Hemi Gold Project
Turner River Dewater Discharge
Tier 2 Environmental Risk Assessment

Prepared for:

De Grey Mining Pty Ltd

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MBS ENVIRONMENTAL

HEMI GOLD PROJECT
DEWATER DISCHARGE TIER 2 ERA

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EXECUTIVE SUMMARY

The Hemi Gold Project (Hemi) is located within the larger Malina Gold Project (MGP) approximately 80 km south of Port Hedland in the Pilbara region of Western Australia.

Dewatering associated with pit development at Hemi is likely to result in large volumes of excess water being produced for approximately 3 years prior to ore processing taking place. This is largely a consequence of the proposed development occurring in an area containing a shallow water table (<5 metres below ground level (mbgl)). Consequently, surplus water of approx. 30 GL will need to be managed. Based on the characteristics of the Hemi site, the most viable option to manage this water is a controlled discharge via natural earth ponds into the nearby Turner River (approx. 14 km to the east). In order to assess the ecological suitability of this approach a Tier 2 Environmental Risk Assessment (ERA) was undertaken, which is the focus of this assessment.

Composition of Proposed Discharge Water and Turner River Surface Water

The raw groundwater proposed to be discharged into the Turner River was found to contain elevated dissolved concentrations of uranium (28–31 µg/L) and vanadium (28–30 µg/L).These concentrations were considerably higher than the ANZG (2018) low reliability freshwater species protection guidelines for uranium (0.5 µg/L) and vanadium (6 µg/L). Selected raw groundwater arsenic concentrations (6–36 µg/L) were also elevated with respect to ANZG (2018) freshwater species protection guidelines (13 µg/L).

The Turner River (investigated for potential controlled discharge) is naturally enriched in uranium with a mean concentration of 5.3 µg/L present across the 2021–23 monitoring period which is much higher than the ANZG (2018) low-reliability (limited toxicity data) freshwater species protection value of 0.5 µg/L. Average vanadium concentrations of 4.1 µg/L in the Turner River are comparable to the ANZG (2018) low-reliability (limited toxicity data) freshwater species protection value of 6 µg/L. Average arsenic concentrations of 3.5 µg/L are much lower than the ANZG (2018) freshwater species protection guidelines (13 µg/L).

Generation of Site and Region-Specific Guideline Values for Uranium and Vanadium

Given the low reliability of ANZG (2018) freshwater species protection guidelines for uranium and vanadium and the elevated concentrations of uranium and to a lesser extent vanadium present in the Turner River, a series of site-specific trigger values were generated. These values were calculated from collated surface water monitoring data across a local scale (i.e. Turner River) and a regional scale — which encompassed sampling locations in both the turner and neighbouring Yule River systems. In addition, guidelines were generated that encompassed a ‘trigger’ value (early warning based off the 80th percentile value of the monitoring dataset) and an ‘action’ value (likely environmental effects based on the 95th percentile value of the monitoring dataset).

The calculated site- and regional-specific guidelines are detailed below:

- Uranium: Site (Turner River)-specific Trigger (80th %) = 5.7 µg/L; Action (95th %) = 12.2 µg/L.
- Uranium: Region-specific Trigger (80th %) = 12.1 µg/L; Action (95th %) = 19.1 µg/L.
- Vanadium: Site (Turner River)-specific Trigger (80th %) = 8.6 µg/L; Action (95th %) = 10.5 µg/L.
- Vanadium: Region-specific Trigger (80th %) = 9.6 µg/L; Action (95th %) = 11.0 µg/L.

Contaminant Loading into the Turner River Post-Discharge

The proposed wetting front into one channel of the Tuner River was predicted (Geowater 2023) to extend 50 km downstream in the absence of rainfall (dry season) within the catchment during the discharge period. Under this scenario, uranium and vanadium concentrations in the Turner River near the discharge point would be between 3–6-fold higher than the site and regional-specific trigger and action values outlined above. In addition, under this scenario uranium and vanadium concentrations in Turner River sediments from untreated groundwater discharge may also increase by an average of 0.3 mg/kg (conservative, assumes 100% sorption) over the predicted length of the discharge. This sediment loading was not considered to represent a significant risk given background and default criteria for uranium and vanadium in soils. It must be noted, however, that concentrations in water column and sediments will be higher closer to the discharge as some attenuation is likely the further the discharge moves downstream (which for uranium would include mixing with groundwater).

If median rainfall were to occur during the discharge period (approx. 6.3 GL in catchment/year) uranium and vanadium concentrations in the Turner River would still exceed calculated interim regional and site-specific trigger and action values. In an average rainfall year (28 GL/year), however, uranium concentrations are only likely to exceed the site and regional trigger values outlined above. Vanadium concentrations, however, are likely to fall below the site and regional trigger values in average rainfall years.

PHREEQC Equilibrium Chemical Modelling

In order to assess the validity of the predicted composition of the Turner River post discharge and also test the efficacy of potential water treatment options PHREEQC equilibrium chemical modelling was conducted.

PHREEQC modelling demonstrated that the presence of iron oxide materials in native soils should be able to remove the bulk of vanadium present in the discharge water if held in soil-based holding ponds prior to discharge. For uranium an additional 1.5 g/L of iron oxide material is required to reduce concentrations to <5.7 µg/L (site-specific 'trigger' value).

Laboratory-Based Water Treatment Experiments

Laboratory experiments were conducted to ground truth the PHREEQC modelling results. Two sets of experiments were conducted in which the discharge water was stood over site soil to assess whether native soil components could remove contaminants of interest in a simulated earthen discharge pond. Additional experiments were then conducted in which a range of additional iron oxide materials were added to the proposed discharge water as a means of facilitating contaminant removal. As predicted in the PHREEQC model, native and added iron oxide minerals were able to significantly reduce vanadium and arsenic concentrations in the final solution/discharge water. Uranium concentrations in the discharge water were, however, largely unaffected by mixing with native soils or when treated with iron oxide and/or phosphate minerals. Uranium concentrations in the post treatment discharge water were predicted to still exceed the calculated regional and site-specific trigger values and thus to reduce uranium to concentrations below these values, an alternate treatment such as ion exchange is likely to be required.

Radiological Modelling

The elevated uranium concentrations in the discharge water meant that an environmental radiation risk assessment was required to assess whether the discharge was likely to have any impacts on biota living in the Turner River or on those species that use the Turner River as a drinking water source. Despite the observed and calculated exceedances of selected radiological screening values, ERICA and RESRAD-BIOTA radiation dose modelling (on non-treated raw water) suggested that there are unlikely to be any radiological risks at the population scale to organisms that reside in the Turner River and organisms who utilise the Turner River as a drinking water source.

Uranium Ecotoxicity Review

As per geochemical modelling and literature review, under the oxygenated and alkaline conditions of the surficial aquifer and surface waters, uranium in solution is present as uranyl (U(VI)) carbonate species such as $UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$ and their calcium complexes $Ca_2(UO_2)(CO_3)_3(aq)$ and $Ca(UO_2)(CO_3)_3^{2-}$ which are highly mobile and resist adsorption to mineral surfaces. Soluble uranium species such as the uranyl ion are known to affect the function of internal organs (especially kidneys) in animals whilst they can also have deleterious effects on the growth and reproductive capacity of plants. In general, however, the uptake and translocation of uranium from roots to above-ground plant tissues is limited, with the bulk of uranium being either absorbed within or adsorbed on root tissues which limits toxicity to plants overall.

A collation of aquatic freshwater literature data and calculation of a species sensitivity distribution (SSD) curve value for uranium indicated a species protection level of approximately 83% for a discharge concentration of between 28 and 31 µg/L as found from tests and calculations for a predicted discharge uranium concentration. The calculated 95% species protection value for uranium was 2.5 µg/L which is much higher than the current ANZG (2018) low-reliability value of 0.5 µg/L. From literature information, a key driver of uranium toxicity is uranium speciation, with uranyl carbonate species indicated to be less toxic than other forms and that the current ANZG low-reliability value of 0.5 µg/L appears overly conservative or inappropriate for such species.

Tier 2 Environmental Risk Assessment (ERA)

The Tier 2 ERA covered the following scenarios:

- The potential effects of the release of metal(loids) into the Turner River system
- The potential effects of metal(loid) accumulation in Turner River sediments.
- The potential effects of the release of radionuclides into the Turner River system
- The potential effects of radionuclide accumulation in Turner River sediments.
- The potential effects of changes to the hydrology of the Turner River system.

The potential effects of the release of metal(loids) into the Turner River system: The ERA outlined that the inherent (uncontrolled) risks to biota inhabiting the Turner River are high due to the presence of elevated uranium and vanadium if the water is not treated prior to discharge. Controls such as the use of soil-based holding ponds, dosing with iron oxide materials and ion exchange treatment are viable options to lower contaminant loads entering the river system thus reducing the residual risk to low. Other receptors, such as organisms that use the Turner River as a drinking water source (livestock, native fauna), were not deemed to be at risk from the discharge, given uranium and vanadium concentrations were well below default livestock drinking water trigger values (ANZECC 2000).

The potential effects of metal(loid) accumulation in Turner River sediments: The inherent risk for organisms residing in sediments was considered low due to the possibility of uranium and vanadium concentrations increasing by up to 0.3 mg/kg (conservative estimate) across the discharge zone in the absence of catchment rainfall. The controls detailed above, however, were also likely to reduce the residual risk to very low as a result of the removal of contaminants pre-discharge into a contained soil ponds and the dispersion of uranium back into surficial groundwater (versus binding to river surface sediment).

The potential effects of the release of radionuclides into the Turner River system/accumulation in Turner River sediments: The release of radionuclides into the Turner River as a result of the discharge was categorised as having a low inherent risk to biota that inhabit the river and organisms that use the river as a drinking water source. This categorisation was based on the results of ERICA and RESRAD-BIOTA radiation modelling which suggested that even under the worst-case scenarios (i.e. no catchment rainfall) there is unlikely to be any radiological risks at the population scale to organisms who reside in the Turner River and those who utilise the Turner River as a drinking water source. The residual risk was categorised as very low if active/environmental controls are able to significantly lower uranium concentrations entering the Turner River system. This risk categorisation was also applicable to the loading of radionuclides in sediments. Consistent with PHREEQC and bench testing results, uranium is indicated to primarily remain soluble and recharge and disperse back into the surficial aquifer.

The potential effects of changes to the hydrology of the Turner River system: The continual inundation of a predicted 50-km stretch of the Turner River over the 3-year discharge period was categorised as having a low inherent risk for organisms who live in or utilise the river system. This is due to the planned discharge being constrained within a 90-m channel which will result in <6% of the river width being inundated as a result of the discharge. This is therefore unlikely to result in significant ecological effects at either the local or regional scale.

Management Options and Implications

Based on the results of the modelling, laboratory experiments and Tier 2 ERA the options available to De Grey include:

- Treating approximately 65% of the discharge water (19.5 GL over 3 years) by ion-exchange and mixing/co-discharging with the remaining 35% of water treated via earthen ponds to ensure that concentrations of uranium, vanadium and to a lesser extent arsenic fall below the relevant regional guideline values (uranium trigger 12 µg/L being the key criteria as arsenic and vanadium can be readily removed in the ponds).
- Providing evidence via ecotoxicity testing of the groundwater (following simulated pond treatment) that elevated uranium concentrations (present as uranyl carbonates) pose no ecological threat to the Turner River system in the concentrations (26 to 30 µg/L uranium) that are likely to be present during discharge. This assumes that test results can provide a sufficiently high species protection level to meet regulatory approval (likely 90 to 95%). A current estimate from literature is approximately 83% species protection, however this includes many data points other than uranyl carbonate solutions which are indicated to be less toxic.
- A combination of the above, whereby with ecotoxicity testing and an agreed species protection level, the discharge target concentration of below 12 µg/L may rise and hence a lower proportion of water would require treatment for uranium removal.
- Alternatively, and most cost effectively would be to explore options for the sale of the water to another organisation for mining or agriculture use.

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1. INTRODUCTION AND SCOPE

1.1 BACKGROUND

The Hemi Gold Project (Hemi) is located within the larger Malina Gold Project (MGP) approximately 80 km south of Port Hedland in the Pilbara region of Western Australia. The MGP comprises six defined mineralised gold zones (Toweranna, Mallina, Withnell, Mt Berghas, Hemi and Wingina) across a 1,200 km^2 contiguous tenement package.

The mineral estimate for the deposit is approximately 6.8 Moz. It is estimated that further intrusions and untested exploration potential remains throughout a 1,500 km^2 area within the basin, which contains a significant mineral resource of (at time of writing) approximately 37.4 Mt grading 1.8 g/t gold for 2.2 Moz. This study focuses on the initial development of the Hemi and Withnell deposits and central infrastructure area to be located at Hemi.

Meetings with De Grey have outlined that dewatering associated with pit development at Hemi/Withnell is likely to result in excess water being produced for approximately 3 years prior to ore processing taking place. This is largely a consequence of the proposed development occurring in an area containing a rainfall fed shallow water table (<5 metres below ground level (mbgl)). Consequently, this surplus water (approx. 30 GL in total or 10 GL/a) will need to be managed.

Based on the characteristics of the Hemi site (volumes, shallow groundwater table, limited spatial extent), the most viable option to manage significant portions of this water was considered a controlled discharge into the nearby Turner River (approx. 14 km to the east). In order to assess the ecological suitability of this approach, a Tier 2 Environmental Risk Assessment was required for this option, which is the focus of this assessment. Other measures to reduce the volumes of potential surface water discharge include a proposed aquifer recharge network, however this is not the subject of current works.

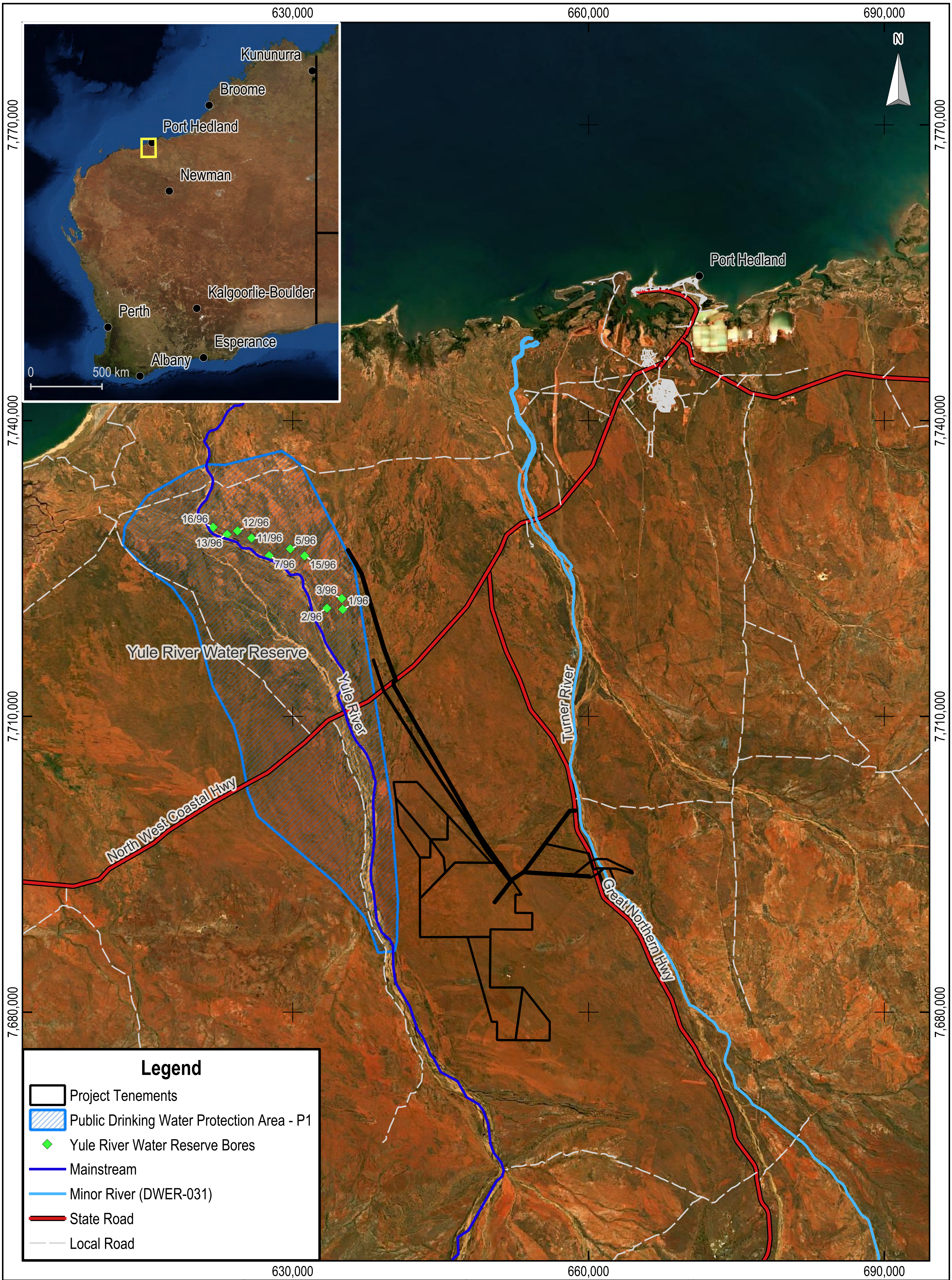
1.2 SCOPE OF WORK

The scope of work for the project was as follows:

- Liaise with De Grey to understand the nature of the Hemi site, advise on collection of site-specific data requirements and assess viable options for surplus water management.
- Review surface water, groundwater, sediment and soil data from the Hemi site to understand:
  - The chemical composition of abstracted groundwater to be discharged into the Turner River during dewatering and whether this differs over time.
  - The composition of surface water within the Turner River system in order to establish ambient background concentrations and site-specific guideline values for the project area.
  - The composition of project area soils and sediments within the Turner River system to understand potential contaminant sources and sinks within the project area.
- Conduct a Tier 2 Ecological Risk Assessment (ERA) in accordance with the NEPC Schedule B5a (2011) in relation to the discharge of raw and treated (options assessment) water into the Turner River which involved the following:
  - Conducting geochemical (USGS PHREEQC) modelling to predict the equilibrium concentrations of key contaminants of potential concern (specifically uranium, arsenic and vanadium) in the discharge water.
  - Conducting laboratory experiments to assess the efficacy of different water-treatment approaches potentially used to remove key contaminants of potential concern (specifically uranium, arsenic and vanadium) from solution.
  - Assessment of impacts from changes in hydrology of the Turner River.

- Perform environmental radiation screening risk assessment covering both the plant and animal species that live in the Turner River discharge zone, plus animals that utilise the groundwater (livestock) or Turner River as a drinking-water source.
- Perform a human health radiation risk assessment which will assess the risks to Hemi site workers if discharge water is to be utilised in the process plant or on site for dust suppression.
- Conduct a review of relevant ecotoxicological data relating to the toxicity of uranium and vanadium in aquatic and riverine ecosystems.

- Produce a report (This report) outlining the findings of the Tier 2 ERA which also encompasses the major findings of the above assessments.



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Original Size: A4
Image: Copernicus Sentinel Data 2020
Grid: GDA94 / MGA zone 50
0 10 20 km

De Grey Mining Pty Ltd
Hemi Gold Project

Figure 1

Location Plan

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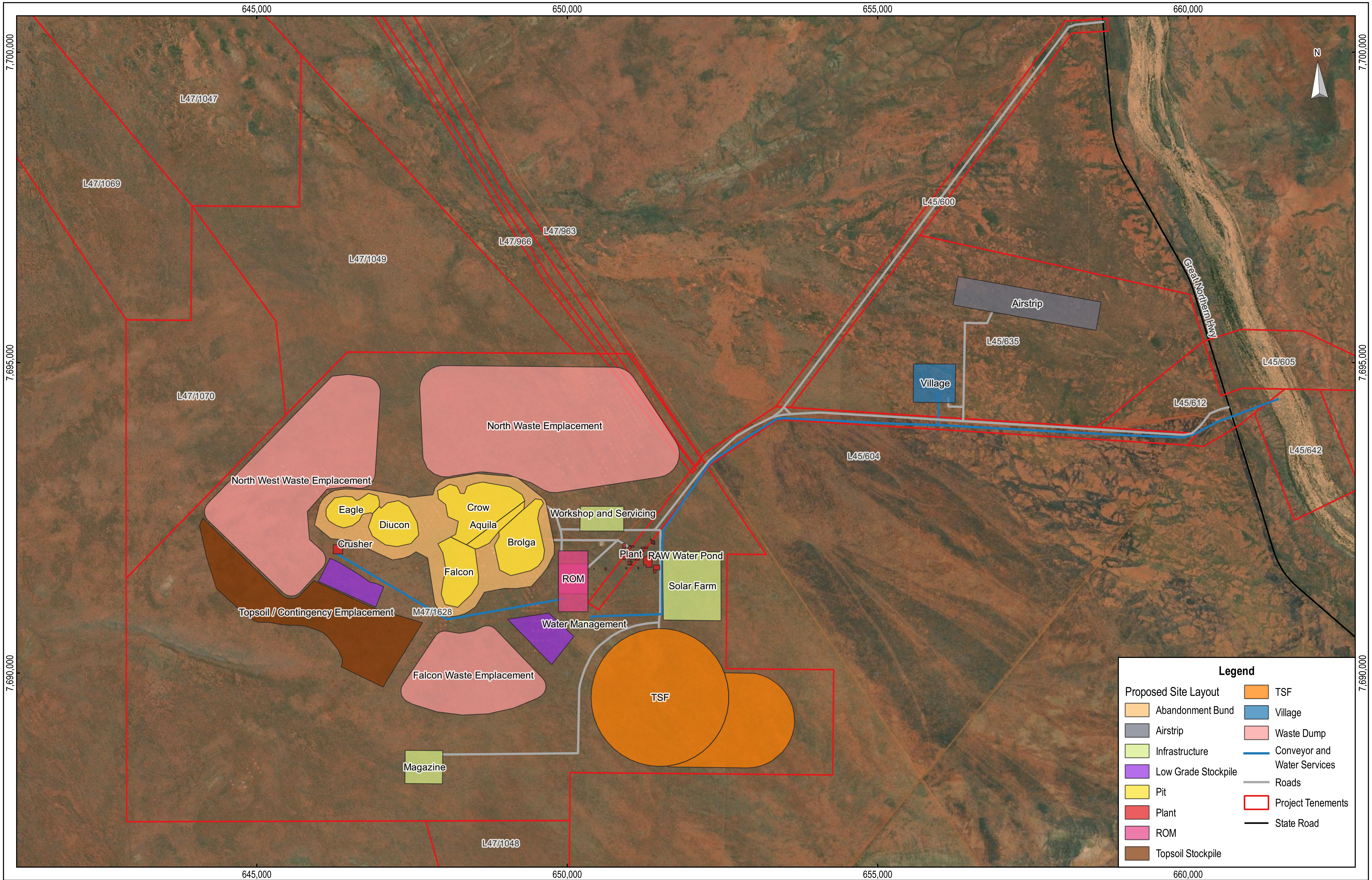
2. PROJECT DETAILS

The Hemi project will utilise open cut mining to extract gold bearing ore from the Hemi deposits. At the time of writing six (6) pits are to be mined (Eagle, Crow, Aquila, Brolga, Diucon and Falcon) which will cover a combined area of approx. 289 ha. Underground development of these may also occur. During mining development significant dewatering will be required given that groundwater is likely to be intercepted within the top 5 m of the profile. During the first 3 years of operation approximately 30 GL of the water to be dewatered during the pit excavation process has been proposed to be discharged into the Turner River. In addition, the following infrastructure has been proposed to be part of the project (as outlined in Figure 2):

- A Tailings Storage Facility (TSF) with a capacity to store the tailings from 100 Mt of processed ore.
- Waste rock landforms (3) and low-grade ore stockpiles (2).
- The construction and subsequent operation of a nominal 7.5-Mtpa to 12.5-Mtpa processing facility located adjacent to the Hemi deposit, capable of achieving 90% to 94% gold recovery from free milling and semi refractory ores.
- A village with messing and accommodation capacity for approximately 900 personnel (600 permanent and 300 temporary).
- A power supply from the 220-kV network grid approximately 40 to 60 km north of the processing facility.
- A 9-km sealed access road from the Great Northern Highway.
- An airstrip with capacity for 100-seat jet aircraft.

Other supporting infrastructure (offices, workshops, waste facilities, laydowns).



Scale: 1: 55,000
Original Size: A3

Grid: GDA94 / MGA zone 50 (EPSG:28350)

0 1 2 km

De Grey Mining Pty Ltd
Hemi Gold Project

Figure 2

Proposed Site Layout

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\\mbssvr\working\De Grey Mining (DGM)\Tier 2 ERA\GIS\De Grey Mining_Tier 2 ERA_Jun23.qgz 19/06/2023 F2 Proposed Site Layout

3. PROJECT ENVIRONMENT

3.1 CLIMATE

Climate data (1997–2024) for the Hemi site was collected from the BoM monitoring station at Port Headland Airport (004032) located approximately 58 km north of the site (BoM, 2024). Temperature and rainfall data from this site has been collected from 1942 to the present. Major considerations from the data include:

- Annual average minimum and maximum temperatures were 19.6 and 33.4°C, respectively.
- November to April is the hottest period of the year with average maximum temperatures between 35.1–36.8°C over this period. Average minimum temperatures over this period were around 25.5°C.
- Maximum Temperatures during May–September are slightly cooler, averaging between 27.4–32.5°C.
- The average annual rainfall for the area is 318.5 mm, with 93% of this falling between December to June. February is on average the wettest month (average rainfall: 89.3 mm), with an average of five (5) wet days occurring.
- In an average year rain falls on 20 days with 12 of these typically occurring between January to March. On average, 7.5 of these days will have rainfall events >10 mm, with 3 typically having >20-mm events.
- Evaporation ranges from 6.5 mm/day in winter (June) to 11.5 mm/day in November.

3.2 REGIONAL GEOLOGY

The Hemi Gold Projects lies within the Western margin of the Pilbara Craton, Western Australia. The Project area is dominated by a broadly east-northeast/west-southwest-trending Archaean greenstone and meta-sediment sequence that has been complexly folded and structurally deformed by the regional deformation and the emplacement of granitic batholiths and smaller, localised intrusions (Blueprint Environmental, 2021).

The major lithostratigraphic units within the project area are the sediments of the craton-wide De Grey Supergroup. Within the West Pilbara the De Grey Supergroup is subdivided into the lower Constantine Formation and the upper Mallina Formation, forming the Mallina Basin. The basement to the Malina Basin and the De Grey Supergroup in the project area is the Warrawoona Group and the Cleaverville Formation (Blueprint Environmental, 2021).

The Warrawoona group comprises schists of mafic-ultramafic origin, expressed at surface by calcrete and sub-cropping chlorite schist and the overlying sedimentary Cleaverville Formation, is expressed as topographically prominent ferruginous chert with interbedded chloritic black shale units. The De Grey Supergroup is interpreted to unconformably overlie the Cleaverville Formation. The Constantine Formation comprises conglomerate, arkose and shale and can form topographic highs, whilst in contrast the Mallina Formation sediments typically outcrop very poorly and are predominantly covered by alluvium and colluvium (Blueprint Environmental, 2021).

After deposition, and before regional deformation, the Mallina Basin was intruded by mafic-ultramafic sills of the Indee, Langenbeck and Millindinna Suites. These intrusions are present as extensive, thin sills in the lower half of the basin. Widespread syn- to post-deformational intermediate to felsic granitoid bodies have intruded and can bound the Mallina Basin. Within the suite of granitoid intrusions is a suite of Sanukitoids, the location and emplacement of which are interpreted to help delineate major structural corridors that are considered prospective for gold mineralisation (Blueprint Environmental, 2021).

The weathering profile in the region ranges from a 1-m to 10-m-thin cover of calcrete or transported sands overlying weathered bedrock to deep transported cover in areas like the Hemi discovery where the depths of the transported sediment range from 30 m to 50 m vertically. Oxidisation of the bedrock ranges from 10 m to 80 m in depth and typically averages around 50 m depth (Blueprint Environmental, 2021).

3.3 PROJECT GEOLOGY

The Hemi discovery is an intrusion related gold deposit consisting predominately of diorite to quartz diorite intrusions and sills. Gold mineralisation is associated with localised to massive zones of brecciated albite, chlorite, and carbonate (calcite) altered intrusion with disseminated sulfides and sulfide stringers containing pyrite and arsenopyrite with minor occurrences of pyrrhotite. There are strong correlations between gold, arsenic, and sulfur. The sulfide mineral assemblage, characterised by pyrite, arsenopyrite and minor pyrrhotite, and anomalous associated elements including Ag, As, Bi, Mo, Sb, Sn, Te and Zn (Blueprint Environmental, 2021).

The intrusions were emplaced into a sequence of sedimentary rocks within the Mallina Basin, currently interpreted to be part of the Mallina Formation which locally comprises greywacke, siltstones, sandstones, shale, and black shale. There are mafic-ultramafic sills of the Langenbeck Suite within the area and these assist in mapping the interpreted folding and faulting within the region around the Hemi discovery amongst the otherwise poorly outcropping and nonmagnetic sediments of the Mallina Formation. The sediments immediately enclosing the intrusions have been hornfelsed, expressed by locally developed hardening and biotitic development related to the heat of the intrusions. The alteration in the wallrock/waste rock units away from the intrusions is typified by regional metamorphic chlorite (possibly with calcite) alteration. Proximal to the intrusions there may be volumetrically minor chlorite-albite-sulfide alteration within the sediments as well as the hornfelsing. Waste rock sourced from intrusions will be characterised by reduced sulfide levels, lower to no albite and increased chlorite and/or carbonate. Away from the deposit the sediments host disseminated metamorphic pyrite, typically at <1% abundances (typically 0.1% to 0.5%) (Blueprint Environmental, 2021).

Sulfide abundance in the mineralised intrusions typically ranges from 2.5 to 10%, whilst marginal alteration zones in the waste/ore transition comprise sulfide contents that typically range from 0.5 to 1%. Away from the ore zones the arsenopyrite content drops off rapidly to <0.5% and pyrite is the main mineral. Arsenopyrite is generally absent within the wallrock away from mineralisation (Blueprint Environmental, 2021).

Within the ore-zones, higher grade domains often have high arsenic and the arsenopyrite to pyrite ratio is 0.75:2.5 (or greater). Outside of the higher grade, arsenopyrite-rich domains within the mineralisation the arsenopyrite to pyrite ratio is typically 0.4:0.75. The ratio rapidly drops to <0.2 away from mineralisation, indicating the prevalence of pyrite away from the main zones of mineralisation. Weathering of the sediments is characterised by progressively increasing kaolinisation and loss of sulfides and carbonate from fresh, through transition to oxide (Blueprint Environmental, 2021).

Mineralogical calculations of sulfide, carbonate, and silicate minerals have been completed using the broad-spectrum multi-element data that has been collected within the Hemi area and this will be able to be used to map sulfide (and other mineral) abundances within geo-metallurgical domains in more detail (Blueprint Environmental, 2021).

3.4 REGIONAL CATCHMENTS

The tenements associated with the Hemi Project are in the catchments of the Yule and Turner Rivers (Figure 1). The tenements occupy 7% of the Turner River catchment and 1% of the Yule River catchment. The conceptual footprint of the Hemi project is 0.3% of the Turner River catchment (Blueprint Environmental, 2021).

3.5 PROJECT HYDROLOGY

Preliminary flood modelling has been conducted (Surface Water Solutions, 2021). The proposed Hemi infrastructure area exhibits relatively shallow flows (<300 mm) with relatively low flow velocities (<0.3 m/s) in a 1% Annual Exceedance Probability (AEP) flood event. Depths and velocities in the Yule and Turner River channels are substantial.

3.6 PROJECT HYDROGEOLOGY

The following aquifers have been identified within the greater Hemi project area (Geowater, 2023):

- Upper alluvium — a laterally extensive aquifer system having low to moderate (but significant) permeability and saturated thickness. This aquifer is shallow and fed directly by rainfall and during floods the water table meets the ground surface (DWER 2019). Shallow groundwater flowing through the project area (to be dewatered) contributes naturally to water flows in the Yule and Turner River systems.
- Lower alluvium — this comprises the basal paleochannel sands and gravels that form a major aquifer system with high permeability and storage values, extensive continuity in the north-south direction and in the order of 1–2 km in the transverse east west direction.
- Saprolite zone — the uppermost sections of weathered bedrock that commonly weather to a clay-rich assemblage with a resultant inherent limited permeability, notably within the sedimentary and ultramafic lithologies.
- Saprock zone — this covers the lower part of the weathering profile and comprises moderately to slightly weathered rock. At Hemi, the intermediate igneous intrusives have developed a relatively higher permeability than the surrounding sedimentary and ultramafic units in the saprock profile.
- Fresh bedrock — the lithologies present at and near Hemi do not form aquifer zones when they are unweathered, including the arkosic wackes (feldspathic sandstones) and sandstones. Extensive reviews of diamond drill core logs and photos indicates that discrete fracture zones related to the brittle ductile nature of the igneous intrusives, and possible later stage cross-cutting faults form permeable but narrow flow paths within bedrock. There is also an indication that the openness (and hence permeability) of these structures gradually declines with depth, such that permeable fractures in core were rarely observed below about 150 m (vertically) below ground.

3.7 LAND SYSTEMS, LANDFORMS AND SOILS

Land systems, landforms and soils present within the project area as outlined in Van Vreeswyk et al., 2004 are summarised below in Table 1.

Table 1: Land Systems, Landforms and Soils Present in Project Area

Land System	% of Project Area	Dominant Landform	Major Soil Groups (WA Soil Group)
Uaroo (281Ua)	75.5	• Depositional surfaces; level sandy plains up to 10 km or more in extent with little organised through drainage. • Pebbly surfaced plains and plains with calcrete at shallow depth. • Broad, mostly unchanneled, tracts receiving more concentrated sheet flow.	• Red Deep Sandy Duplex (405) • Red Sandy Earth (463) • Calcareous Loamy Earth (542)
Mallina (281Ma)	13.6	• Depositional surfaces; level sandy surfaced plains on alluvium with occasional patches of small claypans, minor clay plains with Gilgai microrelief. • Minor stony plains and occasional isolated low hills.	• Red Loamy Earth (544) • Red Deep Loamy Duplex (506) • Red/Brown Non-Cracking Clay (622) • Hard Cracking Clay (601)

Land System	% of Project Area	Dominant Landform	Major Soil Groups (WA Soil Group)
Ruth (281Rt)	5.3	• Erosional surfaces; rounded hills and ridges with restricted lower slopes and stony interfluves, moderately to widely spaced drainage patterns. • Relief up to 90 m.	• Stony Soil (203) • Red Shallow Loam (522) • Red/Brown Non-Cracking Clay (622)
River (281Ri)	3.7	• Flood plains and river terraces subject to fairly regular overbank flooding from major channels and watercourses. • Sandy banks and poorly defined levees and cobble plains.	• Red Deep Sand (445) • Red Loamy Earth (544) • Red Sandy Earth (463)
Gregory (281Gr)	1.7	• Depositional surfaces; linear red sand dunes up to 12 m high with sandy swales and restricted sandplains	• Red Deep Sand (445) • Red Sandy Earth (463)
Robe (281Ro)	0.2	• Erosional surfaces: formed by partial dissection of old Tertiary surfaces, dissected plateaux and long lines of low mesas along present and past river valleys, indented near vertical breakaway faces and steep slopes.	• Stony Soils (203) • Red Loamy Earth (544) • Red Shallow Loamy Duplex (507)

3.8 FLORA AND FAUNA

3.8.1 Vegetative Communities

Major vegetation communities present within the greater project area (DPIRD, 2019) are detailed below in Table 2.

Table 2: Details on Vegetation Communities Present in the Project Area

Description	Vegetation Description	% Project area
Shrub-steppe	Hummock grassland with scattered shrubs or mallee *Triodia* spp., *Acacia* spp., *Grevillea* spp., *Eucalyptus* spp..	92.2
Grass-steppe	Hummock grasslands: *Triodia* spp..	3.5
Short bunch-grass savanna	Mosaic: Short bunch grassland: savanna / grass plain (Pilbara) / Hummock grasslands, grass steppe; soft spinifex.	1.8
Woodland/Riverine	Riverine: *E. camaldulensis.*	2.5

3.8.2 Flora and Fauna

3.8.2.1 Flora of Conservation Significance

Database studies identified that the following plant species of conservation significance have the potential to be present within the project area (DPIRD, 2019):

- *Abutilon* sp. *pritzelianum — Priority 1*.
- *Gymnanthera cunninghamii — Priority 3.*
- *Heliotropium muticum — Priority 3.*
- *Rothia indica* subsp. *Australis — Priority 3.*
- *Eragrostis crateriformis — Priority 3* (can occur in riverine environments).
- *Bulbostylis burbidgeae — Priority 4.*
- *Goodenia nuda — Priority 4.*

The following priority species were found in flora and vegetation assessments performed by Ecoscape Pty Ltd in March 2021 (Blueprint Environmental, 2021).

Numerous populations of *Abutilon* sp. *Pritzellianum* (P1) were recorded, typically from the edges of tracks. The species is a known disturbance opportunist, common on roadsides/tracks particularly following fire.

- A small population of *Eragrostis crateriformis* (P3) small population from a claypan within Mt Berghaus.
- *Euphorbia clementii* (P3) has been recorded within Winjina and another sample that may represent this species is awaiting verification.
- Abundant patches of *Triodia chichesterensis* (P3) found on the southern footslopes of the Winjina and Calvert areas (and nearby corridors).
- Quartzite ridges of Winjina contained widespread populations of *Bulbostylis burbidgeae* (P4). The species is also possibly found in other isolated quartzite outcrops (awaiting verification).
- One plant of *Goodenia nuda* (P4) was observed from Mt Berghaus and was also found in places on the corridors.
- Isolated plants of *Gymnanthera cunninghamii* (P4) were found within the Turner River section of Winjina.
- Various locations of *Heliotropium muticum* (P4) were recorded in Withnell and Hemi. The species is a known disturbance opportunist most abundant after fire.

3.8.2.2 Fauna of Conservation Significance

A search of the NatureMap database (DBCA, 2021) and EPBC Act Protected Matters Tool (DCCEEW, 2023) yielded 43 mammals, 102 reptiles, 168 birds 263 invertebrates and nine amphibians from the search area. Of these, several conservation significant species have been recorded or may occur within the general area as outlined in Table 3.

Table 3: Fauna of Conservation Significance within the Project Area

Species Name	Common Name	Category
Calidrus canutus	Red Knot	Bird
Calidris ferruginea	Curlew Sandpiper	
Falco hypoleucos	Grey Falcon	
Limosa lapponica menzbieri	Bar-tailed Godwit	
Numenius madagascariensis	Eastern Curlew	
Pezoporus occidentalis	Night Parrot	
Rostratula australis	Australian Painted Snipe	
Apus pacificus	Fork-tailed Swift	
Hirundo rustica	Barn Swallow	
Motacilla cinerea	Grey Wagtail	
Motacilla flava	Yellow Wagtail	
Actitus hypoleucos	Common Sandpiper	
Calidris acuminata	Sharp-tailed Sandpiper	
Calidris melanotos	Pectoral Sandpiper	
Charadrius veredus	Oriental Plover	
Glareola maldivarum	Oriental Pratincole	
Pandion haliaetus	Osprey	
Tringa nebularia	Common Greenshank	
Dasycercus blythi	Brush-tailed Mulgara	Mammal
Lagorchestes conspicillatus	Spectacled Hare-Wallaby	
Pseudomys chapmani	Pebble-Mound Mouse	
Tringa brevipes	Grey-tailed Tattler	
Dasyurus hallucatus	Northern Quoll	
Macroderma gigas	Ghost Bat	
Macrotis lagotis	Greater Bilby	
Rhinonicteris aurantia	Pilbara Leaf-nosed Bat	
Liasis Olivaceus	Olive Python	Reptile

3.8.2.3 Common Fauna Within Pilbara Inland Waters

A review of studies from the Pilbara region has identified a range of organisms (at the phylum and genus level) that are 'common' within inland waterways of the Pilbara region. These are summarised below in Tables 4 and 5.

Table 4: Common Invertebrate Fauna Present Within Pilbara Inland Waters and Riparian Zones

Phyla/Class/Order	Common Name	Common Species	Study
Cnidaria	Freshwater hydra	*Hydra* sp.	Biologic 2022, Masini 1983
Turbellaria	Flat worms	*Turbellaria* sp.	
Gastropoda	Freshwater snails	*Bullastra vinosa* *Gyraulus* sp.	
Oligochaeta/Polychatea	Aquatic segmented worms	*Chaetogaster* sp. *Dero nivea* *Naidinae* sp. *Pristina* sp. *Phreodrilidae* sp. *Aeolosomatidae* sp.	
Maxillopoda	Copepods	*Eudiaptomus lumholtzi* *Cyclopidae Eucyclops cf. australiensis* *Mesocyclops brooksi* *Mesocyclops notius* *Mesocyclops* sp. *Microcyclops varicans* *Thermocyclops* sp.	
Cladocera	Water fleas	*Cladocera* sp.	
Ostracoda	Seed shrimp	*Candonopsis* sp.	
Collembolla	Spring tails	*Entomobryoidea* sp.	
Coleoptera	Beetles	*Carabidae* sp. *Allodessus bistrigatus* *Bidessini* sp. *(L)* *Hydroglyphus* sp. *Georissus* sp. *Hydraena* sp. *Hydrochus* sp. *Chaetarthria* sp. *Coelostoma fabricii* *Helochares* sp. *Paracymus spenceri* *Limnichidae* sp. *Ptiliidae* sp. *Scirtidae* sp.	
Diptera	Two winged flies	*Ceratopogonidae* sp. *Dasyhelea* sp. *Chironominae* sp. *Dicrotendipes* sp. *Fittkauimyia disparipes* *Larsia albiceps* *Paratanytarsus* sp. *Polypedilum nubifer* *Procladius* sp.	

Phyla/Class/Order	Common Name	Common Species	Study
Trichoptera	Caddisflies	*Ecnomus pilbarensis* *Leptoceridae* sp. *Oecetis* sp.	
Ephemeroptera	Mayflies	*Baetidae* sp. *Caenidae* sp. *Tasmanocoenis* sp.	
Hemiptera	True bugs	*Corixoidea* sp.	
Lepidoptera	Moth larvae	*Parapoynx* sp.	
Odonata	Dragonflies and damselflies	*Anisoptera* sp. *Hemicordulia koomina* *Hemicordulia* sp. *Hemicordulia tau* *Austrogomphus gordoni* *Diplacodes haematodes* *Macrodiplax cora* *Orthetrum caledonicum* *Tramea* sp. *Ictinogomphus dobsoni*	

Table 5: Common Vertebrate Fauna Present Within Pilbara Inland Waters and Riparian Zones

Type	Common Name	Species Name	Study
Eel	Indian Short-Finned Eel	Anguilla bicolor	Morgan and Gill, 2004
Fish	Herring — Bony bream	Nematalosa erebi	
	Eel-tailed catfish	*Neosilurus hyrtlii*	
	Western Rainbowfish	*Melanotaenia australis*	
	Barred Grunter	*Amniataba percoides*	Masini 1983
	Empire Gudegeon	*Hypseleotris compressus*	
	Pilbara Tandan	*Neosilurus* sp.	
	Spangled Perch	*Leiopotherapon unicolor*	
	Pilbara Bony Bream	*Nematalosa* sp.	
	Murchison River Hardyhead	*Craterocephalus cuneiceps*	
Turtle	Flat-shelled Turtles	*Chelodina steindachneri*	Biologic 2022
Frogs	Pilbara Toadlet	*Uperoleia saxatilis*	
	Main's Frog	*Cyclorana mainii*	
Snake	Pilbara Olive Python	*Liasis olivaceus barroni*	
Birds	Tern	*Chlidonia* sp.	Masini 1983
	Australian Pelican	*Pelecanus consptcullatus*	
	Cormorant	*Phalocrocorax* sp.	
	Black Bittern	*Dupetor flautcollis*	
	Australian Bustard	*Eupodotis australis*	
	Emu	*Dromaius novaehollandiae*	
	Jabiru	*Xenorhynchus asiattcus*	
	Spoonbill	*Platalea jlautpes*	
	White-Faced Heron	*Ardea nouaehollandiae*	
	White-Necked Heron	*Ardea pacifica*	
	White Egret	*Egretta alba*	
	Black-Fronted Dotterel	*Charadrius melanops*	
	Terek Sandpiper	*Xenus cinereus*	
	Black-Winged Stilt	*Himantopus himantopus*	
	Snipe	*Gallinago* sp.	
	Black Duck	*Anas superclliosa*	
	Pink-Eared Duck	*Malacorhynchus membranaceus*	
	Coot	*Fultca atra*	

Type	Common Name	Species Name	Study
	Australian Little Grebe	*Podiceps novaehollandiae*	
	Blue-Winged Kookaburra	*Dacelo leachit*	
	Sacred Kingfisher	*Halcyon sancta*	
	Cuckoo	*Chrysococcyx* sp.	
	Welcome Swallow	*Hirundo neoxena*	
	Galah	*Eolopus roseicaptllus*	
	Little Corella	*Cacatua sanguinea*	
	Port Lincoln Parrot	*Bamardius zonarius*	
	Willie Wagtail	*Rhipidura leucophrys*	
	Crow	*Corous* sp.	
	Magpie Lark	*Grallina cyanoleuca*	
	Painted Finch	*Emblema ptcta*	
	Red-Plumed Pigeon	*Lophophaps plumifera ferruginea*	

3.9 RESERVES AND PROTECTED AREAS

There is one water reserve within the Project area, the Yule River Water Reserve, intersecting Hemi Project exploration tenement E47/3554-I located approximately 45 km west of Port Hedland (Figure 1). The Reserve is a Priority 1 Public Drinking Water Source Area (PDWSA) supplying water to the Port Hedland regional water supply scheme which supplies the communities of Port Hedland, South Hedland, Wedgefield, Finucane Island and Nelson Point. The water is abstracted from a shallow alluvial aquifer beneath the Yule River. The aquifer is vulnerable to contamination from surface-based land uses due to it being a semi-confined system (DWER 2019).

