VRX Silica Limited

Hydrogeological feasibility assessment
Arrowsmith Project

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1. Introduction

VRX Silica Limited (VRX) is considering the development of a high-grade silica sand operation in the Arrowsmith area to the southeast of Dongara (Fig. 1). The Arrowsmith Project (Project) comprises two proposed mining areas being Arrowsmith North and Arrowsmith Central. Both areas will have a processing facility that will improve the grade and quality of the sand before exporting at Geraldton.

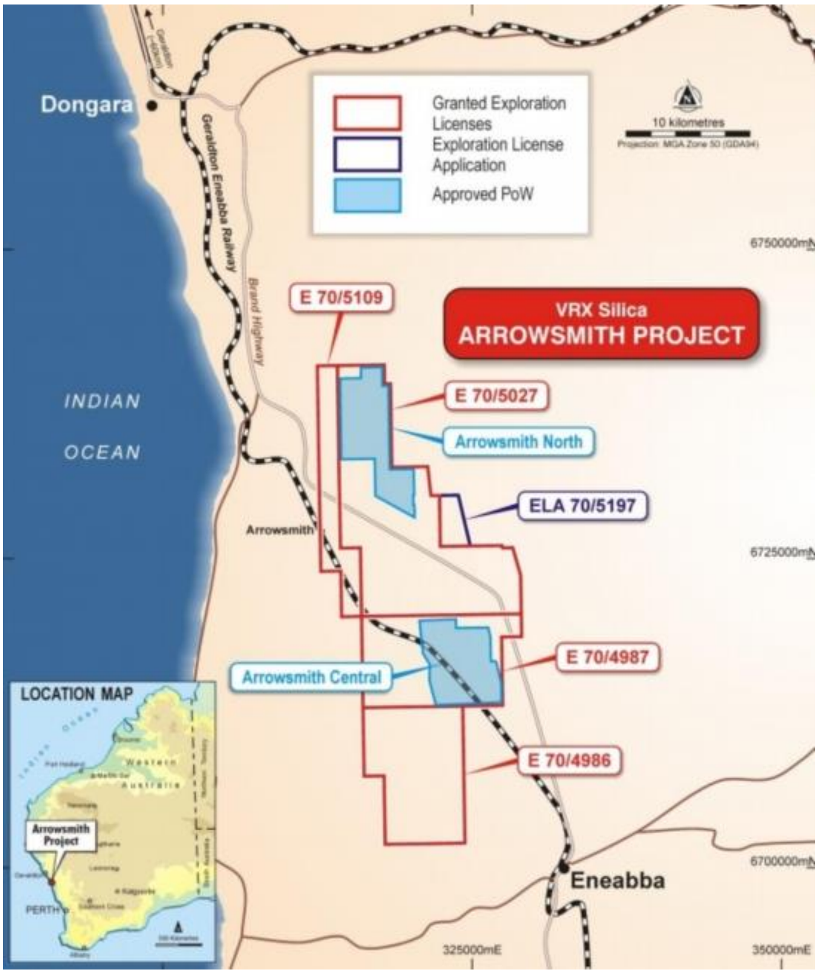

Figure 1. Location of the Arrowsmith Project

Water is required for processing at both sites with groundwater resources being considered the most likely and reliable source. The water demand is approximately 500 ML/yr at both the Arrowsmith North and Arrowsmith Central sites. In order to meet these water requirements, there will be need for a groundwater licence from the Department of Water and Environmental Regulation (DWER).

This document provides a scoping level of hydrogeological assessment that reviews the regional hydrogeology, development constraints, potential borefield layout and design considerations, and the likely approval process within the DWER.

2. Hydrogeology

The VRX Silica tenements at Arrowsmith are situated upon the Swan Coastal Plain (Fig. 2), which is up to about 30 km wide comprising several geomorphic units parallel to the coast. Both project areas are located upon the Eneabba Plain, which is made up of shoreline, lagoonal and dune deposits possibly reworked from late Tertiary alluvial fans.

The Project area lies within the northern Perth Basin, containing a succession of Quaternary to Permian age deposits up to a total of 12 000 m thick, but thinning to around 1 000 m over the Beagle Ridge southwest of the tenements. A detailed description of the geology and hydrogeology in the northern Perth Basin is given by 'Northern Perth Basin: Geology, hydrogeology and groundwater resources' (Department of Water, 2017).

Two aquifers are present beneath the tenements, one within the relatively thin Superficial Formations, which is underlain by a major regional aquifer within the Yarragadee Formation.

2.1 Superficial geology and aquifer

The Swan Coastal Plain is underlain by a sequence of Quaternary and Pliocene sedimentary deposits summarised by Table 1, which unconformably overlie Mesozoic deposits upon a gentle, westward sloping erosional surface (Fig. 3).

Table 1. Stratigraphy of the Superficial Formations in the Arrowsmith Project area.

Period	Epoch	Stratigraphy	Max Thickness (m)	Lithology
Quaternary	Holocene	Alluvium, estuarine and swamp deposits	5	Clay, sand and peat
		Safety Bay Sand	100	Sand
	Pleistocene	Bassendean Sand	40	Sand, minor silt and clay
		Tamala Limestone	150	Calcareous arenite, limestone, sand and clay
		Guildford Clay	30	Clay, sandy clay and clayey sand
Neogene	Pliocene	Ascot Formation	31	Sand, clay and limestone
		Yoganup Formation	21	Sand

The Superficial Formations form an unconfined aquifer referred to as the Superficial aquifer. Both the Arrowsmith North and Arrowsmith Central project areas are underlain by a relatively thin cover of sand belonging to the Bassendean Sand upon a thicker section of predominantly clayey sand forming the Guildford Clay, which are approximately coincident with the Eneabba Plain. Calcarenite limestone of the Tamala Limestone is located west of the project areas beneath the Spearwood Dunes, and frequently contain karstic cavities.

