ARROWSMITH CENTRAL

Surface Water Assessment

EWP19219.001
ARROWSMITH CENTRAL
003d
09 September 2021

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1 INTRODUCTION

1.1 Background

VRX Silica (VRX) is seeking to develop the Arrowsmith Central Silica Sand Project (the Project), a high grade silica sand mine in the Geraldton Sandplain region of WA. The project is about 260km north of Perth and lies within an existing exploration tenement (E 70/4987) held by VRX, refer Figure A.

The inferred resource for Arrowsmith Central is 28Mt comprising 97.7% SiO2; for a life of mine up to 30 years. The mining will progressively remove 2-3m of sand over a mining area of ~450ha, within a mine ~1600ha development envelope, which will be progressively rehabilitated. All mining will occur above the water table. A conceptual schematic section of the proposed mining area is shown in Figure B.

The mining process includes vegetation removal, sand mining in panels, slurrying, processing (gravity and magnetic separation), drying and transportation via rail to Geraldton Port for export; along with continuous rehabilitation of the site.

1.2 Scope of Services

The objective of this study is to provide a desktop Surface Water Assessment for the project for the proposed mining operational period, and post mine closure, for a Mining Proposal submission.

The report includes the following:

- Review of any existing reports and available information (maps, aerial photos) and the latest proposed development plans
- Characterisation and description of the existing surface water environments, including climate, location and size of catchments, existing drainage conditions and flow directions, from both a regional and local project-area perspective
- Investigate soil characteristics, regarding run-off/infiltration characteristics
- Delineation of catchments, and flood estimates and flood extents
- Surface water management including assessment of potential environmental impacts of the project, on natural drainage systems; and mitigation
- Closure / post mining – discussion on final slopes / terrain profiles, trapped low points and drainage issues, rehabilitation

2 HYDROLOGY

2.1 Climate

The Mid West has a Mediterranean climate. The average annual rainfall at this location is about 490mm and variable (300 - 850mm per annum or about 60 – 175% of average). Most rainfall occurs from May – August (winter) and September – April is dry (summer).

Temperatures vary from a min / max mean of 19-36° in summer and 9-20° in winter.

Average annual pan evaporation is ~ 2,200mm (~3mm/d in winter, to ~9mm/day in summer).

2.2 Rainfall

Intensity-Frequency-Depth (IFD) data is required to characterise storm rainfall intensities and is provided by the Bureau of Meteorology (BOM). Information is provided for various AEPs (Average Exceedance Probability), and the equivalent ARIs (Average Recurrence Interval), up to the 2,000-year ARI.

In addition, closure of mines requires contemplation of rare storms that could occur in time undefined after closure. For example, the 10,000-year rainfalls can be used as the basis for extreme rainfalls, taken as 24% greater than the 2,000-year rainfalls (based on extrapolation of actual statistical rainfall data); or ~2x 100-year rainfalls.

On this basis, rainfall intensity data for the Arrowsmith area is shown below:

Table 1: Intensity-Frequency-Duration (IFD) (mm)

AEP/ ARI Duration	63% 1y	50% 1.44y	20% 4.5y	10% 9.5y	5% 20y	2% 50y	1% 100y	2,000y	10,000y
1 hour	16	18	24	29	34	41	47	76	94
2 hour	20	22	30	36	43	52	59	96	119
6 hour	28	31	43	53	62	88	97	139	172
12 hour	34	39	62	66	78	96	111	176	218
24 hour	42	47	78	79	94	116	135	217	269
30 hour	44	50	69	83	99	122	146	241	298
72 hour	55	61	83	99	116	141	161	278	344

2.3 Flood Flow Estimates

The Arrowsmith River runs on the north side of Arrowsmith Central mine site. The river runs west before turning north and ending in Arrowsmith Lake (a permanent pool). There is a stream gauge monitoring station on the river (701005: Robb Crossing, Lat -29.62 Long 115.29), about 11km upstream and with catchment area 810km^2. For calibration purposes, the flows at the gauging station were estimated as follows:

- RFFE (Regional Flood Frequency Estimation) method as shown in Table 2 below - Arrowsmith is in a data-rich region, and confidence limits are higher
- RAFTS is a runoff routing model that develops a stormwater runoff hydrograph, based on catchment areas, slopes, surface roughness, rainfall losses, design rainfall IFDs and storm temporal patterns.

