dec 2009 12:30:00 pm | 6.48 | 5.99 | 3.93 | 0.91 | 0.84 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 11 Nov 2009 10:20:00 am | 6.44 | 6.15 | 2.28 | 0.88 | 0.84 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 14 Oct 2009 03:45:00 pm | 5.97 | 6.27 | −2.47 | 0.92 | 0.96 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 24 Sep 2009 12:30:00 pm | 6.01 | 6.15 | −1.13 | 0.84 | 0.86 | $Na^+$–$Cl^-$ |
| GW041011 | 3.3 | 08 Dec 2005 12:00:00 am | 6.55 | 6.34 | 1.64 | 1.03 | 1.00 | $Na^+$–$Cl^-$ |
| GW041012 | 1.1 | 02 May 2018 12:00:00 pm | 14.2 | 13.5 | 2.72 | 1.00 | 0.94 | $Na^+$–$Cl^-$ |
| GW041012 | 1.1 | 12 Sep 2017 12:00:00 am | 11.4 | 9.61 | 8.72 | n/a | n/a | n/a |
| GW041012 | 1.1 | 26 Apr 2016 12:00:00 am | 9.77 | 7.91 | 10.5 | n/a | n/a | n/a |
| GW041012 | 1.1 | 07 Aug 2014 12:00:00 am | 8.14 | 8.72 | −3.44 | 0.93 | 1.00 | $Na^+$–$HCO_3^-$ |
| GW041012 | 1.1 | 17 Jun 2013 03:15:00 pm | 8.52 | 8.15 | 2.25 | 1.01 | 0.96 | $Na^+$–$HCO_3^-$ |
| GW041012 | 1.1 | 06 Dec 2012 11:15:00 am | 8.03 | 7.74 | 1.82 | 1.00 | 0.96 | $Na^+$–$HCO_3^-$ |
| GW041012 | 1.1 | 13 Jun 2012 03:35:00 pm | 8.55 | 8.01 | 3.23 | 1.04 | 0.98 | $Na^+$–$HCO_3^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| **GW041012** | 1.1 | 07 Jun 2011 11:00:00 am | 8.45 | 7.73 | 4.42 | 1.07 | 0.98 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 16 Sep 2010 10:05:00 am | 8.03 | 7.71 | 2.00 | 1.03 | 0.99 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 22 Jul 2010 12:05:00 pm | 9.02 | 8.41 | 3.54 | 1.08 | 1.00 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 07 Jun 2010 03:40:00 pm | 7.58 | 8.35 | −4.86 | 0.92 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 12 May 2010 12:55:00 pm | 8.48 | 7.97 | 3.10 | 1.09 | 1.02 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 15 Apr 2010 01:40:00 pm | 8.52 | 8.02 | 2.98 | 1.07 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 11 Mar 2010 01:35:00 pm | 8.50 | 7.78 | 4.47 | 1.08 | 0.98 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 18 Feb 2010 03:25:00 pm | 8.00 | 7.38 | 4.07 | 1.06 | 0.98 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 19 Jan 2010 02:30:00 pm | 8.06 | 7.58 | 3.10 | 1.00 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 10 Dec 2009 08:25:00 am | 8.50 | 7.58 | 5.68 | n/a | n/a | n/a |
| **GW041012** | 1.1 | 14 Oct 2009 11:50:00 am | 8.00 | 7.88 | 0.76 | 1.05 | 1.03 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 1.1 | 29 Sep 2009 12:00:00 pm | 8.00 | 7.68 | 2.04 | 1.08 | 1.03 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 02 May 2018 12:00:00 pm | 4.17 | 3.73 | 5.67 | n/a | n/a | n/a |
| **GW041012** | 2.2 | 07 Aug 2014 12:00:00 am | 3.80 | 4.15 | −4.42 | 0.92 | 1.00 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 17 Jun 2013 02:40:00 pm | 4.13 | 3.98 | 1.85 | 1.01 | 0.97 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 06 Dec 2012 10:30:00 am | 4.51 | 4.15 | 4.22 | 1.10 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 13 Jun 2012 03:45:00 pm | 4.21 | 4.01 | 2.40 | 1.03 | 0.98 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 07 Jun 2011 10:20:00 am | 4.54 | 4.14 | 4.56 | 1.10 | 1.00 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 16 Sep 2010 10:25:00 am | 4.15 | 4.15 | 0.06 | 1.01 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 22 Jul 2010 12:25:00 pm | 4.33 | 4.17 | 1.87 | 1.05 | 1.02 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 07 Jun 2010 04:05:00 pm | 3.70 | 4.14 | −5.67 | n/a | n/a | n/a |
