Design Stage (Water)
Environmental Management Plan

Whalers Way Orbital Launch Complex

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EXECUTIVE SUMMARY

Environmental Advice Pty Ltd (EA) was engaged by Southern Launch Space Pty Ltd (SLS) to prepare this Design Stage (Water) Environmental Management Plan (DWEMP) for the Whalers Way Orbital Launch Complex (WWOLC) proposed for construction at Whalers Way, on the southern tip of Eyre Peninsula, South Australia (the project site) approximately 1,200 ha in area. Initially a single 4 ha launch facility will be constructed with a second launch site, an infrastructure site, including a 17 ML dam, and a range operations centre, including and office/visitor centre to be constructed to complete WWOLC.

The WWOLC will offer launch services to a range of clients who operate launch vehicles ranging in size from small sounding rockets to small and medium lift orbital launch vehicles weighing up to 60 tonnes (at launch). During launches of larger rockets approximately 50 kL of deluge water will be released at high flow into the rocket exhaust from a 70 kL overhead tank to adsorb sound and heat energy, which might otherwise damage the rocket or the launch facility.

The aim of this plan was to estimate the potential types and levels of contamination which may occur in the deluge water and provide recommendations for monitoring of potential impacts to water at and near the site.

A review of existing literature indicated that the key chemicals of environmental concern were:

- hydrogen chloride (HCl) which forms hydrochloric acid when dissolved in water,
- unburnt hydrocarbons and carbon black, which may contain traces of polycyclic aromatic hydrocarbons (PAH), and
- aluminium oxide (Al_2O_3).

Some solid aluminium oxide and soot produced may be suspended with HCL and some exhaust gasses being dissolved and at launch a heated “ground cloud” of atomised and vaporised deluge water that rises from the launch site to fall/rain out at some distance from the launch site. The action of the water deluge and ground cloud is expected to diminish the size of the plume (for water soluble chemicals) from those estimated by puff dispersion modelling.

Other chemicals of concern present at lower concentrations with the potential to impact the deluge water include metals which may be present in propellants; organic compounds which may form in the rocket exhaust; and oxides of nitrogen which may form in the rocket exhaust and by ‘after burning’ in air. Chemicals of concern were identified and conservative estimates of deluge water concentration for key contaminants (HCl, PAH and Al) were made.

Surface water monitoring programs were recommended. These are to be detailed in the Construction Environmental Management Plan (CEMP) and Operational Environmental Management Plan (OEMP). A desktop review of regional geology and hydrogeology was undertaken, and an initial Hydrogeological Conceptual Site Model (CSM) was developed.

Installation of groundwater monitoring wells and groundwater monitoring is not recommended at this stage since risks to groundwater are considered to be low subject to implementation of surface water management measures which will mitigate the risk of water borne contaminants migrating from the launch site(s). These measures will be detailed in control plans to be included in the CEMP and OEMP, which may include but need not be limited to:

1. Perimeter earthen bunding of launch site(s);
2. Bitumen and concrete hardstands in operational areas of the lunch site;
3. Concrete bunding of above storage vessels;
4. Installation of “SPEL Puraceptor” to capture water from within concrete bunded areas (See WGA 2020b);
5. Capture of deluge water in flame trench(s);
6. Testing water in flame before pumping out on trench to launch site dam after launch of each new rocket type;
7. Polymer liner of launch site dam(s) (to be specified);
8. Routine (e.g. quarterly) sampling of water in the launch site dam(s);
9. Placement of lower permeability compacted fill over entire launch site including areas to be subsequently covered in top soil and covered with irrigated lawns;
10. Monitoring of irrigated areas to verify that water applied does not saturate underlying engineered fill.

Subject to appropriate mitigation measures the estimated contaminant levels of HCl, PAH and Al during operation of the WWOLC are considered to pose a low risk to human health and nearby receiving (marine) waters.

1. INTRODUCTION

Environmental Advice Pty Ltd (EA) was engaged by Southern Launch Space Pty Ltd (SLS) to prepare this Design Stage (Water) Environmental Management Plan (DWEMP) for the Whalers Way Orbital Launch Complex (WWOLC) proposed for construction at Whalers Way, on the southern tip of Eyre Peninsula, South Australia (the project site), see Figure 1.

Figure 1 - Site Location Map

Source: Property SA Website

2. OBJECTIVE

The aim of this plan was to estimate the potential types and levels of contamination which may occur in the deluge water (used to adsorb sound during launch of larger rockets) and provide recommendations for monitoring of potential impacts to water at and near the site.

3. APPROVALS PROCESS

On 29 August 2019, the Minister for Planning declared the WWOLC to be assessed as a Major Development pursuant to Section 46 of the Development Act 1993 (the Act). Accordingly, the approving authority for the complex development is the Governor of South Australia on the advice of the Minister for Planning and State Planning Commission (SPC). In draft Assessment Guidelines provided to Southern Launch on 20 April 2020, it was indicated the specialist technical reports required to support the proposal would include:

- A Fauna and Flora Assessment and Management Plan;
- A Marine and Coastal Environment Management Plan, (including consideration of potential impacts on marine organisms from launch activities (including water quality) and impacts on the marine environment from spent (discarded) launch vehicles;
- An Air Quality Assessment report;
- A Waste Management and Minimisation Plan (for construction and operation);
- A Noise Report and Vibration Report;
- A Soil Erosion and Drainage Management Plan (SEDMP);
- A Construction Environmental Management Plan (CEMP);
- An Operational Environmental Management Plan (OEMP); and
- A Sustainability and Climate Change Report.

This plan will also address some items required for the SEDMP (at the design/concept stage), including a description of the site characteristics (existing topography and runoff characteristics) and plans for retention, re-use and monitoring of water quality during the operation phase of the project and drainage management to prevent contamination of groundwater on site. The conceptual plans presented in this report will be developed during the detailed engineering design of pavements and stormwater works. Water monitoring plans and measures proposed to prevent soil erosion and contaminated runoff from leaving the site during construction will be further developed and included in the CEMP, and ongoing water quality monitoring will be further developed in the OEMP.

4. METHODOLOGY

The scope of work proposed included the following tasks:

- Project management, including time for liaison with project team members;
- A brief review of existing literature relating to rocket deluge water contamination;
- A review of the environmental setting of the site including local geology and hydrogeology, rainfall and evaporation, and receiving (marine) waters;
- Identification of key chemicals present and produced during launch, preliminary mass balance calculation to estimate the types and amounts of materials generated (e.g. on an annual basis);
- Initial water balance calculations and discussion of water influent makeup, onsite storage/treatment and effluent (volumes, sources and fate);
- Estimates of contaminant concentrations in deluge water and onsite storages comparison to human health and ecologically based risk screening threshold values;
- Preparation of the DWEMP (report) including a (Draft/Design Stage) water monitoring program; and
- External technical review.

5. PROJECT DESCRIPTION

Project Overview

SLS plan to offer launch services to a range of clients operating small to medium lift vehicles. The complex will be constructed within 1,200 ha of land at the southern tip of Eyre Peninsula. Elements of the complex are planned for construction at four sites within this larger area, designated Site A, B, D and E, see Figure 2.

Figure 2 – Launch Complex – Planned facility locations (A, B, D and E)

Source: SLS Pty Ltd

Launch pads are planned for construction at Site A and B, each launch site will have a retention pond to capture spent deluge water and run off from the launch site (each to be around 7 ML). A 17 ML dam is planned for Site D to harvest runoff from surrounding undeveloped land to supply water to the launch sites and the office building planned for Site E.

SLS have advised that the primary demand for water for the operations will be for irrigation of landscaped areas, with a lesser amount used for deluge water and fire-fighting water, and a small amount for potable use. Concept drawings showing the general arrangement of the launch sites and supporting facilities comprising the planned complex are included in Appendix A.

The project is not at a stage where it is possible to predict a specific launch schedule, however, it is estimated that up to 36 launches (requiring deluge water) will occur per annum at each launch site once the complex is fully operational.

5.1 Launch Site Layout

Work at the site will proceed in stages with a single launch facility to be constructed and become operational prior to completion of the remainder of the complex. Initially a single launch facility will be constructed in the area designated Site B. A 3D rendering of the concept launch site layout is show in Figure 3.