RAFTS requires customising for each application. The 100-year flows were calculated (note flows <Q_{100} (100 year) and the $Q_{10,000}$ are based on the flood ratios for the RFFE method)

- Flood Frequency Analysis – the existing maximum instantaneous flood flow for each year (1972-2000) were ranked on an annual basis. The plotting position / exceedance probability versus the flood peaks was plotted, but most of the stream gauge data available over this period shows only relatively minor flood events; and was deemed less accurate than the other two methods
- The $Q_{10,000}$ flood was extrapolated as 1,041 m^3/s, equivalent to ~3 x Q_{100}. The PMF is typically in the order of twice the $Q_{10,000}$ or 6 x Q_{100} in this case

The peak flows for Arrowsmith River using all 3 methods are provided in Table 2. Given the nature of the sand plain and the fact that the Arrowsmith central area is not within the Arrowsmith River catchment area, there are no impacts on the river flows.

Table 2: Peak Flows (m^3/s)

AEP / ARI yrs	RFFE	Fraction of 100y flood	RAFTS	Stream Gauge Data
50% / 1.44	28	0.08	29	24
20% / 4.5	81	0.23	83	69
10% / 9.5	132	0.38	134	114
5% / 20	193	0.55	196	165
2% / 50	280	0.80	285	240
1% / 100	349	1.00	355	300
10,000	1,041	2.98	1,059	894

2.4 External Flooding

The Arrowsmith Central site is located about 1.4km south of the Arrowsmith River, running along the north side of Arrowsmith Central mine site. The river runs west before turning north and terminates in Arrowsmith Lake (a permanent pool). There is no survey data upon which to accurately model and estimate flood levels in the river, or produce a flood map. However, based on SRTM (Shuttle Radar Topography Mission) data, some analysis can be undertaken. The river bed slope is about 0.2%. The main channel appears to be a few metres wide with minimal capacity and suggests that most flood flow is carried in the floodplain. The southern floodplain is extremely flat (north to south axis) and aerial photography indicates possible sheet overflow paths, where the river breaks its south bank and sheets west and southwest through the site of the proposed mining.

It is not possible to accurately estimate break and overflow situations but the flooding regime at the northern edge of the site has been characterised as ~0.2m deep (Q_{10}), ~0.35m (Q_{100}) with 100 year flows up to 0.5m deep locally. As such minor bunding around the current mining plan would be sufficient to divert these flows. Any flows getting into the mining area at that time would infiltrate.

The $Q_{10,000}$ floods would breakout heavily from the river channel (estimated as ~0.65m deep at the northern boundary but locally up to 1m deep).

A smaller water course runs south down the west side of the site to Arro Lake, 2km west of the plant site and is topographically is several metres lower than the proposed mining site. As such it can have no surface water impact on the mine site.

2.5 Internal Flooding

The soils of the Arrowsmith catchment (east of the mine site) are best characterised as moderately well to well drained soils with fine to coarse textures.

The proposed mining tenement is an undulating sand plain (~RL50-65m) that slopes down to the south west. The Arrowsmith tenements are primarily underlain by unconsolidated yellow silica sand above Tamala Limestone, covered by low scrub and very few trees (refer Figure B), topographic relief is low. A surface humus layer is typically about 300 mm thick, and the upper 500mm (top soil) is assumed reserved for rehabilitation purposes.

Infrastructure located on slightly higher topography, or minor bunding around, would alleviate any risk of flooding.

Soil testing and Particle Size Distribution (PSD) analysis (refer Table 3) undertaken by VRX, shows the yellow sand consists predominantly of medium grain sand with a D_{50} (i.e. the 50 percentile grain size of the material) of ~0.4mm (medium sand) and less than 5% fines (silt).

Table 3: Summary of PSD Data

PSD Data		
Particle Size	**Description**	**Yellow Sand (%)**
<0.075mm	Fines (i.e. silt)	3
0.075-0.2mm	Fine Sand	19
0.2-0.6mm	Medium Sand	61
0.6-2mm	Coarse Sand	18

The D_{10} size is about 0.15mm. The D_{10} size is a determinant of hydraulic conductivity and based on Hazens formula estimates the hydraulic conductivity as about 10m/d. The hydraulic conductivity based on published data for a medium sand is about 5-20m/d (fine sand slightly lower).

