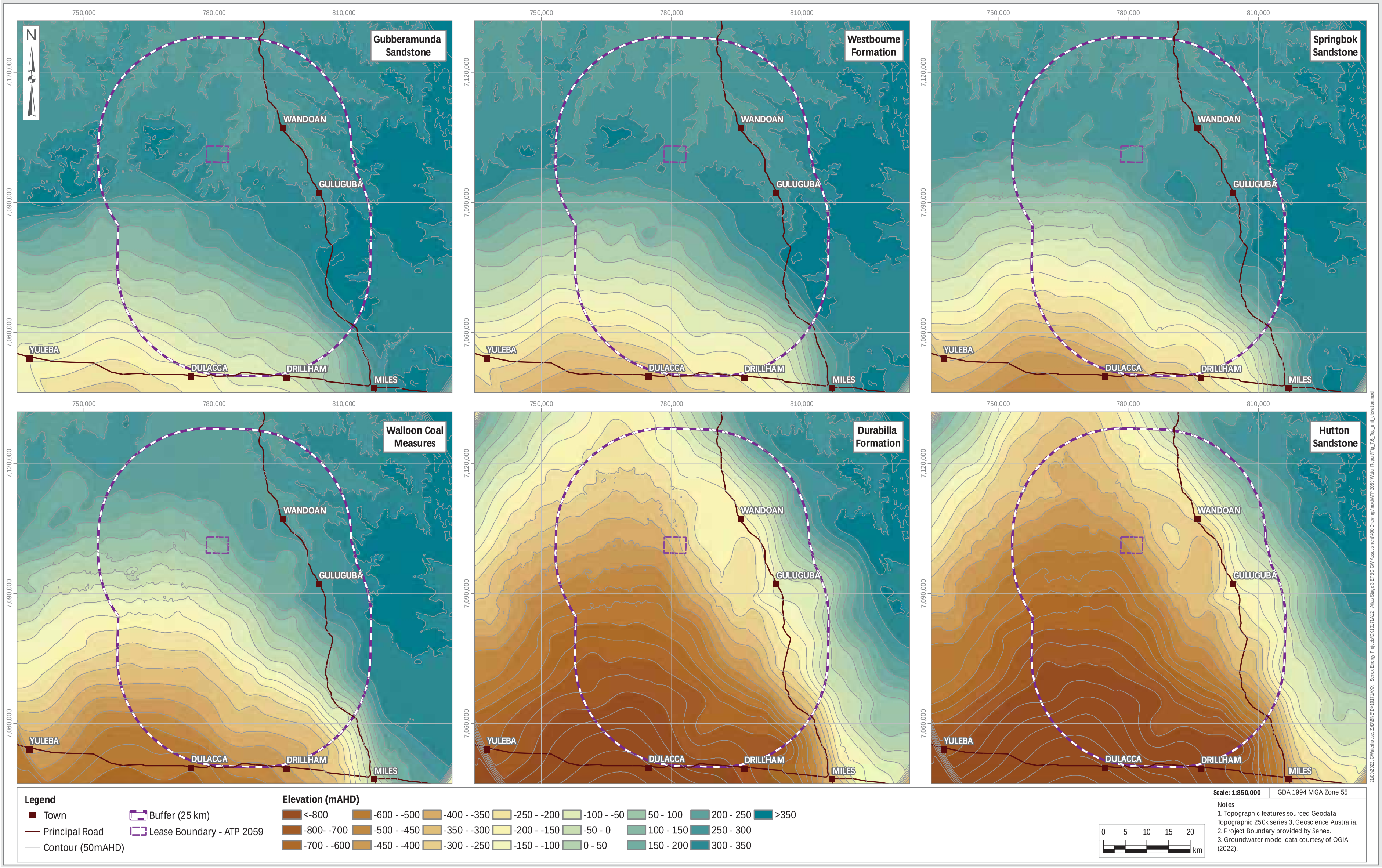


Figure 7.6 Top of Unit Elevation for Relevant Surat Basin Units (OGIA 2021g)

7.3.2 Alluvium

Quaternary-age alluvium is mapped within the Project area and is associated with Wandoan, and Woleebee Creeks. The lateral extent of the alluvium increases in the northeast of ATP 2059 towards the confluence of Wandoan Creek and Woleebee Creek. For Wandoan Creek, due to its location within the sub-catchment, topographic elevation and ephemeral nature, the alluvium is expected to be relatively thin and poorly developed, although sand banks up to 5 m high have been observed. Alluvium associated with Woleebee Creek is deeper and assumed to be well-developed. There are two registered bores installed in the alluvium of Woleebee Creek in the east of ATP 2059 (RN 123247 and RN123246) with alluvium up to 18 m deep.

Observations of the alluvium in Woleebee and Wandoan Creek were made in the field verification for Project Atlas (KCB 2018d), close to and within the Project area and summarised below.

Wandoan Creek Alluvium

- The bedrock geology beneath Wandoan Creek in ATP 2059 is the Westbourne Formation.
- The Gubberamunda Sandstone outcrops further upstream, outside of the Project area to the west. Other Gubberamunda outcrops are present to the north and south of the creek in the Project Atlas tenements.
- The creek bed generally consists of silt / silty sand. The creek bed is generally sandier upstream where the creek is closer to the Gubberamunda Sandstone outcrop and becomes silty and clayey downstream consistent with the underlying geology (Westbourne Formation).
- One small rock outcrop was identified along Wandoan Creek on PL 1037 to the west of ATP 2059. This is described as a fine-grained sandstone, which is friable and considered to be a lithological unit of the Westbourne Formation. This unit had been moulded by surface water flow within the creek (Figure 7.7).
- Alluvial sand was encountered to a distance of approximately 400 m from the creek bed, just south of Weldon's Road, which passes north of Wandoan Creek. This is consistent with the geological mapping.

Figure 7.7 Bedrock and superficial geology encountered at Wandoan Creek A) Outcrop of fine-grained sandstone; B) Sandy creek bed in the upstream sections of the creek

Woleebee Creek Alluvium

- In the upper reaches of the Woleebee Creek (in PL 1037), the creek bed is sandy. The sand is coarse-grained and considered to be associated with the Gubberamunda Sandstone (which outcrops upstream). Further downstream where the creek is underlain by the Westbourne Formation, the creek bed becomes more silty and clayey (Figure 7.8).
- A rock outcrop was identified in the upper reaches of the creek on PL 1037 (Figure 7.8). The base of the outcrop consisted of mudstones considered to be part of the Westbourne Formation, which is overlain by an 'ironstone' and is interpreted to have been formed by the chemical precipitation of iron and manganese. Overlaying the ironstone is a fine gravel conglomerate which in turn is overlain with coarse-grained sandstone with cross-bedding. The coarse-grained sandstone is typical of the Gubberamunda Sandstone. The outcrop is considered to show the conformity between the Gubberamunda Sandstone and the underlying Westbourne Formation.
- Other rock outcrops were observed downstream. These consisted of mudstones and fine-grained sandstone associated with the Westbourne Formation. These rocks were weak and friable.
- The change in bedrock geology could have resulted in the change in the meandering nature of the creek. The presence of the harder coarse-grained sandstone of the Gubberamunda Sandstone may have resulted in a straighter creek channel upstream, with the weak and friable mudstones of the Westbourne Formation resulting in a meandering form downstream.

Figure 7.8 Bedrock and superficial geology encountered at Woleebee Creek A) Outcrop of fine-grained sandstone and mudstone (Westbourne Formation); B) Typical sandy creek bed

7.4 Aquifer / Aquitard Hydraulic Properties

A number of hydraulic tests, to determine hydraulic parameters, have been conducted across the Surat Basin on formations overlying and underlying the WCM.

Hydraulic Conductivity

OGIA (2019b) present the measured range of hydraulic conductivities estimated from core, drill stem tests (DSTs) and pumping tests within the Surat CMA on Figure 7.9. The data was compiled from a range of sources including the Queensland Groundwater Database (GWDB), Queensland Petroleum Exploration Database (QPED), GAB Water Resource Assessment (Smerdon et al. 2012) and public domain sourced investigations undertaken by other CSG proponents including QGC, APLNG and Arrow Energy.

Ranges of horizontal permeability values from these tests, together with model calibrated values indicate that the Gubberamunda and Precipice Sandstones are the most permeable consolidated formations in the Surat CMA (Figure 7.9) (OGIA 2019b).

Limited site-specific hydraulic parameter values are available for the alluvium within the Project area. A hydraulic conductivity of between 0.2 and 1.4 m/d has been reported for the alluvium associated with Horse Creek (AGE 2012), which is located in an adjacent catchment approximately 20 km northwest of the Project.

Storage

Estimates of storage parameters are presented in documentation for the neighbouring QGC tenures (Golder Associates 2009b). The storage coefficient is reported to range between 5×10^{-3} and 5×10^{-4} for all consolidated hydrostratigraphic units.

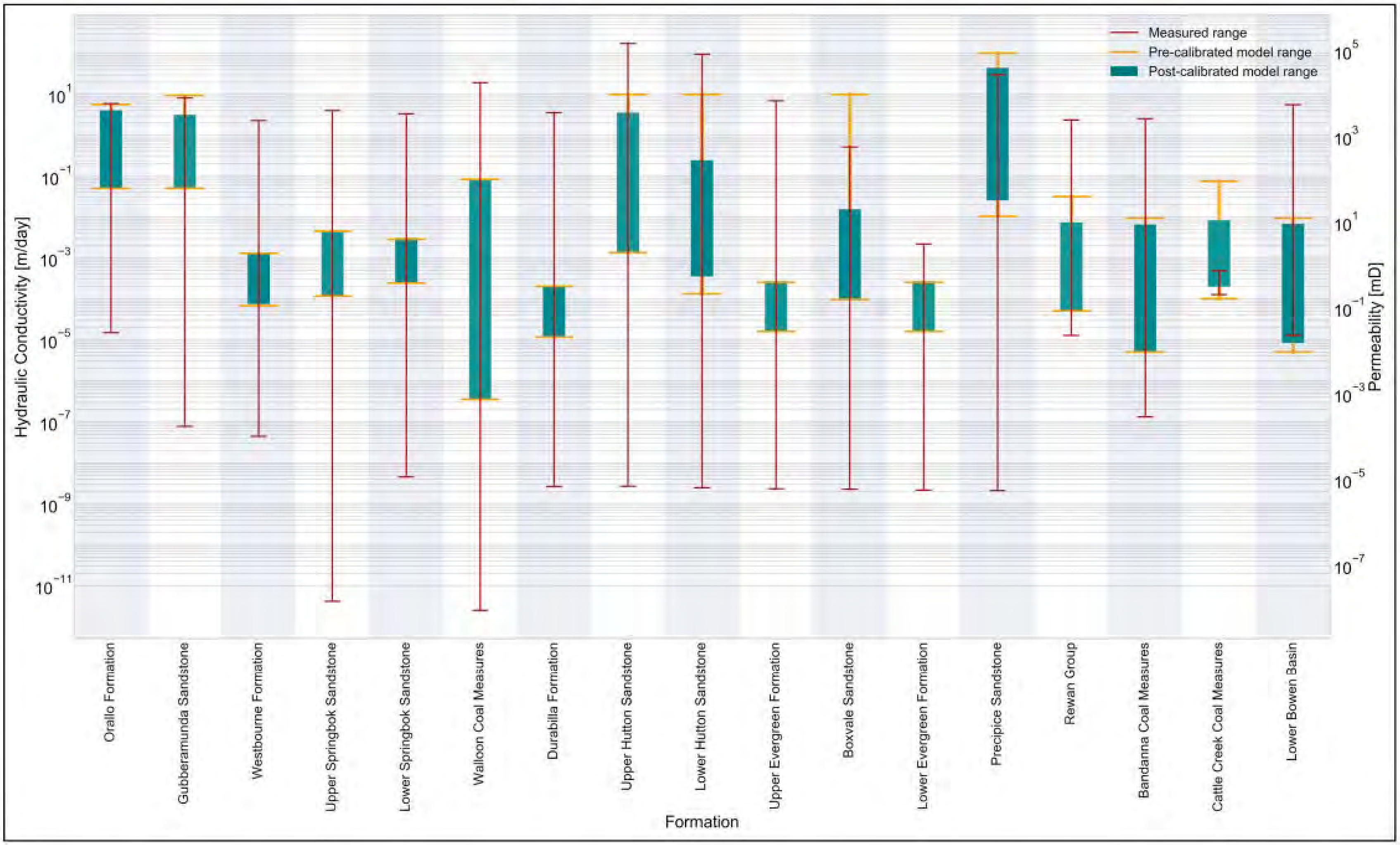


Figure 7.9 Hydraulic Conductivity Values for Surat Basin Units (after OGIA 2019b)

7.5 Inter-Aquifer Connectivity

The Surat Basin comprises layers of aquifers and aquitards of varying hydraulic properties. The formations predominantly comprise fluvial sedimentary deposits that have formed stratifications of sand, silt and clay within and across hydrostratigraphic formations (OGIA 2016b). Groundwater flow within the Surat Basin hydrostratigraphic units is predominantly horizontal, as vertical flow is restricted by the spatial extent and continuity of aquitards, and by lower permeability horizons within the aquifers (OGIA 2016b).

Across the Project extent, there is potential for interaction between the WCM and aquifers above and below, specifically the overlying Springbok Sandstone and underlying Hutton Sandstone (separated from the WCM by the Durabilla Formation). The Durabilla Formation is mapped across the entire Project area, with a mean thickness of 87 m (Figure 7.10), which provides a significant vertical barrier between the WCM and underlying Hutton Sandstone. An upper WCM aquitard has been mapped by OGIA (the Walloon Coal Measures non-productive zone, OGIA 2021g) as being up to 25 m thick across the Project area, separating the WCM coal seams from the overlying Springbok Sandstone.

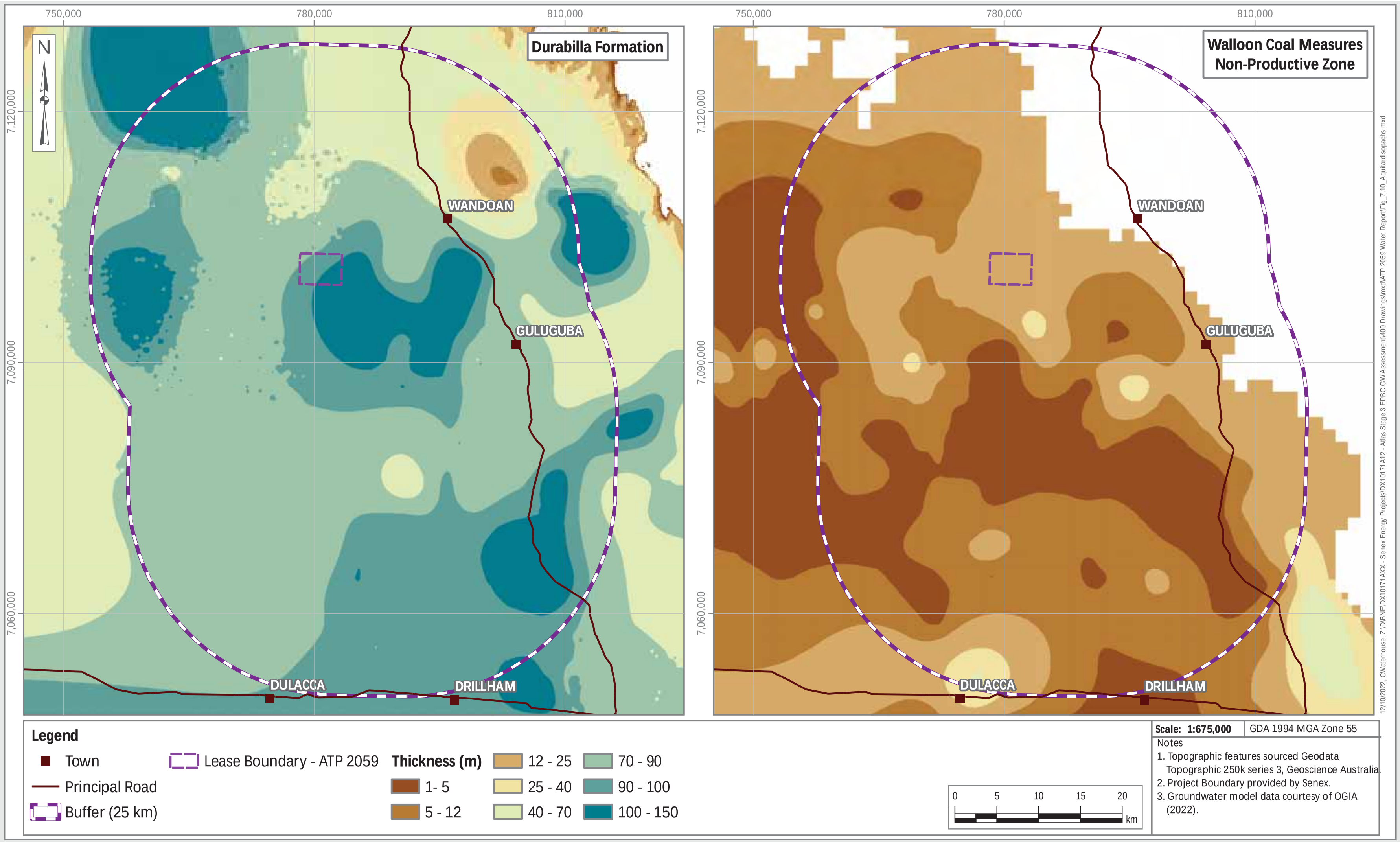


Figure 7.10 Aquitard Isopachs (OGIA 2017a; 2021g)

7.6 Groundwater Recharge

Groundwater recharge processes within the Surat Basin are summarised in the *Hydrogeological Conceptualisation Report for the Surat Cumulative Management Area* (OGIA 2016b) and based on Kellett et al. (2003), and *Regional flow systems and potentiometry in Queensland's Surat and Southern Bowen Basins* (OGIA 2021d). Key processes of recharge include localised recharge, preferential pathway flow and diffuse recharge:

- Localised recharge occurs beneath drainage features including rivers, creeks and alluvial and Tertiary groundwater systems where there is sufficient saturation and hydraulic head to allow water to infiltrate into aquifers. Areas of localised recharge are considered limited in extent in the GAB (Kellett et al. 2003).
- Preferential pathway flow arises from changes in permeability within aquifers and in overlying regolith, providing conduits for water to infiltrate. Zones of higher permeability may include fissures, faults, joints, tree roots and high-permeability beds within individual formations and along bedding planes (Kellett et al. 2003; Sucklow et al. 2016). This mechanism is considered the dominant recharge process in the GAB (Kellett et al. 2003).
- Diffuse discharge is the process by which rainfall infiltrates directly though outcropping aquifers. This is expected to occur within all outcrop areas and therefore this process applies to the largest spatial extent (Kellett et al. 2003).

Within the vicinity of the Project area, groundwater recharge is likely to occur as a result of localised recharge occurring beneath watercourses and alluvial systems where sufficient saturation and hydraulic head allows water to infiltrate into surficial aquifers. Recharge will also occur as diffuse recharge with rainfall infiltrating directly through outcropping aquifers, such as the Gubberamunda Sandstone which outcrops in the south of ATP 2059.

Recharge estimates were made by OGIA (OGIA 2019a):

- Orallo Formation (outcrops to the south) – 2.4 mm/year.
- Gubberamunda Sandstone (outcrops in the Project area) – 3.4 mm/year.
- Westbourne Formation (outcrops in the Project area) – 1.6 mm/year.
- Springbok Sandstone (outcrops to the northeast) – 1.3 mm/year.

7.7 Groundwater Levels and Flow

7.7.1 Regional Groundwater Flow

Basin scale groundwater flow within the Surat Basin is typically north to south from northern outcrop areas. There is also a preference of groundwater to flow towards the north (towards Taroom) on the northern side of the Great Dividing Range with groundwater discharging into the Dawson River catchment (OGIA 2016c; 2021d). South of the Range, groundwater flow is generally southward, broadly consistent with the dip of the formation (OGIA 2021d).

Groundwater movement is slow in the GAB with flow velocities estimated at 1 to 5 m/yr (Habermehl 1980). Generally, groundwater flow and movement occurs as sub-horizontal flow, with limited vertical leakage across formations, where pressure differences may exist (OGIA 2016c). Local groundwater flow conditions may be different from regional flow conditions with potential steeper gradients and increased velocities in response to hydraulic stresses such as groundwater abstraction.

7.7.2 Groundwater Elevation and Monitoring Bores

There are 79 active monitoring bores at 56 sites within the 25 km buffer (State of Queensland 2021c) (Figure 7.11 and Table 7.2). The majority of these monitoring bores are installed as part of the UWIR and other programs, such as the CSG Online or CSG Net programs, which are coordinated by the Queensland Government. In addition, there are ten seepage monitoring bores installed by Senex in the Westbourne Formation, for monitoring of potential seepage from established development infrastructure for Project Atlas (within PL 1037) as required by the EA for that project (EA0001207).

Individual maps of monitoring bore locations, for each formation, are provided in the following sections. It should be noted that some of the monitoring bore data is not currently available through the GWDB, which may be a function of recent installation, or the frequency of data entry into the GWDB. Aquifer attributions for the monitoring bores have been determined by OGIA as part of their 2021 Surat CMA numerical groundwater model update (OGIA 2022).

Table 7.2 Groundwater Monitoring Bores Within 25 km Buffer

Formation	No. of Monitoring Bores
Wallumbilla Formation	1
Mooga Sandstone	3
Gubberamunda Sandstone	11
Westbourne Formation	10
Upper Springbok Sandstone	7
Lower Springbok Sandstone	2
Upper Juandah Coal Measures	9
Lower Juandah Coal Measures	11
Taroom Coal Measures	7
Durabilla Formation	2
Lower Evergreen Formation	1
Upper Hutton Sandstone	8
Lower Hutton Sandstone	3
Precipice Sandstone	4
Total	**79**

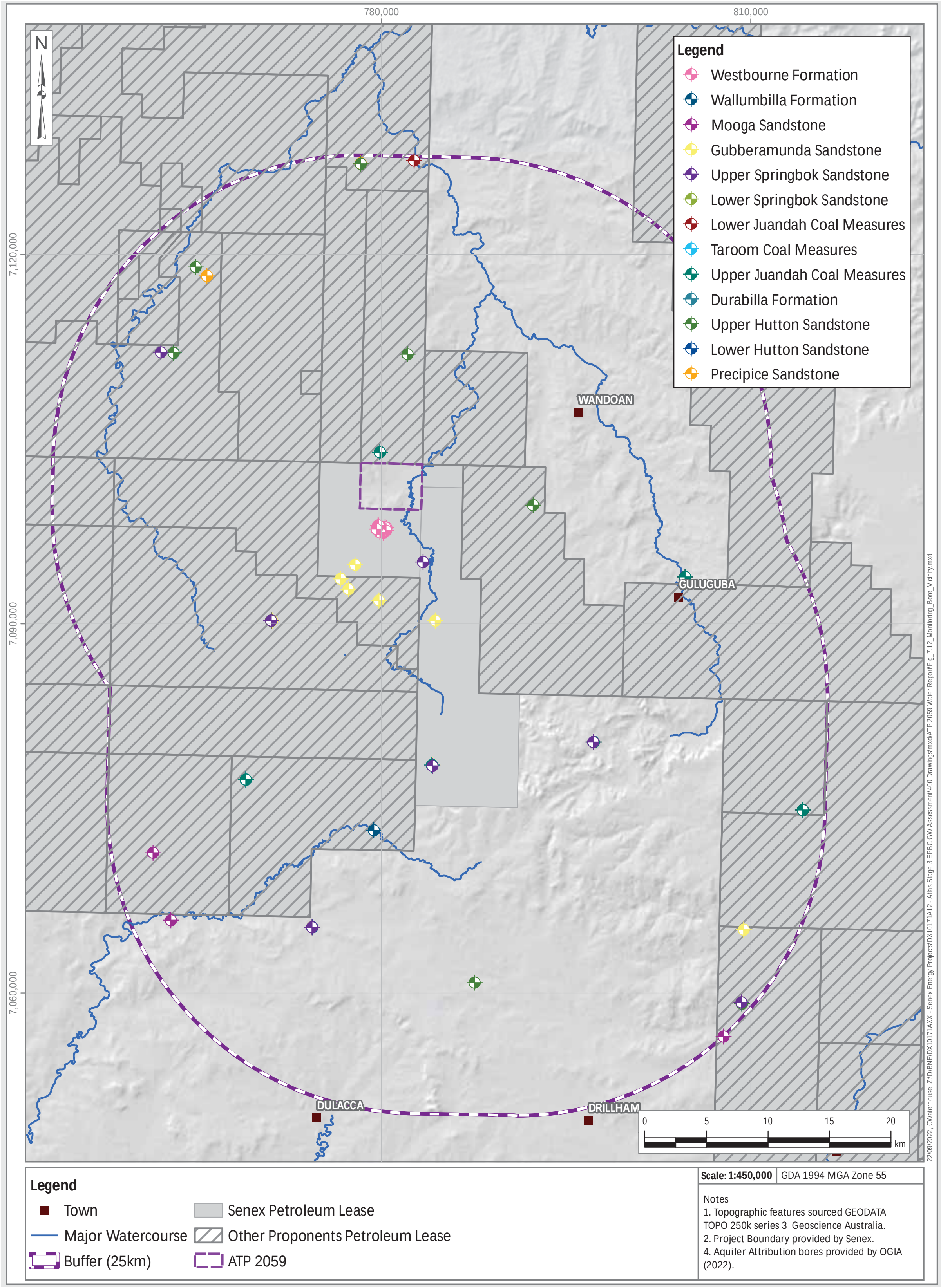


Figure 7.11 Location of Monitoring Bores within the Vicinity of the Project

Gubberamunda Sandstone Monitoring Bores

There are eleven Gubberamunda Sandstone monitoring bores within the 25 km buffer zone surrounding the Project area. Bore locations are shown on Figure 7.12, and a groundwater elevation hydrograph is presented for the bores on Figure 7.13.

Observations from available data include:

- Groundwater elevations range between ~269 and ~314 mAHD, with highest elevations corresponding to highest ground elevations in the southeast. RN43482 exhibits the lowest groundwater elevation, located immediately to the west of PL 445 within ATP 2059.
- Groundwater levels in most bores are either stable (particularly shallow bores) or exhibit slightly declining trends. RN160522 (located due west of PL 445) has seen a steep decline from 2012, followed by an increase to 2016 after which levels stabilised. This observation is supported by rainfall CRD (Figure 5.2), indicating some degree of climatic influence at that location. RN123553 has seen periodic water level increases and decreases of +/- 12 m since 2016 and may be influenced by pumping. RN13030808 located in PL 209 remains stable since pre-2010 with an elevation of ~282 mAHD.
- Inferred groundwater flow within the Gubberamunda Sandstone is northwest and south from a high point at RN160704. This observation corresponds with expected groundwater flow directions on either side of the river basin divide at the southern extent of PL 209.

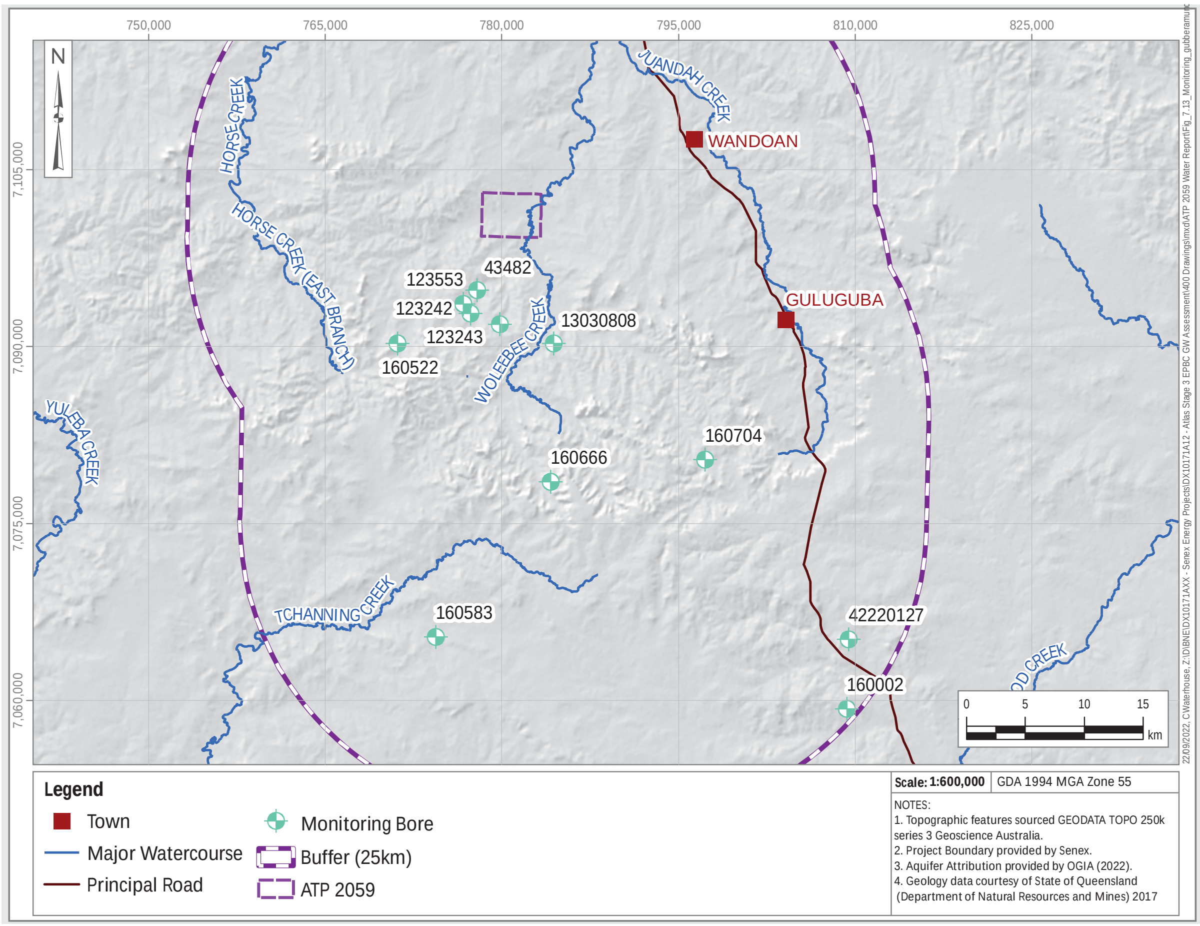


Figure 7.12 Location of Gubberamunda Sandstone Monitoring Bores

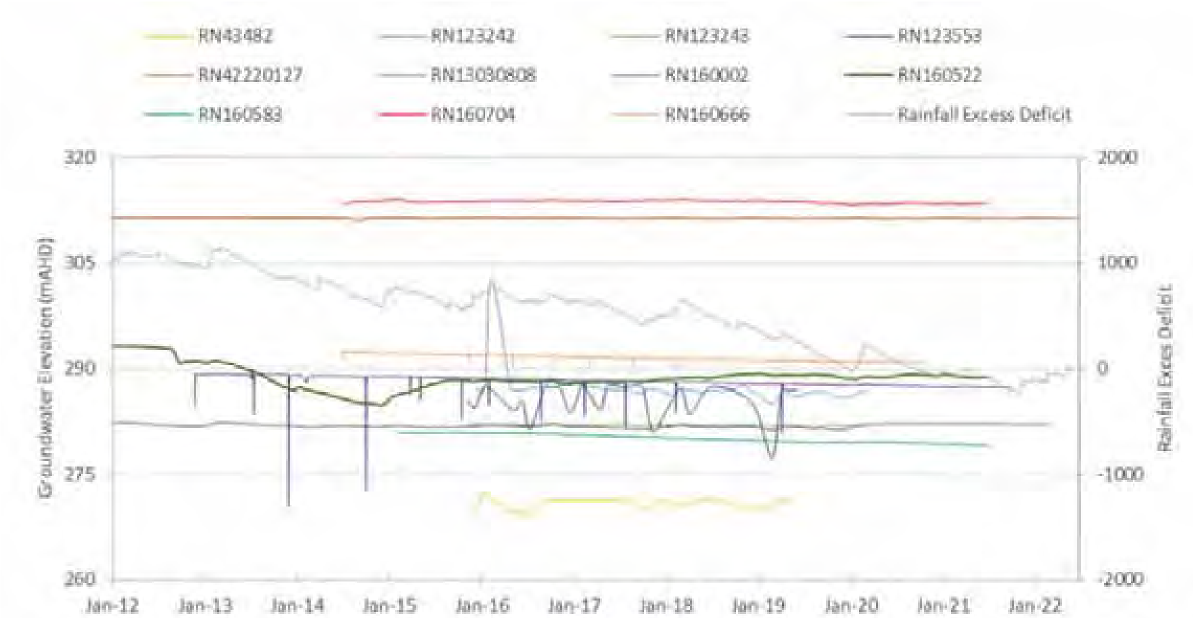


Figure 7.13 Groundwater Elevation Hydrograph – Gubberamunda Sandstone

Westbourne Formation Monitoring Bores

There are ten monitoring bores on the Project Atlas tenure screened within the Westbourne Formation, with the locations shown on Figure 7.14. These bores were installed by Senex for seepage monitoring of Project Atlas produced water dams.

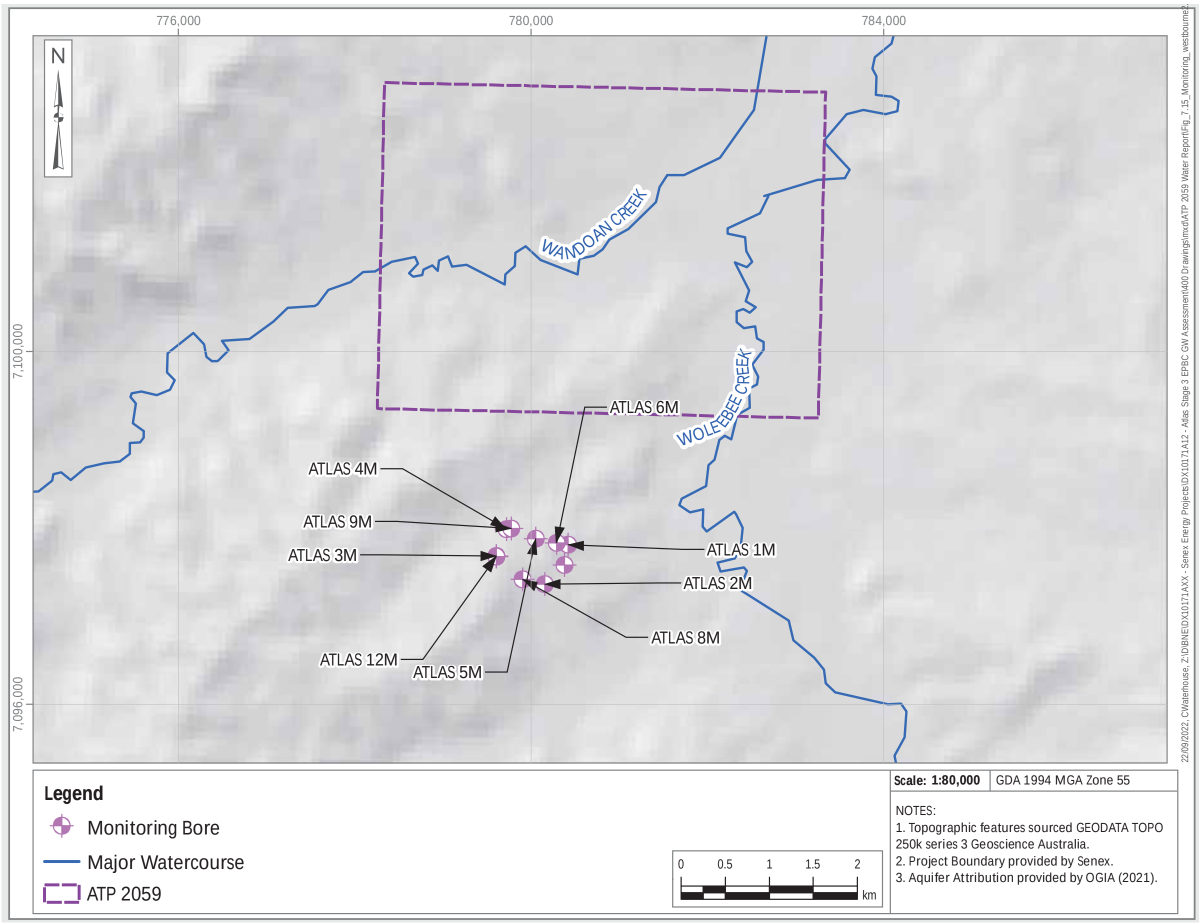


Figure 7.14 Location of Westbourne Formation Monitoring Bores

Figure 7.15 presents the groundwater elevation for seven of the ten bores screened within the Westbourne Formation. These bores have been monitored from June 2020 and were installed by Senex. Of the ten bores, only six are monitored consistently with four being consistently dry (Atlas 6M, 7M, 8M and 12M). The hydrographs identify that groundwater elevations range between ~257 mAHD and 264 mAHD. Groundwater levels in these bores have remained relatively stable across the monitoring period, with a rise of approximately 3 m observed in monitoring bore Atlas 2M.

Groundwater within the Westbourne Formation at the Atlas produced water dams occurs in a shallow and deeper confined groundwater system. In the deeper Westbourne Formation, flow direction is towards the east-southeast with a low horizontal hydraulic gradient across the site (Senex 2022).