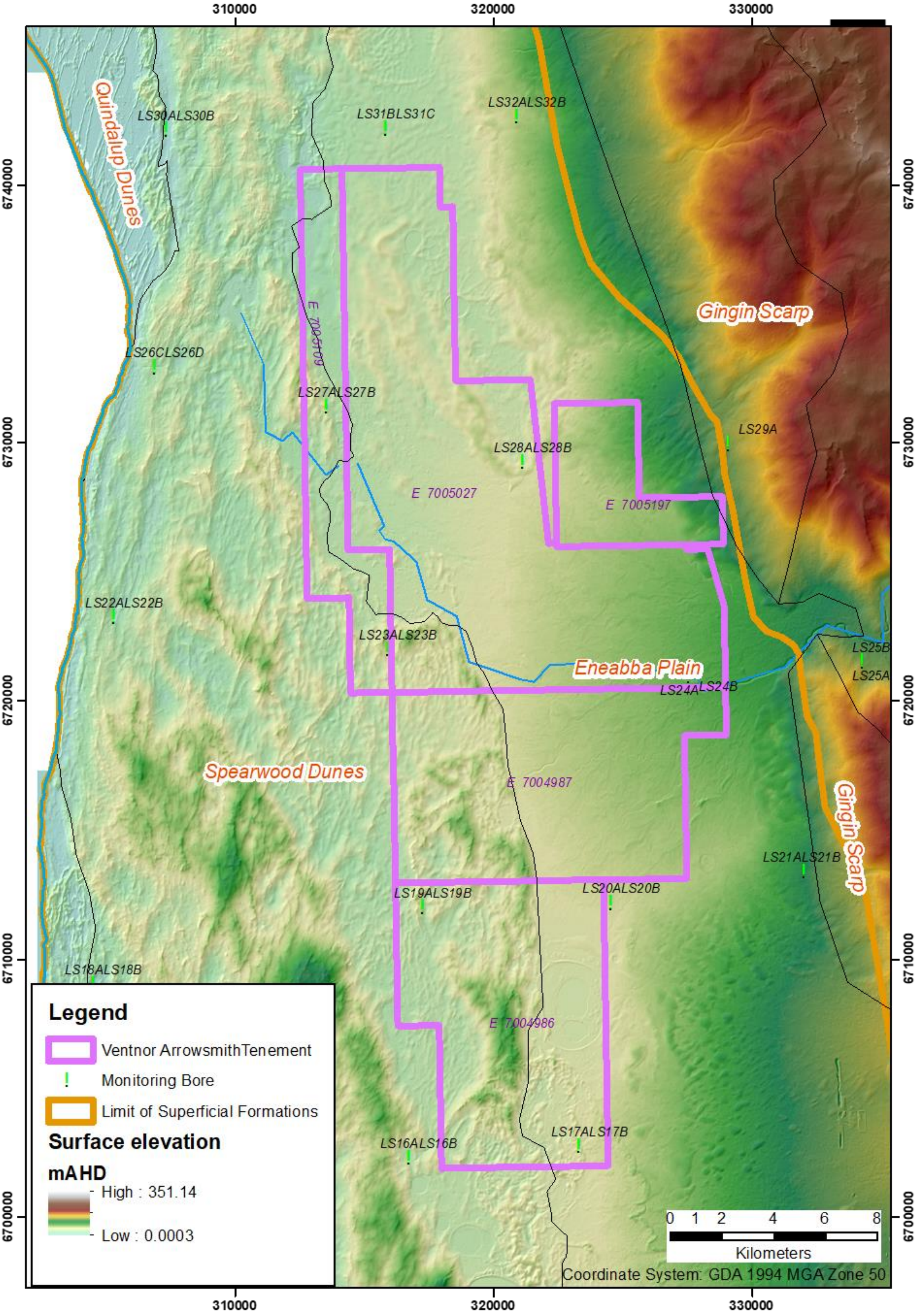

Figure 2. Physiography

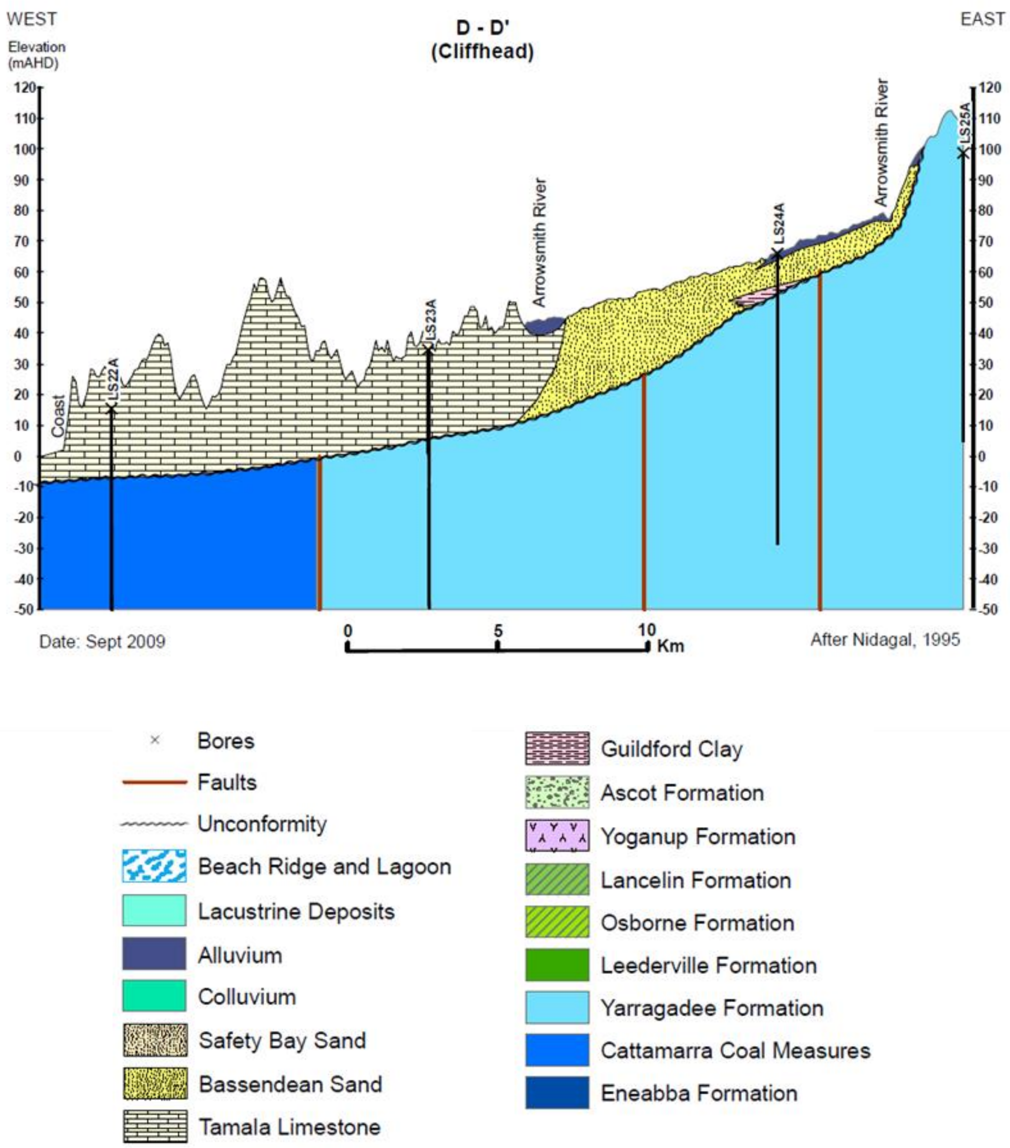

Figure 3. Geological east-west section through the Superficial Formations (after Nidagal, 1995).

Detailed geological logs from Leeman Shallow (LS) monitoring bores are available near each of the project areas (Nidagal, 1991a, b; Kern, 1994). A summary of the Superficial Formation units intersected by these bores near the project areas is given in Table 2.

Table 2. Superficial Formation units intersected in Leeman Shallow monitoring bores located near the Arrowsmith North and Arrowsmith Central project areas.

