FORTESCUE

North Star Extension

Inland Waters: Pool Hydrological and Water Quality Assessment

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17/04/2025

Level 14, 240 St Georges Terrace
Perth WA 6000
Australia

T: +61 8 9278 8111
Worley Services Pty Ltd
ABN 61 001 279 812

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PROJECT 311012-02355 - PM-REP-00001: North Star Extension - Inland Waters: Pool Hydrological and Water Quality Assessment

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date	Customer Approver	Approval Date
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17/04/2025

Level 14, 240 St Georges Terrace
Perth WA 6000
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Executive summary

Background

Worley was engaged to complete a pool impact assessment to support regulatory approvals for the North Star Magnetite Project Extension (NSE). The objectives of the impact assessment are summarised below:

- Identify and map all pools potentially impacted by the NSE development and Near Mine bore field, and define the Study Area.
- Determine and conceptualise the hydrological regimes of the pools in the Study Area and classify them in accordance with recognised frameworks based on water presence.
- Complete hydrological and water quality assessments (surface water and groundwater) for potentially impacted pools to quantify potential changes in quantity and quality of water inflows maintaining the pools.
- Use the results from the hydrological assessments to assess the likelihood of inland water impacts to pools within the Study Area and recommend management measures that could be implemented to mitigate impact to pools.
- The likelihood of inland water impact to pools is then used to inform the pool risk assessment led by Fortescue, which considers the inherent risk of inland water impact to environmental and cultural values and the residual risk with potential management controls.

Impact assessment methodology and results

The methodology and results from the impact assessment are summarised below:

- A total of 102 pools were identified within the Study Area, that have the potential to be impacted by the NSE development. For the purposes of impact assessment, individual pools were grouped into local "reaches" along connecting sections of drainage lines, resulting in a total of 82 reaches (refer Section 3.2). All potentially impacted pools have been assessed based on their corresponding reaches.
- Identified pools were assigned water presence classifications (pool persistence) adapted from the Australian National Aquatic Ecosystems (ANAE) toolkit (Aquatic Ecosystems Task Group, 2012), via the analysis of aerial imagery, satellite data, site observations and available monitoring data (refer Section 3.3). The following water presence classifications were applied:
    - Permanently Inundated: Water always present (100% of the imagery analysed),
    - Commonly Wet: Water present >70% to 99% of the imagery analysed,
    - Seasonally Inundated: Water present 50-70% of the imagery analysed, and

- Periodic Inundation/Ephemeral: Water present <50% of the imagery analysed.

- Conceptual water source models were developed for this study and adapted from Bourke et al. (2023), which define key hydraulic mechanisms maintaining pools in the Study Area. This resulted in the following six alternative conceptualisations for pools (refer Section 3.4):
  - 1a: Alluvium - perched throughflow
  - 1b: Alluvium/bedrock - perched throughflow
  - 2a: Bedrock - perched surface water
  - 2b: Bedrock fracture / regolith flow groundwater source
  - 3: Bedrock aquiclude - groundwater discharge
  - 4: Topographically controlled groundwater outflow
- The identified pools were then assigned conceptualisations based on available information and data, then each pool's sensitivity to change in surface water and/or groundwater inflows was assessed based on the assigned conceptualisations (refer Section 3.4).
- The water persistence classifications and Bourke et. al (2023) conceptualisations were used to identify the reaches (and associated pools) requiring surface water and groundwater impact assessments as follows:
  - **Groundwater Inflow and Quality Impact Assessment:** reaches with potential regional groundwater inflows that are located within the regional groundwater impact area (i.e., reaches with conceptual models 3 or 4). The impact assessment methodology assumes the following:
    - **Local groundwater** is not part of the regionally connected groundwater system, with groundwater either perched or residing in localised fracture networks within other very low permeability host rock. If the local groundwater system is directly impacted by mining, then a groundwater impact assessment is required. This would include any pools assigned conceptualisation Type 2b.
    - **Regional groundwater** is part of a regionally connected groundwater system. If the groundwater system is directly impacted by mining (i.e., mining activities within the groundwater catchment) or indirectly impacted by mining (via regional drawdown from groundwater abstraction), then a groundwater impact assessment is required. This would include any pools assigned conceptualisation Types 3 and 4.
  - **Surface Water Inflow and Quality Impact Assessment:** reaches with potential reduction in catchment area and surface water flows and are located

within the surface water impact area (i.e. reaches with conceptual models 1a, 1b, 2a, 2b, 3 and 4). The assessment is based on the following:

- Reaches (and associated pools) were only assessed where they are located within the surface water impact area which is defined as the extent of the surface water catchment areas affected by the proposed NSE development, beyond which the peak flows are expected to return to within 10-15% of the pre-development flows (Section 3.1).
- The impacts to reaches (and associated pools) located outside the surface water impact area are considered negligible due to the minor changes in flow and the dilution of any potential sources of adverse surface water quality.

- The reaches (and associated pools) requiring groundwater impact assessments and surface water impact assessments were initially identified using this methodology. More detailed analysis of catchments and NSE development footprints was then undertaken to identify reaches which are not impacted by the proposed NSE development or are completely removed by mining. The reaches identified for groundwater and surface water impact assessments are presented in Table ES-1 and Table ES-2. The following reaches were excluded from the impact assessment:
  - GE 10 and Pool 11: as they are not impacted by the proposed NSE development (either directly or indirectly).
  - Pool 62, Pool 50, and Pool 51: as they are located within the NSE development footprint and will be completely removed by mining.

Table ES-1: Reaches requiring groundwater impact assessment.

Reach ID	Water permanence classification	Conceptualisation Type
Mundagoora Pool	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge

Table ES-2: Reaches requiring surface water impact assessment.

Reach ID	Water permanence classification	Conceptualisation Type
Mundagoora Pool	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge

Reach ID	Water permanence classification	Conceptualisation Type
NJA19-002	Seasonal Inundation	Type 2a/2b - Bedrock perched surface water and/or local groundwater source
Pool IB-SW-Dry-Reject-DS-002	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool NJA21-006-US	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool NJA21-006-DS	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool-SW	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 9	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 59	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool 57	Periodic Inundation	Type 2a - Bedrock - perched surface water

- Hydrological and water quality assessments (surface water and groundwater) were completed for the identified reaches (and associated pools) summarised in Table ES-1 and Table ES-2 to quantify potential changes in quantity and quality of water inflows maintaining the reaches and associated pools. Reaches (and associated pools) classified as permanent and commonly wet contain water that persists for longer durations following flood events, so were assessed in greater detail than pools that are seasonally or periodically inundated.
- **Hydrological Impact Assessment:** the methodology involved some or all the following activities (refer Sections 5.1 and 5.2 for more details).
    - **Surface water inflow impact assessment:** To quantify changes in surface water inflows and associated impacts:
        - Catchment delineation and area calculation,
        - Event-based peak inflow estimation,
        - Event-based pool storage volume and inflow assessment,
        - Long-term hydrology simulation modelling to estimate 1,000 years of peak flow and inflow volumes, and
        - High-resolution, event-based 2D hydraulic modelling of pools.

   - **Groundwater inflow impact assessment:** To quantify changes in groundwater inflows and associated impacts:
      - Chloride mass balance (CMB) estimation of available recharge,
      - Linear steady-state flow using Darcy's flow analytical relationship, and
      - Pool flow pulse recession (PFPR) and return to baseflow, after a major rainfall event that initiates groundwater recharge.
- **Water Quality Impact Assessment:** the methodology adopted involved completion of the following tasks (refer Sections 6.2 and 6.3 for more details):
   - **Surface water quality impact assessment:** involved undertaking sediment delivery and flushing impact assessments to reaches (and associated pools) located within the surface water impact area.

     Note: the surface water quality impact assessments assume that runoff from disturbed areas within the surface water impact area shall be managed by Fortescue to minimise impacts associated with other water quality parameters during mining operations (e.g. WRDs will be designed to be internally draining, and thereby minimise sediment-laden runoff reporting to the pools).
   - **Groundwater quality impact assessment:** involved a qualitative, high-level assessment of potential groundwater quality impacts to reaches classified as permanent or commonly wet, due to:
      - Changes in groundwater inflows and potential need for supplementation of water to reaches (and associated pools) during operations.
      - Groundwater seepage from WRDs with potential to inflow to reaches (and associated pools).
- Three levels of potential inland waters impact severity were adopted for the impact assessment (High, Moderate and Low) and assigned to reaches (and associated pools) using the criteria outlined in ES-3. The results from the hydrological and water quality assessments (outlined above), and impact severity criteria were then used to assess potential inland water impacts to reaches (and associated pools) within the Study Area. The results are summarised in Table ES-4.
- The results suggest the following potential inland water impacts from the NSE development:
   - Reaches with High inland water impact include: Mundagoora Pool, Pool 59, and Pool 57.
   - Reaches with Moderate inland water impact include: Site 12 Pool, NJA19-002, Pool 9 and Pool NJA21-006-US, and
   - All other reaches have a Low inland water impact.

Management Controls

The reaches classified as having High or Moderate inland water impacts were then reassessed to identify potential mitigation measures that could be implemented during operations, and residual risk. The results and recommended mitigation measures are presented in Table ES-5.

Table ES-3: Classification of severity levels adopted for inland waters impact assessment.

Severity level	Inland Water Impact			
	Surface water inflow	**Groundwater inflow**	**Surface water inflow quality**	**Groundwater inflow quality**
Low	The pool/reach storage area volume is <30% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is <30% then minor impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) is expected to result in a minor change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is within +/-30% of the baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are expected to result in a minor change to the pool water balance.
Moderate	The pool/reach storage area volume is between 30-50% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is 30%-50% then moderate impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) are likely to result in a moderate change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is of a magnitude between 30% to 50% (+/-) compared to baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are likely to result in a moderate change to the pool water balance.
High	The pool/reach storage area volume is >50% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is >50% then significant impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) are likely to result in significant change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is of a greater magnitude than +/-50% of the baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are likely to result in significant change to the pool water balance.

Table ES-4: Summary of severity of potential inland water impact to reaches (and associated pools) identified in the Study Area due to NSE development

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	Low	High	Low	Low	High	The NSE development and existing Near Mine borefield will create groundwater drawdown which is likely to significantly impact on regional groundwater inflows to Mundagoora Pool during mining operations. The pit also removes 58% of the upstream catchment area resulting in a significant reduction in local groundwater recharge and inflows to the Mundagoora Pool. In relation to sediment transport / pool turbidity, the following minor impacts are expected which are unlikely to result in a significant geomorphological change to Mundagoora Pool: • Reductions in pool turbidity due to decreased supply and retention of fine sediment. • Reductions in soft sediment substrate. • Persistence of sediment capture in vegetated margins. • Armouring of pool bed with coarse sediment. The NSE development is expected to have a minor impact to the quantity of surface water inflows and no significant impact to the quality of surface water and groundwater inflows.
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	Low	Moderate	Low	Moderate	Moderate	Groundwater drawdown is likely to impact on groundwater inflows to Site 12 Pool during mining operations. Infiltration of direct rainfall on the WRD will enhance recharge and likely to result in local groundwater mounding within the extent of the WRD footprint. This has the potential to partially offset the effects of drawdown, resulting in a moderate impact severity to Site 12 Pool reach. In relation to sediment transport / pool turbidity, the following minor impacts are expected which are unlikely to result in a significant geomorphological change to Site 12 Pool: • Reduction in pool turbidity due to decreased fine sediment supply and retention. • Minor reductions in soft sediment substrate, but not as pronounced as Mundagoora Pool. • Continued sediment capture in vegetated margins or at bedrock outcrops. • Event-driven scour of both fine and coarse material to bedrock. The NSE development is expected to have a minor impact to the quantity of surface water inflows to the Site 12 Pool reach.
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to the quantity of surface water reporting to the pool. The development is expected to result in a moderate reduction in sediment supply and flow due to a moderate reduction in catchment area. This is likely to result in some aggradation/accumulation of sediment in pool reach as transport capacity

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
							decreases, with flushing of sediment occurring during larger events. Therefore geomorphological changes to pool area and depth are expected to be episodic but limited over the longer term.
Pool IB-SW-Dry-Reject-DS-002	IB_SW_DryReject_DS_02	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool NJA21-006-US	GV_SW_Pool_NJA21-006-US	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in a moderate reduction in sediment supply and flow due to moderate reduction in catchment area. This is likely to result in some sediment aggradation/accumulation in pool reach as transport capacity decreases, although this is expected to be minor and gradual given that the decrease to catchment area (a proxy for sediment supply) is greater than the decrease in event velocity. The significant distance between the pool and the NSE development footprint also buffers against impacts. Therefore geomorphological changes to pool area and depth are expected to be limited.
Pool NJA21-006-DS	GV_SW_Pool_NJA21-006-DS	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool-SW	55 - GV_SW_Pool_SW 56 - GV_SW_Pool_SWGV_DS	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool 9	9	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in a moderate reduction in headwater region of catchment area compounded by proximity to mining operations and moderate reduction in flushing velocity, so there is potential for increased sediment aggradation/accumulation. Therefore, the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium.
Pool 59	59	Low	N/A	High	N/A	High	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
Pool 57	57 63 64	● Low	N/A	● High	N/A	● High	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.

Table ES-5: Pools identified as having high or moderate impact, recommended management controls and residual impact

Reach ID	Pools Associated with Reach	Overall Unmitigated Impact	Recommended Management Controls	Overall Residual Impact Rating
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	High	Provide suitable infrastructure needed to supplement the inflow to the pool at the following rate if required (refer Section 5.2.3): • Mungagoora Pool: 0.5 L/s The source of supplementation water should have the same or better water quality than the pool to mitigate the risk of impacts. Section 6.1 presents a summary of the baseline water quality, which can be used to identify a suitable supply. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport to Mundagoora Pool and associated water quality impacts.	Low
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	Moderate	Provide suitable infrastructure needed to supplement the inflow to the pool at the following rate if required (refer Section 5.2.3): • Site 12 Pool: 1.5 L/s The source of supplementation water should have the same or better water quality than the pool to mitigate the risk of impacts. Section 6.1 presents a summary of the baseline water quality, which can be used to identify a suitable supply. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport to Mundagoora Pool and associated water quality impacts.	Low
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Moderate	The sediment transport assessment suggests that geomorphological changes to pool area and depth are expected to be limited. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool NJA21-006-US	GV_SW_Pool_NJA21-006-US	Moderate	The sediment transport assessment suggests that geomorphological changes to pool area and depth are expected to be limited. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool 9	9	Moderate	The sediment transport assessment suggests that geomorphological that the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool 59	59	High	The sediment transport assessment suggests that the reach may experience moderate to major increases in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.	High

Reach ID	Pools Associated with Reach	Overall Unmitigated Impact	Recommended Management Controls	Overall Residual Impact Rating
			Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	
Pool 57	57 63 64	● High	The sediment transport assessment suggests that the reach may experience moderate to major increases in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	● High

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Acronyms and abbreviations

Acronym/abbreviation	Definition
1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
ANAE	Australian National Aquatic Ecosystems
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
CL	Continuing Loss
CMB	Chloride Mass Balance
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Digital Elevation Model
DRL	Dry Reject Landform
EPBC	Environment Protection and Biodiversity Conservation
FMG	Fortescue Metals Group (now Fortescue)
GDA94	Geocentric Datum of Australia 1994
GDV	Groundwater Dependent Vegetation
GIS	Geographic Information System
GW	Groundwater
IL	Initial Loss
LiDAR	Light Detection and Ranging
LPB	Low Permeability Boundary
MGA	Map Grid of Australia
MNES	Matters of National Environmental Significance
NDVI	Normalised Difference Vegetation Index
NS	North Star
NSE	North Star Extension
PER	Public Environmental Review
PFPR	Pool flow pulse recession
PSD	Particle Size Distribution
ROM	Run of Mine
SRTM	Shuttle Radar Topography Mission
STM	Sediment Transport Modelling
SW	Surface water
WRD	Waste Rock Dump

1. Introduction

1.1 Background

FMG Iron Bridge (Fortescue) is looking to expand the current North Star Magnetite Project beyond the extent of the existing mine development envelope (North Star Stage 2). This expansion requires environmental approvals from the Environmental Protection Authority (EPA) and the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to enable development of new mine pits, a WRD extension, increased abstraction from the Near Mine borefield and associated infrastructure. This new development is called the NSE.

Several environmentally and culturally sensitive pools have been identified within the North Star Stage 2 and NSE mine development area which are associated to hydrological and hydrogeological (Inland Waters) regimes. Fortescue has previously submitted documentation to regulatory bodies regarding the impact that the NSE development may have on the Inland Waters factor.

Fortescue engaged Worley Services Pty Ltd (Worley) to review and address the existing technical gaps in the two regulatory submissions made for the NSE. The scope includes any work required to develop documentation to support additional regulatory submissions and responses to regulatory feedback.

The relevant regulator comments from the Public Environmental Review (PER) guideline (*North Star Magnetite Project Extension, Pilbara, WA [EPBC 2023/09466]*) are provided in Section 8.

1.2 Study objectives

The overall aim of this study is to assess the likelihood of impact of the proposed development on the identified pools and develop strategies to mitigate the impacts. The specific objectives are outlined below:

- Identify and map all pools potentially impacted by the NSE development and the approved Near Mine borefield and define the Study Area.
- Determine and conceptualise the hydrological regimes of the pools in the Study Area and classify them in accordance with recognised frameworks based on water presence.
- Complete hydrological and water quality assessments (surface water and groundwater) for potentially impacted pools to quantify potential changes in quantity and quality of water inflows maintaining the pools.
- Use the results from the assessments to assess likelihood of inland water impacts to pools within the Study Area and recommend management controls that could be implemented to mitigate impact to pools.

1.3 Scope of work

The following scope of work has been developed to address the relevant regulator comments from the PER guideline pertaining to inland waters specifically for pools:

1. Determine the extent of the Study Area based on the estimated extent of surface water and groundwater related impacts associated with the NSE development.
2. Identification of pools within the Study Area.
3. Classification of pools by water presence (pool persistence) based on the Australian National Aquatic Ecosystems (ANAE) toolkit (Aquatic Ecosystems Task Group, 2012), and analysis of aerial imagery, satellite data, site observations and available monitoring data.
4. Use Bourke et. al (2023) to develop conceptual water source models that define the key hydraulic mechanisms maintaining pools in the Study Area.
5. Assign conceptualisations to identified pools based on available information and use them to determine pool sensitivity to change in surface water and/or groundwater inflows.
6. Use water persistence classifications and hydraulic conceptualisations to identify the reaches (and associated pools) requiring surface water and groundwater impact assessments.
7. Complete hydrological and water quality assessments (surface water and groundwater) to quantify potential changes in quantity and quality of water inflows maintaining the pools.
8. Use results from the hydrological and water quality assessments to assess likelihood of impacts to pools.

2. Supplied information and data

The following data has been received from Fortescue and utilised to perform pool identification, classification, hydrology and hydraulic modelling, impact assessment on the pools and propose mitigation measures.

Table 2-1. Data supplied and utilised in this study.

Data type	Description	File name
Topographic survey	1 m Light Detection and Ranging (LiDAR) topography data captured in March 2024	PIL_ELEV_FMG_IRON_BRIDGE_1M_DEM_MAR2024.TIF
	Bathymetry survey of Mundagoora Pool	LiDAR w Mundagoora Bathy 0_5m mAHD at 288_86m WL 20200627 MGAz50.tif
Aerial imagery	Aerial imagery captured between 2011 and 2023	.ecw format (43 separate files)
Mine infrastructure design surfaces	Run of Mine (ROM) B landform design	rom02_is01_0001_v17_csur.tif
	Dry Reject Landform (DRL) closure landform design	drl_cl_design_1st_lift_v2.tif
	Glacier Valley North Pit	pit_gvn_s01_rev01_201905_cut.tif
	Glacier Valley South Pit	gvs03_pitd_r02.2_sur_cut.tif
	WRD	nts99_00_dump_cut_r001_csur.tif
Rainfall data	Nate Tower rainfall data from 2019 to 2023 in 15-minute recording intervals	NS_Nate_WE_WS_02.xlsx
Streamflow Logger information	Flow depth measurements for five waterway loggers	NSE_Streamflow_Data.xlsx
	Discharge and flow depth measurements of three surface water loggers in pools	NSE_Pool_Streamflow_Data.xlsx
	Location of installed loggers within the area of study	Logger_Location.shp
	Line representing cross section where logger hydrographs are estimated	2d_PO_lines.shp
Groundwater drawdown data	Groundwater drawdown contours from numerical groundwater flow modelling by Fortescue. The contours are based on low recharge, so represents a worst case/conservative drawdown scenario.	New Reduced Recharge Drawdown – End.shp
Particle Size Distribution (PSD) Data	PSD curves of the soil samples collected within the Mundagoora catchment area	EP2110918_PSD.pdf Soil and Gravel Class based on PSD.xlsx
Development Envelopes	Approved Part IV development envelope for NS Stage 2 includes development envelope of Mine, Infrastructure, Water Corridor and Slurry Corridor	Approved IDF.shp
	Proposed development envelope for NSE	North Star Extension Proposed Action Envelope.shp
	Overview of approved and proposed development envelope for NS Stage 2 and NSE	NSE PER_Overview Location Map.jpg
Report	Final PER Guidelines – NS Magnetite Project Extension	Final PER Guidelines - North Star Magnetite Project Extension EPBC 2023-09466 – 20240315.pdf
	North Star Groundwater Operating Strategy – Iron Bridge Near Mine Groundwater Supply Scheme	App 37 NS GW Operating Strategy rev4_Final_v0.pdf
	Iron Bridge Mine Area Hydrogeological Assessment	App 35 IB Mine Area Borefield Hydrogeological Assessment_2023.pdf

Data type	Description	File name
	Environment Protection and Biodiversity Conservation Act Referral: Supporting Documentation	App A NSE EPBC Referral Supporting Doc Rev1 signedMD.pdf
	N North Star Magnetite Project Extension Baseline Hydrology Report	311012-02196-HYD-REP-001-0 (Baseline Hydrology).pdf
	North Star Magnetite Project Extension Hydrological Impact Assessment Report: Waterways	311012-02196-HYD-REP-002-0 (Impact-Assessment).pdf

3. Pool characterisation and classification

3.1 Study area

The impact assessment Study Area was based on the combined extent of the estimated surface water impacts and regional groundwater drawdown impacts associated with the NSE project development and approved project. The extent of the surface water and regional groundwater impacts were defined as follows:

- **Surface Water Impact Area**: Extent of the surface water catchment areas affected by the proposed NSE development, beyond which the peak flows are expected to return to within 10-15% of the pre-development flows (includes both the NSE Pit and WRD catchments). The eastern boundary of the surface water impact area was extended by up to 500 m to ensure all previously identified named pools were included in the assessment.
- **Groundwater Impact Area**: Extent of regional groundwater drawdown impacts due to groundwater abstraction of the existing Near Mine borefield and planned mine dewatering of the NSE development. The 2 m drawdown contour used to define this extent is based on a reduced recharge rate scenario[1] reflecting mining and presumed climate conditions in 2044.

The extent of the surface water and groundwater impact areas and the overall Study Area are presented in Figure 3-1.

[1] Conservative scenario that accounts for uncertainty in the groundwater model.

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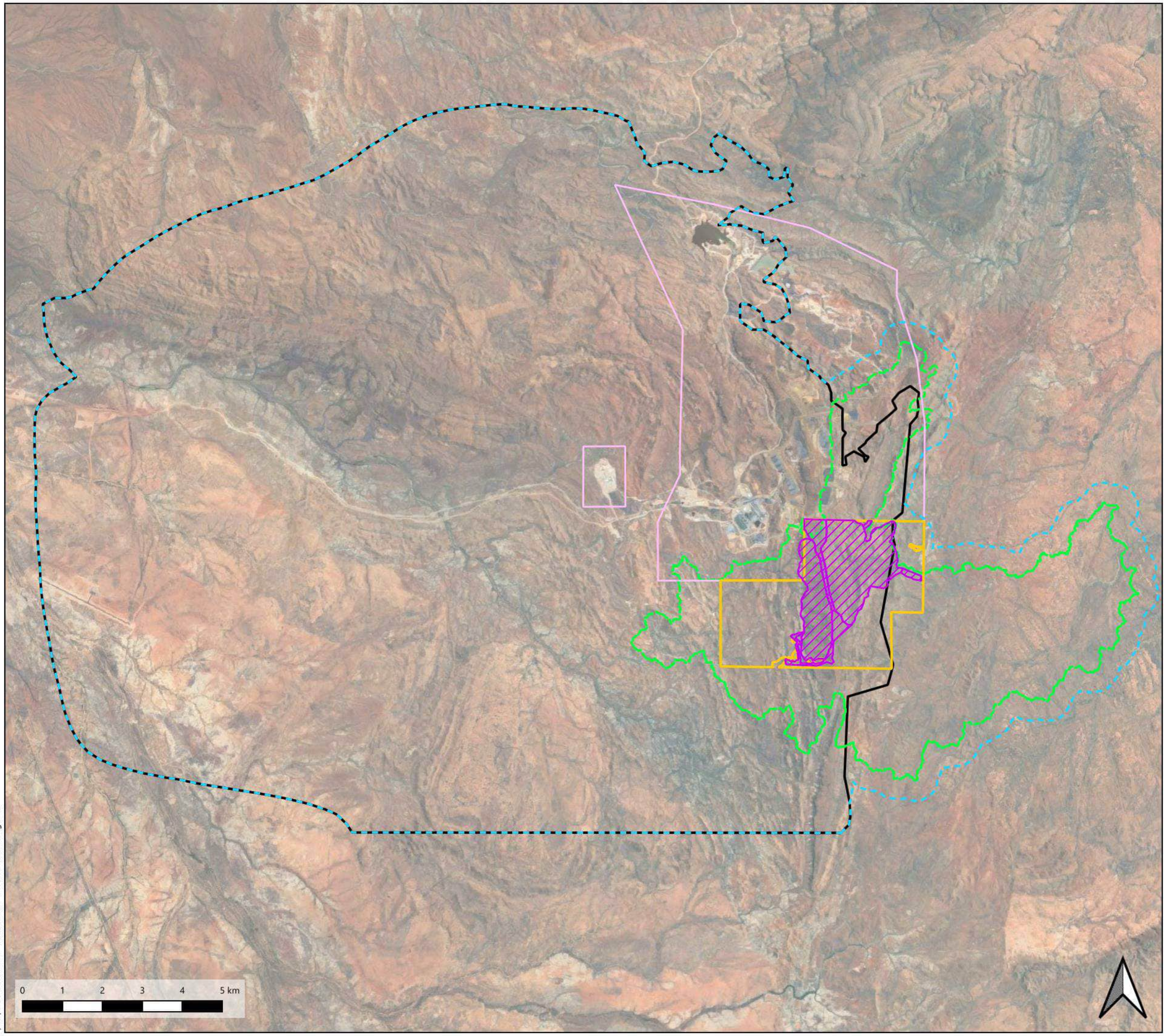

NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

STUDY AREA

Legend

- Study Area
- Surface Water Impact Area
- Groundwater Impact Area
- NSE Proposed Development Envelope
- NSE Indicative Disturbance Footprint
- NS Approved Development Envelope

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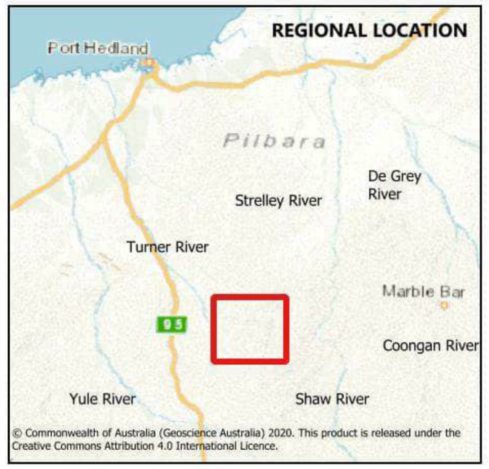
Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 90,000



Fortescue. worley consulting

Figure 3-1. Study Area.

3.2 Pool identification

Pools were identified in the Study Area using a combination of site visits/observations, pool monitoring and satellite/aerial imagery interpretation. A detailed description of the methodology used to identify pools is provided in the Pools Characterisation Report (Hydrobiology, 2025a), provided in Appendix A and summarised below.

The following data sources were used to identify pools:

- Imagery data:
  - High resolution aerial imagery data supplied by Fortescue covering a period from August 2011 to June 2024. There were 43 different aerial photos available during this period, with most images covering only part of the Study Area.
  - Sentinel-2 satellite imagery captured at 10 m resolution across the Study Area every five days since October 2016. This included:
    - True color composite imagery,
    - Normalised difference vegetation index (NDVI) imagery, and
    - Moisture index imagery.
  - Google Earth imagery from 2006 to 2024.
- Topographic survey data:
  - LiDAR data at 1 m resolution, covering only part of the Study Area,
  - Shuttle Radar Topography Mission (SRTM) data (NASA JPL, 2013)
  - Geoscience Australia elevation dataset (ELVIS; https://elevation.fsdf.org.au/)
- Site photos, inspections, and pool monitoring, between December 2019 and November 2024.

A total of 102 pools were identified within the Study Area as shown in Figure 3-2.

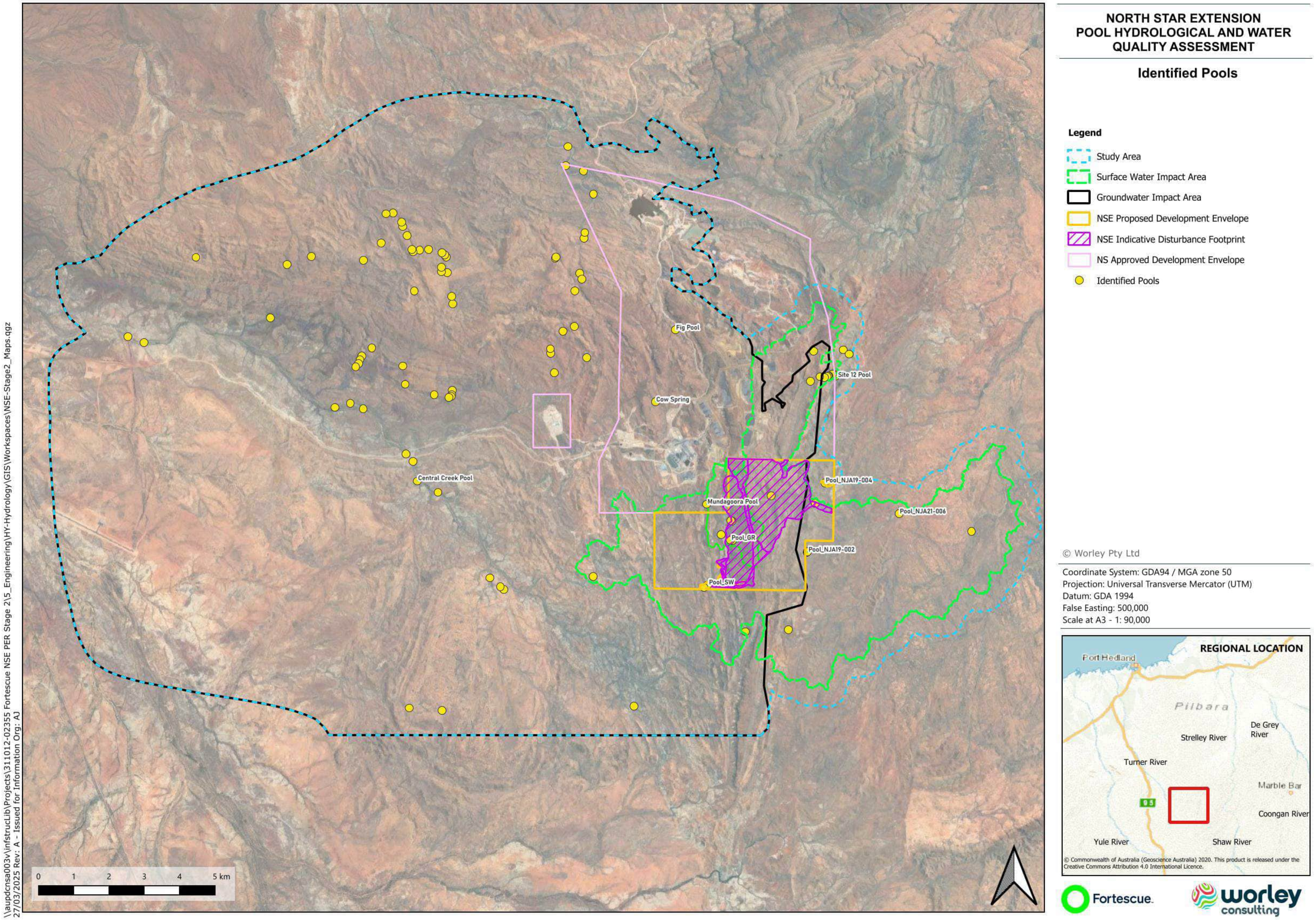


Figure 3-2. Identified pools within the Study Area.

3.3 Water presence classifications

The water presence classifications (pool persistence) presented in Table 3-1 were adopted and adapted from the Australian National Aquatic Ecosystems (ANAE) toolkit (Aquatic Ecosystems Task Group, 2012) based on analysis of aerial imagery, satellite data, site observations and available monitoring data. The overall water presence percentage for each pool was calculated by dividing the number of images with identifiable water present by the total number of images covering the pool.

Table 3-1: Water presence classifications.

Classification	Water Presence Percentage	Description
Permanently Inundated	100%	Water always present within the imagery analysed.
Commonly Wet	>70% to 99%	Water present in >70% to 99% of the imagery analysed (may vary depending on the wet season, though the pool is known to dry out occasionally). This category is derived from the ANAE method.
Seasonally Inundated	50-70%	Water present in 50-70% of the imagery analysed. Mostly over the wet season. Relates to pools that routinely dry out over the dry season and are not likely to provide dry season refugia.
Periodic Inundation / Ephemeral	<50%	Water present in <50% of the imagery analysed. Pools that dry out over the wet season, receding after flow events over a period of days to weeks and which do not tend to persist into the dry season.

The 102 pools were classified using this method, with the results summarised in Table 3-2 and Figure 3-3. The results suggest the following:

- Seven pools were classified as Permanent, meaning water was present in all observed imagery (7% of the total number of pools identified),
- Fourteen pools were categorized as Commonly Wet, with water present in more than 70% of the imagery (15% of the total number of pools identified),
- The remaining pools were either Seasonally Inundated containing water primarily during the wet season or had Periodic Inundation/Ephemeral characteristics where water was present only briefly following rainfall events (11% and 69% of the total number of pools identified, respectively).

Table 3-2: Pool water permanence classification summary.

Permanence Classification	Percentage of images where water was present	Count	Percentage of Total Count (%)
Permanent	100%	7	7%
Commonly Wet	>70% to 99%	14	14%
Seasonal Inundation	50-70%	11	11%
Periodic Inundation/Ephemeral	<50%	70	69%
Total		**102**	**100%**

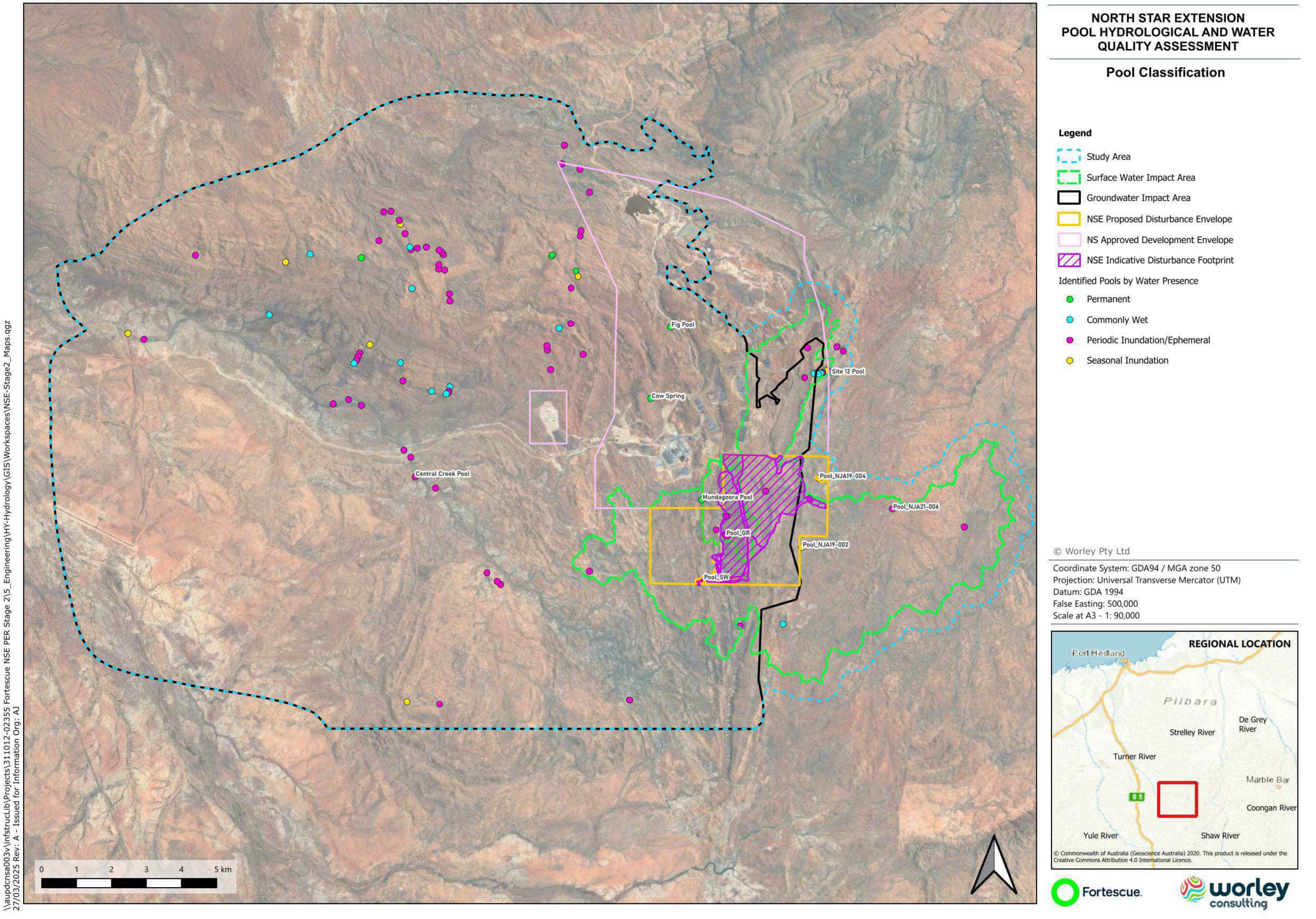


Figure 3-3. Pool classifications within Study Area.

3.4 Conceptualisation of pools (Bourke et al., 2023)

3.4.1 Conceptual models

A recent published peer-reviewed scientific paper titled *A hydrological framework for persistent pools along non-perennial rivers* (Bourke et al., 2023) was identified as providing a suitable basis for categorising the pools identified for the NSE study area based on their hydrologic and hydrogeological characteristics. This paper specifically used Pilbara pools for the case studies of the application of its methodology and therefore was particularly relevant to the NSE study area. Bourke et al. (2023) provides a framework for the classification of the key hydraulic mechanisms that support the persistence of river pools.

Table 3-3 presents the conceptual water source models developed for this study and adapted from Bourke et al. (2023), which outline the key hydraulic mechanisms maintaining pools in the Study Area. Figure 3-4 to Figure 3-9 provide visual conceptualisations for each model applied in the pool classifications for the current study. These have largely been adopted from Bourke et. al. (2023), with minor modifications as noted in the figure captions and markups on the figures.

The Pools Characterisation Report (Hydrobiology, 2025a) provided in Appendix A, assessed each pool conceptualisation in Table 3-3 to determine whether they are sensitive to changes in:

- Surface water inflows reporting to the pool,
- Local groundwater inflows to pool, and/or
- Regional groundwater inflows to pool (i.e., regionally connected groundwater).

The hydraulic conceptualisation Type 2b (Bedrock - fracture flow groundwater source) has been derived specifically for the NSE project and has previously been used by Fortescue (2023) to describe the hydraulic conceptual model for several pools in the Study Area.

These pools are considered not likely to be connected to the regional water table, based on their position in the landscape (relative to inferred regional water table and available groundwater level monitoring records) and the unique presence of the pool where adjacent drainages do not show pool features at the same elevation or lower. It is proposed that this type of pool is supported by inflows from groundwater hosted within fractured rock or regolith; with the extent of these features limited to a localised catchment above and adjacent to the pool. These pools are considered not likely to be connected to the regional water table, based on their position in the landscape (relative to inferred regional water table and available groundwater level monitoring records) and the unique presence of the pool where adjacent drainages do not show pool features at the same elevation or lower.

Table 3-3. Summary of Conceptual Water Source Models used in the current study.

Type #	Conceptualisation type	Description	Potentially Sensitive to Changes in Surface Water Inflows	Potentially Sensitive to Local Groundwater Inflows	Potentially Sensitive to Regional Groundwater Inflows
1a	Alluvium - perched throughflow	Alluvium throughflow, with scour holes and potential for localised perching due to presence of lower permeability units. Pool water primarily reliant on surface water flows, and pool levels higher than "regional" water table.	Yes	No	No
1b	Alluvium/bedrock - perched throughflow	Alluvium throughflow, with scour holes and bedrock expressions, resulting in localised perching of surface water. Pool water reliant on surface water flows, and pool levels higher than "regional" water table.	Yes	No	No
2a	Bedrock - perched surface water	Perched water high in bedrock catchment, pool situated within lower permeability units. Pool water reliant on surface water flows or interflow, and pool levels higher than "regional" water table.	Yes	No	No
2b	Bedrock fracture / regolith flow groundwater source	Pool fed by local groundwater catchment via flow in fractured bedrock or regolith. Fracture systems may be aligned with surface water drainage lines. Connection with regional water table is unlikely due to position of pool in the landscape, comparison with available regional groundwater elevation data, and the unique presence of the pool where adjacent drainages do not show pool features at the same elevation or lower.	No	Yes	No
3	Bedrock aquiclude - groundwater discharge	Groundwater discharge to surface due to catchment constriction across ridge line, presence of low permeability unit and lateral constraint on groundwater flow.	No	Yes	Yes
4	Topographically controlled groundwater outflow	Topographically controlled groundwater outflow either regional or local. These locations are identified based on water presence, geomorphology and catchment setting.	No	Yes	Yes

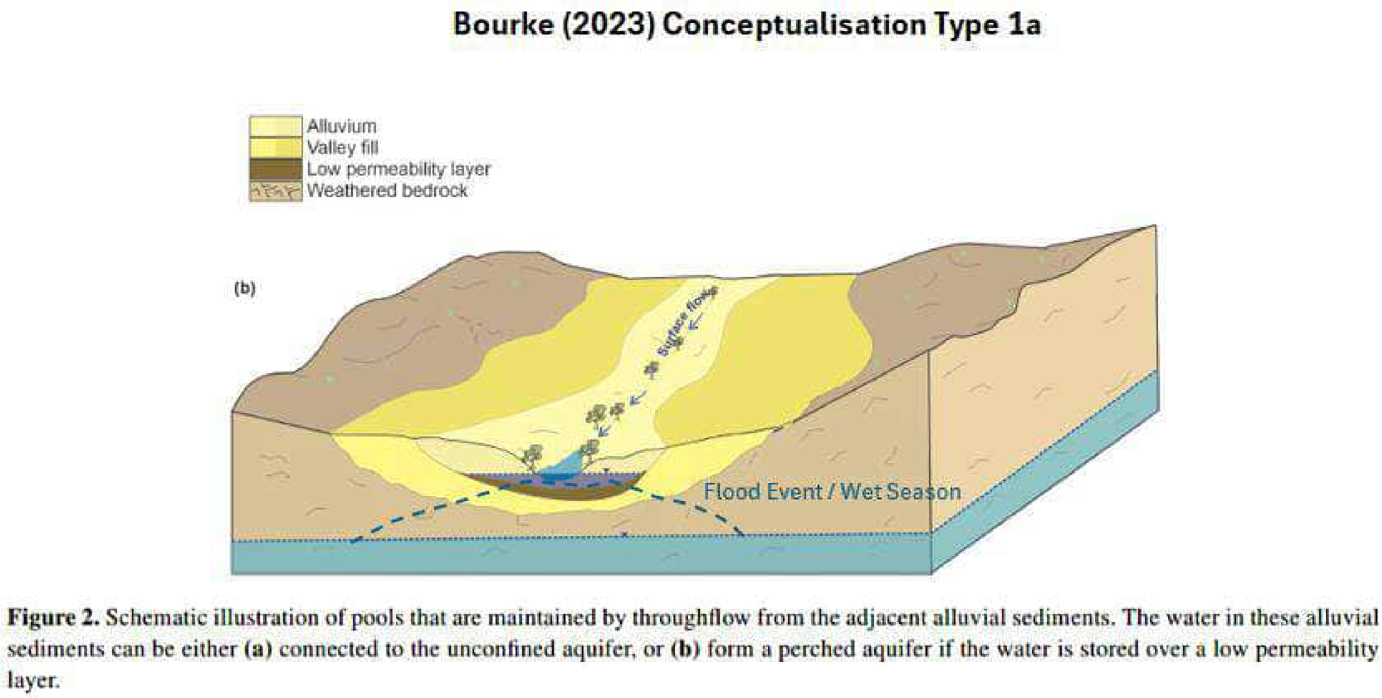


Figure 3-4. Hydraulic mechanism Type 1a: Alluvium - perched throughflow (adapted from Bourke et. al. [2023] Figure 2).

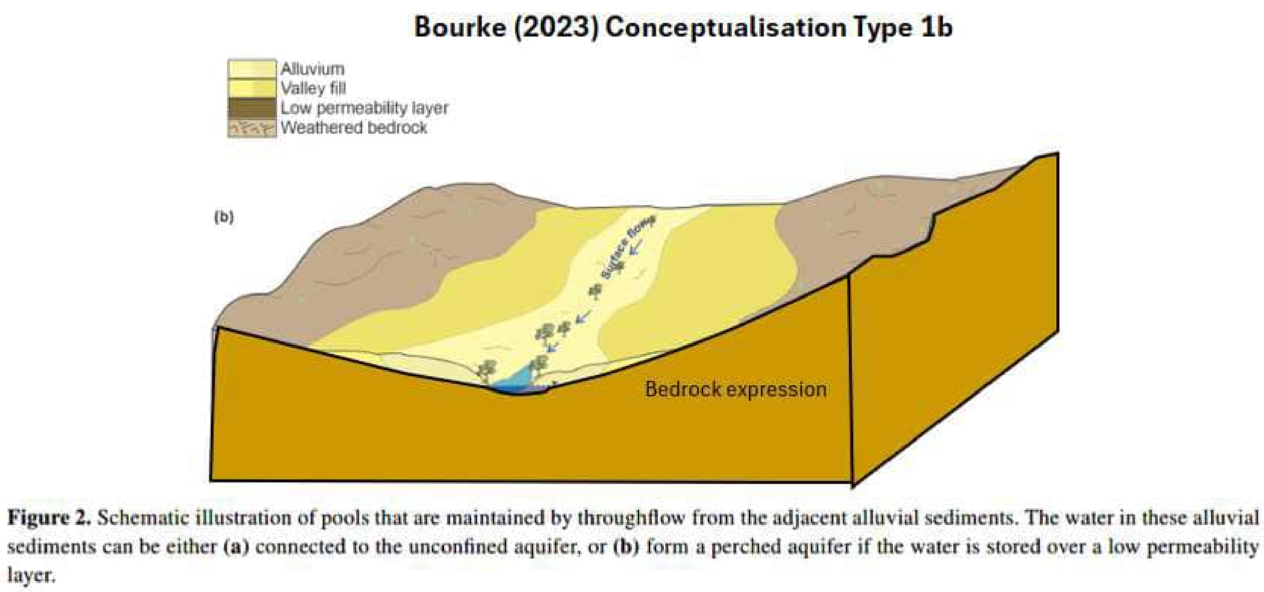


Figure 3-5. Hydraulic mechanism Type 1b: Alluvium/bedrock - perched throughflow (adapted from Bourke et. al. [2023] Figure 2).

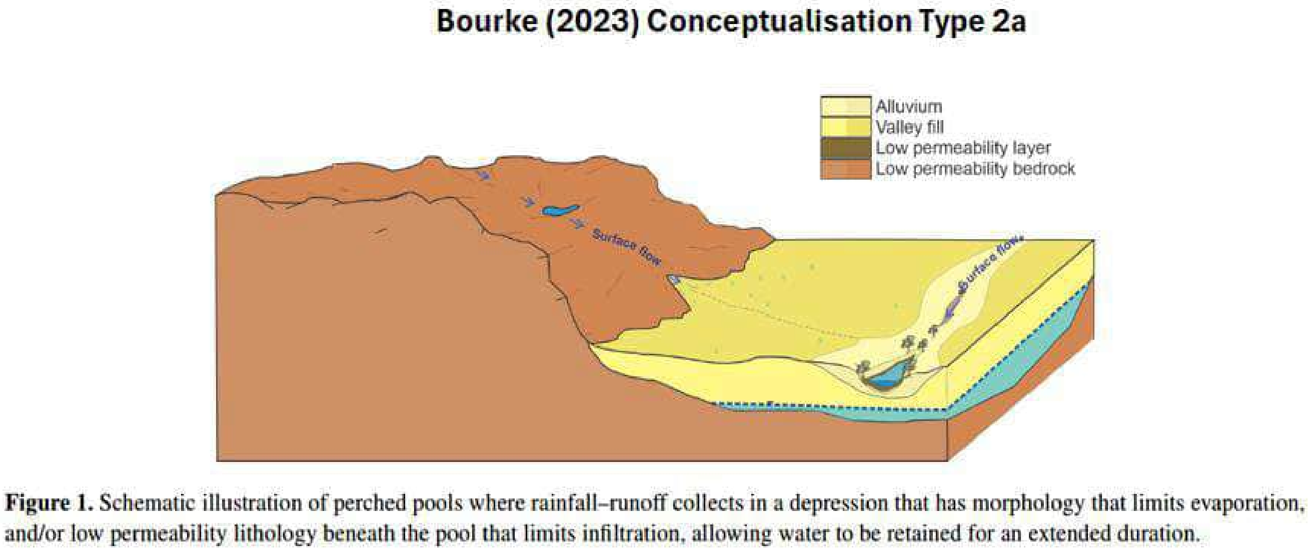


Figure 3-6. Hydraulic mechanism Type 2a: Bedrock - perched surface water (adapted from Bourke et. al. [2023] Figure 1).

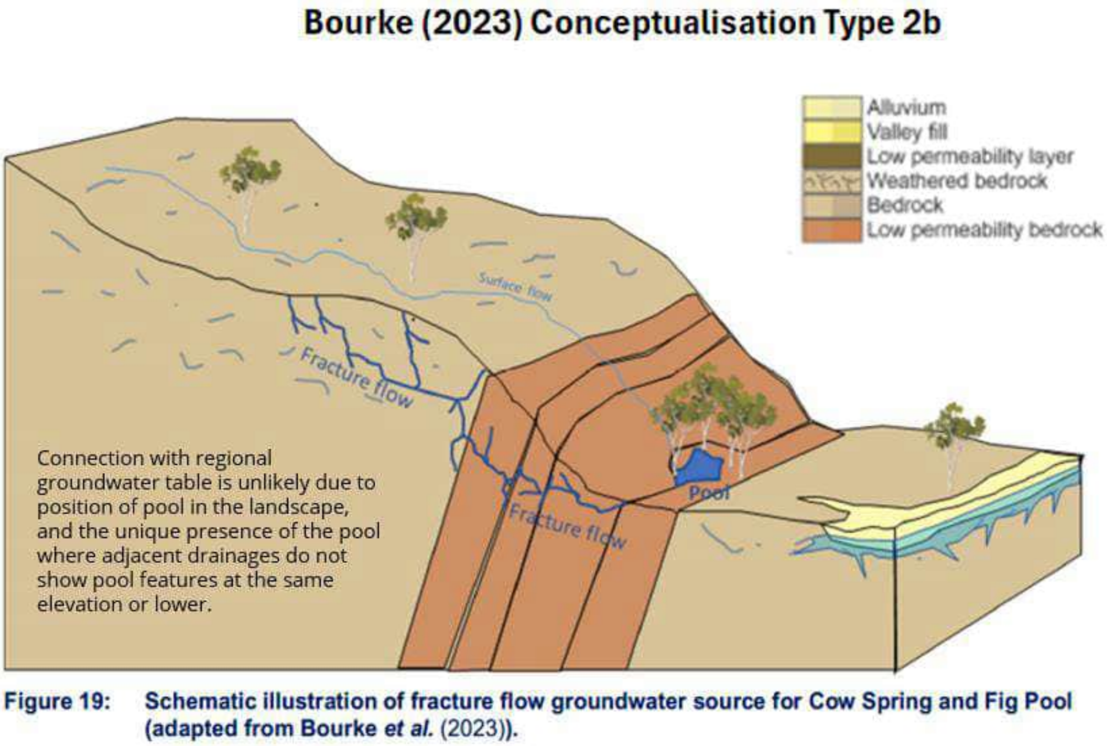


Figure 3-7. Hydraulic mechanism Type 2b: Bedrock fracture / regolith flow groundwater source (adapted from Fortescue [2023] Figure 19, after Bourke et. al. [2023]).

Bourke (2023) Conceptualisation Type 3

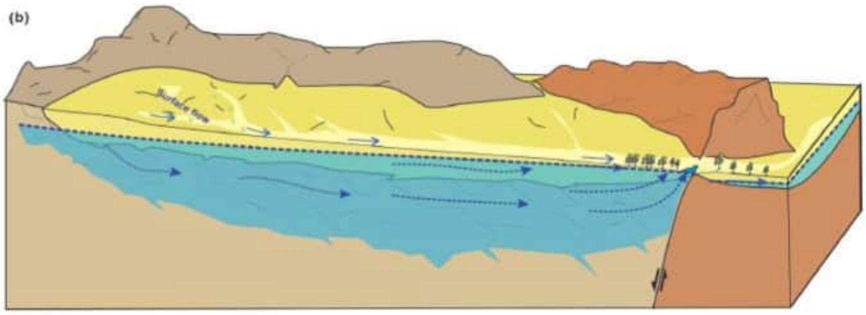


Figure 3. Schematic illustration of a groundwater discharge pools where surface water persistence is driven by geological barriers that **(a)** cause a regional aquifer to pinch out vertically or **(b)** form a lateral constraint on the catchment and underlying regional aquifer.

Figure 3-8. Hydraulic mechanism Type 3: Bedrock aquiclude - groundwater discharge (adapted from Bourke et. al. [2023] Figure 3).

Bourke (2023) Conceptualisation Type 4

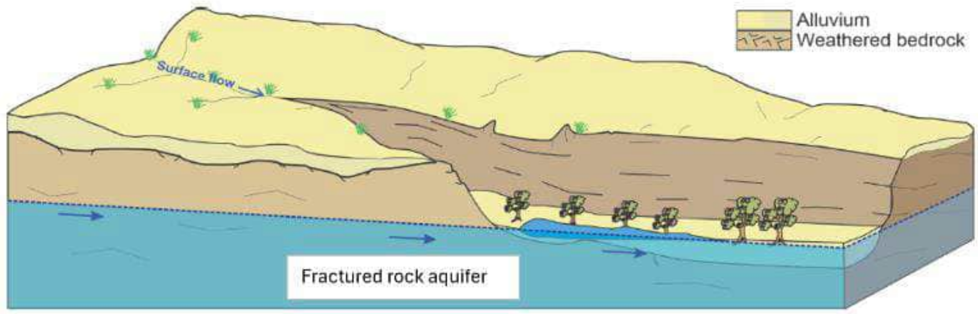


Figure 4. Schematic illustration of a pool receiving topographically-controlled groundwater outflow from a regional aquifer.

Figure 3-9. Hydraulic mechanism Type 4: Topographically controlled groundwater outflow (adapted from Bourke et. al. [2023] Figure 4).

3.4.2 Assigning conceptualisation type to pools

The multiple lines of evidence provided in Table 3-4 were used to assign conceptual models to identified pools. Table 3-5 lists all pools within the Study Area and provides the assigned conceptual models and water presence classifications. Each pool's sensitivity to change in surface water and/or groundwater inflows has also been assessed in Table 3-5 based on the assigned conceptualisations.

A detailed description of the methodology used to assign conceptual models to pools is provided in in the Pools Characterisation Report (Hydrobiology, 2025a), included in Appendix A.

Table 3-4. Evidence matrix description.

Line of Evidence	Description
Evidence matrix-based source	This field contains the general consensus on the likely water source based on the multiple lines of evidence listed below. This is either GW (groundwater), SW (Surface Water) or GW/SW (a combination of both).
EM - Water Presence	SW indicators include: • Water presence typically only after wet season rains (for days to weeks), • Receding water at or faster than evaporation rates after the last rainfall event, or • Water not typically present during the dry season. GW indicators include: • Water presence in the pools for longer than would be expected/calculated based on evaporation and antecedent rainfall. • Water not receding after extended dry periods (months)
EM - Fullness Score	As for Water Presence, the average fullness of the pool can indicate if inflows to the pool are related to rainfall or a more consistent source (i.e., groundwater). For example, pools that are reliant on surface flows will recede (become less full) with time from the previous flow event. Groundwater sourced pools will be more stable/persistent.
EM - Substrate	The substrate of a pool can provide an indication of the permeability and potential for the pool water being perched above an impervious geological layer (e.g., bedrock). Pools within deep alluvial sediments, particularly scour holes at bends (often against a rock-face), can indicate a surface water source of alluvial throughflow.
EM - Location	This line of evidence can be somewhat subjective though useful. For example, a pool located at the base of a cliff face, with a very small catchment above it, could be considered in a location that is likely to be supported by local groundwater derived from the elevated terrain adjacent to the pool (as the catchment would be too small for extended alluvial throughflows). Pools located within a similar setting to other pools, where more data might exist, can have "Location" line of evidence suggesting a likely similar water source.
EM - Elevation	The elevation can be relevant to the potential for regional groundwater to be a source (i.e., the pool is below the measured or inferred regional water table elevation). Similarly, if data exists that indicates groundwater surface expressions occur within a given elevation band, then this can be a potential line of evidence.
EM - Depth to regional GW	As with Elevation, the relative depth of the regional water table to the pool water surface can indicate if there is potential for the pool water to be from or in connection to this source. Pools with surface elevations above the regional water table (within a margin of error for topographically driven

Line of Evidence	Description
	variability), can be attributed to a local aquifer or surface water source depending on the water persistence. The results from the comparison of pool elevations and available regional groundwater elevations, used to assign conceptualisations is provided in Appendix A.
EM - Catchment Size	For alluvial throughflow to generate persistence of pools deep into the dry season, a relatively large catchment may be required to support this as a potential source. Where the catchment area is relatively small, and inflows exist in alluvial substrates or bedrock depressions (substrate) into the dry season, this may indicate that a groundwater source is present.
EM - Flow Regime	The measured flow-regime of a pool can indicate the dominant water source. For example, if a pool only fills with a rainfall event (as indicated by local rainfall records) and recedes at a rate consistent with alluvial throughflow/evaporation post surface water flow events, then a surface water source would be indicated. If the pool continues filling weeks after surface water flows have ceased within the drainage, and persists well into the dry season, this may indicate that a groundwater source is present.
EM - Vegetation	Groundwater near the surface can drive the presence of dense vegetation (groundwater dependent vegetation – GDV) dominated by wetland species (e.g., Melaleuca, Sedges, Typha etc.). If the vegetation vigour extends into the late dry season, relative to regional vegetation, then a groundwater source is likely to be present (e.g., as measured by NDVI). The absence of hydrophilic vegetation, or denser vegetation relative to the regional norm, can indicate that the groundwater table is not close to the root zone within the pools location and therefore the pool may be surface water sourced.
EM - Hydrochemistry	The most common hydrochemical indicator for groundwater inflows is a difference in dissolved ion content (as measured by electrical conductivity/salinity). Groundwater typically contains higher concentrations of dissolved ions than surface water inflows dominated by recent rainfall. In contrast, surface water inflows that have ceased and are perched on impervious substrates (such as in a bedrock depression) will increase in dissolved ion concentrations as the water evaporates into the dry season. A salinity above the local/regional groundwater concentration may indicate a perched surface water source.

3.5 Reach classifications

For the purposes of impact assessment, individual pools were grouped into local “reaches” along a connecting sections of drainage lines. Where there was only a single pool along a reach, a representative section of drainage line upstream and downstream of the pool “point” feature was included as the pool reach. The purpose of generating reaches was to provide a mechanism to group pools within close proximity (i.e., within several hundred meters along the same drainage line) where the same impact mechanisms and assessment could be applied across the reach. This reduced repetition where groups of pools would be similarly potentially impacted. Where there were multiple pools within a reach, the water permanence classifications and conceptualisations of the most persistent pool was adopted for the impact assessment (i.e., if there was both an “ephemeral” and a “seasonally inundated” pool within the reach, then the “seasonally inundated" attribute was adopted).

The methodology and justification for this approach is described in detail in the Pools Characterisation Report (Hydrobiology, 2025a) provided in Appendix A. The resulting reaches assigned to pools are provided in Table 3-5.

Section 3.6 outlines the number of reaches within each identified hydraulic conceptualisation type (after Bourke et. al. 2023).

Table 3-5. Pool classifications, reaches and potential sensitivity to surface water and groundwater changes.

Pool Name	Reach ID	Bourke (2023) Conceptualisation #	Water Permanence	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
1-IB_SW_Pool12	Site 12 Pool	3	Seasonal Inundation	No	Yes	Yes
2-S12string	Site 12 Pool	3	Periodic Inund./Ephemeral	No	Yes	Yes
3-S12string	Site 12 Pool	3	Seasonal Inundation	No	Yes	Yes
4-S12string	Site 12 Pool	3	Periodic Inund./Ephemeral	No	Yes	Yes
5-S12string	Site 12 Pool	3	Periodic Inund./Ephemeral	No	Yes	Yes
6-S12string	Site 12 Pool	3	Commonly Wet	No	Yes	Yes
7-S12string	Site 12 Pool	3	Commonly Wet	No	Yes	Yes
8 - IB_SW_Pool12_01	Site 12 Pool	3	Commonly Wet	No	Yes	Yes
9	Pool 9	1a	Periodic Inund./Ephemeral	Yes	No	No
11	Pool 11	2a	Periodic Inund./Ephemeral	Yes	No	No
15	15	1b	Periodic Inund./Ephemeral	Yes	No	No
36 - IB_SW_TSF_02	36 - IB_SW_TSF_02	1a	Periodic Inund./Ephemeral	Yes	No	No
37	37	1a	Periodic Inund./Ephemeral	Yes	No	No
38	38	1a	Periodic Inund./Ephemeral	Yes	No	No
39 - IB_SW_TSF_03	39 - IB_SW_TSF_03	1a	Periodic Inund./Ephemeral	Yes	No	No
40	40	1a	Periodic Inund./Ephemeral	Yes	No	No
41	41	1a	Periodic Inund./Ephemeral	Yes	No	No
42	42	2b	Permanent	No	Yes	No
43	43	2a/2b	Seasonal Inundation	Yes	Yes	No
44	93	2b	Permanent	No	Yes	No
45	45	2a	Periodic Inund./Ephemeral	Yes	No	No
46	46	1a	Periodic Inund./Ephemeral	Yes	No	No
47	47	1a	Periodic Inund./Ephemeral	Yes	No	No
48	48	2a	Periodic Inund./Ephemeral	Yes	No	No
49	49	1b	Periodic Inund./Ephemeral	Yes	No	No
50	Pool 50	1a	Periodic Inund./Ephemeral	Yes	No	No
51 - GV_SW_WRD _01	Pool 51	1b	Periodic Inund./Ephemeral	Yes	No	No
52	NJA19-002	2a/2b	Seasonal Inundation	Yes	Yes	No
GV_SW_Pool_ Mundagoora_SS	Mundagoora Pool	3	Permanent	No	Yes	Yes
55 - GV_SW_Pool_SW	Pool-SW	1a	Periodic Inund./Ephemeral	Yes	No	No
56 - GV_SW_Pool_SWGV_DS	Pool-SW	1a	Periodic Inund./Ephemeral	Yes	No	No
57	Pool 57	2a	Periodic Inund./Ephemeral	Yes	No	No
59	Pool 59	2a	Periodic Inund./Ephemeral	Yes	No	No
60 - IB_SW_Pool_ Central Ck	60 - IB_SW_Pool_Central Ck	1a	Periodic Inund./Ephemeral	Yes	No	No
61 - GV_SW_Pool_ NJA19-002	NJA19-002	2a/2b	Seasonal Inundation	Yes	Yes	No

Pool Name	Reach ID	Bourke (2023) Conceptualisation #	Water Permanence	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
62	Pool 62	2a	Periodic Inund./Ephemeral	Yes	No	No
63	Pool 57	2a	Periodic Inund./Ephemeral	Yes	No	No
64	Pool 57	2a	Periodic Inund./Ephemeral	Yes	No	No
65	Pool 62	2a	Periodic Inund./Ephemeral	Yes	No	No
78 - GV_SW_Pool _GR	Pool 62	2a	Periodic Inund./Ephemeral	Yes	No	No
79	79	1a	Periodic Inund./Ephemeral	Yes	No	No
80	80	1a	Periodic Inund./Ephemeral	Yes	No	No
81	81	1a	Periodic Inund./Ephemeral	Yes	No	No
82	82	1a	Periodic Inund./Ephemeral	Yes	No	No
83	83	1a	Periodic Inund./Ephemeral	Yes	No	No
84	84	1a	Periodic Inund./Ephemeral	Yes	No	No
85	85	1a	Periodic Inund./Ephemeral	Yes	No	No
86	86	1b	Periodic Inund./Ephemeral	Yes	No	No
87	87	1a	Periodic Inund./Ephemeral	Yes	No	No
88	88	2a	Periodic Inund./Ephemeral	Yes	No	No
93	93	2b	Permanent	No	Yes	No
94	97 - Zanes Gorge Pool	2a/2b	Commonly Wet	Yes	Yes	No
95	97 - Zanes Gorge Pool	2a	Periodic Inund./Ephemeral	Yes	No	No
96	97 - Zanes Gorge Pool	2a	Periodic Inund./Ephemeral	Yes	No	No
97 - Zanes Gorge Pool	97 - Zanes Gorge Pool	2a/2b	Commonly Wet	Yes	Yes	No
98 - Dingo Lair Pool	98 - Dingo Lair Pool	2a	Commonly Wet	Yes	No	No
99	99	2a	Periodic Inund./Ephemeral	Yes	No	No
100	100	2a	Commonly Wet	Yes	No	No
101	101	2a	Seasonal Inundation	Yes	No	No
102	102	1b	Periodic Inund./Ephemeral	Yes	No	No
103	104 - Craigs Pool upper	2a	Periodic Inund./Ephemeral	Yes	No	No
104 - Craigs Pool upper	104 - Craigs Pool upper	2a	Periodic Inund./Ephemeral	Yes	No	No
105	105	2a/2b	Commonly Wet	Yes	Yes	No
106	106	2a	Periodic Inund./Ephemeral	Yes	No	No
107	107	2a	Periodic Inund./Ephemeral	Yes	No	No
108	108	1a	Periodic Inund./Ephemeral	Yes	No	No
109	109	1a	Periodic Inund./Ephemeral	Yes	No	No
110	110	1a	Periodic Inund./Ephemeral	Yes	No	No
111	112	1a	Periodic Inund./Ephemeral	Yes	No	No
112	112	1a	Periodic Inund./Ephemeral	Yes	No	No
113	115	1a	Periodic Inund./Ephemeral	Yes	No	No
114	115	2a	Periodic Inund./Ephemeral	Yes	No	No
115	115	1b	Periodic Inund./Ephemeral	Yes	No	No
116	116	1a	Periodic Inund./Ephemeral	Yes	No	No
117	117	1a	Periodic Inund./Ephemeral	Yes	No	No
118	119	2a	Periodic Inund./Ephemeral	Yes	No	No

Pool Name	Reach ID	Bourke (2023) Conceptualisation #	Water Permanence	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
119	119	2a/2b	Commonly Wet	Yes	Yes	No
120	120	2a	Periodic Inund./Ephemeral	Yes	No	No
121	121	2a/2b	Seasonal Inundation	Yes	Yes	No
122	122	1b	Periodic Inund./Ephemeral	Yes	No	No
124	124	1b	Periodic Inund./Ephemeral	Yes	No	No
125	125	1a	Periodic Inund./Ephemeral	Yes	No	No
IB_SW_Pool_Fig	IB_SW_Pool_Fig	2b	Permanent	No	Yes	No
IB_SW_Pool_ Cow Spring	IB_SW_Pool_Cow Spring	2b	Permanent	No	Yes	No
GV_SW_Pool_NJA21-006-US	Pool NJA21-006-US	2a	Periodic Inund./Ephemeral	Yes	No	No
GV_SW_Pool_NJA19-004	GV_SW_Pool_NJA19-004	2a/2b	Seasonal Inundation	Yes	Yes	No
GV_SW_Pool_NJA21-006-DS	Pool NJA21-006-DS	1a	Periodic Inund./Ephemeral	Yes	No	No
IB_SW_DryReject_ DS_02	Pool IB-SW-Dry-Reject-DS-002	1a	Periodic Inund./Ephemeral	Yes	No	No
GE_1	GE_1	2a	Periodic Inund./Ephemeral	Yes	No	No
GE_2	GE_2	2a	Seasonal Inundation	Yes	No	No
GE_3	GE_3	1a	Periodic Inund./Ephemeral	Yes	No	No
GE_4	GE_4	2b	Permanent	No	Yes	No
GE_5	GE_5	2b	Commonly Wet	No	Yes	No
GE_6	GE_6	2a	Commonly Wet	Yes	No	No
GE_7	GE_7	1a	Seasonal Inundation	Yes	No	No
GE_8	GE_8	1a	Periodic Inund./Ephemeral	Yes	No	No
GE_9	GE_9	1b	Periodic Inund./Ephemeral	Yes	No	No
GE_10	GE_10	2a	Commonly Wet	Yes	No	No
GE_11	GE_11	1a	Periodic Inund./Ephemeral	Yes	No	No
GE_12	GE_12	1a	Seasonal Inundation	Yes	No	No
126 - Craigs Pool lower	126 - Craigs Pool lower	2b	Commonly Wet	No	Yes	No
127 - Astrid Bee Cave	127 - Astrid Bee Cave	2b	Commonly Wet	No	Yes	No

3.6 Reaches requiring impact assessment

Table 3-6 summarises the number of reaches assigned to identified hydraulic conceptualisation types (after Bourke et. al. 2023) and located within the Study and surface water and groundwater impact areas. The water persistence classifications and Bourke et. al (2023) conceptualisations were used to identify the reaches (and associated pools) requiring surface water and groundwater impact assessments as follows:

- **Groundwater Inflow and Quality Impact Assessment:** reaches with potential regional groundwater inflows that are located within the regional groundwater impact area (i.e., reaches with conceptual models 3 or 4). The impact assessment methodology assumes the following:
  - **Local groundwater** is not part of the regionally connected groundwater system, with groundwater either perched or residing in localised fracture networks within other very low permeability host rock. If the local groundwater system is directly impacted by mining, then a groundwater impact assessment is required. This would include any pools assigned conceptualisation Type 2b.
  - **Regional groundwater** is part of a regionally connected groundwater system. If the groundwater system is directly impacted by mining (i.e., mining activities within the groundwater catchment) or indirectly impacted by mining (via regional drawdown from groundwater abstraction), then a groundwater impact assessment is required. This would include any pools assigned conceptualisation Types 3 and 4.
- **Surface Water Inflow and Quality Impact Assessment:** reaches with potential reduction in catchment area and surface water flows and are located within the surface water impact area (i.e. reaches with conceptual models 1a, 1b, 2a, 2b, 3 and 4). The assessment is based on the following:
  - Reaches (and associated pools) were only assessed where they are located within the surface water impact area which is defined as the extent of the surface water catchment areas affected by the proposed NSE development, beyond which the peak flows are expected to return to within 10-15% of the pre-development flows (Section 3.1).
  - The impacts to reaches (and associated pools) located outside the surface water impact area are considered negligible due to the minor changes in flow and the dilution of any potential sources of adverse surface water quality.

Figure 3-10 maps the reaches considered for surface water and groundwater impact assessments. Figure 3-11 presents all identified reaches and the reaches identified as requiring impact assessment.