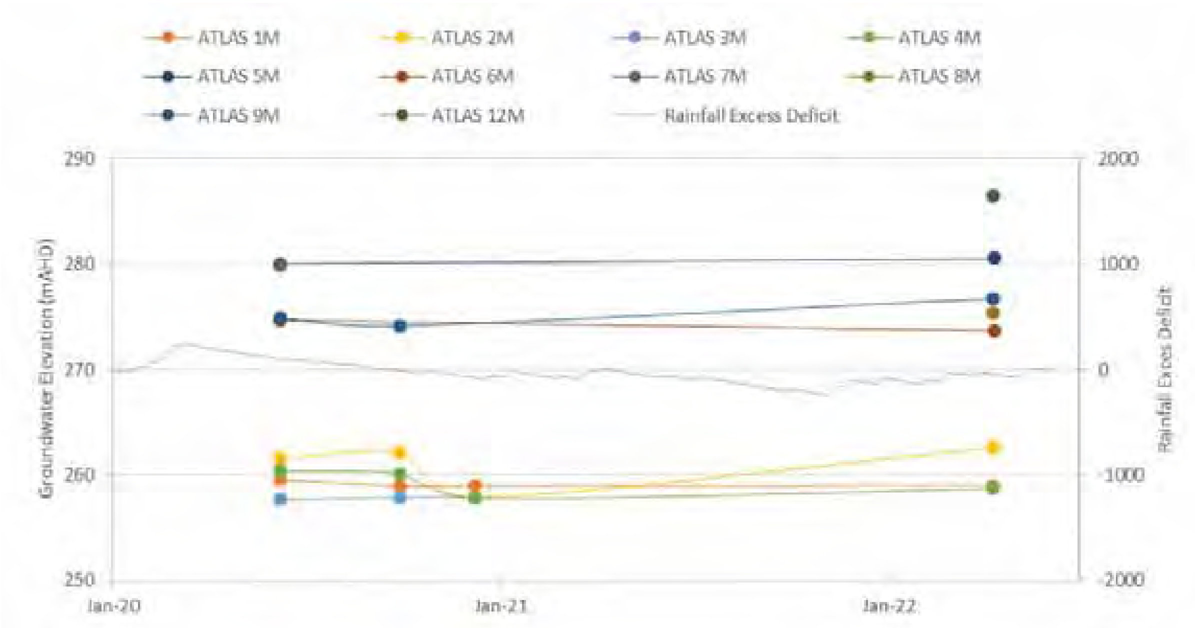


Figure 7.15 Groundwater Elevation Hydrograph – Westbourne Formation

Upper Springbok Sandstone Monitoring Bores

There are seven Upper Springbok Sandstone monitoring bores within the 25 km buffer zone. Bore locations are shown on Figure 7.16, and a groundwater elevation hydrograph is presented for the bores on Figure 7.17.

Observations from available data include:

- Groundwater elevations range between ~250 and ~335 mAHD, with highest elevations corresponding to highest ground elevations in the south (RN160193). RN180018 exhibits the lowest groundwater elevation, located at the northwest extent of the 25 km buffer, adjacent to the east branch of Horse Creek.
- RN160694 and RN160812 exhibit periodic pumping and recovery trends associated with landholder pumping which is common in Springbok Sandstone bores. Slow and frequently incomplete recovery trends indicate homogeneity and low permeability within the Springbok Sandstone (OGIA 2021g).
- Groundwater levels in most bores have remained stable since 2016. RN160431 (located ~12 km due west of PL 209) has seen a steep decline from 2012 until 2019 when levels stabilised. Overall decline was ~36 m over 10 years. A moderate concentration of groundwater use has been noted in this area and is considered to be contributing locally to drawdown (OGIA 2021d).
- Inferred groundwater flow within the Upper Springbok Sandstone is northwest from a high point at RN160193, this aligns with observations from OGIA (OGIA 2021d).

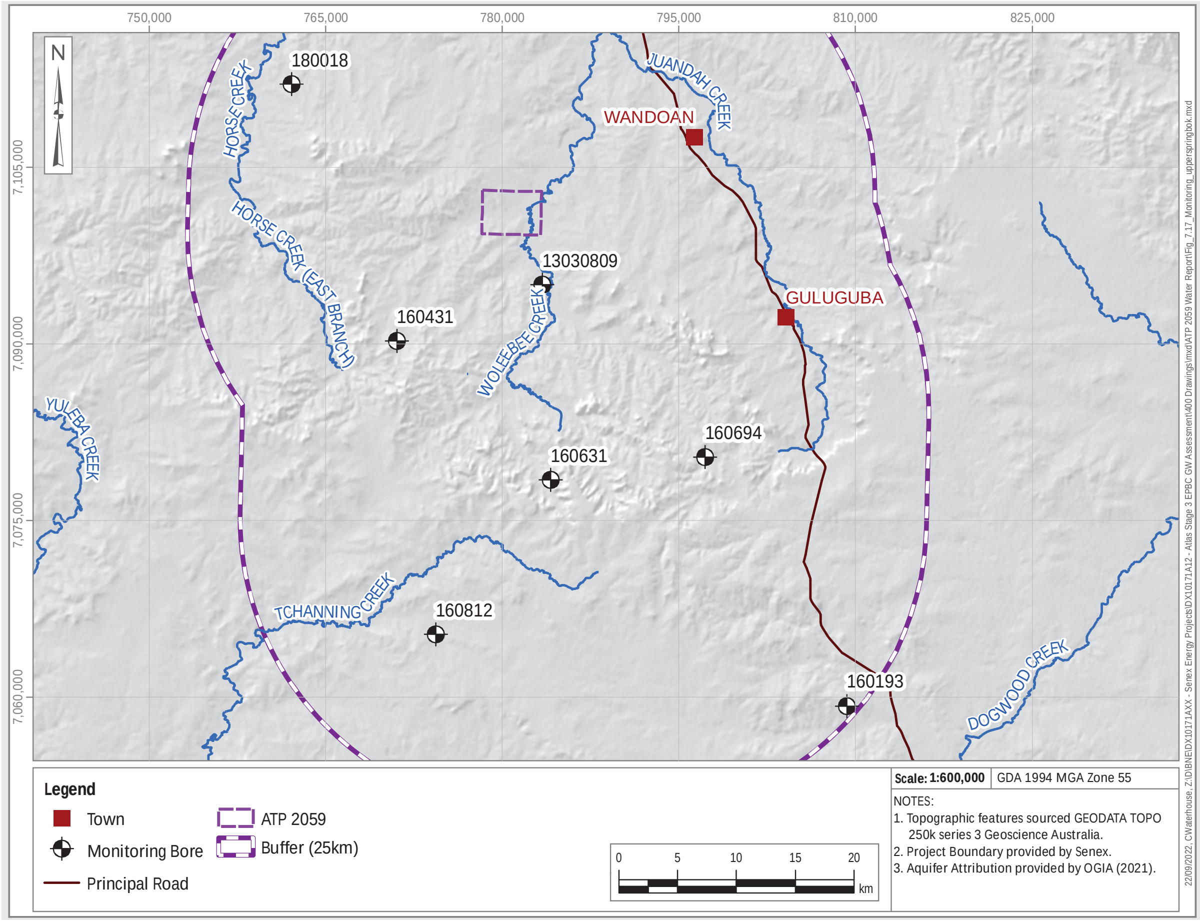


Figure 7.16 Location of Upper Springbok Sandstone Monitoring Bores

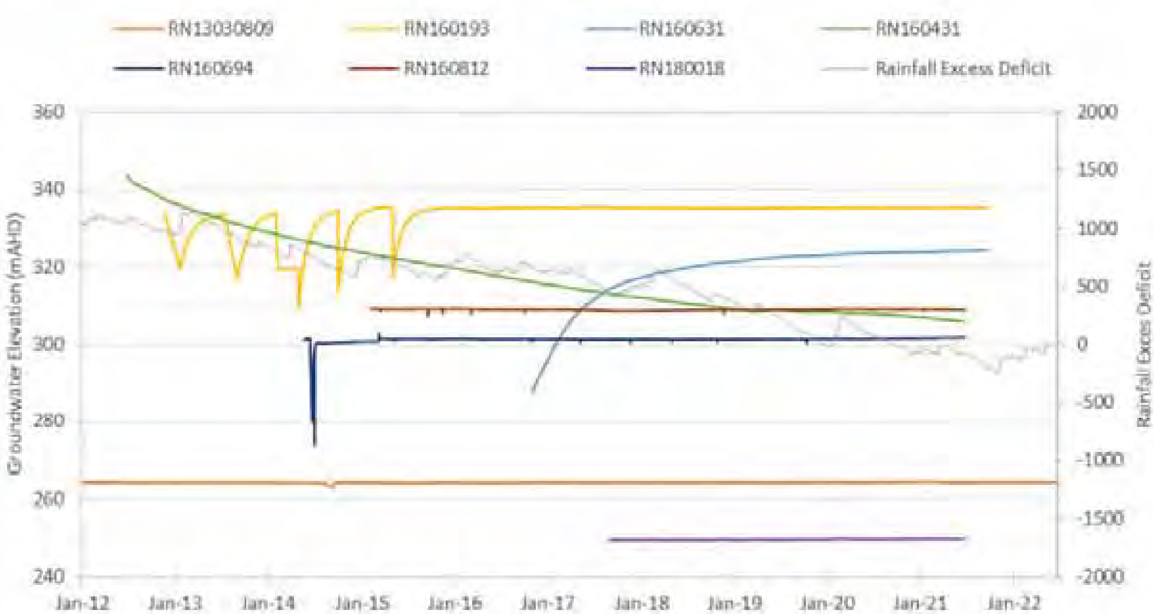


Figure 7.17 Groundwater Elevation Hydrograph – Upper Springbok Sandstone

Lower Springbok Sandstone Monitoring Bores

There are two Lower Springbok Sandstone monitoring bores, at two locations, with groundwater elevation data available in the vicinity of the Project area. The location of these bores is shown in Figure 7.18.

There are two Lower Springbok Sandstone monitoring bores within the 25 km buffer zone, a groundwater elevation hydrograph is presented for those bores on Figure 7.19.

Observations from available data include:

- Groundwater elevations range between ~269 and ~277 mAHD. Groundwater levels in in RN 160853 have remained stable, however RN 160430 may be influenced by pumping in the Upper Sandstone (OGIA 2021d).

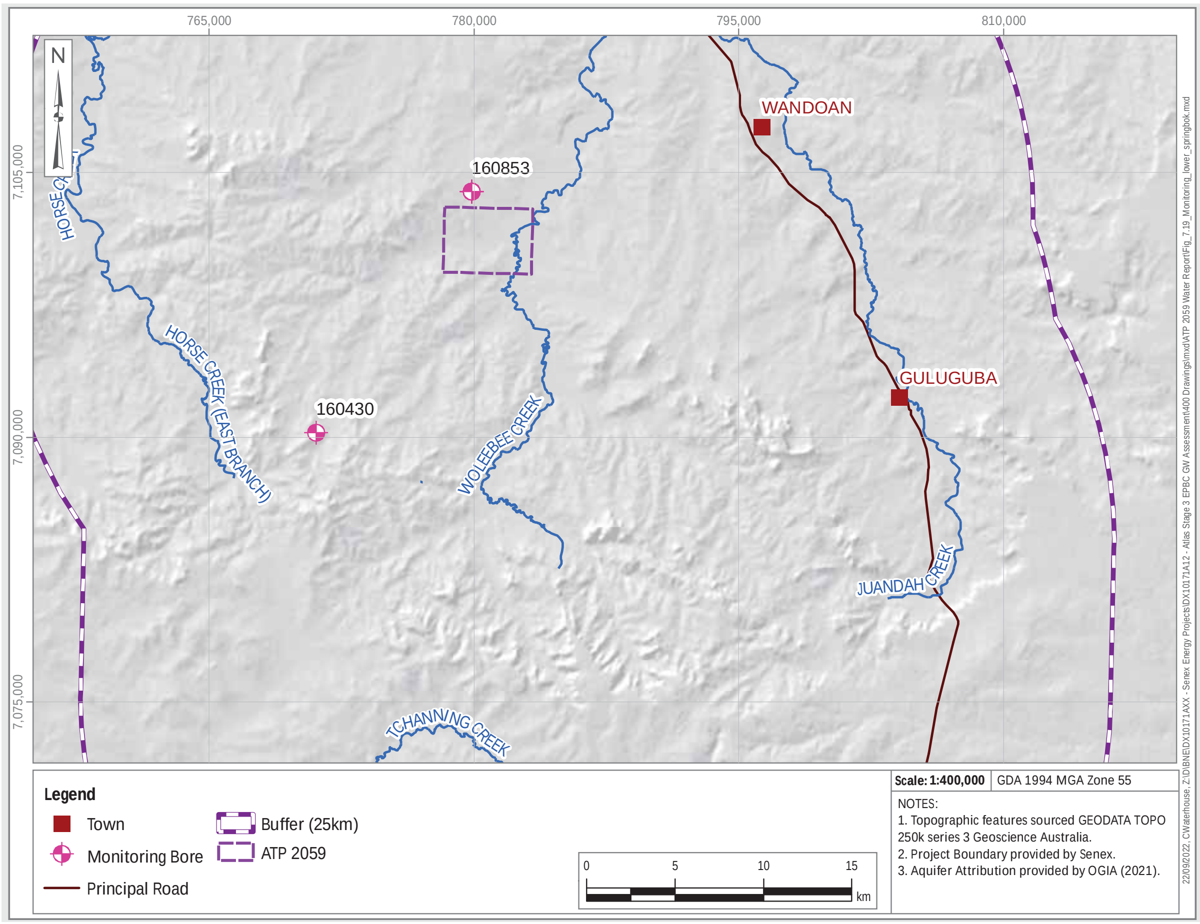


Figure 7.18 Location of Lower Springbok Sandstone Monitoring Bores

Figure 7.19 Groundwater Elevation Hydrograph – Lower Springbok Sandstone

Walloon Coal Measures Monitoring

There are 27 WCM monitoring bores within the vicinity of the Project area. The majority of these locations include multi-unit monitoring bores across the different coal seams of the WCM, at ten locations:

- Nine in the Upper Juandah Coal Measures;
- Eleven in the Lower Juandah Coal Measures; and
- Seven in the Taroom Coal Measures.

These locations are shown on Figure 7.20.

Monitoring records are presented in Figure 7.21, Figure 7.22 and Figure 7.23. These monitoring locations are likely operated by neighbouring CSG tenure holders and show a variety of responses which are likely due to depressurisation or testing which has commenced in these areas. Groundwater elevations within the WCM range between ~340 mAHD and 70 mAHD.

Groundwater flow in the WCM is generally south to north towards Taroom, however CSG development areas result in localised variations to this regional flow direction (OGIA 2021d). The observed drawdown in the CSG areas is steep, with little drawdown observed outside of the operating fields. This is likely to reflect the discontinuous nature of the coal seams in these gas fields and low effective horizontal permeabilities (OGIA 2021d). This explains the variety of responses in the groundwater elevations.

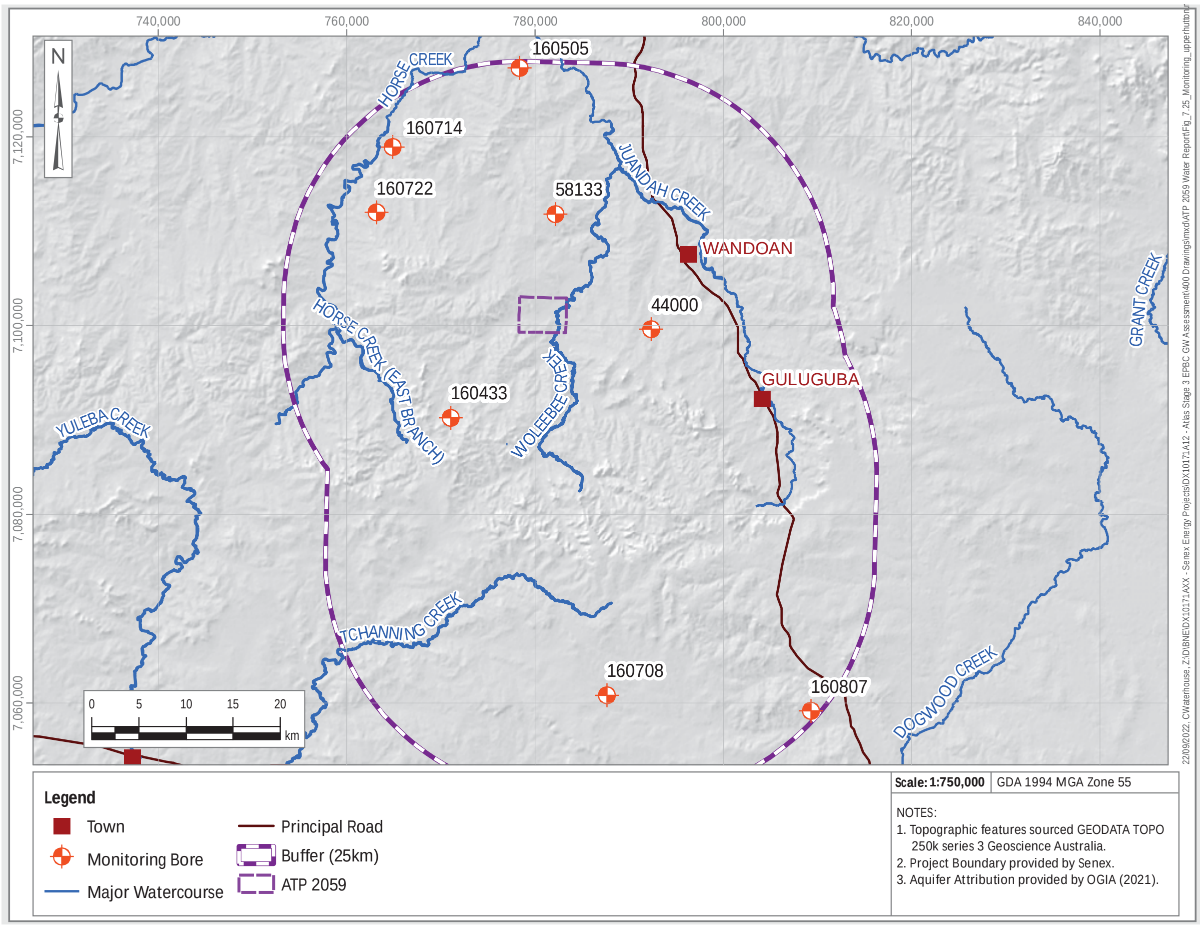


Figure 7.20 Location of WCM Monitoring Bores

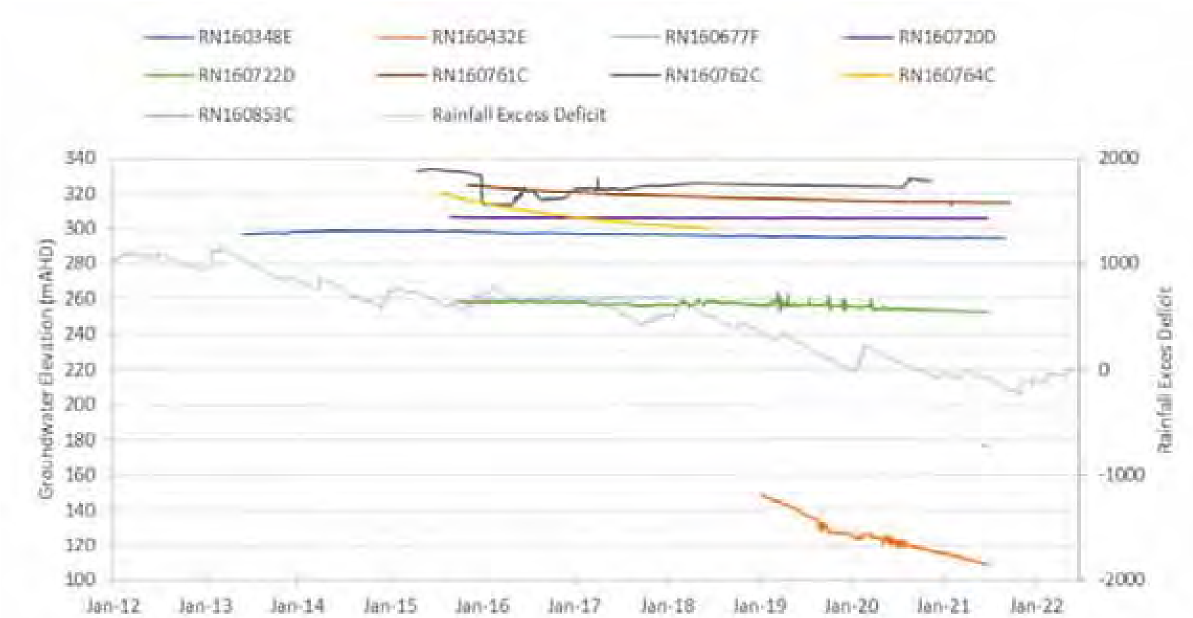


Figure 7.21 Groundwater Elevation Hydrograph for WCM – Upper Juandah Coal Measures

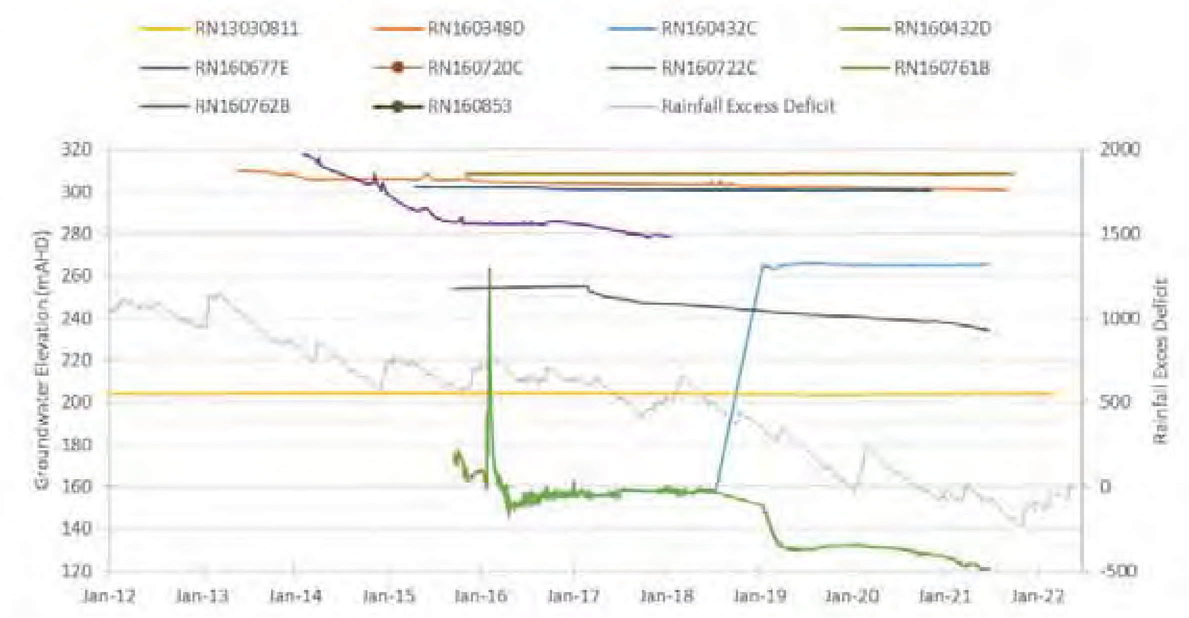


Figure 7.22 Groundwater Elevation Hydrograph for WCM – Lower Juandah Coal Measures

Figure 7.23 Groundwater Elevation Hydrograph for WCM – Taroom Coal Measures

Upper Hutton Sandstone Monitoring Bores

Temporal groundwater elevations for the Hutton Sandstone are available for eight sites within the vicinity of the Project area. The location of these sites is shown on Figure 7.24 with the groundwater elevation hydrograph presented on Figure 7.25.

The range of groundwater elevation from these monitoring bores is between ~235 mAHD and 287 mAHD. Generally, most groundwater level records present relatively static groundwater levels with the exception of RN 160807 and RN 160505 which show a gradual decline. The monitoring record for RN 58133, located north of the Project, indicates a response to local pumping. RN 160722 and RN 44000 may also be responding to local water use.

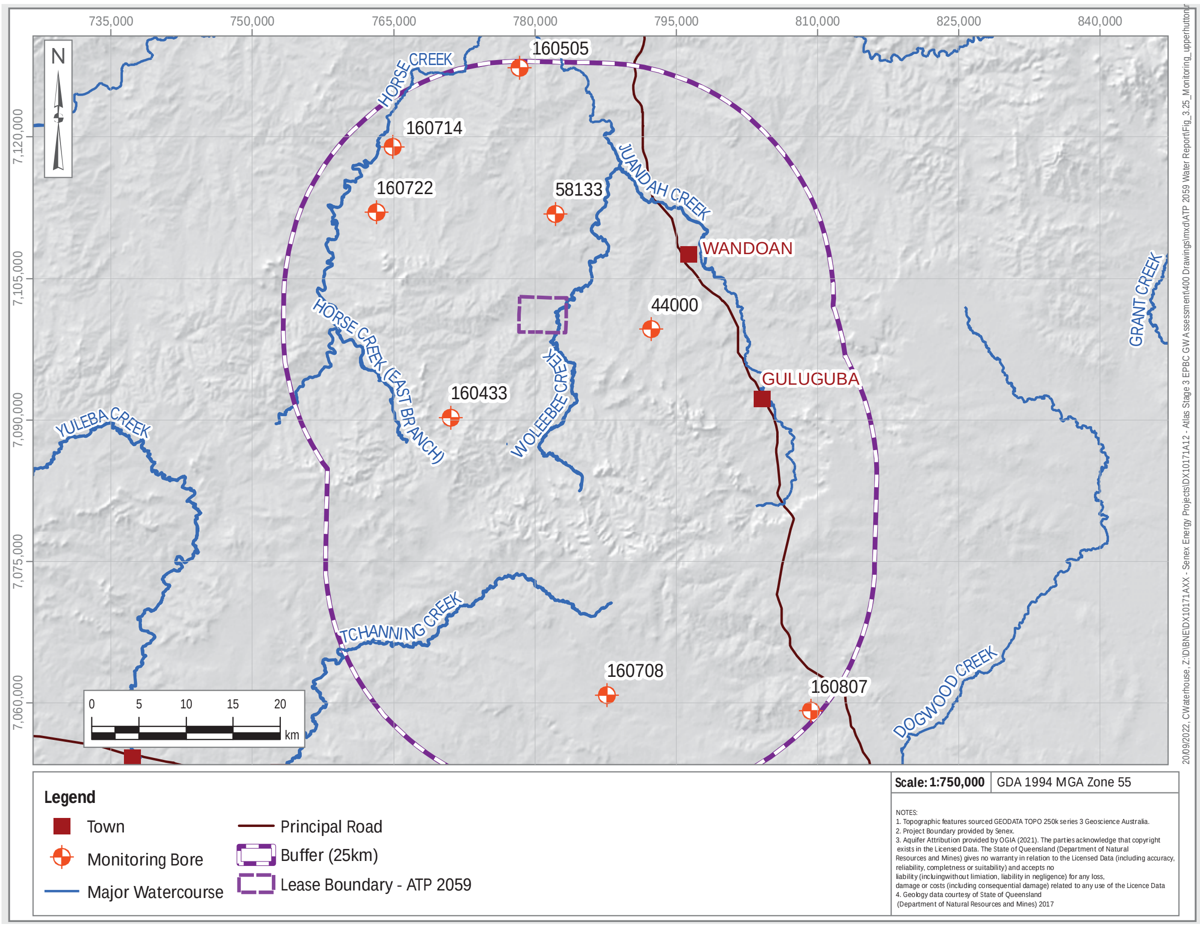


Figure 7.24 Location of Upper Hutton Sandstone Monitoring Bores

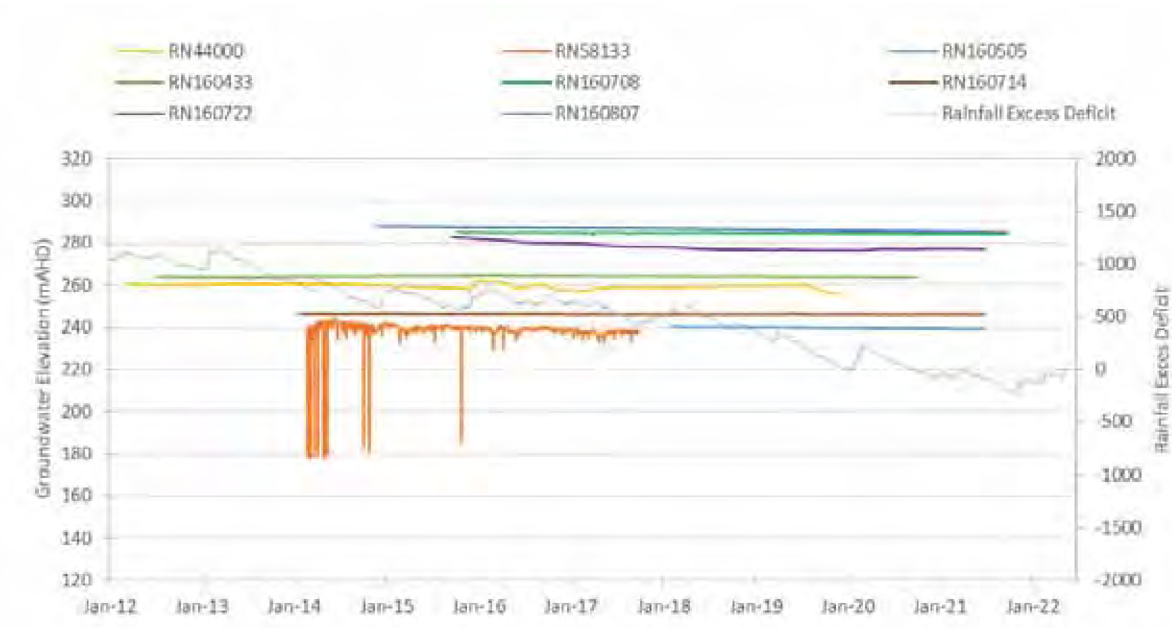


Figure 7.25 Groundwater Elevation Hydrograph – Upper Hutton Sandstone

Lower Hutton Sandstone Monitoring Bores

There are three Lower Hutton Sandstone monitoring bores within the Project 25 km buffer zone (Figure 7.26). Groundwater hydrographs for these bores are presented in Figure 7.27.

Observations from available data include:

- Groundwater elevations range between ~277 and ~285 mAHD.
- Groundwater elevations are generally stable in RN160813. RN160348 experienced a decrease of ~1.5 m in 2016 where the water level remained stable for approximately two years, then increased to previous levels. This pattern repeated in 2019 to 2020. This may be due to issues with the pressure transducer at this bore. The bore exhibits an overall slightly declining trend of 1.2 m over ~7 years, RN160677 exhibits a similar trend.
- Inferred groundwater flow within the Lower Hutton Sandstone is north towards Taroom (recognising limited data) which aligns with OGIA's potentiometric map for the Hutton Sandstone (OGIA 2021d).

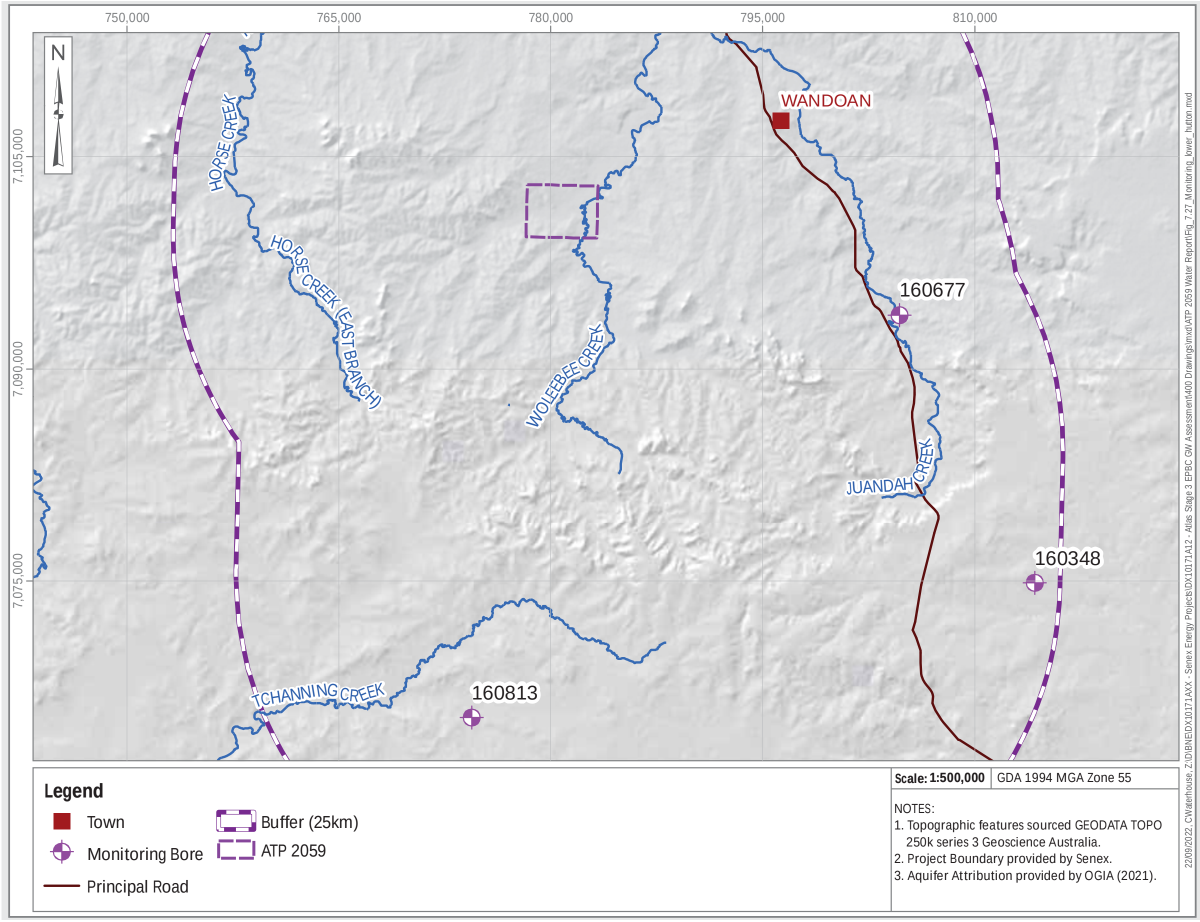


Figure 7.26 Location of Lower Hutton Sandstone Monitoring Bores

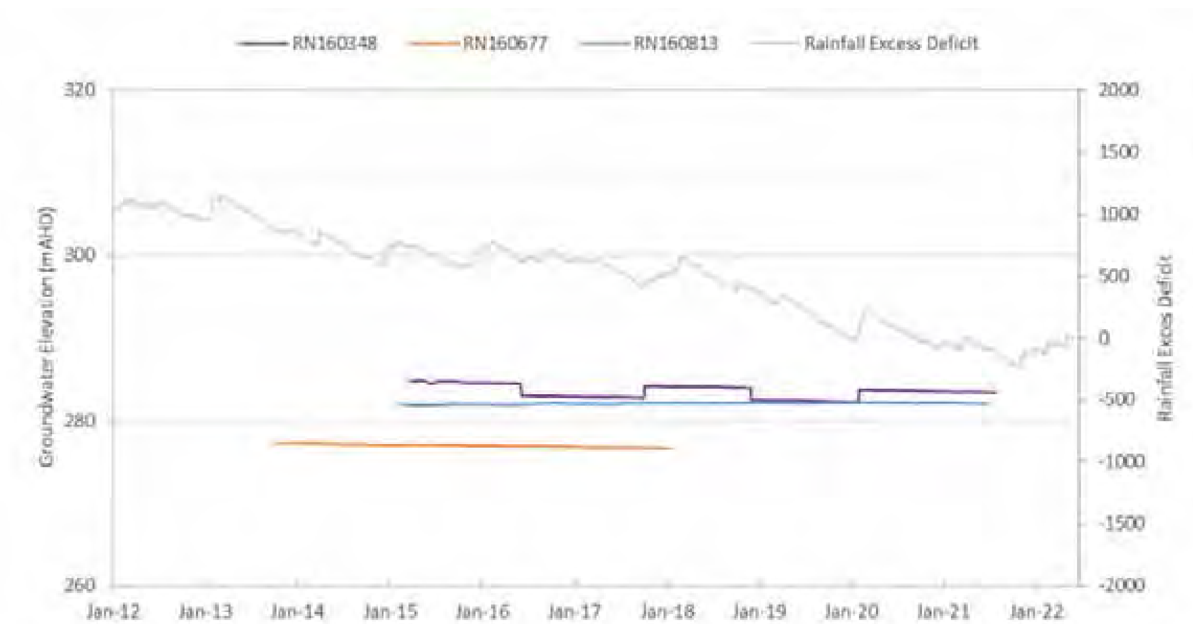


Figure 7.27 Groundwater Elevation Hydrograph – Lower Hutton Sandstone

Evergreen Formation Monitoring Bores

There is one bore monitoring the Evergreen Formation within the vicinity of the Project area, with their locations shown in Figure 7.28. Hydrographs for selected monitoring bores are presented in Figure 7.29.

RN160686 is a multi-level site and includes monitoring of the Evergreen Formation (Pipe B) and Precipice Sandstone (Pipe D) and is located approximately 18 km east of the Project.

The groundwater hydrograph for the Evergreen Formation bore is presented in Figure 7.29 and indicates that the groundwater elevation is ~282 mAHD. The groundwater level in this bore has remained stable within a minimum and maximum range of approximately 2 m.

