Using the spot patterns on the Northern Quolls to identify individuals, images collected from the water seep location suggest that one individual was recorded at the two motion camera locations (**Plate 9-10**). This individual was recorded foraging over several nights, with records on the 9 May 2016 (4am), 11 May 2016 (3:20am) and on 15 May 2016 (12:30am) where it was recorded preying on a Black Rat.

Plate 9: Northern Quoll recorded from water seep (MC052)

Plate 10: Northern Quoll recorded from water seep (MC053)

Recordings from the breakwater area show that one motion camera (MC056) located in a boulder pile of the sheltered side of the breakwater, recorded several different individuals of Northern Quoll over the duration of the survey. One individual was recorded on 6 May 2016 and a different individual was recorded on at least the 10 May 2016 and 20 May 2016. The two individuals can be distinguished by the individual spot pattern (**Plate 11** & **Plate 15**). Northern Quoll were also recorded on the 13 May 2016 and the 21 May 2016 however the spot pattern were not clear enough to confirm the identity based on the spot patterns

Plate 11: Northern Quoll recorded 06 May 2016 (MC056)

Plate 12: Northern Quoll recorded 10 May 2016 (MC056)

Plate 13: Northern Quoll recorded 13 May 2016 (MC056)

Plate 14: Northern Quoll recorded 13 May 2016 (MC056)

Plate 15: Northern Quoll recorded 20 May 2016 (MC056)

Plate 16: Northern Quoll recorded 21 May 2016 (MC056)

At least one additional individual was recorded from the second breakwater site (MC055) which was located on the seaward section (eastern) of the breakwater. Although Northern Quoll were recorded on two nights (4 May 2016 and 9 May 2016), only the individual recorded on the 9 May 2016 had images that were suitable for spot pattern analysis.

Plate 17:Northern Quoll recorded 9 May 2016 (MC055)

Plate 18: Northern Quoll recorded 4 May 2016 (MC055)

3.4 ADDITIONAL NORTHERN QUOLL RECORDS

Based on information provided by site environment staff Northern Quoll have been sighted along the port facility since 2010, with sightings reported every few years from areas such as the barge loader, sample station and in proximity to the reclaimer. Recent site notices requesting any additional sightings have resulted in the following recent pictures from site staff. Sightings of Northern Quoll have also been reported from the Fortescue Village in 2012.

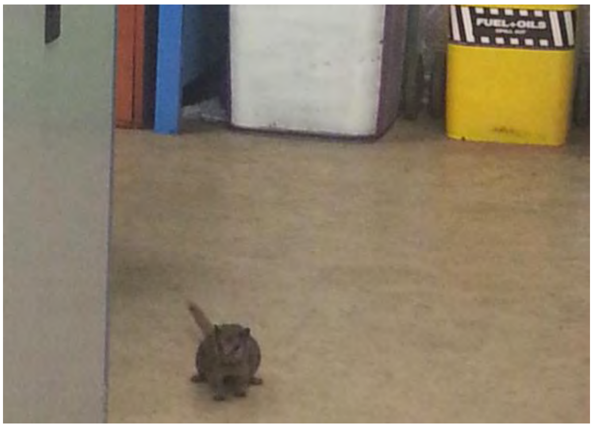
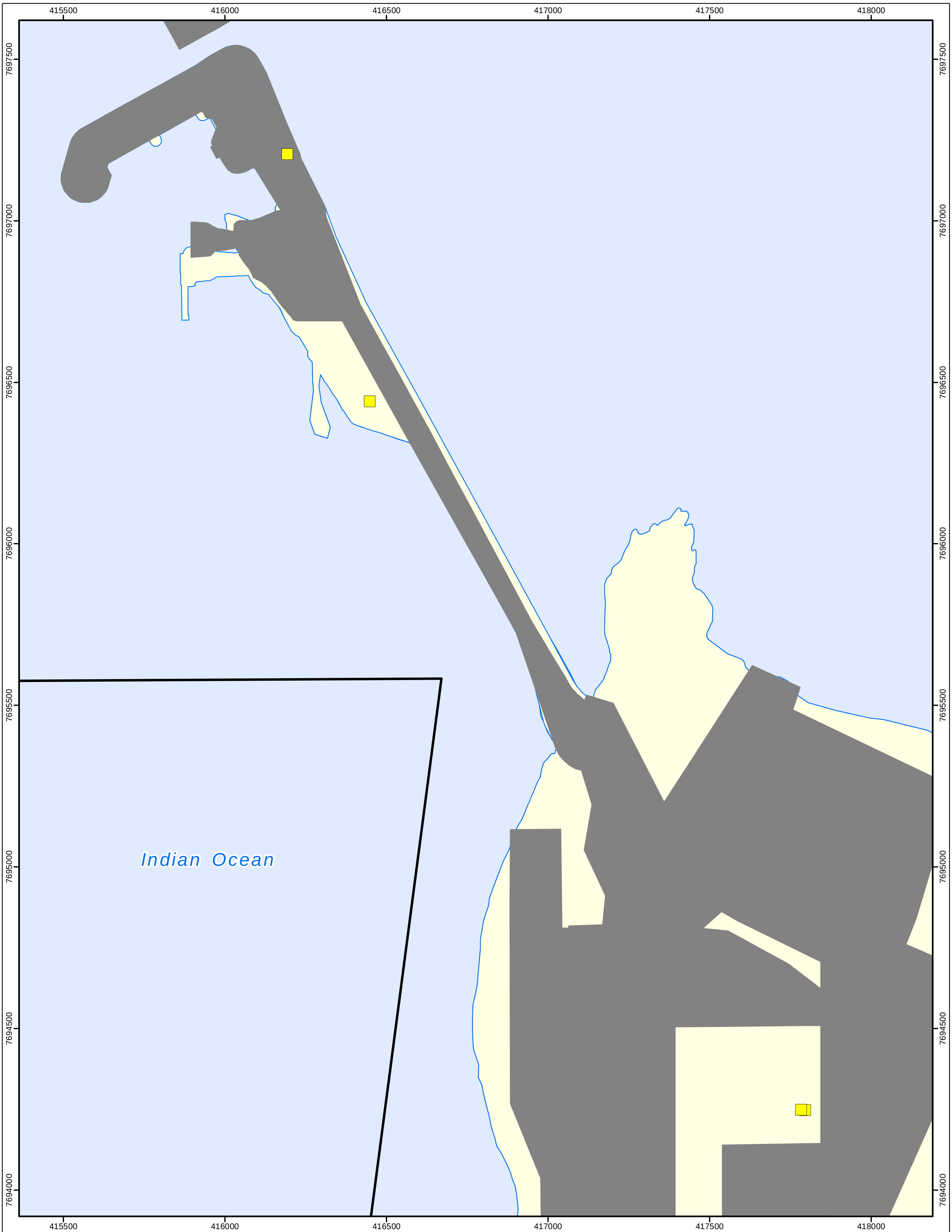


Plate 19:Northern Quoll under wooden pallet

Plate 20: Northern Quoll in workshop



CITIC PACIFIC MINING
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Cape Preston Northern Quoll Reconnaissance Survey
Figure 4

Records of Northern Quoll

0 0.3 0.6
Kilometres
1:15,000

Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Draft

Drawn by	Requested by	Internal Reference
CF	MC, Strategen	4466_00_2017_APP

Legend

- Northern Quoll
- Development Envelope
- Conceptual Footprint

3.5 ADDITIONAL CONSERVATION SIGNIFICANT FAUNA RECORDS

In addition to Northern Quolls, one species of conservation significance, the Rainbow Bee-eater (*Merops ornatus*), was also recorded from three locations throughout the study area. Details of these recordings are listed in **Table 3** and displayed in **Map 5**.

Table 3: Rainbow Bee-eater records

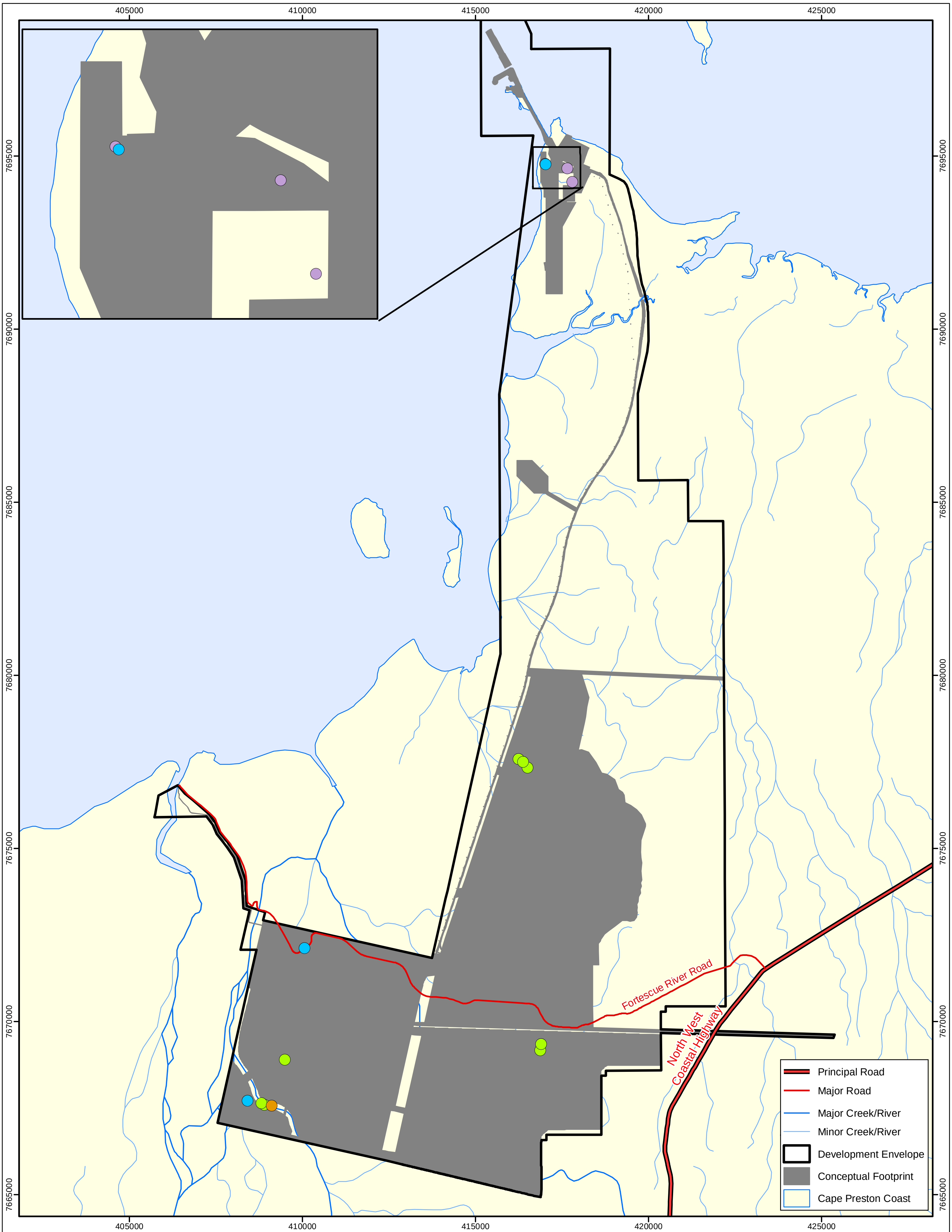
Species	Coordinates		Date	Record
	Eastings	*Northings*		
Rainbow Bee-eater	410057	7672119	4/05/16	1 individual
Rainbow Bee-eater	408417	7667710	5/05/16	1 individual
Rainbow Bee-eater	417030	7694755	24/05/16	2 individuals

3.6 FERAL FAUNA SPECIES RECORDS

Three feral fauna species was recorded on motion cameras during the survey; Cat (*Felis catus*), Black Rat (*Rattus rattus*) and House Mouse (*Mus Map musculus*) **Table 4**. Images of cats were recorded from eight cameras over four locations, all of which were located around the mining area in both drainage lines and along the rocky ridge lines. Black Rats were recorded from three motion cameras at three locations, all of which were located near the Port facility. One house mouse was recorded from a motion camera located in a creek line located to the south west of the mining area. Locations of feral fauna species is displayed in **Map 5**.

Table 4: Feral fauna species records

Species	Motion Camera	Coordinates	
		Eastings	*Northings*
Cat (*Felis catus*)	MC017	416244	7677574
Cat (*Felis catus*)	MC018	416509	7677325
Cat (*Felis catus*)	MC019	416373	7677495
Cat (*Felis catus*)	MC022	408901	7667595
Cat (*Felis catus*)	MC025	416876	7669174
Cat (*Felis catus*)	MC030	408823	7667645
Cat (*Felis catus*)	MC040	416896	7669347
Cat (*Felis catus*)	MC047	409488	7668898
Black Rat (*Rattus rattus*)	MC052	417796	7694247
Black Rat (*Rattus rattus*)	MC054	417657	7694632
Black Rat (*Rattus rattus*)	MC057	417018	7694766
House Mouse (*Mus musculus*)	MC024	409113	7667569



CITIC PACIFIC MINING
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Cape Preston Northern Quoll Reconnaissance Survey

Figure 5

Additional Conservation Significant and Feral Fauna

0 1,600 3,200
Meters
1:140,000

Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Final

Drawn by	Requested by	Internal Reference
DS	MC, Strategen	4474_00_2017_APP

Legend

Conservation Significant

- Rainbow Bee-eater

Introduced

- Black Rat
- Cat
- House Mouse

4 DISCUSSION

4.1 HABITAT AND POPULATION DEFINITIONS

The recent Northern Quoll referral guidelines (DotE 2016) define critical northern Quoll habitat as either;

- Offshore islands where the Northern Quoll is known to exist
- Rocky habitat such as ranges, escarpments, mesas, gorges, breakaways, boulder fields, major drainage lines or treed creek lines
- Structurally diverse woodlands or forest areas containing large diameter trees, termite mounds or hollow logs
- Dispersal and foraging habitat associated with or connecting populations important for the long-term survival of the Northern Quoll.

Population densities are then separated into two categories which are described as

- High density populations may be characterised by numerous camera triggers of multiple individuals across multiple cameras and or traps on site
- Low density populations may be characterised by infrequent captures of one or two individuals confined to one or two traps or where no trapping has identified a northern quoll but latrine evidence remains.

Finally populations important for the long-term survival of the Northern Quoll (critical populations) are defined as:

- high density Quoll populations, which occur in refuge-rich habitat critical to the survival of the species, including where cane toads are present
- occurring in habitat that is free of cane toads and unlikely to support cane toads upon arrival i.e. granite habitats in WA, populations surrounded by desert and without permanent water; and
- subject to ongoing conservation or research actions i.e. populations being monitored by government agencies or universities or subject to reintroductions or translocation.

4.2 NORTHERN QUOLL POPULATIONS AT CAPE PRESTON

4.2.1 MINE AREA

Using the definition of critical habitat described above, there is a small percentage of critical Northern Quoll habitat that occurs in the stage 3 extension areas in the form of boulder fields on top of several ridges, major creek lines and treed drainage lines. The total area of this habitat is considered to be relatively small (0.004% of the study area) and spread out across the landscape with the quality varying from low to moderate.

The population density in the mine area can be considered to be low with no individuals, nor secondary evidence, being recorded during the reconnaissance survey and no additional records from site personnel from this area during the life of the mine.

Based on the above information, the mine area section of the stage 3 extension project is not considered to contain critical populations as there are no high density populations located in this area and the area isn't considered to be refuge rich. The Sino Iron project is also located near the coast which, based on recent Cane Toad distribution modelling, is expected to be suitable for Cane Toads when they arrive in the Pilbara region. Lastly there is currently no ongoing conservation or research actions associated with this area.

4.2.2 PORT AREA

The port area also contains a small area of critical Northern Quoll habitat in the form of boulder piles and a small seep with associated rock formations. The total area of this habitat is considered to be very small (0.12 ha)

The population density in the port area can be considered to be high with multiple individuals being recorded across multiple cameras over several nights during the reconnaissance survey. The population also appears to be stable with sightings being reported by site staff on an ongoing basis since 2010.

Based on the above information, the port area section of the stage 3 extension project is considered to contain critical populations as there are high density populations located in this area. The refuge rich habitat associated with this population however, appears to consist of man-made boulder piles associated with the construction of the Port facility including the breakwater, remnant boulder material not utilised during construction of the Breakwater, and potentially other areas in proximity to the Port.

4.3 NORTHERN QUOLL HABITAT USE

Based on the results of the reconnaissance survey there does not appear to be a population of Northern Quoll within the mine area section of the study area. No individuals were recorded on motion sensitive cameras despite deploying 50 motion sensitive cameras in this area. The lack of reports of Northern Quoll from this area by site staff also indicates that there are potentially no Northern Quoll populations in this area. Although critical Northern Quoll habitat, as defined in the current referral guidelines (DotE 2016), was identified in the mine area section of the study area, the lack of Northern Quoll in this area indicates that impacts to this habitat are not expected to significantly impact regional Northern Quoll populations.

Data collected from the ten motion sensitive cameras deployed within the port area of the study area indicate that multiple individuals are utilising the Port facility and areas on the mainland adjacent to the facility. At least one individual was recorded utilising the water seep which is located inside the study area. The importance of this area as either a water source, denning site or a foraging site is not currently known as the use of other facilities, such as adjacent evaporation ponds associated with the dewatering facility, desalinisation plant by Northern Quoll was not assessed during the current reconnaissance survey. Both a high density population and refuge rich habitat was recorded from the Port facility, however almost all of the observed habitat appears to be associated with the construction of the breakwater and associated Port facility.

Northern Quoll appear to have colonised the breakwater and surrounding areas after the construction of the Port facility and associated breakwater in 2009-2010, with sightings by site staff being first reported in 2010. The implications to environmental impact assessments of Northern Quoll colonising an area based on the presence of man-made habitat is currently not well understood.

5 CONCLUSION

- A reconnaissance survey conforming to the current Northern Quoll referral guidelines was completed covering the stage 3 extension area of the Citic Pacific Mining Management Sino Iron Project at Cape Preston.
- 60 motion sensitive cameras were deployed across the study area for approximately 20 nights to determine the presence of Northern Quoll in the study area. Habitat assessments were also completed to map the presence of critical Northern Quoll habitat across the study area.
- The reconnaissance survey identified a total of 49.75 ha of potential Northern Quoll habitat (denning, foraging and dispersal) across the study area, however the suitability of the habitat was considered of moderate to low quality. 49.65 ha was located within the mine area and 0.12 ha was located within the port area
- Northern Quoll were recorded from two motion sensitive cameras located adjacent to the current study area and an additional two cameras located along the breakwater of the Port facility.
- The mine area was assessed to not contain critical populations as there are no high density populations located in this area and the area isn't considered to be refuge rich.
- The port area was assessed to contain critical populations as high density populations were recorded and there are areas of refuge rich habitat (man-made) located adjacent to the study area.
- Although critical populations were recorded from the port area, the implications of the Northern Quoll habitat being man-made is currently not well understood.

REFERENCES

Department of Environment. 2016. EPBC Act referral guideline for the endangered northern quoll *Dasyurus hallucatus.* EPBC Act Policy Statement.

Department of Sustainability Environment Water Population and Communities. 2011. *Environment Protection and Biodiversity Conservation Act 1999 referral guidelines for the endangered northern quoll, Dasyurus hallucatus. EPBC Act policy statement 3.25*. Available from: http://www.environment.gov.au/epbc/publications/pubs/northern-quoll.pdf.

Trudgen, M. E. 1991, "Vegetation Condition Scale," in *1993 Urban Bushland Policy*, National Trust of Australia (WA) ed., Wildflower Society of Western Australia (Inc.) and the Tree Society (Inc.), Perth, Western Australia.

APPENDIX ONE HABITAT CATEGORIES

Ecoscape's interpretation of habitat categories and suitability based on NQ referral guidelines and Trudgen scale (DSEWPaC 2011; Trudgen 1991).

Table 5: Northern Quoll habitat classifications

Habitat Type	Description	Suitability/Condition	Suitability Criteria
Denning habitat	Rocky ridges, granite outcrop, rocky gorge, boulder pile, rocky springs and seeps, breakaway. Water is often present.	Good	Large extent of rocky habitats (breakaway, gorge or boulder pile) with lots of hiding spots, such as crevices, caves and hollows in proximity to water sources and suitable foraging areas. Vegetation is excellent and feral predators absent. No evidence of recent fires.
		Moderate	Small mesa, granite outcrop or boulder with some caves and crevices, and limited connectivity to foraging and dispersal habitats. Water may be present. Some impacts by grazing or presence of feral predators. Fire history >5 years.
		Low	Isolated patch of habitat with limited extent, some crevices and caves present. No connectivity to dispersal or foraging habitat. Water may be present. Impacts by feral predators (cats, dogs) and possibly grazing evident. Fire history >3 years.
Dispersal habitat	Major creeklines and rivers, low lying linear rocky habitats (boulders).	Good	Major river with fringing mature eucalypt trees and intact understorey (lower vegetation) to provide cover and hiding spots. Lots of hollow trees and/or fringing rocky habitats. Water may be present. Good connectivity to denning habitats. No evidence of recent fires.
		Moderate	Drainage line with eucalypt trees and some understorey or other hiding spots. Water may be present. Some connectivity to denning habitat exists. Fire history >5 years.
		Low	Minor creekline with some eucalypts with very low number of tree hollows and cover, rocky habitats absent. Evidence of grazing and/or presence of feral predators. Fire history >3 years.
Foraging habitat	Rivers and creeklines, some rocky habitats such as smaller granite boulders or low lying boulder piles, water may be present.	Good	Low lying boulder piles, creeklines with structured vegetation or seep/spring which provide good conditions for prey (smaller fauna and fruits). No evidence of recent fires.
		Moderate	Low lying rocky boulders or creeklines with fringing eucalypt trees and some understorey to provide suitable conditions for food resources, some water and shelter may be present. Connectivity to some closeby denning habitat present. Fire history >5 years.
		Low	Isolated drainage lines and small rocky areas such as boulder piles. Vegetation is grazed and/or evidence of feral predators is present. Fire history >3 years.

APPENDIX TWO LOCATION OF MOTION CAMERAS

Table 6: Locations of motion sensitive cameras

Motion Camera	Coordinates		Date set-up	Date collection
MC001	419781	7669142	03/05/16	24/05/16
MC004	420064	7669700	03/05/16	24/05/16
MC005	419692	7668996	04/05/16	24/05/16
MC006	418057	7669545	04/05/16	24/05/16
MC007	418000	7669313	04/05/16	24/05/16
MC008	418081	7669666	04/05/16	24/05/16
MC009	417980	7669187	04/05/16	24/05/16
MC010	417980	7669463	04/05/16	24/05/16
MC011	418087	7675066	04/05/16	24/05/16
MC012	418162	7675101	04/05/16	24/05/16
MC013	417964	7675118	04/05/16	24/05/16
MC014	417859	7675169	04/05/16	24/05/16
MC015	417749	7675281	04/05/16	24/05/16
MC016	416441	7677425	04/05/16	24/05/16
MC017	416245	7677575	04/05/16	24/05/16
MC018	416510	7677326	04/05/16	24/05/16
MC019	416374	7677495	04/05/16	24/05/16
MC020	416563	7677244	04/05/16	24/05/16
MC021	408367	7667647	05/05/16	24/05/16
MC022	408902	7667595	05/05/16	24/05/16
MC024	409113	7667569	05/05/16	24/05/16
MC025	416877	7669175	05/05/16	24/05/16
MC026	408422	7667695	05/05/16	24/05/16
MC027	408566	7667712	05/05/16	25/05/16
MC028	408657	7667684	05/05/16	25/05/16

Motion	Coordinates		Date set-up	Date collection
MC029	408724	7667665	05/05/16	25/05/16
MC030	408824	7667646	05/05/16	25/05/16
MC031	409554	7668894	04/05/16	25/05/16
MC032	409399	7668961	04/05/16	25/05/16
MC033	409264	7668971	05/05/16	25/05/16
MC034	408372	7667557	05/05/16	25/05/16
MC035	409292	7669036	05/05/16	25/05/16
MC036	416950	7669566	05/05/16	25/05/16
MC037	416936	7669494	05/05/16	25/05/16
MC038	416903	7669418	05/05/16	25/05/16
MC039	416873	7669258	05/05/16	25/05/16
MC040	416896	7669347	05/05/16	25/05/16
MC041	415469	7676191	04/05/16	25/05/16
MC042	415485	7676499	04/05/16	25/05/16
MC043	415499	7676317	04/05/16	25/05/16
MC044	415484	7676425	04/05/16	25/05/16
MC045	415514	7676245	04/05/16	25/05/16
MC046	409395	7670870	04/05/16	25/05/16
MC047	409489	7668899	04/05/16	25/05/16
MC048	409327	7670942	04/05/16	25/05/16
MC049	409493	7670623	04/05/16	25/05/16
MC050	409257	7670990	04/05/16	25/05/16
MC051	417945	7693631	03/05/16	25/05/16
MC052	417796	7694248	03/05/16	25/05/16
MC053	417782	7694249	03/05/16	25/05/16
MC054	417657	7694632	03/05/16	25/05/16
MC055	416192	7697205	03/05/16	25/05/16

Motion	Coordinates		Date set-up	Date collection
MC056	416447	7696441	03/05/16	25/05/16
MC057	417018	7694766	03/05/16	25/05/16
MC058	417016	7694705	03/05/16	25/05/16
MC059	417020	7694787	03/05/16	25/05/16
MC060	417006	7694507	03/05/16	25/05/16
MC061	419979	7669558	03/05/16	25/05/16
MC062	419912	7669384	03/05/16	25/05/16
MC063	409028	7667590	03/05/16	25/05/16

Datum: 84WGS, Zone: 50K

APPENDIX THREE SPECIES RECORDED ON MOTION CAMERA

Table 7: Fauna species recorded from motion sensitive cameras

Motion Camera	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6
MC 001	Euro (*Macropus robustus*)					
MC 004	Tree Dtella (*Gehyra variegata*)	Willie Wagtail (*Rhipidura leucophrys*)	Spinifex Pigeon (*Geophaps plumifera*)	Ringtail Dragon (*Ctenophorus caudicinctus*)	Pied Butcherbird (*Cracticus nigrogularis*)	Small sized dasyurid (Pseudantechinus/Red Kaluta)*
MC 005	Common Rock-rat (*Zyzomys argurus*)					
MC 006	Euro (*Macropus robustus*)					
MC 007	Yellow-spotted monitor (*Varanus panoptes*)					
MC 008	Magpie-lark (*Grallina cyanoleuca*)					
MC 009	Euro (*Macropus robustus*)					
MC 010	Euro (*Macropus robustus*)					
MC 011	Euro (*Macropus robustus*)					
MC 012	Little Button-quail (*Turnix velox*)					
MC 013	Euro (*Macropus robustus*)					
MC 014	Euro (*Macropus robustus*)					
MC 015	Euro (*Macropus robustus*)					
MC 016	Euro (*Macropus robustus*)					
MC 017	Feral Cat (*Felis catus*)	Cattle (*Bos taurus*)				
MC 018	Feral Cat (*Felis catus*)	Euro (*Macropus robustus*)	Cattle (*Bos taurus*)			
MC 019	Feral Cat (*Felis catus*)	Cattle (*Bos taurus*)	Magpie-lark (*Grallina cyanoleuca*)			
MC 020	Euro (*Macropus robustus*)					
MC 021	Cattle (*Bos taurus*)	Australian Ringneck (*Barnardius zonarius*)	Crested Pigeon (*Ocyphaps lophotes*)			
MC 022	Emu (*Dromaius novaehollandiae*)	Cattle (*Bos taurus*)	Feral Cat (*Felis catus*)			
MC 024	Cattle (*Bos taurus*)	House Mouse (*Mus musculus*)				
MC 025	Feral Cat (*Felis catus*)					
MC 026	Cattle (*Bos taurus*)	Euro (*Macropus robustus*)				
MC 027	Torresian Crow (*Corvus orru*)	Cattle (*Bos taurus*)				

Motion Camera	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6
MC 028	Cattle (*Bos taurus*)					
MC 029	Cattle (*Bos taurus*)					
MC 030	Feral Cat (*Felis catus*)	Cattle (*Bos taurus*)	Magpie-lark (*Grallina cyanoleuca*)			
MC 031	-					
MC 032	Euro (*Macropus robustus*)					
MC 033	-					
MC 034	-					
MC 035	Australian Bustard (*Ardeotis australis*)	Magpie-lark (*Grallina cyanoleuca*)	Cattle (*Bos taurus*)	Yellow-spotted Monitor *(Varanus panoptes)*		
MC 036	Echidna (*Tachyglossus aculeatus*)	Rothschild's Rock-wallaby (*Petrogale rothschildi*)	Spinifex Pigeon (*Geophaps plumifera*)			
MC 037	Rothschild's Rock-wallaby (*Petrogale rothschildi*)					
MC 038	-					
MC 039	Rothschild's Rock-wallaby (*Petrogale rothschildi*)	Euro (*Macropus robustus*)				
MC 040	Feral Cat (*Felis catus*)					
MC 041	Euro (*Macropus robustus*)	Cattle (*Bos taurus*)	Willie Wagtail (*Rhipidura leucophrys*)	Singing Honey-eater (*Gavicalis virescens*)	Owlet Nightjar (*Aegotheles chrisoptus*)	Spinifex Pigeon (*Geophaps plumifera*)
MC 042	Euro (*Macropus robustus*)	Cattle (*Bos taurus*)				
MC 043	Cattle (*Bos taurus*)					
MC 044	Cattle (*Bos taurus*)					
MC 045	-					
MC 046	Cattle (*Bos taurus*)					
MC 047	Feral Cat (*Felis catus*)					
MC 048	Cattle (*Bos taurus*)	Euro (*Macropus robustus*)				
MC 049	Euro (*Macropus robustus*)					
MC 050	-					
MC 051	Short-beaked Echidna (*Tachyglossus aculeatus*)					
MC 052	Northern Quoll (*Dasyurus hallucatus*)	Black Rat (*Rattus rattus)*				

Motion Camera	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6
MC 053	-					
MC 054	Black Rat (*Rattus rattus*)	Short-beaked Echidna (*Tachyglossus aculeatus*)	Euro (*Macropus robustus*)	*Ctenotus inornatus*		
MC 055	Northern Quoll (*Dasyurus hallucatus*)					
MC 056	Common Rock-rat (*Zyzomys argurus*)	Northern Quoll (*Dasyurus hallucatus*)				
MC 057	Common Rock-rat (*Zyzomys argurus*)	Euro (*Macropus robustus*)	Yellow-spotted Monitor *(Varanus panoptes)*	Black Rat (*Rattus rattus)*		
MC 058	Euro (*Macropus robustus*)	Short-beaked Echidna (*Tachyglossus aculeatus*)				
MC 059	Euro (*Macropus robustus*)					
MC 060	-					
MC 061	Ringtail Dragon *(Ctenophorus caudicinctus)*	Common Rock-rat (*Zyzomys argurus*) or Black Rat (*Rattus rattus*)*				
MC 062	Euro (*Macropus robustus*)					
MC 063	Cattle (*Bos Taurus*)					

*Features cannot be clearly identified on Motion Camera image to determine species

Note: The species Black Rat (*Rattus rattus*) has been determined based on the species' distribution. Motion Camera imagery was not suitable to distinguish this species from other introduced species of rat (e.g. Brown Rat).

APPENDIX FOUR SPECIES IMAGES

Plate 21: Spinifex Pigeon *Geophaps plumifera* (MC004)

Plate 22: Pied Butcherbird *Cracticus nigrogularis* (MC004)

Plate 23: Willie Wagtail *Rhipidura leucophrys* (MC004)

Plate 24: Black Rat *Rattus rattus* (MC054)

Plate 25: Emu *Dromaius novaehollandiae* (MC022)

Plate 26: Cattle *Bos taurus* (MC022)

Plate 27: Feral Cat *Felis catus* (MC017)

Plate 28: Australian Bustard *Ardeotis australis* (MC035)

Plate 29: Rothschild's Rock-wallaby *Petrogale rothschildi* (MC037)

Plate 30: Torresian Crow *Corvus orru* (MC041)

Plate 31: Australian Owlet Night-jar *Aegotheles cristatus* (MC041)

Plate 32: Short-beaked Echidna *Tachyglossus aculeatus* (MC051)

Plate 33: Euro *Macropus robustus* (MC053)

Plate 34: Common Rock-rat *Zyzomys argurus* (MC056)

Plate 35: Ringtail Dragon *Ctenophorus caudicinctus* (MC004)

Plate 36: Tree Dtella *Gehyra varigata* (MC004)

Cape Preston Northern Quoll Targeted Survey

CITIC Pacific Mining Management

ecoscape

VERSION	AUTHOR	QA REVIEWER	APPROVED	DATE
Rev 0	Damien Cancilla	Astrid Heidrich Zoology Team Leader	Marc Wohling-Director, Environment	26/08/2016
Rev 1	Damien Cancilla	Astrid Heidrich Zoology Team Leader	Marc Wohling-Director, Environment	12/09/2016
Rev 2	Astrid Heidrich	Damien Cancilla Associate Zoologist	Damien Cancilla Associate Zoologist	16/12/2016

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TABLES

MAPS

PLATES

ACKNOWLEDGEMENTS

Ecoscape wished to acknowledge the assistance of the following personnel in relation to the Northern Quoll reconnaissance survey at Cape Preston:

- Site Environmental staff Daniel Statham, Harley Barron and Tom Wang (CITIC Pacific)
- Senior Environmental Adviser Rob Wood (CITIC Pacific)
- Associated and Mining Lead Mat Brook (Strategen)

EXECUTIVE SUMMARY

CITIC Pacific Mining Management has developed the Sino Iron Project at Cape Preston. The Sino Iron project is the largest magnetite mining and processing operation in Australia. The project has developed via a staged approach and the work to which this proposal relates is the Stage 3 Sino Iron extension areas (study area).

Ecoscape was engaged to conduct a Northern Quoll reconnaissance survey of the Stage 3 extension of the Sino Iron project at Cape Preston. During this survey the species was recorded from three locations (four cameras) in close proximity to the proposed footprint of the Stage 3 extension areas indicating that a local Northern Quoll population is present in the vicinity of the project.

As a result from the reconnaissance survey, a targeted survey for Northern Quolls was completed with methodology following the the Commonwealth Department of the Environment (DotE) EPBC Act Referral guideline for the Northern Quoll, *Dasyurus hallucatus* (DotE 2016).

Three male Northern Quolls were recorded from the breakwater/port area north of the proposed footprint (Stage 3 extension areas). No individuals were recorded from inside the study area, however the reconnaissance survey recorded motion camera images in close proximity of the northern section of the study area indicating that individuals utilise these areas for foraging and dispersal purposes. No direct use of the proposed Stage 3 footprint has been recorded during the surveys.

The implications of the Northern Quoll utilising and colonising artificial habitat and disturbed areas, is not well understood. This artificial habitat is outside the current Stage 3 extension footprint.

1 INTRODUCTION

CITIC Pacific Mining Management (CPM) has developed the Sino Iron Project at Cape Preston. The Sino Iron project is the largest magnetite mining and processing operation in Australia. The project has been developed via a staged approach and the work to which this report relates is the Stage 3 Sino Iron extension areas (study area) (**Map 1**).

Ecoscape was engaged to conduct a Northern Quoll reconnaissance survey of the Stage 3 extension of the Sino Iron project at Cape Preston in May 2016. The reconnaissance survey identified the presence of Northern Quoll at four locations in the Port area on Cape Preston. To follow up the results of the reconnaissance survey, Ecoscape was engaged to conduct a targeted Northern Quoll survey of the Port area to determine additional population information on the Northern Quolls present.

The methodology for the Northern Quoll targeted survey followed the methodology outlined in the Department of the Environment (DotE) EPBC Act Referral guideline for the Northern Quoll, *Dasyurus hallucatus* (Department of Environment 2016). The information below has been summarised from the current guidelines (DotE 2016) and provides the basis for the survey methodology used.

The current guidelines (DotE 2016) state that Northern Quoll targeted surveys can be conducted between April and September and that the main objective of the survey is to collect data that will allow impact assessments possible with regard to Northern Quoll populations. Information of interest for referrals include;

- What is the size and relative density of the northern quoll population in the study area?
- Is it likely to be a population important for the long-term recovery of the northern quoll?
- In which parts of the study area do northern quolls appear to be sheltering in? Is the area rich in refuges?
- Is it likely to be a permanent or transient (dispersal/mating) population?
- Which habitats in the study area appear important for dispersal?
- How are these areas of dispersal habitat likely to be used?
- What threats are currently operating in the study area?
- In which habitats in the study area should monitoring occur?

Methods are recommended to include the use of a trapping program (wire cage traps and medium/large Elliott traps) to provide detailed information on the Northern Quoll population present in the study area. Habitat assessments should also be conducted to include information on vegetation, potential sheltering sites, fire history, landscape connectivity and condition, presence of introduced predators and grazing history so that habitat quality can be assessed.

The results of the reconnaissance survey determined that Northern Quoll were present within the Port area and that habitat critical to the survival of the Northern Quoll (critical habitat) is present. Critical habitat is defined as:

- Offshore islands where the Northern Quoll is known to exist
- Rocky habitat such as ranges, escarpments, mesas, gorges, breakaways, boulder fields, major drainage lines or treed creek lines
- Structurally diverse woodlands or forest areas containing large diameter trees, termite mounds or hollow logs
- Dispersal and foraging habitat associated with or connecting populations important for the long-term survival of the Northern Quoll.

Populations important for the long-term survival of the Northern Quoll (critical populations) are defined as:

- high density Quoll populations, which occur in refuge-rich habitat critical to the survival of the species, including where cane toads are present
- occurring in habitat that is free of cane toads and unlikely to support cane toads upon arrival i.e. granite habitats in WA, populations surrounded by desert and without permanent water
- subject to ongoing conservation or research actions i.e. populations being monitored by government agencies or universities or subject to reintroductions or translocation.

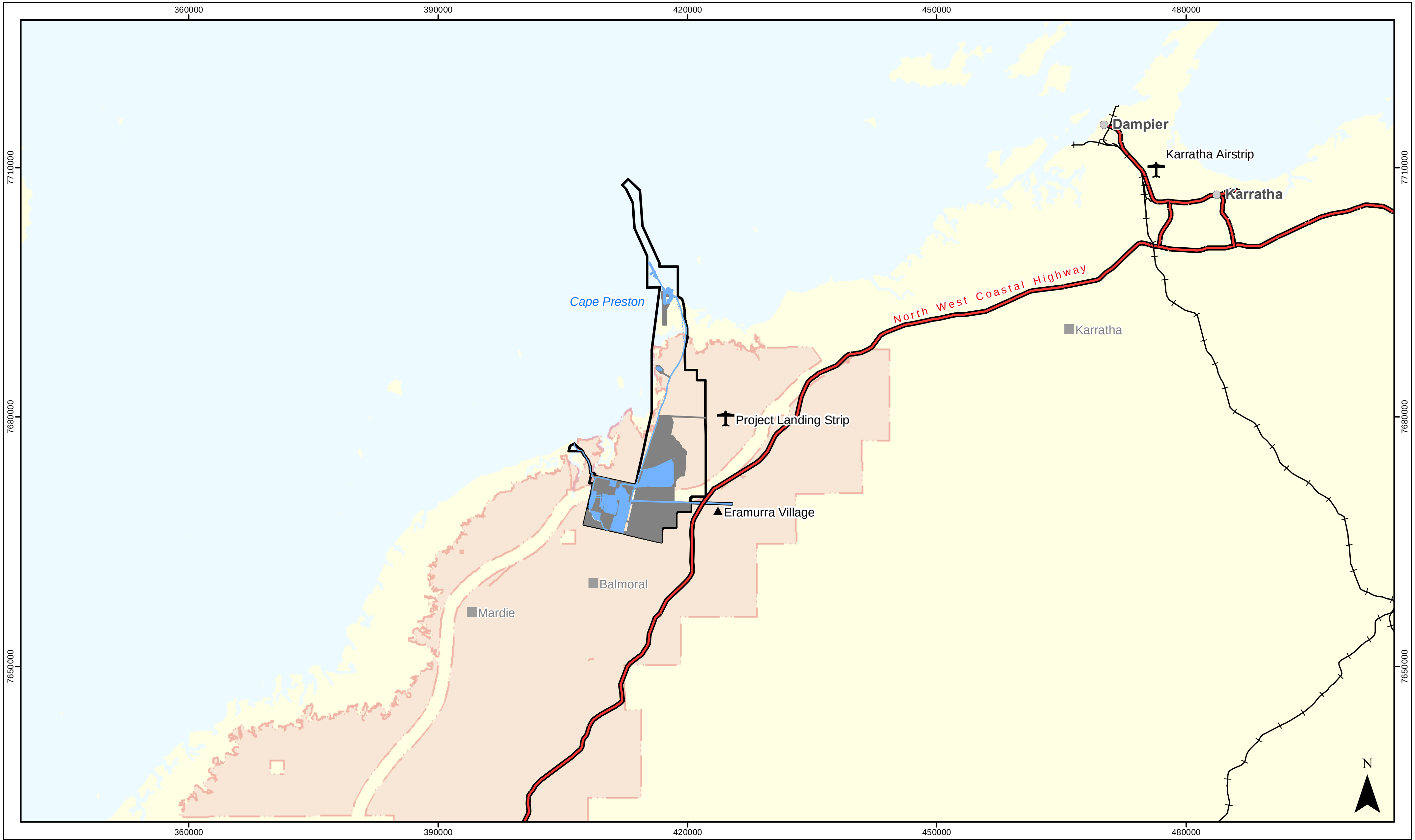
A high density population is characterised by 'numerous camera triggers of multiple individuals across multiple cameras or traps' on site (DotE 2016). Low density populations are characterised by 'infrequent captures of one or two individuals confined to one or two traps' (DotE 2016). .