The sand therefore has a high infiltration rate, but would be reduced by the surface humus layer. If surface runoff is generated, it infiltrates into the sandplain. As such runoff, within and from the site, has low potential, and run-off is only anticipated to occur in short intense rain bursts.

Mining will remain above the water table. The depth of sand above the limestone will however decrease. About 2-3m of yellow sand (no white sand present) will be removed, leaving a minimum 0.5m of sand above limestone (water table sits within the Limestone). The remnant sand will maintain its high permeability and infiltration rate. Rehabilitation will provide a growing substrate above the limestone, however where minimal sand remains above the limestone, the sand horizon remaining will saturate more easily, effectively reduce the permeability of the sand, and allow more run-off in intense rainfall events. Given the unevenness of the underlying impermeable surface (limestone), this effect would be somewhat erratic, but the exposed surface in these areas should be graded (minimally as required) to maintain a surface drainage away from the relevant sites. On this basis, there will be negligible change to internal flooding.

3 SURFACE WATER MANAGEMENT - GENERAL

3.1 General

Arrowsmith Central is located south of Arrowsmith River on a gentle slope from east to west. There is no upstream catchment affecting the site and it will, therefore primarily be affected by rainfall directly on the mine site. The elevations vary from about RL50m to RL65m.

When the Arrowsmith River floods, there is potential for break-outs from the river at two possible locations - either (a) towards the south-west along a flow path south east of the mine site into Arro Lake, or (b) instead of turning north, some flow break-out to the south along a flow path west of the Central mine site and into either Arro Lake or Lake Logue.

The mine areas generally consist of homogeneous sandplain landscape with no natural drainage and avoid existing infrastructure, trees, drainage lines and potential conservation areas.

The vegetation is Kwongan - sandy and open without significant trees but with knee-high scrubby vegetation.

A surface water management plan for Arrowsmith Central is shown in Figure C.

3.2 Arrowsmith Central

Arrowsmith Central is located south of the Arrowsmith River, on slightly undulating ground with a gentle slope from east to west.

- There is no upstream catchment impacting the site and it will, therefore primarily be affected by rainfall directly on the mine site
- Local surface water will run to the south west along minor creeks. Due to the undulating nature of the site, some of the surface water will remain trapped on site and infiltrate into the sandplain
- During heavy rainfall events, the Arrowsmith River will overflow at two possible locations either to the southwest along a creek to the south-east of the mine site into Arro Lake, or to the south along a creek to the west of the mine site into either Arrow Lake or Lake Logue
- During extreme flooding in the Arrowsmith River, there is potential for the river to break its banks and flow into the mine site. In order to properly determine the extents and depth of flooding, further survey would be required at several cross sections along the river that extend from the site to the other side of the river. To reduce the risk of flows impacting the mine site, a notional bund on the north and east side of the site could be considered to divert flow to the creeks on the western and south-eastern sides of the mining area
- As it is proposed the site be continuously rehabilitated (and with no waste dumps), there will be limited exposed disturbed surfaces (sandy) and hence in sand with limited mobility, no surface water treatment is required.

4 EROSION AND RUNOFF

4.1 General Principles

The Mid-West landscape can be subject to heavy rainfall during winter. Activities such as vegetation and topsoil removal, mining activities and general construction activities can increase the risk of erosion and environmental approvals for projects that involve land disturbance require adherence to surface water protection principles. The general objective is to maintain surface water regimes, so that existing and potential uses (including the ecosystem) are also protected.

Soil and water issues need to be identified, planned, managed and monitored during the mine life to minimise adverse impacts. The commitment is to carry out activities in a manner that conforms to relevant regulatory and legislative requirements, by ensuring that controls are properly implemented, and are regularly monitored and audited to assess their effectiveness. Changes to the stipulated controls are instigated if they are not achieving their aims.

Objectives typically include the application of best management practices, minimising disturbed areas and any sediment deposited offsite, compliance with discharge limits and the provision of specific work procedures and environmental control measures for activities which require more detailed attention (such as surface disturbance / excavation, waterway crossings, chemical storage and use, refuelling operations, water monitoring methods, etc).