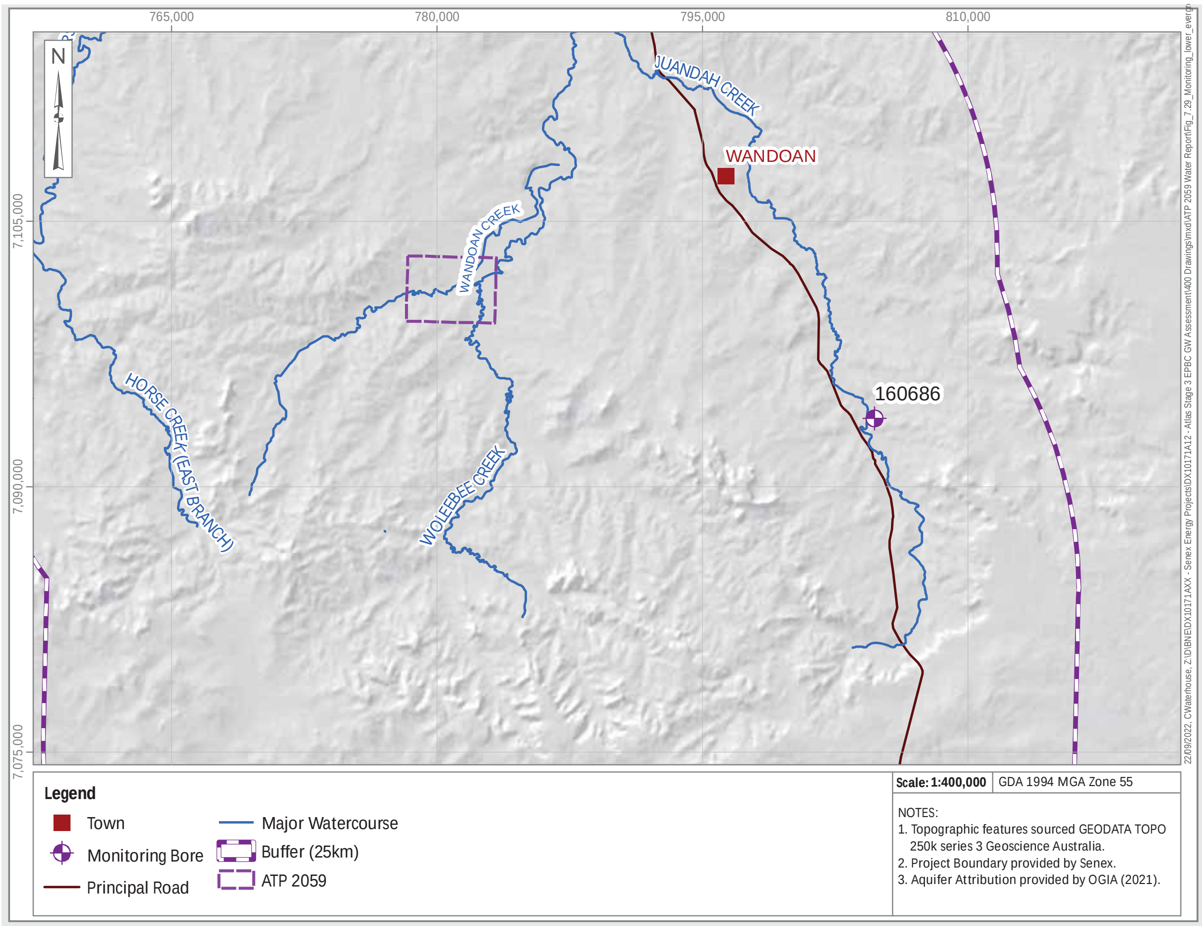


Figure 7.28 Location of Evergreen Formation Monitoring Bore

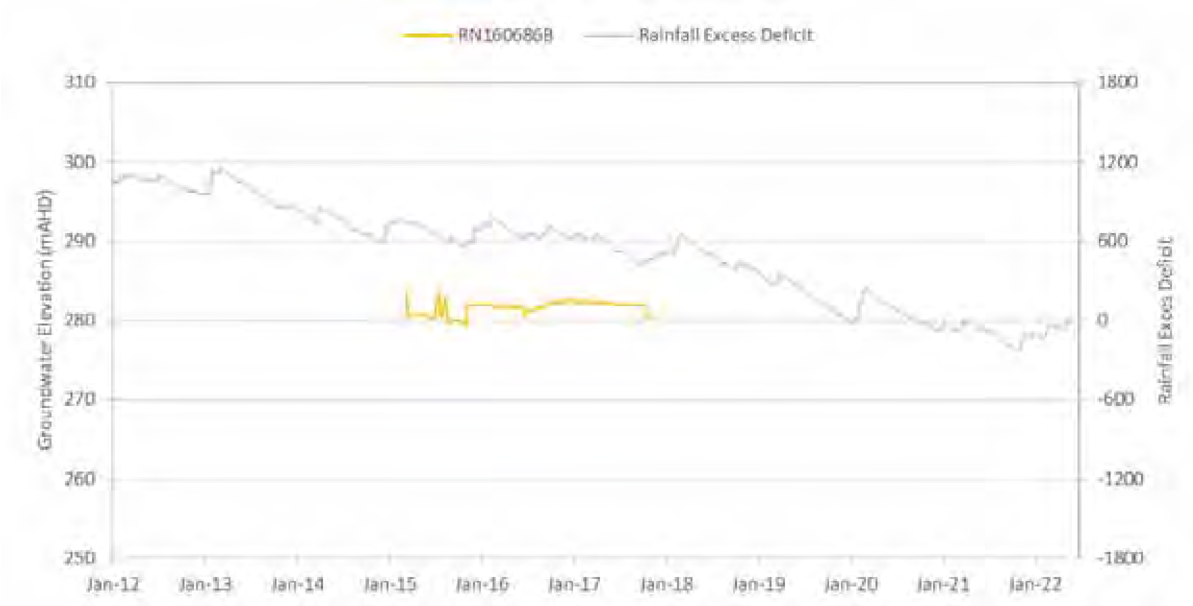


Figure 7.29 Groundwater Elevation Hydrograph – Evergreen Formation

Precipice Sandstone Monitoring Bores

There are four bores monitoring the Precipice Sandstone within the vicinity of the Project area, with their locations shown in Figure 7.30. Hydrographs for selected monitoring bores are presented in Figure 7.31.

The hydrographs indicates that the groundwater elevation in the Precipice Sandstone at RN160441 has been rising since mid-2015 and is likely a function of an aquifer injection scheme occurring ~80 km to the west of the Project at Reedy Creek (OGIA 2021d).

RN 160863 is located ~20 km to the northwest of the Project and monitors the Precipice Sandstone at depth (top of Precipice Sandstone ~1,100 mbgl). The groundwater level in this bore has been rising which is likely due to the Reedy Creek and Spring Gully aquifer reinjection schemes, with trials having commenced in December 2012.

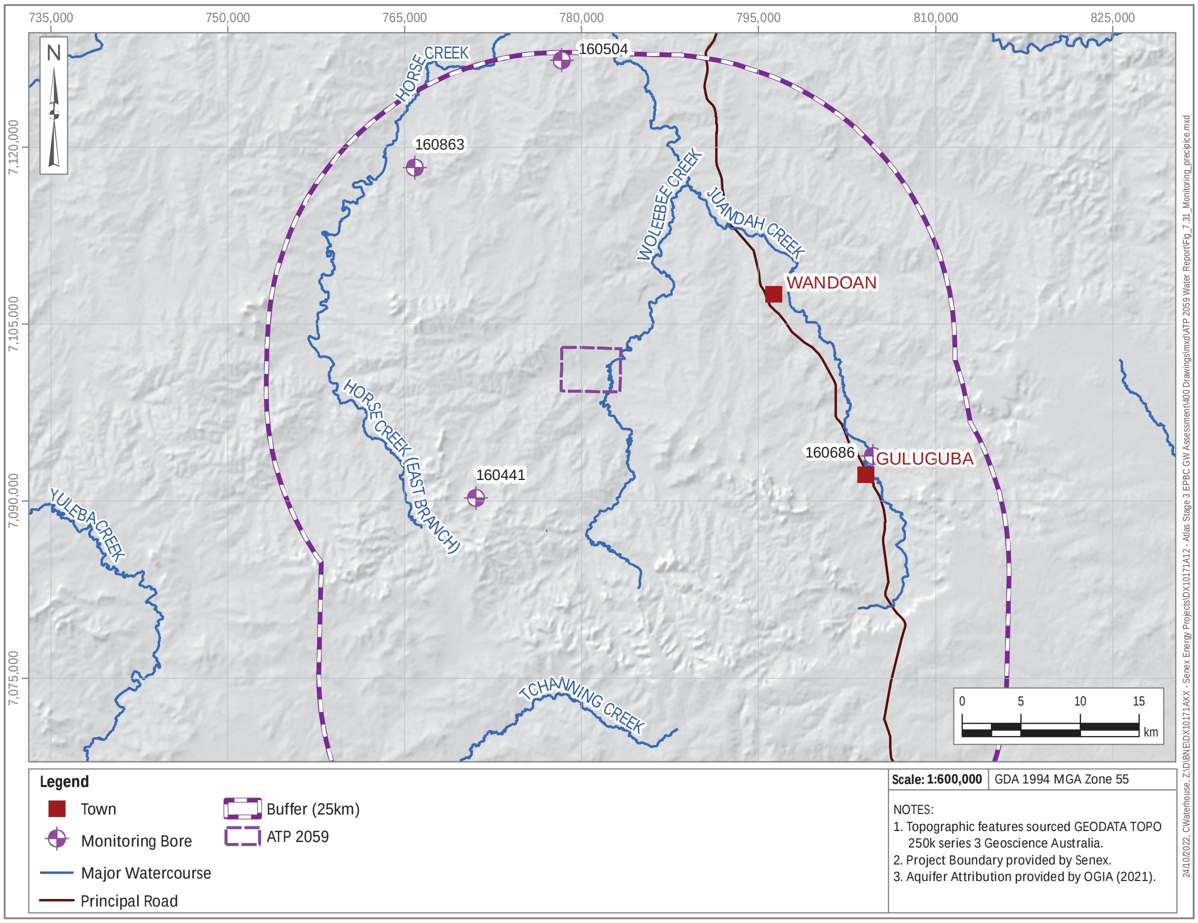


Figure 7.30 Location of Precipice Sandstone Monitoring Bores

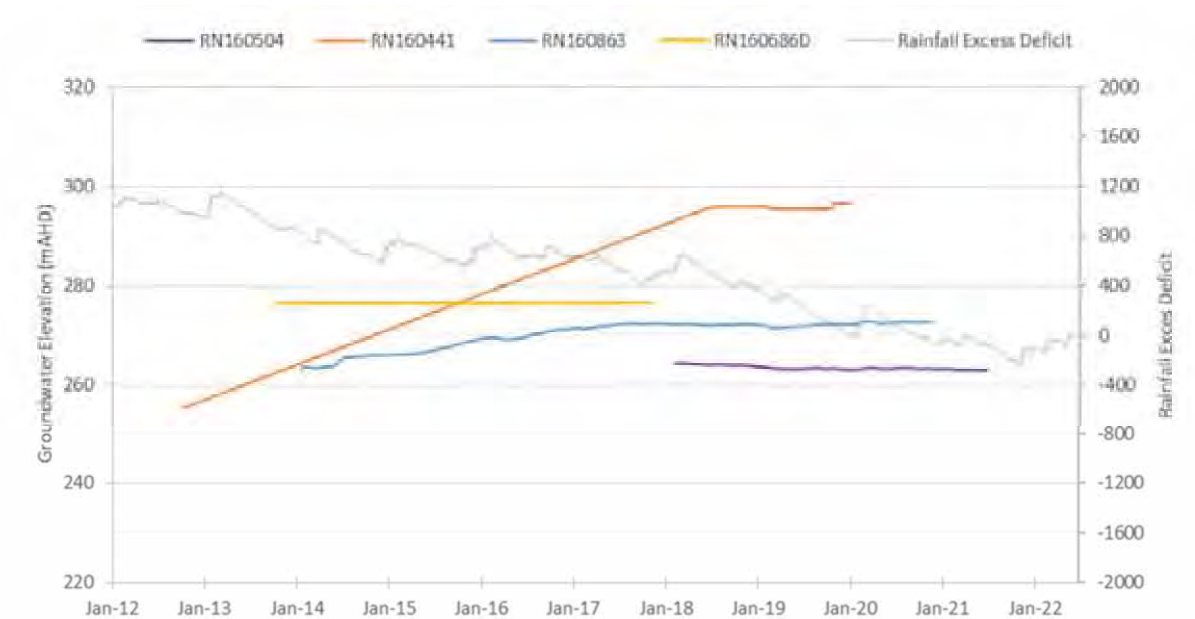


Figure 7.31 Groundwater Elevation Hydrograph –Precipice Sandstone

7.8 Groundwater Chemistry

Groundwater chemistry within the Surat Basin has been considered using information provided in the UWIR. Table 7.3 presents a summary of the regional groundwater chemistry associated with each hydrostratigraphic unit occurring within the Project area from OGIA (2016b). Generally, the total dissolved solids (TDS), used as an indicator of salinity, is a broad range across the basin.

Table 7.3 Summary of Regional Groundwater Chemistry for Each Hydrostratigraphic Unit (OGIA 2016a)

Hydrostratigraphic Unit	OGIA (2016b) Description
Orallo Formation	Fresh to saline conditions with TDS ranging from 75 to 20,000 mg/L, mean of 1,700 mg/L.
Gubberamunda Sandstone	Fresh to brackish water. Mean TDS of 450 mg/L with a range of between 70 and 7,500 mg/L. Mean TDS ranges between 480 to 1,160 mg/L, depending on location category.
Westbourne Formation	Characterised by fresh to saline groundwater (TDS mean of 1,500 mg/L), ranging from 150 to 19,000 mg/L.
Springbok Sandstone	Fresh to brackish water quality, with a mean TDS of 1,000 mg/L (ranging between 200 and 7,000 mg/L).
WCM	Fresh to saline groundwater, TDS ranges from 30 to 18,000 mg/L, with a mean TDS of around 3,000 mg/L.
Hutton Sandstone	TDS ranges from 70 to 16,000 mg/L, with a mean TDS of around 1,600 mg/L, low salinity calcium and magnesium bicarbonate type water in the recharge areas, to a relatively high-salinity sodium-chloride type water in discharge areas.
Evergreen Formation	Low salinity (TDS) and concentrations of sodium and chloride, TDS ranges from 80 to 670 mg/L, with a mean TDS of around 260 mg/L.
Precipice Sandstone	Precipice Sandstone has the freshest groundwater in the Surat CMA, salinity ranges from 50 to 850 mg/L with a mean salinity (TDS) of 193 mg/L.

Further groundwater chemistry data has been sourced from the GWDB for bores within a 25 km buffer of the Project. Figure 7.32 presents a Durov and piper diagram for each relevant hydrostratigraphic unit from the GWDB records. The following observations can be made:

- All of the samples (regardless of formation) show either a sodium-chloride signature or a sodium-bicarbonate signature water type.
- The groundwater samples from the alluvial bores have a different signature to the Surat Basin units, with a stronger sodium-bicarbonate signature.

Fresher groundwater is observed in the samples from the alluvium, Gubberamunda Sandstone and Hutton Sandstone, with higher EC in samples measured from the WCM and Springbok Sandstone.

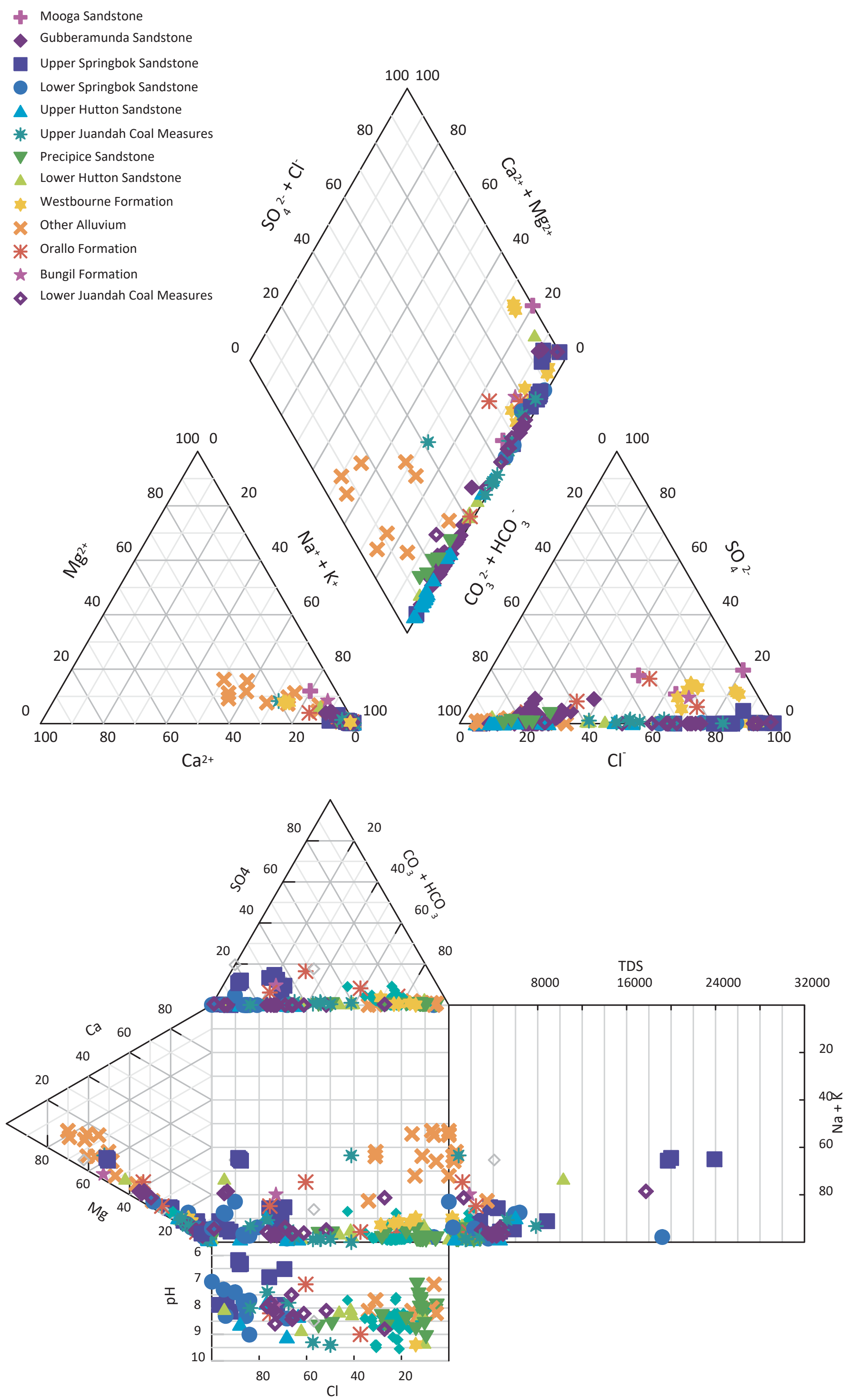


Figure 7.32 Piper and Durov Diagram from GWDB Chemistry Records from Bores within a 25 km Buffer of the Project Area

7.9 Groundwater-Surface Water Interaction

Groundwater-surface water interaction within the Project area may occur from two key processes:

- Discharge of groundwater to watercourses as baseflow; and
- Recharge to aquifers as leakage from watercourses.

Recharge to groundwater systems from watercourses may occur across the Project area, however as discussed in Section 7.6, there must be sufficient saturation and hydraulic head to allow water to infiltrate into aquifers.

A discussion on baseflow fed reaches of watercourses, or watercourse springs, and the groundwater-surface water interaction is discussed further in Section 7.10.1.

7.10 Springs and Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are defined as 'Natural ecosystems which require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services' (Richardson et al. 2011).

There are three categories of GDEs:

- **Aquatic GDEs**, which are ecological communities dependent on the surface expression of groundwater, including springs other than EPBC-listed springs, river baseflow systems (watercourse springs), riparian ecosystems and wetlands;
- **Terrestrial GDEs,** which are surface ecosystems dependent on the subsurface presence of water (i.e., terrestrial vegetation accessing the water table below ground), including ecosystems that are intermittently and permanently dependent on groundwater; and
- **Subterranean GDEs**, which are subterranean ecosystems dependent on the permanent presence of subsurface water. For the purposes of this document, this includes vertebrates and invertebrates only (i.e., excludes unicellular and simple multicellular organisms).

Potential surface expression GDEs and subsurface GDEs are mapped by DES (State of Queensland 2018a) as potentially being present in the vicinity of the Project (Figure 7.35). These generally correspond with the location of the mapped alluvium associated with Woleebee Creek within the Project area and Wandoan Creek, Horse Creek and Juandah Creek further afield but within the 25 km buffer.

There are no spring vents or complexes within the vicinity of the Project.

7.10.1 Potential Aquatic GDEs

Baseflow fed reaches of watercourses, or watercourse springs, are sections of a watercourse where groundwater from an aquifer enters the stream through the streambed (OGIA 2021g). A report published by OGIA in 2017 re-maps potential gaining streams (or baseflow fed reaches, watercourse springs) within the Surat CMA (OGIA 2017b). This report identified sections of Woleebee Creek as a potentially gaining stream. OGIA have re-mapped watercourse springs within the Surat CMA for the 2021 UWIR report (OGIA 2021g), these are shown on Figure 7.32with the details of the springs summarised in Table 7.4.

There is one watercourse spring within the ATP 2059 area associated with Wandoan and Woleebee Creeks. These watercourse springs are identified as being associated with the alluvium. This is noted as a spring of interest but not currently affected or listed as a mitigation site (OGIA 2021g).

Table 7.4 UWIR Watercourse Spring Details

Site Number	Name	Source Aquifer
W279	Woleebee Creek	Alluvium

Reaches of Woleebee Creek within PL 1037 were assessed during the field verification program in 2018 (KCB 2018c). The following observations were made regarding Woleebee Creek as a gaining stream:

- The assessment was conducted during the dry season and no flow was observed within the areas surveyed.
- Pools of water were encountered in the lower reaches of Woleebee Creek (within the PL), which were rainfall derived surface water based on turbid appearance and field water quality (547 µS/cm). The lab TDS of 324 mg/L is much lower than the underlying Westbourne Formation TDS (see Table 7.3 in Section 7.8).
- Based on the difference between the field water quality measured at Woleebee Creek pools, field observations and groundwater elevation monitoring data from the alluvium and Gubberamunda Sandstone, it is considered unlikely that Woleebee Creek is a baseflow fed reach (i.e., it is a losing stream).

The verification program considered it unlikely that Woleebee Creek is a baseflow fed reach. This aligns with the assessment undertaken by CDM Smith for QGC relating to tenements to the south, which concluded the ephemeral creeks feeding Juandah Creek are not ‘gaining’ from alluvial groundwater (CDM Smith 2021).

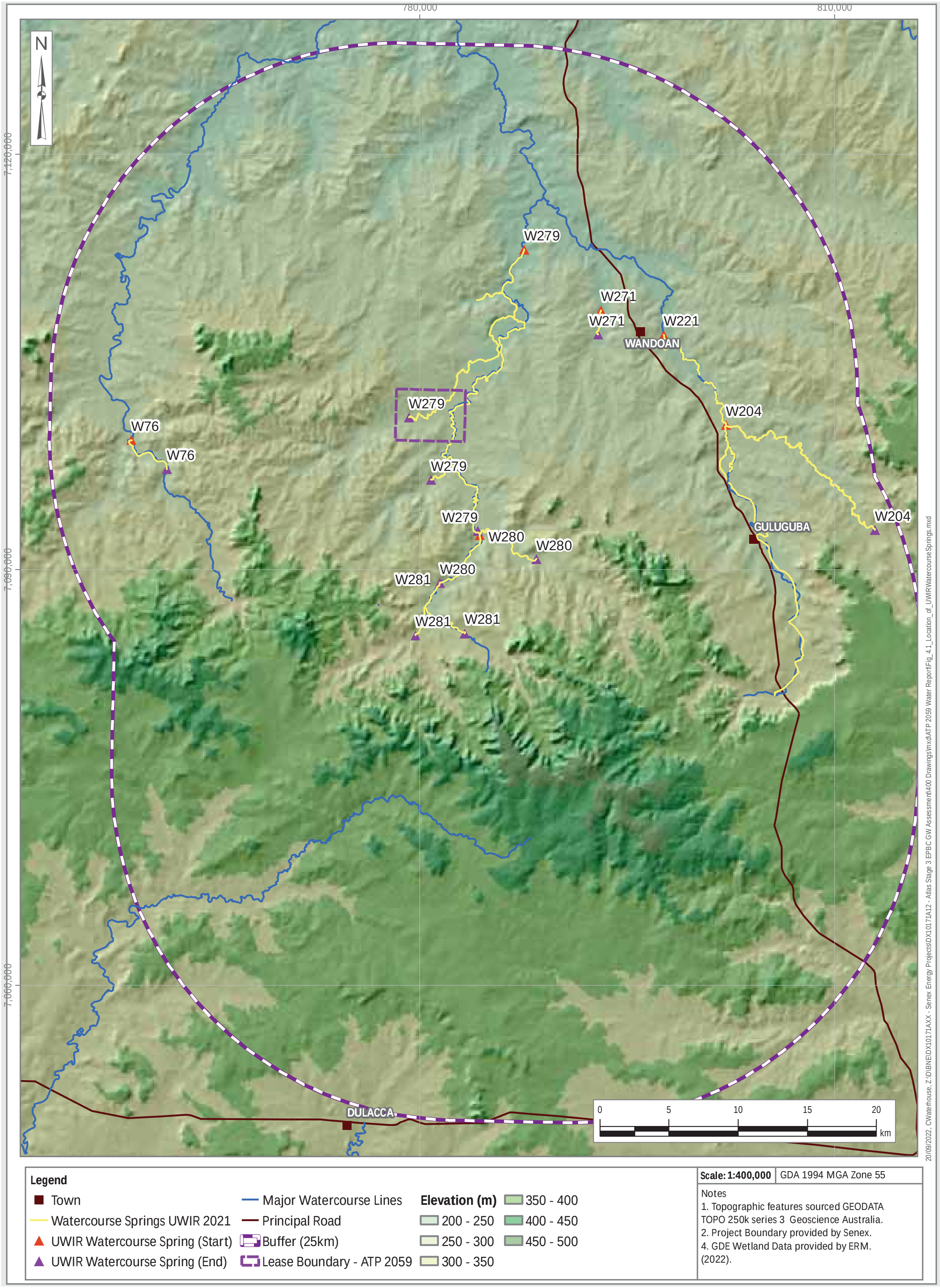


Figure 7.33 Location of Watercourse Springs (OGIA 2021g)

A review of water qualities from the various sources across the Project area has been undertaken, while a piper diagram representing the proportional distribution of the major ionic constituents of these water qualities is presented in Figure 7.34:

- Surface water samples collected locally in Wandoan Creek and from Juandah Creek to the northeast (at the Juandah Creek RDMW gauge);
- Groundwater samples collected locally in PL 209, PL 445, PL 1037 and ATP 2059 (note only two alluvium water quality samples are available locally and these bores are also screened across the Westbourne Formation); and
- Alluvium water quality samples taken within the 25 km buffer of the Project area.

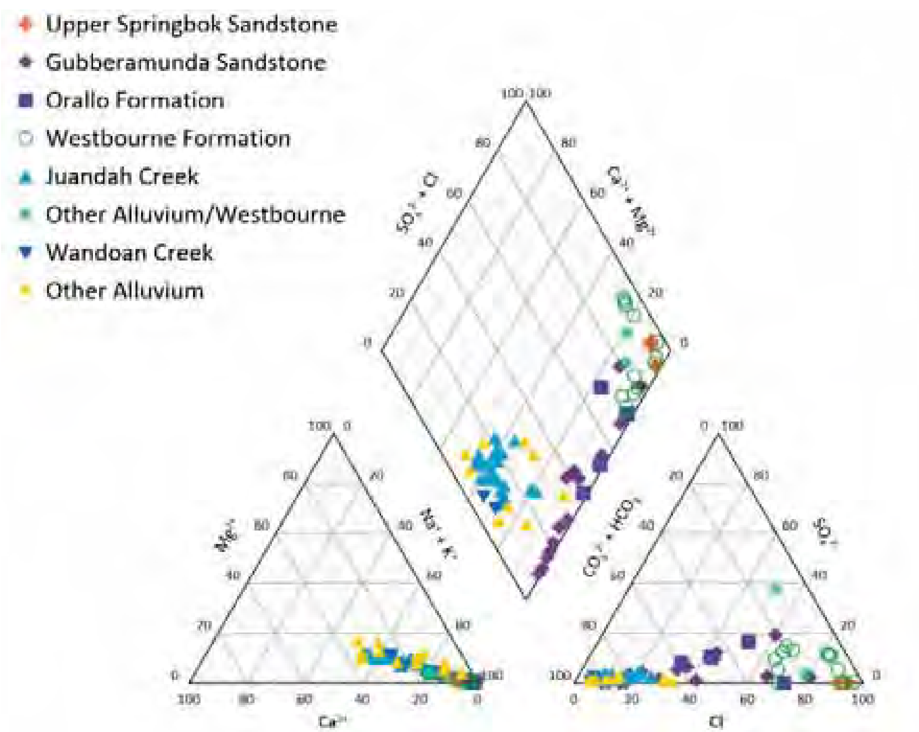


Figure 7.34 Piper Diagram showing Surface Water and Groundwater Samples from Alluvium Bores

Figure 7.34 shows the difference between the water quality of the alluvium and the underlying GAB units. The water quality of the alluvium (in yellow) is very similar to the surface water qualities of Wandoan and Juandah Creeks. The water qualities of the Westbourne Formation and Springbok Sandstone are distinct from the water quality of the alluvium, indicating a lack of connection between the units (i.e., the underlying Westbourne Formation and Springbok Sandstone do not discharge into the alluvium). The underlying GAB units generally have a higher salinity than the alluvium (discussed further in Section 7.8 above).

The comparable water qualities of the surface water and alluvium indicates that the alluvium is recharged/replenished by the surface water systems during flow events following prolonged rainfall event/s.

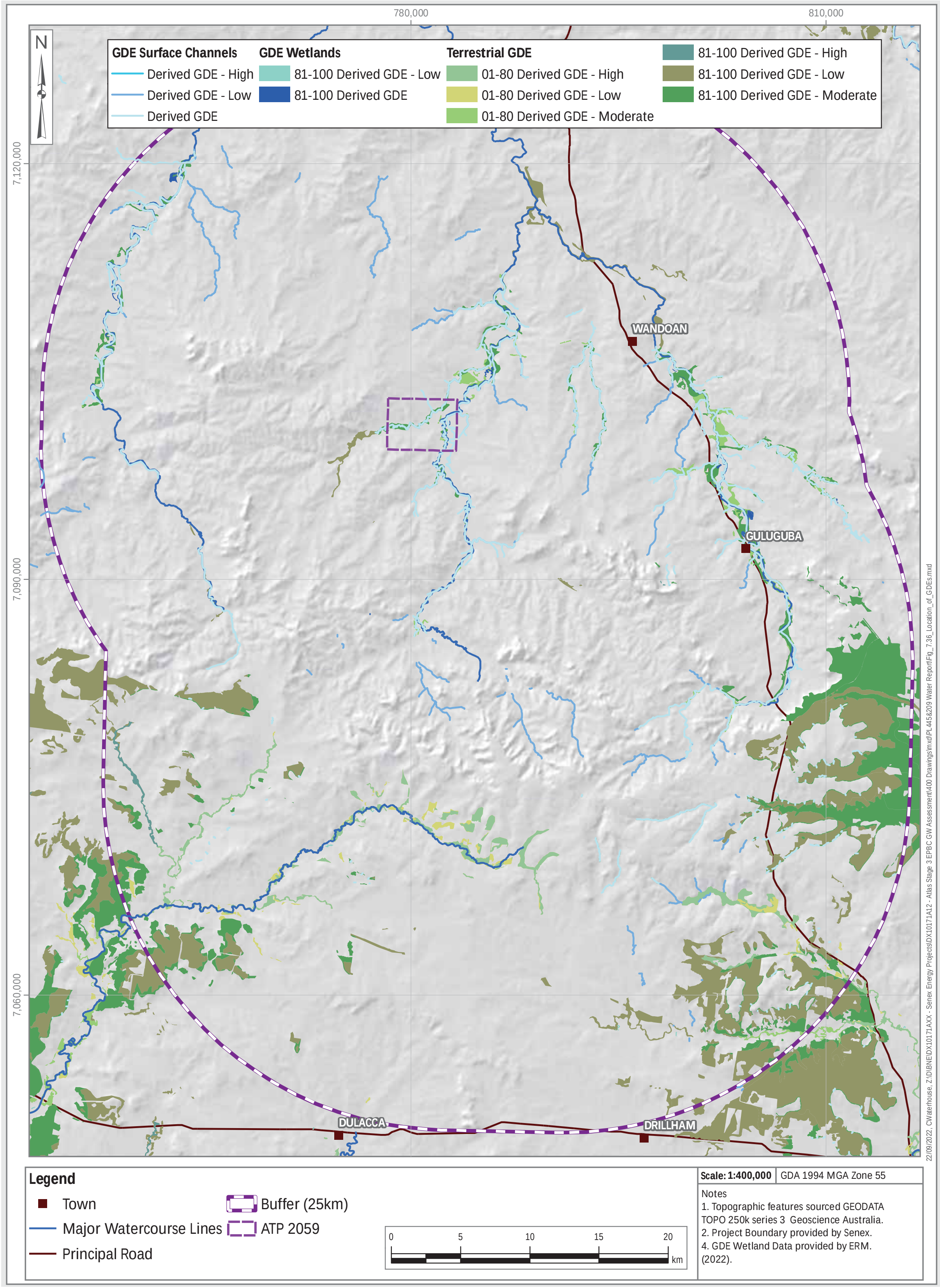


Figure 7.35 Location Mapped Potential GDEs

7.10.2 Potential Terrestrial GDEs

The DES dataset identifies potential terrestrial GDEs within the Project area (State of Queensland 2018d). These GDEs are present in the vicinity of Wandoan and Woleebee Creeks. An assessment of those GDEs was performed by ERM (ERM 2022a). A summary of the findings is provided in this section and in Appendix VI.

The assessment was conducted in two stages. Firstly, a desktop analysis was performed to identify potential terrestrial GDEs based on available GDE mapping. A field survey was then performed to verify the potential Terrestrial GDEs identified during the desktop assessment and collect data to assess their condition and identify other potential ecological values.

Within the Project area, the majority of terrestrial and aquatic GDEs are associated with watercourses and adjacent alluvial plains. This includes the named creeks Woleebee Creek, Wandoan Creek, Conloi Creek and Hellhole Creek, as well as several unnamed creeks and hydrological features.

Using terminology developed as part of the DES GDE mapping, the following potential terrestrial and aquatic GDE types have been identified from the desktop assessment as occurring within the Project area:

1. Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow.
2. Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow.

These potential GDE types correspond with RE types that occur on alluvial landscapes, associated with watercourses and the adjacent floodplain areas. Based on the DES GDE mapping rule sets, these vegetation communities rely on alluvial aquifers that form from gravel, sand, silt and/or clay deposited by fluvial processes in river channels or on floodplains. These deposits store and transmit water to varying degrees through inter-granular voids and pore spaces (ERM 2022a).

RE Verification

The Project area comprises mosaics of remnant and regrowth REs of varying patch size and ecological condition. RE 11.3.25 (Forest Red Gum Eucalyptus tereticornis or River Red Gum Eucalyptus camaldulensis woodland fringing drainage lines) is the most widely abundant vegetation community identified that the potential to be a GDE, however interconnected patches of other REs are present. Historic land clearing is known to have occurred throughout the Project area that has impacted the condition of terrestrial GDEs, particularly along creek lines and water courses. Grazing pressure is also likely to influence the ecological condition of RE patches and their value for maintaining biodiversity levels.

The locations of the field verified RE areas are presented in Figure 7.36.

ATP 2059 is dominated by RE 11.3.25 (Forest Red Gum *Eucalyptus tereticornis* woodland fringing drainage lines), however areas of RE 11.3.2 (Popular Box *Eucalyptus populnea* woodland on alluvial plains), 11.3.27 (Freshwater wetlands: Coolabah *Eucalyptus coolabah* and/or Forest Red Gum open woodland to woodland fringing swamps) and 11.3.17 (Poplar Box woodland with *Brigalow Acacia harpophylla* and/or Belah *Casuarina cristata* on alluvial plains) are also present in smaller more fragmented patches within a wider landscape of modified pastures, cropping and grazing land (ERM 2022a).