There are several survey considerations that are included in the referral guidelines with points edited so that only considerations that are relevant to this aspect of the project (targeted survey) are listed below. How these considerations where addressed by Ecoscape is also included in the below table.

Table 1: Considerations relevant to Northern Quoll reconnaissance surveys (adapted from DotE 2016)

CONSIDERATION	GUIDANCE	ECOSCAPE RESPONSE
Informed project siting and monitoring	Careful survey configuration to address project impact and non-impact zones.	Reconnaissance survey searches covered the entire Stage 3 extension study area, all of which is proposed to be impacted. Targeted survey was focussed on the Port area including non-impacted areas on Cape Preston
Other state and territory guidelines	In WA, conformity with state survey guidelines, statements and operating procedures is recommended (EPA 2004: DEC 2011, EPA and DEC 2010).	All techniques used conform to relevant state guidelines as appropriate.
Timing	Targeted cage or Elliot trapping programs are to be undertaken between April and September to avoid disturbance when females have large or denned pouch young.	The survey timing (July 2016) is considered optimal as males are roaming in search of suitable females, which allow determination of maximum habitat use for this species. Females are not expected to have pouch young at this time and stress on breeding females and young is avoided.
Animal welfare	Surveys conducted by a suitably qualified person or group of persons with demonstrated skill in mammal surveys.	Ecoscape staff that completed this project are all qualified zoologists and highly experienced surveying for Northern Quoll. Fauna survey licences (SF010801) obtained prior to undertaking field survey.
	Traps cleared within 2 hours of sunrise and have adequate shade cover during the day.	All traps were located to allow clearance within 2 hours of sunrise and positioned to minimise exposure.
Detectability	In Western Australia, traps set for seven consecutive nights unless two or more individuals are caught twice, in which case the traps should be closed after four nights of trapping.	All traps were set for seven consecutive nights and any traps where individuals were caught on consecutive nights were closed.
Site coverage	Targeted surveys should be based on the results of the reconnaissance survey. When trapping is used, effort should be concentrated in areas of habitat critical to the survival of the species.	The results of the reconnaissance survey determined that a Northern Quoll population occurred in the Port area. Trapping effort was focussed on areas of suitable rocky habitat (denning and foraging habitat) within this area.
Supplementary survey methods	Survey techniques such as latrine searches, employment of detection dogs or hair tubes are recommended for use with remote cameras or trapping to improve detection probability.	Latrine searches and additional habitat assessments were conducted during the field survey.
Effective Baiting	Traps baited with sardines or a bolus mix of oats and peanut butter (honey optional), chicken wings and / or diced bacon.	All traps were baited with a bolus of mixed oats, peanut butter and sardines. Traps were re-baited every second day.

CONSIDERATION	GUIDANCE	ECOSCAPE RESPONSE
Survey design and effort	Trapping: For a targeted survey, trapping effort will depend on the context of your action with the majority of effort targeted within habitat critical to the survival of the northern quoll. As northern quolls frequently live in linear rocky habitats, particularly in WA, population monitoring is undertaken using trapping transects rather than grids, however in Qld, grids may be more appropriate. If trapping is used, transects or grids should be configured to achieve optimal cover of the sites. Two parallel lines of 25 traps each should be laid across broader habitat types such as breakaways or granite outcrops in WA.	This survey design focussed on covering all of the suitable rocky habitat within the Port area. Habitat consisted of predominantly linear areas and traps were set at 100 m spacing wherever possible with locations of the most suitable rocky boulder piles prioritised whilst maintaining a suitable distance between trap points.
Contribution to knowledge building	Where possible, samples and location data should be provided to institutes and individuals with ongoing research programs with the aim of increasing genetic and spatial knowledge of the Northern Quoll.	All data will be supplied to DPaW as per the requirements of the Regulation 17 permit (permit to take fauna).
	In WA, tissue samples (ear clippings) should be collected and sent to the WA Museum with the following details: Weight, sex, pes length (left hind foot measurement), tail diameter / circumference, crown length, reproductive condition, presence/absence of bite marks and parasites, locality (GPS coordinate in lat and long), collector's name and date.	Tissue samples and suitable scat material was collected during this survey and provided to relevant staff at the DPaW (Judy Dunlop). All morphometric data is included in this report.



CITIC PACIFIC MINING
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Cape Preston Northern Quoll
Targeted Survey

Figure 1

Cape Preston Location Map

0 10 20
Kilometres
1:600,000

Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Final

Drawn by	Requested by	Internal Reference
DS	MB, Strategen	4476_00_2017_APP

Legend

- Development Envelope
- Conceptual Footprint
- Statement 635 approval (MS635)
- Populated Place
- Airport
- Eramurra Village
- Homesteads
- Railway
- Principal Road
- Mardie Station

2 METHODS

The results of the initial reconnaissance survey were used to set the design parameters for this survey. Northern Quoll were recorded on four motion cameras located both along the breakwater structure and also at the water seep that is located to the south of the break water (Ecoscape 2016).

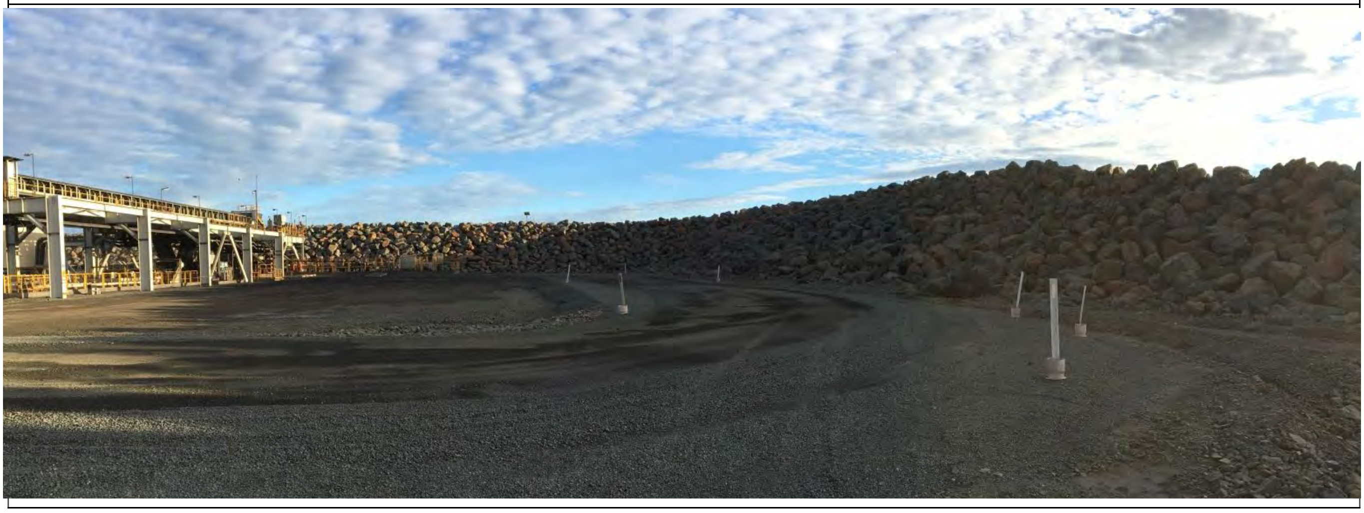
Habitat assessments were completed during the reconnaissance survey using spatial information such as geology and land system maps as well as aerial imagery and then ground truthed in the field. Areas of potential habitat were selected based on the likelihood that habitats suitable for the Northern Quoll, as described in **Appendix One**, occurred in each section of the study area.

Based on the current DotE guidelines for Northern Quoll trapping sites should be established in critical Northern Quoll habitat (denning and foraging habitat) and set-up every 100 m along linear habitats and trapped for a minimum of seven consecutive nights. Areas of suitable habitat in the Port area were mapped and these areas were targeted for the trapping survey.

A total of 80 wire cage and medium Elliott traps were used between 18 and 26 July 2016 (**Table 7**). Trap sites were established at seven locations based on the outcomes from the reconnaissance survey (identification of suitable habitat and recorded Northern Quolls) (**Table 2**). Each trap was baited using a bolus of rolled oats, peanut butter and sardines (as outlined in the DotE guidelines) with the bait refreshed every second day. All traps were checked daily within two hours of sunrise and all captured Northern Quoll processed to determine weight, short pes length, caudal width, head length, sex, and reproductive condition. All captured Northern Quoll were also injected with a PIT microchip for identification of recaptures and a small ear notch taken for future DNA analysis by research institutions. All by-catch was identified and released at the capture point with the exception of one feral cat.

Table 2: Trapping sites

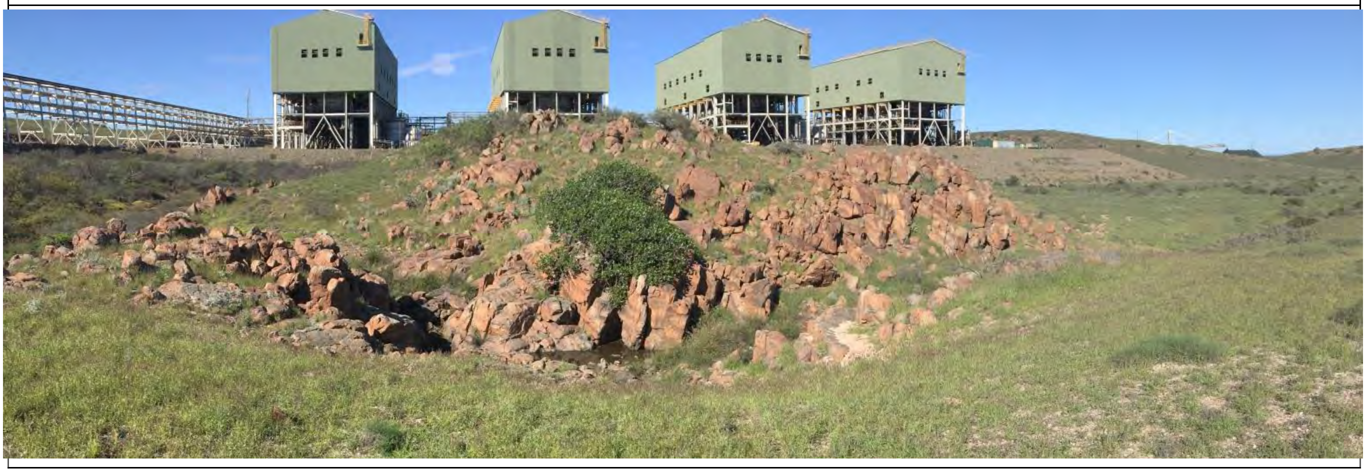
Site Name
Breakwater



Site Name
The Point

Southern Hills

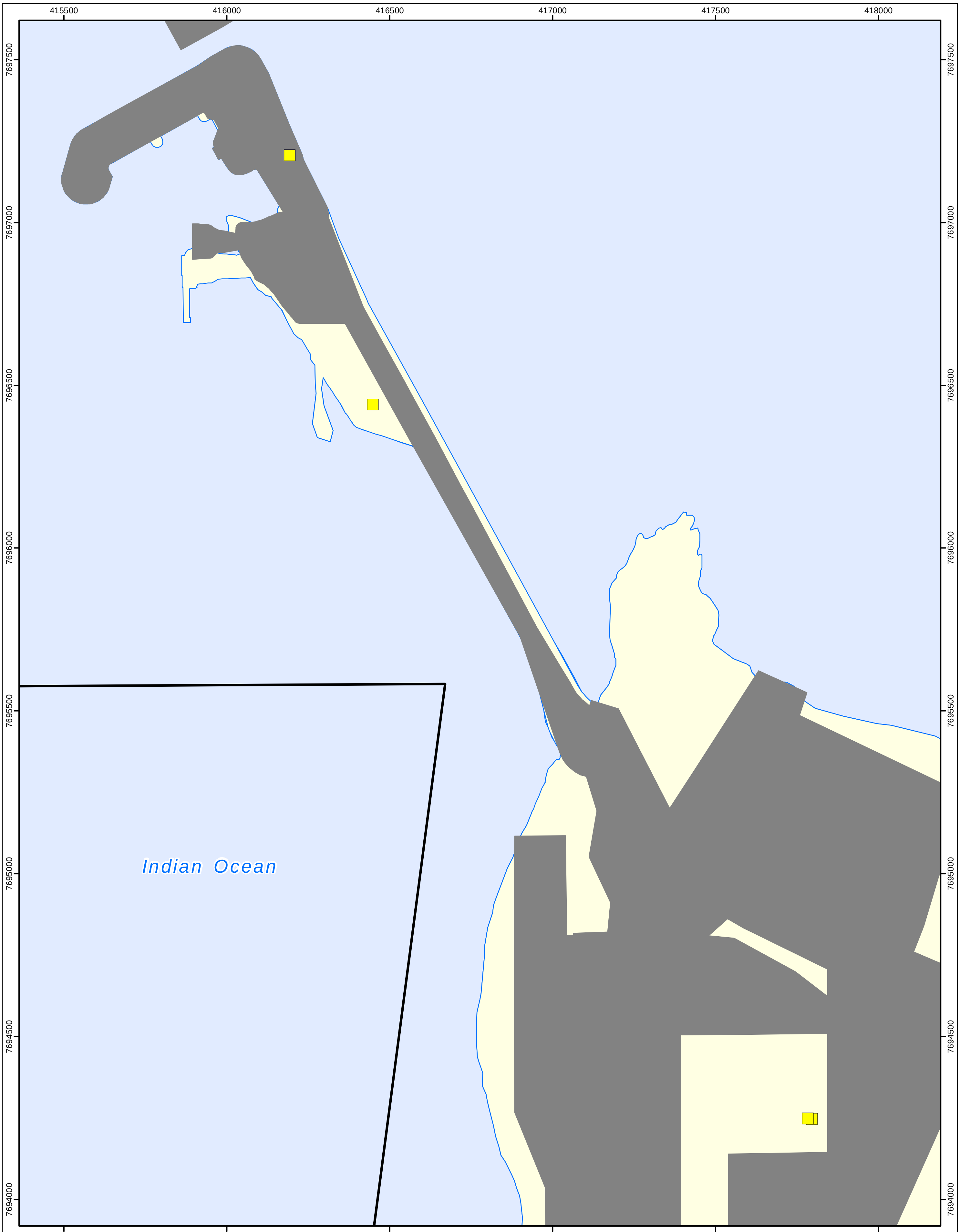
Water Seep

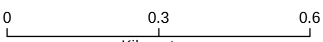


Site Name
Stockpile

Rocky Hill

Quarried Wall





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Cape Preston Northern Quoll Targeted Survey

Figure 2

Northern Quoll locations from Reconnaissance Survey

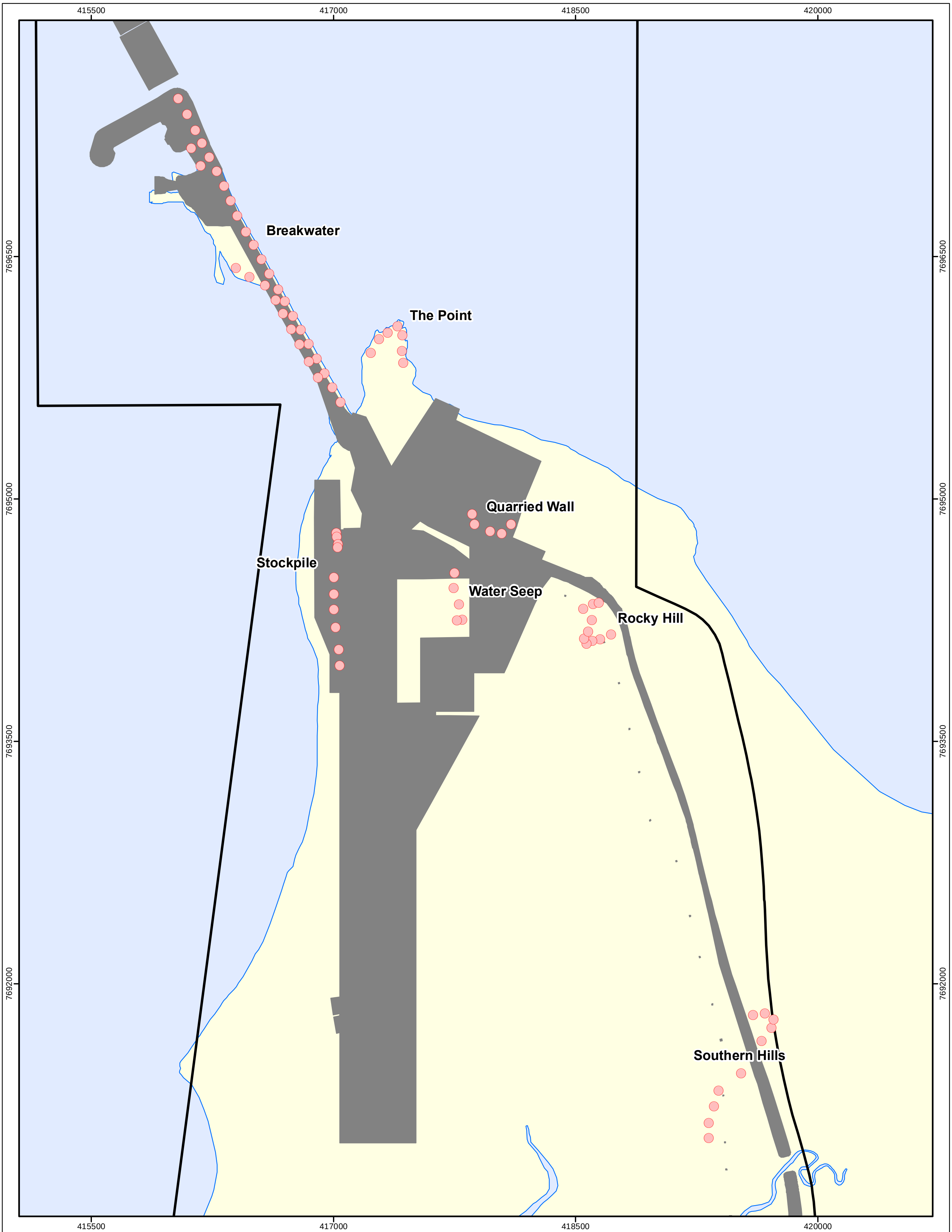
Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Draft

Drawn by CF	Requested by MC, Strategen	Internal Reference 4478_00_2017_APP

Legend

- Northern Quoll
- Development Envelope
- Conceptual Footprint



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Cape Preston Northern Quoll Targeted Survey

Figure 3

Northern Quoll Trap Locations

Datum: GDA94
Projection: MGA Zone 50

Department: ENV	Date: 2/02/2017
Sheet Size: A4	Status: Final

Drawn by	Requested by	Internal Reference
DS	MC, Strategen	4467_00_2017_APP

3 RESULTS

3.1 TRAPPING RESULTS

During the survey, three male Northern Quoll were recorded repeatedly from up to four locations. All captures were located on the northern end of the breakwater (outside the proposed Stage 3 footprint). No females were recorded from the site. Details of each capture are shown in **Table 3** and their locations are displayed in **Map 4**.

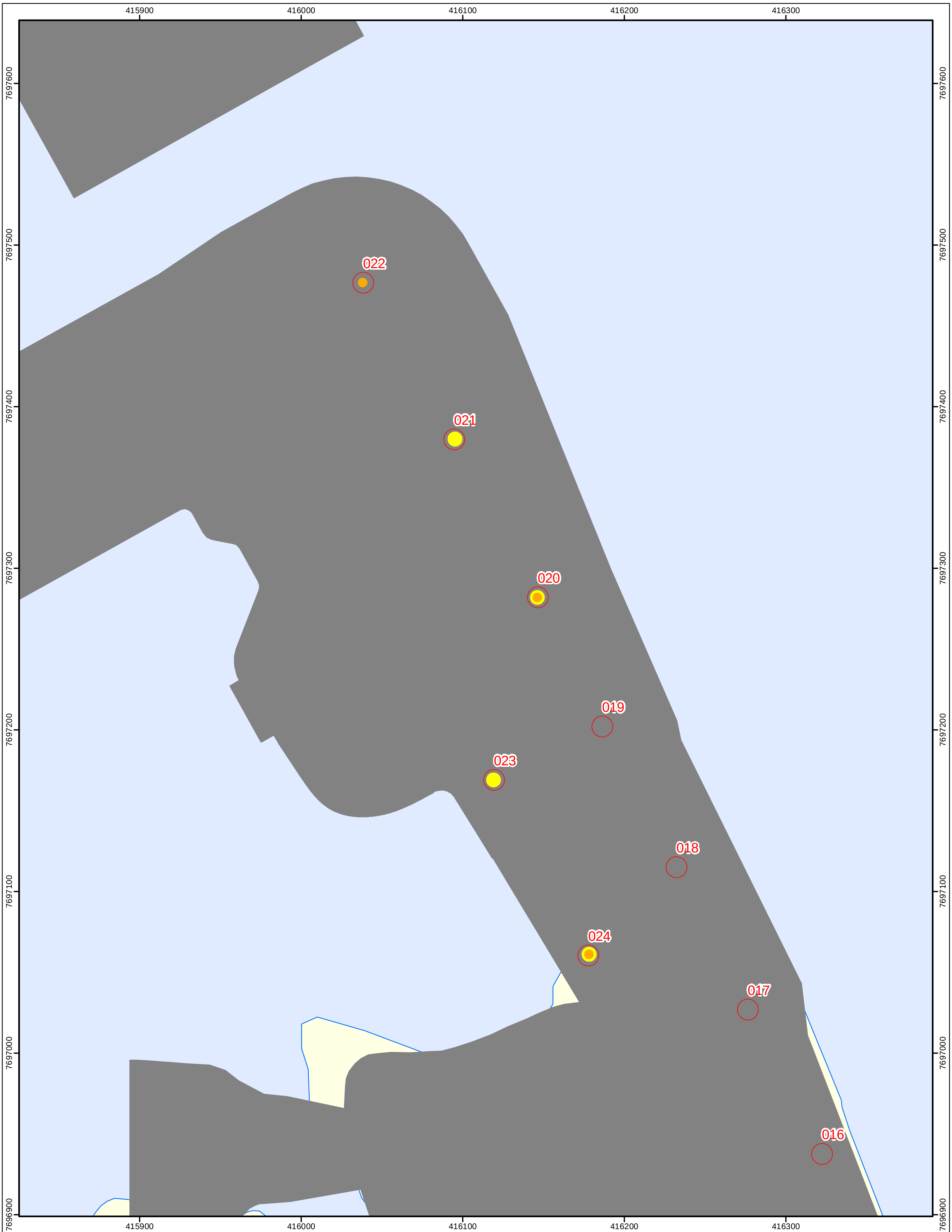
Table 3: Northern Quoll trapping data

<table>
<tr><th>Northern Quoll ID</th><th>Trap Point</th><th>Date</th><th>Sex</th><th>Weight (g)</th><th>S Pes (mm)</th><th>Caudal width (mm)</th><th>Head Lgth (mm)</th><th>Reproductive condition</th></tr>
<tr><td rowspan="4">941000017452066</td><td>T022</td><td>19/07/16</td><td rowspan="4">M</td><td rowspan="4">900</td><td rowspan="4">38.5</td><td rowspan="4">19.5</td><td rowspan="4">73</td><td rowspan="4">Healthy weight, some missing fur, large testes</td></tr>
<tr><td>T020</td><td>20/07/16</td></tr>
<tr><td>T023</td><td>21/07/16</td></tr>
<tr><td>T021</td><td>23/07/16</td></tr>
<tr><td rowspan="3">941000017452034</td><td>T020</td><td>19/07/16</td><td rowspan="3">M</td><td rowspan="3">925</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">-</td><td rowspan="3">Healthy weight, large testes</td></tr>
<tr><td>T021</td><td>22/07/16</td></tr>
<tr><td>T021</td><td>23/07/16</td></tr>
<tr><td rowspan="4">941000017452035</td><td>T024</td><td>20/07/16</td><td rowspan="4">M</td><td rowspan="4">725</td><td rowspan="4">35.3</td><td rowspan="4">21</td><td rowspan="4">72</td><td rowspan="4">Small testes</td></tr>
<tr><td>T024</td><td>22/07/16</td></tr>
<tr><td>T024</td><td>23/07/16</td></tr>
<tr><td>T024</td><td>25/07/16</td></tr>
</table>

In addition to Northern Quolls, five species of mammal (two native and three introduced species) were caught during the survey: Short-beaked Echidna (*Tachyglossus aculeatus*), Little Red Kaluta (*Dasykaluta rosamondae)*, Black Rat (*Rattus rattus*), Feral Cat (*Felis catus*) and House Mouse (*Mus musculus*) (**Table 4**).

Table 4: Trapping bycatch data

Common Name	Species Name	Trap Point	Date
Black Rat	*Rattus rattus*	T038	19/07/16
Black Rat	*Rattus rattus*	T006	21/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T068	21/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T049	21/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T044	21/07/16
Feral Cat	*Felis catus*	T012	23/07/16
Black Rat	*Rattus rattus*	T006	23/07/16
Echidna	*Tachyglossus aculeatus*	T062	23/07/16
Black Rat	*Rattus rattus*	T055	23/07/16
House Mouse	*Mus musculus*	T035	23/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T049	23/07/16
Black Rat	*Rattus rattus*	T040	24/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T066	24/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T054	24/07/16
House Mouse	*Mus musculus*	T035	25/07/16
Black Rat	*Rattus rattus*	T040	25/07/16
House Mouse	*Mus musculus*	T068	25/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T069	25/07/16
House Mouse	*Mus musculus*	T067	26/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T069	26/07/16
Little Red Kaluta	*Dasykaluta rosamondae*	T043	26/07/16



CITIC PACIFIC MINING
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Cape Preston Northern Quoll Targeted Survey

Figure 4

Records of Northern Quoll

0 60 120
Meters
1:3,000

Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Final

Drawn by	Requested by	Internal Reference
DS	MC, Strategen	4465_00_2017_APP

Legend

- Captured Quoll
- Recaptured Quoll
- Trap Location
- Conceptual Footprint

3.2 ADDITIONAL CONSERVATION SIGNIFICANT FAUNA RECORDS

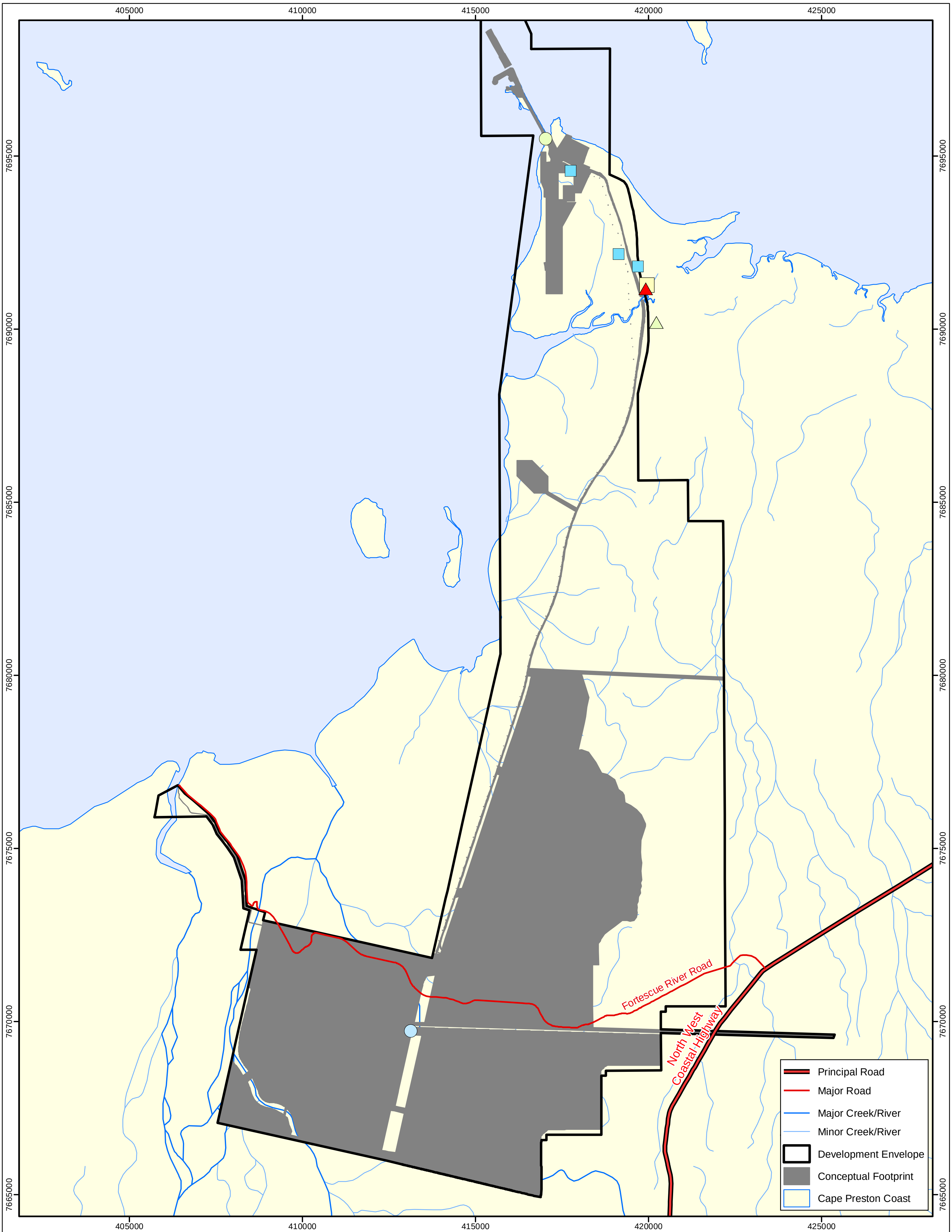
In addition to Northern Quolls, six species of conservation significance, the Grey Falcon (*Falco hypoleucos,* WC Act S3 Vulnerable), the Western Pebble Mound Mouse (*Pseudomys chapmani*, DPaW P4), Little Curlew (*Numenius minutus*), Whimbrel (*Numenius phaeopus*), Osprey (*Pandion haliaetus*) and Common Greenshank (*Tringa nebularia*) which are listed under the EPBC Act as Migratory, and as S5 under the WC Act were also recorded during the survey from outside the proposed footprint. Details of these recordings are listed in **Table 5** and displayed in **Map 5.**

Table 5: Additional conservation significant records

Species	Coordinates		Date	Record
	Eastings	Northings		
Grey Falcon	413124	7669725	22/07/16	3 individuals
Pebble Mound Mouse	419141	7692166	24/07/16	Inactive mound
	417746	7694563	21/07/16	Inactive mound
	419692	7691805	22/07/16	Inactive Mound
Little Curlew	420220	7690200	24/07/16	7 individuals
Whimbrel	419956	7691274	24/07/16	17 individuals
Osprey	417027	7695492	24/07/16	2 individual
Common Greenshank	419919	7691171	24/07/16	2 individuals

Plate 1: Inactive Pebble Mound Mouse mound recorded

Plate 2: Grey Falcon recorded during survey



CITIC PACIFIC MINING 中信泰富矿业

Cape Preston Northern Quoll Targeted Survey

Figure 5

Other Conservation Significant Fauna Recorded

Department:	ENV	Date:	2/02/2017
Sheet Size:	A4	Status:	Final
Drawn by DS	Requested by MC, Strategen	Internal Reference 4473_00_2017_APP	

4 DISCUSSION

4.1 NORTHERN QUOLL POPULATIONS AT CAPE PRESTON

Based on the results of the targeted trapping survey, the Northern Quoll population appears to only utilise the port area, including the breakwater, north of the current proposed Stage 3 footprint. The core denning habitat appears to be confined to the constructed breakwater, the design of which appears to have formed a refuge rich artificial habitat analogous with boulder piles that typically form important natural habitat. Habitat attributes that are considered important for Northern Quoll, such as shelter, high humidity, and abundance of food resources (black rats, house mice, crabs etc.) occur in the constructed breakwater and are a likely driving factor for why Northern Quolls utilise this area.

Records of Northern Quoll made during the reconnaissance survey and sightings made by site staff (Ecoscape 2016), indicate that the northern section of the port area contains a small amount of habitat, both natural (water seep) and artificial (port infrastructure including workshops and other buildings) for the species which is likely to be utilised as foraging ground due to its proximity to the breakwater. This area also contains small piles of remnant boulder material not utilised during construction of the Breakwater, however to date no Northern Quolls have been recorded there.

The ongoing presence of Northern Quoll in the Port area since 2010 has been shown through the several reports of sightings by site personnel (Ecoscape 2016). The presence of three Northern Quoll individuals indicates that a Northern Quoll population persists at the Sino Iron Project at Cape Preston, however the lack of females may indicate that the population is not stable at present.

It is hypothesised that either resident female quolls are present within the Port area and were not trapped during the targeted trapping survey, or a resident population is present in the region surrounding the Sino Iron Project and male Northern Quolls are travelling to the Port area during their dispersal period since males are known to exhibit extensive roaming behaviour (Oakwood 2000; Oakwood 2002). Although the nearest Northern Quoll populations recorded are over 40 km of the Port area; from both the Fortescue River adjacent to the Fortescue River Roadhouse and also along a small range to the east (15 km south east of Karratha) (DPaW 2016), large creeklines extend from the rocky hills down to the coast and may provide dispersal routes for young quolls.

The mine area section of the Stage 3 extension project is not considered to contain a Northern Quoll population nor critical habitat as the area is not considered to be refuge rich (Ecoscape 2016).

5 CONCLUSION

- A reconnaissance survey conforming to the current Northern Quoll referral guidelines was completed covering the stage 3 extension area of the Citic Pacific Mining Management Sino Iron Project at Cape Preston (Ecoscape 2016).
- A follow up survey was conducted to collect more detailed data about the present Northern Quoll population on site.
- A total of 80 cage traps and large Elliott box traps were established across seven areas of suitable and critical habitat and left in place for seven consecutive nights.
- Three male Northern Quolls were trapped along the breakwater adjacent to the current study area (Stage 3 extension area) and Northern Quolls were previously recorded at two additional cameras located at the water seep area of the Port facility.
- Based on the definitions outlined in the Northern Quoll referral guidelines (DotE 2016), the port area was assessed to contain a high density populations in refuge rich habitat (man-made) located adjacent to the study area (Ecoscape 2016), however no females have been recorded on site despite a relatively intensive trapping effort in this area.
- It is hypothesised that females are either residing in the port area and were not trapped or are in the region outside of the Sino Iron Project and that males are dispersing to the Port area of the project.
- The implications of the Northern Quoll utilising and colonising artificial habitat and disturbed areas, is not well understood. This artificial habitat is outside the current Stage 3 extension footprint.

REFERENCES

Department of Environment. 2016. EPBC Act referral guideline for the endangered northern quoll *Dasyurus hallucatus.* EPBC Act Policy Statement.

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APPENDIX ONE HABITAT CATEGORIES

Ecoscape's interpretation of habitat categories and suitability based on Northern Quoll referral guidelines and Trudgen scale (DSEWPaC 2011; Trudgen 1991).

Table 6: Northern Quoll habitat classifications

Habitat Type	Description	Suitability/Condition	Suitability Criteria
Denning habitat	Rocky ridges, granite outcrop, rocky gorge, boulder pile, rocky springs and seeps, breakaway. Water is often present.	Good	Large extent of rocky habitats (breakaway, gorge or boulder pile) with lots of hiding spots, such as crevices, caves and hollows in proximity to water sources and suitable foraging areas. Vegetation is excellent and feral predators absent. No evidence of recent fires.
		Moderate	Small mesa, granite outcrop or boulder with some caves and crevices, and limited connectivity to foraging and dispersal habitats. Water may be present. Some impacts by grazing or presence of feral predators. Fire history >5 years.
		Low	Isolated patch of habitat with limited extent, some crevices and caves present. No connectivity to dispersal or foraging habitat. Water may be present. Impacts by feral predators (cats, dogs) and possibly grazing evident. Fire history >3 years.
Dispersal habitat	Major creeklines and rivers, low lying linear rocky habitats (boulders).	Good	Major river with fringing mature eucalypt trees and intact understorey (lower vegetation) to provide cover and hiding spots. Lots of hollow trees and/or fringing rocky habitats. Water may be present. Good connectivity to denning habitats. No evidence of recent fires.
		Moderate	Drainage line with eucalypt trees and some understorey or other hiding spots. Water may be present. Some connectivity to denning habitat exists. Fire history >5 years.
		Low	Minor creekline with some eucalypts with very low number of tree hollows and cover, rocky habitats absent. Evidence of grazing and/or presence of feral predators. Fire history >3 years.
Foraging habitat	Rivers and creeklines, some rocky habitats such as smaller granite boulders or low lying boulder piles, water may be present.	Good	Low lying boulder piles, creeklines with structured vegetation or seep/spring which provide good conditions for prey (smaller fauna and fruits). No evidence of recent fires.
		Moderate	Low lying rocky boulders or creeklines with fringing eucalypt trees and some understorey to provide suitable conditions for food resources, some water and shelter may be present. Connectivity to some close by denning habitat present. Fire history >5 years.
		Low	Isolated drainage lines and small rocky areas such as boulder piles. Vegetation is grazed and/or evidence of feral predators is present. Fire history >3 years.

APPENDIX TWO LOCATION OF TRAP POINTS

Table 7: Locations of trapping points

Trapping Point	Coordinates		Date set-up	Date collection
Breakwater				
T001	417043	7695600	18/07/16	25/07/16
T002	416993	7695691	18/07/16	25/07/16
T003	416946	7695776	18/07/16	25/07/16
T004	416896	7695868	18/07/16	25/07/16
T005	416845	7695959	18/07/16	25/07/16
T006	416796	7696047	18/07/16	25/07/16
T007	416749	7696133	18/07/16	25/07/16
T008	416699	7696222	18/07/16	25/07/16
T009	416657	7696296	18/07/16	25/07/16
T010	416603	7696394	18/07/16	25/07/16
T011	416554	7696482	18/07/16	25/07/16
T012	416505	7696571	18/07/16	25/07/16
T013	416458	7696653	18/07/16	25/07/16
T014	416404	7696751	18/07/16	25/07/16
T015	416363	7696844	18/07/16	25/07/16
T016	416322	7696938	18/07/16	25/07/16
T017	416276	7697027	18/07/16	25/07/16
T018	416232	7697115	18/07/16	25/07/16
T019	416186	7697202	18/07/16	25/07/16
T020	416146	7697282	18/07/16	25/07/16
T021	416095	7697380	18/07/16	25/07/16
T022	416038	7697477	18/07/16	25/07/16
T023	416119	7697169	18/07/16	25/07/16
T024	416178	7697061	18/07/16	25/07/16
T025	416396	7696429	18/07/16	25/07/16
T026	416482	7696373	18/07/16	25/07/16
T027	416578	7696322	18/07/16	25/07/16
T028	416642	7696231	18/07/16	25/07/16
T029	416688	7696146	18/07/16	25/07/16
T030	416740	7696052	18/07/16	25/07/16
T031	416791	7695956	18/07/16	25/07/16
T032	416847	7695850	18/07/16	25/07/16
T033	416905	7695750	18/07/16	25/07/16
The Point				
T034	417431	7695843	18/07/16	25/07/16
T035	417425	7695916	18/07/16	25/07/16
T036	417428	7696012	18/07/16	25/07/16
T037	417397	7696069	18/07/16	25/07/16
T038	417335	7696029	18/07/16	25/07/16
T039	417283	7695989	18/07/16	25/07/16
T040	417231	7695904	18/07/16	25/07/16

Trapping	Coordinates		Date set-up	Date collection
Southern Hills				
T041	419322	7691045	19/07/16	26/07/16
T042	419323	7691140	19/07/16	26/07/16
T043	419357	7691240	19/07/16	26/07/16
T044	419383	7691340	19/07/16	26/07/16
T045	419525	7691446	19/07/16	26/07/16
T046	419652	7691646	19/07/16	26/07/16
T047	419713	7691728	19/07/16	26/07/16
T048	419725	7691778	19/07/16	26/07/16
T049	419671	7691817	19/07/16	26/07/16
T050	419597	7691807	19/07/16	26/07/16
Water Seep				
T051	417797	7694254	19/07/16	26/07/16
T052	417766	7694250	19/07/16	26/07/16
T053	417777	7694348	19/07/16	26/07/16
T054	417745	7694449	19/07/16	26/07/16
T055	417750	7694544	19/07/16	26/07/16
Stockpile				
T056	417018	7694790	19/07/16	26/07/16
T057	417020	7694766	19/07/16	26/07/16
T058	417029	7694720	19/07/16	26/07/16
T059	417026	7694701	19/07/16	26/07/16
T060	417004	7694516	19/07/16	26/07/16
T061	417003	7694411	19/07/16	26/07/16
T062	417004	7694317	19/07/16	26/07/16
T063	417013	7694206	19/07/16	26/07/16
T064	417034	7694068	19/07/16	26/07/16
Rocky Hill				
T065	417040	7693969	19/07/16	26/07/16
T066	418719	7694162	19/07/16	26/07/16
T067	418651	7694133	19/07/16	26/07/16
T068	418602	7694122	19/07/16	26/07/16
T069	418566	7694103	19/07/16	26/07/16
T070	418551	7694137	19/07/16	26/07/16
T071	418577	7694179	19/07/16	26/07/16
T072	418600	7694252	19/07/16	26/07/16
T073	418548	7694321	19/07/16	26/07/16
T074	418607	7694351	19/07/16	26/07/16
Quarried Wall				
T075	418642	7694357	19/07/16	26/07/16
T076	418099	7694843	19/07/16	26/07/16
T077	418043	7694787	19/07/16	26/07/16
T078	417969	7694799	19/07/16	26/07/16
T079	417875	7694842	19/07/16	26/07/16
T080	417858	7694907	19/07/16	26/07/16

Datum: WGS84, Zone: 50K

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INDEPENDENT REVIEW STATEMENT

ATTENTION:	Anthony Knapton, Principal Groundwater Moeller, CloudGMS Pty Ltd	
CC:	Jillian Baroni, Senior Hydrogeologist, Citic Pacific Mining Management Pty Ltd	
FROM:	Hugh Middlemis, Principal Groundwater Engineer, Hydrogeologic Pty Ltd	
REFERENCES:	30 January 2017	Project ref: Sino Iron Expansion Groundwater Modelling Study
	HGL job#: 61.048	HGL doc#: Middlemis_2016_Sino_review
SUBJECT:	Independent review of groundwater model for Sino Iron Expansion project	

This memo summarises the outcomes of an independent review of the groundwater modelling studies relating to the Sino Iron Expansion project being developed by Citic Pacific Mining (CPM) near Cape Preston, about 80 km south-west of Karratha in the Pilbara region of Western Australia.