4.2 Mitigation of Impacts

Mitigation measures include:

- No dumps / stockpiles (100% use of the silica sand)
- Continuous rehabilitation, minimising the need for stockpiling of topsoil

Infrastructure areas:

- Locate sites away from potential drainage flow paths, avoid extant surface water flow paths
- Minimise disturbance, use existing tracks
- Locate storage areas (chemicals, hydrocarbons, etc) clear of potential flow paths

4.3 Inspection, Auditing & Monitoring

Regular site inspections or informal visual checks should be carried out to ensure appropriate mitigation measures and controls are implemented; and are operational and effective. Site inspections can include event-based inspections, prior to predicted rainfall events, following significant rain events, and prior to extended site shutdowns.

The outcomes of inspections, monitoring, and audits facilitate the identification of problems and recurring issues or areas for improvement.

5 BUNDS AND CHANNELS

5.1 Typical Surface Water Diversions

Construction and infrastructure should preferably lie outside floodplains, and therefore avoid the need for diversion works altogether. In general, the Arrowsmith sites lie outside major floodplains. However, during extreme rainfall events there is potential for river flow to break-out across the Arrowsmith Central site. A low bund on the north and east side of the mine site would divert the flow into the minor drainages either side of the mine site.

Diversions consist of earth bunds, excavated channels or combined bund / channels, with an appropriate freeboard above flood levels.

Earth bunds are typically trapezoidal shaped with side batters (slopes) of 1V:2-3H. The crest width should be commensurate with the height of the bund (and whether road access is required across the embankment). As a minimum, a 1m bund could have a crest width of 1.5m, a 3m bund a width of 2.5m.

Excavated open (trapezoidal) channels typically have side batters of 1V:2H or flatter for silty / sandy material.

5.2 Bund Materials

The performance requirements for temporary storage of water are not specific or high, and construction materials are usually the most suitable available materials at the site. There should preferably be some clay content (clayey gravels and clayey sands are best) but substandard materials (such as sand can be used with more robust dimensions).

5.3 Bund Embankment Construction

Construction requirements typically include:

- Excavate base to strip depth, scarify in preparation
- Maintain moisture content at optimum (which allows maximum density to be achieved by the compaction equipment in use)
- Place, compact in layers to 95% Standard or 90% Modified Maximum Dry Density
- Control batter slopes to line and level.

6 GENERAL GUIDELINES POST-CLOSURE

6.1 Post Closure Design Criteria

The objective of Mine Closure guidelines is to ensure an effective planning process is in place throughout the life of mine, so closure is achieved in an environmentally sustainable manner and without unacceptable liability to the State (refer “Guidelines for Preparing Mine Closure Plans”, Department of Mines and Petroleum, and Environmental Protection Agency).

General mine closure principles include:

- Surface and groundwater hydrological patterns / flows not adversely affected
- Surface and groundwater levels, and water quality reflect original levels and water chemistry
- No long-term reduction in the availability of water to meet local environmental values i.e. a desire that base-flows be maintained

6.2 Land Disturbance and Rehabilitation

Mining is a temporary land use and rehabilitation objectives should be consistent with projected future land use. Rehabilitation strategies are designed to contribute to maintenance free closure over the long term, and integrated with mine planning and operations, to minimise the environmental impacts and maximise rehabilitation success.

Arrowsmith Central is located on undulating ground. The site will be mined to suit the existing minimum ground level and will approximately maintain the existing surface profile. Free draining surfaces must be maintained.

A system of continuous rehabilitation will be undertaken using a specially designed front-end loader. Vegetation will be removed with 200-300mm of topsoil, and placed on a completed mining area. The panel will be placed in a checkerboard pattern with a small gap between panels (a “gully” to encourage the collection of humus and seeds). There will be ~100% utilisation of mined material and waste dumps will not be required during the life of mine.

Decommissioning involves removal of remaining infrastructure, and rehabilitation of all disturbed areas (including trommel screen, process plant, conveyor, wastes, contaminated soil, compacted surfaces (roadways, site compounds, bunds), etc.

There will be no change to the surface runoff from the site (which naturally makes a very low contribution to external flows).

6.3 Monitoring

Post-closure performance monitoring of disturbed areas will be undertaken, to agreed standards to be achieved on various aspects of the project. Progressive rehabilitation and assessment demonstrates the relative success of rehabilitation in achieving desired outcomes, and whether the rehabilitation end point has been reached. Performance criteria include post-closure land use objectives, landform stability, ground water protection, and revegetation targets.

7 SUMMARY

VRX Silica (VRX) is seeking to develop the Arrowsmith Central Silica Sand Project (the Project), a high grade silica sand mine in the Geraldton Sandplain region of WA. The vegetation is Kwongan - sandy and open without significant trees but with knee-high scrubby vegetation.