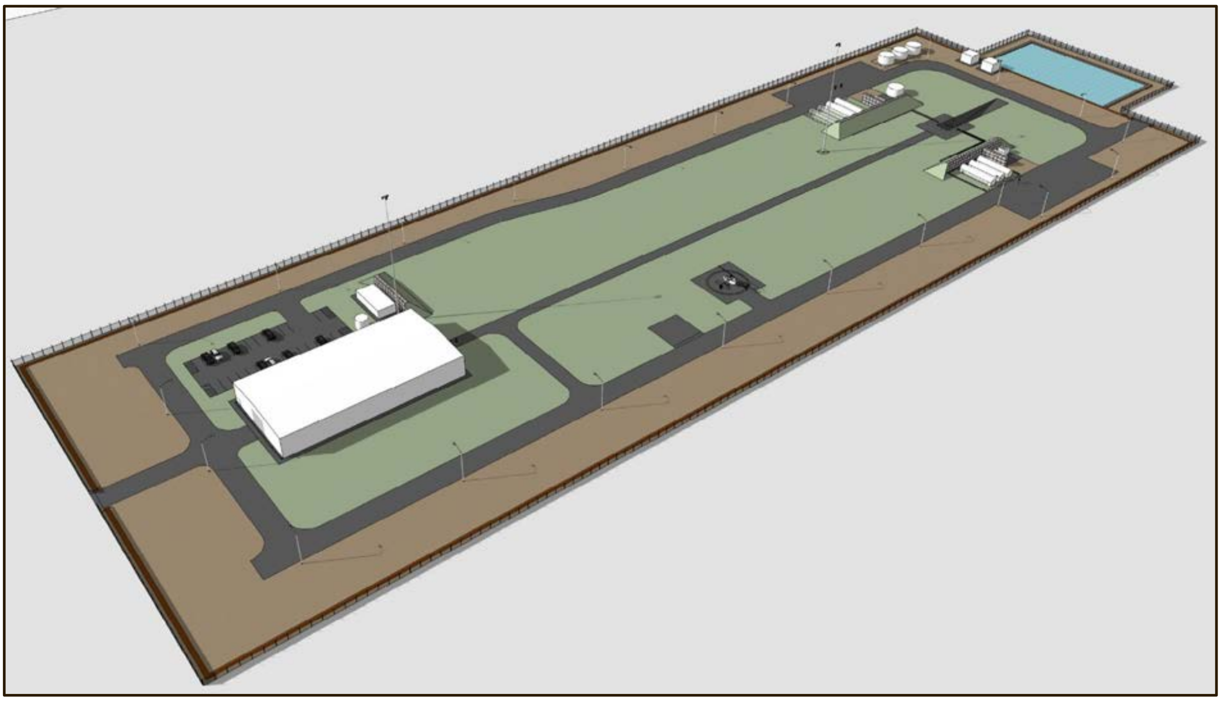

Figure 3 - Concept Site Layout

Source: SLS Pty Ltd

Launch facilities A and B will be constructed on a rectangular site approximately 4 ha in area and include:

- a perimeter fence, swale and concrete lined stormwater drain;
- irrigated landscaping and hardstands (comprising compacted rubble area and paved road);
- buildings and other structures for rocket assembly;
- tanks for storage of fuels, oxidisers and other materials used to prepare the rockets for launch;
- tanks for water storage including a 70kL overhead deluge water tank then gravity feed the deluge water spray nozzles;
- a concrete lined flame diverter trench, 35 m long by 5 m wide, max depth 5 m (capacity 430 m^3); and

- a launch site stormwater detention basin (approximately 7 ML).

5.2 Water Deluge

During launches of larger rockets (low and medium lift orbital launch vehicles) deluge water will be released at high flow from an overhead tank and sprayed into the rocket exhaust for the period between rocket ignition and the rocket clearing the launch structures to adsorb sound and heat energy, which might otherwise damage the rocket or the launch facility. Many of the smaller (e.g. sounding rockets) will not require a water deluge on launch.

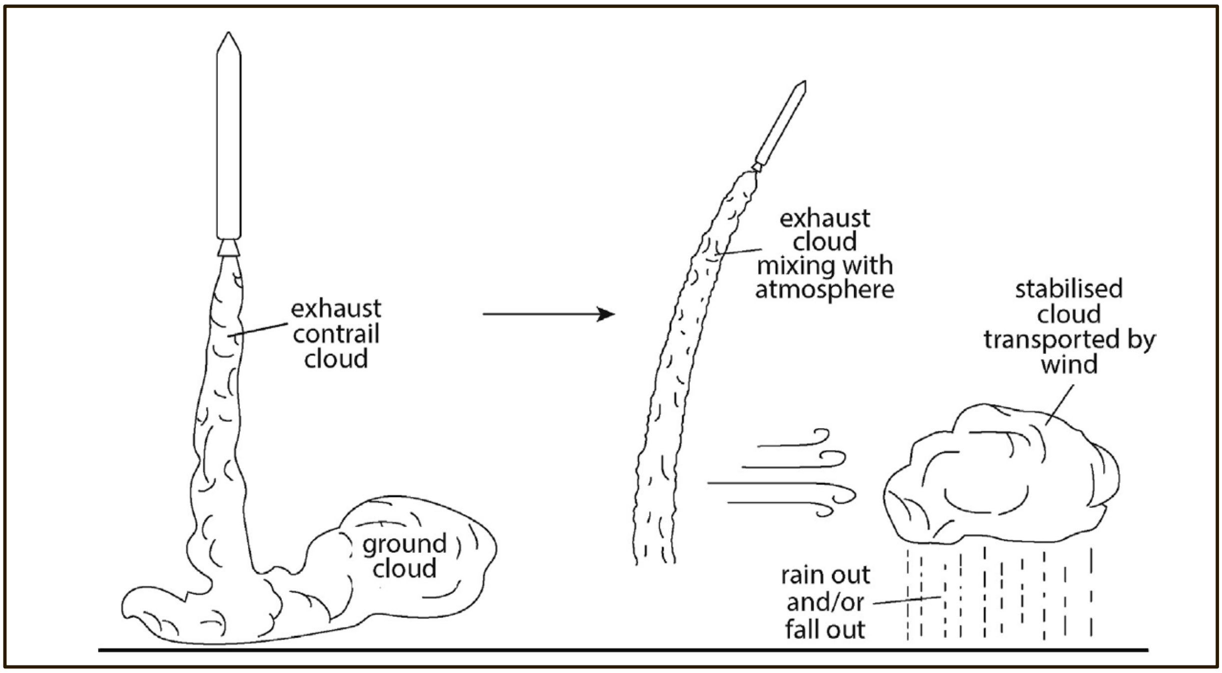

Figure 4 – Ground Cloud Schematic

Source:.JA. Dallas et al. / Journal of Cleaner Production 255 (2020) 120209SLS Pty Ltd

When deluge is required, around 50 kL of water will be released from an overhead tank through spray nozzles. It was estimated that the deluge water will be in contact with the exhaust gasses from the first stage rocket for a period approximately five seconds after ignition. A portion of the deluge water will evaporate and mix with exhaust gasses with atomised droplets to form a heated “ground cloud”, which rise (left hand portion of Figure 4). The ground cloud will then migrate some distance from the launch site, depending on weather conditions, before its contents and rain/fall out some time after launch (right hand portion of Figure 4).

The bulk of the deluge water is expected to flow under gravity into the flame diverter trench. After launch water in the trench will be tested until it is established that it is appropriate to pump it into the launch site stormwater detention basin. Some chemicals present in the rocket exhaust may be transferred to the deluge water, potentially causing contamination of water collected in the launch site stormwater detention basin.

Some chemicals present in the rocket exhaust may be transferred to the heated “ground cloud” of atomised and vaporised deluge water that rises immediately after lift-off. The behaviour of the ground cloud, and fate of any dissolved or suspended chemicals in the cloud, is expected to depend on launch day weather conditions. In general however, it is likely that chemicals (in water droplets) will fall out with the ground cloud more quicky than they might as dry particulates and gases and those captured in the bulk of the liquid will be removed from the air. It is therefore reasonable to assume that, although the effect may be limited the first seconds of each launch, 8-the action of the water deluge and ground cloud is very unlikely to result airborne migration of contamination outside the ‘worst case’ envelope described by existing CALPUFF dispersion modelling (presented in SLR 2020).

5.3 Client Rockets

It is understood that SLS’s client list will change and develop as the project moves into the construction and operation phase. However, it is understood the client’s rockets will range in size from small sounding rockets to medium lift vehicles, capable of placing small to medium-sized satellites into sun synchronous or polar orbits, with launch mass up to approximately 60 tonnes. Details of rocket exhaust composition for specific launch vehicles were not available during the preparation of this plan. However, propellant (fuel + oxidiser) type and load data for three of the largest rockets which may be launched from the complex were provided by SLS. Selected data relating to the first stage of these vehicles is summarised in Table 1.

