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Memorandum

Subject	TNG DARWIN – Groundwater Impact Evaluation		
Date	6 January 2021	**Pages**	13
To	Sharon Arena, Animal Plant Mineral	**From**	Jeremy Haynes, Principal Hydrogeologist
CC	Peter Crichton, Principal Water Resources Engineer		
Project no.		**Doc no.**	HYD_MEM_001_RevC
Project	TNG Darwin		

Introduction

This report addresses the Northern Territory Environmental Protection Agency (NT EPA) comments on the draft Environmental Impact Statement (EIS) pertaining to potential impacts on groundwater from surface water seepage and irrigation. The NT EPA comments are included in Appendix A.

This report is based on information provided within the Technical Report for Hydrogeology which outlines the lithology of the site, the associated hydrogeological properties and a conceptual hydrogeological model (Golder, 2019).

Conclusions and Recommendations

It is the Project's intention to maintain natural groundwater seepage and stormwater runoff flows into the adjacent intertidal zone (TNG Limited, 2019). Seepage into groundwater from irrigated grassy areas and unsealed roads/laydown areas will be typically seasonal and is unlikely to pose a material risk to environmental values and receptors. No mitigation measures, beyond material storage procedures outlined by TNG, are recommended or necessary.

Based on the review of the existing information, site hydrogeological conditions and proposed management practices, the potential for site activities to pose a material risk to groundwater is minimal. The site is underlain by a thin layer of shallow soil, which contain seasonal groundwater and is underlain by 19 m of clay. This clay serves as a natural barrier to groundwater flow and separate deeper groundwater zones from the site. In addition, all waste materials will be containerised for off-site disposal. Further management considerations proposed by TNG include:

- Waste will be containerised for off-site disposal, negating any risk for groundwater impacts.
- Small ore concentrate stockpiles will be lined and located on hardstand to minimize the potential mobilisation of contaminants of interest (COIs).
- Stockpiles of bulk materials will be located well clear of any waterway or drainage systems (TNG Limited, 2019).

- Personnel will be trained in the implementation of safe work practices to minimise risks and impacts through good stockpile management practices.
- With implementation of the aforementioned stockpile management strategies, no material change to surface or ground water quality is anticipated, with no impact on other water users.
- Following substantial rainfall, there is the potential for localised ponding although this poses no risk of groundwater impacts.
- Spill prevention, controls and counter measures will be developed and put into place to counteract any unlikely direct impact to Darwin Harbour. This will be done by addressing any spills before discharged into the harbor through the implementation of Emergency Response Plan focusing on;
    - Prevention Response Plan, and
    - Active Recovery Response Plan.
- The ERP will be also focused on spill recovery with interception and containment of contaminants upon discovery of any spill before it reaches the Darwin Harbour.

Background

TNG Darwin Processing Facility, the 'Project', intends to maintain groundwater regimes and quality at the site, so that environmental values including ecological health, land uses, and the welfare and amenity of people are protected, and the receiving waters of Darwin Harbour and Elizabeth River are not affected. (TNG, 2019). A comprehensive surface water drainage network, effluent and wastewater treatment system and storm water management arrangement to accommodate large rainfall events, will manage water within a controlled water circuit at the site (TNG Ltd/SMS Group, 2020a). All runoff, including runoff generated from dust suppression activities across the site, will be directed into the drainage network and subsequently treated if required.

It is envisaged that treated water from the waste treatment water pond will be used for dust suppression of stockpiles as well as for irrigation of the grassy areas. These processes can potentially affect groundwaters by:

- Dust suppression water mobilising and transporting COIs through stockpiles into groundwater (such as total iron and aluminium, oxidised iron sulphide and other acidifying and/or saline materials, TNG Limited 2019) , and
- Seepage of COIs into groundwater via irrigation water in grassy areas.

A simple seepage model was developed to estimate the infiltration of dust suppression and irrigation water and subsequent mobilisation of COIs and assess the potential of COIs to migrate into groundwaters and receiving waters in Darwin Harbour and Elizabeth River.