The mining will progressively remove 2-3m of sand over a mining area of ~450ha, within a mine ~1600ha development envelope, which will be progressively rehabilitated. All mining will occur above the water table.

The mining process includes vegetation removal, sand mining in panels, slurrying, processing (gravity and magnetic separation), drying and transportation via rail to Geraldton Port for export; along with continuous rehabilitation of the site.

VRX Silica (VRX) is seeking to develop the Arrowsmith Silica Sands Project, consisting of high-grade silica sand mines in the Geraldton Sandplain region of WA. There are two sites which make up the project, Arrowsmith North and Central, with the main focus on Arrowsmith North.

The mining will remove 2-3m of sand for Arrowsmith Central over the total mining area of ~1900ha, that will be progressively mined and rehabilitated (20ha at a time). Mining will remain a minimum of 10m above the water table. The inferred resource is 28Mt, with a life of mine up to 30 years.

The mining process includes vegetation removal, sand mining in panels and processing sand for export to Geraldton. Mined areas will be revegetated progressively, and tailings will be pumped back to the mine face as part of the progressive rehabilitation procedure.

The climate is Mediterranean climate with an average annual rainfall of about 490mm. The Arrowsmith River terminates in Arrowsmith Lake about 2.6km south west of the mining site. The Arrowsmith River has a river bed slope of about 0.2%, and 100-year flood depth (average) of about 1.4m deep.

The best method of water management is to locate infrastructure away from significant creeks and avoid the need for diversion works where possible.

Arrowsmith Central is located south of the Arrowsmith River, on slightly undulating ground with a gentle slope from east to west. Soils are underlain by unconsolidated yellow silica sand, covered by low scrub and very few trees. Soil testing shows that the sand consists predominantly of medium grain sand with a D_{50} of ~0.4mm. The hydraulic conductivity is about 5-20m/d, with a high infiltration rate, but reduced somewhat by a surface humus layer. Runoff, within and from the site, has low potential, and surface run-off is only anticipated to occur in short intense rain bursts.

The depth of sand remaining above the limestone will decrease. The final rehabilitated surfaces should be graded (minimally as required) to maintain a positive surface drainage. On this basis, there will be negligible change to internal flooding.

During extreme flooding in the Arrowsmith River, there is potential for the river to break its banks and flow into the mine site. In order to properly determine the extents and depth of flooding, further survey would be required at several cross sections along the river that extend from the site to the other side of the river. To reduce the risk of flows impacting the mine site, a notional bund on the north and east side of the site could be considered to divert flow to the creeks on the western and south-eastern sides of the mining area

The site will be continuously rehabilitated (and with no waste dumps), there will be limited exposed disturbed surfaces, but with no surface runoff and hence no surface water treatment measures are required.

The post-mining soil profile will visually match the pre-mining profile, at lower land levels. Care is required to maintain continuously draining rehabilitated surfaces, to avoid low / trapped areas that could saturate and pool.

Similarly, the rehabilitated surface will visually blend to the terrain at the tenement edges, matching slopes and taking care to maintain free draining surfaces out of the site.

Post-closure performance (progressive assessment) monitoring is required to achieve agreed rehabilitation standards for various aspects of the project and determine if the rehabilitation end point has been reached. Rehabilitation performance criteria include post-closure land use objectives, landform stability, ground water protection, and revegetation targets.

Figures

LEGEND
Mine Infrastructure

Arrowsmith Lake

ARROWSMITH RIVER

Plant Area

Arrowsmith Central

Arro Lake

Brand Hwy

Indian Oce

GERALDTON
Site
MERREDIN
PERTH
0 90 180 km

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Figure A
Arrowsmith Central
Site Location and General Layout

GDA 1994 MGA Zone 50
0 1,875 3,750 7,500 m

Job Number:EWP19219.001
Doc Number: 001
Date: 09.01.20
Scale: Map 1:125,000 Overview 1:5,000,000 @ A3
Created by: ER
Source: Orthophoto - Esri, DigitalGlobe, GeoEye, Earthstar, Geographics, CNES/Airbus DS, USDA, USGS, Aerogrid, IGN, IGP and the GIS User Community