Table 1 - Medium Lift Vehicles - Stage 1 Propellants

<table>
<tr><th>Data</th><th>Units</th><th>HAPITH-V</th><th>Vega Light</th><th>TBA</th></tr>
<tr><td>Client</td><td>-</td><td>Tispace</td><td>Arianespace</td><td>Rocket Factory Augsburg</td></tr>
<tr><td>Wet Mass</td><td>(kg)</td><td>35,000</td><td>41,362</td><td>58,400</td></tr>
<tr><td>Stage 1 Fuel Type</td><td>-</td><td>SBR</td><td rowspan="3">HTPB/Aluminium Perchlorate/Al Powder</td><td>RP-1</td></tr>
<tr><td>Stage 1 Fuel Load</td><td>(kg)</td><td>3,325</td><td>6,000</td></tr>
<tr><td>Stage 1 Oxidiser Type</td><td>-</td><td>N_2O</td><td>LOX</td></tr>
<tr><td>Stage 1 Oxidiser Load</td><td>(kg)</td><td>23,275</td><td>26,000</td><td>36,000</td></tr>
<tr><td>Burn Time</td><td>(s)</td><td>100 (estimate)</td><td>77</td><td>100 (estimate)</td></tr>
</table>

Source: SLS

Notes,
RP-1 = refined kerosene liquid rocket fuel
LOX = liquid oxygen
HTPB = hydroxyl terminated polybutadiene solid rocket fuel
STB - styrene butadiene rubber hybrid rocket fuel

6. GEOLOGY AND HYDOGEOLOGY

6.1 Regional Geology

The geology of the lower Eyre Peninsula has a sequence of three distinct geological units: the Semaphore Sand (Qhks), Bridgewater Formation (Qpbc), and the Carnot Gneiss. The Semaphore Sand is part of the Holocene-aged St Kilda Formation and comprises unconsolidated quartz-carbonate sand of modern beaches and dunes (WGA 2020a).

Figure 5 – Surface Geology

Source: https://map.sarig.sa.gov.au/

Underlying the Semaphore Sand is the earlier Quaternary-aged sediments of the Bridgewater Formation (which comprises Pleistocene-aged, poorly consolidated yellow-pinkish brown fine to coarse calcareous sand/calcarenite, locally capped by calcrete). The formation is also of aeolian origin and is commonly referred to as aeolian calcarenite (aeolianite). During a drilling program carried out at the site the Bridgewater Formation materials were found to be variably cemented with some zones of collapsing sand and others of strongly cemented rock strength material (WGA 2020a).

Figure 6 – Surface Water Ponding on Calcrete Pavement at Site B

Source: WGA 2020a

Solution features, including hard pavements and voids/caves, are known to occur in some areas of the Bridgewater Formation. Zones of secondary cementation evident as calcretised horizons where evaporation of soil moisture and precipitation of calcium carbonate may occur at the surface (see Figure 6) or at depth, logged as zones of hard rock, during the WGA geotechnical investigation (WGA 2020a). WGA geotechnical advice and mapping provided by Geoscience Australia indicates the karstic conditions, leading to possible voids in the Bridgewater formation, may occur within the project site.

The Bridgewater formation may be underlain by Tertiary Aged clay and sand with silt occurring in depressions in the basement rock. Available information suggest that the Bridgewater Formation may be directly underlain, within the site, by the Archean basement rocks of the Sleaford Complex (ALsc), The Sleaford Complex is described on SARIG as comprising metasediments; metabasalt, sills, dykes; augen gneiss, granulite facies and amphibolite facies. The Sleaford Complex underlies much of the Southern Eyre Peninsula, including the whole of the project site, See Figure 7.

WGA's review of Fanning 1981 indicated that the predominant Sleaford Complex unit at the site is the Garnot Kneiss that comprises thinly layered quartzo-feldspathic gneiss and is typically only exposed at the base of coastal cliffs. These exposed areas of Archean Basement Rocks around the coast are shaded purple on the Surface Geology Map, Figure 5. The red rectangle on Figure 5 indicates the approximate area shown in the Aerial Photograph, Figure 8, in which the basement rock of the Sleaford Complex is visible along the coast in front of the softer materials of the Bridgewater Formation. The Archean Basement Rocks appear to dip below sea level directly to the south of Site B.

Figure 7 – Archean Geology

Source: https://map.sarig.sa.gov.au/

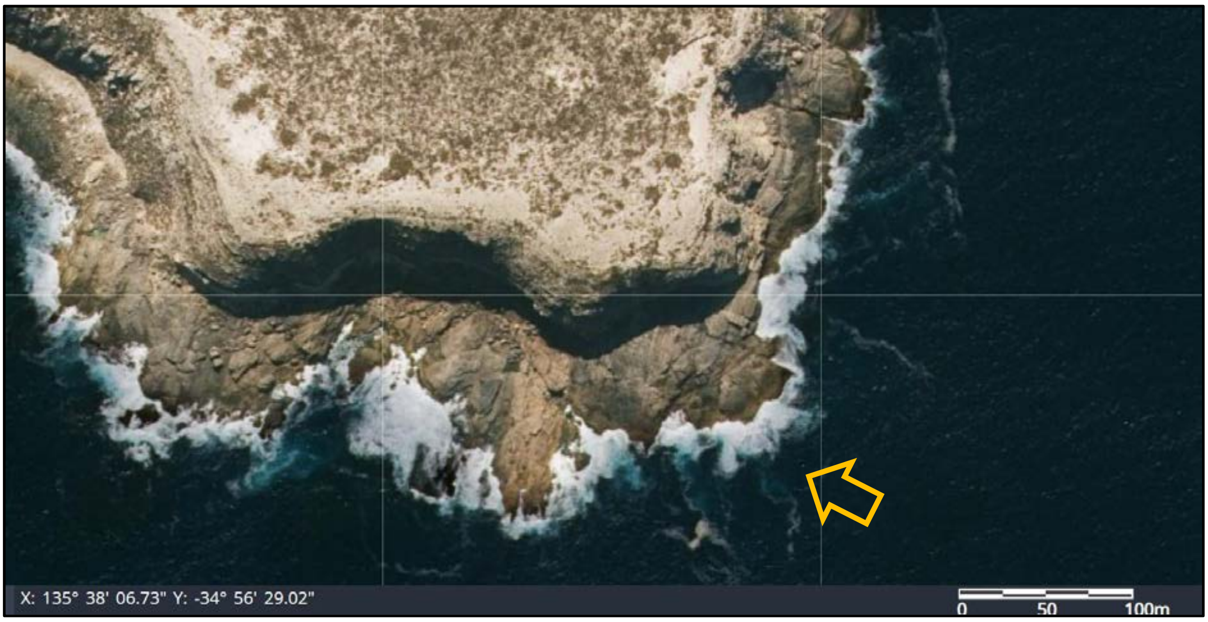

Figure 8 – Archean Basement Rock Exposed on Shore line

Source: https://map.sarig.sa.gov.au/

6.2 Regional Hydrogeology

A review of Eyre Peninsula's water resources was undertaken by ENWS 1984 which led to the establishment of the Southern Basins Prescribed Wells Area (SBPWA) in 1987 (DWR 2001), see Figure 9.

