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Response to DES Comments on the EA Submission – Gemini Project

1. Introduction

This memorandum provides responses to a Department of Environment and Science (DES) information request, for sections that relate to groundwater.

The responses below are provided under the broad headings in the DES information request, with the specific DES queries provided in italics and the JBT response provided below.

2. Comments in Relation to DES Responses

2.1.1. DES Issue No. 84 & 88

DES Comment

Two downstream gauging and water quality monitoring stations are noted to have been installed on Charlevue and Springton Creeks (CC2 and SC2). It is understood that flow will be recorded continuously during a flow event. The date of installation and the data collected should be provided. These monitoring stations are considered to be important in establishing the relationship between creek flow and ground water levels.

DES Requirement

Provide the date of installation of the downstream flow gauging and water quality monitoring stations. Provide the stream flow and water quality data that has been collected to date.

Collate this information with alluvial and groundwater dependent ecosystem (GDE) aquifer information to identify the relationship between streamflow and groundwater levels.

Response:

Water gauge stations were installed at Charlevue Creek and Springton Creek on 19 November 2020.

Groundwater level data loggers installed for Charlevue Creek alluvium (DW7076W) and Springton Creek alluvium (DW729W1) since Dec 2018 and July 2020 respectively.

The locations of existing groundwater monitoring bores and surface water gauging stations are shown in Figure 1. Water level and water quality data for surface water and groundwater (alluvial) monitoring sites are shown in Figure 2. The data is assessed as follows:

- The upper plot shows daily rainfall (derived from the SILO data drill) between January 2019 and April 2021 (the period covered by site data). The increase in daily rainfall associated with the wet season months of December to March is clearly evident from the figure;
- The middle plot shows data for Charlevue Creek, including:
    - Manual and data logger water level readings for Quaternary alluvium bore DW7076W, which is available from November 2018 to present. The seasonal (wet season/dry season) rise and fall

in alluvial water level is evident from the data. The reductions in water level that are evident on a monthly basis are due to water quality sampling events from the bore;

- Water level data from the surface water gauging station installed on Charlevue Creek, with data available at 10-minute intervals from November 2020 to present. The rise and fall in creek level corresponds with the rainfall events shown on the upper plot. Also shown on the middle plot is the base of creek level at the location of the water gauging station. The relationship between surface water level and groundwater level will become more evident over time as additional data is collected. However, from review of initial data the following comments are made with respect to Charlevue Creek surface water and groundwater data is:
  - Surface water levels are highly reactive, with the water level increasing by more than 3 m (based on currently available data) in response to rainfall, with creek levels recessing relatively quickly towards the base of creek level during non-rainfall periods;
  - Groundwater levels within the Charlevue Creek alluvium respond more slowly, rising and falling by up to 1.5 m (based on currently available data) between cycles of wet season high and dry season low levels;
  - The electrical conductivity (EC) of Charlevue Creek surface water is low, ranging between 65 and ~400 µS/cm
  - By contrast, the EC of groundwater within the Charlevue Creek alluvium at the location of bore DW7076W is very high, ranging between ~14,000 to 17,000 µS/cm. A distinct seasonal variation in groundwater EC is not yet evident from the data (i.e. an EC variation that would suggest period recharge). The seasonal increase and decrease in groundwater level does indicate that the alluvium is seasonally recharged, though the seasonal recharge of lower EC water is not evident from the data. This is interpreted to indicate that the alluvium contains a stratified groundwater system, with a lens of fresh, low density water (from seasonal recharge) occurring over a deeper zone of denser, high EC groundwater. This interpretation is consistent with the GDE assessment (3D Environmental 2020), where it is postulated that, in areas where GDE's are assessed to occur (including the Charlevue Creek GDE area – refer Figure 1 for location), an unconfined, fresh alluvial aquifer is perched over higher EC, older Quaternary alluvium and Tertiary sediments.
  - It is noted that bore DW7076W is located immediately downstream of the site that is assessed as the Charlevue Creek GDE area (3D Environmental 2020) and is therefore well located to investigate this theory. Bore DW7076W is screened in a silty zone of alluvium from 8 to 12 mbgl. Above this zone, from 1 to 7.5 mbgl, is a sandy interval where lower EC groundwater could potentially occur. It is recommended that an additional groundwater monitoring bore be installed within the sandy interval at this site (i.e. adjacent to bore DW7076W) that is fitted with a water level/EC data logger, to allow this theory to be tested. It is noted that the highest that the water level has been at this site is 9.5 mbgl, which is below the base of the sandy interval, therefore the presence of water within the sandy unit is likely to be transitory.