| **GW041012** | 2.2 | 12 May 2010 01:36:00 pm | 4.35 | 3.98 | 4.46 | 1.06 | 0.97 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 16 Apr 2010 07:45:00 am | 4.17 | 4.15 | 0.33 | 1.04 | 1.03 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 11 Mar 2010 01:25:00 pm | 4.36 | 4.15 | 2.52 | 1.05 | 1.00 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 18 Feb 2010 04:35:00 pm | 4.22 | 3.98 | 2.92 | 1.05 | 0.99 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 19 Jan 2010 03:45:00 pm | 4.09 | 3.99 | 1.28 | 0.96 | 0.93 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 10 Dec 2009 11:20:00 am | 4.31 | 3.94 | 4.51 | 1.07 | 0.98 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 11 Nov 2009 12:40:00 pm | 4.19 | 3.98 | 2.53 | 1.02 | 0.97 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 14 Oct 2009 10:40:00 am | 4.07 | 3.98 | 1.10 | 1.03 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 2.2 | 29 Sep 2009 10:15:00 am | 4.03 | 4.12 | −1.11 | 0.99 | 1.01 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 02 May 2018 12:00:00 pm | 3.70 | 3.23 | 6.75 | n/a | n/a | n/a |
| **GW041012** | 3.3 | 12 Sep 2017 12:00:00 am | 3.69 | 4.37 | −8.45 | n/a | n/a | n/a |
| **GW041012** | 3.3 | 26 Apr 2016 12:00:00 am | 3.71 | 4.46 | −9.24 | n/a | n/a | n/a |
| **GW041012** | 3.3 | 07 Aug 2014 12:00:00 am | 3.34 | 3.83 | −6.80 | n/a | n/a | n/a |
| **GW041012** | 3.3 | 17 Jun 2013 01:30:00 pm | 3.53 | 3.81 | −3.76 | 0.88 | 0.95 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 06 Dec 2012 01:30:00 pm | 4.18 | 3.82 | 4.42 | 1.03 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 13 Jun 2012 02:50:00 pm | 3.93 | 3.81 | 1.53 | 0.96 | 0.93 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 07 Jun 2011 09:20:00 am | 4.20 | 3.85 | 4.39 | 1.03 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 16 Sep 2010 10:50:00 am | 3.83 | 3.82 | 0.10 | 0.95 | 0.95 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 22 Jul 2010 11:00:00 am | 4.18 | 3.86 | 3.95 | 1.04 | 0.97 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 07 Jun 2010 02:50:00 pm | 3.50 | 3.83 | −4.51 | 0.87 | 0.95 | $Na^+$–$HCO_3^-$ |
| **GW041012** | 3.3 | 12 May 2010 02:40:00 pm | 3.85 | 3.86 | −0.15 | 0.93 | 0.93 | $Na^+$–$HCO_3^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| GW041012 | 3.3 | 15 Apr 2010 03:10:00 pm | 4.00 | 3.87 | 1.63 | 0.98 | 0.95 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 11 Mar 2010 02:10:00 pm | 4.10 | 3.85 | 3.07 | 0.99 | 0.93 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 18 Feb 2010 03:40:00 pm | 4.06 | 3.83 | 2.85 | 0.99 | 0.93 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 19 Jan 2010 02:45:00 pm | 4.00 | 3.82 | 2.26 | 0.93 | 0.89 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 10 Dec 2009 09:25:00 am | 4.16 | 3.98 | 2.22 | 0.99 | 0.94 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 11 Nov 2009 01:40:00 pm | 4.10 | 4.03 | 0.78 | 0.99 | 0.98 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 14 Oct 2009 11:30:00 am | 3.89 | 3.95 | −0.78 | 0.95 | 0.96 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 29 Sep 2009 12:30:00 pm | 4.04 | 4.07 | −0.32 | 0.97 | 0.98 | $Na^+$–$HCO_3^-$ |