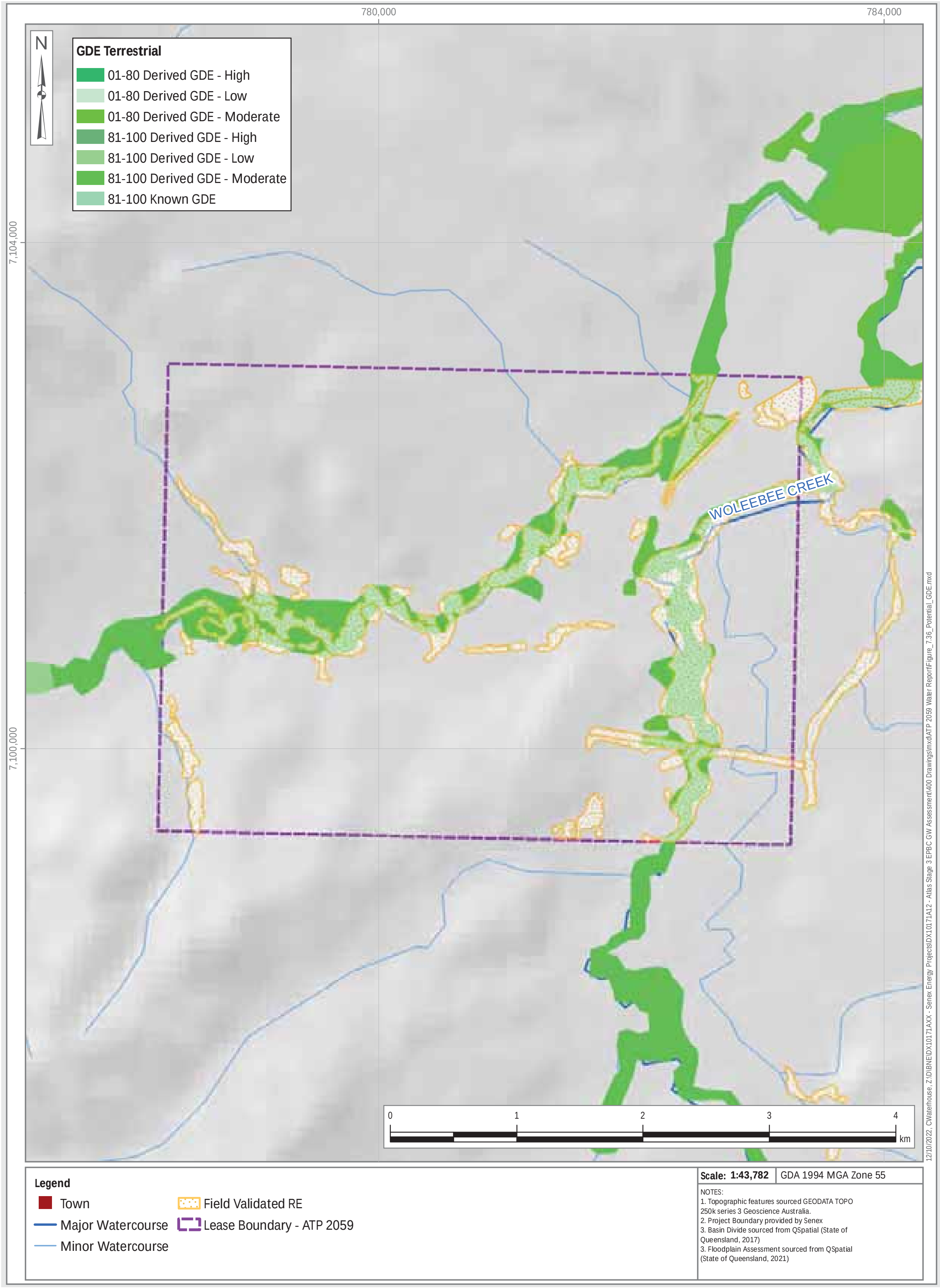


Figure 7.36 Mapped Potential GDEs in the Project Area and Field Verified REs

Groundwater Dependence

The dominant ecosystem, RE 11.3.25, is known to include both ephemeral and permanent wetlands so aquatic vegetation present will vary depending on the presence of permanent, open water. However, these areas were not recorded/mapped within the Project area. The ecology survey identified flora and fauna that do not depend on the permanent presence of water. These communities have built resilience due to the ephemeral nature of these creek systems, which follow an episodic wetting and drying cycle.

Although the presence of tree species that inhabit wetter environments indicate some potential for groundwater use, the leaf water potential and isotope data, from studies undertaken by QGC directly north of the Project area on similar RE's along creek tributaries to Juandah Creek, demonstrated that trees are sourcing water largely from soil moisture stores which fluctuate with rainfall (CDM Smith 2021). This is considered to be a function of the dimorphic rooting systems which access water at multiple depths. In this study, depth profiles of soil moisture showed that most trees were accessing water at relatively shallow depths (and several meters above the water table) where soil moisture is high.

A review of available literature on tree rooting depth for those dominant species present in each of the ground-truthed REs has been completed to understand how dependent these species may be on groundwater (Table 7.5) (ERM 2022a). The average rooting depth for species of Eucalyptus present at the Project area is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits. Eucalypts (including Forest Red Gums) have two rooting systems (known as a dimorphic rooting system), with the ability to access deep groundwater during periods of time where shallower soil moisture is limited, they have shown physiological responses allowing them to adapt to water stress (CDM Smith 2021).

Groundwater dependence of identified vegetation was inferred using established risk assessment guidelines (Serov, Kuginis, and Williams 2012). This assessment is outlined in Table 7.6. The results indicate that the potential terrestrial GDEs located along the creek systems may be groundwater dependent as they occur within an alluvial system (associated with creeks) and the ecosystem is associated with streamlines. This alluvial system, as discussed in Section 7.9, is replenished during prolonged wet periods when the ephemeral creek system is flowing, and is disconnected from the Gubberamunda Sandstone, Westbourne Formation and Upper Springbok Sandstone, which is of a higher salinity.

Table 7.5 Potential GDEs, Vegetation Description and Tree Rooting Depth (ERM 2022a)

Regional Ecosystem Code and Names	GDE Type	Dominant Flora Species	Field Verified Condition	Groundwater Dependence and Rooting Depth	Representative Site Photographs (ERM 2022a)
11.3.2 *Eucalyptus populnea* woodland on alluvial plains	Treed regional ecosystems on alluvial overlying sandstone ranges with fresh, intermittent flow.	Poplar Box *Eucalyptus populnea*	Majority of this RE and potential GDE is in a remnant condition. Occurs on alluvial plains adjacent to riparian vegetation.	12.6 - 22.6 m for Poplar Box	
11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines	Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow.	Forest Red Gum	Largely confined to fringing riparian vegetation along watercourse and is the most common RE and GDE type within the Project area. Varying condition, ranging from advanced regrowth to remnant.	At least 9m and assumed to reach groundwater reservoirs (Forest Red Gum) 12.1 - 22.6 m *(E. camaldulensis)*	

Regional Ecosystem Code and Names	GDE Type	Dominant Flora Species	Field Verified Condition	Groundwater Dependence and Rooting Depth	Representative Site Photographs (ERM 2022a)
11.3.27 Freshwater Wetlands	Riverine wetlands on alluvia overlying sandstone ranges with fresh, intermittent flow	Variable freshwater vegetation ranging from open water to fringing sedgelands and eucalypt woodlands. Forest Red Gum	Occurs largely in closed depressions or oxbows adjacent to watercourses or on adjacent alluvial plains.	*Eucalyptus camaldulensis*- 12.1-22.6 m Forest Red Gum- at least 9m *Eucalyptus coolabah* possibly at least 7-8 m	
11.3.17 *Eucalyptus populnea* woodland with *Acacia harpophylla* and/or *Casuarina cristata* on alluvial plain	Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow	Poplar Box Brigalow *Acacia harpophylla* Belah *Casuarina cristata*	Identified as majority remnant vegetation and occurs on adjacent alluvial floodplains, usually connected to the adjacent riparian zone.	Poplar Box - 12.6-22.6m (Kath, et al., 2014) Brigalow - Unknown Belah - Unknown	

Regional Ecosystem Code and Names	GDE Type	Dominant Flora Species	Field Verified Condition	Groundwater Dependence and Rooting Depth	Representative Site Photographs (ERM 2022a)
11.3.19 *Callitris glaucophylla, Corymbia* spp. and/or *Eucalyptus melanophloia* woodland on Cainozoic alluvial plains	Treed regional ecosystems on alluvia overlying sandstone ranges with fresh, intermittent flow	White Cypress Pine *Callitris glaucophylla*; *Corymbia spp*. And/or Silver-leaved Ironbark Eucalyptus melanophloia	Occurs on alluvial floodplains adjacent to riparian zone	Up to 6m (*Callitris glaucophylla*) (Eberbach, 2003) Silver-leaved Ironbark - Unknown but likely potential to be similar to Forest Red Gum	

Table 7.6 Groundwater Dependence Assessment for Potential Terrestrial GDEs Associated in the Project Area

Groundwater Dependence	Wandoan Creek and Woleebee Creek
General	
Is the ecosystem identical or like another that is known to be groundwater dependent?	There is potential for the identified RE's to access groundwater but this has not been confirmed. The relative reliance on groundwater could not be identified for some of these dominant species, it is likely that the Eucalyptus species present are resilient to changes in groundwater availability due to their dimorphic root structure. For other dominant flora species, such as Brigalow and Belah, at least an indirect reliance on groundwater availability through water discharge should be assumed.
Does the community contain species known to require permanent saturation such as within aquifers, karsts, or mound springs or some wetlands?	No
Is the distribution of the ecosystem consistently associated with known areas of groundwater discharge; e.g., springs, mound springs or groundwater seeps in terrestrial and/or near shore marine environments?	No. Standing water is present but not considered to be groundwater (due to water quality and turbidity) and it is unlikely that groundwater would express as baseflow or watercourse springs along these creeks.
Is the distribution of the ecosystem typically confined to locations where groundwater is known or expected to be shallow? For example, topographically low areas, major breaks of topographic slope; i.e., cliffs or escarpments, alluvial and coastal sand beds aquifers, gaining streams?	Yes. The vegetation is located within the area of sandy alluvium associated with the watercourse. However, these creeks are not considered to be gaining streams, and therefore, not connection to the regional groundwater system of the bedrock.
Terrestrial GDEs	
Is the water table level near or at the surface or within the root zone of the surrounding vegetation? If roots can reach a source of fresh water, is it generally true that this water will be absorbed by the roots and transpired by the canopy.	Yes. There are two registered bores accessing the alluvium on Woleebee Creek in ATP 2059. Measurements at these bores record groundwater at ~7.5 mbgl (April 2022). Average root depth for species of Eucalyptus present is known, based on literature reviews, to range from 9m to 22.6m, depending on the species and the interactions between geomorphology and plant physiological traits (ERM 2022a)
Is the vegetation community composed of species known to require permanent saturation (wet rainforest or wet sclerophyll forests) or high soil moisture levels (dry rainforest)?	No.
Does the vegetation in a particular community occur along stream lines?	Yes. Field verified RE's are associated with water courses and the adjacent alluvial plains.
Is the vegetation community known to function as a refuge for more mobile fauna during times of drought?	No. Wandoan Creek is ephemeral and therefore would not likely have permanent water during the dry season or periods of limited rain.

7.10.3 GDE Subterranean Fauna

Stygofauna are known to occur in alluvial, limestone, fractured rock, calcrete aquifers and coal seams in Australia. Stygofauna are subterranean aquatic animals that live in groundwater. Communities are often dominated by crustacean invertebrates, also containing oligochaetes, insects, other invertebrate groups and occasionally fish. Where stygofauna are abundant, for example in alluvial aquifers, they are likely to contribute to improvement of water quality through processes such as biochemical filtration (Hancock, Boulton, and Humphreys 2005).

The prospective habitat for subterranean fauna is dependent on the presence of underground voids of suitable size and connectivity, to satisfy biological requirements. Subterranean faunae were previously believed to be restricted to alluvial or karst landscapes (limestone or calcrete dominated systems) which provided optimal habitat conditions. In more recent years, subterranean faunae have been found to occur in various types of non-karstic geological units and aquifer systems that exhibit suitable voids for colonisation, including alluvial, fractured rock, calcrete aquifers and coal seams, in addition to limestone (Hose et al. 2015; EPA 2016a).

The extent of subterranean habitat present is dependent on the interconnection of subsurface crevices, fractures, and voids, within suitable geological units and aquifer systems, in addition to connectivity to recharge areas and sources of particulate organic matter for food.

Stygofauna have previously been recorded in the Wandoan area, where sampling of groundwater from Horse Creek alluvium to the west of the Project, and WCM near Wandoan (close to the WCM outcrop) recorded several stygofauna taxa (Xstrata 2008; Hose et al. 2015; State of Queensland 2016). Stygofauna are rarely found more than 100 m below the surface and are usually most abundant within the top 30 m from below ground surface (Hose et al. 2015). Stygofauna are found across a range of water quality conditions (from fresh to saline), but most common in fresh and brackish water (electrical conductivity less than 5000 µS/cm) (Hose et al. 2015).

Sampling for subterranean fauna was undertaken at twelve existing landholder bores within the Project area (Appendix V). The sampling was generally undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b). Sampling was undertaken by Freshwater Ecology (Freshwater Ecology 2022b). Only two specimens of one potential stygofauna (from a single bore) were recorded in the twelve samples collected. Given the location of the bore, it is likely that these two specimens are stygofauna but they could not be formally identified. No stygofauna (stygobites or stygophiles) were recovered from the other eleven bores sampled, although large numbers of stygoxenes[5] (both whole and heavily decomposed) were recorded from most bores.

Stygofauna sampling was undertaken on neighbouring PL 1037 at four existing landholder bores. The sampling was undertaken in accordance with available technical sampling guidelines (DES 2018c; EPA 2016b). Sampling was undertaken by Hydrobiology (KCB 2018d) in accordance with DSITI (2015). The following major taxonomic groups, a representative subset of specimens collected were identified to the genus level: amphipoda, copepoda, isopoda, ostracoda, remipedia, spelaeogriphacea, syncarida and thermosbaenacea. For the following taxonomic groups, a representative subset of specimens collected were, at a minimum, identified to the

[5] Animals found accidentally in groundwater.

order or family level: acarina, coleopteran, decapoda, mollusca, nematode, oligochaete, rotifer, polychaeta and turbellaria.

Stygofauna were recorded at two bores, the first of which is estimated to be screened across both the Westbourne Formation and Gubberamunda Sandstone (Table 7.7). A review of the GWDB bore card and drilling log, and the groundwater chemistry results suggest that the majority of the water inflow is likely to be from the Gubberamunda Sandstone. The Gubberamunda Sandstone is inferred to be present between 19 and 25 mbGL within this bore. The stygofauna found include two Cyprididae species (Cyprinopsinae sp.) and three nematode species (Nematoda sp.).

The second bore is screened within the Upper Springbok Sandstone with depth to water recorded as 18.37 m below ground. Despite the higher EC (20,948 µS/cm), Stygofauna were found to occur in this bore.

In the context of the WCM within the Project area, it is unlikely that stygofauna will be present within the target coal seams. Although there is reported occurrence within coal seams of the Surat Basin, near Wandoan; these were in shallow bores (Xstrata 2008). In the Project, all CSG production will occur from the coal seams greater than 250 mbgl, which is deeper than any known occurrence of stygofauna in the Surat Basin.

Table 7.7 Summary of Stygofauna Sampling Results (KCB 2018d)

Bore	Aquifer Attribution	Bore Depth (mbgl)	EC (µs/cm)	Stygofauna Present
Bore 1	Gubberamunda Sandstone / Westbourne Formation	67.4	3,724	Yes
Bore 4	Upper Springbok Sandstone	25.0	20,948	Yes

Aquifer attribution from OGIA (2017e) and Senex baseline assessment (KCB 2018d)

There are no threatened stygofauna species listed in Queensland under the EPBC Act.

7.11 Existing Groundwater Users

7.11.1 Registered Groundwater Bores

Within a 25 km buffer of the Project area, there are 810 groundwater bores present with aquifer attributions provided by OGIA (OGIA 2022). Of these 810, 79 bores are not recorded in the registered groundwater bores database (GWDB)(State of Queensland 2022a).

Of these 810 bores, 590 are existing bores, including water supply or monitoring bores, with the remainder being either abandoned or decommissioned. A summary of registered bores is presented in Table 7.8 along with their type and status, as derived from the GWDB.

Table 7.8 GWDB Registered Bore Details, 25 km Buffer (State of Queensland 2022a; OGIA 2022)

Type		Abandoned and Destroyed (AD)	Abandoned but Usable (AU)	Existing (EX)	Proposed (PR)	Unknown	Total
Artesian	Condition Unknown (AB)	-	-	6	-		
	Ceased to Flow (AC)	3	-	5	-		
	Controlled Flow (AF)	5	-	14	-		
Sub-Artesian (SF)		116	5	565	12		
Unknown		-	-	-	-	79	
	Total	**124**	**5**	**590**	**12**	**79**	**810**

AB: artesian condition unknown; AF: bores that are under artesian pressure and capped to control free flow; AC: bores that have been artesian in the past but have now become sub-artesian due to a reduction in artesian pressure; AB: likely artesian bores, however their current pressure condition is unknown; SF: bores which do not flow under any condition and where active pumping is required to abstract water.

7.11.2 Bore Baseline Assessment

Under the *Water Act 2000*, petroleum tenure holders are required to undertake baseline assessment of water bores prior to commencement of production. A baseline assessment program within ATP 2059 was undertaken in 2022. Assessments were undertaken in accordance with the 'Baseline Assessment Guideline' (State of Queensland 2021f). The assessment was undertaken to obtain information such as:

- Bore status, type and purpose;
- Information related to the construction of the bore, including depth installed, screen interval and source aquifer;
- Groundwater level and quality and field gas measurement; and
- Bore equipment including pump depth, pumping frequency and flow rate.

A bore baseline assessment has been undertaken in ATP 2059. Of the two bores identified for Baseline Assessment, both have been assessed to date. These bores were identified as not operational (Streamline Hydro 2022).

7.11.3 Groundwater Use and Purpose

Of the 669 existing or unknown status bores in Table 7.8 (OGIA 2022):

- 410 bores have been identified as being used for water supply purposes (WS);
- 32 are potential water supply bores (PWS);
- 219 are not a water supply bore, some are monitoring bores or not currently used for water supply (NWS); and
- Eight are recent drills and the purpose is unknown.

The locations of these existing bores are shown on Figure 7.37.

Groundwater abstraction for stock and domestic (S&D) use is the dominant water use purpose within the vicinity of the Project. There are five bores noted as town water supply and ten for intensive stock use. The location of the bores with their purpose indicated is shown on Figure 7.38.

A summary of aquifer attribution is presented in Table 7.9 (OGIA 2022). OGIA have designated all bores with a primary source aquifer, which has been used to populate the table.

Table 7.9 Summary of Aquifer Attribution, 25 km Buffer of PL 209 and PL 445 (OGIA 2022)

Formation	Number of Bores (EX, AU or Unknown)*
Other alluvium	41
Cenozoic Sediments	8
Wallumbilla Formation	5
Bungil Formation	27
Mooga Sandstone	50
Orallo Formation	61
Gubberamunda Sandstone	145
Westbourne Formation	33
Upper Springbok Sandstone	30
Lower Springbok Sandstone	15
Upper Juandah Coal Measures	100
Lower Juandah Coal Measures	48
Taroom Coal Measures	20
Durabilla Formation	5
Upper Hutton Sandstone	37
Lower Hutton Sandstone	10
Upper Evergreen Formation	1
Lower Evergreen Formation	1
Precipice Sandstone	34
Moolayember Formation	2
Rewan Group	1
Total	**674**

*Includes abandoned but usable (AU), existing (EX) and status unknown bores are included.

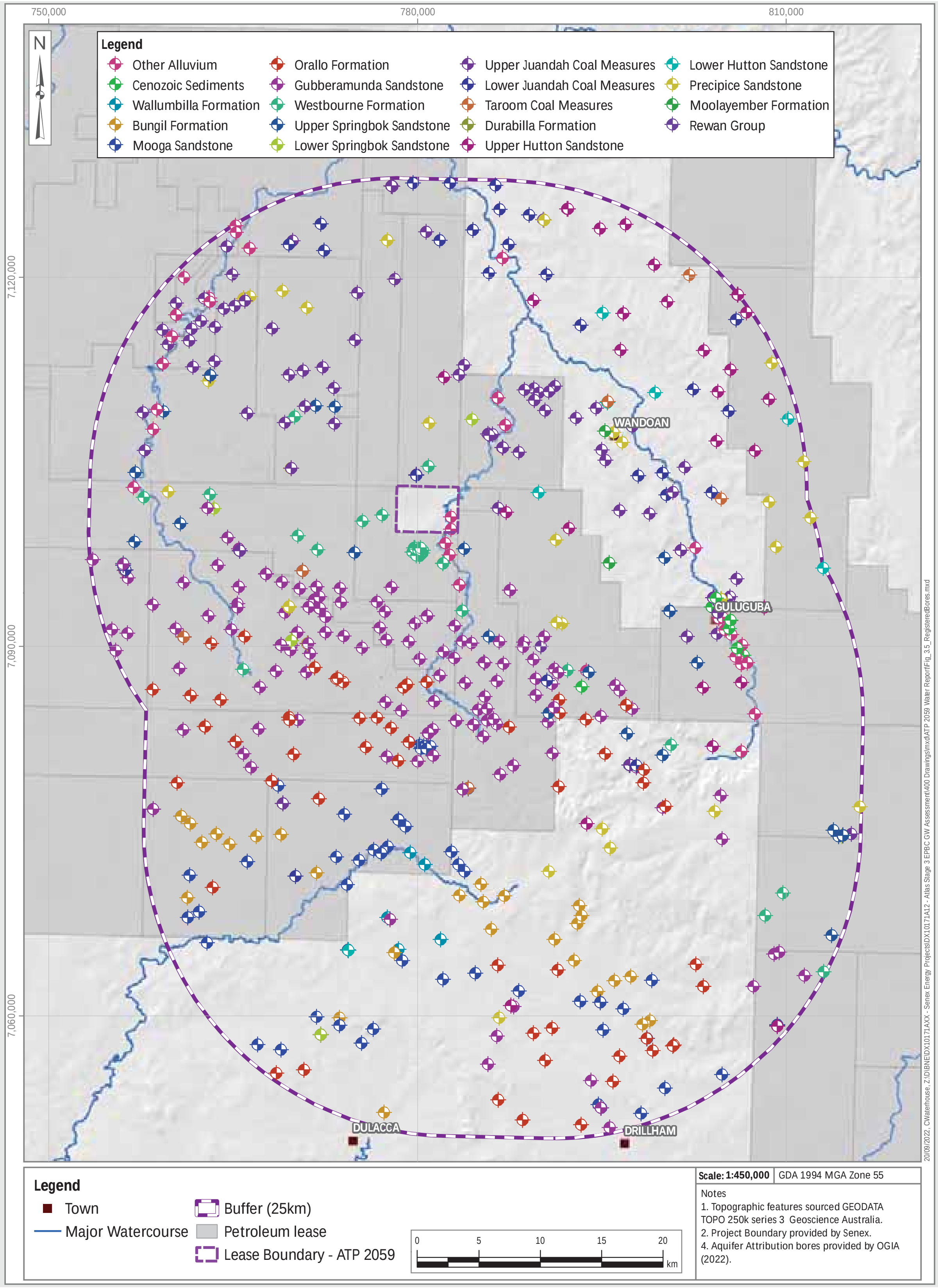


Figure 7.37 Location of Registered Bores within the Vicinity of the Project Area

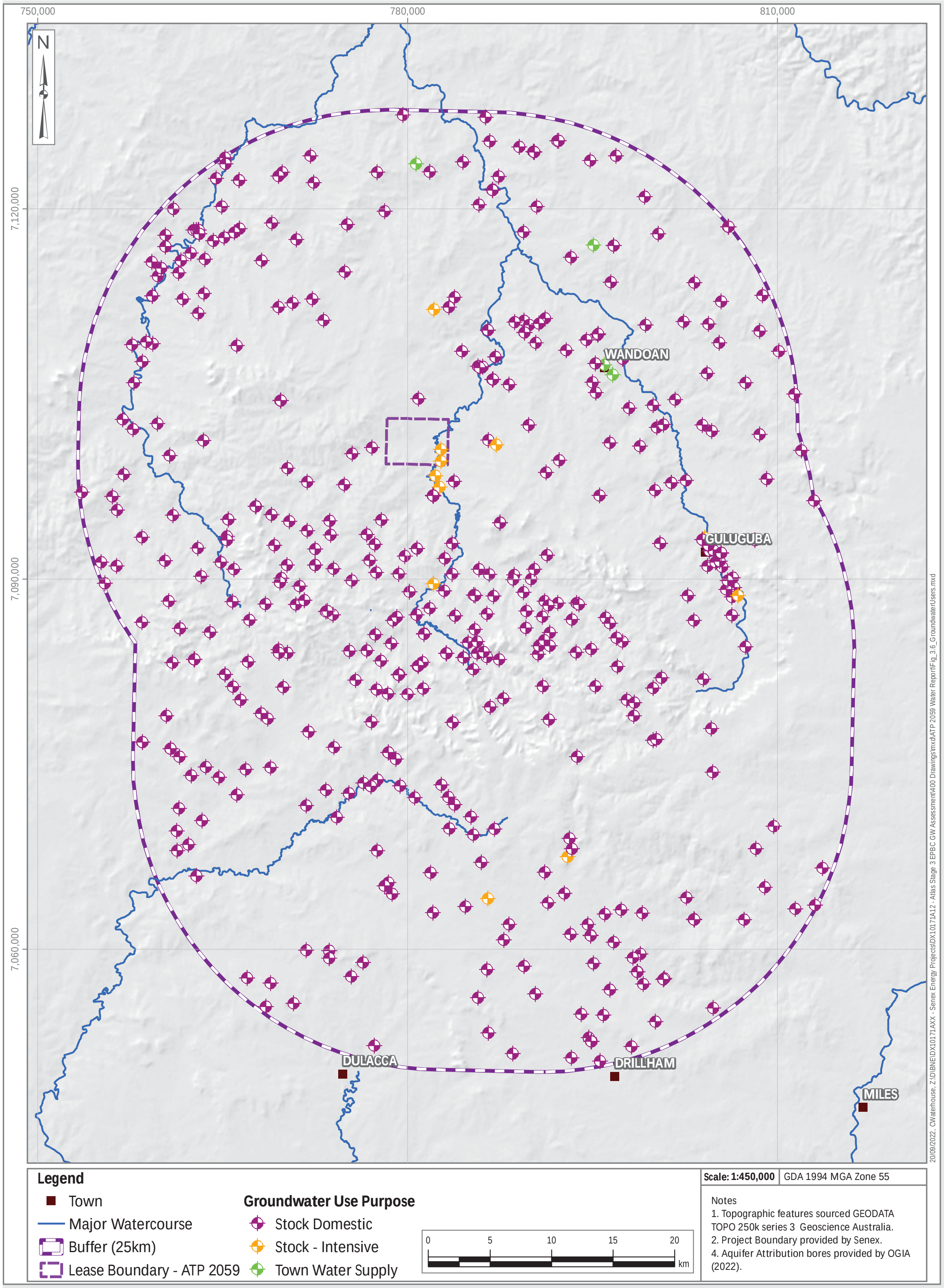


Figure 7.38 Location of Groundwater Users and Purpose of Use

7.12 Hydrogeological Conceptual Model Summary

The hydrological and hydrogeological systems at ATP 2059 can be summarised as follows:

- The target for CSG production is the WCM, which occurs at ~220 to 300 m below ground level; and is ~400 m thick.
- The surface geology within ATP 2059 comprises outcrops of the Gubberamunda Sandstone and Westbourne Formation of the Surat Basin. The Upper Springbok Sandstone outcrops within the north eastern extent of ATP 2059. Quaternary-age alluvium is present along the Woleebee and Conloi Creek systems.
- The WCM outcrop to the north and northeast of the Project area, while the Orallo Formation outcrop to the southeast.
- The WCM is separated from overlying and underlying aquifers by aquitard layers of the Upper WCM aquitard and Durabilla Formation.
- The watercourses within the Project area, Wandoan and Woleebee Creeks, are characteristically ephemeral and typically flow only during significant rainfall events. Pooled water may remain after significant rainfall events, which provides a habitat for a limited number of aquatic species. Shallow pools were identified in the watercourses but were generally turbid with water quality results indicating that these pools are fresh and surface water sourced. The identified aquatic ecosystems are generally of low to fair habitat and had presence (but low diversity) of non-conservation significant native aquatic fauna and flora.
- Baseflow contributions from the alluvium and Surat Basin units to the watercourses are considered unlikely. This has been concluded through previous site verification along these creek systems in PL 1037 from site observations and water quality analyses (fresh water quality but high turbidity). It is likely that the groundwater system in the alluvium is replenished by surface water during prolonged wet periods when the ephemeral creek system is flowing.
- The alluvial systems present within the Project area are generally associated with Wandoan and Woleebee Creeks. Alluvial bank heights of up to 8 m have been observed along Woleebee Creek within PL 445 and alluvial depths of up to 18 m confirmed in registered bores within ATP 2059.

  The water quality of the alluvium indicates that it is recharged and replenished by surface water during prolonged wet periods during periods of creek flow. The water quality is distinct from groundwater in the underlying Westbourne Formation or Springbok Sandstone, which is generally more saline (Section 7.9).
- Terrestrial GDEs have been identified and are generally associated with Wandoan and Woleebee Creek systems. These potential GDEs are considered to be sourcing water from shallow soil systems and the underlying alluvium present along the creek systems (Section 7.10.1).
- These potential terrestrial GDEs are considered to be resilient and adapt well to stress, with the larger eucalypts (including Forest Red Gums) having a dimorphic root system and are well adapted to the drying and wetting ephemeral environment associated with the

creek systems (Section 7.10.1). Groundwater use within the Project area is limited to the shallowest units of the Gubberamunda Sandstone, Westbourne Formation and Springbok Sandstone, with bores used for stock and domestic purposes. Further afield, groundwater is also accessed from the deeper units for both stock and domestic purposes, and town water supply (Section 7.11).

A hydrogeological conceptualisation of the system is presented in Figure 7.39.

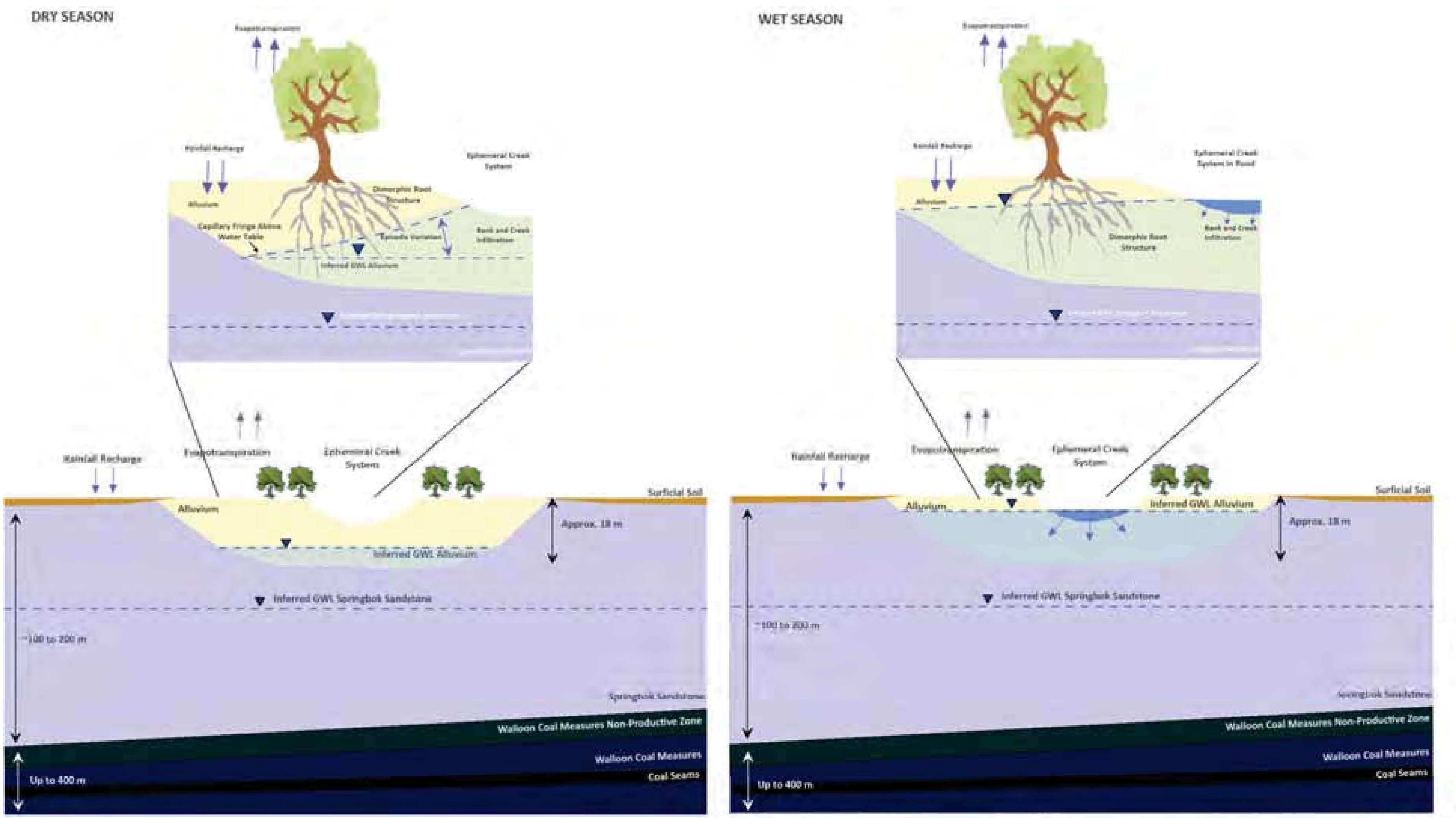


Figure 7.39 Hydrogeological Conceptual Model (Not to Scale)

8 NUMERICAL GROUNDWATER MODELLING

8.1 Overview

As part of the Surat CMA UWIR (OGIA 2021g) OGIA developed a regional numerical groundwater flow model to predict cumulative groundwater pressure impacts due to activities from multiple petroleum and gas tenure holders. The model was first developed and utilised as part of the 2012 UWIR (QWC 2012). An updated UWIR and updated numerical groundwater model was published by OGIA in September, 2016 (OGIA 2016c), July, 2019 (OGIA 2019b) and most recently May 2022 (OGIA 2021g).

The primary purpose of the model is to predict regional water pressure or water level changes in aquifers within the Surat CMA in response to the extraction of gas and associated water from targeted coal seams. In particular, the OGIA numerical groundwater model is used to assess potential impacts to springs and landholder groundwater bores and develop strategies for management of those impacts.

The Surat CMA UWIR is updated periodically (approximately every three years), therefore, the OGIA numerical groundwater model for the Surat CMA is also updated periodically to support the UWIR. Key updates to the model include recalibration of the model based on monitoring data provided by proponents operating within the CMA and the incorporation of newly approved CSG developments within the CMA. Therefore, each update to the OGIA model results in the additional incorporation of site data and an update of the predicted cumulative drawdown impacts across the CMA.

The model domain includes the extent of the Surat CMA, with hydrostratigraphic units from the Surat Basin as well as interconnected basins (Bowen Basin and Clarence-Moreton Basin). The model domain is shown in Figure 8.1. The model consists of 35 layers, of which seven layers represent the Walloon Coal Measures, as shown in Figure 8.2.

A summary of key aspects of the model is presented in Table 8.1, with further detail provided in the following sections. A key update to the 2021 OGIA model is the incorporation of coal mines within the Surat Basin.

Table 8.1 Summary of the OGIA Regional Groundwater Flow Model (OGIA 2021c)

Model Component	Description
Modelling Platform	MODFLOW-USG
Model Domain	Model covers the entire Surat CMA (Figure 8.1), including all coal seam formations and potentially connected aquifers in the Surat, southern Bowen and Clarence-Moreton Basins.
Model Layers	Model consists of 35 layers (Figure 8.2).
Grid Spacing	Model grid spacing is 1.5 km x 1.5 km
Parameterisation	Initial parameters for use in the Surat CMA model were developed using an innovative workflow, developed by OGIA, centred around a suite of detailed numerical permeameters. This workflow was initially developed for use in the 2016 regional groundwater flow model and has been further enhanced for the current model. This approach extracts full value from the large geological and hydraulic parameter dataset available for the CMA. Outputs from this process include formation scale horizontal and vertical permeabilities that are then used as inputs to the regional groundwater flow model for further calibration against water level and other observed data.
Water Production Simulation	Simulated using the MODFLOW-USG ‘drain’ boundary condition. Multiple MODFLOW-USG drains are assigned to each well; these descend over time as pressures in the CSG well are reduced.

Model Component	Description
Calibration	Calibration of the groundwater flow model in three stages: 'pre-development' (1947) to replicate conditions that existed prior to the commencement of any groundwater extraction; pre-CSG extraction conditions commensurate with 1995; and a transient simulation to replicate the period from January 1995 to December 2020, during which CSG extraction commenced initially from the Bandanna Formation and then from the Walloon Coal Measures.

The key changes to the 2021 regional groundwater model include:

- The introduction of an additional layer in the WCM to better represent the geological subdivision of this formation and improve representation of flow between units of the WCM.
- Representation of coal mines where overlapping impacts with CSG development are likely to occur, this included the Wandoan Coal Project located directly north of the Project area.