The model review was conducted in accordance with the best practice principles of the Australian Groundwater Modelling Guideline (Barnett et al., 2012). The 2012 guideline suggests a compliance checklist to summarise review outcomes, presented herein as Table 1 (see next page).

The main evidentiary basis for the review was the Groundwater Modelling Study report (CloudGMS, 2017), and the review process involved the following:

- the model design report was reviewed over the first week of November 2016 and informal meetings and telephone discussions were held with Mr Anthony Knapton (CloudGMS) to discuss technical details
- the FEFLOW numerical model data files were inspected at the CloudGMS office on 16 January 2017; this involved a spot-check type review directed by Mr Middlemis and with software manipulation by Mr Knapton; this session had a focus on post-mining pit void runs (i.e. not all model files were reviewed), but also allowed review of a simulation in progress (iterations and water balances).
- the draft final modelling report was reviewed over the last week of January 2017, and minor documentation issues were discussed with Mr Knapton (and addressed in the final report, version 0.2).

It is my professional opinion that the hydrogeological modelling study has been undertaken consistent with best practice, including careful model design that allows for future aquifer system changes. The model is well designed and executed, achieving a model confidence level classification of Class 2 (with elements of Class 3), meaning it is fit for mining project impact prediction purposes. More importantly, the modelling study is commended for the detailed analysis and quantification of predictive uncertainty (uncommonly good practice in this case). This review endorses the recommendations that further aquifer investigations are required into the area west of the West Pit to provide data for modelling in order to reduce remaining uncertainties relating to hydraulic connections between pit and the superficial aquifer for life of mine and post-mining conditions.

Yours sincerely, Hydrogeologic Pty Ltd

Hugh Middlemis (Principal Groundwater Engineer)

Declaration

For the record, the reviewer (Hugh Middlemis) is an engineer, hydrogeologist and independent modelling specialist with more than 35 years' experience. Hugh is principal author of the MDBA groundwater modelling guidelines (Middlemis et al, 2001) and was awarded a Churchill Fellowship in 2004 to benchmark groundwater modelling against international best practice. We note that Hugh Middlemis has not undertaken any work at Sino, and there is no conflict of interest in relation to this review task.

Table 1 - Groundwater Model Compliance Checklist: 10-point essential summary

Question	Y/N	Comments re Sino Iron project groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Mining impact assessment context in semi-arid area with river pools and GDEs. Class 2 model confidence level target. Review finds some elements of Class 3 achieved (conceptualisation; layer structure & spatial parameterisation; stream-aquifer features; ET-LAI function).
2. Are the objectives satisfied?	Yes	Highly competent model design, calibration & predictions for life of mine & cumulative impacts. Clear results presented on key environmental, mining & closure issues.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Conceptualisation is sound, consistent with available information and previous studies, appropriate for project/study context.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	Model report relies on previous investigations and addresses previous review comments from DoW. This review did not identify any lack of rigour in the investigation or material flaws in the modelling.
5. Does the model design conform to best practice?	Yes	The model software, design, extent, grid, boundaries, parameters and integrated quantitative uncertainty assessment form an excellent example of best practice in design and execution.
6. Is the model calibration satisfactory?	Yes	PEST parameter optimisation applied in 2-stage calibration (focus on alluvial plains and mine area). Adequate statistical calibration performance (10m RMS in context of 100m pit dewatering drawdown). Very good time series matches for almost all the >180 bores. Matches to VWP data not universally good, but the VWP data appears questionable and should be QA-ed (e.g. hydrostatic profiling as a minimum). Comprehensive PEST sensitivity evaluation.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Appropriate level of complexity in parameter values and spatial distributions (effective implementation of conceptual model and use of data available). Some confined specific storage (Ss) values could be somewhat high at 10^{-4} m^{-1} for upper layers in pit area. Calibration period includes substantial hydrological variability and model fluxes are consistent with independent water balance estimates of recharge/throughflow and sump pump volumes, which reduces potential for model non-uniqueness problems.
8. Do the model predictions conform to best practice?	Yes	Prediction scenarios of (40-year) life of mine effects and subsequent long term (100-year) effects of post-mining, consistent with best practice. Comprehensive reporting of drawdown, water balance and water quality impacts on key receptors. Independent analytical estimates of post-mining water balance.
9. Is the uncertainty associated with the predictions reported?	Yes	Study is to be commended for the detailed analysis and quantification of predictive uncertainty for life of mine scenarios (uncommonly good practice in this case). This review endorses the recommendations that further aquifer investigations are required into the area west of the West Pit to provide data to further constrain model calibration and thus reduce remaining uncertainties relating to hydraulic connections between the pit and the superficial aquifer. It should then be feasible to extend the uncertainty analysis to further assess post-mining closure conditions.
10. Is the model fit for purpose?	Yes	My professional opinion is that the model is a good example of best practice in design and execution, notably including comprehensive uncertainty analysis, and is fit for the mining project impact prediction purpose.

References

Barnett, B., Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra. URL: http://archive.nwc.gov.au/library/waterlines/82.

CloudGMS (2017). Sino Iron Expansion Proposal Groundwater Modelling Study version 0.2. Prepared for Citic Pacific Mining. January 2017.

Mattiske Consulting Pty Ltd

Memo

To: Mr M. Brooks (Strategen)

From: Dr E. Mattiske

Date: 7Th December 2016

Re: Review of Flora and Vegetation Reports for the Mineralogy project at Cape Preston

1. INTRODUCTION

The following review is based on the documents supplied by Mr M. Brooks from Strategen in November 2016 for the Mineralogy project at Cape Preston.

- Maunsell (2003), *Cape Preston Iron Ore Development. Seasonal Biological Survey – Threatened Flora.* Prepared for Austeel Pty Ltd, November 2003.
- Astron Environmental Services (2007), *General Purpose Leases G08/52 and G08/53 Additional Vegetation Survey and Mapping.* Prepared for CP Mining Management Pty Ltd, June 2007.
- Mattiske Consulting Pty Ltd (2007a), *Flora and Vegetation Survey of Cape Preston Potential Campsites and Airstrips*. Unpublished Report for CITIC Pacific Mining Management Pty Ltd, April 2007.
- Mattiske Consulting Pty Ltd (2007b), *Comparison of Flora and Vegetation Values on Preferred and Original Campsites Cape Preston.* Unpublished Report for CITIC Pacific Mining Management Pty Ltd, April 2007.
- Maunsell and AECOM (2008), *Cape Preston Mining Estate Consolidated Vegetation, Flora and Fauna Assessment.* Prepared for International Minerals, 25th September 2008.
- Astron Environmental Services (2008), *Sino Iron Project – Cape Preston. Mapping and Surveying of Groundwater Dependent Ecosystems.* Prepared for CITIC Pacific Mining Management Pty Ltd, September/*October 2008.*
- AECOM (2009), *Balmoral North and Balmoral South Stage 2. Flora and Vegetation Assessment*. Report prepared for Mineralogy, 18 June 2009.
- Astron Environmental Services (2009a), *Mineralogy Expansion Proposal Desktop Flora and Vegetation Study.* Prepared for Mineralogy Pty Ltd, June 2009.
- Astron Environmental Services (2009b), *Waste Rock Dump and Tailings Expansion Areas Vegetation, Flora and Fauna Survey.* Prepared for CITIC Pacific Mining Management Pty Ltd, May 2009.

2. REVIEW

The variety of work covers detailed Level 1 studies, targeted work on species, targeted work on communities, targeted work on groundwater dependent ecosystems and Level 2 studies for some areas on the Cape Preston area. The effort is variable due to the different types of work and also different coverage in the Cape Preston area (see Table 1).

The methodologies have been relatively consistent and most authors have tried to align mapping with previous investigations (Table 2). Several of the reports are more comprehensive and the merged interpretation in the more recent documents provides a comprehensive summary; and in particular the Maunsell (2008), Astron 2009 AECOM (2009) reports appear to address many of the issues and provide the most comprehensive summaries on the wider project areas.

Despite some variations in scope and coverage by the different specialists it is apparent that a substantial amount of flora and vegetation studies have been undertaken over a range of seasons (both following the rainfall cyclonic months and the drier months). The specialists involved with the work have had many years of experience in botanical and ecological studies in the Pilbara and therefore this has not been a limitation on the efforts at various times in this project area. The unreliability of seasonal rains in the Pilbara region is an ongoing issue. In this instance any concerns related to the timing are minimized by a few favorable rainfall events prior to several of the assessments (Maunsell 2008; Astron 2009b) and through the experience level of the specialists undertaking the studies at Cape Preston. The data collection for the flora and vegetation studies was based mainly on the accepted standard of 50m x 50m quadrats. The consistency in interpretation also extended to the data analyses for the more extensive studies in the project area and used either PATN or PRIMER with underlying similarities in some of the analytical techniques.

Although not all areas were assessed in multiple seasons, the broad nature of the plant communities and consistency in mapping approaches enabled the correlation and interpretation of data between survey areas. The consistency of mapping units was used by the different specialists and consequently this improved the alignment of mapping units.

There is a need to update the information on the flora lists as there have been some taxonomic changes to recorded species, some changes to the conservation status of the flora species and some changes to the weed species in the Pilbara. The summary supplied in Table 3 illustrates the type of review and amendments that should be undertaken through cross-checking against data on flora with the current Department of Parks and Wildlife Florabase. Such changes may lead to a few minor changes in the interpretation of the impacts of the proposed operations on these values. To assist in these matters the threatened and priority species extracted from the respective reports is summarized below in Table 3. Based on the extent of the surveys, the multiple seasons in which surveys were conducted and the highly experienced personnel conducting the surveys it is unlikely that any additional species of Threatened or Priority Flora would be recorded by additional survey.

AECOM (2009) noted two declared plant species (introduced species) that occur in the project area (see Table 7 in AECOM 2009), namely the **Prosopis pallida* (Mesquite) and **Datura leichhardtii* (Native Thornapple). In addition a range of environmental weed species were highlighted in AECOM 2009. In Astron 2008 **Prosopis glandulosa x velutina* (Mesquite) was also highlighted. Hence the apparent need to rationalize the information on the declared and other weed species in the impact assessment.

There have been several references to the potential Priority and Threatened Ecological Communities (PEC/TEC) in the Cape Preston area. Whilst these were suggested in several of the reviewed documents there appears to be little justification that these values exist in the Cape Preston area (see AECOM 2009 – section 5.3). The interpretation of the latter was based on Kendrick & McKenzie (2001) and Kendrick and Stanley (2001) and information supplied by J Pryde in 2009. Consequently, the grassland communities that have been previously mapped in the Cape Preston Mining Precinct are no longer considered to be equivalent to the Priority 1 Ecological Community "Roebourne Plains Gilgai Grassland). Astron 2008, Astron 2009 and AECOM 2009 address other communities of conservation significance. The justification for highlighting some vegetation mapping units and associated plant communities requires some attention and should include the localized wetlands, the cracking clay communities and some of the areas that are either restricted in the regional context or that have the potential to support particular flora or fauna species that are of conservation significance. Examples of other communities with potential conservation significance include the spring, some of the gullies and some rockpiles (see Astron 2008 and Astron 2009b). Astron 2008, highlighted a range of groundwater dependent ecosystems on the Fortescue and Du Boulay Rivers and associated with the River and Yamerina land systems. Hence there is a need to collate and integrate the other significant communities in the impact report.

There has been some variation in the uses of Trudgen (see Table 8, Astron 2009b) and Keighery (see Table 3, AECOM 2009) condition scales. Whilst there are differences in the condition scales, these do not justify further investigations on the assessment of the condition ratings.

In relation to the need to meet the requirements of the Environment Protection Authority Guidance Statement 51 (Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia) and Position Statement 3 (Terrestrial Biological Surveys as an Element of Biodiversity Protection) currently a substantial amount of work has been undertaken on the various lease areas and the reports by Astron 2009 and AECOM in 2009 which built on the earlier Maunsell (2003 and 2008) studies in particular bring the majority of the work to date in summaries. As such the suggested refinements in relation to the flora species will improve the clarity and currency of information for the impact assessment. To date the survey effort fulfils the Level 1 needs and in view of the depth of experience of the specialists, the extent of the coverage and with some desktop integration and alignment of the known values on the flora and vegetation into the impact assessment report the coverage should then be accepted as addressing the Level 2 needs of the EPA process for the Cape Preston area.

Dr E M Mattiske

Table 1: Summary of Current Coverage of the Different Key Components associated with Flora and Vegetation Assessments

Report	Flora	T & P Flora	Weeds	Range Extensions	Vegetation	PEC and TEC Values	Vegetation Condition	Other Potentially Significant Communities	Representation of Vegetation Mapping units
Maunsell 2003	No	Yes	No	No	No	No	No	No	No
Astron Environmental Services 2007	No	No	No	No	Yes	Yes	No	No	No
Mattiske Consulting Pty Ltd 2007a and 2007b	Yes	Yes	Yes	No	Yes	No	No	No	No
Maunsell/AECOM 2008 (including integration of 2000 to 2006 studies)	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Astron Environmental Services (2008)	Yes	Yes (although none located)	Yes	No	Yes (although concentrate on GDEs)	Yes	Yes	No	Yes
AECOM 2009	Yes	Yes (although none located)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Astron Environmental Services (2009a)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Astron Environmental Services (2009b)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

Table 2: Summary of Methodologies and Timing associated with Flora and Vegetation Assessments

Report/Date	Methodology – Flora and vegetation	Timing	Comments	Limitations
Maunsell 2003	Foot traverses targeting threatened and priority species	June 2003 and July 2003	Recent rains enabled better coverage of flora in July 2003 trip. Cracking clays, creeklines, minor flowlines and rockpiles and rocky outcrops were targeted after desktop studies on potential species	Seasonal conditions led to some limitations in assessment of flora. Also some areas supported degraded vegetation. In part overcome by July assessment in targeted areas.
Astron Environmental Services 2007	50m x 50m quadrats and aerial photograph interpretation.	June 2007	Drier site conditions, used previous HGM et al. (2005) mapping codes and Van Vreeswyk et al. (2004) land system codes.	Some limitations on flora coverage due to drier seasonal rainfall conditions prior to the June 2007 assessment.
Mattiske (2007a and 2007b)	Foot traverses and quadrats and aerial photograph interpretation.	February 2007	Drier site conditions and a reliance on previous studies by Maunsell (2003).	Some limitations due to seasonal conditions. Coverage of localized areas only (as requested).
Maunsell and AECOM 2008	155 quadrats. 50m x 50m quadrats and aerial photograph interpretation. Integration with previous studies. Creekline vegetation in 2m wide transects due to linear nature. Targeted work also on cracking clay areas.	2000 and 2006	Desktop and expansion and consolidation of earlier 2000 to 2006 studies. PATN analysis of 2006 datasets. Lack of clarity on timing of flora and vegetation work in 2000, 2006 and 2007. Analyses appear to have concentrated on 2000 and 2006 data.	Potential seasonal limitations. Positives related to the integration of previous studies in the period 2000 to 2006.
Astron Environmental Services 2008	GDE assessment, targeted work along major and minor creeklines. 27 releves (200 to 500m long as along creeklines and watercourses) and aerial photograph interpretation.	August and September 2008	Desktop on T & P flora species, weeds and GDE communities, targeted GDE work and some integration with previous 2000 to 2006 studies. Condition of vegetation based on Keighery (1994). Some alignment of vegetation mapping unit with previous studies 2000 to 2008 by Maunsell 2001, Maunsell/AECOM 2006 and Astron 2008)	Limitations due to drier seasonal conditions prior to assessment.
AECOM 2009	53 quadrats. 50m x 50m quadrats and aerial photograph interpretation. In creekline areas 10m x 50m quadrats. Foot traverses also to target additional species.	August and September 2008	Desktop, reconnaissance and detailed field survey. Flora and vegetation on Balmoral North and South. Some re-assessment of selected 2000 and 2006 quadrats. Condition assessment based on Keighery 1994 and the Braun-Blanquet Scale of Cover Abundance (from Mueller-Dombois and Ellenberg 1974). Detailed wide review of flora and vegetation values beyond the T&P and TEC and PEC.	Limitations due to timing of assessments in drier months.
Astron Environmental Services 2009a	Extrapolation from previous studies and aerial photograph interpretation, results tentative due to lack of field studies.		Report was based on desktop review and also extrapolation and therefore findings tentative in view of lack of field studies.	Some limitations associated with no field studies and difficulty of covering flora and vegetation values without ground-truthing.
Astron Environmental Services 2009b	5 quadrats in each vegetation type. 50m x 50m quadrats. Foot traverses also to target additional species and aerial photograph interpretation.	May 2009	Shift to Clarke and Green (1988) with Bray-Curtis Similarity Index. Ordination analysis (MDS) also used to examine relationships using Primer 6.1.5 (Clarke and Gorley 2006). This report highlighted a small permanent wetland in a local area (Roc7).	Some limitations associated with seasonal conditions; although good rains in January and early February 2009 the months leading up to the assessment in May 2009 were drier.

Table 3: Summary of Results presented on Potential and Recorded Threatened and Priority Flora Species during Flora and Vegetation Assessments

Threatened and Priority Flora	Maunsell 2003	Background	Comments – Based on Data and Florabase (DPaW 2016)
Abutilon uncinatum P1	See potential in Appendix D in Astron Environmental Services (2008)	Recorded at 21^39'17.0";115^43'33.0"	Now known as Abutilon sp. Onslow (F.Smith s.n. 10/9/61) based on Florabase (DPaW 2016)
Goodenia omearana ms P1	Only recorded once in tussock grassland on clay soils (M027) – Maunsell (2003). Noted in Mattiske (2007a) as a potential Priority 1 and in AECOM (2009a and 2009b) that it had been recorded in the 2000 assessment.	Typically on calcareous soils and known from a few locations in eastern Pilbara near Weeli Wolli Springs and Marillana Creek areas	In Maunsell/AECOM 2008 and Mattiske 2007 some queries over the taxonomy of this species; this is now synonymous with *Goodenia* sp. East Pilbara (A.A. Mitchell PRP727) (Florabase, DPaW 2016). Also suggested as potential priority species in AECOM 2009 (using name change as above). In AECOM (2009) noted that this was recorded in 2000.
Goodenia pallida P1	See potential in Mattiske (2007a), and in Appendix D in Astron Environmental Services (2008) and Astron Environmental Services (2009b).	Recorded at 21^01'55.0";116^15'26.0"	Remains as P1, near Karratha on Florabase (DPaW 2016). Also *Goodenia pallida* raised in the audit table (Mattiske 2007).
Gunniopsis sp. Fortescue (M.E. Trudgen 11019) P1	Potential suggested in Mattiske (2007a) and AECOM 2009 report.	Is an error and should not be used (Florabase, DPaW 2016).	Name should not be used according to Florabase (DPaW 2016). AECOM (2009) included this taxon as likely to occur.
Ischaemum albovillosum P2	Potential suggested as a Priority 2 species in Mattiske (2007a)	Occurs in central and eastern Pilbara and Ashburton.	Not currently a Priority species, based on Florabase (DPaW 2016).
Mukia sp. Barrow Island (DW Goodall 1264) P2	Potential P2 species in Astron Environmental Services (2008)	Recorded from Barrow Island.	Not recorded on assessment areas. Now known as *Cucumis s*p. Barrow Island (DW Goodall 1264), based on Florabase (DPaW 2016).
Abutilon trudgenii ms P3	Low shrub recorded from six locations within survey area. Recorded in minor flowlines through stony hills of the Rocklea or Newman land systems (Maunsell 2003). In Mattiske 2007a, noted as a potential Priority 2 species.	Possibly poorly known rather than rare as recorded from Warralong, Woodstock, Point Samson and Pannowonica (Atkins 1999).	Now known as *Abutilon* sp. Pilbara (W.R. Barker 2025) based on Florabase (DPaW 2016)
Acacia glaucocaesia P3	Potential P3 species in Mattiske (2007a), Astron Environmental Services (2008) and AECOM (2009) and Astron Environmental Services (2009b).	Recorded previously near Karratha, Port Hedland, Mardie, Roebourne and De Grey.	Not recorded on assessment areas, remains as a P3 on Florabase (DPaW 2016). AECOM (2009) included this taxon as likely to occur.
Eriachne tenuiculmis P3	Clumps of this grass species were recorded in 2 locations within creekline habitat in the Paraburdoo Land System (Maunsell 2003 and Mattiske 2007a).	Possibly poorly known rather than rare as recorded from Serpentine Creek, Yandi and Millstream in larger creeklines and on the Burrup Peninsula (Trudgen and Casson 1998).	No longer listed as a Priority species on Florabase (DPaW 2016).

Table 3: Summary of Results presented on Potential and Recorded Threatened and Priority Flora Species during Flora and Vegetation Assessments (continued)

Threatened and Priority Flora	Maunsell 2003	Background	Comments – Based on Data and Florabase (DPaW 2016)
Gymnanthera cunninghamii P3	Potential P3 species in Astron Environmental Services (2009b)	Recorded in Ashburton, Broome, Carnarvon, East Pilbara, Karratha and Port Hedland areas (Florabase, DPaW 2016).	Not recorded, listed as potential species by Astron Environmental Services (2009b).
Goodenia nuda P3	Potential P3 species in in Astron Environmental Services (2008), AECOM (2009) and Astron Environmental Services (2009b).	Habitat, Plains, dry red sands, in Mesquite Scrub.	AECOM (2009) included this taxon as "may occur".
Goodenia pascua P3	Potential P3 species in in Astron Environmental Services (2008), (2009a).	Recorded previously on Hamersley Station, Sandy Creek, Port Hedland, Onslow, Mardie, Roebourne and Little Sandy Desert.	Not recorded on assessment areas. No longer listed as a Priority species on Florabase (DPaW 2016).
Hibiscus brachysiphonius P3	Low spreading herb occurred as scattered individuals on clay soils of clayey or stony plains at 5 locations (Maunsell 2003). Noted as potential in Mattiske (2007a). Most sites within Horseflats or Paraburdoo land systems and 1 collection from the Boolgeeda land system.	This species appears restricted to cracking clays and has been recorded previously near Minilya River, Tom Price, Karratha, Millstream, Balga Mission, Christmas Creek, Wandagee, Warrawagine and Hamersley Range.	Delisted in November 2008. Only recorded in Maunsell in 2003.
Owenia acidula P3	Potential P3 species in in Astron Environmental Services (2008) and AECOM (2009).	Recorded previously on Mardie Station, Millstream, Collier Range, Winning Station, Minilya Station, Boolathana Station, Qld and NSW	Not recorded on assessment areas. Still listed as a Priority 3 species and near coastal species on Florabase (DPaW 2016). AECOM (2009) included this taxon as "may occur".
Phyllanthus aridus P3	Small perennial shrub recorded a 1 location within creekline habitat of Paraburdoo land system (Maunsell 2003). Noted as potential in Mattiske (2007a), noted previous record in 2000 studies (AECOM 2009a, 2009b).	This species is known from several Kimberley populations; but has also been recorded from 12 populations on the southern slopes of the Chichester Ranges and at the time was described as uncommon along creeks in the area (Trudgen and Casson 1998).	Only known from Kimberley region and no longer listed as a Priority species on Florabase (DPaW 2016). In AECOM (2009) noted that this was recorded in 2000.
Rhynchosia bungarensis P3	Potential P3 species in in Astron Environmental Services (2008) and Astron Environmental Services (2009a, 2009b).	Recorded previously on Hamersley Ranges, Chichester Ranges, Yardie Creek, Robe River, Tom Price, Ashburton, East Lewis Island, Burrup Peninsula, Dampier Archipelago	Not recorded on assessment areas. Now a Priority 4 species on Florabase (DPaW 2016).

Table 3: Summary of Results presented on Potential and Recorded Threatened and Priority Flora Species during Flora and Vegetation Assessments (continued)

Threatened and Priority Flora	Maunsell 2003	Background	Comments – Based on Data and Florabase (DPaW 2016)
Sida sp. Wittenoom (W.R. Barker 1962) P3	Perennial shrub was recorded from 1 location within a creek line (Maunsell 2003), noted as potential in Mattiske (2007a).	This species known from several locations including Warralong Station, Nickol Bay, near Onslow, Roy Hill and east of Pannawonica and Fortescue Roadhouse (Atkins 1999).	Now known as *Sida arsiniata*, no longer a Priority species, Florabase (DPaW 2016).
Stackhousia clementii P3	Potential P3 species in Astron Environmental Services (2009b)	Recorded previously in Ashburton, Carnarvon, Karratha, Murchison, Ngaanyatjarraku, Wiluna (Florabase, DPaW 2016).	Not recorded, listed as potential species by Astron Environmental Services (2009b).
Stylidium costulatum P3	Potential P3 species in Astron Environmental Services (2009b)	Recorded previously from Kimberley only (Florabase, DPaW 2016).	Should be excluded as not in Pilbara area.
Tephrosia sp. Cathedral Gorge P3	Noted as potential in Mattiske (2007a).	Occurs through southern and eastern Pilbara and northern section of Ashburton.	Now known as *Tephrosia oxalidea* based on Florabase (DPaW 2016).
Themeda sp. Hamersley station (MR Trudgen 11431) P3	Potential P3 species in Mattiske (2007a) and in Astron Environmental Services (2008)	Recorded previously from Karratha, Millstream, Hamersley Station, West Angelas, Coondewanna Flat	Not recorded on assessment areas. Remains a Priority 3 species on Florabase (DPaW 2016).
Terminalia supranitifolia P3	Potential P3 species in Astron Environmental Services (2009b)	Recorded previously from Ashburton, East Pilbara, Karratha and Port Hedland (Florabase, DPaW 2016).	Not recorded, listed as potential species by Astron Environmental Services (2009b).

EDWARDS CREEK DIVERSIONS AND SOUTHWEST WASTE DUMP

EDWARDS CREEK DIVERSIONS AND SOUTHWEST WASTE DUMP

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Revision a	23 November 2016	Draft for Comments
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APPENDICES

1. BACKGROUND

1.1 General

Citic Pacific Mining (CPM) is developing the Sino Iron Project at Cape Preston, 100km south west of Karratha in Western Australia's Pilbara region. The mine site is situated in the broad low gradient delta / floodplain at the lower reaches of the Fortescue River, about 9km from the river mouth (refer Figure 1-1, Figure 2 and Appendix A).

Edwards and DuBoulay Creeks drain ridges to the east and southeast of the project area, and flow in a north-westerly direction through the development area into the Fortescue River. The creeks typically have main flow channels with 5-10m wide gravel beds and trees along the banks. Floodplains adjacent to the creeks typically comprise open grassed areas with scattered trees.

Edwards Creek has three main branches with a total catchment of about 50km² where the creek enters the Fortescue floodplain - this comprises the southern branch (29km²); and the middle & northern branch (20km²).

The catchment area of DuBoulay Creek is about 200km².

Edwards Creek (southern branch) runs north west diagonally through mining tenement M08/63, from the south east edge of the mining tenement to the north west corner, where there is a set of large culverts under the North-South Road. The creek then enters mining tenement M08/123.

CPM proposes to place a TSF over Edwards Creek in G08/63, and waste rock dumps (WRD) in the remainder of G08/63. These infrastructures will cut-off Edwards Creek.

The objective of this study and report is a desktop assessment to facilitate regulatory approval.

1.2 Edwards Creek Diversion 1

Edwards Creek is to be permanently diverted in M08/123 to accommodate the proposed expansion of the existing North East WRD. Diversion 1 starts immediately after the North South Road culverts.

To accommodate the WRD, the south branch of Edwards Creek will be realigned along the eastern boundary of mining tenement M08/123. The alignment requires the construction of a 1.4km channel and will result in the south branch transferring to the Edwards Creek middle branch (refer Figure 3 and Figure 4).

1.3 Edwards Creek Diversion 2

To accommodate the construction of the TSF in mining tenement G08/63, the southern branch of Edwards Creek will be permanently diverted around the TSF. This diversion will be 7.0km long, starting at Edwards Creek on the southern G08/63 boundary, and then running to the west and then north along the G08/63 boundary to rejoin Edwards Creek (refer Figure 3 and Figure 5).

1.4 South West (M08/125) Waste Rock Dump

CPM also proposes to place a WRD in the south-west corner of mining tenement M08/125 (refer Figure 3 and Figure 6). The area is within the 100 year ARI (Average Recurrence Interval) floodplain of both the Fortescue River and DuBoulay Creek. The average recurrence interval is the average or expected number of years between exceedances of a given flooding extent. It is implicit that the number of years between exceedances is generally random. The Fortescue River main channel lies about 2km to the west of the proposed WRD.

2. DESIGN FLOWS

2.1 Flood Flow Estimates for Edwards and DuBoulay Creeks

Flood flows for Edwards Creek and DuBoulay Creek were estimated using various techniques, including RAFTS, RORB, RORB (calibrated) and RIFM:

- RAFTS is a linear rainfall / runoff program, using design rainfall data derived from ARR (Australian Rainfall and Run-off, 1987), or actual storm events;
- RORB is also a linear rainfall / runoff program, using design ARR rainfall data. RORB uses "Kc" values, derived from ARR values, which are required in the program as part of the non-linear flood routing procedure;
- RORB (calibrated) uses calibrated Kc values (limited data, but in this case based on a single rainfall run-off event at Newman);
- David Flavell developed the Regional Index Flood Frequency Method (RIFM) procedures for the Pilbara region. The RIFM requires a single catchment. Flavell derived two sets of flood procedure equations, and recommended the RFFP2000 "as it gives higher flood estimates for the ARIs commonly used for the design of drainage structures and includes a shape factor" i.e. because it is more conservative than the updated RFFP2006.

The methods provided similar results. The flow values are not critical, but RAFTS has been successfully able to duplicate flood frequency analyses of gauged river data, and the RAFTS values were adopted.

In particular, the Edwards Creek (south branch) 100, 20 and 10 year ARI flood estimation results were 97 / 41 / 25 m^3/s; and for DuBoulay Creek, 616 / 426 / 262 m^3/s. Ultimately, in large floods, some breakout will occur south west from Edwards Creek and the proposed Edwards Creek Diversion 2 across to DuBoulay Creek. Similarly well upstream of the mine site, some breakout will occur west and south west from DuBoulay Creek across to the Fortescue River floodplain.

2.2 Flood Flow Estimates – Other Locations

Using these flood results for the Edwards and DuBoulay Creek catchments, the flows at other locations can be estimated. The relevant catchment areas at the required locations were calculated and peak flood flows estimated by proportioning flows on the basis of the ratio of catchment areas i.e. in proportion to $(A_1/A_2)^{0.7}$.

The Edwards Creek catchment area at the southern boundary of G08/63 is about 11km² or 40% of the original catchment at the North South Road. The flows at the start of the Edwards Creek Diversion 2 are thereby estimated as 50% those at the North South Road.

2.3 Background

The two diversions will be constructed in a staged approach, with Diversion 1 constructed first.

Diversion 1 has been designed to accommodate flows from the southern branch of Edwards Creeks prior to and following construction of Diversion 2.

When Edwards Creek south branch is cut off by the proposed TSF and WRD infrastructure, then this will reduce the flows impacting Diversion 1.

In the post-closure period, the general goal is that surface (and groundwater) hydrological patterns / flows should not be adversely affected i.e. that the TSF and WRDs in G08/63 be rehabilitated and free draining, and the run-off from the disturbed area restored. It is therefore assumed that flood flows from the G08/63 area will be restored to 100% of pre-existing flood flows (although it is anticipated that the peak flows will probably be somewhat permanently reduced).

2.4 Summary

In summary, the relevant flood flows are provided in the table below, as follows:

- Design flood flows for Diversion 1 at the start point of the diversion i.e. existing Edwards Creek south branch flows at the North South Road);
- The middle branch of Edwards Creek passes under the North South Road through 2 x 750mm, adding 5.8km² of catchment, and enters Diversion 1. This is the design flood flow at the end point of Diversion 1;
- Design flood flows for Diversion 2. The minimum flow is the flow in Edwards Creek at the G08/63 southern boundary (i.e. at the start of the Diversion2); the maximum flow is the full flow in Edwards Creek assuming that the contributing catchment, which includes the TSF/ WRD landforms within the G08/63 mining tenement area, are designed to direct surface water runoff into the diversion channel (i.e. the flow at the end of Diversion 2 is equal to the full Edwards Creek flow).

Table 2.1: Flood Flows in Edwards Creek

ARI (years)	Q (m^3/s) - Diversion 1 Start	Q (m^3/s) - Diversion 1 End	Q (m^3/s) - Diversion 2 (Min / Max)
5	14	16	7 / 14
10	25	29	13 / 25
20	41	47	21 / 41
50	78	80	35 / 70
100	97	111	49 / 97
Probable Maximum Flood	1000	1100	500 / 1000

3. DIVERSIONS - GENERAL

3.1 General

Diversion structures carry flood waters via a flow path different from the natural water course back into the original water course at a point downstream (Diversion 2), or less desirably another water course (Diversion 1). The nominal Edwards Creek diversion routes are shown in Figure 3.

3.2 Pre Closure (Operational) Channel Design

3.2.1 Selection of Design Flood Event

A design flood is required to ascertain the dimensions of the diversion and this is typically a cost versus risk consideration. Risk of flooding outside the constructed diversion can be lowered with a larger capacity and more costly channel; or raised with a smaller capacity and less costly channel. A 100 year flow capacity is commonly chosen when the consequences of flooding are high (such as flooding a pit).

Normal drainage provisions are often set at the 5-10 year level, where occasional temporary flooding is acceptable. This is equivalent to the level of current flooding risk from the creeks impacting the site, and existing drainage provisions (open channels, culverts, etc) on the site. It is proposed that the new open channels accommodate the 5-10 year flood flow.

Once the design capacity of the open channel is exceeded, during cyclonic events for example, then flooding will occur around the mine site in general, and around the new channels in particular (i.e. in the “floodplain” of the channel). Mine operations already take place in the floodplain of Edwards Creek, and operations in the floodplain of the proposed diversion channels, would be similarly impacted by flooding. Based on heavy rain and flood alerts, mining sites would be put in order, and personnel evacuated to camps and administration areas.

Road crossings of the diversion need either be culverted, with the same 5-10 year flow hydraulic capacity as the open channel; or the road graded down and through the diversion as a floodway.

3.2.2 Width of Channel

The bed widths are unable to be ascertained without a site inspection. A low channel bank may exist, but generally the "floodplain" batter slopes outside the main flow channel are low e.g. 1V:20-30H, but occasionally steeper.

The bed width of the new open channels should be similar to that of the natural creek that it replaces. The existing watercourse dimensions have not been observed specifically by RPS, however based on aerial photography, the mobile bed width of Edwards Creek near the North South Road appears to be ~8-10m, and has been used as a guide. For other locations with different catchment areas, and therefore different channel forming flows, the bed width can be estimated as (Q1/Q2)0.5 (based on “regime theory”, empirical equations from field data collected from rivers and from successfully operating artificial canals).

3.2.3 Channel Batter Slopes

Excavated open (trapezoidal) diversion channels typically have side batters of 1V:2H. Typical precedent batter slopes vary from 1V:3H for sandy loam or porous clay; to near vertical at 1V:0.25-0.33H or 3-4V:1H in solid well bedded good quality rock, blocky bedrock in deep cuttings.

3.2.4 Erosion

Maximum allowable erosion velocity for various loam soils is approximately 1m/s, and up to 1.5m/s for stiff clays and gravelly soils. During the operational period, some erosion or scour damage is permissible, as there are maintenance resources available for on-site repair.

3.3 Post Closure Channel Design

The diversions will be permanent, with their own mobile bed and riparian vegetation. The shorter term diversion channel can be constructed initially, and modifications carried out at the end of mining; or the long-term channel constructed initially, which would then allow monitoring of diversion performance during the mining period, and allow any required adjustments before closure.

Relevant principles for long term channels are included in Appendix C. Based on the 2014 ACARP (Australian Coal Industry Research Program) hydraulic guideline values for velocity, stream power and shear stress, the minimum requirement is to review the energy and erosion conditions for the bankfull flow (2-10 year ARI, 6-36m³/s) and 50 year (80m³/s) flood events, as follows:

Scenario	Stream Power (Watts/m²)	Velocity (m/s)	Shear Stress (N/m²)
2 yr ARI (no vegetation)	<35	<1.0	<40
2 yr ARI (vegetated)	<60	<1.5	<40
50 year ARI	<150	<2.5	<50

A Mannings n of 0.045 has been assumed as suitable for an alluvial channel (mobile beds and banks), but may be lower initially in a new or clean channel.

Flatter batter slopes of at least 1V:3H are preferred for long-term stability, to reduce potential rilling and gullying and allow establishment of vegetation.

Construction of a “ecohydrological” environment is desirable, a shallow alluvial aquifer commonly found in the depths of alluvium in natural creeks, and which supports riparian vegetation. A mobile bed is therefore important, and can form by keeping stream power low, but can naturally take a long time (centuries) in sediment supply limited creeks. The process can be assisted by transporting alluvium from the diverted creek, or from blasting the bed rock in-situ, or possibly both. Blasting weathered rock can produce material similar to the natural alluvium, depending on rock type.

The channel is shown as a straight alignment on the Figures provided. The course (planform) of the diversion should generally be similar to the original creek; however the main motivation for this is to maintain the length of the diversion at least the same as the original creek, and thereby allow no steepening of the bed grade. In this case, the grades of the diversions are less than the original creek, and the diversions are effectively longer than the original creek. There is thus no particular reason to wander the diversion course (in a manner similar to the existing Edwards Creek), other than aesthetic appearance.

4. EDWARDS CREEK DIVERSION 1

4.1 General

A nominal Edwards Creek Diversion 1 route is shown in Figure 3 and Figure 4, which diverts the creek away from its original course (into another branch of Edwards Creek). The diversion needs to be carried to the northern mining tenement boundary to gain sufficient fall, matching the existing watercourse levels at that location (refer Appendix B).

The start point of the diversion is the existing Edwards Creek south branch at the North South Road culverts (6 no. x 1500mm diameter corrugated steel culvert pipes (CSP) with a catchment of 28km². The middle branch of Edwards Creek passes under the North South Road through 2 x 750mm culverts, and into Diversion 1, adding 5.8km² of catchment.

The diversion passes through the heavy vehicle haul road (to the TSF) to end in the existing creek channel. It is assumed that the existing heavy vehicle haul road is temporary, and that the existing twin 750mm culverts (too small) would be removed.

The existing 10m wide TSF diversion channel that protects the southern side of the TSF passes under the North South Road through 4 x 900mm (estimated) and also discharges in this area - this adds an additional 13.4km² of catchment from the northern branch of Edwards Creek. This channel would need to be incorporated into the Diversion 1 channel design at this end location.

The design flood depth should desirably have a maximum depth of about 1.5m, to match the 1500mm diameter CSP culverts at the North South Road crossing immediately upstream, and therefore avoid surcharging and reducing that culvert capacity.

4.2 Diversion 1 Channel Design (Operational Period)

The diversion design parameters have been taken as follows:

- Length about 1.4km long;
- Design flow - 5-10 year ARI i.e. 14-29m³/s;
- Bed width - 8-10m wide Edwards Creek bed widths near the North South Road;
- The diversion will be all in cut excavation, typically 2-3m deep with an average longitudinal grade of 0.22% (less than the existing average creek grade of ~0.3%).

On this basis, flood depths and velocities are estimated as:

- 5 year ARI - depth ~1.2-1.3m and velocity 1.0m/s;
- 10 year ARI - depth ~1.6-1.8m and velocity 1.2m/s.

The earthworks for a 10m wide channel comprise about 45,000m³ of cut.

4.3 Diversion 1 Channel Design (Post Closure)

The estimated energy and erosion parameters are:

- 2-10 year (6-29m³/s) - depth ~1.5m, velocity 1.1m/s, shear stress 25N/m², and stream power 28W/m² (meeting the ACARP guidelines);
- 50 year (80m³/s) - depth ~2.6m, velocity 1.5m/s, shear stress 38N/m², and stream power 58W/m² (generally meeting the ACARP guidelines, noting that there would be substantial out of channel flooding in this event, which would reduce the ACARP in-channel parameters).

5. EDWARDS CREEK DIVERSION 2

5.1 General

A nominal Edwards Creek Diversion 2 route is shown in Figure 3 and Figure 5, which diverts the creek away from its original course and then back into the same branch of Edwards Creek (refer Appendix B). Two possible routes at the upstream end of the diversion are shown in Figure 5 (Option A and Option B), due to hillier ground in that area at the start of the diversion.

The course (planform) of the existing creek channel upstream of the diversion is defined by structural geology. The start point of the diversion is the existing Edwards Creek south branch in the low hills of the Maddina Volcanics. The diversion then runs west and then north mostly through residual clays, sand and gravels, ending upstream of the North South Road culverts.

5.2 Diversion 2 Channel Design (Operational Period)

The diversion design parameters have been taken as follows:

- Length about 7.0km long;
- Design flow - 5-10 year ARI i.e. 7-25m³/s;
- Bed width - the natural creek cross-section at the start of Diversion 2 may be typified as a trapezoid with bottom width of 5.5-7m wide (this is based on the 8-10m bed width of the Edwards Creek channel downstream, and then factored as described above);
- The diversion will be all in cut excavation, typically 1.5-2m deep for most of the route, but up to 6m deep when passing through higher ground along the western boundary of G08/63, with an average longitudinal grade of 0.45% (less than the existing creek grade of ~0.55%);

For a 7m wide diversion channel nearer the start of the diversion, the estimated energy and erosion parameters are:

- 5 year ARI (7m³/s) - depth ~0.8m and velocity 1.1m/s;
- 10 year ARI (13m³/s) - depth ~1.2m and velocity 1.3m/s.