Table 6: Reserves and Protected Areas Within the Project Footprint

Area Name	Vesting Authority	Purpose	Distance from project
Yule River Water Reserve (P1 PDWSA)	DWER	Water Reserve	Within E47/3554-I
Upper Yule River (Downgraded Wild River)	DWER	Multiple uses	15 km S (upstream) of Hemi
Reserve 12803	Water Corporation	Watering hole for travellers	7 km S (upstream) of Hemi
Reserve 31427	DPLH	Aboriginal Heritage	Within E47/891-I
Reserve 371	DPLH	Aboriginal Heritage	Within E47/891-I
Reserve 42028	Main Roads WA	Gravel	6 km S/SE of Hemi
Reserve 42369	DPLH	Communications – Repeater Station Site	10 km NW of Hemi

3.10 CULTURAL HERITAGE AND SOCIAL SETTING

3.10.1 Aboriginal Heritage

Various aboriginal heritage sites as outlined below in Table 7 were identified within the project area from the Department of Planning, Lands and Heritage mapping tool (DPLH, 2021).

Table 7: Cultural Heritage Sites Within the Project Area

ID	Name	Description
21801	WP02	Artefacts / Scatter: No gender restrictions
8441-2	Port Headland White Springs 03	Artefacts / Scatter: No gender restrictions
11385	Wamerina Ridge	Engraving: No gender restrictions
11585	Mt Dove, Portree	Engraving: No gender restrictions
11638	Mt Dove, Upper Yule	Artefacts/Scatter, Ceremonial, Engraving, Man-made Structure: No gender restrictions
6653	Turner River (Tjirrlil)	Named Place: No gender restrictions
6655	Yule River (kakura)	Named Place: No gender restrictions
6923	Mardagubbidina Pool	Water Source: No gender restrictions
6924	Papawilyuwihi Pool	Water Source: No gender restrictions

The Hemi and Withnell Projects are within the Kariyarra Native Title area, determined on 13 December 2018 and registered under the Kariyarra Aboriginal Corporation (KAP). An Indigenous Land Use Agreement (ILUA) with the Kariyarra is currently being negotiated. Other Traditional Owner stakeholders in the broader MGP include the Ngarluma and the Njamal.

3.10.2 European Heritage

The Heritage Council of Western Australia maintains a State Register of Heritage Places under the *Heritage Act 2018.* No Heritage Places are listed within the Withnell and Hemi Project sites, with two sites located within 12 km of the MGP. Place 18421 (Indee Station; site of a plane crash), is 1.5 km east of the Hemi Project and Place 4029 (Mallina Station) is located 12 km west of Withnell Project (Blueprint, 2021).

3.10.3 Social Use of Project Area

Recreation activities including picnicking, fishing, and camping are common on the Yule River Water Reserve (Section 3.9). The Yule River flows through semi-permanent water pools which are popular for swimming, while camping on the riverbed is common during the dry season (DWER, 2019). The Project is located across three pastoral leases, Mundabullangana Station, Mallina Station, and Indee Station. The Kangan Homestead is 11.3 km south of the Hemi Project.

4. DEFAULT ENVIRONMENTAL GUIDELINES

In order to assess any risks associated with the release of surplus water generated from dewatering, a thorough assessment of the composition of discharge water plus a quantification of the background composition of surface waters was required (in conjunction with site and other consultants) to develop site specific triggers. This information and existing sediment quality in potential discharge areas was required to conduct a Tier 2 (site specific) ERA. Default environmental guidelines relevant for the assessment and detailed assessments of groundwater, surface water and sediment quality are presented in the following sections as are details of the anticipated discharge volumes over time.

In order to determine the environmental risks related to the potential release of groundwater (from dewatering) into the environment, the following Tier 1 default (screening) environmental criteria as outlined in Table 8 for water and Table 9 for sediments were utilised. Note that ANZG 2018 95% criteria assumes a slightly to moderately disturbed ecosystem. Lower species protection levels (90% for example) with higher default criteria would apply if the ecosystem is deemed to be moderately disturbed.

Table 8: Default Water Quality Guidelines Relevant to This Assessment

Analyte	Units	ANZECC (2000) Livestock (Cattle) Drinking Water [2]	DOH (2014) Non-Potable Water Use	ANZG (2018) 95% Freshwater Species Protection
Metals and Metalloids				
Ag	µg/L	N/G	1000	0.5
Al	mg/L	5	0.2	0.055
As	µg/L	25	100	13
B	µg/L	5,000	40,000	370
Ba	µg/L	N/G	20,000	N/G
Cd	µg/L	10	20	0.2
Co	µg/L	1,000	N/G	1.4
Cr	µg/L	500	500	3.3
Cu	µg/L	1,000	20,000	1.4
Fe	mg/L	N/G	0.3	N/G
Mn	mg/L	10	5	1.9
Mo	µg/L	10	500	34
Ni	µg/L	1,000	200	11
Pb	µg/L	10	10	3.4
Sb	µg/L	N/G	30	9
Se	µg/L	20	100	11
U	µg/L	100	170	0.5[1]
V	µg/L	N/G	N/G	6[1]
Zn	µg/L	20,000	3,000	8
Major Ions				
Ca	mg/L	1,000	N/G	N/G
Cl	mg/L	N/G	250	N/G
F	mg/L	2	15	N/G

Analyte	Units	ANZECC (2000) Livestock (Cattle) Drinking Water [2]	DOH (2014) Non-Potable Water Use	ANZG (2018) 95% Freshwater Species Protection
SO_4	mg/L	500	1,000	N/G
General Parameters				
pH	pH Units	6.5 – 8.5	N/G	6.5 – 8.5
TDS	mg/L	4,000	N/G	N/G
Radiological				
U	Bq/L	2.5	N/G	N/G
Gross Alpha	Bq/L	1	5	N/G
Gross Beta	Bq/L	5	5	N/G
Radium 226	Bq/L	5	N/G	N/G
Radium 228	Bq/L	2	N/G	N/G

1 Guideline is a low reliability guideline based on toxicity data which is considered incomplete by ANZECC/ANZG.
2 As updated 2023

Table 9: Sediment Quality Guidelines Relevant to Assessment

Analyte	ANZG 2018 Sediment Default Guideline Value (mg/kg)	ANZG (2018) Sediment Trigger Value (mg/kg)
Ag	1	4
As	20	70
Cd	1.5	10
Cr	80	370
Cu	65	270
Mn	N/G	N/G
Ni	21	52
Pb	50	220
Sb	2.0	25
Zn	200	410

5. DEWATERING SCHEDULE, GROUNDWATER, SURFACE WATER AND SEDIMENT MONITORING LOCATIONS

5.1 DEWATERING SCHEDULE

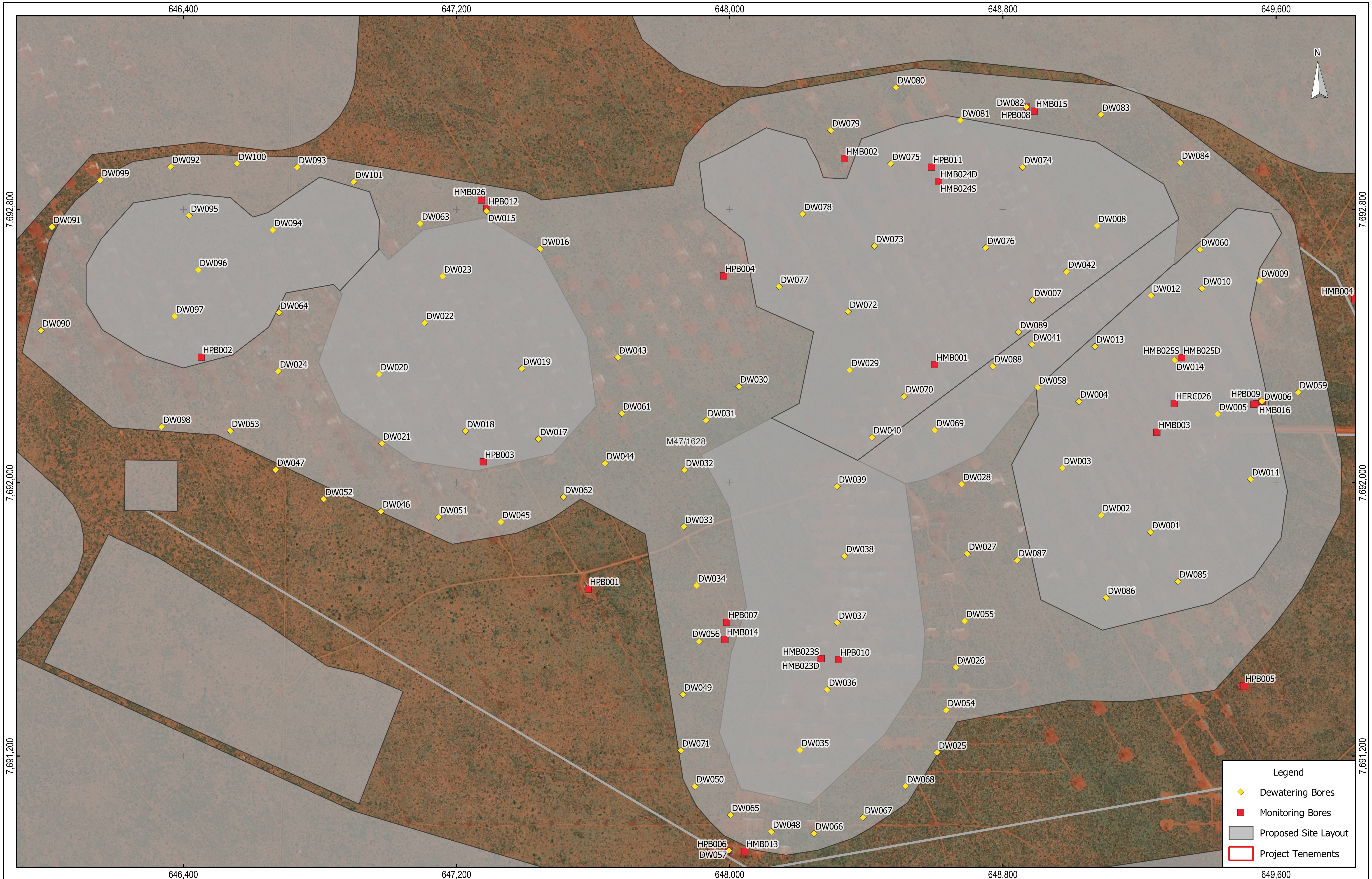
During the excavation of the six (6) proposed pits (Eagle, Crow, Aquila, Brolga, Diucon and Falcon), an excess of approximately 30 GL of water (primarily from the shallow aquifer) has been identified that is currently surplus to requirements within the first three years of operations. This water is proposed to be discharged to the Turner River at a rate of 27.4 ML/day which equates to approximately 0.83 GL per month and 10 GL per annum.

5.2 GROUNDWATER

Groundwater monitoring has been conducted at the Hemi site since December 2020 to the time of writing, with samples typically taken at six-month intervals for water level and external analysis. Monitoring was conducted on 43 monitoring bores (Figure 3) which were classified as either:

- Outside the dewatering area.
- Within the shallow alluvial aquifer.
- Within the saprolite/saprock aquifer.
- Within the fractured bedrock aquifer.

Based on the proposed pit shell outline (Figure 2), a total of 101 dewatering bores have been proposed across the six planned pits as outlined below in Figure 3. In order to estimate the raw (as abstracted) chemical composition of groundwater to be discharged into the Turner River during the discharge period, each dewatering bore was allocated a chemical composition based on the closest monitoring bore representing the same aquifer type as outlined below in Figure 3 and Table 10.



Scale: 1: 10,000
Original Size: A3

Grid: GDA94 / MGA zone 50 (EPSG:28350)

0 250 500 m

De Grey Mining Pty Ltd
Hemi Gold Project

Figure 3

Location of Monitoring and Dewatering Bores at the Hemi Site

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\\mbssvr\working\De Grey Mining (DGM)\Tier 2 ERA\GIS\De Grey Mining_Tier 2 ERA_Jun23.qgz 23/06/2023 F3 Location of Monitoring and Dewatering Bores

Table 10: Allocation of Dewatering Bores to Nearest Monitoring Bore for Chemical Classification

Monitoring Bore	Dewatering Bores
HERC026	DW005, 008, 083
HMB001	DW007, 028, 029, 030, 039, 040, 041, 058, 069, 070, 072, 073, 074, 076, 081, 082, 088, 089, Brolga Sump
HMB003	DW001, 002, 003, 004, 085, 086, 087
HMB004	DW009, 060, 084
HMB012	DW011
HMB016	DW006
HMB025	DW010, 012, 013, 014, 042
HPB002	DW020, 024, 047, 053 064, 096, 098
HPB003	DW017, 018, 019, 021, 044, 045, 046, 051, 052, 061, 062, Diucon Sump
HPB004	DW043, 075, 077, 078, 079, 080
HPB009	DW059
HPB010	DW027, 038
HPB012	DW015, 016, 022, 023, 063, 101

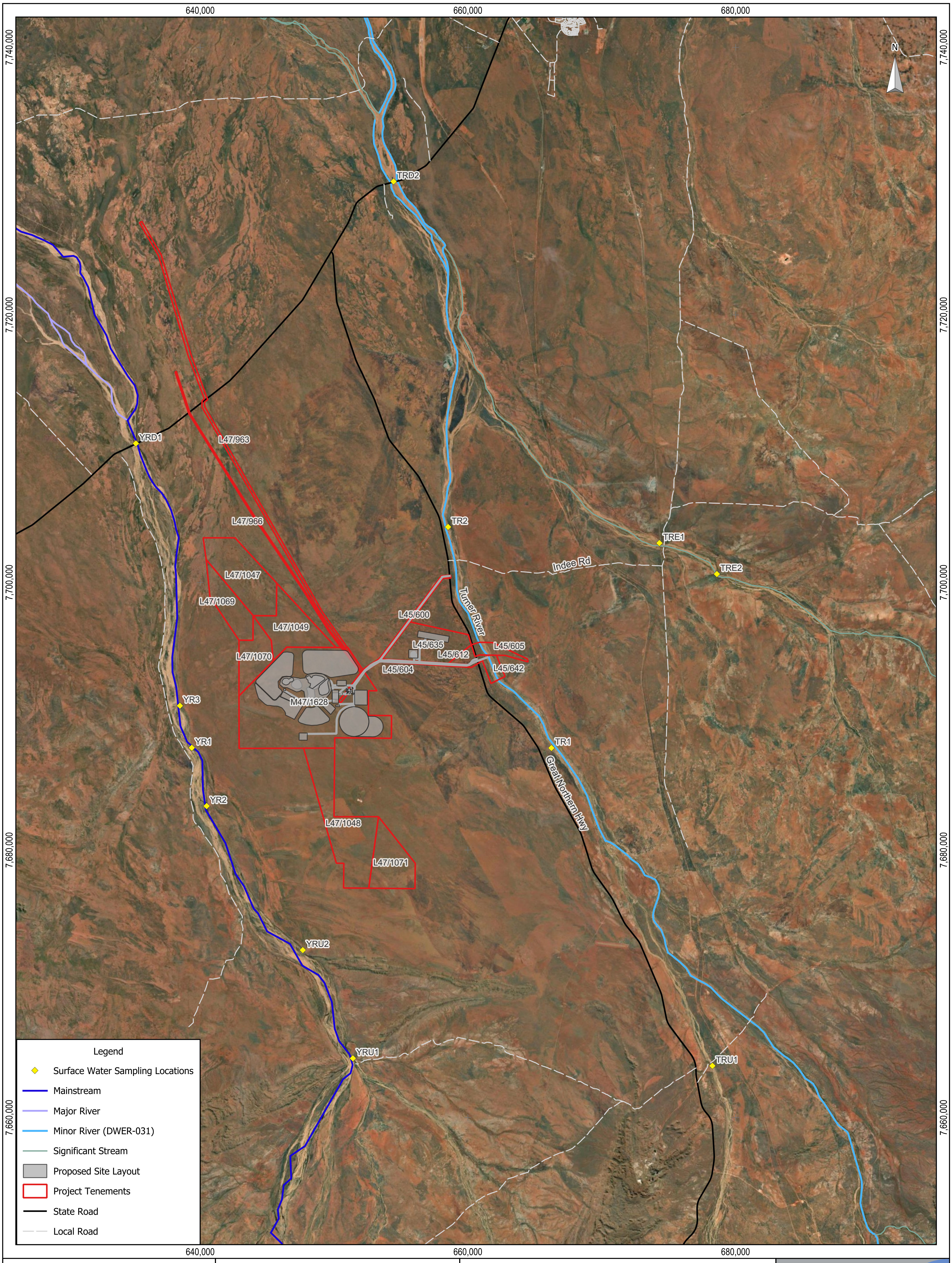
Based on the pumping schedule for each dewatering bore (Appendix 1), a discharge budget was generated for each of the monitoring bores which was used in calculating raw water discharge concentrations by proportional mixing and which is discussed in later sections of this report. The abstraction/intended discharge breakdown by monitoring bore is presented in Table 11.

5.3 SURFACE WATER AND SEDIMENT

Within the Turner River, a total of six surface water sampling locations, which are both up and down stream of the proposed discharge point have been monitored since December 2020. This monitoring was conducted in order to determine the composition of Turner River surface water and generate site-specific water quality triggers for analytes of interest. In addition, a further six surface water sampling locations have been routinely sampled on the Yule River again since December 2020. Surface water samples have typically been collected quarterly assuming there was surface water available to sample (Figure 4). River sediment samples were also taken from all of the above sampling locations within the Turner and Yule Rivers, with samples being taken in November 2021 and May 2022 (Figure 4) and analysed for a range of metals and metalloids.

Table 11: Discharge Schedule and Volumes

Month Interval	HERC026	HMB001	HMB003	HMB004	HMB012	HMB016	HPB001	HPB002	HPB003	HPB004	HPB009	HPB010	HPB012	Total Discharge Volume	Cumulative Discharge Volume
	% of Total Volume													GL	
0–3	5	8	8	3	1	3	8	16	26	3	0	0	18	2.5	2.5
3–6	5	8	7	3	1	4	8	16	26	4	0	0	18	2.5	5.0
6–9	5	8	7	3	1	4	8	16	26	4	0	0	18	2.5	7.5
9–12	4	7	9	2	1	3	6	17	29	3	0	0	16	2.5	10.0
12–15	1	18	7	2	1	0	1	17	28	3	3	2	16	2.5	12.5
15–18	1	17	7	2	1	0	1	17	29	3	3	2	16	2.5	15.0
18–21	2	28	8	3	1	0	1	10	19	7	3	4	15	2.5	17.5
21–24	2	30	8	3	1	0	1	7	22	8	3	4	10	2.5	20.0
24–27	2	32	9	3	1	0	1	5	23	7	3	4	10	2.5	22.5
27–30	2	30	8	2	1	0	1	4	31	6	3	4	9	2.5	25.0
30-33	1	28	9	3	1	0	0	3	34	6	3	4	8	2.5	27.5
33-36	1	29	9	3	1	0	0	3	34	5	3	5	7	2.5	30.0



Scale: 1: 250,000
Original Size: A3

Grid: GDA94 / MGA zone 50 (EPSG:28350)

0 5 10 km

De Grey Mining Pty Ltd
Hemi Gold Project

Figure 4

Location of Surface Water and Sediment Monitoring Locations

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6. GROUNDWATER, SURFACE WATER AND SEDIMENT MONITORING DATA

6.1 GROUNDWATER

Key characteristics of the twelve (12) monitoring bores that are considered reflective of the proposed dewatering area are summarised in Table 12. Full data is provided in Appendix 2. The main characteristics of note which then required further assessment included:

- Arsenic, copper, uranium, vanadium and zinc were identified as key potential contaminants of interest within the site raw groundwater when compared to default Tier 1 screening environmental guidelines. Higher concentrations of arsenic and copper were associated with proximity to the deposit whereas uranium and vanadium, in particular, were more widely spread in the aquifer.
- Arsenic concentrations ranged from 6 to 36 µg/L. Concentrations in bores HERC026 and HPB010 exceeded the updated (2023) ANZECC livestock (cattle) drinking water quality value of 25 µg/L. Concentrations in bores HMB003 and HPB004 contained arsenic concentrations that exceeded the ANZG (2018) 95% freshwater species protection guideline value of 13 µg/L.
- Copper concentrations ranged from <0.1 to 3.6 µg/L, with the following bores: HMB016, HPB002, HPB003, HPB004, HPB010 and HPB012 all exceeding the default ANZG (2018) 95% freshwater species protection guideline value for copper of 1.4 µg/L. However, when corrected for hardness (273 mg/L as $CaCO_3$) the ANZG (2018) 95% freshwater species protection guideline value for copper rises to 9.1 µg/L which is higher than observed concentrations in all monitoring bores (i.e. no exceedances to adjusted default criteria).
- Uranium concentrations ranged from 19 to 45 µg/L across the relevant monitoring bores for abstraction. All bores contained uranium concentrations that exceeded the ANZG (2018) low-reliability (limited toxicity data) freshwater species protection guideline value for uranium of 0.5 µg/L.
- Given the relatively high uranium concentrations, gross alpha and gross beta and radionuclides Ra-226 and Ra-228 were also analysed in water samples from selected bores. All bores tested contained gross beta values below the 5-Bq/L screening guideline value. Gross alpha values, however, in two bores (HMB025 & 035) exceeded the 1-Bq/L livestock drinking water quality guideline screening value (1.7 to 3.2 Bq/L) (Table 13). Calculated total activity of U-238, Th-232, Ra-226 and Ra-228 was below the ANZECC livestock drinking water guideline of 2.5 Bq/L in these bores.
- Vanadium concentrations in monitoring bores ranged from 21 to 37 µg/L. These concentrations exceeded the ANZG (2018) low reliability freshwater species protection guideline value of 6 µg/L.
- Zinc concentrations in monitoring bores ranged from 14 to 25 µg/L. Concentrations in all bores exceeded the default ANZG (2018) 95% freshwater species protection guideline value for zinc, which is 8 µg/L. However, when also corrected for hardness (as for copper), the ANZG (2018) 95% freshwater species protection guideline value for zinc increased to 52 µg/L, resulting in no exceedances of criteria in any monitoring bores.

Table 12: Groundwater Quality from Relevant Monitoring Bores for Selected Chemical Parameters

Bore ID	# of Samples	pH	TDS	Total Alkalinity	Ca	Cl	K	Mg	Na	SO_4	As	Cu	U	V	Zn
		SU	mg/L	mg/L $CaCO_3$	mg/L						µg/L				
HERC026	2	8.31	873	385	28	249	12	52	184	63	36	1.1	42	33	25
HMB001	5	8.13	788	370	24	202	12	43	180	48	11	1.3	32	33	14
HMB003	6	8.17	880	390	26	244	12	50	193	55	15	1.0	40	35	14
HMB004	6	8.11	916	397	31	251	13	55	198	62	11	0.9	45	33	14
HMB012	6	8.05	857	394	26	248	12	52	192	54	11	0.7	38	32	13
HMB016	4	8.13	913	414	27	271	15	55	202	55	10	1.2	39	35	13
HPB002	1	8.22	773	342	33	186	12	42	153	45	7	<0.1	27	28	16
HPB003	1	8.24	673	315	40	169	10	41	135	32	6	2.0	19	23	17
HPB004	1	8.23	727	337	35	184	11	43	144	37	8	3.6	24	26	18
HPB009	1	8.30	856	381	30	228	11	51	179	60	17	2.4	41	31	17
HPB010	1	8.27	886	395	23	250	14	52	198	67	13	0.7	44	37	15
HPB012	2	8.31	749	338	32	226	12	47	176	60	27	2.2	32	21	15
ANZECC (2000) Livestock Drinking Water		6.5–8.5	4,000	N/G	1,000	N/G	N/G	500	N/G	500	25	1,000	200	N/G	20,000
DOH (2014) Non-Potable Use		6.5–8.5	N/G	N/G	N/G	250	N/G	N/G	N/G	5,000	100	20,000	170	N/G	30,000
ANZG (2018) Freshwater Species Protection (95% or low reliability)		6.5–8.5	N/G	N/G	N/G	N/G	N/G	N/G	N/G	N/G	13*	9.1***	0.5**	6**	52***

** Assumes arsenic is present as the more toxic arsenic (V) form rather than arsenic (III) (guideline 24 µg/L) **Low reliability ANZG value* ***Hardness Modified Value using average hardness of 273 mg/L (as $CaCO_3$).

Table 13: Radiological Activity of Selected Groundwater Samples

Bore ID	U	Th	U-238	Th-232	Total Activity	Gross Alpha	Gross Beta	Ra 226	Ra 228
	µg/L	µg/L	Bq/L	Bq/L	Bq/L	Bq/L	Bq/L	Bq/L	Bq/L
HMB023D	17.1	0.01	0.21	0.00004	0.21	0.84	0.29	<0.01	<0.08
HMB025D	43.3	0.19	0.53	0.001	0.59	1.72	0.45	0.05	<0.08
HMB035	53.3	0.01	0.66	0.00004	0.68	3.21	0.38	0.02	<0.08
HPB011	8.93	0.01	0.11	0.00004	0.11	0.43	0.30	<0.01	<0.08
Indee Homestead	84.1	<0.01	1.05	<0.0001	1.14	3.34	0.87	0.097	<0.08
ANZECC (2000) Livestock Drinking Water	200	N/G	2.5	10	2.5	1	5	5	5

6.2 SURFACE WATER

Surface waters from the Turner and Yule River systems were assessed for their chemical composition to quantify the characteristics of the receiving environment prior to any possible discharge and also to calculate site-specific and regional-specific trigger values for ongoing monitoring during and post-discharge (return to equilibrium). Full data is provided in Appendix 2. Major findings from the assessment of surface water chemical characteristics (Table 14: exceedances are highlighted) include:

- Uranium (mean: 3.9–8.7 µg/L) and to a lesser extent copper (max: 13.0 µg/L), vanadium (max: 30 µg/L) and zinc (max: 45 µg/L) were elevated (with respect to the default ANZG (2018) 95% or low-reliability freshwater species protection value) in a number of sampling intervals across both the Turner and Yule Rivers.
- Arsenic (mean: 2.8–3.5 µg/L) was not elevated in any surface water sample with respect to the ANZG (2018) 95% freshwater species protection value of 13 µg/L.

6.3 SEDIMENT

The composition of sediments from the Turner and Yule Rivers was also assessed prior to the proposed discharge to establish the baseline level of sediment quality and metals/metalloids. Full data is provided in Appendix 2.

Major findings of the sediment analysis (Table 15) included:

- Most sediments were of slightly alkaline pH and low to moderate salinity.
- Nickel in sediments of the Yule River (but not Turner) was the only species observed in exceedance (highlighted) of the ANZG (2018) sediment default guideline value (ISQG-low, 21 mg/kg). There were no exceedances of the ANZG (2018) sediment trigger value for any element. The presence of nickel at concentrations above the ISQG-low in soils and sediments is typical for those derived from mafic/ultramafic rocks.

Table 14: Summarised Surface Water Chemical Data from the Turner and Yule River System

Analytes		Turner River	Yule River	Livestock Drinking Water (ANZECC 2000)	Non-Potable Use (DoH 2014)	95% Freshwater Species Protection (ANZG 2018) (* = hardness corrected, ** = low reliability i.e. limited toxicity data)
Number of Samples		15	20	N/A	N/A	N/A
Number of Sample Locations		7	7			
pH	Min	7.74	7.59	6.5–8.5	6.5–8.5	6.5–8.5
	Max	9.41	9.00			
	Mean	8.50	8.42			
TDS (mg/L)	Min	143	136	4,000	N/G	N/G
	Max	2,490	5,500			
	Mean	763	959			
As (µg/L)	Min	0.6	0.4	25	100	13
	Max	9.8	8.0			
	Mean	3.5	2.8			
Cu (µg/L)	Min	0.7	<0.5	1,000	20,000	6.3*
	Max	13	11.0			
	Mean	2.3	2.0			
U (µg/L)	Min	0.5	0.5	200	170	0.5**
	Max	16	58.0			
	Mean	3.9	8.7			
V (µg/L)	Min	1.9	0.3	100	N/G	6**
	Max	11.2	30.0			
	Mean	5.0	6.3			
Zn (µg/L)	Min	4.0	1.0	20,000	30,000	36*
	Max	45.0	26.0			
	Mean	15.5	10.7			

Table 15: Selected Sediment Quality Data from the Turner and Yule River Systems

Analytes		Turner River	Yule River	Default Guideline Value Low (ANZG 2018)	High Guideline Value (ANZG 2018)
Number of Samples		4	6	N/A	N/A
Number of Sample Locations		4	6		
pH	Min	8.1	7.5	N/G	N/G
	Max	9.3	8.9		
	Mean	8.8	8.3		
As	Min	<5	<5	20	70
	Max	<5	<5		
	Mean	<5	<5		
Cr	Min	4.5	12.0	80	370
	Max	32.0	65.0		
	Mean	14.6	36.7		
Cu	Min	2.5	2.5	65	270
	Max	7.0	20.5		
	Mean	3.6	13.8		
Pb	Min	<5	<5	50	220
	Max	<5	10.0		
	Mean	<5	4.8		
Ni	Min	1.0	7.5	21	52
	Max	9.5	35.5		
	Mean	4.8	22.1		
U	Min	0.4	0.4	N/G	N/G
	Max	0.6	4.2		
	Mean	0.5	2.1		
V	Min	2.5	11.0	N/G	N/G

Analytes		Turner River	Yule River	Default Guideline Value Low (ANZG 2018)	High Guideline Value (ANZG 2018)
	Max	13.5	39.0		
	Mean	6.3	25.4		
Zn	Min	<5	6.5	200	410
	Max	8.0	29.0		
	Mean	3.9	18.3		

7. REGIONAL AND SITE-SPECIFIC GUIDELINE VALUES

As outlined in Table 14, baseline concentrations of uranium were typically higher than the low reliability ANZECC/ANZG trigger values (Table 8). As a result, local guideline values were calculated on baseline surface water monitoring data collected across both the Turner and Yule River systems since 2021. Arsenic and vanadium, although exceeding ANZECC/ANZG guidelines at times (as maximums), were also calculated given elevated concentrations in the raw groundwater.

Local guideline values were calculated at two geographic scales which included 'site-specific' values calculated from data from sites along the Turner River (Figure 4, proposed discharge point) whilst a Hemi 'regional' value was calculated from data collected from the Turner and Yule Rivers combined which run either side of the Hemi project.

Guideline values (for screening/further investigation) were calculated using the 80th percentile of all collated data. These act as a 'trigger' or early-warning value — i.e. additional sampling and investigation/analysis if exceeded. An 'action' value — 95th percentile of all collated data was calculated as the point where direct action i.e. alternate discharge options; increased water treatment are required to avoid ecological/environmental harm. At the time of writing, the site-specific (i.e. Turner River) values are 'interim' given that the dataset contains 15 datapoints which does not meet the 24 minimum points over a two-year period as per the ANZG guidelines (2018) to be considered 'final'. The regional trigger values, however, were generated from a total of 35 datapoints and thus can be used as an ongoing monitoring guideline value. It should be noted that as more data becomes available from surface water monitoring, both the trigger (80th percentile) and action (95th percentile) values can shift over time.

Site and regional specific guidelines were implemented for analytes such as uranium and vanadium for which the default environmental criteria are of low quality and are significantly lower than the natural baseline concentrations across both river systems. This was, however, not the case for arsenic for which baseline concentrations are similar to default criteria, which is also generated from a higher reliability dataset than that of U or V.

The calculated guidelines are presented below in Table 16 for surface water and Table 17 for sediments.

Table 16: Calculated Regional and Site-Specific Guideline Values to be used in Project — Surface Water

Analyte (µg/L)	Site Specific (15 Samples)		Regional (35 Samples)	
	Trigger (80th percentile)	Action (95th percentile)	Trigger (80th percentile)	Action (95th percentile)
As	7.7	8.9	5.7	8.0
U	5.7	12.2	12.1	19.1
V	8.6	10.5	9.6	11.0

Table 17: Calculated Regional and Site-Specific Guideline Values to be used in Project - Sediment

Analyte (mg/kg)	Site Specific (4 Samples)		Regional (10 Samples)	
	Trigger (80th percentile)	Action (95th percentile)	Trigger (80th percentile)	Action (95th percentile)
U	0.5	0.6	2.8	3.8
V	9.3	12.5	29.3	37.0

* Site-specific/regional sediment trigger/action values for arsenic could not be calculated as all samples contained arsenic concentrations of <5 mg/kg, i.e. below the analytical limit of reporting (LOR).

8. PREDICTED EFFECTS OF DISCHARGE ON TURNER RIVER HYDROLOGY

8.1 TURNER RIVER DISCHARGE DATA 1985–2024

Flow data for the Turner River has been measured since 1985 at the Pincunah site (709010) which is located upstream (to the south) of the proposed discharge point. This data was accessed using the DWER River Level Monitoring database (DWER, 2024) and is summarised below in Chart 1.

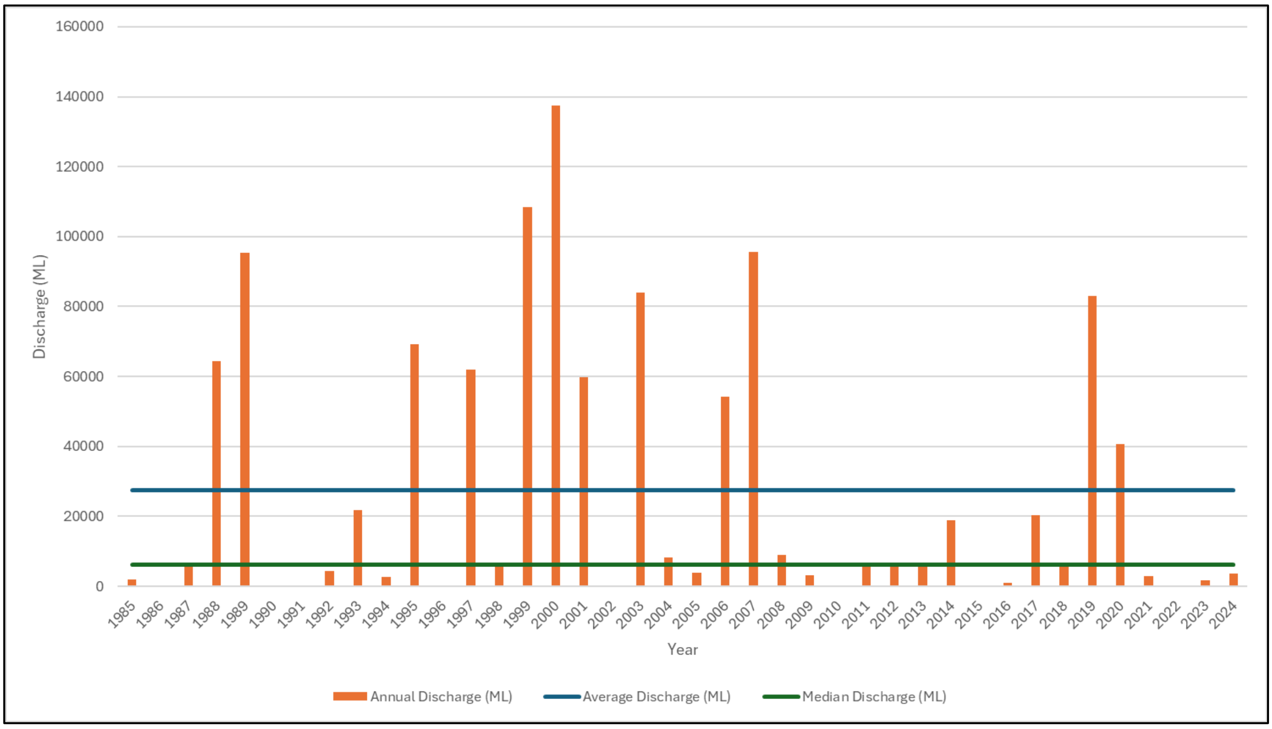


Chart 1: Summarised Turner River Flow Volumes at Pincunah Station (1985–2024)

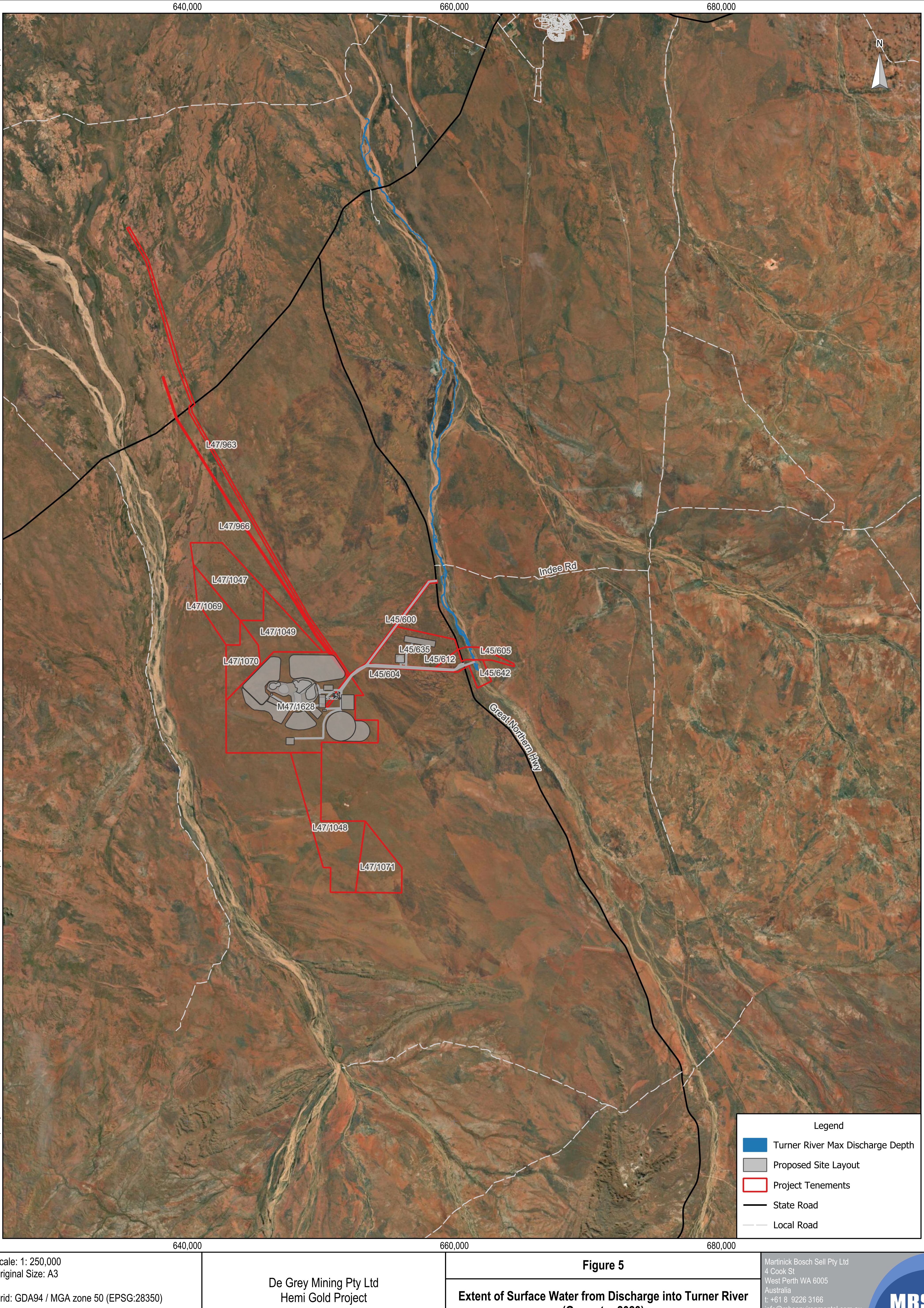
Major findings include:

- Annual volumes ranged from 0 (no flow) to 137 GL/year since monitoring commenced in 1985.
- The median annual discharge volume was 6.15 GL/year, whilst the mean discharge was 27.4 GL/year.
- Twelve (12) years contained annual discharges above the calculated average, whilst in four (4) years (1990, 1991, 2002 and 2010) there was no recorded flow.
- When compared with median, mean and maximum recorded volumes in the Turner River, the planned discharge of 10 GL/year (on an annual basis) will essentially:
  - Be 2.6 times the flow volume present in a median year.
  - Add 27% to the flow volume present in a mean/average year.
  - Add 7% to the volume present in a year that is equivalent to the maximum recorded (137.4 GL/year).

8.2 SPATIAL EXTENT OF PLANNED DISCHARGE ON TURNER RIVER HYDROLOGY

Spatial modelling of the planned discharge was conducted by Geowater consulting as a part of their groundwater and surface water assessment (Geowater 2023). Spatial modelling was conducted in the absence of additional flow within the catchment (i.e. a no-rainfall situation). The inundation area was predicted to travel downstream a distance of approximately 50 km as outlined in Figure 5. Based on this modelling, a number of key findings were noted in the Geowater report (2023) which included:

- Under the conditions of the model (i.e. no rainfall), water was largely retained within the existing channels with channel widths being generally between 50 and 90 m.
- As a consequence of the narrow channel widths, losses to evaporation are likely to be minimal.
- In addition, losses to the subsurface and underlying water table aquifer are relatively low which is a function of both the limited permeability of the underlying bedrock aquifer and the relatively high-water table in the region.
- Calculated seepage rates (from various locations across the channel) were between 0.08 and 0.24 ML/day/km, whilst potential storage volumes (above the water table) were between 110 and150 ML/km.



Scale: 1: 250,000
Original Size: A3

Grid: GDA94 / MGA zone 50 (EPSG:28350)

0 5 10 km

De Grey Mining Pty Ltd
Hemi Gold Project

Figure 5

Extent of Surface Water from Discharge into Turner River (Geowater 2023)

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\\mbssvr\working\De Grey Mining (DGM)\Tier 2 ERA\GIS\De Grey Mining_Tier 2 ERA_Jun23.qgz 17/08/2023 F5 Extent of Surface Water from Discharge into Turner River

9. CALCULATED DISCHARGE WATER, SURFACE WATER AND SEDIMENT COMPOSITION — POST DISCHARGE

In order to conduct a Tier 2 ERA the composition of discharge water, the predicted contaminant loading in surface water of the Turner River and the composition of sediments post discharge were all calculated as detailed in the sections below. Full data for all calculations is provided in Appendix 3.

9.1 RAW GROUNDWATER DISCHARGE COMPOSITION

An estimate of the composition of raw (as abstracted) discharged groundwater over the 3 years of dewatering was performed using the following approach:

- The proportion of the dewatering attributed to each dewatering bore and the total discharge volume (per day) was provided by De Grey as outlined in section (5.1).
- Dewatering bores were allocated a monitoring/processing bore based on their location Table 10 which allowed for chemical data to be attributed to each of the discharge bores.
- Average chemical composition data from the entire monitoring period (approx. 3 years) was used as the 'representative' composition of the discharge water from each bore and then proportionally mixed by dewatering/abstraction rates.
- The results of these calculations were then compared against relevant environmental criteria and site-specific guideline values described previously. These included the ANZECC (2000, updated 2023) livestock drinking water guidelines (cattle), the DoH non-potable use guidelines, the ANZG (2018) 95% (or low reliability for U and V) freshwater species protection guidelines and the calculated interim (15 samples) Turner River site specific guidelines and Hemi regional specific guidelines (Data from Turner and Yule River systems, 35 samples) as detailed in Table 16.

Major findings from these calculations are summarised in Table 18 and include:

- Arsenic concentrations in the raw discharge water were predicted to be equal to or slightly lower than the ANZG (2018) 95% freshwater species protection guideline value of 13 µg/L.
- Previously identified elements of potential significance such as uranium and vanadium are predicted to be present in discharge water at concentrations likely to exceed the respective ANZG (2018) low-reliability species protection guideline value of 0.5 µg/L. Concentrations of both elements were, however, well below the respective livestock drinking water guideline values of 200 µg/L (uranium) and 100 µg/L (vanadium) respectively.
- Of these elements, the greatest exceedance of the ANZG (2018) freshwater protection criteria was for uranium which was present at concentrations approximately 60-fold higher than the low reliability freshwater species protection guideline concentration of 0.5 µg/L. The proposed calculated raw discharge concentrations of approximately 28–31 µg/L were also between 2–6-fold higher than the site-specific and regional 'trigger' and 'action' values outlined in Table 16.
- Vanadium (28–30 µg/L) raw water concentrations also considerably exceeded the ANZG (2018) low-reliability freshwater species protection guideline value guideline (6 µg/L), and all of the site-specific and regional 'trigger' and 'action' values outlined in Table 16.

Table 18: Predicted Raw (Untreated) Groundwater Discharge Concentrations

Analyte		Month of Discharge												Environmental Criteria						
		3	6	9	12	15	18	21	24	27	30	33	36	LDW	NPU	95% FW	Turner River SSGV (interim)		Regional (Turner + Yule Rivers) SSGV	
																	Trigger (80%)	Action (95%)	Trigger (80%)	Action (95%)
As	µg/L	11	11	11	10	10	10	12	12	12	12	12	12	25	100	13	7.7	8.9	5.7	8.0
U	µg/L	29	28	28	28	28	28	31	31	31	31	31	30	200	170	0.5	5.7	12.2	12.1	19.2
V	µg/L	28	28	28	28	28	28	30	30	30	30	30	30	100	N/G	6	8.6	10.5	9.6	11.0

LDW — ANZECC (2000) livestock drinking water; NPU — DoH (2014) non-potable use; 95% FW — ANZG (2018) 95% freshwater species protection, SSGV (Site-specific guideline value).

Turner River SSGV is calculated from both the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner River sampling locations.

Regional SSGV is calculated from the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner and Yule River sampling locations.

9.2 SURFACE WATER COMPOSITION — POST-DISCHARGE

In order to assess the potential environmental significance of the proposed discharge into the Turner River, a high-level calculation of surface water loadings was conducted. Loadings were calculated on the basis of four (4) environmental scenarios which were generated using monitoring data (1985–2024) from the Turner River at Pincunah (709010) (DWER, 2022). These scenarios included:

- No flow (i.e. no rainfall within the catchment) during the proposed 3-year discharge: 0 GL/Year
- Median annual flow: 6.2 GL/year.
- Mean annual flow: 27.4 GL/Year.
- Highest recorded annual flow: 137.4 GL/Year (DWER, 2022).