Monitoring Bore	Location from project area	Superficial Formations	Bassendean Sand	Guildford Clay	Tamala Limestone
Arrowsmith North					
LS27	southwest	30			30
LS28	southeast	33	5	28	
LS31	north	24	10	14	
Arrowsmith Central					
LS19	southwest	47			47
LS20	South-southeast	24	4	20	
LS24	northeast	15	4	11	

The watertable within the Superficial aquifer, shown by Figure 4, falls from around 50 to 60 m AHD about the eastern margin of the coastal plain to sea-level at the coast. About the inland margin of the coastal plain, the watertable is typically within the Mesozoic formation (Yarragadee Formation) underlying the Superficial Formations, so that the Superficial aquifer is unsaturated.

Groundwater is recharged mainly by the infiltration of rainfall, but there is also a component of recharge by upward leakage from underlying aquifers, mostly about the central portion of the coastal plain, and by the infiltration from streams and rivers flowing out onto the coastal plain, including the Arrowsmith River that discharges over the coastal plain. Groundwater flows down the hydraulic gradient toward the coast, where most of the groundwater is discharged to the ocean. A component of groundwater is lost via evaporation from lakes and evapotranspiration.

The saturated thickness of the Superficial aquifer is shown by the interpretive isopach in Figure 5. The inland margin of the Superficial aquifer is unsaturated. At Arrowsmith North, the saturated thickness is mostly 10 to 15 m, with a saturated profile in the nearby monitoring bores of 11.2 m, 26.1 m and 19 m at LS27, LS28 and LS31 respectively. At Arrowsmith Central, the Superficial aquifer has a saturated thickness ranging from less than 10 m to about 20 m, becoming unsaturated east of the project area. The nearby monitoring bores contain 26.3 m and 12.3 m of saturated Superficial aquifer in LS19 and LS20 respectively, while it is unsaturated in LS24.

Groundwater salinity within the Superficial aquifer is generally fresh at less than 1 000 mg/L about its eastern margin, increasing toward the coast where it becomes saline. Groundwater salinity distribution within the Superficial aquifer is shown by Figure 6. Beneath the Arrowsmith North project area, the groundwater salinity is approximately 1 000 mg/L to 1 700 mg/L, while at the Arrowsmith Central project area it is 1 000 mg/L to 1 200 mg/L.