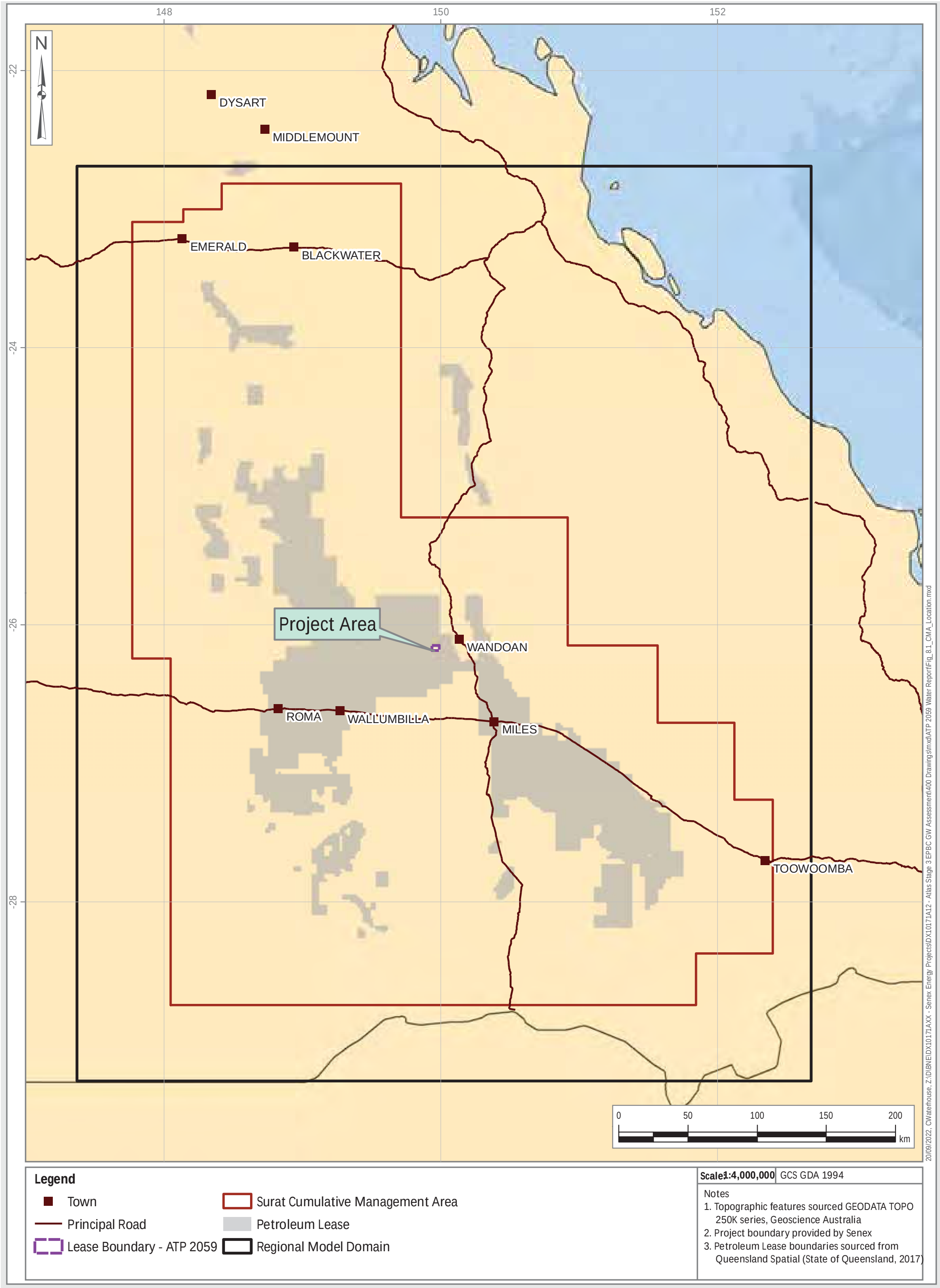


Figure 8.1 Location of the Surat CMA Regional Flow Model Extent and the Project

Model layer	Formation	Basin
1	All Alluvium and Basalt (including Main Range Volcanics)	Cenozoic
2	Upper Cretaceous (Griman Creek Formation & Surat Siltstone) and the Condamine-Walloon transition zone	Surat & Clarence-Moreton basins
3	Wallumbilla Formation	
4	Bungil Formation	
5	Mooga Sandstone	
6	Orallo Formation	
7	Gubberamunda Sandstone	
8	Westbourne Formation	
9	Upper Springbok Sandstone	
10	Lower Springbok Sandstone	
11	Walloon Coal Measures non-productive zone	
12	Upper Juandah Coal Measures - Layer 1	
13	Upper Juandah Coal Measures - Layer 2	
14	Lower Juandah Coal Measures - Layer 1	
15	Lower Juandah Coal Measures - Layer 2	
16	Lower Juandah Coal Measures - Layer 3	
17	Taroom Coal Measures	
18	Durabilla Formation	
19	Upper Hutton Sandstone	
20	Lower Hutton Sandstone	
21	Upper Evergreen Formation	
22	Boxvale Sandstone	
23	Lower Evergreen Formation	
24	Precipice Sandstone	
25	Moolayember Formation	Bowen Basin
26	Clematis Group	
27	Rewan Group	
28	Bandanna Formation non-productive zone	
29	Upper Bandanna Formation	
30	Lower Bandanna Formation	
31	Lower Bowen 1	
32	Cattle Creek Formation non-productive zone	
33	Upper Cattle Creek Formation	
34	Lower Cattle Creek Formation	
35	Lower Bowen 2	

Regional aquifer | Partial aquifer | Tight aquifer | Interbedded aquitard | Tight aquitard

OGIA_017

Figure 8.2 Model Layers and Corresponding Hydrostratigraphic Units Represented in the OGIA Regional Groundwater Flow Model (OGIA 2021c)

8.2 Model Parameters, Boundary Conditions and Calibration

The information provided in the following sections has been summarised from the *Groundwater Modelling Report for the Surat Cumulative Management Area* (OGIA 2016c), *Underground Water Impact Report for the Surat CMA* (OGIA 2021g), and *Modelling of cumulative groundwater impacts in the Surat CMA: approach and methods* (OGIA 2021c).

8.2.1 Model Parameters

OGIA improved their approach to assigning initial numerical groundwater model parameters as part of the update to the regional model for the 2016 UWIR (OGIA 2016c) and have continued to further enhance the model for the 2021 UWIR (OGIA 2021g).

The approach included three steps, as described in OGIA (2019c):

- 'Initial values of hydraulic conductivity for each of six lithology types' (clean sand, dirty sand, siltstone, mudstone, carbonaceous shale and coal) from geophysical logs are derived from expert knowledge, literature and analysis of geophysical logs.
- These initial values are then input to a stochastic permeability model and calibrated (or 'conditioned') through comparison with around 13,000 hydraulic test results at three different scales (i.e., pump tests, core test and geophysical measurement).
- Once calibrated, these values are then used to populate numerical permeameters – detailed 21 x 21 km numerical models of each stratigraphic unit, generated using lithological data for about 6,000 CSG wells and covering the full extent of the twelve stratigraphic units modelled. In total, more than 138,000 model runs were carried out during this part of the process.'

8.2.2 Groundwater Abstraction – Boundary Conditions

Optimal flow conditions for gas production are typically achieved when water pressures within the production well are equivalent to 25 to 80 m of water head (OGIA 2019c). To simulate water production, OGIA have used the MODFLOW-USG 'drain' boundary condition, with multiple drains assigned to each production well descending over time as pressures in the CSG production well reduce. The simulation using the drain boundary condition, is based on the sequencing of development and production well spacing provided by tenure holders across the model domain. Water is removed from the model to achieve the optimal head conditions (25 to 80 m), rather than removing a volume predicted using a modelling tool (e.g., estimated abstraction volume in Section 3).

Groundwater abstraction for non-petroleum and gas purposes, such as stock and domestic, are simulated using the MODFLOW-USG 'well' boundary condition.

8.2.3 Model Calibration

Calibration of the 2021 model was achieved using a three-stage simulation (OGIA 2021c). The first was a pre-development (1947) simulation was to replicate conditions that existed prior to the commencement of any groundwater extraction, for petroleum, gas or other purposes. The second simulation was to replicate pre-petroleum and gas extraction conditions in 1995 to provide starting or initial conditions for the third and final stage. The third stage was a transient simulation to replicate the period from January 1995 to December 2020, during which petroleum and gas production commenced initially from the Bandanna Formation and then from the Walloon Coal Measures.

The calibration was undertaken using the automated calibration software PEST, with a range of qualitative and quantitative measures used to assess each calibration iteration, consistent with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012).

8.3 Senex Model Scenarios

At the request of Senex, OGIA has simulated an appraisal scenario using the 2021 groundwater model based on production plans provided by Senex. Outputs from this model were used as part of this assessment. The original 2021 UWIR model included the approved APLNG 'Woleebee' gas field in PL 445 and PL 209, therefore, this gas field was removed for the modelled scenarios.

These outputs have been provided for use and processed as part of this assessment. All processing and analysis of model outputs was undertaken by KCB based on raw model outputs provided by OGIA.

The modelled scenarios completed by OGIA comprise:

- Cumulative CSG Development without the Project:

  Cumulative drawdown associated with all CSG and coal mining activities but excluding the Project (ATP 2059, PL 209, and PL 445) and the APLNG Woleebee gas field.
- Project Development scenarios (2023 until 2045):

  Drawdown associated with 31 wells on ATP 2059 and 120 wells on PL 445 and PL 209 (total of 151 wells) (Project only).

Total cumulative drawdown of the Project, plus all other CSG and coal mining projects, is calculated by adding the individual drawdown predicted by the Project only, to the cumulative scenario without the project, resulting in a cumulative drawdown scenario for the project development scenario.

The predicted drawdown presented in Sections 8.5 and 8.6 relates to the presence of CSG wells in ATP 2059 and neighbouring PL 209 and PL 445, as the activities on the three PLs were modelled by OGIA together as the full Atlas Stage 3 Project.

8.4 Assumptions and Limitations

Assumptions and limitations of the regional groundwater model are provided in OGIA (2016d). Key assumptions and limitations of the model associated with its use for this assessment are provided in the following:

- Since the model is required to cover the full extent of the Surat CMA and all aquifers potentially impacted by petroleum and gas water extraction within it, groundwater numerical model cell sizes are relatively large in lateral extent (1.5 km × 1.5 km). One outcome of the large cell size is that shallow, unconfined groundwater systems, and the interaction of these systems with deeper systems, can be simulated only approximately.

- Model cell sizes are large in vertical extent. Other than the WCM, most stratigraphic layers in the Surat and Bowen Basins are represented by only one or two model layers. Vertical head gradients within these layers, and geological details which lead to variations of these gradients, are only an approximation for the entire stratigraphic thickness (i.e., heterogeneity of the stratigraphic unit is not fully captured in the numerical model although considerable efforts were made to generate upscaled parameters and test that the model could replicate impact predictions made using highly detailed models with minimal upscaling).
- Desaturation of coal measures leading to desorption of gas, and hence the resulting dual phase flow, is simulated using a van Genuchten function in which water saturation is a function of pressure alone. This is a simplification of more complex processes that include desorption of gas, and then flow of gas together with water towards extraction centres. Buoyant up-dip movement of gas is also not represented.
- The effect of local faulting and abandoned and poorly constructed wells on vertical propagation of drawdown to stratigraphic units adjacent to the WCM units is not currently considered. However, major regional fault systems and are represented in both the model structure and parameterisation and hence their effects on impact propagation are considered. However, major regional fault systems and are represented in both the model structure and parameterisation and hence their effects on impact propagation are considered.
- Limited site-specific hydraulic parameter data is available and therefore the values utilised in the model in the vicinity of the Project have been inferred and calibrated through reference to data outside of the Project area, which may increase / decrease the effects of CSG production, and associated groundwater abstraction, within the Project area.
- CSG production is represented by drain boundary conditions with elevations set for optimal gas production. As a result, the produced volume of water from the drain cells may not necessarily represent actual CSG water production due to localised variability in aquifer hydraulic parameters. The model, however, been calibrated to historic actual production data and is able to replicate production in most current fields to a high degree of accuracy.

8.5 Project Only Scenario Results

Numerical model outputs provided by OGIA, for the scenarios detailed in the previous section, have been used by KCB to assess the extent and magnitude of drawdown related to CSG production from the Project.

Appendix II includes the predicted drawdown for the individual model layers, which represent the modelled hydrostratigraphic units (detailed in Figure 8.2). The figures in Appendix II present the drawdown during field development and post-development. Summary figures are presented in Figure 8.3 and Figure 8.4 showing the maximum Project only predicted drawdown (for the model duration). Observations include:

- Drawdown greater than 0.2 m (spring trigger threshold) is predicted in model layer 8 (Westbourne Formation) to model layer 18 (Durabilla Formation).
- Drawdown greater than 5 m (consolidated bore trigger threshold) is predicted in model layers 10 to 18 (Lower Springbok Sandstone to Durabilla Formation).
- The highest drawdown is predicted in model layer 17, which represents the Taroom Coal Measures.
- Drawdown within the Upper Juandah Coal Measures Layer 2 (model layer 13) has the widest drawdown extent: 13.1 km beyond the Project area extent.

As indicated, Appendix II presents the predicted drawdown during field development and post-development. The post-development timesteps presented are for 2060 (~10-years since end of CSG production), 2100 (50-years since end of CSG production) and 2300 (250-years since end of CSG production. These figures show groundwater level recovery within the WCM, and in the later timesteps, the propagation of drawdown in the overlying / underlying layers.

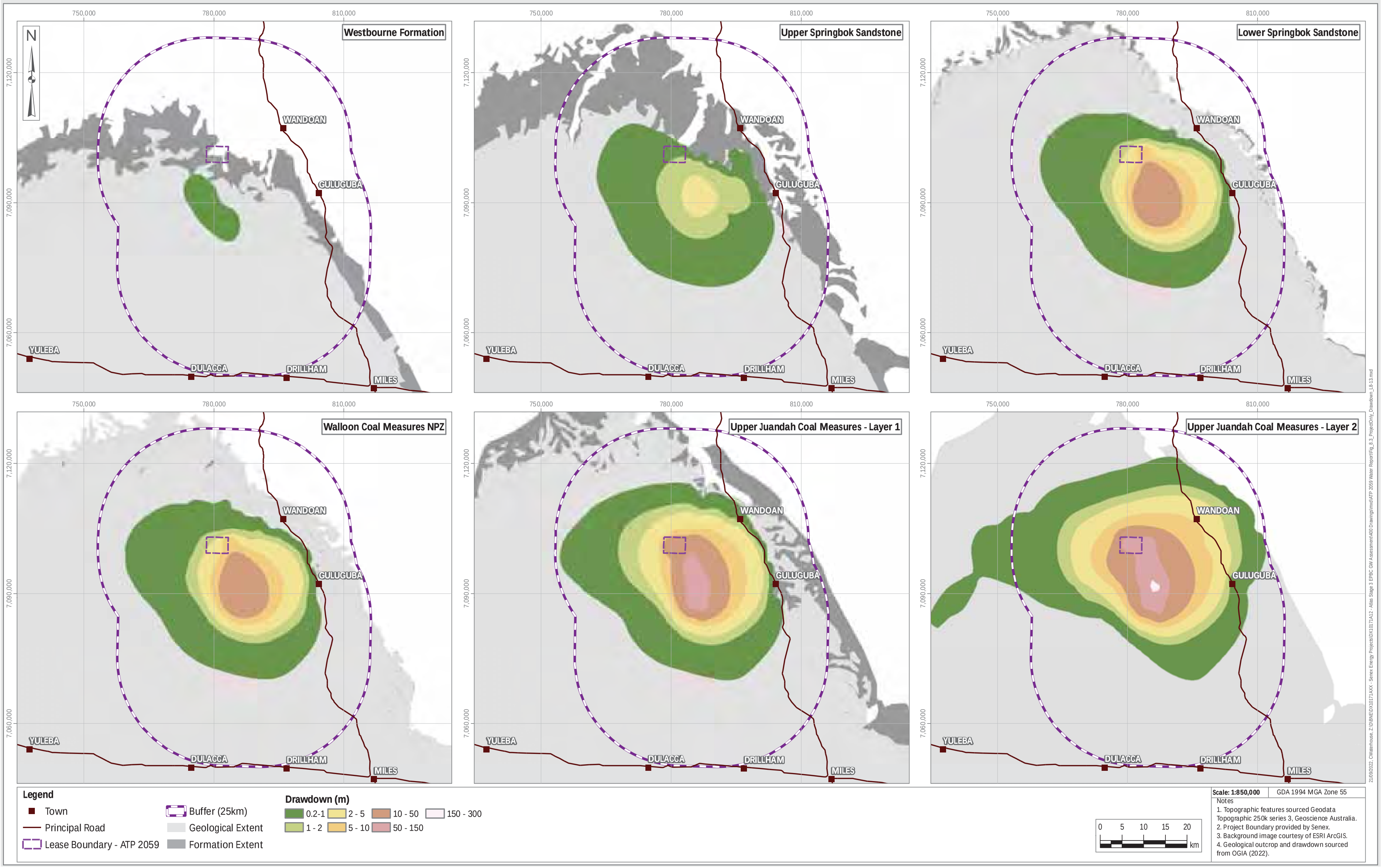


Figure 8.3 Extent of 'Project Only' Maximum Predicted Drawdown for Model Layers 8 (Westbourne Formation) to 13 (Upper Juandah Coal Measures – Layer 2)

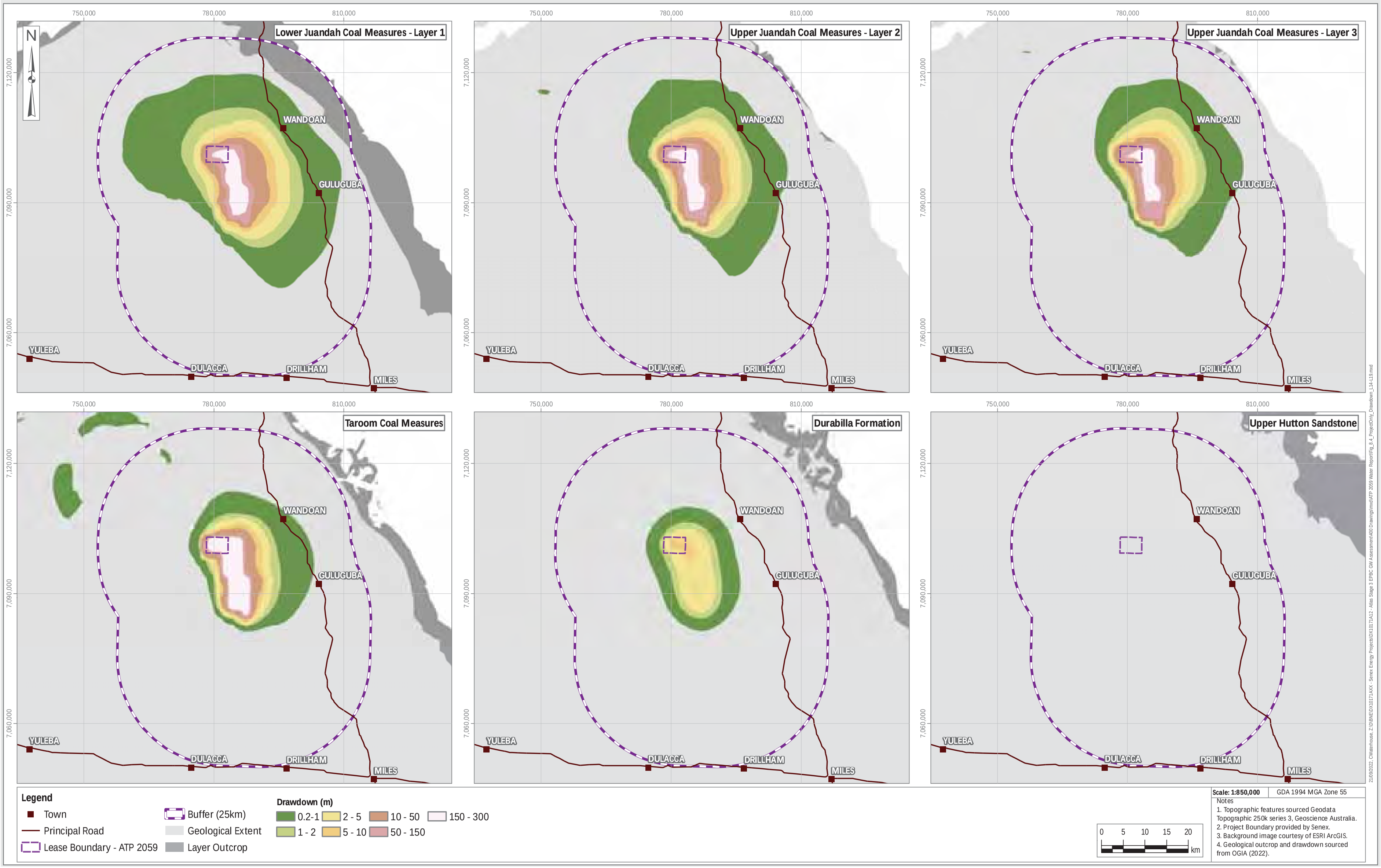


Figure 8.4 Extent of 'Project Only' Maximum Predicted Drawdown Model Layers 14 (Lower Juandah Coal Measures – Layer 1) to 19 (Upper Hutton Sandstone)

8.6 Cumulative Scenario Results

As detailed in Section 2.2.2, the Project is located within the Surat CMA, which was declared under the *Water Act 2000*, as a result of concentrated development by multiple tenure holders.

The Project area is located adjacent to other active and proposed CSG developments. As groundwater is removed via CSG production wells to depressurise the coal seams, there will be a degree of interaction between the individual tenure holders. There is also the potential for planned future mining operations in the area to increase the cumulative impacts.

OGIA, established under the *Water Act 2000*, is responsible for predicting regional impacts on water pressures in the hydrostratigraphic units of the Surat CMA and identifying potentially impacted groundwater bores and springs as presented in the UWIR, which is updated and published every three years.

Drawdown results for the cumulative scenario, focused on the Project area, are presented in Appendix III for individual modelled hydrostratigraphic units. Summary figures for the cumulative scenario are presented in Figure 8.5 and Figure 8.6. These figures show the maximum predicted cumulative drawdown for the model duration.

The cumulative drawdown results indicate drawdown within the vicinity of the Project area for the Westbourne Formation, Springbok Sandstone, WCM and Hutton Sandstone. The majority of the drawdown occurs towards the west of the Project, associated with neighbouring CSG developments. Drawdown also occurs to the southeast, where other CSG proponents are also operating.

The post-development timesteps for cumulative drawdown for the various hydrostratigraphic units are presented in Appendix III. These timesteps include 2060 (10-years since end of CSG production), 2100 (50-years since end of CSG production) and 2300 (250-years since end of CSG production). Similar to the Project only, the figures show groundwater level recovery within the WCM; and, in the later timesteps, the propagation of drawdown in the overlying / underlying layers.

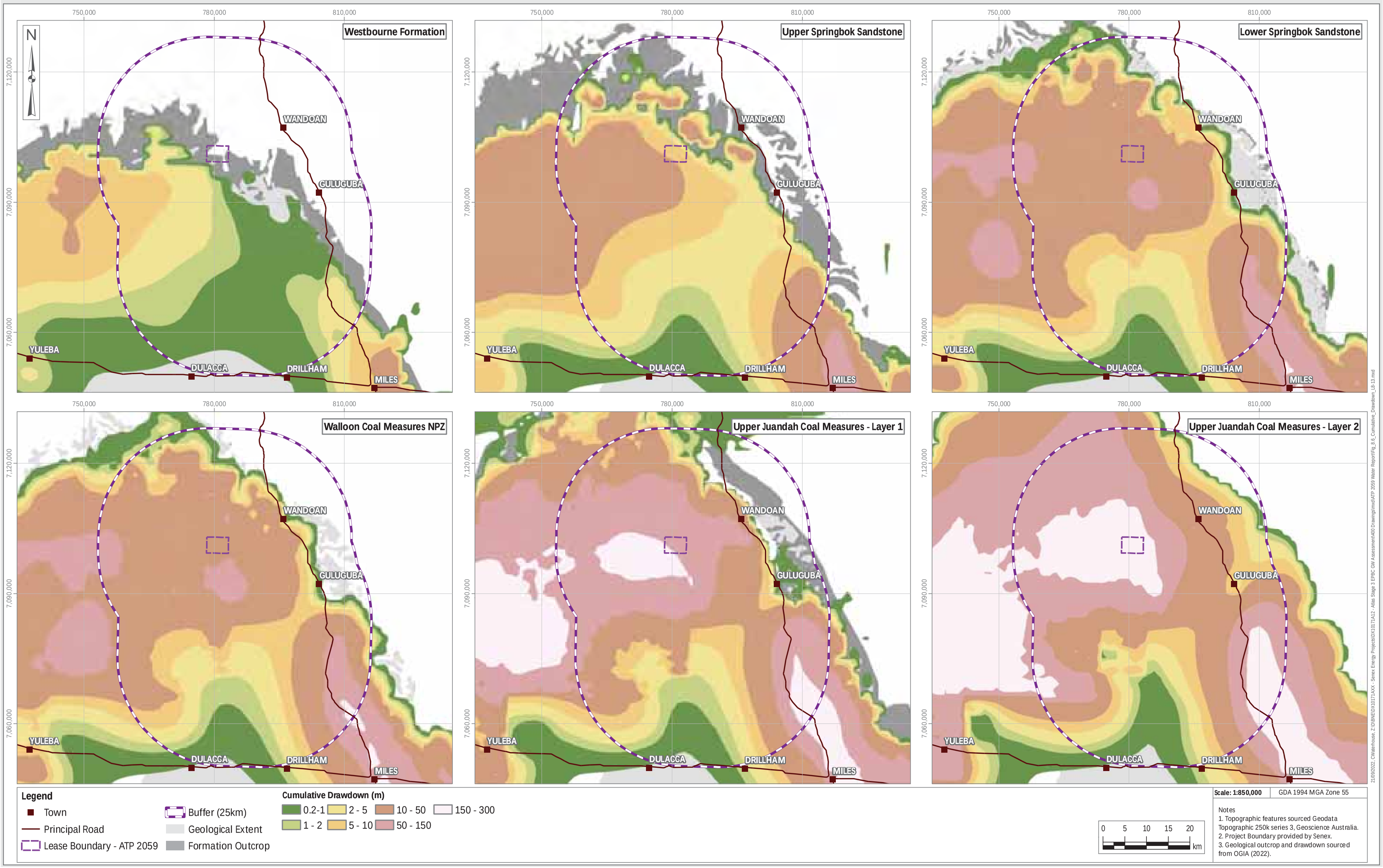


Figure 8.5 Extent of 'Cumulative' Maximum Predicted Drawdown for Model Layers 8 - 13 Westbourne Formation to Upper Juandah Coal Measures – Layer 2

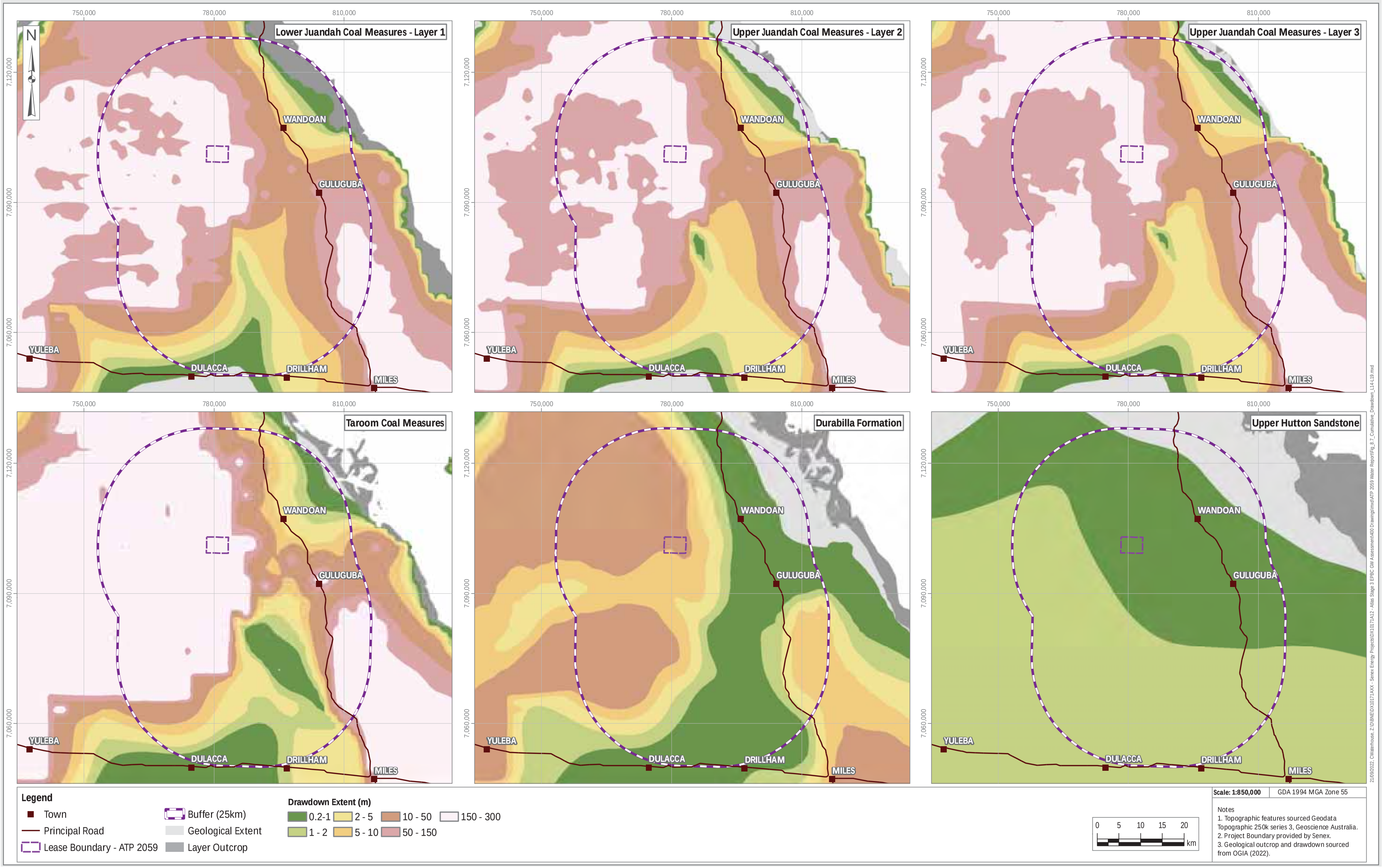


Figure 8.6 Extent of 'Cumulative' Maximum Predicted Drawdown for Model Layers 14 to 19 – Lower Juandah Coal Measures – Layer 1 to Upper Hutton Sandstone

9 IMPACT ASSESSMENT

This section presents the potential project impacts from the drawdown associated with the 31 wells on ATP 2059 and 120 wells on PL 445 and PL 209 (total of 151 wells). The activities on the three PLs were modelled by OGIA together as the full Atlas Stage 3 Project. The results are therefore present an overly conservative assessment of impact from the activities on ATP 2059.

9.1 Potential Project Impacts

9.1.1 Groundwater

CSG water production occurs as part of the CSG extraction process. Groundwater is removed via CSG wells during the process of depressurisation of the coal seams, which then liberates gas flow. This depressurisation and gas flow sustains a groundwater flow from each well to maintain the target gas producing operational pressure.

Senex intend to exercise their underground water rights under the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020c) to produce CSG. Several other authorised petroleum lease holders are also exercising their underground water rights in the vicinity of Project Atlas.

Potential impacts resulting from CSG water production include:

- Decline in groundwater level / pressure at water bores, reducing water availability and potentially impacting groundwater EVs.
- Reduction in groundwater head resulting in a reduction of groundwater discharge at spring complexes, potentially causing degradation of GDEs.
- Reduction of baseflow to watercourses, potentially resulting in degradation of GDEs and reduced water availability to potential users downstream.

These impacts have been quantitatively assessed in the following sections using modelling outputs from the UWIR 2021 numerical groundwater model.

Other potential impacts associated with groundwater are mitigated and managed by adopting the appropriate monitoring, management, and mitigation strategies. These potential impacts may include:

- Introduction of a connection between hydrostratigraphic units which were previously isolated units though drilling and construction of CSG production wells, resulting in the potential for alteration of flow regimes and quality.
- Drilling fluids used during the drilling process, which can impact groundwater quality.
- Seepage from CSG produced water storage impacting groundwater levels and quality, through seepage.
- Localised incidental CSG activities impacting shallow groundwater systems, such as fuel spills or improper storage of chemicals.
- Beneficial use activities impacting shallow groundwater systems through over-irrigation, or the lack of adherence to relevant beneficial use quality guidelines.

Monitoring, management and mitigation practices associated with the above activities are discussed further in Section 10.

9.1.2 Surface Water

Impacts to surface water and associated aquatic systems from the Project are anticipated to be minimal. The Project does not include any:

- Planned discharge to / abstraction from the surface water systems; or
- Surface water diversions.

Potential impacts likely to result from Project activities are summarised below. These impacts are associated with the general construction and day to day operations of CSG surface facilities rather than CSG production; and comprise:

- Localised transport of suspended sediment to waters during construction or site works, resulting in the potential to alter flow regimes and quality;
- Localised release of hydrotest water, effluent or trench water to land (these fluids are not intended for release to the surface water system so has limited potential for any impact to surface water quality);
- Alteration of a watercourse character or changes to riparian buffers due to construction works;
- Unplanned releases from water storage facilities have the potential to impact surface water and associated ecosystems; and
- Fuel and chemicals will be used as part of the project, with the potential for unplanned release that could impact surface water quality.

These impacts are managed and mitigated by adopting and implementing the appropriate monitoring, management, and mitigation strategies. Further discussion of these potential impacts is included in the following sections.

9.2 Impacts to Third-Party Surface Water Users

There are no surface water users identified within the vicinity or immediately downstream of the Project, therefore, no impacts to third-party surface water users are predicted as a result of the Project development.

9.3 Impacts to Third-Party Groundwater Users

Potential long-term impacts to groundwater bores have been assessed against the *Water Act 2000* bore trigger threshold of 2 m for an unconsolidated aquifer (e.g., alluvium) and 5 m for a consolidated aquifer (e.g., Surat Basin units) using the outputs and drawdown predictions from the UWIR numerical model. The maximum predicted drawdown was used for this assessment, irrespective of the timing of predicted drawdown. Assumptions / limitations of this assessment include:

- Many groundwater bores within the vicinity of the Project were constructed to intersect multiple formations. OGIA have assigned each bore a dominant source aquifer, this dominant aquifer was used to assess potential drawdown at each bore. Appendix IX provides the attributed formation (or formations) as discussed in Section 7.11.3 and the formation used as part of the impact assessment.

- Forty-four bores were assigned as 'screened within alluvium'. Where the OGIA model does not simulate alluvium at a bore location, predicted drawdown in the unit directly underlying the alluvium was considered for the impact assessment and assessed against the *Water Act 2000* bore trigger threshold of 2 m for an unconsolidated aquifer. Appendix IV details the unit assigned to those bores for impact assessment purposes.

9.3.1 Project Only Impacts to Third-Party Groundwater Users

A summary of the impacts to groundwater bores from the Project only simulation is presented in Table 9.1, with individual bore results presented in Appendix IV. Table 9.1 indicates the number of bores assessed for each formation; the number of bores which are predicted to have any drawdown; the number of bores which exceed the groundwater bore trigger threshold of 5 m drawdown for consolidated aquifers; and the maximum drawdown modelled for all the bores attributed to that formation.

Table 9.1 Project Only – Summary of Impact Assessment Results for Groundwater Bores

Formation	Number of Bores	Number of Bores with Drawdown	Number of Bores Predicted to Exceed Trigger Thresholds	Maximum Drawdown Predicted Across the Bores (m)
Bungil Formation	29	0	0	0.00
Mooga Sandstone	59	0	0	0.00
Orallo Formation	74	0	0	0.00
Gubberamunda Sandstone	148	62	0	0.01
Westbourne Formation	38	13	0	0.11
Upper Springbok Sandstone	45	35	0	2.33
Lower Springbok Sandstone	15	14	0	1.11
Walloon Coal Measures	228	220	23	123.34
Durabilla Formation	5	2	0	0.02
Hutton Sandstone	47	3	0	0.01
Evergreen Formation	2	0	0	0.00
Precipice Sandstone	37	0	0	0.00

The results indicate:

- Predicted drawdown (of any magnitude) is observed in bores attributed to most hydrostratigraphic units, however, only bores in the WCM are predicted to experience a drawdown greater than 5 m.
- There are 23 bores in the WCM which have a predicted drawdown greater than 5 m. These bores are screened in the Upper Juandah Coal Measures (21 bores) and the Taroom Coal Measures (two bores). Fifteen of these bores are predicted to experience drawdown of less than 10 m, six between 10 and 20 m drawdown, and only two with a drawdown of more than 20 m. The maximum predicted drawdown in any one bore is 123.32 m (screened in the Upper Juandah Coal Measures).
- Of these 23 bores, 12 are noted by OGIA as water supply bores, ten bores are noted as 'not water supply', and one as 'potential water supply'. The location of these bores, where the

water level is predicted to drawdown greater than the trigger threshold, is presented in Figure 9.1.

- The groundwater bores triggered in the Project only scenario, are already triggered by adjacent developments (e.g., without any contribution from the Project).

As discussed in Section 7.11.3, five bores in the vicinity of the Project are used for town water supply which target the Precipice Sandstone, the Lower Hutton Sandstone and the WCM. These bores are located near Wandoan and to the north of the Project area, approximately 14 km away. The results of the impact assessment indicate that there is less than 0.1 m drawdown as a result of the Project at these town water supply bores.