More detailed analysis of catchments and NSE development footprints was then undertaken to identify reaches which are not impacted by the proposed NSE development or are completely removed by mining. Fifteen reaches were identified as potentially impacted by the proposed NSE development.

The following reaches were subsequently excluded from the impact assessment:

- GE 10 and Pool 11: as they are not impacted by the proposed NSE development (either directly or indirectly).
- Pool 62, Pool 50, and Pool 51: as they are located within the NSE development footprint and will be completely removed by mining.

The reaches identified as requiring groundwater and surface water impact assessment are provided in Table 3-7 and Table 3-8.

A more detailed description of the methodology used to identify the pools requiring impact assessment is provided in Appendix A.

Table 3-6. Count of reaches for each hydraulic conceptualisation type.

Hydraulic Conceptualisation Type	Primary Water Source	Count of Reaches in Study Area	Count within Groundwater Impact Area	Count within Surface Water Impact Area
1a	Alluvium - perched throughflow	34	32	5
1b	Alluvium/bedrock - perched surface water throughflow	9	7	1
2a	Bedrock - perched surface water	21	19	6
2b	Bedrock - fracture flow groundwater source	9	9	0
2a/2b	Potentially either 2a or 2b	7	5	1
3	Bedrock aquiclude - groundwater discharge	2	2	2
4	Topographically controlled groundwater outflow	0	0	0
	Total	**82**	**74**	**15**

Table notes:

- *The cells with green shading denote those reaches considered for further groundwater impact assessment, as meeting the criteria outlined in Section 3.6*
- *The cells with orange shading denote those reaches considered for further surface water impact assessment, as meeting the criteria outlined in Section 3.6*
- *Some reaches are within both the surface water and groundwater impact assessment areas. Therefore, the total number of reaches within the Study Area is less than the sum of the reaches within the combined surface water and groundwater impact areas.*

Table 3-7. Reaches within the regional groundwater impact area and requiring groundwater impact assessment.

Reach ID	Pools Associated with Reach	Water permanence classification	Conceptualisation Type
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge

Table 3-8. Reaches within the surface water impact area and requiring surface water impact assessment.

Reach ID	Pools Associated with Reach	Water permanence classification	Conceptualisation Type
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge

Reach ID	Pools Associated with Reach	Water permanence classification	Conceptualisation Type
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Seasonal Inundation	Type 2a/2b - Bedrock perched surface water AND/OR local groundwater source
Pool IB-SW-Dry-Reject-DS-002	IB_SW_DryReject_ DS_02	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool NJA21-006-US	GV_SW_Pool_NJA21-006-US	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool NJA21-006-DS	GV_SW_Pool_NJA21-006-DS	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool-SW	55 - GV_SW_Pool_SW 56 - GV_SW_Pool_SWGV_DS	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 9	9	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 59	59	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool 57	57 63 64	Periodic Inundation	Type 2a - Bedrock - perched surface water

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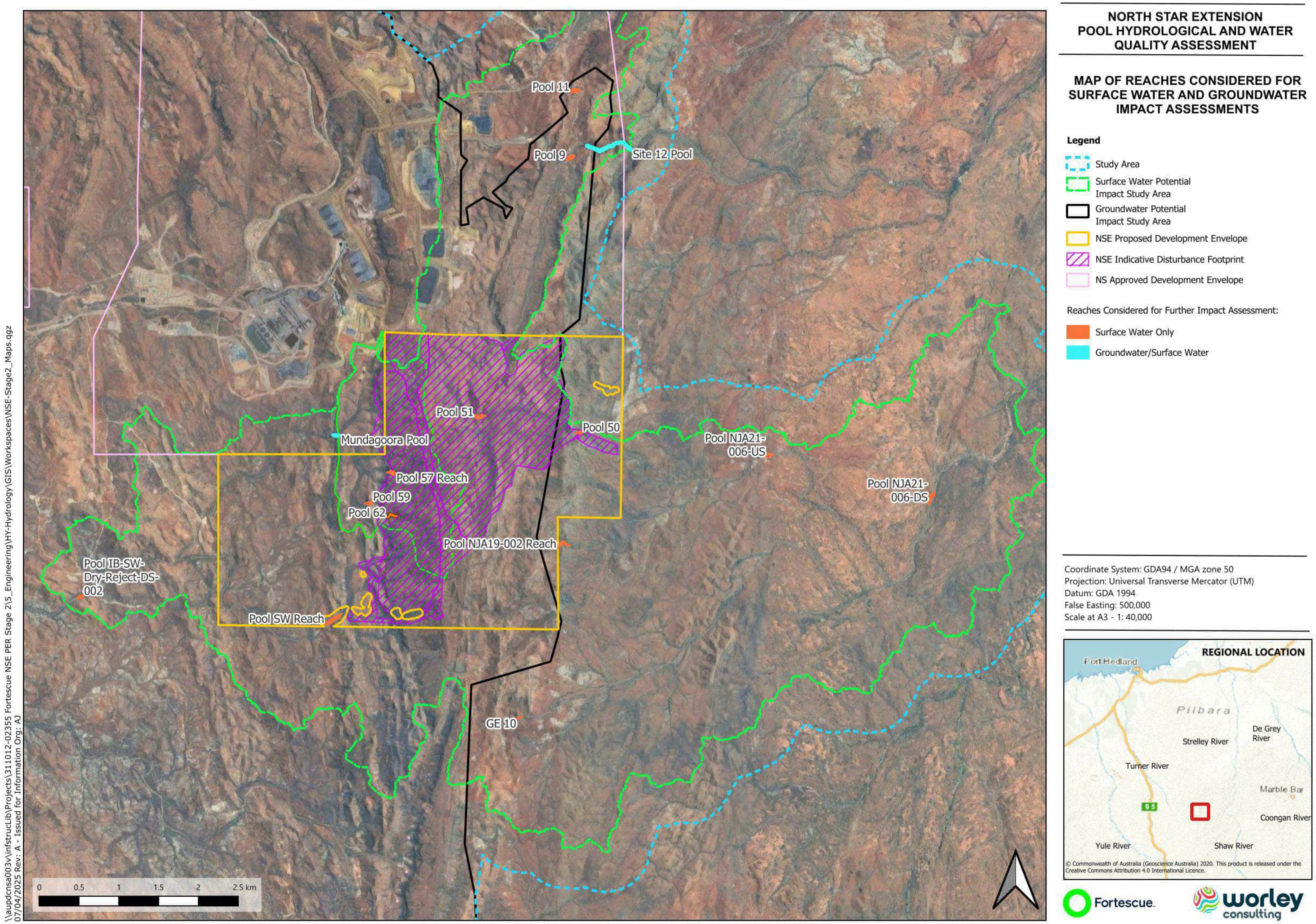

Figure 3-10. Map of reaches considered for surface water and groundwater impact assessments.

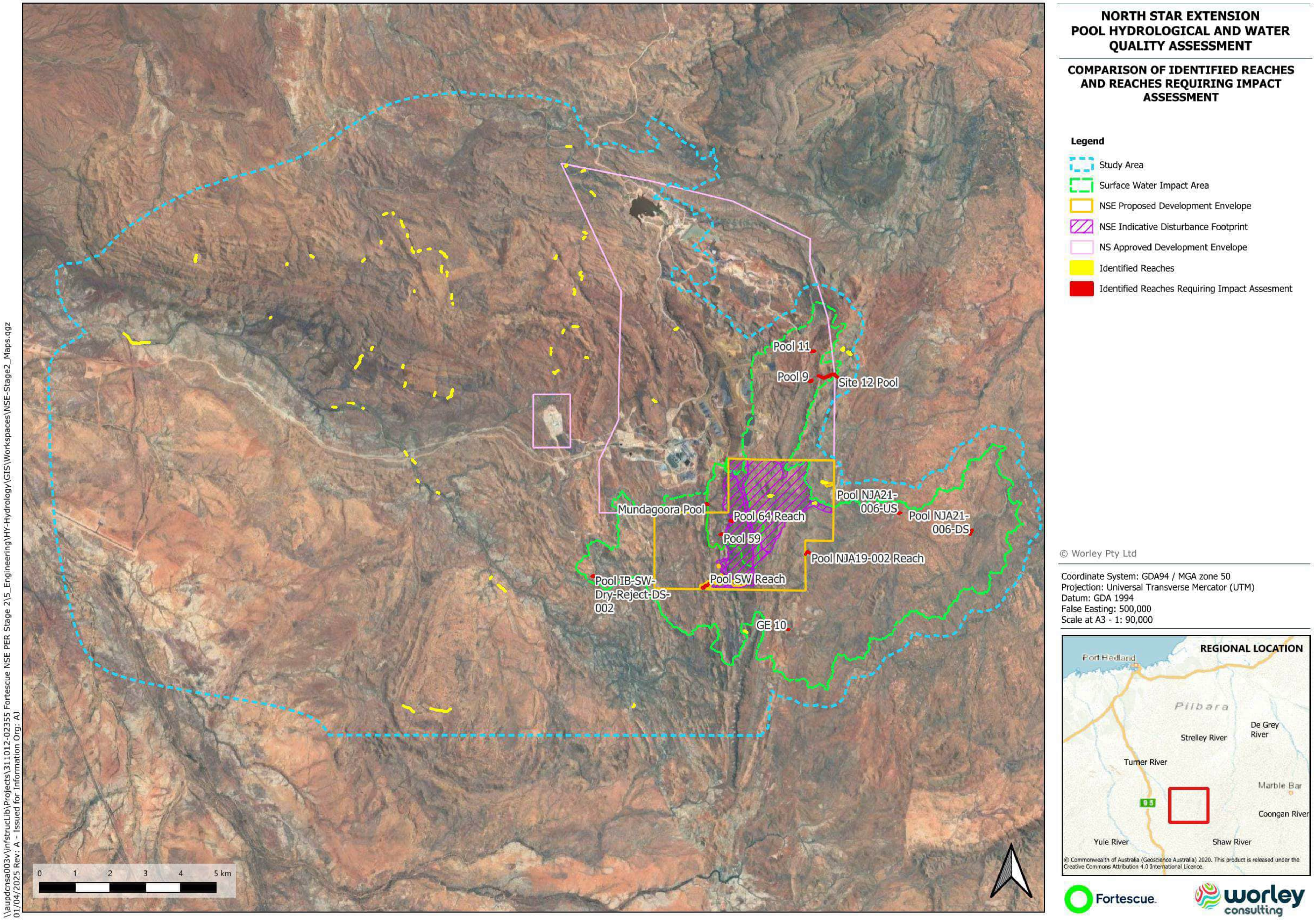

Figure 3-11. Map showing all identified reaches and the reaches identified as requiring impact assessment.

4. Impact assessment approach

4.1 Definitions

The following definitions have been adopted for this assessment:

- **Baseline conditions**: currently approved NS Stage 2 mining conditions (including existing borefield), and
- **Developed conditions**: approved NS conditions plus the proposed NSE development conditions.

Figure 4-1 presents the NS Stage 2 approved disturbance footprint and development envelope (i.e., Baseline conditions), as well as the proposed NSE disturbance footprint and development envelope (i.e., Developed conditions).

As discussed in Section 3.5, for the purposes of impact assessment, individual pools were grouped into local "reaches" along a connecting sections of drainage lines, and the impacts assessed for these reaches. Where there were multiple pools within a reach, the water permanence classifications and conceptualisation of the most persistent pool was adopted for the impact assessment.

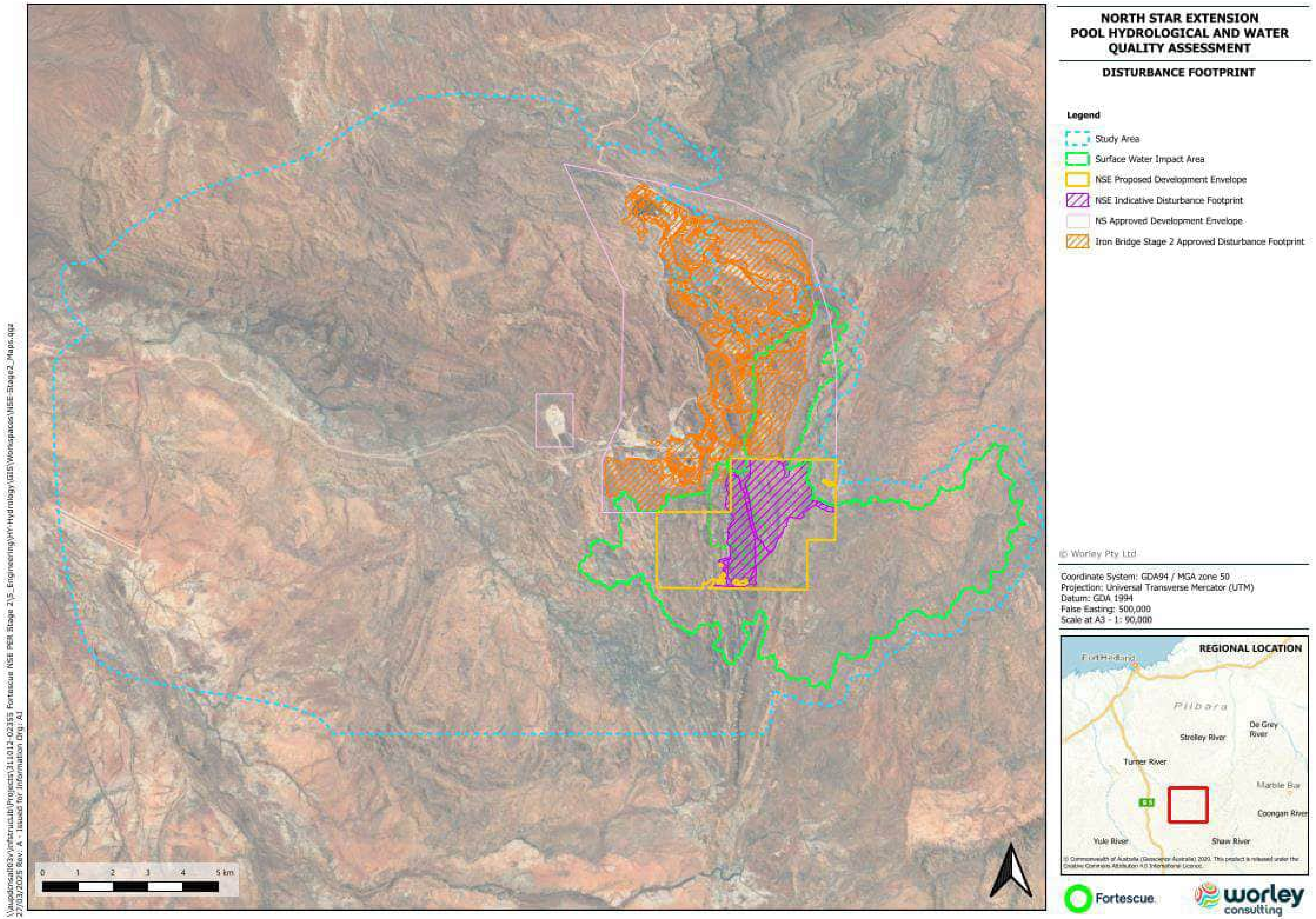

Figure 4-1: Disturbance footprints associated with Baseline and Developed conditions impact assessment.

4.2 Pool water balance

The hydrological and water quality assessment approach adopted for reaches and associated pools, is based on the potential impacts that the NSE development may have on the water balance (quantity and quality) maintaining the pools in the study area. Figure 4-2 shows the typical components of a pool water balance. The proposed NSE development has the potential to impact on the following inputs of the water balance:

- Quantity and quality of surface water inflows, and
- Quantity and quality of groundwater inflows.

The methodology needed to assess and quantify potential hydrological and water quality impacts to reaches and associated pools due to the NSE development, varies depending on the conceptualisations presented in Section 3.4.

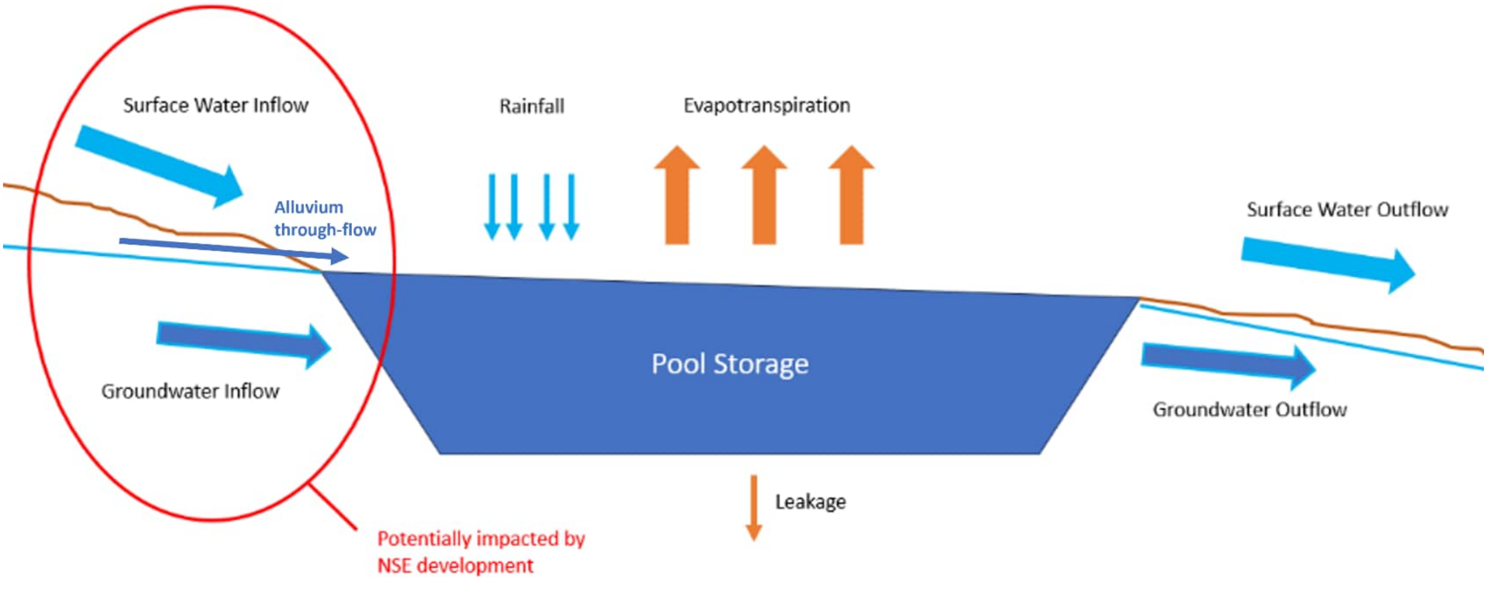

Figure 4-2. Indicative pool water balance schematic.

4.3 Hydrological impact assessment approach

4.3.1 Surface water inflow

The surface water inflow impact assessment methodology has been developed to quantify changes in surface water inflows to pools located within the surface water impact area (Section 3.1). The surface water impact assessment methodology adopted for pools varies depending on the water presence classifications described in Section 3.3, and includes completion of some or all of the following tasks for Baseline and Developed conditions:

- <u>Catchment delineation and area calculation</u>: facilitating a comparison of Baseline vs Developed catchment areas which was used an input to subsequent tasks of the impact assessment,

- Event-based peak inflow estimation: comparing the difference between Baseline vs Developed conditions peak flows reporting to reaches (and associated pools),
- Reach volumetric assessment: assessing the impact of the proposed NSE on the propensity for reaches (and associated pools) to be filled by different magnitude rainfall events,
- Long-term hydrology simulation modelling: to estimate 1,000 years of peak flow and inflow volumes, and quantify the change in pool/reach filling frequence under Baseline and Developed conditions to determine the impact of the NSE on hydrological regime, and
- High-resolution, event-based two-dimensional (2D) hydraulic modelling of reaches (and associated pools): to generate time-varying outputs of various hydraulic parameters[2] used as an input into the sediment transport and flushing impact assessment.

Surface water impact assessment methodologies have been assigned to pools based on water presence classifications in Section 3.3, and summarised in Table 4-1. Reaches (and associated pools) classified as permanent and commonly wet contain water that persists for longer durations following flood events, so were assessed in greater detail than pools that are seasonally or periodically inundated.

This assessment assumes the following in relation to contributing catchment areas and flow estimation:

- **Pits** that are located within a pool catchment, will reduce area contributing surface water runoff to the pool.
- **WRDs** that are located within a pool catchment, will retain and infiltrate direct rainfall-runoff, therefore reducing the area contributing surface water runoff to the pool.

A more detailed description of the adopted impact assessment methodologies is provided in Section 5.1.2. The outputs from the surface water impact assessment directly inform the water quality impact assessment described in Section 4.4.

The results from the assessments outlined above for Baseline and Developed conditions are used to quantify the change in surface water inflows to reaches and the impact severity assessment criteria presented in Section 4.5 then used to assess and classify impacts.

[2] Velocity, bed shear stress, stream power.

Table 4-1. Surface water impact assessment methodology adopted for pools.

Water Presence Classification	Catchment Delineation	Peak Flow Comparison	Pool Volumetric Assessment	Long Term Hydrology	High Resolution Hydraulic Modelling
Permanent	✓	✓	✓	✓	✓
Commonly Wet	✓	✓	✓	✓	✓
Seasonal Inundation	✓	✓	✓	X	X
Periodic Inundation / Ephemeral	✓	✓	✓	X	X

Reaches/pools assigned conceptualisations 1a and 1b are likely to have alluvium throughflow that occurs after a flood event which flows into and maintains the pool for a period of time. For these pools, the duration and volume of throughflow is a function of the catchment area; pools with larger catchments have alluvium throughflow for longer and are likely to have a corresponding longer duration of pool inundation / water presence.

The quantification of throughflow rates and volumes is out of scope for this study, however for the impact assessment the following assumptions have been made for reaches/pools assigned conceptualisations 1a and 1b:

- If the catchment area is significantly reduced due to the presence of a pit void, then there is likely to be a reduction in alluvium throughflow from the upstream catchment, which may reduce the duration of pool inundation / water presence.
- If the catchment area contains a WRD, then there is not expected to be a reduction in alluvium throughflow from the upstream catchment and no significant impact to the duration of pool inundation / water presence. This is due to the percolation of direct rainfall through the WRD that then makes its way to the downstream pool/reach via alluvial throughflow.

4.3.2 Groundwater inflow

As discussed in Section 3.6, reaches and associated pools identified within the groundwater impact area which have conceptualisation Types 3 or 4, were selected for groundwater inflow impact assessment. The groundwater impact assessment methodology adopted for this study is summarised below:

- Discuss and present conceptual hydrogeological models for groundwater systems supporting pools,

- Complete steady state groundwater inflow assessment for Baseline conditions using analytical and/or numerical methods to estimate the rate of groundwater inflow to pools,
- Use the groundwater drawdown data provided by Fortescue (Section 2) for Developed conditions to estimate whether there is likely to be an impact on groundwater inflows to pools,
- Assess whether the NSE development is likely to impact on groundwater recharge in the upstream catchment areas associated with the pools,
- For the pools that are likely to be impacted provide recommendations to maintain inflows to pools during mining operations.

The methodology adopted for specific pools is described in more detail in Section 5.2.

The results from the assessments outlined above for Baseline and Developed conditions are used to quantify the change in groundwater inflows to reaches and the impact severity assessment criteria presented in Section 4.5 then used to assess and classify impacts.

4.4 Water quality impact assessment approach

4.4.1 Surface water quality

The focus of the surface water quality impact assessment is sediment delivery and flushing impacts to reaches and associated pools within the surface water impact area.

Note: the surface water quality impact assessments assume that runoff from disturbed areas within the surface water impact area shall be managed by Fortescue to minimise impacts associated with other water quality parameters during mining operations (e.g. WRDs will be designed to be internally draining, and thereby minimise sediment-laden runoff reporting to the pools).

The adopted impact assessment methodologies are discussed in more detail in Section 6.

The results from the assessments outlined above for Baseline and Developed conditions are used to quantify the change in quality of surface water inflows to reaches and the impact severity assessment criteria presented in Section 4.5 then used to assess and classify impacts.

4.4.1.1 Sediment delivery and flushing impact assessment

The impact assessment methodology adopted for reaches varies depending on the water presence classifications and includes completion of some or all of the following tasks for Baseline and Developed conditions:

- Qualitative sediment transport assessment: this involved an assessment of changes in catchment areas, time-varying velocity data due to NSE development and implications for sediment delivery and flushing,
- Event-based sediment transport modelling: an event-based sediment delivery model was developed to inform the volume of sediment delivered to reaches (and associated pools) under select design AEP events,

- <u>Long-term sediment transport modelling:</u> to estimate 1,000 years of sediment yield, transport and delivery to reaches (and associated pools), and
- <u>Pool flushing assessment using local scale 2D hydraulic modelling data:</u> event-based assessment to quantify the net effect of the NSE development on sediment delivery, transport, deposition and scour within reaches (and associated pools).

The surface water quality impact assessment methodologies have been assigned to reaches based on water presence classifications and summarised in Table 4-2. These assessment methodologies are applied to reaches for Baseline and Developed conditions and the results compared to assess impacts.

Reaches (and associated pools) classified as permanent and commonly wet contain water that persists for longer durations following flood events, so were assessed in greater detail than pools that are seasonally or periodically inundated.

The results obtained from the sediment transport assessments for reaches were interpreted to make an overall assessment of the likely outcomes for the reaches and associated pools.

Table 4-2. Sediment delivery and flushing impact assessment methodology adopted for pools.

Water Presence Classification	Qualitative Sediment Transport Assessment	Events-Based Sediment Delivery Modelling	Long Term Sediment Delivery Modelling	Events-Based Pool Flushing Assessment
Permanent	X	✓	✓	✓
Commonly Wet	X	✓	✓	✓
Seasonal Inundation	X	✓	X	X
Periodic Inundation / Ephemeral	✓	X	X	X

4.4.2 Groundwater quality

The potential groundwater quality impacts to reaches was evaluated via a qualitative, high-level assessment of:

- Changes in groundwater inflows and potential need for supplementation of water to reaches (and associated pools) during operations.
- Groundwater seepage from WRDs with potential to inflow to reaches (and associated pools).

The results from the assessments outlined above for Baseline and Developed conditions are used to quantify the change in quality of groundwater inflows to reaches and the impact severity assessment criteria presented in Section 4.5 then used to assess and classify impacts.

4.5 Impact severity classification

Three levels of potential inland waters impact severity were adopted for the impact assessment and assigned to reaches (and associated pools) using the criteria outlined in Table 4-3.

Table 4-3: Classification of severity levels adopted for inland waters impact assessment.

Severity level	**Inland Water Impact**			
	Surface water inflow	**Groundwater inflow**	**Surface water inflow quality**	**Groundwater inflow quality**
Low	The pool/reach storage area volume is <30% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is <30% then minor impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) is expected to result in a minor change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is within +/-30% of the baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are expected to result in a minor change to the pool water balance.
Moderate	The pool/reach storage area volume is between 30-50% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is 30%-50% then moderate impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) are likely to result in a moderate change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is of a magnitude between 30% to 50% (+/-) compared to baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are likely to result in a moderate change to the pool water balance.
High	The pool/reach storage area volume is >50% of the post-development 50% AEP inflow volume. For reach types 1a/1b (only): if catchment area reduction is >50% then significant impact to duration of alluvium throughflows to reach/pools following flood events.	Estimated changes in groundwater inflow rates to reaches (and associated pools) are likely to result in significant change to the pool water balance.	Sediment delivery to and flushing from the pool/reach in the post-development scenario is of a greater magnitude than +/-50% of the baseline.	Estimated changes in groundwater inflow quality to reaches (and associated pools) are likely to result in significant change to the pool water balance.

5. Hydrological impact assessment

5.1 Surface water inflow impact assessment

5.1.1 Reaches included in impact assessment

Reaches (and associated pools) located within the extent of the surface water impact area described in Section 3.1 (Figure 5-1) require surface water impact assessment. The surface water impact assessment approach presented in Section 4.3 was used to determine the methodology to be adopted for each reach, with the resulting methodologies adopted for each reach listed in Table 5-1.

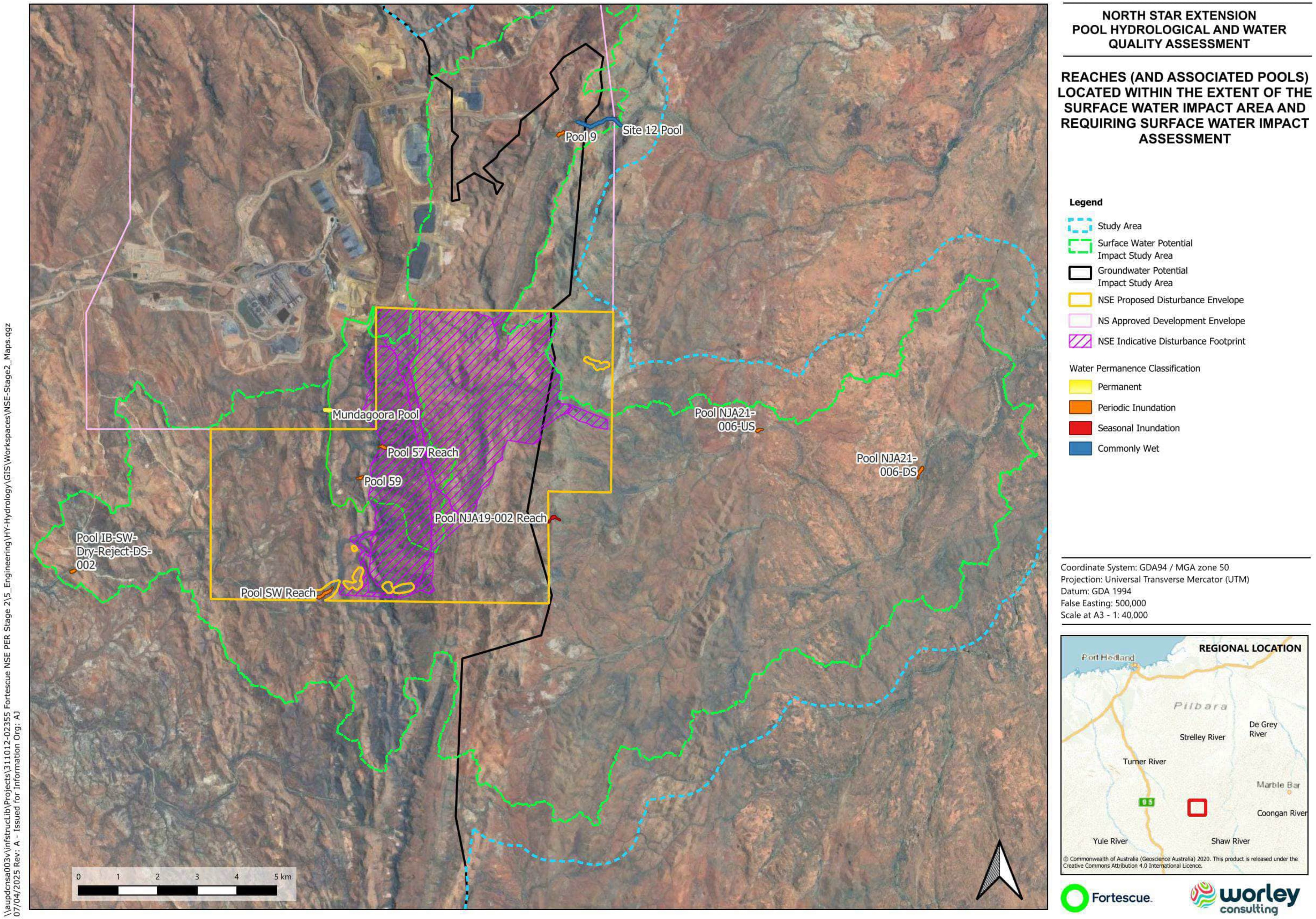

Figure 5-1. Reaches (and associated pools) located within the extent of the surface water impact area and requiring surface water impact assessment.

Table 5-1. Reaches identified within the surface water impact area and associated surface water impact assessment methodologies adopted

Water Permanence Classification	Reach ID	Catchment Delineation	Peak Flow Comparison	Reach Volumetric Assessment	Long Term Hydrology	High Resolution Hydraulic Modelling
Permanent	Mundagoora Pool	✓	✓	✓	✓	✓
Commonly Wet	Site 12 Pool	✓	✓	✓	✓	✓
Seasonal Inundation	Pool NJA19-002	✓	✓	✓	X	X
Periodic Inundation	Pool IB-SW-Dry-Reject-DS-002	✓	✓	✓	X	X
	Pool NJA21-006-US	✓	✓	✓	X	X
	Pool NJA21-006-DS	✓	✓	✓	X	X
	Pool SW	✓	✓	✓	X	X
	Pool 9	✓	✓	✓	X	X
	Pool 59	✓	✓	✓	X	X
	Pool 57	✓	✓	✓	X	X

5.1.2 Methodology

Section 4.3 summarises the approach adopted for surface water inflow impact assessment, and includes completion of some or all of the following tasks for Baseline and Developed conditions depending on water permanence classifications assigned to reaches (and associated pools):

- Catchment delineation and area calculation,
- Event-based peak inflow estimation,
- Event-based pool storage volume and inflow assessment,
- Long-term hydrology simulation modelling to estimate 1,000 years of peak flow and inflow volumes, and/or
- High-resolution, event-based 2D hydraulic modelling of pools.

A detailed description of each task is provided below.

5.1.2.1 Catchment delineation and area calculations

The objective of this task was to quantify the change in catchment area for reaches (and associated pools) due to the NSE development and determine the associated cause of reductions (i.e., proposed mine pit or WRD/other above ground infrastructure).

Digital elevation models (DEMs) were initially developed for both scenarios using a combination of LiDAR data and supplied design files associated with each scenario. The basis of DEM development for Baseline and Developed conditions catchment analysis is presented in Table 5-2.

Table 5-2: Basis for DEM development.

Scenario	Description	Files used for catchment delineation
Baseline Conditions	1 m LiDAR topography data captured in March 2024	PIL_ELEV_FMG_IRON_BRIDGE_1M_DEM_MAR2024.TIF
	Approved Part IV development envelope for NS Stage 2 and associated infrastructure	Approved IDF.shp
Developed Conditions	1 m LiDAR topography data captured in March 2024	PIL_ELEV_FMG_IRON_BRIDGE_1M_DEM_MAR2024.TIF
	Approved Part IV development envelope for NS Stage 2 and associated infrastructure	Approved IDF.shp
	Southern Pit	gvs03_pitd_r02.2_sur_cut.tif
	Northern Pit	pit_gvn_s01_rev01_201905_cut.tif
	WRD Design	nts99_00_dump_cut_r001_csur.tif

The catchment areas for all identified reaches (and associated pools) were then initially delineated using Global Mapper GIS software. The methodology adopted assumes that waste rock dumps (WRDs) constructed within a reach catchment area are internally draining, and therefore don't contribute surface water runoff to the reach.

The results of the catchment delineation are presented in Section 5.1.3.1 and Appendix B.

5.1.2.2 Event-based peak inflow comparison

Several 2D hydraulic models were developed for the baseline and developed scenarios using TUFLOW to simulate and compare the peak inflows to reaches (and associated pools) within the surface water impact area. The model domains are shown in Figure 5-2 and modelling methodologies described in the following reports:

- North Star Magnetite Project Extension Baseline Hydrology Report (Worley, 2024a).
- North Star Magnetite Project Extension Hydrological Impact Assessment Report: Waterways (Worley, 2024b).
- Site 12 Pool Catchment Waterways Assessment – North Star Extension (Fortescue, 2025).

The models were run to extract the peak inflows to all identified reaches (and associated pools) for both scenarios for the 1%, 2%, 5%, 10%, 20% and 50% annual exceedance probability (AEP) events. Peak flows were then compared to assess impacts and percentage change calculated.

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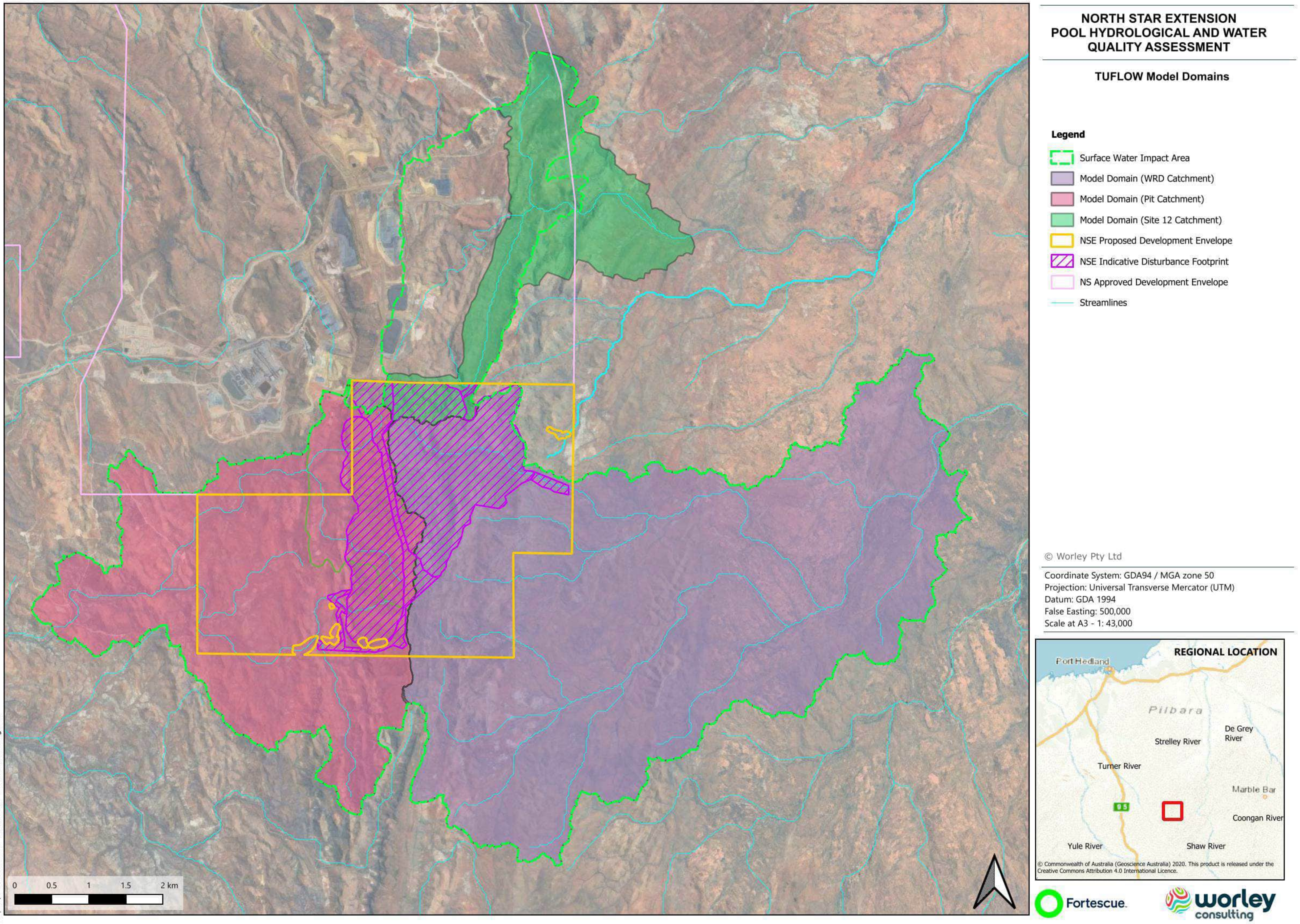

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Figure 5-2. TUFLOW model domains

5.1.2.3 Reach volumetric assessment

The objective of the reach volumetric assessment was to compare the inflow volumes to reaches under Baseline and Developed conditions for a range of design AEP events. These volumes were then compared with the available reach storage (derived from DEM analysis). The results were to assess whether the proposed NSE development is likely to affect the frequency of reach (and associated pool) filling over a range of design AEP events.

The first step of the event-based pool volumetric assessment was to calculate the storage volume of the reaches (and associated pools). This was achieved via the following:

1. A representative storm event was applied to the TUFLOW model to flood all watercourses.
2. The model was run for a sufficient time (~30 hours) after the storm event finished to allow runoff to drain away and exit the model, thereby leaving only the reaches (and associated pools) full of water.
3. On completion of the simulations, the final floodwater surface at each of the reaches (including associated pools) was subtracted from the ground surface to calculate storage volumes.
4. At Site 12 Pool there were a few shallow pool areas present when the LiDAR was flown, so their storages were estimated based on site observations and aerial imagery analysis and added to the total storage volumes. The adopted storage volume of ~2,400 m^3 was comparable to what was previously estimated by Hydrobiology (2020), which was 2,532 m^3.

Note: Mundagoora Pool is permanently wet, and bathymetry data was provided by Fortescue to enable calculation of the total pool storage volume. LiDAR data coverage was available for the other pools. It was not clear if there was water present in the reaches at the time of capture for each of the LiDAR datasets, which may affect the estimated storage volumes.

The next step was to calculate the flow volumes reporting to reaches (and associated pools) for the 1%, 2%, 5%, 10%, 20% and 50% AEP events. As noted in the *North Star Magnetite Project Extension Baseline Hydrology Report* (Worley, 2024), runoff volumes were calculated for both the Baseline and Developed condition scenarios as follows:

- Multiply the catchment areas by areal-reduced design rainfall, with the adopted empirical losses removed from the rainfall event total (including representations of pre-burst rainfall).

The pool storage volume at each of the reaches (and associated pools) was then compared with the corresponding inflow volumes for the range of AEP events. The reach storage volumes were then expressed as a percentage of the inflows for the Baseline and Developed condition scenarios and the results plotted and tabulated to allow a direct comparison of change.

Note: for Mundagoora Pool, the comparison of storage and inflow volumes assumed the pool is dry/empty (which is a conservative assumption, as it is permanently wet).

As discussed in Section 4.3.1, for reaches/pools assigned conceptualisations 1a or 1b:

- If the catchment area is significantly reduced due to the presence of a pit void, then there is likely to be a reduction in alluvium throughflow from the upstream catchment, which may reduce the duration of pool inundation / water presence.

Catchment area reductions due to construction of NSE pits, were used to complete a qualitative assessment of potential impact to duration of pool inundation / water presence at pools with conceptualisation type 1a or 1b. The results of this qualitative assessment are presented in Section 5.1.3.3.

5.1.2.4 Long-term hydrology simulation modelling

The objective of the long-term hydrology simulation modelling was to estimate 1,000 years of peak flow and inflow volumes and quantify the change in pool/reach filling frequence under Baseline and Developed conditions to determine the impact of the NSE on hydrological regime.

The long-term hydrology simulation models were developed for the Mundagoora and Site 12 Pool reaches, using SWMM modelling software (Environmental Protection Agency, 2015) to allow simulation of 1,000 years of rainfall-runoff. The model inputs, setup and calibration are summarised below.

<u>Synthetic rainfall dataset</u>

Five Bureau of Meteorology (BoM) weather stations are located within 75 km of North Star (Table 5-3). Daily rainfall records were downloaded for each site and assessed (http://www.bom.gov.au/climate/data/). The Indee weather station (Site ID: 4016) was selected for synthetic rainfall generation as it had one of the longest and most complete records. While there is a rain gauge installed at the mine site, it has only been recording data for six years and as such was not suitable for use to generate the 1,000 year synthetic rainfall dataset.

The Indee (4016) daily rainfall data was processed using SCL software (eWater, 2021) to produce 1,000 years of synthetic rainfall data. The rainfall statistics for the observed and synthetic data are compared in Figure 5-3, showing good correlation. The resulting 1,000 year synthetic rainfall dataset is plotted in Figure 5-4.

Table 5-3. BoM Rainfall Station Details

Station Name	ID	Easting	Northing	Distance to Mine (km)	Start Date	End Date	Years Recorded	Record Complete
Wallareenya	4038	118.82	-20.75	62	1908	2021	113	74%
Indee	4016	118.6	-20.79	71	1911	2021	110	93%
Marble	4106	119.75	-21.18	73	2000	2021	21	94%
Carlindi	4008	119.24	-20.64	72	1908	2021	113	57%
Hillside	4015	119.4	-21.72	62	1967	2018	51	77%

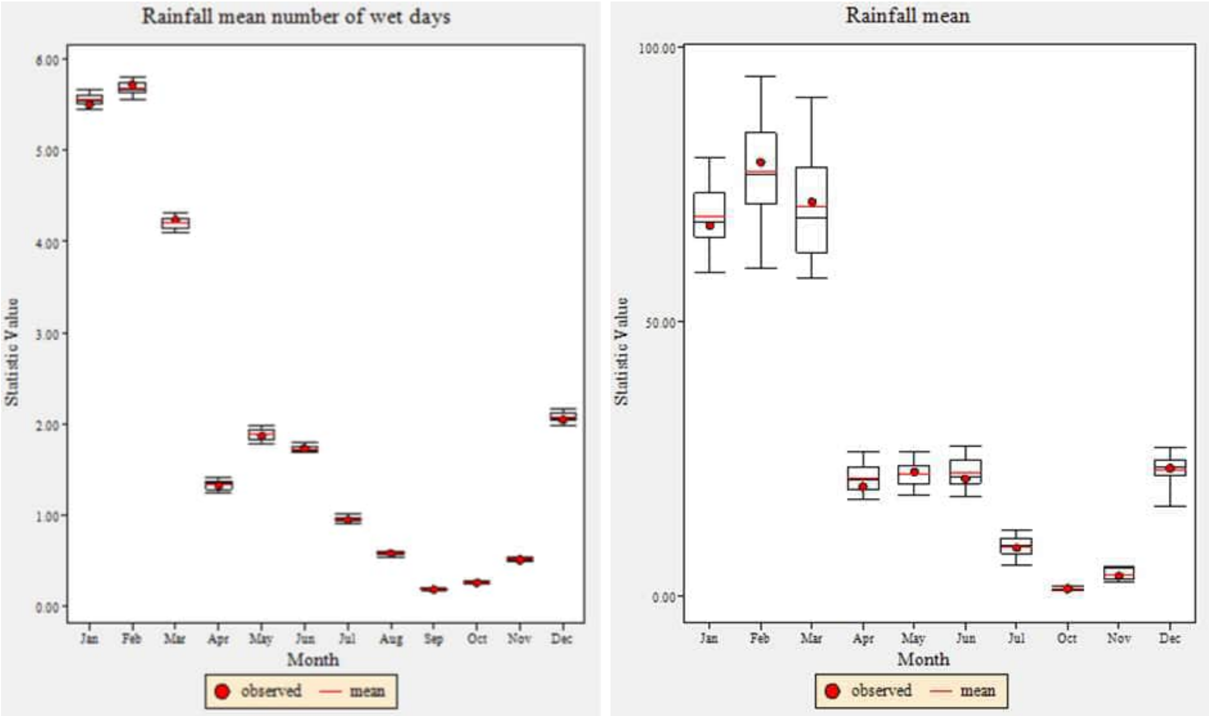

Figure 5-3. Comparison of observed and synthetic rainfall statistics

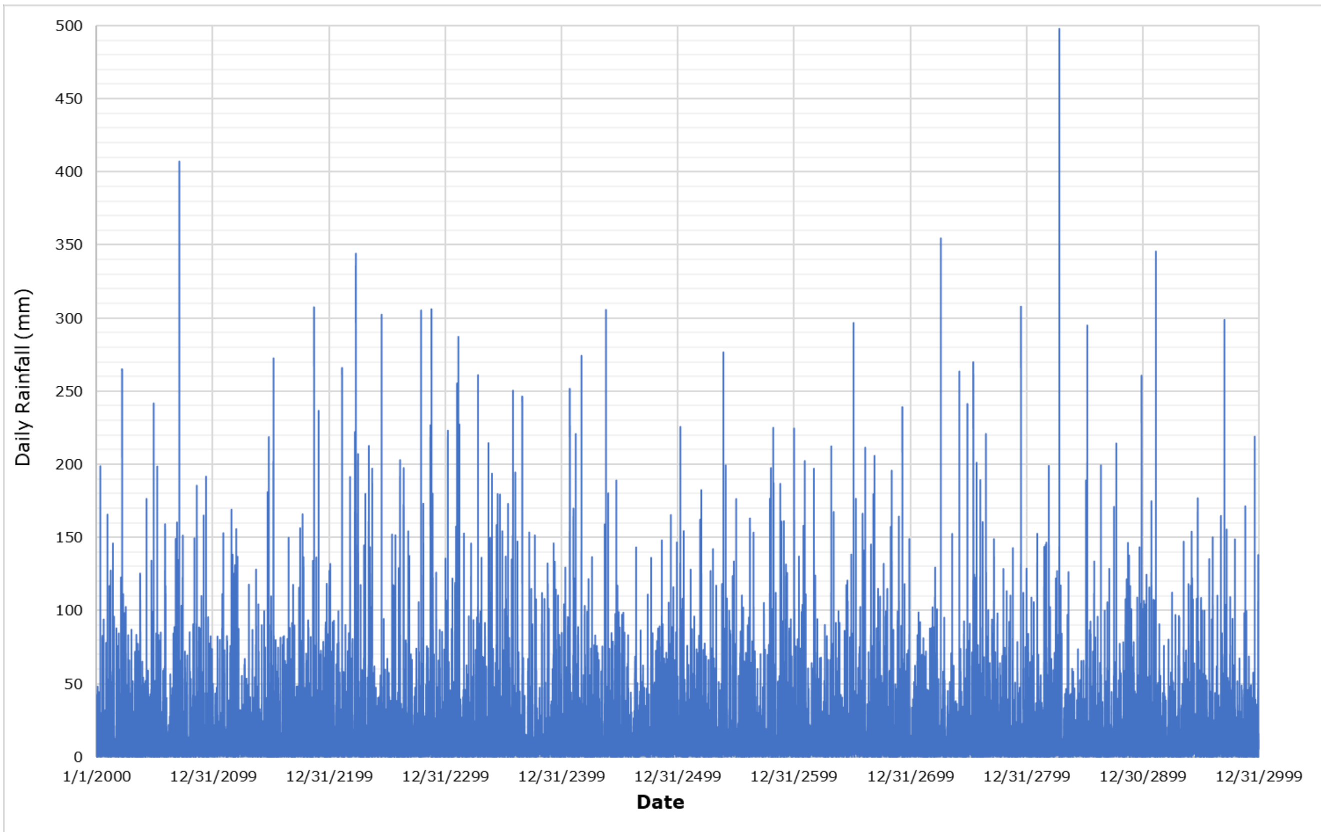

Figure 5-4. 1,000 year synthetic rainfall timeseries produced using BoM rainfall data at Indee (4016) and SCL

SWMM model set up and calibration

The modelling was completed as follows:

- The SWMM model was developed using sub-catchments interconnected by a network of links, through which rainfall runoff is routed to the outlet. The model set ups for Mundagoora and Site 12 Pool reaches are depicted in Figure 5-5 and Figure 5-6 respectively (Baseline conditions). The catchment areas, geometries and slopes were calculated using the LiDAR data. The links were defined as open channels based on typical creek geometries in the catchment (estimated using LiDAR data), and Mannings n values assigned based on catchment characteristics derived from aerial imagery.
- The daily rainfall data was applied in the model using a front-loaded distribution based on the representative critical duration of the Site 12 and Mundagoora Pool catchments across all modelled AEP events (1 hour).
- The SWMM models adopted the Green-Ampt loss model to account for changes in antecedent conditions between rainfall events over a 1,000-year simulation period. This is different to the IL-CL loss model adopted for events-based modelling using TUFLOW. The Green-Ampt loss parameter values were initially based on soil classifications (Clay Loam) obtained from laboratory testing of soil samples collected from the Mundagoora Pool catchment (see Appendix C). Comparison of the catchments suggests the Clay Loam classification is representative of both Mundagoora and Site 12 Pool catchments. The soil classification for the ROM area within the Mundagoora Pool catchment was Sandy Clay Loam based on the laboratory testing. As such, a different loss values were adopted for ROM area compared to the natural catchments (sedimentation pond included). The parameters were then adjusted until the peak flows and volumes were similar to the TUFLOW model for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.
- Adopted SWMM model parameters and calibration results are presented in Appendix C for Mundagoora and Site 12 Pool reaches, respectively. The SWMM modelling results show good correlation with the TUFLOW estimates, as shown in Table 5-4.

Table 5-4: Comparison of TUFLOW and SWMM peak flows and runoff volumes for the range of AEP events.

Pool Name	Difference (%) Between SWMM and TUFLOW	
	Peak Flow	Runoff Volume
Mundagoora Pool	1.0 – 14.0%	3.0 – 9.0%
Site 12 Pool	0.3 – 13.4%	0.3 – 4.2%

- The Baseline and Developed conditions SWMM models were then developed, and the calibrated model parameters applied. The 1,000 years of daily synthetic rainfall data was input to the models and run at hourly timesteps to produce 1,000 years of streamflow data. Rainfall events were front-loaded, applying the daily rainfall totals to the first hour of each day in the 1,000-year simulation. The long-term hydrology modelling was then used to extract 1,000 years of inflow data at each of the reach locations under Baseline and Developed conditions and the results compared to assess impacts.

- The storage volume of the reaches (and associated pools) was also compared with the 1,000 years of daily inflow data and statistical analyses performed to assess and compare the frequency of pool filling under Baseline and Developed conditions.

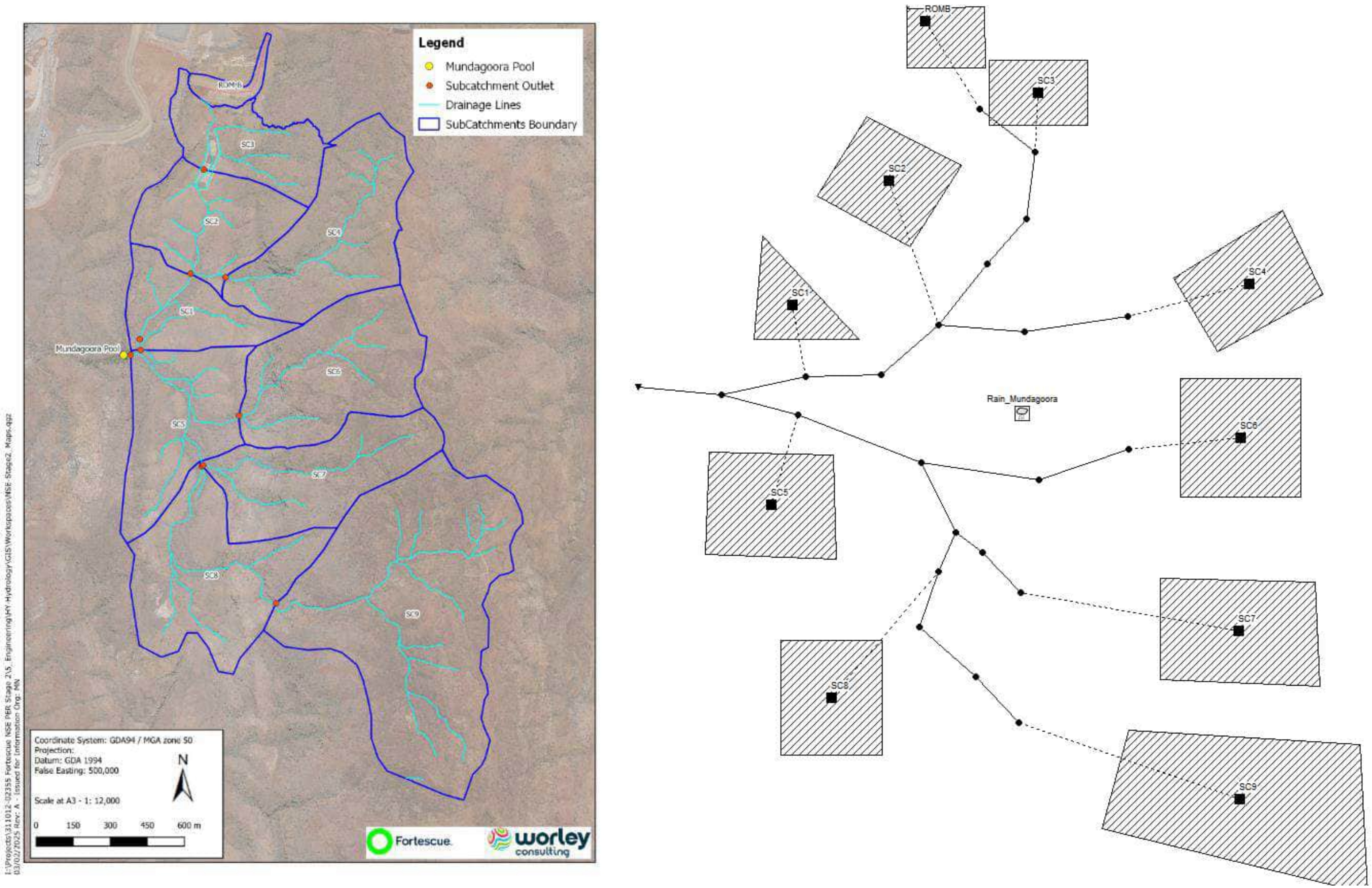

Figure 5-5. Mundagoora Pool SWMM modelling: Baseline sub-catchments (left) SWMM mode setup (right)

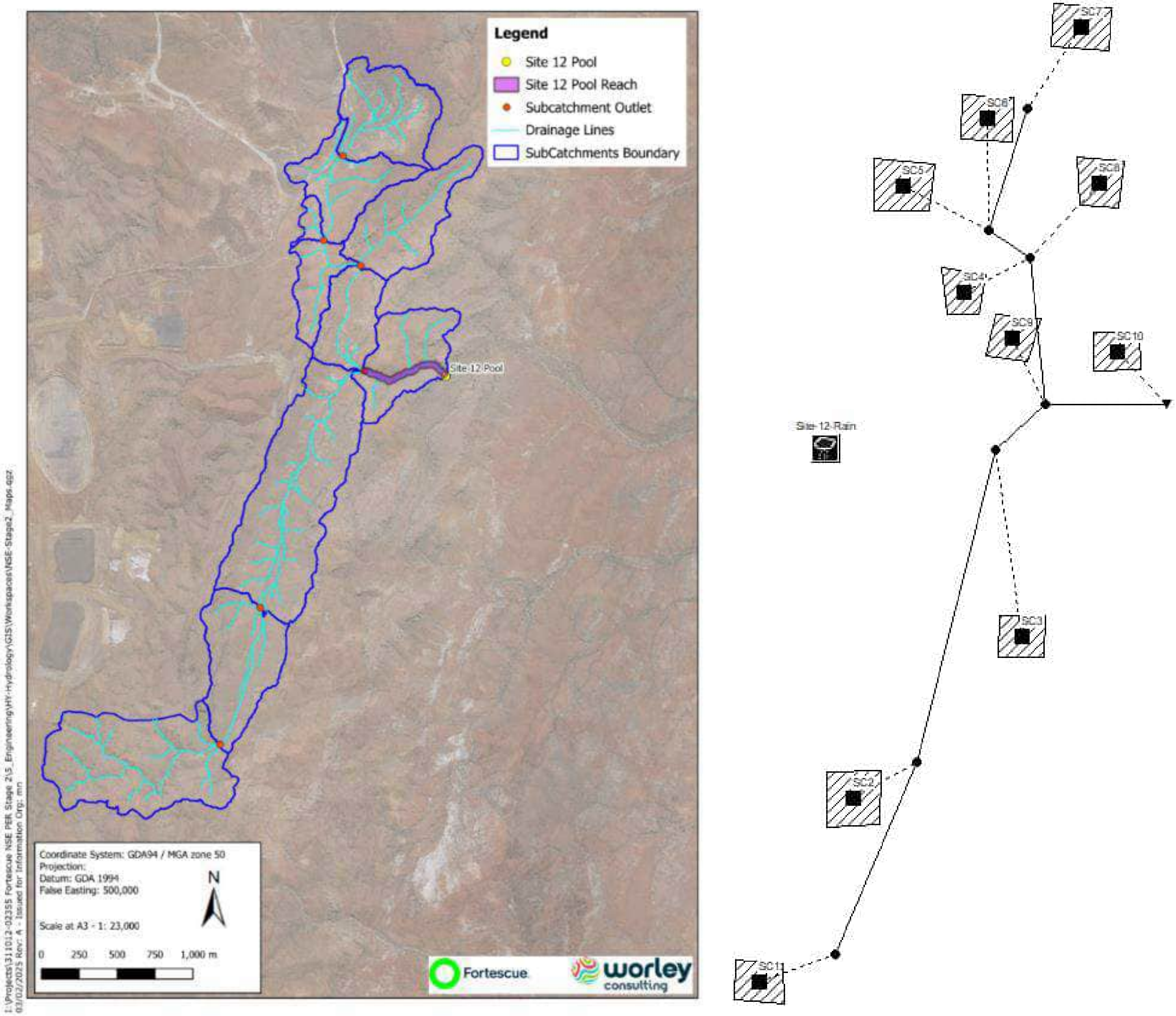

Figure 5-6. Site 12 Pool Reach SWMM modelling: Baseline sub-catchments (left) SWMM mode setup (right)

5.1.2.5 High-resolution, event-based 2D hydraulic modelling of reaches

The objective of the high-resolution, event-based 2D hydraulic modelling of reaches (and associated pools) was to generate time-varying outputs of various hydraulic parameters[3] used as an input into the sediment transport and flushing impact assessment.

High-resolution models were developed for the Mundagoora and Site 12 Pool reaches using TUFLOW software. The regional TUFLOW models described in Section 5.1.2.2 were used to extract the inflow hydrographs at the Mundagoora and Site 12 Pool reach locations for the 1%, 2%, 5%, 10%, 20% and 50% AEP events. These hydrographs were then input to the high-resolution models to facilitate detailed hydraulic modelling of each of the reaches. This task was undertaken to generate the following hydraulic model outputs for use in the sediment delivery and flushing assessment, described in Section 6.2.1:

- Peak flood depth,
- Peak flood velocity,
- Peak bed shear stress, and
- Peak stream power.

The TUFLOW model set up for the Mundagoora and Site 12 Pool reach models and corresponding input parameters are presented in Appendix D.

5.1.3 Results

5.1.3.1 Catchment area change

The Baseline and Developed conditions catchment areas and percentage area reductions are tabulated in Table 5-5 and shown in the figures provided in Appendix B.

The results suggest the following for reaches within the surface water impact area:

- The Mundagoora Pool and Site 12 Pool reaches are expected to experience a 58% and 14% reduction in catchment area due to the NSE development, respectively.
- NJA19-002 Reach, Pool IB-SW-Dry-Reject-DS-002, Pool NJA21-006-DS and Pool SW Reach experience only minor reductions in catchment area (<20%).
- Pool 9 and Pool NJA21-006-US have a catchment area reduction of approximately 30%.
- The catchment areas for Pool 59 and Pool 57 Reach reduce by more than 90%.

[3] Velocity, bed shear stress, stream power.

Table 5-5: Comparison of reach catchment areas under Baseline and Developed conditions

Water Permanence Classification	Reach ID	Catchment Area (km²)		Reduction (%)	Cause of Reduction
		Baseline	Developed		
Permanent	Mundagoora Pool	2.94	1.24	58%	Pit
Commonly Wet	Site 12 Pool	3.66	3.16	14%	WRD
Seasonal Inundation	Pool NJA19-002	0.75	0.71	5%	WRD
Periodic Inundation	Pool IB-SW-Dry-Reject-DS-002	15.34	13.16	14%	Pit
	Pool NJA21-006-US	8.83	6.10	31%	WRD
	Pool NJA21-006-DS	25.03	22.31	11%	WRD
	Pool-SW	3.35	2.87	14%	Pit
	Pool 9	1.87	1.36	27%	WRD
	Pool 57	0.16	0.02	90%	Pit
	Pool 59	0.87	0.05	94%	Pit

5.1.3.2 Event-based peak inflow comparison

A comparison of peak flows reporting to reaches within the surface water impact area, under Baseline and Developed conditions are presented in Table 5-6. The percentage reductions in peak flows are also plotted in Figure 5-7. Appendix E contains the critical duration and peak flows for each pool reach.

The results suggest the following:

- Peak flow reductions due to the NSE development range from 3% to 95%.
- Mundagoora Pool experiences greater than 50% reduction in peak flows across the range of AEP events.
- Site 12 Pool reach shows reductions of less than 15%.
- Pool 59 and Pool 57 reach show reductions in the order of 90%.
- Pool NJA21-006-US shows a reduction of up to 37%.
- Pool IB-SW-Dr-Reject-DS—002, Pool NJA21-006-DS and Pool SW all show reductions of around 15%.
- Pool NJA19-002 Reach shows less than 5% reduction.

Table 5-6: Comparison of peak flows reporting to reaches under Baseline and Developed conditions for the 1%, 2%, 5%, 10%, 20% and 50% AEP events

Water Permanence Classification	Reach ID	Peak Flow (m^3/sec)												Reduction (%)					
		Baseline Conditions						Developed Conditions											
		50%	20%	10%	5%	2%	1%	50%	20%	10%	5%	2%	1%	50%	20%	10%	5%	2%	1%
Permanent	Mundagoora Pool	14	35	45	58	81	98	6	14	20	26	37	45	56%	60%	56%	55%	54%	54%
Commonly Wet	Site 12 Pool	16	33	48	60	80	99	14	30	44	54	72	86	14%	10%	9%	10%	11%	13%
Seasonal Inundation	Pool NJA19-002	5	11	14	20	28	34	5	10	13	19	27	33	3%	3%	5%	4%	4%	3%
Periodic Inundation	Pool IB-SW-Dry-Reject-DS-002	47	107	154	189	231	278	40	90	131	162	199	244	14%	16%	15%	14%	14%	12%
	Pool NJA21-006-US	38	91	111	142	193	230	24	58	75	91	127	156	37%	36%	32%	36%	34%	32%
	Pool NJA21-006-DS	65	148	213	269	328	396	54	125	185	230	290	346	16%	15%	13%	15%	11%	13%
	Pool SW	19	43	57	71	103	126	16	36	49	60	88	109	16%	16%	14%	15%	15%	13%
	Pool 9	9	19	26	33	47	56	7	15	20	25	34	41	26%	22%	24%	23%	28%	26%
	Pool 59	4	10	14	19	28	35	0.3	0.9	1.3	1.8	2.5	3.0	93%	91%	91%	91%	91%	91%
	Pool 57	1	3	4	5	7	8	0.1	0.3	0.4	0.6	0.8	1.0	87%	88%	89%	88%	89%	87%

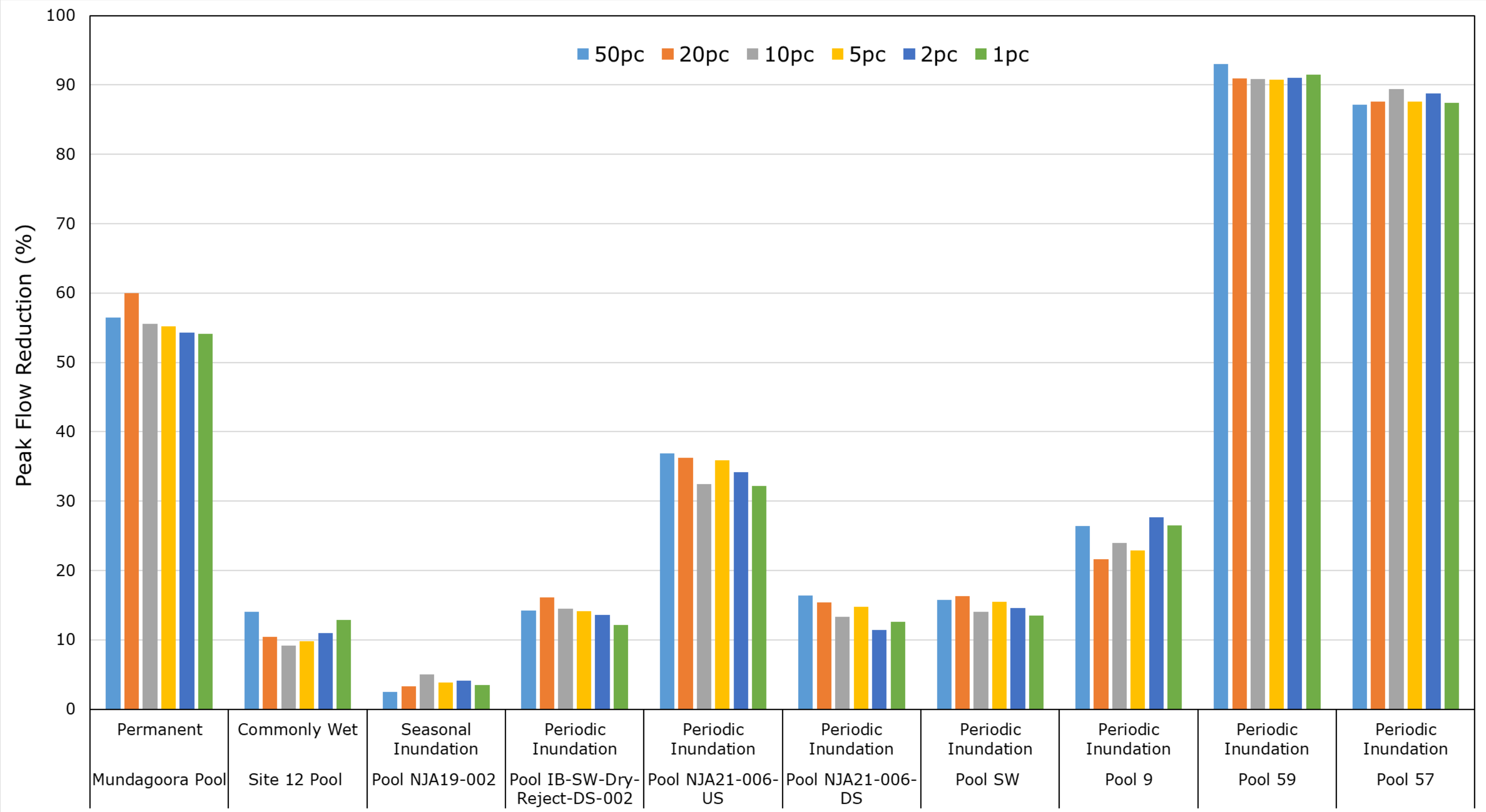

Figure 5-7. Peak flow reductions for the 1%, 2%, 5%, 10%, 20% and 50% AEP events at reaches within the surface water impact area due to NSE development.

5.1.3.3 Event-based reach storage volume and inflow assessment

The estimated reach storage and Developed conditions inflow volumes are provided in Table 5-7 along with reach surface areas. Reach storage volumes have been rounded to the nearest 50 m^3 and the reach storage expressed as a percentage of the inflow volumes.

Figure 5-8 shows the reach storage volume as a percentage of the Developed conditions inflow volumes for the 1%, 2%, 5%, 10%, 20% and 50% AEP events. To assess impacts for more frequent flood events (i.e., environmental flows), Figure 5-9 provides pie charts comparing the reach storage volumes and total inflow volumes for the 50% AEP event (expressing the storage volume as a percentage of the total inflow volume). Appendix E provides the critical duration (for flow volume) as well as the inflow volume compared with reach storage volume for each reach.

Note: Two of the three pools comprising Pool 57 reach (pools 63 & 64) are located within the proposed NSE development footprint, and therefore are assumed to be removed by mining.

The results suggest the following:

- The reach storage volumes are a negligible percentage of the total inflow volume across all AEP events for most reaches and therefore catchment area reductions due to the NSE development are expected to have no significant impact on the frequency of pool filling.
- Pool 57 reach has the largest catchment area reduction however the reach storage volume represents less than 15% of the 50% AEP inflow volume, and less than 5% of the inflow volume for the 20% AEP events under Developed conditions. Therefore, the NSE development is expected to have no significant impact on the frequency of filling.

Catchment area reductions due to construction of NSE pits were used to complete a qualitative assessment of potential impact to alluvium throughflow and duration of pool inundation / water presence at the following reaches with conceptualisation type 1a or 1b:

- Pool IB-SW-Dry-Reject-DS-002
- Pool SW

Both reaches have catchment area reductions of 14% which is minor and unlikely to have a significant impact on alluvium throughflow and duration of pool inundation / water presence.