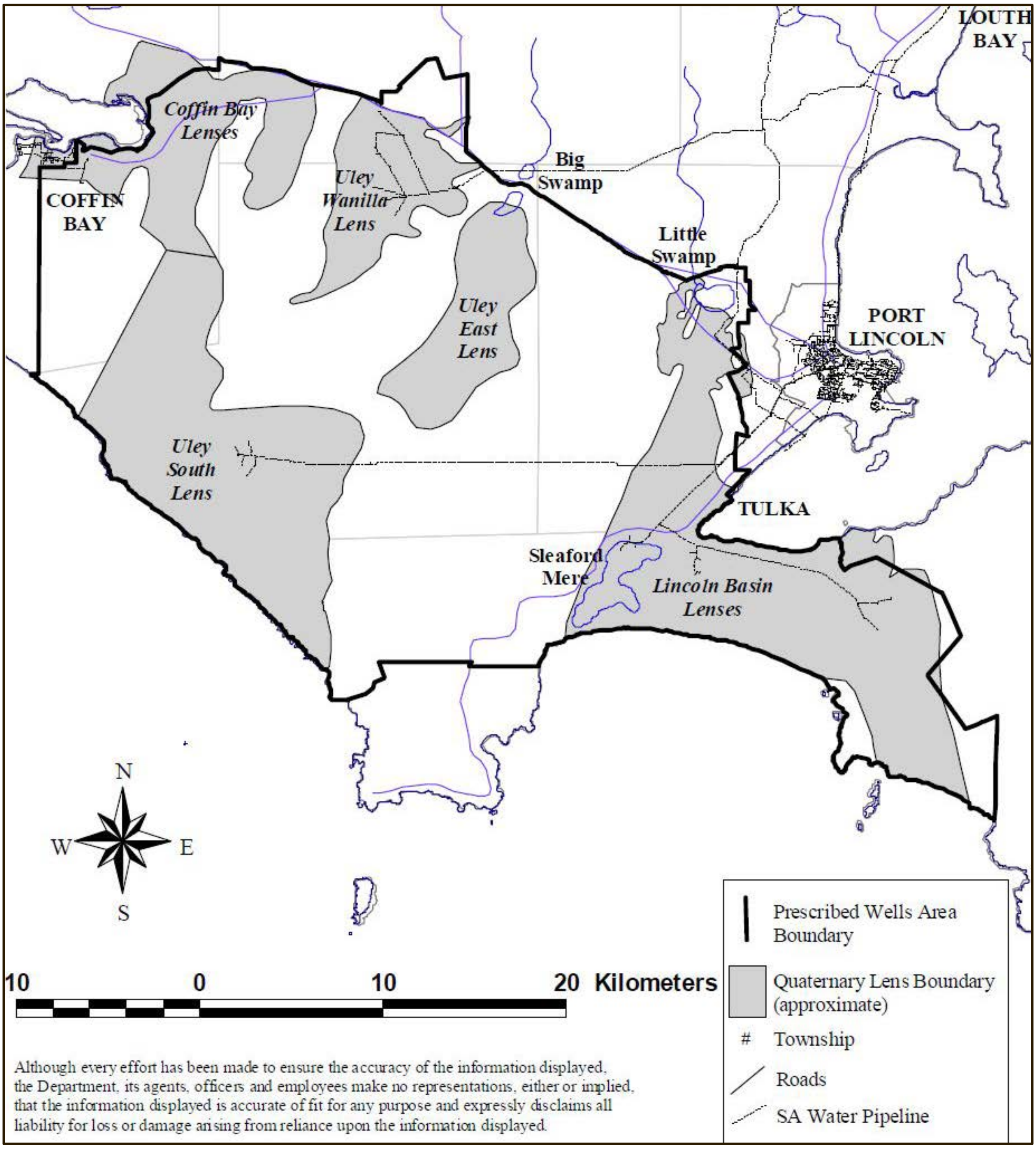

Figure 9 – Southern Basins Prescribed Water Area

Source: SA Water Connect

Prescription establishes a water allocation and licensing framework to protect water resources from overuse and to ensure water users are not adversely affected by other water users. Groundwater from the SBPWA is used by SA Water Corporation for public reticulated water supply. SA Water is the major underground water user within the SWPWA. SA Water were withdrawing between 4350 and 8130 ML of underground water per annum (MLpa) (up to 2001). An additional 100 to 200 MLpa were drawn for other purposes, primarily for stock and domestic use (DWR 2001). Water levels in the supply wells have trended down since the establishment of the PWA due to a combination of increase pumping and lower rainfall (DWR 2001). The planned Sleaford Bay desalination plant, due to begin construction in 2022, will use existing bore field pumping infrastructure to supplement the public reticulated water supply for Eyre Peninsula (*Port Lincoln Times*, June 2020).

The SA Water supply wells access groundwater occurring in an unconfined aquifer occurring in lenses of the Bridgewater formation where it is underlain by a Tertiary Aged clay aquitard. These basin areas, the Coffin Bay and Uley lenses in the west and the Lincoln Basin lens in the east, are shaded grey on Figure 9.

The unconfined aquifer, referred to as the limestone aquifer, is underlain by a second, semi-confined aquifer, occurring in Tertiary sands below the clay aquitard. Groundwater may also occur in fractured bed rock. Figure 10 shows the relationship between these hydrogeological units on schematic cross section of the Uley lens.

Potential for changes to groundwater levels in costal areas within and bordering the SBPWA to allow ingress of more saline water from the sea was noted by DWR (2001) but launch sites A and B lie around 10 km from the southern from the boundary of the SBPWA and the planned actives at the launch sites are not expected to have any influence on groundwater in the SBPWA. Coastal marine zones are not considered to have ecosystems dependent on underground water (DWR 2001).

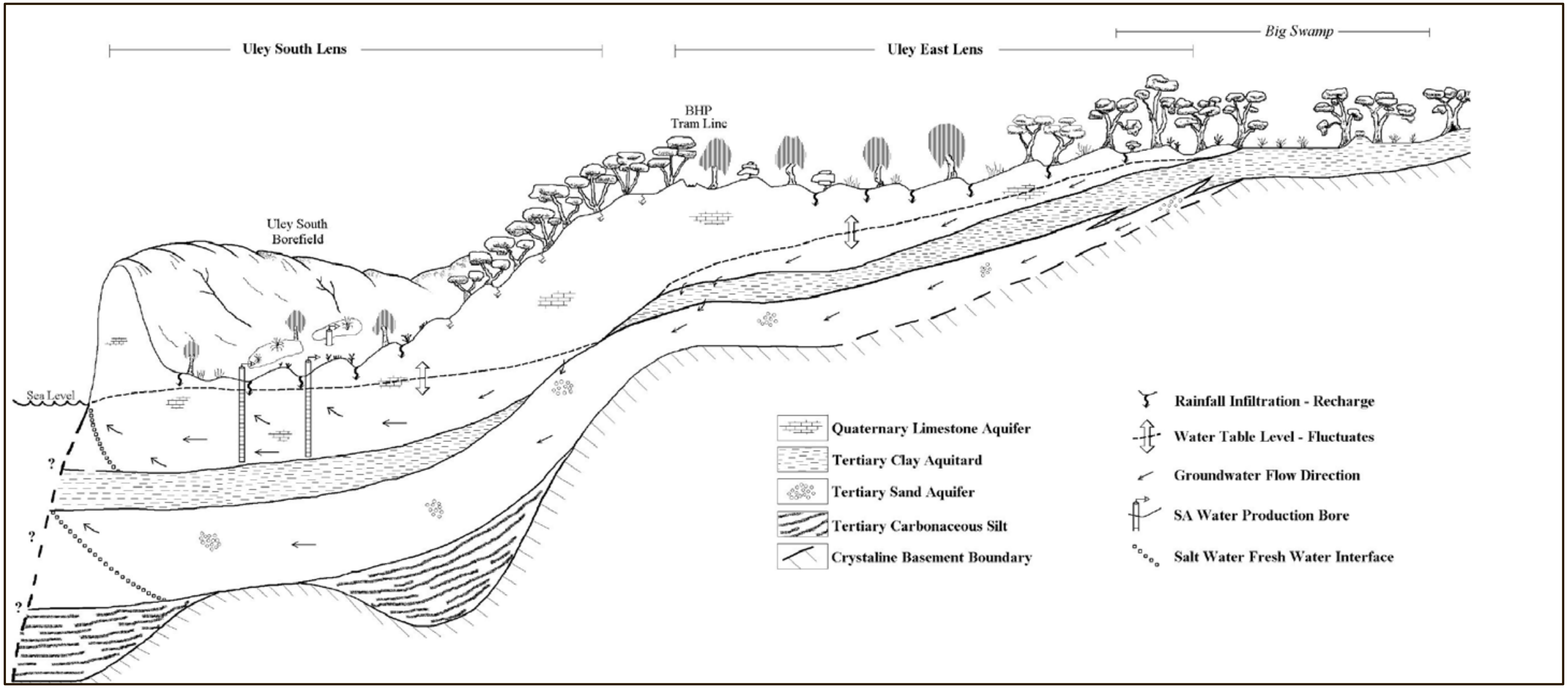

Figure 10 – Schematic Cross Section of Uley Basin

Source: SA DEW 2001

6.3 Local Hydrogeology

The DEW, SA Water Connect web site shows mineral exploration bore holes (squares) and water wells (circles) clustered around 5 km to the north of the launch sites but to the south of the southern border of the SPPWA. The Fishermans Bay spring (Unit Number 6028-620) is located closer to the site boundary and there is a single existing onsite well (Unit Number 6028-1573) located near the planned location of the storage dam (Site D), see Figure 11.

Figure 11 – Well Location Plan

Source: SA, DEW Water Connect

Wells to the north of the site typically access water occurring in the Bridgewater formation with drilled depths ranging from 6 m to 20 m below ground level (bgl) and standing water levels (SWL) between 2 m and 12 m bgl. Clay was recorded at the base of a few of these wells but notes including "pockets of mica' suggest that these bore holes probably terminated in weathered Achaean bedrock rather than the Tertiary clay which occurs in the SBPWA. The salinity of water from these wells ranged from 52 mg/L (very fresh) to 2847 mg/L as Total Dissolved Solids (TDS).

There are few deeper wells shown in the search area covered by Figure 11. These include unit number 6028-3188, located around 100 m from the east coast to the north of Fishermans Bay. This monitoring well was drilled to a depth of 60 m by diamond core on 20 June 2020. The driller's log from this well indicated that hard rock, identified as granite, was encountered at a depth of 10 m and was observed to be "extremely hard with no fractures or breaks" extending to 60 m bgl. A well was installed in the bore hole which was screened between 54 m and 60 m bgl. A salinity of 5,687 mg/L as TDS was recorded in the database for groundwater sampled from this well, but no SWL was presented.