Stockpiles

Watering of active, potentially dust-generating stockpiles will be undertaken regularly at the site (TNG Ltd, 2019) at an estimated rate of 0.3 t/hr (Attachment 1 – TNG Water Balance, TNG Limited/SMS Group, 2020a). Stockpiles of magnetite concentrate and petcoke will be stored in purpose-built membrane structures which will be covered and placed on hardstand. Any runoff generated from internal dust suppression will be directed into the formal drainage network, and managed and treated accordingly (TNG Ltd/SMS Group, 2020a/b). Other saleable potentially dust-generating products including iron oxide and vanadium pentoxide will be stored in containers and bagged, respectively. Any waste generated from these processes will be contained and transported off site in a container (TNG Ltd/SMS Group, 2020c). Any ore concentrate stockpiles will be located on hardstand, thereby minimising any potential for seepage into groundwater. Therefore, these stockpiles are not likely to pose a significant risk to groundwater.

Any neutralised digest residue tailings and inert non-magnetics, will be containerised before being transported off-site by train for disposal (TNG Ltd, 2019). Due to the containerisation, this material is not likely to cause any significant impacts to the groundwater.

Dust suppression waters vary in quality and range from potable water (TNG Ltd/METIX SMS Group, 2020) to treated wastewater including treated effluent sourced from the treated waste water pond (TNG Limited/SMS Group, 2020a). During the dry season, waters used for dust suppression will likely evaporate before reaching groundwaters, as evaporation exceeds rainfall from April to November (Golder, 2019). During the wet season from December to March, seepage into the groundwaters may occur, commencing with a 'first flush' episode following the potential accumulation of COIs in dust and detritus, which have evaporated within the stockpile over the summer months. The potential for COIs to mobilise and seep into groundwater could rise to double the proposed yearly rate.

Irrigation

Water from the treated waste water pond may be utilised to irrigate the various grassy areas which surround the proposed process buildings and plant, an area of 47 ha (based on the revised the North South Surfaces Overview). Estimates from QLD government guidelines for irrigating grasses in wet tropics recommend 20 mm/week for 32 weeks (WaterWise 2019). The use of grey and treated waters for irrigation, including treated effluent, may potentially transport COIs into shallow groundwaters.

Treated Water

Water used for dust suppression and irrigation will be drawn from treated waste water, where outlet values are expected to be within the limits stipulated within the Front-End Engineering and Design – Waste Water Management Report (Tables 3 and 5, TNG Limited/SMS Group 2020c).

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Waste Water Treatment Plant (TNG Limited/SMS Group, 2020c)

Parameter	Unit	Inlet
pH	-	6-10
COD	mg/l	400
Suspended solids	mg/l	30
Ammonia	mg/l	100
Mercury	mg/l	0.02
Cadmium	mg/l	0.2
Chromium, hexavalent	mg/l	0.1
Arsenic	mg/l	0.1
Cyanide	mg/l	0.2
Lead	mg/l	0.5
Chromium, trivalent	mg/l	0.5
Copper	mg/l	0.5
Manganese	mg/l	20
Nickel	mg/l	0.5
Tin	mg/l	1
Zinc	mg/l	2
Iron (Fe)	mg/l	2
Oil and grease	mg/l	7

Sewage Plant outlet values (TNG Limited/SMS Group, 2020c)

Parameter	Unit	Inlet	Required values	Operating values
COD	mg/l	600	125	< 30
BOD5	mg/l	300	25	< 5
Suspended solids	mg/l	350	35	< 8
Fat, oil and grease	mg/l	< 20	<5	< 1
Coliform bacteria (MPN)	-		100 KBE / 100	10 KBE / 100
Viruses	%			red. 99.99

Site Conditions

Groundwater Levels

Shallow groundwater levels typically follow the topography of the site and are strongly influenced by seasonal rainfall and recharge.

During the early dry season (May 2019), levels ranged between RL 4.5 and RL 8.3 m AHD in the northern peninsula and between RL 5.0 and RL 8.6 m AHD in the southern peninsula. Towards the end of the dry season (September 2019), levels had subsided to between RL 3.0 and RL 5.5 m AHD in the northern peninsula and between RL 1.9 and RL 6.3 m AHD in the southern peninsula, an average difference of ~3 m (Golder, 2019).

Monitoring took place during a year which recorded only 50% of the average wet season rainfall. Therefore, groundwater levels could vary between 2.6 m closer to the coast and up to 7.4 m further inland, possibly rising to less than 1 m below ground level (bgl) (Golder, 2019).

Groundwater monitoring undertaken at the site specifically to understand tidal influence indicated levels beneath the site are not significantly affected by tides as monitoring recorded a range of between only a few centimeters and up to 0.1 m (Golder, 2019).