Table 5-7: Comparison of reach storage and Developed conditions inflow volumes for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Water Permanence Classification	Reach ID	Surface Area (m^2)	Storage Volume (x 1000 m^3)	Developed Conditions Inflow Volume (x 1000 m3)						Storage as Percentage of Inflow Volume (%)					
				50%	20%	10%	5%	2%	1%	50%	20%	10%	5%	2%	1%
Permanent	Mundagoora Pool	450	0.6	29	84	129	172	241	298	2.1	0.7	0.5	0.3	0.2	0.2
Commonly Wet	Site 12 Pool	2700	2.4	73	210	324	426	598	744	3.3	1.1	0.7	0.6	0.4	0.3
Seasonal Inundation	Pool NJA19-002	100	0.05	16	48	74	98	138	171	0.3	0.1	0.1	0.1	0.0	0.0
Periodic Inundation	Pool IB-SW-Dry-Reject-DS-002	3300	0.55	297	845	1308	1728	2408	2992	0.19	0.07	0.04	0.03	0.02	0.02
	Pool NJA21-006-US	2500	0.7	142	410	632	838	1172	1445	0.49	0.17	0.11	0.08	0.06	0.05
	Pool NJA21-006-DS	5600	1.5	489	1381	2133	2826	3963	4944	0.31	0.11	0.07	0.05	0.04	0.03
	Pool SW	450	0.15	67	193	299	397	555	687	0.22	0.08	0.05	0.04	0.03	0.02
	Pool 9	800	0.3	32	91	139	184	256	319	1.0	0.3	0.2	0.2	0.1	0.1
	Pool 59	100	0.05	1	3	5	7	9	12	4.4	1.5	1.0	0.7	0.5	0.4
	Pool 57	2200	0.05	0	1	2	2	3	4	13.4	4.6	3.0	2.3	1.6	1.3

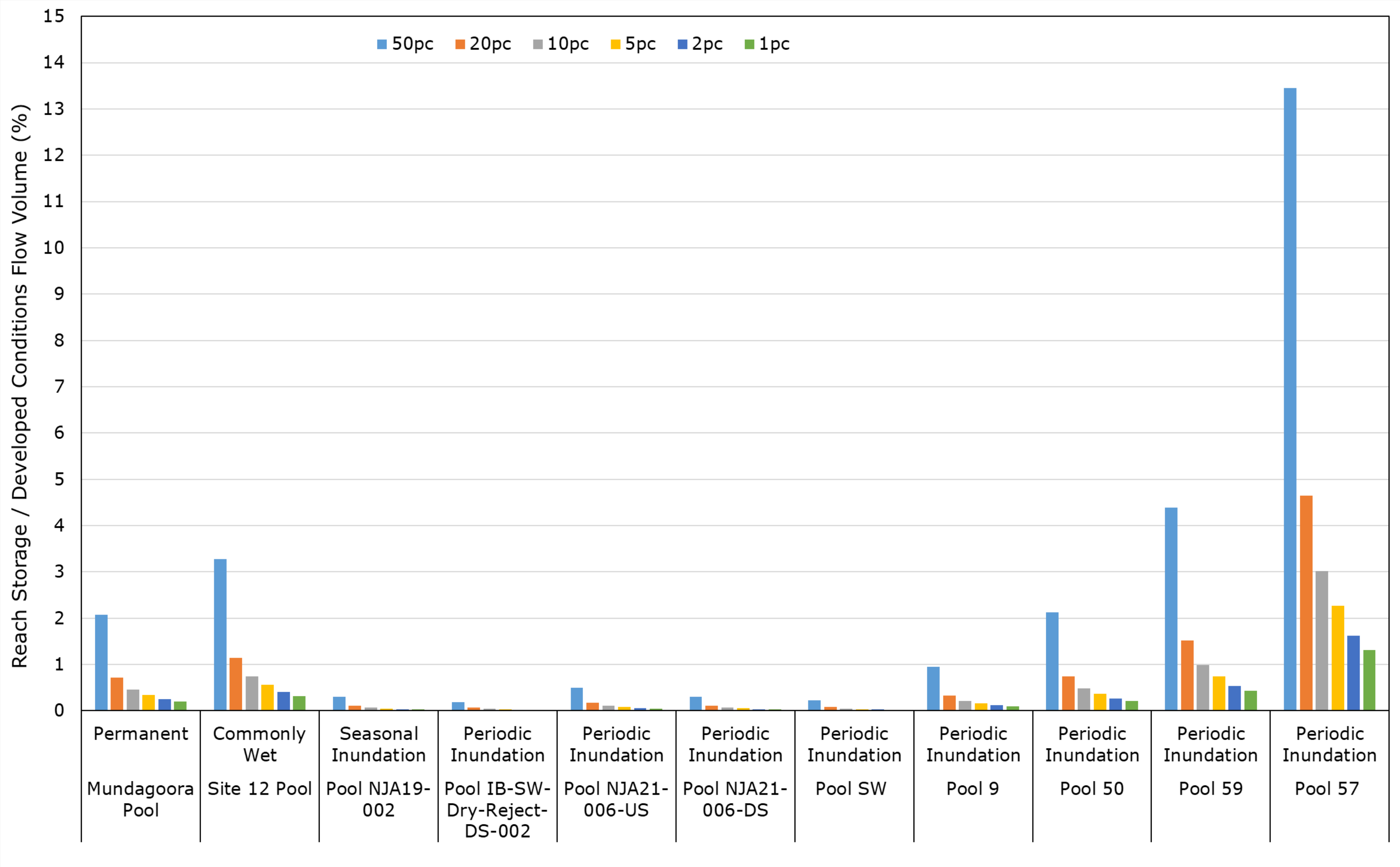

Figure 5-8. Reach storage volume as a percentage of the Developed conditions inflow volumes for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

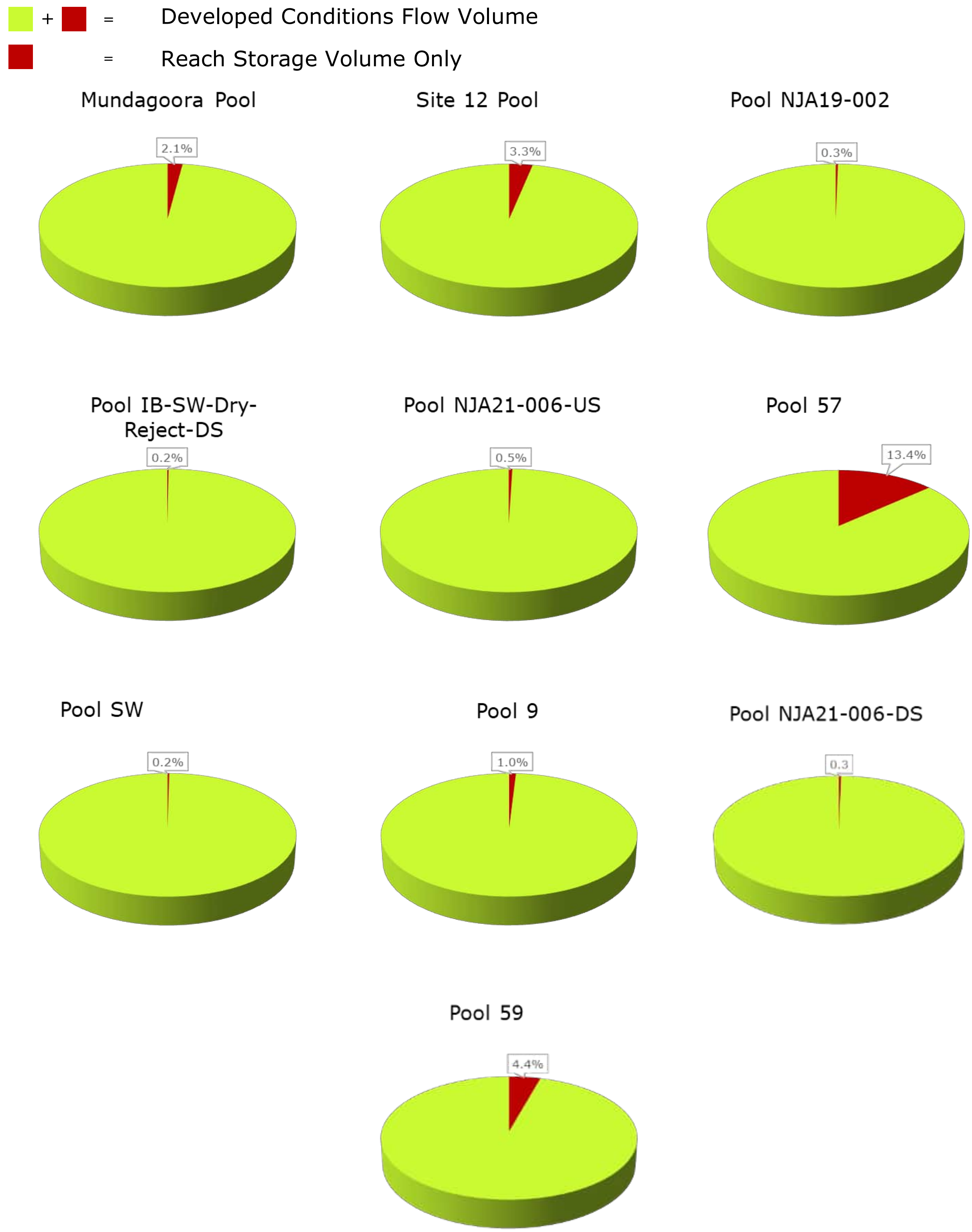

Figure 5-9. Reach storage volumes expressed as a percentage of the Developed conditions inflow volume for the 50% AEP event.

5.1.3.4 Long-term hydrology simulation modelling

The 1,000 daily inflow volumes generated by the SWMM model to Mundagoora Pool under Baseline and Developed conditions, are plotted in Figure 5-10 and Figure 5-11 respectively and compared in Figure 5-12. The results suggest that the median reduction in daily inflow volumes due to the NSE development is 55%, which is consistent with the reduction in catchment area (58%).

The 1,000 daily inflow volumes generated by the SWMM model to the Site Pool reach under Baseline and Developed conditions are plotted in Figure 5-13 and Figure 5-14, respectively. Baseline and Developed conditions are compared in Figure 5-15. The median reduction in daily inflow volumes due to the NSE development is 12%, which is consistent with the reduction in catchment area (14%).

Figure 5-16 presents a statistical comparison of the number of days per year, where the daily surface inflow volume exceeds the pool storage volume (i.e., pool filling days), under Baseline and Developed conditions. The results suggest the following:

- Mundagoora Pool: average number of pool filling days changes from 9.0 to 8.5 days per year.
- Site 12 Pool: average number of pool filling days changes from 8.3 to 8.2 days per year.

Table 5-8 presents the total number of pool filling days over 1,000 years for Baseline and Developed conditions. The results suggest the following:

- Mundagoora Pool: catchment area reduction due to the NSE development reduces the total number of pool-filling days by 6.1% over 1,000 years (from 9,091 to 8,538 days).
- Site 12 Pool: catchment area reduction due to the NSE development reduces the total number of pool-filling days by 1.0% (from 8,309 to 8,227 days).

The results suggest that for both reaches, the number of pool filling days under Baseline and Developed are similar, which suggests the NSE development is unlikely to have a significant impact on the frequency of pool-filling by surface water inflows. The proposed development is therefore not expected to have a significant impact on the hydrological (surface water flow) regime at the pools.

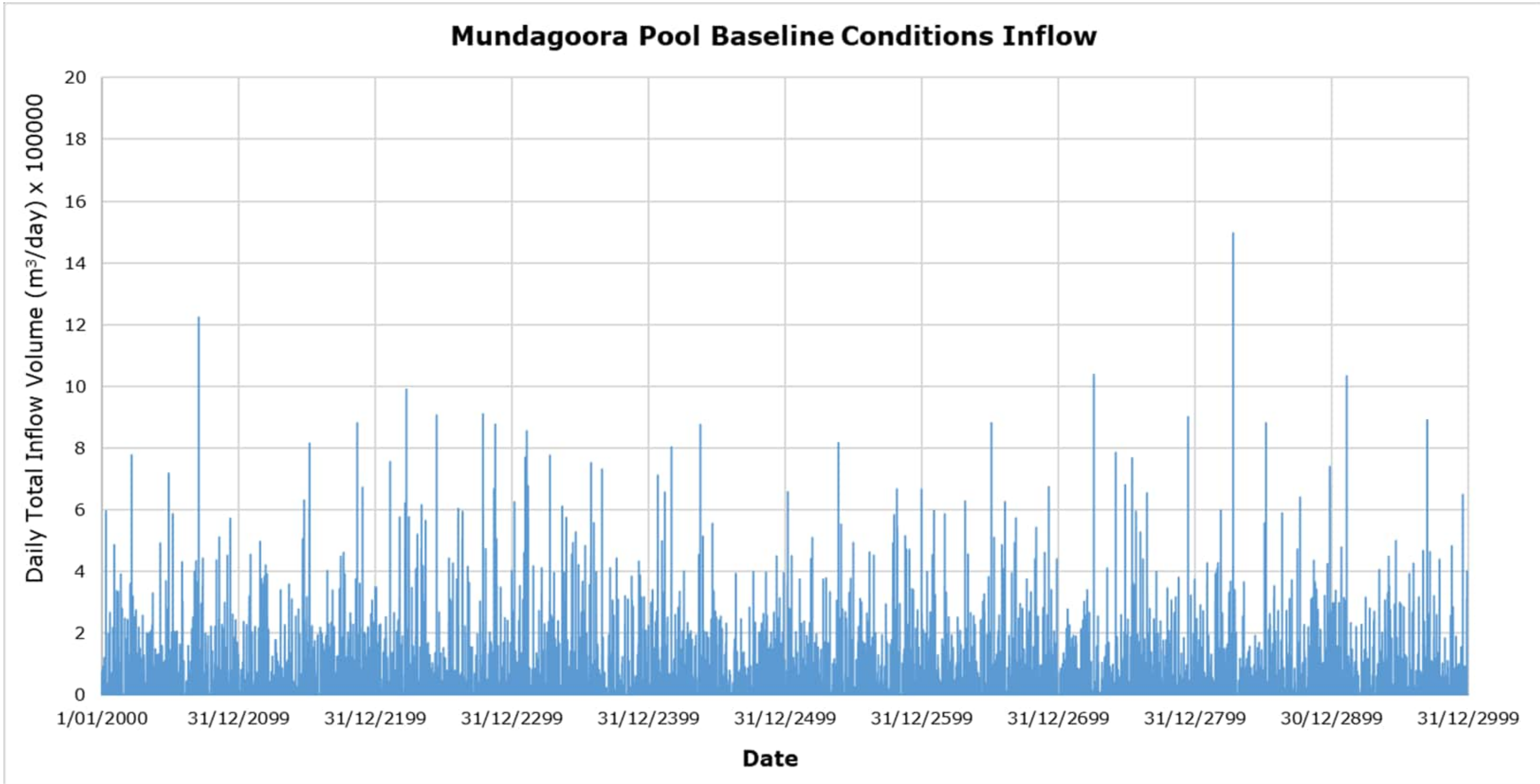

Figure 5-10. Baseline conditions: Mundagoora Pool 1,000-year daily inflow volumes.

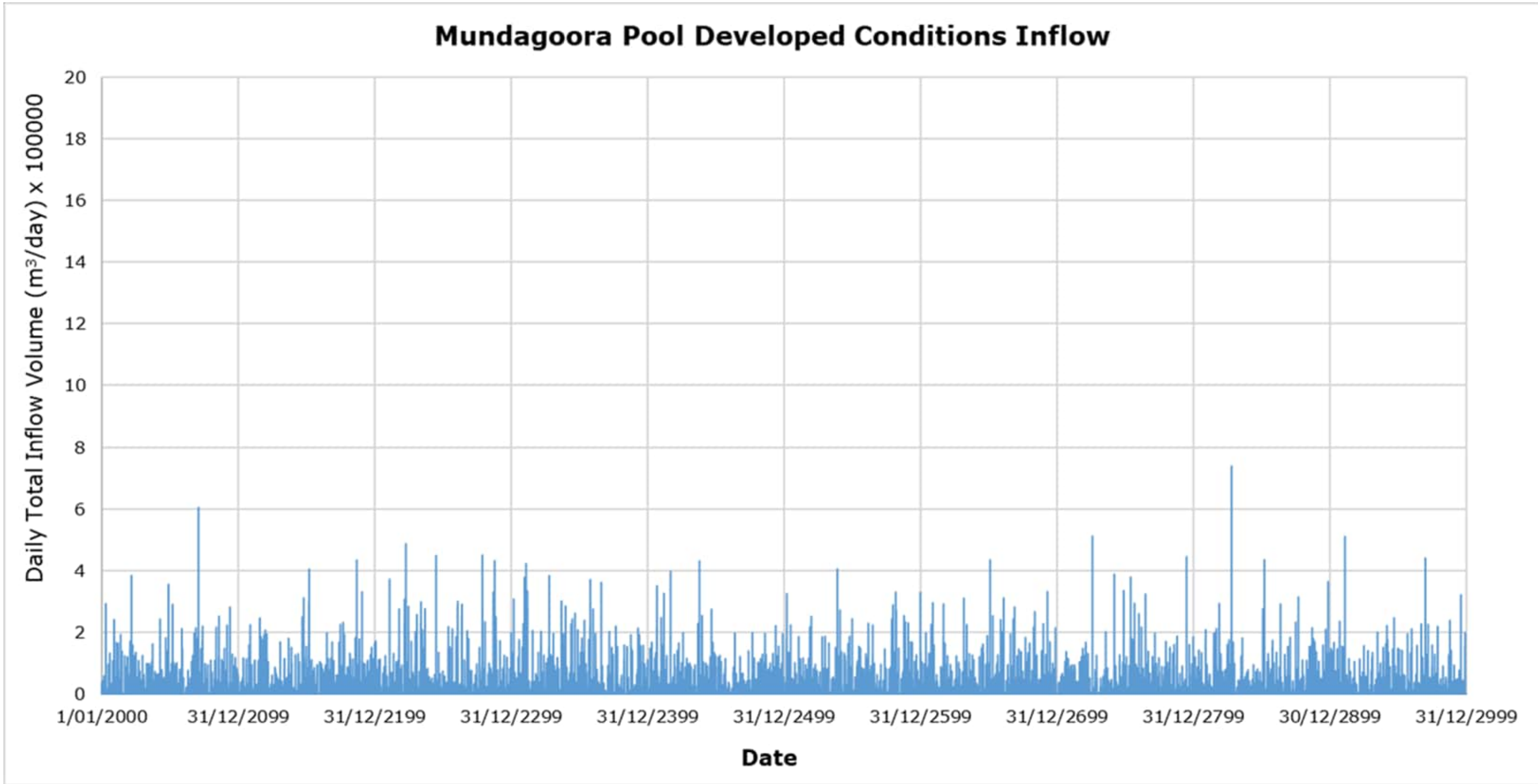

Figure 5-11. Developed conditions: Mundagoora Pool 1,000-year daily inflow volumes

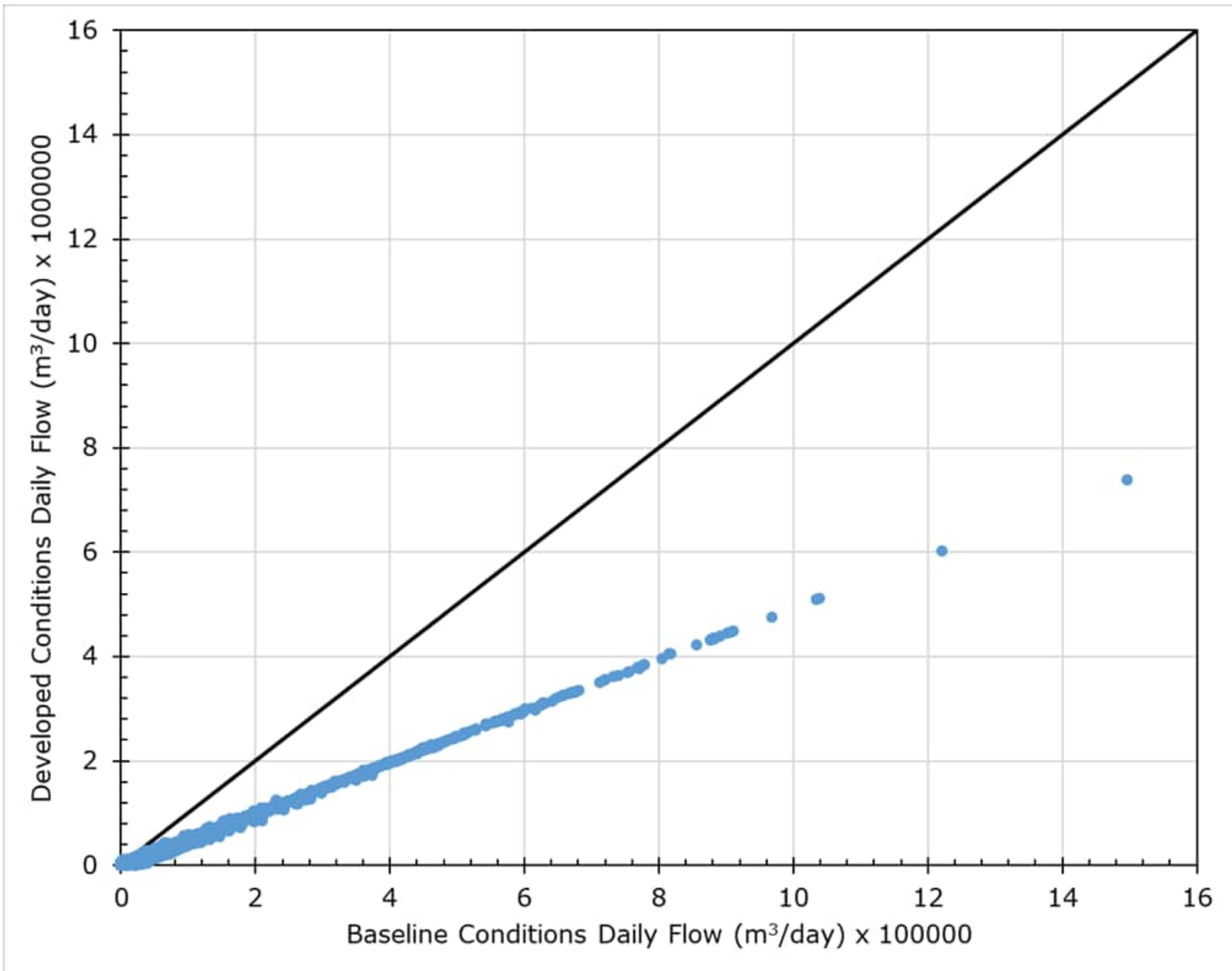

Figure 5-12. Comparison of 1,000 years of Baseline and Developed conditions daily flow volumes at Mundagoora Pool

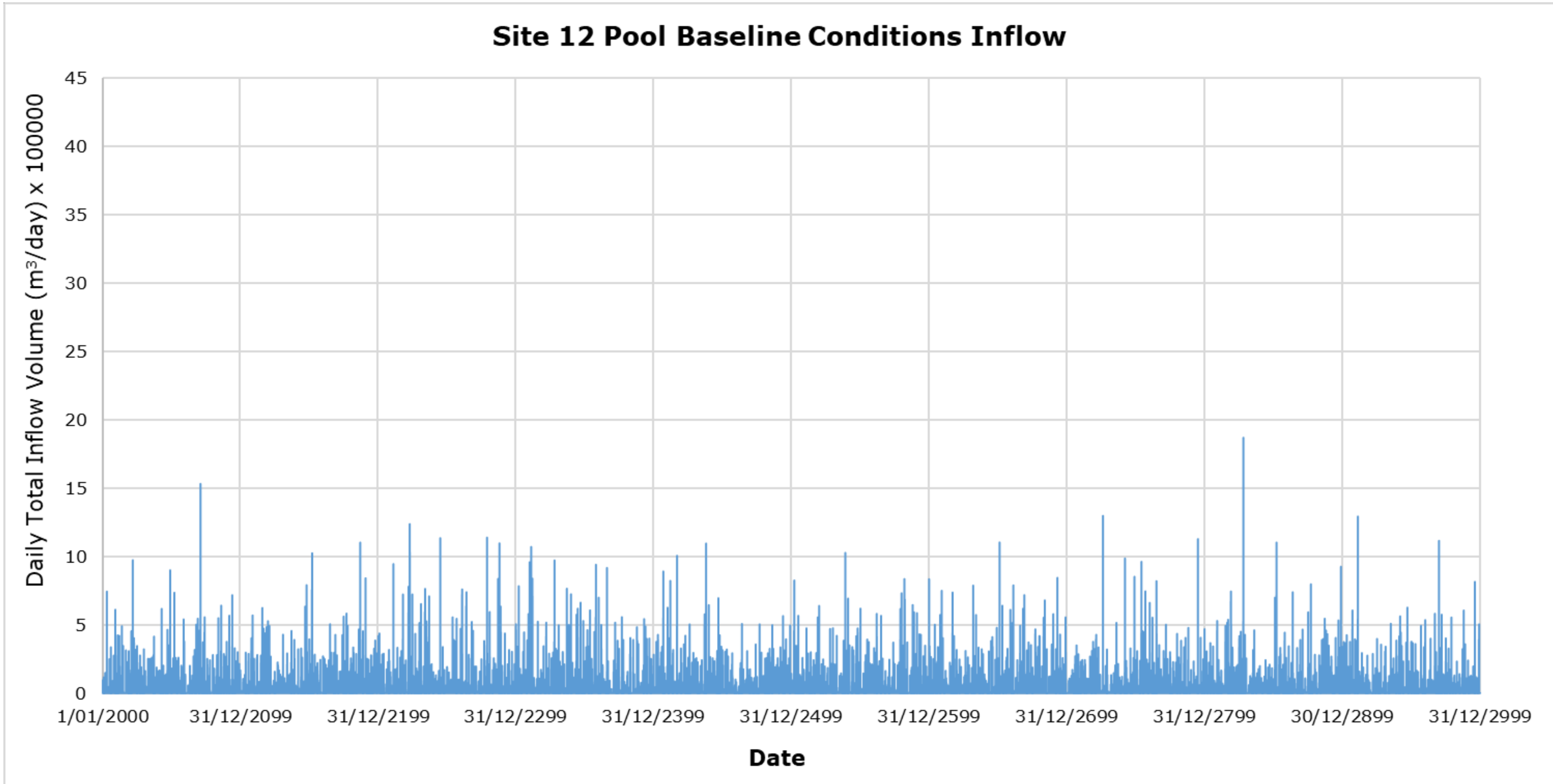

Figure 5-13. Baseline conditions: Site 12 Pool 1,000-year daily inflow volumes.

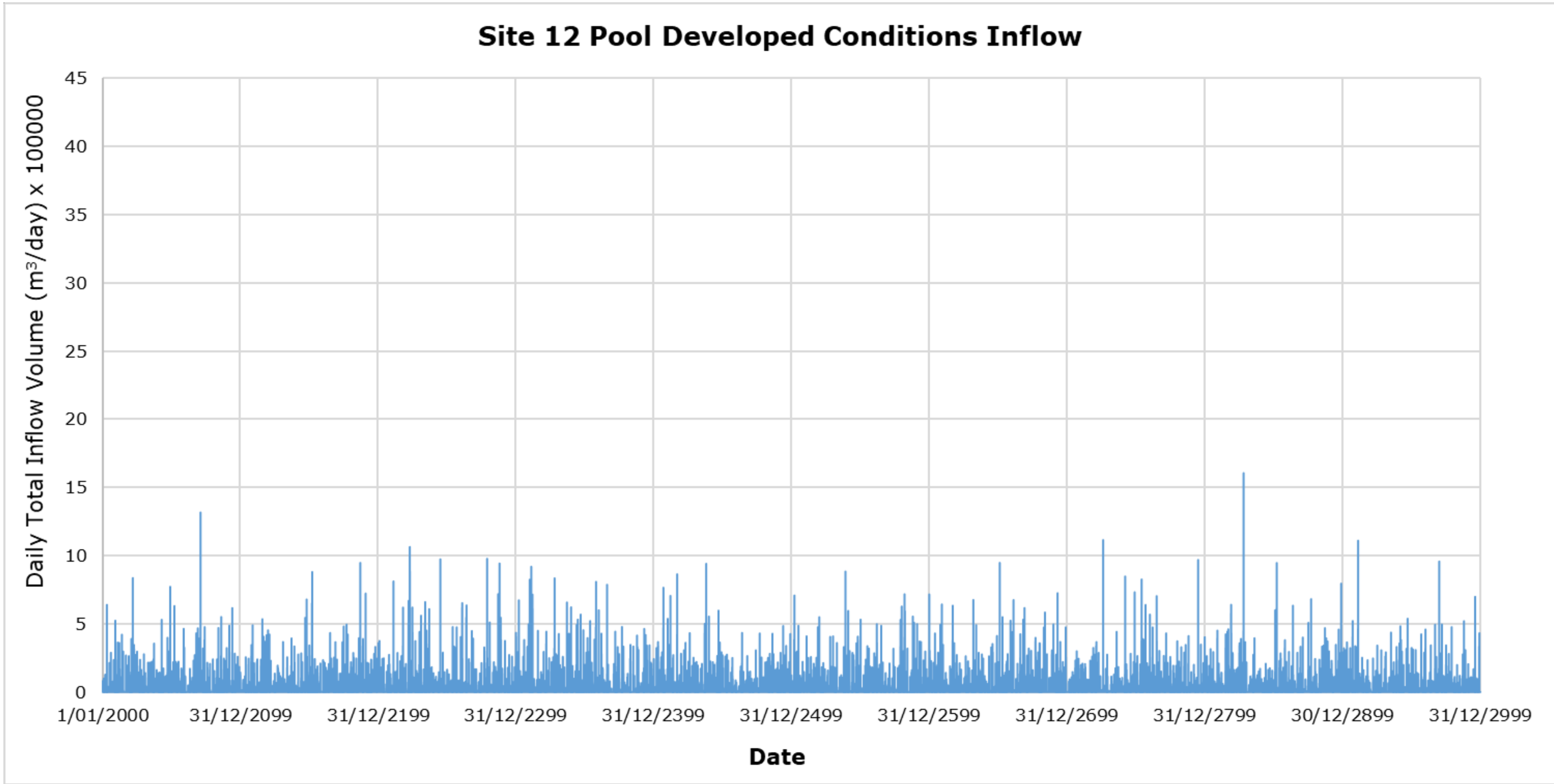

Figure 5-14. Developed conditions: Site 12 Pool 1,000-year daily inflow volumes.

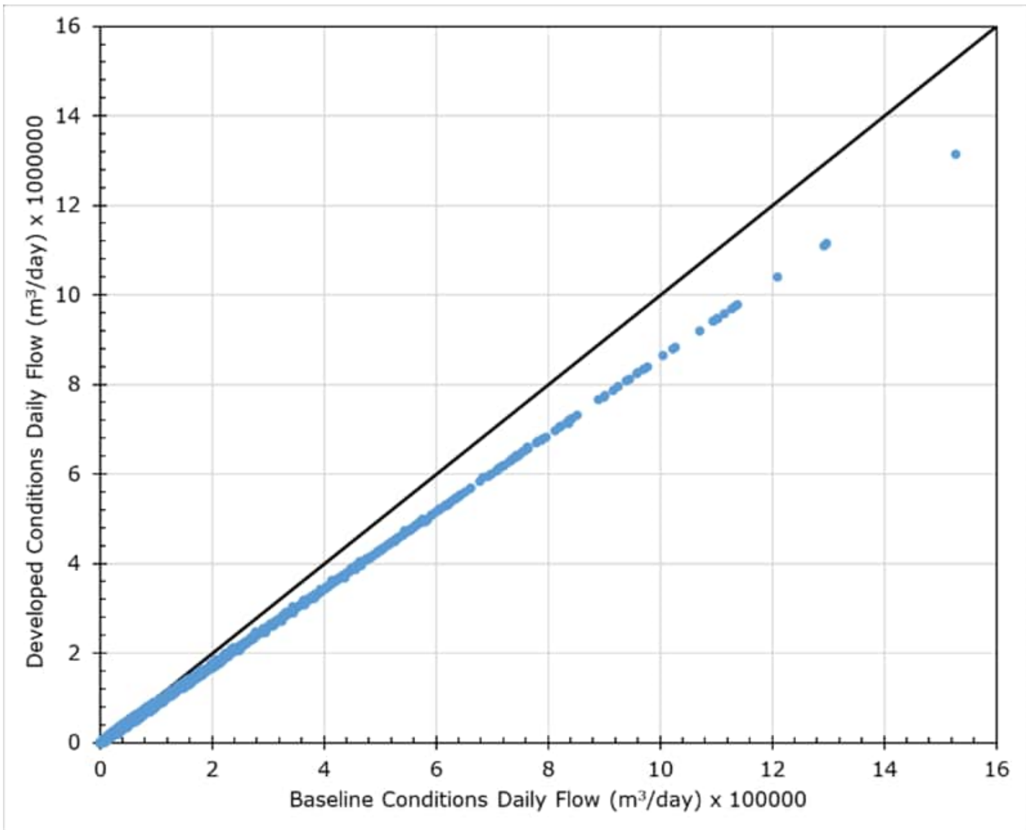

Figure 5-15. Comparison of 1,000 years of Baseline and Developed conditions daily flow volumes at Site 12 Pool

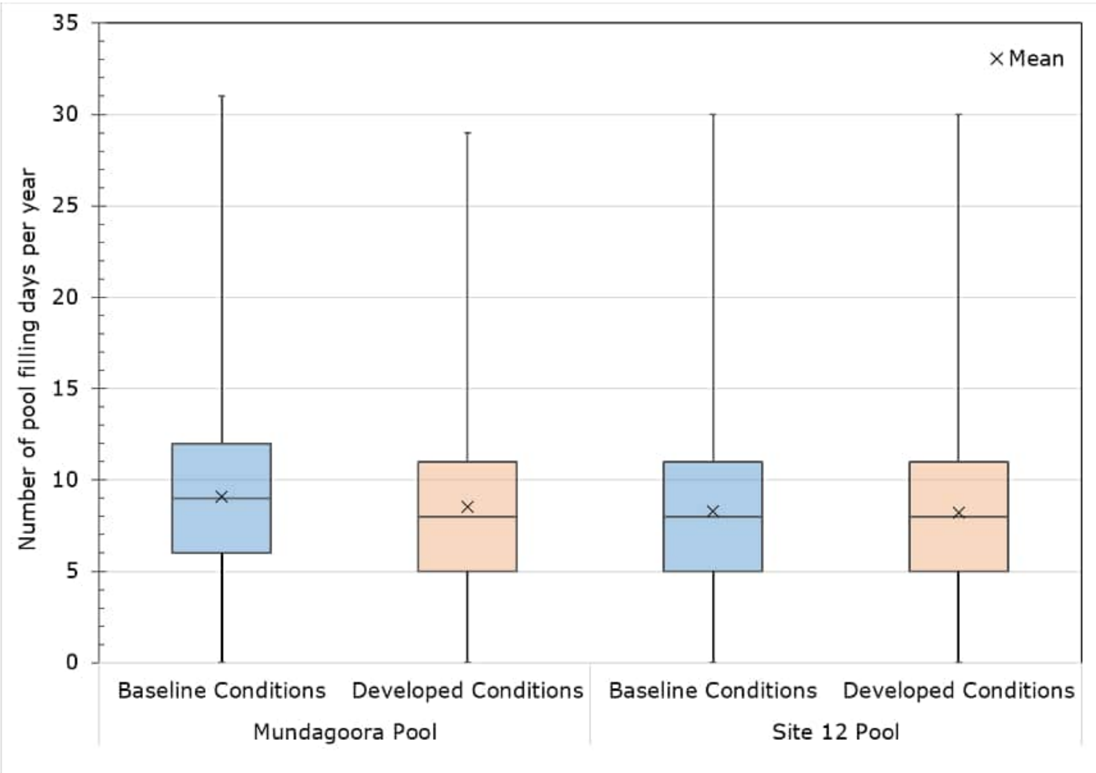

Figure 5-16. Annual pool filling statistics over 1,000 years

Table 5-8: Total reach/pool filling statistics over 1,000 years

Reach ID	Total number of pool filling days over 1,000 years		% Reduction
	Baseline Conditions	Developed Conditions	
Mundagoora Pool	9,091 days	8,538 days	-6.1%
Site 12 Pool	8,309 days	8,227 days	-1.0%

5.1.3.5 High-resolution, event-based 2D hydraulic modelling of pools

Outflow hydrographs were extracted from the regional TUFLOW models (refer to Section 5.1.2.5) at Mundagoora Pool and Site 12 Pool locations for the 1%, 2%, 5%, 10%, 20% and 50% AEP events under Baseline and Developed conditions.

These inflow hydrographs were input to the high resolution TUFLOW models set up for the Mundagoora Pool and Site 12 Pool reaches. The following hydraulic outputs were then extracted from the model to inform the flushing assessment described in Section 6.2.1.1:

- Hydrographs presented in Figure 5-17 to Figure 5-20.
- Time series data for flow rate, flood depth, velocity, stream power and bed shear stress at plot output points distributed across each pool (upstream, deepest point, and downstream for Mundagoora Pool, and eleven different points across the Site 12 Pool reach – see Appendix D), and
- Peak flood depth and velocity maps for the 1%, 10% and 50% AEP events.

The TUFLOW flood maps produced by the local scale models are presented in Appendix F.

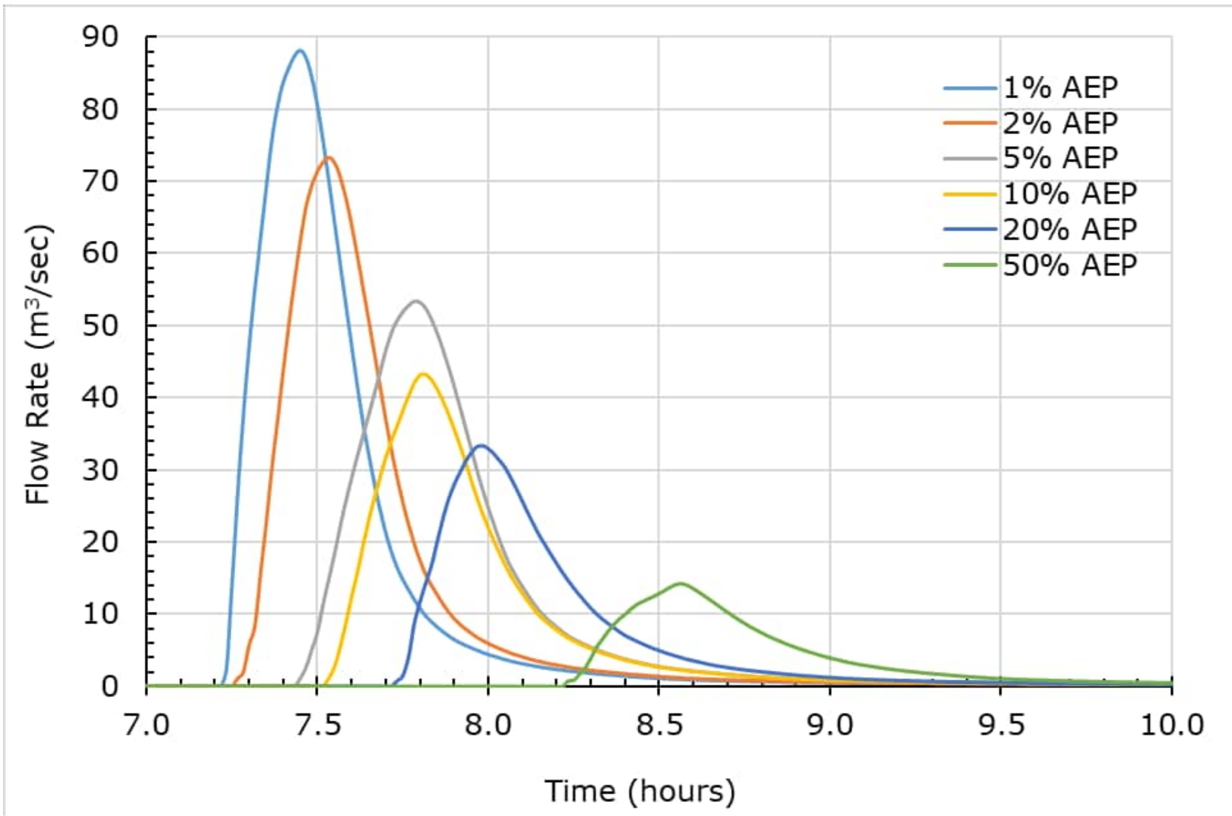

Figure 5-17. Mundagoora Pool: Baseline conditions inflow hydrographs for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

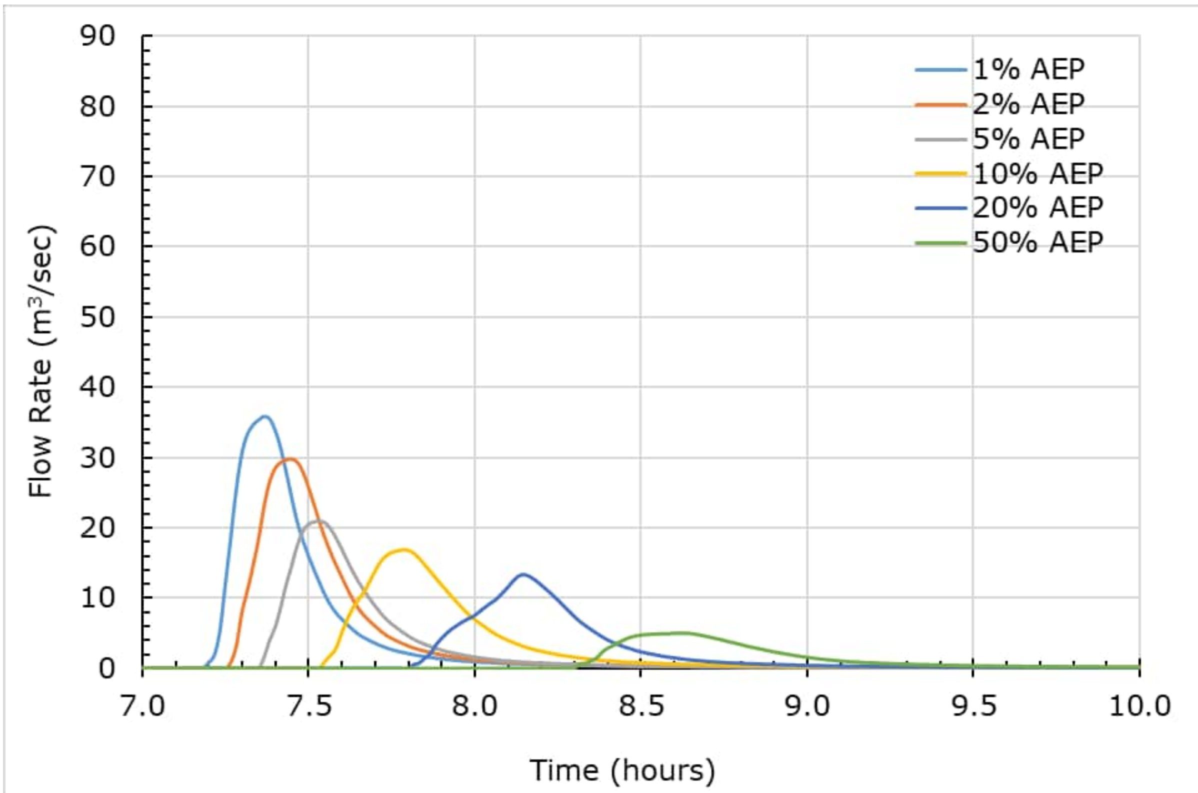

Figure 5-18. Mundagoora Pool: Developed conditions inflow hydrographs for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

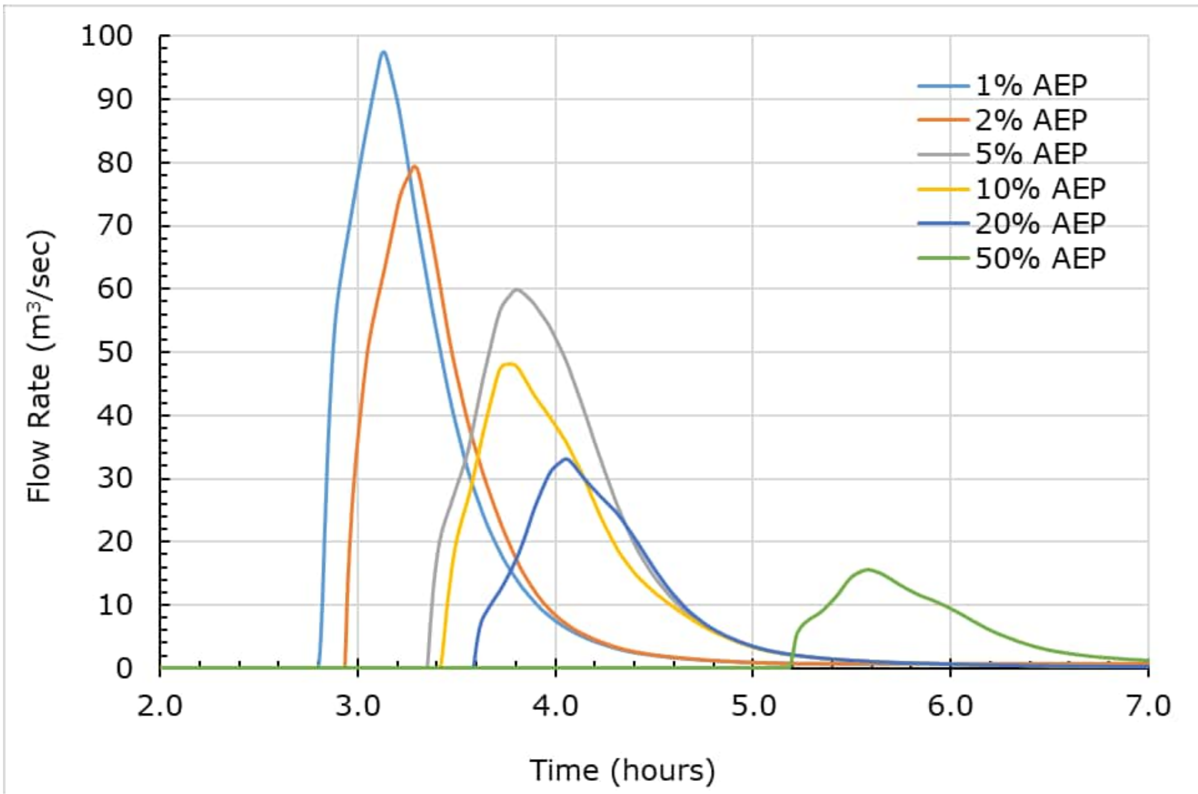

Figure 5-19. Site 12 Pool: Baseline conditions inflow hydrographs for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

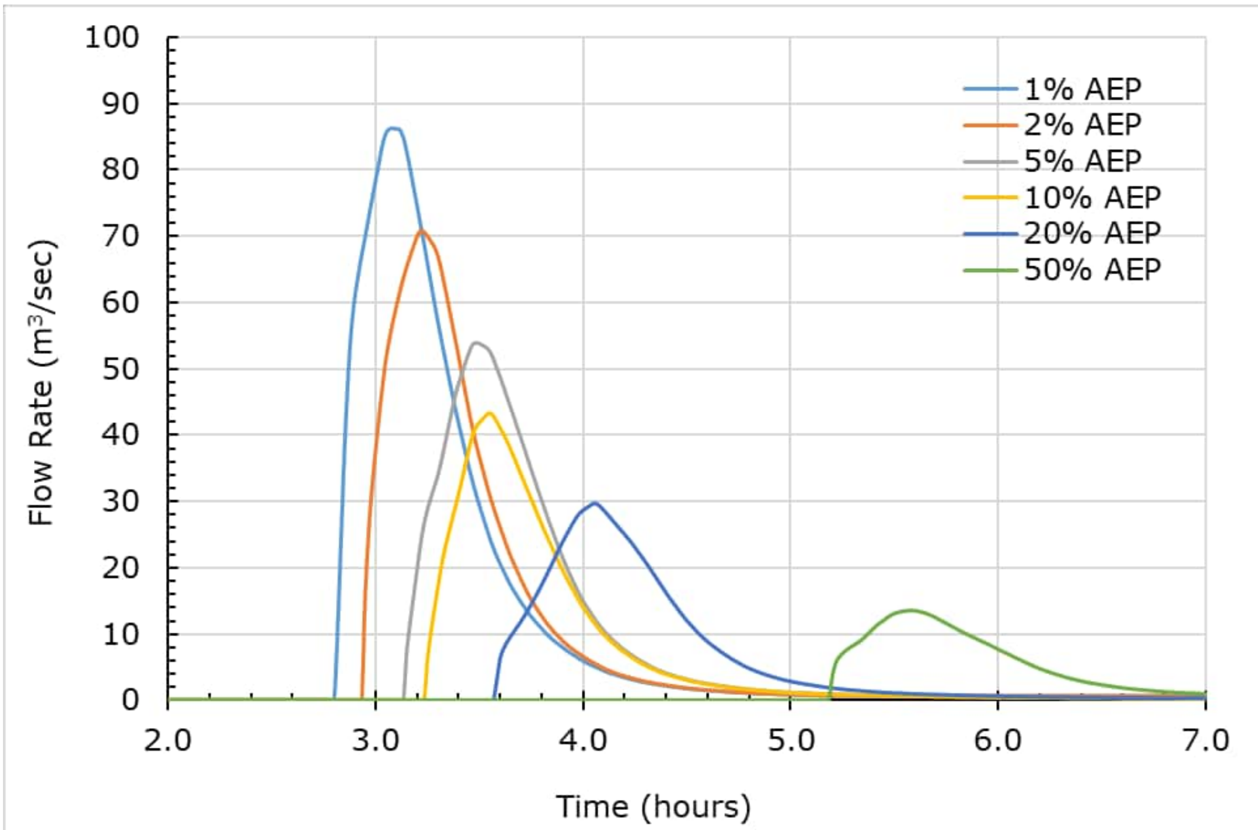

Figure 5-20. Site 12 Pool: Developed conditions inflow hydrographs for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

5.1.4 Surface water inflow impact assessment outcomes

The results from the surface water inflow assessments were used along with the impact severity criteria provided in Section 4.5, to assess impacts to reaches and associated pools, with the results presented in Table 5-9.

The results suggest the following:

- Despite the catchment area reduction and subsequent peak flow / inflow volume reduction as a result of the proposed NSE development, the reduced surface water inflow can still fill the pools during frequent events and pool filling frequency under Developed conditions is expected to be similar to Baseline conditions.
- All reaches and associated pools identified within the surface water impact area are unlikely to be significantly impacted by changes to surface water inflow quantities resulting from the NSE development, and therefore no mitigation measures are required from a surface water inflow perspective.

Table 5-9. Impacts associated with potential changes in surface water inflows due to NSE development.

Reach ID	Change due to NSE Development *		Reduction in number of pool-filling days over 1,000 years (%)	Impact Severity
	% reduction in peak flow	Pool storage as % of total inflow		
Mundagoora Pool	54 - 60%	0.2 – 2.1%	6.1%	Low
Site 12 Pool	9 - 14%	0.1 – 0.6%	1.0%	Low
Pool NJA19-002	3 - 5%	0.03 – 0.3%	-	Low
Pool IB-SW-Dry-Reject-DS-002	12 – 16%	0.02 – 0.2%	-	Low
Pool NJA21-006-US	32 – 37%	0.05– 0.5%	-	Low
Pool NJA21-006-DS	11 – 16%	0.03 – 0.3%	-	Low
Pool-SW	13 – 16%	0.02 – 0.2%	-	Low
Pool 9	22 – 28%	0.1 – 1.0%	-	Low
Pool 57	87 - 89%	0.4 – 4.4%	-	Low
Pool 59	91 - 93%	1.3 – 13.4%	-	Low

** Based on results for 1%, 2%, 5%, 10%, 20% and 50% AEP events*

5.2 Groundwater inflow impact assessment

5.2.1 Reaches included in impact assessment

The following reaches (and associated pools) are located within the groundwater impact area (Section 3.1) and have a conceptualisation that supports connection with the regional aquifer system (Types 3 or 4), so were selected for groundwater impact assessment:

- Mundagoora Pool, and
- Site 12 Pool.

Both pools represent outflow from an upstream catchment through a gap in a low permeability (or practically impermeable) boundary (LPB). The LPBs represented by shales occur along the catchment boundaries, in the north-south direction, forming groundwater “compartments” that are aligned with the catchment boundaries.

The LPB geological control for both catchments is shown in Figure 5-21.

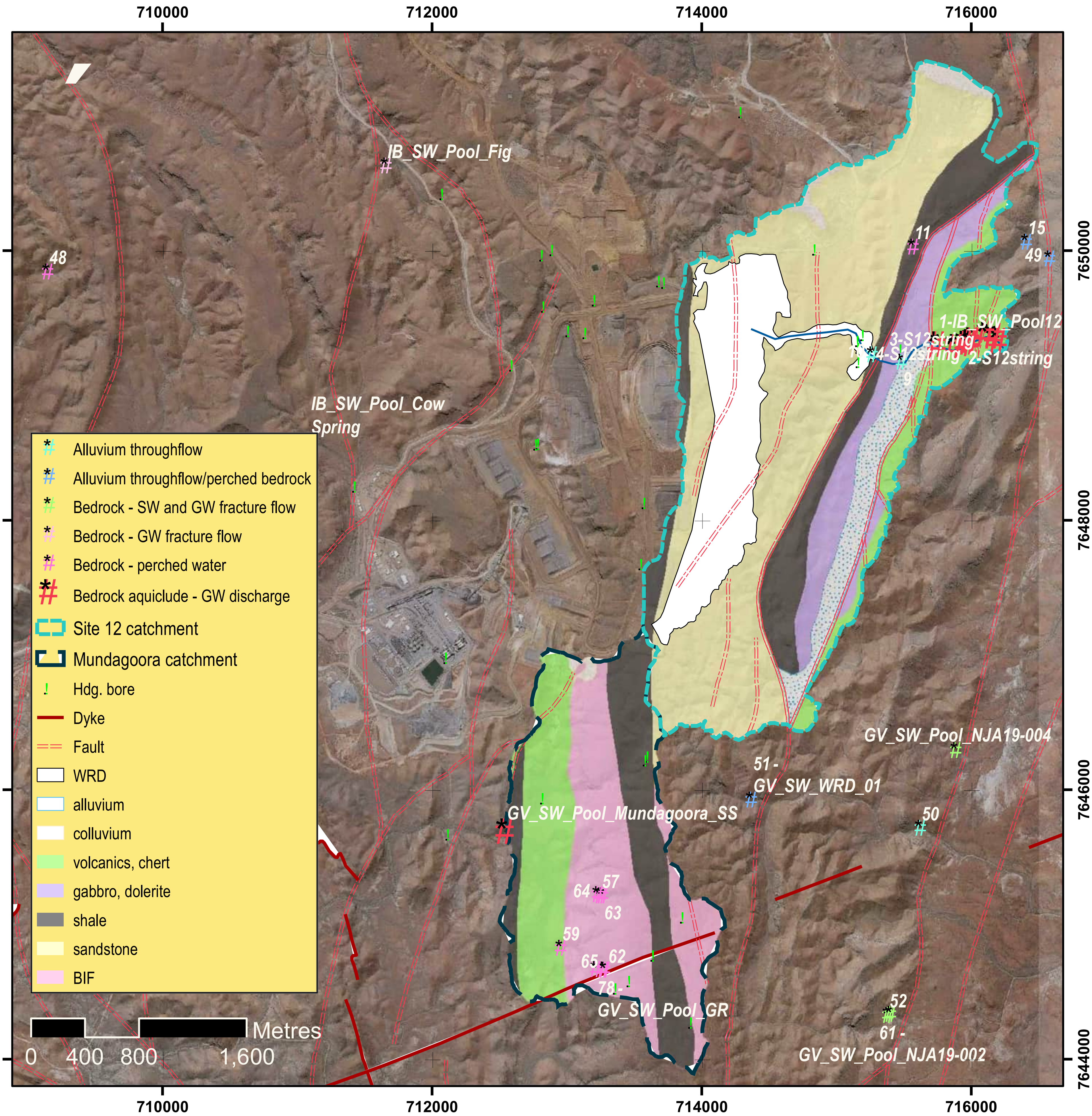

Figure 5-21. Geological controls influencing groundwater (and catchment) compartmentalisation (note dark shading indicating shale occurrences along the catchment boundaries).

5.2.2 Methodology

5.2.2.1 Groundwater inflow estimation

Inflow estimation approaches have been selected to suit the relatively sparse data availability, and to address the fact that direct flow measurements (streamflow in creek upstream or outflow from pool), which would allow for derivation of baseflow, are not available. Three methods were used, as follows:

- Chloride mass balance (CMB) estimation of available recharge, based on a concept implying that pool baseflow is fed predominantly by recharge. This is supported by the catchment position in the landscape, being in elevated areas (Figure 5-22).
- Linear steady-state flow using Darcy's flow analytical relationship. This is based on groundwater throughflow through a defined area, characterised by (lumped) hydraulic conductivity (K, m/d) and groundwater flow gradient (i, dimensionless).
- Pool flow pulse recession (PFPR) and return to baseflow, after a major rainfall event that initiates groundwater recharge. A rainfall event results in a rise in pool flow and dilutes pool solute concentrations (runoff dominated flow). The subsequent flow recession leads to a return to baseflow dominated flow, with groundwater concentration. Timing of concentration returning to its baseflow value and the known pool volume can be used to estimate the baseflow rate.

Outflows from both groundwater systems are considered to occur only through the pools (i.e., any subsurface outflow/leakage is considered negligible).

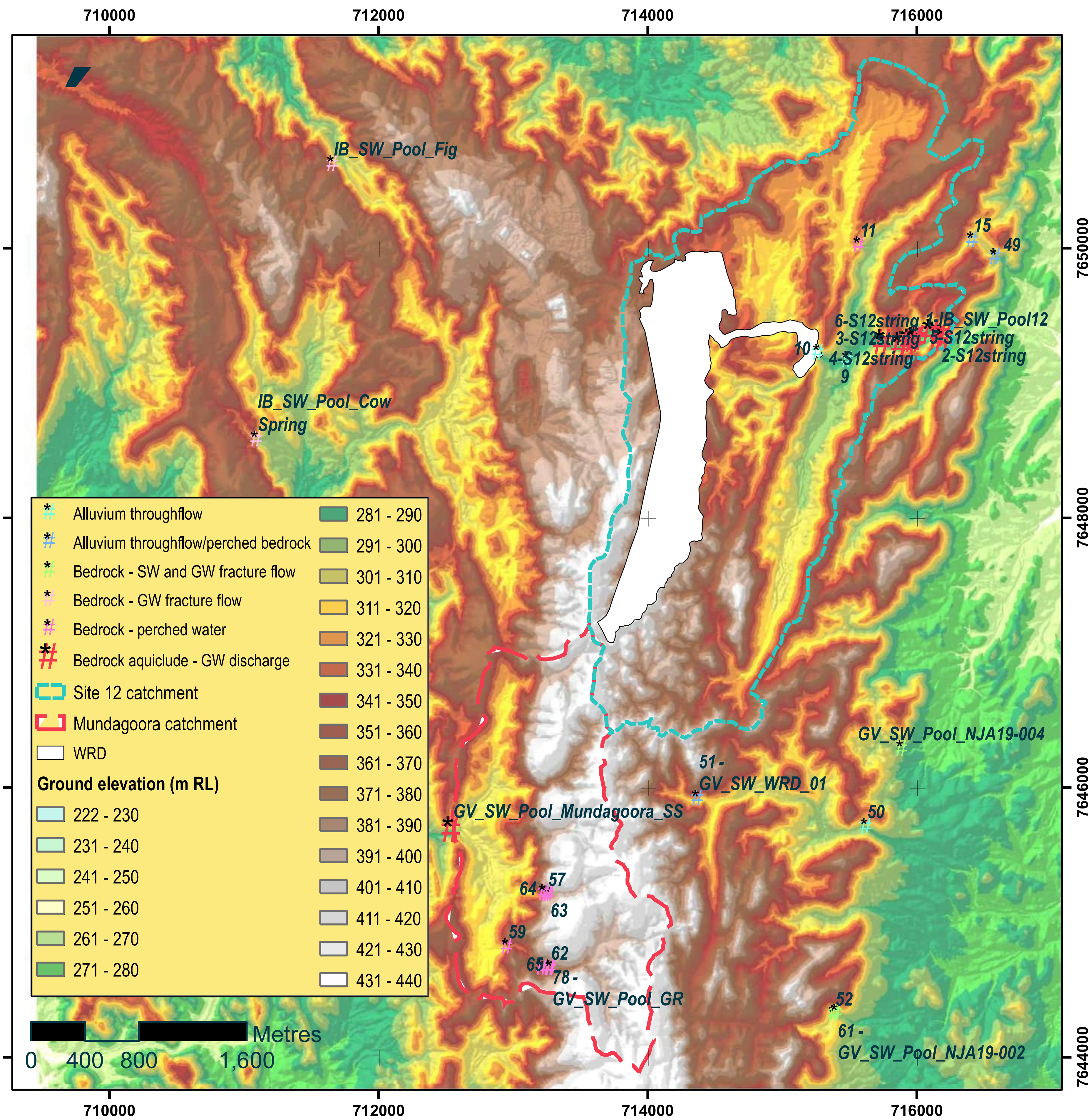

Figure 5-22. Terrain elevations of the two catchments indicating elevated ridge running north-south.

CMB is based on the regionally aggregated groundwater chloride concentration reflecting the accumulation of chloride in the groundwater system originating from atmospheric chloride deposition. The method assumes conservative sources of chloride (i.e., no evaporite sources) and recharge **R** (mm/yr) is based on the following equation[4] (Lee, et al., 2024):

$$R=100D/Cl_{gw}$$

Where **D** is chloride deposition rate (kg/ha/yr), Cl_{gw} is the chloride (“steady-state”) concentration in groundwater (mg/L).

Atmospheric chloride deposition has been mapped nationwide and is estimated at 8 kg/ha/yr for IB area[5] (Wilkins, et al., 2022).

5.2.2.2 Catchment recharge assessment

Catchment recharge change was assessed qualitatively to evaluate the potential impact that the NSE development may have on groundwater recharge in the upstream catchment areas associated with the pools. The following assumptions are made for the impact assessment:

- **Pits:** development of pit voids within the pool catchments will reduce the amount of groundwater recharge reporting to pools, which in turn may impact on groundwater inflows.
- **WRDs:** development of WRDs within the pool catchments will not reduce the amount of groundwater recharge reporting to pools. Direct rainfall runoff is intercepted and infiltrated within the WRD landforms, which may enhance recharge and could lead to localised groundwater mounding, the extent of which depends on the WRD material. Where the WRD is located within the estimated extent of groundwater drawdown, there is potential for this recharge and mounding to partially offset the effect of drawdown and associated impacts on groundwater inflows to pools.

5.2.3 Results

5.2.3.1 Mundagoora Pool

Baseline groundwater inflows estimated using the three methods vary between 0.1 and 0.6 L/s (Table 5-10). The modelled groundwater drawdown for the reduced recharge scenario suggests that groundwater levels at Mundagoora Pool will be reduced by up to 13 m by 2044 under Developed conditions, impacting on groundwater inflows to the pool.

In addition, the upstream catchment area will be reduced by 58% owing to pit development; hence there is expected (refer Section 5.1.3.1) to be a reduction in groundwater recharge and inflows to the pool.

A groundwater inflow estimate of 0.5 L/s has been adopted for the impact assessment and identification of mitigation measures (refer Section 5.2.4).

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[4] Lee S, Irvine DJ, Duvert C, Rau GC, Cartwright I, 2024: A high resolution map of diffuse groundwater recharge rates for Australia. Hydrol. Eart Syst. Sci., 28, 1771-1790, https://doi.org/10.5194/hess-28-1771-2024

[5] Wilkins A, Crosbie R, Louth-Robin T, Davie, P, Raiber M, Dawes W, Gao L, 2022: Australian gridded chloride deposition-rate dataset. Data in Brief 42 (2022) 108189, https://doi.org/10.1016/j.dib.2022.108189, Elsevier

Table 5-10. Groundwater inflow estimates for Mundagoora Pool.

Method	Inflow estimate(s) (L/s)	Assumptions/inputs
CMB	0.5	Atmospheric deposition 8 kg/ha/yr; catchment area 3.25 km^2; IB area average groundwater chloride concentration 178 mg/L
Darcyan flow	0.3 to 0.6	K = 0.2 m/d; i = 0.005, average saturated thickness of regolith/weathered profile 10 to 20 m; profile width = 2,500 m
PFPR and return to baseflow	0.1 to 0.2	Pool volume 448 kL; return time 30 to 60 d (return time uncertain)

Flow estimates may be affected by transpiration that occurs upstream of Mundagoora Pool. Some vegetation cover is evident along the drainage lines feeding into the pool area. It is currently not determined whether these are opportunistic or facultative phreatotypes, however groundwater level along those is relatively shallow.

This vegetation cover is not considered dense (Figure 5-23:), based on imagery, however some transpiration output would occur and may explain the difference between the CMB and PFPR estimates.

5.2.3.2 Site 12 Pool

At Site 12 Pool reach, the estimated groundwater inflows (baseflow) fall in the range of 1.1 L/s to 2.5 L/s (Table 5-11) under Baseline conditions.

The modelled drawdown data for the conservative case with reduced recharge rate suggests that groundwater levels in the upper portion of the Site 12 Pool reach will be reduced by up to 2 m under Developed conditions by 2044, impacting on groundwater inflows to the pool.

However, a large WRD will be constructed in the upstream catchment (refer Section 5.1.3.1) contributing to groundwater recharge dynamics and inflows to the pool. There is potential for this associated mounding under the WRD to at least partially offset the effect of drawdown and associated impacts on groundwater inflows to pools. Mounding will temporarily increase groundwater flow gradient offsetting the possible drawdown impact.

An inflow estimate of 1.5 L/s has been adopted for impact assessment and identification of mitigation measures (Section 5.2.4).

The overall transpiration output from Site 12 catchment is considered minor (Figure 5-24) but may play some role along the reach below the outflow under the WRD structure.

Table 5-11. Groundwater inflow estimates for Site 12 Pool reach.

Method	Inflow estimate(s) (L/s)	Assumptions/inputs
CMB	1.1	Atmospheric deposition 8 kg/ha/yr; catchment area 7.7 km^2; IB area average groundwater chloride concentration 178 mg/L
Darcy flow	1.2 to 2.5	K = 0.1 to 0.2 m/d; i = 0.008, average saturated thickness of regolith/weathered profile 20 m; profile width = 7,000 m
PFPR and return to baseflow	1.4	Pool volume 2,532 kL; return time 20 d (based on high-frequency logger measurements)

Figure 5-23: Potentially transpiring vegetation along drainages leading to Mundagoora Pool.

Figure 5-24. Sparse vegetation cover in Site 12 Pool catchment (i.e., minor transpiration output).

5.2.4 Groundwater impact assessment outcomes

The results from the surface water inflow assessments were used along with the impact severity criteria provided in Section 4.5, to assess impacts to Mundagoora Pool and Site 12 Pool reaches, with the results presented in Table 5-12.

The results suggest that groundwater drawdown is likely to impact on groundwater inflows to both pools. However, the risk of impact to Site 12 Pool is considered lower compared with Mundagoora Pool due to the enhanced recharge and local groundwater mounding at the WRD upstream of Site 12 Pool, which may partially offset the effects of drawdown.

It is recommended that during mining operations, Fortescue provides suitable infrastructure needed to supplement the inflow to both pools at the following rates if required (refer Section 5.2.3):

- Mungagoora Pool: 0.5 L/s
- Site 12 Pool: 1.5 L/s

The source of supplementation water should have similar water quality to the existing pool water and inflows to mitigate the risk of impacts to the water quality and water balance of the pools. Section 6.1 presents a summary of the baseline water quality at both pools, which can be used to identify a suitable supply.

Table 5-12. Risks associated with potential changes in groundwater inflows due to NSE development.

Reach ID	Potential for NSE drawdown to reduce groundwater inflows to pool during mining operations (Yes/No)	Potential for enhanced recharge and local groundwater mounding at WRD to partially offset effects of drawdown (Yes/No)	Impact Severity Rating
Mundagoora Pool	Yes	No	● High
Site 12 Pool	No	Yes	● Moderate

6. Water quality impact assessment

6.1 Baseline pool water quality summary

Baseline water quality statistical summaries for the monitored pools are provided in Appendix G. Monitoring of these pools has taken place since 2019. Data is only provided for pools where water was present on sufficient monitoring surveys to allow for statistical summaries to be produced (n>3). Water quality ranges across the various pools depending on the primary water source, recession dynamics and local influences. The alluvial through-flow pools may be subject to evaporative concentration if the ponded waters are hosted within a non-permeable basin within the alluvium. However, if ponded waters recede to below the alluvium layer through infiltration, then evaporative concentration maybe limited or absent from the water quality signature for those pools.

Fig Pool, Cow Spring, and Mundagoora Pool are permanent pools, while Site 12 pool, Pool NJA21-006-US, and GR Pool are ephemeral. Central Creek and GV Pool are typically dry unless there is a large rainfall or flushing event.

Fig Pool exhibits a lower pH and lower salinity than other pools, reflective of the local groundwater source for this pool hosted within the adjacent mesa/topographic structure and high levels of phytochemical interaction from the surrounding melaleuca tree roots. Cow Spring exhibits similar though less pronounced low pH, likely due to similar processes as Fig Pool though with less phytochemical interaction.

Mundagoora and Site 12 pools are more representative of regional groundwater inflows with temporary surface water inflow influence (flushing) during rainfall/flow events.

6.2 Surface water quality impact assessment

The focus of the surface water quality impact assessment is sediment delivery and flushing impact assessment to reaches and associated pools within the surface water impact area.

The results are presented in the following sections.

6.2.1 Sediment delivery and flushing assessments

6.2.1.1 Reaches included in surface water quality impact assessment

Reaches and associated pools located within the extent of the surface water impact area require sediment delivery and flushing impact assessments. The impact assessment approach presented in Section 4 was used to determine the methodology to be adopted for each reach. The resulting methodologies adopted for each pool are presented in Table 6-1.

Table 6-1. Reaches identified within the surface water impact area and associated sediment delivery and flushing impact assessment.

Water Presence Classification	Reach ID	Qualitative Sediment Transport Impact Assessment	Events-Based Sediment Delivery Modelling	Long Term Sediment Delivery Modelling	Events-Based Pool Flushing Assessment
Permanent	Mundagoora Pool	X	✓	✓	✓
Commonly Wet	Site 12 Pool	X	✓	✓	✓
Seasonal Inundation	NJA19-002 Pool	X	✓	X	X
Periodic Inundation / Ephemeral	Pool IB-SW-Dry-Reject-DS-002	✓	X	X	X
	Pool NJA21-006-US				
	Pool NJA21-006-DS				
	Pool SW				
	Pool 9				
	Pool 59				
	Pool 57				

6.2.1.2 Methodology

The adopted approach for assessing sediment impacts on reaches (and associated pools) combined both quantitative and qualitative methods based on the water permanence classification of the reaches (and associated pools). This tiered approach ensured that more commonly inundated pools, which are likely to be more susceptible to long-term sediment changes, were assessed with greater detail and certainty. The adopted approach for each pool water permanence classification and the specific reaches (and associated pools) assessed using each approach is provided in Table 6-2.

Reaches (and associated pools) were rated as having Low, Moderate, and High Impact based on their likelihood and severity of change which corresponded to the longevity of, and recoverability from, the changed conditions. For Permanently Inundated, Commonly Wet, and Seasonally Inundated reaches (and associated pools), this encapsulated a semi-quantitative assessment of the sum of all outcomes regarding severity/magnitude, rapidity, and duration. For Periodically Inundated/Ephemeral reaches (and associated pools) this used changes to velocity, catchment area and distance from the development to derive impact levels.

The likelihood and severity ratings are consistent with the understanding that larger reductions in catchment area and flow velocities (leading to reduced flushing capacity relative to sediment supply) are more likely to result in significant and potentially long-lasting impacts on pool sediment dynamics. The severity of sediment impact is considered in terms of potential changes to pool morphology, water quality (turbidity), and substrate composition, aligning with general consequence definitions used in environmental risk assessment.

A detailed description of the methodology adopted for the sediment delivery and flushing impact assessments is presented in the Sediment Delivery and Flushing Impact Assessment Report (Hydrobiology, 2025b) provided in Appendix H.

The methodology adopted assumes that catchment area reductions due to construction of WRDs will be accompanied by appropriate sediment control measures to mitigate WRD sediment source impact to the downstream reaches (i.e. no contribution of flow or sediment from WRDs).

Pool 50, Pool 51 and Pool 62 are listed in Table 6-2 as they have been considered in the impact assessment, however more detailed analysis showed they are located within the NSE development footprint and removed by mining, so impacts were not assessed further.

Table 6-2: Summary of sediment delivery and flushing assessment methodologies.