For a 8-10m wide diversion channel nearer the end of the diversion, the estimated parameters are:

- 5 year ARI (14m³/s) - depth ~1.0m and velocity 1.3m/s;
- 10 year ARI (25m³/s) - depth ~1.4m and velocity 1.6m/s.

The earthworks vary from about 310,000m³ to 410,000m³ over the range of possible bed widths. In the operational phase, the TSF and WRDs are generally designed not to shed water, and it is likely flows into the diversion will be somewhat curtailed.

An 8m wide diversion throughout is therefore considered suitable with earthworks of ~370,000m³.

5.3 Diversion 2 Channel Design (Post Closure)

On the basis of an 8m channel:

- 2-10 year (3-13m³/s) - depth ~1.0m, velocity 1.2m/s, shear stress 34N/m², and stream power 41W/m² (meeting the ACARP guidelines);
- 50 year (35m³/s) - depth ~1.7m, velocity 1.6m/s, shear stress 52N/m², and stream power 86W/m² (also generally meeting the ACARP guidelines);
- 50 year (70m³/s if full flow is restored) - flood depths ~2.3m, velocity 2.0m/s, shear stress 70N/m², and stream power 138W/m² (shear stress exceeds ACARP guidelines, but would reduce with out of channel flooding, or otherwise encounter harder substrates in deeper cuts sections of the channel).

The 8m trapezoidal section generally meets the ACARP guidelines. It is not known how much local run-off over and above external flow will find its way into the permanent diverted watercourse; the design of the watercourse is part of the final rehabilitated designs for the TSF and WRDs and can be ascertained at that time.

6. SOUTH WEST (M08/125) WASTE ROCK DUMP

6.1 Management of Run-Off from Waste Rock Dump

6.1.1 General

Ministerial Approval Condition 5-3 requires best practice measures in the design and construction of WRDs, to minimise erosion and run-off. The general objectives with regards to surface water are to maintain the integrity, functions and environmental values of watercourses downstream.

The risk of erosion and sedimentation of disturbed or degraded lands is therefore high. Surface water runoff from disturbed areas, WRD and stockpiles is typically sediment laden, and site-specific surface water controls should be applied.

The proposed WRD area generally drains north west towards the DuBoulay Creek main channel and the Fortescue floodplain.

The Department of Mining and Petroleum (DMP, Environmental Notes on Mining, 2009) notes that lack of adequate drainage control is a major cause of erosion on newly created landforms and drainage control measures. In arid regions, it is preferable that WRDs be water retaining i.e. the top surface, berms and batters are constructed to hold the maximum expected rainfall event. Water retention, minimising slope lengths and deep ripping at intervals on sloping surfaces assists to achieve the necessary control.

6.1.2 Rainfall Run-off Volumes

The 72 hour duration rainfall event (common industry practice for “volume” calculations) has been used to calculate the volumes of rainfall run-off that might collect inside a flood bunded WRD area.

The total catchment area within the proposed WRD flood bund is about 150ha. Initially the allocated area will be bare ground, eventually the WRDs will tend to mitigate runoff volume). The estimated volumes of dirty water are provided below.

Table 6.1: Volumes of Dirty Water

ARI	72hr Rain Total (mm)	Contributing Area inside Bund (ha)	Runoff Coeff.	Flood Vol. (ML)
10	215	150	0.35	113
100	467	150	0.60	420
500	700	150	0.71	746

6.1.3 Dirty Water Collection

A bund / channel collection system is required to direct internal surface dirty water runoff from the SW WRD and direct it to a sedimentation basin in a low-lying area for treatment prior to discharge to the external environment (refer Figure 6 and Figure 7).

Based on available contour data, the collection system would be required on the north east (DuBoulay) and western (Fortescue) sides of the WRD area (refer Figure 6). The collection system would require a nominal 5 year ARI capacity peak inflow, estimated as up to $1m^3/s$.

The floodplain to the south of the SW WRD, drains towards the SW WRD. As such a bund / channel along the southern boundary is required to direct the “clean” water to the west and prevent it entering the SW WRD area.

6.1.4 Sedimentation Basin

The sedimentation basin is located at the low point in the WRD area (refer Figure 6). The basin should be at least 1.2m deep, consisting of a permanent pool settling zone and sediment storage zone (each a minimum 0.6m deep). The sizing (i.e. top surface area of the basin) is based on the rate of inflow, and size and percentage of particles to be removed. Water quality capture and treatment devices are not expected to treat all the flow, but rather focus on smaller, more frequent run-off events. The required top surface area is 635m² for 100% settlement of 50um particles (coarse silt) in a 5 year ARI peak inflow (~1m³/s).

The basin may be partially excavated as required to confine the extent of the surface ponding in flat terrain. A spillway is needed to drain excess water, a rock lined spillway (100 year capacity) over the containing bund, set at the top water surface and 0.5m below the bund crest.

Sedimentation basins may be "dry" or "wet". For a dry basin, a "control structure" is additionally required - a small discharge pipe to drain about 400m³ in 1-2 days i.e. a flow rate of 2.5-5L/s. In a "wet" sedimentation basin, no discharge pipe is required.

At mine closure the WRDs would be rehabilitated, and eventually the dirty water collection bunds and sedimentation basin removed.

6.2 DuBoulay Creek Hydraulic Modelling

6.2.1 Joint Probability

DuBoulay Creek drains north west into the Fortescue River. There is a degree of dependence between DuBoulay Creek and Fortescue River flooding, but the two watercourses vary greatly in catchment size and therefore would respond with different timing to a large rainfall event. The flood level in the Fortescue River is an end downstream condition required when hydraulic modelling flood flows in DuBoulay Creek - a joint probability situation.

DuBoulay Creek was modelled with the 100 year ARI flow, in conjunction with 20 year ARI Fortescue River flood levels at the downstream boundary condition.

The "Karratha Coastal Vulnerability Study" (JDA, August 2012) used the 100 year flood flow in conjunction with 20 year sea levels as the downstream boundary condition (the joint probability between river flood levels and storm surge was studied, but no obvious correlation found).

The "Flood Risk Management Guide" (NSW Department of Environment, Climate Change & Water 2010/759, August 2010) similarly adopts a similar approach using (a) 100 year creek flooding with 20 year sea levels and (b) 20 year creek flooding with 100 year ARI sea levels (assuming coincident peaks).

6.2.2 XP-SWMM

Hydraulic modelling was carried out along DuBoulay Creek using hydraulic model XP-SWMM to simulate flow behaviour. The model requires a digital terrain model or 2D grid domain based on topography; Manning's n roughness values, the flow rate, and the boundary condition - the selected Fortescue River flood level in this case.

The model was run in 2D mode only.

Encroachment onto the flood plain will restrict flow (in significant flood events) and cause water levels to rise upstream. The degree of encroachment may be effectively measured by the rise in flood levels.

Pre-development 100 year modelling (existing situation) was carried out along DuBoulay Creek. The creek flows between two hills (magnetite deposits), but the flood flows are not confined to the main channel, but overflow and spread out broadly onto the flat Fortescue floodplain to the west i.e. minimal flow depth.

Post-development modelling was then carried out by inserting "bunds" either side of DuBoulay Creek to create a flood corridor (refer Figure 6 and Figure 8), at notional 100m, 75m and 50m offset distances from the creek centreline i.e. forming corridors of 200m, 150m and 100m width:

- On the northern side, the notional bund would protect the mining pits, WRDs, etc in the operational areas that encroach into the DuBoulay Creek floodplain;
- On the southern side, the proposed SW WRD area encroaches into the DuBoulay floodplain.

The offset distances are not critical per se, provided the creek main channel remains fully within the corridor as defined, and full corridor widths are maintained. The hydraulic model was run for the

100 year flood, and an estimated 20 year flood level in the Fortescue River (the reverse 20 year DuBoulay Creek flow and 100 year Fortescue River flood level scenario is not critical).

Prior to entering the proposed and confining DuBoulay Creek flood corridor, some of the creek flow would currently spill out onto the Fortescue floodplain to the south side of the proposed WRD (in the same manner as the pre-development flow now does, refer Figure 8). The remainder would then follow the main DuBoulay Creek channel along the flood corridor.

It has been assumed however that flood infrastructure would prevent flow spilling onto the Fortescue floodplain, and the full 100 year flow would be directed down the corridor.

6.2.3 XP-SWMM Results

However, confining the creek causes 100 year flood levels to rise substantially over those in the predevelopment floodplain. The model outputs are indicated in the table below.

Table 6.2: Impact of Confinement on DuBoulay Creek Flood Depths and Velocities

Corridor Width (m)	100 yr Increase in Flood Depth (m)	100 yr Increase in Velocity (m/s)
200	Additional 0.35m depth on average	Additional 0.1m/s on average
150	Additional 0.75m on average	Additional 0.2m/s on average
100	Additional 1.0m depth on average	Additional 0.5m/s on average

Generally the flow velocities are <2m/s at the fringes of the 150m corridor based on DuBoulay Creek flooding.

A minimum DuBoulay Creek corridor width of 150m is recommended (Figure 8).

6.3 Fortescue River

6.3.1 Flood Levels in the Fortescue River Floodplain

Flood studies (Aquaterra and MWH) have been previously carried out to determine Fortescue River flood levels. RPS report 1569C/003b “Sino Iron - Western Flood Protection Bund”, December 2014 discussed and updated this work in relation to Fortescue River flood levels, and a proposed flood bund along the western mining tenement boundary.

The mine site is impacted both by river flooding and sea surge. Based on 100 year and 500 year flood modelling (MWH, Cape Preston Sino Iron Project - Flood Modelling, 2008 and 2013) flood levels in the western area of the CPM mining tenement, a continuous flood profile past the mine site was developed. Based on probability and the Mine Continuation Proposal, the 100 year event was adopted as a basis for the pit flood protection bund height. A 100 year sea surge / flood level of RL6.0m was adopted at the coast (as a separate phenomenon to river flooding).

On this basis, the 100 year flood levels in the Fortescue floodplain are estimated approximately as RL16.9m and 11.5m at the SW and NW corners of mining tenement M08/125 respectively. These Fortescue River flood levels are higher than the flood levels due to predevelopment DuBoulay Creek flooding. The flood level drops about 5.4m over the 2km M08/125 western boundary (average grade ~1 in 370) while the water depths vary from about 3-6m (refer Figure 8).

6.3.2 Fortescue River Impacts on the Proposed 150m Wide Corridor

The flood levels in the Fortescue River are higher than the ground level at the entrance to the proposed DuBoulay flood corridor - and provided these Fortescue flows can reach the entrance to the DuBoulay corridor i.e. are not blocked by bunds or other mine infrastructure, then flood flows of ~1100m³/s (80% greater than the 100 year DuBoulay Creek peak flow) would be generated down the DuBoulay corridor (independently of whether DuBoulay Creek is in flood or not).

The velocities generated are generally <2m/s at the fringes of the 150m corridor, but sometimes greater.

6.4 External Flood Flows Impacting the WRD

6.4.1 Bund around the WRD

The WRD will be constructed within the Fortescue and DuBoulay floodplains. The proposed WRD is therefore subject to inundation from floodwaters overtopping the relatively low dirty water perimeter bund. This flooding can either be accepted or a larger bund constructed around the WRD to limit the entry of flood waters to the site.

WRD inundation can potentially result in:

- Dump erosion (and possibly slumping);
- Sedimentation downstream;
- Disruption of operations and access to the WRD during flooding, while the area dries out.

Flood damage to dumps (undermining and slumping of steep angle of repose slopes) can be accepted or the lower portions of the dump armoured with oversized waste material. Dump erosion and sedimentation downstream is also considered acceptable, provided the frequency of inundation is minimised i.e. the dump is protected at the 5 year level.

If WRD operations can be delayed elsewhere during flooding periods, then the risk is lower and a lower bund is suitable (e.g. 5-10 year ARI flood level – which would occur several times during a 25 year mine life). If it is important to limit disruption to dumping options, then a higher flood bund is desirable (20-100 year flood level – a 70-20% chance of being inundated).

The 100 year and lower flood heights and depths at the edges of the dump site are shown in Figure 8, which would need to be considered if a higher bund was required. If a higher bund is adopted then it may not be possible to remove water from the sedimentation basin without either pumping or providing a pipe culvert through the bund with a flood gate attached.

6.4.2 External Flooding on Southern Side

Minor ponding would occur against the WRD bund / channel where it crosses existing flow paths on the Fortescue floodplain (refer Figure 6). It is anticipated that ponding depths would be relatively minor (up to 2-3m) based on the contour information available. The proposed bund should be sufficiently high to prevent this water accessing the dump site. However minor diversion trenching along the toe of the bund can direct flows further westward into the Fortescue floodplain if required to reduce the depth of ponding.

6.5 Summary

CPM is considering placing a WRD in the south-west corner of tenement M08/125, in the DuBoulay Creek and Fortescue River floodplains.

The dirty runoff from the WRD needs to be directed by a bund / channel system towards a sedimentation basin at a low point in the WRD area. A sedimentation basin with a minimum water top surface area of about 635m² is required, with a rock lined spillway over the containing bund.

The proposed SW WRD area is impacted by (a) DuBoulay Creek and (b) Fortescue River. Pre-development hydraulic modelling was used to estimate flood levels for DuBoulay Creek and floodplain with a 100 year flow of 616m³/s. The Fortescue River (pre-development) flood levels exceed the DuBoulay flood levels at any given point.

DuBoulay Creek was then confined within a corridor, representing the flood protection required for the mining pits, WRDs and proposed SW WRD on both sides of the existing channel. DuBoulay flooding causes confined 100 year flood levels to rise substantially over those in the pre-development case, where flood waters spill out onto a flat floodplain.

The "Aquaterra Mineralogy Expansion Project (Stage 3-5) Surface Water Management" (refer 1002D/D1/005c, August 2009) recommended "a minimum corridor width of 400m .... to maintain reasonable floodplain capacity, limit increases in flood levels and velocities, and minimise erosion against the toe of dumps". Such a width would obviate any possible environmental changes on DuBoulay Creek. However a minimum corridor width of 150m is recommended as a maximum encroachment acceptable to minimise environmental impact, providing the corridor maintains a generous / healthy buffer to the floodplain channels and retains its extant riparian vegetation, and does not cover or destroy main surface flow channels (there are multi main channels in places).

The minimum "flood protection" required of the proposed WRD is the relatively low perimeter bund / channel system to collect internal dirty water runoff from the WRD, and direct it to an internal sedimentation basin at a low point. If greater flood protection to the WRD is desired, to limit disruption of operations during larger scale flooding (either DuBoulay or Fortescue), then a higher perimeter bund is required. This does not assist with access from the pits across the DuBoulay Creek channel.

6.6 Bund Materials and Construction

Earth bunds are typically trapezoidal shaped mounds with stable batter slopes, generally built to an engineering specification. There is no mandatory minimum crest width, but low bunds should have a crest about equal to their height, while bunds from 3-6m high would have a crest 3-4m wide. The upstream (water side) batter slope should be equal to, or flatter than, 1V:3H; the downstream (dry side) slope at least 1V:2.5H.

Construction requirements include excavating to strip depth and scarifying the subgrade. Bund materials, and their subsequent location within the bund, should be subject to investigation and characterisation of materials. Commonly embankments are constructed homogeneously for simplicity, generally using the most suitable available 'watertight' material at the site, but which should typically include some clays for imperviousness, and sands and gravels for mechanical strength.

Piping / internal erosion within a bund relates to particle migration initiated by seepage pressure and is a concern for fine materials such as silts and dispersive clays. However the risk is low for the small bunds required and flood waters are present for a short duration.

Bund material should generally (after breakdown by grid roller) be ≤150mm with a maximum Liquid Limit (LL) of 35% and Plasticity Index (PI) 8-20%. The material should be deposited and spread in uniform level layers to a maximum thickness of 300mm loose measurement, and then each layer compacted to 95% Modified Dry Density and test for density.

The velocities against the confining bunds / structures are mostly <2m/s (100 year ARI flow) and it is not generally considered necessary to rock armour a properly constructed and compacted bund or channel against these velocities (given post flood event inspection repairs as required).

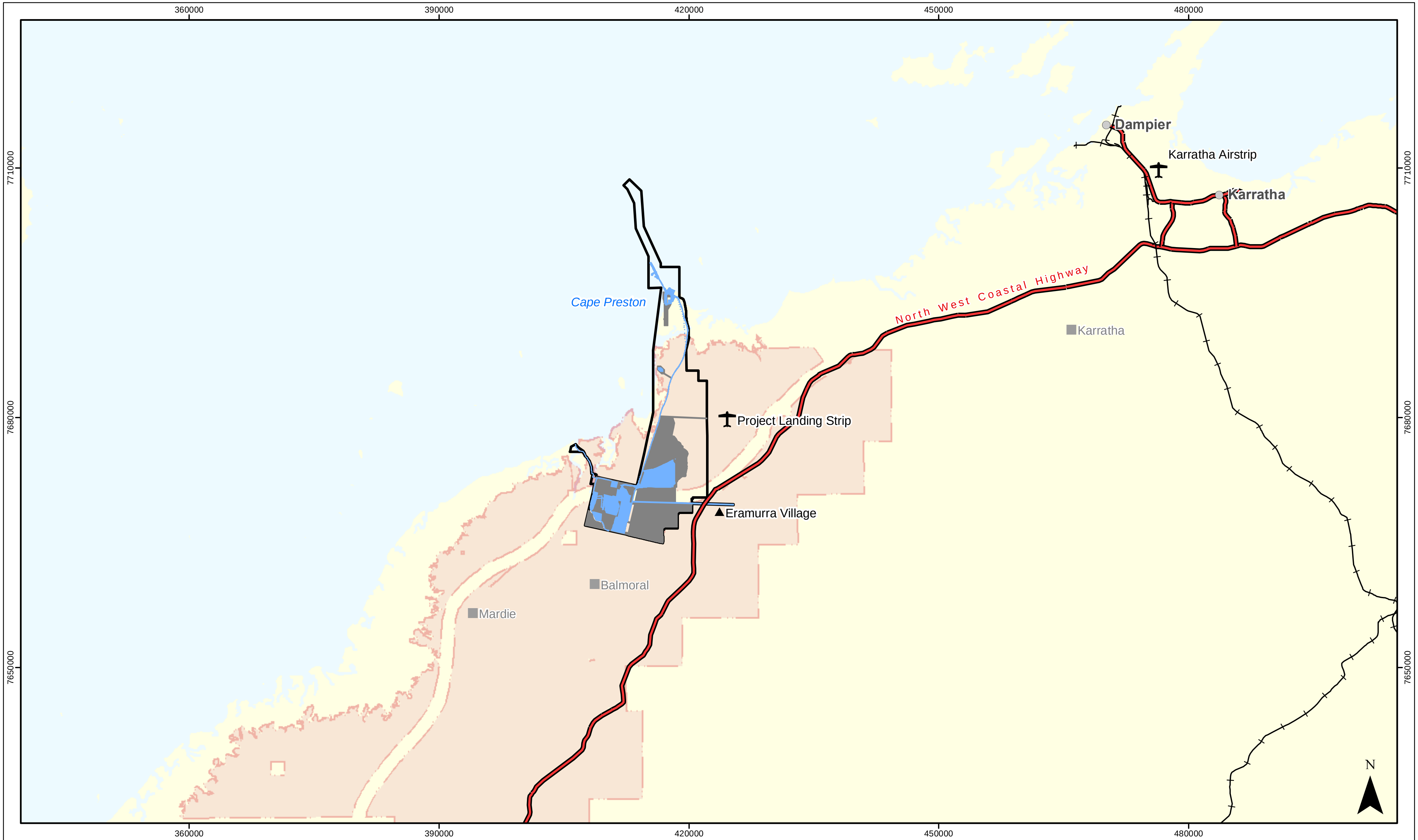
6.7 Post Closure

At closure the site would be rehabilitated to minimise the adverse impacts of the prior mining operations.

All completed surfaces should be able to resist long term erosion. The landforms would be rehabilitated to full ecological function, stable with factors of safety / conservatism to prevent failure, aesthetically compatible with the surrounding landscape, supporting sustainable native vegetation, free draining and non-polluting suitable for alternative land-use. This requires reshaping of the WRD to form a stable land surface, which behaves and evolves in a predictable way.

Generally all mine infrastructures, including confining flood bunds and sedimentation basins would be removed. Landforms such as the WRD would remain in the DuBoulay floodplain and be designed for regular flood events. A rock armour substrate can be applied or additional rock armouring / blocky waste material placed in the lowers areas of the SW WRD up to PMF flood height.

FIGURES



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Mine Continuation Proposal

Figure 1 - 1

Regional location

0 10 20
Kilometres
1:600,000

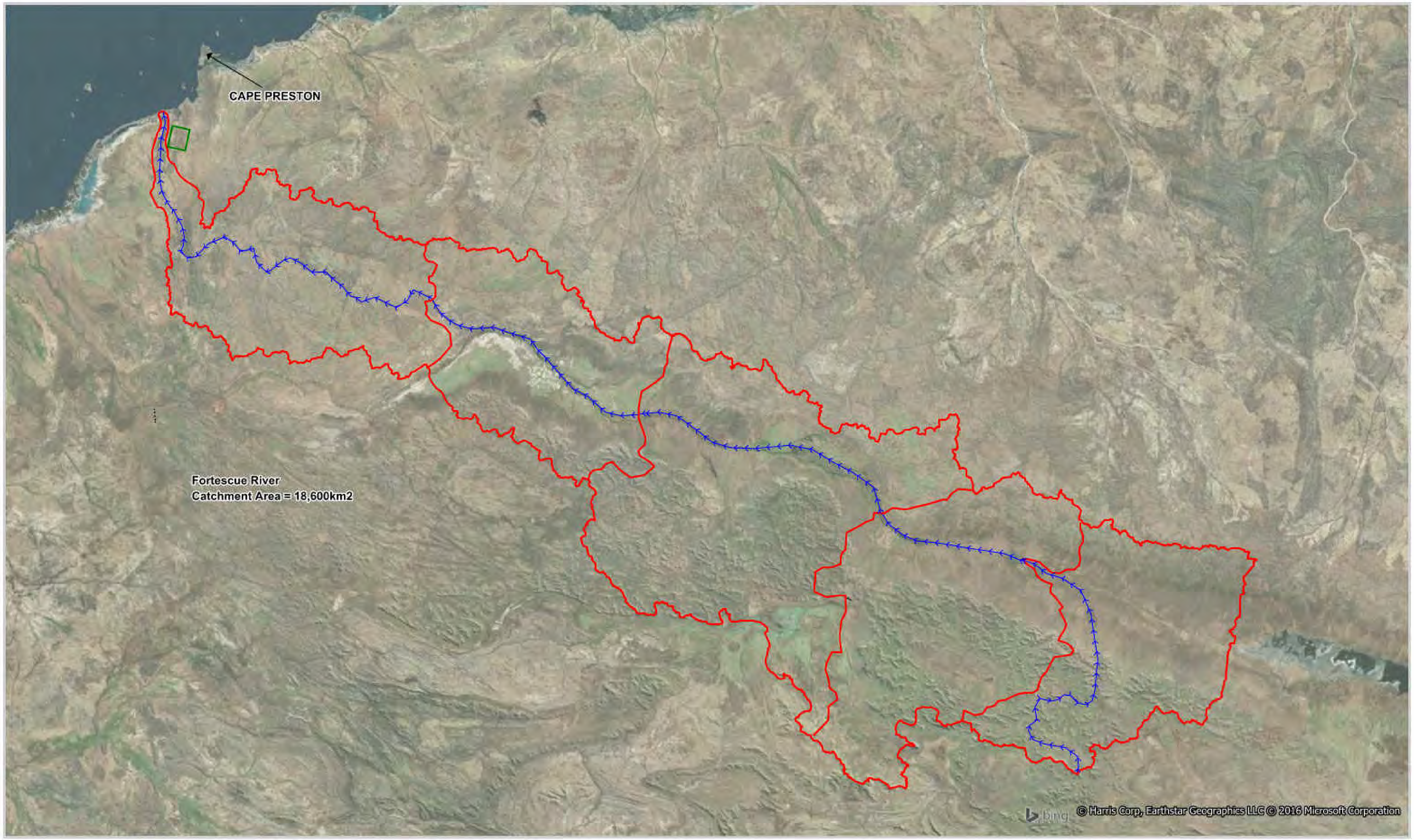
Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	12/01/2017
Sheet Size:	A4	Status:	Draft

Drawn by	Requested by	Internal Reference
DS	MB, Strategen	4397_01_2017_APP

Legend

- Development Envelope
- Conceptual Footprint
- Statement 635 approval (MS635)
- Populated Place
- Airport
- Eramurra Village
- Homesteads
- Railway
- Principal Road
- Mardie Station



N
0 20 40
Kilometres
Scale: 1:1,000,000 @A3
GDA 1994 Zone 50

AUTHOR:	AB	REPORT NO:	003b
DRAWN:	AB	REVISION:	A
DATE:	13/12/2016	JOB NO:	1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003b\1569B_003b_Figure2

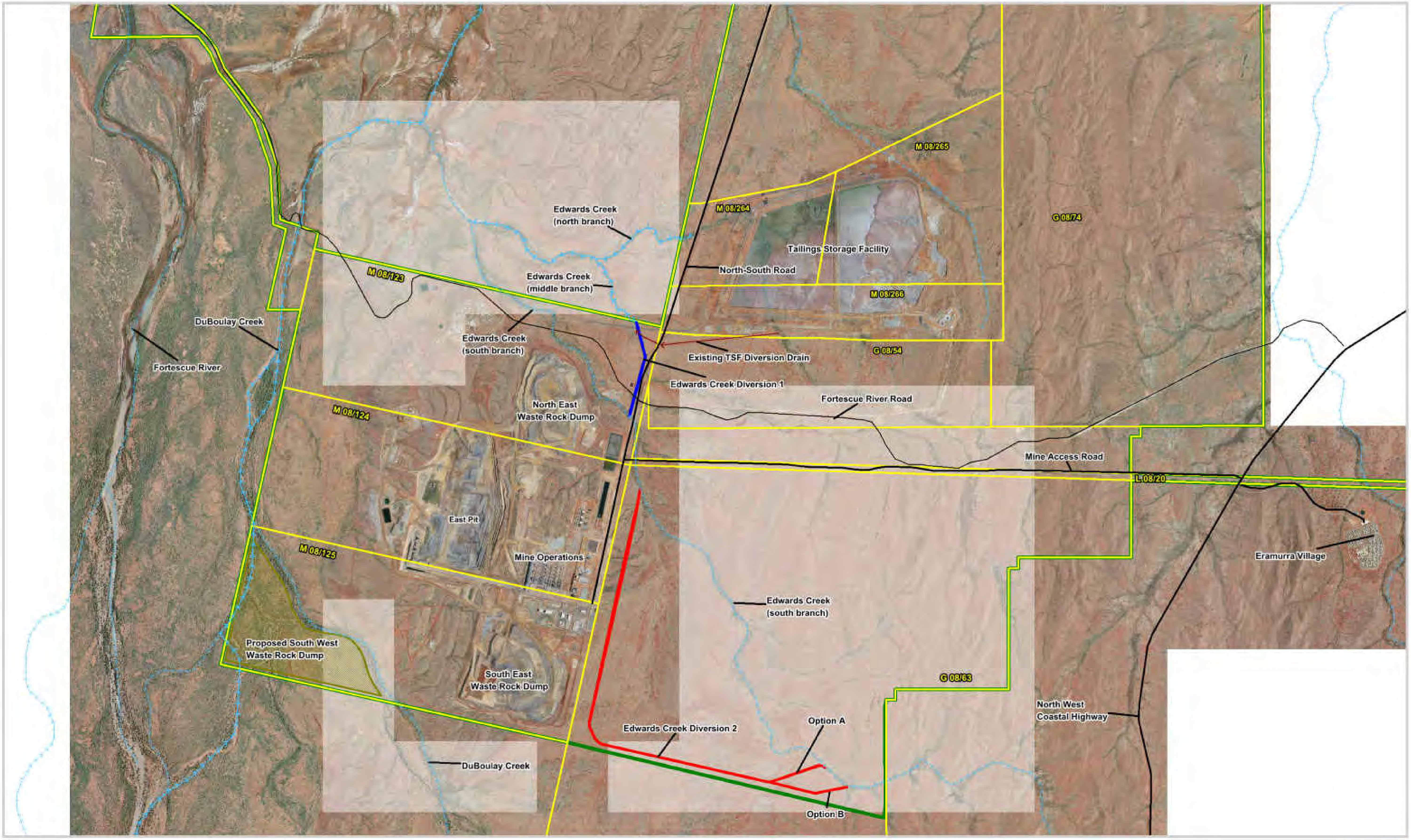
LEGEND

- Catchment Boundary
- Mine Site
- Flow Paths

RPS

FIGURE 2

FORTESCUE RIVER CATCHMENT



LOCATION MAP

N

0 1 2

Kilometers

Scale: 1:50,000 @A3

GDA 1994 Zone 50

AUTHOR:	AB	REPORT NO:	003c
DRAWN:	AB	REVISION:	A
DATE:	17/01/2017	JOB NO:	1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003c\1569B_003c_Figure3

LEGEND

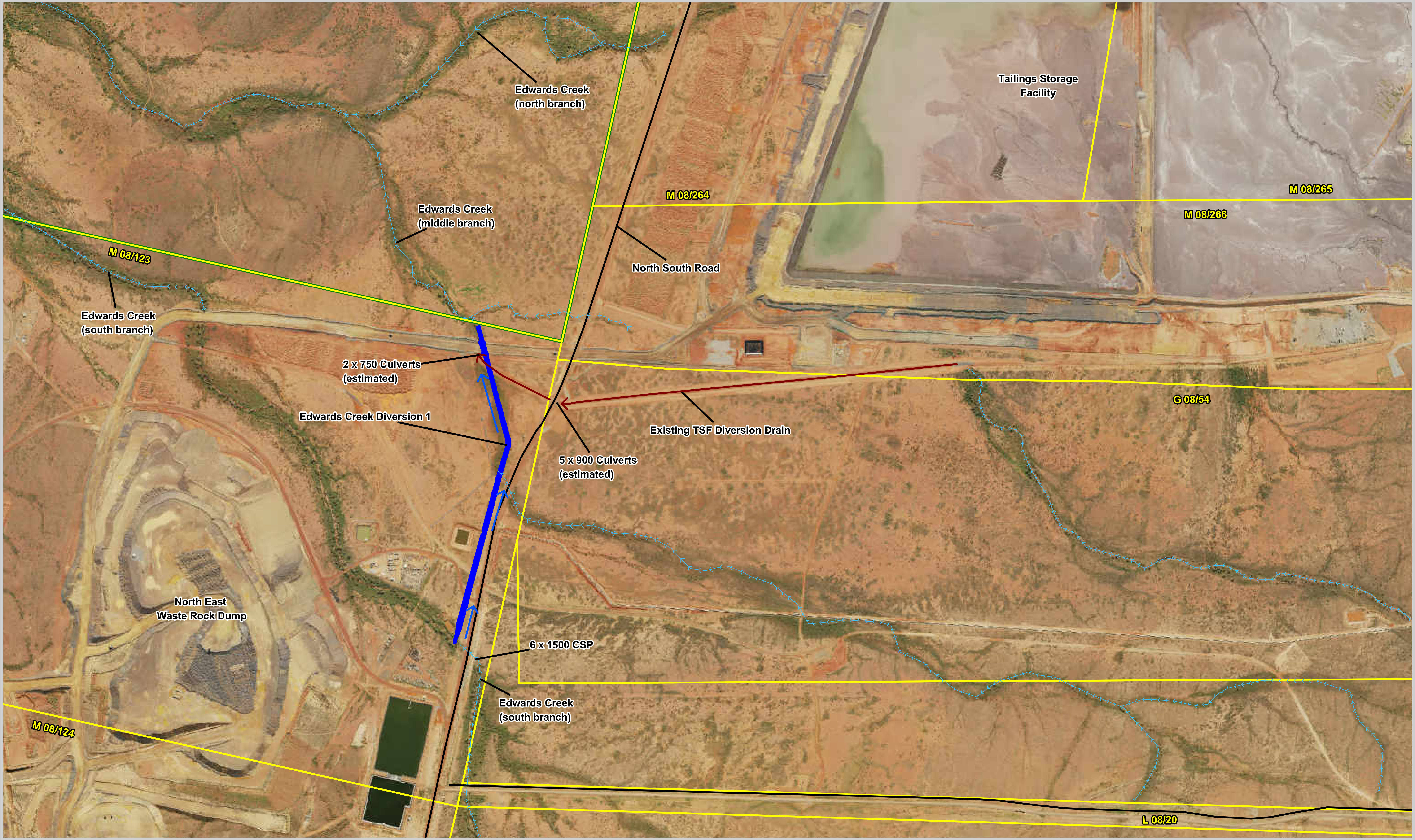
- Mining Tenements
- Sino Conceptual Mine Continuation Development Footprint
- Edwards Creek Diversion 1
- Edwards Creek Diversion 2
- Proposed South West Waste Rock Dump
- Flow Paths

DATA SOURCES:
CITIC Pacific Mining Aerial Photography

RPS

FIGURE 3

SINO IRON MINE LAYOUT



LOCATION MAP

DERBY
PROJECT
NEWMAN
KALGOORLIE
PERTH
ALBANY

N

0 300 600

Meters

Scale: 1:15,000 @A3

GDA 1994 Zone 50

AUTHOR:	AB	REPORT NO:	003c
DRAWN:	AB	REVISION:	A
DATE:	17/01/2017	JOB NO:	1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003c\1569B_003c_Figure4

LEGEND

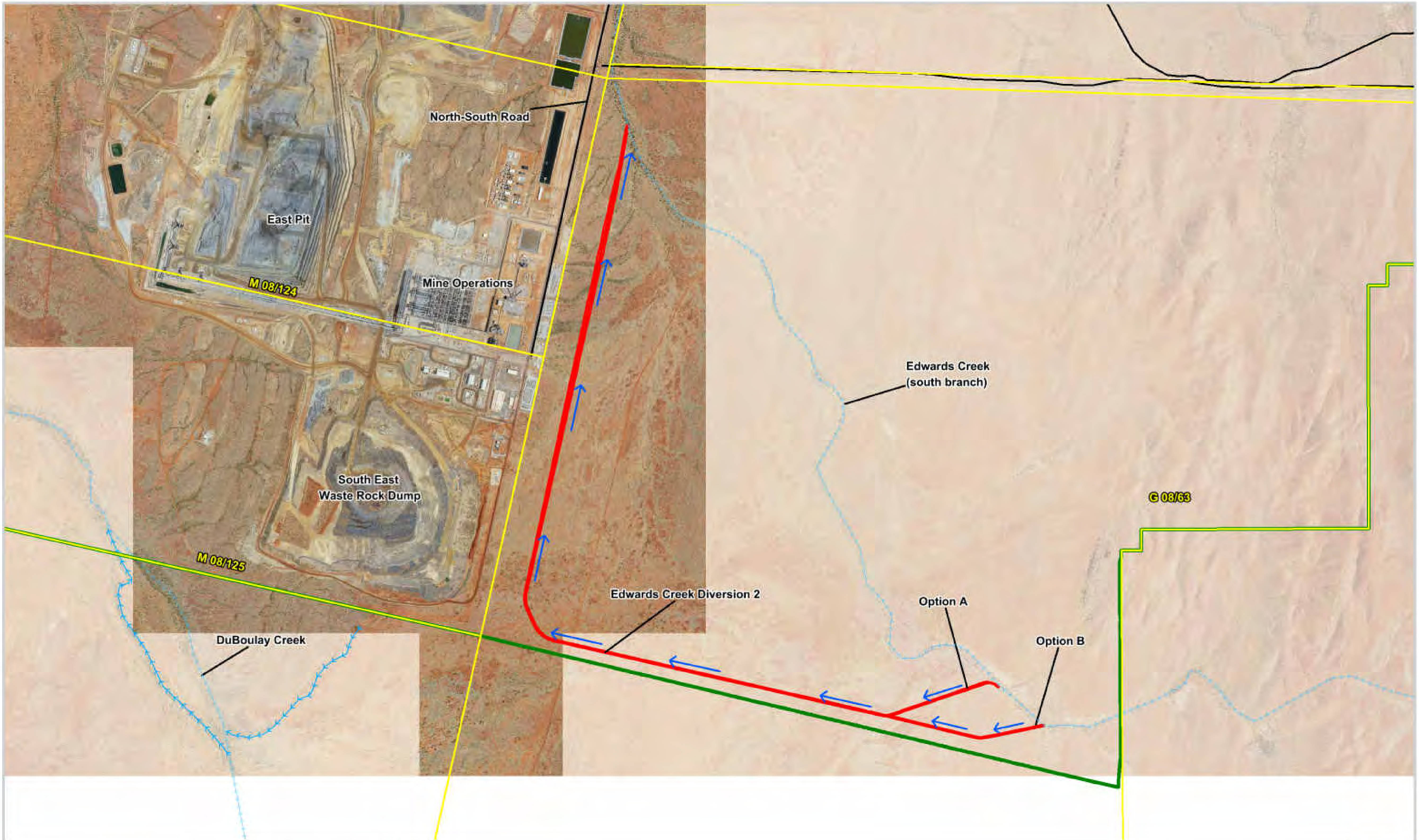
- Mining Tenements
- Sino Conceptual Mine Continuation Development Footprint
- Edwards Creek Diversion 1
- Diverted Flows
- Flow Paths
- Existing TSF Diversion Drain

DATA SOURCES:
CITIC Pacific Mining Aerial Photography

RPS

FIGURE 4

EDWARDS CREEK DIVERSION 1



LOCATION MAP

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Meters

Scale: 1:25,000 @A3

GDA 1994 Zone 50

AUTHOR: AB	REPORT NO: 003c
DRAWN: AB	REVISION: A
DATE: 17/01/2017	JOB NO: 1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003c\1569B_003c_Figure5

LEGEND

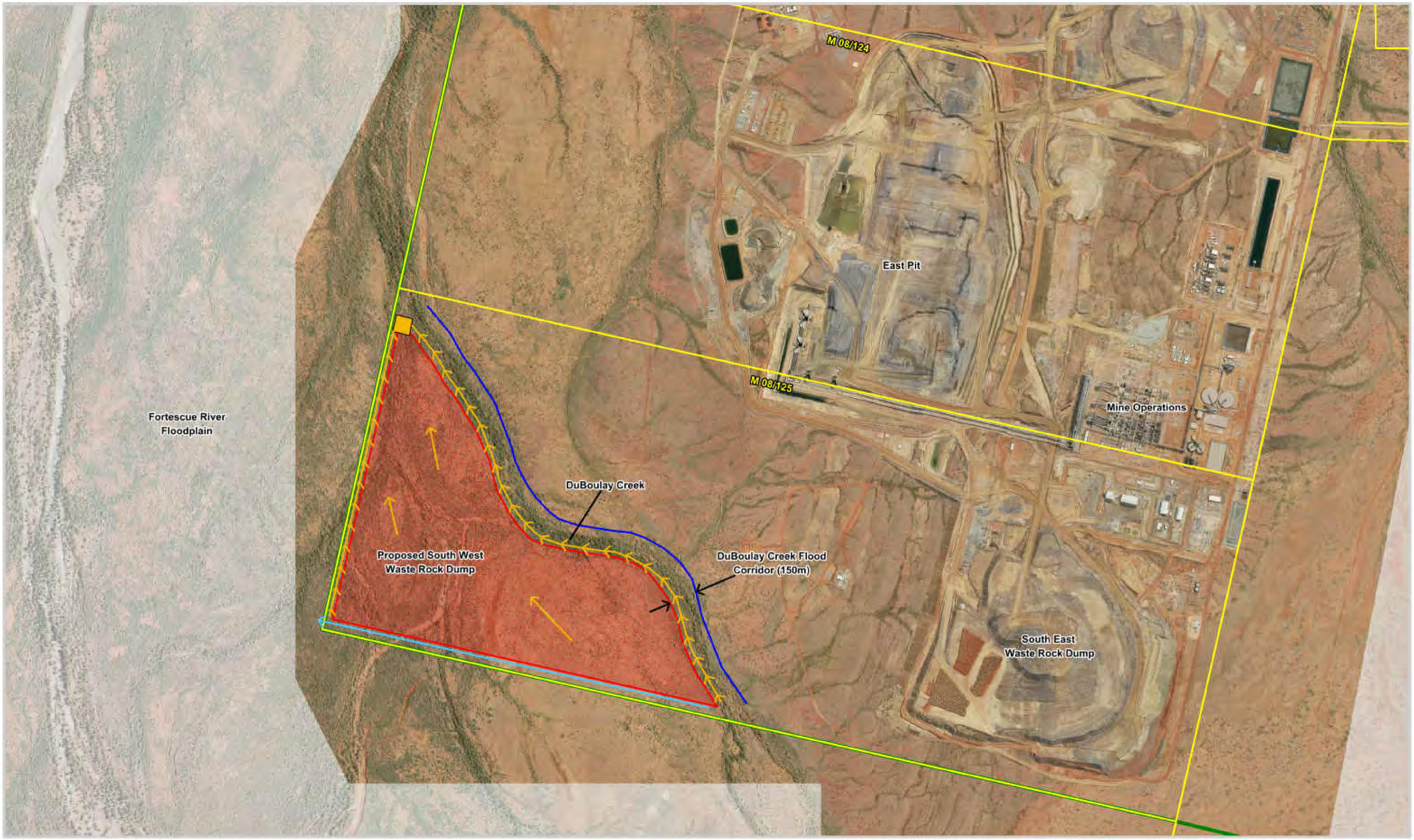
- Mining Tenements
- Sino Conceptual Mine Continuation Development Footprint
- Edwards Creek Diversion 1
- Diverted Flows
- Flow Paths

DATA SOURCES:
CITIC Pacific Mining Aerial Photography

RPS

FIGURE 5

EDWARDS CREEK DIVERSION 2



0 400 800
Metres
Scale: 1:20,000 @A3
GDA 1994 Zone 50

AUTHOR:	AB	REPORT NO:	003c
DRAWN:	AB	REVISION:	A
DATE:	17/01/2017	JOB NO:	1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003c\1569B_003c_Figure6

LEGEND

- Mining Tenements
- Sino Conceptual Mine Continuation Development Footprint
- Dirty Water Bund/Channel
- DuBoulay Flood Corridor (150m wide)
- Clean Water Bund/Channel
- Sedimentation Basin

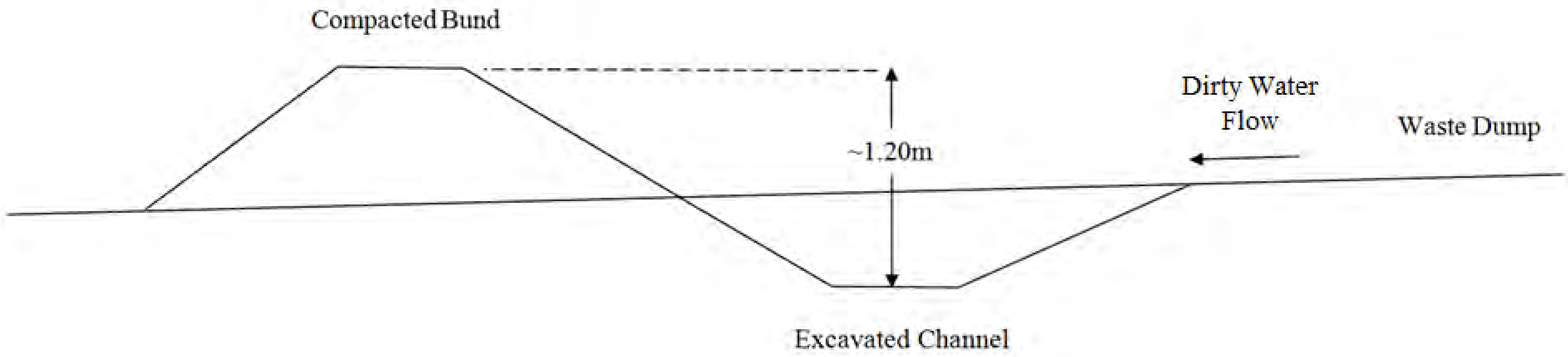
DATA SOURCES:
CITIC Pacific Mining Aerial Photography

Note:
The DeBoulay Creek flood corridor
is shown for hydraulic modelling purposes.