- With respect to the question of interconnectivity between the alluvium and the underlying groundwater units, it is concluded that this would be best assessed via a nested groundwater monitoring site at the location of the Charlevue surface water gauging station. It is therefore recommended that additional monitoring sites be installed at the location of the Charlevue Creek gauging station as follows:
    - Install one bore that is screened within the Charlevue Creek alluvium;
    - Install one bore that is screened within underlying Tertiary strata; and,
    - Install one bore that screened within the underlying Permian strata at the shallowest depth where groundwater occurs;
    - Undertake hydraulic conductivity testing (i.e. slug testing) on all bores
    - Install water level data loggers within all bores
- The lower plot in Figure 2 shows data for Springton Creek, with the plot containing the same data that is described above for Charlevue Creek. Observations that are specific to this plot include:
    - The seasonal water level variation that is evident in the alluvial bore (DW7292W1) is similar to the trend observed for Charlevue Creek bore DW7076W, although the variation in wet season/dry season water level is less that is observed in the Charlevue Creek alluvium. It is noted from the bore log for DW7292W1 that the alluvium is comprised of silty clay at this site, which will act to limit infiltration of surface water relative to the Charlevue Creek site where the upper strata is sandy;
    - The EC of the alluvial groundwater is generally <2,000 µS/cm, which is lower than the Charlevue Creek sample, but higher than the surface water sample. As with the Charlevue Creek site discussed above there is no evidence to date of a reduction in groundwater EC that correlates with the higher groundwater levels that accompany wet season rainfall and/or streamflow and it is possible that the alluvial groundwater system is stratified as postulated above for Charlevue Creek.
    - It is noted that no GDE's are identified for the stretch of Springton Creek in which bore DW7292W1 occurs and no further bores are proposed for this area (it is also noted that the Springton Creek water gauging station is located off-lease and it is therefore more difficult to drill bores at that location than at the location of the Charlevue Creek surface water gauge, which is located within the ML area). Ongoing evaluation of the data that is shown on the bottom plot of Figure 2 will provide further information on the relationship between groundwater and surface water in Springton Creek.

2.1.2. DES Issue No. 88

DES Comment

The information supporting the conclusions that have been made in relation to the limited hydraulic connectivity between the regional groundwater table and the perched aquifer that supports the GDE's (Appendix F:

Groundwater Dependent Ecosystems Assessment) as well as the limited connectivity between the perched alluvium and deeper groundwater systems remain of concern to the department.

The conclusion is that it is unlikely that the project will reduce surface flows that replenish the perched GDE aquifer and that impacts of drawdown will not be propagated into the perched aquifer system, which is likely disconnected.

The proportions of major cations and anions within different monitoring bores can provide an indication of the degree of connectivity between groundwater bores. The major cations include sodium, potassium, calcium and magnesium and the major anions include chloride, sulphate, bicarbonate and carbonate.

Hydraulic conductivity has only been calculated for one (1) of the alluvial bores using the result from a single test to demonstrate that the alluvium is hydraulically isolated. Hydraulic conductivity testing should be provided to justify the conclusions drawn relating to the hydraulic conductivity of the GDE and alluvial aquifers.

The department has been unable to identify indicators/ thresholds/triggers that have been identified specifically for the purpose of protecting GDE values. While it is noted that conclusions have been drawn around the lack of connectivity between surface water, deeper groundwater and the GDE aquifers; there is little data to support the conclusions. A trigger of 2m/year has been assigned for an unconsolidated quaternary alluvial aquifer, and it is unclear how a 2m/year drawdown is believed to afford the relevant necessary protection to GDE's. The department still considers it necessary to include indicators, thresholds and limits in drawdown that will be relevant to the protection of GDE values.

DES Requirement

All major anions and cations must be monitored for all bores in accordance with the current proposed monitoring regime. Produce a figure(s) that visualise the ionic chemistry of the groundwater samples, for example, a piper diagram.

Conduct adequate hydraulic conductivity testing of alluvial aquifers and include the data and results in the response. Identify and justify appropriate draw down triggers and management actions for the protection of GDE values.

Response:

It is noted that hydraulic conductivity (as obtained from bore testing) and hydraulic connectivity are not distinctly related. It is a given that the hydraulic conductivity of the alluvium will be higher than that of the underlying Permian strata, with the issue being the relative permeability of the strata and the flow potential between layers (based on water level). Nonetheless, the installation of additional (nested) groundwater monitoring bores is a recommendation of this assessment and hydraulic testing will be undertaken on these bores to facilitate ongoing assessment.