| GW041012 | 3.3 | 22 Mar 2006 12:00:00 am | 4.24 | 4.56 | −3.67 | 0.99 | 1.07 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| GW273040 | 1.1 | 19 Apr 2018 12:00:00 pm | 168 | 177 | −2.68 | 1.12 | 1.18 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 06 Aug 2014 12:00:00 am | 85.1 | 84.6 | 0.32 | 1.07 | 1.06 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 25 Jun 2013 01:15:00 pm | 78.1 | 81.1 | −1.88 | 1.03 | 1.07 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 26 Nov 2012 11:45:00 am | 87.3 | 84.4 | 1.64 | 1.13 | 1.09 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 21 Jun 2012 10:55:00 am | 87.8 | 85.9 | 1.09 | 1.08 | 1.06 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 10 Jun 2011 12:25:00 pm | 100 | 97.0 | 1.58 | 1.10 | 1.07 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 21 Jul 2010 10:30:00 am | 102 | 104 | −0.84 | 1.10 | 1.12 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 15 Jun 2010 10:15:00 am | 109 | 107 | 0.99 | 1.16 | 1.14 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 21 May 2010 09:25:00 am | 104 | 106 | −1.29 | 1.08 | 1.11 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 16 Mar 2010 09:50:00 am | 109 | 104 | 2.40 | 1.25 | 1.19 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 24 Feb 2010 10:40:00 am | 99.8 | 106 | −3.09 | 1.22 | 1.30 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 02 Dec 2009 12:02:00 am | 109 | 109 | 0.35 | 1.31 | 1.30 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 13 Oct 2009 03:35:00 pm | 113 | 108 | 1.95 | 1.40 | 1.34 | $Na^+$–$Cl^-$ |
| GW273040 | 1.1 | 01 Oct 2009 09:35:00 am | 112 | 114 | −1.05 | 1.41 | 1.44 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 19 Apr 2018 12:00:00 pm | 13.3 | 14.0 | −2.69 | 0.92 | 0.97 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 06 Aug 2014 12:00:00 am | 11.7 | 13.0 | −5.20 | n/a | n/a | n/a |
| GW273040 | 2.2 | 25 Jun 2013 12:30:00 pm | 15.0 | 14.7 | 0.80 | 0.95 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 26 Nov 2012 11:00:00 am | 14.8 | 14.1 | 2.59 | 0.98 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 21 Jun 2012 10:25:00 am | 11.8 | 11.5 | 1.41 | 0.96 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 10 Jun 2011 11:45:00 am | 11.2 | 10.6 | 2.92 | 0.97 | 0.92 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 21 Jul 2010 11:40:00 am | 10.2 | 9.58 | 3.20 | 0.90 | 0.84 | $Na^+$–$Cl^-$ |