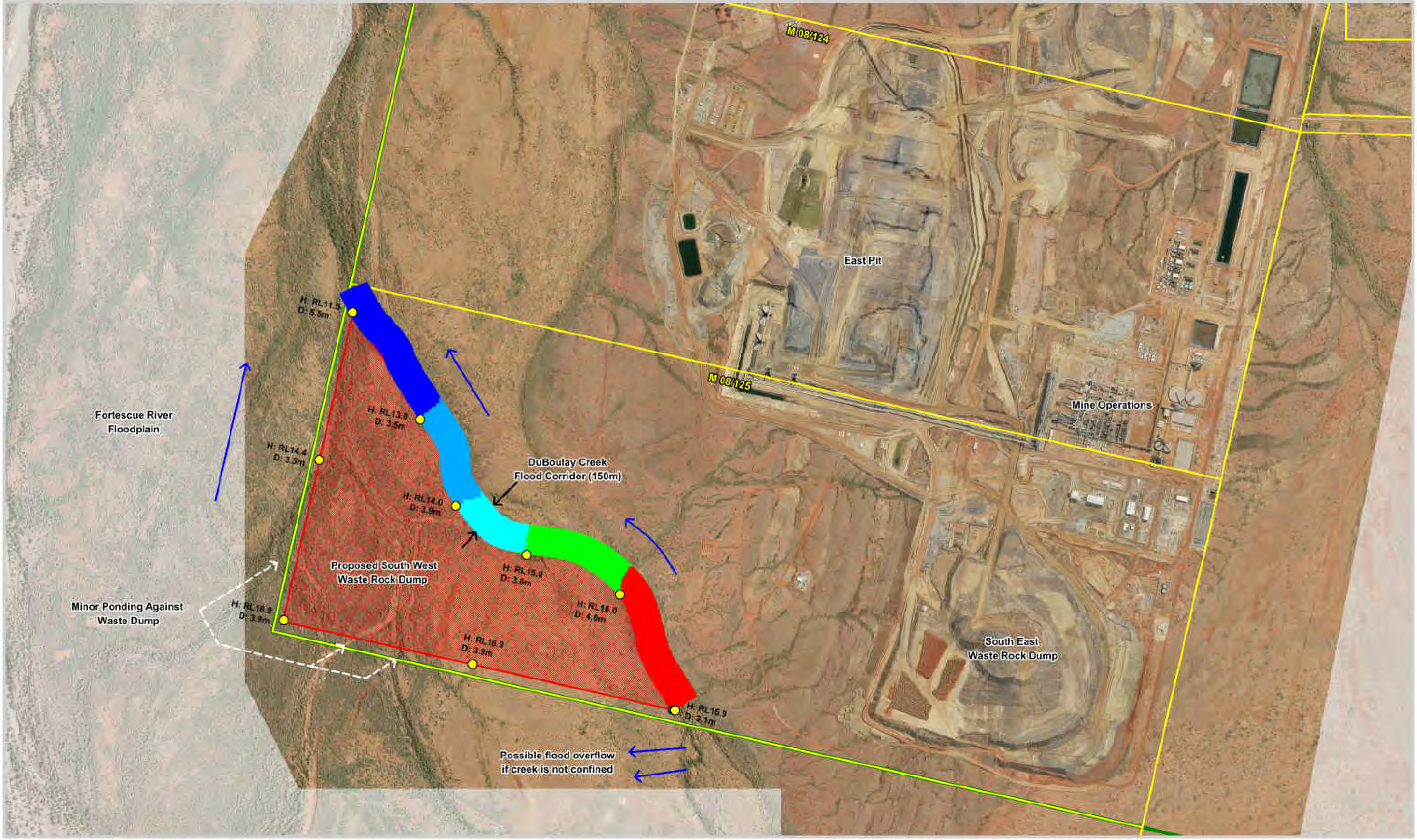
RPS

FIGURE 6

PROPOSED SOUTH WEST WASTE ROCK DUMP SURFACE WATER MANAGEMENT



Diversion Cross Section (Dirty Water Collection)



LOCATION MAP

0 400 800

Metres

Scale: 1:20,000 @A3

GDA 1994 Zone 50

AUTHOR: AB	REPORT NO: 003c
DRAWN: AB	REVISION: A
DATE: 17/01/2017	JOB NO: 1569B

Location: F:\Jobs\1569B\Spatial_Data\MapInfo\Workspaces\003c\1569B_003c_Figure8

LEGEND

- Mining Tenements
- Sino Conceptual Mine Continuation Development Footprint
- 100 Year Flood Levels (H), Flood Depth (D) — 50, 20, 10 year ARI flood levels are expected to be in the order of 1m, 2m, 2.6m, respectively, below the 100 year flood levels.
- 100 Year Flood Levels (H), Flood Depth (D) — 20 and 10 year ARI flood levels are expected to be in the order of 2m and 2.5m, respectively, below the 100 year flood levels. PMF level are ~1.5m above the 100 flood levels

Flood Levels (m)

- 16 to 17
- 15 to 16
- 14 to 15
- 13 to 14
- 12 to 13

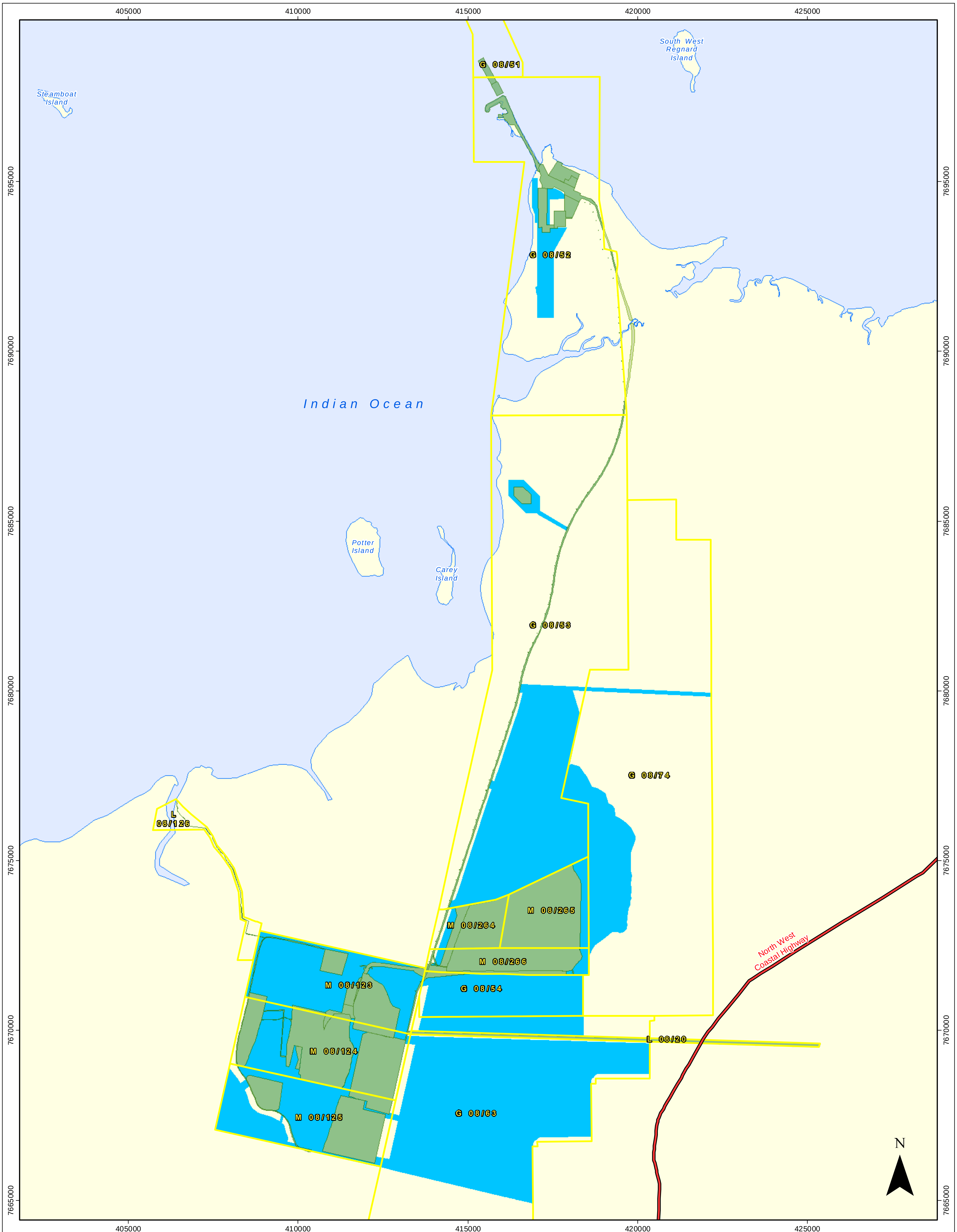
DATA SOURCES:
CITIC Pacific Mining Aerial Photography

RPS

FIGURE 8

PROPOSED SOUTH WEST WASTE ROCK DUMP
100 YEAR ARI FLOOD LEVELS

APPENDIX A:
SINO IRON PROJECT
DEVELOPMENT ENVELOPE



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SINO IRON

Conceptual Mine Continuation Development Footprint

0 1 2 3 4
Kilometres
1:100,000

Datum: GDA94
Projection: MGA Zone 50

Department:	ENV	Date:	14/12/2016
Sheet Size:	A3	Status:	DRAFT
Drawn by CF	Requested by DM/BW	Internal Reference 4381_02_2016_ENV	

Mining Tenements

Sino Conceptual Mine Continuation Development Footprint

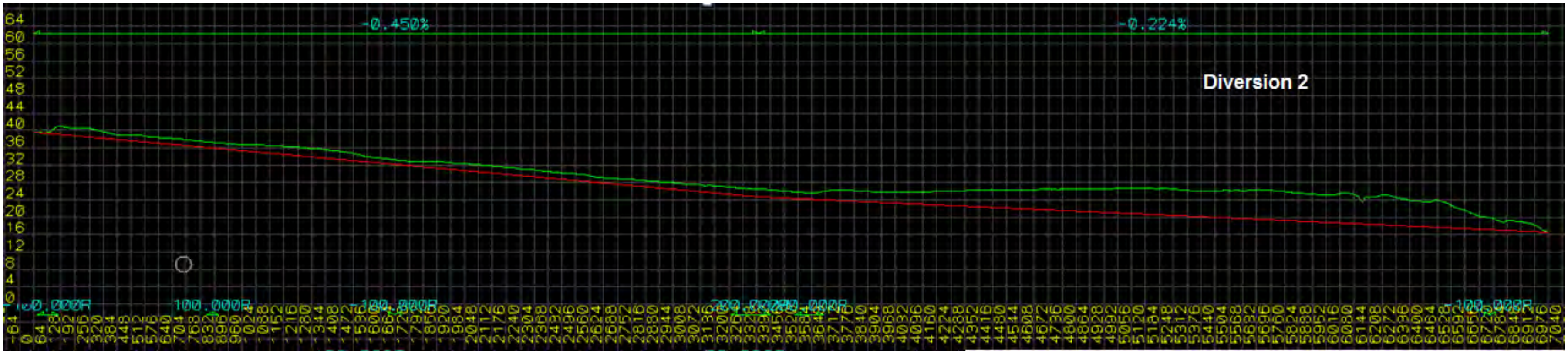
Sino Iron / MS635 Approved

Approved 27.6Mtpa Layout

IOPA / Area D

APPENDIX B: DIVERSION LONGITUDINAL SECTIONS


Diversion 1
-0.215%
-100.000R
1
2


-0.450%
-0.224%
Diversion 2

APPENDIX C:
LONG TERM DIVERSION CRITERIA AND PRINCIPLES

APPENDIX - DIVERSION CRITERION AND PRINCIPLES

1.1 General

A diversion is defined as a constructed channel that diverts or changes the course of water flow from a natural watercourse over a determined length in association with mining activity. Traditionally diversions have been largely designed to discharge a design flow rate, with limited to no consideration of stream geomorphic and ecological performance. Designs typically consist of a straight trapezoidal channel, possibly with drop structures to compensate for reduced channel length and an accompanying increase in bed slope. Rock / concrete bank protection may be used.

Creek diversions are a significant issue in Queensland and inform the discussion on diversions in the Pilbara. Several coal mines are outlaying considerable expenditures on rebuilding poorly performing diversions, in which the "original design engineers gave little or no consideration to fundamental fluvial processes and landform stability aspects including stream length restoration, batter stability and biodiversity values. Poor design outcomes impact the business reputation, make for non compliant outcomes and can have significant adverse impact on the business value" (ref. BMA, 2008).

1.2 Reasonable Objectives

A typical stream has natural features that develop through geomorphologic processes, and watercourse diversions should perform and function as natural stream systems, with appropriate hydraulic design underpinned by geomorphological principles. The intent of the design criteria recommendations is that the proposed diversion is expected to perform in a similar manner during runoff events to the existing channel, and be stable in the long term with similar hydraulic and geomorphic characteristics. It is possible to mimic natural stream characteristics (meanders, channel profiles, cross sections, riffles, vegetation, etc) to provide an environment where the new watercourse can continue to develop naturally with natural ecological recovery. Regional channel geometry relationships can serve as templates for design.

Velocity, shear stress and stream power should be similar to the existing creek, conveying similarly sized bank-full flood flows. The diversion channel should be stable over the mine life and beyond (i.e. not subject to significant erosion or sediment deposition); and should not result in detrimental impacts to the existing creek

1.3 Hydraulic (Abiotic) Factors

The more frequent flood events have the most geomorphologic influence on re-shaping channel cross-sections and alignments. These flows concentrate within the channel banks, and have the potential to produce velocities high enough to induce erosion within the channel. The flows tend to utilise the floodplain for floodwater attenuation, with lower cross-sectional velocities and less potential for erosion.

Large increases in stream power in a diversion are typically the result of (a) increasing channel slope; or (b) reducing the width of the floodplain and the associated potential for flood attenuation, thereby increasing flow depth / velocity (i.e. confining the floodwater to a smaller cross section); or (c) decreasing the channel resistance (friction) by a lack of vegetation and other flow obstructions.

Initially, creek diversion design should achieve the following functions:

- Where practicable, the existing stream length should be re-established (i.e. no short cuts).
- Hydraulic behaviour similar to that of the existing creek;
- Accommodation of bank-full flow events in terms of hydraulic capacity, sediment transport capacity, and erosion / deposition potential;
- Floodplain capacity retained;
- Meet stream length / stream power criteria.
- Riparian vegetation re-established so that ecosystem function is not adversely affected;
- No legacy resulting from a long-term permanent diversion.

1.4 Specific Stream Power (SSP)

Researchers have studied how watercourse diversions should perform and function as natural stream systems. Proposed thresholds have been suggested to predict the transition from unstable to stable states in natural incised channels. One of the most frequently applied is the 35W/m² threshold of specific stream power.

A quantitative estimate of this threshold 'stability point' was produced by Brookes (ref 1990) from assessing the stability of channelised perennial, gravel-bed streams in Denmark, England and Wales. Brookes concluded that when a stream has enlarged to the point that it has a specific stream power (SSP) below 35W/m², then the major phase of erosion is over. 35W/m² has been widely applied in stream rehabilitation work as it provides a neat target for waterway design and assessment. It is noted that other research has concluded that no stream power thresholds appear to predict the attainment of stability in incised channels.

Brookes provided guidelines for defining characteristics of depositional, stable and eroding channels. At low stream power, channels experience deposition. Stable channels usually display moderate stream power (say 10-35W/m²) and neither deposit nor erode sediment. When stream power is >35W/m², channels may erode, the problem progressively increasing as stream power increases.

1.5 ACARP 2002 (Australian Coal Industry Research Program)

An evaluation carried out by ACARP in 2002 found that many diversions were in poor condition largely due to accelerated erosion as a consequence of inadequate design width, increased bed slope as a result of shortening the channel length, increased velocities, absence of vegetation, dispersive soils and increased incidence of rill erosion and piping on banks. A small number of diversions were infilling with sediment due to the design of an over wide channel (White et al, 2014).

The 2002 ACARP research however found significant relationships for hydraulic parameters across three identified stream types (incised, limited capacity and partly bedrock confined). Design criteria were developed for more frequent (2 year ARI) and less frequent (50 year ARI) flow events for different stream types. The ACARP design criteria were adopted by Queensland regulators in 2002.

Velocity, stream power and shear stress and are defined as follows:

- Velocity - criteria selected to minimise the potential for damage to the channel through erosion associated with high flow velocities. There is no direct relationship between velocity and the force exerted on soil particles at the boundary, and shear stress and stream power provide a more reliable indicator of erosion potential. However where calculated velocities exceed the adopted velocity criteria / maximum allowable velocities, additional bank protection (increased vegetation density, or rock protection) will be required.
- Stream power - is a function of discharge, hydraulic gradient and flow width; and a useful indicator of hydraulic conditions reflecting the morphology of the channel, particularly for 'bank-full' flows. To minimise the change in stream power, diversion channels need to have a similar cross-section (channel and floodplain), hydraulic roughness (bed conditions and vegetation) and channel slope as the existing creek. High stream powers are indicative of elevated erosion potential.
- Shear stress - provides a measure of the tractive force acting on sediment particles at the boundary (bed, banks) of the stream, and is used to determine the threshold of motion for bed material. It provides an indication of the potential for erosion of cohesive sediments or movement of non-cohesive sediments.

1.6 ACARP 2014

Over 90 watercourse diversions have been constructed in coal mines in central Queensland over a 40 year period, replacing significant lengths of natural streams. Evaluation of the outcomes after 10 years since the 2002 ACARP guidelines indicated that the design and condition of new diversions had improved, however several issues still remained. The following improvements in diversion design and performance since 2002 were noted:

- No new permanent diversions have been constructed with drop structures (accepting that diversions need to operate as natural stream systems);
- Recognition of the importance of maintaining a bed grade similar to natural adjoining reaches;
- Multistage channel design to enable energy to be dissipated over terraces and benches;
- Spoil piles are located away from diversions limiting the supply of additional sediment;
- Provision for overland flow entry to diversions has improved, although further design guidance is required;
- Geomorphology and riparian vegetation of the river system is now considered part of diversion design process.

Five factors that consistently influence, and often limit the performance of diversions were most importantly sediment supply to the diversion and change in sediment transport capacity, and vegetation condition, as well as the entrance of overland flow drainage and occurrence of major flooding in early years of diversion establishment. The results noted that many diversions require some form of intervention to improve condition.

Queensland mine staff recognise the ACARP criteria as the industry standard, and that diversions should operate like a natural watercourse. However most mines are in an operational phase with a short term perspective, and diversions are typically considered by mine staff as temporary features, designed and maintained in isolation from the wider landscape. Time and resources are not being allocated to rehabilitating old diversions, as mine plans may change requiring diversions to be re-diverted in the future.

A refined ACARP design approach was developed with an update of the hydraulic and geomorphic criteria (ref. Queensland DNRW, 2014). This included:

- Explicit inclusion of channel and planform variability in the channel design;
- Threshold channel design to channel form (to protect the system and increase the confidence in success over the vegetation establishment phase, and protect adjoining infrastructure from extreme events);
- Alluvial channel design in regard to establishing alluvial processes, controlling erosion and maintaining sediment bed load transport capacity of the diversion in keeping with the creek natural adjoining reaches. The annual bed load capacity of the diversion reach is recommended to be within +/- 20 % of the natural adjoining reaches.

1.7 Threshold Design Approaches

Natural alluvial streams experience a wide range of discharges and adjust their shape and size during flow events which have sufficient energy to mobilise the channel boundary materials. Channel instability is the result of an imbalance in sediment supply and transport capacity.

A threshold channel allows only negligible movement of the channel boundary material during the design flow – the applied hydraulic forces are below the movement threshold of the boundary material. Design approaches include "permissible velocity"; or "allowable shear stress & tractive power" approaches. It can be noted that a watercourse designed for non-scouring velocities during a large design flow event would be subject to siltation in more frequent flood events.

In natural situations, a threshold channel may have a stream bed composed of very coarse material, erosion resistant bedrock, or clay soil - streams where the boundary materials are remnants of processes no longer active in the stream.

Major channel change can occur in diversions if flood events occur soon after diversion construction, since the influence of stabilising vegetation in the channel bed and banks is not present. A level of robustness is required prior to opening the diversion to stream flows and flood events. The threshold channel approach aims for negligible movement of the channel boundary material during the design flow, to protect the system and increase the chance of success vegetation is establishing.

Threshold design approaches include allowable velocity and allowable shear stress / tractive power approaches - the applied forces from the design flow are below the movement threshold of the boundary material.

1.8 Alluvial Design Approaches

An principles incorporated into the ACARP guidelines can be applied to the allowable hydraulic parameters for the diversion.

The "channel-forming discharge" to determine appropriate channel dimensions is the bankfull flow, commonly the 2 year ARI flow. The "channel-forming discharge" for design is required to determine appropriate channel dimensions, but there is no generally accepted agreed criteria. Suggestions include (a) the 1-2 year ARI flow as indicated above, but can be up to the 10 year ARI for ephemeral and intermittent streams), (b) the bankfull flow and (c) the flow that transports the most bed-material sediment.

The channel roughness (Mannings n) can be higher reflecting the goal of sediment aggradation (as opposed to the initially lower roughness due to bare earthworks or bare rock).

If there is no material constraint on flood levels, flood depths in the diversion in the short term may be higher than predevelopment flood heights. In a permanent diversion, the goal would be to match pre-existing flood levels with the use of flatter batter slopes, benches / floodplains as required.

The existing watercourse should be used as first preference to develop design parameters for the watercourse diversion.

Secondly, the 2014 ACARP hydraulic guideline values for velocity, stream power and shear stress can be used. The minimum requirement is to review the watercourse and diversion energy conditions for the 2 year and 50 year flood events, as follows:

Scenario	Stream Power (Watts/m²)	Velocity (m/s)	Shear Stress (N/m²)
2 yr ARI (no vegetation)	<35	<1.0	<40
2 yr ARI (vegetated)	<60	<1.5	<40
50 year ARI	<150	<2.5	<50

The 50 year criteria has been reduced as a result of the re-evaluation of the 2002 guidelines.

The two considerations can produce significantly different outcomes, and the natural creek itself may not meet the ACARP guidelines. The general requirements are to match the existing creek cross-section, a similar bed grade to maintain a similar sediment capacity, and preferably no drop structures.

A diversion channel through rock sections should resist erosion since the rock strata has a high threshold stream power.

A permanent watercourse diversion should not rely on rock chutes or grade-control structures to manage in-stream hydraulic conditions, where the structure would become a permanent feature of the landscape with no ongoing management. If drops are unavoidable, then they need to be overdesigned for a long life, including batter armouring to stabilise the banks up and downstream to control outflanking, a flatter grade on the rock-chute to trap sediment and establishment of vegetation throughout the rock armour.

Observation of existing diversions suggests that bed grade that are too "steep" are swept clean, while flat grades are require to acquire a mobile bed and vegetation to establish itself on a rock excavation. In rocky, one possible technique is to mimic a riffle-pool regime (which commonly occurs in nature at 5-7 stream widths) with the flat "pool" section followed by a small "riffle" or drop at regular intervals. Potentially, the predicted stream power for the 2-year ARI event would be limited by the stepped flat bed gradient provided, and alluvial processes will form a natural gradient. In the 50-year ARI event, the stepped gradient would tend to be drowned out.

Potentially, the flat sections would collect sediment and vegetation first, starting at the top, and then finally the riffles / drops would become buried as well to form the required overall gradient. It is likely that most creeks are sediment "supply limited", so this process is generally expected to take some time.

1.9 Biotic Factors

'A Rehabilitation Manual for Australian Streams' (Rutherfurd, Jerie and Marsh, 2000a; 2000b) is an important standard code of practice for the design and construction of river diversions.

Revegetation of the diversion earthworks must be achieved and it is necessary that species, planting densities, vertical zonation of species, seed sources, maintenance of genetic integrity, etc are considered in detail. A greenhouse and nursery may be required, with collection of local seed stocks. The erodibility of the material exposed / filled on the banks of the diversion channel must be considered to avoid rills and gullies before vegetation is established (in particular, dispersive soils should be stabilised with gypsum or lime to additionally prevent tunnels / pipes). Major bank erosion can be a source of failure.

Aquatic habitats, such as pools and riffles, should be included, to involve morphological complexity in the bed profile that creates diverse hydraulic conditions. It is also important to recreate the natural planform.

If the existing creek channels demonstrate large wood loadings, then appropriate sources of large wood should be identified (which do not remove existing trees from river channels). Large wood often induces scour that forms a range of pool types that are an important aquatic habitat.

A channel monitoring program, including biotic factors, should be considered in detail.

1.10 Channel at Closure

It is noted that major channel change can occur in diversions if flood events occur soon after diversion construction, based on the assumption that the resilience of the stream system increases with increasing development of stabilising vegetation in the channel bed and banks. A level of system robustness is required prior to opening the diversion to stream flows and flood events.

In the areas of residual soils nearer the ground surface, resilience can be improved with flatter batter slopes and topsoil and appropriate revegetation with local endemic plant species by seeding, to limit rilling and gullying. Dispersive soil should be identified for additional protection (removal or covering). Rock armour can be applied judiciously in potential points of scour to limit erosion during the first decade of operation, and assist in the process of sediment collection and stabilisation.

If any diversion capture bunds are required at closure, the bund like the channel would need to be rehabilitated to full ecological function, stable with factors of safety / conservatism to prevent failure, aesthetically compatible with the surrounding landscape, supporting native vegetation, and free draining and non-polluting.

Stable slopes should be investigated by testing particularly if waste material is used. All completed surfaces should be able to resist long term erosion. Generally, fine soil tends to increase erosion potential and limit the achievable stability of batters. More erodible materials such as those with high sand, clay, dispersive material, poorer topsoil require flatter slopes.

If very shallow slopes are required to avoid erosion and gullying, benching and a rock armour substrate can be applied. Topsoil can be applied and incorporated into the armouring layer by ripping along the contour. Revegetation forms part of the design, noting that the density of surface cover developed by the majority of vegetation in arid environments is likely to be too low to have a significant impact on erosion. Some additional rock armouring in the main flow area could also be beneficial to limit erosion during the first few years, and assist in the process of sediment collection.

1.11 Rehabilitation Performance Criteria

Rehabilitation works proposed during the active phase of mining will focus on ensuring that the constructed channel and the surrounding areas that contribute runoff to the channel are stable, so that the downstream parts are protected from the effects of sediment erosion, transport and deposition. The objective of this Rehabilitation Plan is to progressively return the creek diversion to a stable condition with resilient, self-supporting, local provenance vegetation. Key components of the Plan are;

Environmental Protection Authority (EPA) Guidance Statement No. 6 - Rehabilitation of Terrestrial Ecosystems (EPA, 2006), promotes the use of completion criteria for the rehabilitation of natural ecosystems, which (i) allow success to be measured within realistic timeframes, (ii) are sufficiently precise to allow outcomes to be effectively audited, but are also flexible when required, (iii) are based on sound scientific principles, and (iv) acknowledge the consequences of permanent changes to landforms, soils and hydrology. EPA (2006) recommends standard criteria that apply to all projects, as well as site specific criteria used to measure the recovery of ecosystems relative to reference sites.

There are a number of reference documents that outline 'best practise' approaches to creek restoration in Australia. In particular, 'A Rehabilitation Manual for Australian Streams' (Rutherfurd et al., 2000a; 2000b) has been adopted as the standard code of practice for the design and construction of river diversions in most Australian states. In Western Australia, the Water and Rivers Commission's report on Stream Stabilisation (WRC, 2001) provides a guideline for the rehabilitation and long-term management of waterways in WA.

Key objectives for the rehabilitation plan are provided below (refer Outback Ecology Services, "Spinifex Ridge Rehabilitation Plan - Coppin Creek Diversion Channel", September 2008):

Table 0.1: Key objectives, Methods of Assessment and Timing of the Rehabilitation Plan

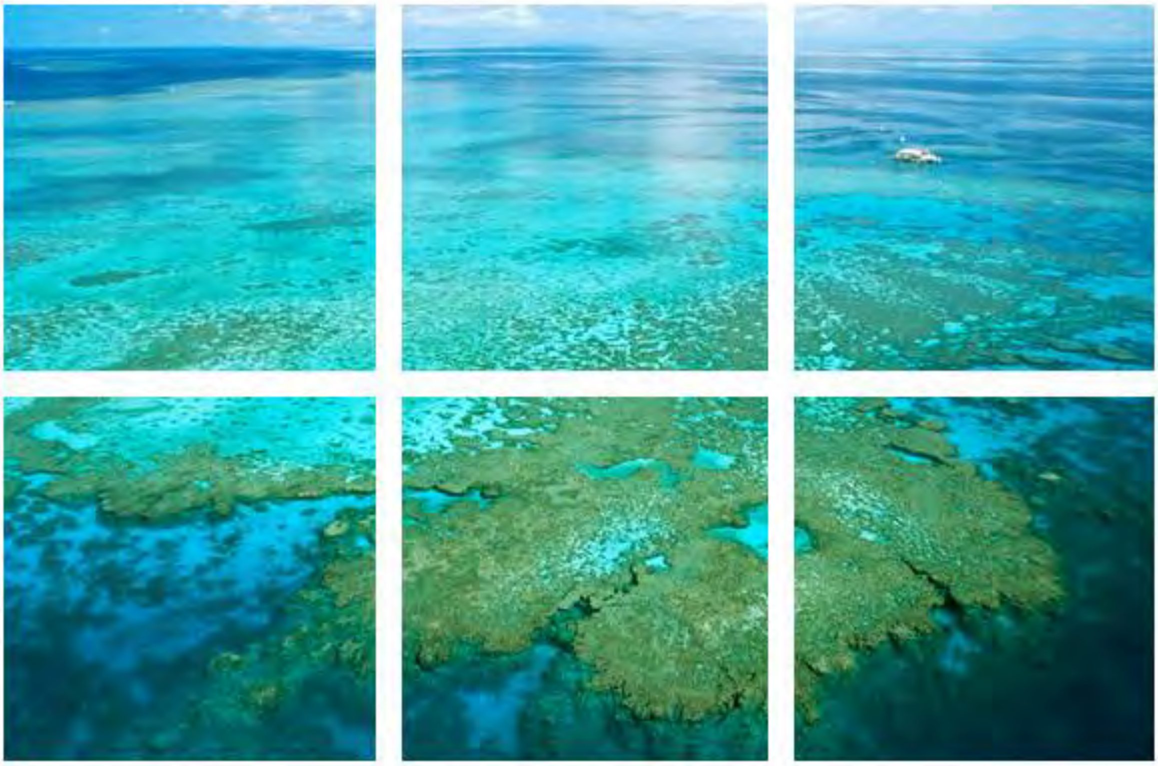
Area of interest	General Objective	Measurable Objective	Type of assessment	Timing
Physical form and channel morphology	Stable banks and floodplain areas so that downstream is protected from the effects of erosion, sediment transport and deposition	The banks of the major channels should be gently inclined as designed and be stable with no major erosive processes occurring. No major erosion of floodplain areas during major flow events	Bank stability assessment Point monitoring using photographic methods and semi-quantitative assessment	Annually for first 3 years and / or opportunistically following significant rainfall events
	Downstream sedimentation	No increase in sedimentation downstream from diversion channel	Rising Stage Samplers	Automated sampling following major rainfall events
Diversion vegetation	Revegetation of creek line vegetation community	After a defined time period to be defined through stakeholder consultation, the diversity and density of riparian vegetation of rehabilitation trial areas should be similar to baseline and control areas	Survey for vegetation diversity, density and health against baseline and control areas Ecosystem function analysis (EFA) transects	Annually following summer growth period
	Restrict weed establishment	Identification of key weed species to be excluded from rehabilitation areas	Vegetation surveys	Annual surveys and weed control as required
Aquatic ecology	Habitat heterogeneity along the diversion	Variation in geomorphology, vegetation communities	Survey of habitats using photo points, vegetation surveys, analysis of	During and after construction Annually for first 3 years

Area of interest	General Objective	Measurable Objective	Type of assessment	Timing
		and abiotic parameters	abiotic parameters	and / or opportunistically following significant rainfall events
	Presence of macroinvertebrates, periphytic diatoms, and algal groups	Return of community structure of macroinvertebrates and selected diatom assemblages within the diversion similar to that observed	Macroinvertebrate sweeps, collection of periphytic scrapings from the vegetation or the establishment of artificial substrates	As per above
	Establishment of emergent vegetation and macrophytes	Diversity of vegetation and increase / replenishment of seed bank (measure of resilience of a wetland)	Vegetation surveys and macrophyte observations when fluvial. If dry, sediment can be examined for remnants and resting stages	During flow periods for macrophytes As above for emergents plus examination of the sediment for resting stages
Hydrology	Comparable flow velocities	Comparable Flow	Flow velocities to be measured	Continuous / real time monitoring following major rainfall events
Water quality	Water quality to be comparable to pre-disturbance values	Physicochemical parameters within the background values of the baseline survey	Sampling of water quality including sediment loads	Opportunistically following major rainfall events
		No increase in sediment transfer	Sampling of sediments both in water and settled	

RPS APASA

Discharge Modelling Assessment

Fortescue River Outfall



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Contents

Executive Summary

CITIC Pacific Mining Management Pty Ltd (CPM) is investigating the potential to expand the discharge capacity of a soon to be commissioned outfall located near the mouth of the Fortescue River (116.10° E, 21.00° S), which is 10 km southwest of Cape Preston.

The present level of regulatory approval that has been granted by the Western Australian Department of Environment Regulation (DER) relates to a discharge rate of 2 GL/year. The approval was supported in part by an analytical and desktop assessment of the expected nearfield diffuser performance that was completed by RPS APASA (APASA 2016). The discharge is expected to be of variable density relative to the ambient waters (due to its salinity), with the most limiting constraint on the diffuser performance being related to relatively high salinity discharge cases. A performance criterion has been established that seeks to maintain median salinity values within 1.2 ppt above background within10-20 m of the diffuser. This is approximately equivalent to a 27 times dilution of the discharge in ambient waters based on expected river and discharge water qualities. The current regulatory approval is also conditional on the timing of the discharge being synchronised with the ebb tide.

More recently, CPM has estimated that higher flow rates than the approved 2 GL/yr might be required as mine operation levels increase over time. RPS APASA Pty Ltd (RPS ASASA) was requested by CPM to assess potential impacts of discharge scenarios with rates of flow equal to 6 GL/yr and 8 GL/yr. In addition to completing near field dilution assessments for these higher flow cases, it was also deemed necessary to perform an additional far field assessment to assess whether the natural diluting capacity of the River would be compromised by any persistent accumulation of the discharge. The far field assessment was conducted using a hydrodynamic model that included the lower Fortescue River. The model was successfully validated by comparison to water levels and current velocities that were recently measured within the river. The far field assessment was also carried out for the 2 GL/yr flow rate case.

The main outcomes of the study for the 2 GL/yr flow rate were as follows:

- The 2 GL/yr flow rate would require a diffuser of length equal to 21 m to be installed along a cross section of the river with the river width being approximately 190 m, ideally at a depth of at least 2.3 m below mean sea level (MSL).
- The median 27 times dilution target for salinity was predicted to be achieved at all near field and far field locations, including the discharge site.
- The 80th percentile dilution was generally above 50 times dilution at all locations, except near to the discharge site where it was in the range of 40 to 50.
- No significant accumulation of salinity was predicted over a 30-day time scale.
- Near to the discharge site the minimum dilution level may temporarily fall below the target threshold in episodic events of short duration (~1 hour). These events are more likely to occur near the end of a discharge period (i.e. approaching slack water) and during neap tides.

The main outcomes of the study for the 6 GL/yr flow rate were as follows:

- The 6 GL/yr flow rate would require a diffuser with an effective length equal to 63 m to be installed along a cross section of the river with the river width being approximately 190 m, ideally at a depth of at least 2.3 m below mean sea level (MSL).

- The median 27 times dilution target for salinity was predicted to be achieved at all near field and far field locations, including the discharge site.

- The 80th percentile dilution was generally above 50 times dilution at most locations in the river. However, dilutions in the range of 30 to 40 times were observed up to around 175 m downstream from the discharge location, and dilutions in the range of 40 to 50 times were observed up to around 350 m downstream from the discharge location.

- No significant accumulation of salinity was predicted over a 30-day time scale.

- Near to the discharge site the minimum dilution level may temporarily fall below the target threshold in episodic events of short duration (~1 hour). These events are more likely to occur near the end of a discharge period and during neap tides.

The main outcomes of the study for the 8 GL/yr flow rate were as follows:

- The 8 GL/yr flow rate would require a diffuser with an effective length equal to 84 m to be installed along a cross section of the river with the river width being approximately 190 m, ideally at a depth of at least 2.3 m below mean sea level (MSL).

- The median 27 times dilution target for salinity was predicted to be achieved at all near field and far field locations, including the discharge site.

- The 80th percentile dilution was generally in the range of 40 to 50 times dilution at most locations. Dilutions in the range of 30 to 40 times were observed up to around 400 m downstream from the discharge location. Dilutions in the range of 27 to 30 times were observed at the actual discharge location. This suggested that the capacity of the river to dilute the discharge in the far field to below target was not exceeded but was approaching its limit.

- No significant accumulation of salinity was predicted over a 30-day time scale.

- Near to the discharge site the minimum dilution level may temporarily fall below the target threshold in episodic events of short duration (~1 hour). These events are more likely to occur near the end of a discharge period and during neap tides.

1.0 Introduction and Background

CITIC Pacific Mining Management Pty Ltd (CPM) is investigating the potential to expand the discharge capacity of a soon to be commissioned outfall located near the mouth of the Fortescue River (116.10° E, 21.00° S). The Fortescue River is approximately 10 km southwest of Cape Preston and the outfall location is approximately 1 km upstream from the mouth (Figure 1-1 and Figure 1-2). The river is tidally influenced and is essentially an estuary at the outfall location.

The present level of regulatory approval that has been granted by the Western Australian Department of Environment Regulation (DER) relates to a 2 GL/year discharge, however, present estimates are that up to around 8 GL/yr may require disposal as mine operation levels increase over time.

The 2 GL/year regulatory approval was supported in part by an analytical and desktop assessment of the expected nearfield diffuser performance that was completed by RPS APASA (APASA 2016). The predicted performance of the diffuser under the designed discharge regime indicated that the targeted centreline dilution level would be achieved within a horizontal scale of approximately less than 10 m in quiescent flow conditions. The existing DER approval has specified that the diffuser should generate the required dilution within 10-20 m of the discharge point. A conceptual design for a nearfield diffuser was developed by RPS APASA (APASA 2016). The conceptual design has 14 ports with diameter of 0.1 m and 1.5 m spacing for a total length of 21 m. The diffuser is to be orientated directly across the river bed and all ports are to be directed downstream and angled 60° upwards from the river bed. It was recommended that a specialist design engineering firm should complete the detailed aspects of the diffuser design including assessment of the required pumping levels, delivery pipe sizes and materials.

The outfall discharge stream consists of mine in-pit water from dewatering operations. The source water will be abstracted from a series of in-pit sumps and pumped to ‘turkey’s nest’ ponds for temporary storage prior to discharge. The feeder pipe to the diffuser outlet will enter the river from its eastern bank and connect to the diffuser intake that will be submerged along a cross section of the river bed. CPM advises that the feeder pipe will connect with the diffuser intake approximately 25 m directly offshore from the low water line.