Document Path: F:\Jobs\EWP19219 - Arrowsmith Silica Sand\600 - Report\Figures\Arrowsmith Central\EWP19219.001 - Fig A - Arrowsmith - Location Plan and General Layout.mxd

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Arrowsmith

VRXSILICA

Proposed Mining Schematic Section

December 2019

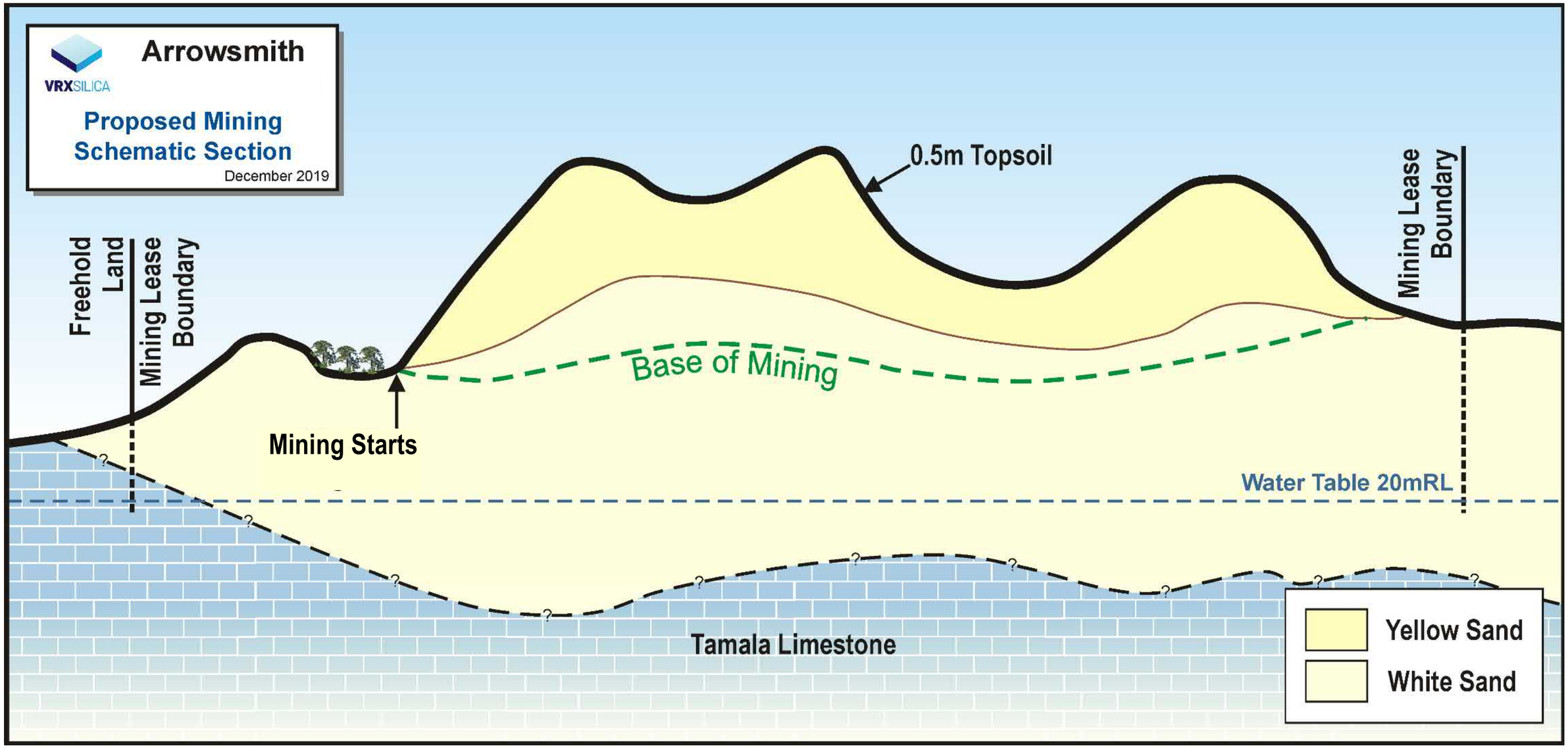

Figure B
Arrowsmith Central
Proposed Mining Schematic Section

Job Number:EWP19219.001
Doc Number: 001
Date: 05.03.20
Scale: Map 1:40,000
Created by: ER
Source: VRXSILICA