Surface water concentrations were thus calculated at the river scale (i.e. total discharge volume vs total volume present in catchment over the 3-year period). The results of surface water contaminant loading for the main analytes of interest for each of the tested scenarios are presented below in Table 19.

Table 19: High-Level Calculation of Mean Surface Water Loading in Turner River

Analyte		Turner River Flow Scenarios (per annum)					Environmental Criteria				
		0 GL	6.2 GL	27.4GL	137.4 GL	Turner River Average	ANZECC (2000) 95th% Freshwater Species Protection	Turner River SSGV (interim)		Regional SSGV	
		Dry (Minimum Recorded)	Median	Average	Maximum Recorded			Trigger (80%)	Action (95%)	Trigger (80%)	Action (95%)
As	µg/L	11.2	8.7	6.4	5.2	3.5	13	7.7	8.9	5.7	8.0
U	µg/L	29.6	20.2	11.7	7.0	3.9	0.5	5.6	12.2	12.1	19.2
V	µg/L	29.0	19.4	10.7	5.8	3.5	6	8.6	10.5	9.6	11.0

Turner River SSGV are presented as the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner River sampling locations.

Regional SSGV are presented as the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner and Yule River sampling locations.

Major findings from these calculations include:

- In the unlikely event that no rain falls within the Turner River catchment during the discharge period (3 years), concentrations of uranium and vanadium throughout the inundation zone would exceed both the site and regional specific action (95%) value (Table 19).
- Concentrations adjacent to the zone of discharge are likely to be higher, although classifying this is beyond the scope of this assessment. Evaporation (particularly post discharge) also has the potential to further increase concentrations and thus exposures for aquatic ecosystems (noting toxicity also depends on form as discussed later in this report). It must be noted, however, that no rainfall occurring within the catchment over the 3-year window is unlikely but does represent the worst-case scenario.
- If median flows of around 6.15 GL/year occur within the catchment during the discharge period, then uranium and vanadium concentrations will exceed both the site and regional specific action (95%) value.
- If annual flows are in the average range for the catchment (27.4 GL/year) then U and V concentrations of raw discharge water are likely to exceed the site and regional specific trigger (80%) value but will not exceed the relevant action (95%) values.

- If flows are above average during the discharge period U and V concentrations are likely to be well below site specific/default trigger values and thus represents a much lower environmental risk than the scenarios that involve lower rainfall within the Turner River catchment.

9.3 SEDIMENT — POST DISCHARGE

In order to characterise the risk of the discharge to the Turner River system, a high-level calculation of metal(loid) loading in riverine sediments was conducted. As outlined in Figure 5, spatial modelling by Geowater has indicated that water is likely to extend a distance of approximately 50 km over the duration of the discharge in the absence of any additional flow from rainfall. Discharge modelling was, however, not conducted for scenarios in which the discharge occurred in conjunction with rainfall (Geowater, 2023). Consequently, in this assessment, sediment loadings for median, average and maximum rainfall years (See Section 9.2) were not conducted due to significant uncertainties regarding the calculation of inundation areas. Predicted sediment loadings from the discharge itself in the absence of rainfall over the expected 50 km inundation area are outlined below in Table 20.

Table 20: Predicted Sediment Contaminant Loading in Turner River

Analyte	Baseline Sediment Concentration (mg/kg)	Calculated Sediment Loading (mg/kg)	ANZG (2018)		Turner River Background		Regional SSGV	
			Low (mg/kg)	High (mg/kg)	80th percentile	95th percentile	Trigger (80th percentile)	Action (95th percentile)
U	0.5	0.3	N/G	N/G	0.5	0.6	2.8	3.8
V	6.3	0.3	N/G	N/G	6.3	12.5	29.3	37.0

The following assumptions were used to generate the above sediment loadings:

- The length of the discharge is 50 km (Geowater, 2023).
- Metals/metalloids will be constrained/bind into (following evaporation etc.) in the top 10 cm of the sediment profile. In reality this is conservative as (especially for uranium) much will remain dissolved and return/recharge into the groundwater and disperse.
- The width of Turner River channels will be up to 90 m (Geowater, 2023) and the final volume of discharge is 30 GL.

Major results from these calculations included:

- Vanadium and uranium concentrations in sediment would increase by up to 0.3 mg/kg over the length of the discharge assuming the complete transfer of these elements from the water column to sediments (conservative as above). There are currently no Australian environmental criteria for vanadium and uranium for sediments however the previous (DER 2010) default ecological screening criteria for soil is 50 mg/kg and the average crustal abundance for uranium is 2.7 mg/kg which means neither would be exceeded if added to Turner river 80th percentile background. These increases suggest a low risk (given flushing, dispersion into groundwater in particular for uranium) for environmental significance of this exposure pathway.
- Site-specific and regional-specific sediment guideline values representing the 80th percentile and 95th percentile of the monitoring data were established as outlined earlier for surface water (Section 7).
- Uranium concentrations in sediments would likely increase from existing Turner River site background levels (particularly near discharge point) but assessed on a regional scale, the increase in uranium concentrations would not exceed the regional guideline values (2.8 mg/kg or 3.8 mg/kg).

- Vanadium concentrations, however, are not expected to exceed any of the site or regional specific guideline values post-discharge although concentrations are likely to be higher in the immediate discharge zone with concentrations attenuating the further the discharge travels downstream.
- Finally, it must also be noted that any rainfall within the catchment is likely to significantly dilute these concentrations as the inundation zone will expand (downstream) thus reducing concentrations at the mg/kg soil scale.

10. Geochemical and Dilution Modelling

In order to assist with the high-level calculations, geochemical modelling was performed (using United States Geological Society PHREEQC) to assess whether the precipitation of elements, particularly contaminants of interest occurs when water from a) different dewatering bores is mixed prior to discharge and when (b) discharge water and Turner River surface water are mixed upon discharge. In addition, PHREEQC modelling was also used to assess how selected physicochemical properties (such as oxygenation, pH etc) control/influence the solubility of contaminants of interest as a means of selecting potential water treatment options. All data used and results generated from PHREEQC modelling are provided in Appendix 4.

10.1 Mixing of Dewatering Bores

Speciation modelling was performed with PHREEQC (i.e. PH REdox EQuilibrium in C language) on the compositions of the "calculated" surface and mixed bore waters after 3, 18 and 36 months (Table 21) to allow formation of key mineral phases when saturation indices were positive (i.e. indicating supersaturation of the species and predicted/potential precipitation). Simulations assumed the waters were in contact and at equilibrium with the ambient atmospheric conditions for carbon dioxide and oxygen. The key results were:

- Silicate minerals in the form of quartz and/or chalcedony are the main mineral phases predicted to precipitate from the mixed raw bore water due to elevated dissolved silica content in the groundwater (24 – 115 mg/L).
- Small amounts of carbonates are predicted to precipitate from the mixed bore waters in the form of dolomite, calcite, magnesite and witherite.
- Negligible amounts of potassic feldspar and iron oxides in the form of hematite/goethite may also precipitate.
- Low levels of mineral phases are expected to form the surface water composition, essentially as clays, quartz/chalcedony, dolomite/calcite and witherite.

Overall, speciation modelling results showed that low amounts of mineral phases are predicted to form from the surface and mixed bore water compositions, and therefore no significant changes are expected from water mixing and exposure to atmospheric conditions (Table 21) based on the PHREEQC database.

Table 21: Calculated and Modelled (PHREEQC) Concentrations of Potential Contaminants in Discharge and Turner River Surface Water

Analyte	3 months (µg/L)		18 months (µg/L)		36 months (µg/L)		Turner River (µg/L)	
	Calculated	PHREEQC	Calculated	PHREEQC	Calculated	PHREEQC	Calculated	PHREEQC
As	13	13	11	11	12	12	3.5	3.5
Cu	2.1	2.1	2.1	2.1	2.1	2.2	2.3	2.3
U	30	30	29	29	31	31	3.9	3.9
V	29	29	29	29	30	30	3.5	5.0
Zn	17	17	16	16	16	16	12	16

As outlined in Table 21, calculated and modelled concentrations of potential contaminants in the discharge water are very similar, which therefore suggests that the elements of interest are unlikely to precipitate when water from different bores are mixed prior to discharge.

10.2 Physicochemical Factors Controlling Contaminant Solubility

A sensitivity analysis was undertaken with PHREEQC to determine the range of geochemical parameters which could trigger reduced concentrations of the dissolved key analytes including arsenic, copper, uranium, vanadium and zinc from the abstracted bore water. The analysis was performed on the water composition of production bore HERC026 showing slightly higher uranium concentrations than other bores but otherwise considered typical of groundwater chemistry. The following assumptions and steps were applied:

- Step 1: Speciation modelling was performed for a range of pH values between 5 and 10 under equilibrium with CO_2 and O_2 atmospheric conditions.
- Step 2: Incremental increase of dissolved oxygen content between fully anoxic (0.5 mg/L) and atmospheric conditions (8.5 mg/L) for constant pH (pH 8.1), iron content and sorption on iron oxides (as Hydrous Ferric Oxides (HFO) on goethite).
- Step 3: Incremental addition of iron as goethite (0.001–3.77 g/L) and amount of surface sorption sites on goethite, for constant pH (pH 8.1) and dissolved oxygen conditions (8.5 mg/L).
- Step 4: Radioactive decay chain of ^{238}U for total period of 365 days and a ^{238}U half-life of 4.468 $x10^9$ years.
- For each of these steps:
  - Surface sorption of metals and metalloids was incorporated as sorption on HFO. Base case initial HFO was established from the total iron content determined in a topsoil sample from site (HMRC492) assuming only ten 10% of this total amount was available to surface sorption reactions.
  - An additional sorption term was included to account for sorption on organic carbon and clay contents detected in the analysis of the final bench test water compositions of the top and subsoils. This was calibrated based on uranium concentrations observed after 18 hours of constant bubbling (See Section 11.
  - Precipitation of key mineral phases including goethite (FeO(OH)), witherite ($BaCO_3$), strontianite ($SrCO_3$), dolomite ($Ca,Mg(CO_3)_2$) and calcite ($CaCO_3$).

Key results of the sensitivity analysis were:

- Radioactive decay of ^{238}U over a period of 365 days (step 4) was negligible and did not affect the dissolved concentrations of uranium. Based on radioactive decay only, concentrations for bore water HERC026 is therefore predicted to remain at ~0.4 Bq/L.
- The key dissolved metals and metalloids were not affected by the variation of the oxygen content under fully anoxic to fully oxic conditions at pH 8.1 (Chart 2). This confirms the aquifer is already oxygenated. Concentrations of copper and zinc were reduced by small amounts by sorption on HFO site under oxic conditions (4.1–8.5 mg/L of dissolved O_2). Uranium tends to be present as dissolved uranyl ion (UO_2^{+2}) or its soluble complexes with carbonates under oxic and alkaline conditions, while under more anoxic conditions the reduced form (U(IV)) is more prone to precipitate as uraninite (UO_2). However, dissolved concentrations of uranium were not influenced by redox conditions, which were attributed to the limited initial concentrations of dissolved uranium in the water. It should be noted that precipitation of uranium could be forced by addition of hydrogen peroxide (H_2O_2) to form uranyl peroxide ($UO_2(O_2)$) (Kim 2015).
- Concentrations as function of pH are shown in Chart 3. This chart demonstrates that dissolved uranium concentrations vary with pH due to change of speciation and subsequent affinity towards surface sorption. Levels of uranium are predicted to increase with increasing pH from 5.0–8.5 where it stabilised to the maximum concentration measured in bore HERC026 (approximately 30 µg/L). This was attributed to the formation of dissolved uranium-carbonate complexes, with the increase of alkalinity, having decreased propensity to sorption. Decrease of pH to circumneutral/acidic conditions can slightly decrease uranium dissolved concentrations (i.e. more affinity of uranyl ion to sorption on HFO), however, levels were still predicted to significantly exceed the calculated regional and site-specific trigger values (Table 16) by almost one order of magnitude. Arsenic and to a lesser extent vanadium are predicted to be more sensitive to the change of pH conditions and decrease with the increase of pH above 8.1 (base case or initial conditions) to stabilise from pH 9.
- Simulated incremental addition of iron, as goethite, was performed under constant fully oxic conditions. Dissolved concentrations of arsenic, copper and zinc were depleted by two-fold (i.e. due to surface sorption) after the initial reactive iron contained in the soil material was doubled to 0.002 g/L. Levels of uranium were

less sensitive to the addition of iron due to the elevated alkalinity of the bore water (373–385 mg $CaCO_3$/L). As described previously, under the alkaline conditions noted in the bore water compositions, uranium will be in the form of dissolved uranyl-carbonate ions ($UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$) and have less affinity for surface sorption on HFO. Prediction indicates that it would require an additional 1.5 g of FeOOH/L to deplete uranium dissolved concentrations below the regional and site-specific trigger values (<12 µg/L) (Chart 4).

- Other treatment options such as hydrogen peroxide, which would result in the precipitation of uranium peroxide and lime, and removal of soluble uranium carbonates were considered and modelled. Both options were, however, discounted: In the case of peroxide treatment, the pH would also need to be adjusted to <2, then making the water unsuitable for discharge unless lime is then used to then raise pH (significant treatment cost). Lime addition alone had a deleterious effect on uranium solubility, whereby the addition of lime increased uranium solubility rather than facilitated its precipitation.

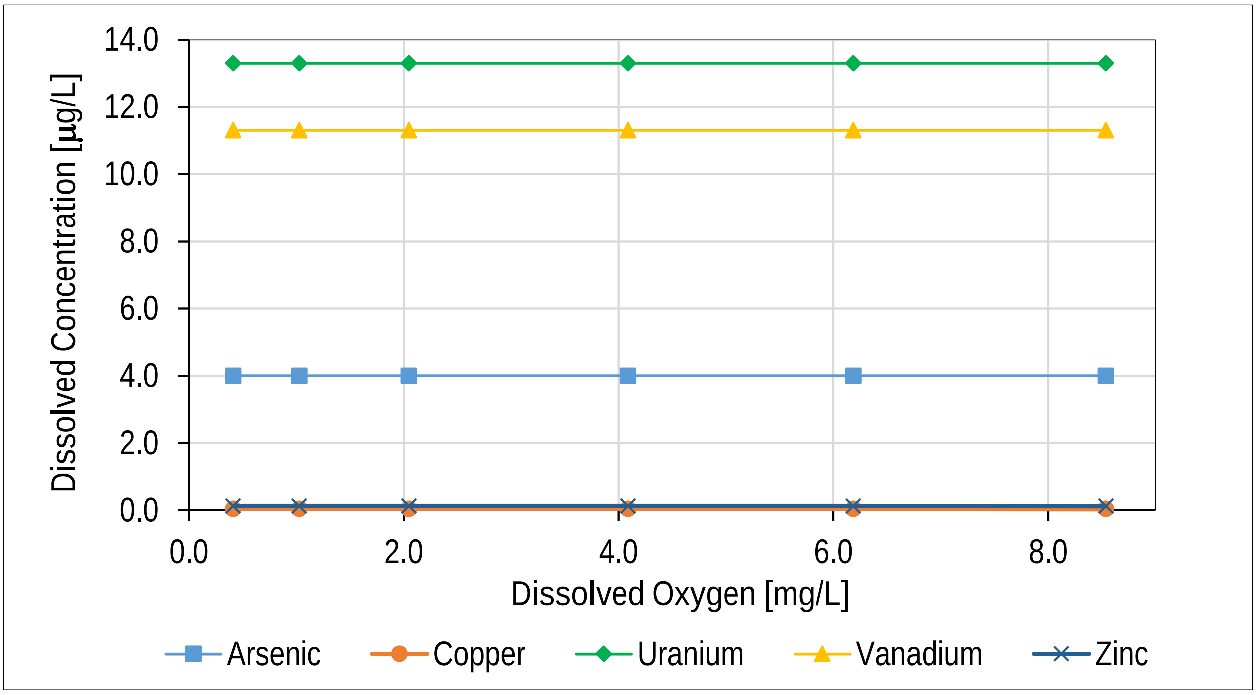

Chart 2: Metals and Metalloids Concentrations as Function of Dissolved Oxygen

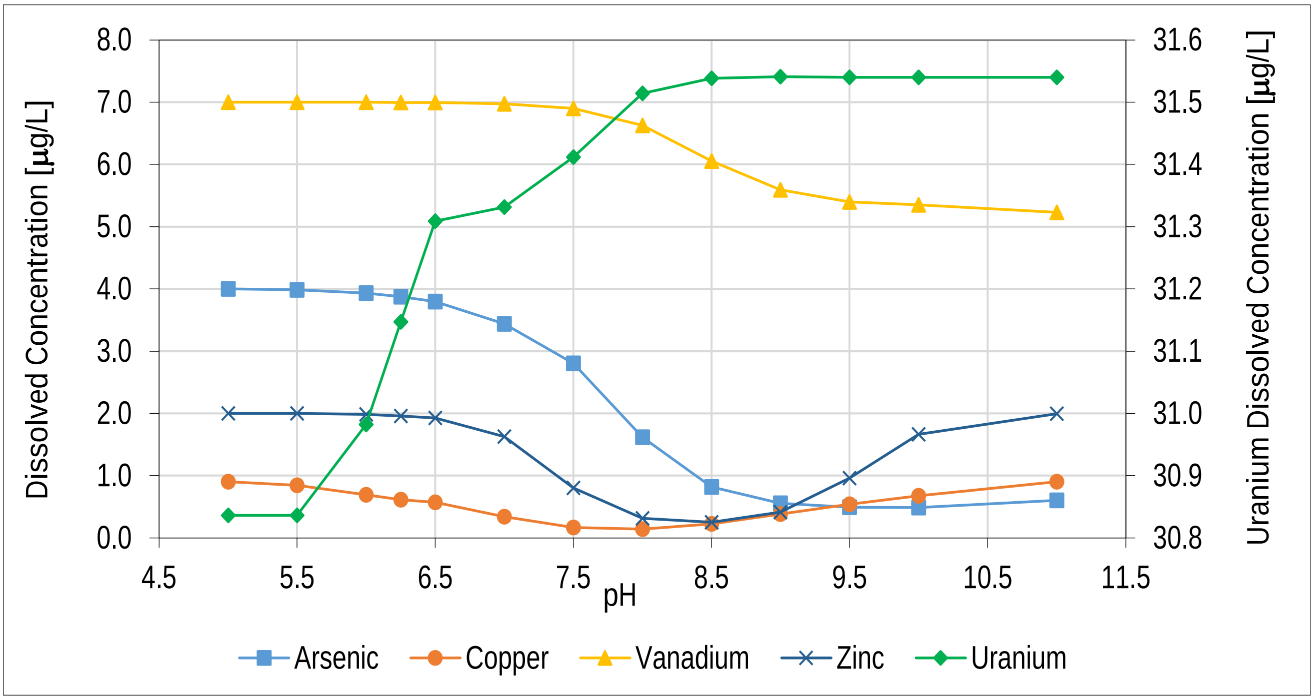

Chart 3: Metals and Metalloids Concentrations as Function of pH

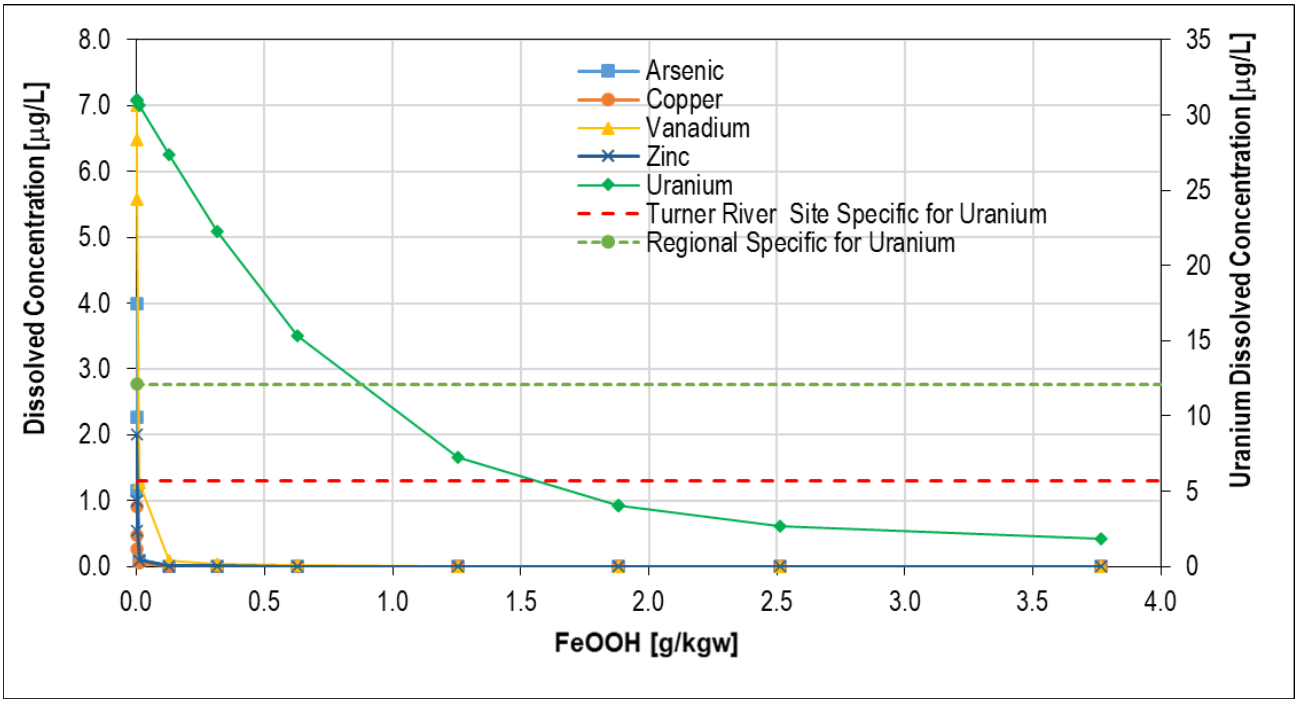

Chart 4: Metals and Metalloids Concentrations as Function of Added FeOOH

11. LABORATORY SCALE SIMULATED DISCHARGE HOLDING POND EXPERIMENTS

11.1 BACKGROUND AND RATIONALE

In order to ground truth the results of the PHREEQC Equilibrium Modelling (Section 10) and inform likely pond sizes and holding periods required to reduce contaminant concentrations within the discharge water, a series of laboratory incubation experiments were conducted by ChemCentre (Bentley, WA). The rationale behind these experiments was that components of the soil matrix such as iron/aluminium hydroxides, organic matter, clays may be effective at adsorbing and thus removing contaminants of concern (in particular As, V and to a lesser degree U) from water prior to it being discharged. In addition, the PHREEQC database does not account for certain reactions such as co-precipitation reactions or biologically mediated reactions. All data generated in laboratory experiments is provided in Appendix 5.

11.2 SOIL AND WATER SAMPLES

11.2.1 Soils

Two soil samples collected from the Hemi site and two water samples taken from bores with elevated arsenic, uranium and/or vanadium were utilised in incubation experiments. Characteristics of soils used in the experiments are summarised below in Table 22.

Table 22: Field Characteristics of Soils Used in Laboratory Incubation Experiments

Soil ID	Collection Location	Soil System	Depth (m)	Textural Characteristics (Field)	Likely WA soil Group
Soil A	HMRC492/528	Uaroo	0.1 – 0.5	Red-Brown Sandy Loam	Red Deep Sandy Duplex (405)
Soil B	HMRC492	Uaroo	1.0 – 1.5	Red-Brown Sandy Clay-Loam	Red Deep Sandy Duplex (405)

In order to characterise the soils prior to experimentation, the following analytical tests were performed on both soil samples:

- pH & EC: 1:10 (*w:v*) extract.
- Total elemental composition: four-acid digest followed by ICPAES/MS analysis for the following elements: Ag, Al, As, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn, Zr.
- Environmental total elemental composition: aqua regia digestion by ICPAES/MS analysis for the elements listed above.
- Particle size distribution: sand/silt/clay %.
- Organic Carbon.
- Hydroxylamine HCl leach: pH 1.5 leach to establish concentrations of selected elements (Ag, Al, As, B, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Si, Sn, Th, Ti, Tl, U, V and Zn) associated with amorphous iron and manganese oxides.
- Leachable metals and metalloids: 1:10 (*w:v*) leach followed by ICPAES/MS analysis for the following analytes: alkalinity, SiO_2, SO_4, Cl, Ca, Mg, Na, K, NO_3-N, Br, Hg, Al, Fe, Sb, Se, As, Ba, Be, Bi, Cd, Cr, Co, Cu, Pb, Li, Mn, Mo, Ni, Ag, Sr, Te, Tl, Th, Sn, Ti, U, V, Zn.

11.2.2 Soil Characterisation Results

Selected physicochemical parameters of the soils are summarised below in Table 23. It was proposed by MBS that dewatering discharge should occur indirectly via constructed earthen ponds allowing a residence time for equilibration/precipitation of species prior to entering the Turner River.

Table 23: Selected Results of Soil Physicochemical Characterisation

<table>
<tr><th>Test</th><th>Analyte</th><th>Units</th><th colspan="3">Soil Type A</th><th colspan="3">Soil Type B</th></tr>
<tr><td rowspan="2">pH/EC</td><td>pH</td><td>pH Units</td><td colspan="3">6.9</td><td colspan="3">7.1</td></tr>
<tr><td>EC</td><td>mS/m</td><td colspan="3">4.4</td><td colspan="3">9.9</td></tr>
<tr><td>Gravel (>2-mm) Content</td><td>Gravel</td><td>%</td><td colspan="3">3.2</td><td colspan="3">42.5</td></tr>
<tr><td rowspan="2">Particle Size Distribution</td><td>Sand/Silt/Clay</td><td>%</td><td>71</td><td>9</td><td>20</td><td>64</td><td>5</td><td>31</td></tr>
<tr><td colspan="2">Classification</td><td colspan="3">Sandy Clay Loam</td><td colspan="3">Sandy Clay Loam</td></tr>
<tr><td>Organic Carbon</td><td>Organic Carbon</td><td>%</td><td colspan="3"><0.05</td><td colspan="3">0.29</td></tr>
<tr><td rowspan="5">4-Acid Digest</td><td>Total As</td><td rowspan="5">mg/kg</td><td colspan="3">4.6</td><td colspan="3">9.1</td></tr>
<tr><td>Total Cu</td><td colspan="3">12</td><td colspan="3">22</td></tr>
<tr><td>Total U</td><td colspan="3">1.7</td><td colspan="3">2.3</td></tr>
<tr><td>Total V</td><td colspan="3">44</td><td colspan="3">70</td></tr>
<tr><td>Total Zn</td><td colspan="3">13</td><td colspan="3">18</td></tr>
<tr><td rowspan="5">Aqua Regia Digest</td><td>Total As</td><td rowspan="5">mg/kg</td><td colspan="3">3.6</td><td colspan="3">6.9</td></tr>
<tr><td>Total Cu</td><td colspan="3">7.8</td><td colspan="3">18</td></tr>
<tr><td>Total U</td><td colspan="3">0.7</td><td colspan="3">1.3</td></tr>
<tr><td>Total V</td><td colspan="3">36</td><td colspan="3">51</td></tr>
<tr><td>Total Zn</td><td colspan="3">6.8</td><td colspan="3">10</td></tr>
<tr><td rowspan="5">Water Leachate</td><td>Total As</td><td rowspan="5">mg/L</td><td colspan="3"><0.001</td><td colspan="3"><0.001</td></tr>
<tr><td>Total Cu</td><td colspan="3">0.002</td><td colspan="3">0.001</td></tr>
<tr><td>Total U</td><td colspan="3"><0.0001</td><td colspan="3"><0.0001</td></tr>
<tr><td>Total V</td><td colspan="3">0.002</td><td colspan="3">0.002</td></tr>
<tr><td>Total Zn</td><td colspan="3">0.003</td><td colspan="3">0.001</td></tr>
<tr><td rowspan="5">Hydroxylamine HCl leach</td><td>Total As</td><td rowspan="5">mg/L</td><td colspan="3">0.005</td><td colspan="3">0.005</td></tr>
<tr><td>Total Cu</td><td colspan="3">0.066</td><td colspan="3">0.080</td></tr>
<tr><td>Total U</td><td colspan="3">0.019</td><td colspan="3">0.028</td></tr>
<tr><td>Total V</td><td colspan="3">0.19</td><td colspan="3">0.33</td></tr>
<tr><td>Total Zn</td><td colspan="3">0.014</td><td colspan="3">0.023</td></tr>
</table>

11.2.3 Water

Water from two groundwater monitoring bores were selected for use in experimentation. These specific bores were chosen as they contain elevated concentrations of all of the contaminants of interest identified in Section 9.1. Selected chemical characteristics of the groundwater from the bores are presented below in Table 24, whilst radiological characteristics are presented below in Table 25.

Table 24: Key Analytes of Discharge Water Utilised in Laboratory Experiments

Bore ID	pH	TDS	As	U	V
	SU	mg/L	µg/L		
HERC026	8.0	1,012	38	44	40
HMB001 — Upper	8.0	884	11	36	42
HMB001 — Lower	8.0	965	15	36	35
Predicted Discharge Concentration	8.2	763–788	11–13	29–32	26–29
ANZECC 95th % Freshwater Protection	6.5–8.5	N/G	13	0.5	6
Interim Turner River SSGV (Calculated)	8.0–9.0	1,490	7.7 – 8.9	5.6 – 12.2	8.6 – 10.5
Regional SSGV (Calculated)	8.1 – 8.9	1,822	5.7– 8.0	12.1 – 19.2	9.6 – 11.0

Turner River SSGV are presented as the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner River sampling locations. Regional SSGV are presented as the 80th percentile (Trigger) and 95th percentile (Action) of all data collected from Turner and Yule River sampling locations.

Table 25: Radiological Characteristics of Selected Groundwater Samples

Bore ID	Gross Alpha	Gross Beta	Ra 226	Ra 228
	Bq/L			
HMB001 — Upper	2.06 ± 0.38	0.103 ± 0.067	<0.059	<0.14
HMB001 — Lower	1.39 ± 0.26	0.058 ± 0.067	<0.06	<0.12
ANZECC Livestock Drinking Water	1	5	5	2

11.3 EXPERIMENTAL DESIGN

In order to assess the effectiveness of a soil-based holding ponds in reducing concentrations of contaminants of concern (As, U, and V) the following laboratory experiment was conducted.

Two samples of approximately 1.5 kg of Soil B (Table 23) was placed in a large container along with 15 L of groundwater from either the HMB001 or HMC026 bores. This soil-water mixture was aerated at room temperature (not stirred) over an 18-hour period with water samples (approx. 200 mL) taken at the following intervals: 0 mins, 15 mins, 30 mins, 45 mins, 1 hour, 1.5 hours, 2 hours, 3 hours, 4 hours and 18 hours.

Water samples were analysed for the following parameters:

- pH and EC.
- Alkalinity.
- Chloride.

- Nitrate.
- Gross alpha & beta.
- Radium 226 & Radium 228.
- Dissolved metals/metalloids including Si, Ca, Mg, Na, K, Hg, Al, Fe, S, Sb, Se, As, Ba, Be, Bi, Cd, Cr, Co, Cu, Pb, Li, Mn, Mo, Ni, Ag, Sr, Te, Tl, Th, Sn, Ti, U, V, Zn.

11.4 RESULTS

Summarised results of the laboratory incubation experiment for the contaminants of potential concern are provided below in Table 26.

Table 26: Selected Chemical Results of Laboratory Incubation Experiments

Time	Arsenic (µg/L)		Uranium (µg/L)		Vanadium (µg/L)	
	HMB001	HERC026	HMB001	HERC026	HMB001	HERC026
Raw/In situ*	11	38	36	44	42	40
0 min	9	17	29	32	10	10
15 min	13	-	32	-	15	-
30 min	9	-	27	-	11	-
45 min	10	-	30	-	12	-
1 h	8	13	30	29	9	8
1.5 h	6	12	29	31	8	8
2 h	4	8	27	29	6	6
3 h	3	5	26	27	6	6
4 h	3	5	26	25	6	5
18 h	2	4	26	31	6	7
ANZECC 95% FW	13		0.5		6	
Turner River Site-Specific	7.7 – 8.9		5.7 – 12.2		8.6 – 10.5	
Regional SSGV	5.7 – 8.0		12.1 – 19.2		9.6 – 11.0	

* Field acidified sample.

Table 27: Selected Radiological Results of Laboratory Incubation Experiments

Bore ID	Gross Alpha	Gross Beta	Ra 226	Ra 228
	Bq/L			
HMB001 — Lower	1.39 ± 0.26	0.058 ± 0.067	<0.06	<0.12
HMB001 — Lower, after 18-hour incubation	1.42 ± 0.26	0.129 ± 0.07	0.052 ± 0.018	<1.4
ANZECC (2000) Livestock Drinking Water	1	5	5	2

Major results from this experiment included:

- The experiments overall indicated a significant and effective reduction in arsenic and vanadium concentrations to levels below site/regional derived guidelines for these species. A slight reduction in uranium concentrations was observed, however, concentrations only fell to between 26 and 30 µg/L.
- Concentrations of all target elements decreased from those measured *in situ* (acidified in the field at time of collection) to those present at time 0 of the incubation experiment (transport of non-acidified sample). This was especially true for samples from the HERC026 bore which decreased by 24–92% across the different elements and for vanadium concentrations in general which decreased by 70% from both bores.
- Arsenic concentrations in both experiments decreased over time. In the HMB001 experiment concentrations fluctuated between 8 and 13 µg/L during the first hour then fell to 2 µg/L by 18 hours. In the HERC026 experiment, concentrations fell from 17 to 13 µg/L during the first hour, then decreased to 4 µg/L by the conclusion of the experiment (18 h). Excluding the time 0 for the HERC026 sample, all concentrations were below the ANZG (2018) 95% freshwater species protection value of 13 µg/L and also below calculated site specific/background guideline values.
- Vanadium behaved in a similar manner to arsenic in which concentrations decreased over time. In both experiments initial concentrations were 10 µg/L; falling to 6 µg/L (HMB001) and 7 µg/L (HERC026) after 18 hours. Both of these concentrations are below the Turner River 'interim' site specific guideline value of 9.1 µg/L.
- Uranium concentrations did not decrease considerably in either of the incubation experiments. In both experiments, concentrations at commencement (29 µg/L and 32 µg/L from field maximums of up to 44 µg/L) were similar to those after 18-hour incubation (26 µg/L and 31 µg/L) all of which were considerably higher than the regional and site-specific values detailed in Table 16. Results do indicate that use of earthen discharge ponds would reduce uranium concentrations to approximately 30 µg/L as equilibrium concentration for any bores which are particularly elevated.
- Radiological activity concentrations were also largely constant over the duration of the laboratory incubation experiment, with gross alpha values (means) remaining between 1.39–1.42 Bq/L over the 18-hour period. These values exceeded the ANZECC (2000) livestock drinking water guideline value of 1 Bq/L. All other radiological measurements (gross beta, Radium 226/228) were also constant over the experiment but were below relevant environmental criteria (Table 27).
- Based on the results of this experiment, the use of constructed soil discharge ponds to provide a suitable residence time prior to discharge into the Turner River is likely to be effective at reducing the concentrations of arsenic and vanadium that will be discharged. This is presumably (as per PHREEQC work above), a result of binding of arsenic and vanadium to iron oxide materials within the native soil matrix. This approach is less effective at lowering the concentrations of uranium in solution although they can be reduced to a maximum of approximately 30 µg/L. This is likely to be a function of the form (soluble uranyl carbonates) and that uranium adsorption occurring on a variety of matrices (e.g. clay materials, aluminium and iron oxides, organic matter and microorganisms) is known to be reversable under different pH and redox conditions (see section 14.1). Based on the results presented in Section 10, additional iron sources (i.e. goethite, ferric sulfate) are likely to be needed to further reduce uranium concentrations prior to discharge — such amount of addition required may not be practicable however.
- Use of soil discharge ponds will also contain deposited arsenic, vanadium in particular to the area of the pond for burial at closure and therefore would not contribute to sediment loading in the Turner River. Remaining equilibrium concentrations in the dissolved phase are unlikely to significantly increase sediment loads in the Turner River.

11.5 CHARACTERISTICS OF PROPOSED DISCHARGE POND

Based on the results presented in Section 10 and Section 11.4 a conservative residence time of 3 h should be sufficient to remove or reduce concentrations of arsenic and vanadium via sorption with natural soil components. Approximately 27.4 ML of water is to be discharged daily which equates to an annual discharge of approximately

1.15 ML per hour. A pond capable of storing 3 hours' worth of discharge (residence time of 3 hours), will thus need to hold at least 3.45 ML of water and would thus need to have a capacity of approximately 4.2 ML which includes a 20% freeboard.

Based on a volume requirement of 4,200 m^3, a constructed earth pond measuring 175 m long x 10 m wide x 2.5 m deep will have a capacity of 4,375 m^3, which should be adequate to hold and treat water prior to discharge. A second pond may be needed to alternate discharge for maintenance/occasional sediment removal to allow continuous discharge. Selection of bores with higher uranium concentration for direction towards aquifer recharge (where/if possible) would reduce slightly the final uranium concentration of discharge water.

12. LABORATORY SCALE SIMULATED WATER TREATMENT EXPERIMENTS

Due to the failure of simple soil ponds to effectively remove uranium below adopted criteria, additional laboratory scale batch experiments were conducted in order to further investigate the efficacy and viability of iron oxide and other chemical water treatments designed to remove U from solution. These experiments were conducted by ChemCentre (Bentley, WA). The rationale behind these experiments was that chemicals such as iron oxides and phosphates applied separately or in combination would facilitate the removal of uranium via adsorption and/or precipitation reactions. The experimental rationale, design, methods and key results and implications are presented in the following sections. All data generated in laboratory experiments is provided in Appendix 5.

12.1 RATIONALE AND LITERATURE REVIEW

The overall objective of these experiments were to both build on the laboratory experiments outlined in Section 11 and ground truth the PHREEQC Equilibrium Modelling (Section 10), specifically the FeOOH concentrations required to remove U from solution (Chart 4).

In order to assess whether Fe oxides or other chemicals have the capacity to remove U from solution a high-level literature review was performed, with the major findings summarised in the sections below.

12.1.1 U Removal via Sorption to Iron Oxides

Under oxic conditions, U is typically present as uranyl (U(VI) - UO_2^{2+}) (Massey et al., 2014). The reduced species urania (U(IV) - UO_2) can produce the sparingly soluble precipitate uraninite (UO_2(s)) (Massey et al., 2014). In the presence of iron oxides there are typically two pathways by which U can be removed from solution: absorption to iron oxide surfaces; or precipitation/incorporation within mineral phases (Massey et al., 2014).

The adsorption of U(VI) onto the surfaces of iron oxides (e.g. ferrihydrite, goethite, hematite) is generally a rapid process, which is strongly influenced by variables such as pH and chemical composition (Massey et al., 2014). For example, under acidic conditions the positively charged U(VI) ion is prone to absorption on iron mineral surfaces, however, as the pH of solutions increase U(VI)-carbonate and U(VI)-calcium carbonate species are more prevalent which do not actively adsorb to iron oxide or other mineral surfaces (Regenspurg et al., 2009).

Humic acids and other organic compounds are known to assist in the adsorption of uranium to mineral surfaces (Noubactep, 2006), although again, the presence of carbonates is well known to inhibit the removal of U and facilitate its transport in aquatic environments (Regenspurg et al., 2009).

In the presence of iron oxide minerals it is, however, possible for U to be removed via precipitation/incorporation via reactions with Fe(II) (Regenspurg et al., 2009). The presence of Fe(II) is able to facilitate the reduction of U(VI) to U(IV) which results in the formation of uraninite (UO_2(s)). In addition, there is also evidence that U species can be incorporated into the structure of iron oxide materials as a result of the Fe(II) mediated uraninite production (Noubactep, 2006). Consequently, in remediation efforts iron oxide minerals (ferrihydrite, goethite, hematite) are often applied in conjunction with an Fe(II) source such as ferrous sulfate ($FeSO_4 \cdot xH_2O$) to allow for absorption and precipitation to occur simultaneously. As detailed previously, the efficacy of these removal techniques are strongly influenced by solution pH, carbonate and humic acid contents.

12.1.2 U Removal via Sorption/Precipitation with Phosphates

Phosphates (PO_4^{3-}) are also well established as a means of removing uranium species from solution which as detailed previously occurs via both adsorption and precipitation reactions. In general there are three main mechanisms in which phosphates can facilitate the removal of U from solution. These include:

- The formation of uranium-phosphate precipitates (uranium hydrogen phosphate ($UO_2HPO_4.3H_2O$(s)) and uranyl orthophosphate ((UO_2)3(-PO_4)^2.4H_2O(s))).

- Incorporation as a trace component of calcium phosphate ($CaPO_4$) minerals.
- Adsorption onto the surfaces of calcium phosphate ($CaPO_4$) minerals (Wen, 2018).

As described in section 12.1.1 the presence of carbonates and calcium ions (Ca^{2+}) strongly influence which of these reactions will occur and the strength of these reactions. For example, under acidic and low calcium conditions uranyl-phosphates have an increased likelihood of forming as the production of uranium-carbonate species and calcium phosphates are both low (Wen et al., 2018). An increased presence of calcium (i.e. >400 mg/L) and a Ca:P ratio greater than 1.5 will favour the formation of $CaPO_4$ minerals rather than uranyl-phosphates (Wen et al., 2018). Under these conditions uranyl species are able to adsorb to $CaPO_4$, however, this will depend on the carbonate content as aqueous species such as $Ca_2(UO_2)(CO_3)_3$(aq) and $Ca(UO_2)(CO_3)_3^{2-}$ are highly mobile and unlikely to adsorb to mineral surfaces. In addition, however, there is evidence to suggest that, under some conditions, uranium can be incorporated into the amorphous $CaPO_4$ structure which also facilitates its removal from solution (Mehta et al., 2016).

Phosphates are also known to adsorb/precipitate on iron oxide surfaces (Singh et al., 2010) and as a result there have been a number of studies that have demonstrated highly efficient U removal when PO_4^{3-} and iron oxide minerals are applied simultaneously. Under these scenarios the production of uranyl–phosphate–Fe(III) oxide ternary surface complexes (Payne et al., 1996; Cheng et al., 2004) have been observed. These complexes, however, are strongly influenced by pH, with PO_4^{3-} adsorption to Fe-oxides becoming less efficient with increasing pH (Singh et al., 2010).

12.1.3 Summary

In summary, both iron oxides and phosphates have the ability to remove U from solution via adsorption and precipitation reactions. Variables such as pH, carbonate, and calcium content are, however, critical in determining both the extent of U removal and the method of removal i.e. adsorption or precipitation.

12.2 EXPERIMENTAL DESIGN

Based on the findings of the literature review performed above (Section 12.1) the following materials were utilised in laboratory experiments:

- Iron ore fines (OREAS403 standard, hematite): 52.3% Fe.
- Rusted Fine Steel wool: assumed 98% Fe.
- Ferric sulfate ($FeSO_4$): 36.8% Fe.
- Single Super phosphate: 9% P; 19.1% Ca.
- Potassium dihydrogen phosphate (KH_2PO_4): 22.7% P.
- Groundwater abstracted from bore HMB001: circa 32 µg/L U; 32 µg/L V; 11 µg/L As.

The above-mentioned materials were utilised across eight experimental treatments which are outlined below in Table 28.

Table 28: Details of Treatments for Laboratory Experiments

#	Treatment Name	Fe-Oxide Mineral (Conc)	Fe(II) Source (Conc)	PO_4 Source (Conc)	Rationale
1	Control	N/A	N/A	N/A	U solubility in absence of treatment chemicals
2	Rusted Steel Wool	Rusted steel wool (3 g Fe/L)	N/A	N/A	Cost-effective means of delivering and Fe oxide and Fe(II) source. Applied at 200% of modelled requirement (1.5 g Fe /L: Section 10.2)

#	Treatment Name	Fe-Oxide Mineral (Conc)	Fe(II) Source (Conc)	PO_4 Source (Conc)	Rationale
3	Fe-Oxide Std Conc 1	OREAS403 standard (3 g Fe/L)	N/A	N/A	Fe-oxide mineral applied at 200% of modelled requirement (1.5 g Fe/L): no dedicated Fe(II) source to reduce U(VI) to U(IV)
4	Fe-Oxide Std Conc 2	OREAS403 standard (6 g Fe/L)	N/A	N/A	Fe-oxide mineral applied at 400% of modelled requirement (1.5 g Fe/L): no dedicated Fe(II) source to reduce U(VI) to U(IV)
5	Fe-Oxide Std + Fe(II)	OREAS403 standard (3 g Fe/L)	$FeSO_4$ (25 mg Fe /L)	N/A	Fe-oxide mineral applied at 200% of modelled requirement (1.5 g Fe/L): Fe(II) source applied to stimulate U(VI) to U(IV) reduction
6	Fe-Oxide Std + $CaPO_4$	OREAS403 standard (3 g Fe/L)	N/A	Single Super phosphate - (6 mg P/L)	Fe-oxide mineral applied at 200% of modelled requirement (1.5 g Fe/L): $CaPO_4$ applied as a source of PO4 for precipitation/adsorption
7	Fe-Oxide Std + KH_2PO_4	OREAS403 standard (3 g Fe/L)	N/A	KH_2PO_4 (6 mg P/L)	Fe-oxide mineral applied at 200% of modelled requirement (1.5 g Fe/L): KH_2PO_4 applied as a source of PO4 for precipitation/adsorption, without competition from Ca addition
8	$CaPO_4$	N/A	N/A	Single Super phosphate - (6 mg P/L)	$CaPO_4$ applied as a source of PO_4 for precipitation/adsorption in absence of Fe oxides

Based on the eight experimental treatments outlined in Table 28 this experiment aimed to address the following :

- The stability of U at concentrations of ≈30 µg/L in aerated solutions over time.
- The ability of commercial and recycled iron oxide materials to reduce U concentrations in solution.
- Whether the co-application of iron oxides and an Fe(II) source enhances U removal capacity.
- Whether the application of phosphates in the presence and absence of iron oxides and calcium facilitates U removal from solution.