Box and whisker plots and Piper ternary diagrams have been prepared to facilitate the interpretation of existing groundwater quality data. These data are discussed as follows:

- Box and whisker plots for field pH, field EC and sulphate (as general indicators of groundwater quality) are presented as Figures 3, 4 and 5 respectively. These figures each contain separate plots for samples from Quaternary alluvium and creeks, Tertiary sediments, and Permian sediments. Observations from review of box and whisker plots are as follows

- The pH range (Figure 3) is generally between 5.5 and 7.5, with one bore (Permian bore DW7105W2) recording a pH in the range of 7.5 to 8.5. The pH range is consistent with the range expected for groundwater within the geology encountered at the Gemini site
- The EC range (Figure 4) is highly variable:
  - Groundwater within the site creeks ranges from 65 to 392 µS/cm (Charlevue Creek) and 1 to 615 µS/cm (Springton Creek)
  - Within the alluvium the EC tends to be relatively high, ranging from 14,079 µS/cm to 17,106 µS/cm (Charlevue Creek) and 1,594 to 5,948 µS/cm (Springton Creek)
  - Within the Tertiary sediments the EC is generally >7,000 µS/cm, with two sites (DW7068W and DW7178W1) generally recording an EC of >20,000 µS/cm. One bore records a relatively low EC (DW7220W1), ranging from 1,387 to 1,757 µS/cm
  - Within the Permian sediments the EC is generally >10,000 µS/cm. However, three sites generally record an EC <4,000 µS/cm, including DW7105W2, DW7220W2 and DW7221W2
  - It is noted that a number of the low EC Tertiary and Permian bores are located in one distinct area of the lease, with observations as follows:
    - At site DW7220, both the Tertiary bore (W1) and shallow Permian bore (W2) record an EC of <2,000 µS/cm. The deeper Permian bore at this site (W3) records an EC range of 17,398 to 20,693 µS/cm. It is noted that this site is located near the Springton Tributary Area 1 GDE system that was identified in 3D Environmental (2020) (refer Figure 1 for location)
    - At site DW7221, which is also close to the Springton Tributary Area 1 GDE system discussed above, the shallow Permian bore (W1) records a relatively low EC ranging from 3,325 to 3,979 µS/cm with the deeper Permian bore (W2) recording an EC range of 7,851 to 16,059 µS/cm.
    - The GDE assessment (3D Environmental 2020) concludes that the potential GDE's in this area are supported by a seasonally variable perched aquifer. This conclusion is supported by the water level data in this area as the Tertiary bore at DW7220W1 records a water level that is approximately 16 mbgl (below the root zone of plants), while the deeper bores record a water level of approximately 20 mbgl, indicating a potential for downward flow (i.e. recharge potential) at this site. A seasonal alluvial groundwater system that could provide periodic support to plants could also provide recharge to the underlying groundwater system at this location, though it is apparent from the water level data that the perennial groundwater system occurs at too great a depth to support vegetation.
    - At site DW7105 the Tertiary bore (W1) is dry, while the shallow Permian bore (W2) records a water level of approximately 32 mbgl. Recharge is evidently occurring from the shallow groundwater system to the Permian strata at this site, as the EC range in bore DW7105W2 is from 949 to 1,367 µS/cm. The depth to groundwater at this site (~32 mbgl) is too deep to support vegetation.

- Figure 6 presents a Piper Diagram, which is based on the mean major ion data for each monitoring site. Observations are as follows:
    - Separate Piper diagrams are shown in Figure 6 for all data, as well as Quaternary alluvium/surface water samples, Tertiary sediments groundwater samples and Permian sediments groundwater samples;
    - In the plot showing data for Quaternary alluvium and surface water, the surface water data plots at a location on the anion plot that is indicative of relatively low chloride and relatively high bicarbonate concentration, and plots on the cation plot at a location that is indicative of a slightly higher concentration of calcium relative to the majority of groundwater samples. It is concluded that the chemical signature of the surface water samples is indicative of the signature of recharge water to the groundwater system.
    - On the Piper diagram for Tertiary bores, data for one bore (DW7220W1) plots at a location that is high in carbonate relative to chloride, and high in calcium relative to sodium, which is interpreted to be indicative of recharge water. As discussed above, this site also records relatively low EC
    - On the Piper diagram for Permian bores, data for bores DW7105W2, DW7221W1 and 7220W2 plots at a location on the anion diagram that is indicative of relatively high concentrations of bicarbonate relative to chloride. As discussed above, these three sites all record low EC concentrations relative to other Permian groundwater sites.
    - With increasing groundwater residence time (i.e. as groundwater moves further along flow lines and increases in salinity) the groundwater could be expected to become more dominated by the cation sodium and the anion chloride (i.e. become more dominantly Na-Cl type water and plot to the lower right corner of both the cation and anion plots)
    - The data from the Piper diagrams is therefore consistent with the interpretation of areas that are receiving groundwater recharge, as discussed in Section 2.1.1
- As noted in Section 2.1.2, hydraulic testing will be undertaken on the new groundwater bores that are proposed to be drilled in Charlevue Creek, as well as existing bore DW7076W.