| GW273040 | 2.2 | 20 Aug 2008 12:05:00 am | 12.7 | 13.5 | −2.98 | 0.94 | 1.00 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 19 Apr 2018 12:00:00 pm | 9.70 | 10.2 | −2.49 | 0.91 | 0.96 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 06 Aug 2014 12:00:00 am | 8.85 | 9.65 | −4.33 | 0.85 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 25 Jun 2013 11:20:00 am | 9.96 | 9.72 | 1.23 | 0.95 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 26 Nov 2012 10:10:00 am | 10.5 | 9.71 | 3.99 | 1.01 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 21 Jun 2012 09:20:00 am | 9.44 | 9.15 | 1.55 | 0.93 | 0.90 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 10 Jun 2011 11:05:00 am | 10.1 | 9.42 | 3.51 | 0.99 | 0.93 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 21 Jul 2010 01:10:00 pm | 19.3 | 17.7 | 4.15 | 1.06 | 0.97 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 15 Jun 2010 11:20:00 am | 8.59 | 9.54 | −5.25 | n/a | n/a | n/a |
| GW273040 | 3.3 | 21 May 2010 10:35:00 am | 9.24 | 9.32 | −0.45 | 0.77 | 0.78 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 16 Mar 2010 10:40:00 am | 10.1 | 9.62 | 2.25 | 0.86 | 0.82 | $Na^+$–$Cl^-$ |
| GW273040 | 3.3 | 24 Feb 2010 11:20:00 am | 9.80 | 9.74 | 0.30 | 0.89 | 0.89 | $Na^+$–$Cl^-$ |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| **GW273040** | 3.3 | 02 Dec 2009 12:01:00 am | 10.1 | 9.88 | 0.91 | 0.83 | 0.81 | $Na^+$–$Cl^-$ |
| **GW273040** | 3.3 | 13 Oct 2009 02:20:00 pm | 9.88 | 9.68 | 1.01 | 1.05 | 1.03 | $Na^+$–$Cl^-$ |
| **GW273040** | 3.3 | 01 Oct 2009 11:20:00 am | 9.49 | 9.74 | −1.28 | 1.01 | 1.04 | $Na^+$–$Cl^-$ |
| **GW273040** | 3.3 | 20 Aug 2008 12:04:00 am | 10.6 | 11.5 | −3.75 | 0.93 | 1.00 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 19 Apr 2018 12:00:00 pm | 18.7 | 18.9 | −0.62 | 0.93 | 0.94 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 06 Aug 2014 12:00:00 am | 16.9 | 18.2 | −3.78 | 0.90 | 0.97 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 25 Jun 2013 09:50:00 am | 18.6 | 19.4 | −2.02 | 0.94 | 0.98 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 26 Nov 2012 11:15:00 am | 19.6 | 19.3 | 0.71 | 0.96 | 0.95 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 21 Jun 2012 10:45:00 am | 17.7 | 17.9 | −0.58 | 0.91 | 0.92 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 10 Jun 2011 09:55:00 am | 19.2 | 18.3 | 2.53 | 0.99 | 0.94 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 15 Jun 2010 11:30:00 am | 18.6 | 18.0 | 1.47 | 1.00 | 0.97 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 21 May 2010 11:00:00 am | 18.2 | 18.3 | −0.38 | 0.95 | 0.96 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 16 Mar 2010 11:45:00 am | 19.2 | 18.3 | 2.34 | 1.04 | 0.99 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 02 Dec 2009 12:00:00 am | 20.8 | 20.4 | 0.97 | 1.09 | 1.07 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 13 Oct 2009 04:00:00 pm | 18.9 | 20.1 | −2.86 | 1.06 | 1.12 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 01 Oct 2009 10:30:00 am | 19.9 | 20.4 | −1.37 | 1.10 | 1.13 | $Na^+$–$Cl^-$ |
| **GW273040** | 4.4 | 20 Aug 2008 12:03:00 am | 17.4 | 18.6 | −3.25 | 0.96 | 1.03 | $Na^+$–$Cl^-$ |