The precise location of the diffuser has not been finalised, but the approximate location has been provided by CPM (116.0981° E, 21.00968° S). This location was selected as it represents a good compromise between dilution performance and practical considerations, such as land tenure and potential for terrestrial disturbance. At the proposed discharge location the river is approximately 190 m wide at low water level and its depth ranges from approximately 2 m to 4 m below MSL.

The current regulatory approval is conditional on the discharge from the outfall being synchronised with the ebbing tide to minimise upstream migration of the discharge water. Discharge is scheduled to commence 30 minutes after the turning of the tide and will cease 1 hour prior to the next low tide.

The discharge stream is hypersaline, potentially also containing elevated levels of nitrate and metals (boron, copper, nickel and zinc). There could also be potential for the discharge water to have a pH, temperature or dissolved oxygen concertation that varies from the receiving waters. However, test results for in-pit groundwater and in-river samples that were commissioned by CPM in April 2013 and June 2015, and which were presented to the DER as part of the previous approval, have indicated that the concentrations of metals and nutrients in the undiluted source water were below the 80% marine protection levels specified in ANZECC (2000) Guidelines (Tropical Australia), except for one of the two nitrate samples. To account for the possibility that concentrations of nutrients and metals may change over time, CPM have undertaken with the

DER to sample nutrients and metals on a monthly basis (during periods of active discharge) at the discharge site and at two additional sites 1 km further upstream and 1 km downstream.

Based on the expected concentrations of potential contaminants in the discharge and the relevant threshold concentrations for each contaminant, the initial water quality variables of most relevance were salinity, temperature and nitrate. Based on the expected ranges for these variables salinity was clearly identified as the discharge contaminant that will require the highest dilution to achieve its concentration target. The salinity of the discharge stream will increase over the life of the mine due to the changing nature of the mining operations. The discharge stream is expected to eventually reach a maximum concentration of 70 ppt. The regulatory salinity target is for median salinity concentration to be no more than 1.2 ppt above median ambient background at a suitable reference site. If the background salinity is assumed to be 37 ppt, this implies that a 27 times dilution is required.

RPS ASASA was requested by CPM to assess potential impacts of discharge scenarios with higher rates of flow, up to around 8 GL/yr. For these higher flows a more detailed assessment than the previous near field study was considered necessary. Specifically, the dilution of near field discharge into the far field scale (i.e. scales greater than ~15 m) needed to be assessed with a hydrodynamic model. The purpose of the hydrodynamic modelling is to ensure that the natural diluting capacity of the River isn't compromised by any persistent accumulation of discharge contaminants (i.e. salinity in this case). This objective is significant because persistent accumulation of salinity would reduce the dilution capability of the river and invalidate the assumptions adopted in the near field modelling.

Figure 1-1: Map approximately indicating the proposed discharge location in the Fortescue River.

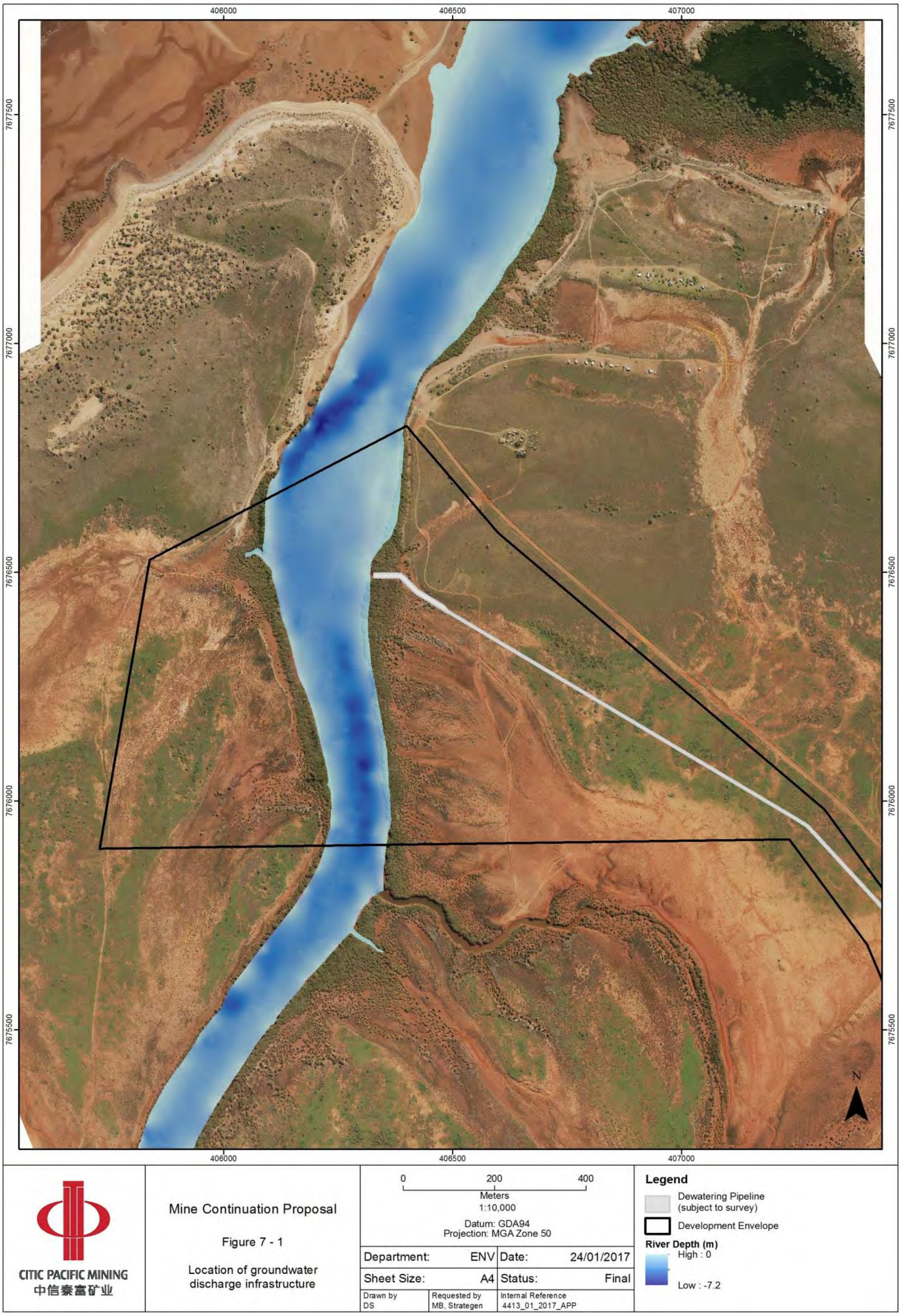


Figure 1-2: Map indicating the proposed installation path of the feeder pipe to the river discharge location

2.0 Scope of Work

RPS APASA has previously developed and validated a hydrodynamic model framework for CPM that spans the coastline around Cape Preston and offshore. The scope of work for this study involved refining and adapting that model framework to include the Fortescue River as a new sub-domain.

The new hydrodynamic model was to be run for a 15 to 30 day simulation period and was to be validated by comparison to 15 days of field measurements from an instrument deployed in the Fortescue River.

The validated hydrodynamic model framework was to be used to assess three potential discharge scenarios:

- Case A: intermittent discharge with a flow rate of 2 GL/yr. This case represents the flow rate and ebb tide discharge schedule that has been approved by the DER, that is, commencing 30 minutes after the turning of the tide and ceasing 1 hour prior to the next low tide. The outfall consists of one diffuser unit that is 21 m in length.

- Case B: intermittent discharge with a flow rate of 6 GL/yr. This case uses the same ebb tide discharge schedule as Case A. To manage the higher flow rate it is assumed that the outfall diffuser from Case A will be extended across the river by two additional 21 m diffuser units installed in serial, giving a total diffuser length of 63 m.

- Case C: intermittent discharge with a flow rate of 8 GL/yr. This case uses the same ebb tide discharge schedule as Case A. To manage the higher flow rate it is assumed that the outfall diffuser from Case A will be extended across the river by three additional 21 m diffuser units that will be installed in serial, giving a total diffuser length of 84 m.

For all cases, the salinity and temperature of the outfall discharge was specified by CPM to be 70 ppt and 20°C, respectively. The temperature selected was conservative, as explained in Section 3.2.

The scope of the assessment for each discharge scenario was to involve the preparation of salinity dilution maps for each scenario to demonstrate the potential zone of influence within the River, with a focus on the 27 times dilution threshold for salinity at a height 0.5 m above the river bed. This height above the river bed was selected because it is consistent with typical field sampling practices when dense plumes or intrusions are expected. The median and 80th percentile dilution values were extracted from the model for the analysis depth to allow comparison to the relevant water quality criteria.

3.0 Near Field Discharge Modelling

3.1 Background

A nearfield dilution assessment for the Case A discharge rate of 2 GL/yr was previously completed by RPS APASA (APASA 2016). The purpose of the previous assessment was to establish the required parameters for the detailed engineering design of a diffuser that would achieve the target of 27 times dilution for salinity within 10-20 m of the discharge location.

The proposed diffuser design was a ‘coflowing’ style diffuser (Figure 3-1), which is recommended in the case of unidirectional flow (Roberts, 2011). Unidirectional flow is an appropriate assumption because of the ebb tide discharge schedule.

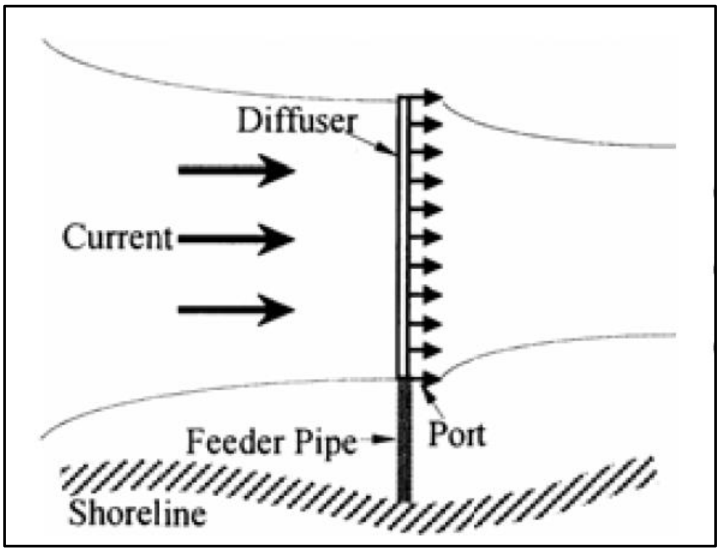


Figure 3-1: Plan view of a “Coflowing” style diffuser (source: Roberts, 2011)

The previous assessment was done using the scaling method of Roberts et al (1997) and Roberts and Sternau (1997). The scaling method assumed that the diffuser ports would be orientated 60° above the horizontal (Figure 3-2), which has historically been considered a “de facto standard” for dense discharges (Bleninger and Jirka, 2008). However, studies by Bleninger and Jirka (2007) suggest that there is likely to be very little difference in the initial dilution performance for ports oriented between 30-60°.

The results of the scaling method indicated that a conceptual diffuser solution with 14 ports, each 0.1 m in diameter, would provide an initial dilution of 27 in stagnant conditions (i.e. S_m at a distance X_m in Figure 3-2). This dilution represents the centreline value of a Gaussian shaped plume (worst case) rather than an across plume average, which would have a higher dilution than the centreline. The downstream mixing zone (i.e. the near-field zone to distance X_m in Figure 3-2), was predicted to extend 10 m downstream in the absence of currents. With downstream currents of 0.1 m/s the mixing zone may extend 50% further downstream. The terminal rise height of the plume was expected to be approximately 2.3 m above the diffuser port outlets. Given the rise height of the plume may exceed the depth of the water at lower tides, it is possible that the plume could intersect the surface. This would create a visual cue at the discharge location and reduce the dilution efficiency.

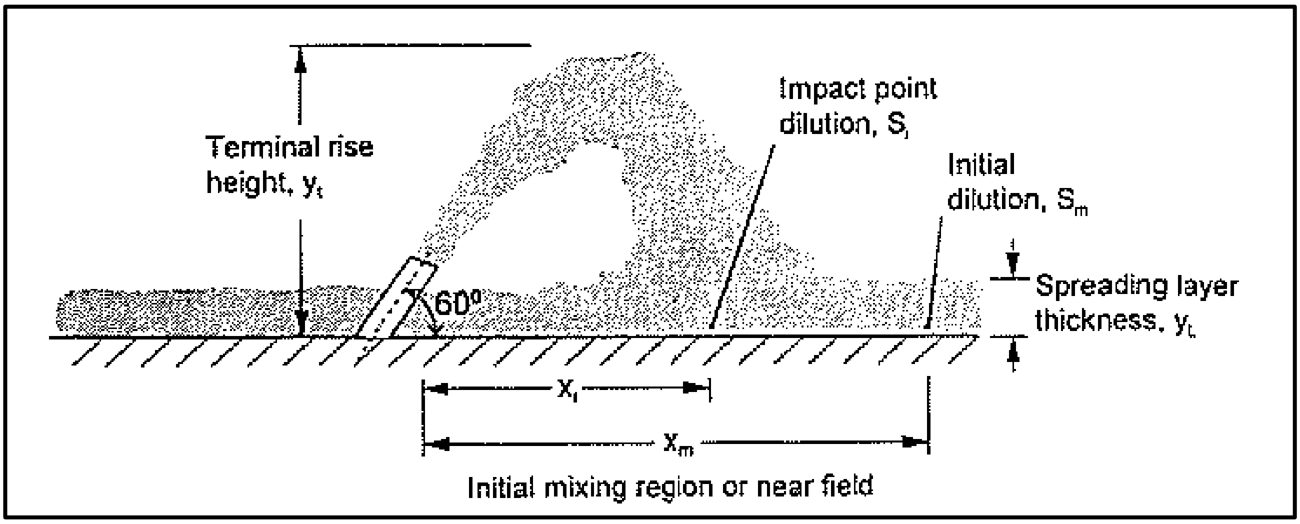


Figure 3-2: Characteristics of a dense jet (source: Roberts and Sternau 1997)

The scaling analysis does not directly provide the port spacing requirements, however this was separately assessed via a sensitivity assessment using Visual Plumes.

3.2 Discharge Considerations

The 70 ppt salinity that was specified for all cases is considered by CPM to be representative of the worst case (i.e. the densest case). The discharge and estuarine water temperatures will vary seasonally and the former may also be subject to additional heating within the supply pipes. However, even when temperature is at the high end of its expected range due to this effect (~65°C) the hypersaline discharge is still expected to be dense relative to ambient waters. Therefore, a model discharge temperature of 20°C was chosen from the lower end of the expected range because this leads to a worst case density. The higher the density difference the more mixing energy that is required to achieve a given dilution.

The ambient salinity in the Fortescue River was assumed to be constant at 37 ppt for the purposes of the modelling, and for calculation of dilution results. This salinity value is within the range of those measured in the Fortescue River by CPM in 2015 (i.e. 36.4 to 42.2 ppt). In practice, the ambient salinity may on occasion be reduced significantly by freshwater inflows from the Fortescue River following cyclonic rain. This case was not modelled because it was assumed that increased flow and turbulent mixing would enhance dilution and flushing in the river relative to the base case of tide only forcing (considered in the desktop assessment). These turbulence effects are assumed to dominate over an opposing effect that would be caused by a relative increase in plume density due fresher ambient waters.

3.3 Near Field Dilution Results

The near field scaling analysis completed previously (APASA 2016) was revised for the 2 GL/yr case to take account of a slightly revised discharge temperature. In addition, the scaling analysis method was extended to cover the two new flow rates of 6 GL/yr and 8 GL/yr. It was determined that the most efficient diffuser arrangement in terms of dilution would involve replicating the design of the 2 GL/yr diffuser unit (i.e. 21 m diffuser) on a pro rata basis for the higher flow rates. Each additional diffuser unit required would be installed in serial, with each diffuser extending further outward into the river to minimise interaction. The results of the scaling analysis are summarised in Table 3-1.

Table 3-1: Results of near-field scaling analysis following Roberts and Sternau (1997)

	Case A	Case B	Case C
Flow Rate (GL/yr)	2	6	8
Temperature (°C)	20	20	20
Salinity (ppt)	70	70	70
Density of Discharge (kg/m^3)	1052	1052	1052
Number of Ports	14	42	56
Port Diameter (m)	0.1	0.1	0.1
Terminal Rise Height Y_t (m)	2.3	2.3	2.3
*Impact Dilution S_i	16.6	16.6	16.6
*Initial Centreline Dilution S_m	27.0	27.0	27.0
*End of Mixing Zone X_m (m)	9.4	9.4	9.4
*Thickness of Bottom Layer y_L (m)	0.7	0.7	0.7
Total Diffuser Length (m)	21	63	84
Shoreline Offset Length From Low Water Line (m)	~25	~25	~25

*Following definitions of Roberts and Sternau (1997), see Figure 3-2

4.0 Far Field Discharge Modelling

4.1 Local Ocean Characteristics

The inshore region of the North West Shelf that is offshore from the Fortescue River experiences strong tidal flows, with wind driven flow being a secondary forcing mechanism. The influence of large scale systems, such as the Leeuwin Current oceanic eddies is lessoned in the nearshore regions, where shallow water, high tides ranges and complex topography are prominent.

Tidal currents are strongly steered by the bathymetry in the shallow areas among the islands and along the coast of the Pilbara region within which Cape Preston and the Fortescue River mouth are located. Tides are typically macro-tidal and semi-diurnal in the region, fluctuating over spring-neap cycles with a period of approximately 14.5 days. The typical spring tidal range at Cape Preston is around 4.7 m (GEMS, 2009).

In the region around Cape Preston the flood tide flows around the Montebello Islands towards the coast, and towards the southwest and southeast around Cape Preston. The ebb tide flows north to northwest around the Montebello Islands towards the open ocean. Current measurements from around the site show speeds generally up to 1 knot, with little ambient thermal stratification observed.

4.2 Hydrodynamic Model Development

To simulate the hydrodynamics surrounding the discharge and the adjacent regional area, a three-dimensional model with accurate representations of the bathymetry, bottom roughness and spatially-varying wind stress was utilised for the region. The model framework was developed through the combination of a large-scale regional model with smaller refined regions, allowing for the inclusion of baroclinic processes which govern the impact of buoyancy-dominated sources such as the discharge stream of pit water.

The Delft3D-FLOW (D3D-F) model, which is the hydrodynamic component of the Delft3D suite of modelling products developed by Deltares, is ideally suited for representing the hydrodynamics of complex coastal waters, including regions where the tidal range creates large intertidal zones and where buoyancy processes are important.

D3D-F is a multi-dimensional (2-D or 3-D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena that result from tidal, meteorological and baroclinic forcing on a rectilinear or a curvilinear, boundary-fitted grid. In three-dimensional simulations, the vertical grid can be defined following the sigma coordinate approach, where the local water depth is divided into a series of layers with thickness at a set proportion of the depth.

D3D-F allows for the establishment of a series of interconnected (two-way, dynamically-nested) curvilinear grids of varying resolution; a technique referred to as “domain decomposition”. This allows for the generation of a series of grids with progressively increasing spatial resolution, down to an appropriate scale for the accurate resolution of the hydrodynamics associated with features such as rivers, inlets or dredged channels. The main advantage of domain decomposition over traditional one-way, or static, nesting systems is that the model domains interact seamlessly, allowing transport and feedback between the regions of different scales. The ability to dynamically couple multiple model domains offers a flexible framework for hydrodynamic model development.

D3D-F has been used for a vast array of applications all over the world, and is considered to be a reliable and robust model for oceanic, coastal, estuarine, riverine and flooding applications. The model adheres to the International Association for Hydro-Environment Engineering and Research guidelines for documenting the validity of computational modelling software, closely replicating an array of analytical, laboratory, schematic and real-world data.

Inputs to the model included:

- Bathymetry of the study area, including shipping channels, islands, and adjacent features. The wetting and drying of the intertidal zones was simulated in applicable areas.
- Boundary forcing data, including water elevations, temperatures, and salinities.
- Spatially-varying surface wind and pressure data.
- A suitably-defined bottom roughness grid.
- The discharge specifics.

Note that waves were not modelled in this study, with the effects considered to be of sufficiently low order to the mixing and dispersion and general hydrodynamics to warrant exclusion.

River inflows from the upstream catchment were not considered in the model. The effects of upstream river inflow were considered to be small relative to the influence of the tide at the proposed discharge site. This is considered a conservative assumption as additional downstream freshwater flow would increase the amount of energy available for mixing.

4.2.1 Bathymetry and Domain Definition

The hydrodynamic model was established over the broad domain shown in Figure 4-1 and Figure 4-2. The bathymetry was developed using data from Geoscience Australia and from the C-MAP electronic chart database, supplemented in the nearshore Cape Preston region with high-resolution multi-beam survey data supplied to RPS APASA by CPM. Bathymetry data for the Fortescue River was also supplied to RPS APASA by CPM. The Fortescue River bathymetry data set was surveyed in December 2016 with a remotly operated hydrographic boat.

Accurate bathymetry is a significant factor in development of a model framework for dense discharge fate assessment, given that the behaviour of high-salinity plumes is dependent on the local seabed slope and general topography. The composite bathymetric data was interpolated onto the D3D-F Cartesian. The resultant bathymetry is shown in Figure 4-3. Note that depths are stated relative to Mean Sea Level (MSL), with positive values below MSL and negative values above MSL, and that the extent and shape of the coastline changes as water levels rise and fall with tidal movements.

The vertical grid of the model comprised up to 20 layers of varying thickness, depending on location. Twenty layers were applied in the near vicinity of the discharge location, with 10 layers applied to the majority of the surrounding region. As the model was set up as a proportional sigma grid in the vertical, these layers therefore represented a seabed following arrangement with layer thickness of 10% (10 layers case) or 5% (20 layers case) of the total water depth.

To offset the computational effort required for a large, multi-layered model domain, and to achieve adequate spatial and temporal resolution, a multiple-grid (domain-decomposition) strategy was applied using several sub-domains of varying horizontal grid cell size, which are indicated in Figure 4-1 to Figure 4-3. A horizontal resolution of approximately 16 m was used for the region around the discharge point (sub-grid 4), 50 m for the surrounding region (sub-grid 3), 100 m for the intermediate region (sub-grid 2), and 2 km for the outer domain region (sub-grid 0). Each sub-domain is an individual hydrodynamic model simulated in parallel with the others, with dynamic coupling at the shared boundaries between sub-domains. The outermost sub-domain captured large-scale oceanographic phenomena, which progressively fed into the finer-resolution domains representing the area of interest. The resolution of the innermost sub-domain was specified after assessment of the likely behaviour of the discharge dynamics and balancing practical computation constraints.

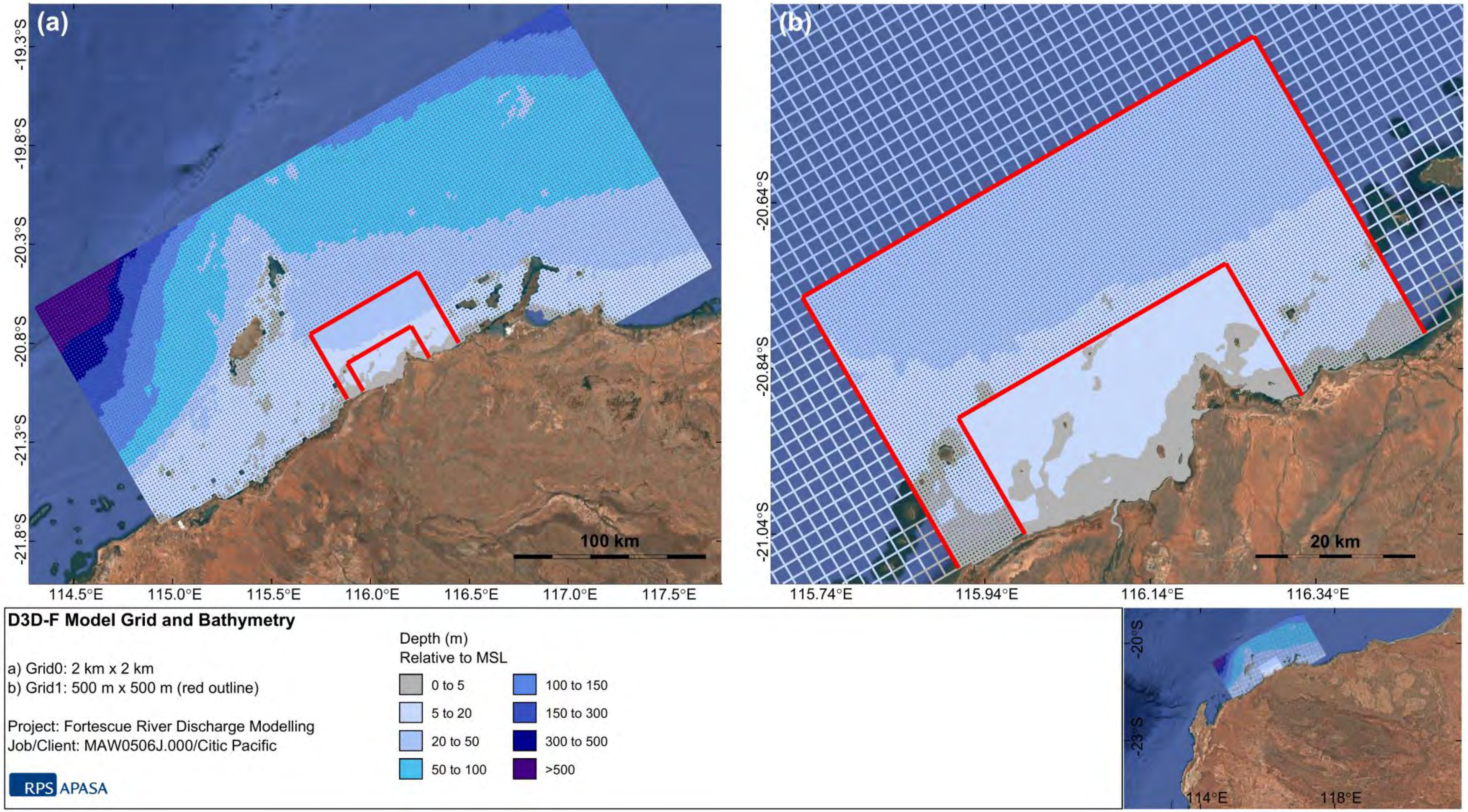


Figure 4-1: Model grid setup showing the outer model grid (grid0) and domain-decomposition scheme applied for the adjacent inner grid (Grid1).

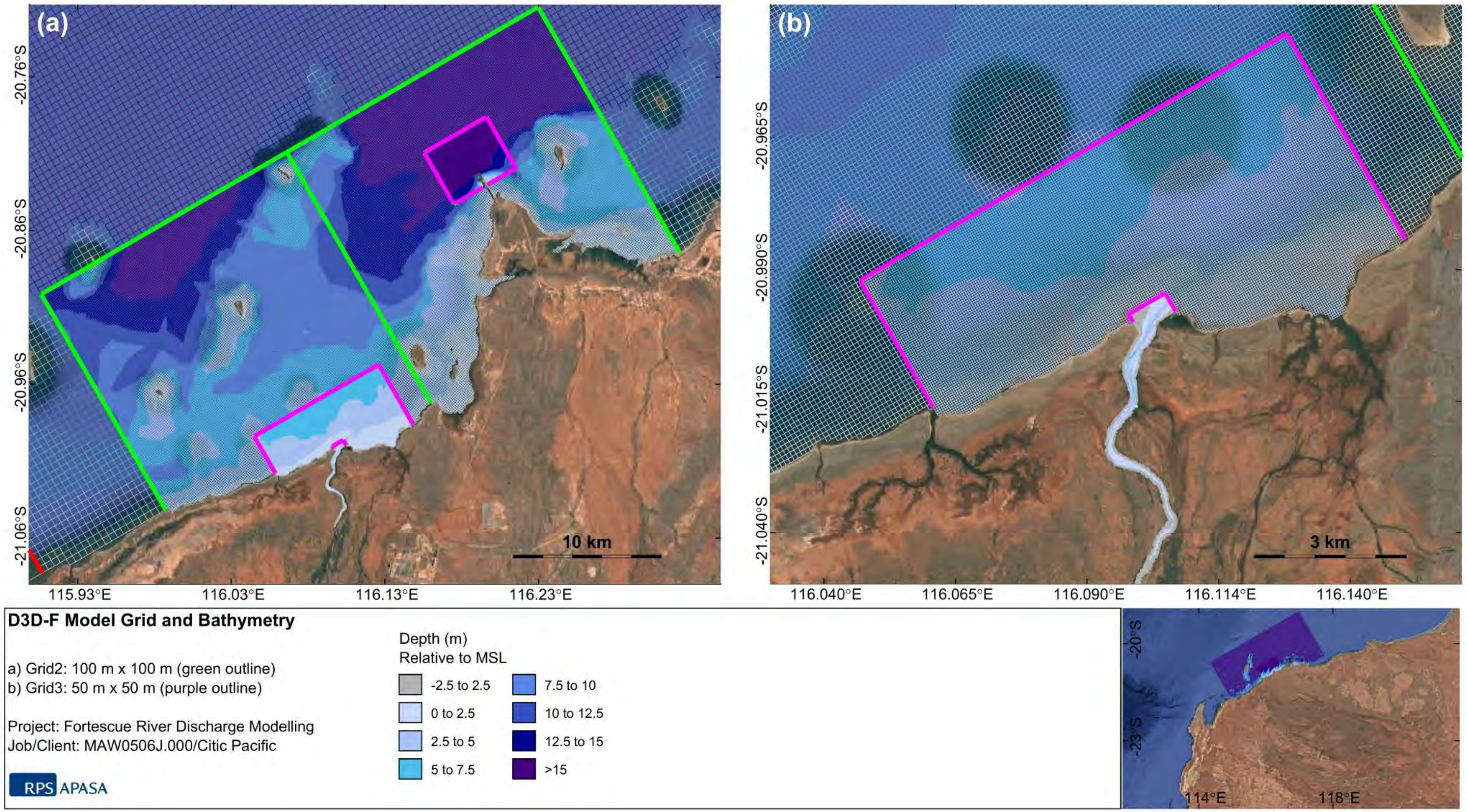


Figure 4-2: Model grid setup showing the bathymetry and domain-decomposition scheme applied for the connection of intermediate scale grids. The 100 m scale grid (Grid2) was split for computational efficiency. The 50 m scale grids cover two separate regions. Panel (b) shows the 50m scale Grid3 region that surrounds the Fortescue River, which was the focus area for this study.

Figure 4-3: Model grid setup showing the bathymetry and domain-decomposition scheme applied for the connection of the fine scale (16 m x 16 m) Fortescue River grid (Grid4)

4.2.2 Boundary Conditions and Model Parameters

4.2.2.1 Overview

As the hydrodynamics in the study area are controlled by tidal flows, density-driven flows and wind forcing, these processes were explicitly involved in the developed model.

The model was forced on the open boundaries of the outer sub-domain with time series of predicted water elevation for the chosen simulation period. Spatially-varying wind speed and direction data was used to force the model across the entire domain.

The tidal, density, and wind forcing data time series were linearly interpolated by D3D-F to suit the hydrodynamic model time-step, which was set at 15 s to comply with the Courant number requirements of the model, including the Fortescue River grid.

The horizontal eddy viscosity parameters used for the model were sent within the recommended range of model settings (Deltares 2013) and ranged from 100 m^2/s for the coarsest grid to 3 m^2/s for the finest grid. The horizontal eddy diffusivity parameters used for the model ranged from 1 m^2/s for the coarsest grid to 0.05 m^2/s for the finest grid. Turbulence was modelled using the k-Epislon scheme.

The bottom roughness was set using a uniform Chezy coefficient of 65 $m^{1/2}/s$. This roughness value was the same for all domains.

4.2.2.2 Water Elevation

Water elevations at hourly intervals were obtained from the TPXO8.0 database, which is the most recent iteration of a global model of ocean tides derived from measurements of sea-surface topography by the TOPEX/Poseidon satellite-borne radar altimeters. Tides are provided as complex amplitudes of earth-relative sea-surface elevation for eight primary (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1), two long-period (M_f, M_m), and three non-linear (M_4, MS_4, MN_4) harmonic constituents at a spatial resolution of 0.03° in this region.

The tidal sea level data were augmented with non-tidal sea level elevation data from the global Hybrid Coordinate Ocean Model (HYCOM; Bleck, 2002; Chassignet *et al.*, 2003; Halliwell, 2004), created by the USA's National Ocean Partnership Program (NOPP) as part of the Global Ocean Data Assimilation Experiment (GODAE). The HYCOM model is a three-dimensional model that assimilates observations of sea surface temperature, sea surface salinity and surface height, obtained by satellite instrumentation, along with atmospheric forcing conditions from atmospheric models to predict drift currents generated by such forces as wind shear, density, and sea height variations and the rotation of the Earth.

The HYCOM model is configured to combine the three vertical coordinate types currently in use in ocean models: depth (*z*-levels), density (isopycnal layers), and terrain-following (σ-levels). HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to *z*-level coordinates in the mixed layer and/or unstratified seas. Thus, this hybrid coordinate system allows for the extension of the geographic range of applicability to shallow coastal seas and unstratified parts of the world ocean. It maintains the significant advantages of an isopycnal model in stratified regions while allowing more vertical resolution near the surface and in shallow coastal areas, hence providing a better representation of the upper ocean physics than non-hybrid models. The model has global coverage with a horizontal resolution of $1/12^{th}$ of a degree (~7 km at mid-latitudes) and a temporal resolution of 24 hours.

4.2.2.3 Water Temperature and Salinity

Salinity and temperature in the model were set to a uniform initial constant value of 29°C and 37 ppt, respectively. These constant values were maintained at the model open boundaries at all times and no surface heat fluxes were permitted. Therefore, the only source of temperature and salinity variability in the model was the temperature and salinity of the discharge into the Fortescue River.

4.2.2.4 Surface Winds and Pressure

Wind and pressure data was sourced from the “Reanalysis 1” variant of the Climate Forecast System Reanalysis (CFSR) model (Saha *et al.*, 2010). This model, operated by the National Center for Environmental Prediction (NCEP) in the USA, is a fully-coupled, data-assimilative hindcast model representing the interaction between the Earth’s oceans, land and atmosphere. The gridded data output is available at 0.25° resolution and 1-hourly time intervals.

4.2.3 Hydrodynamic Model Implementation of Near Field Discharge

For this study, a horizontal grid scale of 16 m was used for the Fortescue River subdomain. This length scale was considered to be a good balance between practical computational considerations, near field diffuser and dilution characteristics and other process resolution.

The grid length approximately matches the mixing zone length found from the near field scaling analysis (~10 m). A grid length scale slightly longer than 10 m is appropriate, particularly given that the mixing zone length was based on quiescent flow conditions and may extend by around 50% at current speeds of 0.1 m/s (APASA 2016).

A further consideration for the grid scale was the length of the proposed diffuser units. The angle of the model grid relative to the downstream direction at the discharge location is approximately 40° (Figure 4-4). Therefore, the 'across stream' width of the model grid is roughly equal to the diagonal length of the grid (22.6 m), and this is convenient as it approximately equals the width of a single diffuser unit (21 m). This implies that for the Case A flow rate of 2 GL/yr, the single diffuser unit required can be represented as spanning one grid cell (i.e. green shaded cell, Figure 4-4).

For the higher flow rate cases, additional discharge source cells were added to the model setups as indicated in Figure 4-4. Although the Case B flow rate of 6 GL/yr would ideally be represented with three model discharge source cells, it was decided that four grid points in total were needed (i.e. red and green shaded cells, Figure 4-4). This was to ensure that the representation of the diffusers would be continuous across the river; three source cells would have led to a virtual gap in the model due to the model grid diagonal not being exactly orientated in the across stream direction.

It was considered that such a gap might lead to artefacts in the dilution results so one additional cell was added to close the virtual gap. The discharge rates for the source cells unique to Case B (i.e. red shaded cells) were adjusted to account for the additional cell so that the discharge volume was conserved. For the Case C flow rate of 8 GL/yr only one additional source cell needed to be added (i.e. yellow shaded cell, Figure 4-4).

From the perspective of the D3D-F model, the combined discharge from the all of the diffuser ports that are located within a particular model grid point are integrated to give a single flow rate for that grid point. The initial concentration of the discharge in the far field model is the same as in the diffuser pipe (i.e. 70 ppt). However, the nearfield dilution is implicitly accounted for by the fine grid scale in the far field model. That is, an instantaneous dilution occurs when the discharge is distributed according to the volume of the far field model grid cell. The finest model grid scale was selected such that this dilution approximately matches the near field dilution results.

D3D-F allows discharges to be constrained to specified sigma depth layers but not specific depth ranges. In this case, practical considerations led to a decision to distribute the discharge evenly over the full depth. Under this approach, at lower tides, the depth of the water column approximately matches the thickness of the dense bottom plume predicted by the near field modelling (~0.75 m). At higher tides the near field dilution performance may be overestimated, but mass will still be conserved in the far field. It is worth noting that the near field modelling predicted overall plume rise heights through the full water column during most tides, and given the scales considered here, full depth application was considered appropriate. Further, as the limiting dilution cases were more likely to be associated with low water phases it was important not to understate the plume thickness at these times because this would be overly conservative.

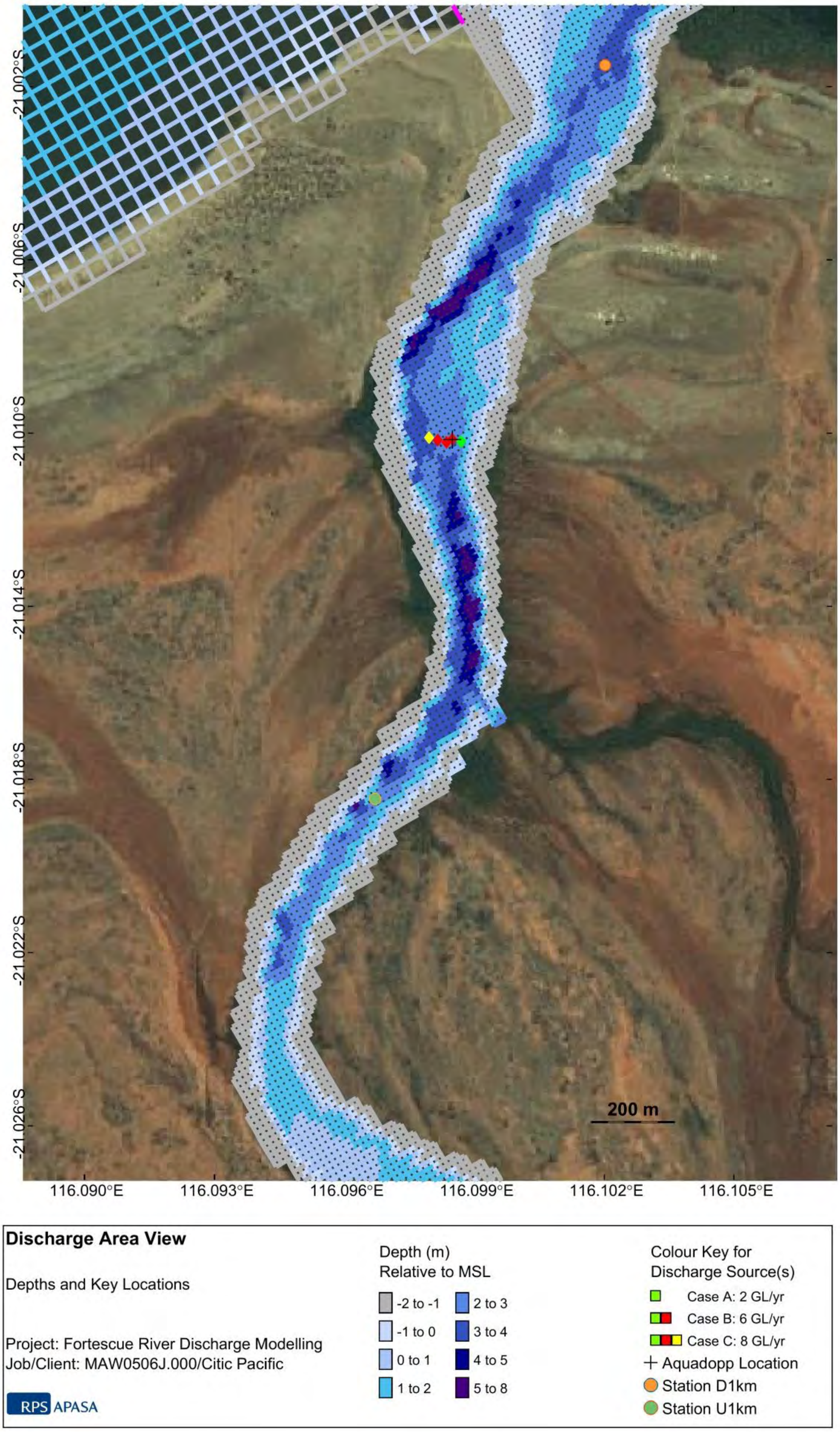


Figure 4-4: Map view of discharge area showing grid points used for each flow rate case, for example, for Case B, four grid points are marked on the map (1 green, 3 red). The Aquadopp deployment location is also indicated.

4.3 Model Validation

4.3.1 Comparison of Modelled and Measured Currents

Water levels and water current velocities in the Fortescue River were measured for 22-day period covering spring and neap tide cycles.

An acoustic current profiler (Nortek-AS Aquadopp) was deployed near to the proposed discharge location by RPS MetOcean. The deployment period was from 22 November 2016 to 14 December 2016. The location of the Aquadopp deployment (116.0981°E, 21.0098°S) was near (<50 m) the proposed discharge location in water of 3 m depth (Figure 4-4).