12.3 METHODS

Incubation experiments were conducted using the following protocols:

- Prior to the commencement of experiments the following analyses were conducted on selected materials:
  - The composition of the HMB001 groundwater was established focusing on the following analytes: Dissolved U, V, As, pH, EC, DOC, alkalinity, major anions (Cl, SO_4, NO_3) and cations (Na, K, Ca, Mg). This measurement was also used as a "time 0" value for the batch experiment.
  - Leachable concentrations of metals, metalloids and major ions were established from the: OREAS403 standard, the rusted steel wool and single super phosphate using a 1:20 (solid: liquid) extraction.
- All eight (8) experimental treatments outlined in Table 28 were set up vials containing 2L of the HMB001 groundwater which was aerated using an aquarium air pump and continuously stirred using a magnetic stirrer.
- All chemicals were added at the commencement of the experiment and were applied as follows:
  - Control: 2L HMB001 groundwater.
  - Rusted Steel Wool: 2 L HMB001 groundwater + 6.1g rusted iron oxide
  - Fe-Oxide Conc 1: 2 L HMB001 groundwater + 11.5 g of OREAS403 iron ore standard.

- Fe-Oxide Conc 2: 2 L HMB001 groundwater + 23 g of OREAS403 iron ore standard.
- Fe-Oxide + Fe(II): 2 L HMB001 groundwater + 11.5 g of OREAS403 iron ore standard + 136 mg of $FeSO_4$.
- Fe-Oxide + $CaPO_4$: 2 L HMB001 groundwater + 11.5 g of OREAS403 iron ore standard + 134 mg of super phosphate.
- Fe-Oxide + KH_2PO_4: 2 L HMB001 groundwater + 11.5 g of OREAS403 iron ore standard + 53 mg of KH_2PO_4.
- $CaPO_4$: 2 L HMB001 groundwater + 134 mg of super phosphate.

- Water samples (20 mL) were taken after 1-, 2- and 4-hour intervals, filtered through a 0.45-µm filter and analysed for the following analytes:
  - pH, EC, alkalinity, U, V, As, Na, K, Ca, Mg, S, Fe, Mn.

12.4 KEY RESULTS

Table 29: Composition of HMB001 Bore Water

Analyte	Units	HMB001 Value	ANZG 2018 95% FW Protection	Turner River Site Specific	Hemi Regional Value
pH	pH Units	8.0	6.5 – 8.5	N/A	N/A
EC	mS/m	140	N/G	N/A	N/A
DOC	mg/L	<1.0	N/G	N/A	N/A
Alkalinity	mg/L (as $CaCO_3$)	375	N/G	N/A	N/A
Ca	mg/L	29	N/G	N/A	N/A
As	µg/L	15	13	7.7 – 8.9	5.7 –8.0
U	µg/L	41	0.5	5.6 – 12.2	12.1 – 19.2
V	µg/L	42	6	8.6 - -10.5	9.6 – 11.0

The HMB001 bore used as the source water in these experiments was similar in composition to that used in the previous experiments (Table 24). Uranium concentrations (41 µg/L) were considerably higher than the default and site/region-specific values presented in Table 16.

Table 30: Noted Leachable (1:20 w:v) Elements from Selected treatment Chemicals

Analyte	Units	OREAS403 Iron Oxide	Super Phosphate	Rusted Steel Wool
Al	mg/L	<0.005	30	<0.005
As	mg/L	<0.001	0.34	<0.001
Ca	mg/L	6	2,450	0.4
Cu	mg/L	<0.0001	0.78	0.021
Mn	mg/L	<0.0001	10	0.63
Ni	mg/L	<0.01	0.78	0.05
SO_4	mg/L	5	1,900	<1
U	mg/L	<0.0001	0.87	<0.0001
V	mg/L	<0.0001	0.37	<0.0001
Zn	mg/L	0.001	6.3	0.005
pH	pH Units	7.2	2.9	3.9
EC	mS/m	5.1	753	7.2

A 1:20 (*w:v*) extraction was performed on the OREAS403 iron ore standard, the super phosphate and rusted steel wool materials in order to establish whether the use of these materials for water treatment purposes would result in the unintentional delivery of potential contaminants. The key results of these extractions are summarised in Table 30. Both the OREAS403 iron ore standard and rusted steel wool were unlikely to deliver any potential contaminants if used as a water treatment chemicals. The super phosphate material, however, was likely to be a source of a range of metal(loid) contaminants (including those relevant to the study: As, U and V) if used as a water treatment chemical and is thus unlikely to be fit for purpose.

Table 31: Concentrations of (U, V, As) in Solution Throughout Batch Experiments

Treatment	Uranium (µg/L)				Vanadium (µg/L)				Arsenic (µg/L)			
	0 h	1 h	2 h	4 h	0 h	1 h	2 h	4 h	0 h	1 h	2 h	4 h
Control (none)	41	40	40	39	42	39	40	39	15	14	14	14
Rusted Steel Wool	41	23	25	27	42	0.4	0.5	0.6	15	0.5	0.5	0.5
Fe-Oxide Std Conc 1	41	36	36	36	42	9.3	9.9	11	15	6	6	6
Fe-Oxide Std Conc 2	41	30	34	33	42	2.6	3.4	4.6	15	1	2	3
Fe-Oxide Std + $FeSO_4$	41	36	36	38	42	2.2	2.9	4	15	0.5	0.5	0.5
Fe-Oxide Std + $CaPO_4$	41	37	39	39	42	18	19	21	15	12	13	13
Fe-Oxide Std + KH_2PO_4	41	36	38	32	42	19	20	17	15	12	13	10
$CaPO_4$	41	41	42	43	42	41	40	42	15	14	14	15

The key results of the batch experiments in the context of the removal of U and other contaminants from solution include:

- In the absence of any treatment chemicals, U concentrations in solution remained largely constant over time (39 – 41 µg/L).

- The rusted steel wool was the most efficient U removal treatment which was able to remove approximately 44% of U in solution during the first hour of incubation. Between 1-4 hours there was a decrease in U removal capacity from 44% (1 hour) to 34% (4 hours). Possibly due to re-dissolution with carbonates from increasing dissolved carbon dioxide levels over time.
- The OREAS403 iron ore material was less effective than the rusted steel wool in removing U from solution when applied at either 3g/L or 6g/L. At 3g/L 12% of the U in solution was removed across all sampling intervals. At the higher concentration (6 g/L) between 17–27% of U in solution was removed, with the highest rates of removal after 1 hour incubation.
- The application of $FeSO_4$, $CaPO_4$ and KH_2PO_4 in conjunction with the OREAS403 iron ore material generally had little effect on the efficacy of U removal, with rates similar to those observed when the OREAS403 iron ore material was applied on its own at 3g/L.
- The only exception to this was after 4 hours incubation when KH_2PO_4 was applied in conjunction with the OREAS403 iron ore material. In this instance up to 22% of the U in solution was removed compared to 12% removed in the absence of KH_2PO_4.
- $CaPO_4$ when applied on its own had no effect on U removal, with concentrations slightly increasing over time.
- The rusted steel wool was also effective in removing V and As from solution with removal rates being between 96% and 98%. In this instance, however, the OREAS403 iron ore standard was also efficient at removing V and As from solution at all tested concentrations. This reinforces the idea that Fe-minerals in the native soil profile were the likely mechanism behind the removal of V and As in the laboratory experiments outlined in Section 11.

Based on the composition of the HMB001 bore water (Table 29) and the results of the batch experiments (Table 31), it is likely that the relatively high alkalinity and calcium concentrations in solution favoured the formation of species such as $Ca_2(UO_2)(CO3)_3(aq)$ and $Ca(UO_2)(CO_3)_3^{2-}$ which are labile and unlikely to adsorb to mineral surfaces. The rusted steel wool material was the most effective U removal treatment but is more practically challenging to generate a sufficiently high surface area reagent in large volumes. The steel wool effectiveness may be a result of an increased capacity to reduced U(VI) to U(IV) in the presence of zero valent iron (Fe^0) (Noubactep, 2006), which is generally higher than in materials which are predominantly Fe(II)/Fe(III) based.

12.5 WATER TREATMENT OPTIONS

Based on the results of the laboratory experiments summarised in Sections 11 and 12 the following options are available to De Grey to treat the water prior to discharge.

12.5.1 Removal of Vanadium and Arsenic

Both vanadium and arsenic were effectively removed from solution via interactions with iron oxide materials from existing project area soils (Table 26) or applied as treatment chemicals (Table 31). As outlined in Section 11.5 a soil pond measuring 175 m x 10 m x 2.5 m (L x W x D) is predicted to be effective in lowering V and As concentrations in the discharge water to below relevant default and site/regional specific trigger values (Table 26). The application of iron oxide materials to the discharge water had a similar efficacy with respect to lowering concentrations to below guideline levels (Table 31). This approach, however, requires a significant financial outlay (approximately $19 million in reagents alone, based on an iron ore spot price of $110/tonne (13/6/2024)) and as will be highlighted in the sections below (12.5.2), it will not resolve the issues regarding elevated uranium in the discharge water. Consequently, discharging the water via in soil-ponds appears the most cost-effective means of ensuring that vanadium and arsenic concentrations are not elevated within the Turner River system post discharge

12.5.2 Removal of Uranium

The removal of uranium was, however, far more complex than for vanadium and arsenic as outlined in the experiments detailed in Sections 11 and 12. When held in the soil-pond U concentrations fell from approximately

40 µg/L to 27 µg/L (Table 26). If discharged at a concentration of 27 µg/L the site-specific and region-specific trigger guidelines outlined in Table 16 would be exceeded unless rainfall is also above average over the entire discharge period (Table 32), which is akin to the outcomes if the water underwent no treatment prior to discharge.

The rusted steel wool treatment was slightly more effective than the soil holding pond alone and was able to reduce uranium concentrations to 23 µg/L (Table 31). However, a discharge at this concentration would still exceed the site-specific and region-specific trigger guidelines outlined in Table 16 unless there is also significant rainfall throughout discharge. In addition, this approach would require a multi-million dollar investment in reagents, infrastructure and waste disposal at the conclusion of the dewatering period.

Neither approach is therefore likely to be suitable to ensure that the ecological integrity of the Turner River system is maintained and thus three alternate approaches are proposed and outlined below.

Table 32: Summary of Treatment Results on U, V and As Concentrations in Discharge Water

Analyte	Treatment	Post-Treatment Concentration	Discharge Scenario							
			1 - No flow		2 - Median Rainfall		3 - Mean Rainfall		4 - Extreme Rainfall	
		µg/L	µg/L	%	µg/L	%	µg/L	%	µg/L	%
Arsenic	Soil holding pond	4.0	4.0	64	4.3	51	4.5	29	4.7	9
	Iron oxide	0.5	0.5	96	2.1	75	3.6	44	4.5	14
Uranium	Soil holding pond	27	27	9	19	8	11	6	6.8	3
	Iron oxide	23	23	22	16	20	10	15	6.5	6
Vanadium	Soil holding pond	6.0	6.0	79	5.3	73	4.6	57	4.2	27
	Iron oxide	0.4	0.4	99	1.8	91	3.1	71	3.9	33

% - % improvement compared to no-treatment

12.5.3 Alternate Approaches to Uranium Removal

Given that both of the tested approaches for the removal of uranium from solution prior to discharge were unsuccessful, three other options are considered available to De Grey. These include:

- Treatment of the water via uranium specific ion exchange treatment.
- Selling the water for other mining or agricultural/pastoral use — i.e. no discharge occurs.
- Providing evidence that elevated uranium concentrations pose no ecological threat to the Turner River system in the concentrations that would be seen.

MBS requested Clean TeQ Water Limited (Clean TeQ) provide an estimate regarding the installation of a water treatment system at the Hemi site which utilises ion exchange technology to remove uranium from solution. Based on its current demonstrated use for treating the Yule River catchment water for drinking water supply, it is anticipated that this technology should be able to lower uranium concentrations to approximately 1 µg/L. Characteristics of potential ion exchange treatment options are provided below in Table 33.

Table 33: Summary of Costs for Ion Exchange Treatment for U Removal

Option	Operating Costs (approx.) ($ AUD)	Infrastructure Costs (approx.) ($ AUD)	Waste Volumes (m^3)	Volume of water required for treatment	Concentration of water post discharge (µg/L)	Estimated cost (3 years) ($AUD)
Regenerate resin with NaCl	$70,800/GL/Year	$3.5 million (excludes shipping and installation)	520 m^3/year (liquid)	6.5 GL/year (65%)	10.8 µg/L	$4.88 million*
No resin regeneration replace resin when exhausted	$120,000/GL/Year	$3.2 million (excludes shipping and installation)	40 m^3/year (solid)			$5.54 million*

** costs exclude shipping, installation and waste disposal.*

Although this cost outlay will still be significant it is likely to be much cheaper and more effective than treating the water using iron oxide materials which was expected to cost in excess of $19 million in reagents alone. This treatment could be combined with use of earthen holding ponds to also be effective in lowering vanadium and arsenic concentrations in the discharge water.

Alternatively, the water could be sold/given to another mining or agricultural company given that the water is non-saline and contains no exceedances of livestock or long-term irrigation default guideline values (ANZECC 2000). Some cost outlay would be required in order to transport this water to an alternate site (i.e. pipeline construction), however, these costs are likely to be far less than either of the water treatment approaches.

Finally, there is one final option available to De Grey which is to demonstrate that the discharge water will not have deleterious effects on biota living within the Turner River system. This is based on conducting ecotoxicological tests that expose organisms (ideally from the Pilbara region) from varying trophic levels to the proposed discharge water can be used as evidence to demonstrate (to regulators) that the planned discharge is unlikely to have any deleterious effects on biota within the Turner River. This is considered viable based on the known lower toxicity of uranium in water present as uranyl carbonates (discussed later in report). These tests are likely to cost in the order of $30,000 and thus represent a much lower financial outlay than the other options mentioned above. These tests, however, do still have the potential to be inconclusive or to still require some lowering of uranium to meet the new derived criteria and thus the alternate options in some form detailed above may still be required even if these tests are conducted.

13. RADIATION MODELLING

Given the elevated uranium concentrations in the discharge water and in the Turner River water post-discharge and the exceedance of some radiological criteria (i.e. Gross alpha emissions) ecological radiation modelling using the ERICA and RESRAD programs were conducted to assess risks to organisms that reside in the Turner River and those who use the Turner River as a drinking water source. Radiation modelling results are provided in Appendix 4. Radiation modelling was performed on the proportionally mixed raw bore water concentrations not accounting for any potential decreases in uranium concentrations (and radon gas) by treatment of discharge through soil ponds prior to release as described above.

13.1 SCENARIOS AND ASSUMPTIONS

When selecting representative organisms for both models, the following information was considered:

- Plants and animals that are likely to live or pass through the discharge catchment area and utilise the water.
- The occupancy (i.e. time spent in the water) of plants and animals noted above.
- Whether organisms use the water for drinking.
- The sensitivity of ionising radiation on organisms.

Table 34 provides the assumed occupancy of flora and fauna within the Turner River.

Table 34: Flora and Fauna Occupancy Assumptions

Organism	Occupancy Factor			Details
	Water: Surface	Water	Sediment: Surface	
Amphibian		0.5	0.5	Amphibians such as frogs are assumed to spend 50% of their time within the Turner River, and 50% of their time on the sediment surface.
Bird	0.5			Birds do not live on the river and are assumed to spend up to 50% (conservative assumption) of their time on the water surface for cooling and drinking.
Crustacean (1)*			1	Two separate crustacean types were used in the model: • Crustacean 1 lives completely within the river sediment. • Crustacean 2 lives completely within the water column.
Crustacean (2)*		1		
Reptile		0.5		Reptiles, such as the olive python, are assumed to spend up to 50% of their time within the water. They are ground-dwelling but are found in areas associated with water courses (Perth Zoo, 2023).
Pelagic Fish		1		Fish are water assumed to spend 100% of their time within the river
Vascular Plant			1	Vascular Plants are assumed to grow in the river sediment.
Zooplankton**		1		Zooplankton are assumed to spend 100% of their time within the Turner River.

** Crustaceans have variable life-habits with some species being sediment dwelling and other inhabit the water column/water surface.*

*** Zooplankton are aquatic invertebrates that live in water columns or streams.*

Five scenarios were used in the radiation modelling section which are summarised with their respective assumptions below in Table 35.

Table 35: Scenarios and Assumptions used for Erica and RESRAD Modelling.

<table>
<tr><th colspan="2">Scenario</th><th>Assumptions</th></tr>
<tr><td>1</td><td>• No Rainfall during the 2.5-year discharge period.
• No dilution of discharge water to occur.
• Continual flow from discharge to occur over the 2.5-year period.</td><td rowspan="3">• 100% of drinking water is sourced from discharge by livestock and fauna during this period.
• 100% of typical beef consumption by local residents from livestock in the area.</td></tr>
<tr><td>2</td><td>• Median annual rainfall of 6.3 GL/year during discharge period.
• Dilution ratio of 1:1.27 rainwater to discharge water.
• Continual flow from discharge and rainfall to occur over the 2.5-year period</td></tr>
<tr><td>3</td><td>• Mean annual rainfall of 28 GL/year during discharge period.
• Dilution ration of 1:0.4 rainwater to discharge water.
• Continual flow from discharge and rainfall to occur over the 2.5-year period.</td></tr>
<tr><td colspan="3">Additional Scenarios</td></tr>
<tr><td>4</td><td>Turner River Background
• Background concentrations.
• Dewater discharge does not occur.</td><td>• 100% of drinking water is sourced from river by livestock and fauna during this period.
• Microalgae and invertebrates living in the water and sediment.</td></tr>
<tr><td>5</td><td>Indee Homestead
• Water from Indee Homestead bore (most elevated bore, U 84 µg/L) used exclusively as drinking water by local residents and livestock in the area.</td><td>• 100% of drinking water is sourced from Indee bore by livestock and fauna during this period.
• 100% beef consumption by local residents from livestock in the area.</td></tr>
</table>

13.2 ENVIRONMENTAL RADIATION RISK ASSESSMENT

To quantify the risk, modelling was used to calculate the effective radiation dose rate to representative fauna and flora. The calculated dose rate is compared to an environmental reference level (ERL)/screening value (Section 13.2.2). Where the dose to an organism to be less than the screening level value, it can be concluded that there is no increased risk to biota. If the modelled dose rate is above the screening value, a more refined exposure assessment may be appropriate (e.g. using more detailed site-specific data) (ARPANSA 2015).

The following two scenarios were used in the initial modelling process:

- Scenario 1: Discharge into the Turner River with no rainfall during discharge period — "worst-case scenario".
- Scenario 2: No discharge occurs (i.e. background levels in the Turner River) — "best-case scenario".

13.2.1 Modelling Software

13.2.1.1 ERICA

The ERICA assessment involves estimating or measuring activity concentrations in environmental media and organisms, defining exposure conditions, and estimating radiation dose rates to selected biota. The ERICA database has been built around a number of Reference Organisms, each with its own specified geometry (and default transfer data) and is representative of terrestrial, freshwater or marine systems. There are three tiers of assessments with a Tier 2 assessment utilised in this report.

Tier 2 is a detailed, site-specific risk assessment, using site specific information. At Tier 2, estimated absorbed dose rates for each organism of interest are put into context by comparing to summarised tables of benchmarks for potential radiation effects and to natural background exposure. Any high-risk areas identified will require a more detailed site-specific radiological assessment for identified radionuclides and organisms.

13.2.1.2 RESRAD-BIOTA

RESRAD-BIOTA implements the U.S. Department of Energy's (DOE) graded approach methodology for evaluating radiation doses to aquatic and terrestrial biota. It calculates absorbed radiation doses to various biota organisms, default or user-created, from contaminated environmental media, as well as derives Biota Concentration Guides (BCGs) in terms of medium concentration levels, corresponding to a specific biota absorbed dose limit.

Radiation exposures to biota in a terrestrial or aquatic ecosystem are considered to result from contaminated soil, water, and sediment, which subsequently result in contamination in air and in different food sources. A graded approach that consists of three tiers of analysis is implemented in the RESRAD-BIOTA code. At Level 1, screening BCGs for contaminated soil, water, and sediment that were pre-developed by DOE considering four default categories of organisms—terrestrial animal, terrestrial plant, riparian animal, and aquatic animal—are used for comparison with input environmental media concentrations, to determine the potential that the recommended biota dose limit could be exceeded. At Levels 2 and 3, more site- and organism-specific input data are accepted to perform a more realistic dose calculation for comparison with a specified dose limit. Both external radiation and internal radiation are considered in the dose calculation.

The external dose is calculated considering the time fractions an organism spends close to or in the contaminated media. For internal dose calculation, three options are provided, with measured tissue concentrations, with a lumped medium-to-tissue concentration ratio, or with allometric equations that estimate the maximum tissue concentration considering the inhalation and food intake rate, biological and radiological decay, body weight, and lifetime of the organism. To account for the influence of body size, eight different ellipsoidal geometries each with its own set of dose coefficients are provided for selection.

13.2.2 Screening Values and Modelling Information

The following environmental reference levels refer to dose limits where measurable affects are noted at a population level. Below these values (of chronic exposure) no measurable population effects would occur (IAEA 1992). They were selected as screening levels for the radiation modelling:

- 40 µGy/h terrestrial animals, birds, amphibians and reptiles.
- 400 µGy/h plants and other aquatic organisms.

Additional information used for the modelling include (ANZECC, 2000):

- Livestock drinking water consumption: 45 L/day.
- Body weight of beef cattle: 800 kg.
- Large bird drinking water consumption: 0.32 L/day.
- Body weight of large bird (i.e. chicken): 2.8 kg.

- Reptile drinking water consumption: 0.1 L/day.
- Body weight of olive python: 15 kg (Perth Zoo, 2023).

13.2.3 Results

A tier 2 site-specific ERICA model was used to determine dose rates to flora and fauna based on occupancy within the Turner River for background and no flow conditions. Table 36 presents the ERICA model findings for the two scenarios.

The modelled dose rates were below the relevant radiological screening values in both scenarios for all organisms. No measurable population effects are therefore expected to occur as a result of radiation impacts on any organism occupying the Turner River from the discharge.

Table 36: Summary of Modelled Dose Rates for Flora and Fauna (Occupancy)

Organism	Occupancy Factor			Scenario	Scenario 1: No Flow	Background: Turner River
	Water: Surface	Water	Sediment: Surface	Screening Value (µGy/h)	Total Dose (µGy/h)	Total Dose (µGy/h)
Amphibian		0.5	0.5	40	13.3	2.18
Bird	0.5			40	31.5	5.28
Crustacean (1)			1	400	6.96	1.1
Crustacean (2)		1		400	3.45	0.53
Reptile		0.5		40	14.2	2.38
Pelagic Fish		1		400	6.49	1.08
Vascular Plant			1	400	11.7	1.83
Zooplankton		1		400	271	45.4

RESRAD-biota modelling was undertaken to determine the dose rate to local fauna and livestock drinking from the Turner River. Table 37 presents the RESRAD-biota model findings for the two scenarios.

Three main terrestrial organisms were modelled using RESRAD-Biota:

- Cattle: Beef Cattle.
- Large Bird (similar to duck or chicken).
- Reptile (similar to the known Olive Python which is known to inhabit the area).

The modelled dose rates were below the relevant screening values in both scenarios for all organisms. No measurable population effects are likely to occur as a result of radiation impacts on any organism consuming water the turner river.

Table 37: Summary of Modelled Dose Rates for Fauna and Livestock (Drinking Water Consumption)

Organism	Weight (kg)	Water Intake Rate (L/day)	Screening Value (µGy/h)	Scenario 1 No Flow	Scenario 4 Turner River: BG
				Total Dose (µGy/h)	Total Dose (µGy/h)
Cattle: Beef Cattle	800	45	40	0.012	0.00044
Bird (Large)	2.8	0.32	40	0.006	0.00019
Reptile	15	0.1	40	0.006	0.0002

The results of the ERICA and RESRAD-biota were combined to determine total dose from both occupancy and drinking water for a bird and reptile (Table 38).

Table 38: Calculated Total Dose Rate for Large Birds and Reptiles

Details		Total Dose (µGy/h)	
		Scenario 1 (No Flow)	Scenario 4 (Background)
Large Bird			
Occupancy	0.5 (50%) Water Surface	31.50	5.28
Water Intake (100%)	0.32 L/day	0.006	0.00019
Total Dose Rate		31.51	5.28
Reptile			
Occupancy	0.5 (50%) Water	14.20	2.38
Water Intake (100%)	0.1 L/day	0.006	0.0002
Total Dose Rate		14.21	2.38
Screening Dose Rate		40	40

The total dose rates associated with occupancy and water consumption for a large bird and reptile were below the screening dose. The radiological risk to flora and fauna is considered low even at the most conservative, Scenario 1 where water in the river comprises pure untreated dewater discharge only. As such, no other scenarios were modelled.

13.3 HUMAN HEALTH RADIATION RISK ASSESSMENT

The effective dose rates to adults and children were calculated for two “worst-case” scenarios:

- Turner River water source during discharge with no rainfall (Scenario 1).
- Indee Homestead well water source (Scenario 5) — Indee Homestead being the most elevated uranium groundwater bore measured (possibly depth related, no information on this was available).

13.3.1 Screening Values and Modelling Information

The effective dose limit for public exposure in Australia is 1 mSv per year (ARPANSA 2018). This dose limit was used as the human health screening value.

Both scenarios assume:

- 100% of drinking water for both local community and livestock is from the specific scenario water source.
- 100% of beef consumption by the local community is from the livestock drinking from the water source.

Additional information used for the calculations include:

- Livestock drinking water consumption: 45 L/day (ANZECC, 2000).
- Human drinking water consumption: 2 L/day (NHMRC, 2022).
- Tissue activity concentration within meat products: determined via RESRAD-biota modelling.
- Human consumption of meat products: 50 kg/year (adult) and 35 kg/year (child) (UNSCEAR, 2000).
- Effective Dose Coefficients (UNSCEAR, 2000):
  - Ra-226: 0.28 µSv/Bq (Adult) and 0.80 µSv/Bq (Children).
  - U-238: 0.05 µSv/Bq (Adult) and 0.07 µSv/Bq (Children).

13.3.2 Results

The calculations indicate that even at the worst-case scenario, the effective annual dose is significantly below the public dose limit of 1 mSv/year (ARPANSA 2018). Overall, the risk to human health from a radiation perspective is considered very low being at least four-fold below the public dose limit for the worst case scenario (children, Indee Homestead bore).

Table 39: Human Health Annual Effective Dose Rates (Scenario 1)

Total Human Consumption Dose Rates		
Consumption Type	Annual Effective Dose (mSv)	
	Adult	Children
Water Consumption	0.0181	0.0345
Beef Consumption	0.0005	0.0012
Total	0.0186	0.0357
Public Dose Limit	1	1

Table 40: Human Health Annual Effective Dose Rates (Scenario 5)

Total Human Consumption Dose Rates		
Consumption Type	Annual Effective Dose (mSv)	
	Adult	Children
Water Consumption	0.1301	0.212
Beef Consumption	0.0064	0.0179
Total	0.1365	0.2301
Public Dose Limit	1	1

14. LITERATURE REVIEW — URANIUM AND VANADIUM ECOTOXICOLOGY

As outlined in Section 9, five contaminants of potential concern (CoPC) were identified for this project which included: arsenic, copper, uranium, vanadium and zinc. Contaminants such as arsenic, copper and zinc are well understood environmentally with multitudes of toxicological and field studies performed that detail typical concentrations present environmentally, their speciation in the environment, their typical speciation and fate in the environment. Elements such as uranium and vanadium, however, are less well understood with respect to their potential environmental effects and fate(s) in natural ecosystems. This section summarises available literature on both uranium and vanadium with respect to:

- Typical concentrations and species present in the environment.
- Known ecotoxicological effects.
- Interactions with soil components.
- Species sensitivity distributions (SSD) and calculated default guideline values (DGVs).

14.1 URANIUM

Uranium is the heaviest metal in nature. It has 14 natural isotopes all of which are radioactive. Uranium is chemically very active and has the potential to react with most elements. It can form oxides as either UO_2 or U_3O_8. Typically, uranium is present as Uranium (IV) or Uranium (VI) environmentally (Del Carmen Llamas, 2005). Uranium (VI) is the dominant species under oxygenated (oxic) conditions. In most typical environments where the pH >5 $(UO_2)_3(OH)^{5+}$ is the dominant form, with this species also known to form complexes with halogens (chloride, fluoride) and various oxo-anions such as nitrate, sulfate, perchlorate, phosphate and carbonate (Del Carmen Llamas, 2005). Uranium is present in a number of minerals with the most important being uranite (U_3O^8), carnotite ($K_2(UO_2)2(VO_4)2 \cdot 3H_2O$), koffinite ($U(SiO_4)1–x(OH)4x$), and brannerite ($UTi_2O_6$) (Fuller et al., 2020).

In natural groundwaters uranium concentrations typically range from 0.1–10 µg/L, whilst the typical concentration in seawater is approximately 3 µg/L (Del Carmen Llamas, 2005). In soils, background concentrations typically range from 0.1–11 mg/kg (Fuller et al., 2020). The composition of soils has a significant effect on uranium concentrations with concentrations in coarse grained soils (<0.3 mg/kg) typically much lower than those in finer grained/clay rich soils (approx. 10.7 mg/kg) (Fuller et al., 2020).

Unlike most metal(loid) contaminants, uranium has two main forms of toxicity which includes the chemical toxicity of soluble uranium species with the second being the inherent radioactivity of uranium (Schott, 2003). The potential for radiological effects were thus also investigated in the previous section.

Soluble uranium species such as UO_2^{2+} are known to affect the function of internal organs (especially kidneys) in animals whilst they can also have deleterious effects on the growth and reproductive capacity of plants (Fuller et al., 2020). In general, however, the uptake and translocation of uranium from roots to above-ground plant tissues is limited, with the bulk of uranium being either absorbed within or adsorbed on root tissues (Del Carmen Llamas, 2005). The toxicity of uranium is manifested in oxidative stress and a misbalance in the redox system of cells (Del Carmen Llamas, 2005).

Uranium is an alpha emitter and thus if consumed it has the potential to damage cellular functions such as permeability, mobility, protein synthesis, and mitotic cycles (Del Carmen Llamas, 2005). Macromolecules like deoxyribonucleic acid, proteins and polypeptides are particularly affected (Del Carmen Llamas, 2005). The radiation doses to osteo-progenitor cells (stem cells), living bone surfaces and the bone marrow are usually considered to be of greater biological significance than doses absorbed by other tissues, due to the fact that they can produce bone sarcomas and leukaemia (Del Carmen Llamas, 2005).

Despite having two distinct modes of toxicity most studies have proposed that the chemical toxicity of uranium exceeds the radiological toxicity (Sheppard et al., 2005; Zeman et al., 2008). This is attributed to the fact that alpha particles have a limited ability to penetrate through skin and thus the main radiation risk relates to the consumption of these particles in drinking water (Sheppard et al., 2005; Zeman et al., 2008). Consequently, for truly aquatic species the chemical toxicity of uranium likely exceeds the radioactive toxicity, whereas for higher organisms that utilise aquatic environments as a drinking water source the radioactive toxicity and chemical toxicity are both of potential significance (Sheppard et al., 2005; Zeman et al., 2008).

The affinity of uranium to form complexes with various ions is one of the major factors in its adsorption in soils. Studies have demonstrated that uranium sorption is rapid, with a significant proportion (approx. 90%) removed from solution within a few hours (Willet and Bond, 1995). Uranium has been shown to interact with a number of soil components including clay materials, aluminium and iron oxides, organic matter and microorganisms all off of which are able to remove large uranium concentrations from solution (Barnett et al., 2000; Tipping, 1996; Willet and Bond, 1995; Zhang et al., 1997). These interactions are, however, reversable with uranium shown to be re-solubilised when pH conditions are either highly acidic or alkaline. In the context of this work there are a number of examples of treatment ponds being used to remove uranium from solution (Amrhein et al., 1993; Batson et al., 1996; Ribera et al., 1996; Fellows et al., 1998).

As outlined earlier, a number of environmental criteria have been developed for uranium. In addition to these criteria Hemi site-specific 'action' (5.6 µg/L) and 'trigger' (12.2 µg/L) values and regional-specific 'action' (12.1 µg/L) and 'trigger' (19.2 µg/L) values have been developed for the project as detailed in Table 24. In order to provide further insights into the potential toxicity of uranium in aquatic environments, a species sensitivity distribution (SSD) was generated based on ecotoxicological data found within the EPA ecotoxicology database (EPA, 2023). A limited number (19) of peer-reviewed published ecotoxicological studies focusing on uranium toxicity were reviewed to provide a basis for calculating freshwater ecosystem protection level concentrations in accordance with Australian and New Zealand Guidelines for Fresh and Marine Water Quality protocols (ANZG 2018b).

The review data included 23 species and/or species assemblages which covered the following taxonomic groups: algae, crustaceans, insects/spiders, invertebrates, fish, amphibians, molluscs and aquatic plants. Both chronic (e.g. EC_{50}, LOEC) and acute (e.g. LC_{50}) endpoint concentrations were adjusted to chronic EC_{10}/NOEC equivalents using the default acute-to-chronic ratios (ACRs) provided in Batley et al., (2018); ACR of 2.5 from LOEC; ACR of 5 from EC_{50} and ACR of 10 from LC_{50}. The adjusted endpoint values were used to perform a generalised species sensitivity distribution (SSD) analysis using the statistical package, Burrlioz V.2 (Barry and Henderson 2014), following guidance provided in ANZG (2018b). The graphical output of the sensitivity distribution is shown in Figure 6.

Based on the SSD approach, these published values indicate (Figure 6 line of best fit) uranium trigger values of:

- 99% freshwater ecosystem protection = 0.087 µg/L.
- 95% freshwater ecosystem protection = 2.5 µg/L.
- 90% freshwater ecosystem protection = 10 µg/L.
- 80% freshwater ecosystem protection = 44 µg/L.

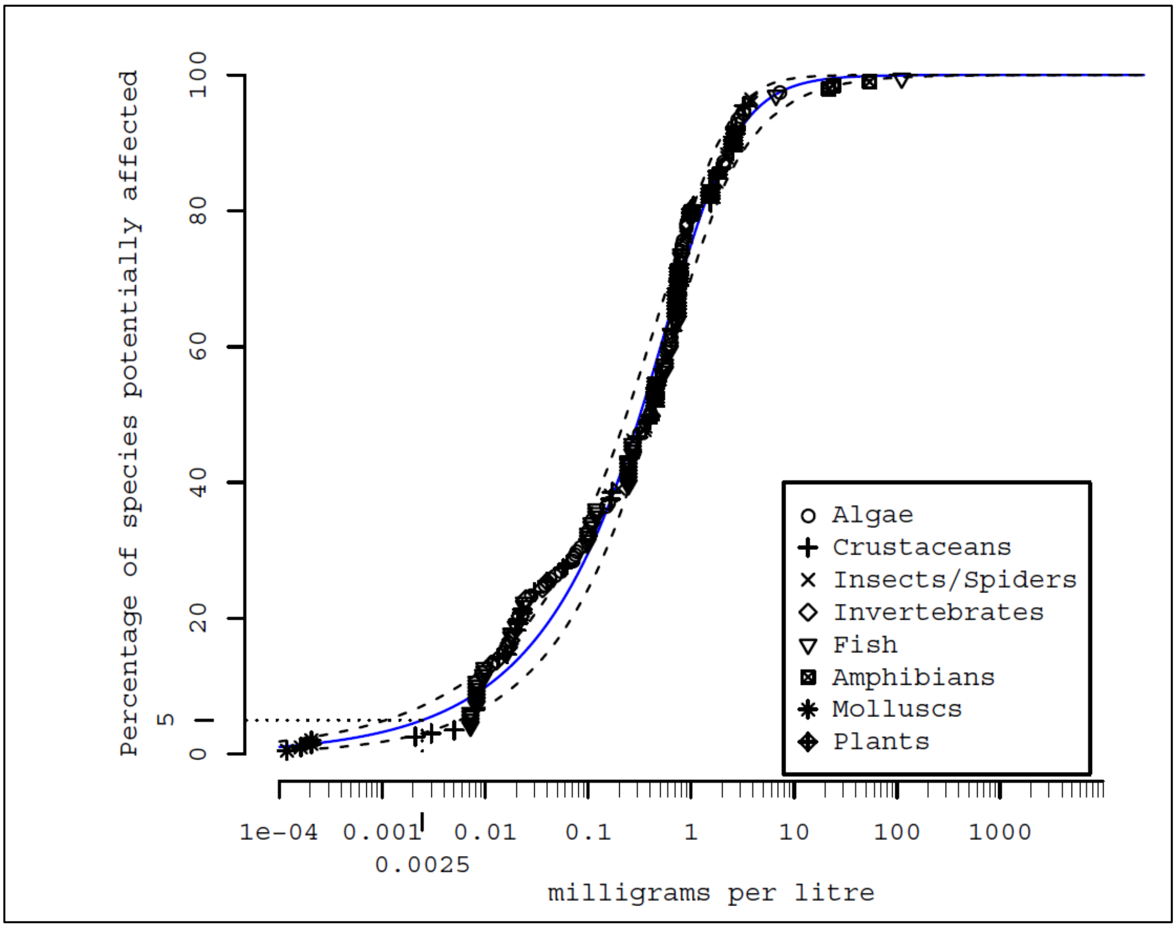

Figure 6: Species Sensitivity Distribution (SSD) Plot for Uranium

As stated earlier, the results of the SSD presented in Figure 6 should be viewed conservatively given the limited number of species (and studies) assessed plus the fact that the majority of species were from the northern hemisphere and are not necessarily reflective of the species that inhabit the Pilbara region of Western Australia. Conversely effects of form (namely uranyl carbonate complexes at higher alkalinity) which is indicated to reduce toxicity have not been accounted for due to the lack of uranium-carbonate exposure experiments in the published literature. If we are to use the ecosystem protection values generated in Figure 6, however, the 95% and 90% protection values of 2.5 and 10 µg/L are in the same order of magnitude as the calculated site- and region-specific values outlined in Table 8. The calculated 95% species protection vales were much higher than the ANZG (2018) low reliability freshwater species protection value of 0.5 µg/L.

As outlined in Table 18, raw discharge water is predicted to contain U concentrations between 28–31 µg/L. Based on the results of the SSD in Figure 6, this would result in a species protection level of approximately 83%.

14.2 VANADIUM

Vanadium is a relatively abundant element with a very wide distribution which accounts for 0.01% of the earth's crust (Costigan et al., 2001). Vanadium is present in a range of minerals such as vanadinite, chileite, patronite, and carnotite. Titaniferous magnetites containing 1.5–2.5% vanadium pentoxide are mined in countries including South Africa, Russia, and China (Costigan et al., 2001).

Vanadium can exist in a range of oxidation states for -1 to +5. Vanadate (Vanadium (V)) is the dominant species present under oxic and circum neutral conditions whilst vanadyl (Vanadium (IV)) can occur under both acidic and mildly reducing conditions (Bennett, 2016).

Vanadium concentrations in ground and surface water are generally <1 µg/L, with average seawater concentrations slightly higher at approximately 1.8 µg/L. Background soil concentrations are typically in the realm of 100 mg/kg (Gustaffson, 2019).

As is the case with most trace elements vanadium can be both beneficial and toxic to biota. Vanadate is likely to have a greater toxicity than vanadyl which has been attributed to the structural similarities between Vanadate and phosphate (Gustaffson, 2019). It has been proposed that due to this similarity vanadate can be accumulated through phosphate uptake pathways in plants and also act as a substitute for phosphate in a range of biochemical processes that occur in both plants and animals (Gustaffson, 2019). For example, some studies have shown that any phosphatase enzymes (which catalyse the hydrolysis of organophosphate ester bonds) are inhibited by vanadate(V), likely due to its ability to form a complex at the active site of the enzyme (Gustaffson, 2019). In addition, vanadate could also inhibit ATP synthesis whilst there is also evidence that exposure to elevated vanadium concentrations can inhibit ionic balances and thus alter the ability of fish to osmoregulate and deal with oxidative stress (Valko et al., 2005).

Unlike uranium, vanadium has been shown to have some beneficial functions in selected plant and animal species, although it does not have a direct biological function (Gustafsson, 2019). For example, numerous studies have demonstrated that vanadium nitrogenase can be used as a catalyst for biological nitrogen fixation in plants, whilst vanadate-dependent haloperoxidases (VHPOs), catalyse the oxidation of halides by H_2O_2 in macroalgae, fungi, and bacteria (Gustafsson, 2019). Several macroalgae species have been shown to have Vanadium-dependent iodoperoxidases, which area means of oxidising iodine compounds which assists these organisms in avoiding bacterial attack (Tripathi et al., 2017).

As is the case for uranium there are numerous mechanisms by which vanadium is adsorbed by components of soils. In the literature there are numerous examples of vanadium species adsorbing on iron (III) and aluminium (III) oxides (Gustafsson, 2019), and on organic matter (Shiller and Mao, 2000). The structural similarities between vanadate and phosphate make it unsurprising that the fate of both compounds in soils is similar. Some studies have also noted that the sorption of vanadium is higher under acidic conditions (Gustafsson, 2019).

As outlined earlier (Section 7) a number of environmental criteria have been developed for vanadium. In addition to these, a Hemi site-specific 'action' (8.6 µg/L) and 'investigation trigger' (10.5 µg/L) values and regional-specific 'action' (9.6 µg/L) and 'investigation trigger' (11.0 µg/L) have been developed for the project as detailed in Table 24. In order to provide further insights into the potential toxicity of uranium in aquatic environments a species sensitivity distribution (SSD) was generated on ecotoxicological data found within the EPA ecotoxicology database (EPA, 2023).

The review data included 47 species and/or species assemblages which covered the following taxonomic groups: algae, crustaceans, invertebrates, fish, amphibians, molluscs and worms. Both chronic (e.g. EC_{50}, LOEC) and acute (e.g. LC_{50}) endpoint concentrations were adjusted to chronic EC_{10}/NOEC equivalents using the default acute-to-chronic ratios (ACRs) provided in Batley et al., (2018); ACR of 2.5 from LOEC; ACR of 5 from EC_{50} and ACR of 10 from LC_{50}. The adjusted endpoint values were used to perform a generalised species sensitivity distribution (SSD) analysis using the statistical package, Burrlioz V.2 (Barry and Henderson 2014), following guidance provided in ANZG (2018b). The graphical output of the sensitivity distribution is shown in Figure 7.

Based on the SSD approach, these published values indicate (Figure 7 line of best fit) vanadium trigger values of:

- 99% freshwater ecosystem protection = 0.87 µg/L.
- 95% freshwater ecosystem protection = 13 µg/L.
- 90% freshwater ecosystem protection = 42 µg/L.
- 80% freshwater ecosystem protection = 140 µg/L.

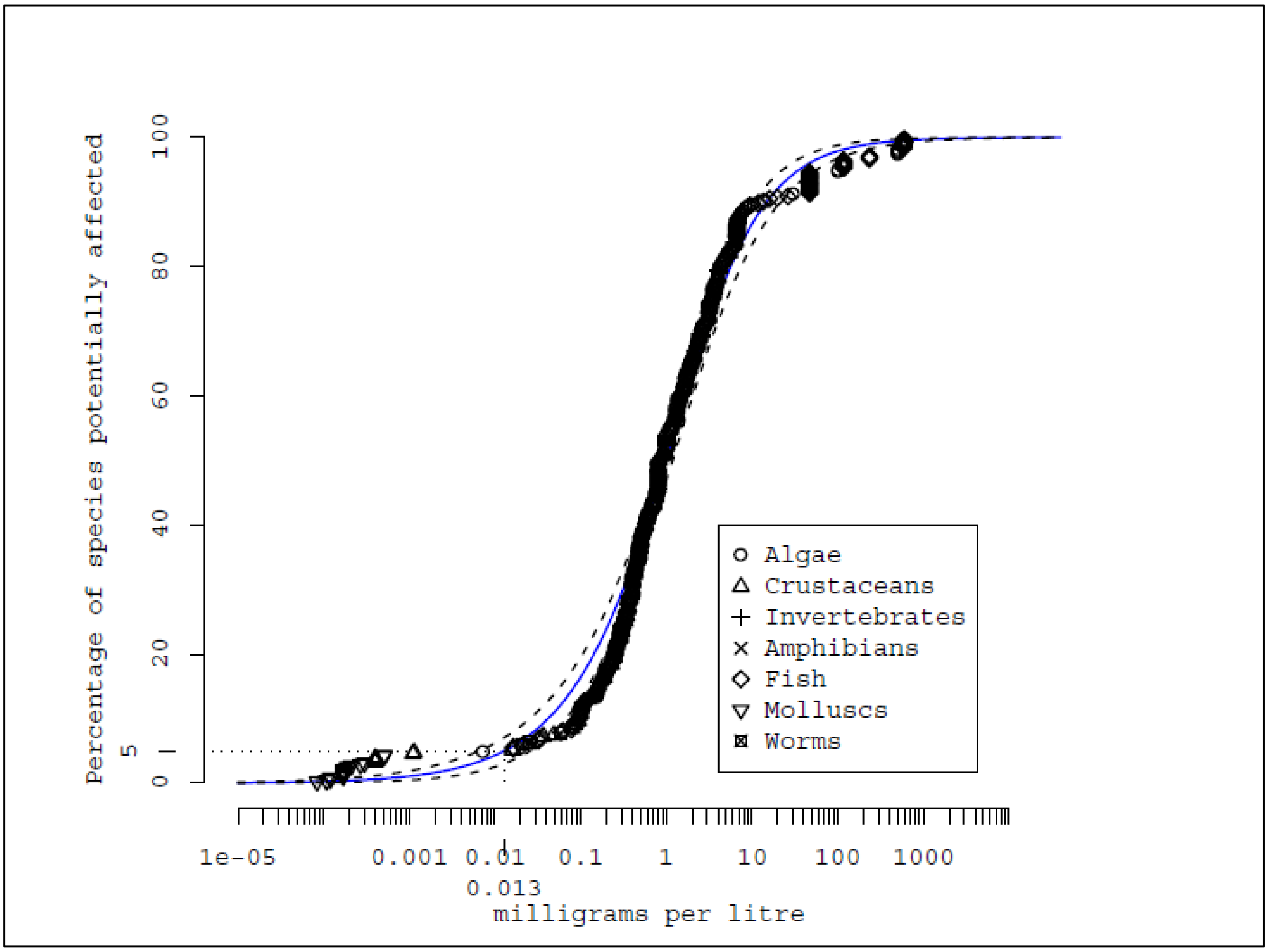

Figure 7: Species Sensitivity Distribution (SSD) Plot for Vanadium

As stated earlier, the results of the SSD presented in Figure 7 should be viewed conservatively given the limited number of species (and studies) assessed plus the fact that the majority of species were from the northern hemisphere and are not necessarily reflective of the species that inhabit the Pilbara region of Western Australia. If we are to use the ecosystem protection values generated in Figure 7, however, the 95% species protection value of 13 µg/L is largely equivalent to the site and regional specific vales outlined in Table 8. The calculated 95% species protection value is more than double the low reliability ANZG (2018) freshwater protection value of 6 µg/L (a similar result to uranium discussed above).