<table>
<tr><th>Pool Water Permanence Classification</th><th>Reaches</th><th>Method</th></tr>
<tr><td>Permanently Inundated</td><td>• Mundagoora Pool</td><td rowspan="2">Long-Term Sediment Yield and Transport Model: A stochastic Monte Carlo framework was used to estimate long-term sediment yield based on catchment sediment supply and transport capacity. This method used probability distributions for input variables to generate a range of potential sediment delivery outcomes over time. The purpose was to understand broad-scale trends in catchment sediment dynamics and cumulative impacts from event-based delivery.
Event-Based Sediment Delivery Model: This model quantified sediment delivery under selected flow events of different Average Exceedance Probabilities (AEP). It disaggregated long-term sediment delivery components based on the flow hydrographs and empirically calculated hillslope erosion. The aim was to verify more immediate impacts, identify drivers of long-term trends, and assess how sediment supply changes across different event magnitudes.
Event-Based Flushing Assessment: The Hjulström Curve, parameterized by Miedema (2013), was used to evaluate sediment scour and transport potential under the same range of AEP events. Event velocity time series data were used to determine the duration of scour and transport for different sediment sizes. The objective was to understand localized sediment dynamics (scour, deposition, transport) within the reaches (and associated pools) to complement the catchment-scale delivery assessments.
Consolidation of Models: Results from the above assessments were interpreted together using a conceptual sediment storage model. This model considered sediment delivery into the pool and sediment scour and transport out of the pool to infer likely changes in sediment storage.
These methods allowed for a detailed understanding of sediment supply, transport, deposition, and scour dynamics under various flow conditions and cumulatively over longer timeframes.</td></tr>
<tr><td>Commonly Wet</td><td>• Site 12 Pool</td></tr>
<tr><td>Seasonally Inundated</td><td>• NJA19-002 Pool</td><td>Event-Based Sediment Delivery Model: As per the above method to inform potential changes in the sediment balance (delivery, transport) of the pool. This allowed for an understanding of sediment dynamics during flow events likely to impact the reach (and associated pool).</td></tr>
</table>

Pool Water Permanence Classification	Reaches	Method
Periodic Inundation/ Ephemeral	• Pool 62 • Pool IB-SW-Dry-Reject-DS-002 • Pool NJA21-006-US • Pool NJA21-006-DS • Pool-SW • Pool 9 • Pool 51 • Pool 50 • Pool 59 • Pool 57	**Qualitative Sediment Impact Assessment:** For periodically inundated and ephemeral pools, the assessment focused on changes in catchment area and hydraulic velocity (derived from catchment-scale hydraulic modelling) due to the NSE development. A matrix combining the mean change in event velocity, the reduction in catchment area, and distance from the NSE development was used to determine the likelihood and potential severity of negative impacts on these pools. The rationale was that changes in these factors are primary drivers of sediment transport in these ephemeral systems.

6.2.1.3 Results

The results from the Sediment Delivery and Flushing Impact Assessment Report (Hydrobiology, 2025b) are summarised in the following sections, which highlight the changes resulting from the NSE development. The results were then incorporated as part of the overall impact assessment outcomes, using the methodology summarised in Section 4.4.1.1 (a more detailed description of the method is provided in Appendix H), with the results outlined in Section 6.2.2.

6.2.1.3.1 Long-term sediment delivery modelling

The results from long-term sediment delivery modelling at Mundagoora Pool and Site 12 Pool reaches are summarised below.

Mundagoora Pool

The results from Baseline and Developed conditions long-term sediment delivery modelling at Mundagoora Pool are presented in Table 6-3 and Figure 6-1. The results suggest that the proposed NSE development may result in the following changes in median sediment delivery at Mundagoora Pool:

- 55% reduction in total sediment delivery.
- 56% reduction in fine sediment delivery.
- 56% reduction in course sediment delivery.

Site 12 Pool

The results from Baseline and Developed conditions long-term sediment delivery modelling at Site 12 Pool are presented in Table 6-4 and Figure 6-2. The results suggest that the proposed NSE development may result in the following changes in median sediment delivery at Site 12 Pool:

- 21% reduction in median sediment delivery.
- 31% reduction in median fine sediment delivery.
- 13% reduction in median course sediment delivery.

Table 6-3. Comparison of long-term sediment delivery modelling results for Mundagoora Pool under Baseline and Developed conditions.

Scenario	Transport Type	Statistic (t / year) Median	90% CI	Minimum	Maximum	Mean
Baseline Conditions	Total sediment delivery	5,668	± 33	130	396,577	6,673
	Coarse mass	4,082	± 27	0	305,762	4,832
	Fine mass	1,368	± 13	52	302,524	1,841
Developed Conditions	Total sediment delivery	2,545	± 13	44	129,497	3,031
	Coarse mass	1,797	± 12	0	94,852	2,224
	Fine mass	601	± 5	21	123,701	807
Percentage Change (%) *	Total sediment delivery	-55%	-61%	-66%	-67%	-55%
	Coarse mass	-56%	-56%	0%	-69%	-54%
	Fine mass	-56%	-62%	-60%	-59%	-56%

** Negative values represent a reduction in sediment delivery due to NSE development*

Table 6-4. Comparison of long-term sediment delivery modelling results for Site 12 Pool under Baseline and Developed conditions.

Scenario	Transport Type	Statistic (t / year) Median	90% CI	Minimum	Maximum	Mean
Baseline Conditions	Total channel transport	5,410	± 40	29	913,024	7,332
	Coarse mass	2,728	± 34	0	834,569	4,792
	Fine mass	1,817	± 17	22	215,161	2,540
Developed Conditions	Total channel transport	4,298	± 30	20	361,547	5,860
	Coarse mass	2,383	± 27	0	271,292	4,105
	Fine mass	1,253	± 10	14	201,779	1,755
Percentage Change (%) *	Total channel transport	-21%	-25%	-31%	-60%	-21%
	Coarse mass	-13%	-21%	0%	-67%	-14%
	Fine mass	-31%	-41%	-36%	-6%	-31%

** Negative values represent a reduction in sediment delivery due to NSE development*

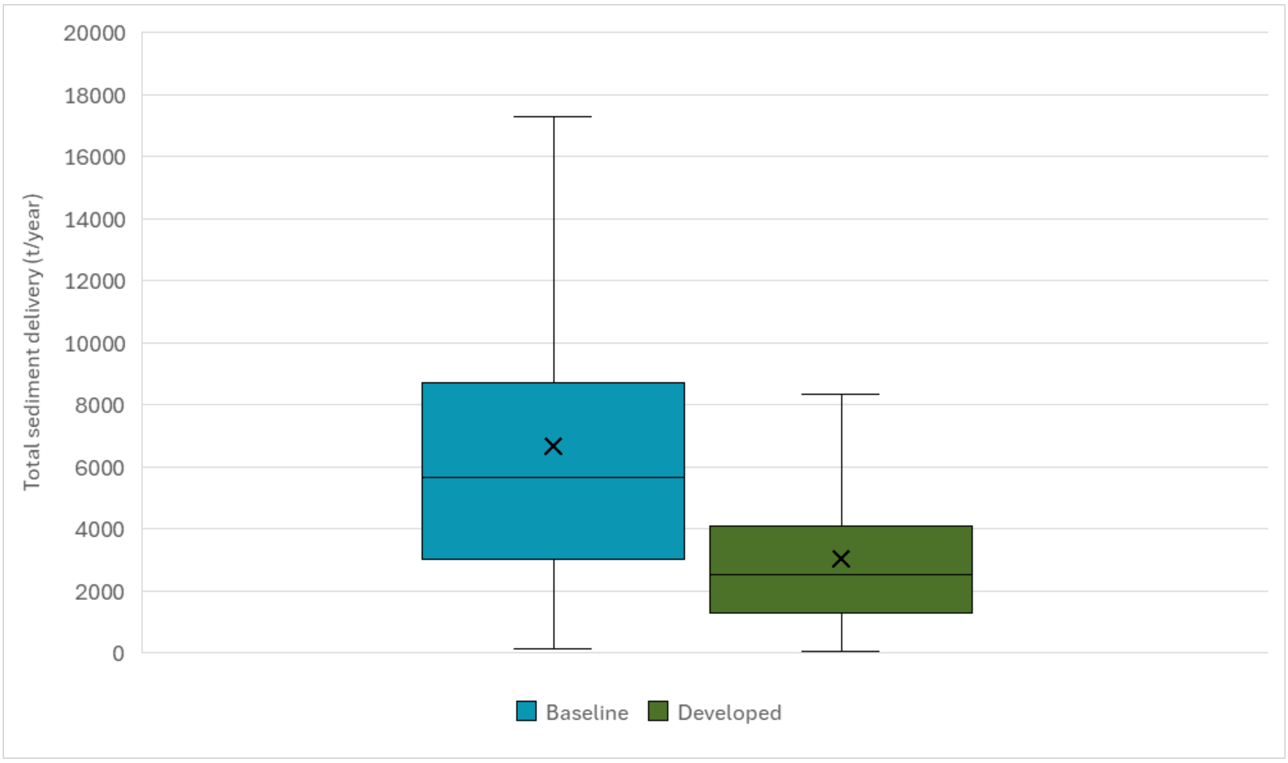

Figure 6-1. Box plots showing distribution of total channel delivery to Mundagoora Pool for Baseline and Developed conditions.

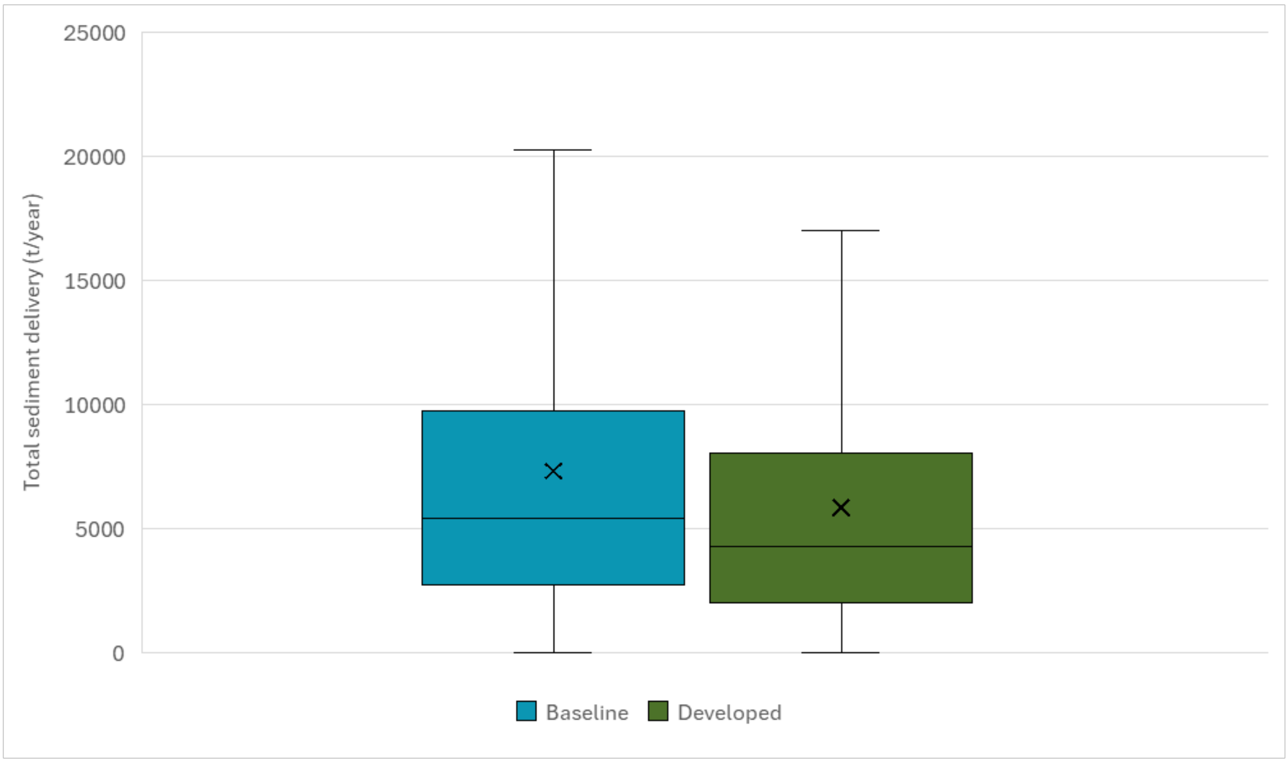

Figure 6-2. Box plots showing distribution of total channel delivery to Site 12 Pool for Baseline and Developed conditions.

6.2.1.3.2 Events-based sediment delivery modelling

The results from the 1%, 2%, 5%, 10%, 20% and 50% AEP events-based sediment delivery modelling for Mundagoora, Site 12 and NJA19-002 Pool reaches are summarised below. The inflow hydrographs extracted from the regional TUFLOW models to inform this assessment are provided in Appendix I.

Mundagoora Pool

The results from Baseline and Developed conditions events-based sediment delivery modelling at the Mundagoora Pool reach are presented in Table 6-5 and Figure 6-3. The results suggest that the proposed NSE development may result in the following changes in mean sediment delivery at Mundagoora Pool:

- 63% mean reduction in delivery of fines material.
- 57% mean reduction in delivery of coarse material.

Site 12 Pool

The results from Baseline and Developed conditions long-term sediment delivery modelling at the Site 12 Pool reach are presented in Table 6-6 and Figure 6-4. The results suggest that the proposed NSE development may result in the following changes in median sediment delivery at Site 12 Pool:

- 36% mean decrease in delivery of fines material.
- 36% mean decrease in delivery of coarse material.

NJA19-002 Pool

The results from Baseline and Developed conditions long-term sediment delivery modelling at the NJA19-002 Pool reach are presented in Table 6-7 and Figure 6-5. The results suggest that the proposed NSE development may result in the following changes in median sediment delivery at NJA19-002 Pool:

- 9% mean increase in delivery of fines material.
- 34% mean decrease in delivery of coarse material.

The difference in sediment delivery trends observed at NJA19-002 when compared with Site 12 and Mundagoora Pool, can be attributed to the size of NJA19-002 catchment compared to Site 12 and Mundagoora Pool, and the fact that the area removed from the NJA19-002 catchment is an area of much higher relief and greater producer of coarse sediment, than the remaining catchment areas.

Table 6-5. Estimated percentage change in sediment delivery to Mundagoora Pool due to the NSE development for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Sediment type	AEP						Mean Change (%)
	1%	2%	5%	10%	20%	50%	
Fine sediment	-65%	-64%	-63%	-63%	-62%	-63%	-63%
Coarse sediment	-59%	-58%	-56%	-56%	-55%	-56%	-57%

** Negative values represent a reduction in sediment delivery due to NSE development*

Table 6-6. Estimated percentage change in sediment delivery to Site 12 Pool due to the NSE development for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Sediment type	AEP						Mean Change (%)
	1%	2%	5%	10%	20%	50%	
Fine sediment	-26%	-46%	-27%	-48%	-25%	-43%	-36%
Coarse sediment	-26%	-47%	-26%	-48%	-25%	-43%	-36%

Table 6-7. Estimated percentage change in sediment delivery to NJA19-002 Pool due to the NSE development for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Sediment type	AEP						Mean Change (%)
	1%	2%	5%	10%	20%	50%	
Fine sediment	+1%	+3%	+5%	+9%	+13%	+19%	+9%
Coarse sediment	-35%	-35%	-34%	-34%	-34%	-32%	-34%

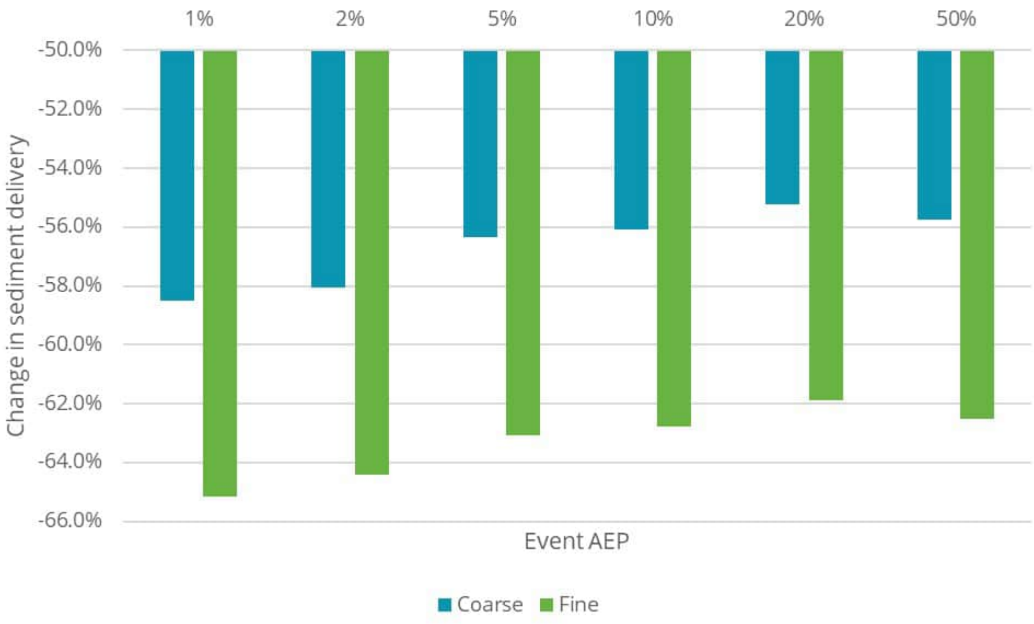

Figure 6-3. Estimated changes in fine and coarse sediment delivery to Mundagoora Pool due to the NSE development.

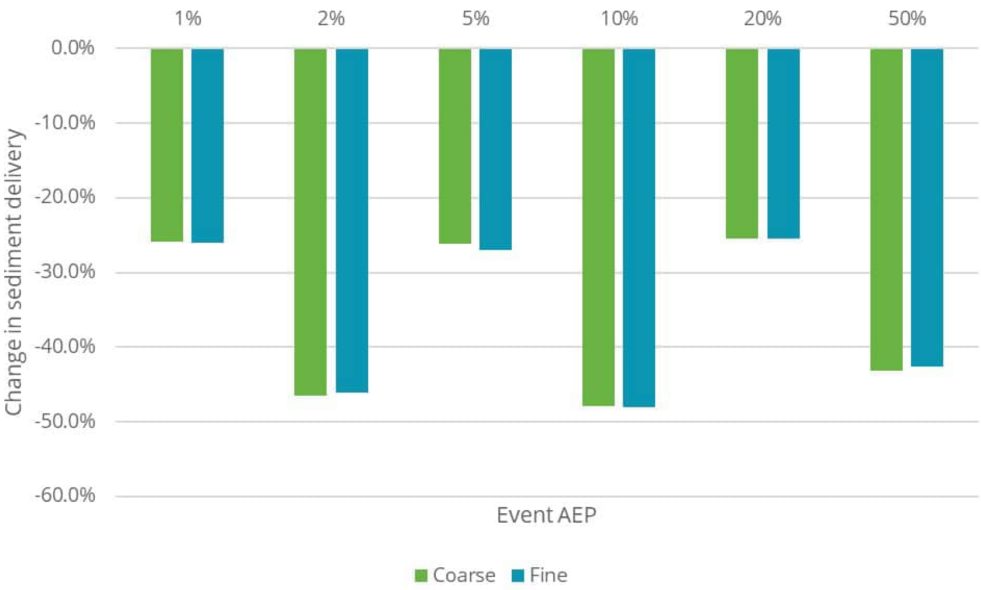

Figure 6-4. Estimated changes in fine and coarse sediment delivery to Site 12 Pool due to the NSE development.

Figure 6-5. Estimated changes in fine and coarse sediment delivery to NJA19-002 Pool due to the NSE development.

6.2.1.3.3 Events-based pool flushing assessment

The results from the 1%, 2%, 5%, 10%, 20% and 50% AEP events-based flushing assessments in Mundagoora Pool and Site 12 Pool reaches are summarised below.

Mundagoora Pool

The results from Baseline and Developed conditions events-based events-based flushing assessments in the Mundagoora Pool reach are presented in Table 6-8. The results suggest that the proposed NSE development may result in the following changes in mean sediment flushing in Mundagoora Pool:

- 44% mean reduction in scour of fines material.
- 18% mean reduction in transport of fine material.
- 33% mean reduction in scour of coarse material.
- 70% mean reduction in transport of coarse material.

Site 12 Pool

The results from Baseline and Developed conditions events-based events-based flushing assessments in the Site 12 Pool reach are presented in Table 6-9. The results suggest that the proposed NSE development may result in the following changes in mean sediment flushing in Site 12 Pool:

- 11% mean reduction in scour of fines material.
- 4% mean reduction in transport of fine material.
- 18% mean reduction in scour of coarse material.
- 12% mean reduction in transport of coarse material.

Table 6-8. Estimated percentage change in sediment flushing in Mundagoora Pool due to the NSE development for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Sediment Scour and Transport	AEP 1%	2%	5%	10%	20%	50%	Mean Change (%)
Fine Scour	-57%	-56%	-65%	-40%	-43%	0%	-44%
Fine Transport	-21%	-21%	-24%	-20%	-18%	0%	-18%
Coarse Scour	-100%	-100%	0%	0%	0%	0%	-33%
Coarse Transport	-58%	-60%	-100%	-100%	-100%	0%	-70%

** Negative values represent a reduction due to NSE development*

Table 6-9. Estimated percentage change in sediment flushing in Site 12 Pool due to the NSE development for the 1%, 2%, 5%, 10%, 20% and 50% AEP events.

Sediment Scour and Transport	AEP 1%	2%	5%	10%	20%	50%	Mean Change (%)
Fine Scour	-2%	-2%	-16%	-17%	-7%	-21%	-11%
Fine Transport	0%	0%	-13%	-13%	<+1%	0%	-4%
Coarse Scour	-11%	-12%	-47%	-24%	-7%	-9%	-18%
Coarse Transport	-8%	-7%	-21%	-23%	-8%	-6%	-12%

** Negative values represent a reduction due to NSE development*

6.2.1.3.4 Qualitative sediment transport assessment

The results from the qualitative sediment transport assessment are presented in Table 6-10 and Table 6-11, with a summary below:

- Pools 59 and 64: The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.
- NJA21-006_US: The development is expected to result in a moderate reduction in sediment supply and flow due to moderate reduction in catchment area. This is likely to result in some sediment aggradation/accumulation in pool reach as transport capacity decreases, although this is expected to be minor and gradual given that the decrease to catchment area (a proxy for sediment supply) is greater than the decrease in event velocity. The significant distance between the pool and the NSE development footprint also buffers against impacts. Therefore geomorphological changes to pool area and depth are expected to be limited.
- Pool 9: The development is expected to result in a moderate reduction in headwater region of catchment area compounded by proximity to mining operations and moderate reduction in flushing velocity, so there is potential for increased sediment aggradation/accumulation. Therefore the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium.
- Pool IB-SW-Dry-Reject-DS-002, Pool NJA21-006_DS and Pool SW: have a low risk of experiencing a change in sediment transport due to small reduction in catchment area or event flushing velocities.

Table 6-10. Ephemeral reaches: changes in catchment area, changes in mean event velocity for all AEP's, and proximity to the NSE development footprint.

Catchment	Change in catchment area	Change in mean event velocity for all AEPs	Proximity to NSE Development Footprint (m)
Pool IB-SW-Dry-Reject_DS-002	<-5%	-6%	3,353
Pool NJA21-006_US	-32%	-13%	1,907
Pool NJA21-006_DS	-11%	-9%	4,015
Pool SW	-23%	-7%	130
Pool 9	-27%	-24%	160
Pool 59	>- 95%	-94%	157
Pool 57	>- 95%	-83%	18

** Negative values represent a reduction due to NSE development*

6.2.2 Impact assessment outcomes

Table 6-12 summarises the likely sediment transport risks and impacts to reaches/pools due to the NSE development, based on the sediment delivery and flushing assessments presented in Section 6.2.1.

It is assumed that Fortescue will implement appropriate surface water management measures on site to mitigate other water quality related risks to the pools within the Study Area.

Table 6-11. Likelihood of experiencing a persistent change in sediment storage at reaches/pools and potential outcomes.

Reach ID	Likelihood of change	Potential outcomes
Pool IB-SW-Dry-Reject-DS-002	Low	Small reductions in catchment area and event velocity, combined with significant distance between the reach and the NSE development footprint suggest limited impacts to sediment dynamics.
Pool NJA21-006_US	Moderate	The development is expected to result in a moderate reduction in sediment supply and flow due to moderate reduction in catchment area. This is likely to result in some sediment aggradation/accumulation in pool reach as transport capacity decreases, although this is expected to be minor and gradual given that the decrease to catchment area (a proxy for sediment supply) is greater than the decrease in event velocity. The significant distance between the pool and the NSE development footprint also buffers against impacts. Therefore, geomorphological changes to pool area and depth are expected to be limited.
Pool NJA21-006_DS	Low	Small reductions in catchment area and event velocity, combined with significant distance between the reach and the NSE development footprint suggest limited impacts to sediment dynamics.
Pool SW	Low	Moderate reduction in catchment area (and thus sediment supply) is offset by a small reduction in event velocity which will maintain flushing capability. Pool is, however, susceptible to impacts posed by its close proximity to the NSE development footprint, such as increased turbidity, although these impacts are likely to be remediated during flushing events.
Pool 9	Moderate	The development is expected to result in a moderate reduction in headwater region of catchment area compounded by proximity to mining operations and moderate reduction in flushing velocity, so there is potential for increased sediment aggradation/accumulation. Therefore, the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium.
Pool 59	High	Extreme reductions in both catchment area and event velocities are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint,

Reach ID	Likelihood of change	Potential outcomes
		combined with reduced flushing is likely to lead to deposition within pool reach – may incur a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.
Pool 57	● High	Extreme reductions in both catchment area and event velocities are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach – may incur a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.

Table 6-12. Surface water quality impact assessment outcomes

Reach ID	Pools associated with reach	Water permanence classification	Surface Water Quality Impact Severity	Description of potential impacts
Mundagoora Pool	GV_SW_Pool_ Mundagoora_ SS	Permanent	● Low	The following minor sediment transport impacts are expected which are unlikely to result in a significant geomorphological change to Mundagoora Pool: • Reductions in pool turbidity due to decreased supply and retention of fine sediment. • Reductions in soft sediment substrate. • Persistence of sediment capture in vegetated margins. • Armouring of pool bed with coarse sediment. The predicted geomorphological changes resulting from NSE development are depicted in Figure 6-6.
Site 12 Pool	1- IB_SW_Pool1 2 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool1 2_01	Commonly Wet	● Low	In relation to sediment transport the following minor impacts are expected which are unlikely to result in a significant geomorphological change to Site 12 Pool: • Reduction in pool turbidity due to decreased fine sediment supply and retention. • Minor reductions in soft sediment substrate, but not as pronounced as Mundagoora Pool. • Continued sediment capture in vegetated margins or at bedrock outcrops. • Event-driven scour of both fine and coarse material to bedrock. The predicted geomorphological changes resulting from NSE development are depicted in Figure 6-7.
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Seasonal Inundation	● Moderate	The development is expected to result in a moderate reduction in sediment supply and flow due to a moderate reduction in catchment area. This is likely to result in some aggradation/accumulation of sediment in pool reach as transport capacity decreases, with flushing of sediment occurring during larger events. Therefore, geomorphological changes to pool area and depth are expected to be episodic but limited over the longer term.
Pool IB-SW-Dry-Reject-DS-002	IB_SW_DryRe ject_ DS_02	Periodic Inundation	● Low	Reduction in sediment supply and transport capacity is likely to be limited due to small reduction in event velocities.
Pool NJA21-006-US	GV_SW_Pool_ NJA21-006-US	Periodic Inundation	● Moderate	The development is expected to result in a moderate reduction in sediment supply and flow due to moderate reduction in catchment area. This is likely to result in some sediment aggradation/accumulation in pool reach as transport capacity decreases, although this is expected to be minor and gradual given that the decrease to catchment area (a proxy for sediment supply) is greater than the decrease in event velocity. The significant distance between the pool and the NSE development footprint also buffers against impacts. Therefore, geomorphological changes to pool area and depth are expected to be limited.
Pool NJA21-006-DS	GV_SW_Pool_ NJA21-006-DS	Periodic Inundation	● Low	Limited reduction in sediment supply and flow due to reduction in catchment area is likely to be offset somewhat by maintenance of magnitude of frequent and extreme events.
Pool-SW	55 - GV_SW_Pool_ SW	Periodic Inundation	● Low	Moderate reduction in sediment supply and flow due to reduction in catchment area likely to be offset by maintenance of event velocities.

Reach ID	Pools associated with reach	Water permanence classification	Surface Water Quality Impact Severity	Description of potential impacts
	56 - GV_SW_Pool_SWGV_DS			
Pool 9	9	Periodic Inundation	Moderate	The development is expected to result in a moderate reduction in headwater region of catchment area compounded by proximity to mining operations and moderate reduction in flushing velocity, so there is potential for increased sediment aggradation/accumulation. Therefore, the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium.
Pool 59	59	Periodic Inundation	High	The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.
Pool 57	57 63 64	Periodic Inundation	High	

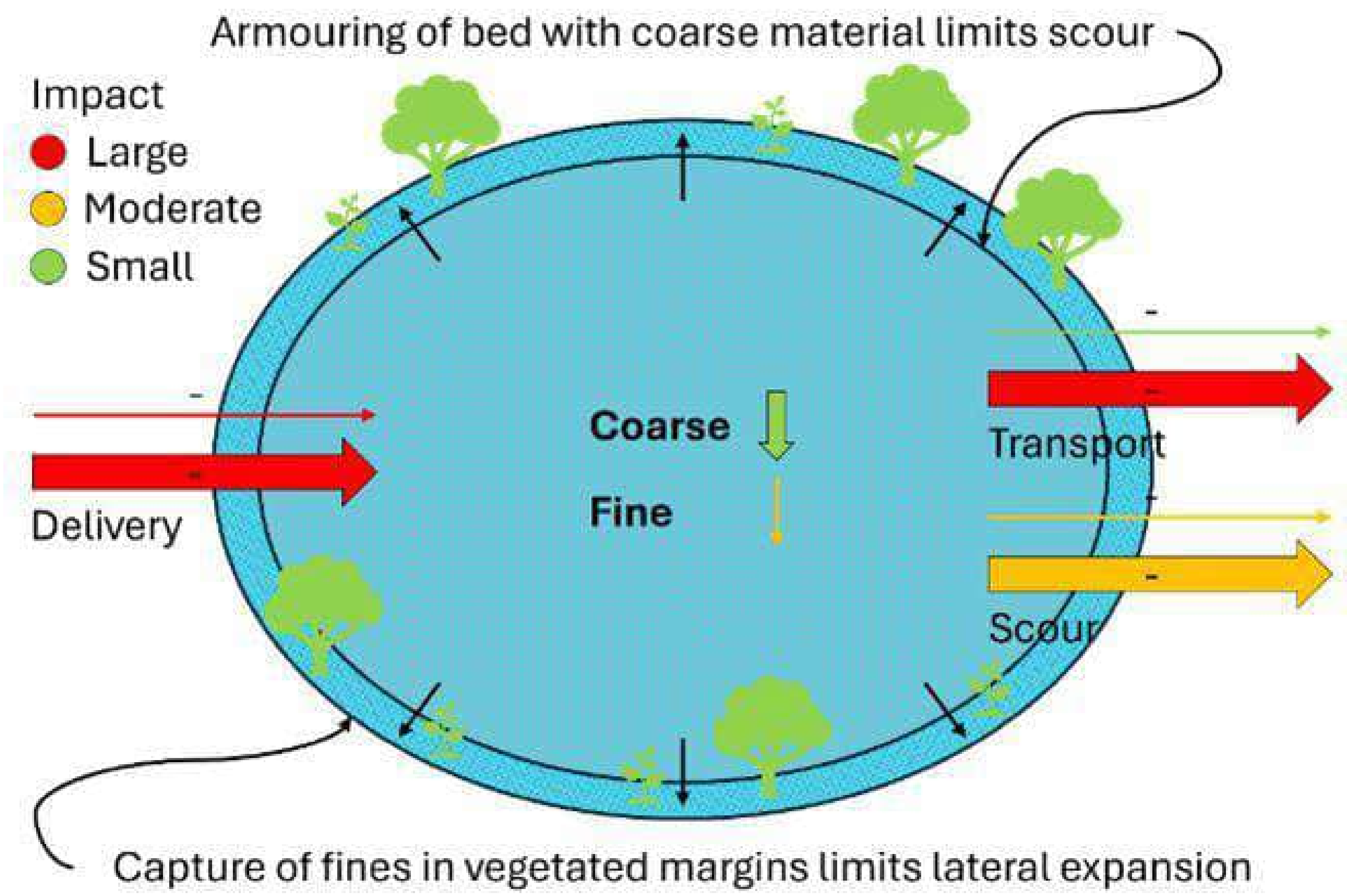

Figure 6-6: Impacts to Mundagoora Pool resulting from NSE (Hydrobiology, 2025b).

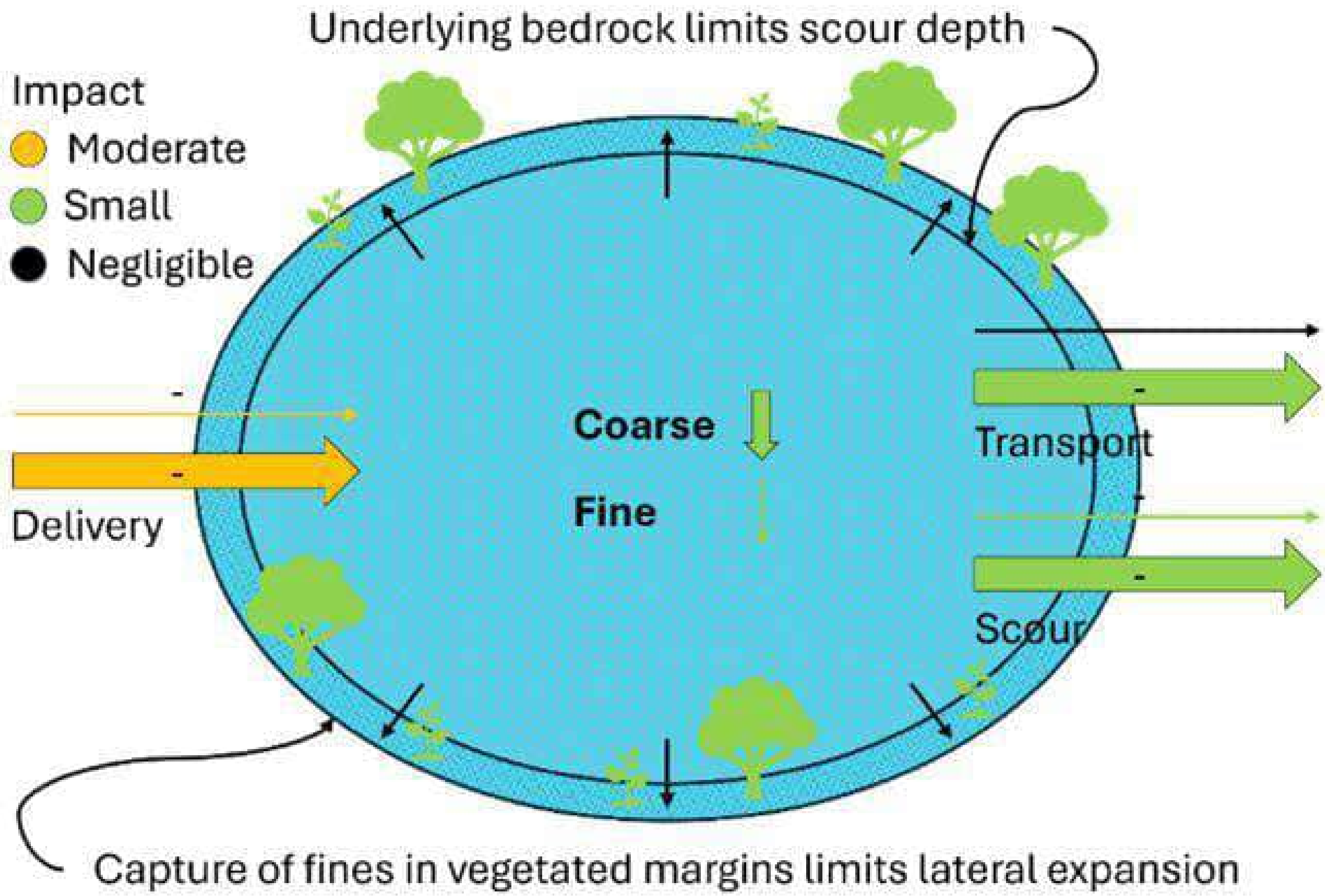

Figure 6-7: Impacts to Site 12 Pool resulting from NSE (Hydrobiology, 2025b).

6.3 Groundwater quality impact assessment

As discussed in Section 4.4.2, potential groundwater quality risks and impacts to reaches are qualitatively assessed, with the results summarised below:

- Mundagoora Pool and Site 12 Pool are the two pools identified in the Study Area which are considered to be dependent on regional groundwater inflows. The results from groundwater inflow assessments (Section 5.2) suggest that groundwater inflows to both pools are likely to be impacted by the NSE development and supplementation of water may be required to maintain water levels and quality in the pools. The source of supplementation water should have the same or better water quality than the pool to mitigate the risk of impacts. Section 6.1 presents a summary of the baseline water quality at both pools, which can be used to identify a suitable supplementation supply.
- Infiltration and seepage of water into/under the WRD upstream of Site 12 Pool reach has the potential to impact on local groundwater quality and impact on groundwater inflows to Site 12 Pool. Seepage is expected to be diluted by the groundwater prior to reaching the pool, reducing impact severity (to Moderate).

The results above were used along with the impact severity criteria provided in Section 4.5, to assess impacts to reaches and associated pools, with the results presented in Table 6-13.

Table 6-13: Groundwater quality impact assessment outcomes

Reach ID	Impact to Groundwater Inflow Quality (Yes/No)	Impact Severity Rating
Mundagoora Pool	No*	● Low
Site 12 Pool	Yes	● Moderate

* Groundwater inflows reduced / removed by NSE development, no impact to quality of groundwater inflow.

7. Conclusions

7.1 Summary of Inland Waters Impact Assessment

Reaches (and associated pools) have been identified within the Study area that are sensitive to changes in surface water and/or groundwater inflows and/or water quality, that require groundwater and surface water impact assessments due to the proposed NSE development, and are summarised in Table 7-1 and Table 7-2.

Table 7-1: Reaches requiring groundwater impact assessment.

Reach ID	Water permanence classification	Conceptualisation Type
Mundagoora Pool	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge

Table 7-2: Reaches requiring surface water impact assessment.

Reach ID	Water permanence classification	Conceptualisation Type
Mundagoora Pool	Permanent	Type 3 - Bedrock aquiclude - groundwater discharge
Site 12 Pool	Commonly Wet	Type 3 - Bedrock aquiclude - groundwater discharge
NJA19-002	Seasonal Inundation	Type 2a/2b - Bedrock perched surface water and/or local groundwater source
Pool IB-SW-Dry-Reject-DS-002	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool NJA21-006-US	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool NJA21-006-DS	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool-SW	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 9	Periodic Inundation	Type 1a - Alluvium - perched throughflow
Pool 59	Periodic Inundation	Type 2a - Bedrock - perched surface water
Pool 57	Periodic Inundation	Type 2a - Bedrock - perched surface water

Hydrological and water quality assessments (surface water and groundwater) were completed for identified reaches/pools to quantify potential changes in quantity and quality of water inflows maintaining the reaches and associated pools. Reaches (and associated pools) classified as permanent and commonly wet contain water that persists for longer durations following flood events, so were assessed in greater detail than pools that are seasonally or periodically inundated.

Three levels of potential inland waters impact severity were adopted for the impact assessment (High, Moderate and Low) and assigned to reaches (and associated pools) using the criteria presented in Table 4-3. The results from the hydrological and water quality assessments and impact severity criteria were then used to assess potential inland water impacts to reaches (and associated pools) within the Study Area. The results are summarised in Table 7-3.

- The results suggest the following potential inland water impacts from the NSE development:
  - Reaches with High inland water impact include: Mundagoora Pool, Pool 59, and Pool 57.
  - Reaches with Moderate inland water impact include: Site 12 Pool, Pool 9, NJA19-002 and Pool NJA21-006-US, and
  - All other reaches have a Low inland water impact.

Figure 7-1 shows the location of reaches and associated inland water impact severity.

7.2 Management controls

The reaches classified as having High or Moderate inland water impacts were then reassessed to identify potential mitigation measures that could be implemented during operations, and residual risk. The results and recommended mitigation measures are presented in Table 7-4 along with residual inland water impact severity.

Figure 7-2 shows the location of reaches and associated residual inland water impact severity with management controls in place.

Table 7-3: Summary of severity of potential inland water impact to reaches (and associated pools) identified in the Study Area due to NSE development

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	● Low	● High	● Low	● Low	● High	The NSE development and existing Near Mine borefield will create groundwater drawdown which is likely to significantly impact on regional groundwater inflows to Mundagoora Pool during mining operations. The pit also removes 58% of the upstream catchment area resulting in a significant reduction in local groundwater recharge and inflows to the Mundagoora Pool. In relation to sediment transport / pool turbidity, the following minor impacts are expected which are unlikely to result in a significant geomorphological change to Mundagoora Pool: • Reductions in pool turbidity due to decreased supply and retention of fine sediment. • Reductions in soft sediment substrate. • Persistence of sediment capture in vegetated margins. • Armouring of pool bed with coarse sediment. The predicted geomorphological changes resulting from NSE development are depicted in Figure 6-6. The NSE development is expected to have a minor impact to the quantity of surface water inflows and no significant impact to the quality of surface water and groundwater inflows.
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	● Low	● Moderate	● Low	● Moderate	● Moderate	Groundwater drawdown is likely to impact on groundwater inflows to Site 12 Pool during mining operations. Infiltration of direct rainfall on the WRD will enhance recharge and is likely to result in local groundwater mounding within the extent of the WRD footprint. This has the potential to partially offset the effects of drawdown, resulting in a moderate impact severity to Site 12 Pool reach. Seepage from the WRD may affect the quality of local groundwater reporting to the Site 12 pool. There is likely to be significant dilution of seepage in groundwater prior to entering Site 12 pool, reducing the potential impacts. In relation to sediment transport / pool turbidity, the following minor impacts are expected which are unlikely to result in a significant geomorphological change to Site 12 Pool: • Reduction in pool turbidity due to decreased fine sediment supply and retention. • Minor reductions in soft sediment substrate, but not as pronounced as Mundagoora Pool. • Continued sediment capture in vegetated margins or at bedrock outcrops. • Event-driven scour of both fine and coarse material to bedrock. The predicted geomorphological changes resulting from NSE development are depicted in Figure 6-7. The NSE development is expected to have a minor impact to the quantity of surface water inflows to the Site 12 Pool reach.

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to the quantity of surface water reporting to the pool. The development is expected to result in a moderate reduction in sediment supply and flow due to a moderate reduction in catchment area. This is likely to result in some aggradation/accumulation of sediment in pool reach as transport capacity decreases, with flushing of sediment occurring during larger events. Therefore, geomorphological changes to pool area and depth are expected to be episodic but limited over the longer term.
Pool IB-SW-Dry-Reject-DS-002	IB_SW_DryReject_ DS_02	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool NJA21-006-US	GV_SW_Pool_NJA21-006-US	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in a moderate reduction in sediment supply and flow due to moderate reduction in catchment area. This is likely to result in some sediment aggradation/accumulation in pool reach as transport capacity decreases, although this is expected to be minor and gradual given that the decrease to catchment area (a proxy for sediment supply) is greater than the decrease in event velocity. The significant distance between the pool and the NSE development footprint also buffers against impacts. Therefore, geomorphological changes to pool area and depth are expected to be limited.
Pool NJA21-006-DS	GV_SW_Pool_NJA21-006-DS	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool-SW	55 - GV_SW_Pool_SW 56 - GV_SW_Pool_SWGV_DS	Low	N/A	Low	N/A	Low	The NSE development is expected to have low impact to surface water inflows (quantity and quality) to the reach.
Pool 9	9	Low	N/A	Moderate	N/A	Moderate	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in a moderate reduction in headwater region of catchment area compounded by proximity to mining operations and moderate reduction in flushing velocity, so there is potential for increased sediment aggradation/accumulation. Therefore, the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium.
Pool 59	59	Low	N/A	High	N/A	High	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase

Reach ID	Pools Associated with Reach	Severity of potential inland water impact to pools due to changes in:				Overall severity of unmitigated inland water impact	Description of potential inland water impact (if unmitigated)
		Surface water inflow	Groundwater inflow	Surface water inflow quality	Groundwater inflow quality		
							in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.
Pool 57	57 63 64	Low	N/A	High	N/A	High	The NSE development is expected to have low impact to surface water inflow quantities to the reach. The development is expected to result in extreme reductions in both catchment area and event velocities which are likely to lead to high impacts to pool morphology. Persistent sediment delivery from background processes (hillslope erosion) and proximity to NSE development footprint, combined with reduced flushing is likely to lead to deposition within pool reach. This may result in a moderate to major increase in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.

Table 7-4: Pools identified as having high or moderate impact, recommended management controls and residual impacts

Reach ID	Pools Associated with Reach	Overall Unmitigated Impact	Recommended Management Controls	Overall Residual Impact Rating
Mundagoora Pool	GV_SW_Pool_ Mundagoora_SS	High	Provide suitable infrastructure needed to supplement the inflow to the pool at the following rate if required (refer Section 5.2.3): • Mungagoora Pool: 0.5 L/s The source of supplementation water should have the same or better water quality than the pool to mitigate the risk of impacts. Section 6.1 presents a summary of the baseline water quality, which can be used to identify a suitable supply. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport to Mundagoora Pool and associated water quality impacts.	Low
Site 12 Pool	1-IB_SW_Pool12 2-S12string 3-S12string 4-S12string 5-S12string 6-S12string 7-S12string 8 - IB_SW_Pool12_01	Moderate	Provide suitable infrastructure needed to supplement the inflow to the pool at the following rate if required (refer Section 5.2.3): • Site 12 Pool: 1.5 L/s The source of supplementation water should have the same or better water quality than the pool to mitigate the risk of impacts. Section 6.1 presents a summary of the baseline water quality, which can be used to identify a suitable supply. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport to Mundagoora Pool and associated water quality impacts.	Low
NJA19-002	52 61 - GV_SW_Pool_ NJA19-002	Moderate	The sediment transport assessment suggests that geomorphological changes to pool area and depth are expected to be limited. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool NJA21-006-US	GV_SW_Pool_NJA21-006-US	Moderate	The sediment transport assessment suggests that geomorphological changes to pool area and depth are expected to be limited. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool 9	9	Moderate	The sediment transport assessment suggests that geomorphological that the reach may experience minor to moderate changes in pool morphology as it re-establishes a new state of sediment transport equilibrium. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	Moderate
Pool 59	59	High	The sediment transport assessment suggests that the reach may experience moderate to major increases in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time.	High

Reach ID	Pools Associated with Reach	Overall Unmitigated Impact	Recommended Management Controls	Overall Residual Impact Rating
			Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	
Pool 57	57 63 64	● High	The sediment transport assessment suggests that the reach may experience moderate to major increases in pool turbidity, as well as a large, although gradual reduction in pool area and depth over time. Appropriate sediment control measures will be implemented by Fortescue within the NSE development footprint to mitigate risks associated with sediment transport. Therefore, no additional mitigation measures are required.	● High

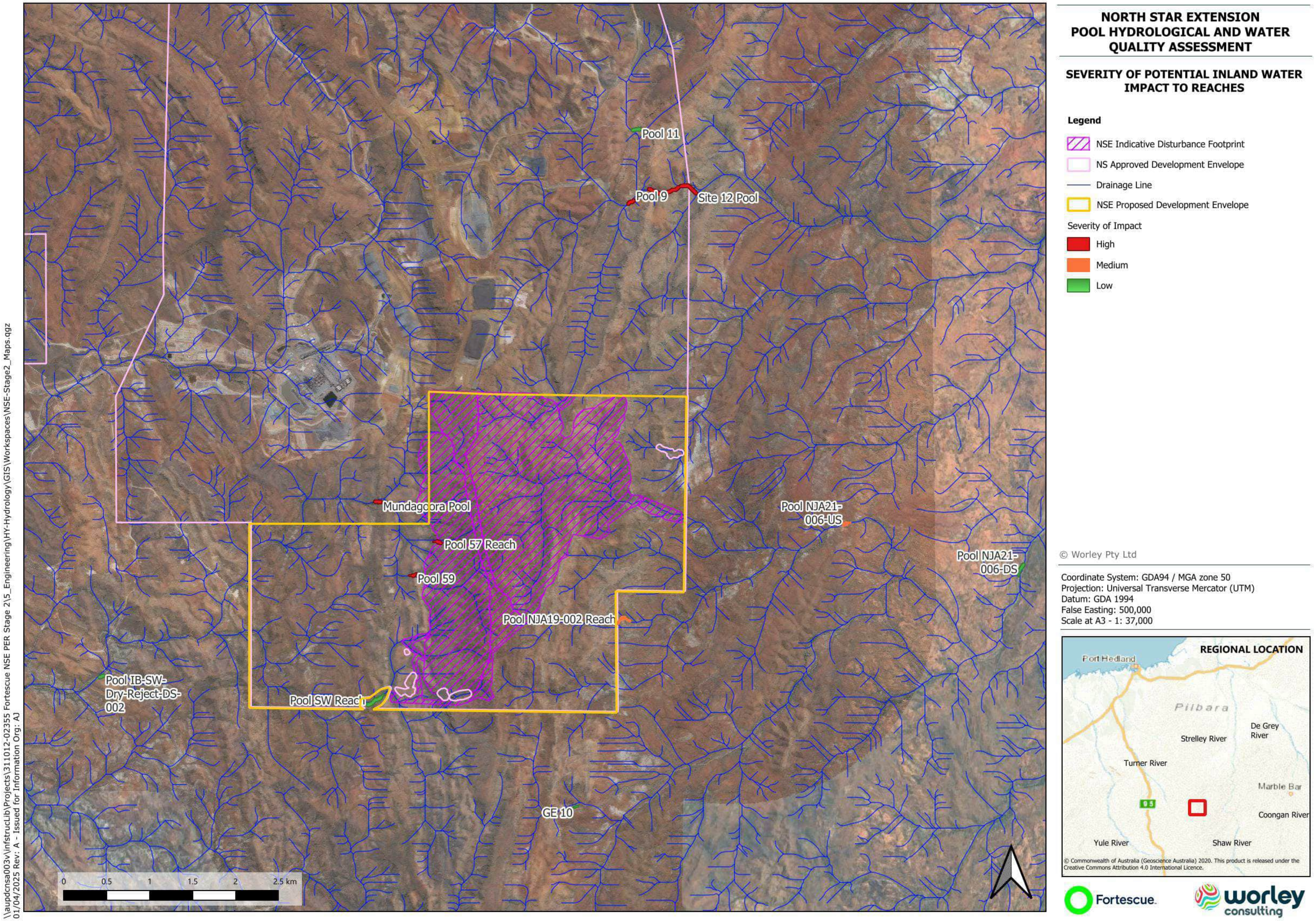

Figure 7-1. Map showing severity of potential inland water impact to reaches (and associated pools) identified in the Study Area due to NSE development.

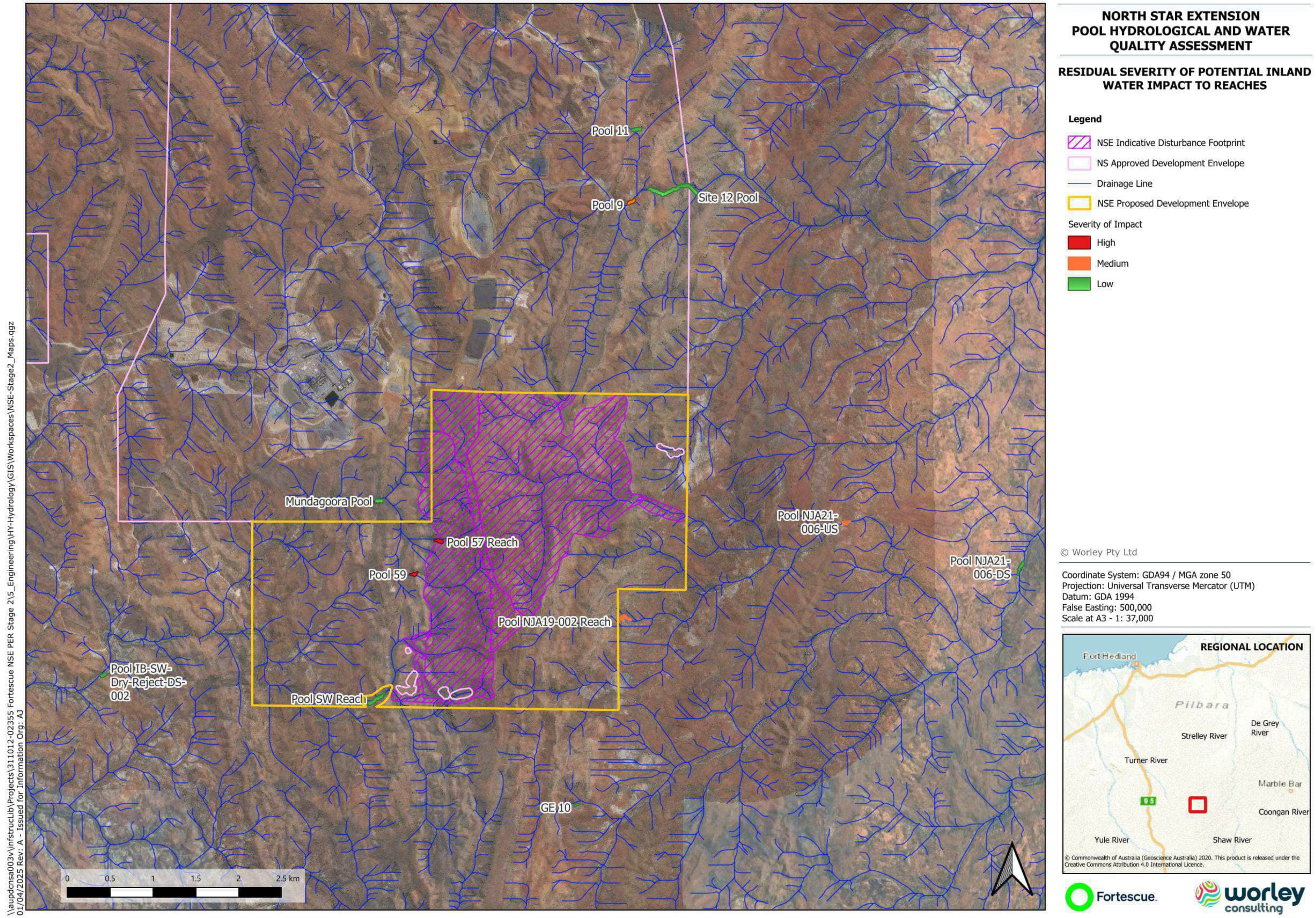

Figure 7-2. Map showing residual severity of potential inland water impact to reaches (and associated pools) identified in the Study Area due to NSE development, with recommended management controls in place

8. DCCEEW Comments

Detailed responses and links to relevant report sections which address comments pertaining to pools in Guidelines for the content of a draft Public Environment Report – North Star Magnetite Project Extension, Pilbara, WA (EPBC 2023/09466) (DCCEEW, 2024) are presented in Table 8-1.

Table 8-1: Inland water pool related items of the DCCEEW Guideline and applicable sections in this report

Item no.	DCCEEW Comment	Relevant section in this report	Comments
39 (f)	Map all water pools within the development envelope.	Section 3	See Figure 3-2 and Figure 3-3.
39 (g)	Classify all water pools within the development envelope as permanent or ephemeral and state if they are surface water or ground water fed.	Section 3.3, 3.4 & 3.5	All pools within and downstream of the development envelope have been classified.
58	The section must include an assessment of the potential impacts to MNES associated with hydrological changes due to the construction and operation of the mine and associated infrastructure. This must include the following details: a) A detailed description of changes to water regimes through dewatering operations impacting groundwater and groundwater dependent assets (i.e. pools). b) Pollution to hydrology (including permanent and semi-permanent water pools, main rivers, and drainage lines within the development envelope) resulting from mining activities should also be discussed here.	Section 5.2 and 6	a) Description of changes to water regimes through Near Mine borefield is outlined in Section 5.2. b) The potential sediment transport impact to pools are assessed in Section 6.2.

Item no.	DCCEEW Comment	Relevant section in this report	Comments
65 (i)	Pool_GR is to be removed by the mine pit (FMGIB 2023, p. 105). Pool_GR is considered critical habitat for listed MNES species (FMGIB 2023, p. 105). Information regarding the pool's depth, volume, whether water is present year-round or the pool's water source (groundwater or surface water) is required to allow an impact assessment.	Appendix A	Pool GR's depth and volume varies in response to rainfall events. Site visit indicated a depth of 0.65 m (Hydrobiology, 2023), while analysis of LiDAR topography data indicated a max depth of 1.17 m and a volume of ~50 m³. Water presence has been classified as "periodic inundation / ephemeral" with available evidence suggesting that Pool GR is a surface water fed pool (Hydrobiology, 2025a).
65 (ii)	Pool NJA21_006 is a pool located downstream of the waste rock dump. Flood mapping showed a reduction in surface water flow of between 30 - 40% during a 1 in 10-year event (FMGIB 2023, p. 107); however, this pool was not included in the hydrological assessment. The PER must clarify if Pool NJA21_006 is ground or surface water fed.	Section 5.1.3 & Appendix E	Assuming the comment refers to Pool NJA21-006-US, the predicted reduction in peak flow has been estimated between 32-37%, depending on the AEP event. This pool has been included in the hydrological impact assessment, with outcome being that the risk of impact is moderate. This is due to the potential for sediment aggradation resulting from the moderate reduction in peak flows.
65 (iii)	Include the impact assessment for the Mundagoora Pool which was not included in the provided documentation (BG&E 2021, p. 19).	Sections 5 & 6	The NSE development and existing Near Mine borefield will create groundwater drawdown which is likely to significantly impact on regional groundwater inflows to Mundagoora Pool during mining operations. The pit also removes 58% of the upstream catchment area resulting in a significant reduction in local groundwater recharge and inflows to the Mundagoora Pool. In relation to sediment transport / pool turbidity, the following minor impacts are expected which are unlikely

Item no.	DCCEEW Comment	Relevant section in this report	Comments
			to result in a significant geomorphological change to Mundagoora Pool: • Reductions in pool turbidity due to decreased supply and retention of fine sediment. • Reductions in soft sediment substrate. • Persistence of sediment capture in vegetated margins. • Armouring of pool bed with coarse sediment. The predicted geomorphological changes resulting from NSE development are depicted in Figure 6-6. The NSE development is expected to have a minor impact to the quantity of surface water inflows and no significant impact to the quality of surface water and groundwater inflows. Adoption of impact mitigations such as providing suitable sediment control measures and infrastructure needed to supplement the inflow to the pool at a rate of 0.5 L/s (refer Section 5.2.3) are expected to reduce the severity of impact to Mundagoora Pool to low.
65 (iv)	Include sufficient information to monitor, manage, and mitigate potential impacts on the Mundagoora Pool, noted as NSE's most important environmentally sensitive receptor (FMGIB 2023, p. 88).	Section 7.2	Monitoring of water level and quality in Mundagoora Pool has taken place since 2019. Management of potential impacts will involve the implementation of sediment control measures upstream of the pool reach, as well as the provision of suitable infrastructure to supplement the inflow to the pool. The source of supplementation water should have the same or better water quality than the pool to mitigate the impacts.

Item no.	DCCEEW Comment	Relevant section in this report	Comments
65 (b)	The impact assessment is limited to exploring the reduction of peak flows and catchment area as a result of the project (BG&E 2021, pp. 19 – 23). However, this has not included discussion of impact pathways associated with such changes, such as potential changes to sediment deposition and water quality. Additionally, groundwater related impacts must be explored	Sections 5.2 & 6	Changes to sediment deposition, water quality and groundwater inflow have been assessed for relevant pool reaches.
68	Information is required regarding the dewatering and abstraction of groundwater by the proposed project to enable an assessment of potential impacts related to these activities. a) The department considers that there are possible potential impacts from dewatering and groundwater abstraction as groundwater dependent vegetation and the groundwater fed Mundagoora Pool are present within the project area.	Section 5.2	Potential impacts from groundwater abstraction have been assessed as part of the groundwater inflow impact assessment (results for Mundagoora Pool are presented in Section 5.2.3.1 and outcomes in Section 5.2.4).
76	Mitigation measures for impacted surface water pools where they are classified as critical habitat and foraging habitat for MNES listed species (FMGIB 2023, pp. 103 – 107) must be included in the PER.	Section 7.2	Relevant mitigation measures have been outlined, where feasible.

Item no.	DCCEEW Comment	Relevant section in this report	Comments
77	Mitigation, monitoring, and / or management of impacts as a result of the changes in surface water flows and likely changes to the health of vegetation downstream of the Waste Rock Dump (FMGIB 2023, p. 90) is required.	Section 7.2	Management of potential impacts will involve the implementation of sediment control measures downstream of the WRD. All pools downstream of the WRD were found to be at low risk of impact with the appropriate sediment control measures in place.

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Appendix A. NSE PER Inland Waters - Pools Characterisation Report

Hydrobiology

NSE PER INLAND WATERS – POOLS CHARACTERISATION

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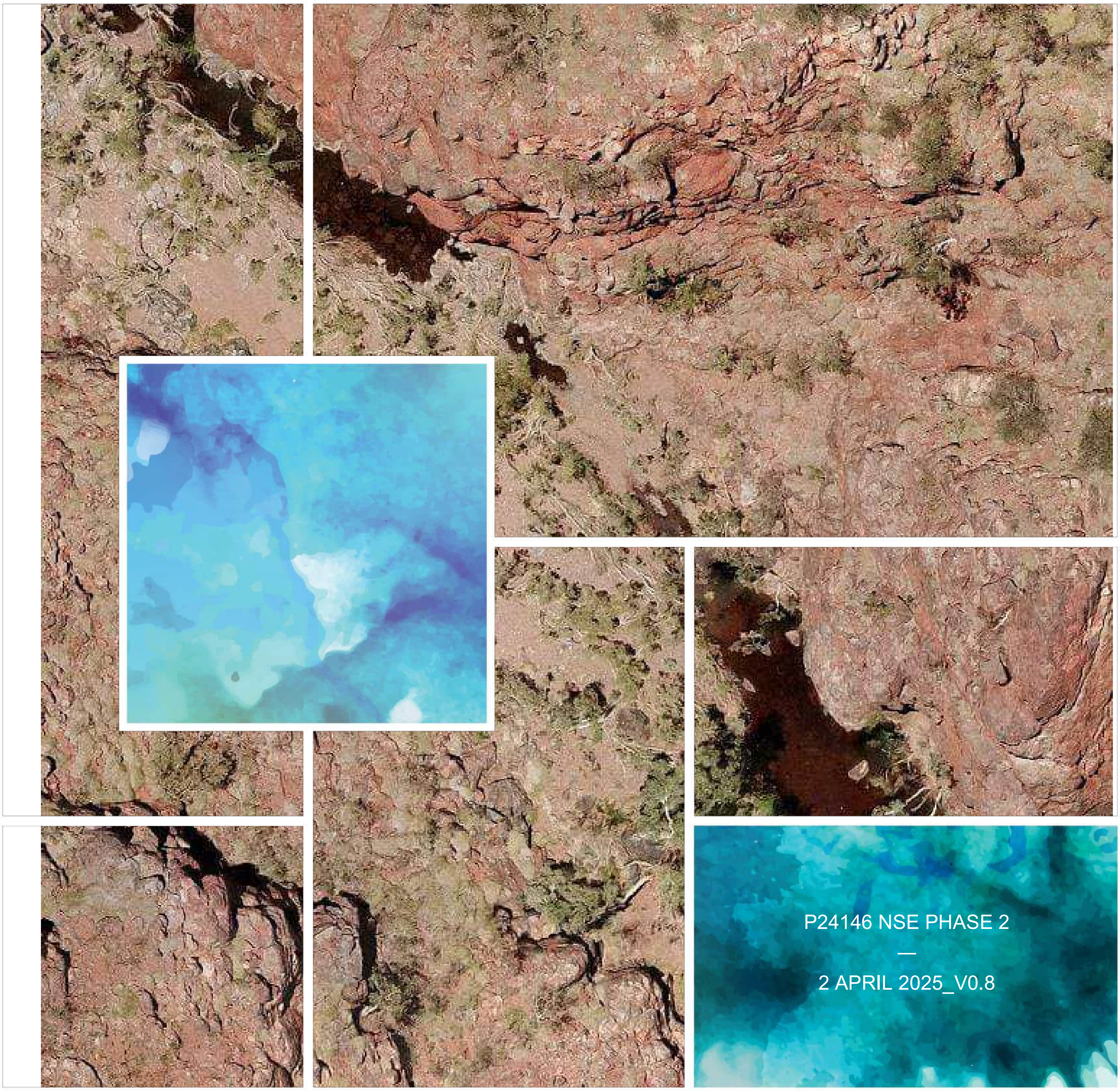

P24146 NSE PHASE 2

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STREET
1/71 Troy Terrace
Jolimont 6014
WESTERN AUSTRALIA

REGISTERED
c/- de Blonk Smith and
Young Accountants
GPO 119, Brisbane 4001
QUEENSLAND

POSTAL
PO Box 1034
West Leederville 6901
WESTERN AUSTRALIA

CONTACT
+61 (0)8 6218 0900 P
infowa@hydrobiology.com

ABN 68 120 964 650

www.hydrobiology.com

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1. INTRODUCTION

This report presents the results of a systematic identification and classification of the Inland Waters – Pool features of the North Star Extension (NSE) project area.

1.1 BACKGROUND

Fortescue Metals Group (Fortescue) is seeking to expand the current North Star Magnetite Project to the south of the existing mine development envelope. This expansion requires environmental approvals from the Environmental Protection Authority (EPA) and the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to enable development of new mine pits, a waste rock dump (WRD) extension and associated infrastructure. This new development is called the North Star Extension (NSE).

Several pools have been identified along creek lines within the North Star Stage 2 and NSE mine development area which are associated with hydrological and hydrogeological (Inland Waters) regimes. The DCCEEW issued PER Guidelines in December 2023, which included the need to identify and classify pools, then assess the risks associated with the NSE development.

Hydrobiology (as a sub-consultant to Worley) was engaged by Fortescue to identify and classify pools within the North Star Extension (NSE) area of influence. This report presents the results from a systematic identification and classification of the Inland Waters – Pool features of the NSE development area.

1.2 SCOPE

The objective of this study is to support the information requested to be provided by the PER Guidelines issued by DCCEEW as part of their assessment of the NSE under the EPBC Act 1999, relating to the identification and classification of pools in the NSE development area.

The scope of this report is to complete the systematic identification and classification of pools within the potential impact area (surface and groundwaters) of the NSE development. This is scope of work forms part of a pool impact assessment process as outlined in Figure 1-1. The impact assessment and subsequent risk assessment phases are being conducted separately to this scope of work.

The classification of pools is to be based on an assessment of whether the pools are permanent or ephemeral and whether they are surface water or groundwater fed, or both, with reference to the paper *A hydrological framework for persistent pools along non-perennial rivers* (Bourke et al, 2023) when conceptualising each pool's setting within the landscape.

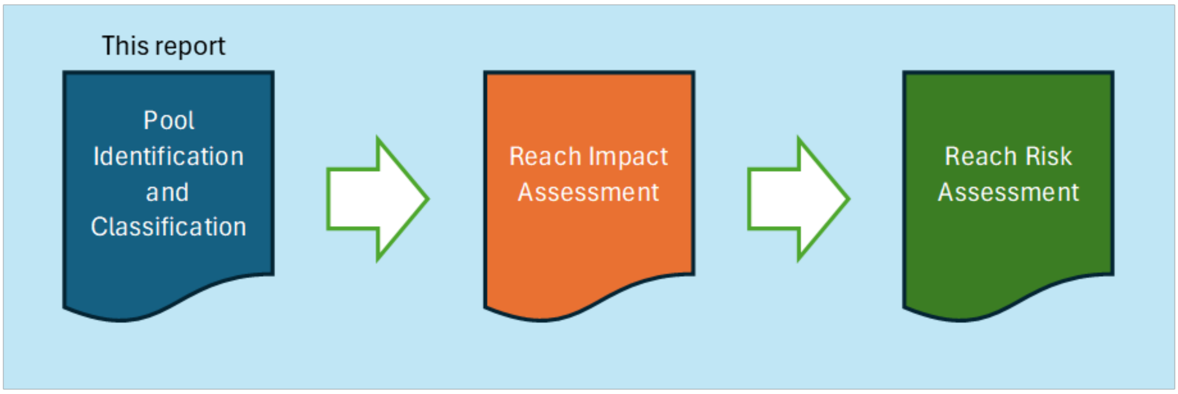


Figure 1-1 Schematic of workflow including the current report (Pool Identification and Classification).

2. METHODOLOGY

2.1 STUDY AREA DELINEATION

The Study Area applicable to this study was based on the combined extent of the estimated surface and groundwater impacts associated with the NSE project development. The delineation of these zones is discussed in the following sections. The eastern boundary of the surface water impact area was extended to ensure all named pools were included in the assessment. The extent of surface and groundwater impacts were then combined to define the Study Area.

2.1.1 DEFINITIONS

The following definitions have been adopted for this assessment:

- Baseline conditions**:** currently approved NS Stage 2 mining conditions, and
- Developed conditions**:** approved NS conditions plus the proposed NSE development conditions.

2.1.2 POTENTIAL GROUNDWATER IMPACTED AREA

Fortescue estimated groundwater drawdown extent associated with its proposed mine plan using a groundwater numerical model developed in Groundwater Vistas. Various scenarios were modelled to assess the impact that variations in groundwater recharge may have over the life of mine.

It was agreed with Fortescue that the 'reduced recharge' scenario would be adopted to inform the impact assessment, as it represents the most conservative approach. Fortescue provided estimated drawdown extents associated with the proposed NSE development (developed conditions), and the 2 m drawdown contour was used to set the boundary of the potential groundwater impact area, shown in Figure 2-1 (black polygon).

2.1.3 POTENTIAL SURFACE WATER IMPACTED AREA

Impacts to surface water flows and waterways were assessed as part of the *North Star Magnetite Project Extension Hydrological Impact Assessment Report: Waterways* (Document number: 311012-02916-HYD-REP-002-0) and the *Site 12 Pool Catchment Waterways Assessment – North Star Extension* (Fortescue 2025). The outcomes of this study were used to inform the extent of the impact assessment for surface water dependent pools. The boundary for the impact assessment area for surface water dependent pools was selected as the point at which the surface water peak flow rates under developed conditions are predicted to be within 10%-15% of baseline conditions surface water peak flow rates (Figure 2-1; light green dashed polygon). The eastern boundary of the surface water impact area was then extended by up to 500m to ensure all named pools were included in the assessment. There were no additional named pools to the western, northern or southern extent of the study areas and therefore it was not extended any further.