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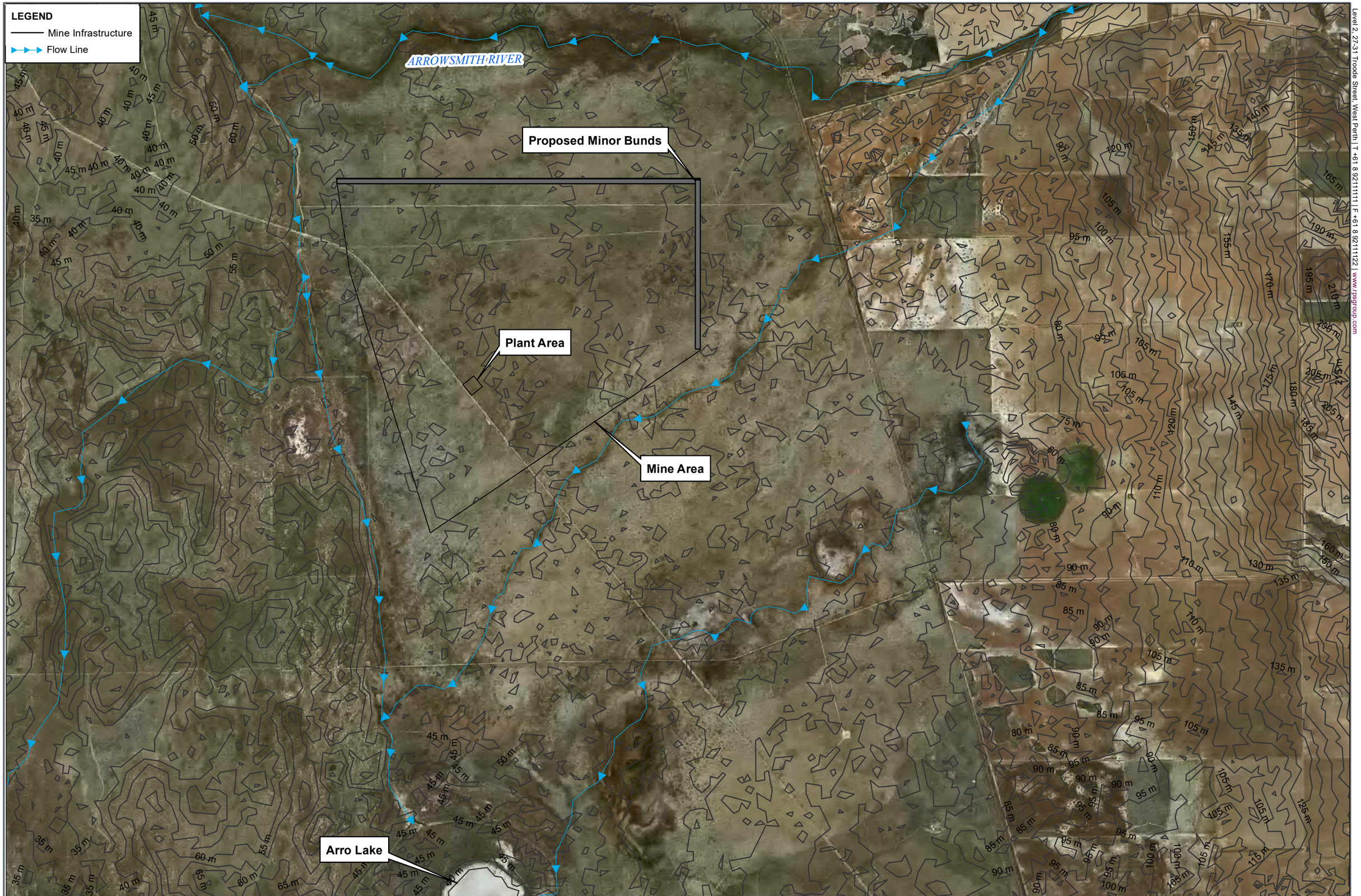

Figure C
Arrowsmith Central
Surface Water Management Plan

GDA 1994 MGA Zone 50

0 750 1,500 3,000 m

Job Number:EWP19219.001
Doc Number: 001
Date: 09.01.20
Scale: Map 1:50,000
Created by: ER
Source: Orthophoto - Esri, DigitalGlobe, GeoEye, Earthstar, Geographics, CNES/Airbus DS, USDA, USGS, Aerogrid, IGN, IGP and the GIS User Community

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