The elevations of the Aquadopp sensors were approximately 0.15 m above the river bed. The heights of the Aquadopp depth bins were 0.5 m. The sampling interval was 10 minutes, with an averaging period of 60 seconds. The depth averaged current speeds and directions were calculated during post-processing and a 1-hour smoothing filter was applied to the depth averaged data for comparison with model output.

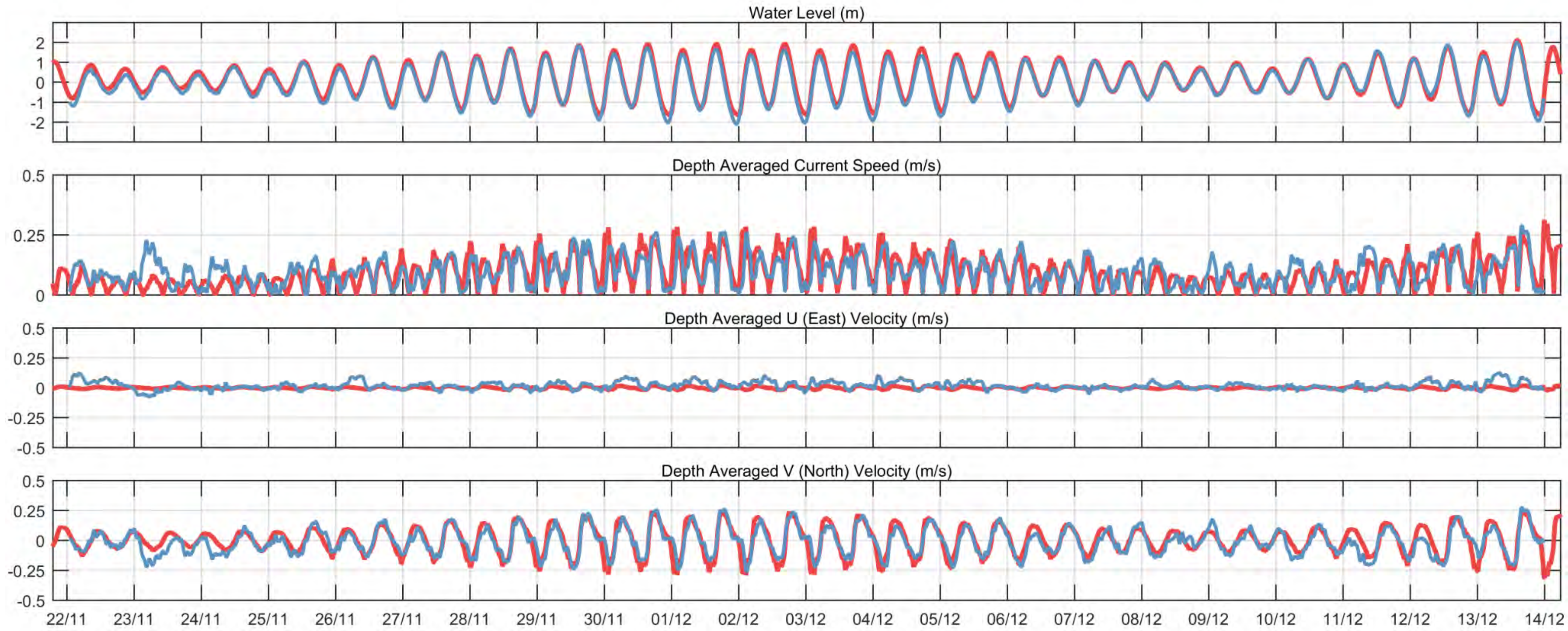
Validation of the model predicted current was done by comparing to measured depth averaged currents and water levels at the Aquadopp location (Figure 4-5).

Visual comparison indicates that the model provides a very good prediction of water levels and currents at the Aquadopp deployment site. The currents and water level were dominated by tidal influence as expected. The maximum tidal range for the deployment period was approximately 4 m, maximum current speeds were around 0.25 m/s during spring tide and around 0.1 m/s during neap tide. The data from the Aquadopp indicates the positive north component of velocity, which is approximately downstream in direction at this location, is in phase with the ebb tide. This indicates that the ebb tide discharge regime is reasonably well synchronised with the currents at this location as intended. This can be seen more clearly in Figure 4-6, which shows a 7-day spring tide period from the simulation period in an expanded view.

Although there was a generally strong agreement between measured and modelled data, there were some relatively minor differences on occasion. During spring tides the model slightly over-predicts the peak water level and slightly under-predicts the tidal trough. The measured current speeds displayed some current fluctuations of several hours duration that were under-predicted by the model (e.g. 23 Nov, 24 Nov). These fluctuations were not observed consistently and may have been caused by a weather features that were not represented in the boundary forcing currents and/or winds.

There was a very small periodic fluctuation in the east component of the measured current speed that was not captured in the model. The fluctuations appeared more frequently during spring tides, and therefore are more likely to be linked to tidal flow than localised wind forcing. They may have been caused by a small difference in the orientation of the modelled river bed or a localised bathymetric feature leading to a slight difference in the steering of currents by the river bed.

Both the range and percentile distribution of modelled current speeds compared very well to the range and percentile distribution of the measured current speeds (Figure 4-7). Overall, the strong agreement indicates that the river flow conditions were well capture by the model.



Time Series Comparison of D3D-F Model to Field Measurements

Field Instrument: Aquadopp
Location: 116.0981 E, 21.0098 S

Project: Fortescue River Discharge Modelling
Job/Client: MAW0506J.000/Citic Pacific

Measured (1hr filtered)
D3D-F Model

RPS APASA

Figure 4-5: Comparison of measured and modelled water level and currents at the Aquadopp location.

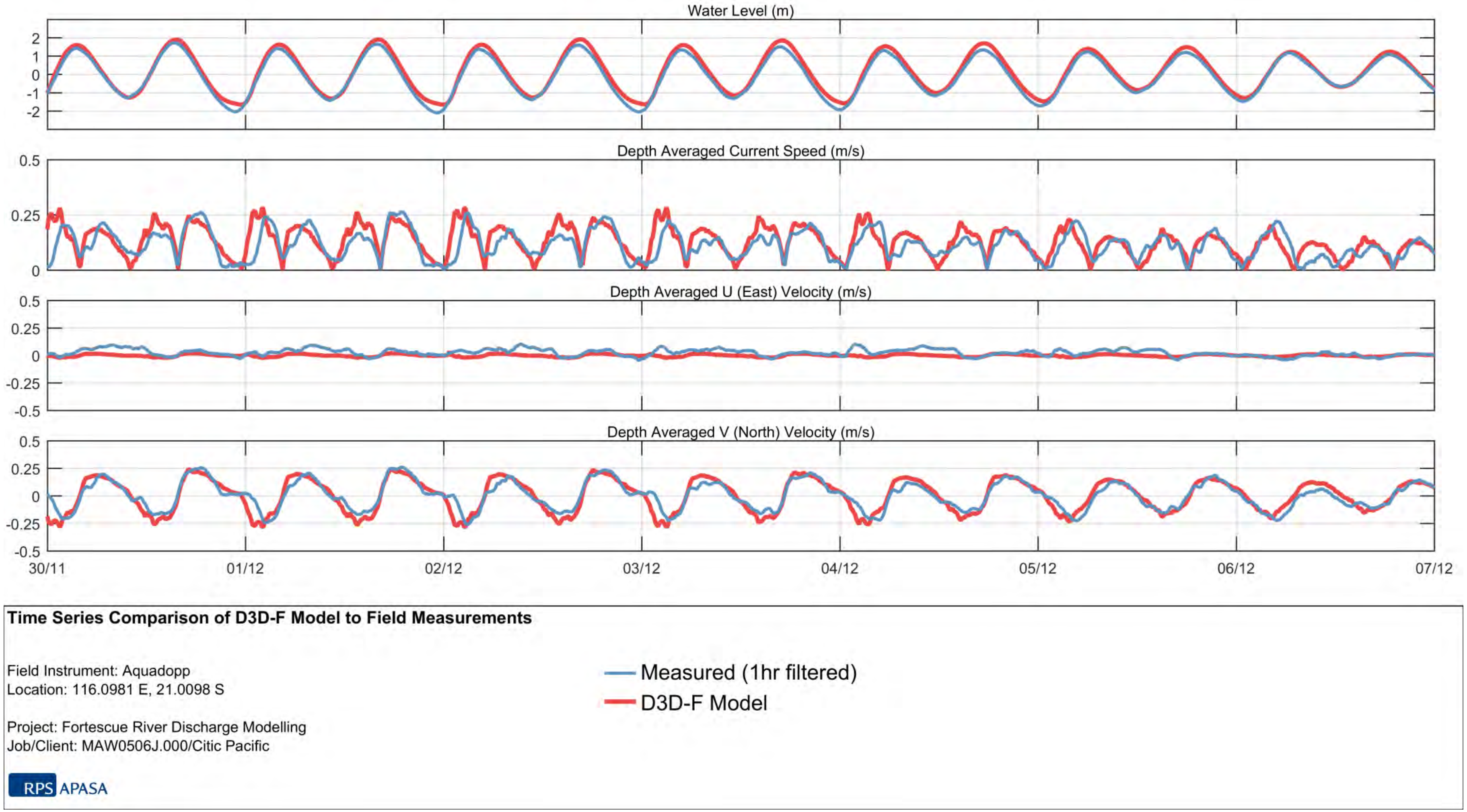


Figure 4-6: Zoomed view of comparison of measured and modelled water level and currents at the Aquadopp location during a spring tide period.

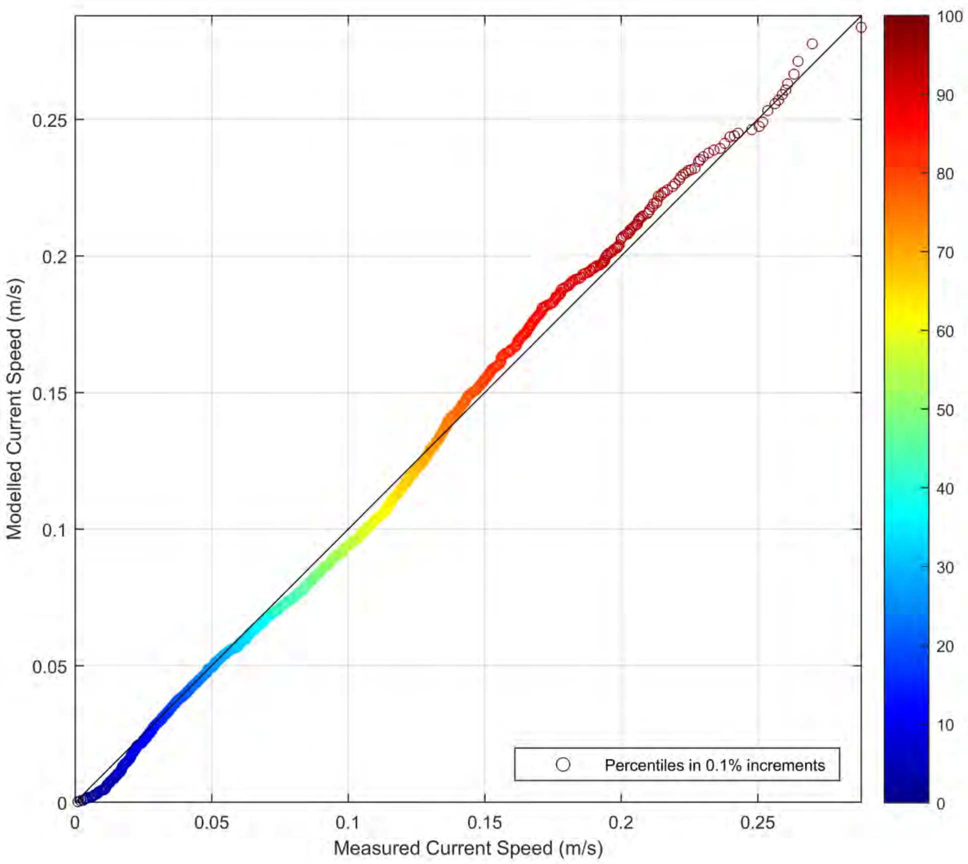


Figure 4-7: Q-Q Plot of Measured and Modelled Current Speeds

5.0 Far Field Discharge Scenarios

5.1 Discharge Model Cases

Three far field discharge scenarios were considered for this study:

- Case A: intermittent discharge with a flow rate of 2 GL/yr. This case represents the flow rate and ebb tide discharge schedule that has been approved by the DER, that is, commencing 30 minutes after the turning of the tide and ceasing 1 hour prior to the next low tide. The outfall consists of one diffuser unit that is 21 m in length.

- Case B: intermittent discharge with a flow rate of 6 GL/yr. This case uses the same ebb tide discharge schedule as Case A. To manage the higher flow rate it is assumed that the outfall diffuser from Case A will be extended across the river by two additional 21 m diffuser units installed in serial, giving a total diffuser length of 63 m.

- Case C: intermittent discharge with a flow rate of 8 GL/yr. This case uses the same ebb tide discharge schedule as Case A. To manage the higher flow rate it is assumed that the outfall diffuser from Case A will be extended across the river by three additional 21 m diffuser units installed in serial, giving a total diffuser length of 84 m.

For all cases, the salinity and temperature of the outfall discharge was specified by CPM to be 70 ppt and 20°C, respectively. The 20°C temperature was chosen because it is conservative with respect to the overall discharge plume density. The ambient salinity and temperature in the model was uniformly set to 37 ppt and 29°C, respectively. The ambient value was based on water temperatures measured in the Fortescue River by the Aquadopp during its November-December 2016 deployment period. Given that this period is a relatively warm time of the year, the ambient temperature is conservative with respect to maximising the density difference with the discharge. Although the analysis period only covered the summer season, the flow in the lower section of the river is expected to be dominated by tide in all months.

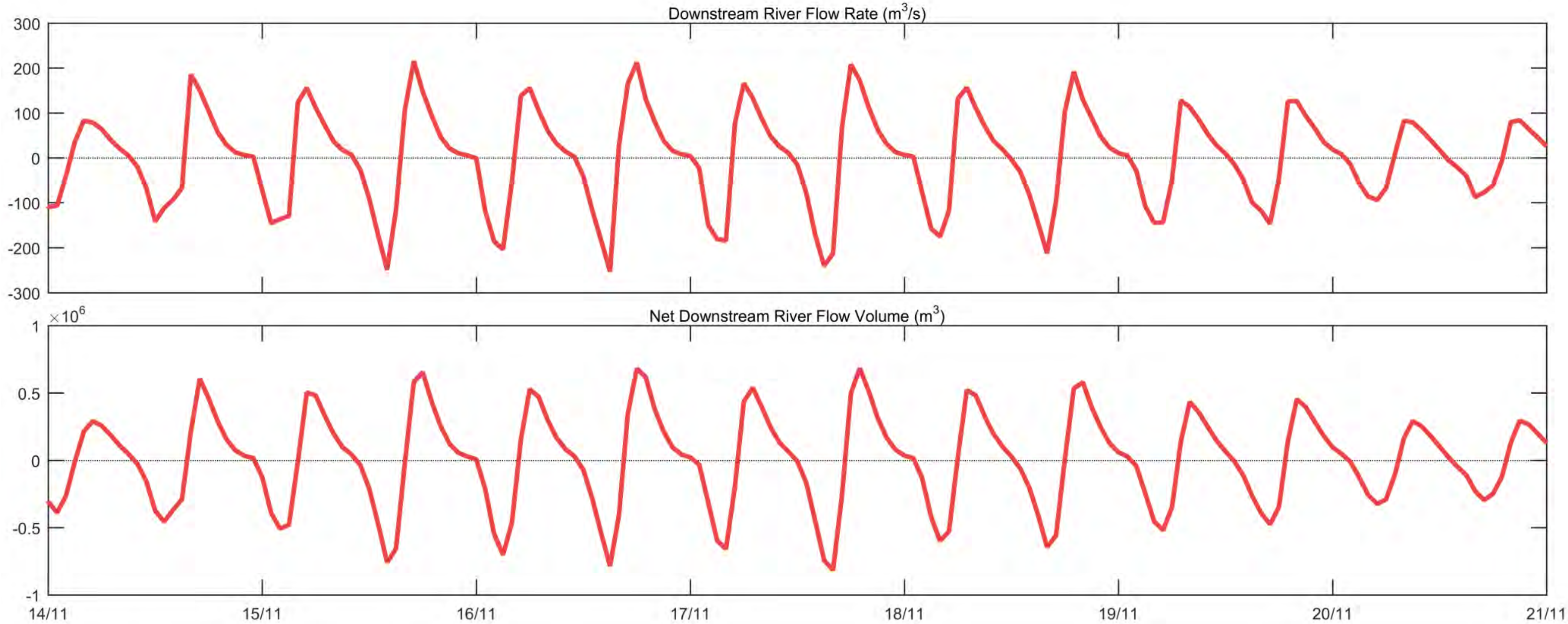
The selected model period used for all cases was from 12 November 2016 to 14 December 2016. The first two days of the simulation were reserved for a model ‘spin-up’ period, so are not included in the results period that has been presented.

5.2 Modelled River Discharge Characteristics

To provide a background context to the different discharge rate scenarios, the hydrodynamic model was used to characterise the dynamics of flow in the Fortescue River. Model results were analysed for a cross section of the river that is approximately 270 m upstream of the proposed discharge location. The location of this cross section was chosen because it is reasonably near to (and upstream) of the discharge site and the northward component of velocity is orientated in the downstream direction, which simplified the required calculations.

The dynamics of the river flow were assessed for a spring tide period (Figure 5-1) and a neap tide period (Figure 5-2). The results indicate that the peak downstream river flow rates ranged from 40 m^3/s during neap tide to 200 m^3/s during the spring tide. These peak values can be compared to flow rates of 0.06 m^3/s for Case A (i.e. 2 GL/yr), 0.18 m^3/s for Case B (i.e. 6 GL/yr) and 0.24 m^3/s for Case C (i.e. 8 GL/yr).

The volume of water that passes downstream during an ebb tide was calculated to range from $1x10^5$ m^3 during neap tide ebb to $5x10^5$ m^3 during the spring tide ebb. Caution should be used in the interpretation of these volumes as that much of the water will be recycled by the next incoming tide.



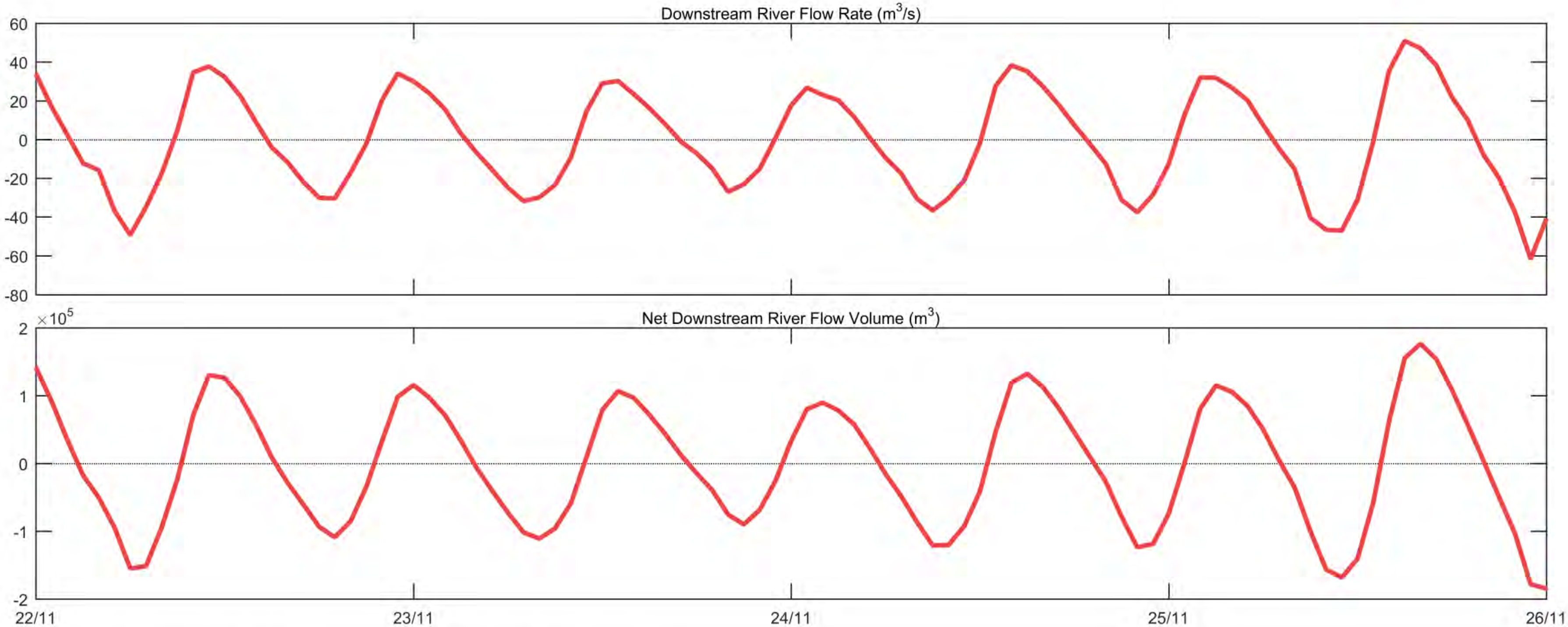
Predicted Tide Component of River Discharge During a Spring Tide Period

Location: River Cross Section 270 m
Upstream of Discharge Location
Coordinates: 116.098° E, -21.012° S

Project: Fortescue River Discharge Modelling
Job/Client: MAW0506J.000/Citic Pacific

RPS APASA

Figure 5-1: Predicted bulk flow dynamics for the lower Fortescue River with the time series centred on a spring tide period.



Predicted Tide Component of River Discharge During a Neap Tide Period

Location: River Cross Section 270 m
Upstream of Discharge Location
Coordinates: 116.098° E, -21.012° S

Project: Fortescue River Discharge Modelling
Job/Client: MAW0506J.000/Citic Pacific

RPS APASA

Figure 5-2: Predicted bulk flow dynamics for the lower Fortescue River with the time series centred on a neap tide period.

5.3 Far Field Dilution Results

5.3.1 Case A: 2 GL/yr

A time-series analysis of the model results for Case A was carried out for three locations; the diffuser location, and two locations 1 km upstream and downstream from the diffuser (see Figure 4-4). All results presented refer to model outcomes at a height 0.5 m above the river bed. Two time series figures (Figure 5-3 and Figure 5-4) were used to separate the results from the November and December periods for visual clarity.

The upper two panels of Figure 5-3 and Figure 5-4 indicate that relatively high levels of dilution are predicted for the upstream and downstream locations. The dilution is always above 50 times at these locations. At the diffuser location there were some episodic instances in the time series when the dilution was temporarily less than the target threshold of 27. These instances always occurred at the end of discharge periods (which are shaded in grey in the time series figures) and were more likely to occur during neap tide periods. In all of these instances the maximum time duration that the dilution threshold was exceed was around 1 hour (the model output interval was 1 hour which limits the resolution of this duration calculation to ~1 hour).

Considering the time series from Figure 5-3 and Figure 5-4 together, the 30 day time series of dilutions showed no evidence of any increased tendency to exceed threshold with time. This indicates that there was no significant accumulation of salinity in the model over the 30-day time scale.

The model outputs were used to calculate spatial maps for median and 80th percentile dilutions (Figure 5-5 and Figure 5-6). For each grid point shown in Figure 5-5, time series like those shown in Figure 5-3 and Figure 5-4 had to be extracted to allow calculation of the percentile results shown. The time series results were extracted for the analysis depth (0.5 m above the river bed).

The map results for the median dilution level (Figure 5-5) indicate that the median dilution is greater than 50 times dilution for the time series at every grid point. The results for the 80th percentile dilution level (Figure 5-6) indicate dilutions greater than 50 times throughout most of the domain except for a localised area at the diffuser outlet where dilution for the time series was in the range of 40 to 50 times.

5.3.2 Case B: 6 GL/yr

The time series results for 6 GL/yr (Figure 5-7 and Figure 5-8) indicate relatively high levels of dilution are predicted for the upstream and downstream locations during spring tides. However, during neap tides the dilution at these upstream and downstream locations was significantly lower, but remained above 30 times. There were some episodic instances when the dilution at the discharge location was temporarily less than the target threshold of 27. These events were more frequent than was observed for the 2 GL/yr flow case. During neap tide periods there were occasions when the 27 times dilution threshold was either neared or breached before the end of a discharge period, which meant that duration of exceedance was approximately 2 hours on some occasions, but was more typically around 1 hour.

The full 30 day time series of dilutions from the simulation period showed no evidence of any increased tendency to exceed threshold with time. Rather, the 27 times threshold was breached more often in the first half of the simulation period (Figure 5-7) than the second half (Figure 5-8). This indicates that there was no significant accumulation of salinity in the model over the 30-day time scale.

The map results for the median dilution level (Figure 5-9) indicate that the median dilution was greater than 50 times dilution for the time series data at every grid point.

The map results for the 80th percentile dilution level (Figure 5-10) indicate dilutions in excess of 27 times throughout the domain. Dilutions in the range of 30 to 40 times were observed up to around 175 m downstream from the discharge location. Dilutions in the range of 40 to 50 times were observed up to around 350 m downstream from the discharge location. There were some isolated model cells up to 1 km upstream of the discharge location that also had dilutions in the range of 40 to 50 times. These cells are located in intertidal areas and their 80th percentile values may a attributable in part to very shallow water depths. The upstream migration of the salinity signal occurs because a small proportion of the salt from the discharge that remains in the river at the end of the ebb tide is transported upstream on the incoming tide. However, because the magnitude of this effect was relatively small the 27 times dilution target was still met.

5.3.3 Case C: 8 GL/yr

The time series results for the 8 GL/yr case (Figure 5-11 and Figure 5-12) indicate that the incidence of exceedance 27 times dilution target was similar to the 6 GL/yr case, but the duration of threshold exceedance at the discharge location was typically longer, and was up to 4 hours in the worst case. During the neap tide periods the 27 times dilution target was approached at the upstream and downstream locations, and on two occasions the target was breached at the downstream location for a period of around 2 hours.

The map results for the median dilution level (Figure 5-13) indicate that the median dilution is greater than 50 times dilution for the time series at almost every grid point, except at the discharge location where the dilution was in the range of 40 to 50 times.

The map results for the 80th percentile dilution level (Figure 5-14) indicate dilutions in excess of 27 times were met throughout the domain. However, dilutions in the range of 27 to 30 times were observed at the discharge location and the general level of dilution was evidently less than that found 6 GL/yr case (i.e. Figure 5-10). Dilutions in the range of 30 to 40 times were observed up to around 400 m downstream from the discharge location. Dilutions in the range of 40 to 50 times were consistently observed up to around 550 m downstream from the discharge location and up to around 1 km upstream of the discharge location. There were some isolated cells located in in intertidal areas with dilutions in the range of 40 to 50 times that were further than 1 km upstream of the discharge location.

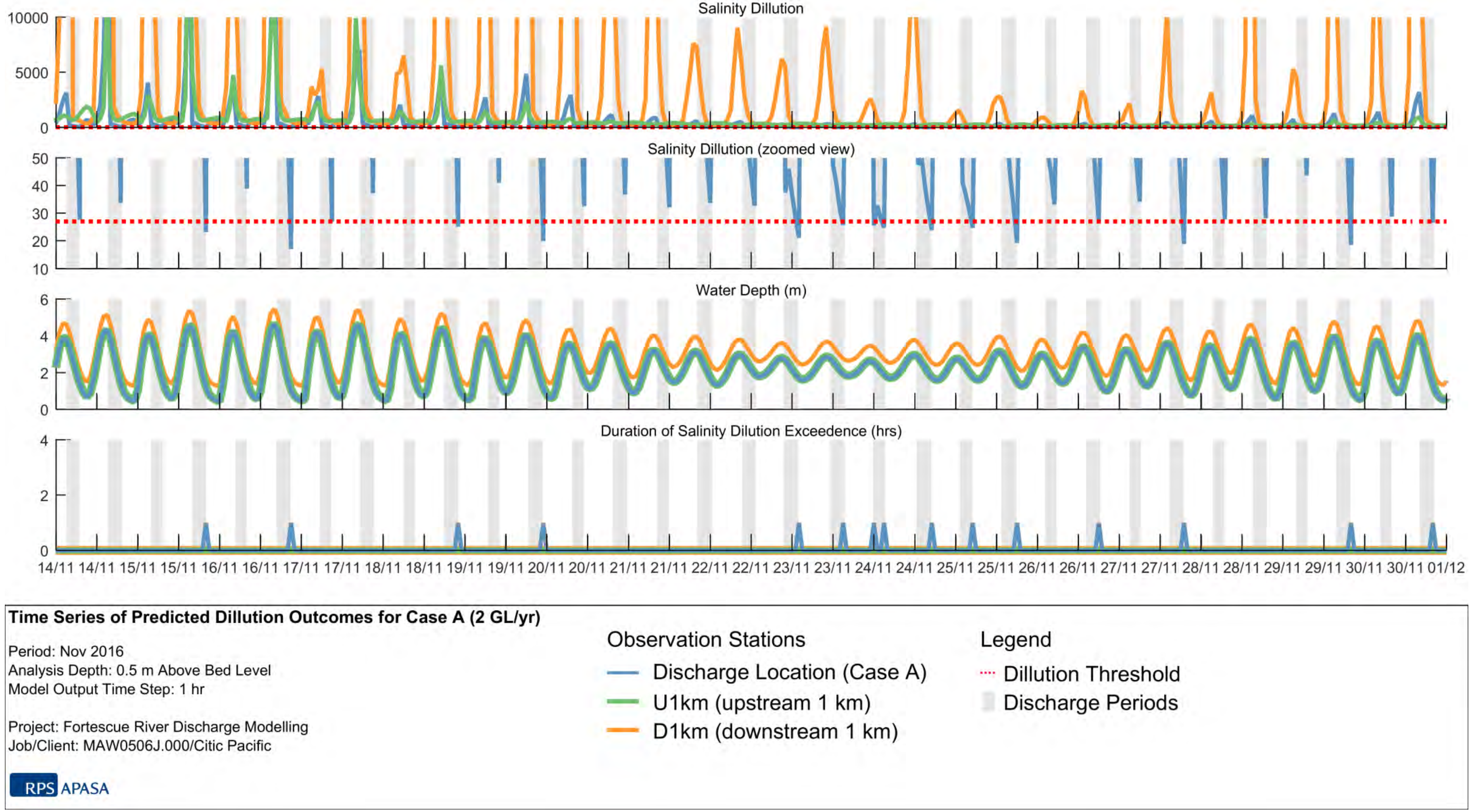


Figure 5-3: November period time-series results for Case A (2 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

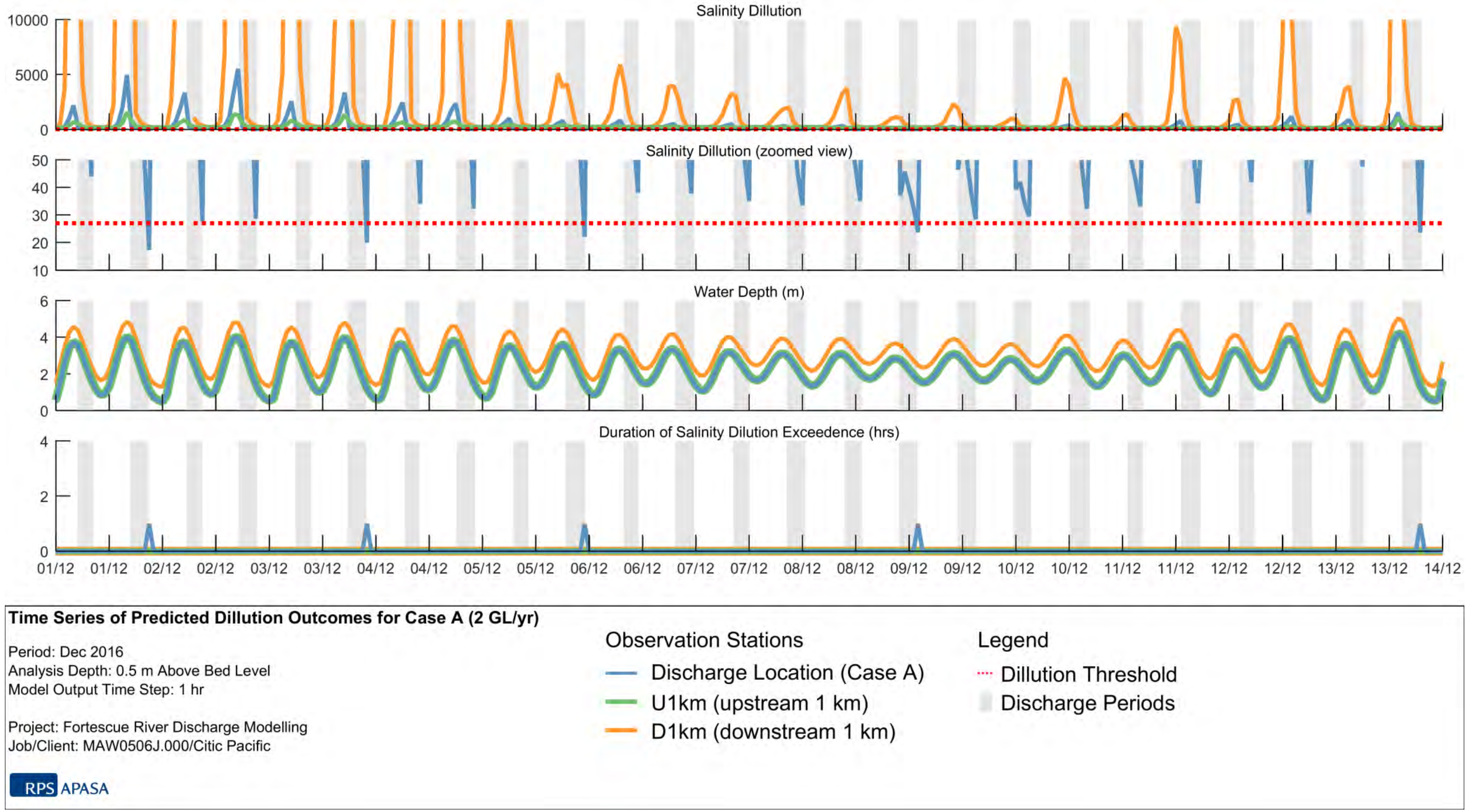


Figure 5-4: December period time-series results for Case A (2 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

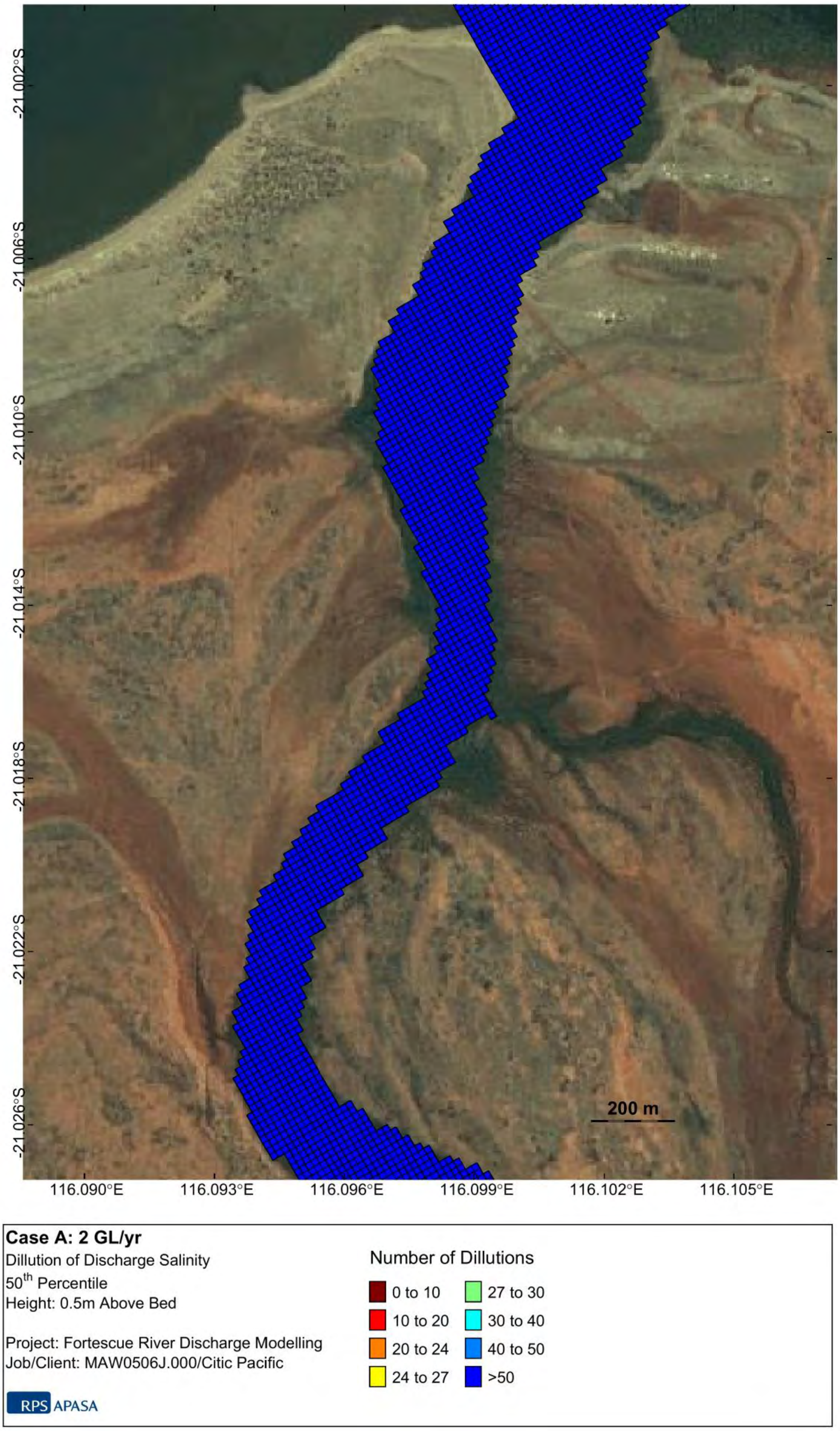


Figure 5-5: Median dilution result for Case A (2 GL/yr) at a height 0.5 m above the river bed

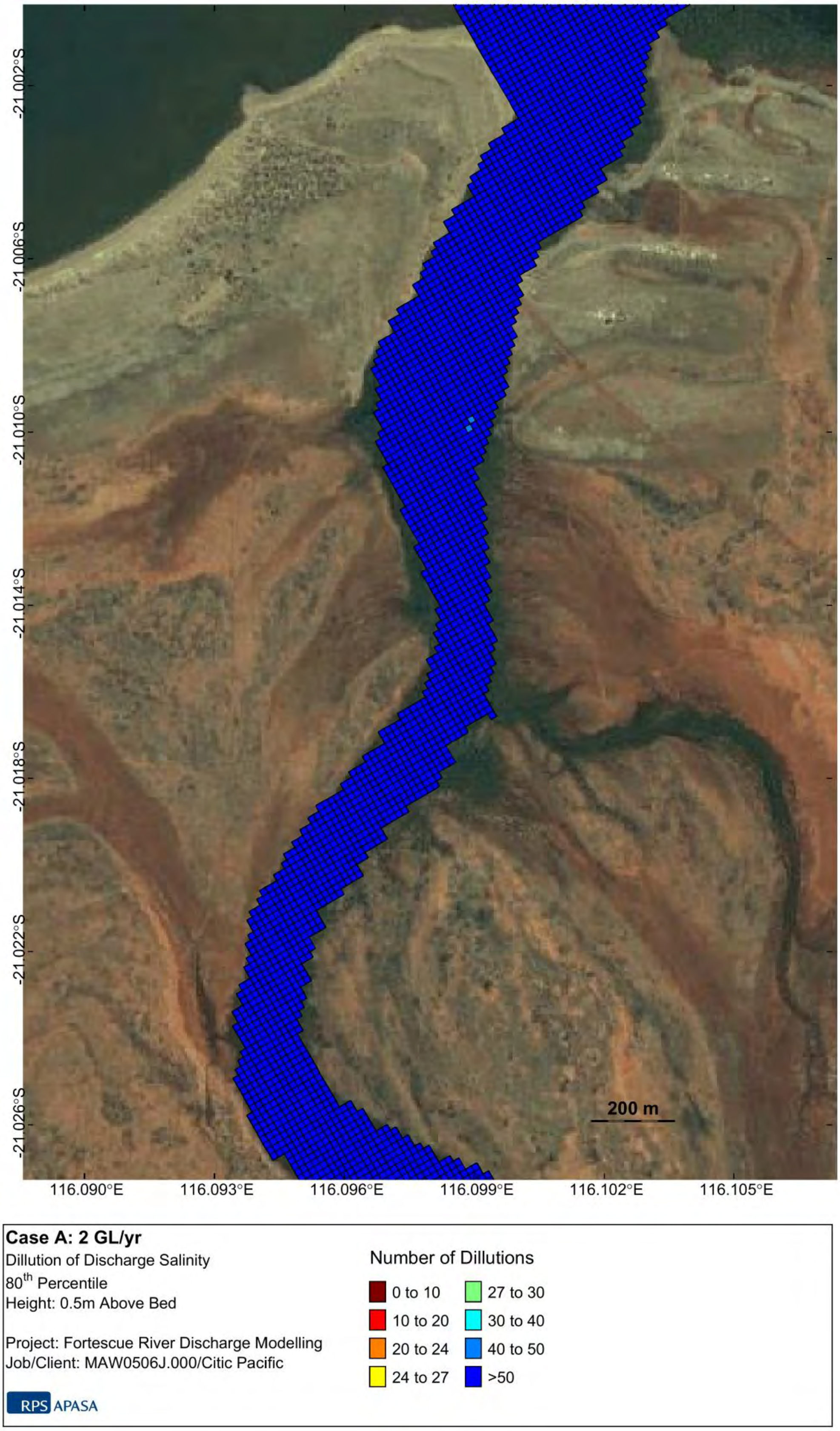


Figure 5-6: 80th percentile dilution result for Case A (2 GL/yr) at a height 0.5 m above the river bed