Hydrostratigraphy

Borehole logs and infiltration tests detailed in the Technical Hydrogeological Report (Golder, 2019) record the hydrostratigraphy at the site consists of a thin, unconsolidated lateritic sand and gravel overlying a weathered basement rock comprising silts and clays. The lateritic sand and gravel were encountered at the site from surface, extending to the maximum depth of 2.5 m bgl. The lateritic sand and gravel were found to be unsaturated at all monitoring well locations during the investigation which took place during the dry season (Golder, 2019), and it is likely the presence of groundwater within this unit is seasonally influenced. Hydraulic conductivity of this unit is highly transmissive with low storativity, and when saturated, would be the preferential flow pathway.

Silt and clay inferred to be weathered Burrell Creek Formation was encountered from the shallowest depth of 0.5 m bgl to the end of investigation depth at 21.5 m bgl. This unit had a general low bulk aquifer permeability and therefore low hydraulic conductivity. A 2 m thick gravel lens, locally found in BH06 (between 1.16 to -0.84 m AHD), has been disregarded due to the overlying 3 m thickness of clay which has negligible vertical permeability.

Groundwater levels indicate these two aquifers are hydraulically connected and flow is in a north-westerly direction towards Darwin Harbour and Elizabeth River.

Hydrogeological properties associated with each lithology are detailed below (Table 1).

Table 1 Summarised hydrogeological properties

Aquifer 1	Parameters
Depth (m bgl)	2.5
Thickness (m)	2.5
Lithology	Sandy GRAVEL/gravelly SAND
Type	Unconfined
K_x horizontal (m/d)	20
K_y	K_x
K_z vertical (m/d)	20
S_y (Aqtesolv, 2020)	0.22

Aquifer 2	Parameters
Depth (m gbl)	2.5 – 21.0
Thickness (m)	19
Lithology	SILT/CLAY recovered as silt with fine grained sand (Weathered Burrell Creek Formation)
Type	Low conductivity
K_x horizontal (m/d)	0.5
K_z vertical (m/d)	E^{-6}
S_y (Aqtesolv, 2020)	0.02

Water Quality

Baseline groundwater quality at the site indicates slightly acidic with locally fresh groundwaters (Golder, 2019). During monitoring, waters recorded oxidising/aerobic conditions with localised slightly elevated metal concentrations (copper, lead, nickel) with groundwater contaminants of interest below detection limits eg. hydrocarbons, MAH, PAH, pesticides, halogenated benzenes or volatile organic compounds (Golder, 2019). A limited actual acid sulphate soil assessment (AASS) indicated the presence of AASS at some locations at the site (Golder, 2019).

Conceptual Hydrogeological Model

A conceptual hydrogeological model for the wet and dry seasons, adapted from Golder 2019, show the groundwater table is within the silts and clays of the weathered Burrell Creek Formation during the dry season. The overlying laterite is mainly unsaturated with groundwater flow occurring in the low permeability weathered Burrell Creek Formation. During the wet season, groundwater levels rise due to rainfall recharge, resulting in the laterite becoming partially saturated with localised groundwater inundation/ponding where the laterite is thin.

The two aquifers are in hydraulic continuity, and the shallow unconsolidated lateritic aquifer behaves as unconfined (Golder, 2019) and the cohesive weathered Burrel Creek Formation is of low permeability. Regional flow is in a north-westerly direction towards the Elizabeth River, with local groundwater flowing radially from the higher elevated areas in the centre of each peninsular. Final groundwater discharges are into the tributaries to the west, and north east of the site and the Elizabeth River to the north (Golder, 2019).

Considering the lithology of the Weathered Burrell Creek Formation and its aquifer characteristics of low permeability and hydraulic conductivity, flow/movement of groundwater through this layer is likely to be very low. Thus, the risk of contaminants migrating into groundwater is very minimal.

A source-pathway-receptor model (Table 2) was developed to identify exposure pathways for COIs in the case of release into groundwater. The model also identifies management controls to mitigate exposure risk and prevention if COIs potentially mobilise.