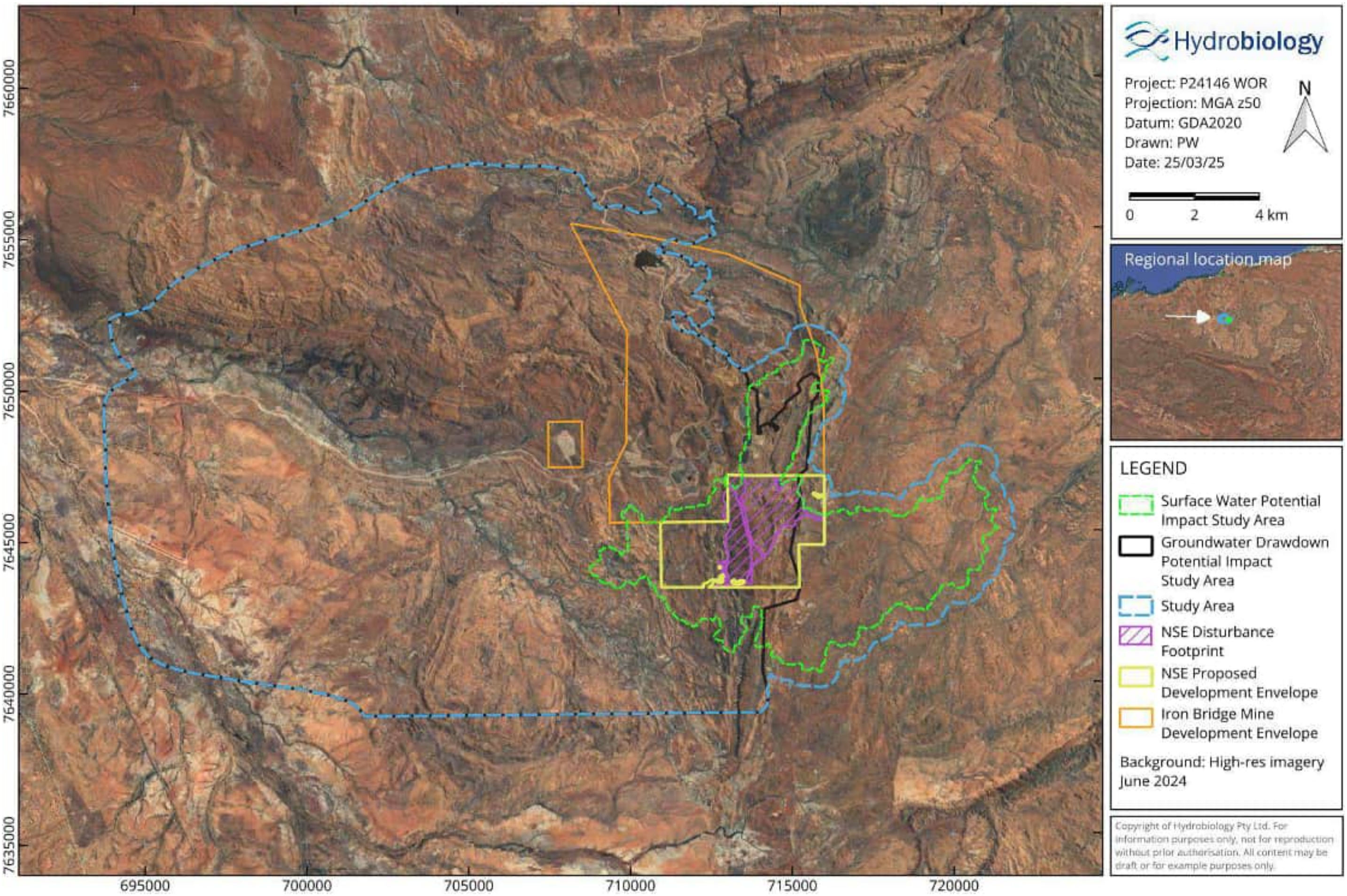


Figure 2-1 NSE surface water and groundwater potential impact areas.

2.2 DATA SOURCES

A range of data sources, described in the following sections, were analysed and assessed for the purposes of identifying and classifying pools within the study area. These data sources were targeted at completing a water permanence and source assessment following the method of Bourke et al. (2023); see Section 2.4.

2.2.1 AERIAL IMAGERY

Aerial imagery was supplied by Fortescue covering the period from August 2011 to June 2024. A total of 43 images were assessed with most images covering only part of the study area (Figure 2-2). A complete list of the image file names and dates is provided in Appendix A.

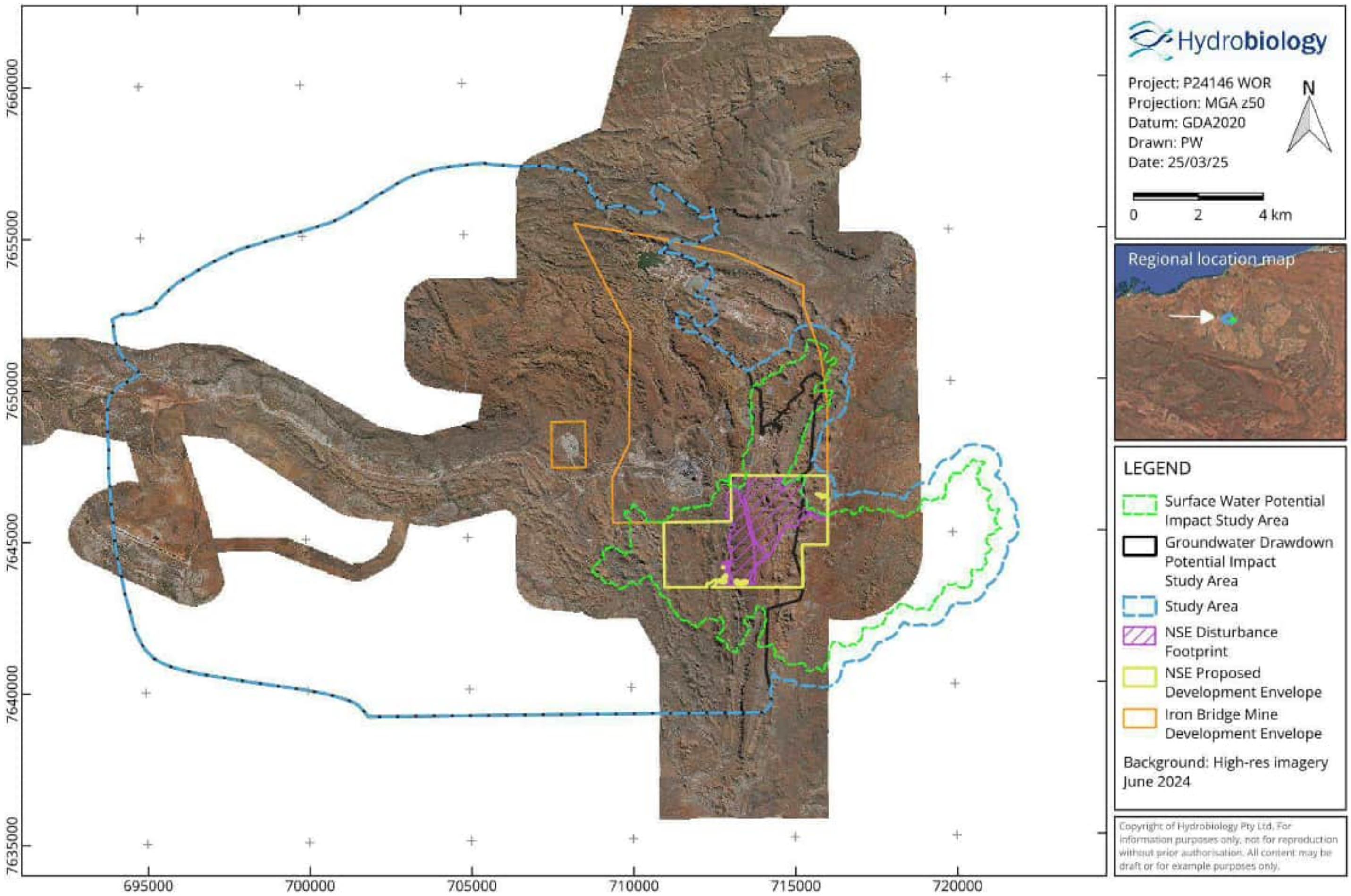


Figure 2-2 Example of aerial imagery capture area with study areas overlay – June 2024

2.2.2 SATELLITE IMAGERY

2.2.2.1 TRUE COLOUR COMPOSITE

Sensors on the Sentinel-2 satellite can image the Earth in different regions of the electromagnetic spectrum, called bands, with Sentinel-2 possessing 13 bands. True colour composite uses visible light bands, red, green and blue in the corresponding red, green and blue channels, resulting in a natural-coloured image that represents the Earth as it would naturally by seen by the human eye.

2.2.2.2 NORMALISED DIFFERENCE VEGETATION INDEX (NDVI)

The presence of denser vegetation and maintenance of high levels of vegetation vigour in the late dry season (October/November) are potential indicators of groundwater dependent vegetation (GDV). As a supporting line of evidence for water permanence and pool source classification, late dry season vegetation health was assessed across the study area using multi-spectral satellite data from the Sentinel 2 satellite array.

The two Sentinel 2 (S2) satellites captured 10 m resolution data across the study area every five days since October 2016. The Normalised Difference Vegetation Index (NDVI; B8-B4/B8+B4) was used to identify dense and healthy vegetation areas within the study area across the late dry season (October/November). The wet season in the study area is typically from December to May each year, with the April-May period being considered "late wet season". June to August is a period of drying of the landscape with increasing temperatures. September to November is the typical dry season, with late October/November (and occasionally early December) being the "late dry season".

Where pools were identified from true colour aerial or satellite imagery as being potentially permanent or semi-permanent, an assessment of the vegetation within the immediate vicinity of the pool was used to support the water permanence classification.

2.2.2.3 MOISTURE INDEX

As with the NDVI analysis (see Section 2.2.2.2), the S2 satellite data derived Moisture Index (B8A-B11/B8A+B11) was used as a line of evidence to support the classification of pools where imagery analysis had identified them as potentially permanent or semi-permanent. The Moisture Index provides a map of the soil and vegetation moisture content and can identify areas with non-meteoric (non-rainfall derived) water source such as groundwater and perched hyporheic water.

2.2.2.4 GOOGLE EARTH IMAGERY

The timeseries function in Google Earth was used to assess water presence for pools outside of the higher resolution aerial imagery capture area (see Section 2.2.1). The following Google Earth image dates were available and assessed for the study area:

- Sep-2006
- Feb-2007
- May-2011
- Sep-2011
- Jul-2013
- Sep-2013
- Nov-2015
- Jun-2018
- Mar-2020
- Jan-2021
- Dec-2022
- Apr-2023
- Mar-2024

2.2.3 LIDAR AND PHOTOGRAMMETRY

A site-wide digital elevation model has been captured using Light Detection and Ranging (LiDAR) at a 1 m resolution. In addition, drone-based photogrammetry was used to capture high-resolution imagery and elevation data for the Site 12 pool area in November 2024. This data was used to support the assessment of elevation for comparison to other datasets such as the modelled regional groundwater level contours.

For areas outside of the site wide 1 m LiDAR, SRTM data (NASA, 2024) and the Geoscience Australia elevation dataset (ELVIS; https://elevation.fsdf.org.au/) were used to obtain elevation data for the pools. When compared with LiDAR, the SRTM and ELVIS datasets are of much lower resolution and accuracy and provide less reliable estimates of pool elevation and water levels.

2.2.4 SITE PHOTOS AND INSPECTIONS

For many of the identified pools, physical inspection and collection of site photos was achieved during surface water monitoring[1] from December 2019 to November 2024. These photos were used to confirm water presence, substrate type and other hydrologic/hydrogeological features (such as seeps and vegetation changes). For difficult to access areas, helicopter overflight was conducted during routine surface water monitoring surveys in some cases.

2.2.5 CONCEPTUAL MODELS

Fortescue have developed conceptual models for several of the identified potentially permanent or semi-permanent pools in the study area. These conceptual models have been previously reported in environmental approvals submission documents (e.g., Fortescue, 2023).

2.3 HYDROLOGY / HYDROGEOLOGY

2.3.1 REGIONAL GROUNDWATER LEVELS

Fortescue provided modelled pre-mining regional groundwater level (mbgl) contours for assessment against pool elevations and landscape setting. The relative position of the groundwater table to estimated pool surface water levels is a key component of the pool classification method adopted from Bourke et al (2023; see Section 2.4.2).

2.4 POOL IDENTIFICATION AND CLASSIFICATION

2.4.1 IMAGERY ANALYSIS

Aerial and satellite imagery were accessed in a variety of GIS software platforms depending on functionality and format. Manifold GIS v8.0.34 was used to load .ECW (compressed wavelet image files) provided by Fortescue for the study area (see Section 2.2.1 and Appendix A) in Map Grid of Australia zone 50 projection, Geodetic Datum Australia 1994 (MGAz50, GDA94; EPSG:28350). Google Earth was used to generate pool register points (pool locations) for sites outside of the high-resolution aerial imagery capture areas. QGIS was used to format SHP files and some processing steps.

An initial pool register (points of pool locations) was developed from a combination of the following:

- Pools within the existing North Star project surface water monitoring program;
- Pools identified during site monitoring surveys (from 2019 to 2024) including helicopter overflights;
- Systematic visual review of satellite imagery (Google Earth) from the late dry season (Oct-Nov);
- Systematic visual review of aerial imagery provided by Fortescue for the late wet season period (Feb-April);

The location of late wet season pools observed in images from particularly wet years (surface water presence widely observed across the study area drainages) was recorded into a GIS layer (SHP file). Where there were strings of pools within the same reach that were clearly ephemeral (i.e. only present under recent rainfall conditions), a selection of the larger representative pools was chosen for assessment of those pool "reaches".

This was most common in the lower elevation drainages that were supported by alluvium flow-through during active flow periods (e.g., Figure 2-3). In addition to true colour visual identification of pools, the NDVI and moisture index for the late dry season (October 2023) was interrogated from the Sentinel 2 (ESO) satellite datasets to identify any wet/moist areas that persisted into the dry season. These areas were then interrogated in the high-resolution true colour aerial imagery for the presence of pools.

The pool persistence or water presence classifications were adapted from the Australian National Aquatic Ecosystems (ANAE) toolkit (Aquatic Ecosystems Task Group, 2012). This system does not provide quantitative ranges or detailed guidance on water permanence classification except for a suggestion of calling pools with water present over 70% of the time as "Commonly Wet". The other categories (see Table 2-1) were quantitatively defined for the purposes of this project.

Table 2-1 Water presence classification

Classification	Description
Permanently Inundated	Water always present (within the imagery analysed).
Commonly Wet	Water present >70% to 99% of the imagery analysed (may vary depending on the wet season, though the pool is known to dry out occasionally). This category is derived from the ANAE method.
Seasonally Inundated	Water present 50-70% of the imagery analysed. Mostly over the wet season. Relates to pools that routinely dry out over the dry season and are not likely to provide dry season refugia.
Periodic Inundation/Ephemeral	Water present <50% of the imagery analysed. Pools that dry out over the wet season, receding after flow events over a period of days to weeks and which do not tend to persist into the dry season.

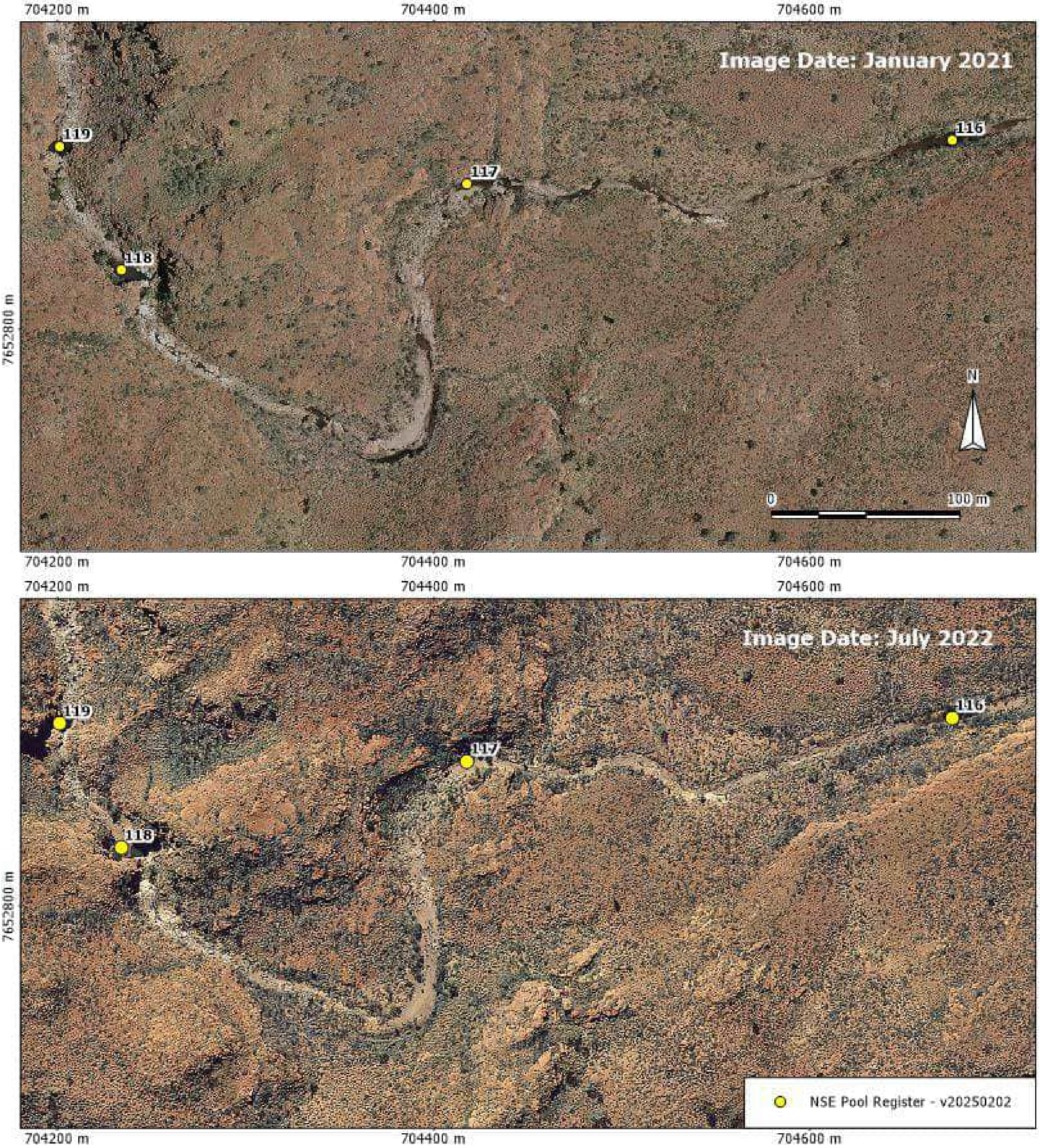


Figure 2-3 Example of a lower elevation drainage reach with a string of pools during the wet season (top: Jan 2021) and selection of the deeper/more persistent pools for the pool register assessment (yellow points; bottom).

Each identified pool was given a unique ID attribute (site name/number) and attribute columns generated for each image date.

Processing steps included:

1. Loading the data layers (image and pool register points files) into Manifold GIS;
2. For each image, the pool points register was overlaid, and the location of each individual pool was interrogated (zoomed into) and visually assessed for water presence as follows:
    a. A score of 0-5 for water presence (Table 2-2) was recorded in an excel spreadsheet against each pool in a separate column for each image. The percentage full assigned to each score in was based on visual assessment of the channel morphology and the maximum extent of water observed for each pool (i.e., where recent rains/flow had occurred):
    b. Where there was shadow over the pool, it was not clear if water was present or the image did not extend over the pool area, a null value was indicated.
3. The overall water presence classification for each pool (Table 2-1) was calculated based on the percentage of images with identifiable water present (score 1 to 5; Table 2-2). An additional metric of pool "fullness" was generated from the average water presence score (Table 2-2; Appendix B) across all images, though this was not used in classification, other than as a line of evidence to establish the hydrologic conceptual model for the pool (Appendix C).

Table 2-2 Water presence score

Score	Description
0	Dry
1	<10% full (small remnant puddle)
2	10-25% full
3	25-50% full
4	50-75% full
5	>75% Full - flowing reach

The Study Area features multiple pools that exist within narrow crevices/gorges and/or at the bottom of cliffs. For four of these sites, it was assessed that sufficient certainty over water presence could not be achieved from the available imagery (i.e., the pools were mostly in shadow or under overhangs in the imagery). It was assumed for reporting and assessment purposes that, as the pools had been named, they were conservatively classified as "Commonly Wet" (water present over 70% of the time). This applied to Astrid Bee Cave, Dingo Lair Pool, Craig's Pool and Zane's Gorge Pool. These pools are described and discussed further in Section 3.2.3.2.

2.4.2 BOURKE ET AL., 2023 METHODOLOGY

A recent published peer-reviewed scientific paper titled *A hydrological framework for persistent pools along non-perennial rivers* (Bourke et al., (2023) was identified as providing a suitable basis for categorising the pools identified for the NSE study area based on their hydrologic and hydrogeological characteristics. This paper specifically used Pilbara pools for the case studies of the application of its methodology and therefore was particularly relevant to the NSE study area. Bourke et al. (2023) proposed a framework for the classification of the key hydraulic mechanisms that support the persistence of river pools.

The three main hydraulic mechanisms identified by Bourke et al. (2023) are:

- **Perched surface water**;
  - "*Perched surface water can persist in topographic lows that retain rainfall and runoff during the dry season but are disconnected from the (regional) groundwater system*."
- **Throughflow of alluvial groundwater**;
  - *"During rainfall events, increases in water levels in rivers result in water storage and flow within the unconsolidated alluvial sediments in the beds and banks of stream channels (Cranswick and Cook, 2015). As the streamflow recedes after a flood, continuous surface flow ceases, resulting in isolated pools along the river channel. Some vertical thickness of the alluvial sediments that line the stream channel will remain saturated with water beyond the period of surface water flow; this water is hereafter referred to as alluvial groundwater.*"
- **Groundwater discharge**;
  - Geological contacts and barriers to flow: "*Two subtypes: (i) catchment constriction across ridges, or (ii) aquifer thinning due to geological barrier intersecting topography. Presence of waterfalls or surface geological features (hard-rock ridges). Hydraulic head step changes across pool feature*".
  - Topographically controlled seepage from regional aquifer: "*Topography intersects (i) water table or (ii) preferential flow from… aquifer. Standing water persists during dry season due to groundwater discharge in absence of rainfall*".
  - A third groundwater discharge mechanism has been added to the above classifications for the purposes of the current study. In discussions with Fortescue and Worley hydrogeologists, a conceptual mechanism of localised "perched" groundwater supported by a geological structure (intrusion/fault/aquitard) has been proposed. The NSE study area contains several permanent or semi-permanent (commonly wet) pools that appear to be situated above the regional groundwater table (based on groundwater levels from regional monitoring bores or on inferred pre-mining water level from groundwater modelling). Given that water persistence in these pools is greater than would be expected if they were perched surface water supported (i.e., due to losses to evaporation), a localised or discrete source of groundwater "seepage" could be responsible for supporting these pools into the dry season.

The Bourke et al. (2023) method does not provide any classification system for water persistence, only water source. However, the Australian National Aquatic Ecosystems (ANAE) classification framework does have broad guidance on classifying water persistence (see Section 2.4.2.2).

Bourke et. al. (2023) also suggests diagnostic tools for mapping and classifying persistent pools including:

- Regional-scale Tools:
  - Remote sensing and image analysis
  - Landscape position and geological context
  - Hydrogeological context
- Pool-scale tools:
  - Pool hydrography and water balance
  - Pool hydrochemistry
  - Stable isotopes of water
  - Temperature

These datasets were utilised within the current assessment and classification as available. Regional scale geology mapping, fault mapping, depth to groundwater, water quality and elevation data were attributed to the pool points using GIS layers of each dataset.

2.4.2.1 CONCEPTUAL MODELS

The following conceptual models for water source in persistent pools were adapted from Bourke et. al (2023) for the current study (Table 2-3):

Table 2-3 Summary of Conceptual Water Source Models used in the current study

Type #	Conceptualisation	Description	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
1a	Alluvium - perched throughflow	Alluvium throughflow, with scour holes and potential for localised perching due to presence of lower permeability units. Pool water primarily reliant on surface water flows, and pool levels higher than "regional" water table.	Yes	No	No
1b	Alluvium/bedrock - perched throughflow	Alluvium throughflow, with scour holes and bedrock expressions, resulting in localised perching of surface water. Pool water reliant on surface water flows, and pool levels higher than "regional" water table.	Yes	No	No
2a	Bedrock - perched surface water	Perched water high in bedrock catchment, pool situated within lower permeability units. Pool water reliant on surface water flows or interflow, and pool levels higher than "regional" water table.	Yes	No	No
2b	Bedrock fracture / regolith flow groundwater source	Pool fed by shallow and/or deep groundwater via flow in fractured bedrock or regolith. Fracture systems may be aligned with surface water drainage lines. Connection with regional water table is unlikely due to position of pool in the landscape, and the unique presence of the pool where adjacent drainages do not show pool features at the same elevation or lower.	No	Yes	No
3	Bedrock aquiclude - groundwater discharge	Groundwater discharge to surface due to catchment constriction across ridge line, presence of low permeability unit and lateral constraint on groundwater flow.	No	Yes	Yes
4	Topographically controlled groundwater outflow	Topographically controlled groundwater outflow either regional or local. These locations identified based on water presence, geomorphological and catchment setting.	No	Yes	Yes

Figure 2-4 to Figure 2-9 provide visual conceptualisations for each model applied in the pool classifications for the current study. These have largely been adopted from Bourke et. al. (2023) though with minor modifications as noted in the figure captions and markups on the figures.

The hydraulic conceptualisation Type 2b (Bedrock - fracture flow groundwater source) has been derived specifically for the NSE project and has previously been used by Fortescue (2023) to describe the hydraulic conceptual model for several North Star Project area pools. It is proposed that this type of pool is supported by dry season inflows from **local** groundwater, potentially hosted within fractured rock or regolith above and adjacent to the pool. These pools are not likely to be connected to the regional water table, based on their position in the landscape (relative to regional water table monitoring records) and the unique presence of the pool where adjacent drainages do not show pool features at the same elevation or lower.

Bourke (2023) Conceptualisation Type 1a

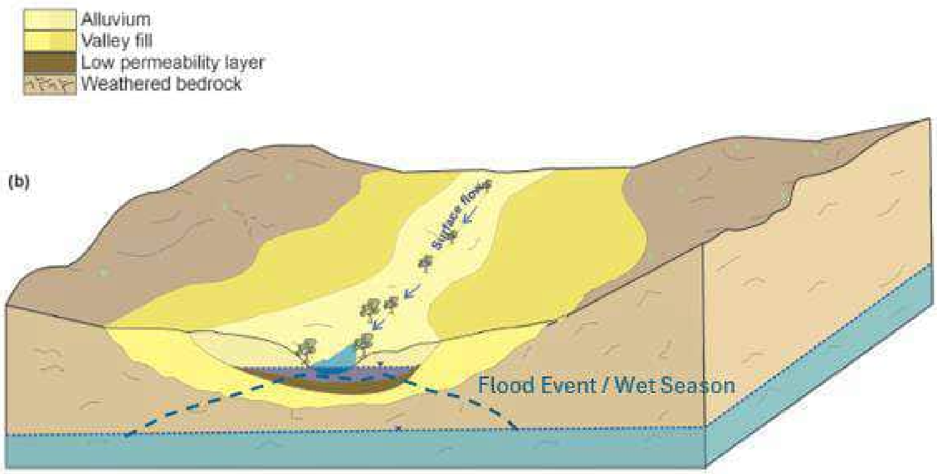


Figure 2. Schematic illustration of pools that are maintained by throughflow from the adjacent alluvial sediments. The water in these alluvial sediments can be either **(a)** connected to the unconfined aquifer, or **(b)** form a perched aquifer if the water is stored over a low permeability layer.

Figure 2-4 Hydraulic mechanism Type 1a: Alluvium - perched throughflow (adapted from Bourke et. al. (2023) Figure 2).

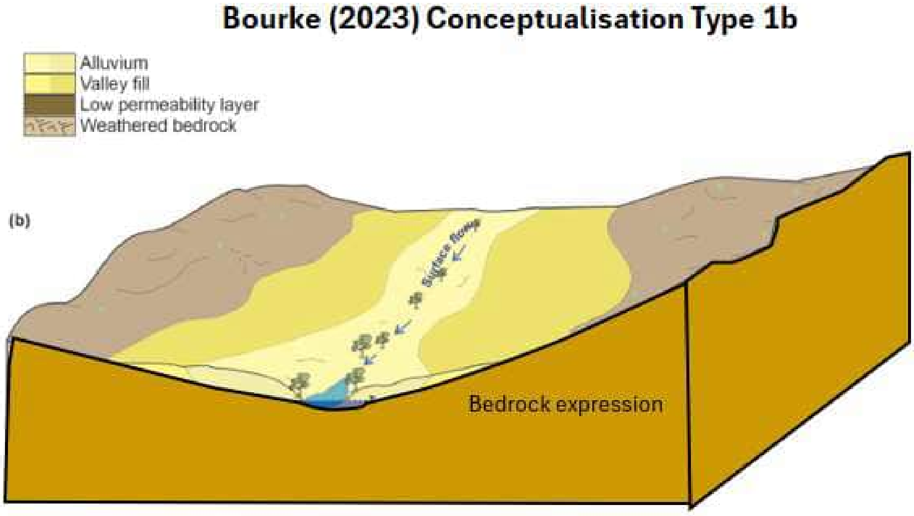


Figure 2. Schematic illustration of pools that are maintained by throughflow from the adjacent alluvial sediments. The water in these alluvial sediments can be either **(a)** connected to the unconfined aquifer, or **(b)** form a perched aquifer if the water is stored over a low permeability layer.

Figure 2-5 Hydraulic mechanism Type 1b: Alluvium/bedrock - perched throughflow (adapted from Bourke et. al. (2023) Figure 2).

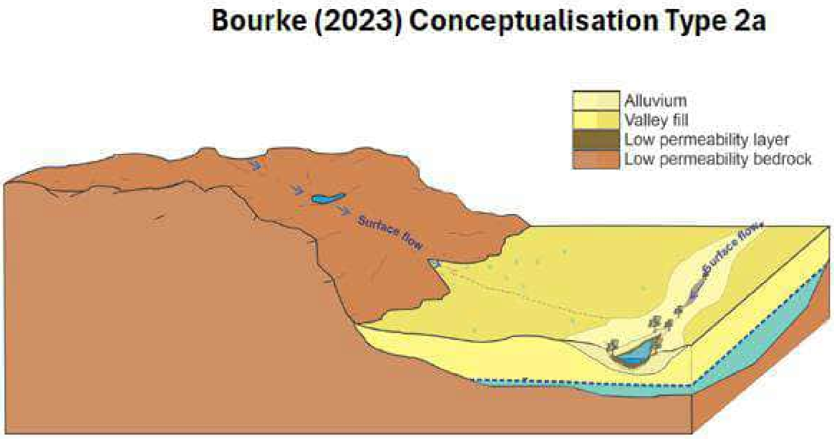


Figure 1. Schematic illustration of perched pools where rainfall–runoff collects in a depression that has morphology that limits evaporation, and/or low permeability lithology beneath the pool that limits infiltration, allowing water to be retained for an extended duration.

Figure 2-6 Hydraulic mechanism Type 2a: Bedrock - perched surface water (adapted from Bourke et. al. (2023) Figure 1).

Bourke (2023) Conceptualisation Type 2b

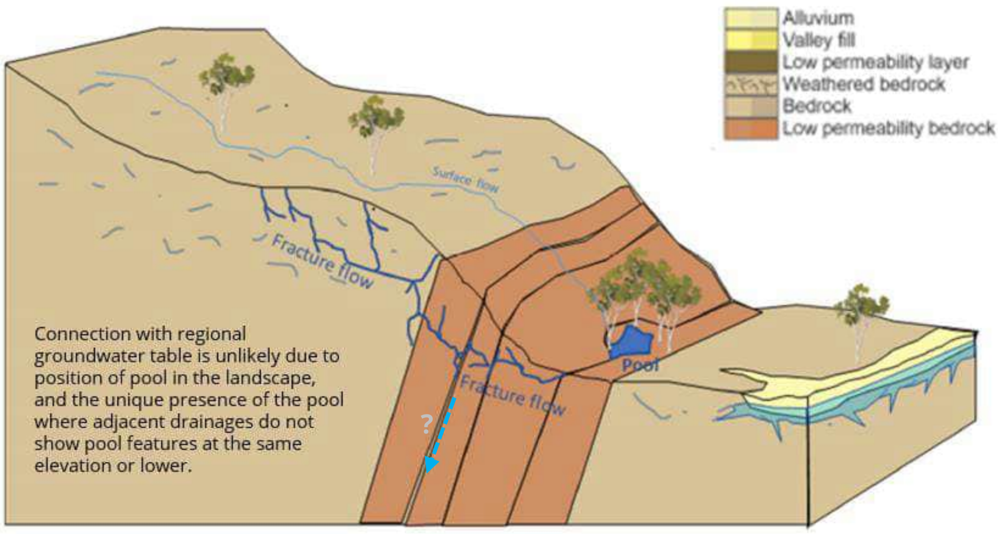


Figure 19: Schematic illustration of fracture flow groundwater source for Cow Spring and Fig Pool (adapted from Bourke *et al.* (2023)).

Figure 2-7 Hydraulic mechanism Type 2b: Bedrock fracture / regolith flow groundwater source (adapted from Fortescue (2023) Figure 19, after Bourke et. al. (2023).

Bourke (2023) Conceptualisation Type 3

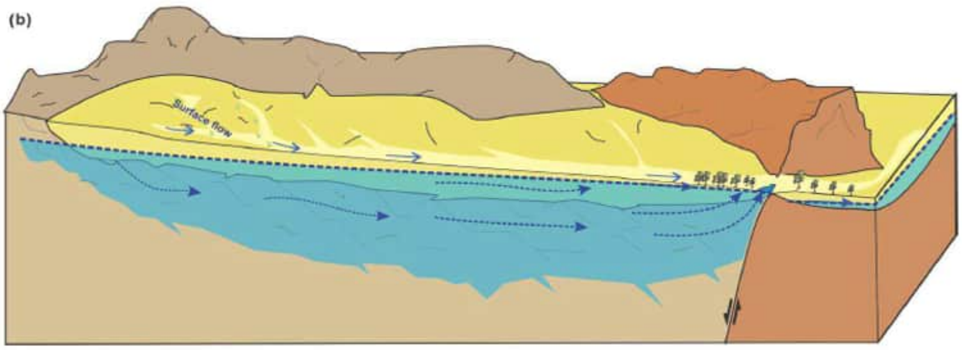


Figure 3. Schematic illustration of a groundwater discharge pools where surface water persistence is driven by geological barriers that **(a)** cause a regional aquifer to pinch out vertically or **(b)** form a lateral constraint on the catchment and underlying regional aquifer.

Figure 2-8 Hydraulic mechanism Type 3: Bedrock aquiclude - groundwater discharge (adapted from Bourke et. al. (2023) Figure 3).

Bourke (2023) Conceptualisation Type 4

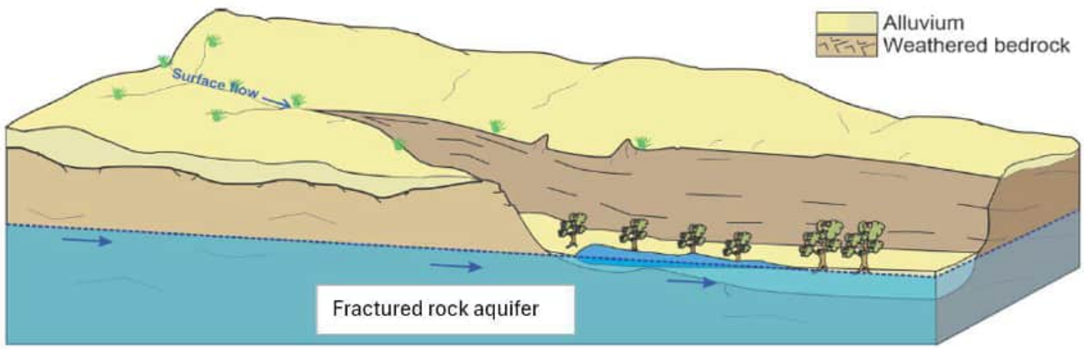


Figure 4. Schematic illustration of a pool receiving topographically-controlled groundwater outflow from a regional aquifer.

Figure 2-9 Hydraulic mechanism Type 4: Topographically controlled groundwater outflow (adapted from Bourke et. al. (2023) Figure 4).

2.4.2.2 AUSTRALIAN NATIONAL AQUATIC ECOSYSTEMS (ANAE) COMPARISON

The ANAE classification framework is a broad-scale, semi-hierarchical, attribute-based scheme, which provides a nationally consistent and flexible framework for classifying different aquatic ecosystems and habitats including rivers, floodplains, lakes, palustrine wetlands, estuaries, and subterranean ecosystems (Aquatic Ecosystems Task Group, 2012).

The ANAE framework consists of three levels which are designed to capture the broad spatial patterns and ecological diversity of aquatic ecosystems and habitat types. Level 1 is regional scale, Level 2 is landscape scale, and Level 3 is aquatic classes, systems and habitats.

Levels 1 and 2 are large scale, national regionalisations for landform, climate, hydrology, topography and water influence, which provide context relative to both the regional and landscape scales. Level 3 identifies the classes of aquatic ecosystems (surface water and subterranean), major aquatic systems (e.g. estuarine, lacustrine, riverine, and floodplain), and the pool of attributes used to classify those systems into habitats.

The water persistence classification within the ANAE toolkit (Aquatic Ecosystems Task Group, 2012) provides general classes of persistence as outlined in Table 2-4. These have been adapted to have numeric thresholds for the current NSE study to allow for pool classification using the water presence data obtained from imagery interrogation (see Section 2.4.1; Table 2-2).

Table 2-4 Water persistence classification framework taken from the ANAE toolkit (Table 2)

Attribute	Metrics and Thresholds	References
Water Regime: Water regime conditions have a major influence in determining the nature and persistence of aquatic ecosystems. For example, permanent systems are often highly important in providing refugia for plants and animals during dry/drought conditions, while the unique nature of ephemeral systems, especially those in arid areas, leads to interesting endemic and highly adapted flora and fauna. As such, water regime is a key attribute used to characterise and differentiate between different habitats and ecosystems. A range of metrics and thresholds have been identified which differentiate the range of influence water regime has on aquatic ecosystems.	Presence of water*: • Permanently inundated • Seasonally inundated • Aseasonally inundated • Waterlogged'*' OR** • Commonly wet (>70% of time) • Periodic inundation • Waterlogged'*' * This attribute may include sub-metrics to support environmental flow assessment where data is available. Potential sub-metrics for detailed flow regime include flow to achieve inundation/commence-to-flow, duration, 10-year representation of flow etc. available from records or modelling. ** Where data is limited. Based on remote sensing plus expert knowledge. *** Included to accommodate seasonally waterlogged areas in temperate Australia and Alpine bogs etc. that are generally not inundated.	Information for this category is often derived from remote imagery to identify extent over a range of wet and dry periods. The following information is derived from Boulton and Brock (1999): • Permanent - may be static or flowing, with varying levels, however is predictably filled. • Seasonally - covers intermittent with wet and dry periods on a regular basis according to season. Such areas often have a higher flora and fauna diversity than permanently inundated areas. • Aseasonal - captures areas that alternate between wet and dry but not on a predictable basis. This includes such regimes as: – Intermittent: alternating wet and dry periods but less frequently and regularly than seasonal. – Episodic: dry most of the time with irregular wet phases that may persist for months. Annual inflow is less than minimum annual loss in 90% of years. – Ephemeral: only filled after unpredictable rainfall and runoff. Surface water dries within days of filling and seldom supports macroscopic aquatic life. • Waterlogged must have hydric soils as a minimum (and associated wetland flora and fauna).

2.4.2.3 EVIDENCE MATRIX

Multiple lines of evidence were used to derive a hydraulic conceptualisation for each identified pool. Appendix C provides a results summary for each line of evidence as detailed in Table 2-5.

Table 2-5 Evidence Matrix description

Line of Evidence	Description
Evidence matrix based source	This field contains the general consensus on the likely water source based on the multiple lines of evidence listed below. This is either GW (groundwater), SW (Surface Water) or GW/SW (a combination of both).
EM - Water Presence	SW indicators include: • Water presence typically only after wet season rains (for days to weeks) • Receding water at or faster than evaporation rates after the last rainfall event • Water not typically present during the dry season GW indicators include: • Water presence in the pools for longer than would be expected/calculated based on evaporation and antecedent rainfall. • Water not receding after extended dry periods (months)
EM - Fullness Score	As for Water Presence, the average fullness of the pool (see Section 2.4.1) can indicate if inflows to the pool are related to rainfall or a more consistent source (i.e. groundwater). For example, pools that are reliant on surface flows will recede (become less full) with time from the previous flow event. Groundwater sourced pools will be more stable/persistent.
EM - Substrate	The substrate of a pool can provide an indication of the permeability and potential for the pool water being perched above an impervious geological layer (e.g., bedrock). Pools within deep alluvial sediments, particularly scour holes at bends (often against a rock-face), can indicate a surface water source of alluvial throughflow.
EM - Location	This line of evidence can be somewhat subjective though useful. For example, a pool located at the base of a cliff face, with a very small catchment above it, could be considered in a location that is likely to be supported by local groundwater derived from the elevated terrain adjacent to the pool (as the catchment would be too small for extended alluvial throughflows). Pools located within a similar setting to other pools, where more data might exist, can have "Location" line of evidence suggesting a likely similar water source.
EM - Elevation	The elevation can be relevant to the potential for regional groundwater to be a source (i.e., the pool is below the measured or inferred regional water table elevation). Similarly, if data exists that indicates groundwater surface expressions occur within a given elevation band, then this can be a potential line of evidence.
EM - Depth to regional GW	As with Elevation, the relative depth of the regional water table to the pool water surface can indicate if there is potential for the pool water to be from or in connection to this source. Pools with surface elevations above the regional water table (within a margin of error for topographically driven variability), can be attributed to a local aquifer or surface water source depending on the water persistence.
EM - Catchment Size	For alluvial throughflow to generate persistence of pools deep into the dry season, a relatively large catchment may be required to support this as a potential source. Where the catchment area is relatively small, and inflows exist in alluvial substrates or bedrock depressions (substrate) into the dry season, this may indicate that a groundwater source is present.
EM - Flow Regime	The measured flow-regime of a pool can indicate the dominant water source. For example, if a pool only fills with a rainfall event (as indicated by local rainfall records) and recedes at a rate consistent with alluvial throughflow/evaporation post surface water flow events, then a surface water source would be indicated. If the pool continues filling weeks after surface water flows have ceased within the drainage, and persists well into the dry season, this may indicate that a groundwater source is present.
EM - Vegetation	Groundwater near the surface can drive the presence of dense vegetation (groundwater dependent vegetation – GDV) dominated by wetland species (e.g. Melaleuca, Sedges, Typha etc.). If the vegetation vigour extends into the late dry season, relative to regional vegetation, then a groundwater source is likely to be present (e.g. as measured by NDVI). The absence of hydrophilic vegetation, or denser vegetation relative to the regional norm, can indicate that the groundwater table is not close to the root zone within the pools location and therefore the pool may be surface water sourced.
EM - Hydrochemistry	The most common hydrochemical indicator for groundwater inflows is a difference in dissolved ion content (as measured by electrical conductivity/salinity). Groundwater typically contains higher concentrations of dissolved ions than surface water inflows dominated by recent rainfall. In contrast, surface water inflows that have ceased and are perched on impervious substrates (such as in a bedrock depression) will increase in dissolved ion concentrations as the water evaporates into the dry season. A salinity above the local/regional groundwater concentration may indicate a perched surface water source.

2.4.3 REACH CLASSIFICATION

For the purposes of impact assessment, individual pools were grouped into local reaches along a connecting section of drainage line (generated from the site wide 1 m resolution LiDAR elevation model, e.g. Figure 2-10). Where there was only a single pool along a reach, a representative section of drainage line upstream and downstream of the pool “point” feature was included as the pool reach. The length of the reach upstream and downstream of the pool point was variable, based on the nearest intersection of tributaries to the main channel, though was typically on the order of 50-100m upstream and downstream of the pool “point”.

The purpose of generating reaches was to provide a mechanism to group pools within close proximity (i.e. within several hundred meters along the same drainage line) where the same impact mechanisms and assessment could be applied across the reach. This reduced repetition where groups of pools would be similarly potentially impacted.

A buffer polygon of 10 m either side of the reach drainage line was generated for mapping and figure production purposes. This buffer polygon was also used to overlay pool points and transfer data attributes from the point layer to the reach layer from the pools within each reach.

The attributes from the pool register point file (SHP file) were overlaid onto the Reaches polygon SHP file. Where there were multiple pools within a reach, the water permanence classification of the most persistent pool was applied (i.e., if there was both an “ephemeral” and a “seasonally inundated” pool within the reach, then the “seasonally inundated" attribute was applied).

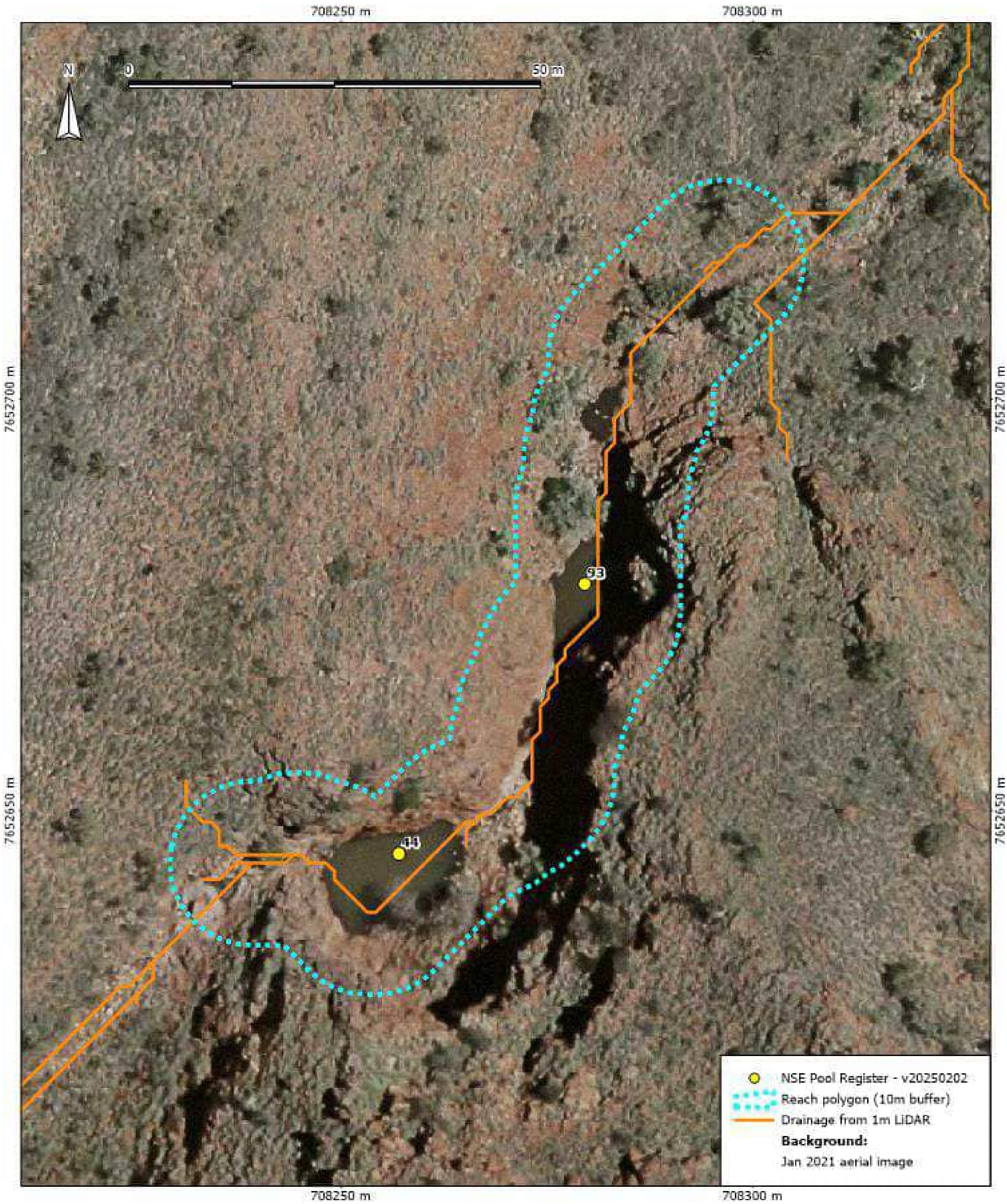


Figure 2-10 Example of two pools (#44 and 93) being combined into a single reach for impact assessment purposes.

3. RESULTS

3.1 POOL IDENTIFICATION AND CLASSIFICATION

A total of 102 pools were identified and assessed for water presence across the NSE Inland Waters study area (Figure 3-1). An average of 26 images (+- 10.7 st.dev; min. 0, max. 45) were available for the water presence classification of each pool. A total of 2,715 pool images across the 103 pools were assessed with water being present on average in 35% of the images.

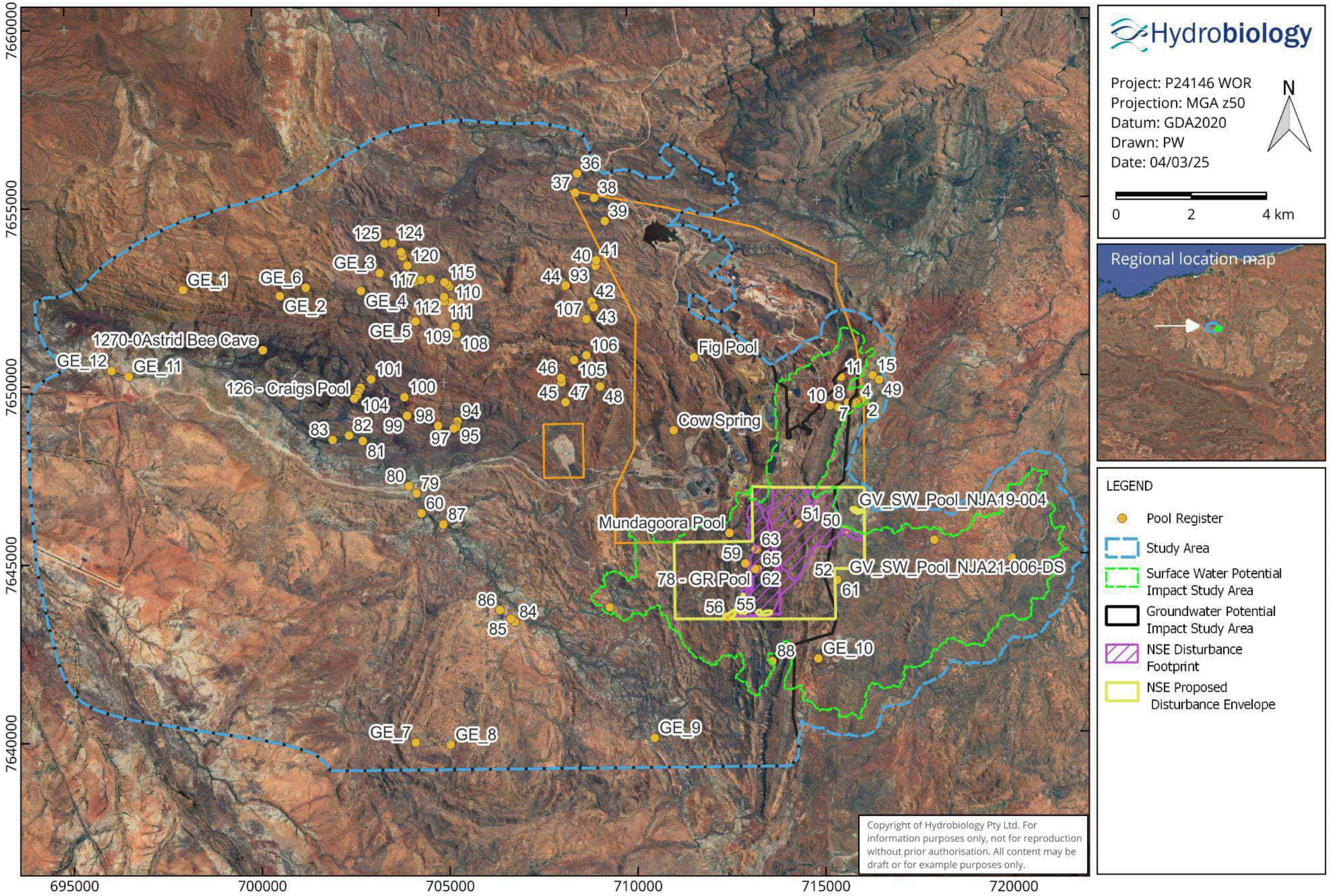


Figure 3-2 NSE Pool identification.

Water was most present in the mid-wet season (January; 79%) and least present in the late dry (November; 15%) as would be expected (Figure 3-1). Note that the May dataset had only 7 data points and therefore is not representative.

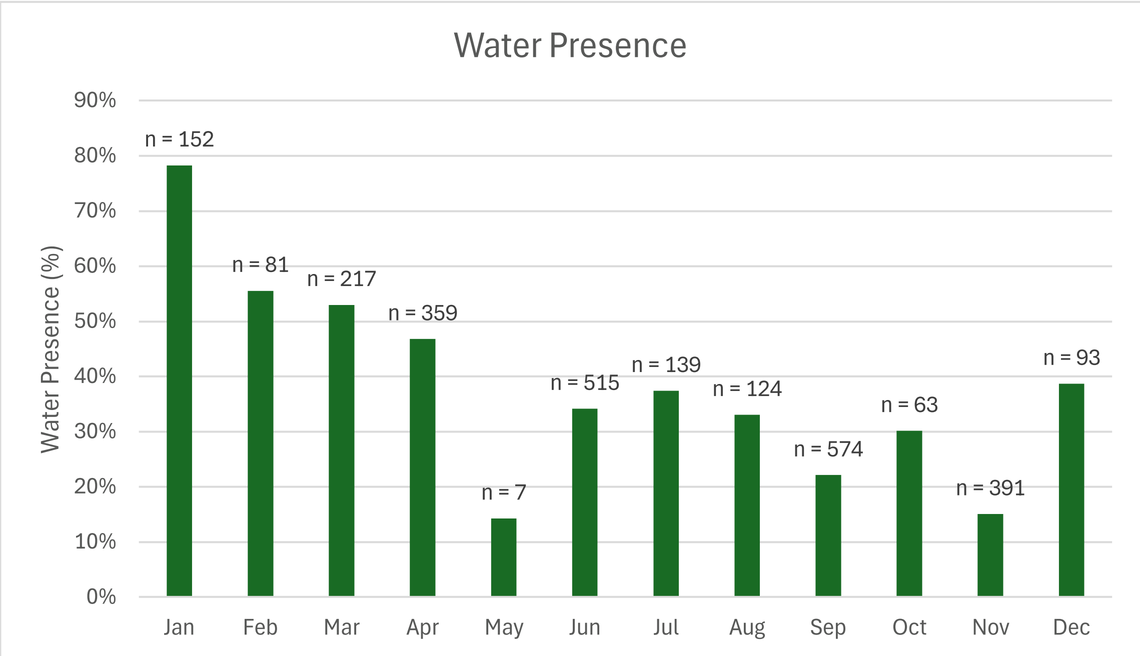


Figure 3-3 Percentage of pools containing water by month across all images

Table 3-1 provides a summary of the number of pools identified within the NSE Inland Waters study area within each water presence category. Seven pools (7%) were identified as permanent (having water present in all imagery) and 14 pools (14%) as Commonly Wet (having water present in over 70% of imagery). The vast majority were either Seasonally Inundated (11%; water present during the wet season) or had Periodic Inundation/Ephemeral (69%; water present for a shorter period after rainfall events).

Table 3-1 Pool water permanence classification summary

Permanence Classification	Fraction of images in which water was present	Count	Percentage of Total Count (%)
Permanent	1	7	7%
Commonly Wet	0.7 <> 1	14	14%
Seasonal Inundation	0.5 <> 0.7	11	11%
Periodic Inundation/Ephemeral	<0.5	70	69%
	Total	**102**	**100%**

Figure 3-2 presents the point location of all pools assessed within the current study area across both the potential groundwater impact and surface water impact areas. The pool points are thematically coloured by their respective water presence categories. As described in Section 2.4.3, a section of the drainage line upstream and downstream of each pool was selected as the pool “reach” for the purposes of impact assessment. Where multiple pools were located within close proximity, a single reach was created containing these adjacent pools, for the purpose of subsequent impact assessment. Note that impact assessment is not within the scope of this report and will be covered by subsequent reporting by Worley and Fortescue. Appendix D provides detailed maps of the pools including pool name labels for reference.

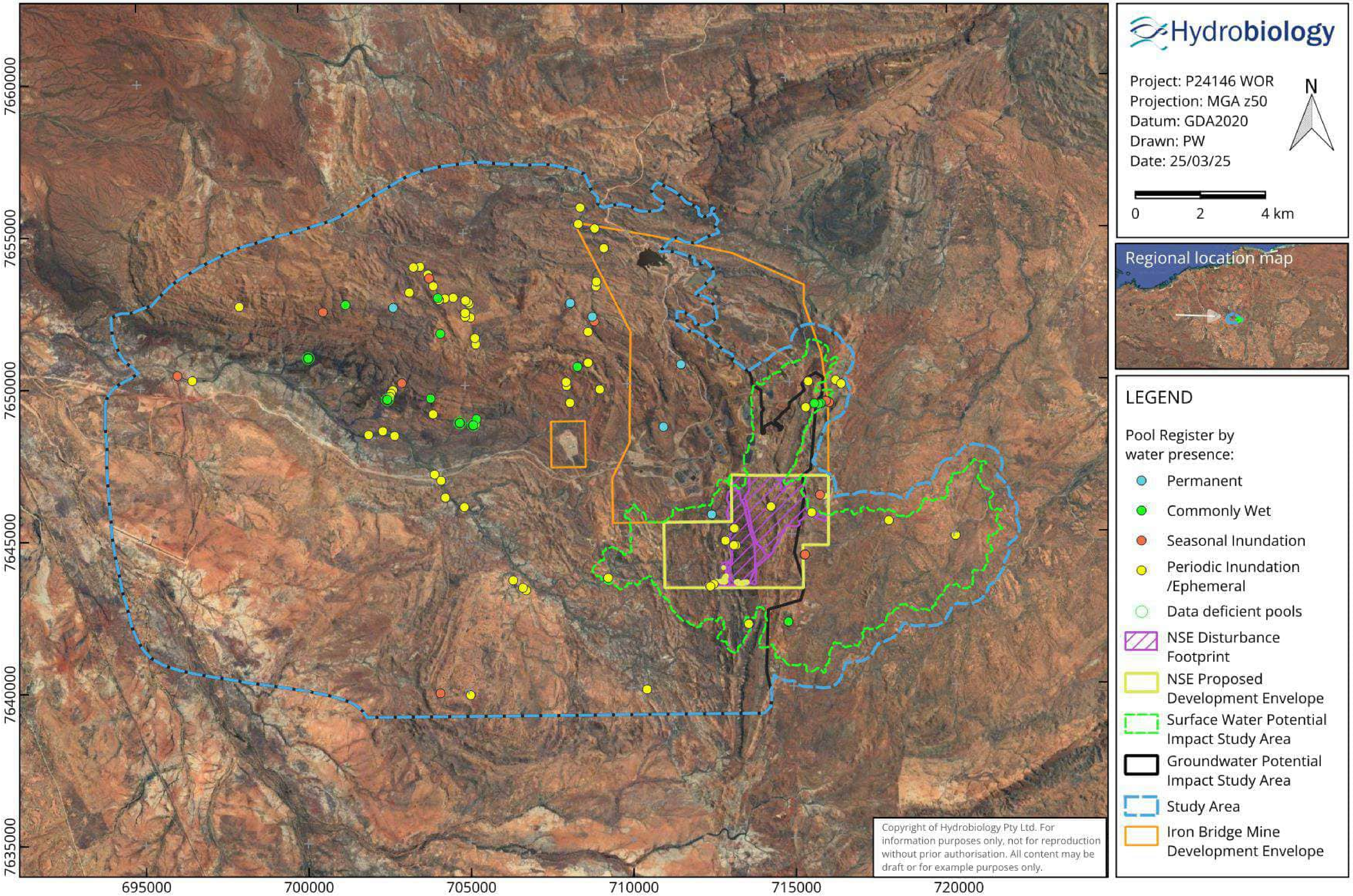


Figure 3-4 NSE Pools by water presence category

3.2 APPLICATION OF HYDROLOGICAL FRAMEWORK FOR PERSISTENT POOLS ALONG NON-PERENNIAL RIVERS (BOURKE ET AL., 2023)

The application of a hydrological conceptual model to each identified pool within the NSE study area was undertaken using a range of lines of evidence. These included data sources described in Section 2.2 and the approach outlined in Bourke et. al. (2023). While impact assessment is not within the scope of this report, the identification and classification of pools was primarily to inform the impact assessment process being completed by Worley. Therefore, the conceptual hydrologic models attributed to each identified pool were focused on the source of the sustaining waters for each pool. This included if each pool was supported by groundwater inflow, surface water inflow or, a combination of both (see Section 2.3).

Alluvial flowthrough was treated as a surface water source for the purposes of classification, although it is recognised that groundwater is part of alluvial flows. Further, groundwater can be sourced from a local aquifer (e.g., perched aquifer, fractured rock, or fault zones) or the regional aquifer (major aquifer with relatively high intra-aquifer hydraulic connection, allowing for equilibration of water levels on a sub-decadal timescale across the relevant region).

Pools fed by regional groundwater, have higher potential to be impacted by drawdown of the regional aquifer. Local aquifers are unlikely to be affected by drawdown in the regional aquifer although, the area is host to a complex interaction of faults and geological structures that may affect connectivity between the mining area and individual pools.

Within the current study, it was assumed that any pool which persisted into the dry season, beyond what would be likely supported by alluvial throughflow (taking into account evaporative losses), was likely to be groundwater supported to some extent. The source of this groundwater could be either a local aquifer (e.g., perched, fractured rock / regolith), or regional groundwater (i.e., the pool surface is at or below the regional groundwater table). Conversely, pools that were seasonally inundated or periodically inundated/ephemeral were likely to be supported by surface water inflows (runoff) including shallow aquifer inflows into channels and alluvial throughflow. These pools would be unlikely affected by regional aquifer drawdown, though may have potential impacts from any catchment alteration and flow velocity changes due to the NSE project.

Appendix B provides information on which pools were identified as being within the potential groundwater and surface water impact areas.

3.2.1 EVIDENCE MATRIX

For each identified pool, a conceptual model of the potential water source was assigned based on a range of evidence. An evidence matrix for the various lines of evidence for assigning a groundwater or surface water source to each pool, and subsequent hydraulic conceptual model assignment (as outlined in Section 2.4.2.3) is provided in Appendix C.

As an example of the role of elevation as a line of evidence, Figure 3-3 provides a cross-plot of the elevation data and pool fullness score (see Section 2.4.1) for the NSE study area. There is a clear correlation between the fullness or persistence of pools and elevation with pools within the 280-320 m elevation range (ELVIS ground elevation dataset is used to include areas for which Lidar is not available) having a greater representation within the more persistent pools categories. This is not an exclusive relationship, in that pools of low persistence also exist within this elevation band and, some pools with high persistence exist outside this band. For this reason, it is important to consider multiple lines of evidence when assigning a potential conceptual hydrological model to each pool.

Section 2.4.2.3 provides further information on how these lines of evidence were defined and applied.

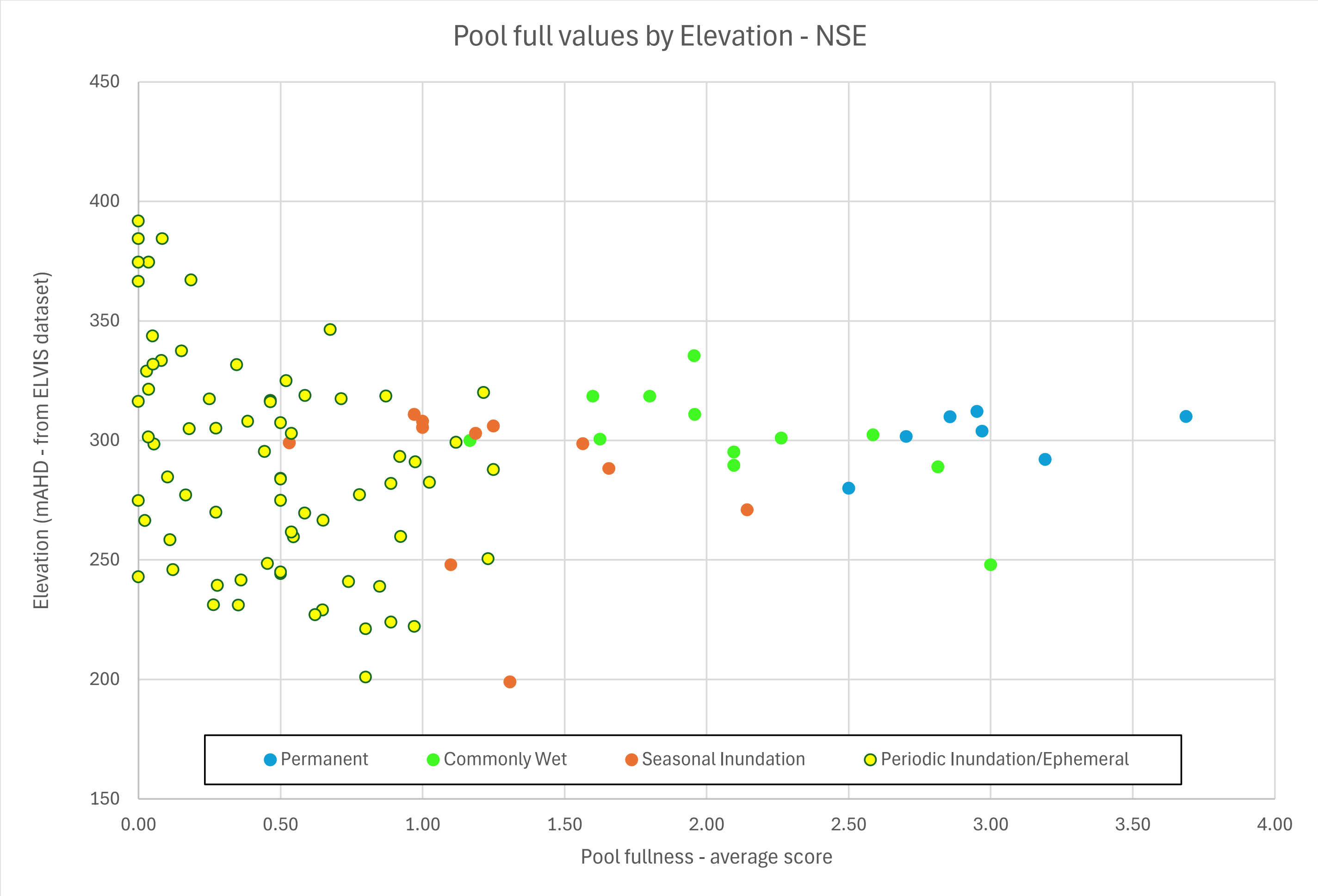


Figure 3-5 Pool fullness score by elevation for NSE study area pools

3.2.2 REACH IDENTIFICATION AND CLASSIFICATION

As described in Section 2.4.3, for the purposes of impact assessment, the individual pools were included within a "reach". The majority of the reaches had only one pool (72 of 82 reaches). Six reaches included 2 pools, 3 reaches included 3 pools, 1 reach had 4 pools and 1 reach had 8 pools (the Site 12 Pool string of pools; Figure 3-4).

Table 3-2 provides a summary of the number of reaches within each water persistence type identified within the potential groundwater and potential surface water impact assessment areas respectively

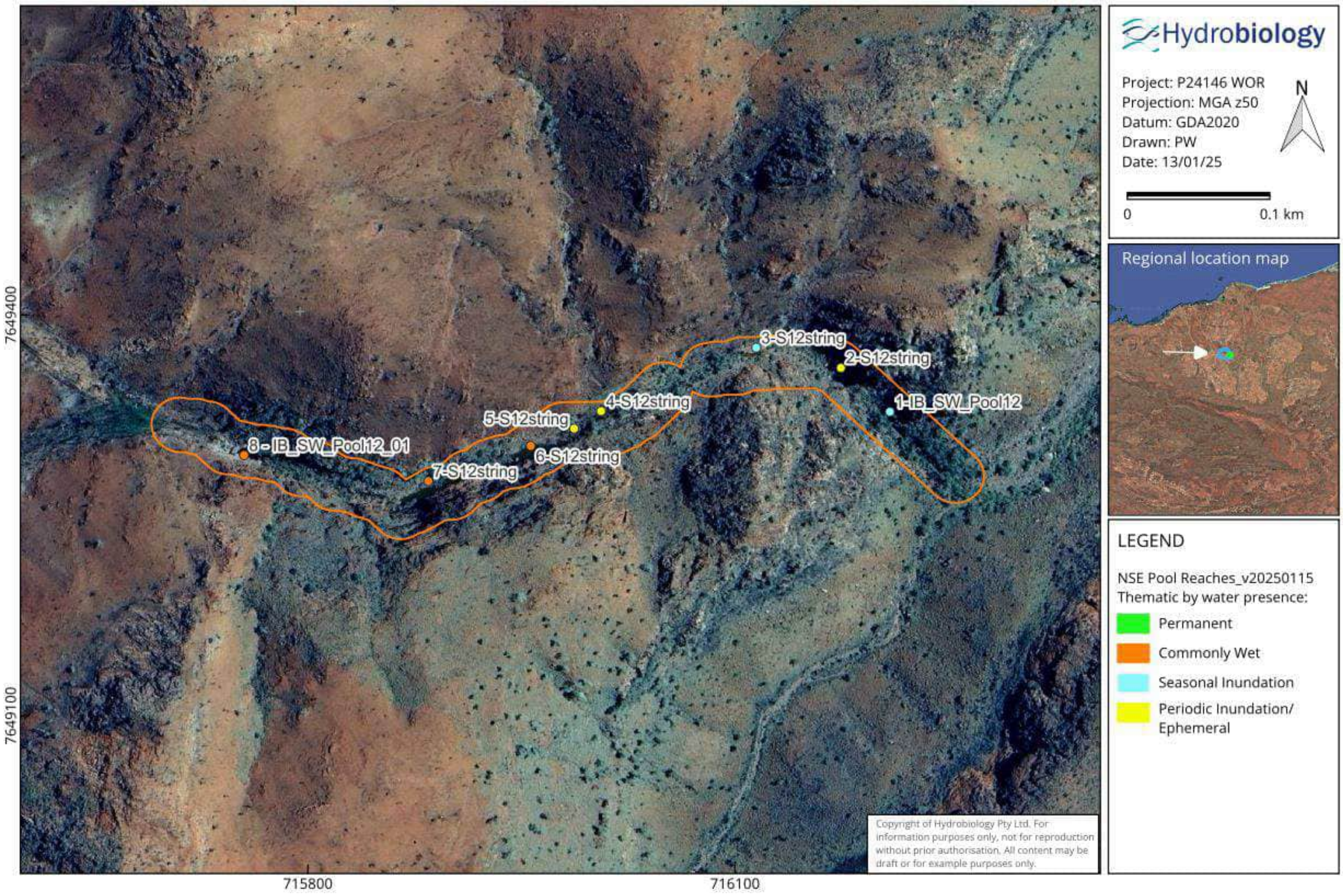


Figure 3-6 Site 12 string of pools showing individual pools and assessed reach

Table 3-2 Count of reaches by water persistence type within the Groundwater and Surface Water Impact areas.

Water Persistence Type	Within Groundwater Impact Area	Within Surface Water Impact Area
Permanent	7	1
Commonly Wet	11	2
Seasonal Inundation	*6*	1
Periodic Inundation/ Ephemeral	*50*	11
Total	**74**	**15**

Table notes:

- *Pools with only seasonal inundation or periodic inundation/ephemeral water persistence types (greyed italic text) were considered unlikely to be groundwater fed.*

Table 3-3 provides a summary of the number of reaches within each identified hydraulic conceptualisation type (after Bourke et. al. 2023). The majority of reaches were identified as being sourced by 1a - alluvium throughflow (35) with the second most common water source being 2a - perched surface water (21) within bedrock features of low permeability (i.e. scoured rock-holes within creek beds). A thematic map of the reaches by hydraulic conceptualisation type presented in Figure 3-5.

As the pool identification and reach allocation was completed largely in GIS software, the primary data repository for this dataset is in the form of electronic shapefiles (SHP). Interrogation of the data at an individual pool or reach level is best achieved within a GIS system, allowing for viewing of attribute information and providing geographic context. Therefore, individual pool maps/images have not been included within this report. The appendix data does include pool coordinate information and therefore can also be converted to GIS format(s) if required.