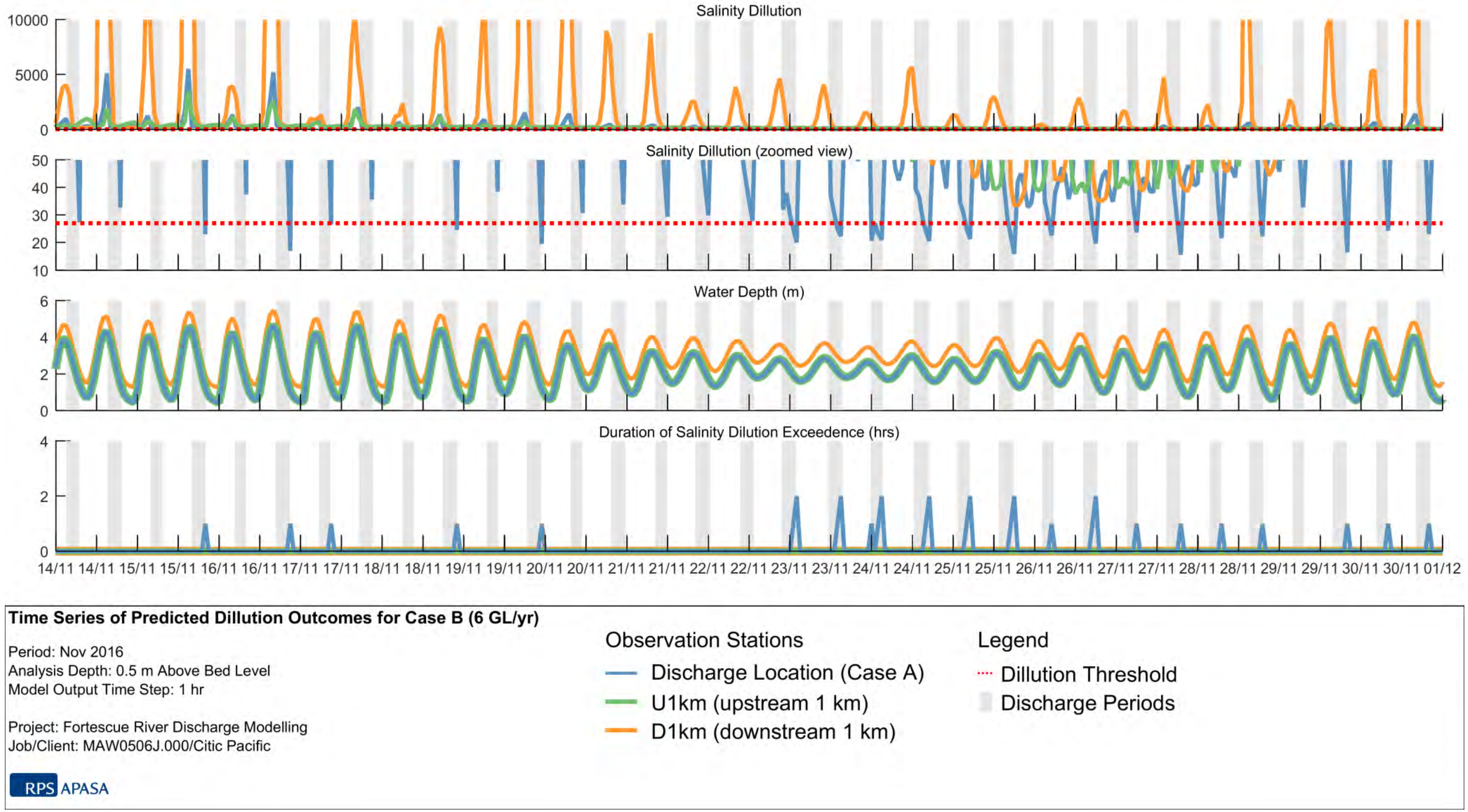


Figure 5-7: November period time-series results for Case B (6 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

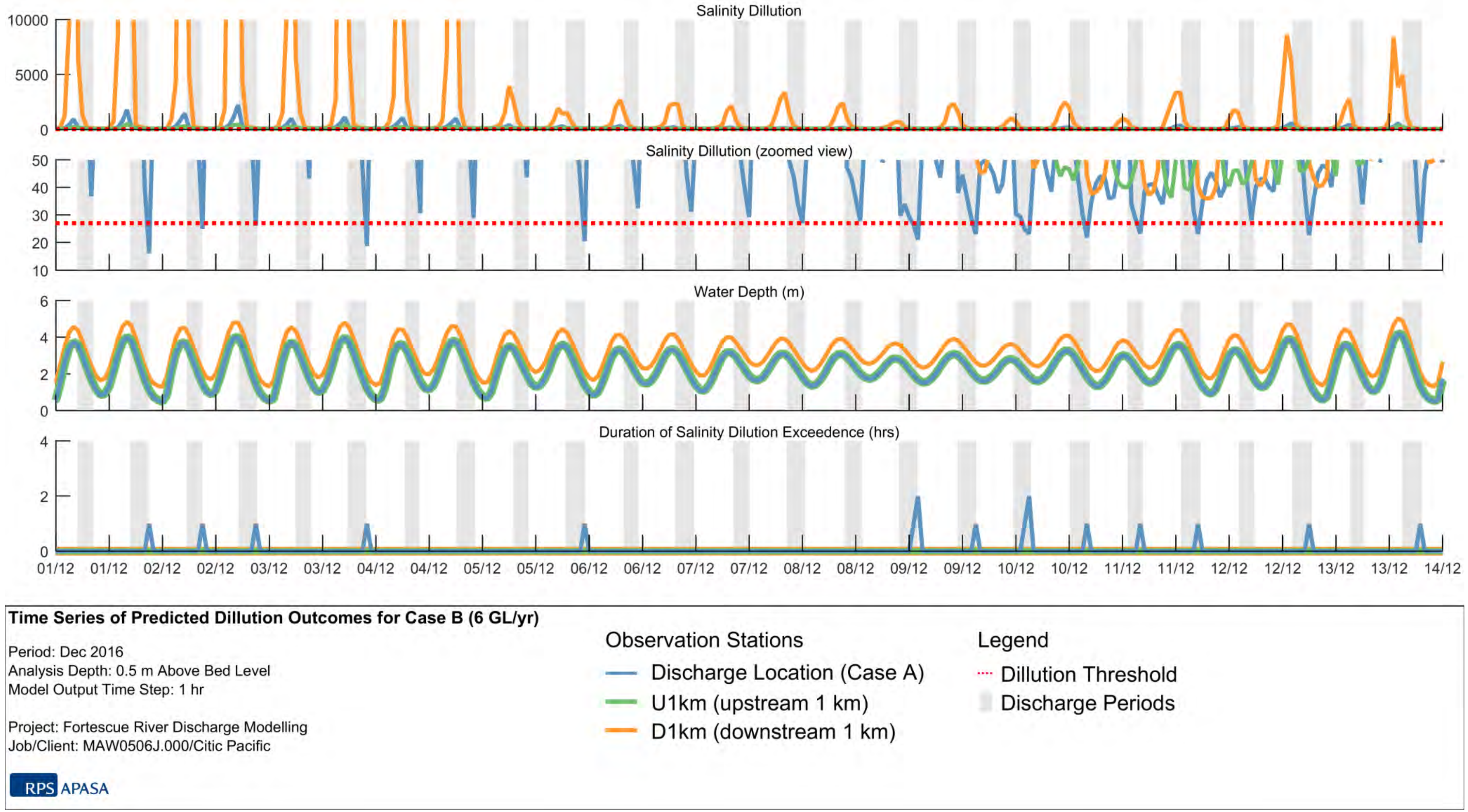


Figure 5-8: December period time-series results for Case B (6 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

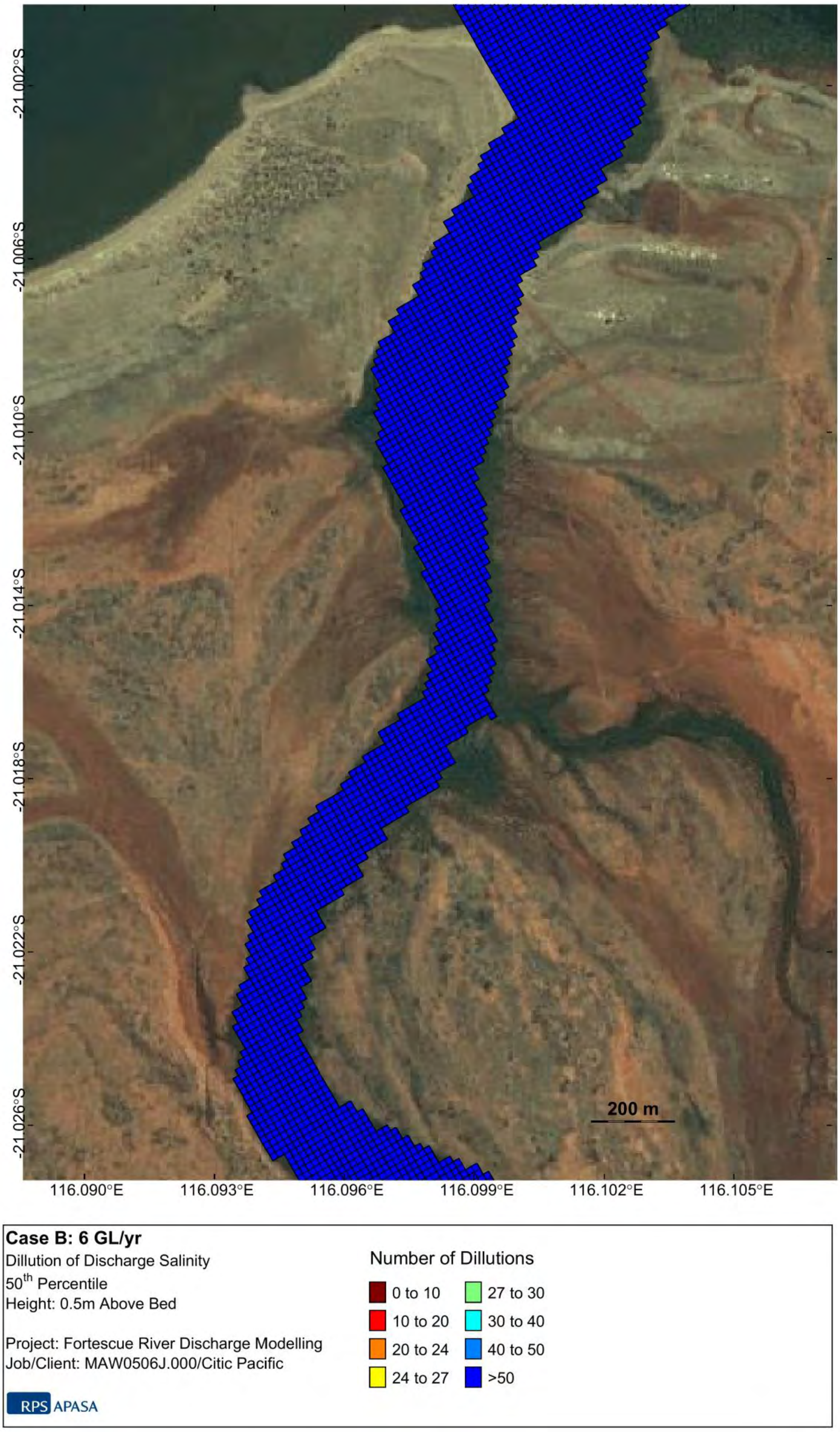


Figure 5-9: Median dilution result for Case B (6 GL/yr) at a height 0.5 m above the river bed

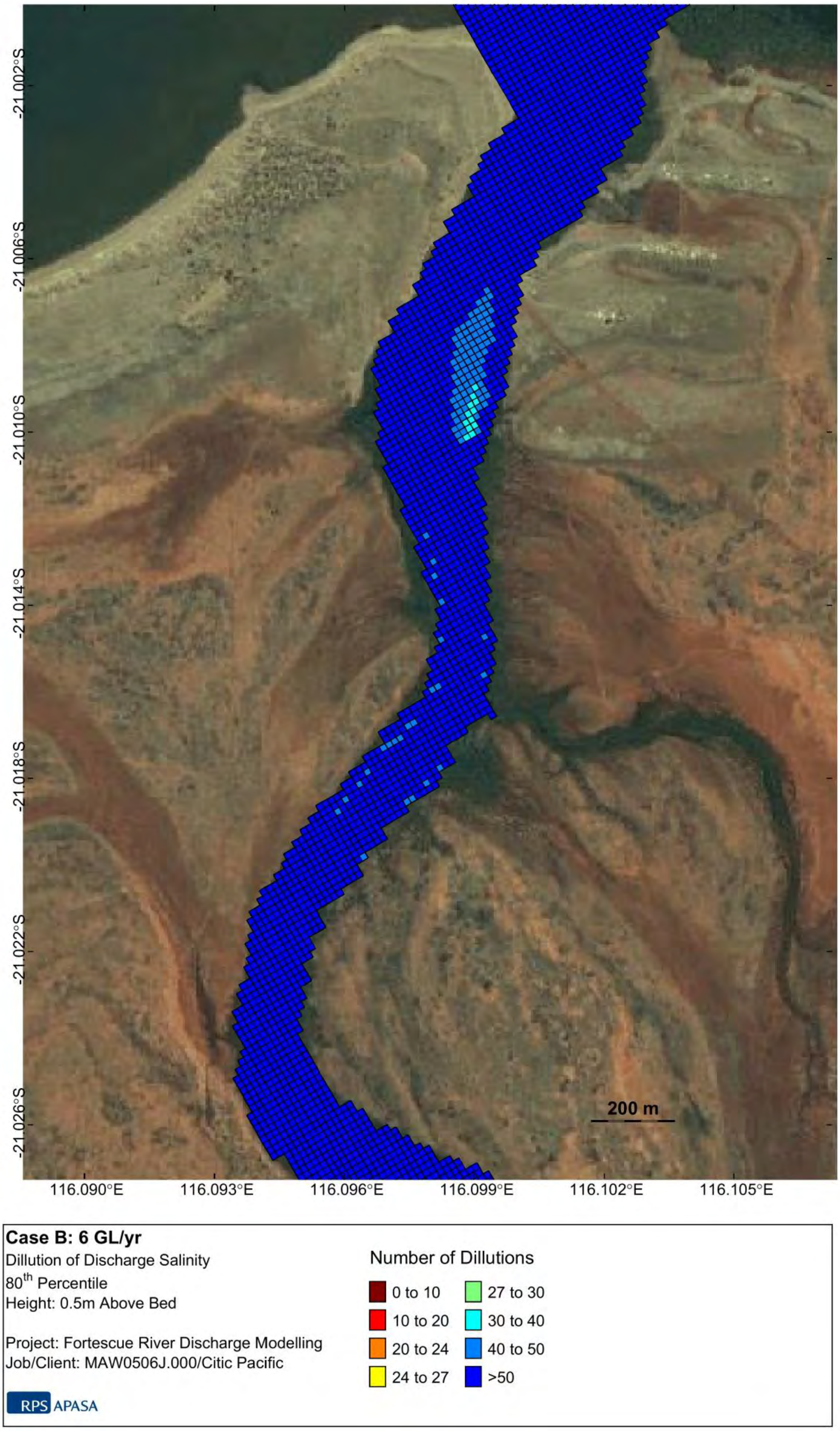


Figure 5-10: 80th percentile dilution result for Case B (6 GL/yr) at a height 0.5 m above the river bed

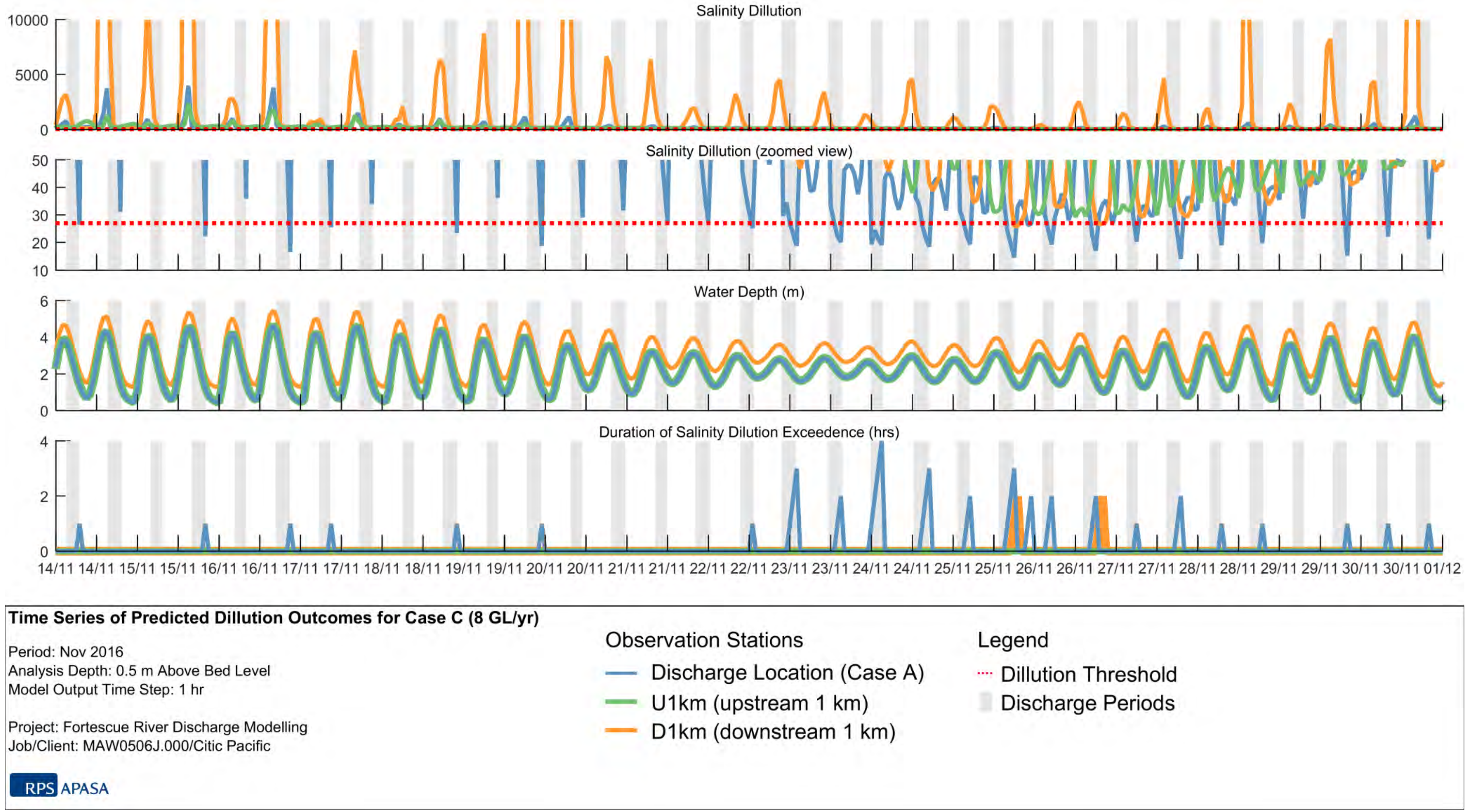


Figure 5-11: November period time-series results for Case C (8 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

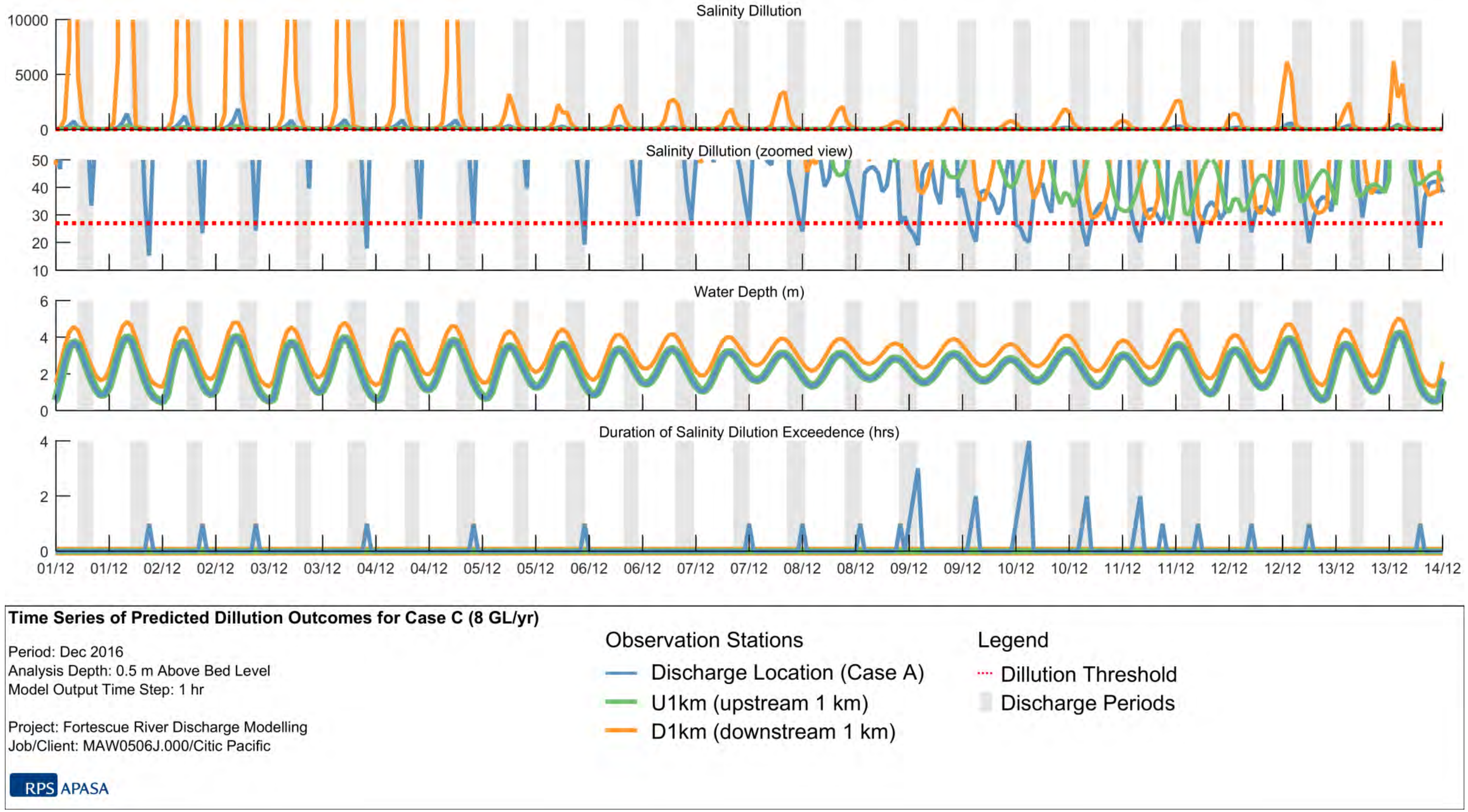


Figure 5-12: December period time-series results for Case C (8 GL/yr) indicating dilution outcomes at the discharge location (see green shaded cell, Figure 4-4) and at stations upstream and downstream of the discharge location (see green and orange circle markers, Figure 4-4).

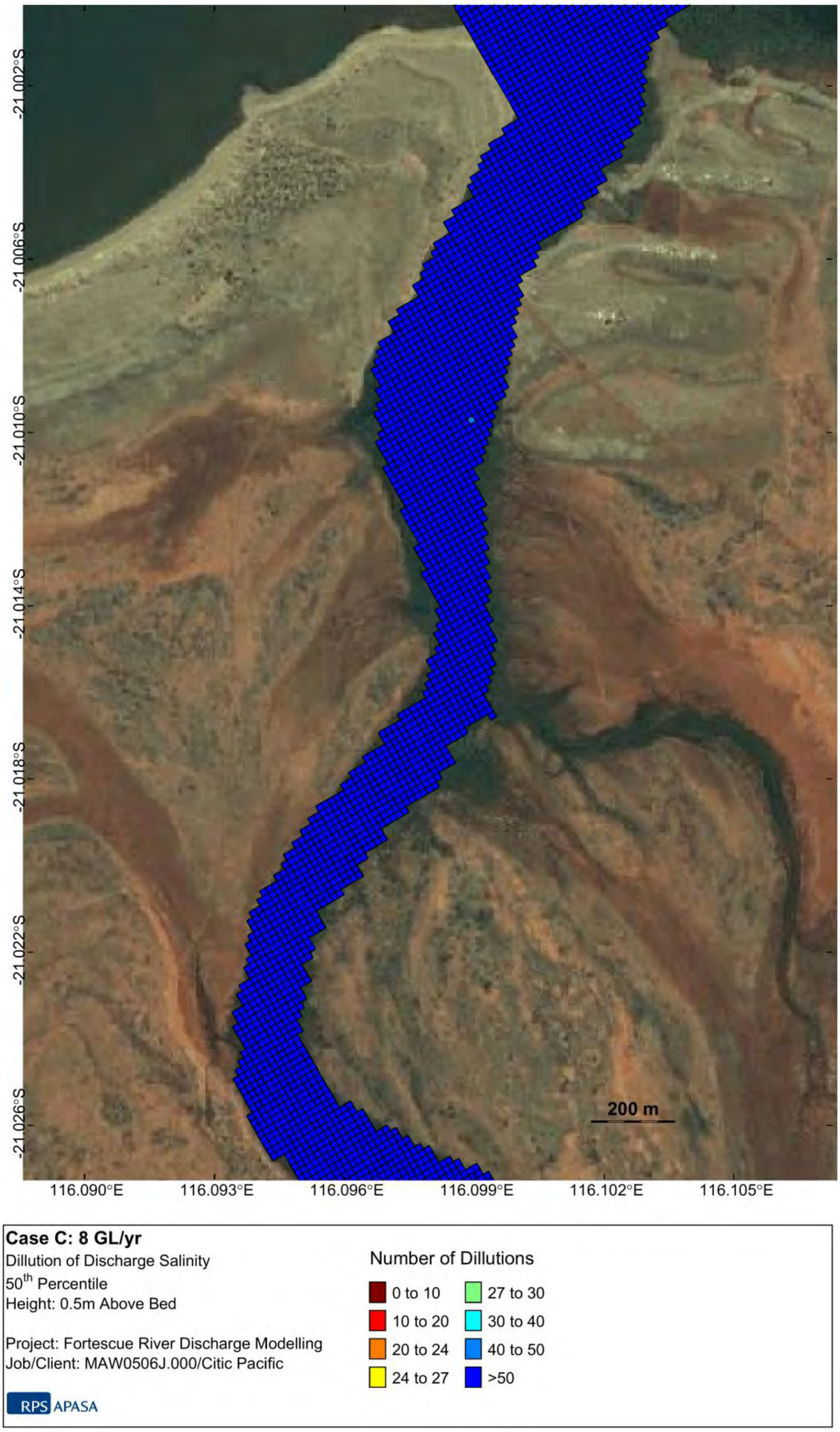


Figure 5-13: Median dilution result for Case C (8 GL/yr) at a height 0.5 m above the river bed

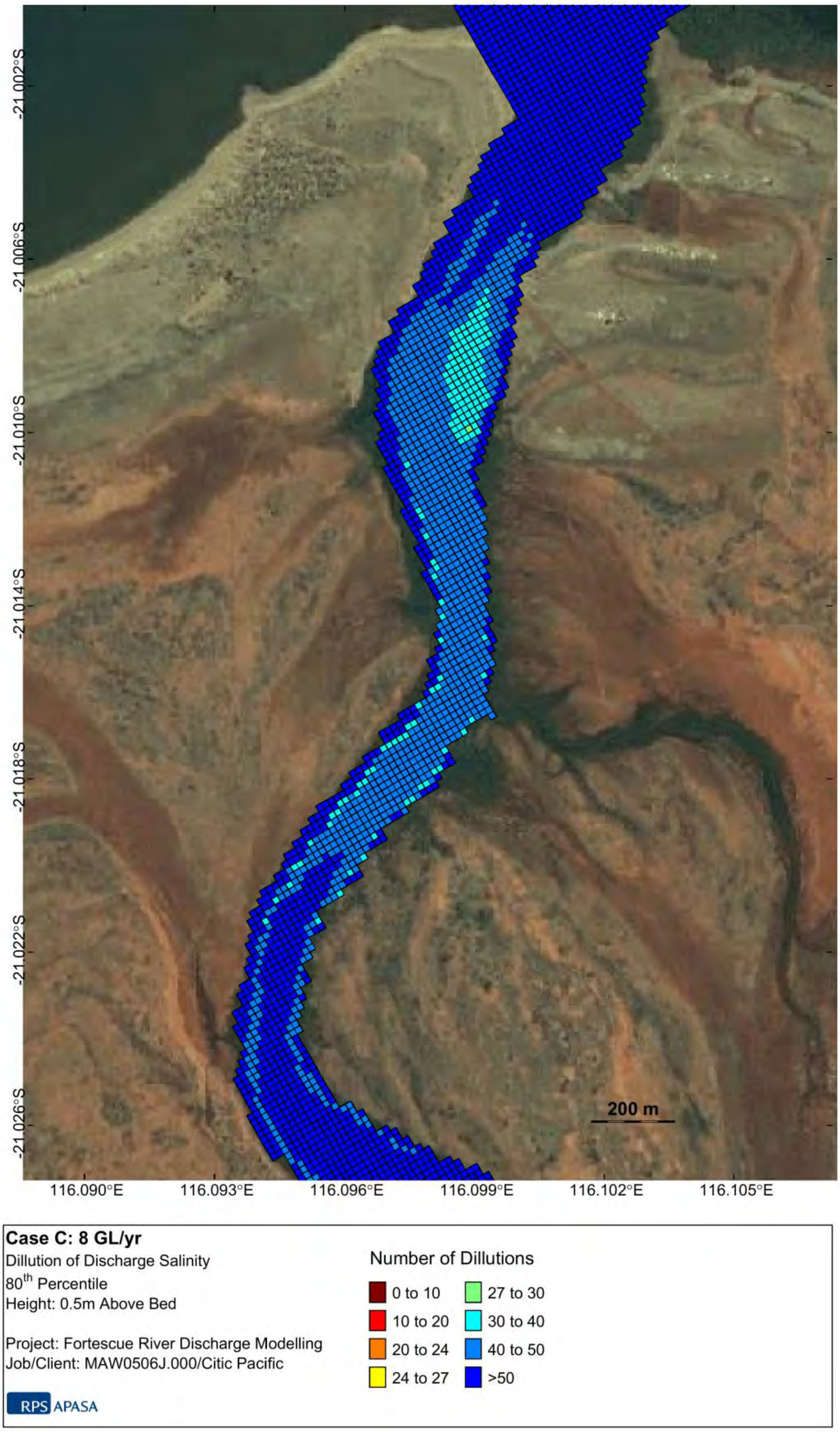


Figure 5-14: 80th percentile dilution result for Case C (8 GL/yr) at a height 0.5 m above the river bed

6.0 Conclusion

The near field analysis indicates that it is possible to install a diffuser that will be able to achieve the required level of median dilution in the nearfield to meet the mixing zone requirements for flow rates up to 8 GL/yr. The far field analysis has confirmed that under the proposed ebb tide discharge schedule the Fortescue River has the capacity to dilute and transport the discharge to the extent that the median dilution is predicted to remain above the target threshold of 27 times dilution for flow rates up to 8 GL/yr. For the 8 GL/yr flow rate case, the target dilution level of 27 was approached near the discharge site (i.e. median of 40 to 50 times dilution), but was always exceeded. The ebb tide discharge regime is considered an important factor contributing to the median dilution results.

With respect to the analysis of 80th percentiles, for the 2 GL/yr case the dilution results showed 80th percentile dilutions were always above 50 times at all locations. For the 6 GL/yr case, the 80th percentile dilutions were always above the 27 times dilution target, but were less than 50 diluted times up to 350 m downstream of the diffuser. For the 8 GL/yr case, the 80th percentile dilutions were always above the 27 times target but were between 27 and 50 times dilution up to 1 km upstream of the diffuser. The significant difference in the 80th percentile dilutions between the 6 GL/yr and 8 GL/yr cases suggests that at these higher flow rates the river may be approaching its capacity to maintain far field dilutions below target.

The near field modelling predicted that the jet flow from the diffuser would rise 2.3 m above the height of the diffuser port outlet. This rise height may exceed the water column height at the discharge point, especially when the tide is relatively low. In considering the potential for surface interaction, which can reduce nearfield dilution and also lead to a visual indication of the discharge, the port orientation in the vertical could be adjusted. Studies by Bleninger and Jirka (2007) suggest that there is likely to be very little difference in the initial dilution performance for ports oriented between 30° to 60°. The benefit of a lower angle is that the rise height is reduced significantly, reducing interaction with the water surface. It is recommended that the depth of the river be surveyed along the proposed installation path of the diffuser before the port orientation angle is finalised. If surface interaction remains an issue it may be necessary to limit the discharge period to avoid the lowest tides. Alternatively, the pipe might be partially buried to increase the height of the water column between the diffuser outlet at the water surface.

It is emphasised that the diffuser designs presented in this report are conceptual. We suggest that the required dilution performance and conceptual design specifications be passed to either a detailed design engineer or solution provider such as Tideflex Australia for implementation, including assessment of the required pumping levels, delivery pipe sizes and materials. The detailed design should give consideration to the potential for the diffuser to become blocked by sediments. If blockage is likely, regular flushing of the diffusers ports using higher flow rates for a short period (minutes) may help to mitigate any potential accumulation of sediment. In addition, the installation of a removable endplate on the diffuser pipe would make it simpler to maintain the diffuser if blockage did occur.

7.0 References

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Australian Government
Department of the Environment

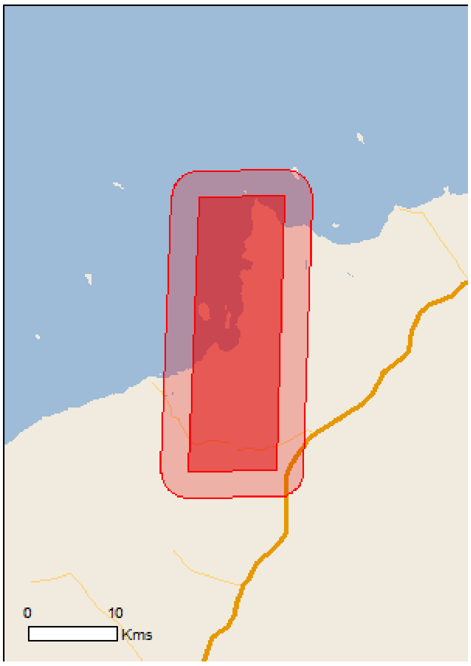
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 13/07/16 11:04:00



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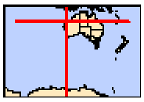

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	24
Listed Migratory Species:	28

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	64
Whales and Other Cetaceans:	12
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	1
Regional Forest Agreements:	None
Invasive Species:	7
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Limosa lapponica baueri Bar-tailed Godwit (baueri), Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat likely to occur within area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Bar-tailed Godwit (menzbieri) [86432]	Critically Endangered	Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Pezoporus occidentalis Night Parrot [59350]	Endangered	Species or species habitat may occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area
Mammals		
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [331]	Endangered	Species or species habitat likely to occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Macrotis lagotis Greater Bilby [282]	Vulnerable	Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Rhinonicteris aurantia (Pilbara form) Pilbara Leaf-nosed Bat [82790]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Ctenotus angusticeps Airlie Island Ctenotus [25937]	Vulnerable	Species or species habitat likely to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Liasis olivaceus barroni Olive Python (Pilbara subspecies) [66699]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Sharks		
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat likely to occur within area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding likely to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Migratory Marine Species		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat likely to occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Breeding likely to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Motacilla cinerea Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Fish		
Bulbonaricus brauni Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area
Campichthys tricarinatus Three-keel Pipefish [66192]		Species or species habitat may occur within area
Choeroichthys brachysoma Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area
Mammals		
Dugong dugon Dugong [28]		Species or species habitat known to occur within area
Reptiles		
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area
Aipysurus tenuis Brown-lined Seasnake [1121]		Species or species habitat may occur within area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Breeding likely to occur within area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hydrelaps darwiniensis Black-ringed Seasnake [1100]		Species or species habitat may occur within area
Hydrophis czeblukovi Fine-spined Seasnake [59233]		Species or species habitat may occur within area
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area
Hydrophis mcdowelli null [25926]		Species or species habitat may occur within area
Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [1111]		Species or species habitat may occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area
Delphinus delphis Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops aduncus (Arafura/Timor Sea populations) Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Great Sandy Island	WA

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence

Name	Status	Type of Presence
Mammals		
Felis catus		
Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus		
House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus		
Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes		
Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Cenchrus ciliaris		
Buffel-grass, Black Buffel-grass [20213]		Species or species habitat likely to occur within area
Parkinsonia aculeata		
Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Prosopis spp.		
Mesquite, Algaroba [68407]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-20.830645 116.233609,-21.089693 116.225369,-21.090334 116.135419,-20.831928 116.146405,-20.830645 116.232922,-20.830645 116.233609

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Parks and Wildlife Commission NT, Northern Territory Government
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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SINO Iron Project

Draft Operational Environmental Management Plan

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Author/Custodianship

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2.0	10/04/2013	Rob Wood	Amend S2.2.2 to reflect Part V Approvals
3.0	23/01/2017	Gabby Pracilio	Full revision of OEMP

Distribution list

When this document is updated, the following people must receive a copy of the updated version:

Name	Position/title
CPM Leadership Team	CPM-LeadershipTeam@citicpacificmining.com
CPM Environment Team	EnvironmentTeam@citicpacificmining.com

Related/referenced documents

Document title	Document ID
Sino Iron Project – Environmental Management System	DR028188

Document approval

	Name	Signature	Date
Written by	**Gabby Pracilio**		
Reviewed by	**Harley Barron** **Damien Mcalinden** **Mat Brook**		
Approved by	**Bruce Watson**	**BW**	

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1 Introduction

In August 2014, the Office of the Environmental Protection Authority (**OEPA**) approved the Operational Environmental Management Plan (**approved 2014 OEMP**) for the Project in accordance with Condition 2-1, Commitment 2 of MS635 in August 2014.

On behalf of Sino Iron and Korean Steel, CPM is seeking approval under Part IV of the *Environment Protection Act* 1986 (**EP Act**), for the Sino Iron Mine Continuation Proposal (**the Proposal**).

The Project is also subject to three Environmental Licences, issued under Part V of the EP Act. The Department of Environment Regulation (**DER**) issues and administers licences to authorise prescribed premises.

1.1 Purpose and Scope

This revision of the Sino Iron Project Operational Environmental Plan (**OEMP**) has been prepared to support CPM's referral of the Proposal to the OEPA under Part IV of the EP Act.

The purpose of this OEMP is to outline the environmental management measures associated with the operation of the Project as expanded in accordance with the Proposal. This OEMP incorporates updates to the management actions described within the approved 2014 OEMP.

The purpose of this OEMP is to demonstrate how the Project will be operated to ensure:

- Compliance is maintained;
- Environmental issues identified during project impact assessments are appropriately managed; and
- Alignment with CPM's Environmental Management System (**EMS**).

This OEMP applies to all current and future operational activities associated with the Project.

1.2 Project Description

Figure 1 describes the Mine Continuation Proposal Development Envelope and Conceptual Footprint incorporating the existing approved Project footprint. Figure 2 provides a schematic representation of the Project's operations. Note that Figure 2 also includes the pellet plant process, which has not yet been installed.

1.2.1 Existing Project Overview

The Project is focussed on mining iron ore in the form of magnetite at the George Palmer Orebody located at Cape Preston, 80 km south west of Karratha in the Pilbara Region of Western Australia. The existing mining and processing activities are expected to eventually achieve the approved mining rate of up to 95million tonnes per annum (**Mtpa**) and magnetite concentrate production rates of up to 27.6 Mtpa.

Key characteristics of the Project (as defined within MS635) include:

- Mine:

  - Open pit up to a depth of 220 metres (**m**); and
  - Rate of mining up to 95 Mtpa.
  - North east, south east and western waste rock dumps.
- Process Plant:
  - Concentrator rate up to 27.6 Mtpa;
  - Produced waste to tailings storage facility (**TSF**) up to 67.4 Mtpa;
  - Pellet production up to 13.8 Mtpa (yet to be constructed); and
  - Direct reduced/hot briquetted iron up to 4.7 Mtpa (yet to be constructed).
- Infrastructure:
  - Power station capacity of 640MW;
  - North South infrastructure corridor including: access roads, power lines, buried magnetite concentrate slurry pipeline;
  - Dewatering plant at the port;
  - East West infrastructure corridor including Project access road and underground gas pipeline;
  - Port iron ore product stockpiles and bulk ship loading facilities;
  - 44 gigalitres per annum (**GLpa**) Desalination plant and disposal of up to 57.8GLpa of brine per annum;
  - Accommodation villages;
  - Groundwater bore field; and
  - Pit dewatering and disposal of up to two GLpa to per annum to the Fortescue River.
- Port Terminal Facilities:
  - Product stockyard capacity of approximately 1 Mt;
  - Approximately 1.1 km, bridging structures or rock causeway to Preston Island and breakwater which allows for transhipment of magnetite concentrate; and
  - Trestle jetty and dredging of up to 4.5 million metres cubed to allow for direct ship loading (yet to be constructed).

1.2.2 Proposal Overview

The Proposal will involve disturbance of an additional area of approximately 7,366 hectares (**ha**), increasing the potential cumulative footprint (including the Project) to 10,100 ha. The Proposal will involve extensions or alterations to existing infrastructure, including:

- extension of the mine pit to the west within Mining Leases M08/123, M08/124 and M08/125 with an increase in depth from 220 m to 455 m;
- increase to tailings capacity within M08/264, M08/265 and M08/266 and onto additional tenements including G08/53, G08/63 and G08/74;