Table 2 Contaminant exposure pathways and mitigation controls

Source	Control	Pathway	Control	Receptor
Potential COIs in stockpiles	• Ensure stockpiles of bulk materials are located well clear of any waterway or drainage systems • Safe storage and management practices • Bunding	• Surface run-off • Seepage via misting / fogging / spray	• All runoff waters will be diverted into managed water circuit for monitoring and treatment (if required) • Low permeability base ie hardstanding	Groundwater under site Tributaries Elizabeth River Receiving waters in Darwin Harbour
Potential COIs within treated waste water used for irrigation	• All waters are managed within the water circuit and monitored/treated prior to discharge	• Seepage in irrigated areas	• All waters are treated prior to discharge (refer TNG Limited/SMS Group, 2020c for outflow values)	
Potential COIs within existing soils at site including AASS	• AASS sites identified and managed according to ASS Management Plan (TNG Ltd, 2019)	• Seepage in irrigated / bare land / unlined operational areas	• Low permeability covering majority of the site ie hardstanding/ buildings/ roads	

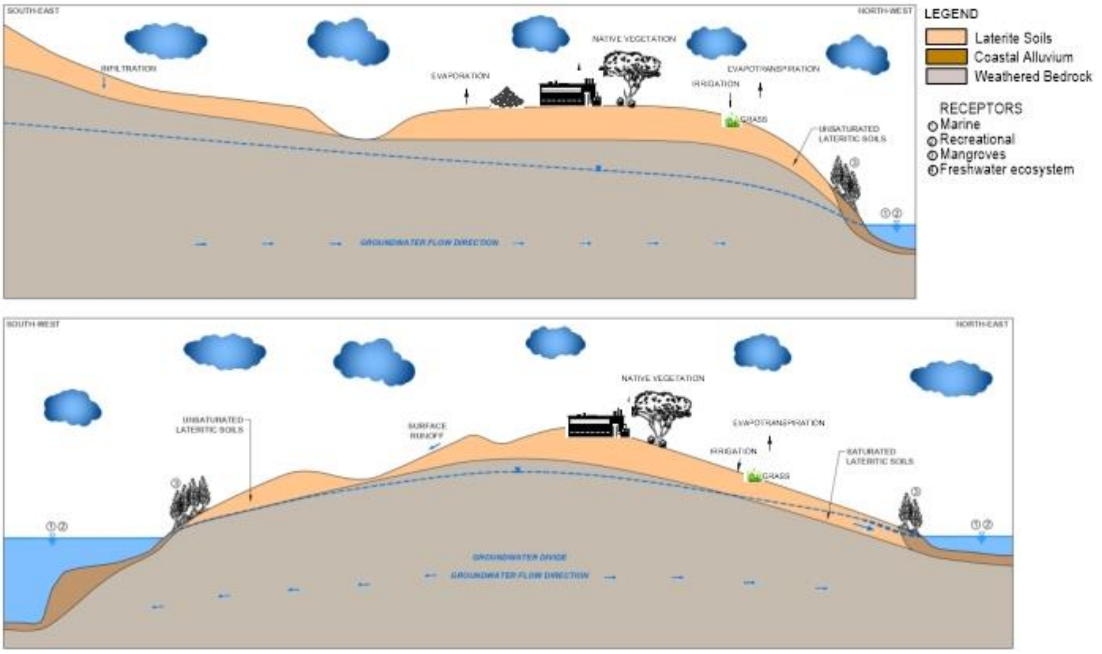
Note: adapted from Golder 2019

Seepage Model Results

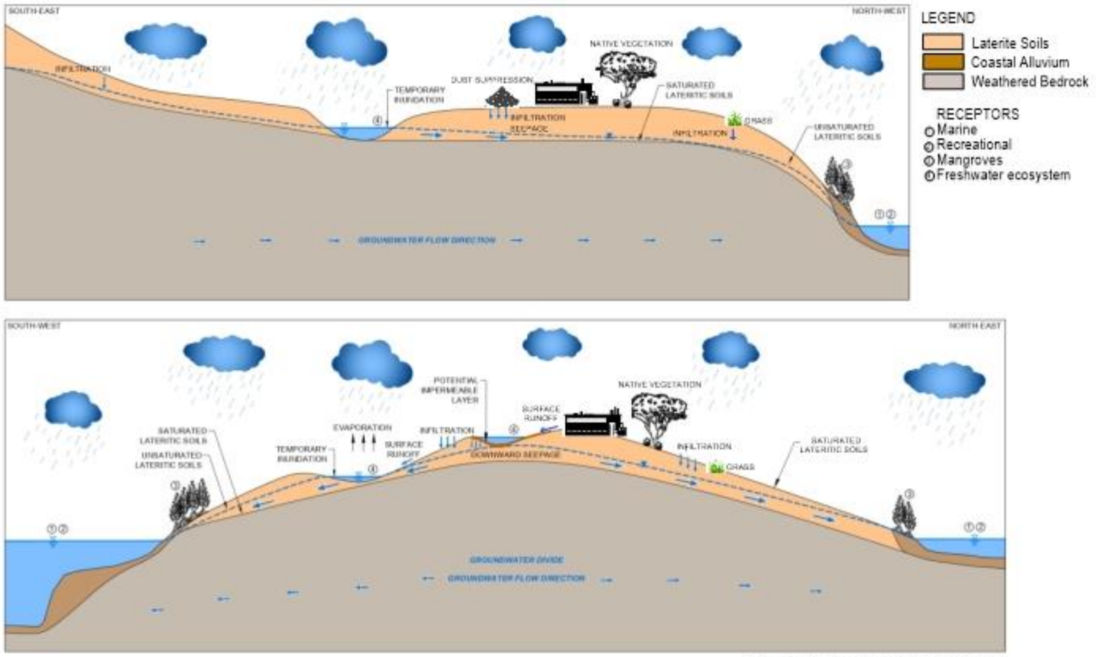
A simple groundwater seepage model was developed using Groundwater Vistas with ModFlow – NWT (ESI, 2020) to assess the potential for COIs within seepage to enter groundwaters underlying the site. Initial conditions were set on steady state using the parameters below, followed by a transient simulation to illustrate seasonal groundwater flux to receiving waters. Properties used in the model are found in Appendix A and include climate and hydrogeological values established in Technical Groundwater Report (Golder, 2019).

Horizontal flow will dominate due to the more granular nature of the near surface lateritic soils. Due to the cohesive nature of the silts and clays of the weathered bedrock, vertical migration will be very low. Groundwater contours modelled show a steady state (or average conditions), for the end of the dry and wet seasons respectively. During the dry season, the laterite is mostly unsaturated with the groundwater table present in the weathered bedrock. During the wet season, groundwater flow is both to the west and north, following the defined drainage paths into the mangrove and estuarine areas.

A time series of 100 years indicated the transportation of potential COIs show only a small number of pathways reaching the receiving waters. This is due to most of the seepage evaporating. The high conductivity of the shallow lithology being the predominant flow path allows a combination of evapotranspiration, dilution due to recharge and natural attenuation to provide an effective measure against any COIs at concentrations exceeding regulatory thresholds reaching the receiving waters.



Anticipated Dry Season Hydrogeological Conceptual Model
(adapted from Golder, 2019)



Anticipated Wet Season Hydrogeological Conceptual Model
(adapted from Golder, 2019)