As outlined in Table 18, non-treated (i.e. holding tank or plastic lined ponds without contact to iron sources) discharge water is predicted to contain vanadium concentrations between 28 and30 µg/L. Based on the results of the SSD in Figure 7, this would result in a species protection level of approximately 92%. If the water is treated through earthen ponds prior to discharge, vanadium concentrations are predicted to fall to <11 µg/L which would result in a greater than 95% species protection rate.

15. TIER 2 ENVIRONMENTAL RISK ASSESSMENT

A Tier 2 ERA was undertaken based on data and modelling generated in the previous sections of this report. The following sections describe the risk characterisation methodology and summarise the results. Full results of the Tier 2 ERA are presented in Appendix 6.

15.1 METHODOLOGY

The assessment was completed with consideration of the International Standard ISO 31000:2018: 'Risk Management — Guidelines' (ISO 2018) and Schedule B5a of the NEPC (2011) program. Risk was determined based on an assessment of the consequence and likelihood of a potential impact. This approach is outlined further in the following sections.

15.1.1 Consequence Scale

A number of aspects were considered in determining the consequence of each potential impact, including:

1. Type of impact (direct or indirect).
2. Geographic extent, size and scale.
3. Duration, frequency and reversibility of the potential impact.
4. Whether the potential impacts are from planned or unplanned events.
5. Sensitivity of the receptor/resource and the value of the receptor/resource.

Based on the above criteria five (5) consequence ratings were utilised in the ERA as outlined below in Table 41.

Table 41: Tier 2 ERA Consequence Ratings

Consequence Scale		Explanation
5	Catastrophic	• Severe environmental impact. • Local species destruction and likely long recovery period. • Extensive cleanup involving external resources. • Impact on a regional scale.
4	Major	• Major environmental impact. • Considerable cleanup effort required using site and external resources. • Impact may extend beyond the lease boundary.
3	Moderate	• Moderate environmental impact. • Cleanup by site staff and/or contractors. • Impact confined within lease boundary.
2	Minor	• Low environmental impact. • Rapid cleanup by site staff and/or contractors. • Impact contained to area currently impacted by operations.
1	Insignificant	• No or very low environmental impact. • Impact confined to small area.

15.1.2 Likelihood Scale

Likelihood is the probability of a stressor impacting on an environmental factor. Where practicable, likelihood was quantified based on quantitative information or data. Definitions for likelihood are presented in Table 42.

Table 42: Tier 2 ERA Likelihood Scale

Likelihood Scale		Explanation
A	Almost Certain	The event is expected to occur in most circumstances.
B	Likely	The event should occur and there is a higher percentage chance that it will occur.
C	Possible	The event could occur, but there is a higher percentage chance that it will not occur.
D	Unlikely	The event could occur, but it is very improbable.
E	Rare	The event is extremely unlikely, only a slight chance of occurring.

15.1.3 Inherent and Residual Risk

Inherent risks were determined by assessing the likelihood and consequence of an impact before the application of mitigation or management measures. The residual risks were then determined taking into account the application of any recommended mitigation and management measures. The level of risk (both inherent and residual) was determined using the matrix shown in Table 43 , with the definitions of risk levels outlined in Table 44.

Table 43: Tier 2 ERA Risk Level Matrix

Likelihood		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
		1	2	3	4	5
Certain	A	11	16	20	23	25
Likely	B	7	12	17	21	24
Possible	C	4	8	13	18	22
Unlikely	D	2	5	9	14	19
Rare	E	1	3	6	10	15

Table 44: Tier 2 ERA Risk Level Definitions

Risk Assessment Score	Risk level	Risk Treatment Criteria
1-6	Very Low	No further controls required
7-11	Low	Pro-active monitoring controls required
12-16	Medium	Pro-active monitoring and engineering controls
17-22	High	Substantial engineering controls required to mitigate impacts
23-25	Very High	Unacceptable, modification of proposal required

15.2 ERA RESULTS

The major focus of the Tier 2 ERA was to explore the risks related to the discharge of excess groundwater to the Turner River. In this context the main considerations included the:

- Release of Metal/Metalloid Contaminants into the Turner River system.
- Release of Radioactive Materials into the Turner River system.
- Loading of Metal/Metalloid Contaminants in Turner River sediments.
- Loading of Radioactive Materials in Turner River sediments.
- Significant Changes to the Hydrology of the Turner River system.

15.2.1 Release of Metal/Metalloid Contaminants into the Turner River System

The ecological significance of the potential water column loading of the Turner River with metal/metalloid contaminants as a result of the proposed discharge is heavily dependent on rainfall that occurs within the catchment during the discharge period. Based on the data generated in this assessment, the receptor most likely to be affected by the discharge of metal(loids) into the Turner River was aquatic biota that reside fully within the river system itself. The inherent risk to these organisms was adjudged to be high (17) largely because elements such as uranium and vanadium in untreated groundwater discharge were likely to considerably exceed both the ANZG (2018), low-reliability freshwater species protection guideline and the calculated Turner River and regional 'interim' site specific guideline values (Table 19).

A number of potential controls/environmental factors were identified that had the potential to reduce the inherent risk to low (8) which included:

- Holding discharge water in soil-based ponds prior to discharge as outlined in section 11, which was demonstrated to be successful to lower concentrations of vanadium and arsenic in the discharge water.
- Treating the water chemically via dosing with iron oxide minerals which was also successful in lowering concentrations of vanadium and arsenic in the discharge water (Section 12)
- Treating the water via ion-exchange to lower uranium concentrations in the discharge as outlined in section 12. A pre-treatment earthen pond to this would also remove the arsenic and vanadium.
- In addition to these, if the discharge were to occur during a period of above average rainfall in the catchment, it is likely the dilution effects would lower concentrations to below the site and regional trigger values (See section 9.2). The key criteria for this scenario is to reduce the final uranium concentration below the regional trigger of 12.1 µg/L.

The inherent risk to other identified receptors such as, terrestrial fauna (inc livestock), floodplain soils/vegetation and downstream water users was much lower largely due to predicted concentrations in the Turner River being well below any animal/human drinking water trigger values and that flooding of adjacent soils was considered unlikely to occur even under extreme rainfall scenarios. Despite the low inherent risks, the treatment of discharge water as outlined above would further reduce environmental risks resulting in them becoming largely insignificant.

15.2.2 Release of Radionuclide Materials into the Turner River System

At a conceptual level, the release of uranium into the Turner River from the discharge could have affected the health of organisms who utilise the river as a habitat or drinking water source due to the radioactive effects of uranium. Uranium, being an alpha emitter has the potential to have significant health effects if ingested (as drinking water).

Despite uranium and gross alpha activity concentrations exceeding the ANZECC (2000) livestock drinking water guideline values (which are screening values), the results of ERICA and RESRAD-BIOTA modelling in Section 13 suggests that the radiological effects of the potential discharge would have no measurable effect on populations of organisms who typically reside in the Turner River or utilise it as a drinking water source even if discharge water was their only source and 100% residence time. As a result of this modelling, the inherent risk was classified as low (<6). The removal (or reduction) of uranium concentrations via the addition of iron oxide or other treatment (ion exchange) as outlined in Section 10.2 is likely to further reduce the residual risk, resulting in classification as 'very low'.

15.2.3 Loading of Metal/Metalloid Contaminants in Turner River Sediments.

The loading of metal(loid) contaminants in sediments of the Turner River was considered to have a low inherent risk to receptors such as sediment and aquatic biota for the following reasons:

- Background concentrations of metal(loids) in Turner River sediments are low and well below the ANZG (2018) default guideline values for relevant elements. The proposed discharge would be likely to add some arsenic, copper and zinc to Turner River sediments, however, concentrations are likely to be environmentally insignificant based on the ANZG (2018) default guideline values for soils and sediment.
- Under low rainfall conditions, concentrations of uranium and vanadium could increase by up to 0.3 mg/kg over the 50-km inundation area. This is based on untreated water concentrations and assuming full sorption into the upper 10 cm of river sediment. Use of earthen ponds (vanadium) and ion exchange (uranium) would further reduce sediment loading.
- The significance of these results can be considered based on:
  - Whether uranium and/or vanadium will end up within sediments or will migrate to groundwater below the river channel. For uranium it is most likely given all observed results and literature that it will mostly remain dissolved and return to the surficial groundwater.
  - Based on the results presented in section 11 it would appear likely that vanadium will end up associated with sediments due to strong interactions with iron minerals. The increase in concentration however (0.3 mg/kg) is small compared to regional trigger values (29.3 mg/kg) and a DWER 2010 default ecological investigation level of 50 mg/kg. .
  - Uranium concentrations in sediments would likely increase from existing Turner River site background levels (particularly near discharge point) but assessed on a regional scale, the increase in uranium concentrations will at worst case, not exceed the regional guideline values (2.8 mg/kg or 3.8 mg/kg).
- As detailed in the previous Sections (15.2.1 and 15.2.2) the treatment of discharge water (in soils ponds, holding tanks or via iron oxide or ion exchange) prior to discharge and the inherent variability in annual rainfall within the catchment are both likely to lower the residual risk (to very low) as a result of lowering contaminant concentrations at the kg soil scale as result of dilution and expansion of the inundation area.

15.2.4 Loading of Radionuclides in Turner River Sediments

The loading of radionuclides in sediments of the Turner River was considered to have a low to very low inherent risk to receptors such as sediment and aquatic biota for the following reasons:

- Although uranium concentrations are elevated with respect to livestock/human drinking water guidelines the relatively short duration of the discharge makes the accumulation of radionuclides in sediment to a point that biota will be affected is unlikely.
- In addition, uranium is unlikely to have a significant effect on biota in a radiological sense given that the main mode of action is via ingestion rather than via skin penetration, which is the most plausible effect for sediment and aquatic biota. This was indicated by radiological screening using ERICA modelling.

- As detailed in the previous sections (15.2.1 and 15.2.2), any treatment of discharge water (in holding ponds or chemically) prior to discharge and the inherent variability in annual rainfall within the catchment are both likely to lower the residual risk (to very low) as a result of lowering uranium (and therefore radionuclide) concentrations in the discharge water via removal/dilution.

15.2.5 Changes to Hydrology of Turner River System

In an environmental context, the risk of significant change to the hydrology of the Turner River system as a consequence of the planned discharge was adjudged to be in the very low to low range (1–8). The main reason for the low classification was that the planned discharge is expected to inundate only the main 90-m to 150-m channel within the 1.5-km full width of the river. Consequently, only approximately 6% to 10% of the river area is likely to be influenced by the discharge which will almost certainly not have significant ecological effects at the regional scale.

16. SUMMARY AND MANAGEMENT IMPLICATIONS

The following sections highlight the major findings of the Tier 2 ERA on the proposed discharge of groundwater from the Hemi site into the adjacent Turner River system. These findings are discussed with respect to the concentrations of metals/metalloids and radionuclides entering the Turner River system as well as the ecological effects of the planned discharge. In addition, suitable approaches to manage the discharge to minimise potential ecological effects are discussed.

16.1 METALS AND METALLOIDS

The major findings with respect to metals and metalloids within the discharge water includes:

- Monitoring bores that are reflective of those to be used in pit dewatering were observed to contain concentrations of uranium, vanadium, zinc and to a lesser extent arsenic and copper that exceeded either the ANZG (2018) low reliability (limited toxicity data) freshwater species protection guideline (vanadium and uranium) or the 95% freshwater species protection guideline (arsenic, zinc, copper) used as screening values.
- Groundwater throughout the project area has a high hardness value of 273 mg/L (as $CaCO_3$) which results in copper and zinc concentrations in groundwater being well below the hardness modified 95% freshwater species protection guidelines as outlined in Table 12. This is also likely to lower the toxicity of other potential contaminants (uranium, vanadium), however, there is no publicly available data to support this claim given limited studies on these elements.
- When water from these bores was proportionally combined for eventual proposed discharge into the Turner River, it was calculated that specifically uranium and vanadium concentrations would overall exceed the relevant ANZG (2018) freshwater species protection (low reliability) guidelines for uranium (0.5 µg/L) and vanadium (6 µg/L). The calculated regional and Turner River site-specific guideline values (Table 18) were also exceeded.
- Surface water from the Turner River typically contained a mean uranium concentration of 5.3 µg/L, well in excess of the low reliability ANZG (2018) freshwater species protection value of 0.5 µg/L, which implies that uranium is naturally elevated within the local environment. Other contaminants of interest such as arsenic and vanadium were typically present in concentrations at or below relevant environmental criteria with only particular maximum results exceeding.
- Uranium concentrations in the Yule River (mean 8.7 µg/L, maximum 58 µg/L) were notably higher than those in the Turner River, however the Yule River is considered analogous for environmental values (biota species etc.).
- River sediment concentrations of major metal(loid) contaminants were low and were typically well below the default ANZG (2018) sediment quality guideline values with the exception of nickel in Yule River sediment associated with mafic/ultramafic derived soils/sediments.
- The potential loading of metal(loid) contaminants into the Turner River of untreated raw groundwater was assessed over four scenarios in which the discharge would occur in conjunction with: a) no rainfall; b) median annual rainfall; c) mean annual rainfall and; d) maximum recorded annual rainfall within the catchment.
- The proposed wetting front into one channel of the Tuner River was predicted (Geowater 2023) to extend 50 km downstream in the absence of rainfall (dry season) within the catchment during the discharge period. Under this scenario, uranium and vanadium concentrations in the Turner River near the discharge point would be between 3-6-fold higher than the site and regional-specific trigger and action values outlined above. In addition, under this scenario uranium and vanadium concentrations in Turner River sediments from untreated groundwater discharge may also increase by an average of 0.3 mg/kg (conservative, assumes 100% sorption) over the predicted length of the discharge. This sediment loading was not considered to represent a significant risk given background and default criteria for uranium and vanadium in soils. It must be noted, however, that concentrations in water column and sediments will be higher closer to the discharge

as some attenuation is likely the further the discharge moves downstream (which for uranium would include mixing with groundwater).

- If median rainfall were to occur during the discharge period (approx. 6.3 GL in catchment/year) uranium and vanadium concentrations from discharge of completely untreated groundwater in the Turner River would still exceed calculated interim regional and site-specific trigger and action values. In an average rainfall year, however, only uranium concentrations are likely to exceed the site and regional trigger values outlined above. Vanadium concentrations, however, are likely to fall below the site and regional trigger values in average rainfall years.
- Laboratory tests and PHREEQC modelling demonstrated that vanadium (and arsenic) had a strong affinity for iron oxide materials and thus could be readily removed from solution (final concentration <5 µg/L) if the discharge water is held in a soil-based holding pond for a 3 hours residence time prior to discharge into the Turner River. Vanadium concentrations would thus fall below both the regional and Turner River site specific guideline vale and the ANZG low reliability freshwater species protection guideline value. Arsenic concentrations would also be reduced.
- Uranium, however, was harder to remove via natural or added iron-oxide minerals, which is likely to be a function of uranium being present in a uranium-carbonate (uranyl carbonate) form, which are highly soluble. The use of ion exchange resins was the most likely means of removing uranium from the water prior to discharge, however, this would require a significant financial outlay (circa $5 million AUD).
- The ERA outlined that the inherent risks to biota inhabiting the Turner River system was high in the absence of any controls on discharge, largely due to the considerable exceedances of default and site-specific environmental criteria for both uranium and vanadium. Controls such as the use of soil-based discharge ponds/dosing with iron oxide materials and treatment via ion exchange together are viable options to lower contaminant loads entering the river systems thus reducing the residual risk to low.
- The inherent risk to other receptors such as terrestrial fauna (inc. livestock), floodplain soils/vegetation and downstream water users was much lower largely due to predicted concentrations in the Turner River being well below any animal/human drinking water trigger values and that widespread inundation of floodplains is considered unlikely even in extreme rainfall events.

16.2 RADIOLOGICAL

Given the elevated uranium concentrations present in the discharge water and the predicted elevated concentrations in Turner River post discharge a radiological assessment was conducted as a part of the Tier 2 ERA. Major findings included:

- Gross alpha activity concentrations (0.8–3.1 Bq/L) in selected monitoring bores exceeded the ANZECC (2000) livestock drinking water value of 0.5 Bq/L.
- Consequently, under low catchment rainfall conditions the Turner River water was also likely to exceed ANZECC (2000) livestock drinking water value of 0.5 Bq/L.
- Based on these results tier 2 site-specific ERICA and RESRAD-BIOTA models was used to determine dose rates to flora and fauna based on occupancy within the Turner River. The scenarios tested were:
  - 1) discharge into the Turner River with no additional rainfall (worst-case) and
  - 2) no discharge (i.e. Turner River Background, best-case).
- The ERICA model demonstrated that all key biological groups (amphibians, birds, crustaceans, reptiles, plants etc) were calculated to have radiological exposures far below relevant screening values, thus making it highly unlikely that measurable population effects would occur as a result of radiological effects from the discharge.
- RESRAD-BIOTA modelling was also used to assess the possible effects on the consumption of Turner River water post-discharge as a drinking water source including as undiluted discharge (no natural flow). This

modelling demonstrated that organisms such as cattle, reptiles and birds were also unlikely to suffer population effects as a consequence of the use of Turner River water as a drinking water source.

- Consequently, based on modelling results the inherent risks resulting from the release of radionuclides into the Turner River is likely to be low. Treatment to remove or minimise uranium concentrations in the discharge water as outlined above (Section 16.1) are likely to reduce this risk further to the very low category.

16.3 ECOLOGICAL

In addition to assessing the potential ecological effects of metal(loids) and radionuclides in the Turner River post discharge a high-level ecological assessment was also undertaken regarding the likely ecological effects of the discharge itself. Major findings included:

- The planned discharge will release a total volume of 30 GL over a 3-year period which will result in a narrow (90-m to 150-m) channel of the Turner River being inundated for approximately 50 km over the bulk of this period.
- Given that this will only inundate approximately 6% to 10% of the river width it is highly unlikely that the planned discharge will have any noticeable ecological effects at the local or regional scale.

16.4 MANAGEMENT APPROACHES AND IMPLICATIONS

Based on the results of the Tier 2 ERA the two main issues of ecological concern related to the proposed discharge include:

- Elevated uranium and vanadium concentrations in untreated discharge water would result in surface water in the Turner River exceeding the regional, site specific and default (ANZG (2018) low reliability freshwater species protection) environmental guideline values. The vanadium can be fairly easily removed by treatment with earthen discharge ponds/iron oxides, however the uranium is more difficult to remove.

In order to ensure that the proposed discharge minimises potential ecological effects on the Turner River system the following options are available to De Grey:

- Treating approximately 65% of the discharge water (19.5 GL over 3 years) by ion-exchange and mixing/co-discharging with the remaining 35% of water treated via earthen ponds to ensure that concentrations of uranium, vanadium and to a lesser extent arsenic fall below the relevant regional guideline values (uranium trigger 12 µg/L being the key criteria as arsenic and vanadium can be readily removed in the ponds).
- Providing evidence via ecotoxicity testing of the groundwater (following simulated pond treatment) that elevated uranium concentrations (present as uranyl carbonates) pose no ecological threat to the Turner River system in the concentrations (26 to 30 µg/L uranium) that are likely to be present during discharge. This assumes that test results can provide a sufficiently high species protection level to meet regulatory approval (likely 90 to 95%). A current estimate from literature is approximately 83% species protection however this includes many data points other than uranyl carbonate solutions which are indicated to be less toxic.
- A combination of the above, whereby with ecotoxicity testing and an agreed species protection level, the discharge target concentration of below 12 µg/L may rise and hence a lower proportion of water would require treatment for uranium removal.
- Alternatively, and most cost effectively would be to explore options for the sale of the water to another organisation for mining or agriculture use.

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APPENDICES

APPENDIX 1: DEWATERING SCHEDULE

Appendix 1: Dewatering Schedule

ID	Nearest main pit	Kl/day											
		0 - 3	**3 - 6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**
DW001	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864	864	864
DW002	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864	866	734
DW003	Brolga Stage 1	864	864	864	864	864	864	579	190	86			
DW004	Brolga Stage 1	2160	1728	1728	1296								
DW005	Brolga Stage 1	2160	2160	2160	2160								
DW006	Brolga Stage 1	2160	2160	2160	2160								
DW007	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864		
DW008	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864		
DW009	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864	864	864
DW010	Brolga Stage 1	864	864	864	864								
DW011	Brolga Stage 1	864	864	864	864	864	864	864	864	777	593	455	362
DW012	Brolga Stage 1	864	864	864	864								
DW013	Brolga Stage 1	1728	1728	1728	1728								
DW014	Brolga Stage 1	864	864	345	136								
DW015	Diucon	2592	2592	2592	2592	2592	2592	2592	2592	2592	2592	1990	1687
DW016	Diucon	2592	2592	2592	2592	2592	2592	2592	2592	2592	2592	1101	805
DW017	Diucon	2160	2160	2160	2160	2160	2160						
DW018	Diucon	2160	2160	2160	2160	2160	2160						
DW019	Diucon	2160	2160	2160	2160	2160	2160						
DW020	Diucon	2160	2160	2160	2160	2160	2160	2160					
DW021	Diucon	2160	2160	2160	2160	2160	2160						
DW022	Diucon	2160	2160	2160	2160	2160	2160	2160					
DW023	Diucon	2160	2160	2160	2160	2160	2160	2160					
DW024	Eagle	2160	2160	2160	2160	2160	2160						
DW027	Falcon					1296	1296	1296	1296	1296	1296	1296	1296
DW028	Falcon					1728	1728	1728	1728	1728	1728		
DW029	Falcon					1728	1728	1728	1728	1728	1728	1728	1728
DW030	Falcon							2160	2160	2160	2160	2160	2160
DW038	Falcon							1728	1728	1728	1728	1728	1728
DW039	Falcon							1296	1296	1296	1296	1296	1296
DW040	Falcon							1296	1296	1296	1296	1296	1296
DW041	Brolga Stage 1	1728	1728	1728	1728	1728	1728	1728	1728	1216	653		
DW042	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864		
DW043	Diucon	2160	2160	2160	2160	2160	2160	2160	2592	2592	2592	2176	1135
DW044	Diucon	1728	1728	1728	1728	1728	1728	2160	2592	2592	2592	1029	333
DW045	Diucon	1728	1728	1728	1728	1728	1728	2160	2592	2592	2592	2592	2592
DW046	Diucon	2160	2160	2160	2160	2160	2160	2160	2592	2592	2592	2592	2592
DW047	Diucon	2160	2160	2160	2160	2160	2160	2160	1671	1310	681	131	
DW051	Diucon				2160	2160	2160	2160	2160	2160	2160	2160	2160
DW052	Diucon				2160	2160	2160	2160	2160	2160	2160	2160	2160
DW053	Eagle				2160	2160	2160	2160	2160	2160	2160	2160	2160
DW058	Brolga Stage 1	2160	2160	2160	2160	2160	1750	635	96				
DW059	Brolga Stage 1					2160	2160	2160	2160	2160	2160	2160	2160
DW060	Brolga Stage 1	864	864	864	864	864	864	864	864	864	864	864	864
DW061	Diucon	864	864	864	864	864	864	2160	2160	2160	1117		
DW062	Diucon	864	864	864	864	864	864	2160	2160	2160	2160	2160	2160
DW063	Diucon	864	864	864	864	864	864	2160	2160	2160	2160	2160	2275
DW064	Eagle	1728	1728	1728	1728	1728	1728	1728	1728				
DW069	Falcon					1296	1296	1296	1296	1296	1296		
DW070	Falcon					1296	1296	1296	1296	1296	1296	1296	1296
DW072	Aquila-Crow							432	432	218	138	94	86
DW073	Aquila-Crow							432	432	218	138	94	86
DW074	Aquila-Crow					864	864	864	864	634	271		
DW075	Aquila-Crow							432	432	218	138	94	86
DW076	Aquila-Crow					432	432	432	86				
DW077	Aquila-Crow							864	833	326	130	86	86
DW078	Aquila-Crow							432	86				
DW079	Aquila-Crow							864	864	864	864	864	864
DW080	Aquila-Crow							864	864	864	864	864	864
DW081	Aquila-Crow					432	432	432	432	353	221	146	123
DW082	Aquila-Crow							432	290	177	113	86	86
DW083	Aquila-Crow							864	864	864	864	864	864
DW084	Aquila-Crow							432	247	118	86		
DW085	Brolga Stage 2				864	864	864	1728	1728	1728	1728	1728	1728
DW086	Brolga Stage 2				864	864	864	1728	1728	1728	1728	1728	1728
DW087	Brolga Stage 2				864	864	864	864	864	864	864	864	864
DW088	Brolga Stage 2							1296	1296	1102	445		
DW089	Brolga Stage 2							1296	1296	1296	1296		
DW096	Eagle	864	864	864	864	864	864						
DW098	Eagle	864	864	864	864	864	864						
DW101	Eagle	864	864	864	864	864	864						
Sumps - Brolga S1							260	2600	4100	5600	9300	10500	10200
Sumps - Diucon											9000	10000	10000
Total (kl/day)		**61776**	**61344**	**60825**	**69256**	**71280**	**71130**	**80278**	**74558**	**71105**	**79615**	**67294**	**64372**