The single existing well within the site area, (Unit Number 6028-1573) was drilled in 1983 to a depth of 30 m. The well is shown as operational in the database and it is understood that it is fitted with a wind driven pump and can draw water. The database indicates the well could produce water with a TDS of 1,233 mg/L at a rate of 1.12 L/s, in 1983, from a production zone between 24 m and 30 m below the local ground level of around 33 m AHD. This surface level was estimated by DEW by interpolation from existing contour maps. The SWL in well 6028-1573 was recorded at 15 m bgl in 1983. Unfortunately, no drillers or lithological log was provided for Unit Number 6028-1573.

Copies of bore hole summary data plus drillers and lithological logs for the bore holes shown on Figure 11 are included in Appendix A.

The initial Hydrogeological Conceptual Site Model (CSM) is illustrated in the schematic north-south cross section, Figure 12. This CSM will be used to inform planning of further hydrogeological investigation to be carried out before and during construction at Site B comprising the drilling and installation of monitoring wells to further characterise groundwater conditions at Site B, and if groundwater is present, to establish a network of wells for ongoing groundwater monitoring at Site B. Investigations in other areas (Sites A, D and E) will be carried out, subsequently, as these sites are developed, if required.

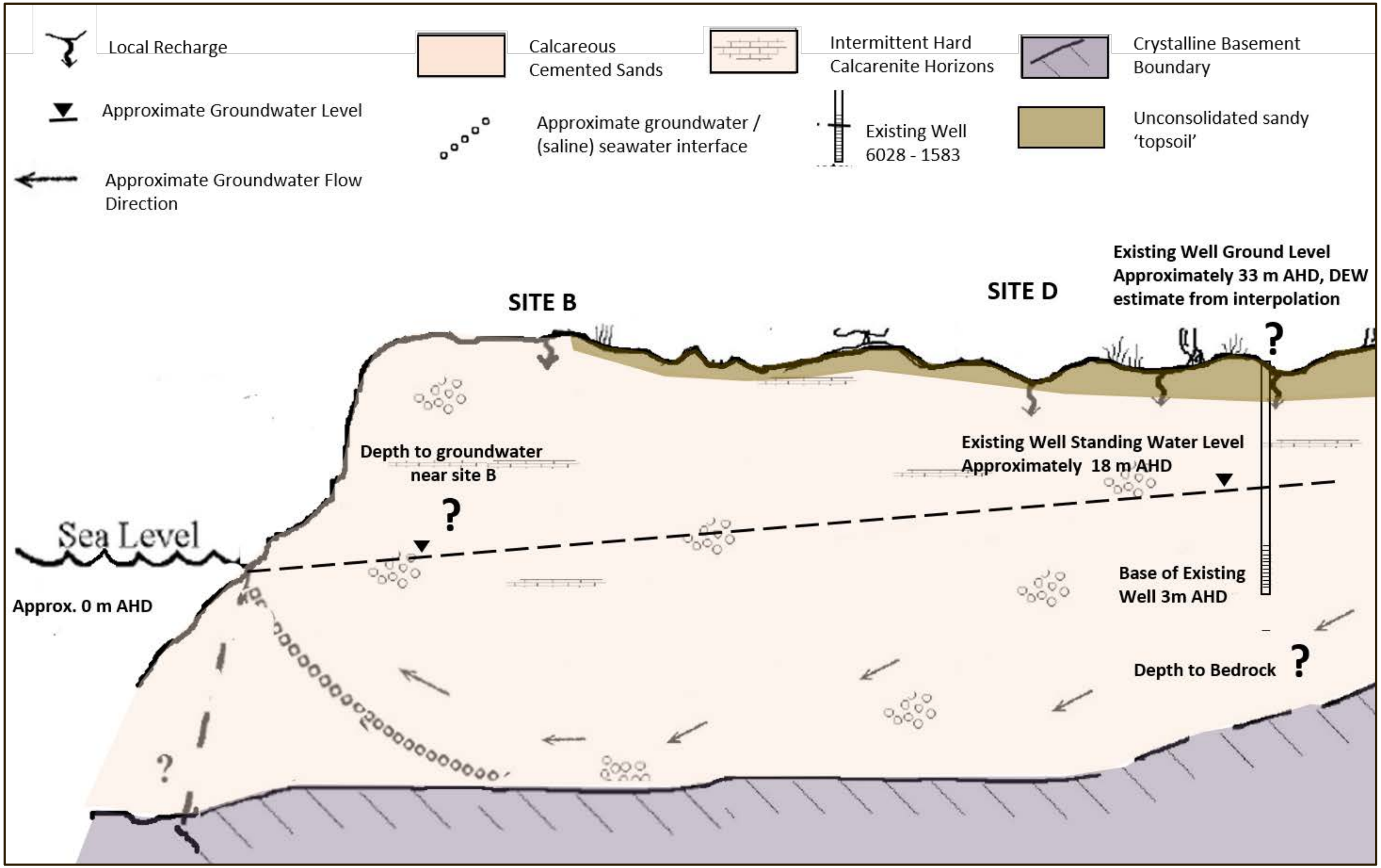

Figure 12 – Initial Conceptual Site Model

Source: Adapted from DEW 2001

7. RAINFALL AND EVAPORATION

Rainfall data collected at the Westmere Station were obtained from the Bureau of Meteorology (BoM) web site. The Westmere Station is located approximately 10 km to the north east of the site. Monthly total rainfall data has been collected for each year from 1906. The average (arithmetic mean) and 90th percentile monthly and annual rainfall calculated from data collected between 1961 and 1990 is summarised in Table 2. Monthly average pan evaporation data interpolated from maps provided on the BoM web site are also included in Table 2.

Table 2 - Rainfall Data and Pan Evaporation

Month	Average Rainfall (mm)	Average Pan Evaporation (mm)	10th Percentile Rainfall (mm)	Median Rainfall (mm)	90th Percentile Rainfall (mm)
Jan	11.3	250	2.2	5.2	19.7
Feb	14.7	200	1.3	11.1	28.2
Mar	25.0	150	2.0	14.5	53.4
Apr	49.1	100	12.8	34.6	100.7
May	72.9	80	31.2	70.7	105.3
Jun	84.9	50	43.5	76.4	120.7
Jul	112.4	80	63.4	101.9	158.6
Aug	88.4	80	53.8	80.1	126.7
Sep	58.2	100	21.7	56.4	100.3
Oct	37.9	150	15.9	32.2	58.9
Nov	22.5	200	6.1	19.5	39.7
Dec	21.4	250	5.6	17.4	44.1
Annual	**598.8**	**1,690**	**454.8**	**564.9**	**745.7**

Source: BoM

8. SITE TOPOGRAPHY AND RUNOFF

It is understood that launch sites will be enclosed by bunds and constructed stormwater drains and will be graded to direct stormwater runoff and deluge water into launch area detention ponds approximately 6.3 ML in volume and 3,800 m^2 in area at each launch area, sites A and B (WGA 2020b). The volume of the pond was calculated to prevent stormwater from leaving the site during extreme rainfall events.

Water for deluge will be drawn from these ponds and pumped up to the deluge tank (70 kL) in preparation for each deluge, nominally up to three times per month. After each deluge (50 kL), the bulk of the deluge water will return to the pond, excepting water leaving the site via the ground cloud and other losses (estimated as up to 30%).

Simplified runoff calculations were made for the 4 ha launch site based on the average rainfall and evaporation data presented in Table 2 and an very conservative (low) estimate for the runoff coefficient of 0.3 (for mixed hardstands and very permeable landscaped areas with assumed mostly low rainfall intensity rainfall events). Pond evaporation was estimated to be equal to pan evaporation (actual pond evaporation is likely to be less). Results from these calculations are presented in Table 3.

Table 3 – Launch Site Runoff Estimates

Month	Runoff from Site (kL)	Evaporation Loss (kL)	Deluge Water Loss (kL)	Net Water Collected
Jan	135.6	1200	45	-1109.4
Feb	176.4	960	45	-828.6
Mar	300	720	45	-465
Apr	589.2	480	45	64.2
May	874.8	384	45	445.8
Jun	1018.8	240	45	733.8
Jul	1348.8	384	45	919.8
Aug	1060.8	384	45	631.8
Sep	698.4	480	45	173.4
Oct	454.8	720	45	-310.2
Nov	270	960	45	-735
Dec	256.8	1200	45	-988.2
Annual	**7185.6**	**8112**	**540**	**-1467.6**

Table 3 suggests that a single 4,800 m^2 pond would be dry in the summer months, however if the pond were subdivided, evaporation losses could be reduced and deluge water demands could potentially be supplied by stormwater harvested from within the launch site. In practice it is understood that additional water may be pumped to the launch sites A and B via rising mains from the planned 15.9 ML water storage in Site D to be used for irrigation of landscaped areas within sites A, B and E.