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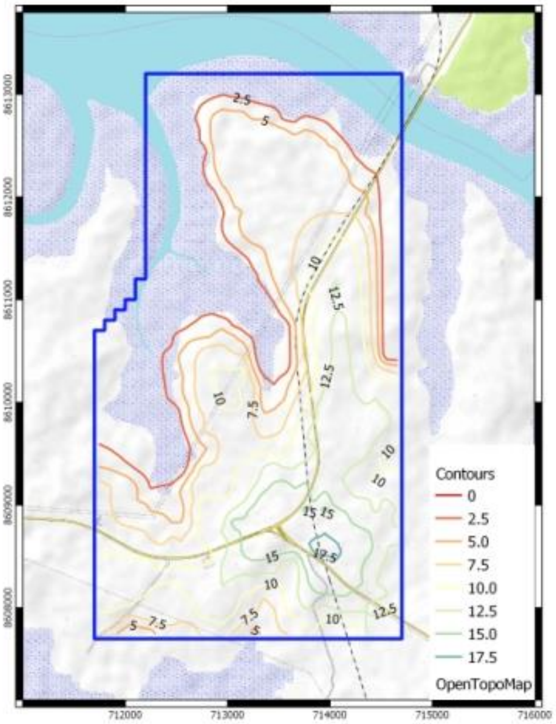
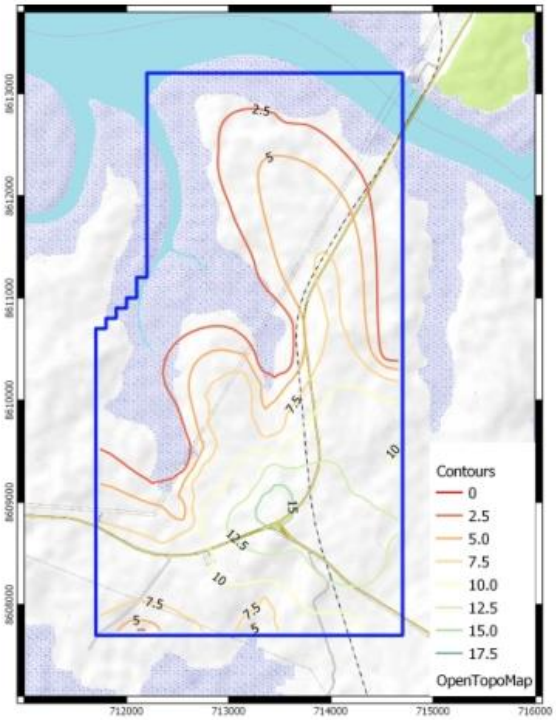
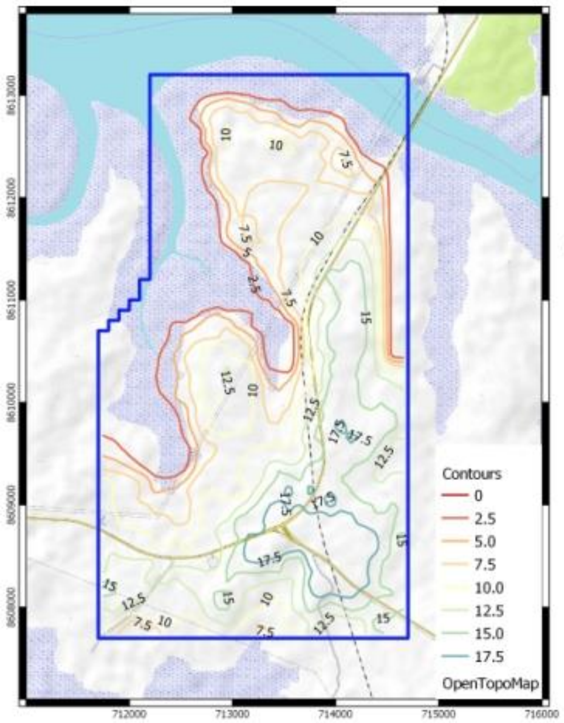


Groundwater Contours (Average)



Groundwater Contours (End of Dry Season)



Groundwater Contours (End of Wet Season)

Groundwater contours as modelled in Groundwater Vista - ModFlow NWT for dry and wet seasons, plus the average.