APPENDIX 2: GROUNDWATER, SURFACE WATER AND SEDIMENT MONITORING DATA

BORE	DATE	pH Value	EC	TDS	TSS	OH Alkalinity	CO3 Alkalinity	HCO3 Alkalinity	Total Alkalinity	SiO2	SO4	Chloride	Calcium	Magnesium	Sodium	Potassium	Mercury	Aluminium	Iron	Antimony	Selenium	Arsenic	Barium	Beryllium	Boron	Bismuth	Cadmium	Chromium	Cobalt	Copper	Lead	Lithium	Manganese	Molybdenum	Nickel	Silver	Strontium	Tellurium	Thallium	Thorium	Tin	Titanium	Uranium	Vanadium	Zinc	Nitrate as N	Bromide
		pH Unit	µS/cm	mg/L	mg/L	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
HMB001	02/12/2020	8.35	1470	890	15	<1	8	358	366	91.0	63	233	32	56	196	13	<0.1	<5	<2	<0.2	3.0	15.8	122.0	<0.1	490	<0.05	<0.05	3.6	<0.1	<0.5	<0.1	17.8	1.2	6.7	<0.5	<0.1	614	<0.2	<0.02	<0.1	<0.2	<1	42.80	30.8	8	6.53	0.67
HMB002	02/12/2020	8.44	1500	898	118	<1	19	346	365	88.6	66	238	30	54	197	14	<0.1	6	<2	<0.2	3.1	51.8	116.0	<0.1	504	<0.05	<0.05	3.7	<0.1	<0.5	<0.1	18.1	0.9	6.6	<0.5	<0.1	624	<0.2	<0.02	<0.1	<0.2	<1	47.50	30.8	10	6.20	0.60
HPB001	02/12/2020	8.30	1280	798	60	<1	3	331	335	91.2	42	187	36	44	161	13	<0.1	26	29	<0.2	2.9	6.5	163.0	<0.1	497	<0.05	<0.05	1.8	<0.1	<0.5	<0.1	22.0	8.9	5.6	<0.5	<0.1	586	<0.2	<0.02	<0.1	<0.2	<1	27.70	27.1	15	7.62	0.43
HMB003	03/12/2020	8.43	1500	898	49	<1	19	353	372	93.1	62	241	30	53	195	13	<0.1	<5	<2	<0.2	3.1	30.2	126.0	<0.1	506	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	18.6	0.9	7.0	<0.5	<0.1	614	<0.2	<0.02	<0.1	<0.2	<1	44.60	34.3	8	6.75	0.58
HMB004	03/12/2020	8.48	1530	929	173	<1	24	354	378	86.9	65	245	34	58	202	14	<0.1	6	<2	<0.2	3.6	9.9	140.0	<0.1	592	<0.05	<0.05	3.2	<0.1	<0.5	<0.1	18.6	<0.5	6.3	<0.5	<0.1	664	<0.2	<0.02	<0.1	<0.2	<1	47.60	32.8	8	6.52	0.61
HMB005	03/12/2020	8.48	1670	1030	754	<1	23	351	373	78.2	77	284	32	53	232	16	<0.1	<5	<2	<0.2	4.2	54.4	186.0	<0.1	695	<0.05	<0.05	3.5	0.4	<0.5	<0.1	15.6	48.7	6.2	<0.5	<0.1	606	<0.2	0.0	<0.1	0.3	<1	36.70	22.7	13	6.28	0.71
HMB007	03/12/2020	8.47	1280	794	117	<1	22	340	362	90.3	39	191	34	44	160	13	<0.1	<5	<2	<0.2	3.0	6.1	170.0	<0.1	488	<0.05	<0.05	3.0	<0.1	<0.5	<0.1	20.6	4.1	5.7	<0.5	<0.1	581	<0.2	<0.02	<0.1	<0.2	<1	25.30	25.0	10	7.86	0.47
HMB008	03/12/2020	8.44	1260	768	93	<1	18	314	332	93.7	36	183	35	43	155	13	<0.1	5	<2	<0.2	2.9	5.5	157.0	<0.1	494	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	21.0	2.2	5.4	<0.5	<0.1	597	<0.2	<0.02	<0.1	<0.2	<1	23.30	28.9	8	8.47	0.43
HMB009	03/12/2020	8.45	989	598	257	<1	15	265	281	80.0	22	126	33	30	126	10	<0.1	<5	<2	<0.2	2.1	4.7	172.0	<0.1	342	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	5.0	0.7	3.7	<0.5	<0.1	483	<0.2	<0.02	<0.1	<0.2	<1	7.37	24.0	10	7.13	0.30
HMB010	03/12/2020	8.47	1030	661	224	<1	18	281	300	82.1	26	125	31	30	140	10	<0.1	9	5	<0.2	2.0	6.2	214.0	<0.1	341	<0.05	<0.05	2.7	<0.1	<0.5	<0.1	4.6	6.0	5.2	<0.5	<0.1	521	<0.2	<0.02	<0.1	<0.2	<1	8.26	30.0	10	8.58	0.29
HMB006	04/12/2020	8.38	1780	1070	304	<1	14	345	359	102.0	43	350	42	61	225	19	<0.1	<5	<2	<0.2	5.5	5.0	257.0	<0.1	716	<0.05	<0.05	1.7	<0.1	<0.5	<0.1	18.5	1.6	1.9	<0.5	<0.1	804	<0.2	<0.02	<0.1	<0.2	<1	16.80	20.4	12	7.14	0.97
HMB011	04/12/2020	8.40	1250	754	58	<1	14	311	325	81.0	43	183	36	44	157	13	<0.1	5	3	0.3	3.0	3.4	124.0	<0.1	475	<0.05	<0.05	3.1	0.2	1.4	<0.1	14.9	13.8	5.3	1.1	<0.1	509	<0.2	<0.02	<0.1	<0.2	<1	19.30	17.9	52	7.07	0.45
WPB001	05/12/2020	8.34	11400	6920	206	<1	11	456	468	26.1	740	3160	91	190	2180	32	<0.1	<5	12	1.0	2.3	1.1	52.3	<0.1	856	<0.05	0.36	<0.2	2.4	1.8	<0.1	52.7	121.0	7.9	3.6	<0.1	3130	<0.2	<0.02	<0.1	<0.2	<1	35.80	1.0	18	1.58	7.51
HMB008	21/04/2021	8.08	1190	732	<5	<1	<1	316	316	95.7	34	185	33	41	157	13	<0.1	<5	<2	<0.2	2.7	4.7	180.0	<0.1	497	<0.05	<0.05	2.2	<0.1	<0.5	<0.1	18.1	<0.5	4.4	<0.5	<0.1	617	<0.2	<0.02	<0.1	<0.2	<1	19.30	28.1	14	11.30	0.53
HMB009	21/04/2021	8.08	1020	614	<5	<1	<1	286	286	77.6	23	145	33	32	128	10	<0.1	<5	<2	<0.2	2.1	4.4	212.0	<0.1	352	<0.05	<0.05	2.5	<0.1	<0.5	<0.1	6.0	<0.5	3.0	<0.5	<0.1	520	<0.2	<0.02	<0.1	<0.2	<1	7.70	25.4	14	8.05	0.45
HMB010	21/04/2021	8.07	996	616	<5	<1	<1	304	304	76.6	23	125	29	30	134	9	<0.1	<5	2	<0.2	2.0	4.9	224.0	<0.1	344	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	5.4	<0.5	4.1	<0.5	<0.1	525	<0.2	<0.02	<0.1	<0.2	<1	8.53	30.0	13	9.33	0.40
HERC026	22/04/2021	8.26	1450	872	<5	<1	<1	369	369	85.5	60	253	29	54	188	12	<0.1	<5	<2	<0.2	3.2	31.3	136.0	<0.1	546	<0.05	<0.05	2.7	<0.1	0.7	0.2	20.4	<0.5	6.7	<0.5	<0.1	625	<0.2	<0.02	<0.1	<0.2	<1	43.90	33.9	18	7.16	0.76
HMB001	22/04/2021	8.04	1310	746	<5	<1	<1	348	348	89.9	46	204	26	46	183	12	<0.1	<5	<2	<0.2	2.8	10.3	117.0	<0.1	539	<0.05	<0.05	2.0	<0.1	<0.5	<0.1	20.0	<0.5	6.0	<0.5	<0.1	590	<0.2	<0.02	<0.1	<0.2	<1	34.20	34.0	13	7.12	0.60
HMB002	22/04/2021	8.02	1450	829	5	<1	<1	361	361	86.5	61	245	30	56	189	12	<0.1	<5	<2	<0.2	3.1	56.0	128.0	<0.1	545	<0.05	<0.05	3.6	<0.1	<0.5	<0.1	20.6	<0.5	6.5	<0.5	<0.1	638	<0.2	<0.02	<0.1	<0.2	<1	45.50	31.3	13	6.76	0.73
HMB003	22/04/2021	8.06	1440	865	<5	<1	<1	369	369	93.2	53	248	28	52	195	12	<0.1	<5	<2	<0.2	3.2	11.3	139.0	<0.1	595	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	21.6	<0.5	6.9	<0.5	<0.1	605	<0.2	<0.02	<0.1	<0.2	<1	39.40	35.7	14	7.51	0.74
HMB007	22/04/2021	8.04	1220	760	72	<1	<1	325	325	93.9	40	198	34	45	157	12	<0.1	<5	4	<0.2	3.0	5.8	141.0	<0.1	513	<0.05	<0.05	3.0	<0.1	<0.5	<0.1	24.6	<0.5	5.6	<0.5	<0.1	582	<0.2	<0.02	<0.1	<0.2	<1	27.50	29.3	10	8.55	0.59
HMB011	22/04/2021	8.05	1270	768	<5	<1	<1	335	335	90.7	43	205	32	44	165	12	<0.1	<5	<2	<0.2	3.0	6.7	159.0	<0.1	492	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	21.9	<0.5	5.6	<0.5	<0.1	596	<0.2	<0.02	<0.1	<0.2	<1	30.50	28.8	14	8.05	0.62
INDEE HOMESTEAD	22/04/2021	7.89	3420	1950	<5	<1	<1	377	377	50.2	178	861	66	114	469	13	<0.1	6	<2	<0.2	2.6	2.4	98.2	<0.1	396	<0.05	<0.05	<0.2	<0.1	0.8	<0.1	20.9	<0.5	4.9	<0.5	<0.1	1490	<0.2	<0.02	<0.1	<0.2	<1	84.10	5.3	17	3.46	2.81
HMB004	23/04/2021	7.98	1490	1030	<5	<1	<1	374	374	83.1	62	259	30	56	194	13	<0.1	<5	5	<0.2	3.8	10.1	136.0	<0.1	666	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	22.2	<0.5	6.5	<0.5	<0.1	663	<0.2	<0.02	<0.1	<0.2	<1	46.20	33.7	13	7.01	0.77
HMB005	23/04/2021	7.94	1600	985	49	<1	<1	370	370	66.8	79	290	30	56	225	15	<0.1	<5	<2	<0.2	3.8	47.7	122.0	<0.1	752	<0.05	<0.05	3.6	<0.1	<0.5	<0.1	19.2	0.6	6.2	<0.5	<0.1	633	<0.2	<0.02	<0.1	0.3	<1	41.50	26.3	16	6.31	0.87
HMB006	23/04/2021	7.93	2100	1240	<5	<1	<1	442	442	98.2	45	473	41	64	296	22	<0.1	<5	<2	<0.2	6.7	4.3	210.0	<0.1	860	<0.05	<0.05	1.0	<0.1	<0.5	<0.1	20.6	<0.5	1.6	<0.5	<0.1	835	<0.2	<0.02	<0.1	<0.2	<1	19.00	21.8	14	8.07	1.57
HMB011D	23/04/2021	8.05	1180	688	<5	<1	<1	348	348	76.2	42	187	33	43	151	12	<0.1	<5	<2	<0.2	2.8	9.5	148.0	<0.1	443	<0.05	<0.05	3.6	<0.1	<0.5	<0.1	19.8	<0.5	5.3	<0.5	<0.1	555	<0.2	<0.02	<0.1	<0.2	<1	28.00	26.2	12	7.66	0.57
NO 10 WELL	23/04/2021	8.21	1410	854	<5	<1	<1	368	368	86.0	55	230	30	51	191	12	<0.1	<5	2	<0.2	2.9	21.5	124.0	<0.1	586	<0.05	<0.05	2.9	<0.1	23.3	0.2	20.5	<0.5	6.0	<0.5	<0.1	628	<0.2	<0.02	<0.1	<0.2	<1	40.00	30.9	17	7.84	0.68
UNK1	23/04/2021	8.41	1750	1070	<5	<1	22	423	445	110.0	42	333	28	66	243	19	<0.1	<5	<2	<0.2	4.9	5.6	216.0	<0.1	823	<0.05	<0.05	0.7	<0.1	9.5	<0.1	23.0	<0.5	3.1	<0.5	<0.1	908	<0.2	<0.02	<0.1	<0.2	<1	40.90	31.6	10	7.87	1.13
UNK2	23/04/2021	8.41	1580	1010	<5	<1	16	278	295	100.0	44	296	56	49	199	13	<0.1	<5	5	<0.2	5.8	3.1	291.0	<0.1	407	<0.05	<0.05	0.9	0.2	12.7	<0.1	11.9	<0.5	2.0	<0.5	<0.1	834	<0.2	<0.02	<0.1	<0.2	<1	7.29	20.0	12	32.80	0.79
HMB001	20/10/2021	8.21	1340	828	<5	<1	<1	376	376	95.2	45	210	24	42	174	11	<0.1	<5	<2	<0.2	2.7	13.4	122.0	<0.1	495	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	20.6	0.5	6.2	<0.5	<0.1	697	<0.2	<0.02	<0.1	<0.2	<1	34.20	33.4	16	7.10	0.68
HMB002	20/10/2021	8.17	1440	866	<5	<1	<1	375	375	83.5	58	235	27	49	174	11	<0.1	<5	<2	<0.2	2.8	72.7	126.0	<0.1	484	<0.05	<0.05	3.4	<0.1	0.5	<0.1	19.6	<0.5	6.6	0.6	<0.1	773	<0.2	<0.02	<0.1	<0.2	<1	42.20	29.7	19	6.56	0.79
HMB003	20/10/2021	8.24	1450	881	<5	<1	<1	392	392	95.7	50	240	24	48	186	12	<0.1	<5	<2	<0.2	3.0	14.1	141.0	<0.1	514	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	21.3	<0.5	6.8	<0.5	<0.1	748	<0.2	<0.02	<0.1	<0.2	<1	38.30	33.8	17	7.35	0.79
HMB003	20/10/2021	8.16	1460	872	<5	<1	<1	382	382	96.5	51	235	25	49	190	12	<0.1	<5	<2	<0.2	2.9	14.0	145.0	<0.1	503	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	21.0	<0.5	6.8	<0.5	<0.1	746	<0.2	<0.02	<0.1	<0.2	<1	38.50	33.8	16	7.35	0.79
HMB004	20/10/2021	8.15	1490	907	7	<1	<1	393	393	84.3	58	248	28	52	189	13	<0.1	<5	<2	<0.2	3.4	12.8	133.0	<0.1	564	<0.05	<0.05	2.8	<0.1	1.2	<0.1	21.1	<0.5	6.5	<0.5	<0.1	803	<0.2	<0.02	<0.1	<0.2	<1	44.00	31.4	17	6.86	0.82
HMB005	20/10/2021	8.13	1610	957	<5	<1	<1	394	394	74.0	75	278	25	48	210	14	<0.1	<5	<2	<0.2	3.5	65.5	111.0	<0.1	669	<0.05	<0.05	3.3	<0.1	<0.5	<0.1	18.8	<0.5	6.0	<0.5	<0.1	797	<0.2	<0.02	<0.1	<0.2	<1	40.00	26.7	18	6.36	0.94
HMB006	20/10/2021	8.09	2020	1160	<5	<1	<1	424	424	101.0	46	425	41	62	260	20	<0.1	<5	4	<0.2	6.2	5.0	254.0	<0.1	734	<0.05	<0.05	1.1	<0.1	127.0	<0.1	20.9	<0.5	3.6	0.6	<0.1	1100	<0.2	<0.02	<0.1	<0.2	<1	18.20	19.7	40	7.68	1.57
HMB007	20/10/2021	8.23	1230	756	26	<1	<1	340	340	89.0	40	192	28	38	147	11	<0.1	<5	13	<0.2	2.6	7.4	152.0	<0.1	466	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	23.6	0.8	5.6	1.9	<0.1	720	<0.2	<0.02	<0.1	<0.2	<1	24.60	27.5	16	8.37	0.62
Colins Well	21/10/2021	8.00	3460	2010	<5	<1	<1	397	397	51.9	167	788	62	107	448	12	<0.1	<5	<2	<0.2	2.2	3.0	85.2	<0.1	329	<0.05	0.06	0.2	<0.1	6.9	0.2	21.5	<0.5	4.9	3.6	<0.1	1860	<0.2	<0.02	<0.1	0.6	<1	77.80	5.0	35	3.23	2.71
HERC026	21/10/2021	8.35	1460	874	<5	<1	8	392	400	87.2	66	244	26	50	180	11	<0.1	<5	<2	<0.2	2.8	40.4	129.0	<0.1	489	<0.05	0.08	2.8	<0.1	1.4	0.5	20.2	<0.5	6.9	1.6	<0.1	755	<0.2	<0.02	<0.1	<0.2	<1	40.50	31.8	31	6.99	0.71
HMB008	21/10/2021	8.25	1160	734	<5	<1	<1	335	335	99.4	32	170	27	35	144	12	<0.1	<5	<2	<0.2	2.5	5.6	178.0	<0.1	495	<0.05	<0.05	1.9	<0.1	<0.5	<0.1	18.6	0.6	3.9	<0.5	<0.1	777	<0.2	<0.02	<0.1	0.3	<1	18.20	26.3	16	10.70	0.52
HMB009	21/10/2021	8.17	995	618	<5	<1	<1	306	306	81.5	22	139	30	29	124	9	<0.1	<5	13	<0.2	1.9	5.6	203.0	<0.1	258	<0.05	<0.05	2.4	<0.1	1.8	<0.1	5.5	0.5	3.1	<0.5	<0.1	639	<0.2	<0.02	<0.1	<0.2	<1	7.16	23.1	21	7.82	0.40
HMB010	21/10/2021	8.24	997	629	10	<1	<1	323	323	84.4	22	129	25	27	128	8	<0.1	<5	3	<0.2	2.0	6.0	237.0	<0.1	270	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	5.2	0.7	4.0	<0.5	<0.1	650	<0.2	<0.02	<0.1	<0.2	<1	7.71	27.8	17	9.01	0.36
HMB011	21/10/2021	8.27	1290	761	<5	<1	<1	352	352	91.5	42	199	29	39	155	12	<0.1	<5	<2	<0.2	2.6	8.4	161.0	<0.1	469	<0.05	<0.05	2.6	<0.1	<0.5	<0.1	22.6	<0.5	5.6	<0.5	<0.1	715	<0.2	<0.02	<0.1	<0.2	<1	26.60	27.9	16	7.85	0.63
HPB001	21/10/2021	8.19	1220	750	<5	<1	<1	347	347	87.8	52	189	28	38	148	11	<0.1	<5	<2	<0.2	2.6	8.5	158.0	<0.1	464	<0.05	<0.05	3.0	<0.1	<0.5	<0.1	24.0	<0.5	5.5	<0.5	<0.1	711	<0.2	<0.02	<0.1	<0.2	<1	25.90	27.7	19	8.03	0.63
HPB008	28/10/2021	8.18	1480	882	<5	<1	<1	394	394	88.0	63	249	24	52	198	13	<0.1	<5	<2	<0.2	2.9	59.0	133.0	<0.1	776	<0.05	<0.05	2.9	<0.1	0.5	<0.1	25.2	3.6	5.9	<0.5	<0.1	738	<0.2	<0.02	<0.1	0.5	<1	46.20	35.5	15	6.66	0.67
HPB006	08/11/2021	8.29	1260	766	<5	<1	<1	346	346	94.1	45	191	26	40	160	13	<0.1	<5	<2	<0.2	2.6	8.9	145.0	<0.1	603	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	25.2	0.6	5.4	<0.5	<0.1	680	<0.2	<0.02	<0.1	0.8	<1	29.40	30.5	15	8.09	0.60
HPB009	08/11/2021	8.27	1500	886	<5	<1	<1	395	395	95.7	67	250	23	52	198	14	<0.1	<5	<2	<0.2	2.9	13.4	135.0	<0.1	690	<0.05	<0.05	2.5	<0.1	0.7	<0.1	22.9	<0.5	5.9	<0.5	<0.1	752	<0.2	<0.02	<0.1	<0.2	<1	44.10	36.6	15	7.10	0.68
HPB007	13/11/2021	8.13	1270	780	<5	<1	<1	357	357	93.4	56	197	28	41	162	12	<0.1	<5	<2	<0.2	2.5	8.3	129.0	<0.1	476	<0.05	<0.05	3.0	<0.1	0.9	<0.1	22.1	5.4	5.2	<0.5	<0.1	642	<0.2	<0.02	<0.1	<0.2	<1	32.40	30.8	13	7.08	0.02
HPB010	17/11/2021	8.31	1320	749	<5	<1	3	336	338	69.8	60	226	32	47	176	12	<0.1	<5	<2	<0.2	2.5	27.2	88.8	<0.1	484	<0.05	<0.05	3.3	4.7	2.2	<0.1	17.3	54.7	6.0	2.5	<0.1	662	<0.2	0.1	<0.1	<0.2	<1	31.80	21.1	15	6.96	0.57
HPB012	22/11/2021	8.40	1250	742	<5	<1	14	336	350	90.8	48	205	30	42	168	12	<0.1	27	<2	<0.2	3.2	12.3	136.0	<0.1	510	<0.05	<0.05	3.1	<0.1	1.8	<0.1	22.6	<0.5	5.4	<0.5	<0.1	613	<0.2	<0.02	<0.1	<0.2	<1	26.60	27.8	14	8.07	0.61
HPB011	23/11/2021	9.10	1560	871	<5	<1	84	251	335	33.5	86	302	13	12	289	28	<0.1	5	6	0.5	2.2	705.0	11.7	<0.1	414	<0.05	<0.05	3.6	2.1	1.6	<0.1	70.5	32.3	19.2	2.1	<0.1	174	<0.2	<0.02	<0.1	<0.2	<1	20.50	45.6	4	0.01	0.63
HMB026	01/12/2021	8.00	1220	752	7	<1	<1	349	349	87.4	51	202	29	40	161	12	<0.1	<5	4	<0.2	2.8	8.0	129.0	<0.1	490	<0.05	<0.05	3.1	<0.1	0.7	<0.1	18.4	1.2	4.9	0.8	<0.1	534	<0.2	<0.02	<0.1	0.3	<1	31.30	28.8	11	6.88	0.19
HMB012S	02/12/2021	8.00	1480	920	<5	<1	<1	406	406	86.9	54	266	28	53	212	13	<0.1	<5	<2	<0.2	2.4	12.8	147.0	<0.1	555	<0.05	<0.05	0.5	<0.1	<0.5	<0.1	18.7	99.5	6.0	0.8	<0.1	628	<0.2	0.0	<0.1	<0.2	<1	40.00	30.5	15	4.07	0.29
HMB016	02/12/2021	8.09	1500	926	<5	<1	<1	394	394	95.7	55	276	26	55	199	14	<0.1	<5	5	<0.2	3.3	9.1	142.0	<0.1	573	<0.05	<0.05	2.1	<0.1	2.1	<0.1	17.1	1.0	5.2	0.7	<0.1	649	<0.2	<0.02	<0.1	<0.2	<1	40.40	33.1	17	6.20	0.31
HMB022	18/12/2021	7.87	901	554	1320	<1	<1	325	325	27.4	24	108	40	42	67	3	<0.1	<5	81	<0.2	0.3	2.6	258	<0.1	120	<0.05	<0.05	<0.2	1.3	<0.5	<0.1	7.8	469	1.2	1.1	<0.1	517	<0.2	<0.02	<0.1	<0.2	<1	7.9	2.4	34	0.08	0.322
HMB024D	20/12/2021	8.01	1970	1210	34	<1	<1	582	582	42.1	96	279	34	51	322	10	<0.1	<5	1240	<0.2	<0.2	290.0	258	<0.1	559	<0.05	<0.05	<0.2	2.5	<0.5	<0.1	57.4	2930	10.5	1.5	<0.1	739	<0.2	<0.02	<0.1	<0.2	<1	8.15	0.7	2	<0.01	0.864
HMB028D	20/12/2021	8.29	1250	740	<5	<1	<1	339	339	87.1	40	193	35	47	155	11	<0.1	<5	2	<0.2	3.1	7.1	124	<0.1	503	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	25.5	1.5	5.5	<0.5	<0.1	622	<0.2	<0.02	<0.1	<0.2	<1	26.8	26.7	8	7.32	0.613
HMB018	21/12/2021	8.1	803	470	158	<1	<1	201	201	49.5	12	153	46	37	63	4	<0.1	<5	<2	<0.2	0.4	1.8	194	<0.1	114	<0.05	<0.05	1.1	<0.1	0.5	<0.1	11.5	2.4	0.9	<0.5	<0.1	569	<0.2	<0.02	<0.1	<0.2	<1	6.07	8.6	15	0.82	0.428
HMB019	21/12/2021	7.96	627	370	1210	<1	<1	278	278	32.5	10	42	50	33	37	3	<0.1	<5	<2	<0.2	0.6	0.9	206	<0.1	121	<0.05	<0.05	1	<0.1	0.6	<0.1	4.2	2.3	0.9	1.1	<0.1	481	<0.2	<0.02	<0.1	<0.2	<1	8.97	5.1	34	1.78	0.132
HMB019	21/12/2021	8	626	362	211	<1	<1	284	284	32.9	9	41	46	34	33	2	<0.1	<5	19	<0.2	0.6	1.0	161	<0.1	117	<0.05	<0.05	1.2	<0.1	<0.5	0.8	4.3	1	0.8	<0.5	<0.1	488	<0.2	<0.02	<0.1	<0.2	<1	9.01	5	28	1.79	0.131
HMB022	21/12/2021	7.9	902	519	558	<1	<1	324	324	27.8	26	112	41	43	68	3	<0.1	21	64	<0.2	0.5	1.7	250	<0.1	121	<0.05	<0.05	0.2	1.4	<0.5	<0.1	7.5	326	1.3	5.7	<0.1	528	<0.2	<0.02	<0.1	<0.2	<1	7.85	2.4	38	0.2	0.323
HPB004	14/01/2022	8.3	1440	856	<5	<1	<1	381	381	94.8	60	228	30	51	179	11	<0.1	<5	<2	<0.2	3	16.6	153	<0.1	576	<0.05	<0.05	3	<0.1	2.4	<0.1	21	8.7	5.6	<0.5	<0.1	729	<0.2	<0.02	<0.1	<0.2	<1	40.5	31.3	17	6.57	0.625
HPB002	17/01/2022	8.24	1140	673	<5	<1	<1	315	315	84.5	32	169	40	41	135	10	<0.1	<5	<2	<0.2	2.6	5.5	175	<0.1	520	<0.05	<0.05	2.6	<0.1	2	<0.1	21.2	<0.5	3.7	<0.5	<0.1	679	<0.2	<0.02	<0.1	<0.2	<1	18.9	23.3	17	7.34	0.466
HMB020	18/01/2022	7.89	2370	1360	274	<1	<1	408	408	42.1	73	547	88	74	273	9	<0.1	<5	469	<0.2	0.5	2.2	447	<0.1	652	<0.05	<0.05	<0.2	8.6	<0.5	<0.1	63.5	2350	5.5	15.2	<0.1	907	<0.2	<0.02	<0.1	0.2	<1	18.7	2.7	15	0.14	1.55
HMB021	18/01/2022	7.96	1850	1220	<5	<1	<1	253	253	82.8	60	443	63	70	196	8	<0.1	<5	<2	<0.2	2	5.2	440	<0.1	279	<0.05	<0.05	1.6	<0.1	2.2	<0.1	21.4	0.5	1	<0.5	<0.1	1120	<0.2	<0.02	<0.1	<0.2	<1	20.4	13	13	3.39	1.25
HMB022	18/01/2022	7.92	921	514	452	<1	<1	323	323	28.7	23	109	66	40	68	3	<0.1	<5	684	<0.2	<0.2	9.0	250	<0.1	99	<0.05	<0.05	<0.2	0.9	<0.5	<0.1	19.2	921	1.5	<0.5	<0.1	586	<0.2	<0.02	<0.1	<0.2	<1	7.1	0.6	4	0.01	0.287
HMB022	18/01/2022	7.95	965	530	9	<1	<1	329	329	28.7	27	116	68	41	70	3	<0.1	7	208	<0.2	0.9	4.9	196	<0.1	95	<0.05	<0.05	<0.2	1.2	<0.5	<0.1	12.1	409	1.2	1.4	<0.1	586	<0.2	<0.02	<0.1	<0.2	<1	8.61	2.1	8	0.65	0.301
HMB023D	18/01/2022	8.06	1440	847	6	<1	<1	408	408	41.6	55	222	36	47	189	12	<0.1	20	154	<0.2	<0.2	818.0	198	<0.1	455	<0.05	<0.05	<0.2	0.2	<0.5	<0.1	25.7	1240	6.6	0.5	<0.1	763	<0.2	<0.02	<0.1	<0.2	<1	18.6	2	6	<0.01	0.611
HMB025D	18/01/2022	8.23	1660	1030	14	<1	<1	509	509	92.5	41	252	34	50	234	18	<0.1	<5	48	<0.2	0.2	52.6	143	<0.1	536	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	49.3	206	5.3	<0.5	<0.1	770	0.3	<0.02	<0.1	0.2	<1	44.9	6.8	2	0.12	0.63
HMB013	19/01/2022	8.21	1290	760	<5	<1	<1	350	350	94.1	44	183	33	43	154	11	<0.1	<5	<2	<0.2	2.9	8.3	150	<0.1	533	<0.05	<0.05	3.1	<0.1	1	<0.1	23.7	0.7	5	<0.5	<0.1	687	<0.2	<0.02	<0.1	<0.2	<1	31.4	26.4	12	6.69	0.503
HMB017	19/01/2022	7.75	1880	1120	8	<1	<1	328	328	42.7	82	408	92	61	192	6	<0.1	<5	2	<0.2	0.5	0.6	146	<0.1	373	<0.05	0.11	<0.2	0.3	<0.5	<0.1	49.6	116	2.8	0.6	<0.1	840	<0.2	0.06	<0.1	<0.2	<1	27	7.2	11	0.38	1.06
HMB023S	19/01/2022	8.18	1600	968	1850	<1	<1	368	368	108	58	283	28	38	227	12	<0.1	<5	20	<0.2	3.2	9.2	302	<0.1	597	<0.05	<0.05	1.9	<0.1	0.5	<0.1	19.2	1.7	4	2	<0.1	639	<0.2	<0.02	<0.1	0.8	<1	25.6	25.3	74	6.71	0.721
HMB014	20/01/2022	8.04	1290	851	1900	<1	<1	366	366	88.1	51	203	32	46	176	12	<0.1	<5	<2	<0.2	2.6	8.2	120	<0.1	446	<0.05	<0.05	4.1	<0.1	<0.5	<0.1	18.1	<0.5	4.9	1.5	<0.1	638	<0.2	<0.02	<0.1	0.3	<1	32.1	27.1	4	6.51	0.535
HMB014	20/01/2022	8.18	1300	788	<5	<1	<1	359	359	87.3	50	203	30	44	173	12	<0.1	<5	<2	<0.2	2.7	8.2	69.6	<0.1	444	<0.05	<0.05	3.4	<0.1	<0.5	<0.1	18.5	0.8	5.1	0.6	<0.1	628	<0.2	<0.02	<0.1	<0.2	<1	31.7	27.2	1	6.67	0.533
HMB029D	20/01/2022	8.21	1210	734	<5	<1	<1	336	336	89.3	38	184	35	43	146	11	<0.1	<5	<2	<0.2	3	9.0	163	<0.1	540	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	22.5	2.3	4.4	<0.5	<0.1	689	<0.2	<0.02	<0.1	<0.2	<1	23.8	25.1	8	6.82	0.499
HMB029S	20/01/2022	8	2960	1920	<5	<1	<1	426	426	71.5	80	723	82	115	324	19	<0.1	5	1580	<0.2	0.3	6.3	1150	<0.1	536	<0.05	<0.05	0.2	1.3	0.6	<0.1	50.4	3100	4.3	2.1	<0.1	1940	<0.2	<0.02	<0.1	<0.2	<1	16.8	1.6	12	0.38	2.03
HMB030D	20/01/2022	8.22	1260	755	<5	<1	<1	346	346	89	43	187	34	43	152	11	<0.1	<5	5	<0.2	2.8	10.0	148	<0.1	531	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	22.8	10.4	4.8	<0.5	<0.1	700	<0.2	<0.02	<0.1	<0.2	<1	26.5	23.4	10	6.16	0.515
HMB030S	20/01/2022	8.31	1310	763	<5	<1	2	367	368	67.7	57	195	37	45	164	12	<0.1	<5	257	<0.2	0.4	7.2	474	<0.1	546	<0.05	<0.05	0.6	0.8	<0.5	<0.1	23.1	1040	6.3	1	<0.1	708	<0.2	<0.02	<0.1	<0.2	<1	34.9	0.8	13	0.65	0.539
HPB003	20/01/2022	8.23	1220	727	<5	<1	<1	337	337	88.6	37	184	35	43	144	11	<0.1	<5	<2	<0.2	2.8	7.6	178	<0.1	538	<0.05	<0.05	2.6	<0.1	3.6	<0.1	23.1	<0.5	4.5	<0.5	<0.1	707	<0.2	<0.02	<0.1	<0.2	<1	23.7	26.2	18	7.5	0.508
HMB020	21/01/2022	7.87	2310	1310	85	<1	<1	409	409	41.3	74	558	84	73	280	10	<0.1	<5	<2	0.5	0.8	1.4	420	<0.1	574	<0.05	<0.05	<0.2	4.6	2.4	<0.1	60.7	2010	7.3	8.6	<0.1	829	<0.2	0.06	<0.1	<0.2	<1	26.1	3.4	17	0.08	1.51
HMB001	23/04/2022	7.93	1220	731	12	<1	<1	361	361	95.7	41	174	22	36	169	12	<0.1	<5	<2	<0.2	2.3	8.0	130	<0.1	484	<0.05	<0.05	1.1	<0.1	1.3	<0.1	12.2	<0.5	4.9	<0.5	<0.1	453	<0.2	<0.02	<0.1	<0.2	<1	23.6	32.3	20	7.34	<0.020
HMB003	23/04/2022	7.97	1490	882	14	<1	<1	379	379	98.3	53	246	29	51	191	13	<0.1	<5	<2	<0.2	3.3	10.5	128	<0.1	467	<0.05	<0.05	2.2	<0.1	1	<0.1	16.9	<0.5	5.8	<0.5	<0.1	547	<0.2	<0.02	<0.1	<0.2	<1	35.3	35	17	6.98	<0.050
HMB004	23/04/2022	7.87	1520	885	22	<1	<1	390	390	88.8	62	257	31	55	186	13	<0.1	<5	<2	<0.2	3.5	10.1	133	<0.1	500	<0.05	<0.05	2.9	<0.1	0.6	<0.1	18.1	<0.5	5.5	<0.5	<0.1	602	<0.2	<0.02	<0.1	<0.2	<1	43.7	32.8	21	6.53	0.708
HMB006	23/04/2022	7.81	1840	1090	17	<1	<1	398	398	100	45	380	44	59	227	32	0.2	<5	<2	0.2	5.9	4.2	198	<0.1	627	<0.05	<0.05	1.4	<0.1	2.1	<0.1	18.2	0.6	3.5	4.3	<0.1	712	<0.2	<0.02	<0.1	0.3	<1	17	20.8	22	7.2	1.27
HMB007	23/04/2022	7.91	1220	770	226	<1	<1	338	338	92.6	40	202	34	43	150	12	<0.1	<5	<2	<0.2	2.9	6.0	145	<0.1	416	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	20.1	<0.5	4.6	<0.5	<0.1	533	<0.2	<0.02	<0.1	0.3	<1	24.1	29	16	7.93	0.544
HMB008	23/04/2022	7.97	1090	702	34	<1	<1	333	333	105	29	156	31	38	136	12	<0.1	<5	<2	<0.2	2.4	4.2	152	<0.1	398	<0.05	<0.05	1.4	<0.1	0.6	<0.1	13.1	<0.5	2.8	<0.5	<0.1	560	<0.2	<0.02	<0.1	<0.2	<1	16.4	26.2	16	9.15	0.454
HMB009	23/04/2022	7.89	995	596	32	<1	<1	295	295	86	23	141	33	31	121	10	<0.1	<5	<2	<0.2	2	4.6	190	<0.1	297	<0.05	<0.05	2.5	<0.1	1.4	<0.1	5.3	<0.5	2.7	<0.5	<0.1	467	<0.2	<0.02	<0.1	<0.2	<1	6.94	25.6	20	7.43	0.446
HMB010	23/04/2022	7.95	992	612	56	<1	<1	315	315	87.3	23	124	34	32	123	9	<0.1	<5	<2	<0.2	1.9	4.4	241	<0.1	258	<0.05	<0.05	2.2	<0.1	<0.5	<0.1	4.4	<0.5	2.8	<0.5	<0.1	529	<0.2	<0.02	<0.1	<0.2	<1	7.6	29.2	19	8.84	0.403
HMB011	23/04/2022	7.93	1270	760	21	<1	<1	350	350	93.5	44	199	33	42	156	12	<0.1	<5	<2	<0.2	2.8	6.8	143	<0.1	417	<0.05	<0.05	2.7	<0.1	1.1	<0.1	19.4	0.8	4.6	<0.5	<0.1	535	<0.2	<0.02	<0.1	<0.2	<1	26	29.3	20	7.41	0.646
HMB012D	23/04/2022	7.95	1510	899	10	<1	<1	401	401	83.4	57	254	30	55	183	13	<0.1	8	<2	<0.2	2.1	10.0	142	<0.1	438	<0.05	<0.05	<0.2	0.3	0.8	<0.1	17	237	5.6	1	<0.1	571	<0.2	0.03	<0.1	0.3	<1	39	25.9	21	2.4	0.713
HMB012S	23/04/2022	7.95	1500	893	110	<1	<1	384	384	93.2	52	251	30	61	207	13	<0.1	61	<2	0.8	2.8	12.3	104	<0.1	432	<0.05	<0.05	1.5	<0.1	0.6	<0.1	15.2	11.7	4.8	<0.5	<0.1	421	<0.2	<0.02	<0.1	0.2	<1	27.5	28	13	6.53	0.71
HMB013	23/04/2022	7.96	1240	720	<5	<1	<1	343	343	88.4	46	189	33	42	151	12	<0.1	<5	<2	<0.2	2.6	7.3	137	<0.1	406	<0.05	<0.05	3.4	<0.1	<0.5	<0.1	20.1	<0.5	4.9	<0.5	<0.1	513	<0.2	<0.02	<0.1	<0.2	<1	26.4	27.9	17	7.21	0.617
HMB016	23/04/2022	7.93	1520	916	60	<1	<1	399	399	95	55	267	29	56	194	15	<0.1	<5	<2	<0.2	3.4	7.7	137	<0.1	493	<0.05	<0.05	2.2	<0.1	0.8	<0.1	15.8	<0.5	5	<0.5	<0.1	584	<0.2	<0.02	<0.1	<0.2	<1	33.7	32.4	18	6.52	0.755
HMB017	23/04/2022	7.44	1680	1000	51	<1	<1	309	309	38.2	70	394	84	54	179	6	<0.1	<5	4	<0.2	0.4	0.6	102	0.1	304	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	40.6	28.3	2.8	<0.5	<0.1	583	<0.2	0.07	<0.1	3.8	<1	24.6	8.5	14	0.32	1.08
HMB018	23/04/2022	7.8	741	488	222	<1	<1	194	194	52.7	12	138	44	33	61	4	<0.1	<5	<2	<0.2	0.3	1.7	196	<0.1	84	<0.05	<0.05	1.2	<0.1	0.8	<0.1	9.8	1.4	1	<0.5	<0.1	451	<0.2	<0.02	<0.1	2.4	<1	5.19	8.9	22	0.82	0.411
HMB020	23/04/2022	7.64	2360	1340	56	<1	<1	428	428	37.4	77	583	88	73	265	10	<0.1	<5	621	<0.2	<0.2	2.2	491	<0.1	526	<0.05	<0.05	<0.2	0.5	<0.5	<0.1	50.6	2610	5	0.6	<0.1	717	<0.2	<0.02	<0.1	0.9	<1	18.9	0.5	10	<0.01	1.64
HMB014	24/04/2022	7.93	1310	805	9	<1	<1	356	356	86.6	52	207	32	44	164	12	<0.1	<5	<2	<0.2	2.6	7.6	98.2	<0.1	406	<0.05	<0.05	3.5	<0.1	<0.5	<0.1	17.1	1.6	5.1	<0.5	<0.1	513	<0.2	<0.02	<0.1	<0.2	<1	31.7	27.9	15	6.94	0.571
HMB019	24/04/2022	7.85	629	359	371	<1	<1	280	280	35.2	10	44	53	32	34	3	<0.1	<5	<2	<0.2	0.6	0.9	102	<0.1	77	<0.05	<0.05	1	<0.1	<0.5	<0.1	3.8	0.6	0.9	<0.5	<0.1	419	<0.2	<0.02	<0.1	1.6	<1	8.4	5.1	15	1.8	0.14
HMB021	24/04/2022	7.75	1800	1130	414	<1	<1	252	252	81.7	61	472	60	65	185	8	<0.1	<5	<2	<0.2	1.9	4.4	385	<0.1	208	<0.05	<0.05	1.6	<0.1	0.8	<0.1	19.6	0.7	1.1	<0.5	<0.1	844	<0.2	<0.02	<0.1	0.9	<1	19.8	13.8	21	3.58	1.47
HMB022	24/04/2022	7.74	929	523	259	<1	<1	317	317	27.5	32	123	67	40	70	4	<0.1	<5	1200	<0.2	0.3	4.0	222	<0.1	81	<0.05	<0.05	<0.2	1.5	<0.5	<0.1	12.2	688	2	0.7	<0.1	451	<0.2	<0.02	<0.1	0.6	<1	14.6	1.9	24	0.24	0.364
HMB023S	24/04/2022	8	1590	888	18	<1	<1	357	357	105	61	294	32	42	217	14	<0.1	<5	<2	<0.2	2.9	8.6	138	<0.1	448	<0.05	<0.05	2.1	<0.1	<0.5	<0.1	18.1	0.6	4.1	<0.5	<0.1	518	<0.2	<0.02	<0.1	<0.2	<1	25.4	27.5	27	7.2	0.82
HMB024S	24/04/2022	8.32	1510	910	20	<1	5	365	370	75.2	95	257	37	40	208	12	<0.1	68	47	0.6	1.6	192.0	204	<0.1	439	<0.05	<0.05	<0.2	0.2	<0.5	<0.1	21	462	12.8	0.9	<0.1	528	<0.2	<0.02	<0.1	<0.2	<1	31.3	3.3	12	0.01	0.744
HMB025S	24/04/2022	8.21	1560	940	313	<1	<1	418	418	48.2	55	258	32	30	242	19	<0.1	24	<2	0.7	2.7	51.4	178	<0.1	459	<0.05	<0.05	<0.2	0.2	2	<0.1	20.7	21.1	13.8	1.2	<0.1	438	<0.2	0.02	<0.1	1.1	<1	45.9	33.3	10	3.14	0.709
HMB026	24/04/2022	8	1250	797	20	<1	<1	348	348	92.2	48	182	33	42	155	12	<0.1	<5	<2	<0.2	2.7	8.2	135	<0.1	411	<0.05	<0.05	3.2	<0.1	0.8	<0.1	19.9	0.6	5.4	<0.5	<0.1	513	<0.2	<0.02	<0.1	1.9	<1	28.7	28.5	21	6.96	0.627
HMB027D	24/04/2022	7.99	1230	755	6	<1	<1	338	338	95.7	40	185	33	43	149	12	<0.1	<5	<2	<0.2	2.9	6.6	117	<0.1	413	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	22	0.6	5.3	<0.5	<0.1	527	<0.2	<0.02	<0.1	<0.2	<1	25.2	29.9	14	7.62	0.65
HMB027S	24/04/2022	8.08	1200	740	136	<1	<1	352	352	97.8	38	169	34	40	150	12	<0.1	11	<2	<0.2	2.8	5.3	174	<0.1	432	<0.05	<0.05	1.9	<0.1	1	0.2	21.3	7.4	4.6	0.9	<0.1	512	<0.2	<0.02	<0.1	<0.2	<1	24.1	32.5	22	7.5	0.58
HMB028D	24/04/2022	8	1240	730	9	<1	<1	340	340	92.9	40	184	34	43	148	12	<0.1	<5	<2	<0.2	2.7	6.4	129	<0.1	412	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	21.3	1.3	5	<0.5	<0.1	520	<0.2	<0.02	<0.1	<0.2	<1	24.4	29.4	14	8.02	0.646
HMB028S	24/04/2022	8.03	1240	732	28	<1	<1	337	337	99.9	40	180	33	40	147	13	<0.1	<5	<2	<0.2	2.5	5.2	146	<0.1	430	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	16.9	<0.5	4	<0.5	<0.1	545	<0.2	<0.02	<0.1	<0.2	<1	20.7	29.8	14	8.24	0.601
HMB029D	24/04/2022	7.91	1210	745	20	<1	<1	338	338	86.6	38	176	35	41	144	12	<0.1	6	<2	0.3	2.4	7.8	146	<0.1	410	<0.05	<0.05	1.8	0.1	1	<0.1	19.4	35.4	4.5	<0.5	<0.1	502	<0.2	<0.02	<0.1	<0.2	<1	22.6	25.7	24	6.34	0.602
HMB029S	24/04/2022	7.93	1280	747	71	<1	<1	345	345	66.4	58	192	36	41	163	12	<0.1	<5	42	0.2	1.2	5.3	502	<0.1	448	<0.05	<0.05	<0.2	1.4	<0.5	<0.1	22.7	1250	7.4	1.8	<0.1	539	<0.2	<0.02	<0.1	<0.2	<1	25.6	2.5	38	1.18	0.549
HMB030D	24/04/2022	8.07	1240	844	21	<1	<1	339	339	86.1	44	186	34	43	151	12	<0.1	<5	<2	<0.2	2.8	10.0	142	<0.1	404	<0.05	<0.05	2.6	<0.1	0.7	<0.1	20	12.3	4.9	<0.5	<0.1	527	<0.2	<0.02	<0.1	<0.2	<1	25.7	28.6	14	7.07	0.638
HMB030S	24/04/2022	7.9	1270	762	220	<1	<1	341	341	87.2	48	192	35	42	156	12	<0.1	<5	<2	<0.2	3.2	8.8	192	<0.1	420	<0.05	<0.05	2.1	0.2	1	<0.1	18.8	29.7	5.1	1.4	<0.1	525	<0.2	0.04	<0.1	0.4	<1	26.6	39.7	35	7.09	0.56
HPB001	24/04/2022	8.16	1250	771	<5	<1	<1	343	343	93.8	40	183	34	43	151	12	<0.1	<5	<2	<0.2	2.8	7.0	144	<0.1	379	<0.05	<0.05	3	<0.1	<0.5	<0.1	21.6	<0.5	4.8	<0.5	<0.1	594	<0.2	<0.02	<0.1	<0.2	<1	25.9	27.9	15	7.67	<2.00
HMB002	25/04/2022	7.94	1450	842	8	<1	<1	380	380	88	60	240	30	53	177	13	<0.1	8	3	<0.2	3	52.8	108	<0.1	412	<0.05	<0.05	3.2	0.1	2	<0.1	17.3	8.5	5.3	<0.5	<0.1	579	<0.2	<0.02	<0.1	2.1	<1	40.4	31	40	6.13	<0.050
HMB005	25/04/2022	8.18	1600	924	40	<1	<1	383	383	74.1	78	282	31	55	210	15	<0.1	<5	<2	<0.2	3.9	55.6	101	<0.1	561	<0.05	<0.05	3.8	<0.1	<0.5	<0.1	16.4	2	5.3	<0.5	<0.1	576	<0.2	<0.02	<0.1	<0.2	<1	37.2	26.6	20	5.8	0.802
HMB023D	25/04/2022	7.86	1380	806	<5	<1	<1	376	376	44.6	57	232	35	42	204	10	<0.1	16	139	<0.2	<0.2	671.0	179	<0.1	399	<0.05	<0.05	<0.2	0.1	<0.5	<0.1	22.2	956	7.4	<0.5	<0.1	547	<0.2	<0.02	<0.1	<0.2	<1	17.1	2.6	4	<0.01	0.641
HMB024D	25/04/2022	7.91	1680	961	133	<1	<1	416	416	55.6	115	273	39	56	229	9	<0.1	<5	<2	0.4	2	408.0	152	<0.1	445	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	18.9	33.5	7.8	0.8	<0.1	619	<0.2	0.04	<0.1	0.5	<1	36.8	25.2	20	1.6	0.781
HMB025D	25/04/2022	7.84	1570	955	350	<1	<1	437	437	62.1	71	257	34	49	240	12	<0.1	<5	16	0.4	2.1	52.7	408	<0.1	463	<0.05	<0.05	<0.2	1.3	0.9	<0.1	23.7	592	9.7	1.8	<0.1	700	<0.2	0.02	<0.1	2.7	<1	43.3	22.5	42	1.38	0.689
HMB034	25/04/2022	8.09	1510	938	<5	<1	<1	396	396	115	54	241	30	64	177	15	<0.1	<5	<2	<0.2	3.3	8.6	134	<0.1	461	<0.05	<0.05	1.1	<0.1	<0.5	<0.1	17.3	1.2	5.1	<0.5	<0.1	666	<0.2	<0.02	<0.1	3.6	<1	30.2	34.8	16	6.57	0.786
HMB035	25/04/2022	7.94	1970	1170	42	<1	<1	460	460	87.7	67	354	39	66	289	13	<0.1	<5	<2	<0.2	5.5	6.0	122	<0.1	664	<0.05	0.12	1.2	<0.1	2.4	0.1	30.8	13.1	6.7	0.8	<0.1	797	<0.2	0.02	<0.1	<0.2	<1	53.3	31.2	23	7.27	1.22
HPB011	25/04/2022	8.86	1340	750	36	<1	48	255	303	24.5	59	238	26	25	230	10	<0.1	<5	<2	0.2	0.5	636.0	25.4	<0.1	298	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	26.4	28.6	13	0.6	<0.1	382	<0.2	<0.02	<0.1	<0.2	<1	8.93	4.4	2	0.1	0.737
HMB036	12/06/2022	8.05	1360	832	<5	<1	<1	381	381	96.2	50	238	31	52	184	13	<0.0001	<5	<2	<0.2	3	6.5	142	<0.1	473	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	22.2	<0.5	5.6	<0.5	<0.1	598	<0.2	<0.02	<0.1	<0.2	<1	30.3	32	57	7.43	0.632
HMB037	12/06/2022	8.13	1400	851	<5	<1	<1	416	416	107	41	238	26	58	176	17	<0.0001	<5	<2	<0.2	3.5	9.9	122	<0.1	528	<0.05	<0.05	1.1	<0.1	<0.5	<0.1	20.6	0.8	3.9	<0.5	<0.1	680	<0.2	<0.02	<0.1	<0.2	<1	30.6	39.2	18	6.21	0.659
HMB039	12/06/2022	8.02	1570	922	39	<1	<1	372	372	91.4	56	270	34	69	188	16	<0.0001	<5	<2	<0.2	4.1	6	136	<0.1	565	<0.05	<0.05	1.9	<0.1	<0.5	<0.1	23.1	<0.5	3.7	<0.5	<0.1	796	<0.2	<0.02	<0.1	<0.2	<1	34.2	32	37	8.09	0.835
HMB040	12/06/2022	7.97	1430	842	186	<1	<1	384	384	57.9	65	238	31	51	176	14	<0.0001	<5	<2	<0.2	3.3	3.7	125	<0.1	530	<0.05	<0.05	<0.2	0.4	<0.5	<0.1	14.8	22.5	5	0.9	<0.1	556	<0.2	<0.02	<0.1	<0.2	<1	17.1	15.7	1270	3.48	0.733
HMB042	12/06/2022	8.02	1460	918	168	<1	<1	412	412	94.8	51	245	32	63	190	14	<0.0001	<5	<2	<0.2	3.5	14.3	165	<0.1	550	<0.05	<0.05	1.8	<0.1	<0.5	<0.1	24.7	1	5.3	<0.5	<0.1	670	<0.2	<0.02	<0.1	<0.2	<1	40.1	35	22	6.2	0.713
HMB040	29/06/2022	7.96	1420	770	20	<1	<1	426	426	67.9	53	240	35	57	186	15	<0.1	5	<2	<0.2	3.2	4.3	119	<0.1	490	<0.05	<0.05	<0.2	0.2	<0.5	<0.1	14.1	20.7	4.8	0.7	<0.1	617	<0.2	0.02	<0.1	<0.2	<1	23.5	21.2	841	3.81	0.708
HMB006	15/11/2022	7.82	1980	1160	20	<1	<1	478	478	101	49	422	42	61	273	20	<0.1	<5	<2	<0.2	7.3	4.7	247	<0.1	862	<0.05	<0.05	1.3	<0.1	<0.5	<0.1	23.9	1.0	1.7	<0.5	<0.1	942	<0.2	<0.02	<0.1	<0.2	<1	19.8	21.4	17	6.11	1.22
HMB30S	15/11/2022	7.95	1210	742	34	<1	<1	370	370	86.0	44	189	29	40	163	12	<0.1	<5	<2	<0.2	3.0	11.6	150	<0.1	544	<0.05	<0.05	3.3	<0.1	0.8	<0.1	25.5	<0.5	4.7	<0.5	<0.1	623	<0.2	<0.02	<0.1	<0.2	<1	26.5	27.6	18	6.56	0.481

BORE	DATE	pH Value	EC	TDS	TSS	OH Alkalinity	CO3 Alkalinity	HCO3 Alkalinity	Total Alkalinity	SiO2	SO4	Chloride	Calcium	Magnesium	Sodium	Potassium	Mercury
		pH Unit	µS/cm	mg/L	mg/L	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L
HMB30D	15/11/2022	7.87	1190	740	<5	<1	<1	372	372	82.4	43	181	28	39	157	12	<0.1
HMB011	15/11/2022	7.98	1280	777	24	<1	<1	399	399	96.5	43	200	28	41	172	13	<0.1
HMB029S	15/11/2022	7.98	1200	743	42	<1	<1	372	372	87.9	38	182	28	38	160	12	<0.1
HMB029D	15/11/2022	7.88	1140	668	36	<1	<1	384	384	71.9	29	177	27	34	155	11	<0.1
HMB010	15/11/2022	7.95	992	611	14	<1	<1	355	355	86.2	23	119	23	26	133	9	<0.1
HMB009	15/11/2022	7.99	945	576	<5	<1	<1	315	315	81.9	22	126	29	28	129	9	<0.1
HMB028S	15/11/2022	8.03	1130	701	8	<1	<1	344	344	106	33	167	27	36	152	13	<0.1
HMB028D	15/11/2022	8.02	1190	738	11	<1	<1	374	374	88.2	38	184	28	40	158	12	<0.1
HMB027S	15/11/2022	8.00	1180	734	114	<1	<1	389	389	93.9	34	164	26	37	158	12	<0.1
HMB027D	15/11/2022	8.05	1220	750	12	<1	<1	382	382	91.2	39	188	28	40	159	12	<0.1
HMB008	15/11/2022	8.05	1100	696	5	<1	<1	368	368	102	30	152	26	36	146	12	<0.1
HMB042	15/11/2022	7.90	1440	903	510	<1	<1	439	439	95.7	53	236	26	54	194	13	<0.1
HMB040	15/11/2022	7.94	1400	858	16	<1	<1	443	443	88.2	50	232	26	52	189	14	<0.1
HMB039	15/11/2022	8.03	1540	944	28	<1	<1	442	442	95.3	51	274	24	58	189	15	<0.1
HMB037	15/11/2022	8.05	1400	883	6	<1	<1	446	446	104	42	221	21	52	187	16	<0.1
HMB035	15/11/2022	7.94	1910	1160	10	<1	<1	506	506	85.0	64	365	29	67	254	16	<0.1
HMB036	15/11/2022	8.03	1320	778	<5	<1	<1	401	401	99.2	47	209	25	44	186	12	<0.1
HMB034	15/11/2022	8.08	1490	936	34	<1	<1	438	438	117	55	256	25	60	187	15	<0.1
HMB034B	15/11/2022	8.08	1490	916	50	<1	<1	444	444	117	54	258	26	62	192	16	<0.1
HMB016	16/11/2022	8.11	1490	886	9	<1	<1	440	440	99.4	57	254	24	52	203	15	<0.1
HMB012S	16/11/2022	8.06	1190	691	<5	<1	<1	342	342	71.8	42	210	17	36	163	10	<0.1
HMB012D	16/11/2022	8.03	1440	863	8	<1	<1	425	425	85.2	59	244	23	48	190	12	<0.1
HMB004	16/11/2022	8.02	1480	872	32	<1	<1	424	424	84.8	62	249	26	52	199	13	<0.1
HMB005	16/11/2022	8.00	1600	931	14	<1	<1	427	427	72.0	78	278	25	50	222	15	<0.1
HMB025S	16/11/2022	8.12	1480	868	422	<1	<1	437	437	85.0	59	237	26	48	202	14	<0.1
HMB025D	16/11/2022	7.83	1520	870	160	<1	<1	501	501	49.6	64	226	26	46	216	15	<0.1
HMB015	16/11/2022	7.99	1450	848	<5	<1	<1	427	427	78.2	69	237	27	53	195	13	<0.1
HMB024S	16/11/2022	8.04	1470	880	13	<1	<1	432	432	87.4	79	243	28	51	194	12	<0.1
HMB024D	16/11/2022	7.96	1530	902	65	<1	<1	442	442	53.3	93	251	30	53	204	11	<0.1
HMB002	16/11/2022	8.10	1420	850	66	<1	<1	416	416	86.5	62	231	24	48	185	12	<0.1
HMB001	16/11/2022	8.13	1270	744	<5	<1	<1	401	401	96.6	44	191	17	34	180	12	<0.1
HMB026	16/11/2022	8.02	1230	818	45	<1	<1	384	384	88.8	48	181	25	36	161	12	<0.1
HMB014	16/11/2022	8.07	1280	766	<5	<1	<1	391	391	85.7	54	202	28	42	176	12	<0.1
HMB013	16/11/2022	8.15	1210	738	<5	<1	<1	375	375	85.8	44	184	28	39	162	12	<0.1
HMB007	16/11/2022	8.13	1220	743	91	<1	<1	373	373	89.7	39	180	29	40	158	12	<0.1
HMB023S	16/11/2022	8.06	1700	999	20	<1	<1	399	399	98.2	69	307	29	42	237	14	<0.1
HMB023D	16/11/2022	7.97	1310	753	8	<1	<1	391	391	36.6	76	210	28	40	178	13	<0.1
HMB003	16/11/2022	8.10	1440	866	<5	<1	<1	422	422	96.8	56	234	22	46	198	12	<0.1
HMB022	16/11/2022	7.84	897	497	74	<1	<1	355	355	27.4	27	109	59	37	70	3	<0.1
HMB021	16/11/2022	7.90	1770	1060	132	<1	<1	274	274	77.7	62	437	55	63	195	7	<0.1
HMB021B	16/11/2022	7.89	1760	1060	676	<1	<1	269	269	78.9	60	441	58	63	194	8	<0.1
HMB020	16/11/2022	7.75	2250	1310	33	<1	<1	460	460	56.2	82	504	87	73	260	6	<0.1
HMB019	17/11/2022	8.01	622	352	58	<1	<1	302	302	33.2	9	39	50	31	36	3	<0.1
HMB018	17/11/2022	8.03	839	562	76	<1	<1	221	221	52.5	12	169	47	37	69	4	<0.1
HMB018B	17/11/2022	8.05	853	554	227	<1	<1	220	220	52.0	12	164	47	37	69	4	<0.1
HMB017	17/11/2022	7.60	1610	923	44	<1	<1	337	337	39.4	74	349	73	48	182	5	<0.1
HMB003	27/11/2023	8.20	1500	894	N.D	<1	<1	415	415	99.7	58	264	27	52	197	13	<0.1
HMB004	12/12/2023	8.13	1650	870	N.D	<1	<1	424	424	87.9	64	250	34	59	220	11	<0.1
HMB012S	23/11/2023	8.31	1570	874	N.D	<1	4	399	403	90.0	60	260	28	56	196	13	<0.1
HMB016	23/11/2023	8.37	1620	925	N.D	<1	14	410	424	104.0	54	285	27	58	212	15	<0.1
HPB012	12/12/2023	8.27	1360	790	N.D	<1	<1	368	368	89.8	45	192	36	45	178	10	<0.1

BORE	DATE	Aluminium	Iron	Antimony	Selenium	Arsenic	Barium	Beryllium	Boron	Bismuth	Cadmium	Chromium	Cobalt	Copper	Lead	Lithium	Manganese
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
HMB30D	15/11/2022	19	3	<0.2	3.1	11.3	160	<0.1	527	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	25.2	1.3
HMB011	15/11/2022	<5	<2	<0.2	3.1	7.0	173	<0.1	599	<0.05	<0.05	2.5	<0.1	1.3	<0.1	26.4	<0.5
HMB029S	15/11/2022	<5	<2	<0.2	2.8	7.0	187	<0.1	558	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	25.6	9.4
HMB029D	15/11/2022	9	4	<0.2	2.2	7.6	205	<0.1	512	<0.05	<0.05	2.2	0.1	0.6	<0.1	25.0	157
HMB010	15/11/2022	<5	<2	<0.2	2.2	5.0	252	<0.1	352	<0.05	<0.05	2.4	<0.1	1.3	<0.1	5.3	0.7
HMB009	15/11/2022	<5	<2	<0.2	2.0	5.1	204	<0.1	365	<0.05	<0.05	2.5	<0.1	<0.5	<0.1	6.3	<0.5
HMB028S	15/11/2022	<5	<2	<0.2	2.5	5.6	164	<0.1	503	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	18.5	<0.5
HMB028D	15/11/2022	<5	<2	<0.2	2.9	7.4	148	<0.1	533	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	27.9	1.4
HMB027S	15/11/2022	<5	<2	<0.2	2.8	6.1	178	<0.1	543	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	25.0	<0.5
HMB027D	15/11/2022	<5	<2	<0.2	2.9	6.3	146	<0.1	488	<0.05	<0.05	2.9	<0.1	<0.5	<0.1	27.4	<0.5
HMB008	15/11/2022	<5	<2	<0.2	2.4	4.7	196	<0.1	486	<0.05	<0.05	1.7	<0.1	<0.5	<0.1	17.1	<0.5
HMB042	15/11/2022	<5	<2	<0.2	3.3	14.3	188	<0.1	563	<0.05	<0.05	2.1	<0.1	<0.5	0.1	23.2	<0.5
HMB040	15/11/2022	<5	<2	<0.2	3.1	7.9	121	<0.1	574	<0.05	<0.05	1.0	<0.1	0.9	<0.1	19.2	0.9
HMB039	15/11/2022	<5	<2	<0.2	3.9	7.5	183	<0.1	627	<0.05	<0.05	1.8	<0.1	<0.5	<0.1	23.2	<0.5
HMB037	15/11/2022	<5	<2	<0.2	3.3	9.8	178	<0.1	603	<0.05	<0.05	1.3	<0.1	0.6	<0.1	21.6	<0.5
HMB035	15/11/2022	<5	<2	<0.2	5.6	7.0	158	<0.1	815	<0.05	<0.05	1.4	<0.1	<0.5	<0.1	38.8	<0.5
HMB036	15/11/2022	<5	<2	<0.2	2.9	7.8	166	<0.1	528	<0.05	<0.05	2.5	<0.1	<0.5	<0.1	23.0	<0.5
HMB034	15/11/2022	<5	<2	<0.2	3.4	8.3	156	<0.1	557	<0.05	<0.05	1.2	<0.1	<0.5	<0.1	20.8	<0.5
HMB034B	15/11/2022	<5	<2	<0.2	3.6	8.4	147	<0.1	560	<0.05	<0.05	1.2	<0.1	<0.5	<0.1	20.8	<0.5
HMB016	16/11/2022	<5	<2	<0.2	3.3	10.3	128	<0.1	598	<0.05	<0.05	2.1	<0.1	0.6	<0.1	22.6	<0.5
HMB012S	16/11/2022	5	<2	<0.2	3.3	11.8	116	<0.1	566	<0.05	<0.05	2.1	<0.1	<0.5	<0.1	22.4	6.3
HMB012D	16/11/2022	13	<2	<0.2	3.6	7.4	130	<0.1	540	<0.05	<0.05	0.3	<0.1	0.6	<0.1	20.4	44.3
HMB004	16/11/2022	<5	<2	<0.2	3.8	11.3	128	<0.1	604	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	22.3	<0.5
HMB005	16/11/2022	<5	<2	<0.2	4.0	56.0	102	<0.1	689	<0.05	<0.05	3.8	<0.1	<0.5	<0.1	20.3	<0.5
HMB025S	16/11/2022	<5	<2	<0.2	3.1	17.0	231	<0.1	589	<0.05	<0.05	1.4	<0.1	0.6	<0.1	23.0	4.0
HMB025D	16/11/2022	<5	1800	<0.2	0.3	69.2	410	<0.1	555	<0.05	<0.05	<0.2	1.2	2.0	<0.1	25.7	1210
HMB015	16/11/2022	<5	<2	<0.2	2.8	39.9	137	<0.1	563	<0.05	<0.05	2.8	<0.1	<0.5	<0.1	21.5	1.1
HMB024S	16/11/2022	<5	<2	<0.2	2.7	108	136	<0.1	562	<0.05	<0.05	2.0	<0.1	<0.5	<0.1	23.8	7.1
HMB024D	16/11/2022	<5	10	<0.2	0.4	239	248	<0.1	560	<0.05	<0.05	<0.2	1.0	<0.5	<0.1	23.3	1180
HMB002	16/11/2022	<5	<2	<0.2	2.9	59.0	117	<0.1	539	<0.05	<0.05	3.5	<0.1	<0.5	<0.1	22.6	<0.5
HMB001	16/11/2022	<5	<2	<0.2	2.5	9.0	131	<0.1	581	<0.05	<0.05	1.7	<0.1	<0.5	<0.1	17.7	<0.5
HMB026	16/11/2022	<5	<2	<0.2	2.5	8.6	149	<0.1	512	<0.05	<0.05	3.3	<0.1	<0.5	<0.1	25.1	<0.5
HMB014	16/11/2022	<5	<2	<0.2	2.5	8.5	112	<0.1	520	<0.05	<0.05	3.5	<0.1	<0.5	<0.1	22.6	<0.5
HMB013	16/11/2022	<5	<2	<0.2	2.7	8.2	146	<0.1	525	<0.05	<0.05	3.3	<0.1	0.6	<0.1	26.6	<0.5
HMB007	16/11/2022	<5	<2	<0.2	2.8	6.4	153	<0.1	495	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	25.5	<0.5
HMB023S	16/11/2022	<5	<2	<0.2	3.0	8.0	155	<0.1	487	<0.05	<0.05	2.1	<0.1	0.5	<0.1	21.0	<0.5
HMB023D	16/11/2022	8	57	<0.2	<0.2	634	234	<0.1	433	<0.05	<0.05	<0.2	5.0	<0.5	<0.1	19.4	966
HMB003	16/11/2022	<5	<2	<0.2	3.1	11.5	139	<0.1	536	<0.05	<0.05	2.4	<0.1	<0.5	<0.1	21.5	0.5
HMB022	16/11/2022	<5	8	<0.2	<0.2	1.4	171	<0.1	113	<0.05	<0.05	<0.2	1.1	<0.5	<0.1	7.3	240
HMB021	16/11/2022	<5	<2	<0.2	1.8	4.9	434	<0.1	259	<0.05	<0.05	1.7	<0.1	<0.5	<0.1	21.5	<0.5
HMB021B	16/11/2022	<5	<2	<0.2	1.8	4.8	443	<0.1	263	<0.05	<0.05	1.7	<0.1	<0.5	<0.1	21.5	<0.5
HMB020	16/11/2022	<5	<2	<0.2	1.8	0.9	297	<0.1	564	<0.05	<0.05	<0.2	1.6	<0.5	<0.1	72.3	879
HMB019	17/11/2022	<5	<2	<0.2	0.5	1.0	130	<0.1	127	<0.05	<0.05	1.1	<0.1	<0.5	<0.1	4.8	<0.5
HMB018	17/11/2022	<5	<2	<0.2	0.4	1.7	226	<0.1	118	<0.05	<0.05	1.0	<0.1	0.6	<0.1	12.2	<0.5
HMB018B	17/11/2022	<5	<2	<0.2	0.4	1.7	224	<0.1	116	<0.05	<0.05	1.0	<0.1	<0.5	<0.1	12.3	4.9
HMB017	17/11/2022	<5	<2	<0.2	0.4	0.6	109	0.2	336	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	50.3	19.1
HMB003	27/11/2023	<5	<2	<0.2	3.1	13.1	104	<0.1	589	<0.05	<0.05	2.8	0.1	<0.5	<0.1	25	<0.5
HMB004	12/12/2023	<5	<2	<0.2	3.6	11.7	96	<0.1	567	<0.05	<0.05	3.1	<0.1	<0.5	<0.1	19.3	<0.5
HMB012S	23/11/2023	<5	3	<0.2	3.6	12.1	140	<0.1	612	<0.05	<0.05	2.2	0.5	<0.5	<0.1	23.7	44.2
HMB016	23/11/2023	<5	<2	<0.2	3.5	12.1	114	<0.1	652	<0.05	<0.05	2.3	<0.1	<0.5	<0.1	26.3	<0.5
HPB012	12/12/2023	<5	<2	<0.2	2.6	10.6	109	<0.1	494	<0.05	<0.05	3.6	<0.1	0.6	<0.1	21.8	<0.5