Table 3-3 Count of reaches within each hydraulic conceptualisation type

Hydraulic Conceptualisation Type	Primary Water Source	Count of Reaches within Study Area	Count within Groundwater Impact Area	Count within Surface Water Impact Area
1a	Alluvium - perched throughflow	34	32	**5**
1b	Alluvium/bedrock - perched surface water throughflow	9	7	**1**
2a	Bedrock - perched surface water	21	19	**6**
2b	Bedrock - fracture flow groundwater source	9	9	0
2a/2b	Potentially either 2a or 2b	7	5	**1**
3	Bedrock aquiclude - groundwater discharge	2	**2**	**2**
4	Topographically controlled groundwater outflow	0	**0**	0
	Total	**82**	**74**	**15**

Table notes:

- *Some reaches are within both the surface water and groundwater impact assessment areas. Therefore, the total number of reaches within the Study Area is less than the sum of the reaches within the combined surface water and groundwater columns.*

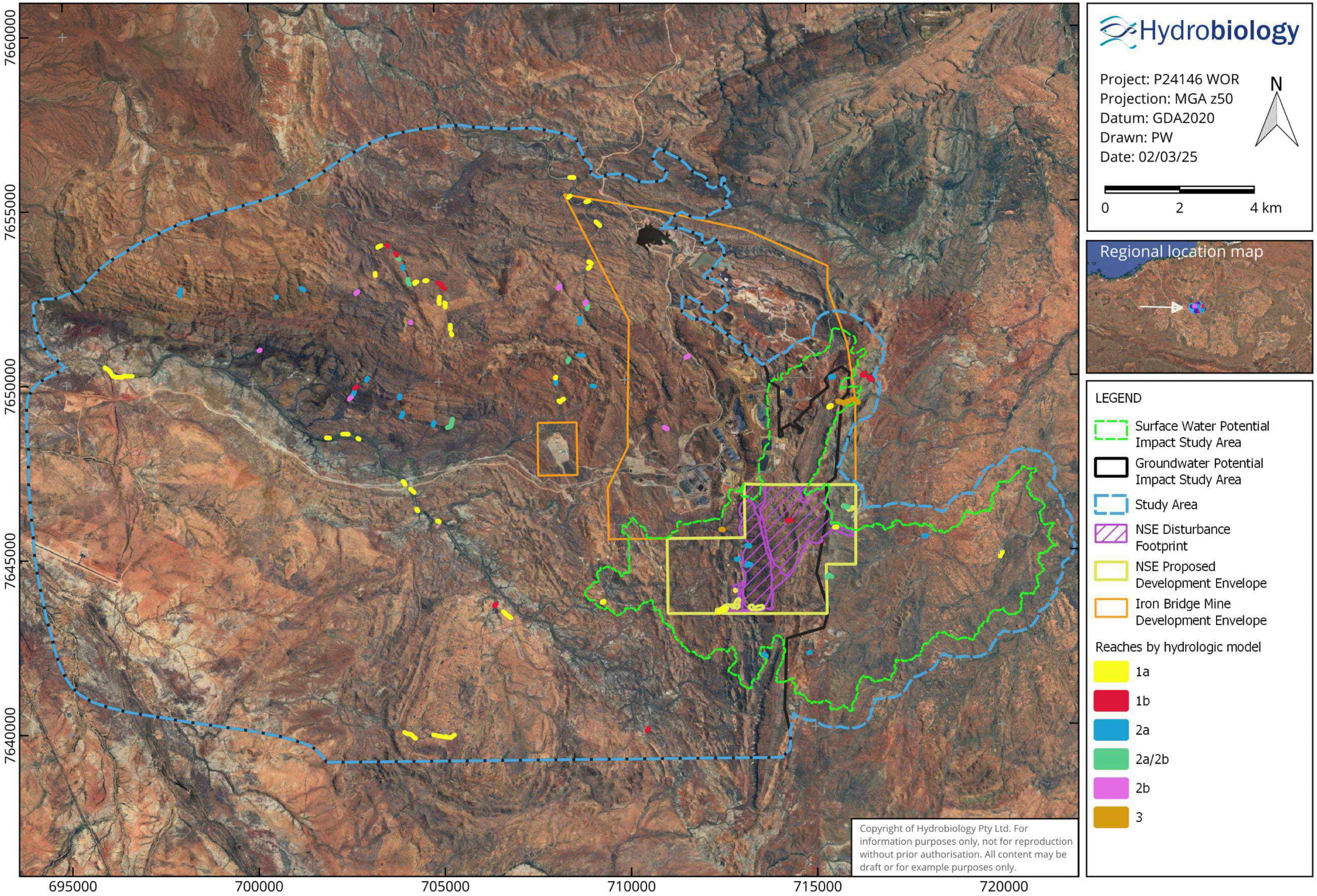


Figure 3-7 Map of reaches by hydraulic conceptualisation type

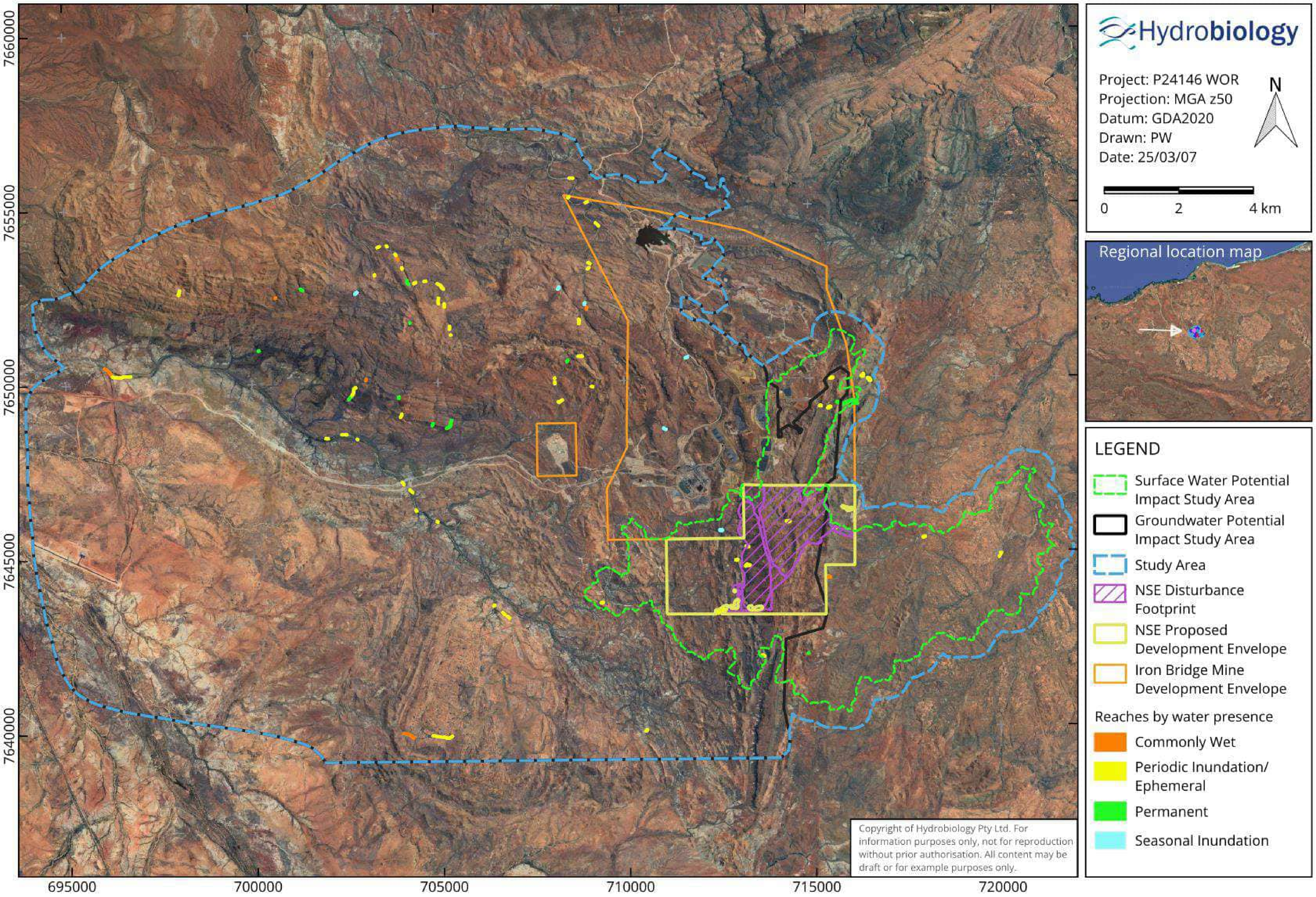


Figure 3-8 Map of reaches by dominant water presence type

3.2.3 CONCEPTUAL MODELS FOR SELECTED POOLS/REACHES

To avoid repetition, we have not provided individual visual conceptual models for every pool identified as potentially impacted within the groundwater and surface water impact assessment areas. However, this section provides conceptual models for previously reported pools (Fortescue, 2023) and newly identified permanent pools, drawing on multiple lines of available evidence to support the hydraulic conceptualisations following Bourke et. al. (2023). Appendix C provides a complete listing of the hydrologic conceptualisation for every pool identified within the current study.

Monitoring data indicates shallow depths to groundwater occur in areas of mapped potential groundwater dependent vegetation which coincide with drainage features in the landscape. Recharge and discharge mechanisms imply a cyclical connection between surface water and groundwater systems. The conceptual interrelationship between these aspects of the environment is illustrated in Figure 3-7.

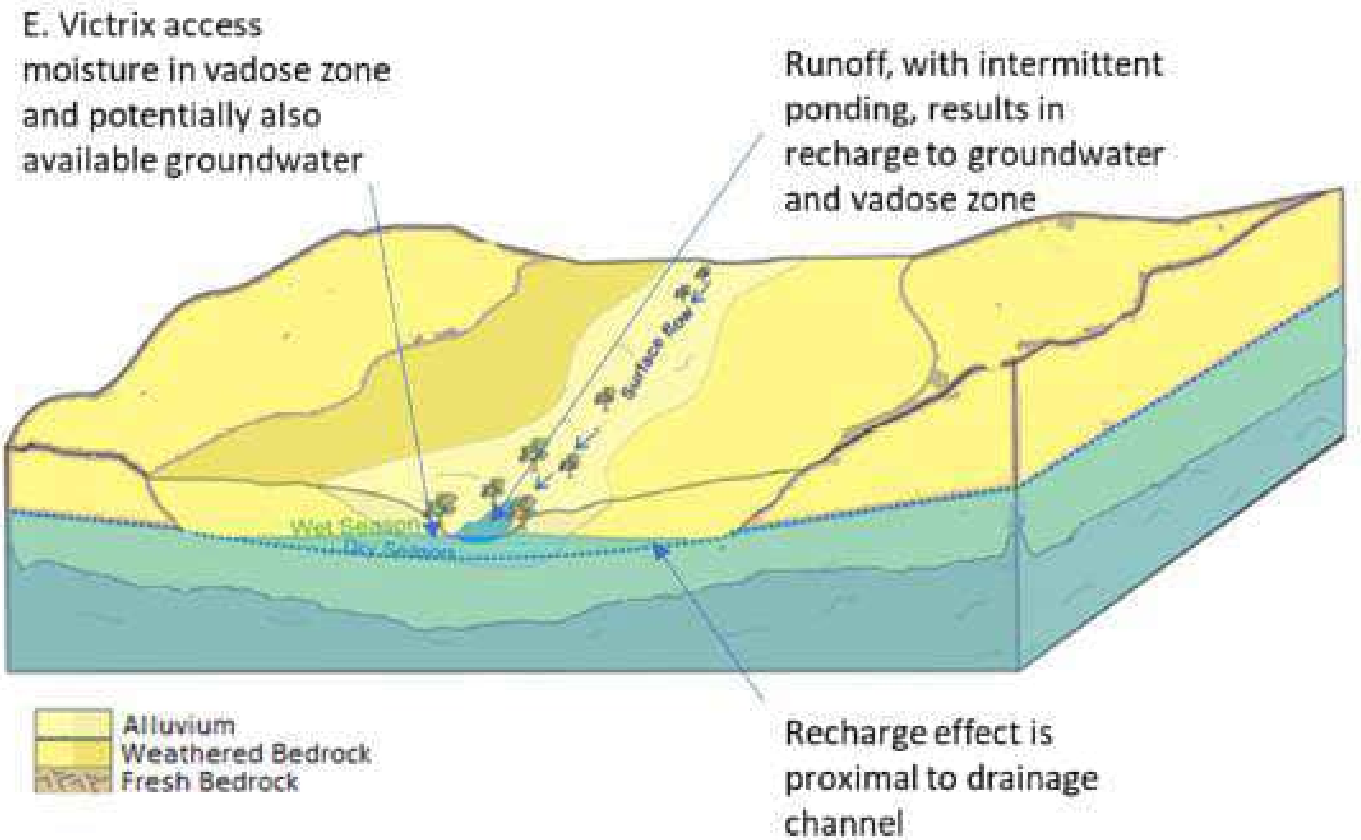


Figure 3-9 Conceptual schematic of generalised groundwater, surface water and vegetation interaction at Iron Bridge Mine (adapted from Bourke et al. [2023]) (Fortescue, 2023).

3.2.3.1 TYPE 1A - ALLUVIUM - PERCHED THROUGHFLOW

Central Creek Pool

The conceptual hydrological model for Central Creek Pool is representative of the majority of the pools within the NSE study area (Type 1a). This pool is within deep alluvium material and has been formed by scouring of the alluvium on a bend in the drainage channel where the flow meets a rock outcrop (Figure 3-8).

The pool forms after the first flow event for the wet season within the creek and typically persists for most of the wet season. The pool recedes between flow events and early in the late wet season/early dry season. The pool does not persist into the dry season and is routinely dry for much of the year. Central Creek pool is classified as “Periodic inundation/Ephemeral” based on water presence data at this site.

The conceptual mechanism is one of filling by alluvial throughflow and receding as the alluvials drain to lower elevations over time (Figure 3-9). There may be some loss to the deeper vadose/groundwater zone vertically, as the pool is perched above the regional groundwater table at this location. It is considered unlikely that there is connection to regional groundwater, other than through losses.

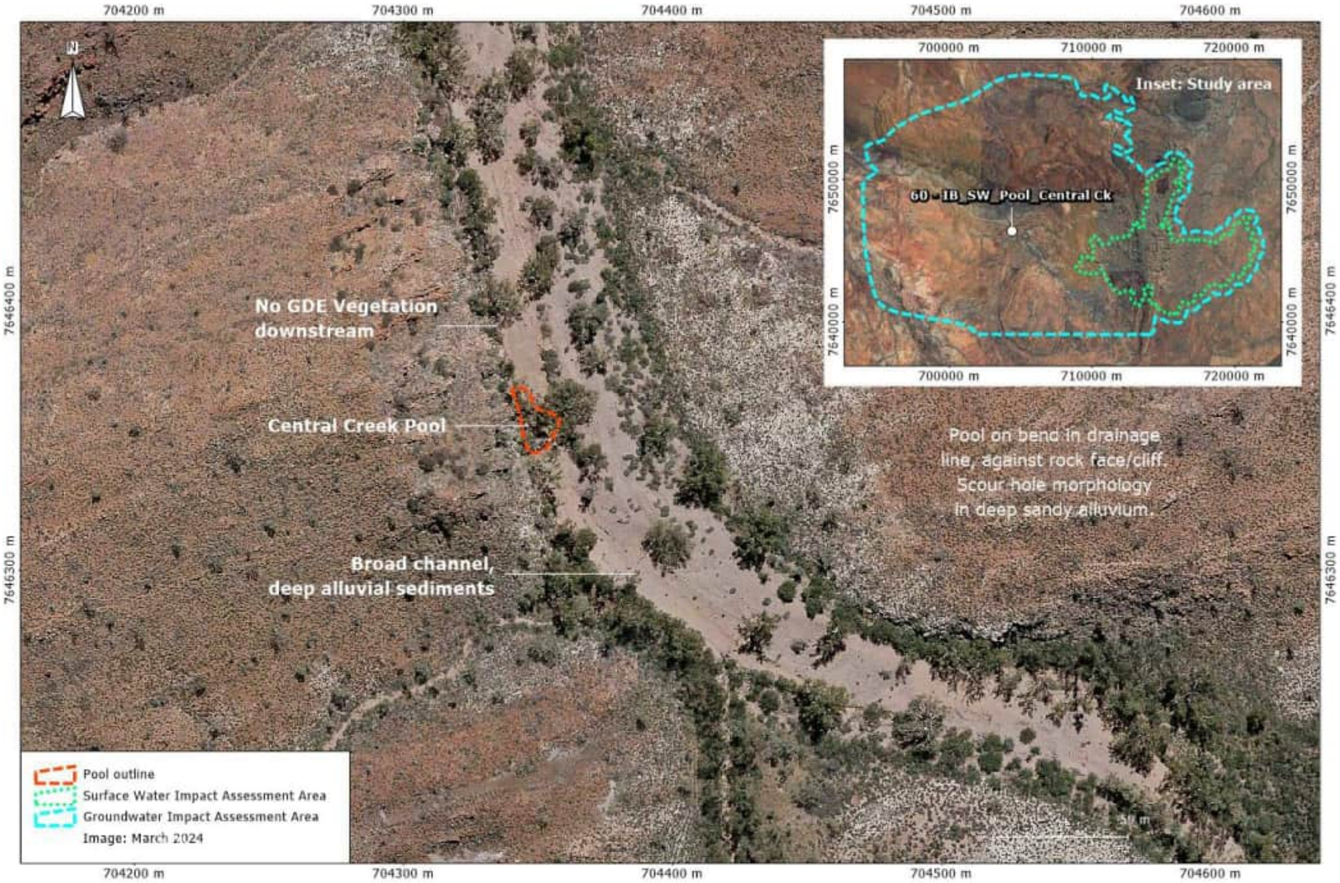


Figure 3-10 Map of Central Creek Pool showing hydrological features.

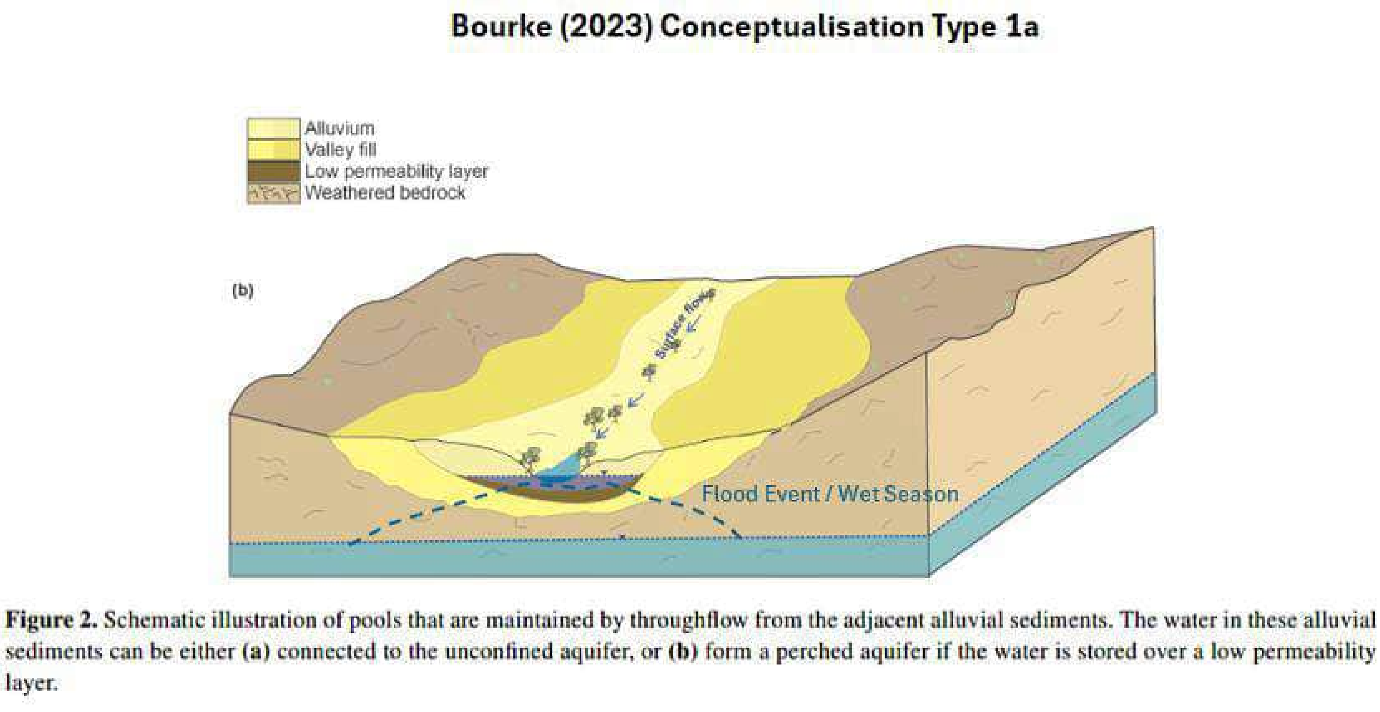


Figure 3-11 Conceptual hydrologic model for Central Creek Pool, Type 1a - Alluvium - perched throughflow

3.2.3.2 TYPE 2B - BEDROCK FRACTURE / REGOLITH FLOW GROUNDWATER SOURCE

Fig Pool

Fig Pool is a small, isolated pool that lies at the base of a rockface with a small catchment area (Figure 3-10). The water level is stable as it is maintained by fresh groundwater and is periodically flushed with fresh surface water flows after rainfall events (Figure 3-11). There is no obvious inflow channel for surface waters and therefore the conceptual model is one of localised shallow groundwater inflow with rainfall entering a fractured rock or regolith material and driving local groundwater within the elevated terrain above the pool to discharge.

The water within this pool is typically of low pH and low in dissolved solids (mean EC is ~200 µS/cm, varying between 20 and 606 µS/cm), indicative of a shallow subsurface circulation source with leached aquifer material (possibly chert). While the dissolved solids (as measured by EC) drop with rainfall events, indicating a surface water inflow connection, the levels increase to a stable ~250-260 µS/cm within days-weeks, indicating replacement by a local groundwater source (i.e., the typical EC within Fig Pool is significantly lower than regional groundwater).

The conceptual model of localised groundwater inflows is supported by the fact that there are large mature melaleuca trees (GDV) immediately downstream of the pool.

Based on the above, Fig Pool has been assigned a “permanent” water persistence classification and a Type 2b hydrologic conceptual model - Bedrock fracture / regolith flow groundwater source (Figure 3-12).

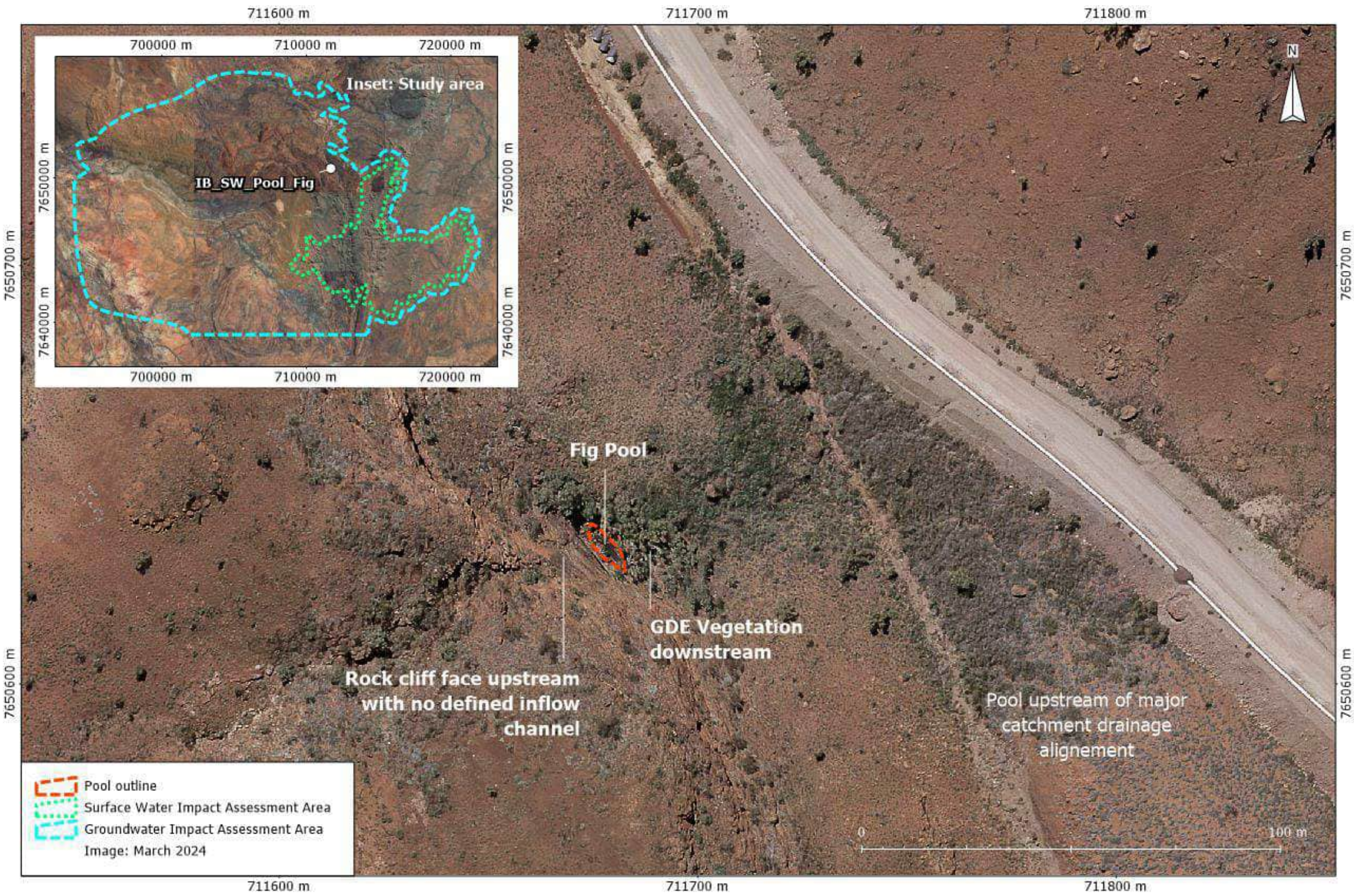


Figure 3-12 Map of Fig Pool showing hydrologic features

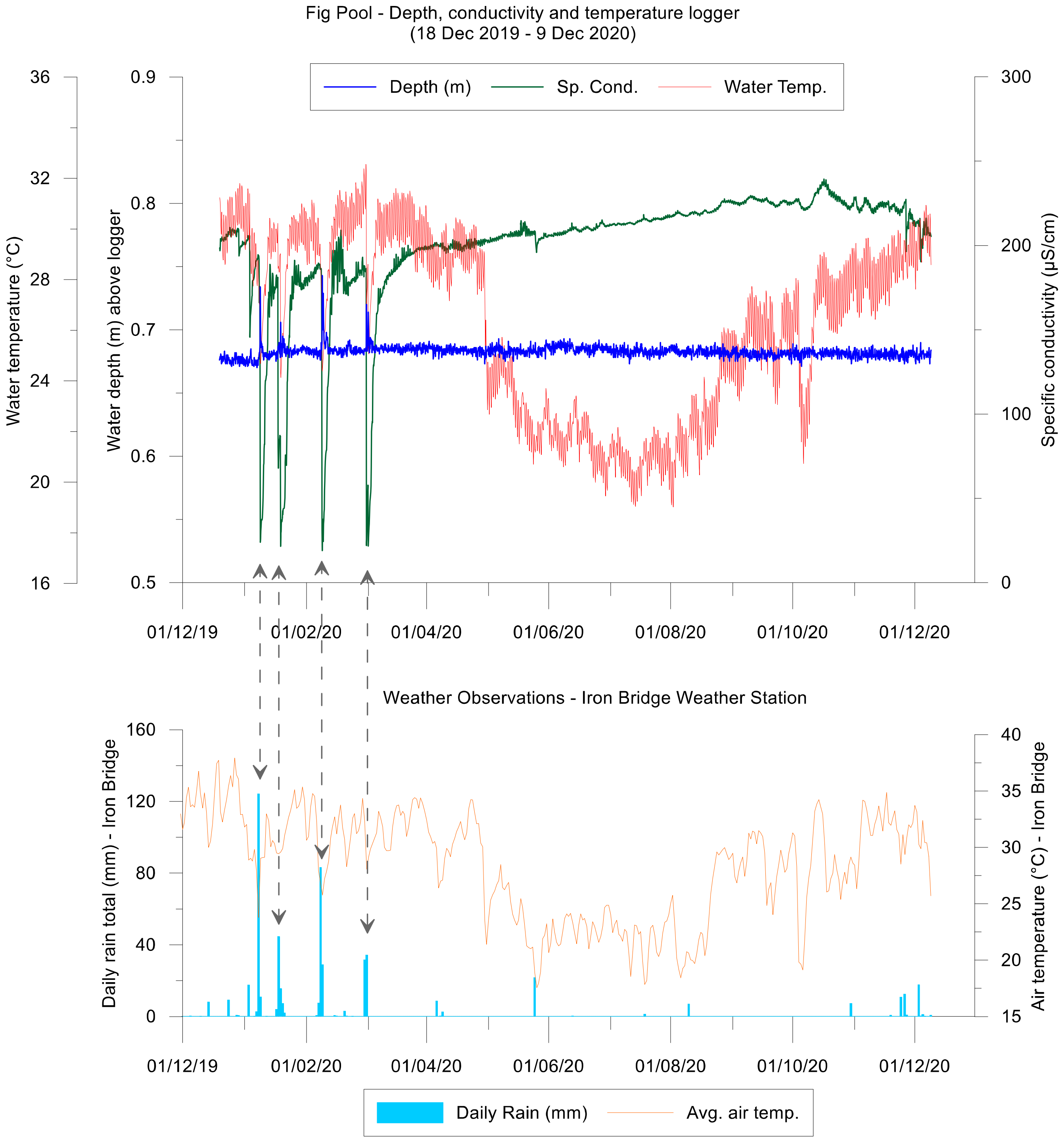


Figure 3-13 Water level, specific conductivity, temperature logger data from Fig Pool over an annual cycle in relation to inflow events – Dec 2019 to Dec 2020.

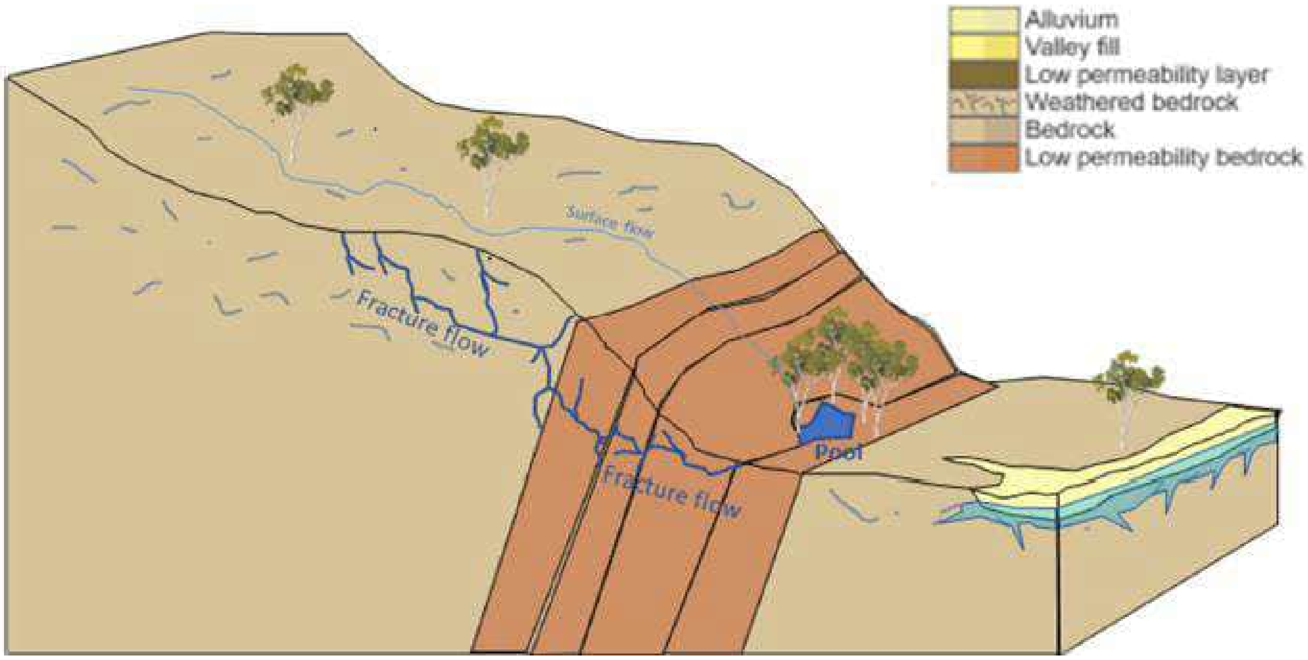


Figure 3-14 Schematic illustration of fracture flow groundwater source for Fig Pool (adapted from Bourke et al. [2023]) (Fortescue 2023).

Cow Spring Pool

Cow Spring is a small pool confined by bedrock habitat that is likely to be sustained by groundwater (Figure 3-13). There is a waterfall above the pool that flows during rainfall events and temporarily replenishes the pool with lower salinity surface waters. These are replaced over days to weeks with a constant inflow of groundwater, as indicated by the overflow from the pool supporting GDV for ~50 m downstream year-round (Figure 3-18). The water level within the pool is constant with only small variations during flow events and in response to vegetation dams downstream being flushed out (Figure 3-14). The mean EC value is 450 µS/cm, varying within a range of 278 to 595 µS/cm. This is fresher than the regional groundwater, indicating a local groundwater source.

Cow Spring pool has a constant fish population, constant water levels and submerged macrophytes. The Pilbara Olive Python has also been observed within this pool, indicating elevated ecological values.

Cow Spring pool has been classified as having a Type 2b hydrologic conceptualisation - Bedrock fracture / regolith flow groundwater source with a “permanent” water persistence category (Figure 3-15).

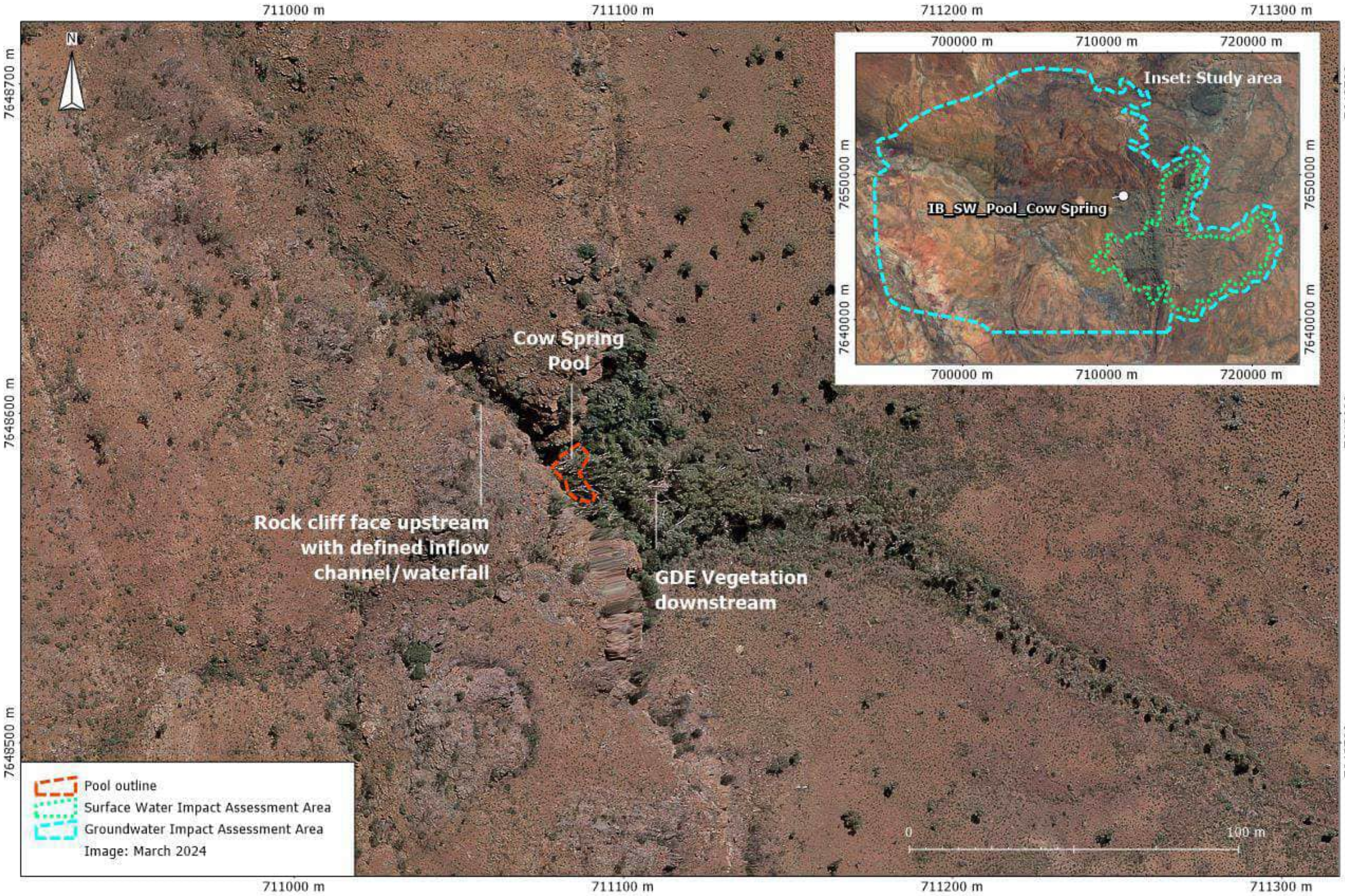


Figure 3-15 Map of Cow Spring Pool showing hydrologic features

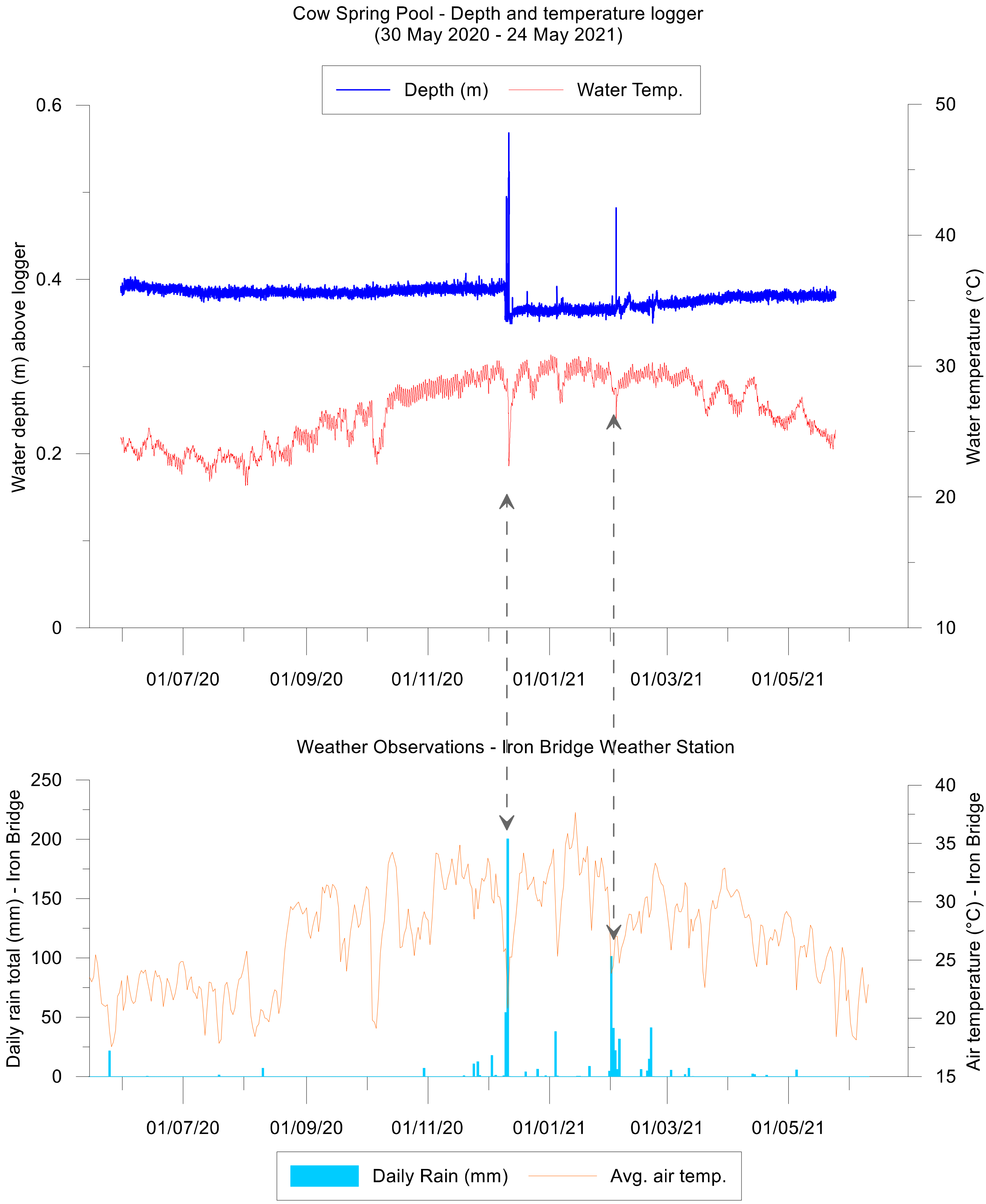


Figure 3-16 Water level and temperature at Cow Spring Pool in relation to rainfall and air temperature – May 2020 to May 2021

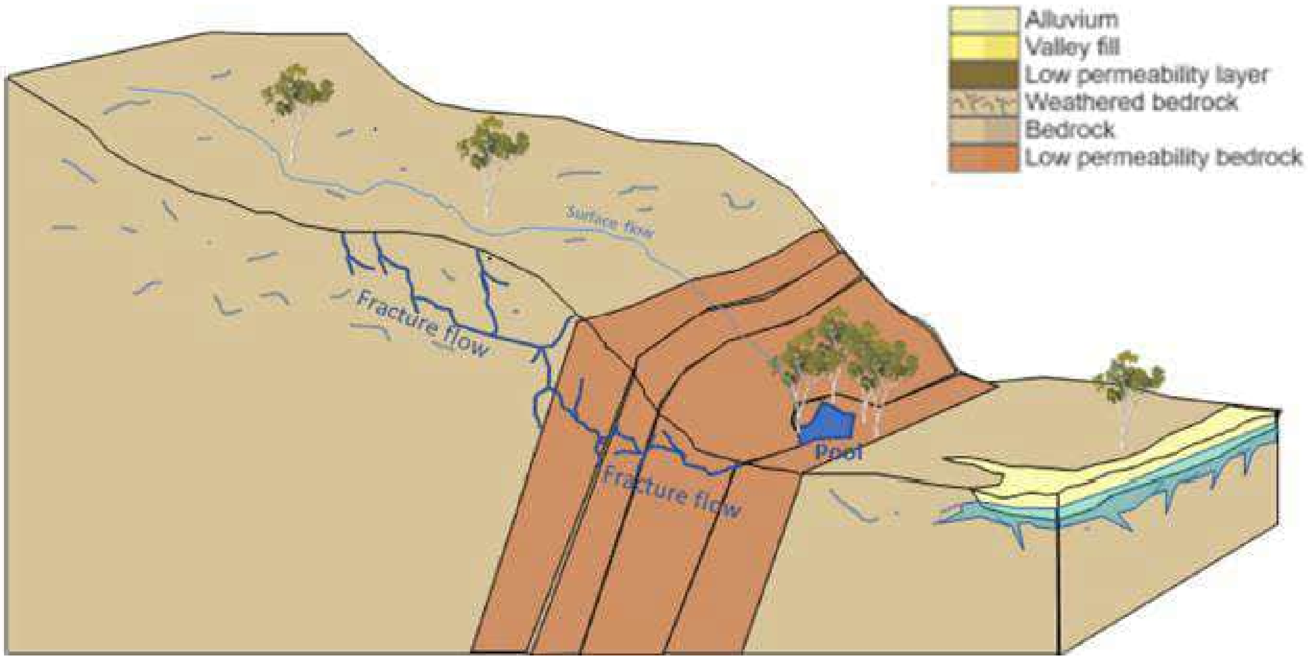


Figure 3-17 Schematic illustration of fracture flow groundwater source for Cow Spring (adapted from Bourke et al. [2023]) (Fortescue 2023).

Pools 93, 44 and 42

Four newly identified pools (from the current pool identification process) have been classified as potentially having permanent water presence and therefore a groundwater source. Three of these pools exist in close proximity to each other to the north of the project area (Pools 93, 44 and 42; Figure 3-16). The fourth pool (GE_4) is discussed separately below. These pools are classified as "Permanent" as water has been present in all available imagery.

Of these three pools, only Pool 44 has been accessed (Figure 3-16). During a site inspection in October 2024, it was noted that there were fish (Spangled Perch) present at Pool 44 and that the water was fresh (149 µs/cm), oxygenated (88% saturation), clear (<1 NTU) and near-neutral pH (6.84). The presence of water and fish at this site during the late dry season, in a relatively dry year, indicates that a groundwater source is present. The low EC (149 µS/cm) indicates this is likely a local groundwater source due to being fresher than regional groundwater (~800 to 1500 µS/cm). Pool 44 had an active seep in the rockface below Pool 93 in October 2024, about 0.5m above the waterline (Figure 3-17, Figure 3-18) indicating inflow from the local aquifer.

Pool 42 is located approximately 800 m to the south-east of Pools 44 and 93 and is within a similar setting within the landscape (273 m elevation, steep elevation drop, constricted channel and bedrock substrate). Note that Pool 93 is at the essentially the same elevation as Pool 42 (274 m). Pool 42 also has a small seasonally inundated pool ~180 m upstream (Pool 43; 307 m elevation) within a similar bedrock setting (Figure 3-19).

These pools (42, 44 and 93) have been classified as Type 2b - Bedrock fracture / regolith flow groundwater source based on their position in the landscape and the indicative geochemistry from Pool 44. All of these pools are classified "permanent" within the water persistence category.

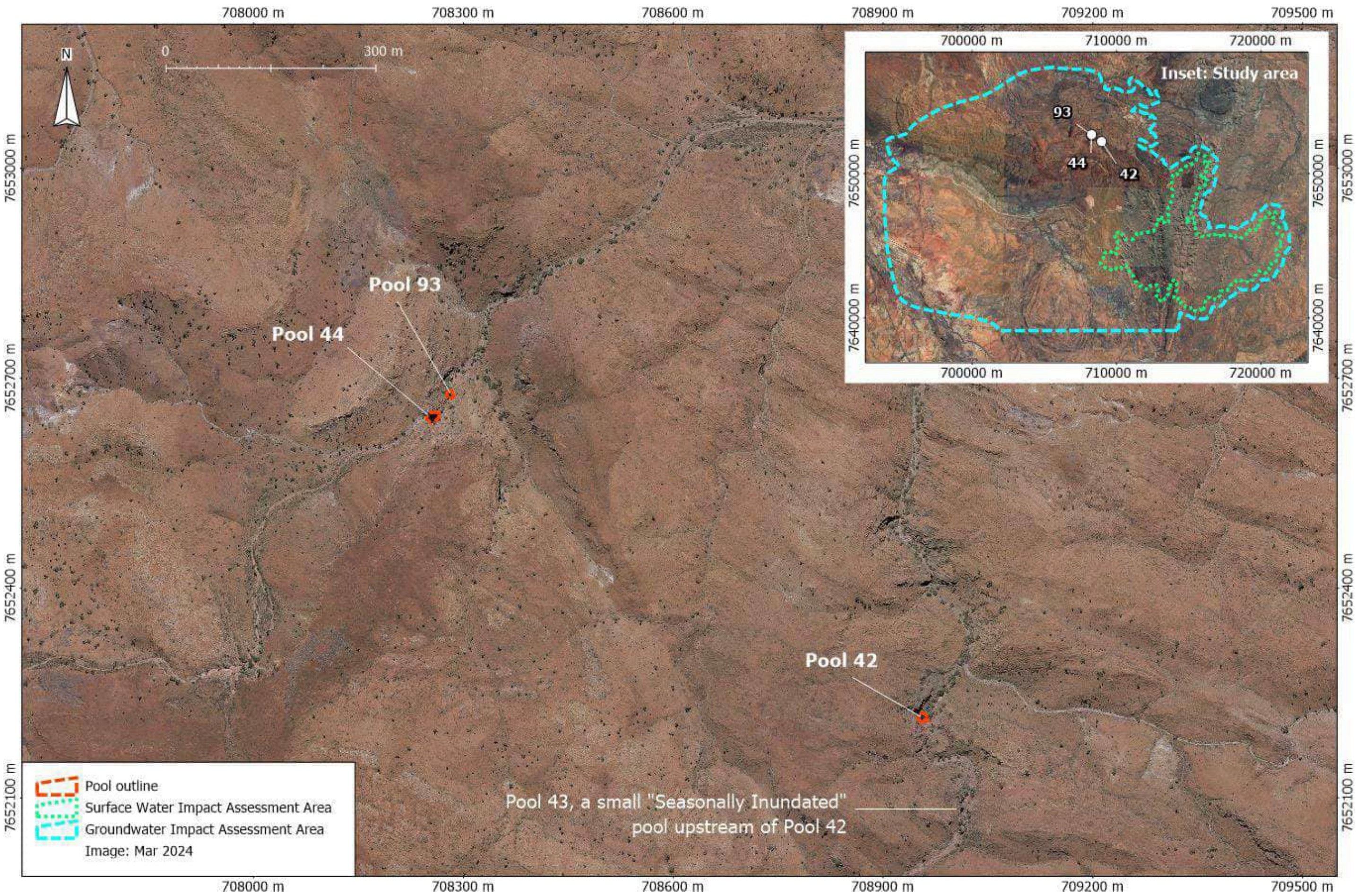


Figure 3-18 Map of Pools 42, 44 and 93.

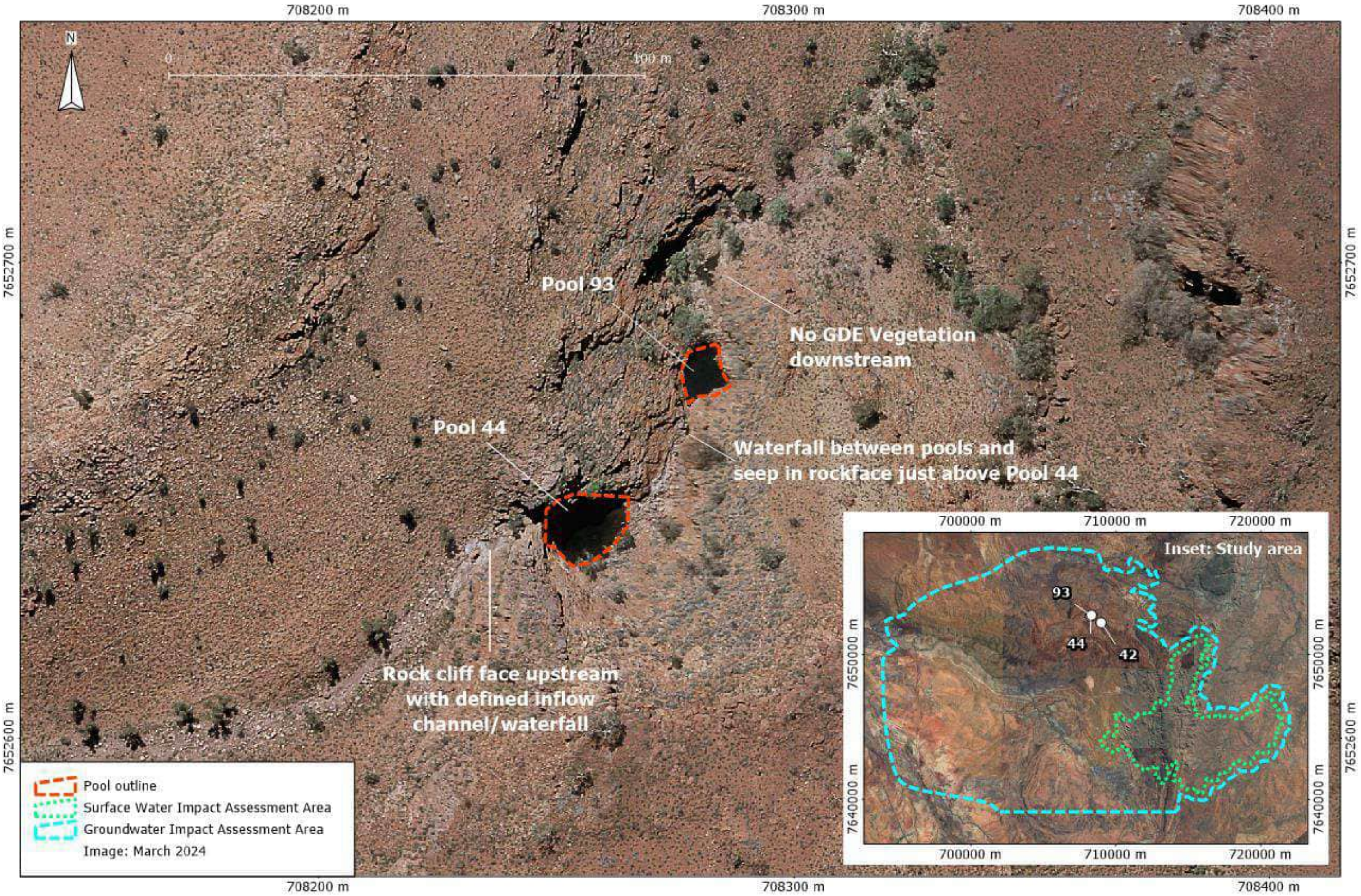


Figure 3-19 Map of Pools 44 and 93 showing hydrologic features.

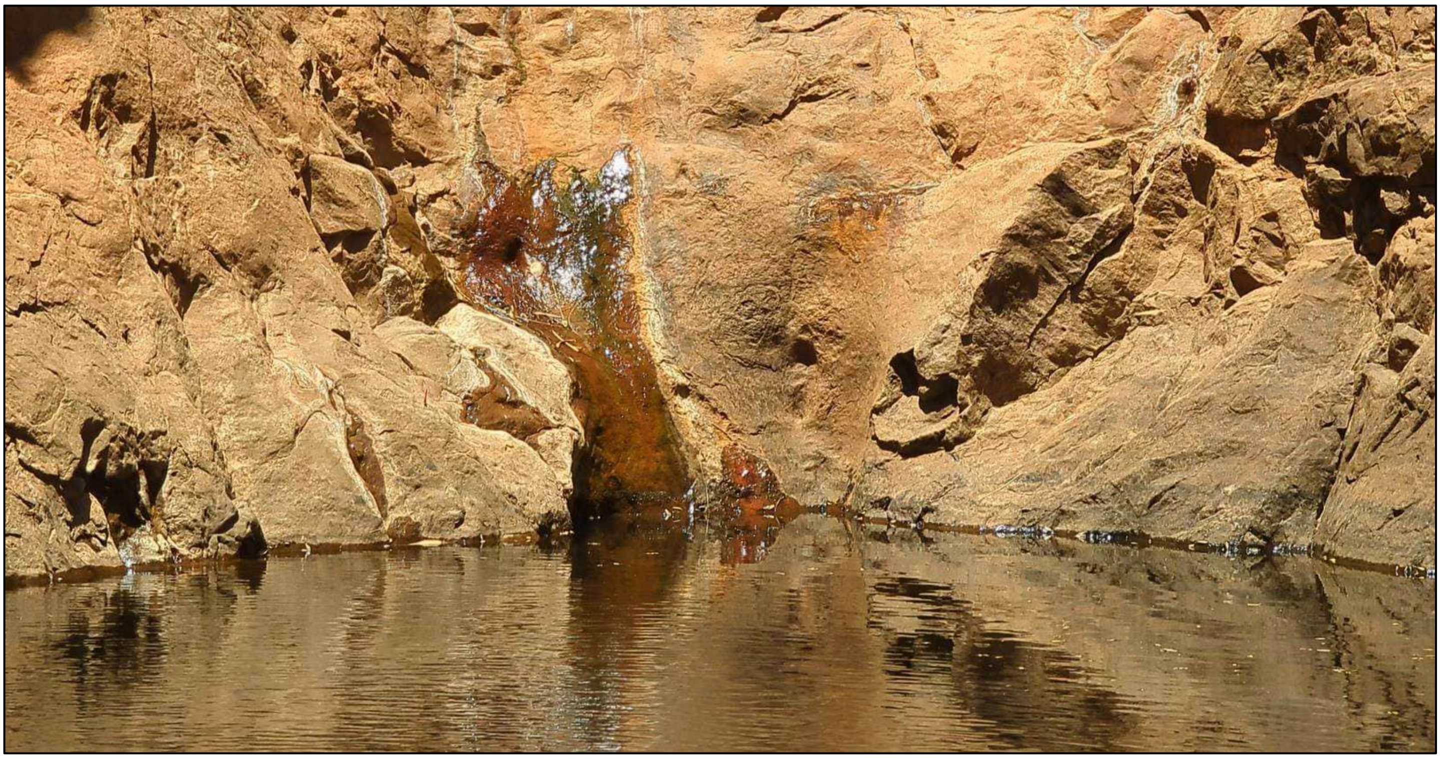


Figure 3-20 Active seep at the upstream end of Pool 44 in October 2024 – 0.5 m above the water line.

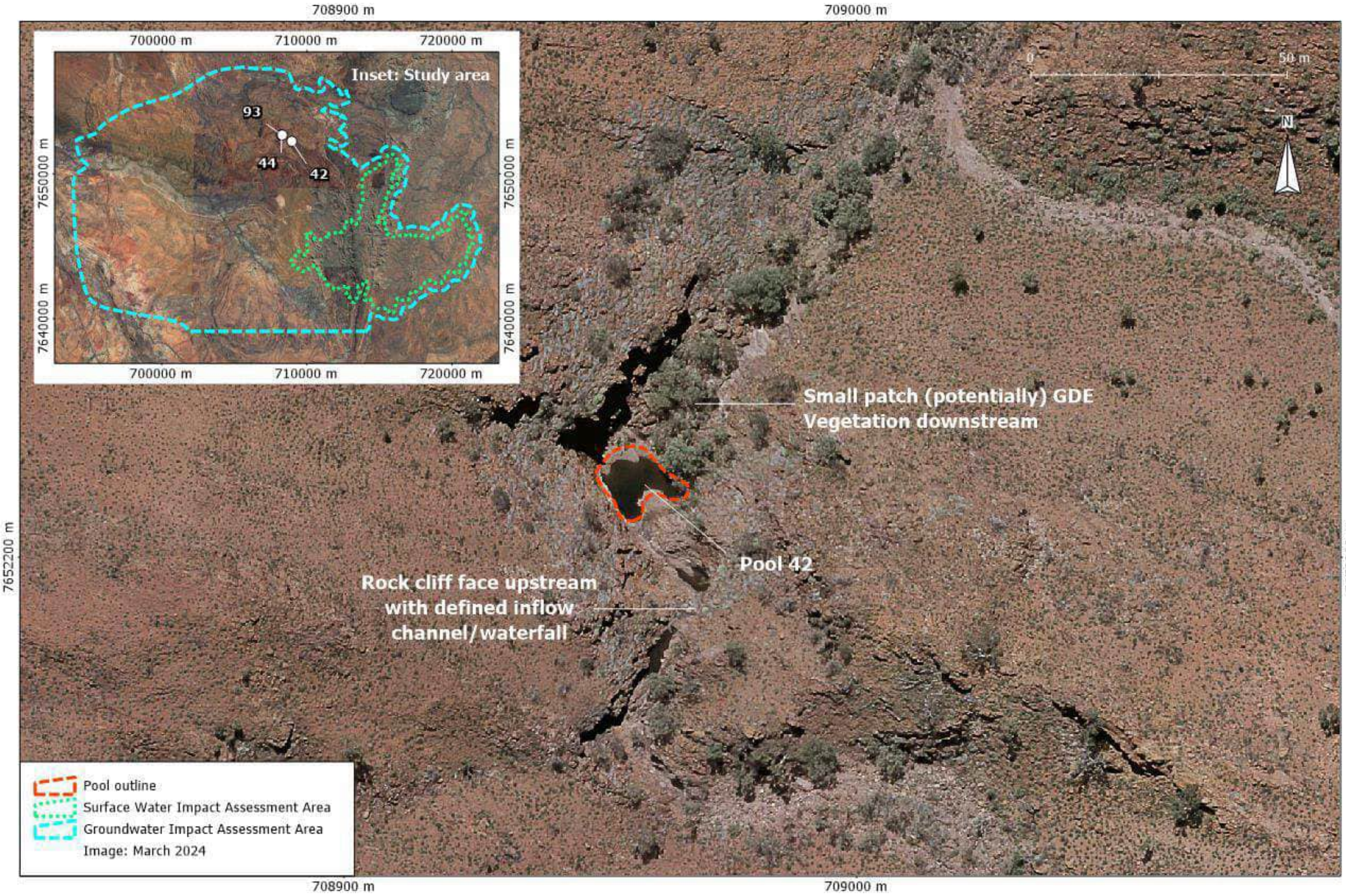


Figure 3-21 Map of Pool 42 showing hydrologic features.

Astrid Bee Cave; Craig's Pool; Dingo Lair Pool; Zane's Gorge Pool.

Whilst no data exists for these pools, their position in the landscape is considered a strong indication of conceptual similarity to Cow Spring and Fig Pools. Figure 3-20 provides an overview map of the location of these pools.

These pools all exist at the base of steep elevation changes (cliffs) and are situated at a similar elevation. As the pools were typically within the shadow of the cliff and their exact location/morphology has not been determined, the water presence and persistence could not be estimated using the aerial imagery provided. Based on their location in the landscape, there is a strong potential for these pools to be supported by a groundwater source. Therefore, as a conservative measure, it has been assumed that these pools are commonly wet and have some groundwater dependency.

Figure 3-21 presents a map figure of the Zane's Gorge string of pools. These pools do not show a GDE vegetation signature though are located within a similar geographic setting to other permanent or semi-permanent pools within the study area. There was water present on 26th October 2024 (late dry season) based on a helicopter overflight undertaken at that time. A Type 2a/2b conceptual hydrologic model (2a - Bedrock - perched surface water; 2b - Bedrock fracture / regolith flow groundwater source) has been applied to this pool based on its position in the landscape and limited available data.

Figure 3-22 presents a map figure of the Dingo Lair pool. This pool did not have high-resolution imagery coverage and was characterised based on publicly available satellite imagery (Google Earth and Virtual Earth), as well as vegetation (NDVI) and elevation datasets. A Type 2a conceptual hydrologic model (2a - Bedrock - perched surface water) has been applied to this pool based on its position in the landscape and limited available data.

Figure 3-23 provides a map figure of Craig's Pool, which has a series of semi-permanent pools on top of the escarpment and a pool of unknown permanence at the base of the cliff face (Figure 3-24). If any GDE vegetation exists adjacent to this pool it is likely to be of limited extent, based on the oblique aerial imagery. A Type 2b conceptual hydrologic model (2b - Bedrock fracture / regolith flow groundwater source) has been applied to this pool based on its position in the landscape and limited available data.

Figure 3-25 provides a map figure of the Astrid Bee Cave pool area. The exact location of this pool is not known, due to the shadow present in satellite/aerial imagery. To date, this pool had not been inspected by the surface water monitoring team on-site due to access difficulty. A Type 2b conceptual hydrologic model (2b - Bedrock fracture / regolith flow groundwater source) has been applied to this pool based on its position in the landscape and limited available data.

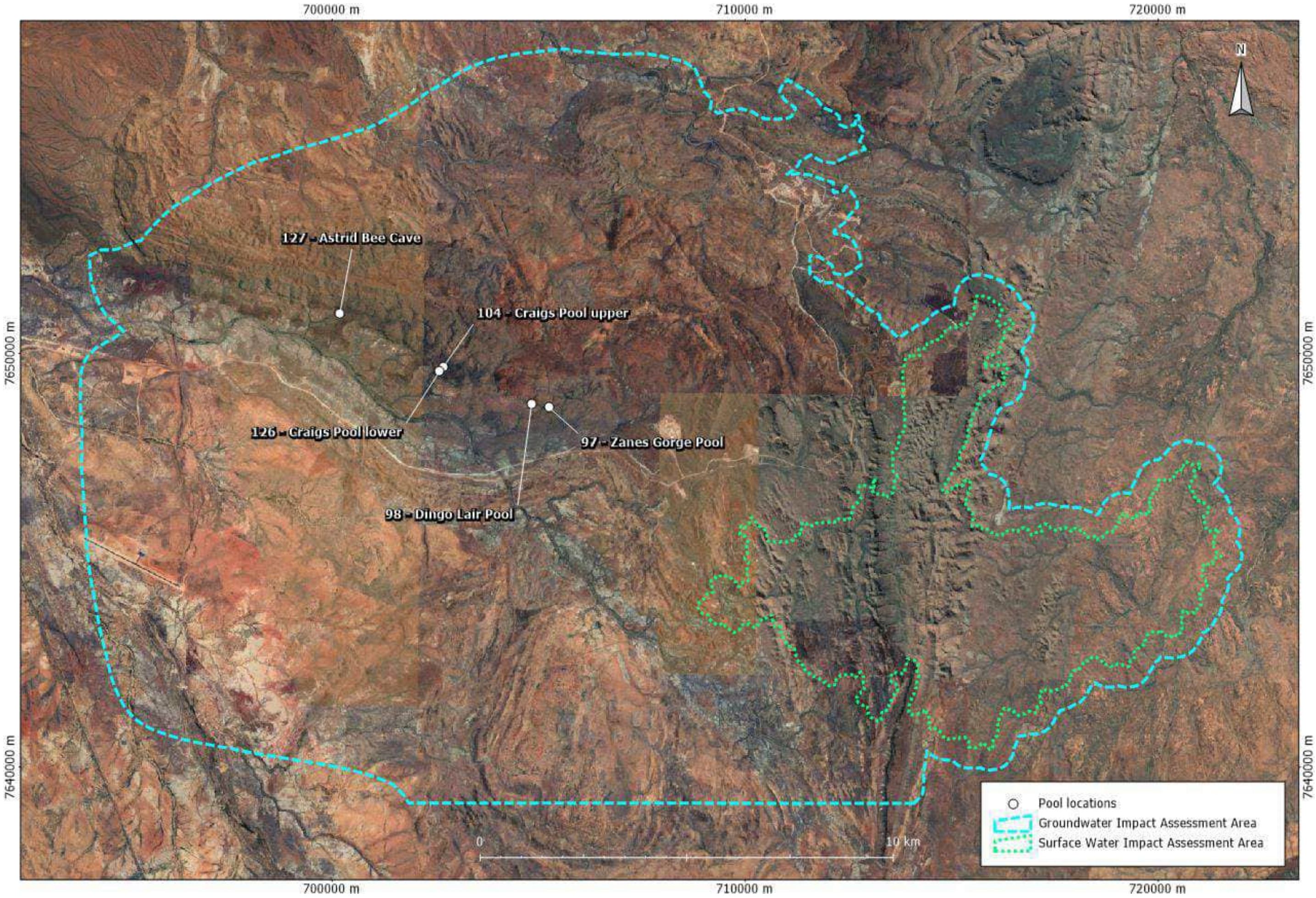


Figure 3-22 Map location of Astrid Bee Cave, Craig's, Zane's Gorge and Dingo Lair pools

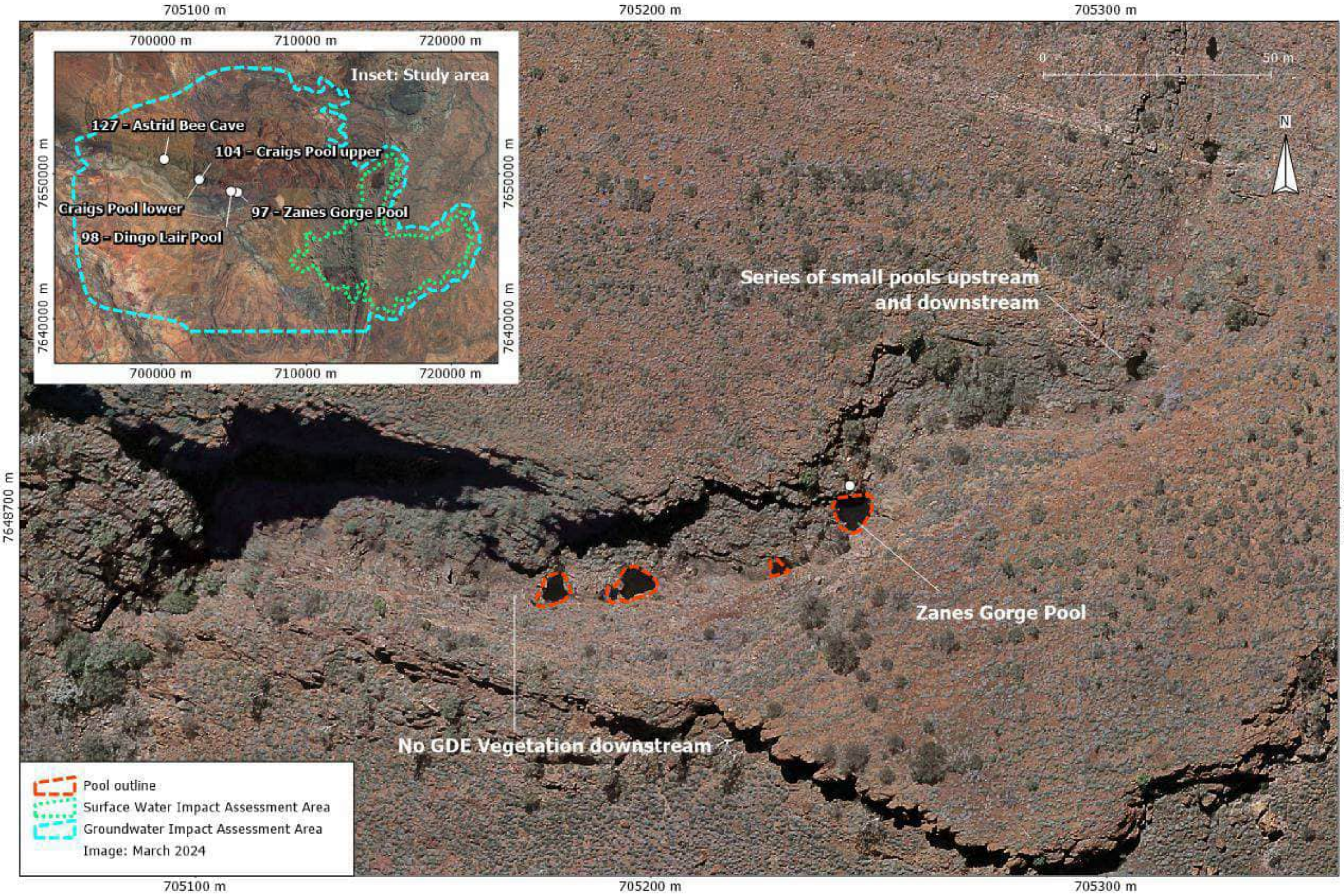


Figure 3-23 Map of Zane's Gorge Pool showing hydrologic features

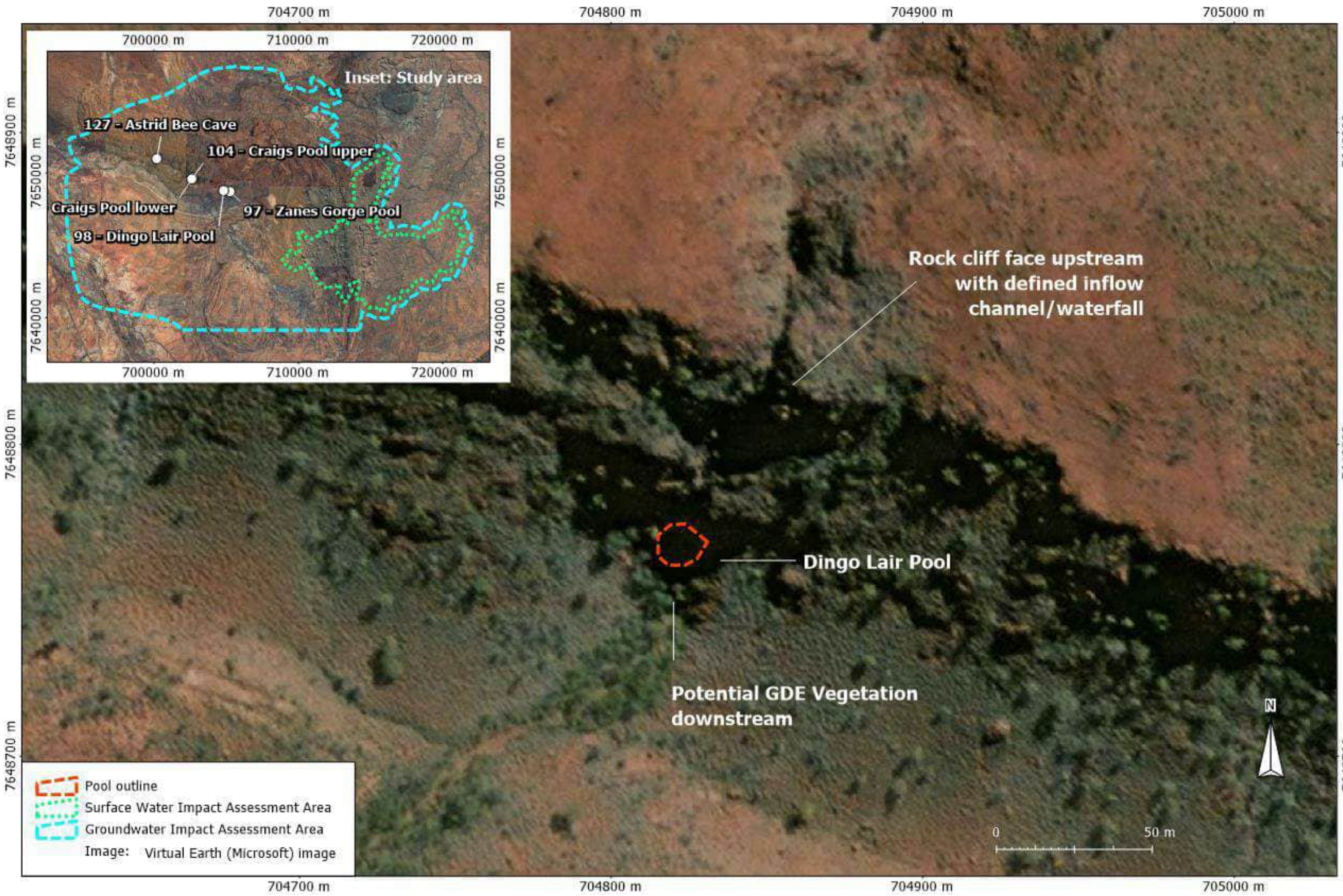


Figure 3-24 Map of Dingo Lair Pool showing hydrologic features.