2.1.3. DES Issue No. 85

DES Comment

The groundwater network is representative of the groundwater units present, in that bores are located within each of the groundwater units; however, the bore locations have not been demonstrated to be representative of the directional flow of groundwater and reflect the up and down gradient for each groundwater unit. Furthermore, bore location continues to appear to be random and the spatial distribution is not well justified in terms of anticipated impacts from potential sources of contamination. Locations of reference bores should be located upgradient as opposed to just being 'distant'. The demonstration of conceptual understanding of ionic chemistry and groundwater flow direction is important to evaluate if the bore network is appropriate and representative. There does not currently appear to be an upgradient or reference bore proposed for the alluvial aquifers.

DES Requirement

Detailed conceptual understanding of the direction of groundwater flow needs to be demonstrated. Provide a figure illustrating ground water level contours indicating directional flow of groundwater. To demonstrate that the bore network is entirely representative of up and down gradient for each groundwater unit, produce a figure that visualises the ionic chemistry of the groundwater samples, for example, a piper diagram. Provide justification for a lack of reference bores and up/down gradient bores for the alluvial aquifer or alternatively install the necessary bores.

Response

The groundwater monitoring network was designed to provide both spatial and vertical coverage within all groundwater units that have been identified at site.

Available groundwater level data is included (as bore hydrographs) in Figures 7 to 12.

Figure 13 shows a map of water level data for Tertiary sediment bores. Observations from Figure 13 include:

- The contours that are shown in Figure 13 represent the elevation of base of Tertiary, based on data from the site geological model. Figure 13 also shows the water level data in each Tertiary monitoring bore and the RL of the base of bore.
- A Permian ridge is present through the centre of the ML, where the base of Tertiary occurs at elevations from RL110 mAHD to >RL130 mAHD. Based on available Tertiary water level data, the Tertiary sediments are assessed to be dry at elevations in excess of 110 mAHD, which includes the greyed out area in Figure 13;
- The Tertiary groundwater system is therefore assessed to be separated in the ML area to a distinct groundwater system to the south of the Permian ridge and a system to the north of the Permian ridge. The system to the north of the Permian ridge has a distinctly lower RL for the base of Tertiary (the areas shown in green shading), resulted in a greater saturated thickness of Tertiary sediments in that area. The direction of groundwater flow in the Tertiary sediments is interpreted to be towards the areas where the base of Tertiary occurs at a lower elevation and away from areas where the Tertiary sediments are preferentially recharged, which includes the area around bore DW7220W1;
- Groundwater level contours for the Permian sediments are shown in Figure 14. The data indicates that the groundwater flow direction in the Permian sediments is from the south-southwest to north-north-east.
- It is concluded that the existing groundwater network is sufficient to be able to demonstrate the mechanisms for groundwater occurrence as well as groundwater flow direction in the groundwater units that have been identified at site.

3. Recommendations:

Following from the review of data undertaken for this memorandum it is recommended that:

- an additional groundwater monitoring bore be installed within the alluvium at site of Charlevue Creek alluvium bore DW7076W, to allow assessment of the theory that a seasonal fresh-water lens may exist within the alluvium at this site. The proposed bore would be screened/gravel

packed from approximately 5 to 7.5 mbgl and sealed via bentonite/ grout from 0-5 mbgl to be compliant with the requirements of the Minimum Construction Requirements for Water Bores in Australia;

- additional monitoring sites be installed at the location of the Charlevue Creek gauging station as follows:
  - Install one bore that is screened within the Charlevue Creek alluvium;
  - Install one bore that is screened within underlying Tertiary strata; and,
  - Install one bore that screened within the underlying Permian strata at the shallowest depth where groundwater occurs;

  For the bores described above it is recommended that:
  - hydraulic conductivity testing (i.e. slug testing) be undertaken on all bores; and,
  - water level data loggers are installed within all bores

Please contact the undersigned if you have any queries in relation to this letter.

Yours Faithfully,

John Bradley
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