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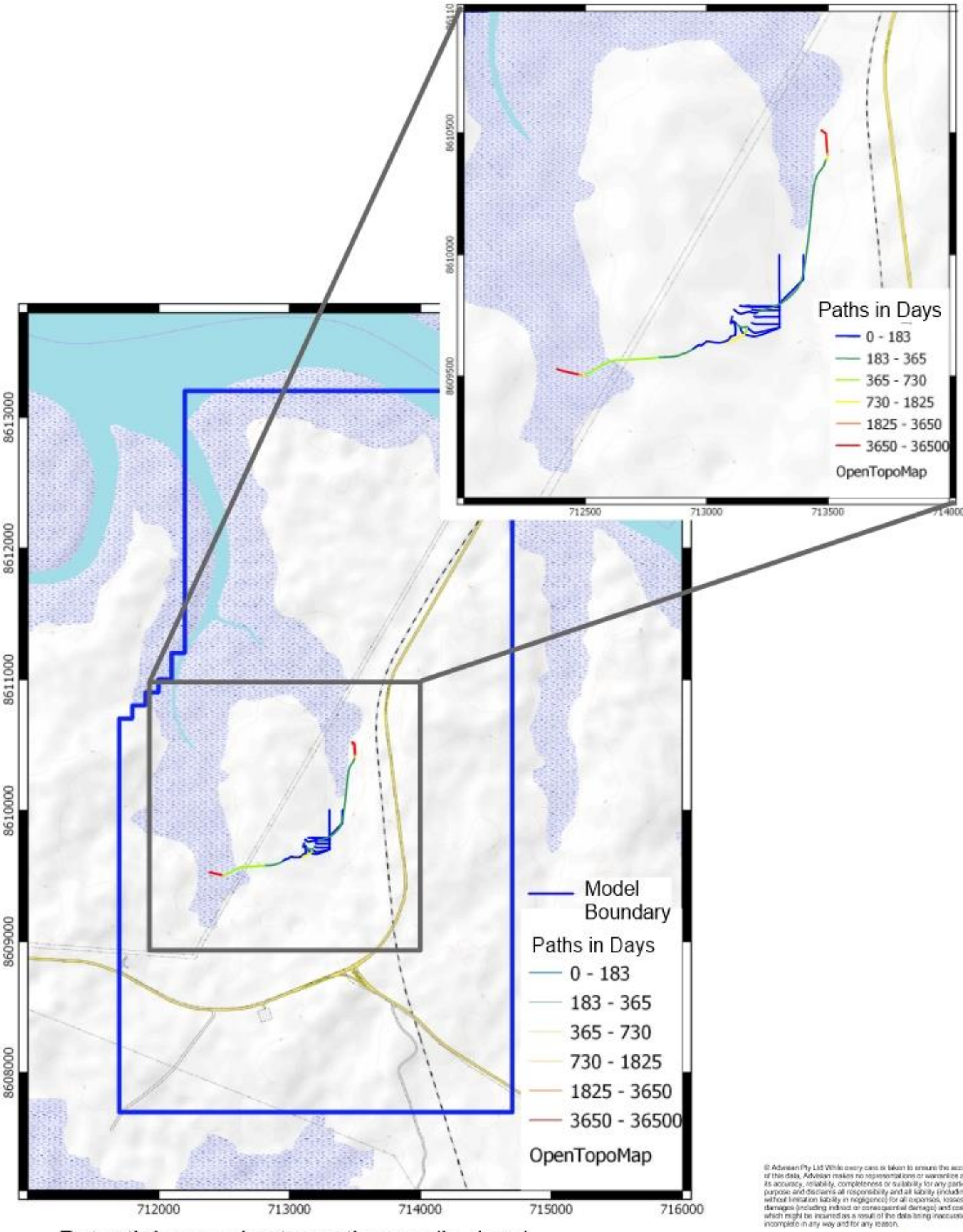

Potential groundwater pathways (in days) as modelled in Groundwater Vista - ModPath

References

Advisian (2019), TNG Darwin Processing Facility – Hydrology and Coastal Assessment

Aqtesolv (2020), Representative Values of Hydraulic Properties, retrieved from http://www.aqtesolv.com/aquifer-tests/aquifer_properties.htm

Baird (2019a), TNG Darwin Processing Facility Outfall – Pollutant Outfall Modelling Report, Report No. 13135.101.R2Rev0

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TNG Limited (2019), Draft Environmental Impact Statement – Executive Summary.

TNG Limited/SMS Group (2020a), Front-End Engineering and Design – Water Management.

TNG Limited/SMS Group (2020b), Front-End Engineering and Design – Processing Plant – Stockpile data.

TNG Limited/SMS Group (2020c), Front-End Engineering and Design – Waste Water Management.

WaterWise (2019), Efficient irrigation for water conservation: guideline for water for urbane gardens and landscapes. Queensland Government

APPENDIX A Model Properties

	Properties							
	Zone	Represents	Layers	Kx (m/d)	Kz (m/d)	Ss (/m)	Sy	
	1	Gravelly sands	1	20	20	1.00E-05	0.22	
	2	Silty-clays-sands	2	0.5	0.05	1.00E-05	0.02	
	Boundary Conditions							
Layers	Feature	Type BC	Values	Value 1	Value 2			
1,2	Open wat	Specified head	Value1=Head	0				
1,2	Mangrove	Drainage BC	Value1 = Head	0.1	10000			
				Recharge (m/d) avg				
Layers	Surface BCs			avg	dry	wet		
1	Recharge	Native vegetation		0.0015	0	0.003		
	Recharge	Mangroves		0	0	0		
	Recharge	Grass		0.005	0.0015	0.008		
	Recharge	hard surface		0	0	0		
				ET				
				Rate	Extinction depth			
	ET	Native vegetation		0.01	5			
	ET	Mangroves		0.01	1			
	ET	Grass		0.005	1			
	ET	Hard Surface		na	na			