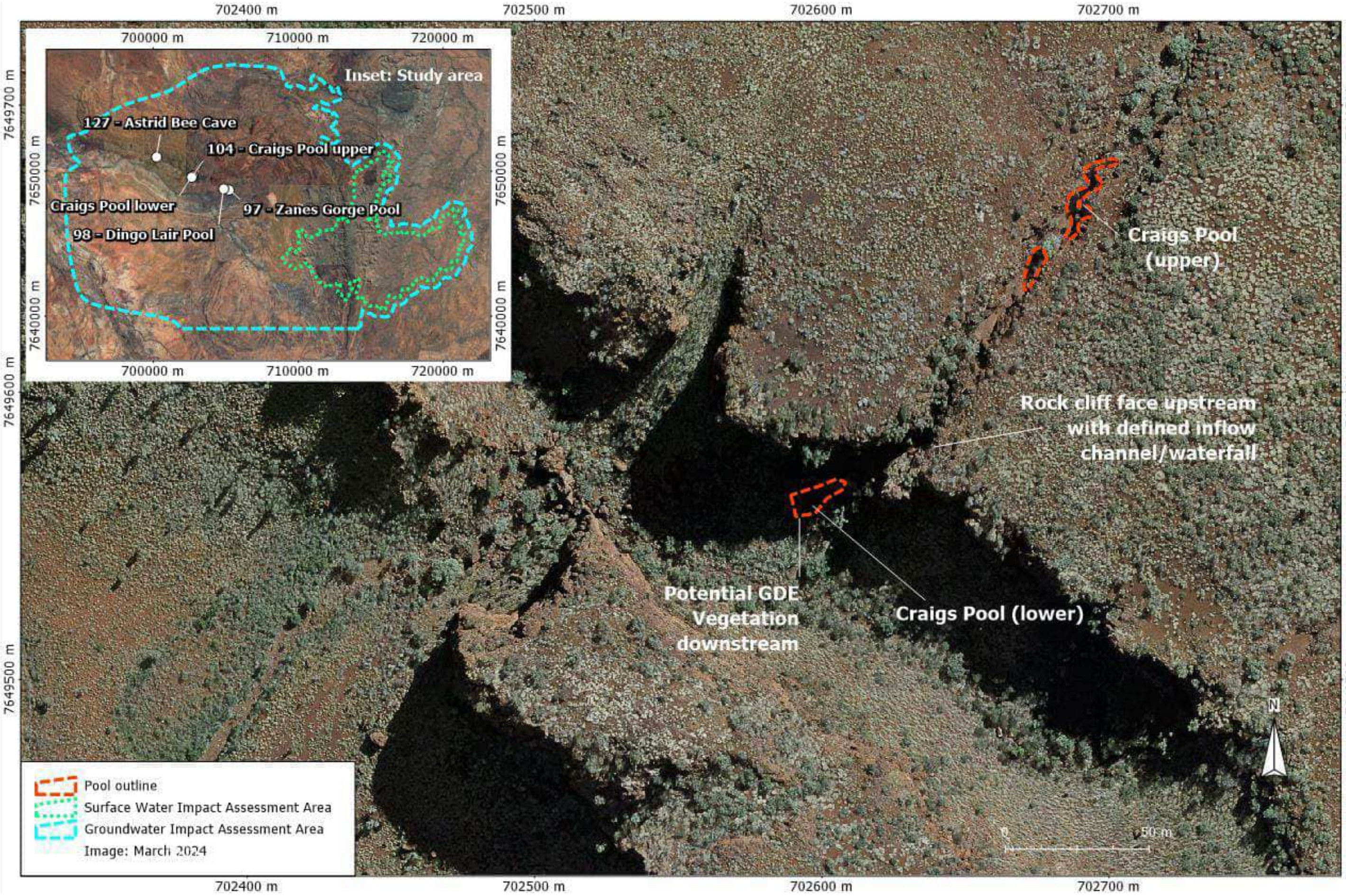


Figure 3-25 Map of Craig's Pool showing hydrologic features.

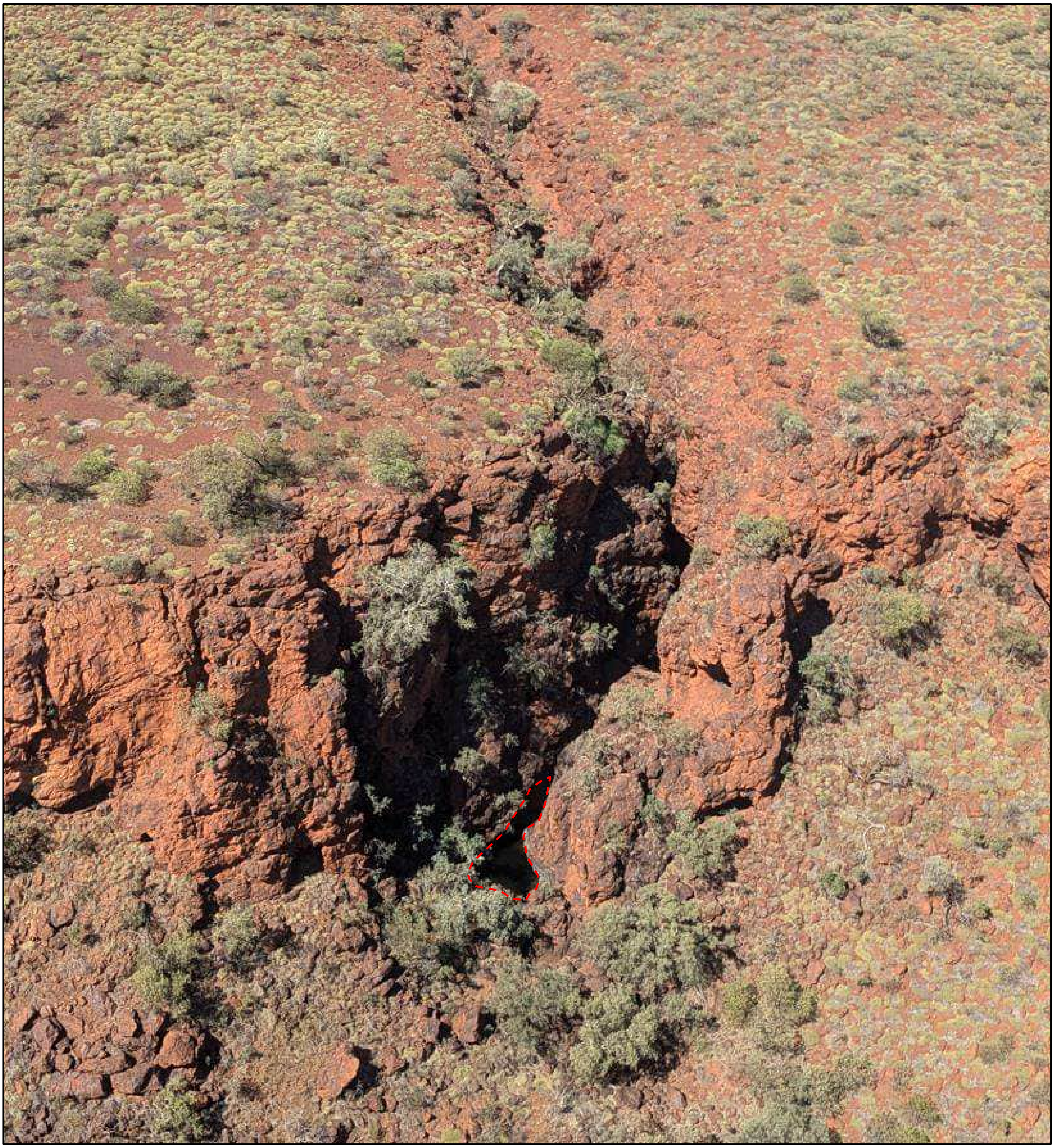


Figure 3-26 Oblique aerial photograph of Craig's Pool (lower) on 26th October 2024 showing water presence (red dash polygon)

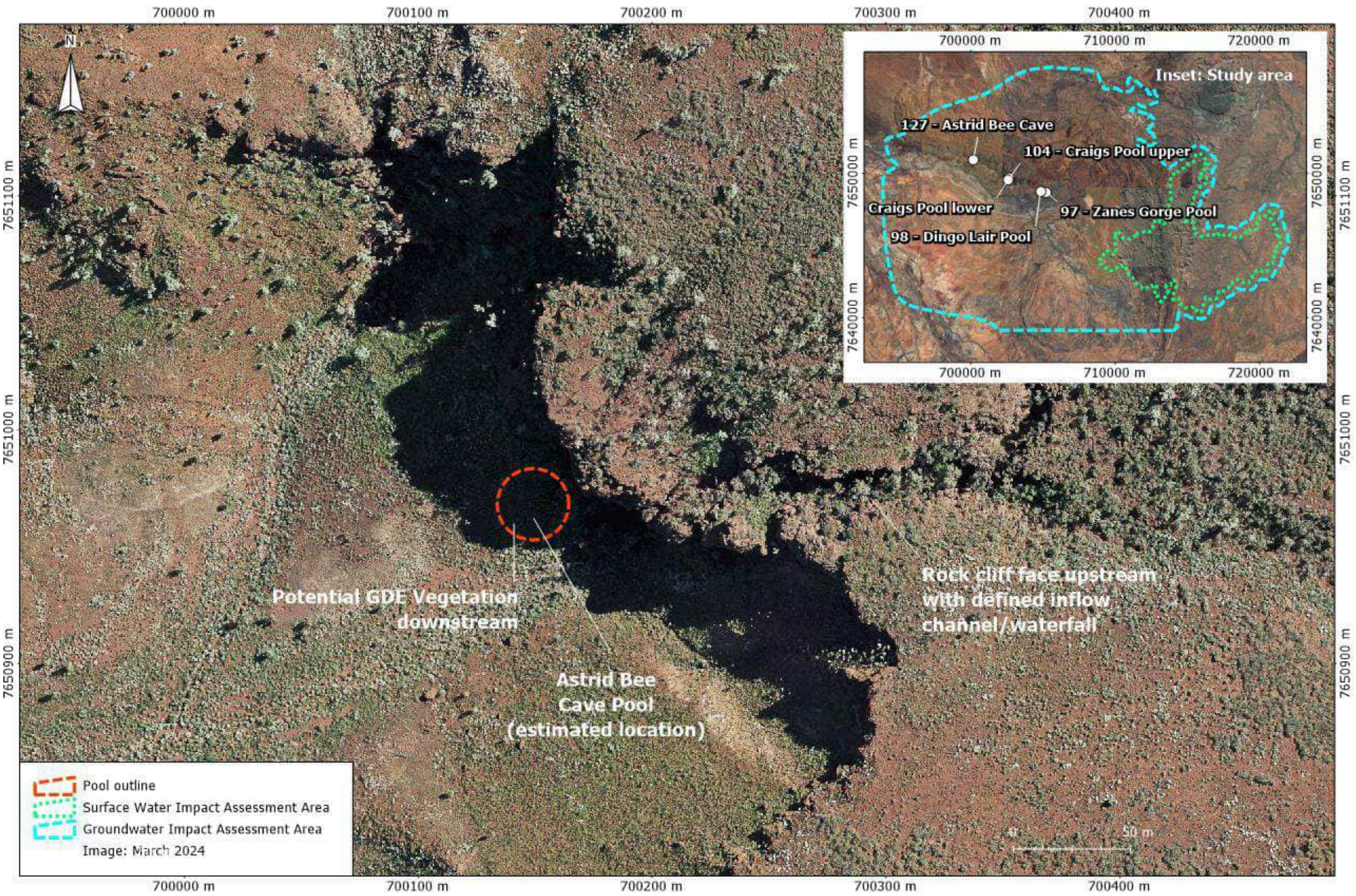


Figure 3-27 Map of Astrid Bee Cave Pool (estimated location) showing hydrologic features.

GE_4 Pool

As part of the review of pools outside the high-resolution imagery capture area for the NSE project, a set of pools were identified based on Google Earth imagery. One pool, GE_4, had water present on all nine images available in Google Earth (ranging from September 2011 to March 2024). GE_4 is located at the base of a rockface/cliff, similar to many other study area permanent pools, and has evidence of thicker vegetation adjacent to the pool suggesting potential GDE. This pool has two smaller pools immediately above it (on top of the cliff) and one small pool adjacent to the east (Figure 3-26). There appears to be a seep (from staining) on the rockface above the pool, which maybe a source of groundwater inputs (and/or drainage from the pool above it). In this respect it potentially has a similar arrangement to the Pool 44/93 hydrology.

Investigation of the NDVI and moisture index (Sentinel 2 dataset) for the GE_4 pool area indicates a similar pattern to Cow Spring and Mundagoora Pool with a concentrated soil moisture area downstream of the pool and elevated dry season NDVI signature.

GE_4 Pool has been classified as a Type 2b - Bedrock fracture / regolith flow groundwater source based on its position in the landscape and supporting features. GE_4 has a “permanent” water persistence classification.

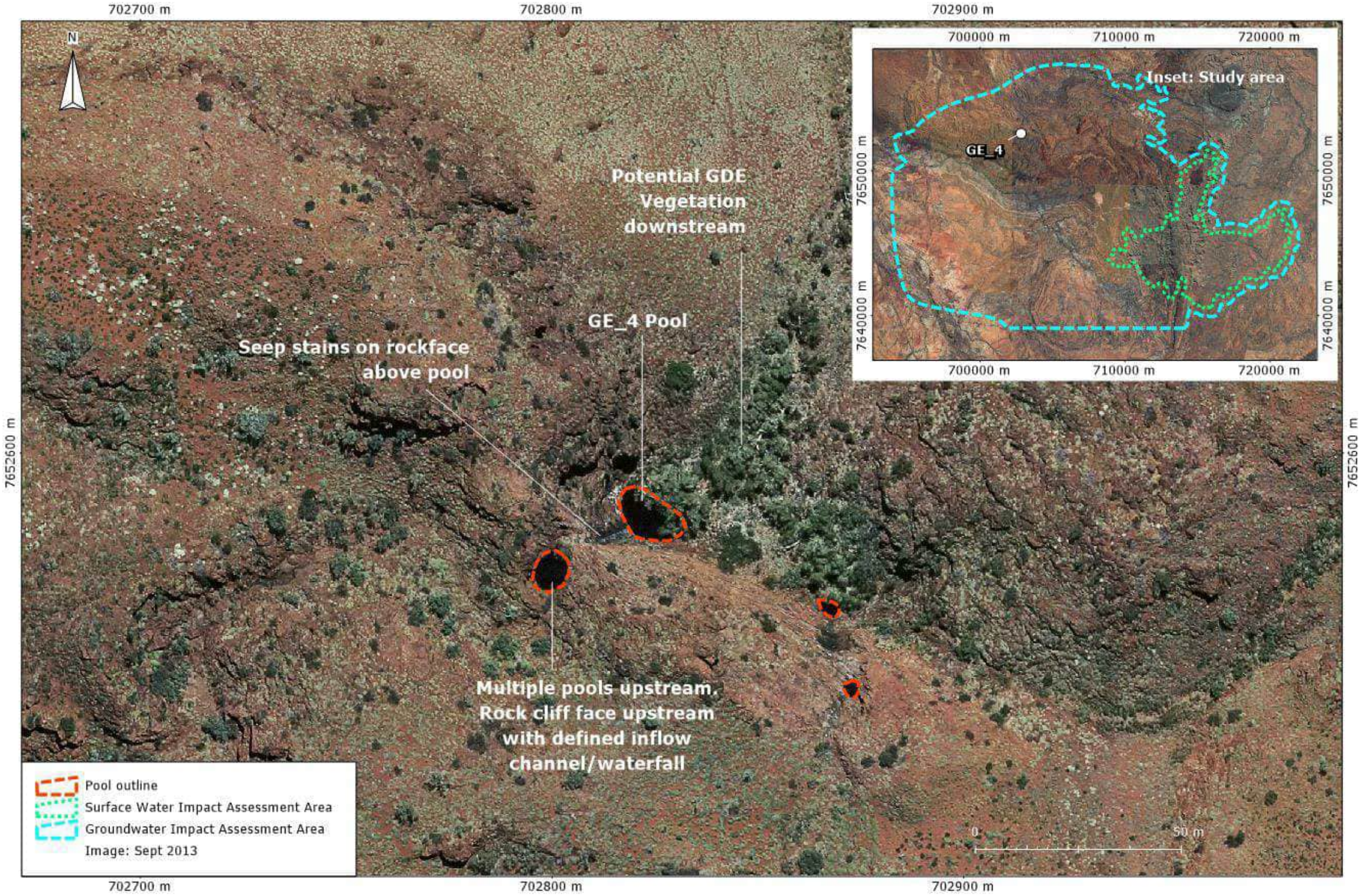


Figure 3-28 Map of GE_4 Pool showing hydrologic features.

3.2.3.3 TYPE 3 - BEDROCK AQUICLUDE - GROUNDWATER DISCHARGE

Mundagoora Pool

Mundagoora Pool is a relatively deep permanent pool located at the base of an intermittent waterfall, with surface water inflow only occurring during high rainfall events. The pool is located to the west of the NSE development area and south of the existing Operational Processing Facility (OPF; Figure 3-8). The pool water level is controlled by a sill at the downstream edge, with water levels remaining relatively consistent within the pool except for short duration peaks during high rainfall. Monitoring survey data indicates the pool is largely sustained by groundwater with periodic flushing of fresh surface water flows after rainfall events. The discharge or overflow from Mundagoora Pool supports a groundwater dependent ecosystem (GDE) downstream for a length of 150-300 m depending on the strength of the antecedent wet season and discharge rates (Figure 3-8).

The hydrochemistry of this pool shows that large rainfall events can flush the pool with surface water from once to several times per wet season (Figure 3-9). The fresher (less salty) surface waters are replaced by groundwater inflows (indicated by higher salinities) over a period of 2-3 weeks following these rainfall/flow events (pool's mean EC is ~900 µS/cm, within a range of 50 to 1000 µS/cm). The estimated groundwater inflow rate, based on the rate of salt replacement following a surface water flow event, is ~0.19 L/s.

This indicates that for the majority of the annual hydro-cycle, the pool is supported by groundwater inflows. The pool surface level is relatively constant throughout the year with fluctuations of <0.3 m from dry to wet season at a maximum depth of over 3 m. Over the monitoring period, flood peaks were observed to be limited to only ~0.6 m above the normal pool levels.

The permanent near-full status of the pool and, the dense groundwater dependent vegetation immediately downstream of the pool, indicates a groundwater source. The conceptual model applied to Mundagoora Pool is

Type 3 - Bedrock aquiclude - groundwater discharge (Figure 3-10). Appendix C provides a listing of all pool/reach conceptual model classifications.

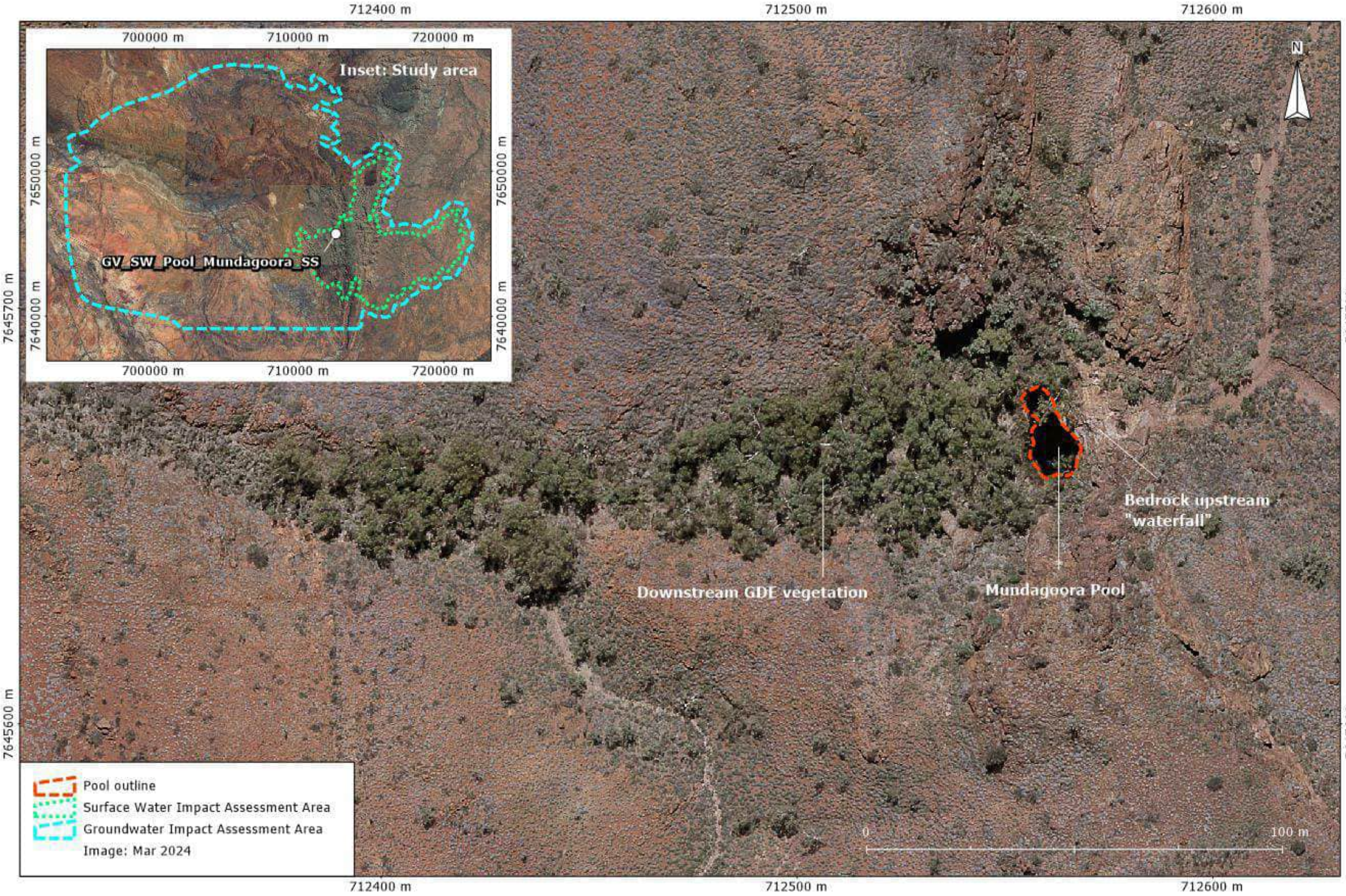


Figure 3-29 Map of Mundagoora Pool

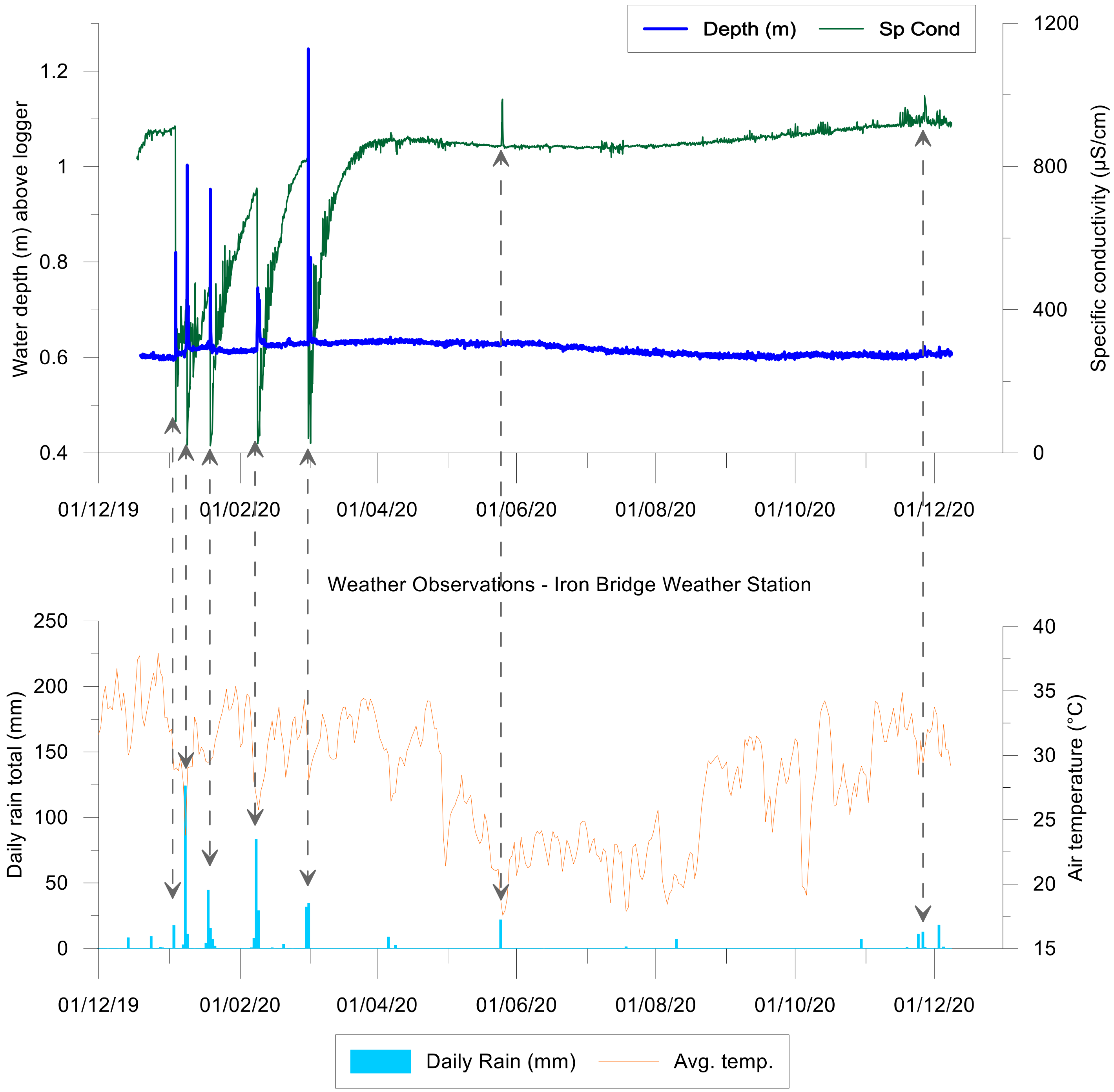


Figure 3-30 Annual water level and salinity (EC) at Mundagoora Pool in response to rainfall events (2019/20 season)

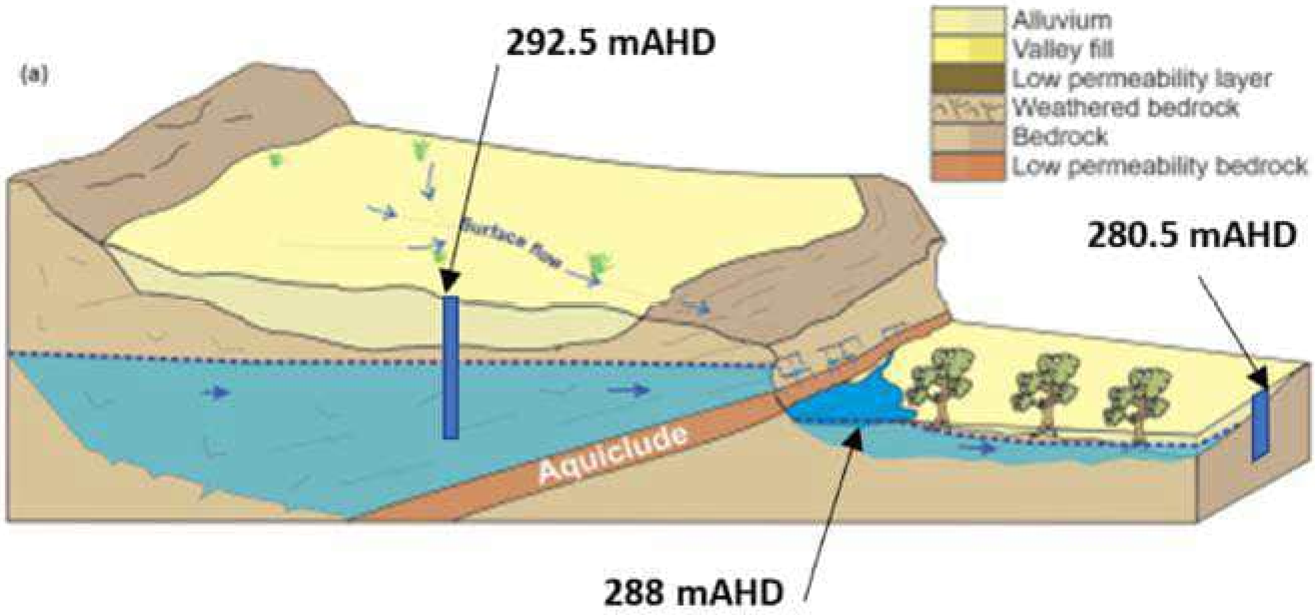


Figure 3-31 Conceptual schematic of Mundagoora Pool, showing relative water levels in upstream catchment, the pool and downstream (adapted from Bourke et al. [2023]) (Fortescue, 2023).

Site 12 Pool

Site 12 pool is part of a series of shallow pools that lie to the east of the active mining area, on a small tributary to the upper Six Mile Creek (Figure 3-11). The pool is connected to both surface water and groundwater until the local groundwater levels drops below the pool base level over the late dry season. The pool is frequently perennial though has been known to dry out following small wet seasons. What is referred to as "Site 12 Pool" is the lower or last pool within the string of pools, with the uppermost pool in the string is referred to by its monitoring site name "IB_SW_Pool12_01" around 400m upstream. The upper three pools in this string are "Commonly Wet" with the lower pools being seasonally inundated.

The hydrochemistry of this pool indicates that the upper pools in this reach are likely to be supported by regional groundwater, with very little change in water quality even when near dry (indicating that the water levels are receding to the subsurface rather than evaporation; Figure 3-12). The lower-lying pools in the string/reach, including Site 12 Pool, demonstrate a more fresh/surface water dominant signature and are likely to have less reliance/support from groundwater inflows than the upper pools (Figure 3-13; see also Figure 3-4 in Section 3.2.2) for context. Site 12 Pool in a poor wet season can recede faster than calculated for evaporation alone, indicating that loss to groundwater is likely to be occurring when groundwater levels are relatively low.

The Site 12 pools also contain significant environmental values including GDV, three fish species (the only pool in the NSE area to contain catfish), emergent and submerged macrophytes and, the Dinner Plate Turtle (*Chelodina steindachneri*). These indicators suggest water permanence or semi-permanence with common persistence into the late dry season.

There is a small wetland/waterlogged area upstream of the Site 12 pools which occurs immediately upstream of a bedrock outcrop within the drainage channel. The conceptual model for this site suggests that this rock outcrop within the drainage channel may be a sill or aquiclude behind which groundwater mounds and overflows, feeding the Site 12 pools (Figure 3-11).

The Type 3 - Bedrock aquiclude - groundwater discharge hydrologic model has been applied to Site 12 Pool, though it is noted that this applies most completely to the upper pool(s) in the string, which have more water persistence and a greater groundwater hydrologic and geochemical signal. While the Type 3 conceptualisation has been applied to all pools within the Site 12 string, the lower pools are less persistent and have a greater proportion of their persistence supported by surface water inflows (residual ponded surface waters, as indicated by salinity logger measurements). Appendix C provides a listing of all pool/reach conceptual model classifications.

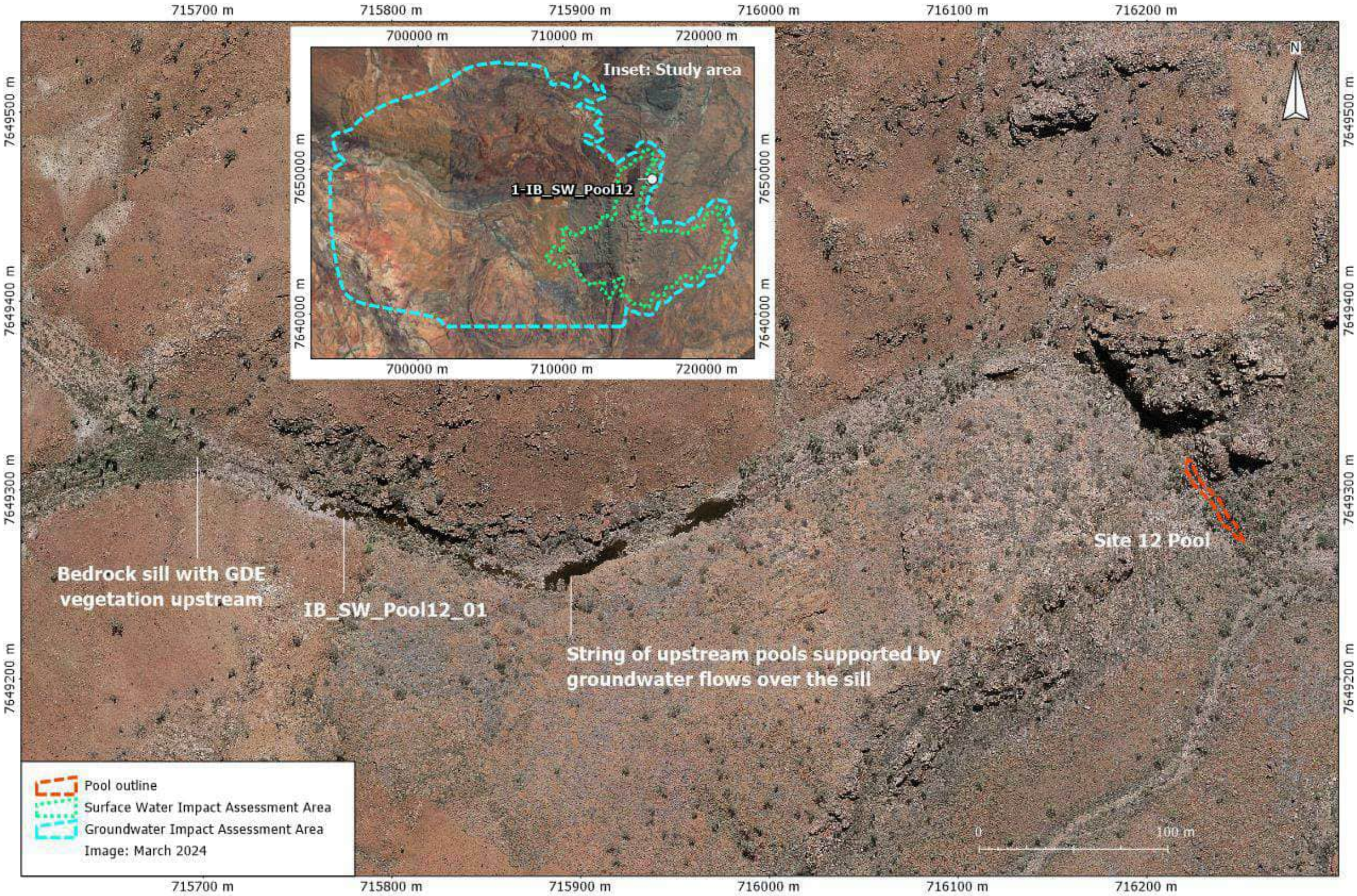


Figure 3-32 Map of Site 12 Pool showing hydrologic features

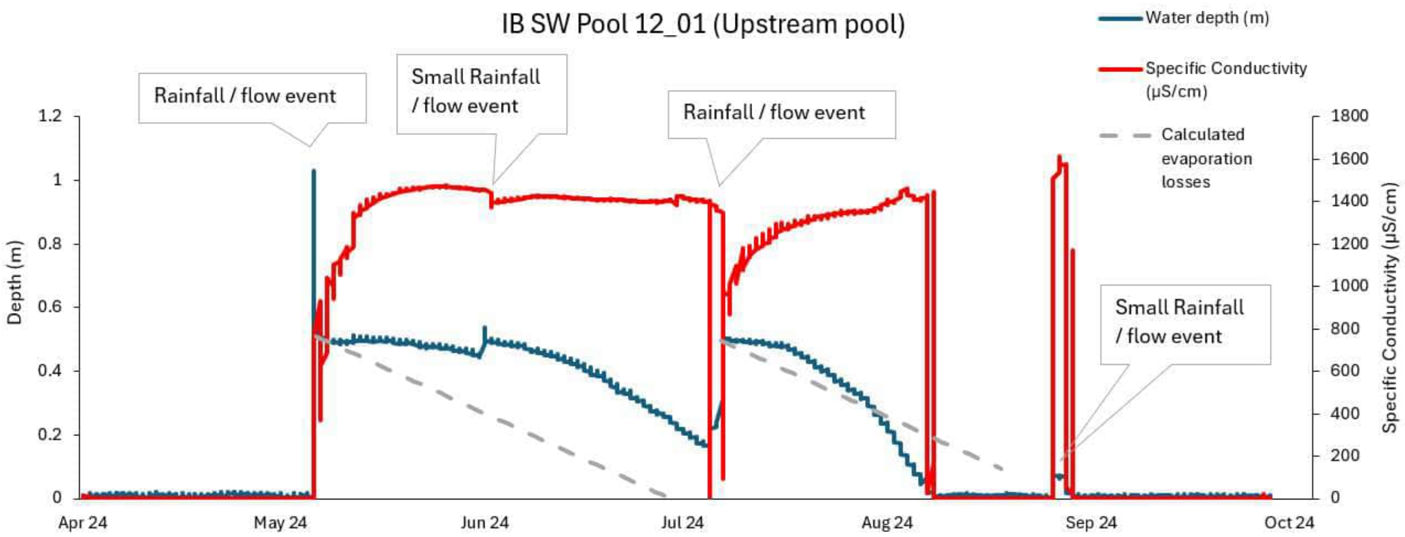


Figure 3-33 Water level and specific conductivity plot for IB_SW_Pool12_01 – April to Oct 2024

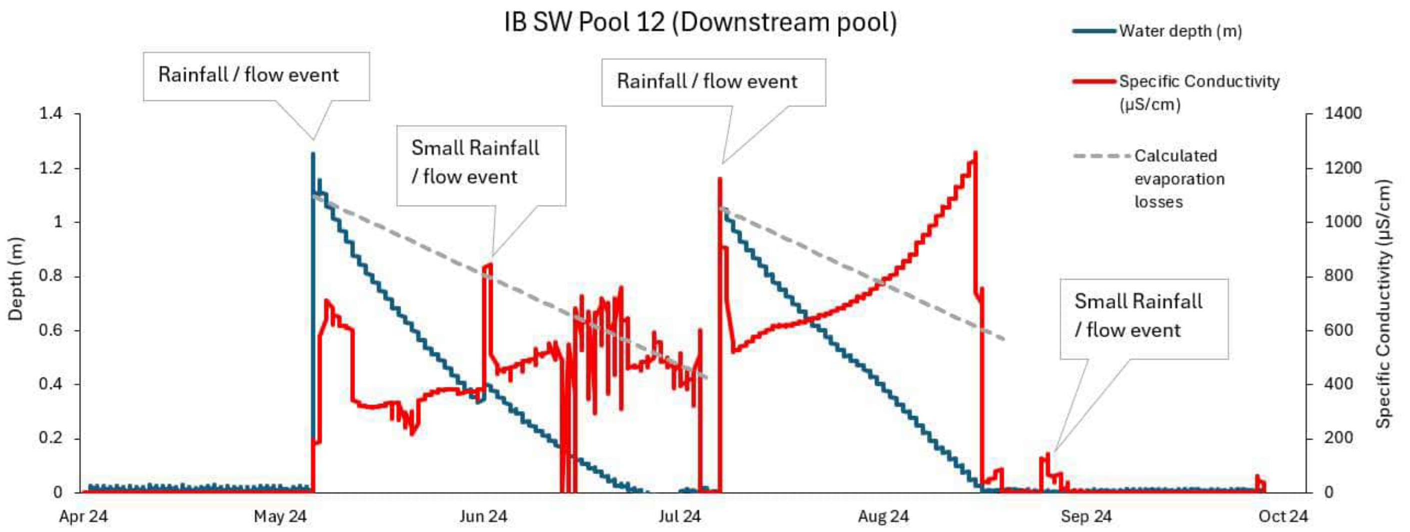


Figure 3-34 Water level and specific conductivity plot for Site 12 pool – April to Oct 2024

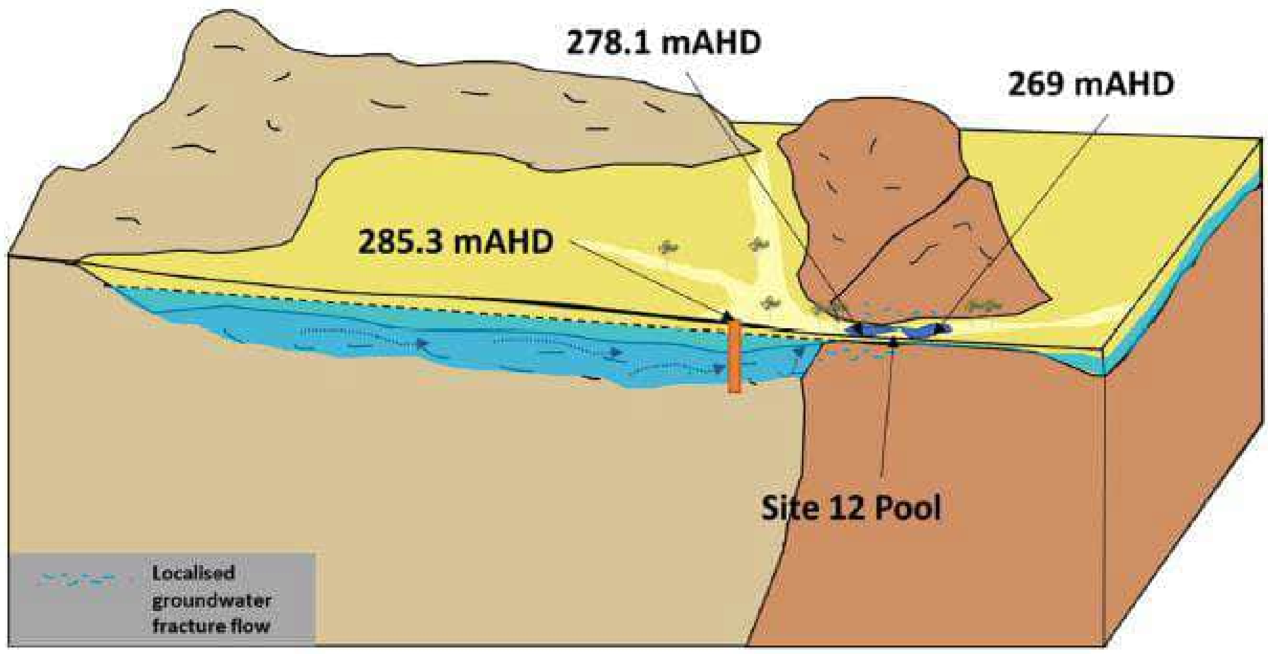


Figure 3-35 Conceptual schematic of Site 12 Pool, showing relative water levels in upstream catchment and pool system (adapted from Bourke et al., [2023]) (Fortescue, 2023).

4. CONCLUSIONS

The application of the Bourke et. al (2023) method for deriving a conceptual hydraulic model for pools within the NSE study area has provided a useful framework to understand potential impact mechanisms for each pool. The method has been adapted to the conceptual models relevant to the pools of this specific study area and, additional water persistence information added to the methodology.

The Bourke et. al (2023) approach has been combined with the ANAE classification system to provide a more comprehensive framework including hydrologic (water persistence) considerations.

We have systematically identified pools across the study area and provided an important pre-cursor step to the impact assessment process.

A total of 102 pools were identified within the Study Area, that have the potential to be impacted by the NSE development. The majority of the identified pools (69%) were periodic or ephemeral with respect to water permanence with 11% being seasonally inundated, 14% commonly wet and 7% permanent.

For the purposes of impact assessment, individual pools were grouped into local "reaches" along connecting sections of drainage lines, resulting in a total of 82 reaches. Of the 82 pools, 41% were type 1A (Alluvium - perched throughflow), 11% were Type 1b (Alluvium/bedrock - perched surface water throughflow), 26% were Type 2a (Bedrock - perched surface water), 11% were Type 2b (Bedrock - fracture flow groundwater source), 9% were Type 2a/2b (Potentially either 2a or 2b) and 2% were Type 3 (Bedrock aquiclude - groundwater discharge). No reaches of Type 4 were identified (Topographically controlled groundwater outflow).

5. REFERENCES

Aquatic Ecosystems Task Group (2012). Aquatic Ecosystems Toolkit. Module 2. Interim Australian National Aquatic Ecosystem Classification Framework. Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Bourke, S. A., Shanafield, M., Hedley, P., Chapman, S., & Dogramaci, S. (2023). A hydrological framework for persistent pools along non-perennial rivers. Hydrology and Earth System Sciences, 27(3), 809–836. https://doi.org/10.5194/hess-27-809-2023

Fortescue (2023). Iron Bridge Mine Area Hydrogeological Assessment. Strategic Planning. 10/03/2023. IB-5700-RP-WM-0002 Rev 0.

Fortescue. (2025). Site 12 Pool Catchment Waterways Assessment – North Star Extension.

NASA (2024). EARTHDATA: Shuttle Radar Topography Mission (SRTM) dataset (30m grid). https://www.earthdata.nasa.gov/data/instruments/srtm

APPENDIX A. IMAGE LIST

File Name	Month	Year
FMG_North_Star_2011_Aug.ecw	Aug	2011
FMG_North_Star_2012_Feb_40cm.ecw	Feb	2012
FMG_North_Star_2012_Dec_15cm.ecw	Dec	2012
FMG_North_Star_2013_Sept_15cm.ecw	Sept	2013
FMG_North_Star_2014_Jan.ecw	Jan	2014
FMG_North_Star_Area1_2014_Feb_15cm.ecw	Feb	2014
FMG_North_Star_Area3_2014_Feb_15cm.ecw	Feb	2014
FMG_North_Star_Area2_2014_Feb_15cm.ecw	Feb	2014
FMG_North_Star_2014_March_15cm.ecw	March	2014
FMG_North_Star_2014_June_15cm.ecw	June	2014
FMG_North_Star_Mine_2014_Sept_15cm.ecw	Sept	2014
FMG_North_Star_2014_Nov_15cm.ecw	Nov	2014
FMG_North_Star_2015_April_15cm.ecw	April	2015
FMG_North_Star_2015_June_15cm.ecw	June	2015
FMG_North_Star_2015_Sept_15cm.ecw	Sept	2015
FMG_North_Star_Mine_2015_Nov_15cm.ecw	Nov	2015
FMG_North_Star_2016_Apr_15cm.ecw	April	2016
FMG_North_Star_2016_June_15cm.ecw	June	2016
FMG_North_Star_2016_Sept_15cm.ecw	Sept	2016
FMG_North_Star_2016_Dec_15cm.ecw	Dec	2016
FMG_North_Star_2017_April_15cm.ecw	April	2017
FMG_North_Star_2017_June_15cm.ecw	June	2017
FMG_North_Star_2017_Sept_15cm.ecw	Sept	2017
FMG_North_Star_2017_Nov_15cm.ecw	Nov	2017
FMG_North_Star_2018_June_15cm.ecw	June	2018
FMG_Iron_Bridge_2019_July_15cm.ecw	July	2019
FMG_Iron_Bridge_2019_Oct_15cm.ecw	Oct	2019
FMG_Iron_Bridge_2020_April_15cm.ecw	April	2020

File Name	Month	Year
FMG_Iron_Bridge_2020_June_15cm.ecw	June	2020
FMG_Iron_Bridge_2020_Sept_15cm.ecw	Sept	2020
FMG_Iron_Bridge_2021_Jan_15cm.ecw	Jan	2021
FMG_Iron_Bridge_South_2021_Jan_15cm.ecw	Jan	2021
FMG_Iron_Bridge_Extra_2021_Jan_15cm.ecw	Jan	2021
FMG_Iron_Bridge_North_2021_Jan_15cm.ecw	Jan	2021
FMG_Iron_Bridge_South_2021_Nov_15cm.ecw	Nov	2021
FMG_Iron_Bridge_North_2021_Nov_15cm.ecw	Nov	2021
FMG_Iron_Bridge_2022_Jul_15cm.ecw	July	2022
FMG_Iron_Bridge_2022_Aug_15cm.ecw	Aug	2022
FMG_Iron_Bridge_Decarb_2023_Mar_15cm.ecw	March	2023
FMG_Iron_Bridge_2023_Mar_15cm.ecw	March	2023
FMG_Iron_Bridge_2023_June_15cm.ecw	June	2023
FMG_Iron_Bridge_2023_Nov_15cm.ecw	Nov	2023

APPENDIX B.
POOL IDENTIFICATION DATA

Site_Name	Easting	Northing	# Images Assessed	# Images showing water present	Water Pres_ by Count %	Water_Pres_by Count_Class ANAE_1_0.7_0.5	Average fullness score	Bourke (2023) Concept. #	Substrate - Air Photo Interpretation	Elevation mAHD (from Elvis)	Elevation mAHD (from LiDAR)	Fortescue Groundwater Level (mAHD)	Reach Name
1-IB_SW_Pool12	716214	7649319	23	13	0.57	Seasonal Inundation	1.57	3	Alluvium	299	271	N/A	Site 12 Pool
2-S12string	716180	7649353	17	8	0.47	Periodic Inund./Ephemeral	1.12	3	Alluvium	299	272	N/A	Site 12 Pool
3-S12string	716120	7649369	32	17	0.53	Seasonal Inundation	1.66	3	Bed/Alluv	288	273	N/A	Site 12 Pool
4-S12string	716011	7649323	32	10	0.31	Periodic Inund./Ephemeral	0.50	3	Bed/Alluv	284	277	N/A	Site 12 Pool
5-S12string	715992	7649310	32	15	0.47	Periodic Inund./Ephemeral	1.25	3	Bed/Alluv	288	277	N/A	Site 12 Pool
6-S12string	715961	7649297	31	22	0.71	Commonly Wet	2.10	3	Bedrock	290	277	N/A	Site 12 Pool
7-S12string	715889	7649272	29	24	0.83	Commonly Wet	2.59	3	Bedrock	302	278	N/A	Site 12 Pool
8 - IB_SW_Pool12_01	715759	7649293	31	26	0.84	Commonly Wet	2.10	3	Bedrock	295	279	242	Site 12 Pool
9	715493	7649165	39	14	0.36	Periodic Inund./Ephemeral	0.97	1a	Alluvium	291	285	265	Pool 9
11	715579	7650019	31	8	0.26	Periodic Inund./Ephemeral	0.87	2a	Bedrock	319	301	272	Pool 11
15	716422	7650055	28	5	0.18	Periodic Inund./Ephemeral	0.25	1b	Bed/Alluv	317	308	N/A	15
36 - IB_SW_TSF_02	708623	7655816	36	10	0.28	Periodic Inund./Ephemeral	0.50	1a	Alluvium	244	229	N/A	36 - IB_SW_TSF_02
37	708560	7655276	36	8	0.22	Periodic Inund./Ephemeral	0.36	1a	Alluvium	242	234	229	37
38	709063	7655126	36	7	0.19	Periodic Inund./Ephemeral	0.28	1a	Alluvium	239	234	224	38
39 - IB_SW_TSF_03	709342	7654472	36	8	0.22	Periodic Inund./Ephemeral	0.50	1a	Alluvium	245	240	221	39 - IB_SW_TSF_03
40	709078	7653220	36	3	0.08	Periodic Inund./Ephemeral	0.11	1a	Alluvium	258	251	N/A	40
41	709098	7653376	33	7	0.21	Periodic Inund./Ephemeral	0.55	1a	Alluvium	260	248	N/A	41
42	708956	7652223	37	37	1.00	Permanent	2.70	2b	Bedrock	302	273	N/A	42
43	709016	7652062	34	19	0.56	Seasonal Inundation	0.97	2a/2b	Bedrock	311	307	N/A	43
44	708259	7652648	33	33	1.00	Permanent	2.97	2b	Bedrock	304	280	N/A	93
45	708135	7649959	41	15	0.37	Periodic Inund./Ephemeral	1.02	2a	Bedrock	282	273	226	45
46	708122	7650085	39	4	0.10	Periodic Inund./Ephemeral	0.10	1a	Alluvium	285	276	224	46
47	708232	7649402	41	7	0.17	Periodic Inund./Ephemeral	0.59	1a	Bed/Alluv	270	262	237	47
48	709157	7649833	39	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	316	295	213	48
49	716592	7649930	28	3	0.11	Periodic Inund./Ephemeral	0.18	1b	Bedrock	305	291	N/A	49
50	715631	7645705	29	1	0.03	Periodic Inund./Ephemeral	0.03	1a	Alluvium	301	289	N/A	Pool 50
51 - GV_SW_WRD _01	714379	7645915	35	1	0.03	Periodic Inund./Ephemeral	0.03	1b	Bed/Alluv	329	315	306	Pool 51
52	715393	7644317	32	18	0.56	Seasonal Inundation	1.25	2a/2b	Bedrock	306	297	N/A	NJA19-002
GV_SW_Pool_ Mundagoora_SS	712553	7645679	32	32	1.00	Permanent	3.69	3	Bedrock	310	289	294	Mundagoora Pool
55 - GV_SW_Pool_SW	712578	7643390	33	5	0.15	Periodic Inund./Ephemeral	0.27	1a	Alluvium	305	293	N/A	Pool-SW
56 - GV_SW_Pool_SWGV_DS	712479	7643316	36	8	0.22	Periodic Inund./Ephemeral	0.44	1a	Alluvium	295	290	N/A	Pool-SW
57	713259	7645204	29	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	384	380	323	Pool 57
59	712964	7644815	20	1	0.05	Periodic Inund./Ephemeral	0.05	2a	Bedrock	344	313	295	Pool 59
60 - IB_SW_Pool_ Central Ck	704355	7646334	37	9	0.24	Periodic Inund./Ephemeral	0.35	1a	Alluvium	231	223	205	60 - IB_SW_Pool_Central Ck
61 - GV_SW_Pool_ NJA19-002	715410	7644325	32	17	0.53	Seasonal Inundation	1.19	2a/2b	Bedrock	303	293	N/A	NJA19-002
62	713280	7644655	28	1	0.04	Periodic Inund./Ephemeral	0.04	2a	Bedrock	375	366	331	Pool 62
63	713276	7645204	35	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	392	386	326	Pool 57
64	713239	7645214	24	2	0.08	Periodic Inund./Ephemeral	0.08	2a	Bedrock	385	372	320	Pool 67
65	713289	7644654	27	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	375	370	335	Pool 62
78 - GV_SW_Pool _GR	713224	7644657	27	5	0.19	Periodic Inund./Ephemeral	0.19	2a	Bedrock	367	354	324	Pool 62
79	704231	7646892	37	12	0.32	Periodic Inund./Ephemeral	0.65	1a	Alluvium	229	222	206	79
80	704031	7647099	37	9	0.24	Periodic Inund./Ephemeral	0.62	1a	Alluvium	227	221	215	80
81	702817	7648380	36	11	0.31	Periodic Inund./Ephemeral	0.89	1a	Alluvium	224	217	209	81
82	702453	7648540	30	8	0.27	Periodic Inund./Ephemeral	0.80	1a	Alluvium	221	216	208	82

Site_Name	Easting	Northing	# Images Assessed	# Images showing water present	Water Pres_ by Count %	Water_Pres_by Count_Class ANAE_1_0.7_0.5	Average fullness score	Bourke (2023) Concept. #	Substrate - Air Photo Interpretation	Elevation mAHD (from Elvis)	Elevation mAHD (from LiDAR)	Fortescue Groundwater Level (mAHD)	Reach Name
83	702015	7648422	35	13	0.37	Periodic Inund./Ephemeral	0.97	1a	Alluvium	222	214	209	83
84	706803	7643258	33	8	0.24	Periodic Inund./Ephemeral	0.45	1a	Alluvium	249	238	N/A	84
85	706705	7643341	33	4	0.12	Periodic Inund./Ephemeral	0.12	1a	Alluvium	246	237	N/A	85
86	706410	7643591	20	9	0.45	Periodic Inund./Ephemeral	0.85	1b	Bed/Alluv	239	236	N/A	86
87	704935	7646015	34	6	0.18	Periodic Inund./Ephemeral	0.26	1a	Alluvium	231	225	219	87
88	713647	7642067	17	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	367	353	N/A	88
93	708280	7652681	26	26	1.00	Permanent	3.19	2b	Bedrock	292	274	N/A	93
94	705344	7648904	23	18	0.78	Commonly Wet	1.96	2a/2b	Bedrock	336	322	241	97 - Zanes Gorge Pool
95	705323	7648785	26	6	0.23	Periodic Inund./Ephemeral	0.35	2a	Bedrock	332	314	249	97 - Zanes Gorge Pool
96	705307	7648735	25	10	0.40	Periodic Inund./Ephemeral	0.52	2a	Bedrock	325	312	255	97 - Zanes Gorge Pool
97 - Zanes Gorge Pool	705244	7648705	15	11	0.73	Commonly Wet	1.60	2a/2b	Bedrock	319	304	249	97 - Zanes Gorge Pool
98 - Dingo Lair Pool	704831	7648782	0	0	0.75	Commonly Wet	N/A	2a	Bedrock	296	266	204	98 - Dingo Lair Pool
99	704008	7649076	2	0	0.00	Periodic Inund./Ephemeral	0.00	2a	Bedrock	275	244	186	99
100	703940	7649597	5	4	0.80	Commonly Wet	1.80	2a	Bedrock	318	308	206	100
101	703061	7650110	4	2	0.50	Seasonal Inundation	1.00	2a	Bedrock	306	288	186	101
102	702778	7649877	9	3	0.33	Periodic Inund./Ephemeral	0.89	1b	Bed/Alluv	282	272	196	102
103	702725	7649772	9	3	0.33	Periodic Inund./Ephemeral	0.78	2a	Bedrock	277	269	198	104 - Craigs Pool upper
104 - Craigs Pool upper	702686	7649667	6	1	0.17	Periodic Inund./Ephemeral	0.17	2a	Bedrock	277	268	208	104 - Craigs Pool upper
105	708476	7650583	38	34	0.89	Commonly Wet	2.26	2a/2b	Bedrock	301	289	N/A	105
106	708797	7650684	33	2	0.06	Periodic Inund./Ephemeral	0.15	2a	Bedrock	337	332	N/A	106
107	708817	7651728	37	16	0.43	Periodic Inund./Ephemeral	0.68	2a	Bedrock	346	335	N/A	107
108	705354	7651357	37	3	0.08	Periodic Inund./Ephemeral	0.08	1a	Alluvium	333	327	N/A	108
109	705329	7651564	39	2	0.05	Periodic Inund./Ephemeral	0.05	1a	Alluvium	332	325	N/A	109
110	705199	7652242	28	1	0.04	Periodic Inund./Ephemeral	0.04	1a	Alluvium	321	315	N/A	110
111	705033	7652270	28	11	0.39	Periodic Inund./Ephemeral	1.21	1a	Alluvium	320	312	N/A	112
112	705034	7652395	29	6	0.21	Periodic Inund./Ephemeral	0.59	1a	Alluvium	319	312	N/A	112
113	705172	7652684	28	7	0.25	Periodic Inund./Ephemeral	0.46	1a	Alluvium	317	308	N/A	115
114	705129	7652745	28	5	0.18	Periodic Inund./Ephemeral	0.46	2a	Bedrock	316	307	N/A	115
115	705049	7652807	28	8	0.29	Periodic Inund./Ephemeral	0.71	1b	Bed/Alluv	318	305	N/A	115
116	704676	7652900	26	5	0.19	Periodic Inund./Ephemeral	0.50	1a	Alluvium	308	301	N/A	116
117	704418	7652877	26	3	0.12	Periodic Inund./Ephemeral	0.38	1a	Alluvium	308	299	N/A	117
118	704234	7652831	26	6	0.23	Periodic Inund./Ephemeral	0.54	2a	Bedrock	303	291	N/A	119
119	704201	7652897	24	18	0.75	Commonly Wet	1.63	2a/2b	Bedrock	301	287	N/A	119
120	704065	7653289	25	8	0.32	Periodic Inund./Ephemeral	0.92	2a	Bedrock	293	275	N/A	120
121	703938	7653549	21	13	0.62	Seasonal Inundation	2.14	2a/2b	Bedrock	271	258	N/A	121
122	703904	7653670	13	2	0.15	Periodic Inund./Ephemeral	0.54	1b	Bed/Alluv	262	256	N/A	122
124	703665	7653928	13	5	0.38	Periodic Inund./Ephemeral	0.92	1b	Bed/Alluv	260	241	N/A	124
125	703463	7653911	13	5	0.38	Periodic Inund./Ephemeral	1.23	1a	Bedrock	251	235	N/A	125
IB_SW_Pool_Fig	711667	7650621	42	42	1.00	Permanent	2.86	2b	Bedrock	310	303	266	IB_SW_Pool_Fig
IB_SW_Pool_ Cow Spring	711101	7648578	42	42	1.00	Permanent	2.95	2b	Bedrock	312	297	264	IB_SW_Pool_Cow Spring
GV_SW_Pool_NJA21-006-US	718007	7645416	20	5	0.25	Periodic Inund./Ephemeral	0.65	2a	Bedrock	267	260	N/A	Pool NJA21-006-US
GV_SW_Pool_NJA19-004	715896	7646284	32	17	0.53	Seasonal Inundation	0.53	2a/2b	Bedrock	299	285	N/A	GV_SW_Pool_NJA19-004
GV_SW_Pool_NJA21-006-DS	720057	7644905	20	1	0.05	Periodic Inund./Ephemeral	5.55	1a	Alluvium	243	240	N/A	Pool NJA21-006-DS
IB_SW_DryReject_ DS_02	709338	7643632	45	1	0.02	Periodic Inund./Ephemeral	0.02	1a	Alluvium	267	252	231	Pool IB-SW-Dry-Reject-DS-002
GE_1	698078	7652675	6	1	0.17	Periodic Inund./Ephemeral	0.50	2a	Bedrock	275	258	N/A	GE_1

Site_Name	Easting	Northing	# Images Assessed	# Images showing water present	Water Pres_ by Count %	Water_Pres_by Count_Class ANAE_1_0.7_0.5	Average fullness score	Bourke (2023) Concept. #	Substrate - Air Photo Interpretation	Elevation mAHD (from Elvis)	Elevation mAHD (from LiDAR)	Fortescue Groundwater Level (mAHD)	Reach Name
GE_2	700658	7652474	9	5	0.56	Seasonal Inundation	1.00	2a	Bedrock	308	279	N/A	GE_2
GE_3	703325	7653085	23	9	0.39	Periodic Inund./Ephemeral	0.74	1a	Alluvium	241	236	N/A	GE_3
GE_4	702821	7652593	10	10	1.00	Permanent	2.50	2b	Bedrock	280	247	N/A	GE_4
GE_5	704264	7651720	27	23	0.85	Commonly Wet	2.81	2b	Bedrock	289	262	N/A	GE_5
GE_6	701353	7652700	6	5	0.83	Commonly Wet	1.17	2a	Bedrock	300	286	N/A	GE_6
GE_7	704124	7639903	10	6	0.60	Seasonal Inundation	1.10	1a	Alluvium	248	N/A	N/A	GE_7
GE_8	705054	7639832	11	2	0.18	Periodic Inund./Ephemeral	0.27	1a	Alluvium	270	N/A	N/A	GE_8
GE_9	710488	7639953	10	3	0.30	Periodic Inund./Ephemeral	0.50	1b	Bedrock	284	273	N/A	GE_9
GE_10	714871	7642125	24	19	0.79	Commonly Wet	1.96	2a	Bedrock	311	297	N/A	GE 10
GE_11	696605	7650254	25	7	0.28	Periodic Inund./Ephemeral	0.80	1a	Alluvium	201	196	N/A	GE_11
GE_12	696149	7650428	26	13	0.50	Seasonal Inundation	1.31	1a	Alluvium	199	N/A	N/A	GE_12
126 - Craigs Pool lower	702605	7649573	1	1	1.00	Commonly Wet	3.00	2b	Bedrock	248	N/A	N/A	126 - Craigs Pool lower
127 - Astrid Bee Cave	700186	7650960	N/A	N/A	N/A	Commonly Wet	N/A	2b	Bedrock	246	N/A	N/A	127 - Astrid Bee Cave

APPENDIX C. EVIDENCE MATRIX BY POOL FOR HYDROLOGIC CONCEPTUALISATION

Site Name	Bourke (2023) Conceptualisation #	Water Permanence	EM based source	EM - Water Presence	EM - Fullness Score	EM - Substrate	EM - Location	EM - Elevation	EM - Depth to regional GW	EM - Catchment Size	EM - Flow Regime	EM - Vegetation	EM – Hydro-chemistry	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
1-IB_SW_Pool12	3	Seasonal Inundation	SW/GW	SW	SW	nc	GW	GW	GW-R	nc	SW	GW	SW	No	Yes	Yes
2-S12string	3	Periodic Inund./Ephemeral	SW/GW	SW	SW	nc	GW	GW	GW-R	nc	na	GW	na	No	Yes	Yes
3-S12string	3	Seasonal Inundation	SW/GW	SW	SW	nc	GW	GW	GW-R	nc	na	GW	na	No	Yes	Yes
4-S12string	3	Periodic Inund./Ephemeral	SW/GW	SW	SW	nc	GW	GW	GW-R	nc	na	GW	na	No	Yes	Yes
5-S12string	3	Periodic Inund./Ephemeral	SW/GW	SW	SW	nc	GW	GW	GW-R	nc	na	GW	na	No	Yes	Yes
6-S12string	3	Commonly Wet	GW	GW	GW	GW	GW	GW	GW-R	GW	GW	GW	GW	No	Yes	Yes
7-S12string	3	Commonly Wet	GW	GW	GW	GW	GW	GW	GW-R	GW	GW	GW	GW	No	Yes	Yes
8 - IB_SW_Pool12_01	3	Commonly Wet	GW	GW	GW	GW	GW	GW	GW-R	GW	GW	GW	GW	No	Yes	Yes
9	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	nc	SW	nc	SW	SW	SW	Yes	No	No
11	2a	Periodic Inund./Ephemeral	SW	SW	SW	GW	GW	nc	nc	nc	na	SW	na	Yes	No	No
15	1b	Periodic Inund./Ephemeral	SW	SW	SW	nc	SW	SW	SW	SW	na	SW	na	Yes	No	No
36 - IB_SW_TSF_02	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
37	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
38	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
39 - IB_SW_TSF_03	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
40	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
41	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
42	2b	Permanent	GW	GW	GW	nc	nc	GW	GW-L	GW	na	SW	na	No	Yes	No
43	2a/2b	Seasonal Inundation	SW	SW	SW	nc	nc	GW	GW-L	nc	na	SW	na	Yes	Yes	No
44	2b	Permanent	GW	GW	GW	nc	nc	GW	GW-L	GW	na	SW	na	No	Yes	No
45	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
46	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
47	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
48	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	nc	na	SW	na	Yes	No	No
49	1b	Periodic Inund./Ephemeral	SW	SW	SW	nc	SW	SW	nc	nc	na	SW	na	Yes	No	No
50	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
51 - GV_SW_WRD_01	1b	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	nc	SW	SW	SW	na	Yes	No	No
52	2a/2b	Seasonal Inundation	SW	SW	SW	nc	GW	GW	nc	GW	na	SW	na	Yes	Yes	No
GV_SW_Pool_Mundagoora_SS	3	Permanent	GW	GW	GW	nc	GW	GW	GW-R	nc	GW	GW	GW	No	Yes	Yes
55 - GV_SW_Pool_SW	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	nc	nc	nc	SW	SW	SW	Yes	No	No
56 - GV_SW_Pool_SWGV_DS	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	nc	nc	nc	SW	SW	SW	Yes	No	No
57	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
59	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
60 - IB_SW_Pool_Central Ck	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	SW	SW	SW	Yes	No	No
61 - GV_SW_Pool_NJA19-002	2a/2b	Seasonal Inundation	SW/GW	SW/GW	SW/GW	SW	SW	SW	GW-L	GW	GW	SW	na	Yes	Yes	No
62	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
63	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
64	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
65	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
78 - GV_SW_Pool_GR	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	SW	Yes	No	No
79	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No

Site Name	Bourke (2023) Conceptualisation #	Water Permanence	EM based source	EM - Water Presence	EM - Fullness Score	EM - Substrate	EM - Location	EM - Elevation	EM - Depth to regional GW	EM - Catchment Size	EM - Flow Regime	EM - Vegetation	EM – Hydro-chemistry	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
80	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
81	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
82	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
83	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
84	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
85	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
86	1b	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
87	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
88	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
93	2b	Permanent	GW	GW	GW	nc	nc	GW	GW-L	GW	na	SW	na	No	Yes	No
94	2a/2b	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	SW	na	Yes	Yes	No
95	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	nc	nc	na	SW	na	Yes	No	No
96	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	nc	nc	na	SW	na	Yes	No	No
97 - Zanes Gorge Pool	2a/2b	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	Yes	Yes	No
98 - Dingo Lair Pool	2a	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	Yes	No	No
99	2a	Periodic Inund./Ephemeral	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	Yes	No	No
100	2a	Commonly Wet	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
101	2a	Seasonal Inundation	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	Yes	No	No
102	1b	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
103	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
104 - Craigs Pool upper	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	nc	SW	nc	na	SW	na	Yes	No	No
105	2a/2b	Commonly Wet	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	Yes	No
106	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
107	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	GW	SW	nc	na	SW	na	Yes	No	No
108	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
109	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
110	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
111	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
112	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
113	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
114	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
115	1b	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
116	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
117	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
118	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
119	2a/2b	Commonly Wet	GW	GW	GW	nc	GW	GW	GW-L	nc	na	SW	na	Yes	Yes	No
120	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
121	2a/2b	Seasonal Inundation	GW	GW	GW	nc	GW	GW	GW-L	nc	na	SW	na	Yes	Yes	No
122	1b	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
124	1b	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
125	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No