9. LITERATURE REVIEW

The scope of work included a brief review of relevant published information. Environmental reports relating to the Rocket Lab Launch Complex (RLLC) on the Mahia Peninsula, Hawkes Bay, New Zealand were reviewed (NIWAR 2017, ZNME 2018). The liquid fuel (RP-1/LOX) Electron Rocket is launched from the RLLC. The Electron Rocket is a small lift orbital launch vehicle with a wet mass of 12,500 kg. In its two-stage configuration it is designed to launch a 150 to 225 kg payload to a 500 km Sun-synchronous orbit (WP 2020). Environmental reports for the RLLC focused on the effects of rocket debris (including batteries used to drive the fuel and oxidiser pumps) on the marine environment. Deluge water is not used at the RLLC site, but it is located in a similar southern costal location to the WWOLC with similar perimeter fencing and drainage into a local retention basin, see Figure 13.

Figure 13 - Rocket Lab NZ Launch Complex 1

Source: NZME 2018

An environmental assessment report was completed by Environment Australia (now the Department for Agriculture Water and the Environment) in 2000 for a proposed orbital launch facility on the southern point of Christmas Island (EvAus 2000). The assessment report was prepared in response to a draft environmental impact statement (EIS) submitted by Asia Pacific Space Centre Pty Ltd (APSC).

Although the APSC proposal was for much larger rockets than proposed at the WWOLC and the EIS report could not be located, some useful information was provided in the Environment Australia assessment report. The launch plume from combustion of kerosene and liquid oxygen in the rocket engines produces water, carbon dioxide, carbon monoxide, smaller amounts of hydrogen, nitrogen and oxygen (EvAus 2000). Solid fuel rockets (such as the boosters used on the Space Shuttle) produce hydrochloric acid and aluminium oxides (EvAus 2000).

A recent review of literature related to environmental effects of space launches (J.A. Dallas, et. al. 2020) summarised the exhaust products and key environmental impacts of commonly used rocket propellants, information adapted from this summary and other reference material is included in Table 4.

Table 4 – Major Constituents of Rocket Exhaust

Propellants	Main Exhaust Products
Solid Fuel e.g. hydroxyl terminated polybutadiene (HTPB), Ammonium Perchlorate (Al NH_4ClO_4))/Al Powder	HCl, H_2O, CO_2, CO, NO_x, AL_2O_3, Soot
Hybrid e.g. hydroxyl terminated polybutadiene (HTPB), Liquid Oxygen (LOX)	H_2O, CO_2, CO, NO_x, OH, Soot
Liquid Hydrocarbon Fuel e.g. 'Kerosene' (DP-1) and Liquid Oxygen (LOX)	H_2O, CO_2, CO, NO_x, OH, Soot
Cryogenic Hydrogen Fuel Liquid Hydrogen (LH_2), Liquid Oxygen LOX),	H_2O, CO_2, NO_x, OH

Most of the literature relating to impacts of rocket emissions on the environment reviewed by Dallas, et al, focused on upper atmosphere impacts. Where effects to surface were investigated, they were focused on accumulation of metals and acidification of water or soil near the launch sites.

To estimate potential for deluge water contamination detailed and quantitative data relating to the rocket exhaust and ground cloud/spent deluge water interaction was required. These will depend on specific fuel and oxidiser composition, rocket engine configuration and many other factors. It is understood that some rocket manufacturers may have test data, but this remains confidential at this stage. Exhaust composition may be estimated from propellant composition using thermodynamic/chemical models.

Early modelling of rocket exhaust and ground cloud composition was carried out for NASA by the University of Michigan by Cicerone, et. al. in 1973. They estimated the composition of the exhaust from the shuttles HTPB/Ammonium Perchlorate/Al Powder solid rocket boosters (SRBs) and the liquid hydrogen/LOX orbiter engines (which produced only water with some excess hydrogen) at different stages of the shuttle's ascent. The results for recent modelling of rocket exhausts were presented in a study prepared by NASA in 2011 including products from an "average" RP-1/LOX motor (NASA 2011). The percent by weight of rocket exhaust products calculated from these sources are presented in Table 5 (rocket exhaust before dilution with air).

Table 5 - Solid and Liquid Fuel Exhaust Composition

Rocket	Shuttle SRB	Average RP1 - LOX
Exhaust Compound	**% w/w**	**%w/w**
Water, H_2O	10.351	29.05
Carbon dioxide, CO_2	4.324	45.85
Carbon monoxide, CO	24.372	25.85
Hydrogen Chloride, HCl	20.899	0.00
Chlorine, Cl_2	0.060	0.00
Aluminium III Oxide, Al_2O_3	28.368	0.00
Iron III Chloride, $FeCl_3$	0.970	0.00
Aluminium III Chloride, $AlCL_3$	0.020	0.00
Nitrogen, N_2	8.504	0.00
Hydrogen, H_2	2.111	0.01
Oxygen, O_2	0.00	0.01
Free radicals, H+/OH-	0.020	0.00

Sources: (NASA 1973, 2011)

Observation from Table 4 include the significant quantities of hydrogen chloride (HCl) produced by the HTPB/Ammonium Perchlorate/Al Powder solid rocket. HCl has a high affinity for water and is readily absorbed into water droplets in the ground cloud. Some references suggest that only a small proportion of the HCl migrates into deluge water runoff. Significant quantities of carbon monoxide (CO) are also generated by both solid and liquid fuels, references generally suggest that most of the CO and unspent fuel are largely converted to carbon dioxide (CO_2) by afterburning in atmospheric oxygen (O_2). The modelling results also do not show any soot (carbon and carbon rich organic compounds) or any oxides of nitrogen, produced by reactions with atmospheric nitrogen.

A comparison of model results with results from analytical test data of samples of exhaust gasses collected from bench scale (0.28 inch throat diameter, 1.0 inch exit diameter) rocket motors was conducted by the Oak Ridge National laboratories for the US Army in 1991 (Jenkins, et.al 1991). Four solid rocket fuels were selected including “Compound L” which comprised ammonium perchlorate (73.93% w/w) by weight, polyvinyl chloride 11.67% w/w, di (2 ethyl hexyl) adipate 11.67% w/w, other additives 2.73% w/w. Analytical data from testing of exhaust gasses produced from 25 g of propellant L (internal rocket pressure 2500 psi) summarised in Table 6.

Table 6 - Solid Fuel Test Rocket Exhaust

Exhaust Compound	Result mg/m3	Estimated %w/w
Water, H_2O	Not tested	10.000%
Carbon dioxide, CO_2	154	21.313%
Carbon monoxide, CO	344	47.608%
Hydrogen Chloride, HCl	114	15.777%
Particulates (soot)	30	4.152%
Alumina, Aluminium III Oxide, Al_2O_3	3.5	0.484%
Nitric Oxide (NO)	0.75	0.104%
Hydrogen Cyanide HCN	Not Detected	0.00
Nitrogen, N_2	8.504	1.177%
Hydrogen, H_2	2.111	0.292%
Oxygen, O_2	0.00	0.000%
Free radicals, H+/OH-	0.020	0.003%

Source Jenkins et.al 1991

Further analysis of test rocket ‘L’ exhaust for trace organics identified only the relatively low risk compound octamethyl cyclotetrasiloxane above background levels (other fuel formulations produced a wide range of trace organics including higher risk compounds trichloroethene (TCE) and benzene). Analysis of the soot identified trace amounts of polycyclic aromatic hydrocarbons (PAH). Total PAH concentrations in the soot from the type L fuel was less than 10 μg/kg and benzo-a-pyrene concentrations were less than 0.5 μg/kg.

10. POTENTIAL DELUGE WATER CONTAMINATION

The key chemicals of environmental concern identified in the literature review were HCl (which form hydrochloric acid when dissolved in water), carbon black (which may contain a traces of PAHs) and aluminum oxide (Al_2O_3). HCl and Al_2O_3 are only produced by solid fuel rockets. Soot is expected to be produced by solid fuel, hybrid and liquid fueled rockets. Although some published data relating to these emissions and other (lower level) contaminants present rocket exhaust were identified in the literature, no quantitative information regarding the portioning of exhaust products between vapors and (aqueous) liquid phase was found in the literature, with exception of comments that most of the HCl produced by the shuttle SRBs on launch was expected to be absorbed into atomized water droplets suspended in the ground cloud (NASA 1973). Most of the dissolved HCl and an unknown proportion of the soot (carbon black) produced are expected to migrate with the ground cloud and fall/rain out at some distance from the launch site.