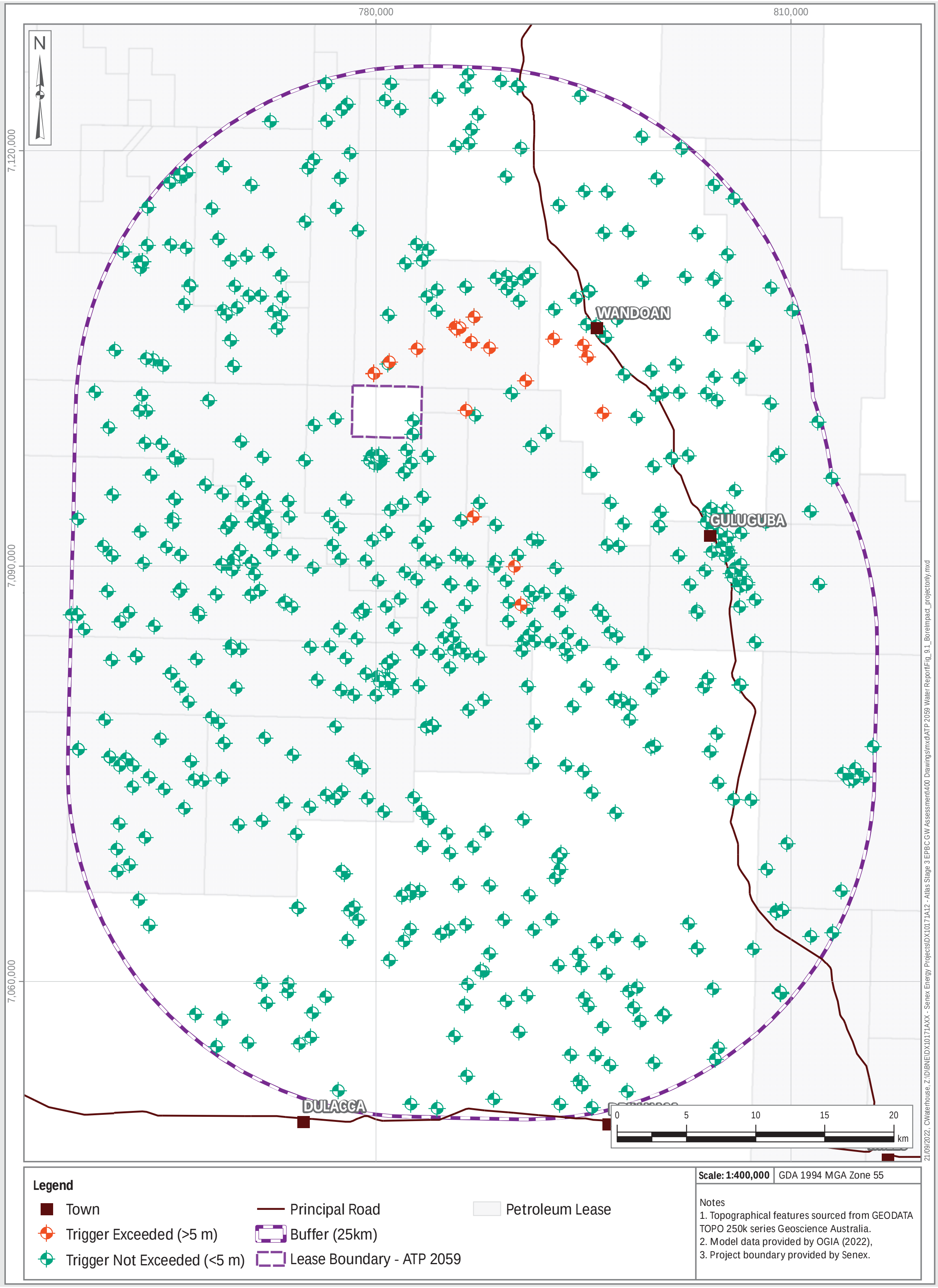


Figure 9.1 Summary of Impacts to Groundwater Bores – Project Only

9.3.2 Cumulative Impact to Third-Party Groundwater Users

The cumulative impact assessment was undertaken using the same approach adopted for the Project only impacts (e.g., *Water Act 2000* trigger thresholds).

A summary of the cumulative impact results for groundwater bores is presented in Table 9.2, with results for individual bores presented in Appendix IV. The results indicate the following:

- Within the 25 km buffer from the Project, 248 bores are triggered (i.e., >5 m drawdown) in the cumulative scenario.
- There are five additional bores triggered as part of the cumulative scenario (i.e., the contribution of the Project development results in five additional bores being triggered in the cumulative scenario, these bores would not have been triggered without the presence of the Project). Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. The locations of these bores are presented on Figure 9.2.
- Of the five additional bores, none are located on tenement and are all located off-site to the east. One of these bores is noted as “Abandoned and destroyed”, two are noted as “Monitoring bores (and not water supply bores)”, and two are noted as “Existing bores”. Of the existing bores, a bore baseline assessment confirmed one of these bores is blocked and has not been used since 1996 (Arrow 2013). The maximum Project only contribution to drawdown on the only existing, usable bore is 26%.
- Of the 248 bores, the Project only contribution to drawdown of more than 1% occurs at 99 bores, and more than 10% at 36 bores. The maximum contribution from the Project is 81%, this bore is located on PL 209 which has been confirmed as not existing through the 2022 Baseline Assessment (KCB 2022).

Table 9.2 Cumulative Scenario – Summary of the Impact Assessment Results for Groundwater Bores

Formation	Number of Bores within 25 km	Project Only – Number of Bores Triggered	Cumulative – Number of Bores Triggered
Bungil Formation	29	0	0
Mooga Sandstone	59	0	0
Orallo Formation	74	0	0
Gubberamunda Sandstone	148	0	0
Westbourne Formation	38	0	3
Upper Springbok Sandstone	45	0	22
Lower Springbok Sandstone	15	0	14
Walloon Coal Measures	228	23	205
Durabilla Formation	5	0	4
Hutton Sandstone	47	0	0
Evergreen Formation	2	0	0
Precipice Sandstone	37	0	0

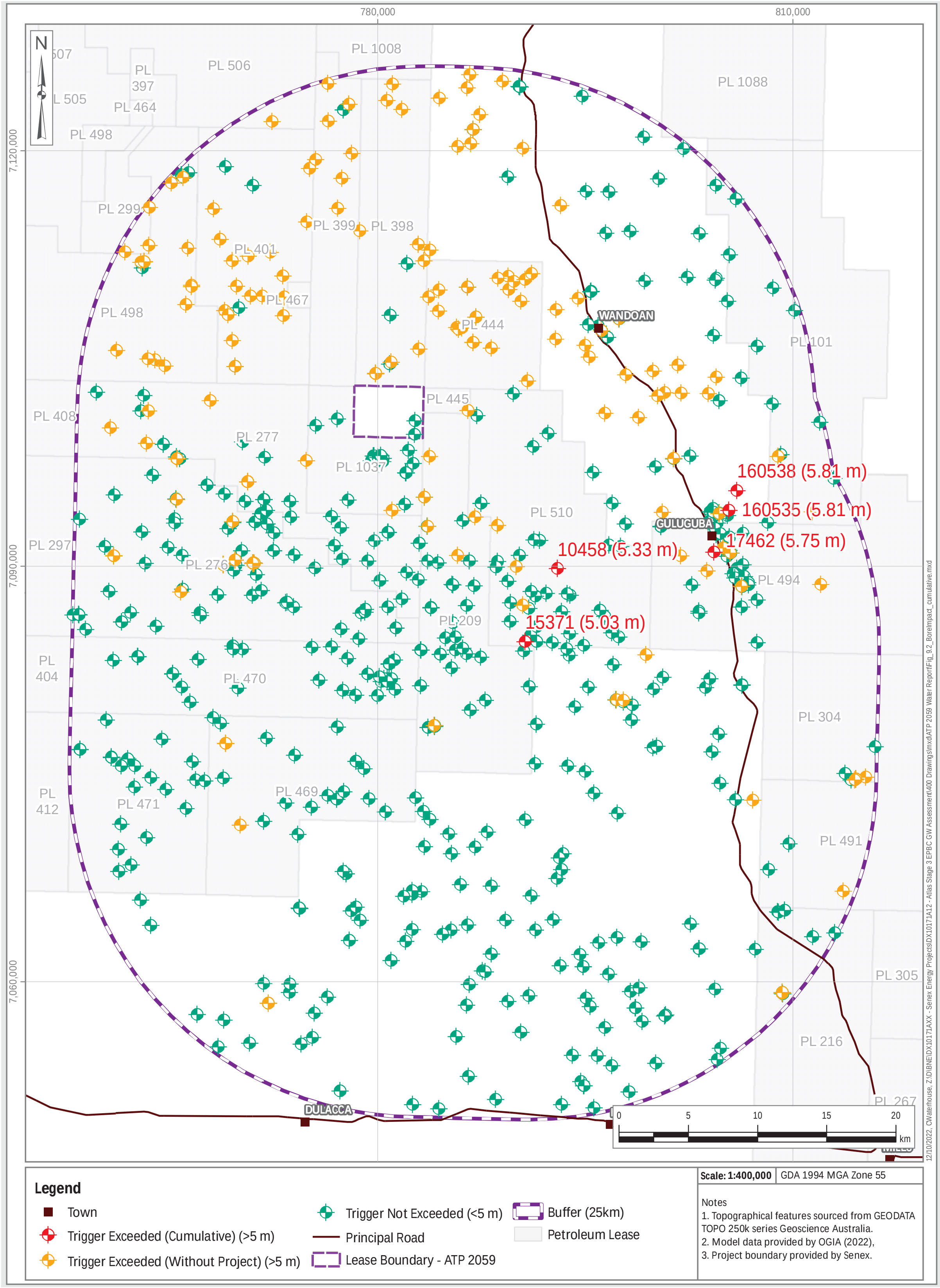


Figure 9.2 Summary of Impacts to Groundwater Bores – Cumulative

9.4 Impacts to Groundwater Dependent Ecosystems

Outcropping geological formations in the Project area have the potential for connection to aquatic and terrestrial GDEs, either directly, or through connections to overlying alluvial deposits. The areas of interest for assessment of impacts to GDEs are the outcrop areas of:

- Upper Springbok Sandstone – this unit outcrops under PL 445 and to the north / northeast of PL 445 and PL 209 to the east of ATP 2059.
- Westbourne Formation – this unit outcrops within ATP 2059.
- Gubberamunda Sandstone – this outcrops under the southern extent of ATP 2059.

Areas of interest were identified by the 0.2 m drawdown extent for each outcrop formation. Potential drawdown greater than 0.2 m in these outcropping geological units have been compared to locations of potential GDEs and springs from the Queensland GDE mapping (State of Queensland 2018a) and field verification by ERM ecologists for GDEs located within the Project area.

In summary:

- Project only drawdown of more than 0.2 m is not predicted for the Gubberamunda Sandstone for the Project only scenario, and cumulatively the Project does not contribute to any further potential GDE areas exceeding the 0.2m trigger. Potential GDEs on the Gubberamunda Sandstone are not considered further in the GDE assessment.
- Project only drawdown in the Westbourne Formation is predicted to be less than 0.2 m on any Westbourne Formation outcrops. The Project does contribute cumulatively to additional drawdown in the outcrop area of the Westbourne Formation. This occurs in a small area of the Westbourne Formation outcrop in PL 1037 (Atlas) and neighbouring tenement PL 277 to the west (QGC).
- The groundwater in the Upper Springbok Sandstone outcrop area is predicted to have a drawdown greater than 0.2 m due to the Project development (Project only simulation), resulting in this formation being the main formation of interest for this GDE impact assessment.

9.4.1 Impacts to Aquatic GDEs Areas

There are three potential aquatic GDEs areas of interest within or close to the Project area. These aquatic GDEs are defined by the Queensland GDE mapping as being sourced from Quaternary alluvial aquifers overlying sandstone ranges with fresh, intermittent groundwater connectivity; there is moderate confidence in their presence (State of Queensland 2018a). The locations and summary of predicted drawdown is presented in Figure 9.3 and Table 9.3.

The one mapped aquatic GDE located within the Project area of ATP 2059 (No. 1; Table 9.3 and Figure 9.3) is located on the Westbourne Formation outcrop and is interpreted to be sourcing water from the Westbourne Formation which is not predicted to experience drawdown greater than 0.2 m (for any scenario). The alluvium overlying the Westbourne Formation is also not predicted to drawdown greater than 0.2 m. GDE No. 2, located on neighbouring PL 209 is also located on the alluvium and Westbourne Formation and is not predicted to experience drawdown greater than 0.2 m.

The aquatic GDE located to the north of PL 445 (No. 3), is located on the Springbok Sandstone outcrop (Site 3 in Table 9.3 and Figure 9.3). The alluvium overlying the Springbok Sandstone is not predicted to experience drawdown due to the development of the Project. Drawdown in the Upper Springbok Sandstone, of up to 19.7 m, is predicted at this location due to surrounding development activities (i.e., without the development of the Project). This drawdown is due to the proposed development of the Wandoan Coal Project. The GDE is located directly adjacent to a planned area of disturbance. **The predicted drawdown from the presence of the Project only, at the location of aquatic GDEs of interest, is predicted to be less than the 0.2 m trigger.**

The proposed development of the Project is predicted to contributes less than 1% of the cumulative drawdown at the location of this GDE, with the model predicting the same drawdown both with and without the Project due to the close proximity of the Wandoan Coal Project.

Table 9.3 Predicted Drawdown at Potential Aquatic GDEs Areas of Interest

No.	GDE Rule ID	Location	Source Aquifer[1]	Project Development Scenario Only Drawdown (m)	Cumulative with Project (m)	Proportion Contribution of the Project %
1	SURAT_RS_01A	ATP 2059	Alluvium	0.00	0.08	-
			Westbourne Formation	0.00	0.00	-
2	SURAT_RS_01A	PL 209	Alluvium	0.00	0.09	-
			Westbourne	0.00	0.00	-
3	SURAT_RS_01A	1.8 km north of PL 445	Alluvium	0.00	0.08	-
			Upper Springbok	0.12	19.71	0.6

1. Source aquifer as defined the Queensland GDE mapping and GDE Rule ID dataset.

It is also unlikely that these potential aquatic GDE areas are sourced from the deeper GAB units of the Westbourne Formation and Upper Springbok Sandstone given the evidence from the field verification provided in Section 7.10.1 and 7.10.2.

Reaches of Woleebee Creek within PL 1037 were assessed during field verification in 2018 (KCB 2018c) directly adjacent to ATP 2059. Field verification was undertaken as part of this assessment (KCB 2018a). The 2018 field verification identified that there is unlikely to be significant baseflow provided to this creek, however it is likely that during some periods, groundwater levels in the alluvium will rise up into the sandy base of the creek. The field verification also concluded that based on the difference between the alluvial groundwater and surface water major ionic chemistry signatures, and groundwater chemistry signatures from the Surat Basin units, groundwater within the alluvium is not considered to be sourced from the underlying Surat Basin unit (Westbourne Formation) at the locations assessed.

As described in Section 6.9 these ephemeral creeks of low diversity and of non-conservation significant aquatic fauna and flora, lack suitable habitat for EVNT aquatic species.

Impacts to aquatic ecosystems are expected to be minimal and will be managed through implementation of the appropriate management, mitigation and monitoring practices associated with construction and operation. These are detailed in Section 10. Based on the characteristics of the Aquatic GDEs present (as described in Section 6.9) a change of less than 0.2 m is unlikely to affect those species that are present or the ecological function of these ecosystems.

Impacts to threatened EPBC-listed aquatic species are considered unlikely.

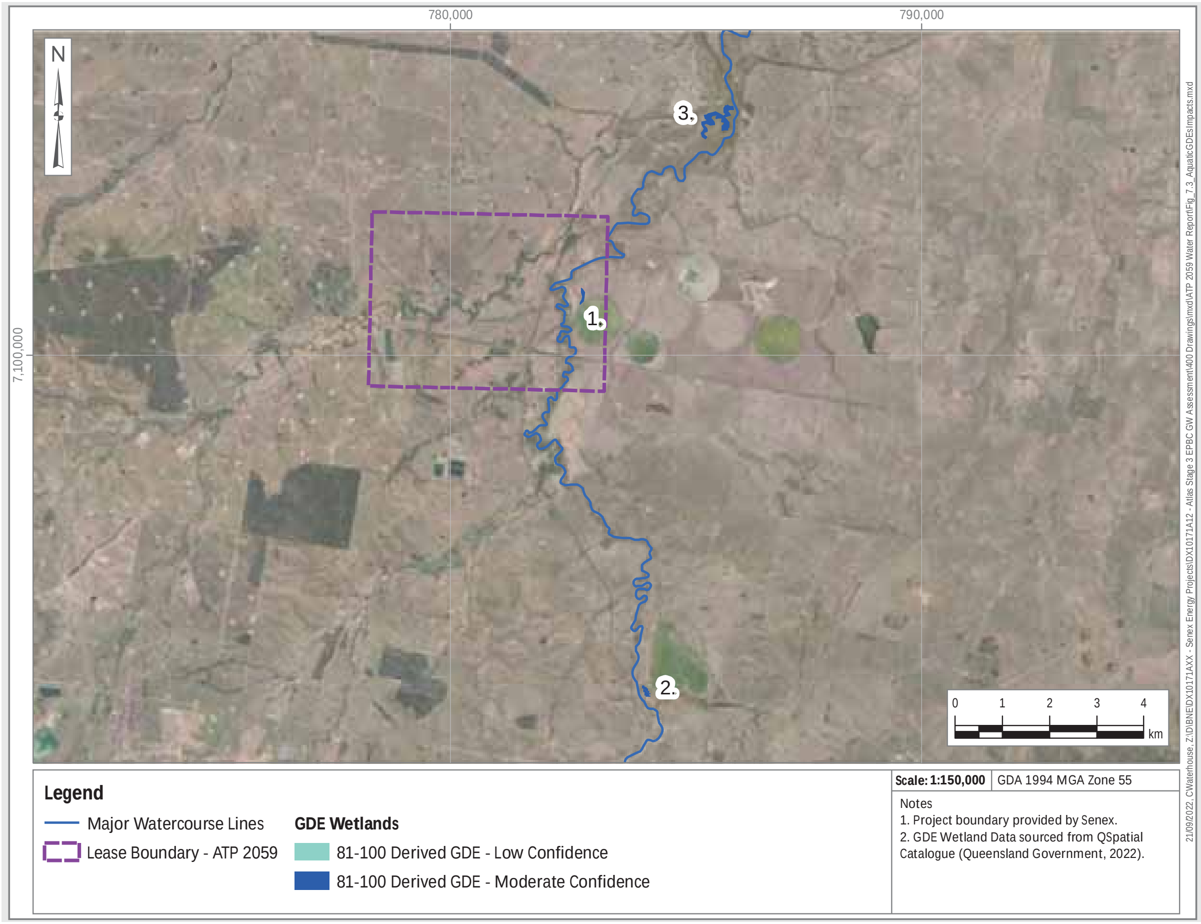


Figure 9.3 Aquatic GDEs of Interest within the Vicinity of the Project

9.4.2 Impacts to Watercourse Springs

OGIA has identified the potential for watercourse springs on tenement along Woleebee Creek, these are:

- W279 – alluvium.
- W280 – alluvium/Gubberamunda Formation.
- W281 – alluvium/Orallo Formation.

These springs have been assessed against the *Water Act 2000* spring trigger threshold of 0.2 m using the outputs and drawdown predictions from the UWIR numerical model. The Project only scenario does not result in drawdown at these locations in the potential source aquifers, the predicted cumulative drawdown is also <0.2 m.

Reaches of Woleebee Creek within PL 1037 were assessed during field verification in 2018 (KCB 2018c) directly adjacent to ATP 2059. Field verification was undertaken as part of this assessment (KCB 2018a). The 2018 field verification identified that there is unlikely to be significant baseflow provided to this creek, however it is likely that during some periods, groundwater levels in the alluvium will rise up into the sandy base of the creek. The field verification also concluded that based on the difference between the alluvial groundwater and surface water major ionic chemistry signatures, and groundwater chemistry signatures from the Surat Basin units, groundwater within the alluvium is not considered to be sourced from the underlying Surat Basin unit (Westbourne Formation) at the locations assessed.

There is no drawdown predicted at these locations and therefore the spring trigger threshold is not predicted to be exceeded.

9.4.3 Impacts to Terrestrial GDEs

Westbourne Formation

There is only one potential terrestrial GDE mapped on the Westbourne Formation outcrop within the predicted 0.2 m cumulative drawdown extent. There are no terrestrial GDEs mapped in the predicted 0.2 m Project only drawdown extent of the Westbourne Formation outcrop. **The Project alone does not result in drawdown greater than the 0.2 m trigger at GDE areas on the Westbourne Formation outcrop.** This area is shown on Figure 9.4 and predicted drawdown summarised in Table 9.4.

This terrestrial GDE is located on PL 277 (QGC) approximately 2.7 km west of ATP 2059 and is described as a 'treed regional ecosystem with alluvia on fresh, intermittent flow'. It has an assigned GDE rule of Surat_RS_01C, and there is low confidence of its dependence on groundwater (State of Queensland 2018a). The dominant regional ecosystem (RE) is identified as 11.3.25, which is *Eucalyptus tereticornis* or *E. camaldulensis* woodland fringing drainage lines. The average rooting depth for species of Eucalyptus present at the Project area is known, based on literature reviews, to range from 9 m to 22.6 m, depending on the species and the interactions between geomorphology and plant physiological traits. The groundwater source for this GDE is described as 'Quaternary alluvial aquifers with a fresh, intermittent groundwater connectivity regime' and 'shallow alluvial, local, unconfined, and unconsolidated'.

Predicted drawdown in the alluvium, the source aquifer, at this location is less than the 0.2 m drawdown trigger. The cumulative drawdown in the Westbourne Formation is greater than 0.2 m, with a predicted drawdown of 2.6 m. The Project contribution to this cumulative drawdown is ~6%.

Table 9.4 Terrestrial GDEs within the Predicted 0.2 m Drawdown Extent on the Westbourne Formation Outcrop

Location	GDE Rule ID	Source aquifer	Project Development Scenario Only Drawdown (m)	Cumulative with Project (m)	Proportional Contribution of the Project %	Area Of Potentially Affected GDE (km^2)
2.7 km west of ATP 2059 in PL 277	Surat_RS_01C	Alluvium	0.00	0.09	-	-
		Westbourne	0.19	3.68	5.16	0.09
			0.16	2.60	6.15	0.27

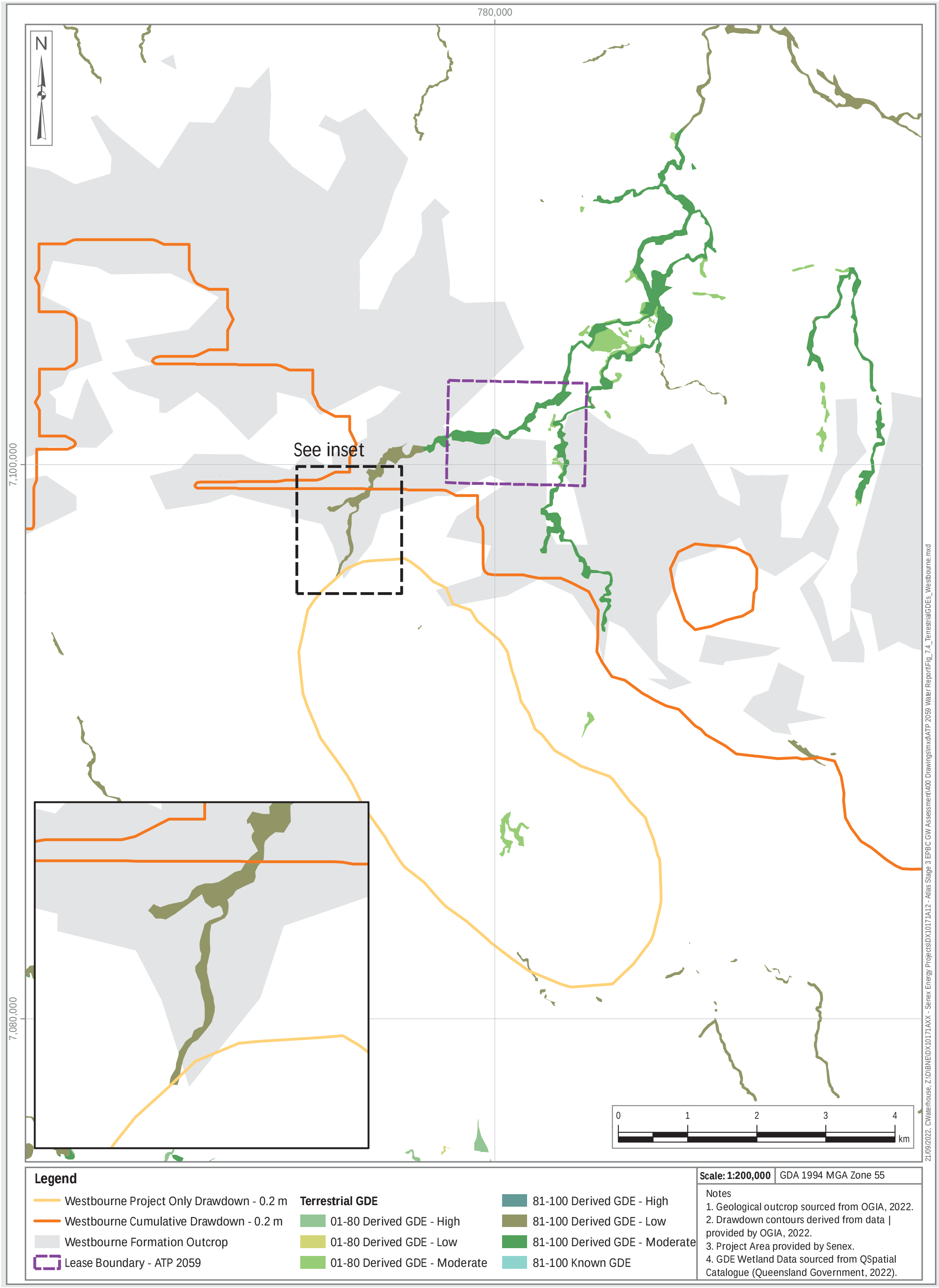


Figure 9.4 Mapped Potential Terrestrial GDEs and Predicted Drawdown Area – 0.2 m Contours Westbourne Formation

Springbok Sandstone

There are four potential terrestrial GDEs located on the Springbok Sandstone outcrop within the 0.2 m Springbok Sandstone Project only drawdown extent. These areas are shown on Figure 9.5, with the predicted drawdown summarised in Table 9.5. One of these potential GDEs (No. 1) is located on Senex tenement PL 445.

These GDEs are described as:

- Surat_RS_01A: Quaternary alluvial aquifers overlying sandstone ranges with fresh, intermittent groundwater connectivity regime (moderate confidence in GDE status).
- Surat_RS_03A: permeable consolidated sedimentary rock aquifers with fresh, intermittent groundwater connectivity regime (low confidence in GDE status).

Project only drawdown is not predicted in the alluvium at these mapped GDE locations.

These four potential GDEs are cumulatively triggered by surrounding project activities (without the presence of the Project). The Project contributes to the cumulative drawdown at these GDEs (see Table 9.5), with the highest contribution being at GDE No. 4 which is located ~12 km east of ATP2059. GDE No. 2 and 3 are located directly on, or close to, proposed areas of disturbance associated with the proposed Wandoan Coal Mine, with the Project contributing less than 6% of the predicted drawdown. The approved Wandoan Coal Project is planned to excavate both alluvium and Springbok Sandstone with pit depths of 24 to 60 m. The Springbok Sandstone will likely need to be dewatered by the Wandoan Coal Project for pit excavation.

These potential terrestrial GDEs are all located along ephemeral creek systems. As discussed in Section 7.10.1, the likely source of water for these three GDEs is the alluvium. Bore logs from nearby registered bores confirm the presence of alluvium at each of these locations, with the alluvium identified as having a depth of up to 18 m in ATP 2059, in the vicinity of GDE No. 1. The water quality of the alluvium indicates that groundwater in this aquifer is replenished by surface water during prolonged periods of rainfall (Section 7.9), when the ephemeral creeks are flowing. The distinction between the alluvium water quality and underlying Westbourne Formation and Springbok Sandstone water quality (which is of higher salinity) indicates that these units are disconnected. These potential terrestrial GDEs are considered to be resilient and adapt well to stress, with the larger eucalypts (including Forest Red Gums) having a dimorphic root system and are well adapted to the drying and wetting ephemeral setting associated with the creek systems (Section 7.10.1).

Based on the available characteristics of the GDE physiographic setting, it is interpreted that these potential GDEs:

1. may be intermittently supported by groundwater in the alluvium (as discussed in Section 7.10.1), which is not predicted to experience drawdown;
1. the alluvium source aquifer is not considered to be connected to the Upper Springbok Sandstone (as discussed in Section 7.9) which is predicted to experience drawdown; and,
2. are being triggered cumulatively by neighbouring activities without the presence of the Project (by the Wandoan Coal Project and other CSG activities).

Based on the above, it is concluded that the contributing drawdown impacts from the Project to potential terrestrial GDEs are not considered significant.

Table 9.5 Terrestrial GDEs within the Predicted 0.2 m Drawdown Extent on the Upper Springbok Sandstone Outcrop

No.	Location	GDE Rule ID	Source aquifer	Project Development Scenario Only Drawdown (m)	Cumulative with Project (m)	Proportional Contribution of the Project %	Area Of Potentially Affected GDE (km^2)	RE
1	Within PL 445 at the boundary of ATP 2059 and PL 445	Surat_RS_01A	Alluvium	0.00	0.08	-	-	11.3.25 (Forest Red Gum *Eucalyptus tereticornis* woodland fringing drainage lines) however areas of RE 11.3.2 (Poplar Box *Eucalyptus populnea* woodland on alluvial plains), RE 11.3.27 (Freshwater wetlands: Coolabah *Eucalyptus coolabah* and/or Forest Red Gum) open woodland to woodland fringing swamps) and RE 11.3.17 (Poplar Box woodland with Brigalow *Acacia harpophylla* and/or *Belah Casuarina cristata* on alluvial plains) are also present
		Surat_RS_03A	Upper Springbok Sandstone	0.90	4.57	19.69	0.07	
2	10.3 km E of ATP 2059	Surat_RS_01A	Alluvium	0.00	0.08	-	-	RE 11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland
		Surat_RS_03A	Upper Springbok Sandstone	0.28	5.12	5.47	0.17	
				0.48	8.42	5.70	0.05	
3	13.7 km east of ATP 2059	Surat_RS_03A	Upper Springbok Sandstone	0.45	36.74	1.22	0.001	11.9.5/11.9.10
				0.32	29.3	1.09	0.01	
4	~15 km southeast of ATP 2059	Surat_RS_01A	Alluvium	0.00	0.07	-	-	RE 11.3.25 *Eucalyptus tereticornis* or *E. camaldulensis* woodland
		Surat_RS_03A	Upper Springbok Sandstone	0.51	2.24	22.76	0.02	

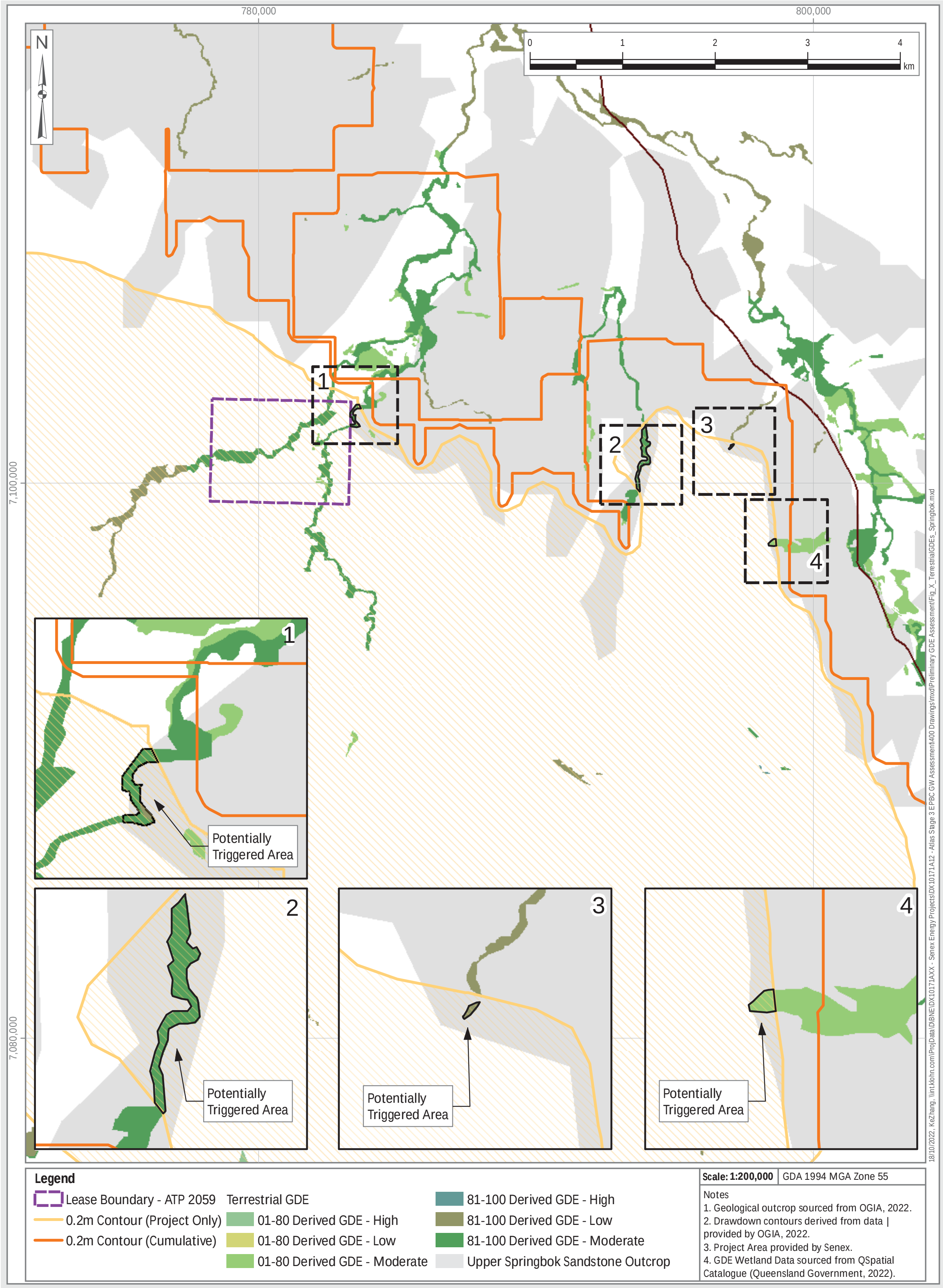


Figure 9.5 Mapped Potential Terrestrial GDEs and Predicted Drawdown Area – 0.2 m Contours Upper Springbok Sandstone Formation

9.4.4 Impacts to Subterranean Fauna

Impacts to potential stygofauna habitats are limited to the unconfined outcrop areas. Stygofauna have been identified in PL 1037 in the Gubberamunda Sandstone/Westbourne Formations and Upper Springbok Sandstone (KCB 2018d). The potential impact is summarised as follows:

- For ecological systems potentially reliant on groundwater within the shallow aquifers, the cumulative scenario does not predict any drawdown within the Gubberamunda Sandstone from the Project.
- For ecological systems potentially reliant on groundwater in the Westbourne Formation outcrop, the Project only drawdown in the Westbourne is predicted to be less than 0.2 m. The results of the numerical modelling indicate that there is negligible (at most a 2%) reduction in saturated thickness in the outcrop areas of the Westbourne Formation to the west and east of the Project area.
- Drawdown is predicted in the Upper Springbok Sandstone within outcrop areas to the north and northeast of the Project area. These areas are cumulatively triggered without the presence of the Project with the Project contributing up to 0.9m of drawdown within PL 445, this equates to a proportional drawdown contribution of the Project of ~20%. Given the overall thickness of the Springbok Sandstone of ~100 m, the reduction in saturated thickness from the Project only is negligible.

No discernible impacts to subterranean fauna as a result of the Project development are predicted.

10 MITIGATION, MANAGEMENT AND MONITORING

This section provides further detail on Senex's proposed mitigation, management and monitoring practices for the Project.

10.1 CSG Production Wells and General Project Activities

Measures to minimise impacts to groundwater quality and avoid introducing connectivity between formations during the construction of CSG production wells, include the following:

- CSG production wells will be designed, constructed and decommissioned in accordance with the "Code of Practice for the construction and abandonment of petroleum wells, and associated bores in Queensland Version 1" (State of Queensland 2019a). This code outlines mandatory requirements and good practice to reduce the risk of environmental harm. CSG production wells will be designed to:
  - Prevent any interconnection between target hydrocarbon bearing formations and aquifers;
  - Ensure that gas is contained within the well and associated pipework and equipment without leakage;
  - Ensure zonal isolation between different aquifers is achieved; and
  - Not introduce substances that may cause environmental harm.

A chemical risk assessment has been undertaken for the Project to consider drilling fluids used in CSG production well drilling. Drilling fluids and additives used during drilling activities will be water based, appropriate for the well design and local geological conditions, and will be used in accordance with the mandatory requirements and good practice guidelines outlined in the code of practice (State of Queensland 2019a), as well as the Safety Data Sheets (SDS) provided with each fluid/additive. With relation to drilling fluids, the mandatory requirements include:

- Drilling fluids must be selected and managed to ensure all manufactured products used during well procedures on CSG wells are in accordance with the manufacturer's recommendations and relevant SDS.
- The name, type and quantity of each chemical used on each well throughout the life of the well must be recorded.

Good industry practice for CSG drilling includes:

- Drilling fluid should be a carefully monitored and controlled mixture designed to:
  - Achieve best drilling results and ensure efficient removal of formation cuttings.
  - Control formation pressures.
  - Minimise damage to formations.
- Petroleum tenure holders should ensure that the drilling fluid selected is appropriate for the well design to manage any locally experienced drilling problems and the geological conditions likely to be encountered.
- The use of biodegradable substances in the drilling fluid is preferred.

- The source of water for all well procedures (drilling, completion, workover and abandonment) should be recorded for future well monitoring purposes.
- Products should be chosen, stored, and used at concentrations that minimise the risk of causing environmental harm.
- Personnel, including contractors, should be aware of the environmental impact and emergency spill procedures for the products and substances in use on site.
- Petroleum tenure holders should use established, effective drilling practices to achieve a stable, uniform and, as far as possible, in-gauge hole.

Drilling fluids will be disposed of in accordance with EA conditions outlined in Schedule B (waste). Additionally, hydraulic fracture stimulation will not be undertaken as part of the Project.Further details on the management practices associated with chemical and fuel storage are provided in Section 10.6.2.

10.2 CSG Water Production

10.2.1 CSG Production Well Monitoring

As per the requirements outlined in the *Petroleum and Gas (Production and Safety) Act 2004* (State of Queensland 2020b), the volume of CSG water produced will be monitored and recorded and provided to the relevant authority as required.