Site Name	Bourke (2023) Conceptualisation #	Water Permanence	EM based source	EM - Water Presence	EM - Fullness Score	EM - Substrate	EM - Location	EM - Elevation	EM - Depth to regional GW	EM - Catchment Size	EM - Flow Regime	EM - Vegetation	EM – Hydro-chemistry	Potentially Sensitive to Surface Water Changes	Potentially Sensitive to Local Groundwater Changes	Potentially Sensitive to Regional Groundwater Changes
IB_SW_Pool_Fig	2b	Permanent	GW	GW	GW	GW	GW	GW	GW-L	GW	GW	GW	GW	No	Yes	No
IB_SW_Pool_Cow Spring	2b	Permanent	GW	GW	GW	GW	GW	GW	GW-L	GW	GW	GW	GW	No	Yes	No
GV_SW_Pool_NJA21-006-US	2a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	SW	SW	SW	Yes	No	No
GV_SW_Pool_NJA19-004	2a/2b	Seasonal Inundation	SW	SW	SW	nc	SW	SW	nc	SW	SW	SW	SW	Yes	Yes	No
GV_SW_Pool_NJA21-006-DS	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	SW	SW	SW	Yes	No	No
IB_SW_DryReject_DS_02	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	SW	SW	SW	Yes	No	No
GE_1	2a	Periodic Inund./Ephemeral	SW	SW	SW	nc	nc	SW	nc	nc	na	SW	na	Yes	No	No
GE_2	2a	Seasonal Inundation	SW	SW	SW	nc	nc	nc	nc	nc	na	SW	na	Yes	No	No
GE_3	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
GE_4	2b	Permanent	GW	GW	GW	nc	GW	SW/GW-L	nc	GW	na	GW	na	No	Yes	No
GE_5	2b	Commonly Wet	GW	GW	GW	nc	GW	nc	GW-L	nc	na	SW	na	No	Yes	No
GE_6	2a	Commonly Wet	SW	SW	SW	nc	nc	nc	nc	nc	na	SW	na	Yes	No	No
GE_7	1a	Seasonal Inundation	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
GE_8	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	nc	SW	na	SW	na	Yes	No	No
GE_9	1b	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	nc	nc	SW	na	SW	na	Yes	No	No
GE_10	2a	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	SW	na	Yes	No	No
GE_11	1a	Periodic Inund./Ephemeral	SW	SW	SW	SW	SW	SW	SW	SW	na	SW	na	Yes	No	No
GE_12	1a	Seasonal Inundation	SW	SW	SW	SW	SW	SW	SW	SW	na	SW	na	Yes	No	No
126 - Craigs Pool lower	2b	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	No	Yes	No
127 - Astrid Bee Cave	2b	Commonly Wet	GW	GW	GW	nc	nc	nc	GW-L	nc	na	nc	na	No	Yes	No

Notes:

GW = Groundwater

GW-L = Groundwater from a local aquifer

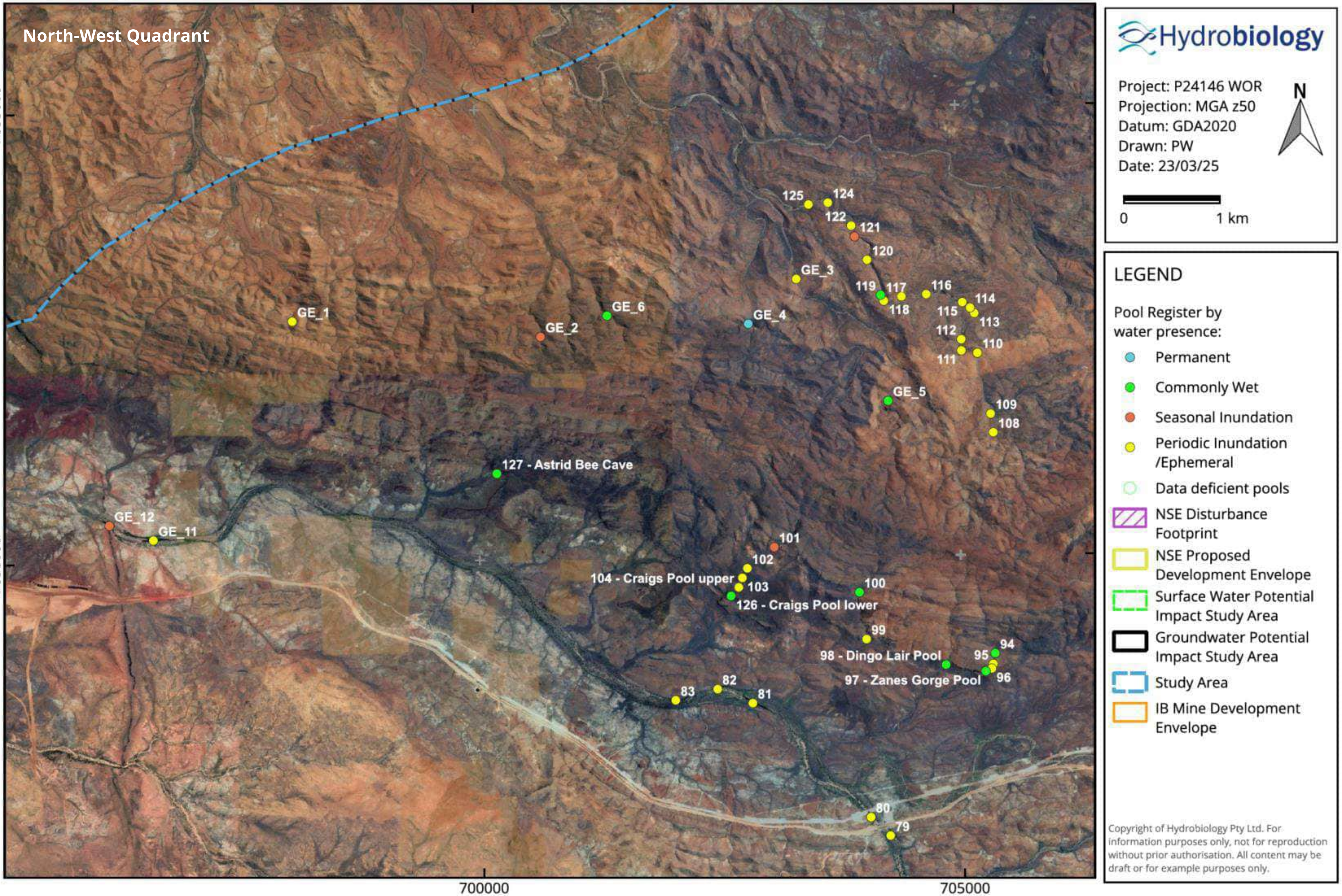
GW-R = Groundwater from the regional aquifer

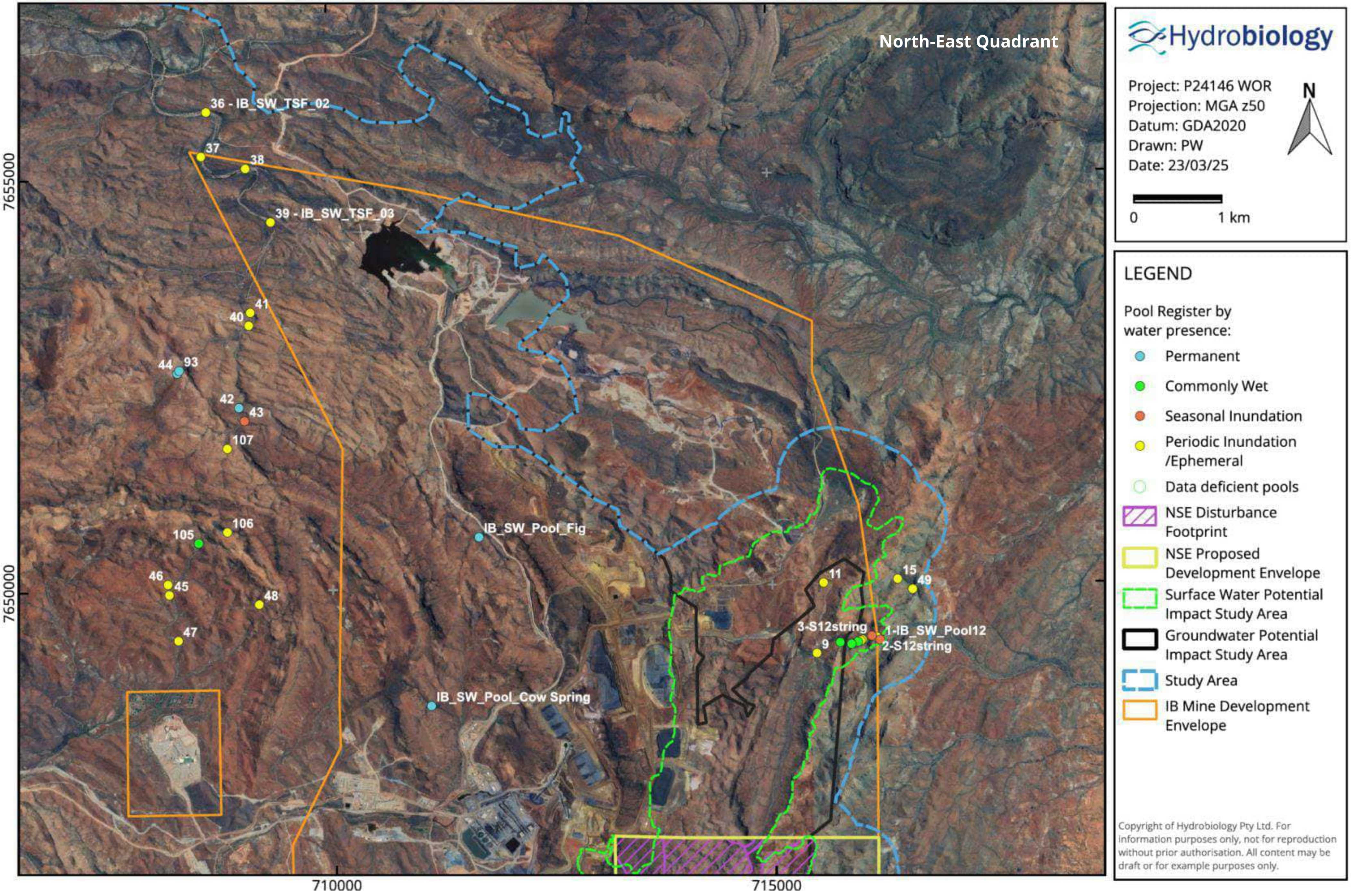
SW = Surface Water (including alluvial throughflow)

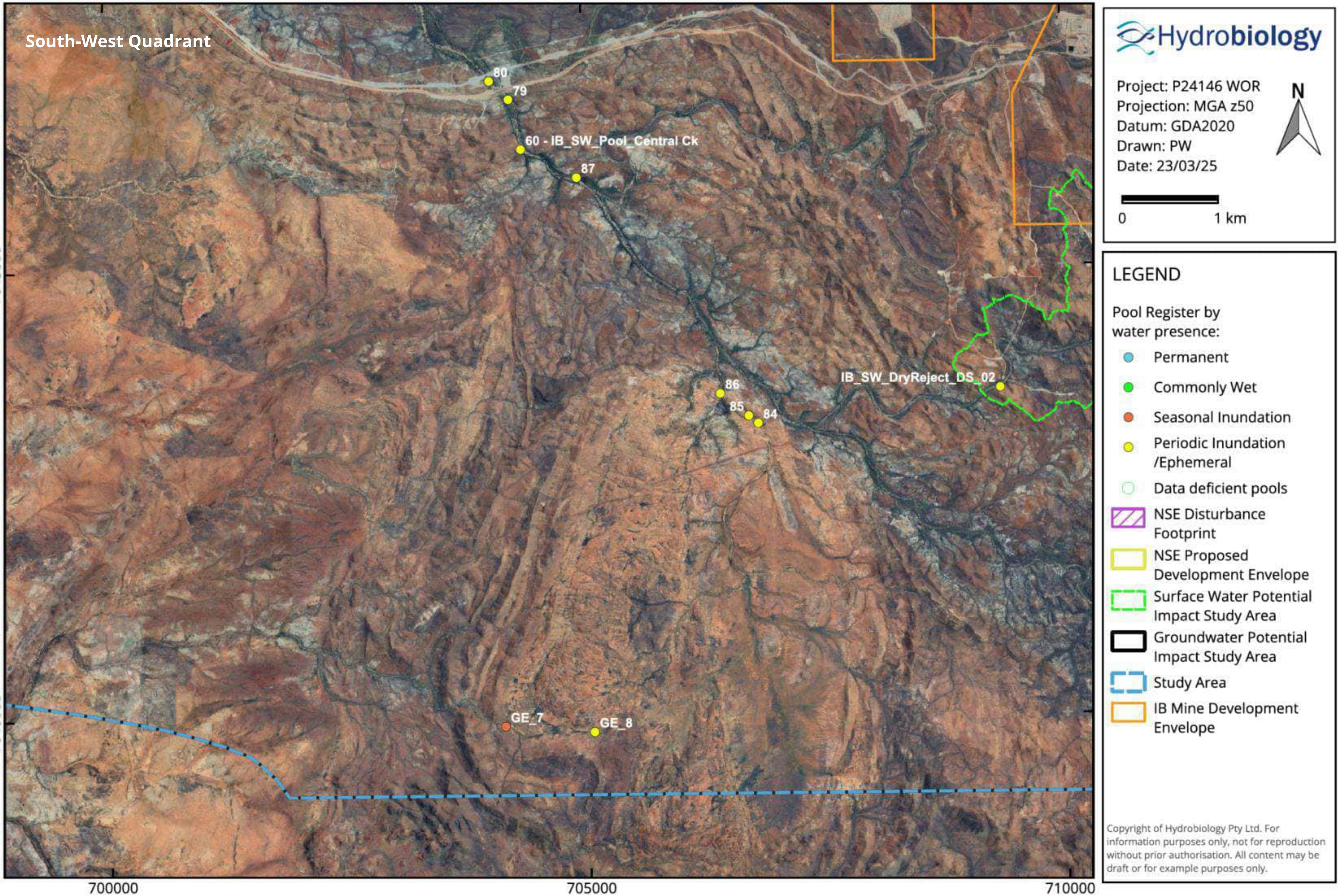
nc = not conclusive (or no reasonable conclusion could be reached from this line of evidence)

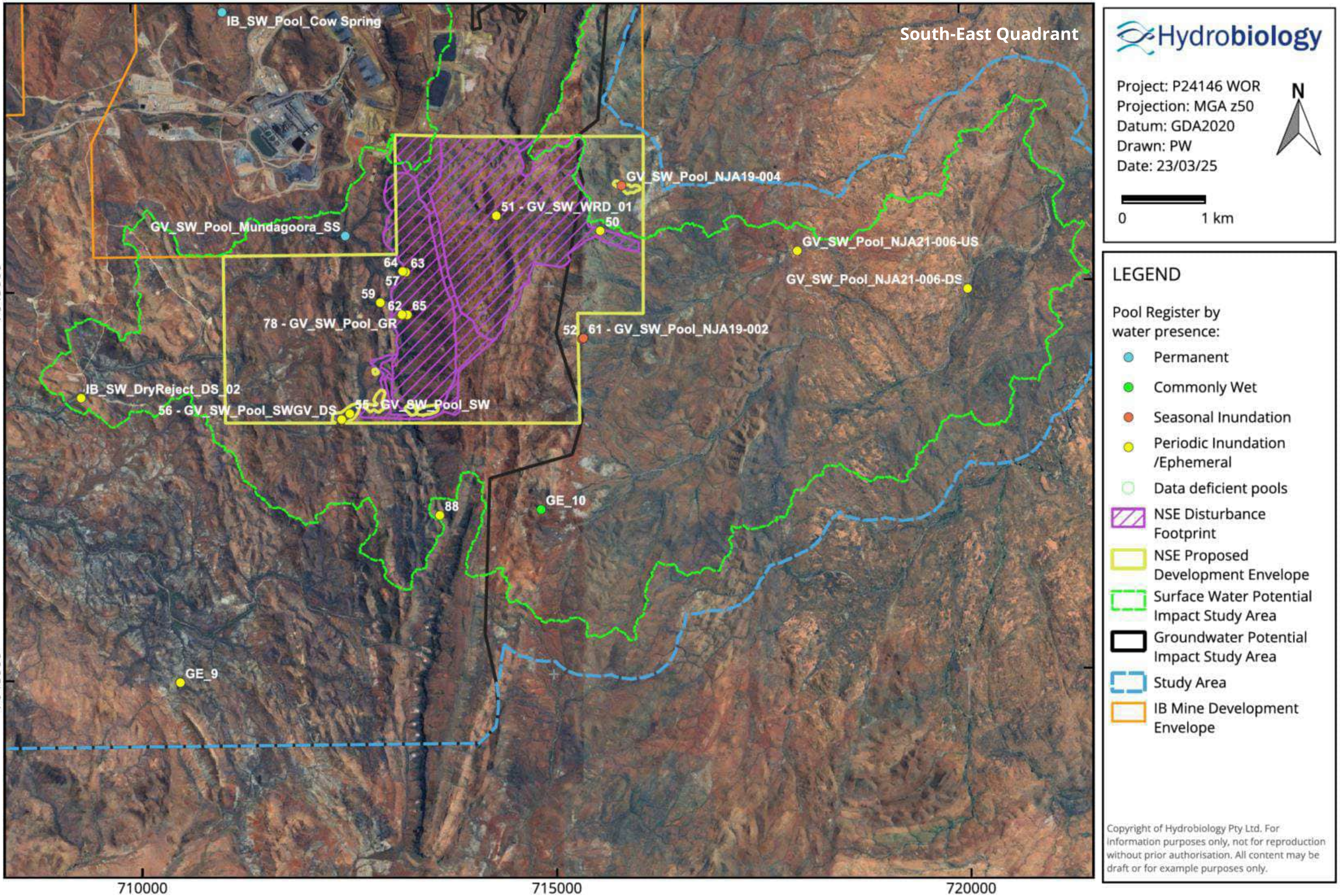
na = not available. There was not sufficient data or evidence to support a conclusion

APPENDIX D. POOL DETAIL MAPS


North-West Quadrant
Hydrobiology
Project: P24146 WOR
Projection: MGA z50
Datum: GDA2020
Drawn: PW
Date: 23/03/25
N
0
1 km
LEGEND
Pool Register by water presence:
Permanent
Commonly Wet
Seasonal Inundation
Periodic Inundation /Ephemeral
Data deficient pools
NSE Disturbance Footprint
NSE Proposed Development Envelope
Surface Water Potential Impact Study Area
Groundwater Potential Impact Study Area
Study Area
IB Mine Development Envelope
7655000
7650000
700000
705000
125
124
122
121
120
GE_3
119
117
116
118
115
114
113
112
110
111
GE_1
GE_6
GE_2
GE_4
GE_5
109
108
127 - Astrid Bee Cave
GE_12
GE_11
101
102
104 - Craigs Pool upper
103
100
126 - Craigs Pool lower
99
98 - Dingo Lair Pool
95
94
97 - Zanes Gorge Pool
96
83
82
81
80
79


North-East Quadrant
36 - IB_SW_TSF_02
37
38
39 - IB_SW_TSF_03
40
41
44
93
42
43
107
105
106
IB_SW_Pool_Fig
46
45
48
47
IB_SW_Pool_Cow Spring
11
15
49
3-S12string
1-IB_SW_Pool12
2-S12string
9
7655000
7650000
710000
715000
Hydrobiology
Project: P24146 WOR
Projection: MGA z50
Datum: GDA2020
Drawn: PW
Date: 23/03/25
N
0
1 km
LEGEND
Pool Register by water presence:
Permanent
Commonly Wet
Seasonal Inundation
Periodic Inundation /Ephemeral
Data deficient pools
NSE Disturbance Footprint
NSE Proposed Development Envelope
Surface Water Potential Impact Study Area
Groundwater Potential Impact Study Area
Study Area
IB Mine Development Envelope


South-West Quadrant
80
79
60 - IB_SW_Pool_Central Ck
87
86
85
84
IB_SW_DryReject_DS_02
GE_7
GE_8
7645000
7640000
700000
705000
710000
Hydrobiology
Project: P24146 WOR
Projection: MGA z50
Datum: GDA2020
Drawn: PW
Date: 23/03/25
N
0
1 km
LEGEND
Pool Register by water presence:
Permanent
Commonly Wet
Seasonal Inundation
Periodic Inundation /Ephemeral
Data deficient pools
NSE Disturbance Footprint
NSE Proposed Development Envelope
Surface Water Potential Impact Study Area
Groundwater Potential Impact Study Area
Study Area
IB Mine Development Envelope


South-East Quadrant
IB_SW_Pool_Cow Spring
GV_SW_Pool_NJA19-004
51 - GV_SW_WRD_01
50
GV_SW_Pool_Mundagoora_SS
GV_SW_Pool_NJA21-006-US
GV_SW_Pool_NJA21-006-DS
64 63
57
59
62 65
78 - GV_SW_Pool_GR
52 61 - GV_SW_Pool_NJA19-002
IB_SW_DryReject_DS_02
56 - GV_SW_Pool_SWGV_DS
55 - GV_SW_Pool_SW
88
GE_10
GE_9
7645000
7640000
710000
715000
720000
Hydrobiology
Project: P24146 WOR
Projection: MGA z50
Datum: GDA2020
Drawn: PW
Date: 23/03/25
N
0
1 km
LEGEND
Pool Register by water presence:
Permanent
Commonly Wet
Seasonal Inundation
Periodic Inundation /Ephemeral
Data deficient pools
NSE Disturbance Footprint
NSE Proposed Development Envelope
Surface Water Potential Impact Study Area
Groundwater Potential Impact Study Area
Study Area
IB Mine Development Envelope
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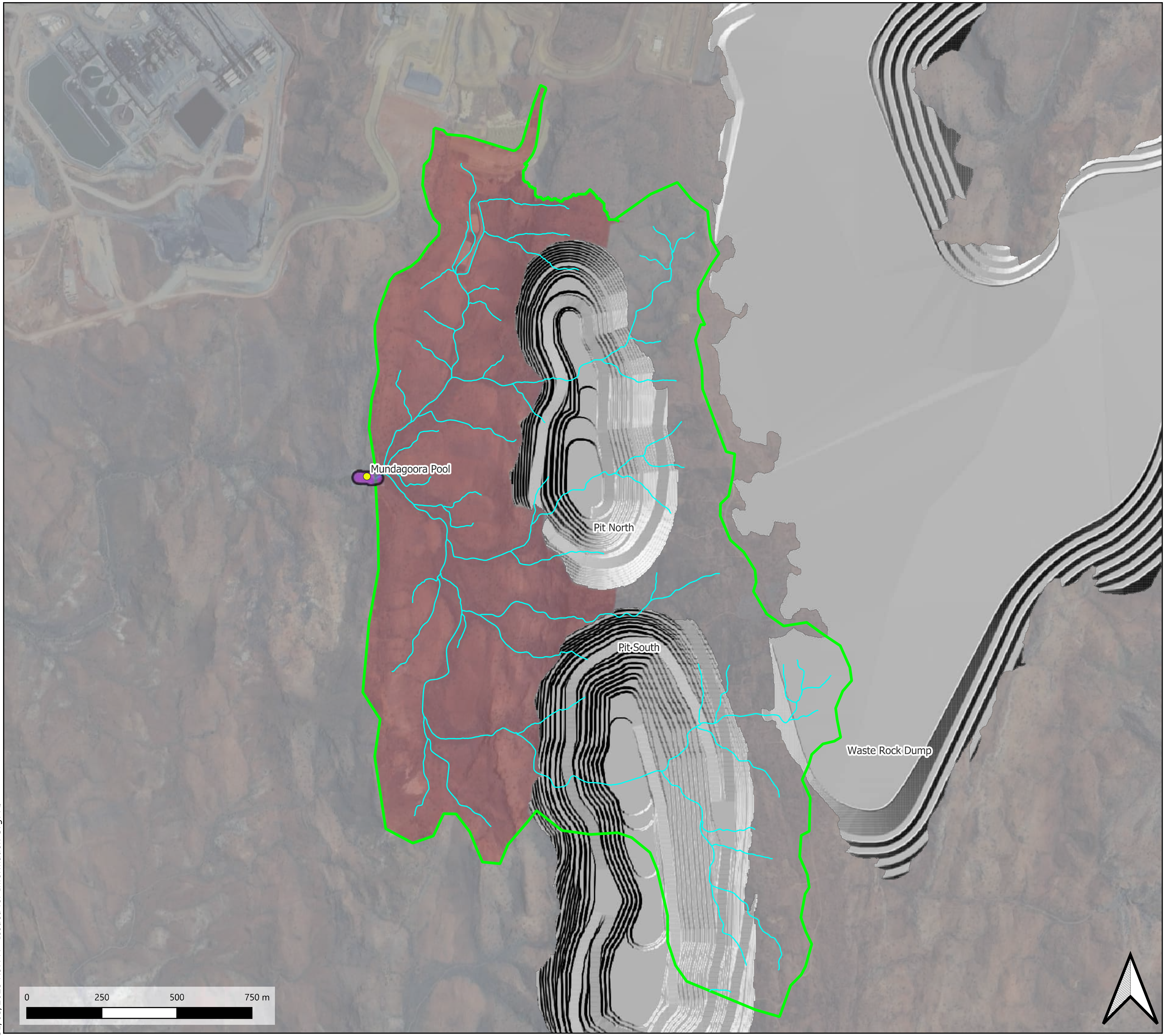
Appendix B. Comparison of Baseline and Development Conditions Catchment Areas

NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Mundagoora Pool Catchment



Legend

- Mundagoora Pool
- Mundagoora Pool Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 12,000

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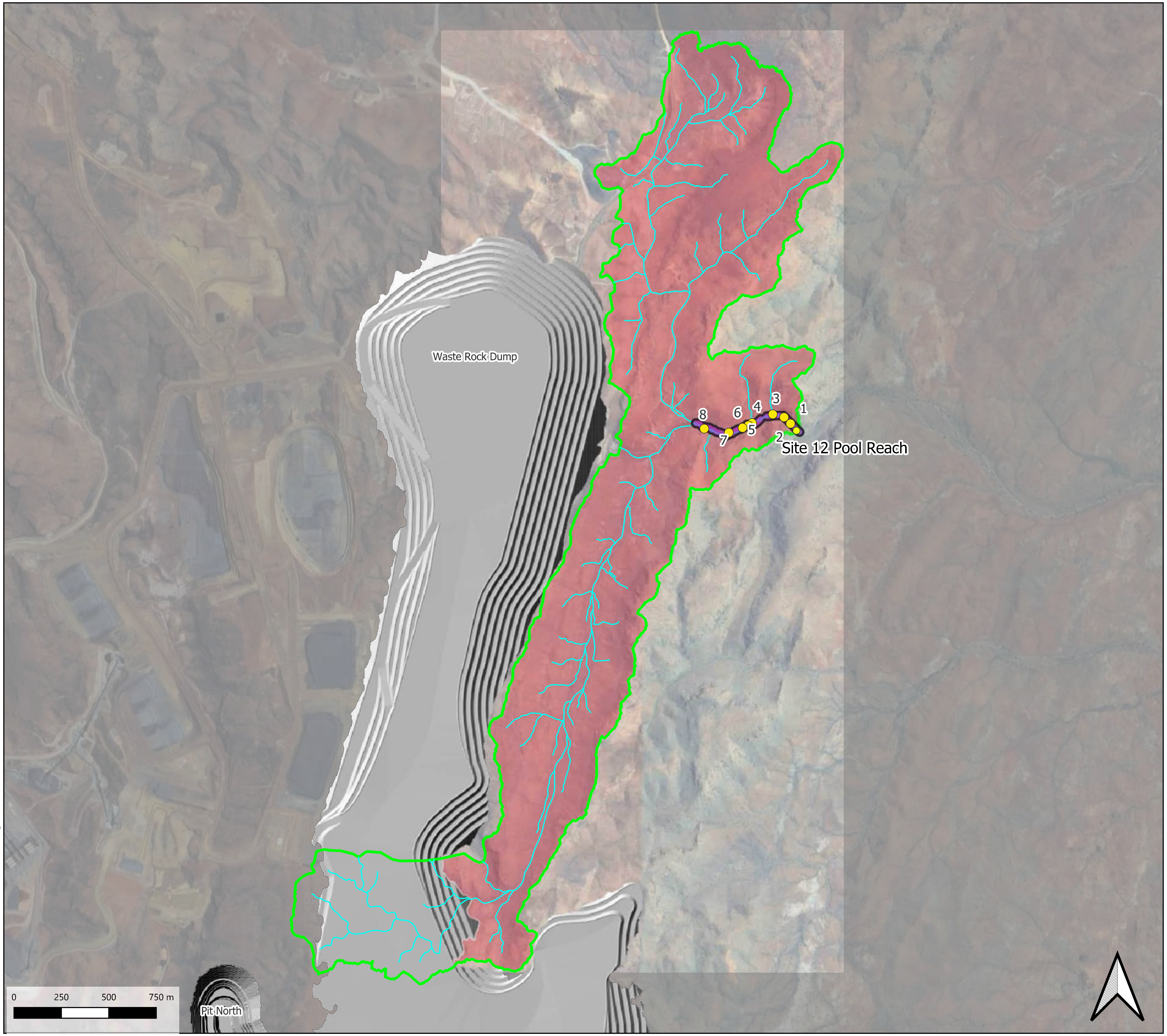
NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Site 12 Pool Catchment



Legend

- Site 12 Pool
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 19,000

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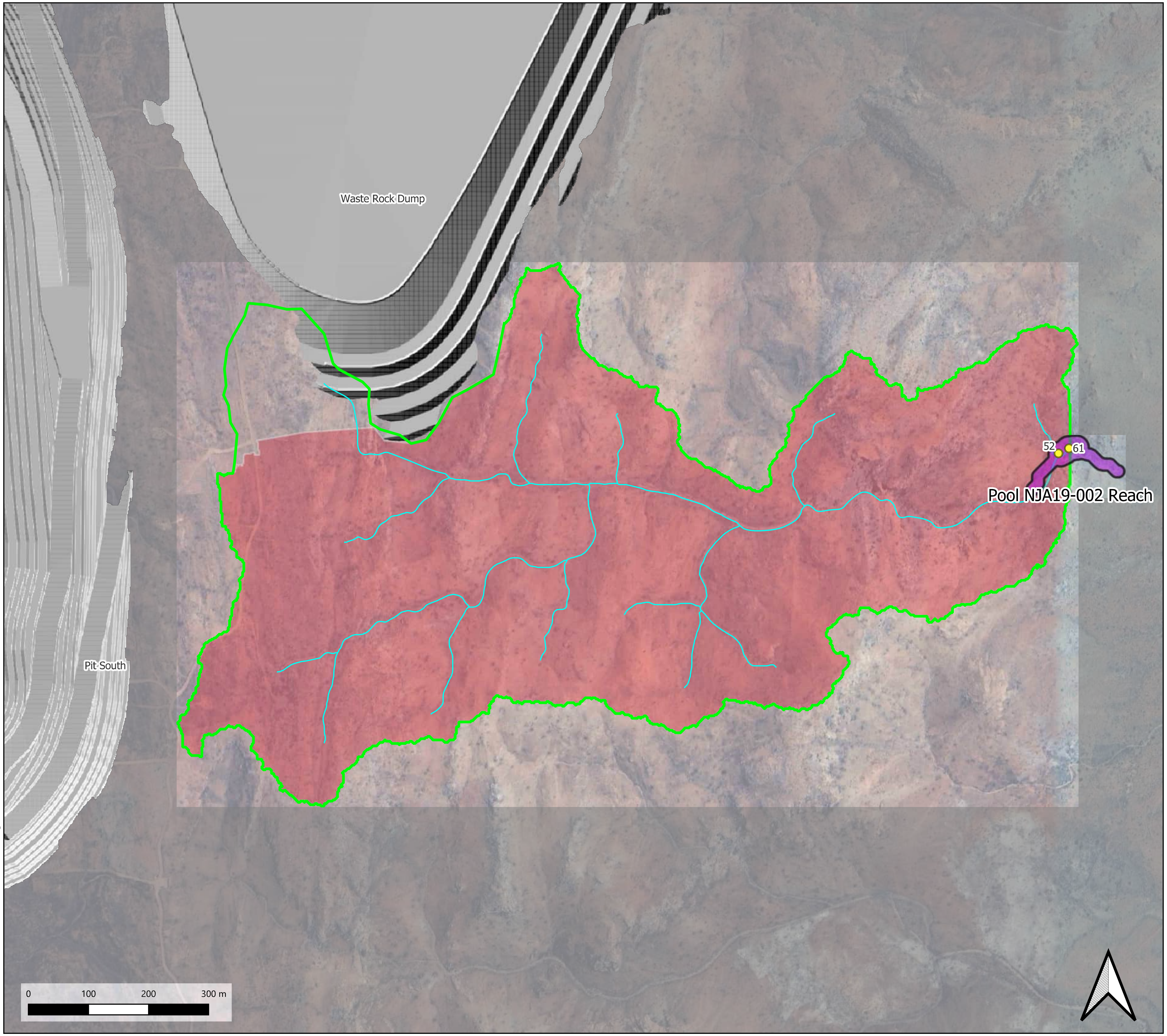
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool NJA19-002 Catchment



Legend

- Individual Pool
- NJA19-002 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 6,000

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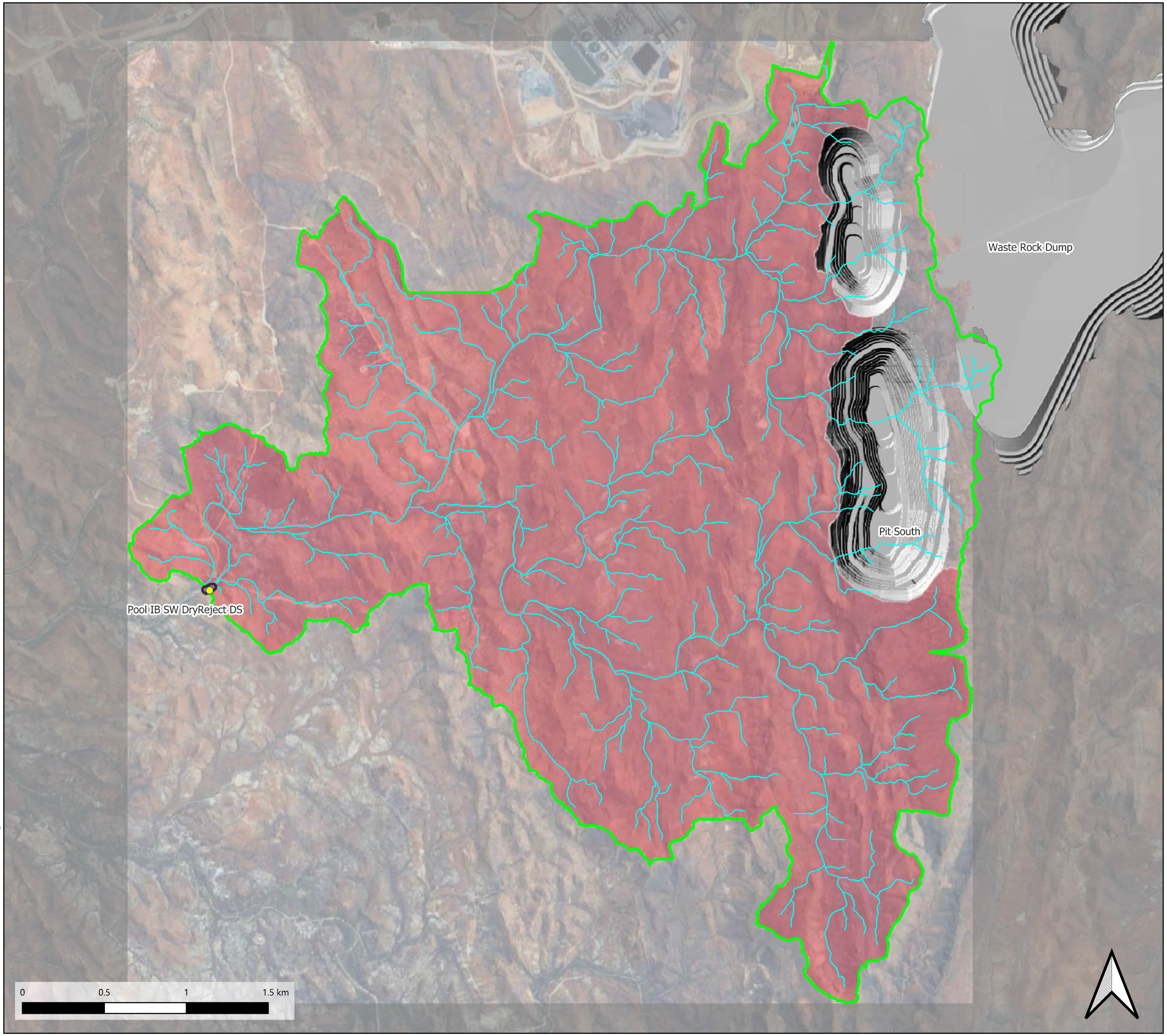
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool IB SW DryReject DS-002 Catchment



Legend

- Pool IB SW DryReject DS-002
- Pool IB SW DryReject DS-002 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 22,000

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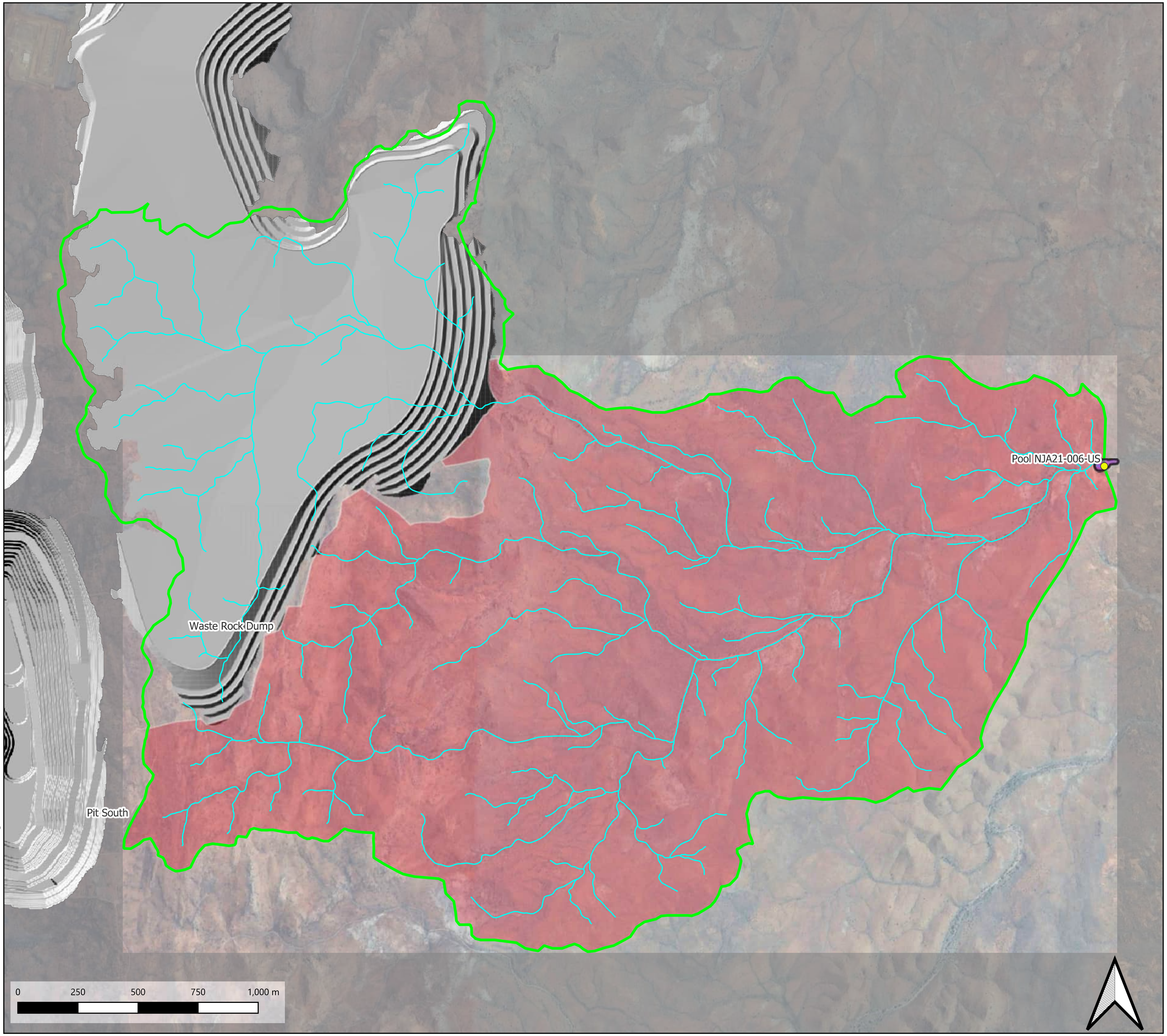

NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool NJA21-006-US Catchment

Legend

- Pool NJA21-006-US
- Pool NJA21-006-US Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 15,000

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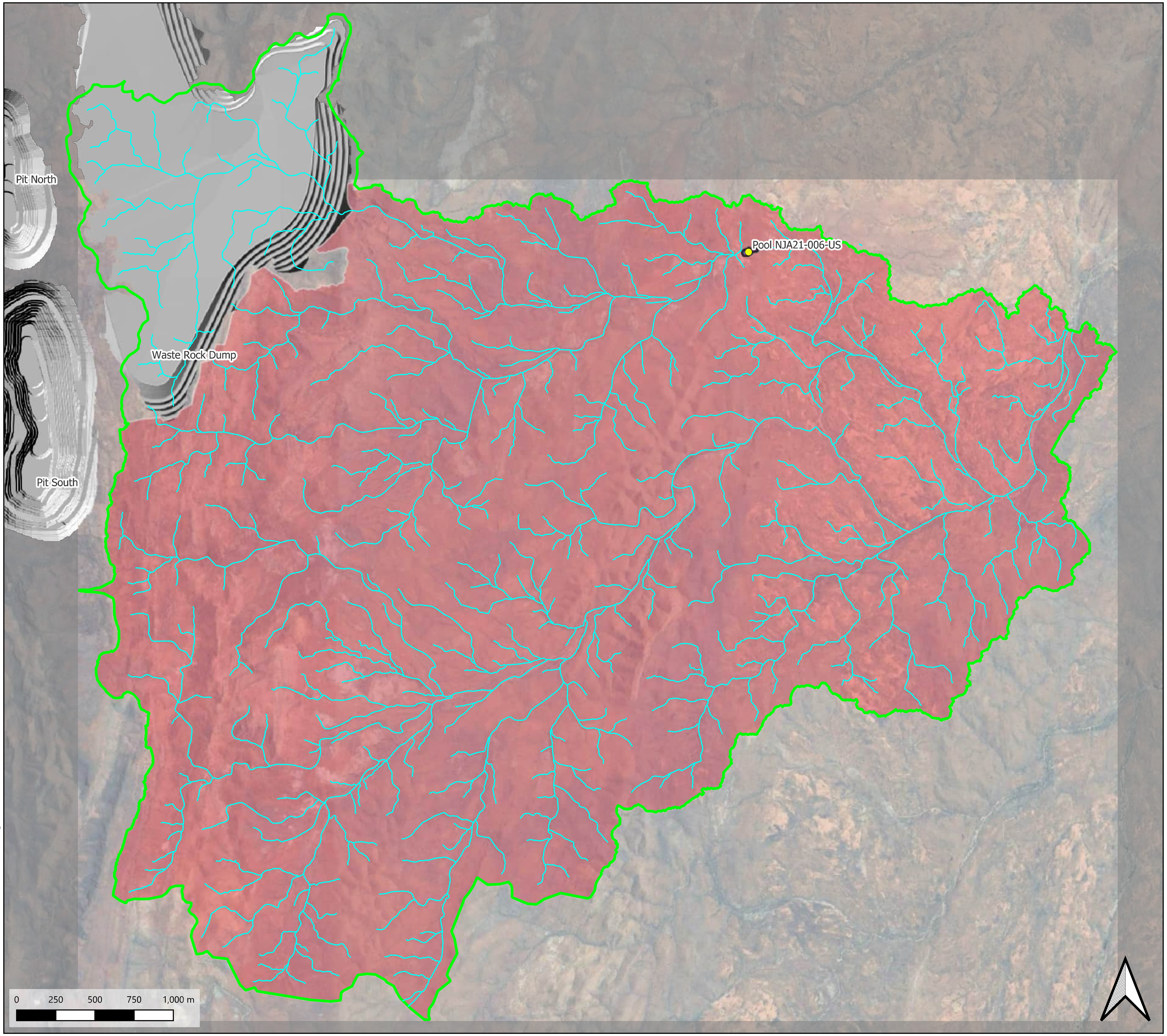
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool NJA21-006-DS Catchment



Legend

- Pool NJA21-006-DS
- Pool NJA21-006-DS Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 23,000

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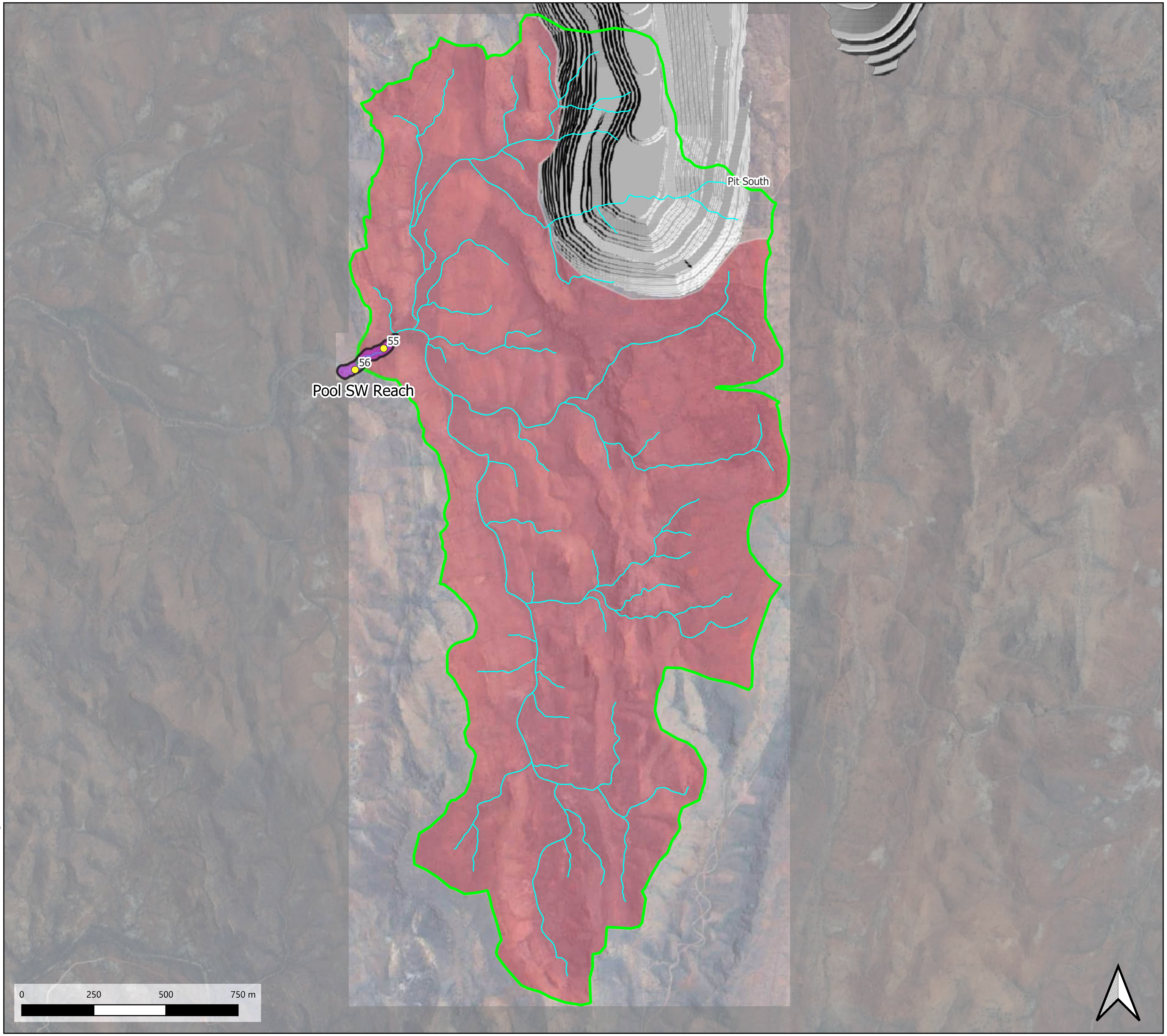

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**NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT**

Pool SW Reach Catchment

Legend

- Individual Pool
- Pool SW Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 12,500

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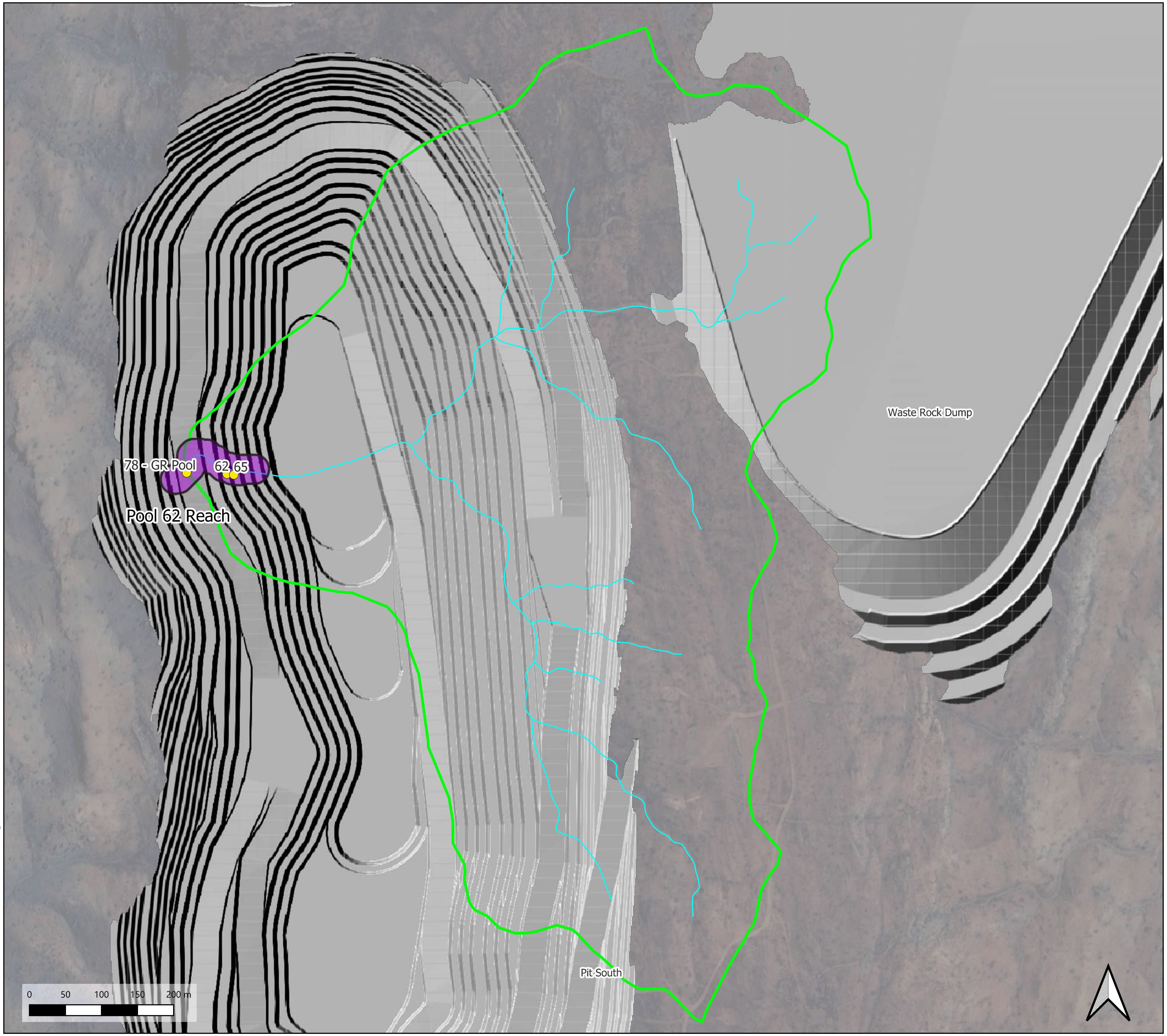

NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 62 Reach

Legend

- Individual Pool
- Pool 62 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 5,000

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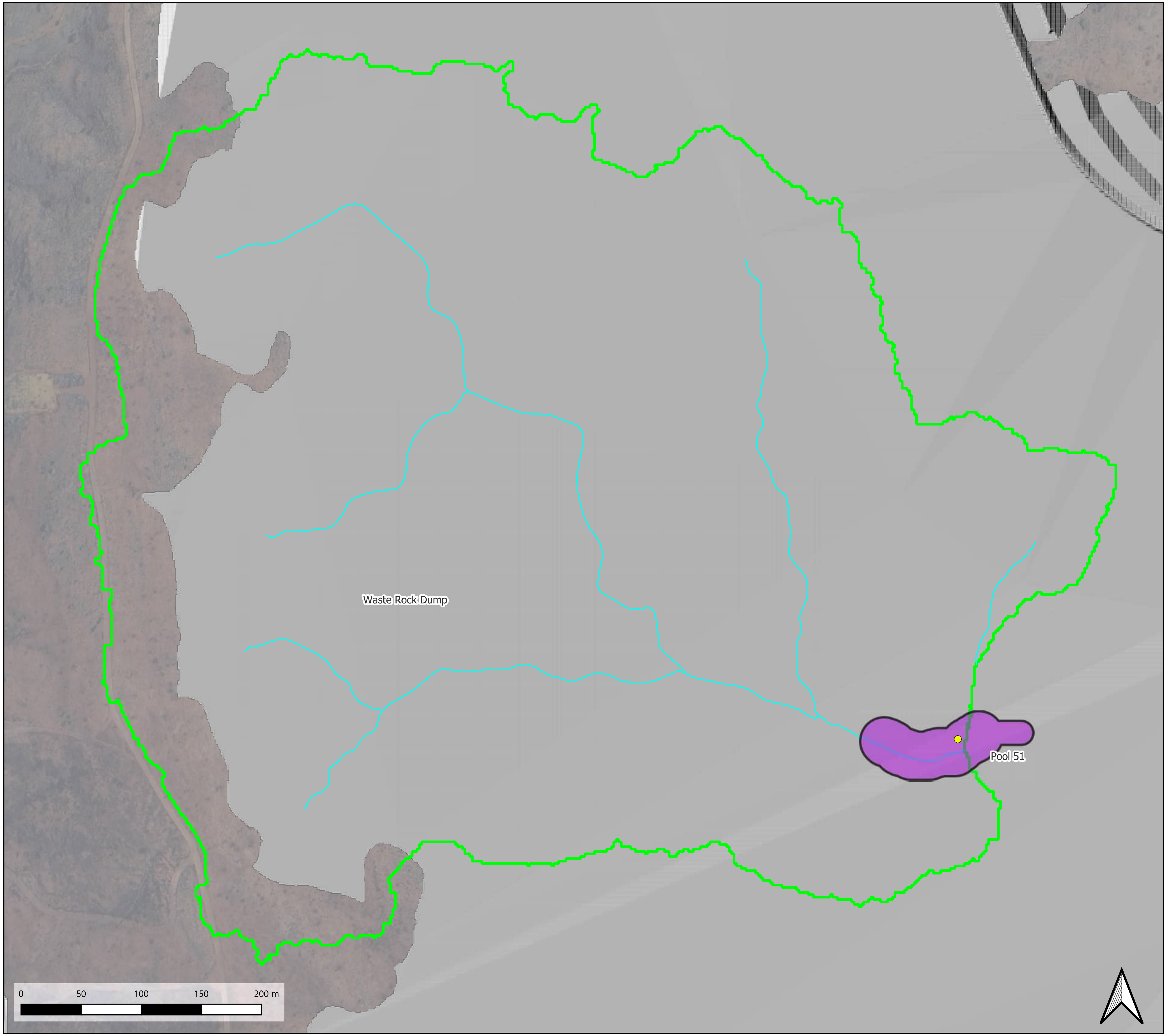

NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 51 Catchment

Legend

- Pool 51
- Pool 51 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 3,000

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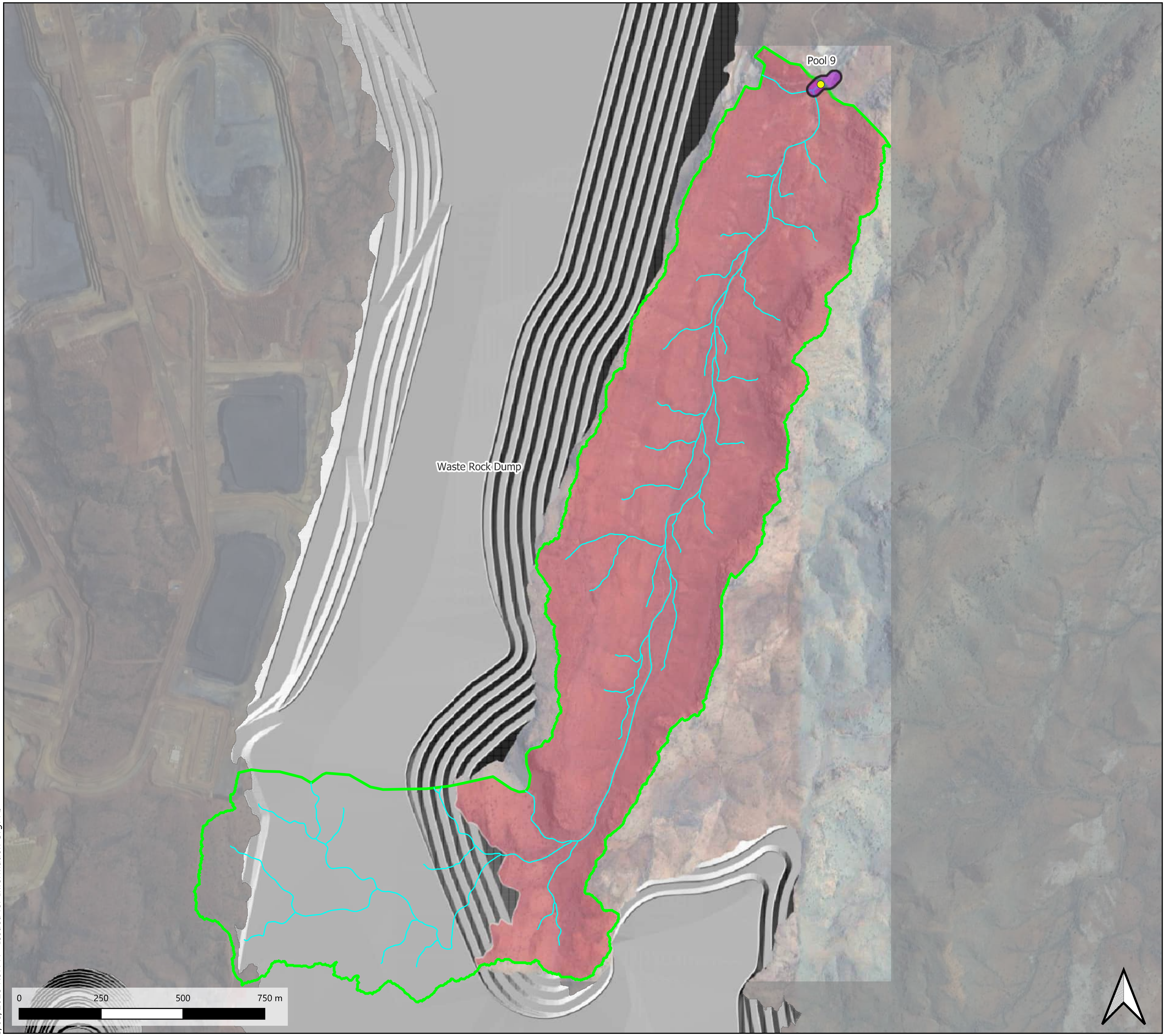
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 9 Catchment



Legend

- Pool 9
- Pool 9 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 11,000

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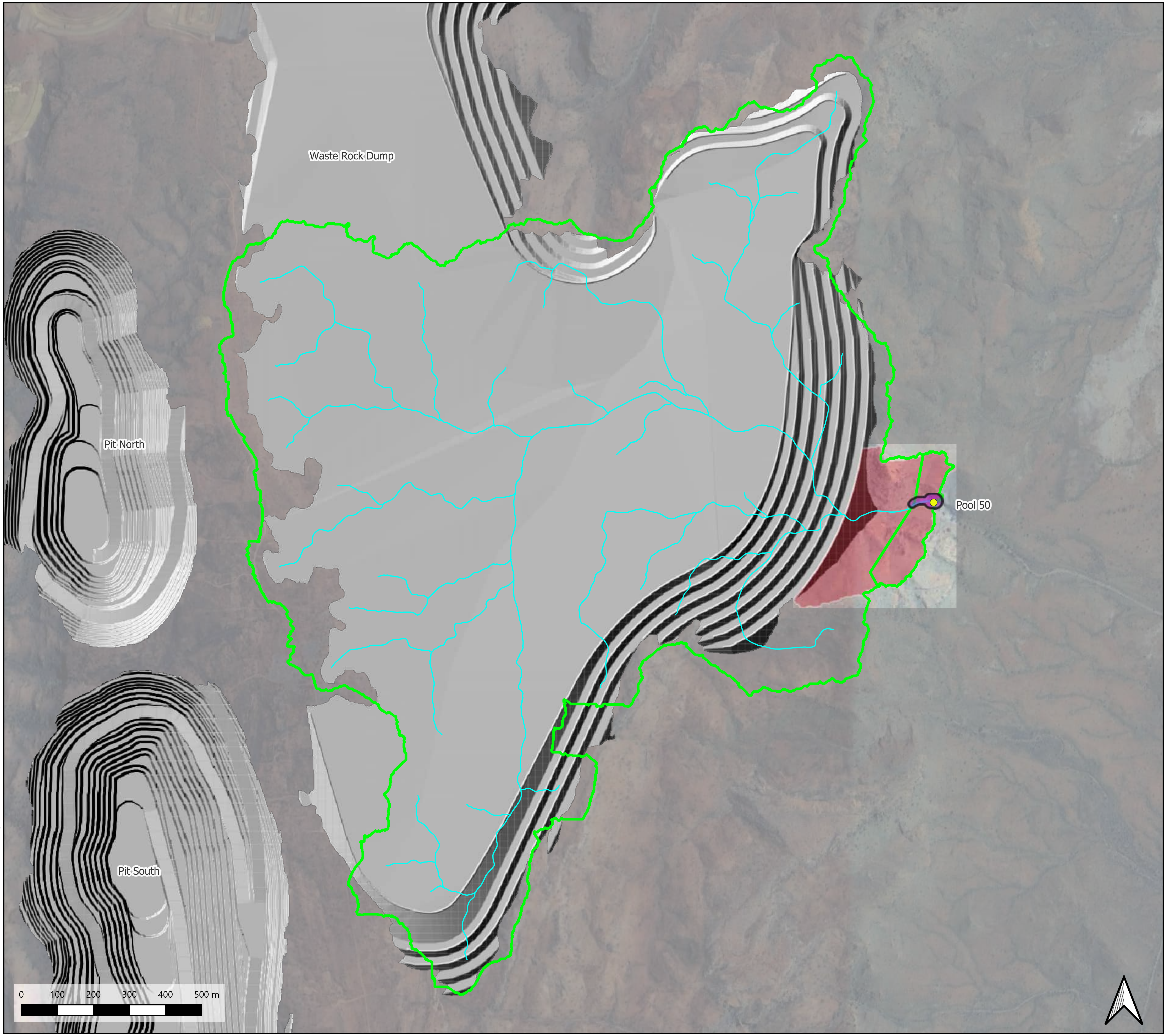
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 50 Catchment



Legend

- Pool 50
- Pool 50 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 10,000

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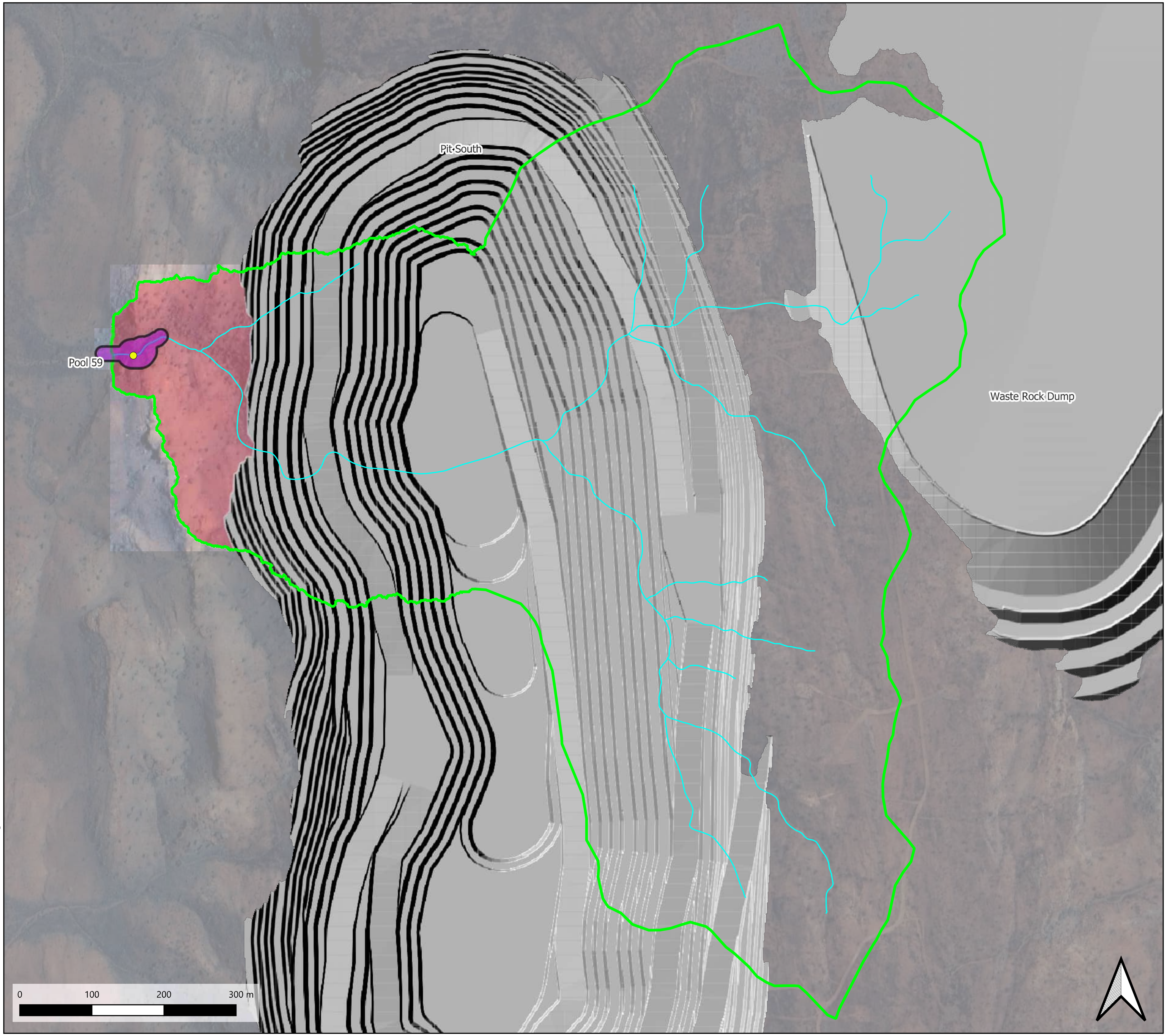
NORTH STAR EXTENSION
POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 59 Catchment



Legend

- Pool 59
- Pool 59 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 5,000

REGIONAL LOCATION

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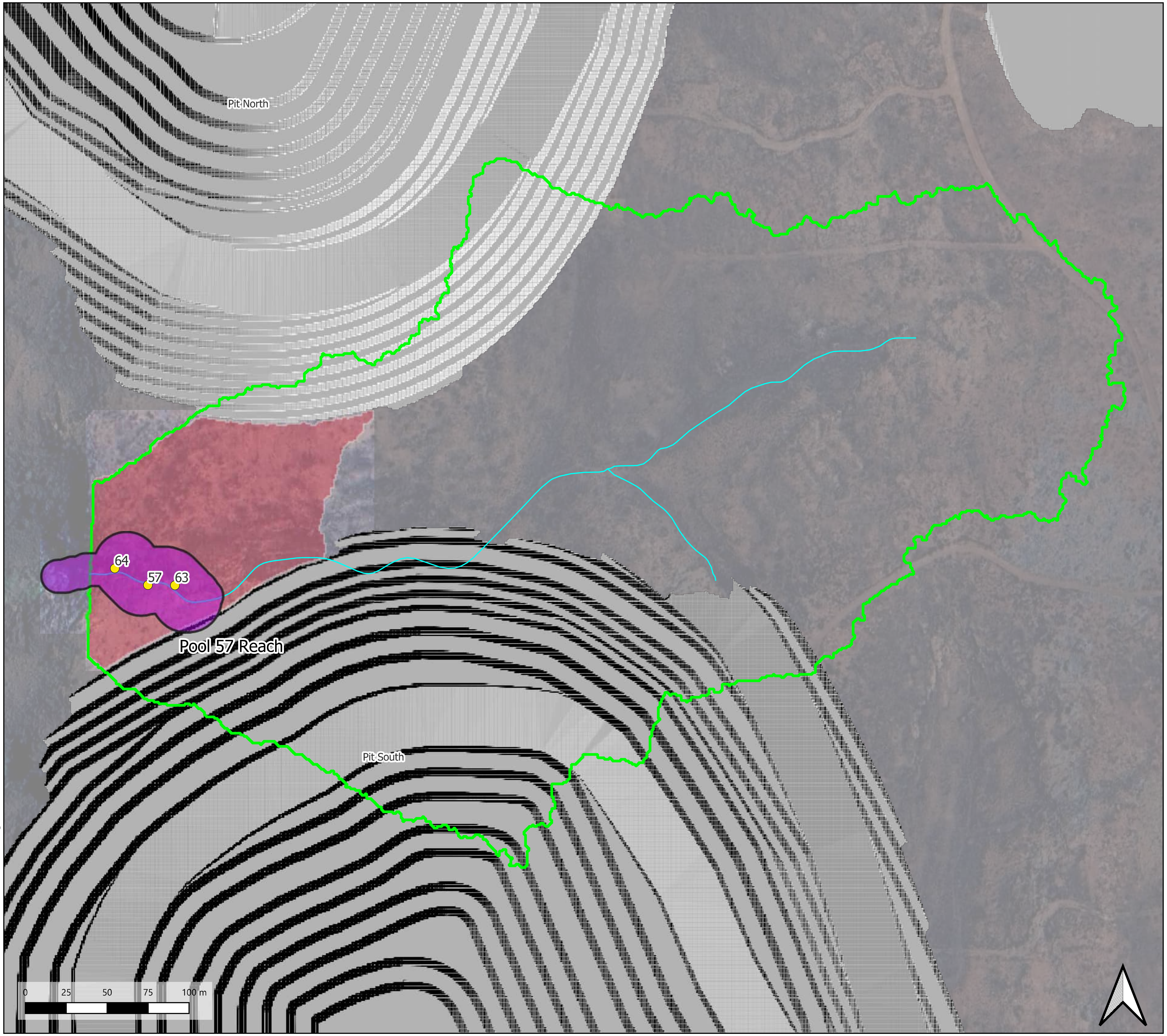


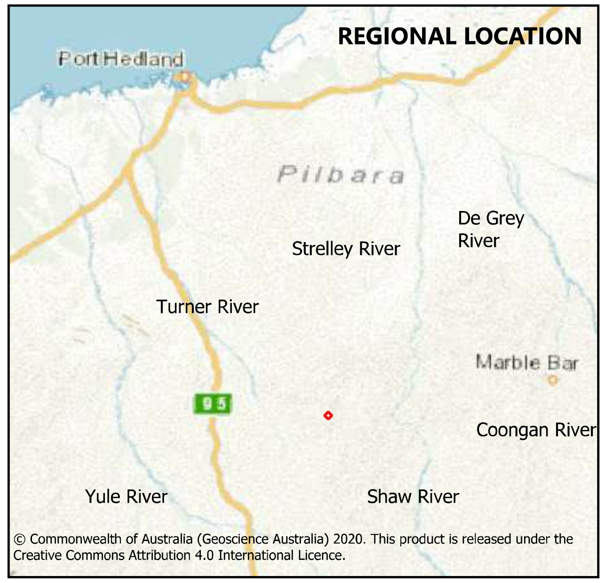
NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 57 Catchment

Legend

- Individual Pool
- Pool 57 Reach
- Drainage Lines
- Catchment Area (Baseline Conditions)
- Catchment Area (Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 2,200



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NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool 11 Catchment

Legend

- Pool 11
- Pool 11 Reach
- Drainage Lines
- Catchment Area (Baseline & Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 8,460

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NORTH STAR EXTENSION POOL HYDROLOGICAL AND WATER QUALITY ASSESSMENT

Pool GE 10 Catchment

Legend

- Pool GE 10
- Pool GE 10 Reach
- Drainage Lines (Baseline)
- Catchment Area (Baseline & Developed Conditions)

Coordinate System: GDA94 / MGA zone 50
Projection: Universal Transverse Mercator (UTM)
Datum: GDA 1994
False Easting: 500,000
Scale at A3 - 1: 14,000

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