BORE	DATE	Molybdenum	Nickel	Silver	Strontium	Tellurium	Thallium	Thorium	Tin	Titanium	Uranium	Vanadium	Zinc	Nitrate as N	Bromide
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
HMB30D	15/11/2022	5.0	<0.5	<0.1	615	<0.2	<0.02	<0.1	<0.2	<1	28.8	27.9	27	6.26	0.477
HMB011	15/11/2022	5.0	<0.5	<0.1	672	<0.2	<0.02	<0.1	0.2	<1	30.2	28.7	33	6.46	0.515
HMB029S	15/11/2022	4.8	<0.5	<0.1	623	<0.2	<0.02	<0.1	<0.2	<1	24.1	27.5	15	5.49	0.487
HMB029D	15/11/2022	4.5	<0.5	<0.1	584	<0.2	<0.02	<0.1	<0.2	<1	20.5	21.4	27	2.89	0.503
HMB010	15/11/2022	3.2	<0.5	<0.1	609	<0.2	<0.02	<0.1	<0.2	<1	8.81	27.3	22	7.94	0.336
HMB009	15/11/2022	3.0	<0.5	<0.1	544	<0.2	<0.02	<0.1	<0.2	<1	7.79	24.0	20	6.46	0.307
HMB028S	15/11/2022	4.0	<0.5	<0.1	633	<0.2	<0.02	<0.1	<0.2	<1	22.0	28.4	10	7.37	0.439
HMB028D	15/11/2022	5.6	<0.5	<0.1	607	<0.2	<0.02	<0.1	<0.2	<1	28.1	28.4	14	6.50	0.487
HMB027S	15/11/2022	4.5	<0.5	<0.1	601	<0.2	<0.02	<0.1	<0.2	<1	25.9	30.5	13	6.87	0.438
HMB027D	15/11/2022	5.3	<0.5	<0.1	596	<0.2	<0.02	<0.1	<0.2	<1	28.1	30.0	15	7.21	0.492
HMB008	15/11/2022	3.1	<0.5	<0.1	660	<0.2	<0.02	<0.1	<0.2	<1	19.3	26.4	25	9.76	0.381
HMB042	15/11/2022	5.6	<0.5	<0.1	664	<0.2	<0.02	<0.1	<0.2	<1	42.6	35.8	55	5.60	0.598
HMB040	15/11/2022	5.1	<0.5	<0.1	647	<0.2	<0.02	<0.1	<0.2	<1	29.7	28.4	49	5.41	0.634
HMB039	15/11/2022	4.1	1.4	<0.1	822	<0.2	<0.02	<0.1	<0.2	<1	40.3	35.4	26	7.04	0.730
HMB037	15/11/2022	4.2	<0.5	<0.1	701	<0.2	<0.02	<0.1	<0.2	<1	36.7	38.6	25	5.74	0.569
HMB035	15/11/2022	6.1	<0.5	<0.1	926	<0.2	<0.02	<0.1	<0.2	<1	60.8	31.9	15	6.86	0.939
HMB036	15/11/2022	6.5	<0.5	<0.1	610	<0.2	<0.02	<0.1	<0.2	<1	34.8	33.0	24	6.62	0.571
HMB034	15/11/2022	5.4	<0.5	<0.1	818	<0.2	<0.02	<0.1	<0.2	<1	33.8	33.7	13	6.48	0.712
HMB034B	15/11/2022	5.2	<0.5	<0.1	806	<0.2	<0.02	<0.1	<0.2	<1	33.0	33.8	15	7.52	0.702
HMB016	16/11/2022	5.3	<0.5	<0.1	705	<0.2	<0.02	<0.1	<0.2	<1	39.3	35.9	4	6.35	0.681
HMB012S	16/11/2022	5.8	<0.5	<0.1	650	<0.2	<0.02	<0.1	<0.2	<1	38.6	34.1	5	3.52	0.579
HMB012D	16/11/2022	5.3	<0.5	<0.1	628	<0.2	0.03	<0.1	<0.2	<1	40.9	33.4	9	4.64	0.625
HMB004	16/11/2022	5.6	<0.5	<0.1	660	<0.2	<0.02	<0.1	<0.2	<1	43.2	33.9	10	6.29	0.627
HMB005	16/11/2022	5.4	<0.5	<0.1	647	<0.2	<0.02	<0.1	<0.2	<1	39.9	28.2	13	5.81	0.706
HMB025S	16/11/2022	6.5	<0.5	<0.1	649	<0.2	0.02	<0.1	<0.2	<1	38.6	36.1	25	5.76	0.627
HMB025D	16/11/2022	6.8	0.8	<0.1	722	<0.2	<0.02	<0.1	<0.2	<1	11.8	5.0	20	0.15	0.552
HMB015	16/11/2022	6.6	<0.5	<0.1	664	<0.2	<0.02	<0.1	<0.2	<1	46.6	30.1	10	5.54	0.583
HMB024S	16/11/2022	5.2	<0.5	<0.1	683	<0.2	0.02	<0.1	<0.2	<1	39.4	33.4	20	4.40	0.571
HMB024D	16/11/2022	8.8	0.6	<0.1	718	<0.2	<0.02	<0.1	<0.2	<1	18.6	6.8	16	0.75	0.647
HMB002	16/11/2022	5.1	<0.5	<0.1	644	<0.2	<0.02	<0.1	<0.2	<1	38.4	31.1	12	6.19	0.526
HMB001	16/11/2022	5.0	<0.5	<0.1	540	<0.2	<0.02	<0.1	<0.2	<1	26.5	33.1	15	6.20	0.477
HMB026	16/11/2022	4.7	<0.5	<0.1	587	<0.2	<0.02	<0.1	<0.2	<1	26.7	28.3	13	6.93	0.476
HMB014	16/11/2022	4.9	<0.5	<0.1	588	<0.2	<0.02	<0.1	<0.2	<1	30.2	28.0	14	6.83	0.466
HMB013	16/11/2022	4.8	<0.5	<0.1	595	<0.2	<0.02	<0.1	<0.2	<1	26.7	27.8	17	7.12	0.494
HMB007	16/11/2022	4.8	<0.5	<0.1	577	<0.2	<0.02	<0.1	<0.2	<1	26.6	30.4	14	7.71	0.497
HMB023S	16/11/2022	4.0	<0.5	<0.1	650	<0.2	<0.02	<0.1	<0.2	<1	33.1	25.8	12	7.13	0.748
HMB023D	16/11/2022	22.8	5.6	<0.1	628	<0.2	0.16	<0.1	<0.2	<1	15.0	2.8	10	0.05	0.505
HMB003	16/11/2022	6.4	<0.5	<0.1	599	<0.2	<0.02	<0.1	<0.2	<1	39.4	36.8	14	6.88	0.632
HMB022	16/11/2022	1.2	4.6	<0.1	484	<0.2	<0.02	<0.1	<0.2	<1	9.11	3.0	11	0.07	0.311
HMB021	16/11/2022	1.2	<0.5	<0.1	940	<0.2	<0.02	<0.1	<0.2	<1	21.9	14.3	24	3.51	1.26
HMB021B	16/11/2022	1.1	<0.5	<0.1	937	<0.2	<0.02	<0.1	<0.2	<1	21.4	14.2	18	3.52	1.22
HMB020	16/11/2022	4.7	2.8	<0.1	784	<0.2	0.05	<0.1	<0.2	<1	43.9	13.3	14	0.85	1.42
HMB019	17/11/2022	1.0	<0.5	<0.1	440	<0.2	<0.02	<0.1	<0.2	<1	10.2	5.3	16	1.63	0.117
HMB018	17/11/2022	1.0	<0.5	<0.1	567	<0.2	<0.02	<0.1	<0.2	<1	6.86	9.2	13	0.88	0.407
HMB018B	17/11/2022	1.0	<0.5	<0.1	556	<0.2	<0.02	<0.1	<0.2	<1	6.91	9.2	14	0.88	0.442
HMB017	17/11/2022	2.8	<0.5	<0.1	610	<0.2	0.07	<0.1	<0.2	<1	26.0	9.5	8	0.34	0.824
HMB003	27/11/2023	6.9	<0.5	<0.1	624	<0.2	<0.02	<0.1	<0.2	<1	41.7	35.8	<1	7.2	0.604
HMB004	12/12/2023	6.2	<0.5	<0.1	677	<0.2	<0.02	<0.1	<0.2	<1	44.9	32.8	<1	6.34	1.25
HMB012S	23/11/2023	6.4	<0.5	<0.1	651	<0.2	<0.02	<0.1	<0.2	<1	44.5	38.7	<1	6.28	0.591
HMB016	23/11/2023	5.8	<0.5	<0.1	680	<0.2	<0.02	<0.1	<0.2	<1	42.8	38	<1	6.78	0.637
HPB012	12/12/2023	5.8	<0.5	<0.1	541	<0.2	<0.02	<0.1	<0.2	<1	28	27.9	<1	7.14	0.968

Sample Location	River System	Date	pH	EC	TDS	TSS	OH Alkalinity	CO3 Alkalinity	HCO3 Alkalinity	Total Alkalinity	SiO2	SO4	Cl	Ca	Mg	Na	K	Hg	Al	Fe	Sb	Se	As	Ba	Be	B	Bi	Cd	Cr	Co	Cu	Pb	Li	Mn	Mo	Ni	Ag	Sr	Te	Tl	Th	Sn	Ti	U	V	Zn	NO3-N	Br
			pH Unit	µS/cm	mg/L	mg/L	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L as CaCO3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L
TR01	Turner	05/11/2021	9.01	3830	2490	15	<1	140	356	496	N.D	56	988	19	77	679	17	N.D	<5	<2	N.D	<0.2	5	90	N.D	770.0	N.D	<0.05	<0.2	<0.1	13	<0.5	ND	17	4	6	N.D	N.D	N.D	N.D	N.D	N.D	N.D	16	<0.2	45	<0.01	N.D
TRE2	Turner	05/11/2021	8.25	754	490	17	<1	4	182	186	N.D	4	145	43	18	98	4	N.D	30	70	N.D	<0.2	1	86	N.D	140	N.D	<0.05	<0.2	<0.1	2	<0.5	ND	35	<0.1	1	N.D	N.D	N.D	N.D	N.D	N.D	N.D	2	<0.2	<1	<0.01	N.D
TRU1	Turner	06/11/2021	8.35	1830	1190	<5	<1	21	312	333	N.D	93	410	46	65	243	7	N.D	<5	160	N.D	<0.2	2	169	N.D	400	N.D	<0.05	<0.2	<0.1	2	<0.5	ND	91	1	1	N.D	N.D	N.D	N.D	N.D	N.D	N.D	5	<0.2	5	<0.01	N.D
TRD2	Turner	06/11/2021	9.05	1030	670	19	<1	55	200	256	N.D	6	216	16	38	158	9	N.D	60	60	N.D	<0.2	5	49	N.D	250	N.D	<0.05	<0.2	<0.1	1	<0.5	ND	20	2	1	N.D	N.D	N.D	N.D	N.D	N.D	N.D	3	<0.2	<1	<0.01	N.D
TR01	Turner	03/01/2022	9.27	3200	1800	147	<1	193	272	465	15.1	61	798	8	71	531	24	<0.1	<5	17	0.4	<0.2	8	101	<0.1	740	<0.05	<0.05	<0.2	0.2	1.4	<0.1	10.2	16	3.4	1.6	<0.1	75	<0.2	<0.02	<0.1	0.2	1	4.84	8.6	9	0.01	2.25
TR01	Turner	11/02/2022	9.41	3030	1690	53	<1	172	251	422	22.4	25	786	7	60	478	22	<0.1	<5	8	0.5	0.4	9.8	155	<0.1	807	<0.05	<0.05	<0.2	0.4	1.4	<0.1	9.6	3.4	3.5	1.4	<0.1	62	<0.2	<0.02	<0.1	0.4	1	5.65	9.8	8	0.01	2.51
TR01	Turner	13/03/2022	8.91	269	165	<5	<1	15	77	92	20.9	3	28	20	9	28	6	<0.1	9	17	<0.2	<0.2	2.8	78.8	<0.1	68	<0.05	<0.05	<0.2	0.3	1.2	<0.1	1.8	6.3	1	1.7	<0.1	181	<0.2	<0.02	<0.1	<0.2	1	1.39	4.8	4	0.01	0.012
TR08	Turner	13/03/2022	8.49	888	663	128	<1	25	302	327	22.7	<5	112	50	30	113	17	<0.1	5	5	0.4	0.6	7.7	202	<0.1	440	<0.05	<0.05	0.3	2.7	4.5	<0.1	2.1	132	5.5	19.2	<0.1	490	<0.2	<0.02	<0.1	<0.2	1	8.45	11.2	17	0.01	0.399
TR01	Turner	26/04/2022	8.07	236	146	13	<1	<1	112	112	16.0	2	11	26	7	13	4	<0.1	<5	13	<0.2	<0.2	1.4	106	<0.1	39	<0.05	<0.05	<0.2	0.3	0.7	<0.1	1	42.5	0.8	1.6	<0.1	171	<0.2	<0.02	<0.1	<0.2	1	1.37	2.3	15	0.02	0.01
TR south	Turner	03/06/2022	7.94	235	155	<5	<1	<1	53	53	11.6	16	33	10	5	30	2	<0.1	11	10	<0.2	0.4	0.7	92.9	<0.1	55	<0.05	<0.05	0.5	<0.1	1	<0.1	1.8	3.7	0.9	0.6	<0.1	64	<0.2	<0.02	<0.1	0.4	<1	0.65	1.9	30	1.08	0.071
TR North	Turner	03/06/2022	7.74	225	143	<5	<1	<1	48	48	11.3	15	30	9	5	28	2	<0.1	<5	8	<0.2	0.2	0.7	73.7	<0.1	45	<0.05	<0.05	0.7	<0.1	0.8	<0.1	1.4	2.3	0.9	<0.5	<0.1	59	<0.2	<0.02	<0.1	0.6	<1	0.52	1.9	18	1	0.064
TR South	Turner	06/06/2022	7.97	234	158	<5	<1	<1	53	53	12.6	15	31	10	6	30	2	<0.1	6	9	<0.2	0.3	0.6	83.8	<0.1	44	<0.05	<0.05	0.5	<0.1	0.7	<0.1	1.7	2.4	0.8	<0.5	<0.1	61	<0.2	<0.02	<0.1	<0.2	<1	0.71	2.3	12	1.2	0.065
TR North	Turner	06/06/2022	8.04	258	158	<5	<1	<1	79	79	13.2	17	34	11	6	33	3	<0.1	7	8	<0.2	0.3	0.7	62.3	<0.1	44	<0.05	<0.05	0.6	<0.1	0.7	<0.1	1.5	1.8	0.8	<0.5	<0.1	66	<0.2	<0.02	<0.1	<0.2	<1	0.74	2.4	8	1.12	0.076
TR Flow before Indee access rd	Turner	08/02/2023	7.94	276	175	<5	<1	<1	86	86	18.4	15	34	13	8	35	4	<0.1	6	9	<0.2	<0.2	0.8	26.3	<0.1	73	<0.05	<0.05	0.5	<0.1	0.5	<0.1	2.3	<0.5	0.8	0.6	<0.1	104	<0.2	<0.02	<0.1	<0.2	<1	1.25	2.9	<1	<0.01	0.085
TR Flow on Indee access rd	Turner	08/02/2023	8.10	274	166	<5	<1	<1	90	90	18.3	10	34	12	7	35	4	<0.1	6	7	<0.2	0.2	0.8	26.5	<0.1	76	<0.05	<0.05	0.4	<0.1	0.5	<0.1	2.4	<0.5	0.8	0.6	<0.1	104	<0.2	<0.02	<0.1	<0.2	<1	1.30	2.9	<1	<0.01	0.083
YR01	Yule	02/01/2022	8.63	1290	788	6	<1	35	389	424	38.3	<1	225	30	34	189	8	<0.1	<5	29	<0.2	<0.2	2.1	186	<0.1	265	<0.05	<0.05	<0.2	0.2	0.6	<0.1	1.7	64.7	0.6	<0.5	<0.1	423	<0.2	<0.02	<0.1	<0.2	1	0.5	2.2	10	0.01	0.557
YR02	Yule	02/01/2022	8.15	459	258	17	<1	<1	170	170	28.6	<1	50	24	12	60	3	<0.1	<5	20	<0.2	<0.2	0.4	75.7	<0.1	105	<0.05	<0.05	<0.2	0.1	0.6	<0.1	0.9	4.8	0.8	<0.5	<0.1	177	<0.2	<0.02	<0.1	<0.2	1	2.22	1.6	9	0.01	0.154
YR03	Yule	02/01/2022	8.92	3140	1820	9	<1	170	592	762	32.2	53	661	17	76	557	11	<0.1	<5	9	0.8	<0.2	5.8	99.2	<0.1	836	<0.05	<0.05	<0.2	0.2	0.9	<0.1	2.9	6.5	3.6	1	<0.1	420	<0.2	<0.02	<0.1	<0.2	1	18.2	9.8	10	0.01	1.78
YR04	Yule	02/01/2022	8.38	658	460	27	<1	9	285	294	49.5	<1	50	25	16	95	10	<0.1	8	600	<0.2	<0.2	4.2	183	<0.1	315	<0.05	<0.05	<0.2	0.6	2.7	0.1	1.1	886	1	1.3	<0.1	416	<0.2	<0.02	<0.1	0.4	1	1.13	3.1	21	0.01	0.174
YR01	Yule	10/02/2022	8.23	1300	738	14	<1	<1	398	398	37.9	2	212	32	30	180	8	<0.1	<5	50	<0.2	0.2	2.9	205	<0.1	338	<0.05	<0.05	<0.2	0.3	<0.5	<0.1	1.4	98.8	1	<0.5	<0.1	348	<0.2	<0.02	<0.1	<0.2	1	0.77	1.4	11	0.01	0.521
YR02	Yule	10/02/2022	8.43	478	264	<5	<1	6	168	174	31.8	4	53	23	10	62	3	<0.1	<5	23	<0.2	<0.2	0.7	86.6	<0.1	130	<0.05	<0.05	<0.2	0.2	0.5	<0.1	0.9	36.7	1	<0.5	<0.1	181	<0.2	<0.02	<0.1	0.5	1	2.29	4.7	8	0.09	0.016
YR03	Yule	10/02/2022	8.9	3280	1880	19	<1	169	624	793	31.8	39	687	15	74	557	14	<0.1	<5	6	1	<0.2	5.4	86.8	<0.1	918	<0.05	<0.05	<0.2	0.3	<0.5	<0.1	3	1.3	3.9	1	<0.1	296	<0.2	<0.02	<0.1	<0.2	1	18.8	10.4	8	0.01	2.14
YR01	Yule	13/03/2022	8.26	1740	1040	7	<1	<1	475	475	39.2	<1	366	43	41	296	11	<0.1	<5	52	<0.2	<0.2	3.2	222	<0.1	495	<0.05	<0.05	<0.2	0.2	<0.5	<0.1	2.1	45.8	1	0.5	<0.1	523	<0.2	<0.02	<0.1	<0.2	1	0.68	0.5	12	0.01	0.774
YR02	Yule	13/03/2022	8	525	294	<5	<1	<1	193	193	31.1	5	52	37	14	67	4	<0.1	<5	56	<0.2	<0.2	0.4	66.9	<0.1	94	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	1	68.4	0.7	<0.5	<0.1	237	<0.2	<0.02	<0.1	<0.2	1	2.07	0.3	1	0.01	0.016
YR03	Yule	13/03/2022	8.9	3200	1850	<5	<1	165	575	740	29	42	695	21	87	599	15	<0.1	<5	9	0.8	0.2	5.8	88.1	<0.1	895	<0.05	<0.05	<0.2	0.2	<0.5	<0.1	3.1	2.2	3.9	0.8	<0.1	328	<0.2	<0.02	<0.1	<0.2	1	19.3	8.5	9	0.01	1.89
YR04	Yule	19/06/2022	8.59	224	136	10	<1	6	70	76	12.9	9	24	14	4	32	3	<0.1	7	9	<0.2	<0.2	0.6	69.9	<0.1	16	<0.05	<0.05	0.4	0.2	1.7	<0.1	0.8	1.8	0.8	0.6	<0.1	112	<0.2	<0.02	<0.1	0.3	<1	1.72	6.3	3	0.01	0.055
YR05	Yule	21/06/2022	8.72	343	180	5	<1	14	104	118	13.9	11	39	17	9	58	3	<0.1	<5	4	<0.2	<0.2	0.5	69.4	<0.1	23	<0.05	<0.05	<0.2	<0.1	0.6	<0.1	0.7	1.6	1.1	<0.5	<0.1	145	<0.2	<0.02	<0.1	<0.2	<1	2.44	4.9	7	0.01	0.106
YR06	Yule	21/06/2022	8.81	337	182	<5	<1	17	99	116	13.6	11	37	13	7	41	2	<0.1	<5	3	<0.2	<0.2	0.4	59.5	<0.1	28	<0.05	<0.05	<0.2	<0.1	<0.5	<0.1	0.6	1.5	1.1	<0.5	<0.1	147	<0.2	<0.02	<0.1	<0.2	<1	2.26	4.7	6	0.01	0.108
YR07	Yule	19/06/2022	8.3	405	221	11	<1	<1	153	153	19.3	19	33	26	8	50	2	<0.1	<5	18	<0.2	<0.2	0.5	113	<0.1	22	<0.05	<0.05	<0.2	<0.1	0.5	<0.1	0.6	10.6	1	<0.5	<0.1	166	<0.2	<0.02	<0.1	<0.2	<1	1.89	3	26	0.01	0.087
YR01	Yule	09/11/2021	8.8	2820	1830	28	<1	149	524	673	N.D	34	605	24	68	514	7	N.D	40	70	N.D	<0.2	4	74	N.D	830	N.D	<0.05	<0.2	<0.1	1	<0.5	ND	18	2	1	N.D	N.D	N.D	N.D	N.D	N.D	N.D	13	10	<1	<0.01	N.D
YR02	Yule	07/11/2021	7.97	510	332	<5	<1	2	194	197	N.D	4	55	30	14	65	2	N.D	<5	<2	N.D	<0.2	<0.2	86	N.D	140	N.D	<0.05	<0.2	<0.1	<0.5	<0.5	ND	61	<0.1	<0.5	N.D	N.D	N.D	N.D	N.D	N.D	N.D	2	<0.2	<1	<0.01	N.D
YR03	Yule	09/11/2021	7.69	1320	858	<5	<1	<1	421	421	N.D	<1	225	38	35	212	5	N.D	10	220	N.D	<0.2	<0.2	125	N.D	310	N.D	<0.05	<0.2	<0.1	<0.5	<0.5	ND	184	<0.1	<0.5	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.025	<0.2	<1	<0.01	N.D
YRD1	Yule	07/11/2021	8.16	459	298	7	<1	<1	180	180	N.D	2	43	31	13	56	3	N.D	<5	140	N.D	<0.2	<0.2	205	N.D	120	N.D	<0.05	<0.2	<0.1	<0.5	<0.5	ND	1110	<0.1	<0.5	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.025	<0.2	<1	0.02	N.D
YRU1	Yule	08/11/2021	9	8460	5500	62	<1	552	1030	1580	N.D	202	2200	22	235	1530	26	N.D	20	<2	N.D	<0.2	8	235	N.D	2790	N.D	<0.05	<0.2	2	2	<0.5	ND	3	7	9	N.D	N.D	N.D	N.D	N.D	N.D	N.D	58	30	<1	<0.01	N.D
YRU2	Yule	08/11/2021	7.59	380	247	<5	<1	<1	141	141	N.D	4	41	22	10	50	2	N.D	10	130	N.D	<0.2	<0.2	64	N.D	180	N.D	<0.05	<0.2	<0.1	11	<0.5	ND	100	<0.1	1	N.D	N.D	N.D	N.D	N.D	N.D	N.D	0.025	<0.2	20	0.05	N.D

Site	River System	Sample Period	pH	EC	Tot Sol Salts	Moisture	OH Alkalinity	CO3 Alkalinity	HCO3 Alkalinity	Total Alkalinity	SO4	Cl	Ca	Mg	Na	K	Al	As	Ba	B	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	Se	V	Zn	S	U	Hg	NO2/NO3	TN	TP	Org Matter
			pH Units	uS/cm	mg/kg	%	mg/kg as CaCO3	mg/kg as CaCO3	mg/kg as CaCO3	mg/kg as CaCO3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%
TR1	Turner	2021	9.2	258	877	22	<5	<5	277	279	20	250	30	40	230	20	740	<5	<10	<50	<1	20	<2	<5	4620	<5	33	<2	6	<5	7	<5	2090	0.4	<0.1	<0.1	30	22	<0.5
TRE2	Turner	2021	7.8	55	187	17	<5	<5	51	51	70	30	20	20	100	<10	570	<5	<10	<50	<1	5	<2	<5	1760	<5	19	<2	<2	<5	<5	<5	<50	0.2	<0.1	<0.1	40	22	<0.5
TRU1	Turner	2021	8.6	167	568	24	<5	<5	239	239	100	110	40	40	100	<10	630	<5	<10	<50	<1	4	<2	<5	3830	<5	118	<2	<2	<5	<5	<5	180	0.4	<0.1	<0.1	80	22	<0.5
TRD2	Turner	2021	8.9	64	217	16	<5	<5	80	80	<10	20	<10	10	20	<10	540	<5	<10	<50	<1	24	<2	<5	4510	<5	14	<2	3	<5	6	<5	<50	0.2	<0.1	<0.1	20	14	<0.5
YRD1	Yule	2021	8.6	87	296	25	<5	<5	162	162	20	10	60	10	20	<10	1630	<5	20	<50	<1	8	2	<5	6210	<5	70	<2	5	<5	9	5	60	0.1	<0.1	<0.1	220	46	<0.5
YR2	Yule	2021	7.7	270	918	33	<5	<5	519	519	70	120	110	30	210	30	4850	<5	50	<50	<1	22	7	10	16500	<5	344	<2	18	<5	23	16	260	1.2	<0.1	<0.1	980	86	1
YRU1	Yule	2021	9.2	3110	10600	47	<5	176	962	1140	1020	6370	20	160	4490	120	8900	<5	70	<50	<1	66	10	18	24300	5	332	<2	32	<5	35	24	2210	4.8	<0.1	<0.1	1150	132	6
YRU2	Yule	2021	7.2	112	380	19	<5	<5	153	153	20	20	30	<10	50	<10	2510	<5	30	<50	<1	14	4	<5	10300	<5	289	<2	9	<5	13	8	<50	0.4	<0.1	<0.1	270	54	<0.5
YR3	Yule	2021	8.0	655	2230	76	<5	<5	788	788	490	1780	270	220	1670	130	16800	<5	160	<50	<1	97	18	34	41200	10	421	<2	58	<5	63	48	1310	4.4	<0.1	1.6	4830	385	13
YR1	Yule	2021	8.5	581	1980	58	<5	23	870	893	340	790	80	160	970	50	9870	<5	240	<50	<1	48	10	22	26800	6	691	<2	29	<5	37	27	2600	5.9	<0.1	<0.1	3730	280	7
TR1	Turner	12-15 May 2022	9.2	277	942	17	<5	42	165	208	50	310	20	30	350	20	770	<5	<10	<50	<1	12	<2	<5	4620	<5	47	<2	7	<5	6.00	<5	60.0	0.5	<0.1	<0.1	80	31	<0.5
TRE1	Turner	12-15 May 2022	8.4	110	375	18	<5	<5	245	245	10	10	50	10	20	10	860	<5	<10	<50	<1	7	<2	<5	2560	<5	33	<2	2	<5	<5	<5	<50	0.5	<0.1	0.7	180	38	<0.5
TRU1	Turner	12-15 May 2022	8.9	463	1570	25	<5	66	342	407	120	490	50	110	390	40	800	<5	30	<50	<1	5	<2	<5	4180	<5	258	<2	<2	<5	<5	<5	490	0.5	<0.1	<0.1	490	68	0.6
TRD1	Turner	12-15 May 2022	9.7	551	1870	30	<5	267	382	649	150	1050	20	40	910	120	3310	<5	40	<50	<1	40	4	7.0	14200	<5	181	<2	16	<5	21	8	400	1.0	<0.1	0.1	700	77	1.0
YRD1	Yule	12-15 May 2022	7.7	298	1010	36	<5	<5	445	445	160	50	180	40	110	30	7070	<5	60	<50	<1	37	9	16.0	23900	<5	230	<2	26	<5	31	24	420	1.8	<0.1	2.2	820	100	3.0
YR2	Yule	12-15 May 2022	8.3	183	622	32	<5	5	352	357	20	50	50	30	110	20	3820	<5	50	<50	<1	17	5	7.0	13600	<5	132	<2	14	<5	17	13	140	0.6	<0.1	1.9	710	78	0.6
YRU1	Yule	12-15 May 2022	8.5	179	609	29	<5	<5	395	395	100	70	70	40	160	40	9180	<5	80	<50	<1	64	10	20.0	23700	6	306	<2	33	<5	34	26	200	3.6	<0.1	0.2	620	100	2.0
YRU2	Yule	12-15 May 2022	7.8	58	199	20	<5	<5	104	104	20	10	30	<10	20	<10	1450	<5	10	<50	<1	10	2	<5	6080	<5	46	<2	6	<5	9	5	<50	0.3	<0.1	<0.1	110	45	<0.5
YR3	Yule	12-15 May 2022	9.6	663	2250	19	<5	178	321	499	540	460	10	30	630	40	3200	<5	30	<50	<1	19	4	7.0	10500	<5	106	<2	13	<5	15	10	450	1.0	<0.1	0.3	300	69	<0.5
YR1	Yule	12-15 May 2022	8.8	258	877	35	<5	27	462	489	60	260	60	50	450	40	4210	<5	70	<50	<1	38	6	11.0	14700	<5	305	<2	22	<5	19	13	220	0.7	<0.1	0.5	910	103	2.9
TR1-A	Turner	12-15 May 2022	7.4	136	462	36	<5	<5	186	186	30	<10	60	20	30	30	5240	<5	50	<50	<1	51	7	11.0	19900	7	234	<2	24	<5	26	19	180	1.8	<0.1	0.4	1140	98	3.1
YRU1-A	Yule	12-15 May 2022	8.6	111	378	25	<5	<5	159	159	60	30	60	20	50	10	4680	<5	40	<50	<1	18	6	9.0	15900	<5	237	<2	18	<5	22	16	160	1.2	<0.1	0.3	310	70	<0.5

APPENDIX 3: DISCHARGE CALCULATIONS

	pH	EC	TDS	Hydroxide Alk	Carbonate	Bicarbonate	Total Alkalinity as CaCO3	SiO2	SO4	Cl	Ca	Mg	Na	K	NO3-N	Br
Month	pH Units	uS/cm	mg/L	mg/L (as $CaCO_3$)				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
3	8.23	1294	771	0.5	7	351	354	90	44	201	33	45	163	11	7	0.60
6	8.23	1293	770	0.5	7	351	353	90	44	201	33	45	162	11	7	0.60
9	8.23	1293	770	0.5	7	351	353	90	44	201	33	45	162	11	7	0.60
12	8.23	1289	768	0.5	6	350	352	90	44	200	33	45	161	11	7	0.60
15	8.23	1286	763	0.5	6	351	352	90	44	199	32	44	163	11	7	0.60
18	8.23	1286	763	0.5	6	351	352	90	44	199	32	44	163	11	7	0.60
21	8.22	1316	781	0.5	7	358	360	90	47	205	30	45	169	11	7	0.62
24	8.21	1320	784	0.5	7	359	361	90	47	206	30	45	170	12	7	0.61
27	8.21	1323	786	0.5	7	360	362	91	48	207	30	45	171	12	7	0.61
30	8.21	1313	780	0.5	6	358	359	90	47	204	30	45	168	12	7	0.60
33	8.21	1314	780	0.5	6	358	359	90	47	205	30	45	168	12	7	0.60
36	8.21	1313	780	0.5	6	357	359	90	47	205	30	45	168	12	7	0.60

	Hg	Al	Fe	Sb	Se	As	Ba	Be	B	Bi	Cd	Cr	Co	Cu	Pb	Li
Month	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
3	0.05	9.3	3.6	0.1	2.9	10.7	151	0.05	522	0.025	0.03	2.7	0.06	1.9	0.06	22
6	0.05	9.3	3.6	0.1	2.9	10.7	151	0.05	521	0.025	0.03	2.7	0.06	1.9	0.06	22
9	0.05	9.2	3.4	0.1	2.9	10.7	151	0.05	522	0.025	0.03	2.7	0.06	1.9	0.06	22
12	0.05	8.3	3.1	0.1	2.9	10.5	153	0.05	524	0.025	0.03	2.7	0.06	2.0	0.06	22
15	0.05	7.0	1.5	0.1	2.8	10.3	150	0.05	529	0.025	0.03	2.6	0.14	2.0	0.05	21
18	0.05	7.0	1.5	0.1	2.8	10.3	150	0.05	529	0.025	0.03	2.6	0.14	2.0	0.05	21
21	0.05	6.6	1.4	0.1	2.8	11.8	142	0.05	529	0.025	0.03	2.6	0.23	1.8	0.06	21
24	0.05	5.5	1.5	0.1	2.8	12.0	142	0.05	531	0.025	0.03	2.6	0.25	1.9	0.06	20
27	0.05	5.6	1.5	0.1	2.8	12.1	141	0.05	531	0.025	0.03	2.6	0.26	1.9	0.06	20
30	0.05	5.2	1.4	0.1	2.8	11.7	144	0.05	531	0.025	0.03	2.6	0.23	2.0	0.06	21
33	0.05	4.6	1.1	0.1	2.8	11.6	145	0.05	534	0.025	0.03	2.6	0.27	2.1	0.05	21
36	0.05	4.5	1.1	0.1	2.8	11.6	145	0.05	533	0.025	0.03	2.6	0.28	2.1	0.05	21

	Mn	Mo	Ni	Ag	Sr	Te	Tl	Th	Sn	Ti	U	V	Zn
Month	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
3	2.4	5.1	0.3	0.05	653	0.1	0.01	0.05	0.1	0.5	29	28	16
6	2.4	5.1	0.3	0.05	653	0.1	0.01	0.05	0.1	0.5	28	28	16
9	2.4	5.1	0.3	0.05	653	0.1	0.01	0.05	0.1	0.5	28	28	16
12	2.1	5.1	0.3	0.05	657	0.1	0.01	0.05	0.1	0.5	28	28	16
15	2.6	5.1	0.3	0.05	652	0.1	0.01	0.05	0.1	0.5	28	28	16
18	2.6	5.1	0.3	0.05	653	0.1	0.01	0.05	0.1	0.5	28	28	16
21	4.0	5.4	0.4	0.05	642	0.1	0.01	0.05	0.1	0.5	31	30	16
24	4.3	5.4	0.4	0.05	645	0.1	0.01	0.05	0.1	0.5	31	30	16
27	4.3	5.5	0.4	0.05	644	0.1	0.01	0.05	0.1	0.5	31	30	16
30	3.7	5.4	0.4	0.05	648	0.1	0.01	0.05	0.1	0.5	31	30	16
33	3.9	5.4	0.4	0.05	653	0.1	0.01	0.05	0.1	0.5	31	30	16
36	3.8	5.4	0.4	0.05	653	0.1	0.01	0.05	0.1	0.5	30	30	16

Scenario	pH	EC	TDS	OH Alk	Carbonate Alk	Bicarbonate Alk	Total Alk	SiO2	SO4	Cl	Ca	Mg	Na	K
	pH Unit	µS/cm	mg/L	mg/L (as CaCO3)				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Scenario 1 - no flow	8.22	1303	775	0.5	6	355	356	90	46	203	31	45	166	11
Scenario 2 - median rainfall	8.43	1447	875	0.5	26	306	334	63	39	274	29	44	202	12
Scenario 3 - average rainfall	8.62	1577	966	0.5	44	262	314	38	33	339	27	42	235	12
Scenario 4 - extreme rainfall	8.72	1649	1016	0.5	54	238	303	24	29	376	26	42	254	12

Scenario	Hg	Al	Fe	Sb	Se	As	Ba	Be	B	Bi	Cd	Cr	Co	Cu	Pb
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Scenario 1 - no flow	0.05	7	2	0.1	2.8	11	147	0.05	528	0.025	0.03	2.6	0.2	2.0	0.06
Scenario 2 - median rainfall	0.05	9	16	0.2	1.8	9	135	0.05	481	0.025	0.03	1.7	0.3	2.4	0.08
Scenario 3 - average rainfall	0.06	11	29	0.2	0.9	6	124	0.05	438	0.025	0.03	0.8	0.3	2.7	0.11
Scenario 4 - extreme rainfall	0.06	13	36	0.2	0.4	5	117	0.05	414	0.025	0.03	0.3	0.4	3.0	0.12

Scenario	Li	Mn	Mo	Ni	Ag	Sr	Te	Tl	Th	Sn	Ti	U	V	Zn
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Scenario 1 - no flow	21	3	5.3	0.4	0.05	651	0.1	0.01	0.05	0.10	0.5	30	29	16
Scenario 2 - median rainfall	15	18	4.1	1.7	0.05	475	0.1	0.01	0.05	0.12	0.5	20	19	14
Scenario 3 - average rainfall	9	31	3.1	2.9	0.05	315	0.1	0.01	0.05	0.14	0.5	12	11	11
Scenario 4 - extreme rainfall	6	38	2.6	3.6	0.05	227	0.1	0.01	0.05	0.15	0.5	7	6	10

Scenario	Hg	Al	Fe	Se	As	Ba	B	Cd	Cr	Co	Cu	Pb	Mn	Mo	Ni	U	V	Zn
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Scenario 1 - no flow	0.46	63	19	26	103	1362	4889	0.25	24	1.57	18	0.54	30	49	3	274	269	149

APPENDIX 4: PHREEQC AND RADIATION MODELLING DATA

O2 Sensitivity

pH	O2 diss	Ca	Cl	K	Mg	Na	SO4	NO3	Al	As	B	Ba	Br	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Se	Si	Sr	U	V	Zn
8.10	0.41	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.31E-04	2.00E-07	2.22E-02	5.78E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.25E-04
8.10	1.03	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.31E-04	2.00E-07	2.22E-02	5.79E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.25E-04
8.10	2.05	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.31E-04	2.00E-07	2.22E-02	5.81E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.25E-04
8.10	4.09	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.31E-04	2.00E-07	2.22E-02	5.84E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.24E-04
8.10	6.18	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.30E-04	2.00E-07	2.22E-02	5.87E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.23E-04
8.10	8.54	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.30E-04	2.00E-07	2.22E-02	5.91E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	4.40E-02	3.74E-02	4.23E-04

pH Sensitivity

pH	O2	Ca	Cl	K	Mg	Na	SO4	NO3	Al	As	B	Ba	Br	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Se	Si	Sr	U	V	Zn
5.00	8.53	2.75E+01	2.49E+02	9.59E+00	5.18E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.79E-02	6.01E-01	8.61E-02	8.82E-01	5.01E-04	1.44E-03	7.91E-04	5.07E-06	2.22E-02	7.02E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.33E-02	4.01E-02	2.98E-03
5.50	8.53	2.75E+01	2.49E+02	9.59E+00	5.18E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.77E-02	6.01E-01	8.61E-02	8.82E-01	5.01E-04	1.44E-03	7.41E-04	1.68E-06	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.31E-02	4.01E-02	2.98E-03
6.00	8.53	2.75E+01	2.49E+02	9.59E+00	5.18E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.72E-02	6.01E-01	3.40E-02	8.82E-01	5.01E-04	1.44E-03	6.07E-04	6.56E-07	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.33E-02	4.01E-02	2.96E-03
6.25	8.53	2.75E+01	2.49E+02	9.59E+00	5.18E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.67E-02	6.01E-01	1.91E-02	8.82E-01	5.01E-04	1.44E-03	5.41E-04	4.51E-07	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.35E-02	4.01E-02	2.92E-03
6.50	8.53	2.75E+01	2.49E+02	9.59E+00	5.18E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.60E-02	6.01E-01	1.08E-02	8.82E-01	5.01E-04	1.44E-03	5.02E-04	3.37E-07	2.22E-02	7.00E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.37E-02	4.00E-02	2.87E-03
7.00	8.53	8.48E+00	2.49E+02	9.59E+00	4.03E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.26E-02	6.01E-01	4.32E-03	8.82E-01	5.01E-04	1.44E-03	3.00E-04	2.36E-07	2.22E-02	6.95E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.40E-01	4.37E-02	3.99E-02	2.43E-03
7.50	8.54	1.22E+00	2.49E+02	9.59E+00	3.59E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	2.66E-02	6.01E-01	1.54E-03	8.82E-01	5.01E-04	1.44E-03	1.48E-04	2.06E-07	2.22E-02	6.63E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	4.85E-01	4.39E-02	3.95E-02	1.19E-03
8.00	8.54	1.36E-01	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.53E-02	6.01E-01	5.07E-04	8.82E-01	5.01E-04	1.44E-03	1.22E-04	2.00E-07	2.22E-02	5.95E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.60E-01	4.40E-02	3.80E-02	4.69E-04
8.50	8.54	1.62E-02	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	7.74E-03	6.01E-01	1.70E-04	8.82E-01	5.01E-04	1.44E-03	1.95E-04	2.08E-07	2.22E-02	6.43E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	5.41E-02	4.40E-02	3.47E-02	3.77E-04
9.00	8.54	2.50E-03	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	5.28E-03	6.01E-01	6.33E-05	8.82E-01	5.01E-04	1.44E-03	3.36E-04	2.44E-07	2.22E-02	6.97E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	2.04E-02	4.40E-02	3.20E-02	6.21E-04
9.50	8.54	6.46E-04	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	4.65E-03	6.01E-01	2.92E-05	8.82E-01	5.01E-04	1.44E-03	4.73E-04	3.60E-07	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	9.71E-03	4.40E-02	3.09E-02	1.43E-03
10	8.54	3.10E-04	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	4.63E-03	6.01E-01	1.84E-05	8.82E-01	5.01E-04	1.44E-03	5.94E-04	7.27E-07	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	6.33E-03	4.40E-02	3.06E-02	2.49E-03
11	8.54	2.82E-04	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	5.72E-03	6.01E-01	1.74E-05	8.82E-01	5.01E-04	1.44E-03	7.92E-04	5.56E-06	2.22E-02	7.01E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	6.02E-03	4.40E-02	2.99E-02	2.98E-03