The possible impacts to deluge water during a single HTPB/Aluminium Perchlorate/Al Powder propellant, Arianespace Vega Light launch were estimated based on the available data (adapted from Tables 1, 5 and 6), an assumption of constant burn rates, and other estimates included in Table 7.

Table 7 - Vega Light Launch – Single Deluge

Quantity Estimated	Units	Estimate
Exhaust / deluge contact period	s	5
Concentration of HCl in exhaust w/w	%	20
Proportion HCL dissolved in deluge w/w/	%	20
Concentration of Al_2O_3 in exhaust w/w	%	10
Proportion Al_2O_3 dissolved in deluge w/w	%	5
Soot production w/w	%	5
Proportion PAH in soot	μg/kg	10
Estimated Proportion PAH dissolved in deluge w/w	%	5
Total deluge	L	50,000
Estimated Concentrations in Spent Deluge	**Units**	**Estimate**
Estimated $[Al^{3+}]_{aq}$	mg/L	3.7
Estimated $[HCl]_{aq}$ w/w	%	0.134
Estimated [PAH]	μg/L	0.0025

Hydrogen chloride gas produced from the solid fuels may result in acidification of the deluge water. Some pH correction of water captured in the flame trench after launches of the Vega Light may be required depending on water monitoring results. In practice the changes in pH may be sufficiently adjusted alkalinity of stormwater from the launch site, and additional water being pumped up from the Site D storage for irrigation, via the launch site pond(s).

Table 7 suggested that a single launch of the Vega Light is not likely to produce significant PAH contamination of the deluge water. There was insufficient data to develop ANZECC 2000 threshold values and most PAHs for marine waters, the 99% trigger values for naphthalene is 50 µg/L, well above the estimate in Table 7 for total PAH.

Assuming the launch site is operated as a closed system with deluge water being recycled through the launch site pond only, contamination can be expected to accumulate over time. Assuming a year with 12 launches of each of the three rockets described in Table 1 and applying the same estimates and assumption in Table 7 estimates launch site pond concentrations at the end of the year can be made, see Table 8.

Table 8 - Potential Contaminant Accumulation in Launch Site Detention Basin

Estimate / Assumptions	Units	Annual Total
Total Stage 1 - Solid Rocket Propellant Burnt	kg	300,000
Total Liquid and Hybrid Rocket Propellants	kg	700,000
Annual total propellant consumption	kg	1000,000
50% launch site stormwater detention basin volume	L	1,000,000
Quantities Calculated from Estimated	**Units**	**Annual Total**
Estimated Launch Site Pond $[Al^{3+}]_{aq}$	mg/L	6.6
Estimated Launch Site Pond $[HCl]_{aq}$ w/w	%	0.0008
Estimated Launch Site Pond [PAH]	µg/L	0.05

In Table 8 the total annual propellant burn estimated in Table 1 may produce around 2.5 tonnes of soot near the flame trench (from the first five seconds of each launch). Depending on how much of the soot stays within the launch site, a process of soot removal collection, storage, classification and appropriate disposal may be required, so that it does not accumulate in the ponds.

The estimates presented in Table 8 could be considered representative of a situation where the residence time of water in the launch site detention pond(s) was around 12 months. It is planned that water be pumped from irrigation of landscaped areas within the launch sites from the planned 17 ML main storage dam at Site D. Depending on irrigation demand at the launch sites residence time in the launch site ponds may be less than 12 months.

11. DESIGN STAGE WATER QUALITY MONITORING PLAN

Although deluge water and launch site detention pond concentration estimates in Table 7 and 8 are only indicative, they provide a guide to the potential contaminants that should be targeted during water quality monitoring at the site. Although not identified in the limited literature search undertaken, it is possible that deluge water may be impacted by trace metals (other than aluminium) and other additives which may be present in propellants. Trace organic compounds, including chlorinated organic compounds, may also be formed during rocket combustions and after burning or rocket exhausts, e.g. water-soluble oxides of nitrogen which may form nitrates and nitrites in the deluge water. These should also be considered when developing a scope for water monitoring at the site.

A broad suite of analysis for water samples is provided in Table 9.

Table 9- Preliminary Water Analysis Suite

Nominal Water Analyses
pH
TDS
Major + and – ions
Total N (all forms), Total P
Total Metals (NEPM 13 + Al)
Total Recoverable Hydrocarbons (TRH)
Volatile Organic Compounds (VOC) Suite (including TCE and Benzene)
Semi Volatile Organic Compounds (SVOC) Suite (including PAHs)

Water monitoring should also include potential contaminants including any fuels, lubricants, cleaners, firefighting foams and other materials handled on the launch site (not considered in this report). Other testing relevant to water treatment (if required) may also be included in the broad suite. Details of surface water monitoring will be included in the Construction Environmental Management Plan (CEMP) and Operational Environmental Management Plan (OEMP).

Installation of groundwater monitoring wells and groundwater monitoring is not recommended at this stage since risks to groundwater are considered to be low subject to implementation of surface water management measures which will mitigate the risk of waterborne contaminants migrating from the launch site(s). These measures will be detailed in control plans to be included the CEMP and OEMP, which may include but need not be limited to:

1. Perimeter earthen bunding of launch site(s);
2. Bitumen and concrete hardstands in operational areas of the lunch site;
3. Concrete bunding of above storage vessels;
4. Installation of “SPEL Puraceptor” to capture water from within concrete bunded areas (See WGA 2020b);
5. Capture of deluge water in flame trench(s);
6. Testing water in flame before pumping out on trench to launch site dam after launch of each new rocket type;
7. Polymer liner of launch site dam(s) (to be specified);
8. Routine (e.g. quarterly) sampling of water in the launch site dam(s);
9. Placement of lower permeability compacted fill over entire launch site including areas to be subsequently covered in top soil and covered with irrigated lawns;
10. Monitoring of irrigated areas to verify that water applied does not saturate underlying engineered fill.

Subject to appropriate mitigation measures the estimated contaminant levels of HCl, PAH and Al during operation of the WWOLC are considered to pose a low risk to human health and nearby receiving (marine) waters.

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13. LIMITATIONS

This report has been prepared with appropriate reference to industry recognised standards and procedures current at the time of the work. The report presents the advice based on the quoted scope of works (unless otherwise agreed in writing) for the specific purposes of the engagement by the Client.

The advice presented in this report has been prepared at the request and for the purposes of the client only. No warranties expressed or implied are offered to any third parties and no liability will be accepted for use of this report by third parties

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APPENDIX A **Bore Hole Data Base Data**