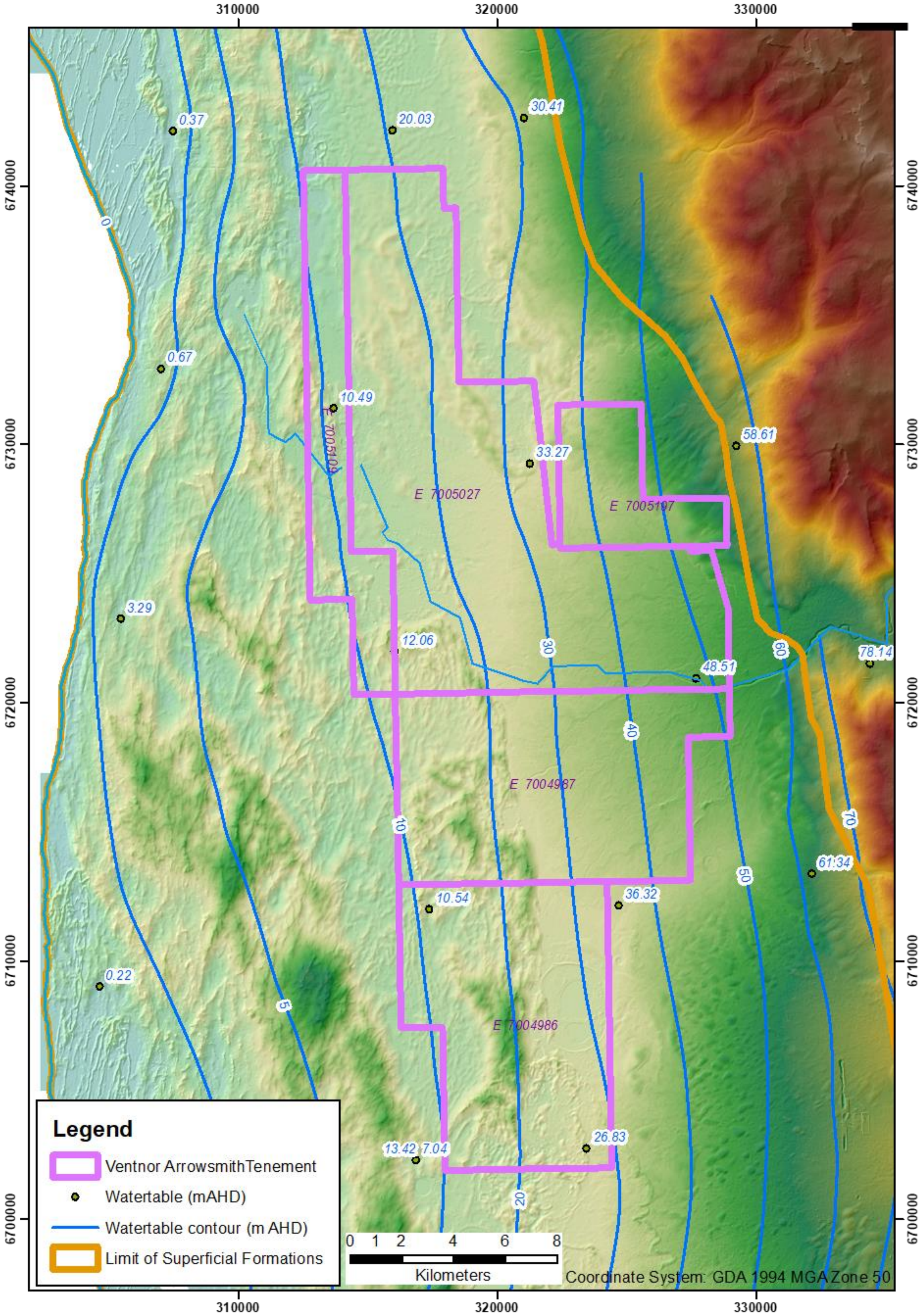

Figure 4. Watertable across the coastal plain

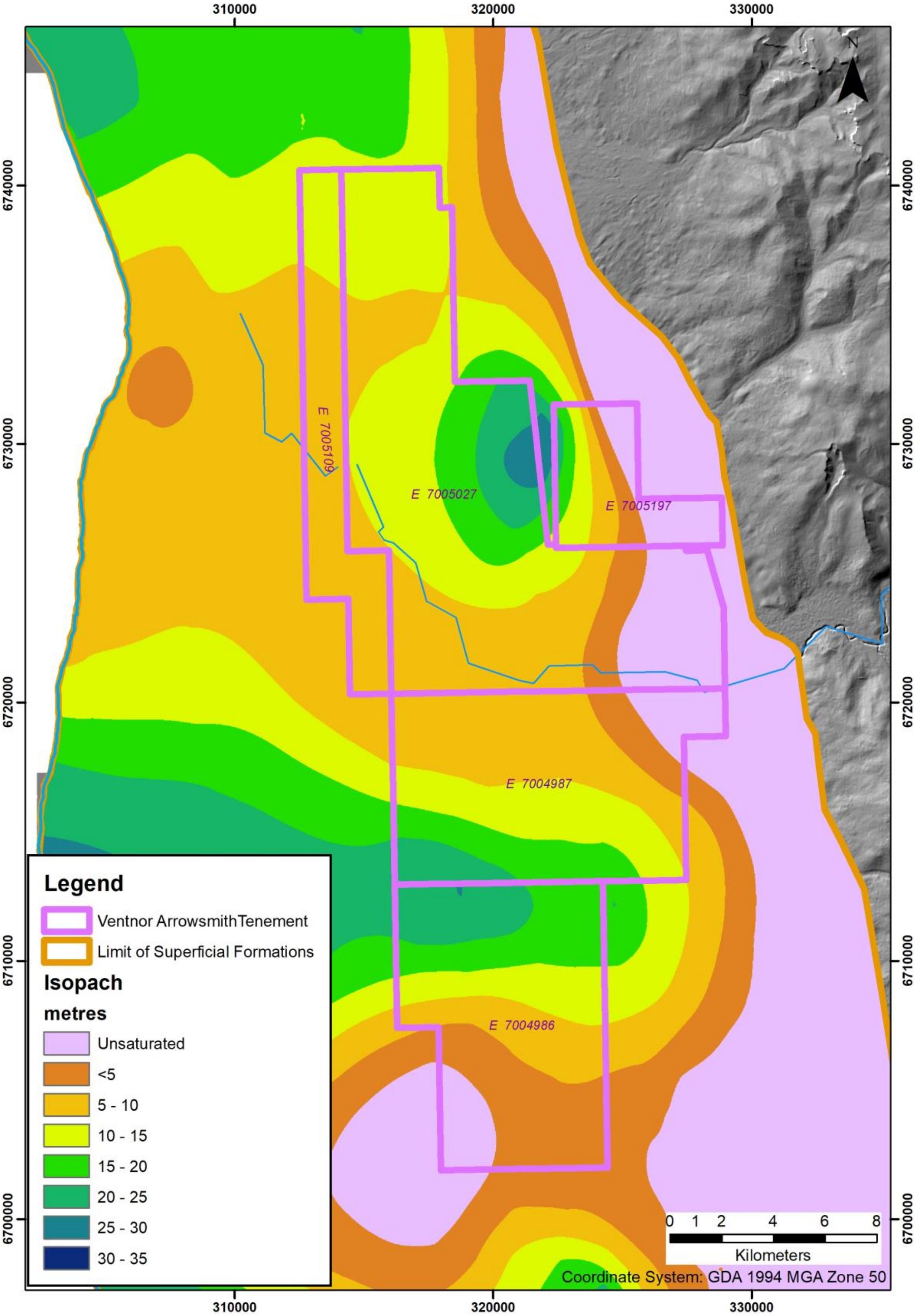

Figure 5. Interpretive isopach of the Superficial aquifer

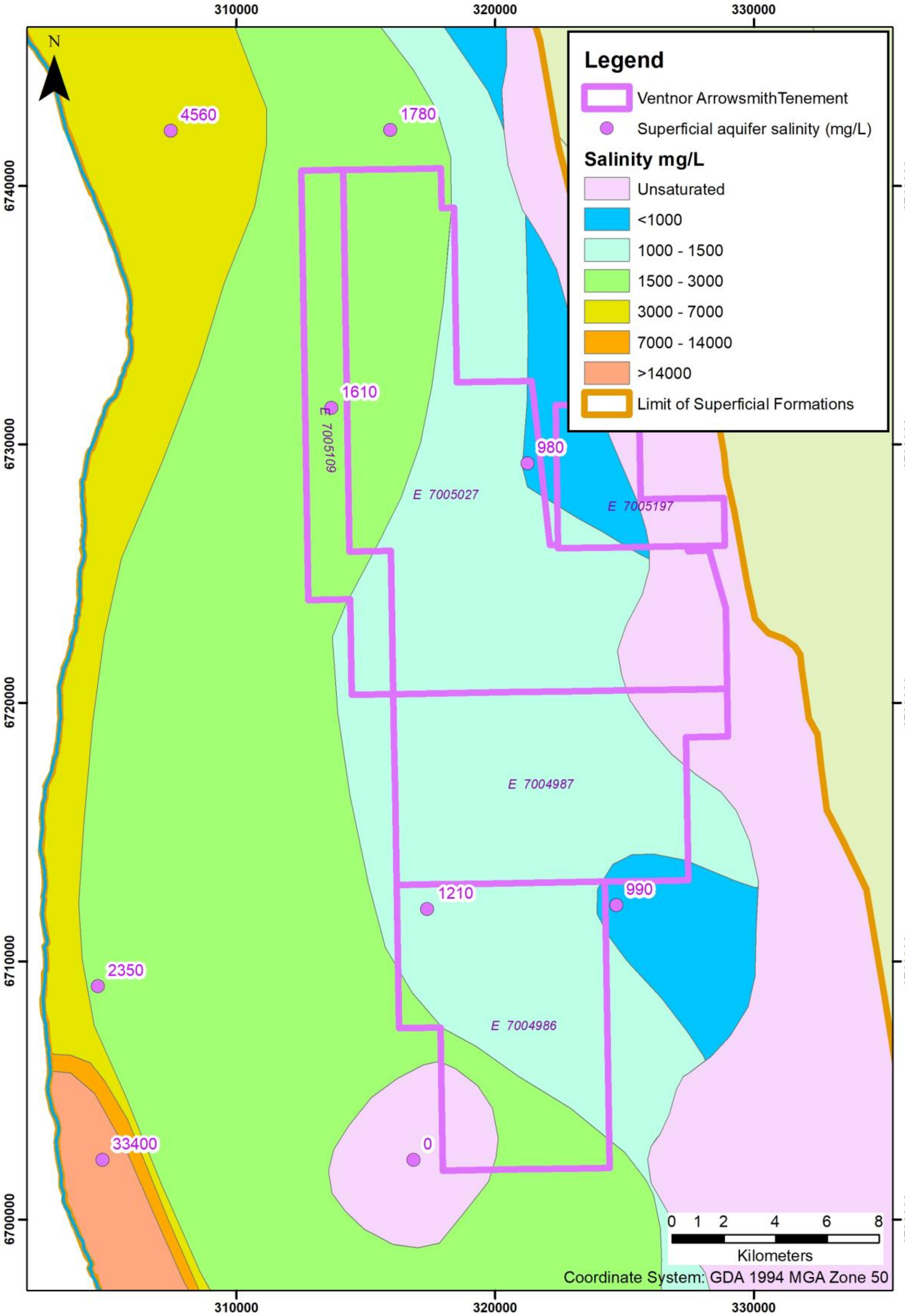

Figure 6. Groundwater salinity distribution within the Superficial aquifer.

Transmissivity of the Superficial aquifer typically increases toward the coast, mostly because of more permeable strata present toward the coast. Tamala Limestone forms the most permeable portion of the aquifer due to the presence of karst features, from which relatively large bore yields can be obtained, such as around 1 000 to 2 000 kL/day from bores of the Jurien Bay town water supply borefield south of Arrowsmith. Hydraulic conductivity will be highly variable depending on the development of karst features below the watertable but is mostly between 50 and 1 000 m/day (Department of Water, 2017).