10.2.2 Groundwater Monitoring

Groundwater monitoring will serve as a key mechanism for the early identification of the changes in groundwater levels as a result of CSG water production, within the WCM and other formations where groundwater receptors exist.

The groundwater monitoring requirements for CSG tenure holders within the Surat CMA are provided as part of the UWIR WMS (OGIA 2021g), which establishes baseline trends, identifies any changes within or near CSG development areas or locations of interest and informs future improvement of groundwater modelling. Due to the relatively small scale of the Project, and location in relation to existing tenure holders, and monitoring infrastructure (required by the UWIR WMS), Senex are not currently required by OGIA to install any groundwater monitoring facilities within the Project. Senex will comply with any updates to the WMS that may be required in any future updates of the UWIR. The location of existing monitoring within the vicinity of the Project is shown in Figure 7.11.

Senex is currently obligated to maintain and monitor two WMS monitoring points (a Springbok Sandstone and a multi zone WCM), located within the adjacent PL209 (Table 10.1).

Table 10.1 Groundwater Monitoring on Senex Tenements

RN	Owner	Source Aquifer	Location	Monitoring Status
160631	RDMW/Senex	Upper Springbok	PL 209	Senex WMS obligation (formerly APLNG monitoring)
160764	RDMW/Senex	Upper Juandah Coal Measures Lower Juandah Coal Measures Taroom Coal Measures	PL 209	Senex WMS obligation (formerly APLNG monitoring)

Note: RDMW – Department of Regional Development, Manufacturing and Water

10.2.3 Groundwater Bore Baseline Assessments

Senex were required by DES to undertake baseline assessments for two bores within the ATP 2059 (Section 7.11.2). To date baseline assessments have been completed for both bores, with neither bore identified as operational.

Senex will comply with any updates to the bores required for baseline assessment as part of the WMS that may be required in any future updates of the UWIR. Any future baseline assessments will be conducted in accordance with the DES 'Baseline Assessment Guideline' (DES 2022a).

10.2.4 Surface Water Monitoring

There are no planned discharges to surface water from the proposed Project infrastructure (e.g., water storage facilities). Should this change, monitoring will be undertaken prior to installation of infrastructure to confirm baseline conditions of the surface water system and to confirm potential impacts associated with discharge from the Project infrastructure.

Any releases from the various facilities during operation will be unplanned or a result of extreme climatic conditions. Details of the event-based monitoring program associated with beneficial use releases from the Project infrastructure is provided in Section 10.4.3.

Further discussion of mitigation and management associated with surface water systems is provided in Section 10.6.

10.3 Bore Impact Management Measures

The *Water Act 2000* outlines requirements for make good obligations of a resource tenure holder for a bore located in immediately affected areas. Tenure holders must carry out a bore assessment and enter into a make good agreement with the bore owner if the bores are located within an immediately affected area. The UWIR assigns bores to tenure holders located within immediately affected areas. There is currently one bore assigned to Senex within an immediately affected area in PL 445 (formerly assigned to Origin APLNG; RN 58910 in the Upper Juandah Coal Measures).

The results of the impact assessment to bores indicate that there would be five additional bores that may potentially experience water level decline greater than 5 m as a result of the cumulative scenario (i.e., the contribution of the Project development results in five additional bores being triggered in the cumulative scenario). Two of these bores are attributed to the Upper Springbok Sandstone and three are attributed to the Upper Juandah Coal Measures. These bores are not located on Senex tenements and of the five, only one appears to be existing and in a 'usable' condition.

Senex will comply with any updates to the make good agreements required in future updates of the UWIR and undertake bore assessments as required as a result of make good obligations. Any required bore assessments will be undertaken in accordance with the DES 'Bore Assessment Guideline' (DES 2022b).

Senex has developed their CSG Water Management Strategy, outlined in the CSG Water Management Plan (ATP 2059: SENEX-ATLS-EN-PLN-013; PL 445 and PL 209: SENEX-ATLS-EN-PLN-014) , and described in the following section, to maximise beneficial use of CSG water. To minimise impacts to landowner bores, Senex proposes to establish Landowner Water Supply Agreements (WSAs).

10.4 CSG Water Management

CSG water management will be undertaken in accordance with the Senex CSG Water Management Plan (SENEX-ATLS-EN-PLN-006), which has been developed to meet the requirements of the CSG Water Management Policy (State of Queensland 2012).

10.4.1 CSG Water and Treated CSG Water Quality Monitoring

Untreated CSG water quality will be monitored on a quarterly frequency or based on licensing requirements for the intended use (e.g., stock watering or irrigation). The water quality data from **untreated** CSG water will be used to:

- Inform the water treatment facility design and operation; and
- Monitor the water quality for suitability for the designated beneficial use and in accordance with water quality objectives in the *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b), and conditions provided in the 'Streamlined Model Conditions for Petroleum Activities' (DES 2016b) that are aligned with the beneficial reuse of produced water.

Water quality data from **treated** CSG water will be monitored regularly and used to:

- Confirm that the water quality is suitable for the designated use or water supply arrangement and in accordance with water quality objectives in the End of Waste (EOW) codes (as noted above); and
- Confirm the water treatment facility is effectively treating the CSG water.

10.4.2 Water Storage Pond Monitoring

CSG produced water and brine will be stored in existing storage facilities on PL 1037. These facilities have the potential to impact the shallow groundwater quality should over-topping or a breach of the facility liner occur. CSG water storage ponds will be constructed in accordance with the *'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures'* (DES 2016a) and relevant EA conditions. Water storage facilities will be monitored to ensure the operating water levels are maintained within the specifications of the dam design.

Senex have established a seepage monitoring program for the CSG water storage pond on PL 1037, in which ten shallow seepage monitoring bores monitor the underlying Westbourne Formation (see Section 7.7.2). and one private landholder bore as required by the EA requirements for PL 1037. This is in compliance with Senexs' existing obligations to the State.

Should additional water storage ponds be constructed, Senex may consider installing additional monitoring bores, or utilise existing water bores within the Project area. Where new monitoring bores are required, they will be drilled and installed in accordance with the Minimum Construction Requirements for Water Bores in Australia (NUDLC 2020) and monitored in accordance with relevant Queensland regulations.

Any monitoring program will be designed and implemented to monitor for pond seepage in accordance with the relevant EA conditions, and the requirements outlined in the *'Streamlined Model Conditions for Petroleum Activities'* (DES 2016b). Shallow groundwater monitoring will also be conducted in conjunction with monitoring of the water quality within the water storage pond. The monitoring program will be designed to:

- Be undertaken by a suitably qualified person, and in accordance with 'Groundwater Sampling and Analysis – A Field Guide' (Sundaram et al. 2009);
- Be undertaken on a quarterly basis;
- Submit all water quality samples for analysis at a laboratory with NATA accreditation;
- Identify water quality associated with the water stored within the dam;
- Identify the background groundwater quality in the vicinity of the dam as a reference site;
- Provide information to develop trigger levels and detection limits associated with dam seepage; and
- Be documented and updated should new containment facilities be constructed.

10.4.3 Beneficial Use Activities

To minimise impacts to shallow groundwater quality, as a result of beneficial use activities such as irrigation, water quality will be monitored to confirm compliance with water quality objectives in the *End of Waste Code Associated Water (including coal seam gas water)* (DES 2019a), and the *End of Waste Code Irrigation of Associated Water (including coal seam gas water)* (DES 2019b), and conditions provided in the 'Streamlined Model Conditions for Petroleum Activities' (DES 2016b) that are aligned with the general beneficial use approval.

10.5 Infrastructure Location Planning

To avoid, minimise and manage potential impacts to GDEs and watercourses across the Project area, and to support well field layout for all surface infrastructure, including wells and gathering pipelines, Senex will implement a 'Environmental Protocol for Field Development and Constraints Analysis' (SENEX-QLDS-EN-PRC-019) (the Constraints Protocol). The Constraints Protocol aims to ensure that infrastructure siting:

- Considers biodiversity values and environmental constraints, such as sensitive receptors, when selecting preferential locations; and aligning with planning principles to avoid, minimise, mitigate and then manage potential environmental impacts; and
- Identifies any additional external environmental approvals required and that those are secured prior to the commencement of construction activities.

With respect to environmental values, the protocol addresses avoiding or minimising and managing potential impacts to:

- Biodiversity values contributing to ESAs, MNES and MSES;
- Habitat for wildlife, including threatened MSES and MNES threatened communities, flora and fauna; and
- Wetlands, watercourses, springs and GDEs.

The Constraints Protocol also recognises that, in addition to environmental constraints, landholder, engineering and cultural heritage constraints must be considered during infrastructure siting.

The process involves a desktop constraints analysis, site surveys, post-survey environmental constraints analysis and preparing a report that includes a list of site-specific environmental conditions and associated constraints maps. These are included in the final Access to Work (ATW) documentation, issued upon sign-off by the Project Manager to relevant staff and contractors prior to commencing construction.

The final location of production wells will also be determined in consultation with relevant landholders to ensure that the location does not disrupt land use.

10.6 Environmental Management Practices

Senex have developed a Project Atlas Environmental Management Plan (SENEX-ATLS-EN-PLN-001) that describes how Senex will manage potential environmental impacts associated with conducting gas production activities and to ensure compliance with EA conditions, industry guidelines and regulatory requirements. The relevant environmental controls relating to minimising the impact to groundwater and surface water are described below.

10.6.1 Watercourses and Riparian Ecosystems

Watercourses and riparian ecosystems, depending on their location, may be intersected by Right-of-way's (RoWs) for the gathering system, where they cannot be avoided. Impacts to these features have been considered as part of the Project impact assessment. Potential impacts that may result from these crossings during construction and operation include generation of suspended sediment in the watercourse, altered geomorphic watercourse characteristics (e.g. changes to bed and bank profile), changes to riparian buffers (vegetation clearing), construction in bed and/or banks of waterways, and habitat fragmentation. A number of mitigation and management measures are planned to limit the impact to waterways and riparian ecosystems. These include:

- **Site Selection** – During field planning for site selection, watercourse crossings are avoided where possible because of environmental impacts (including impacts such as fragmentation and disruption of flows), and their associated additional construction requirements, including erosion and sediment control and monitoring. Where possible, existing watercourse crossings will be utilised to minimise land disturbance and impacts to riparian vegetation and associated habitat.
- **Construction Planning** – Overall, construction activities will not interfere or block natural drainage. Stormwater will be allowed to pass through the sites in a controlled manner and at non-erosive flow velocities. Watercourse crossing points will be adequately stabilised to prevent erosion and the RoW construction period when working in waterways will be minimised.
- **Erosion and Sediment Control** – works on site will not commence until any relevant Contractor erosion and sediment control procedures have been approved and installed as required. Erosion and sediment control structures will be inspected periodically and after rain events and maintenance carried out where required.

- **Rehabilitation** – The scale of the initial disturbance for construction is planned to be 18 m wide for RoWs. This width will be reduced during the operating phase to a nominal area that will be rehabilitated directly over the pipeline to maintain pipeline integrity, and a 6 m access track will be maintained to access wells and infrastructure. Within the life of the well field, RoWs through watercourses may be rehabilitated sooner than the gas field life, depending on their location and the well's operational life.

To minimise the impacts of water quality in surface watercourses and wetlands during construction and operation, the following measures will be implemented:

- Petroleum activities within any wetland area or watercourse must be carried out in accordance with an approved Authority To Work (ATW). Watercourse crossings will be limited to those strictly necessary for construction or operation of infrastructure and only at locations approved in the ATW.
- Any waterway barrier works (works that pose a barrier to water flow) must only be undertaken where authorised under an ATW and only at the location specified.
- Where required, watercourse crossing points will be adequately stabilised to prevent erosion.
- 'No-go' areas will be GPS located and clearly marked.
- Construction activities will be managed to minimise interference with overland flow paths.
- Clean stormwater will be diverted around disturbed land wherever practicable.
- For linear infrastructure – construction or maintenance activities in wetlands or a watercourse will be required to be carried out under the authorisation of an ATW and under the supervision of a Senex environment representative to ensure conditions of the EA are achieved.

In addition, the following monitoring and reporting will be undertaken:

- Watercourse crossings to be monitored for erosion and sedimentation during construction, regularly during dry conditions, and daily inspections during rainfall of >50 mm in one day or >100 mm over four days or as soon as watercourse access is re-established after flooding.
- During periods of flow, surface waters downstream of construction areas near a watercourse or wetland area will be monitored for water quality as per the Project Atlas Environmental Management Plan (SENEX-ATLAS-EN-PLN-001).
- Records of all erosion and sediment control and water quality checks will be maintained by Senex staff and provided to the Senex Environment Manager.
- Construction or maintenance works on linear infrastructure in wetlands or watercourses will be monitored by a Senex representative to ensure compliance with the EA conditions.

10.6.2 Chemical and Fuel Storage

To minimise the impacts of a chemical or fuel spill to surface or groundwater the following measures will be implemented:

- All fuel, oil and chemicals are to be stored, transported and handled in accordance appropriate standards including AS 3780:2008 – The storage and handling of corrosive substances, AS 1940:2004 – The storage and handling of flammable and combustible liquids, AS 3833:2007 – Storage and handling of mixed classes of dangerous goods in packaged and intermediate bulk containers.
- Storage areas will be sealed, bunded, and adequately ventilated.
- Storage and refuelling areas will be preferentially located away from watercourses, sensitive areas and any source of ignition as determined by the Senex Site Supervisor.
- Containment bunds and/or sumps will be drained periodically of accumulated rainwater to prevent overflow and subsequent pollution of the surrounding land and watercourses.

In addition, the following monitoring and reporting will be undertaken:

- All chemical, oil and fuel storage areas are to be inspected regularly for temporary storage, and for permanent storage areas during the operating phase by the Contractor Site Supervisor and/or the Senex Site Supervisor.
- All spills are to be contained immediately and managed through the Senex Spill Response procedure (see Project Atlas Environmental Management Plan).
- Emergency events will be managed in accordance with the contingency procedures in the Emergency Response Plan.
- Incident details will be recorded immediately and notified through the Senex Incident reporting systems, reported and investigated.

10.6.3 Soil and Erosion Management

Senex have developed an 'Erosion and Sediment Control Procedure' (SENEX-QLDS-EN-PRC-003; Senex 2018c), which outlines measures to ensure Senex meets its regulatory obligations relating to managing disturbed land that has potential to release soil directly or indirectly to land or water on, or adjacent to, Senex work sites. The procedure provides guidance to implement erosion and sediment controls during civil earthworks for activities in Queensland, where there is significantly disturbed land. The objective of the procedure is to set out methods to manage soil erosion and control sediment generated close to the source, thereby minimising the potential for onsite activities adversely impacting the surrounding environment.

To minimise soil erosion, mass movement and gully erosion, the following measures will be implemented:

- Ensure stormwater passes through the site in a controlled manner and at non-erosive flow velocities. Divert clean water from the work site where practical.
- Minimise the duration that disturbed soils are exposed to the erosive forces of wind rain and flowing water.
- Minimise work-related soil erosion and sediment runoff.
- Minimise negative impacts to land or properties adjacent to the activities (including roads).

- Inspect worksites periodically as required, before expected rainfall events, and after rain events and undertake maintenance where required as per the Erosion and Sediment Control Plan.

In addition, the following monitoring and reporting will be undertaken:

- Regular inspections to monitor for potential erosion and sedimentation during construction works will be undertaken. These inspections will occur regularly during dry conditions, and daily inspections during rainfall of >50 mm in one day or >100 mm over 4 days or as soon as site access is re-established.
- Watercourse crossings will be monitored for erosion and sedimentation during construction regularly during dry conditions, and during rainfall of >50 mm in one day or >100 mm over 4 days or as soon as watercourse access is re-established after flooding.
- Records of all erosion and sediment control and water quality monitoring will be maintained by the Senex staff.

10.6.4 Emergency and Incident Response: Spills

In the event of an environmental incident:

- Personnel who observe an environmental incident including a spill are required to immediately notify the Contractor Site Supervisor who will then notify the Senex Site Supervisor.
- In the event of a chemical, oil or fuel spill, the spill will be contained and cleaned up as outlined in the Senex Spill Response Plan.
- Contractors are required to have in place procedures for spill response which are in accordance with the Senex Spill Response Plan and will include details requirements for:
  - Minimising release;
  - Containing spilled material;
  - Raising the alarm and response;
  - Locations of spill kits; and
  - Management of contaminated material if necessary.
- Any spills will be assessed by the Senex Site Supervisor supported by the Senex Environment Manager as required to determine appropriate remediation options such as the removal of contaminated material.
- Incident reports are required to contain information required by the Safety Management Plan and Incident Reporting and Investigation Procedure.
- Emergency Response drills will be performed to ensure readiness and identify opportunities for improvement.

Senex requires that all incidents including spills are reported and fully investigated in accordance with their specific level of potential risk.

10.7 Reporting

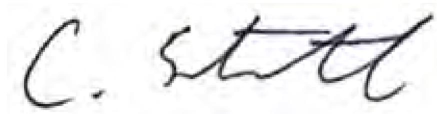
Senex will undertake all reporting as per the requirements under the State legislation, including to OGIA as part of the UWIR requirements and in accordance with the Project's EA conditions.

11 CLOSING

We would like to thank you for the opportunity to work on this assignment. Should you have any questions, please do not hesitate to contact the undersigned.

KCB AUSTRALIA PTY LTD.

Carly Waterhouse, RPGeo
Project Manager, Senior Hydrogeologist



Chris Strachotta, RPGeo
Senior Reviewer, Principal Hydrogeologist

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APPENDIX I

OGIA Model Parameters

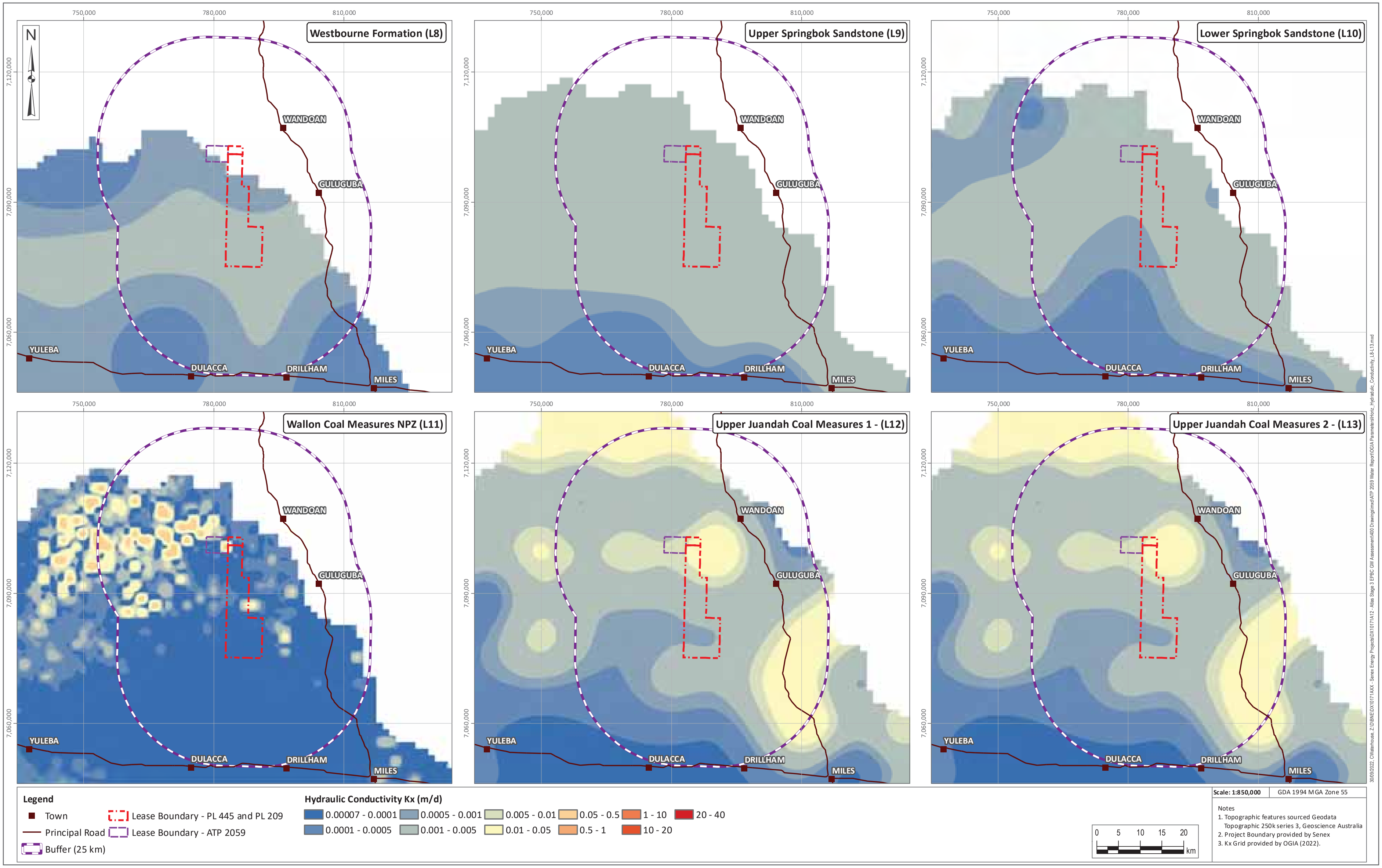

Figure I-1 Horizontal Hydraulic Conductivity (L8 – Westbourne Formation to L 13 – Upper Juandah Coal Measures – Layer 2)

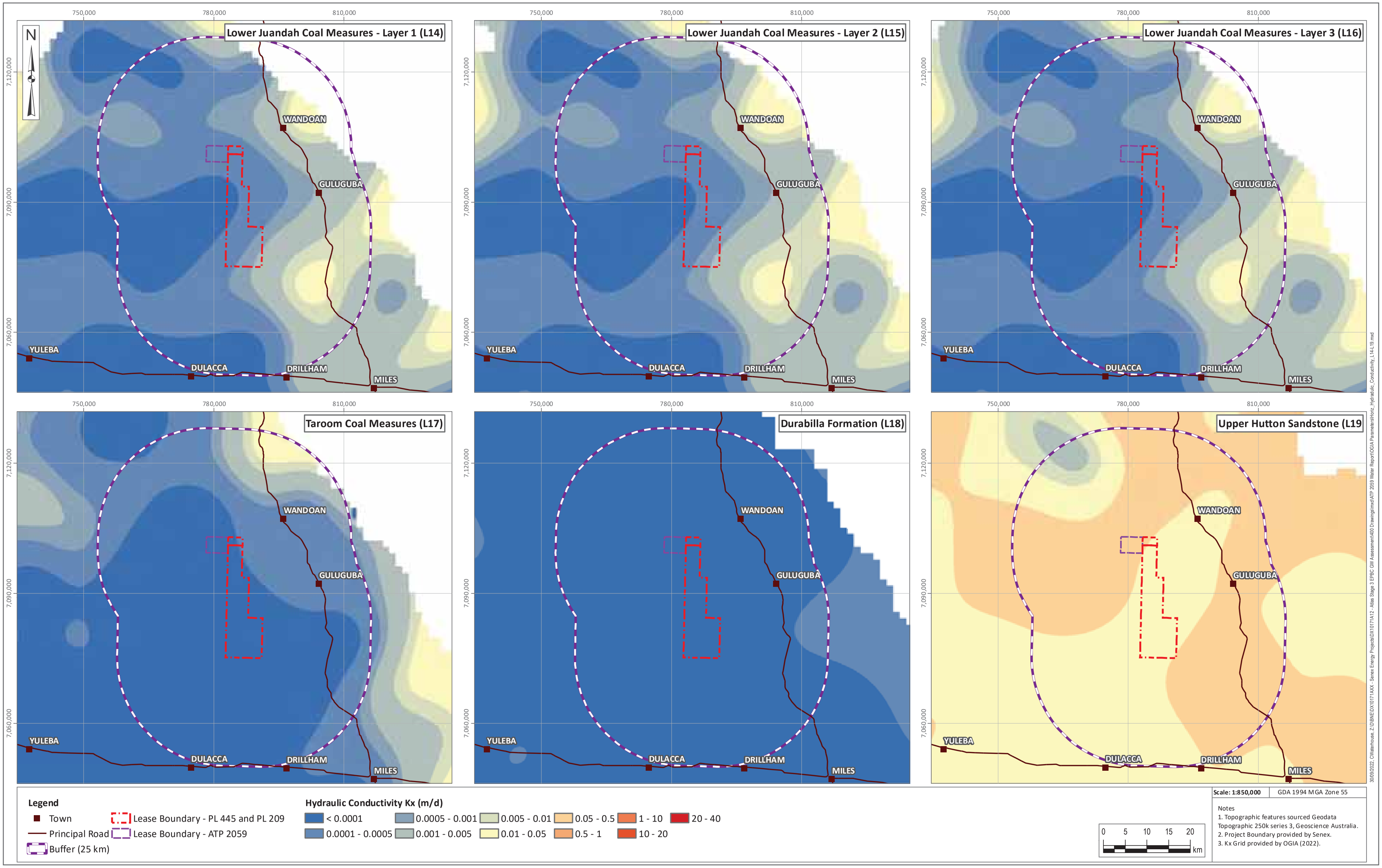

Figure I-2 **Horizontal Hydraulic Conductivity (L14 Lower Juandah Coal Measures Layer 1 to L 19 Upper Hutton Sandstone)**

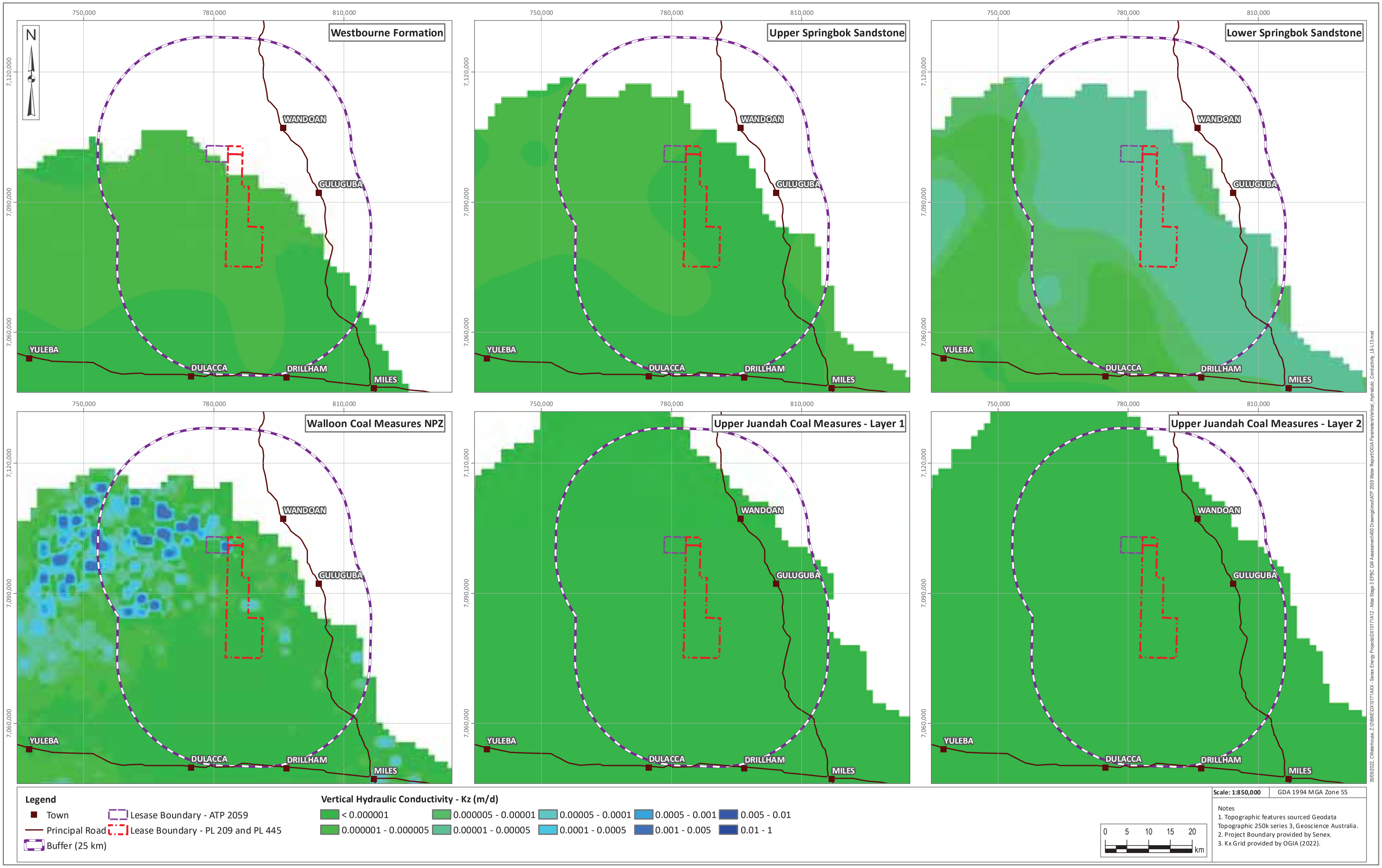

Figure I-3 **Vertical Hydraulic Conductivity (L8 – Westbourne Formation to L 13 – Upper Juandah Coal Measures – Layer 2)**

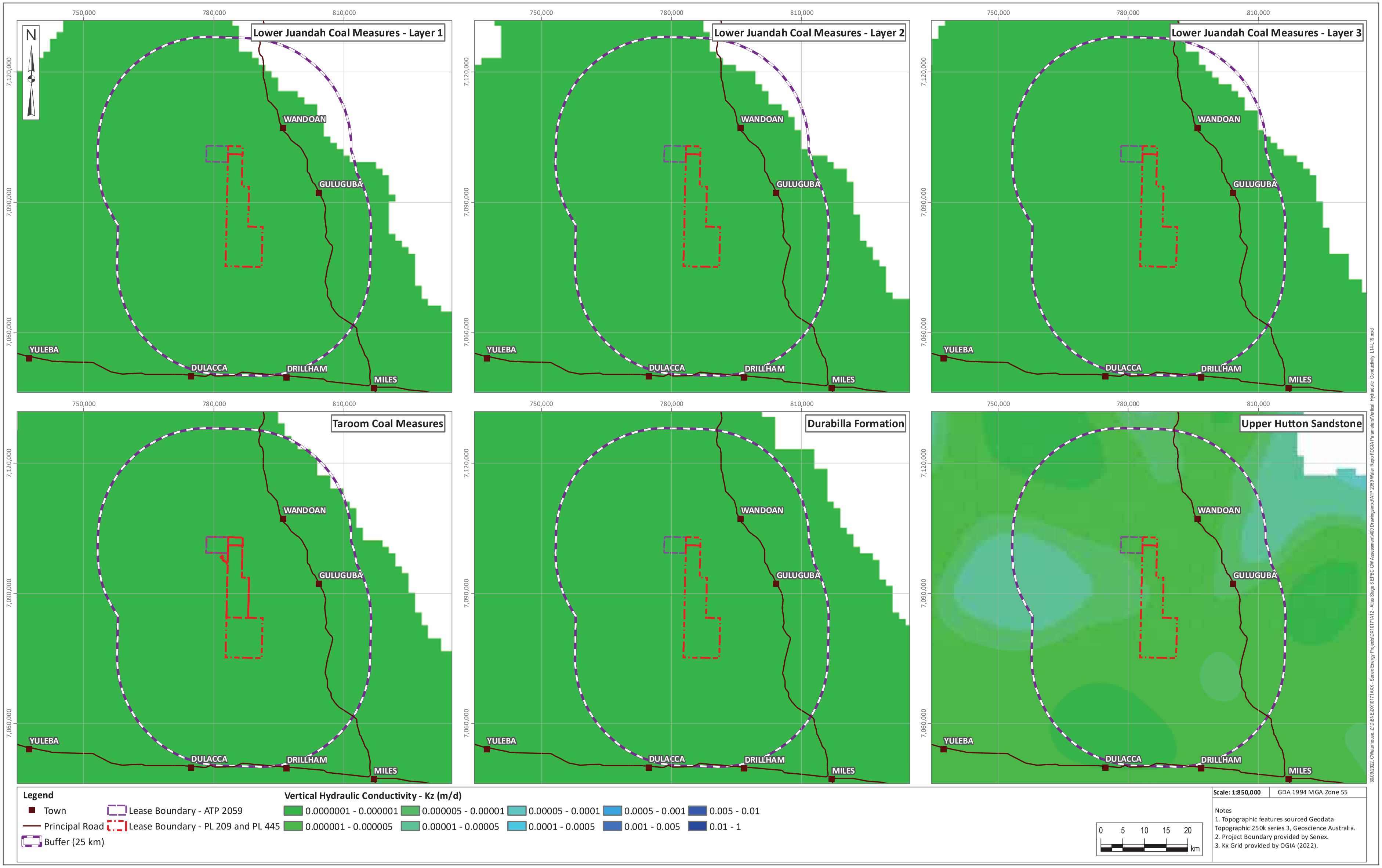

Figure I-4 **Vertical Hydraulic Conductivity (L14 Lower Juandah Coal Measures Layer 1 to L 19 Upper Hutton Sandstone)**