Iron Oxide Discharge

pH	O2	Ca	Cl	K	Mg	Na	SO4	NO3	Al	As	B	Ba	Br	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Se	Si	Sr	U	V	Zn
8.10	8.54	8.81E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	1.32E-02	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	1.30E-04	2.00E-07	2.22E-02	5.91E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	3.17E-02	3.74E-02	4.22E-04
8.10	8.54	8.82E-02	2.49E+02	9.59E+00	3.52E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	7.52E-03	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	6.85E-05	2.00E-07	2.22E-02	4.97E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	3.16E-02	3.47E-02	2.09E-04
8.10	8.54	8.83E-02	2.49E+02	9.59E+00	3.51E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	3.80E-03	6.01E-01	4.06E-04	8.82E-01	5.01E-04	1.44E-03	3.86E-05	2.00E-07	2.22E-02	3.94E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.28E-01	3.16E-02	2.98E-02	1.14E-04
8.10	8.54	8.91E-02	2.49E+02	9.58E+00	3.50E+01	1.94E+02	6.30E+01	3.13E+01	0.00E+00	2.99E-04	6.01E-01	4.07E-04	8.82E-01	5.01E-04	1.44E-03	7.07E-06	2.00E-07	2.22E-02	1.26E-04	8.01E-03	2.00E-03	3.00E-03	1.92E+01	1.29E-01	3.13E-02	6.85E-03	2.01E-05
8.10	8.54	9.95E-02	2.49E+02	9.58E+00	3.30E+01	1.94E+02	6.29E+01	3.13E+01	0.00E+00	1.75E-05	6.00E-01	4.19E-04	8.81E-01	5.01E-04	1.43E-03	6.64E-07	2.00E-07	2.22E-02	1.42E-05	8.00E-03	2.00E-03	3.00E-03	1.92E+01	1.32E-01	2.80E-02	4.74E-04	1.92E-06
8.10	8.54	1.20E-01	2.49E+02	9.57E+00	2.99E+01	1.94E+02	6.28E+01	3.13E+01	0.00E+00	6.82E-06	5.99E-01	4.38E-04	8.80E-01	5.00E-04	1.43E-03	2.47E-07	2.00E-07	2.22E-02	5.55E-06	7.99E-03	2.00E-03	3.00E-03	1.92E+01	1.39E-01	2.28E-02	1.86E-04	7.48E-07
8.10	8.54	1.66E-01	2.48E+02	9.55E+00	2.52E+01	1.94E+02	6.26E+01	3.12E+01	0.00E+00	3.49E-06	5.98E-01	4.73E-04	8.78E-01	4.99E-04	1.43E-03	1.10E-07	2.00E-07	2.21E-02	2.65E-06	7.97E-03	2.00E-03	2.99E-03	1.91E+01	1.50E-01	1.57E-02	9.57E-05	3.60E-07
8.10	8.54	3.16E-01	2.47E+02	9.52E+00	1.75E+01	1.93E+02	6.21E+01	3.11E+01	0.00E+00	1.95E-06	5.95E-01	5.45E-04	8.75E-01	4.97E-04	1.42E-03	4.55E-08	2.00E-07	2.20E-02	1.24E-06	7.94E-03	1.99E-03	2.98E-03	1.91E+01	1.73E-01	7.43E-03	5.35E-05	1.71E-07
8.10	8.54	5.60E-01	2.46E+02	9.48E+00	1.23E+01	1.92E+02	6.17E+01	3.10E+01	0.00E+00	1.51E-06	5.91E-01	6.10E-04	8.72E-01	4.95E-04	1.42E-03	2.73E-08	2.00E-07	2.20E-02	8.32E-07	7.92E-03	1.98E-03	2.97E-03	1.90E+01	1.86E-01	4.12E-03	4.14E-05	1.16E-07
8.10	8.54	8.82E-01	2.45E+02	9.44E+00	9.07E+00	1.91E+02	6.13E+01	3.09E+01	0.00E+00	1.31E-06	5.87E-01	6.58E-04	8.69E-01	4.94E-04	1.42E-03	2.01E-08	2.00E-07	2.19E-02	6.68E-07	7.89E-03	1.97E-03	2.96E-03	1.89E+01	1.53E-01	2.77E-03	3.59E-05	9.38E-08
8.10	8.54	1.62E+00	2.44E+02	9.36E+00	5.80E+00	1.90E+02	6.07E+01	3.07E+01	0.00E+00	1.10E-06	5.80E-01	7.12E-04	8.64E-01	4.91E-04	1.41E-03	1.48E-08	2.00E-07	2.17E-02	5.61E-07	7.85E-03	1.95E-03	2.95E-03	1.88E+01	1.26E-01	1.84E-03	3.01E-05	7.91E-08

ERICA - Flora and Fauna Exposure

Organism	Occupancy Factor: Water - Surface	Occupancy Factor: Water	Occupancy Factor: Sediment - Surface	Screening Value (µGy/h)	Scenario 1 No Flow Total Dose (µGy/h)	Scenario 2 Median Annual Flow 6.3 G/Ly Total Dose (µGy/h)	Scenario 3 Mean Annual Flow 28 GL/y Total Dose (µGy/h)	Background Turner River Total Dose (µGy/h)
Amphibian		0.5	0.5	40	13.3	6.49	3.52	2.18
Bird	0.5			40	31.5	15.7	8.31	5.28
Crustacean1			1	400	6.96	3.37	1.79	1.1
Reptile		0.5		40	14.2	7.1	3.74	2.38
Pelagic Fish		1		400	6.49	3.23	1.7	1.08
Vascular Plant			1	400	11.7	5.68	3	1.83
Zooplankton		1		400	271	135	71	45.4
Crustacean2		1		400	3.45	1.66	0.876	0.53

RESRAD - Livestock and Native Fauna Exposure through Drinking Water

Only source of drinking water - 100% of water consumption from here

Organism	Weight (kg)	Water Intake Rate (L/day)	Screening Value(µGy/h)	Scenario 1a No Flow Total Dose (µGy/h)	Scenario 1a No Flow Tissue Concentration (Bq/kg)	Scenario 2a Median Annual Flow 6.3 G/Ly Total Dose (µGy/h)	Scenario 2a Median Annual Flow 6.3 G/Ly Tissue Concentration (Bq/kg)	Scenario 3a Mean Annual Flow 28 GL/y Total Dose (µGy/h)	Scenario 3a Mean Annual Flow 28 GL/y Tissue Concentration (Bq/kg)	Background Turner River Total Dose (µGy/h)	Indee Homestead Indee Homestead Well Total Dose (µGy/h)	Indee Homestead Indee Homestead Well Tissue Concentration (Bq/kg)
Cattle - Beef Cattle	800	45	40	0.012	0.0699	0.00717	0.0434	0.00185	0.023	0.00044	0.055	0.536
Bird (Large)	2.8	0.32	40	0.006	0.0329	0.00345	0.0194	0.00183	0.013	0.00019	N/A	N/A
Reptile	15	0.1	40	0.006	0.0336	0.00349	0.0201	0.00378	0.0106	0.0002	N/A	N/A

RESRAD - Livestock and Native Fauna Exposure through Drinking Water

Other drinking water sources available - 50% of water consumption from here

Organism	Weight (kg)	Water Intake Rate (L/day)	Screening Value (µGy/h)	Scenario 1b No Flow Total Dose (µGy/h)	Scenario 1b No Flow Tissue Concentration (Bq/kg)	Scenario 2b Median Annual Flow 6.3 G/Ly Total Dose (µGy/h)	Scenario 2b Median Annual Flow 6.3 G/Ly Tissue Concentration (Bq/kg)	Scenario 3b Mean Annual Flow 28 GL/y Total Dose (µGy/h)	Scenario 3b Mean Annual Flow 28 GL/y Tissue Concentration (Bq/kg)	Background Turner River Total Dose (µGy/h)	Indee Homestead Indee Homestead Well Total Dose (µGy/h)	Indee Homestead Indee Homestead Well Tissue Concentration (Bq/kg)
Cattle - Beef Cattle	800	22.5	40	0.0064	0.0388	0.004	0.022	0.0019	0.00115	N/A	N/A	N/A
Bird	2.8	0.16	40	0.001	0.0054	0.002	0.01	0.0009	0.0051	N/A	N/A	N/A
Reptile	15	0.05	40	0.0063	0.0359	0.003	0.02	0.0018	0.0106	N/A	N/A	N/A

BIRD	Details	Scenario 1	Scenario 4
		No Flow	Turner River
		Total Dose (µGy/h)	Total Dose (µGy/h)
Occupancy	0.5 Water Surface	31.5	5.28
Water Intake (100%)	0.32 L/day	0.006	0.00019
Total Dose Rate		31.506	5.28019
Screening Dose Rate (µGy/h)		**40**	**40**

REPTILE (i.e. Olive Python)	Details	Scenario 1	Scenario 4
		No Flow	Turner River
		Total Dose (µGy/h)	Total Dose (µGy/h)
Occupancy	0.5 Water	14.2	2.38
Water Intake (100%)	0.1 L/day	0.006	0.0002
Total Dose Rate		14.206	2.3802
Screening Dose Rate (µGy/h)		**40**	**40**

Details		Total Dose (µGy/h)	
		Scenario 1	Scenario 4
Large Bird			
Occupancy	0.5 Water Surface	31.5	5.28
Water Intake (100%)	0.32 L/day	0.006	0.00019
Total Dose Rate		31.506	5.28019
Reptile			
Occupancy	0.5 Water	14.2	2.38
Water Intake (100%)	0.1 L/day	0.006	0.0002
Total Dose Rate		14.206	2.3802
Screening Dose Rate (µGy/h)		**40**	**40**

Organism	Indee Homestead Indee Homestead Well Total Dose (µGy/h)	Tissue Concentration (Bq/kg)
Cattle - Beef Cattle	0.055	0.536

Assumption: 100% of yearly water intake from this souce, AND
100% yearly beef consumption from cattle who has drunk 100% of its water

Consumption Rates:		
Meat products	50 kg/y A and 35kg/y C	UNSCEAR. 2000.
Water	2 L/day = 730 L/year	NHMRC ADWG 6, update Jan 2022

Human Consumption of Water Calcs

Nuclide	Estimated Annual Activity Intake (Bq/y)	Effective Dose Coefficient (µSv/Bq)		Annual Effective Dose (µSv)		
		Adult	Children	Adult	Children	
Ra-226	73.7	0.28	0.8	20.636	58.96	
Th-232	0	0.69	0.29	0	0	
U-238	2190	0.05	0.07	109.5	153.3	
Total	2263.7			130.136	212.26	µSv
				0.130136	0.21226	mSv

Groundwater	U-238	Th-232	Ra-226
Bq/L	3.00	0.00	0.10
L/Y	730.00	730.00	730.00
Bq/Y	2190.00	0.00	73.73

Human Consumption of Beef Calcs

Nuclide	Estimated Annual Activity Intake (Bq/y)	Effective Dose Coefficient (µSv/Bq)		Annual Effective Dose (µSv)		
		Adult	Children	Adult	Children	
Ra-226	21.9	0.28	0.8	6.132	17.52	
Th-232	0	0.69	0.29	0	0	
U-238	4.9	0.05	0.07	0.245	0.343	
Total				6.377	17.863	µSv
				0.006377	0.017863	mSv

Beef	U-238	Th-232	Ra-226
Bq/kg	0.438	0.000	0.098
Bq/Y	21.900	0.000	4.900

Effective Dose coefficients Ref:
UNSCEAR. 2000. *Exposures to Natural Radiation Sources – Annex B* . In *Sources and Effects of Ionizing Radiation* , *Volume 1 – Sources* : 83-156. Report to the General Assembly. United Nations Scientific Committee on the Effects of Atomic Radiation. New York,

Total Human Consumption Dose Rates

Consumption Type	Annual Effective Dose (mSv)	
	Adult	Children
Water Consumption	0.130136	0.21226
Beef Consumption	0.006377	0.017863
Total	0.136513	0.230123
Public Dose Limit	1	1

	Scenario 1	
Organism	**Total Dose (µGy/h)**	**Tissue Concentration (Bq/kg)**
Cattle - Beef Cattle	0.012	0.0669

Assumption: 100% of yearly water intake from this souce, AND
100% yearly beef consumption from cattle who has drunk 100% of its water intake from this source.

Consumption Rates:		
Meat products	50 kg/y A and 35kg/y C	UNSCEAR. 2000.
Water	2 L/day = 730 L/year	NHMRC ADWG 6, update Jan 2022

Human Consumption of Water Calcs						
Nuclide	**Estimated Annual Activity Intake (Bq/y)**	**Effective Dose Coefficient (µSv/Bq)**		**Annual Effective Dose (µSv)**		
		Adult	**Children**	**Adult**	**Children**	
Ra-226	22.63	0.28	0.8	6.3364	18.104	
Th-232	0.2	0.69	0.29	0.138	0.058	
U-238	233.6	0.05	0.07	11.68	16.352	
Total	256.43			18.1544	34.514	µSv
				0.0181544	0.034514	mSv

Groundwater	U-238	Th-232	Ra-226
Bq/L	0.32	0.00	0.03
L/Y	730.00	730.00	730.00
Bq/Y	233.60	0.20	22.63

Beef	U-238	Th-232	Ra-226
Bq/kg	0.043	0.000	0.027
Bq/Y	2.150	0.000	1.350

Human Consumption of Beef Calcs						
Nuclide	**Estimated Annual Activity Intake (Bq/y)**	**Effective Dose Coefficient (µSv/Bq)**		**Annual Effective Dose (µSv)**		
		Adult	**Children**	**Adult**	**Children**	
Ra-226	1.35	0.28	0.8	0.378	1.08	
Th-232	0	0.69	0.29	0	0	
U-238	2.15	0.05	0.07	0.1075	0.1505	
Total				0.4855	1.2305	µSv
				0.0004855	0.0012305	mSv

Effective Dose coefficients Ref:

UNSCEAR. 2000. *Exposures to Natural Radiation Sources – Annex B*. In *Sources and Effects of Ionizing Radiation*, *Volume 1 – Sources*: 83-156. Report to the General Assembly. United Nations Scientific Committee on the Effects of Atomic Radiation. New

Total Human Consumption Dose Rates		
Consumption Type	**Annual Effective Dose (mSv)**	
	Adult	**Children**
Water Consumption	0.0181544	0.034514
Beef Consumption	0.0004855	0.0012305
Total	0.0186399	0.0357445
Public Dose Limit	1	1

APPENDIX 5: LABORATORY INCUBATION EXPERIMENT DATA

Appendix 5: Soil Elemental Composition

Samples	Digest Type	Ag	Al	As	B	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%
Soil A 0.1 to 0.5 m	4-Acid	<0.05	46089	4.6	N.D	330.6	1.08	0.17	467	<0.01	23.76	16.2	115.4	4.04	12.0	2.228
Soil B 1 to 1.5 m	4-Acid	<0.05	64621	9.1	N.D	308.1	1.29	0.25	528	<0.01	40.35	16.1	174.1	4.77	22.0	3.721
Soil A 0.1 to 0.5 m	Aqua Regia	<0.05	14200	3.6	<50	20	0.37	0.11	300	<0.05	15	4	100	1.2	7.8	2.2
Soil B 1 to 1.5 m	Aqua Regia	<0.05	18100	6.9	<50	23	0.6	0.17	370	<0.05	34	8.9	130	2.2	18	3.2

Samples	Digest Type	Ga	Ge	Hf	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Rb
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Soil A 0.1 to 0.5 m	4-Acid	11.42	1.1	2.01	0.02	18454	12.28	24.9	685	113.9	0.49	1195	6.83	36.5	86	15.8	121.77
Soil B 1 to 1.5 m	4-Acid	16.48	1.3	2.71	0.04	16190	15.18	39.1	1240	193.8	0.97	1052	9.18	66.6	89	19.0	116.68
Soil A 0.1 to 0.5 m	Aqua Regia	5.2	0.09	0.18	<0.05	700	7.7	12	450	83	0.33	140	0.06	24	<50	5.3	13
Soil B 1 to 1.5 m	Aqua Regia	7.7	0.13	0.29	<0.05	940	11	17	870	140	0.6	300	0.09	45	<50	9.5	21

Samples	Digest Type	Re	S	Sb	Sc	Se	Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr
		mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Soil A 0.1 to 0.5 m	4-Acid	<0.02	0.005	0.42	5.05	<0.1	1.7	24.1	1.09	<0.1	8.29	1545	0.94	1.655	43.8	96.6	9.08	13	65.37
Soil B 1 to 1.5 m	4-Acid	<0.02	0.005	0.82	8.15	0.1	2.4	25.2	1.37	<0.1	11.60	1962	0.94	2.334	70.1	58.9	9.00	18	82.20
Soil A 0.1 to 0.5 m	Aqua Regia	<0.05	<50	0.13	2.9	0.13	0.8	4.7	<0.05	<0.05	4.7	200	0.12	0.68	36	<0.5	3.3	6.8	3.3
Soil B 1 to 1.5 m	Aqua Regia	<0.05	<50	0.22	5.1	0.17	1.4	7.1	<0.05	0.05	8.9	230	0.21	1.3	51	<0.5	4.6	10	5.2

Appendix 5: Soil Characteristics

Samples	Sand.	Silt.	Clay.	Stones	OrgC
	%	%	%	%	%
Soil A 0.1 to 0.5 m	71	9	20	3.2	<0.05
Soil B 1 to 1.5 m	64	5	31	42.5	0.29

Sample	Ag	Al	As	B	Ba	Be	Bi	Br	Cd	Co	Cr	Cu	Fe	Hg	K	Li	Mg
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HMB001 upper	<0.0001	<0.005	0.011	0.59	0.066	<0.0001	<0.0001	0.75	<0.0001	<0.0001	0.0026	0.0002	<0.005	<0.0001	9.5	0.022	42.3
HMB001 Lower	<0.0001	0.009	0.015	0.57	0.073	<0.0001	<0.0001	0.91	<0.0001	0.0002	0.0066	0.0026	0.051	<0.0001	9.5	0.021	48.6
HERC026	<0.0001	<0.005	0.038	0.59	0.086	<0.0001	<0.0001	0.88	<0.0001	0.0005	0.0032	0.0008	0.015	<0.0001	9.6	0.022	51.8

Sample	Mn	Mo	Na	Ni	Pb	Sb	Se	Si	Sn	Sr	Te	Th	Ti	Tl	U	V	Zn
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
HMB001 upper	0.0008	0.006	185	<0.001	<0.0001	<0.0001	0.003	46	<0.0001	0.49	<0.0001	<0.0001	<0.0005	<0.0001	0.036	0.042	0.001
HMB001 Lower	0.0062	0.007	189	0.006	<0.0001	<0.0001	0.003	42	<0.0001	0.54	<0.0001	<0.0001	<0.0005	<0.0001	0.036	0.035	0.006
HERC026	0.0007	0.008	194	0.002	<0.0001	<0.0001	0.003	41	<0.0001	0.54	<0.0001	<0.0001	<0.0005	<0.0001	0.044	0.04	0.003

Appendix 5: Leachate Composition

Sample	Leachant	Ag	Al	Alkalinity	As	B	Ba	Be	Bi	Br	Ca	Cd	Cl	Co	Cr	Cu
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Soil A 0.1 to 0.5 m	DI Water	<0.0001	0.17	5	<0.001	0.03	0.002	<0.0001	<0.0001	<0.1	0.3	<0.0001	8	0.0002	0.0006	0.0016
Soil B 1 to 1.5 m	DI Water	<0.0001	0.12	8	<0.001	0.07	0.0012	<0.0001	<0.0001	<0.1	0.3	<0.0001	21	0.0001	<0.0005	0.0013
Soil A 0.1 to 0.5 m	Hydroxylamine HCl	0.0004	29	N.D	0.005	0.034	0.48	0.0059	0.0005	N.D	11.6	<0.0001	N.D	0.57	0.036	0.066
Soil B 1 to 1.5 m	Hydroxylamine HCl	0.0003	26	N.D	0.005	0.054	0.74	0.0076	0.0004	N.D	14.6	<0.0001	N.D	0.45	0.03	0.08

Sample	Leachant	ECond	Fe	Hg	K	Li	Mg	Mn	Mo	N_NO2	N_NO3	N_NOx	Na	Nb	Ni	P	Pb
		mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Soil A 0.1 to 0.5 m	DI Water	4.4	0.079	<0.0001	0.6	0.0001	0.1	0.003	0.001	0.02	0.55	0.57	8.2	N.D	<0.001	N.D	0.0002
Soil B 1 to 1.5 m	DI Water	9.9	0.049	<0.0001	1	0.0001	0.2	0.0015	0.004	<0.01	0.58	0.58	18.5	N.D	0.002	N.D	0.0001
Soil A 0.1 to 0.5 m	Hydroxylamine HCl	N.D	11	N.D	7.3	0.013	6.5	1.8	<0.001	N.D	N.D	N.D	4.7	0.0003	0.064	<1.0	0.07
Soil B 1 to 1.5 m	Hydroxylamine HCl	N.D	12	N.D	6.5	0.014	15.4	3.9	<0.001	N.D	N.D	N.D	9.9	0.0003	0.094	<1.0	0.1

Sample	Leachant	Rb	SO4	Sb	Sc	Se	Si	Sn	Sr	Te	Th	Ti	Tl	U	V	Zn	pH
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	pH Units
Soil A 0.1 to 0.5 m	DI Water	N.D	4	<0.0001	N.D	<0.001	5.4	<0.0001	0.0015	<0.0001	<0.0001	0.0009	<0.0001	<0.0001	0.0017	0.003	6.9
Soil B 1 to 1.5 m	DI Water	N.D	5	<0.0001	N.D	<0.001	9.2	<0.0001	0.0026	<0.0001	<0.0001	0.0005	<0.0001	<0.0001	0.0019	0.001	7.1
Soil A 0.1 to 0.5 m	Hydroxylamine HCl	0.09	<1.0	<0.0001	0.025	<0.001	19	0.0005	N.D	N.D	0.0025	0.054	0.001	0.019	0.19	0.014	N.D
Soil B 1 to 1.5 m	Hydroxylamine HCl	0.07	<1.0	<0.0001	0.04	<0.001	23	0.0005	N.D	N.D	0.0044	0.046	0.002	0.028	0.33	0.023	N.D

Appendix 5: Radiation Results

Analyte	Units	Sample Name	HMB001 Upper field	HMB001 Lower field	HMB001 Lower field	HMB001 Lower t18 hrs
		Matrix	Water	Water	Water	Water
		Reporting Limit	Result	Result	Result	Result
Radium-226	Bq/L	0	0.052 ±0.018	<0.059	N.D	<0.06
Radium-228	Bq/L	0	<0.14	<0.14	N.D	<0.12
Gross alpha activity	Bq/L	0	1.42 ±0.26	2.06 ±0.38	N.D	1.39 ±0.26
Gross beta activity (excluding K-40)	Bq/L	0	0.129 ±0.07	0.103 ±0.067	N.D	0.058 ±0.067
Uranium	mg/L	N.D	0.036	0.036	0.029	0.026
Thorium	mg/L	N.D	<0.0001	<0.0001	N.D	N.D
Potassium	mg/L	0.1	9.5	9.5	N.D	N.D

Treatment and time	Ag	Al	Alkalinity	As	B	Ba	Be	Bi	Ca	Cd	Cl	Co	Cr	Cu	EC	Fe
	µg/L	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mS/m	mg/L
HMB001 Lower 0min	<0.1	0.014	360	9	0.56	78	<0.1	<0.1	28.3	<0.1	219	0.3	3.4	2.4	144	<0.005
HMB001 Lower 15min	<0.1	0.014	371	13	0.57	79	<0.1	<0.1	29	<0.1	226	0.4	3.7	2.2	149	<0.005
HMB001 Lower 30min	<0.1	0.009	373	9	0.57	79	<0.1	<0.1	28.9	<0.1	224	0.3	3.4	1.8	150	<0.005
HMB001 Lower 45min	<0.1	0.006	376	10	0.57	79	<0.1	<0.1	28.3	<0.1	226	0.3	3.8	2.4	150	<0.005
HMB001 Lower 1Hour	<0.1	0.012	379	8	0.57	85	<0.1	<0.1	29.9	<0.1	225	0.3	3.7	1.4	151	<0.005
HMB001 Lower 1.5Hour	<0.1	0.007	373	6	0.57	82	<0.1	<0.1	28.8	<0.1	227	0.4	4.2	1.8	153	0.006
HMB001 Lower 2Hour	<0.1	0.006	365	4	0.57	82	<0.1	<0.1	28.2	<0.1	228	0.3	3.7	1.6	152	<0.005
HMB001 Lower 3Hour	<0.1	0.009	376	3	0.56	89	<0.1	<0.1	30.4	<0.1	233	0.3	3.7	1.9	153	<0.005
HMB001 Lower 4Hour	<0.1	0.012	363	3	0.54	87	<0.1	<0.1	29.7	<0.1	226	0.3	3.9	4.2	149	0.006
HMB001 Lower 18Hour	<0.1	0.009	358	2	0.53	78	<0.1	<0.1	29.1	<0.1	228	0.3	3.5	1.7	148	<0.005
HERC026 0min	<0.1	0.01	371	17	0.56	84	<0.1	<0.1	29.2	<0.1	221	0.7	2.3	0.7	149	<0.005
HERC026 1Hour	<0.1	0.007	380	13	0.59	89	<0.1	<0.1	30.5	<0.1	235	0.5	2.1	0.6	154	<0.005
HERC026 1.5Hour	<0.1	<0.005	381	12	0.57	83	<0.1	<0.1	28.7	<0.1	234	0.5	2.4	0.7	155	<0.005
HERC026 2Hour	<0.1	0.007	381	8	0.56	89	<0.1	<0.1	31	<0.1	236	0.5	2.5	0.8	158	<0.005
HERC026 3Hour	<0.1	0.007	360	5	0.54	85	<0.1	<0.1	30.2	<0.1	233	0.5	2.3	0.8	154	<0.005
HERC026 4Hour	<0.1	0.029	360	5	0.54	84	<0.1	<0.1	30.2	<0.1	236	0.4	2.1	0.8	154	0.007
HERC026 18Hour	<0.1	0.007	356	4	0.52	75	<0.1	<0.1	28.8	<0.1	236	0.5	2.5	0.9	154	<0.005

Treatment and time	Hg	K	Li	Mg	Mn	Mo	N_NO2	N_NO3	N_NOx	Na	Ni	Pb	S	Sb	Se	Si
	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L
HMB001 Lower 0min	<0.1	9.5	16	47.8	9.7	7	<0.01	6.5	6.5	196	2	<0.1	18	<0.1	3	40
HMB001 Lower 15min	<0.1	9.7	16	48	11	8	<0.01	6.6	6.6	197	2	<0.1	19	<0.1	3	40
HMB001 Lower 30min	<0.1	9.6	14	47.1	8.6	7	<0.01	6.5	6.5	195	2	<0.1	19	<0.1	3	40
HMB001 Lower 45min	<0.1	9.5	15	46.7	9.7	7	<0.01	6.7	6.7	193	2	<0.1	19	<0.1	3	41
HMB001 Lower 1Hour	<0.1	9.8	14	48.2	9.6	8	<0.01	6.7	6.7	202	1	<0.1	19	<0.1	3	40
HMB001 Lower 1.5Hour	<0.1	9.5	13	45.9	9.9	8	<0.01	6.8	6.8	195	1	<0.1	20	<0.1	4	40
HMB001 Lower 2Hour	<0.1	9.2	11	44.5	8.9	8	<0.01	6.9	6.9	195	1	<0.1	20	<0.1	4	39
HMB001 Lower 3Hour	<0.1	9.8	9.5	46.9	8.2	8	<0.01	7.0	7.0	205	1	<0.1	19	<0.1	4	37
HMB001 Lower 4Hour	<0.1	9.6	8.4	45.6	7.4	8	<0.01	6.8	6.8	200	2	0.1	19	<0.1	4	36
HMB001 Lower 18Hour	<0.1	9.4	5.2	44.1	2.5	8	<0.01	6.9	6.9	202	<1	<0.1	19	<0.1	4	32
HERC026 0min	<0.1	9.6	17	49.6	6.2	7	<0.01	6.5	6.5	200	2	<0.1	18	<0.1	3	40
HERC026 1Hour	<0.1	9.9	15	50.0	4.6	7	<0.01	6.9	6.9	207	<1	<0.1	19	<0.1	3	41
HERC026 1.5Hour	<0.1	9.3	14	45.7	4.7	8	<0.01	6.9	6.9	196	<1	<0.1	20	<0.1	3	40
HERC026 2Hour	<0.1	10	12	48.6	4.2	8	<0.01	7.1	7.1	213	<1	<0.1	19	<0.1	3	39
HERC026 3Hour	<0.1	9.7	8.8	46.4	3.1	8	<0.01	6.9	6.9	207	<1	<0.1	19	<0.1	3	35
HERC026 4Hour	<0.1	9.8	7.9	46.8	2.7	8	<0.01	6.9	6.9	210	<1	<0.1	19	<0.1	3	35
HERC026 18Hour	<0.1	9.2	5	43.6	1.5	9	<0.01	6.9	6.9	203	<1	<0.1	20	<0.1	3	31

Treatment and time	Sn	Sr	Te	Th	Ti	Tl	U	V	Zn	pH
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	pH units
HMB001 Lower 0min	<0.1	480	<0.1	<0.1	<0.5	<0.1	29	10	8	8.4
HMB001 Lower 15min	0.3	490	<0.1	<0.1	<0.5	<0.1	32	15	4	8.4
HMB001 Lower 30min	0.1	490	<0.1	<0.1	<0.5	<0.1	27	11	19	8.1
HMB001 Lower 45min	0.2	480	<0.1	<0.1	<0.5	<0.1	30	12	6	8.3
HMB001 Lower 1Hour	0.3	490	<0.1	<0.1	<0.5	<0.1	30	9.2	15	8.5
HMB001 Lower 1.5Hour	0.4	460	<0.1	<0.1	<0.5	0.1	29	8	9	8.2
HMB001 Lower 2Hour	0.4	440	<0.1	<0.1	<0.5	0.1	27	6.3	16	8.7
HMB001 Lower 3Hour	0.4	470	<0.1	<0.1	<0.5	0.1	26	5.7	5	8.3
HMB001 Lower 4Hour	0.6	450	<0.1	<0.1	<0.5	0.1	26	5.5	16	8.5
HMB001 Lower 18Hour	1.9	430	<0.1	<0.1	<0.5	<0.1	26	6.2	12	8.5
HERC026 0min	0.1	490	<0.1	<0.1	<0.5	<0.1	32	9.8	2	8.5
HERC026 1Hour	0.3	490	<0.1	<0.1	<0.5	0.1	29	8.1	1	8.6
HERC026 1.5Hour	0.3	450	<0.1	<0.1	<0.5	0.1	31	7.5	1	8.6
HERC026 2Hour	0.3	470	<0.1	<0.1	<0.5	0.1	29	6.3	1	8.4
HERC026 3Hour	0.3	450	<0.1	<0.1	<0.5	0.1	27	5.5	1	8.7
HERC026 4Hour	0.4	450	<0.1	<0.1	<0.5	<0.1	25	5.4	2	8.6
HERC026 18Hour	1.2	420	<0.1	<0.1	<0.5	<0.1	31	6.8	2	8.6

Treatment	1 Hour		2 Hours		4 Hours	
	µg/L	**% removed**	**µg/L**	**% removed**	**µg/L**	**% removed**
Control	40	2	40	2	39	5
Rusted Steel Wool	23	44	25	39	27	34
Fe-Oxide Std Conc 1	36	12	36	12	36	12
Fe-Oxide Std Conc 2	30	27	34	17	33	20
Fe-Oxide Std + $FeSO_4$	36	12	36	12	38	7
Fe-Oxide Std + $CaPO_4$	37	10	39	5	39	5
Fe-Oxide Std + KH_2PO_4	36	12	38	7	32	22
$CaPO_4$	41	0	42	-2	43	-5

APPENDIX 6 TIER 2 ERA RESULTS

Risk Event / Pathway	Receptors	Potential Impacts	Key Considerations	Risk Assessment (Inherent)			Available Controls	Risk Assessment (Residual)			Other Comments
				Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating	
Release of metal(oids) into Turner River System	Aquatic biota	Death, reproduction inhibiton, physiological impairment at organism scale - population and species diversity effects at the population scale as a reuslt of living in a metal(oid) contaminated environment	The radionuclidies U is likely to exceed ANZG (2018) freshwater species protection DGVs and/or Turner River site/regional specific guideline values in discharge water. Under most rainfall scenarios As ands V concentrations in Turner River post discharge will be at or below the Site specific guideline value. U concentrations, however, likely to be elevated at least within a 'zone of discharge' (approx. 50 km) unless rainfall is above average during the discharge period Rainfall (and the subsequent flow of water) within the Turner River catchment has a very strong effect on overall risk	B - Likely	3 - Moderate	17 - High	Water can be treated using ion exchange to remove U from solution prior to discharge Ecotoxicity tests to be conducted to demonstrate that the discharge is of low risk to biota within the Turner River Surface water monitoring and ecological monitoring to measure contaminant concentrations in Turner River over time and assess ecological impacts post discharge	C - Possible	2 - Minor	8 - Low	Rainfall within the catchment during the discharge period is a major consideration in assessing risk.
	Terrestrial Organisms	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of consuming Turner River water (post discharge) as a drinking water source	Discharge water and Turner River water pre- and post-discharge contain concentrations of contaminants well below the ANZECC (2000) livestock drinking water guidelines which are used to assess the risk to terrestrial fauna.	D - Unlikely	2 - Minor	5 - Very low		E - Rare	2 - Minor	3 - Very low	
	Floodplain Soils/Vegetation	Long-term contamination of soils, loss of vegetation, recolonisation by weed species if metal(oid) contaminated water overflows from the Turner River onto adjacent floodplains	Background concentrations of U and V in project area soils are relatively low and therefore short-term loading with U and V from a flood event is unlikely to have a significant effect on soil quality Predicted U concentrations in Turner River water post-discharge exceed the ANZECC (2000) long-term irrigation guideline value of 10 µg/L, which suggests that plants may be susceptible if exposed, keeping in mind, however, that these guidelines are for crop rather than native species. Predicted V concentrations, however, are unlikely to exceed the long-term irrigation GV of 100 µg/L. Inundation of floodplain soils highly unlikely to occur even after extreme rainfall events as spatial modelling predicts that water is likely to be constrained to channels and/or anabranches. In any case high rainfall events will result in significant contaminant dilution, which will result in negligible U and V concentrations being deposited in terrestrial soils which is unlikely to have any ecological effect.	E - Rare	2 - Minor	3 - Very low	Controls such as treatment with ion exchange to remove U from solution are also applicable to avoid contaminant loading to floodplain soils Water to be treated using ion exchange to remove U from solution prior to discharge	E - Rare	1 - Insignificant	1 - Very low	
	Downstream Water Users (Humans - drinking and recreation, pastoral leases, other mining/industrial; operations, heritage sites)	Health effects to humans/livestock as a result of the consumption of metal(oid)contaminated water	Concentrations of U and V in the Turner River post discharge are almost certain to be well below either the NHMRD drinking water guidelines or the ANZECC Livestock drinking water guidelines	D- Unlikely	3 - Moderate	9 - Low	Controls such as the placement of discharge water in holding ponds to remove As and V from solution and iron oxide treatment to remove U from solution are also applicable to further reduce contaminant exposure	E - Rare	2 - Minor	3 - Very low	
		Metal(oid) contamination of water resources used for industrial/recreational purposes	U and V concentrations in the Turner River water post discharge are unlikely to limit the use of water downstream for other processes/purposes. Ion exchange techniques would be able to remove the majority of contaminants if required. In addition, the movement of Turner River surface water into groundwater is of little concern given the contaminants were initially present in groundwater	D- Unlikely	2 - Minor	5 - Very low	Controls such as treatment via ion exchange to remove U from solution are also applicable to further reduce contaminant exposure	E - Rare	1 - Insignificant	1 - Very Low	
		Metal(oid) contamination of water resources considered to be places of Aboriginal significance	Losses in species diversity/richness due to elevated U and V exposures could alter ecosystem processes and therefore the integrity of sites of cultural significance, which are numerous along the Tuner River	C - Possible	3 - Moderate	13 - Medium	Water to be treated using ion exchange - to remove U from solution prior to discharge	D - Unlikely	2 - Minor	5 - Very Low	As outlined earlier rainfall within the catchment is likely to significantly effect contaminant exposures (due to dilution effects) thus directly influencing the extent of risk

Risk Event / Pathway	Receptors	Potential Impacts	Key Considerations	Risk Assessment (Inherent)			Available Controls	Risk Assessment (Residual)			Other Comments
				Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating	
Release of radionuclides into the Turner River System	Aquatic biota	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of exposure to radiological materials	The radionuclidies U is likely to exceed ANZG (2018) freshwater species protection DGVs and/or Turner River site/regional specific guideline values in discharge water. Under most rainfall scenarios As ands V concentrations in Turner River post discharge will be at or below the Site specific guideline value.	D- Unlikely	3 - Moderate	9 - Low	Water can be treated using ion exchange to remove U from solution prior to discharge Surface water and ecological monitoring to establish levels of radionuclides within the Turner River system and any ecological effects	E - Rare	3 - Moderate	6 - Very Low	High rainfall within the catchment will lower the radiological dose received by organisms as a result of dilution effects
	Terrestrial Organisms	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of consuming Turner River water (post discharge) as a drinking water source	Radiological doses in the discharge water are likely to exceed the livestock drinking water quality value of 0.2 Bq/L, which will also be the case even if rainfall within the catchment is typical of median years (i.e. 5GL/year) RESRAD-BIOTA modelling demonstrates that there are unlikely to be any population-level effects on fauna consuming water from the Turner River post discharge	D- Unlikely	3 - Moderate	9 - Low	Water can be treated using ion exchange to remove U from solution prior to discharge Surface water and ecological monitoring to establish levels of radionuclides within the Turner River system and any ecological effects Discharge zone to not be located in close proximity to known habitats of protected faunal species or adjacent to pastoral stations Alternative drinking water sources provided for livestock species	E - Rare	3 - Moderate	6 - Very Low	
	Adjacent Soils/Vegetation	Long-term contamination of soils, loss of vegetation, recolonisation by weed species if radiologically contaminated water overflows from the Turner River onto adjacent floodplains	Radiological doses in the discharge water are likely to exceed the long-term irrigation water quality value of 0.2 Bq/L, which may effect some plant species, although the value is designed for crop species The accumulation in soils is also potentially deleterious for future plant growth, although U is unlikely to have deleterious effects on biota within the soil ecosystem (alpha emitter) Inundation of floodplain soils highly unlikely to occur even after extreme rainfall events as spatial modelling predicts that water is likely to be constrained to channels and/or anabranches. In any case high rainfall events will result in significant contaminant dilution, which will result in negligible U concentrations being deposited in terrestrial soils which is unlikely to have any radiological effects.	D - Unlikely	2 - Minor	5 - Very Low	Water can be treated using ion exchange to remove U from solution prior to discharge Levees could be constructed if areas are identified that would likely become inundated from the planned discharge in the absence of any rainfall	E - Rare	2 - Minor	3 - Very Low	Extensive inundation of floodplain soils only remotely possible in high rainfall years - this would likely dilute U content in Turner River thus reducing radionuclide content.
	Downstream Water Users (Humans - drinking and recreation, pastoral leases, other mining/industrial; operations, heritage sites)	Health effects to humans/livestock as a result of the consumption of radiologically contaminated water	Radionuclide concentrations in discharge water are likely to exceed human and livestock drinking water guideline values of 0.2 Bq/L in years that are dry or have median flows (approx. 5GL/year). Human health radiation risk assessments demonstrated that consumption of drinking water from area (Indee station) is highly unlikely to have any deleterious effects	C - Possible	2 - Minor	8 - Low	Water to be treated using iron oxides to remove U from solution prior to discharge Alternate drinking water sources provided for livestock/humans if required	D - Unlikely	2 - Minor	5 - Very Low	
		Radiological contamination of water resources used for industrial/recreational purposes	U is able to be removed by ion exchange systems thus making the water suitable for downstream use. Concentrations, also should not prohibit its use in industrial processes given the main radiological risk relates to exposure from consumption i.e. drinking water.	D- Unlikely	2 - Minor	5 - Very Low	Water to be treated using ion exchange - to remove U from solution prior to discharge	E - Rare	2 - Minor	3 - Very low	
		Radiological contamination of water resources considered to be places of Aboriginal significance	As detailed above U is unlikely to have radiological effects on aquatic organisms as mode of action is via ingestion. It is therefore unlikely that the radiological effects of U in the Turner River water post discharge will effect ecosystem function.	D- Unlikely	3 - Minor	6 - Very Low	Water to be treated using ion exchange - to remove U from solution prior to discharge	E - Rare	2 - Minor	3 - Very low	

Risk Event / Pathway	Receptors	Potential Impacts	Key Considerations	Risk Assessment (Inherent)			Available Controls	Risk Assessment (Residual)			Other Comments
				Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating	
Accumulation of metal(oids) in Turner River Sediments	Sediment biota	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of the accumulation of contaminants in sediments	The radionuclidies U is likely to exceed ANZG (2018) freshwater species protection DGVs and/or Turner River site/regional specific guideline values in discharge water. Under most rainfall scenarios As ands V concentrations in Turner River post discharge will be at or below the Site specific guideline value. Rainfall within the catchment again likely to dictate extent of contaminant accumulation - i.e. more water will result in contaminant dilution both in concentration and distance V likely to become less bioavailable once adsorbed into sediment phases - lower toxicity Fate and bioavailability of key contaminants (V and U) in sediments is uncertain	C - Possible	3 - Moderate	13 - Medium	Pre-treatment of water in holding tanks to remove U, V and other contaminants via sorption and/or treatment with iron oxides to reduce concentrations prior to discharge. Water can be treated using ion exchange to remove U from solution prior to discharge	D - Unlikely	2 - Minor	5 - Very Low	Rainfall likely to influence contaminant loads in the zone of discharge and across he river system as a whole
	Aquatic biota	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of the recycling of contaminants from sediments to the water column upon disturbance	Although some remobilisation of contaminants from sediments to the water column is possible the majority will likely remain bound so sediment components thus reducing the content in the water column and decreasing the potential ecological risk	D - Unlikely	2 - Minor	5 - Very Low	Controls such as holding the water in soil ponds prior to discharge or treatment with ion exchange to remove U from solution are also applicable to avoid contaminant loading to the Turner River system.	E- Rare	2 - Minor	3 - Very Low	

Risk Event / Pathway	Receptors	Potential Impacts	Key Considerations	Risk Assessment (Inherent)			Available Controls	Risk Assessment (Residual)			Other Comments
				Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating	
Accumulation of radionuclides in Turner River Sediments	Sediment biota	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of the accumulation of radionuclides in sediments	The radionuclidies U is likely to exceed ANZG (2018) freshwater species protection DGVs and/or Turner River site/regional specific guideline values in discharge water. Rainfall within the catchment again likely to dictate extent of contaminant accumulation - i.e. more water will result in contaminant dilution both in concentration and distance ERICA modelling suggests sediment dwelling organisms are unlikely to be effected by radionuclide inputs at the population scale	D - Unlikely	3 - Moderate	9 - Low	Water can be treated using ion exchange to remove U from solution prior to discharge	D - Unlikely	2 - Minor	5 - Very Low	Rainfall likely to influence contaminant loads in the zone of discharge and across he river system as a whole
	Aquatic biota	Death, reproduction inhibition, physiological impairment at organism scale - population and species diversity effects at the population scale as a result of the recycling of radionuclides from sediments to the water column upon disturbance	Although some remobilisation of radionuclides from sediments to the water column is possible the majority will likely remain bound so sediment components thus reducing the content in the water column and decreasing the potential ecological risk.	D - Unlikely	2 - Minor	5 - Very Low	Water can be treated using ion exchange to remove U from solution prior to discharge	E- Rare	2 - Minor	3 - Very Low	

Risk Event / Pathway	Receptors	Potential Impacts	Key Considerations	Risk Assessment (Inherent)			Available Controls	Risk Assessment (Residual)			Other Comments
				Likelihood	Consequence	Risk Rating		Likelihood	Consequence	Risk Rating	
Increased Water within the Turner River System	Aquatic biota	Habitat loss/alteration, change in foodweb dynamics, change in physicochemical properties all leading to effects at both the organism and population scale	Turner River typically fluctuates between wet-dry, therefore 2.5 years of constant inundation has the potential to result in short-term effects. Discharge likely to be contained to a 90m channel which means that <6% of the river will be continually inundated (River is 1.5km wide) Rainfall within the discharge period will have a strong influence on ecological effects, however, the significance is open for debate as the ecosystem is a naturally fluctuating one. For example if above-average rainfall occurs during the discharge period the effect of the discharge is in reality likely to be minimal as the river would have been in a wet-state regardless of whether the discharge took place. Long term effects are less likely to be deleterious, however, given the inherent variability and fluctuating nature of the environment	C - Possible	2 - Minor	8 - Low	Ensuring discharge is contained within exisitng channels as planned Ecological monitoring to establish if any effects are occurring so that discharge plans can be altered if required.	D - Unlikely	2 - Minor	5 - Very Low	As with many of the risk events assessed - rainfall within the catchment during the discharge window is critical in determining the overall significance of the risk
	Terrestrial biota	Habitat loss/alteration, change in foodweb dynamics, leading to effects at both the organism and population scale	Altered flow patterns of river has potential to eliminate or at least alter habitats used by terrestrial biota Changes in aquatic foodwebs can also impact terrestrial species who utilise them as a food source Higher trophic species likely to suffer more long term effects if ecosystems change i.e. food shortage, habitat loss etc Discharge likely to be contained to a 90m channel which means that <6% of the river will be continually inundated (River is 1.5km wide)	D - Unlikely	2 - Minor	5 - Very Low	Ensuring discharge is contained within exisitng channels as planned Ecological monitoring to establish if any effects are occurring so that discharge plans can be altered if required.	D - Unlikely	1 - Insignificant	2 - Very Low	As with many of the risk events assessed - rainfall within the catchment during the discharge window is critical in determining the overall significance of the risk
	Floodplain soils and vegetation	Habitat loss, soil degradation, altered inundation patterns for GDEs, weed recolonisation	Short term ecosystem-level effects are possible, particularly for GDE's and their adaptations to constant inundation vs wet/dry cycles Long-term effects less likely to be significant as system likely to return to wet-dry cycling Again the long-term effects are likely to be heavily dependent on annual rainfall as this has the potential to override the effects of the discharge	E - Rare	2 - Minor	3 - Very Low	Ensuring discharge is contained within exisitng channels as planned Ecological monitoring to establish if any effects are occurring so that discharge plans can be altered if required.	E - Rare	1 - Insignificant	3 - Very Low	As with many of the risk events assessed - rainfall within the catchment during the discharge window is critical in determining the overall significance of the risk