Bassendean Sand within the eastern portion of the Superficial Formations is largely unsaturated, with the aquifer mostly comprising the Guildford Clay. As the Guildford Clay lithology is principally a clayey sand, it is anticipated to have a relatively low permeability, possibly in the range of 0.4 to 1 m/day, similar to that reported for comparable lithologies of the Guildford Clay in the Perth area (Davidson, 1995).

2.2 Yarragadee geology and aquifer

Beneath the Superficial Formations, both tenements are mostly underlain by the Yarragadee Formation (shown by Figure 7), which is Middle to Late Jurassic in age. Numerous deep wells have been drilled as part of petroleum exploration and development in the Arrowsmith area, which has facilitated geological mapping.

The Yarragadee Formation is a major, regionally extensive formation within the Perth Basin that can exceed 3 600 m thick. It consists of predominantly weakly to moderately cemented sandstone, with interbedded siltstone, shale and claystone (Department of Water, 2017). Several sub-units are identified within the Yarragadee Formation based on palynological ages and the lithological portions of sand compared with finer-grained sand, silt and clay, and are informally referred to as units A, B, C and D in ascending order. Units A and C are predominantly sand, while unit B contains approximately 50% siltstone and shale, and Unit D can comprise more than 80% fine-grained sediments. The Yarragadee Formation is conformably underlain by the Cadda Formation, comprising sandstone, siltstone and claystone.

Petroleum exploration wells North Yardanogo 1 (Barrack Energy, 1990) is drilled to the north of Arrowsmith North and South Yardanogo 1 (Arrow Petroleum, 1991) is in the central part, while Beekeeper 1 is located just to the south of Arrowsmith Central. Figure 8 shows the Yarragadee Formation sub-divisions present within North Yardanogo 1 and Beekeeper 1, together with the downhole groundwater salinity derived from regional mapping.

Arrowsmith North is situated upon a down-faulted block just east of the Mountain Bridge Fault. The Superficial Formations are underlain by the Yarragadee Formation which extends to between about 1,000 m and 1,200 m depth. North Yardanogo 1 drilled through the Yarragadee Formation intersecting 1,055 m of the formation (below about 30 m of Superficial Formations), including Unit D extending to 94 m depth. Lithology of Unit D is not logged within the well, although monitoring bore LS31 located to the north intersected coarse-grained sand with a large component of interbedded grey-black siltstone, black clay and shale over the comparable interval.