| **GW273041** | 1.1 | 18 Apr 2018 12:00:00 pm | 308 | 289 | 3.13 | 1.07 | 1.01 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 04 Aug 2014 12:00:00 am | 347 | 337 | 1.56 | 1.14 | 1.11 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 27 Jun 2013 01:45:00 pm | 357 | 365 | −1.07 | 1.14 | 1.17 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 03 Dec 2012 01:20:00 pm | 395 | 365 | 3.95 | 1.27 | 1.18 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 07 Jun 2012 01:20:00 pm | 374 | 365 | 1.20 | 1.19 | 1.16 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 16 Jun 2011 01:00:00 pm | 379 | 365 | 1.82 | 1.18 | 1.14 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 11 Jun 2010 08:55:00 am | 388 | 366 | 2.86 | 1.24 | 1.17 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 13 May 2010 08:55:00 am | 366 | 366 | −0.07 | 1.16 | 1.16 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 15 Apr 2010 08:15:00 am | 371 | 367 | 0.54 | 1.48 | 1.46 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 17 Feb 2010 09:15:00 am | 375 | 365 | 1.25 | 1.56 | 1.52 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 18 Jan 2010 01:40:00 pm | 388 | 364 | 3.08 | 1.64 | 1.54 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 01 Dec 2009 12:02:00 am | 366 | 365 | 0.16 | 1.69 | 1.69 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 22 Oct 2009 01:30:00 pm | 379 | 366 | 1.75 | 1.71 | 1.66 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 22 Sep 2009 04:15:00 pm | 348 | 366 | −2.54 | 1.90 | 2.00 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 1.1 | 21 Aug 2008 12:00:00 am | 378 | 364 | 1.91 | 1.42 | 1.36 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$Cl^-$ |
| **GW273041** | 2.2 | 18 Apr 2018 12:00:00 pm | 3.83 | 3.69 | 1.86 | 0.94 | 0.91 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 2.2 | 06 Sep 2017 12:00:00 am | 4.00 | 4.63 | −7.22 | n/a | n/a | n/a |
| **GW273041** | 2.2 | 27 Apr 2016 12:00:00 am | 3.86 | 4.68 | −9.61 | n/a | n/a | n/a |
| **GW273041** | 2.2 | 04 Aug 2014 12:00:00 am | 3.30 | 3.83 | −7.40 | n/a | n/a | n/a |
| **GW273041** | 2.2 | 27 Jun 2013 01:20:00 pm | 3.42 | 3.82 | −5.57 | n/a | n/a | n/a |
| **GW273041** | 2.2 | 03 Dec 2012 12:40:00 pm | 4.01 | 3.83 | 2.31 | 0.92 | 0.88 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 2.2 | 07 Jun 2012 02:00:00 pm | 3.87 | 3.87 | −0.01 | 0.94 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 2.2 | 16 Jun 2011 12:30:00 pm | 3.11 | 3.79 | −9.88 | n/a | n/a | n/a |
| **GW273041** | 2.2 | 20 Aug 2008 12:00:00 am | 4.17 | 4.39 | −2.54 | 0.90 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 3.3 | 18 Apr 2018 12:00:00 pm | 4.12 | 3.47 | 8.62 | n/a | n/a | n/a |

| Station[8] | Pipe | Sample time | Cation sum (mEq/L) | Anion sum (mEq/L) | Anion-cation balance (%) | Cation sum / electrical conductivity | Anion sum / electrical conductivity | Water type |
|---|---|---|---|---|---|---|---|---|
| **GW273041** | 3.3 | 06 Sep 2017 12:00:00 am | 3.99 | 4.57 | −6.76 | n/a | n/a | n/a |
| **GW273041** | 3.3 | 27 Apr 2016 12:00:00 am | 3.82 | 4.62 | −9.49 | n/a | n/a | n/a |
| **GW273041** | 3.3 | 04 Aug 2014 12:00:00 am | 3.52 | 4.04 | −6.90 | n/a | n/a | n/a |
| **GW273041** | 3.3 | 27 Jun 2013 12:20:00 pm | 4.03 | 3.93 | 1.32 | 0.96 | 0.94 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 3.3 | 03 Dec 2012 11:30:00 am | 4.31 | 4.08 | 2.81 | 1.02 | 0.97 | ($Na^+$–$Mg^{2+}$)–$HCO_3^-$ |