APPENDIX II

Predicted Drawdown Extent – Project Only

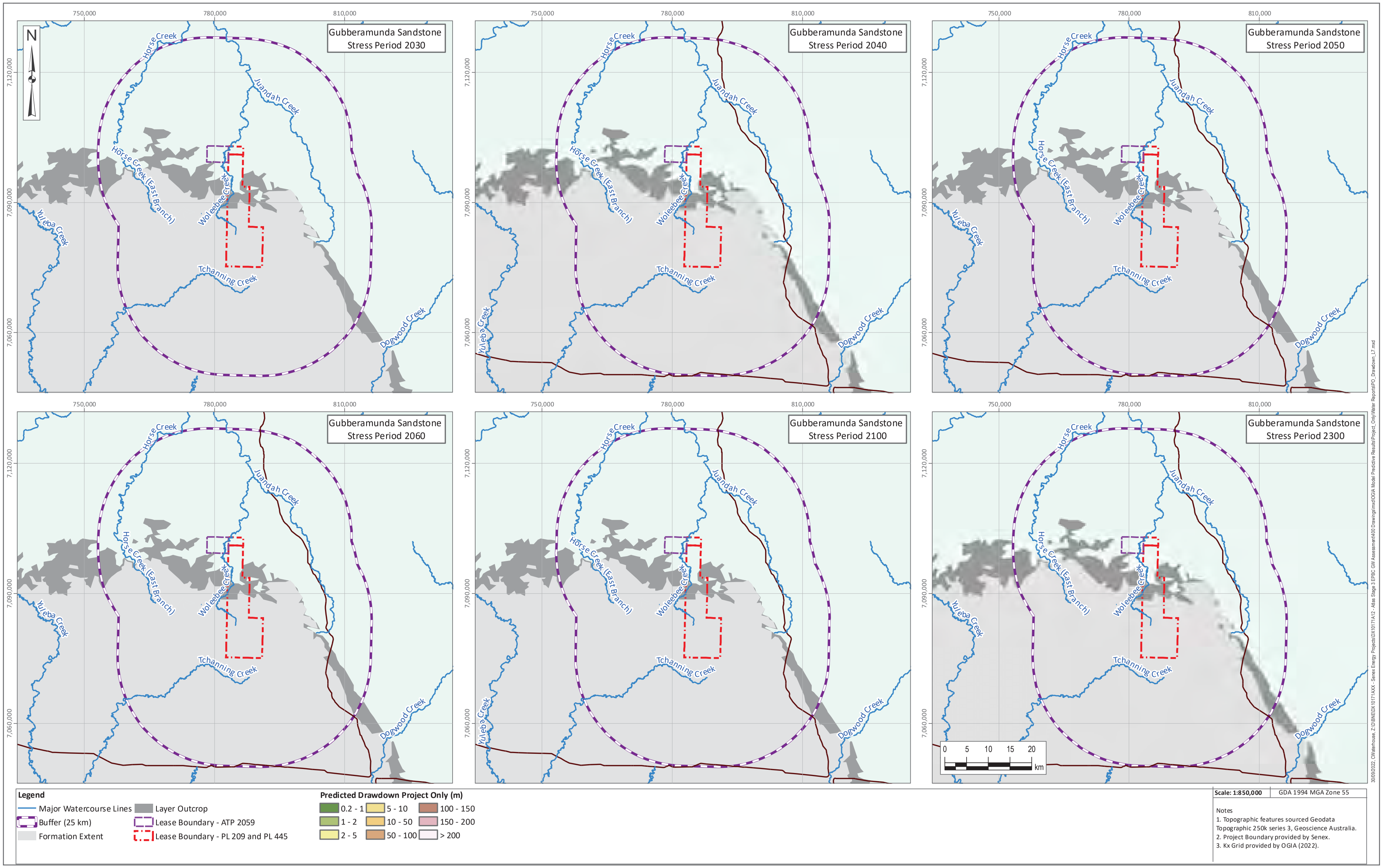

Figure II-1 Project Only Drawdown – Layer 7 – Gubberamunda Sandstone

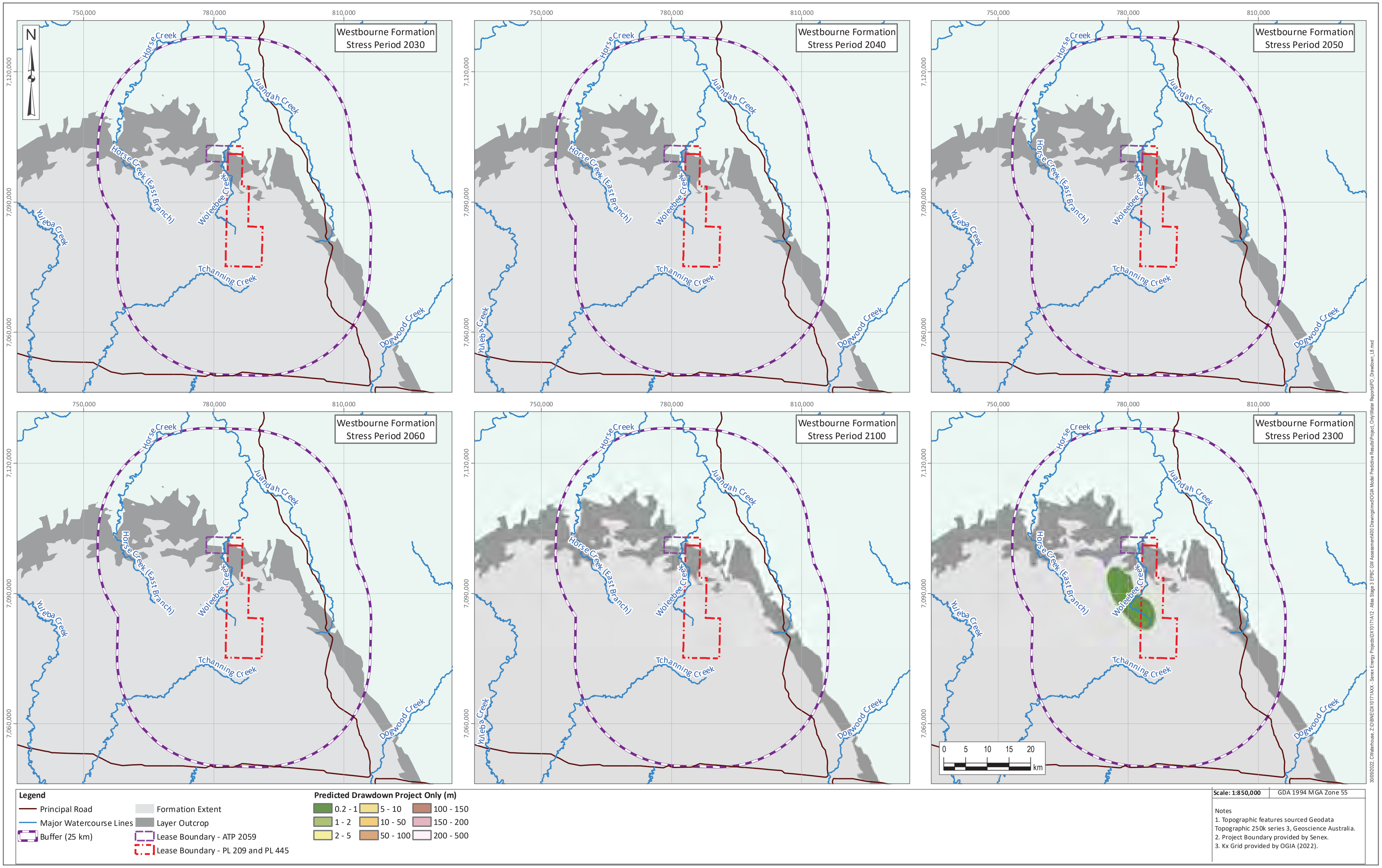

Figure II-2 Project Only Drawdown – Layer 8 – Westbourne Formation

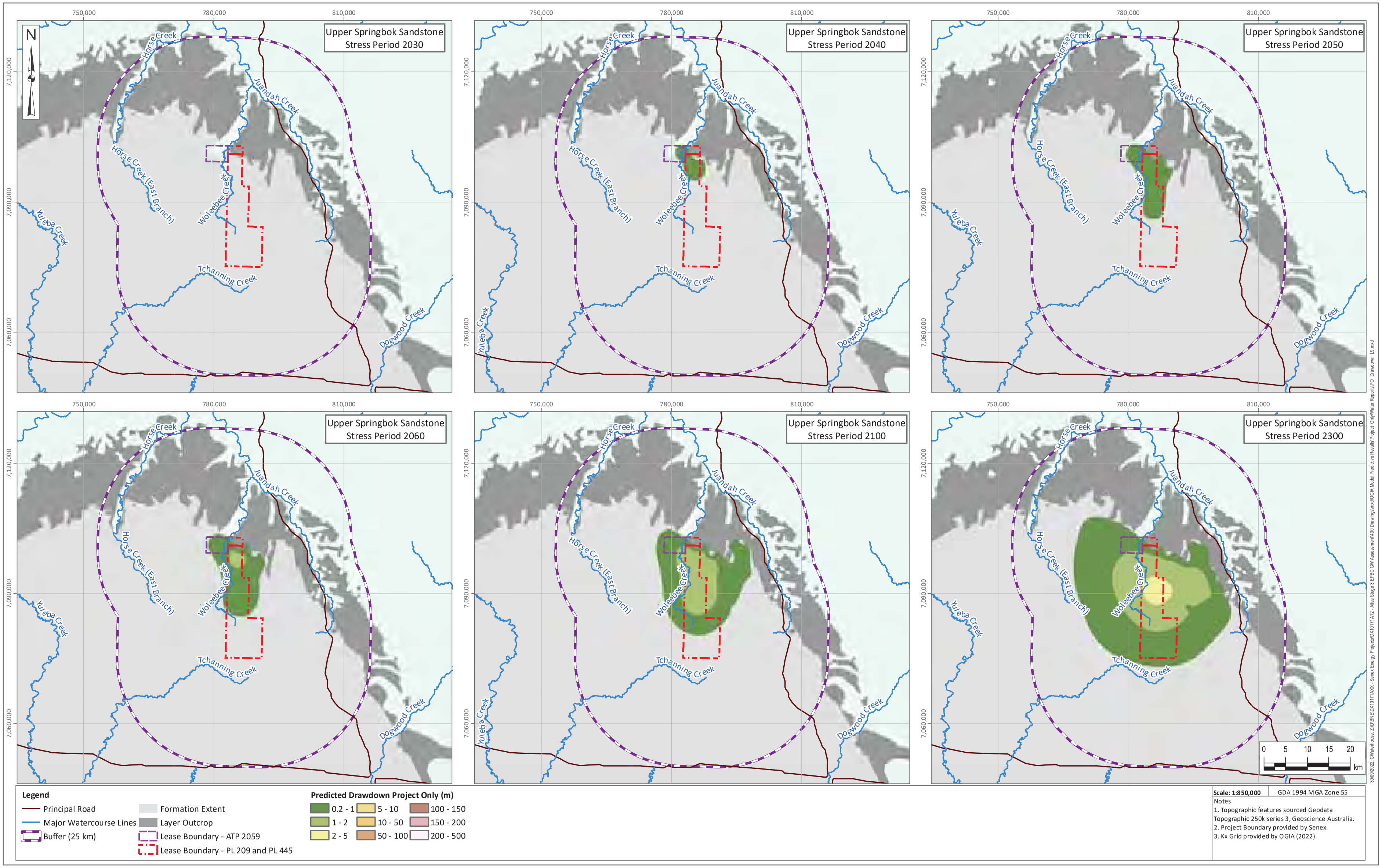

Figure II-3 Project Only Drawdown – Layer 9 – Upper Springbok Sandstone

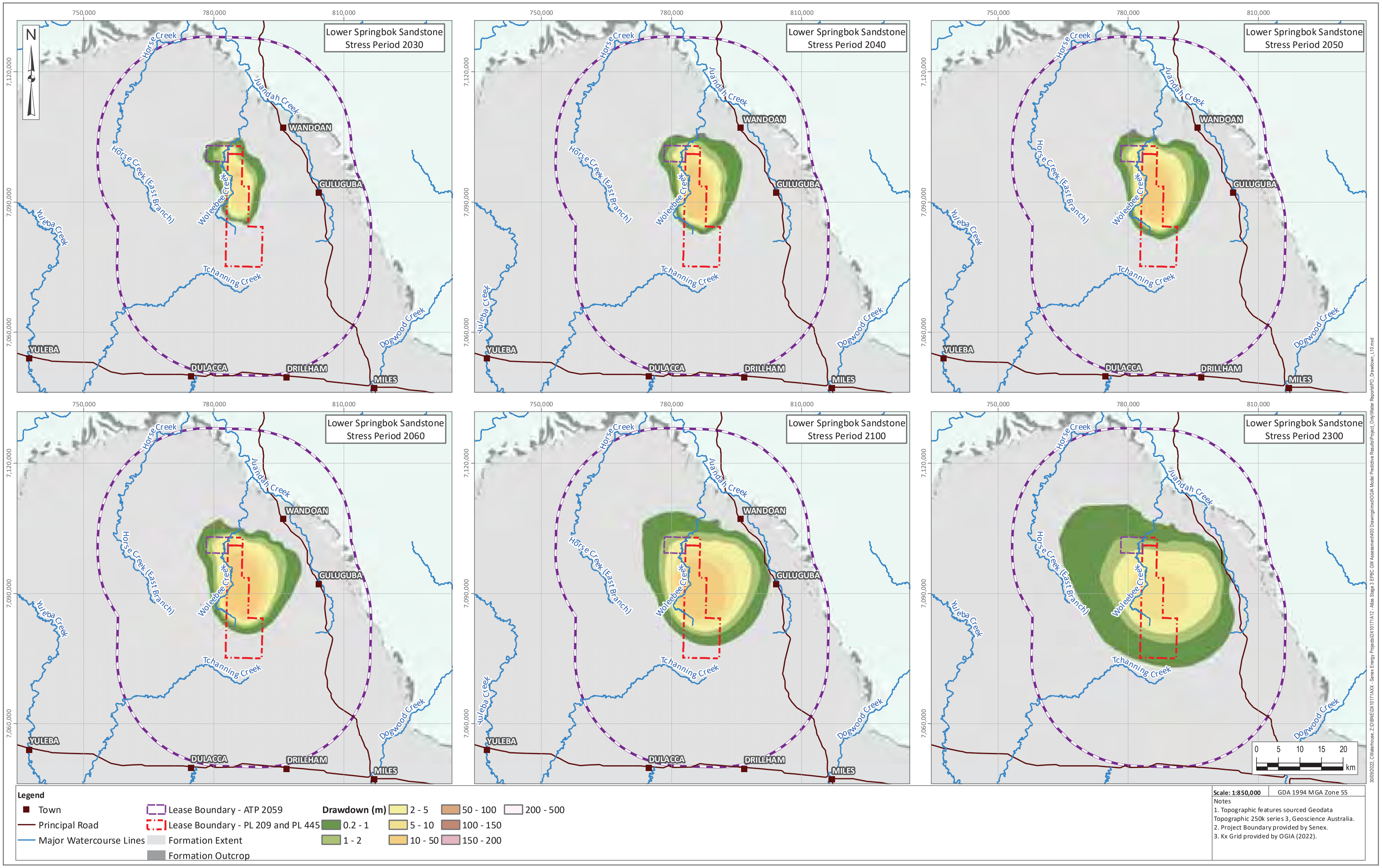

Figure II-4 Project Only Drawdown – Layer 10 – Lower Springbok Sandstone

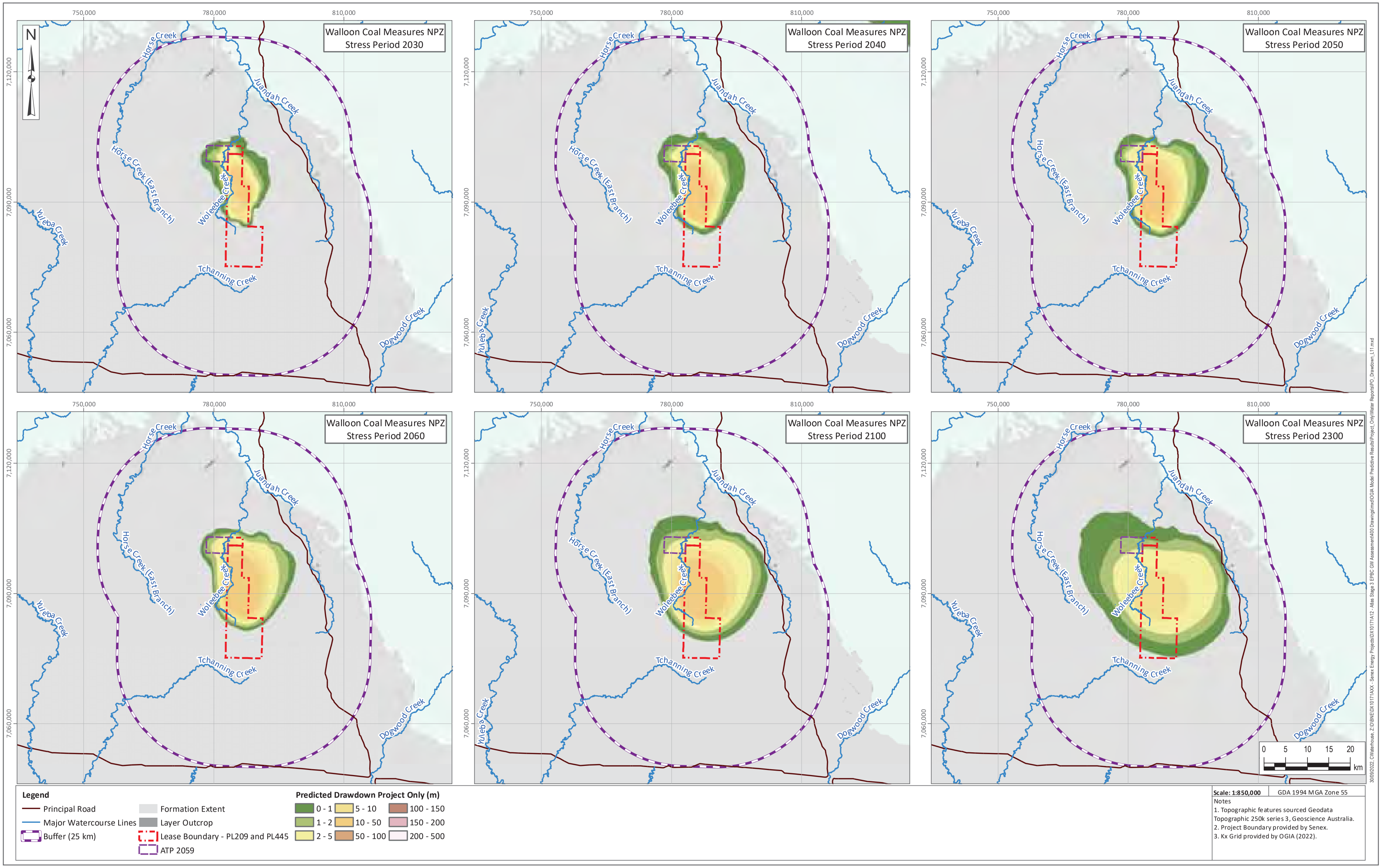

Figure II-5 Project Only Drawdown – Layer 11 – Walloon Coal Measures Non-Productive Zone

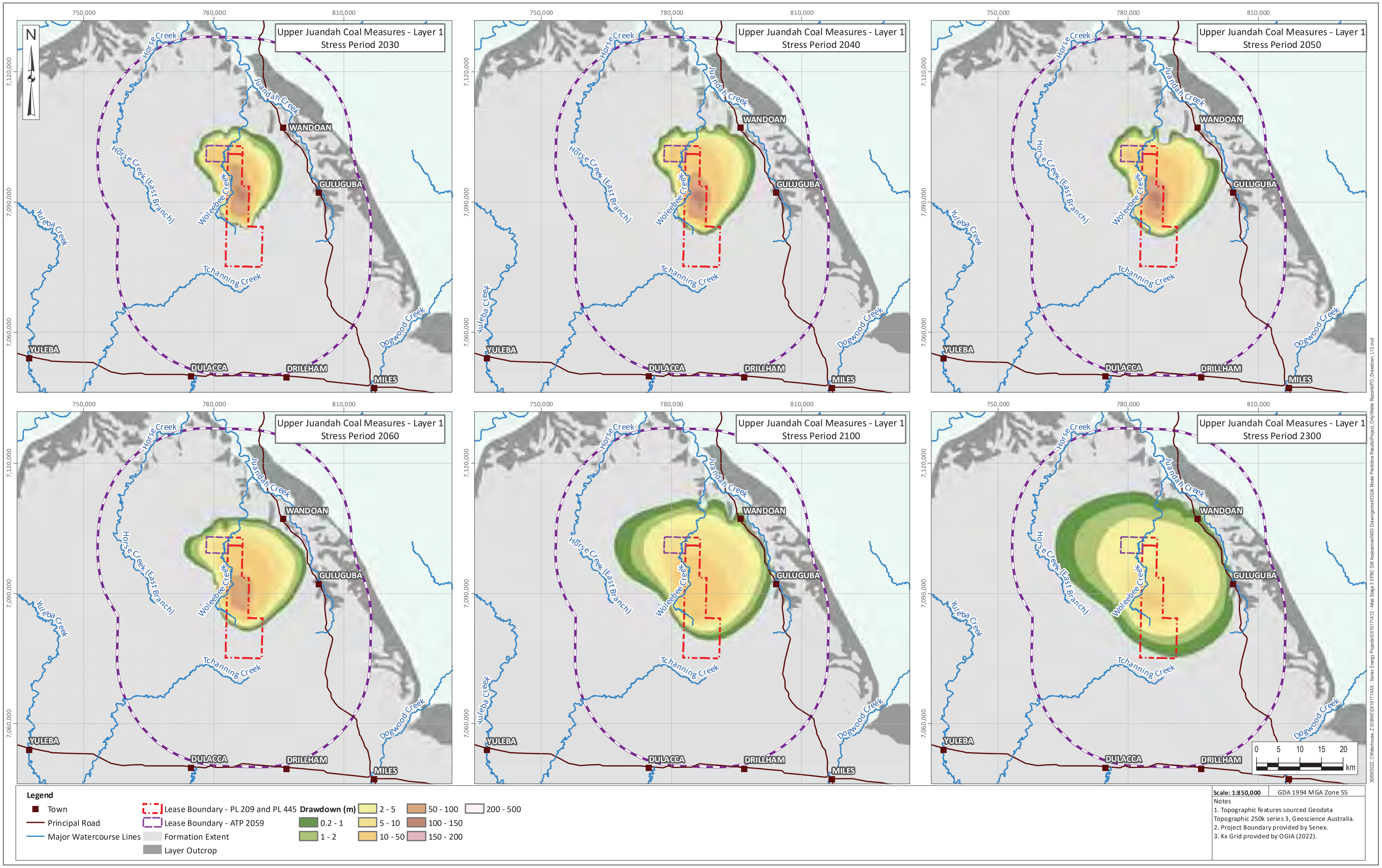

Figure II-6 Project Only Drawdown – Layer 12 – Upper Juandah Coal Measures Layer 1

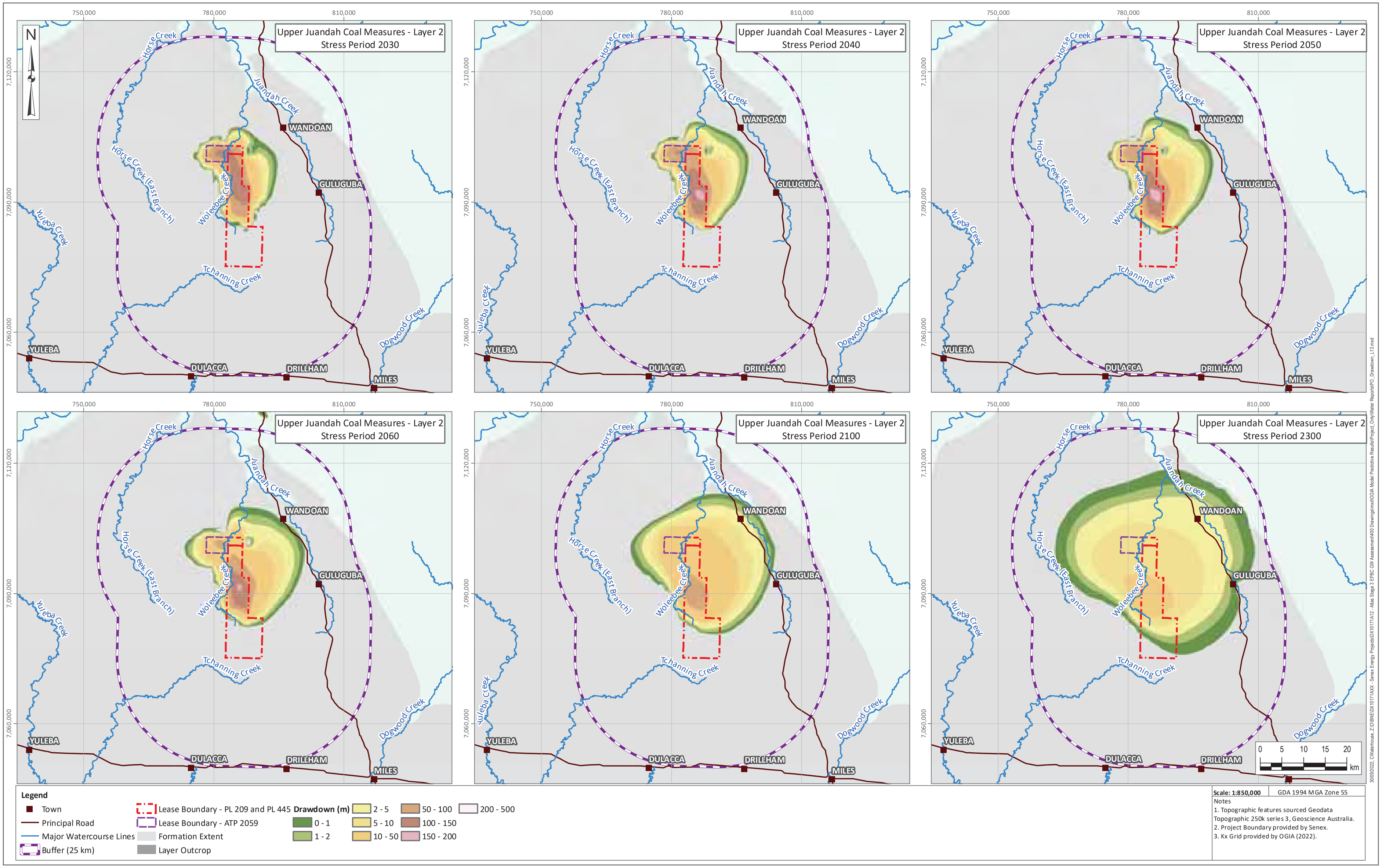

Figure II-7 Project Only Drawdown – Layer 13 – Upper Juandah Coal Measures Layer 2

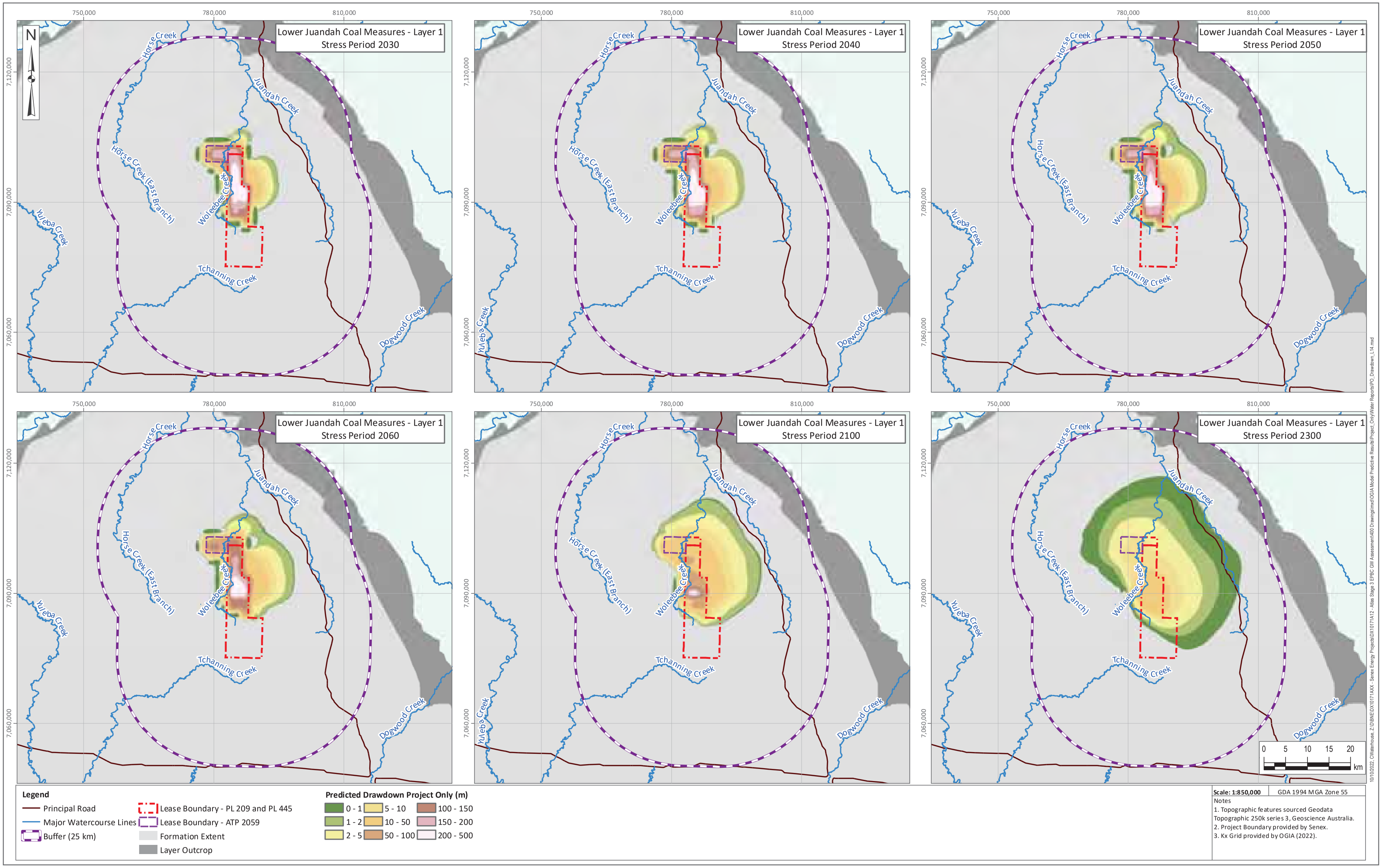

Figure II-8 Project Only Drawdown – Layer 14 – Lower Juandah Coal Layer 1

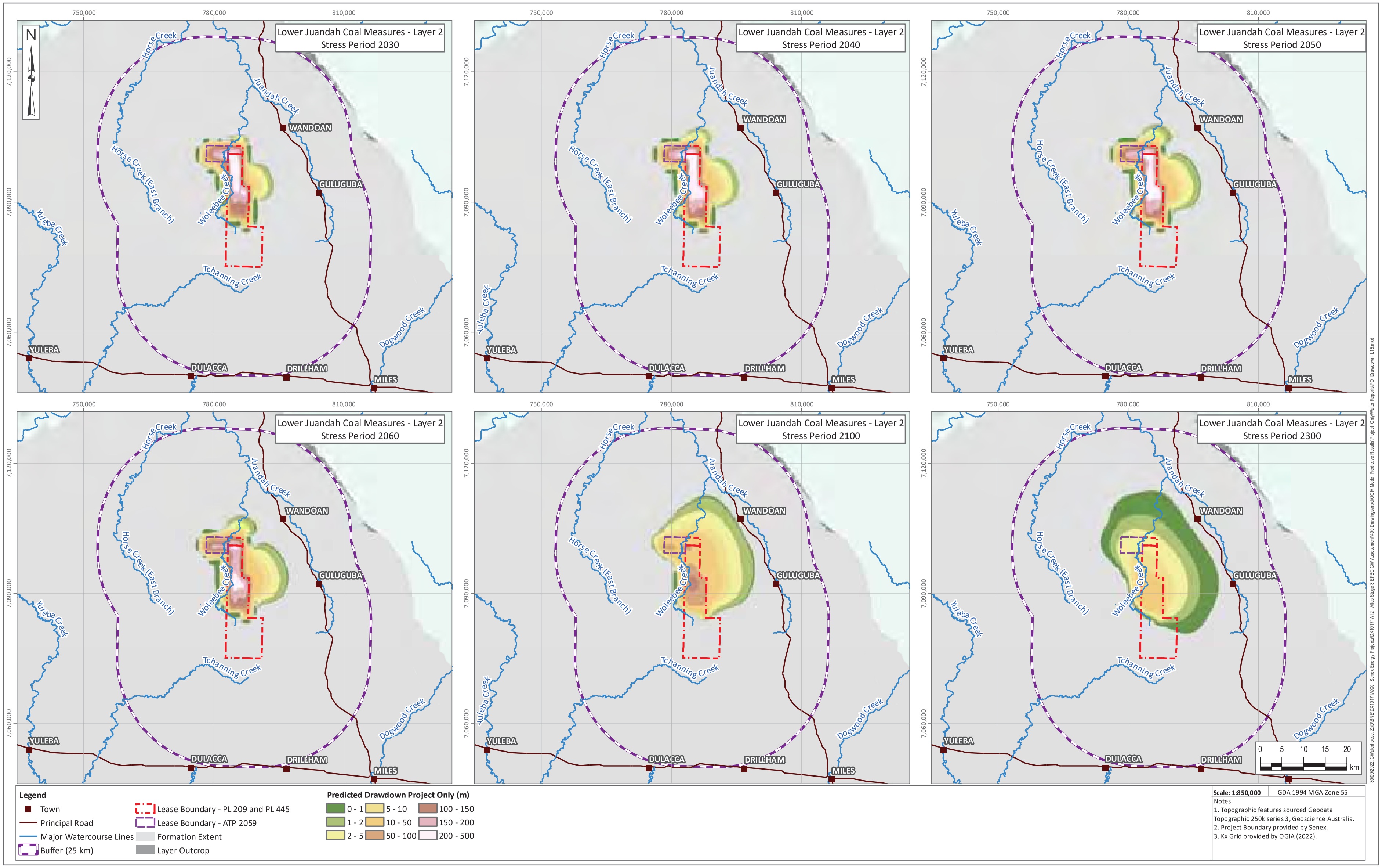

Figure II-9 Project Only Drawdown – Layer 15 – Lower Juandah Coal Layer 2

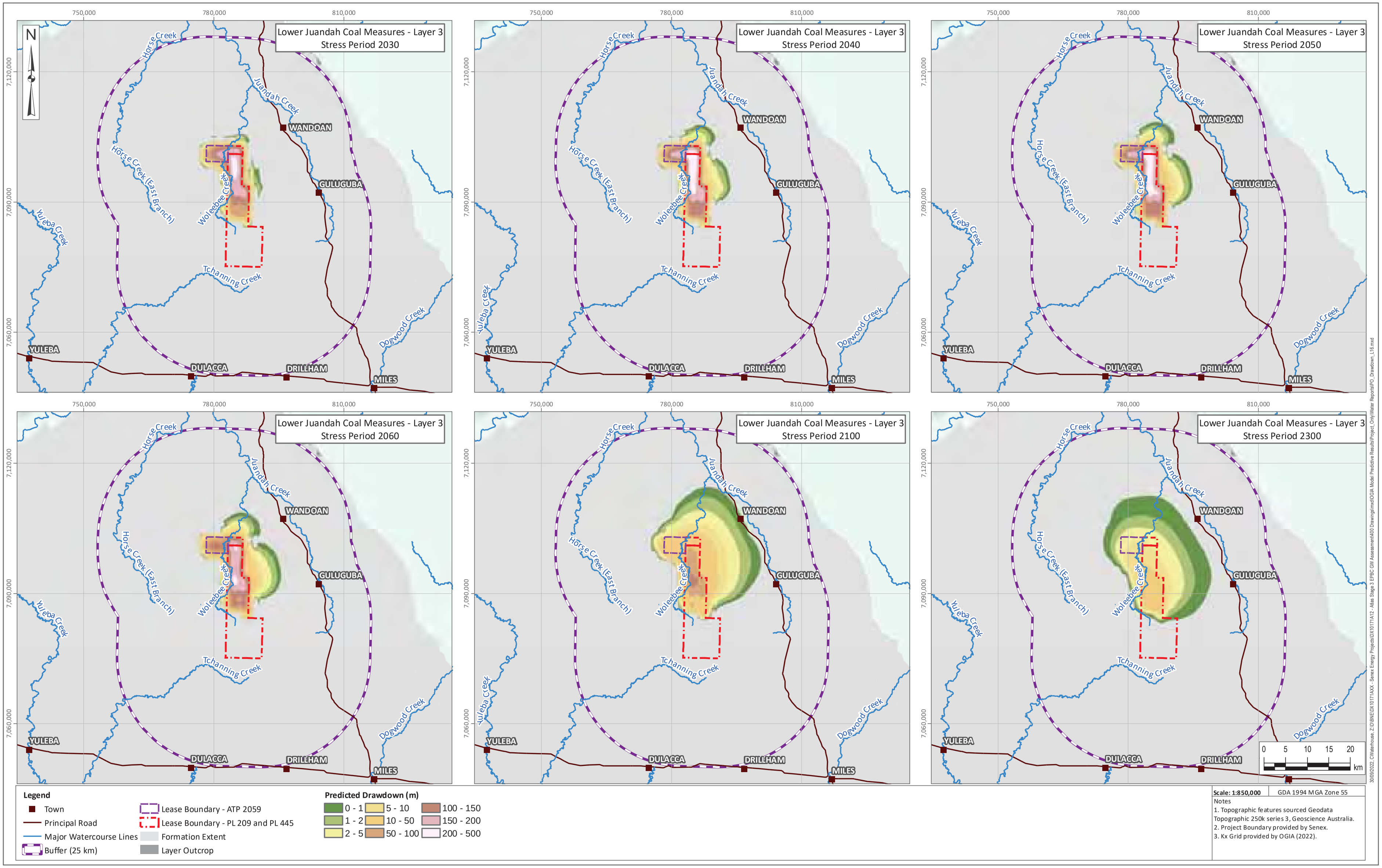

Figure II-10 Project Only Drawdown - Layer 16 – Lower Juandah Coal Layer 3

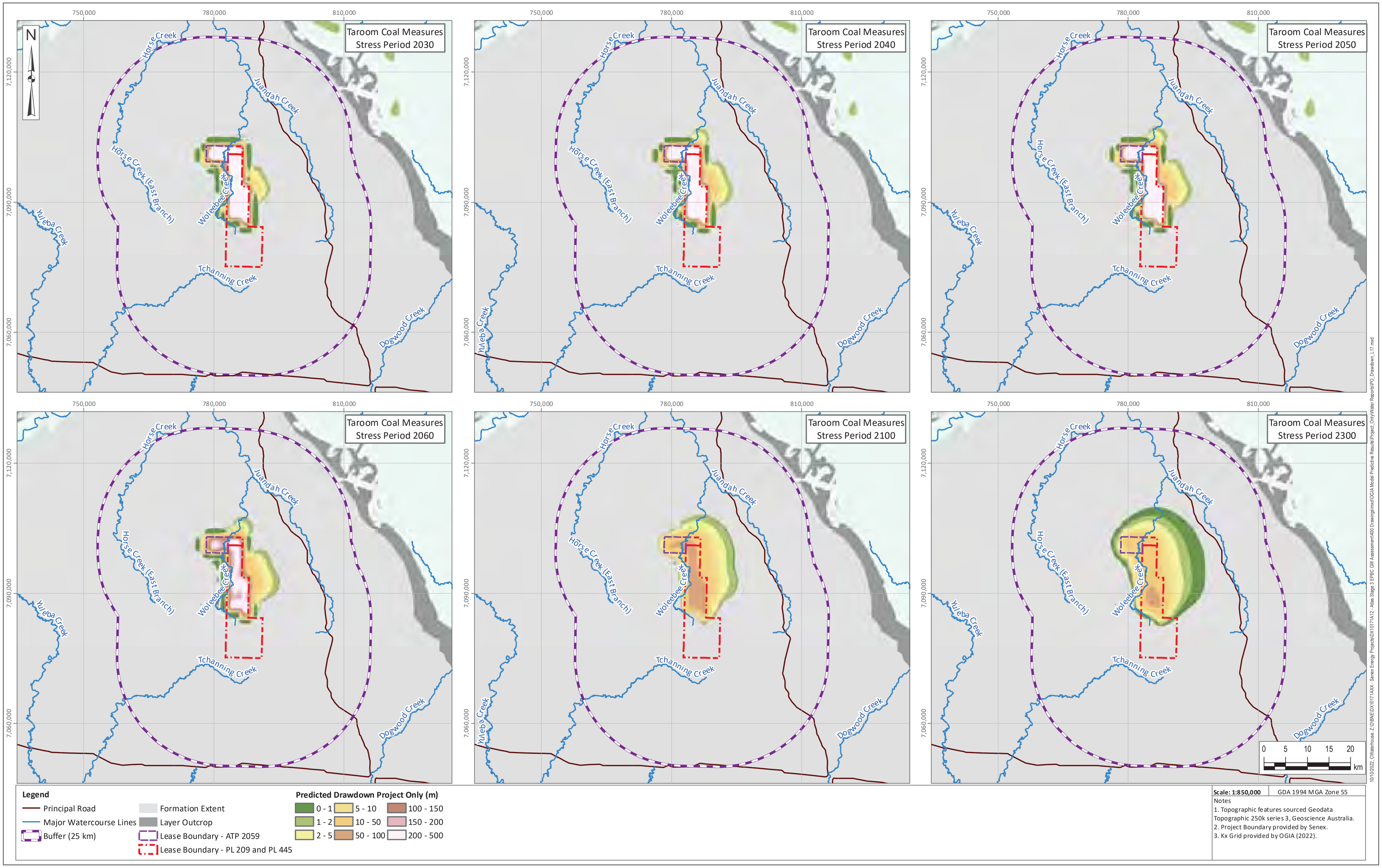

Figure II-11 Project Only Drawdown - Layer 17 – Taroom Coal Measures