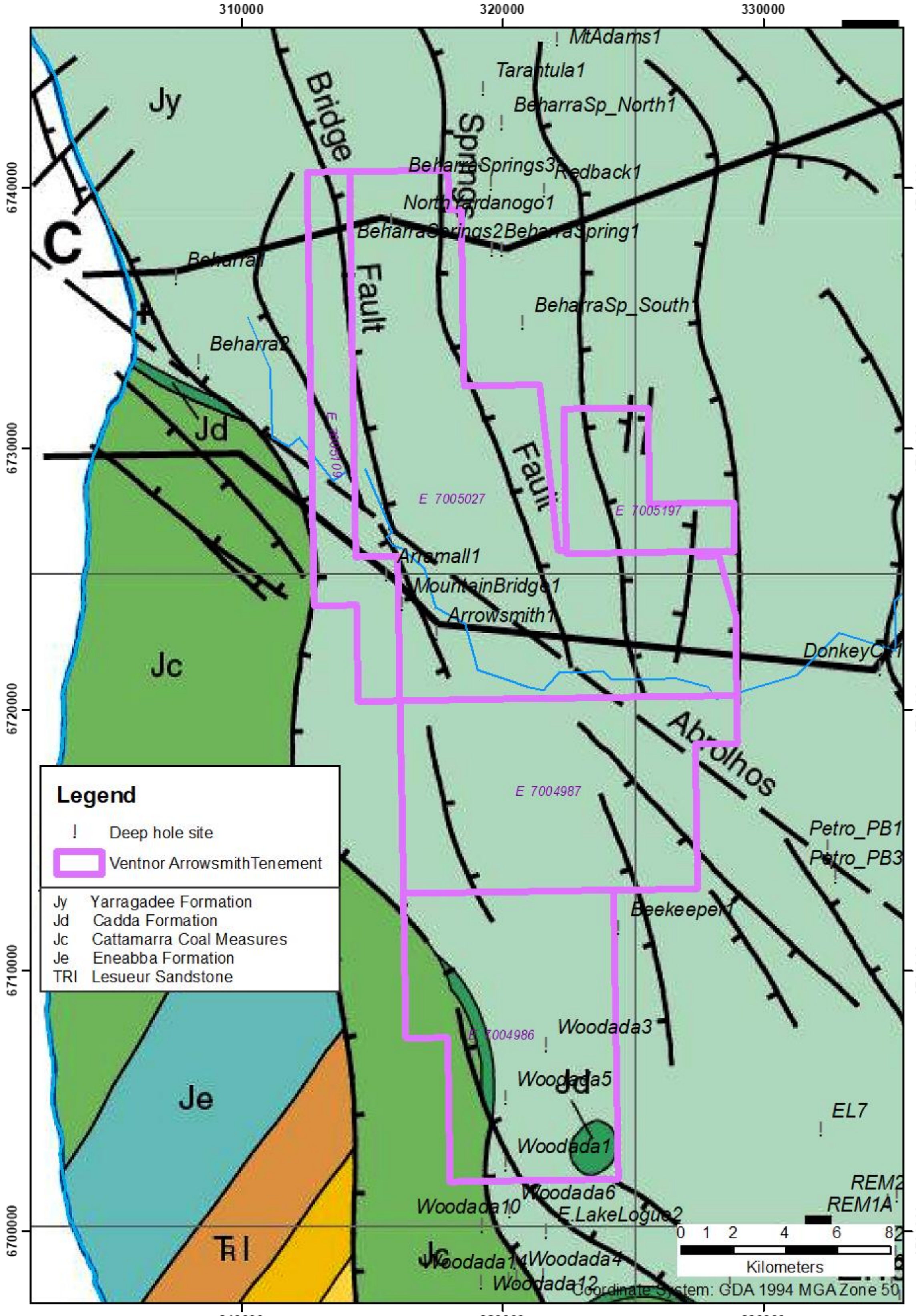

Figure 6. Mesozoic geology in the Arrowsmith area

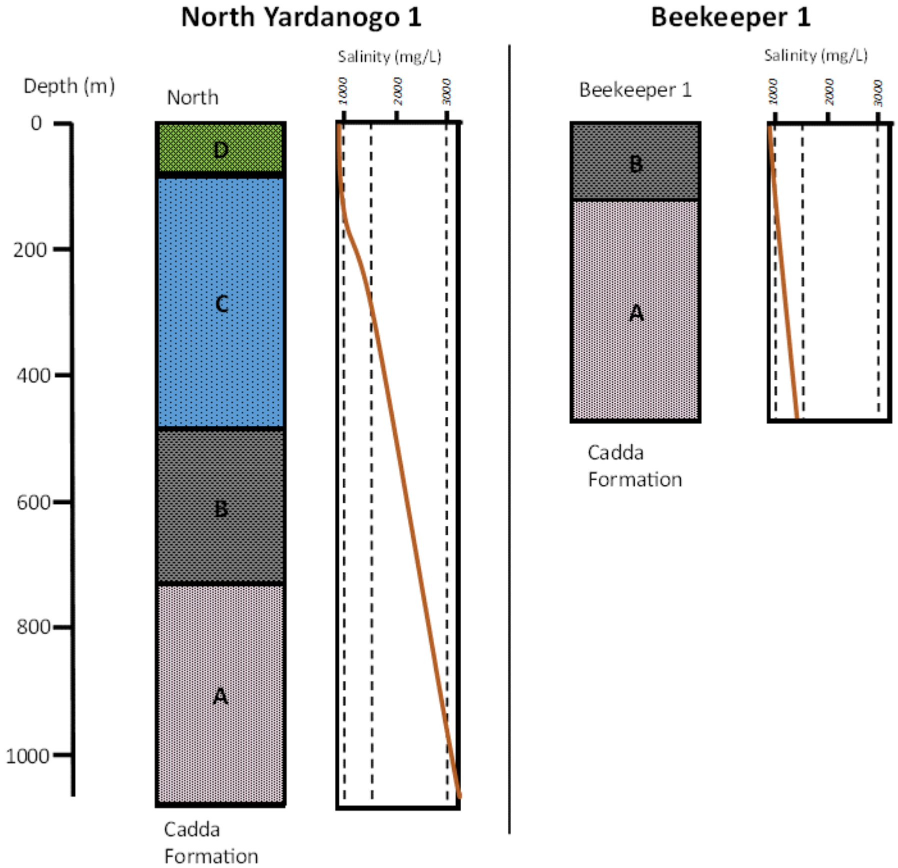

Figure 7. Geological profile showing the sub-division units (A-D) and interpretive groundwater salinity through the Yarragadee Formation within North Yardanogo 1 and Beekeeper 1

Unit C is the sandiest portion in the Yarragadee Formation with only minor interbedded siltstone and shale is present over about 94 to 486 m depth. Downhole gamma-ray logging shows around 50% of clayey strata through Unit B over 486 m to 733 m depth. Unit A was intersected over 733 m to 1 085 m depth where the profile is dominantly sand with approximately 20% clayey intervals. Exploratory petroleum well South Yardanogo 1 located in the central portion of Arrowsmith North intersected 1 020 m of the Yarragadee Formation (below about 40 m of Superficial Formations). The base of Unit C is at about 373 m depth, while Unit D appears to be absent.

Arrowsmith Central located south of the Abrolhos Transfer Fault has a thinner interval of the Yarragadee Formation present, which is projected to thicken beneath Arrowsmith Central from around 400 m in the western portion to 800 m in the east. Only Units A and B of the Yarragadee Formation are present. Unit B extends to about 250 m deep around the eastern portion of the area but pinches out toward the western margin where only the lower-most Unit A is present.

Beekeeper 1 (Australian Aquitaine Petroleum, 1982) drilled just south of the area intersected the Yarragadee Formation to 477 m depth. Unit B extends to 113 m depth in the well, and while the lithology over this unit was not logged the equivalent section in the adjacent monitoring bore LS20 (Nidagal, 1991a) comprises dominantly coarse-grained sandstone with abundant intervals of fine-grained sandstone, siltstone and shale. The underlying Unit A extends to 470 m depth, with a gamma-ray log showing that it is dominantly sandstone with some finer-grained intervals making no more than about 20% of the unit.

The Yarragadee Formation contains the Yarragadee aquifer which is the largest regional aquifer within the northern and central Perth Basin, forming a thick, permeable aquifer. Hydraulic properties are dependent on the portions of sand versus silt and clay, and the degree of cementation. Overall, the transmissivity of Unit C and A would be greater, however, good sand intervals within Units D and B can also be of high permeability. Siltstone and shale layers within Units D and B can form local aquitards.

Evaluation of many pumping tests have found average and median values for hydraulic conductivity of 12 m/day and 5.6 m/day respectively (Department of Water, 2017), although generally lower values are associated with Units D and B. Bore yields are generally large, with pumping rates up to 6000 kL/day obtained from production bores at Eneabba (Johnson and Commander, 2006).

Groundwater within the Yarragadee aquifer is recharged by downward rainfall infiltration over the dissected plateau region inland of the coastal plain referred to as the Arrowsmith Region. From the Arrowsmith Region groundwater flow is westward, discharging about the western margin of the Yarragadee Formation approximately coincident with the central portion of the coastal plain by upward leakage into the Superficial aquifer.

There is no direct measure of groundwater salinity from deeper portions of the Yarragadee aquifer in the Arrowsmith project area, but the salinity has been recorded from the upper portion of the aquifer in nearby Leeman Shallow monitoring bores. The salinity in deeper sections have been estimated from regional mapping.

At Arrowsmith North, LS31B (94 to 100 m) obtained groundwater from the upper portion of Yarragadee aquifer with a salinity of 860 mg/L (Nidagal, 1994). Regional groundwater salinity mapping suggests that the salinity rises to 1 500 mg/L by around 300 m depth, and 3 000 mg/L toward the base of the Yarragadee aquifer.

Near Arrowsmith Central, LS20A (97 to 100 m), located just south-southwest of the project area, yielded groundwater with a salinity from the upper portion of the Yarragadee aquifer of 520 mg/L (Nidagal, 1991a), and at LS24A (96 – 99 m) northeast of the area the salinity was 600 mg/L. Groundwater of salinity less than 1 000 mg/L is projected to extend to about 150 m depth beneath Arrowsmith Central, remaining below 1 500 mg/L to the base of the aquifer.

3. Development constraints

The most significant constraint to groundwater abstraction in the Arrowsmith Project area is the potential impact on groundwater dependent ecosystems due to a decline in water levels, particularly in areas of shallow watertable including wetlands and damplands. Figure 9 shows the depth of watertable below the land surface over the coastal plain in the Arrowsmith tenements area.

Areas of shallow watertable are found about (east, north and west) and within Arrowsmith North, where a series of wetlands are present along the eastern margin that may have some dependency on groundwater within the Bassendean Sand. Another group of wetlands/damplands is located west of the area where the watertable is within the Tamala Limestone.

Potential wetlands or groundwater dependent ecosystems are present within several kilometres south of Arrowsmith Central. However, this area does not appear to be associated with a shallow watertable within the Superficial aquifer, where the watertable is projected to be at least 10 m depth. These wetlands may represent areas of perched groundwater developed upon clay in the Guildford Clay. At LS20, several metres of clay (6.9 to 9.0m) is present within the Guildford Clay (Nidagal, 1991a) which could potentially support a local overlying perched groundwater system. A significant wetland situated from about 3 km south of the project area has a white lake floor, possibly due to salt deposits, which is characteristic of perched groundwater discharging upon a claypan.

The Arrowsmith River will not be impacted by groundwater abstraction from either project area as the river bed is well above the potentiometric head of the Yarragadee aquifer and watertable in the Superficial aquifer, and there is no groundwater discharge to the river. Over the Arrowsmith Region plateau area further east, there may potentially be some seepage to the river from perched groundwater higher within the Yarragadee Formation, most likely associated with Unit D, but this would not be influenced by groundwater abstraction from the Arrowsmith tenements area.