| **GW273041** | 3.3 | 07 Jun 2012 12:30:00 pm | 3.82 | 3.96 | −1.80 | 0.89 | 0.92 | ($Na^+$–$Mg^{2+}$)–$HCO_3^-$ |
| **GW273041** | 3.3 | 16 Jun 2011 11:40:00 am | 4.25 | 3.98 | 3.24 | 0.98 | 0.92 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 11 Jun 2010 10:10:00 am | 4.28 | 4.28 | −0.06 | 0.44 | 0.44 | ($Na^+$–$Mg^{2+}$–$Ca^{2+}$)–$HCO_3^-$ |
| **GW273041** | 3.3 | 13 May 2010 10:15:00 am | 4.31 | 4.31 | 0.00 | 0.36 | 0.36 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 15 Apr 2010 11:30:00 am | 4.04 | 4.15 | −1.27 | 0.93 | 0.95 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 17 Feb 2010 03:15:00 pm | 4.21 | 4.04 | 2.10 | 0.98 | 0.94 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 18 Jan 2010 02:45:00 pm | 4.22 | 3.86 | 4.41 | 0.95 | 0.87 | ($Na^+$–$Mg^{2+}$)–$HCO_3^-$ |
| **GW273041** | 3.3 | 01 Dec 2009 12:00:00 am | 4.26 | 4.10 | 2.00 | 0.86 | 0.83 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 22 Oct 2009 12:45:00 pm | 4.04 | 4.15 | −1.39 | 0.93 | 0.96 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 28 Sep 2009 05:00:00 pm | 4.05 | 4.15 | −1.28 | 0.93 | 0.95 | ($Na^+$–$Mg^{2+}$)–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 3.3 | 18 Aug 2008 12:01:00 am | 4.19 | 4.34 | −1.84 | 0.91 | 0.94 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| **GW273041** | 4.4 | 18 Apr 2018 12:00:00 pm | 3.65 | 3.20 | 6.59 | n/a | n/a | n/a |
| **GW273041** | 4.4 | 06 Sep 2017 12:00:00 am | 3.91 | 4.80 | −10.2 | n/a | n/a | n/a |
| **GW273041** | 4.4 | 27 Apr 2016 12:00:00 am | 3.78 | 4.73 | −11.1 | n/a | n/a | n/a |
| **GW273041** | 4.4 | 04 Aug 2014 12:00:00 am | 3.76 | 3.67 | 1.22 | 0.94 | 0.92 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 4.4 | 27 Jun 2013 10:40:00 am | 3.86 | 3.71 | 2.02 | 0.95 | 0.92 | $Na^+$–$Cl^-$ |
| **GW273041** | 4.4 | 03 Dec 2012 10:30:00 am | 4.05 | 3.95 | 1.29 | 0.99 | 0.96 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 4.4 | 07 Jun 2012 11:00:00 am | 3.95 | 3.79 | 2.07 | 0.96 | 0.92 | $Na^+$–$Cl^-$ |
| **GW273041** | 4.4 | 16 Jun 2011 10:20:00 am | 4.05 | 3.73 | 4.05 | 0.98 | 0.91 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| **GW273041** | 4.4 | 11 Jun 2010 10:50:00 am | 3.52 | 3.90 | −5.11 | n/a | n/a | n/a |
| **GW273041** | 4.4 | 13 May 2010 10:35:00 am | 3.80 | 3.96 | −2.14 | 0.88 | 0.92 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 4.4 | 15 Apr 2010 09:40:00 am | 3.87 | 3.98 | −1.45 | 0.93 | 0.96 | $Na^+$–($HCO_3^-$–$Cl^-$) |
| **GW273041** | 4.4 | 17 Feb 2010 12:20:00 pm | 3.96 | 3.67 | 3.77 | 0.98 | 0.91 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| **GW273041** | 4.4 | 18 Jan 2010 11:53:00 am | 3.77 | 3.67 | 1.35 | 0.93 | 0.91 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 4.4 | 01 Dec 2009 12:01:00 am | 4.09 | 3.80 | 3.64 | 1.02 | 0.95 | $Na^+$–$Cl^-$ |
| **GW273041** | 4.4 | 22 Oct 2009 09:30:00 am | 3.78 | 3.69 | 1.20 | 0.95 | 0.92 | $Na^+$–($Cl^-$–$HCO_3^-$) |
| **GW273041** | 4.4 | 25 Sep 2009 12:00:00 pm | 3.82 | 3.91 | −1.16 | 0.95 | 0.97 | $Na^+$–$HCO_3^-$ |
| **GW273041** | 4.4 | 18 Aug 2008 12:00:00 am | 3.43 | 3.64 | −2.94 | 0.92 | 0.97 | $Na^+$–$HCO_3^-$ |