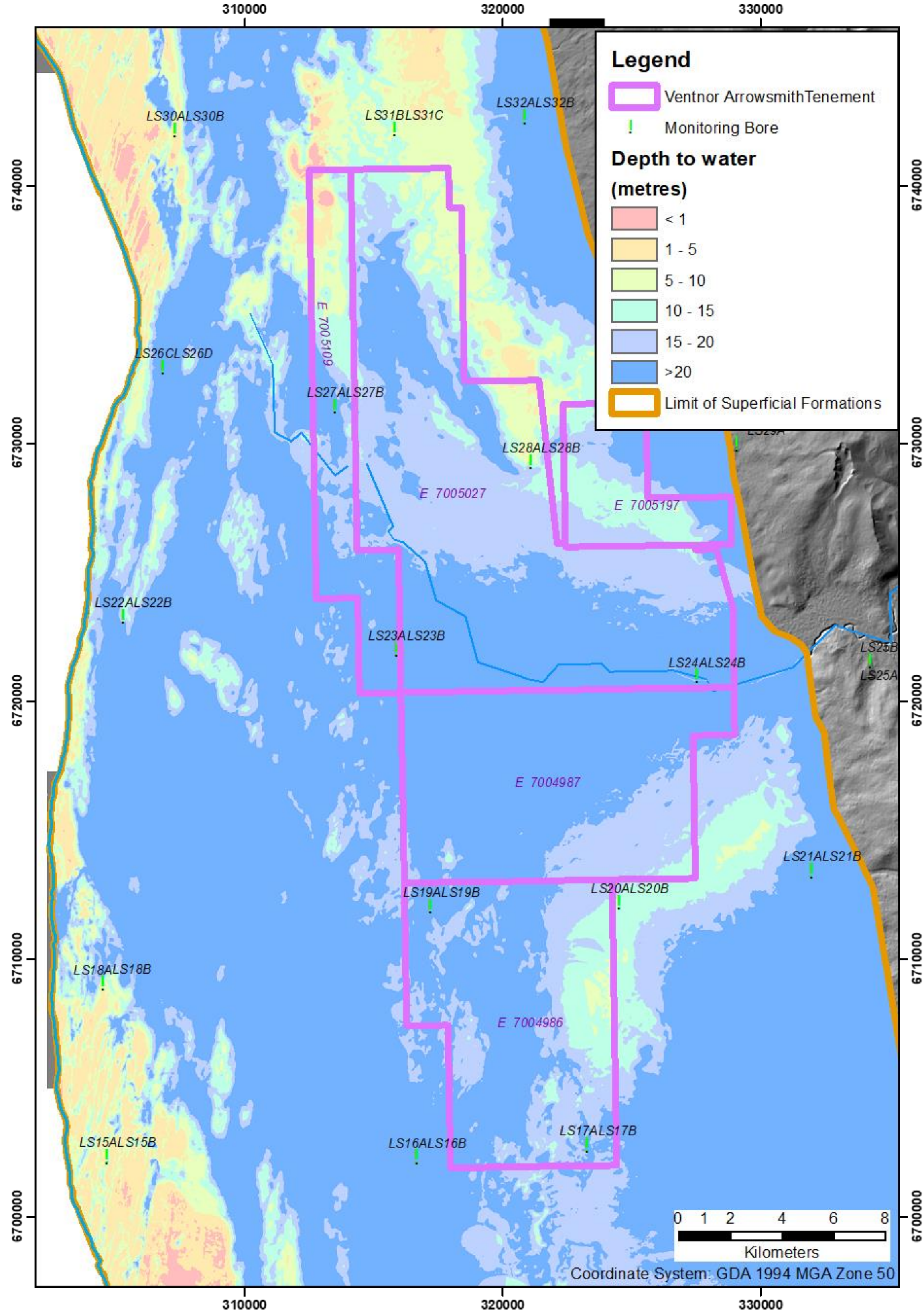

Figure 8. Depth to the watertable over the coastal plain in the Arrowsmith area

4. Potential development of groundwater

The most viable option for developing a groundwater supply would be the construction of bores into the Yarragadee aquifer. The production bores would need to be constructed to a minimum depth of 200 m; however, about 300 m is recommended with screens in the lower 60 m. A single bore for each operation should be sufficient and capable of providing 5000 kL/day.

At Arrowsmith North, the suggested bore design should place the screen interval in Unit C of the Yarragadee Formation with a groundwater salinity of 1 200 to 1 500 mg/L. Whereas at Arrowsmith Central, the screen interval is likely to be within Unit A and have a groundwater salinity of around 1 000 mg/L. An advantage of screening the bores deeper below Unit D or Unit B is that the siltstone and shale beds should impede the upward propagation of water level drawdown resulting from the abstraction. This would minimise the local decline of the watertable and reduce the impact on any groundwater dependent ecosystems.

The development of groundwater resources in the Superficial aquifer is also potentially viable for Arrowsmith Central area. It would need to be located in the Tamala Limestone portion of the aquifer and situated about the western margin of Tenement E7004989. There would be a requirement for two to four production bores that are about 55 m deep. The bores would be capable of yielding around 1 000 to 2 000 kL/day and providing a groundwater salinity of about 1 300 mg/L. It necessary for bores to be separated by 500 m along a north – south line. The larger depth to the watertable in this area should minimise any environmental impacts resulting from abstraction.

Arrowsmith North is constrained by areas of shallow watertable that are likely to be impacted by groundwater abstraction from the Superficial aquifer. The most viable option would be the construction of at least four bores in a north – south transect to the east of the project area into the Tamala Limestone within E7005109. These production bores would be 20 to 30 m deep with a potential yield around 1 000 kL/day and groundwater salinity of about 1 600 mg/L. The bores should be located to the south of the wetland areas to minimise drawdown impacts on the wetlands.

5. Exploration strategy

This section provides an overview of the next stages in the development of the groundwater resources for the project. It should be emphasised that close consultation with the DWER is highly recommended to ensure a smooth groundwater licensing process and to be clear on the exact requirements of any groundwater resource assessment.

5.1 Water demand

As part of the DWER licensing process, there is a need to demonstrate the water requirements and the development schedule of any project. This will require confirmation of the water demands, any timings in terms of changes in supply requirements, and water quality requirements. The DWER is keen to ensure that there is a genuine need and groundwater will be used in an agreed timeframe. In terms of water quality, the DWER aims to ensure that fit-for-purpose water is used – in that some mining operations can use lower quality water, and this is preferred where possible.

5.2 Access and tenure

There is a need to demonstrate tenure as part of the DWER licensing process. The preference is for operators have either direct ownership of the land or agreements in place with landowners.

Prior to undertaking groundwater investigations, it would be appropriate to apply for a Miscellaneous Licence from the Department of Mines, Industry Regulation and Safety to explore for groundwater resources over the focus area. Another Miscellaneous Licence would be applied for once the location of the production bores and pipeline infrastructure is understood.

5.3 Licensing

The DWER issues groundwater licenses under the Rights in Water and Irrigation Act to permit the abstraction of groundwater resources. This is a two-step process with the licensing of any exploration bores to be installed (Section 26D) and the licensing of the proposed abstraction (Section 5C). The process is easily completed using an online submission, which is reviewed by the DWER prior to setting of any licensing and/or assessment conditions.

5.4 Assessment

Once the groundwater license has been received by the DWER, there is an initial assessment of potential impacts that is rated to determine the level of hydrogeological assessment required to be completed by the proponent. This rating process and requirements of the different assessments are described in DWER Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence (Department of Water, 2009).

Based on the water requirements and allocation status of the Superficial and Yarragadee aquifers, it is likely that either a H2 or H3 hydrogeological assessment will be requested by the DWER. This will require a thorough understanding of the hydrogeology with appropriate aquifer testing, and in the case of a H3 assessment, a numerical groundwater flow modelling to demonstrate impacts. This assessment is undertaken by a qualified hydrogeologist with a report presented to the DWER for their consideration prior to granting of a groundwater license.

The cost of these assessments varies depending on requirements of the DWER. A H2 assessment would typically cost between $20 000 and $30 000, whereas a H3 assessment that requires a numerical model (see Section 5.7) may be about $70 000 to $80 000.

5.5 Drilling and bore construction

As part of the assessment, VRX will be required to undertake its own investigations to confirm the site-specific conditions. It would be necessary for the groundwater investigations to install a test production bore (which should be constructed as a final production bore) with a screened interval between 240 and 300 m below ground level. The cost of the test production bore would be between $200 000 and $300 000. The location of the test production bore is still to be fully resolved: however, it should be positioned near the processing plant.

To facilitate a meaningful aquifer test, a monitoring bore is also installed to the same aquifer interval at a distance from the test production bore. This would cost about $50 000 to $100 000. This would be confirmed prior to the development of the investigation program.

In support of the drilling operations, there would be need for hydrogeological supervision for the logging of the drill spoil, design of the bore, and providing technical direction to the drillers. It also useful to have access to a drilling consultant who is a Class 3 driller when drilling deep bores into the Perth Basin in the case that problems arise. The cost of the drilling supervision would be about $40 000 to $50 000.

5.5 Geophysics

It is common practice for a downhole geophysical tool be run in the open hole before the bore is and designed and installed. These geophysical techniques include gamma-ray to confirm the presence of clay and sand horizons and resistivity (a measure of conductivity) to confirm the likely salinity of the groundwater. The cost of the downhole survey is about $5000.

It may be prudent to also run a downhole survey using Borehole Magnetic Resonance (BMR) which provides a more accurate logging of the geological formations and provides an accurate measure of permeability. The cost of this survey is about $10 000 but it wouldn’t be necessary to complete the gamma and resistivity techniques as these are already included.

5.6 Pumping tests

Aquifer testing (pumping tests) are required as part of the assessment to provide an appreciation of the hydraulic characteristics associated with the proposed abstraction. There are typically two tests – a step rate test to assess bore efficiency and capacity, and a constant rate test for a fixed period of between one and seven days. The result from the aquifer testing is a measure of aquifer transmissivity and storativity. The indicative cost of these tests is about $50 000 per bore hole but it is dependent on the length requested by DWER.

5.7 Numerical modelling

In the event that the DWER request a H3 assessment, there will be a requirement for a demonstrated understanding of impacts associated with the proposed abstraction. A numerical groundwater model would be developed to incorporate the data and information on the local hydrogeology collected from drilling and aquifer testing, in order to provide a numerical representation of the groundwater resource. The model would enable a number of abstraction scenarios to be run and understand the influence on groundwater levels and salinity, as well as the environment.

6. Schedule

Table 3 provides an indication of the timeline for the approval of a groundwater licence through the DWER from initial consultation to the final approval and development of the operating strategy.

Table 3. Schedule for groundwater licence approval

Task	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
DWER liaison										
Licence application – 26D and 5C										
Field investigations										
Drilling										
Aquifer testing										
Groundwater assessment										
H2 assessment										
H3 assessment										
Approved groundwater licence										
Operating strategy										

7. Conclusions

A groundwater assessment has been undertaken for VRX Silica Limited for locating suitable groundwater resources for a 500 ML/yr water supply for its proposed project areas near Arrowsmith. The focus of the assessment has been the sediments associated with the Northern Perth Basin.

The Yarragadee aquifer is the most prospective groundwater resource for the project. There have been previous investigations that provide confidence that aquifer horizons are present in different units of the Yarragadee Formation. The aquifer is capable to provide the required water supply from one production bore at each site. There are no other groundwater users in close proximity; however, it will be necessary to demonstrate that abstraction will not impact on groundwater dependent ecosystems.

There are options in the Superficial aquifer; however, this resource is under stress from declining rainfall and there will be likely preference by DWER to consider the deeper Yarragadee aquifer. This is also preferred to minimize impacts on any groundwater dependent ecosystems.

The exploration strategy would be to confirm the water demand and quality requirements for the project, apply to the DWER for groundwater licenses, and undertake groundwater investigations. The investigations are likely to require the drilling of a test production and monitoring bore to facilitate aquifer testing. There may be need for numerical groundwater flow modelling to understand the impacts on the environment under different abstraction regimes.

HydroConcept is willing to work with VRX Silica to deliver a groundwater supply for the project. There will be need for ongoing consultation with DWER to ensure that the groundwater licensing and assessment is efficient as practicable.

8. References

Arrow Petroleum, 1991. South Yardanogo No. 1 well completion report – EP 320 Perth Basin. Western Australia Geological Survey S-Series report W20055 A2.

Australian Aquitaine Petroleum, 1982. Beekeeper No. 1 well completion report – EP 174. Western Australia Geological Survey S-Series report W1099.

Barrack Energy, 1990. North Yardanogo No. 1 well completion report. Western Australia Geological Survey S-Series report W3995 A2.

Davidson, W.A., 1995. Hydrogeology and groundwater resources of the Perth region, Western Australia. Western Australia Geological Survey, Bulletin 142.

Department of Water, 2017. Northern Perth Basin: Geology, hydrogeology and groundwater resources. Department of Water, Hydrogeological Bulletin Series, Report No. HB1, Perth, Western Australia.

Johnson, S.L. and Commander, D.P., 2006. Mid West Regional Minerals Study – Groundwater Resource Appraisal. Department of Water, Hydrogeological Record Series HG 17.

Kern, A.M., 1994. Leeman Shallow drilling project, bore completion reports (Vol. 2 – Sites 9 – 17). Western Australia Geological Survey, Hydrogeology Report 1994/28.

Nidagal, V., 1991a. Leeman Shallow drilling project, bore completion reports (Vol. 1 – Sites 18 – 25). Western Australia Geological Survey, Hydrogeology Report 1991/19.

Nidagal, V., 1991b. Leeman Shallow drilling project, bore completion reports (Vol. 2 – Sites 26 – 34). Western Australia Geological Survey, Hydrogeology Report 1991/19.

Nidagal, V., 1995. Hydrogeology of the coastal plain between Leeman and Dongara, Perth Basin. Western Australia Geological Survey, Record 1994/10.