Unit_No	dh_name	network	Obs_No	drillhole_c	water_poi	Aquifer	Orig_drille	Orig_drilled_dat	max_drill_	max_drill_date	late_open	late_open_date	late_perm	cased_to	case_min_	purpose	latest_stat	latest_status_date	dtw	swl	rswl	water_level_date	TDS	EC	salinity_date	pH	pH_date	yield	yield_date	water_inf	salinity	water_che	geophys_l	drill_log	lith_log
6028-566	138		SLE018	WW, MW		Tbw	42.06	29/09/1961	42.06	29/09/1961	42.06	29/09/1961				OBS	ABD	29/09/1961	17.07	17.07	0.84	29/09/1961								Y	N	N	N	Y	Y
6028-588	1			WW			15.85	26/10/1961	15.85	26/10/1961	15.85	26/10/1961					ABD	26/10/1961	13.11	13.11	61.02	26/10/1961								Y	N	N	N	N	Y
6028-589				WW			13.11	27/10/1961	13.11	27/10/1961	13.11	27/10/1961					ABD	27/10/1961												N	N	N	N	N	Y
6028-594				WW		TQ	12.8	30/10/1961	12.8	30/10/1961	12.8	30/10/1961		12.29	127		COM	30/10/1961	2.44	2.44	53.74	30/10/1961	1382	2498	27/10/1961			0.51	30/10/1961	Y	Y	Y	N	N	Y
6028-600	10			WW		ALs	9.75	11/03/1963	9.75	11/03/1963	9.75	11/03/1963		9.2	127	STK	COM	11/03/1963	3.33	3.33	66.25	11/03/1963	1730	3118	11/03/1963			0.25	11/03/1963	Y	Y	Y	N	N	Y
6028-601	9			WW			10.06	7/03/1963	10.06	7/03/1963	10.06	7/03/1963				GEN	ABD	7/03/1963				7/03/1963								Y	N	N	N	N	Y
6028-604				WW			16.15	5/03/1963	16.15	5/03/1963	16.15	5/03/1963				GEN	ABD	5/03/1963				5/03/1963								Y	N	N	N	N	Y
6028-605				WW					6.71	12/10/1962	6.71	12/10/1962				DOMIRR	UKN	12/10/1962	5.79	5.79	44.78	12/10/1961	613	1115	12/10/1961			0.25	12/10/1961	Y	Y	N	N	N	N
6028-606				WW		TQ	15.85	20/10/1961	15.85	20/10/1961	15.85	20/10/1961		13.87	152	GEN	COM	20/10/1962	6.4	6.4	41.23	20/10/1961	613	1115	20/10/1961			2.53	20/10/1961	Y	Y	Y	N	N	Y
6028-607				WW		TQ	14.63	23/10/1961	14.63	23/10/1961	14.63	23/10/1961		12.04	127	GEN	COM	23/10/1961	3.35	3.35	57.78	23/10/1961	983	1782	23/10/1961			0.38	23/10/1961	Y	Y	Y	N	N	Y
6028-608				WW			8.23	19/10/1961	8.23	19/10/1961	8.23	19/10/1961				GEN	ABD	19/10/1961												N	N	N	N	N	Y
6028-609				WW, MW			38.1	10/10/1961	38.1	10/10/1961	38.1	10/10/1961				OBS	ABD	10/10/1961												N	N	N	N	N	Y
6028-610				WW, MW		TpQau	44.2	13/10/1961	44.2	13/10/1961	44.2	13/10/1961		15.44	127	OBS	COM	13/10/1961	3.35	3.35	23.66	13/10/1961	1952	3513	11/10/1961			0.38	13/10/1961	Y	Y	N	N	N	Y
6028-611				WW		Qpcb	13.72	24/10/1961	13.72	24/10/1961	13.72	24/10/1961		11.46	127	GEN	COM	24/10/1961	5.72	5.72	36.21	2/12/2019	613	1115	24/10/1961			1.26	24/10/1961	Y	Y	Y	N	N	Y
6028-612				WW		Qpcb	8.84	16/10/1961	8.84	16/10/1961	8.84	16/10/1961		8.74	152	GEN	COM	16/10/1961	3.05	3.05	39.5	16/10/1961	698	1267	16/10/1961			1.89	16/10/1961	Y	Y	Y	N	N	Y
6028-613				WW		Qpcb	7.62	1/03/1963	18.5	31/03/1999	18.5	31/03/1999	47016			GEN	COM	1/03/1963	4	4	35.98	31/03/1999	556	1011	1/03/1963			20	31/03/1999	Y	Y	Y	N	Y	Y
6028-614				WW		Qpcb	8.53	4/03/1963	8.53	4/03/1963	8.53	4/03/1963		8.53	127	STK	COM	4/03/1963	2.85	2.85	28.84	2/12/2019	2847	5093	4/03/1963			1.26	4/03/1963	Y	Y	Y	N	N	Y
6028-615				WW			6.1	17/10/1961	6.1	17/10/1961	6.1	17/10/1961				GEN	ABD	17/10/1961										0.03	17/10/1961	N	N	N	N	N	Y
6028-616				WW		TpQau	7.01	19/10/1961	7.01	19/10/1961	7.01	19/10/1961		6.1	127	GEN	COM	19/10/1961	3.05	3.05	25.83	19/10/1961	798	1447	18/10/1961			0.25	19/10/1961	Y	Y	Y	N	N	Y
6028-617				WW		ALs+Qpcb	12.19	18/10/1961	12.19	18/10/1961	12.19	18/10/1961		7.52	127	GEN	COM	18/10/1961	3.12	3.12	29.87	18/10/1961	1382	2498	18/10/1961			1.26	18/10/1961	Y	Y	Y	N	N	Y
6028-618				WW		Qpr	16.76	26/10/1961	16.76	26/10/1961	16.76	26/10/1961				GEN	ABD	26/10/1961				26/10/1961								Y	N	N	N	N	Y
6028-619				WW			13.72	6/03/1963	13.72	6/03/1963	13.72	6/03/1963				GEN	ABD	6/03/1963				6/03/1963								Y	N	N	N	N	Y
6028-620	FISHERY BAY SPRI			WP	SPR											SPR							1084	1963	26/02/1940					N	N	Y	N	N	N
6028-621				WW		Qpcb	9.14	18/10/1961	9.14	18/10/1961	9.14	18/10/1961		8.1	127	GEN	COM	18/10/1961	2.13	2.13	13.92	18/10/1961	52	95	17/10/1961			0.38	18/10/1961	Y	Y	Y	N	N	Y
6028-630				WW, MW		TQ	13.72	6/04/1956	13.72	6/04/1956	13.72	6/04/1956				OBS	COM	6/04/1956	4.57	4.57		6/04/1956	7416	12893	6/04/1956					Y	N	Y	N	N	Y
6028-1573				WW			30	1/09/1983	30	1/09/1983	30	1/09/1983	11242	24	150	IRR	OPR		15.2	15.2	18.68	1/09/1983	1233	2230	1/09/1983	7.5	1/09/1983	1.12	1/09/1983	Y	Y	N	N	N	N
6028-1623				WW			14	1/07/1986	14	1/07/1986	14	1/07/1986	18245	14	150				12	12	44.76	17/07/1986	1676	3020	1/07/1986	7.7	1/07/1986	0.76	1/07/1986	Y	Y	N	N	N	N
6028-1639				WW			12.2	12/01/1988	12.2	12/01/1988	12.2	12/01/1988	20504	8.53	150				7.6	7.6	55.92	29/01/1988	2256	4050	29/01/1988	7.5	12/01/1988	0.12	12/01/1988	Y	Y	N	N	N	N
6028-2210				WW		ALs+Qpcb	12	14/04/1999	12	14/04/1999	12	14/04/1999	47877	12	150	STK			3.3	3.3	14.2	14/04/1999	2585	4630	14/04/1999			1.25	14/04/1999	Y	Y	N	N	Y	N
6028-2234				WW			15	3/09/1998	15	3/09/1998	15	3/09/1998	46266	15	125	DOM			12	12	-7.33	3/09/1998	1564	2820	3/09/1998			0.66	3/09/1998	Y	Y	N	N	Y	N
6028-2269				WW					17	8/01/2001	16.14	8/01/2001	54357	16.14	125	STK			4.4	4.4	66.23	8/01/2001						1	8/01/2001	Y	N	N	N	Y	N
6028-2315				WW		Qpcb	14.6	13/07/2003	14.6	13/07/2003	14	13/07/2003	61871	4	125	DOMSTK			4.61	4.61	39	2/12/2019	666	1210	12/07/2003			1	13/07/2003	Y	Y	N	N	Y	N
6028-2344	18R			WW, ENG					15	30/04/2004	0	30/04/2004	65499			INV	ABD	30/04/2004												N	N	N	N	Y	N
6028-2345	19S			WW, ENG					15	23/04/2004	0	23/04/2004	65499			INV	ABD	23/04/2004												N	N	N	N	Y	N
6028-2346	20T			WW, ENG					17	13/04/2004	0	13/04/2004	65499			INV	ABD	13/04/2004												N	N	N	N	Y	N
6028-2347	21A			WW, ENG					15	21/04/2004	0	21/04/2004	65500			INV	ABD	21/04/2004												N	N	N	N	Y	N
6028-2348	22B			WW, ENG					20	20/04/2004	0	20/04/2004	65500			INV	ABD	20/04/2004												N	N	N	N	Y	N
6028-2349	23C			WW, ENG					15	9/04/2004	0	9/04/2004	65500			INV	ABD	9/04/2004												N	N	N	N	Y	N
6028-2350	24D			WW, ENG					15	20/04/2004	0	20/04/2004	65500			INV	ABD	20/04/2004												N	N	N	N	Y	N
6028-2351	25E			WW, ENG					15	23/04/2004	0	23/04/2004	65500			INV	ABD	23/04/2004												N	N	N	N	Y	N
6028-2352	26F			WW, ENG					15	18/04/2004	0	18/04/2004	65500			INV	ABD	18/04/2004												N	N	N	N	Y	N
6028-2353	27G			WW, ENG					15	16/04/2004	0	16/04/2004	65500			INV	ABD	16/04/2004												N	N	N	N	Y	N
6028-2354	28H			WW, ENG					15	18/04/2004	0	18/04/2004	65500			INV	ABD	18/04/2004												N	N	N	N	Y	N
6028-2355	29-I			WW, ENG					15	10/04/2004	0	10/04/2004	65500			INV	ABD	10/04/2004												N	N	N	N	Y	N
6028-2356	30 J			WW, ENG					20	11/04/2004	0	11/04/2004	65500			INV	ABD	11/04/2004												N	N	N	N	Y	N
6028-2357	31K			WW, ENG					20	12/04/2004	0	12/04/2004	65500			INV	ABD	12/04/2004												N	N	N	N	Y	N
6028-2358	32L			WW, ENG					20	14/04/2004	0	14/04/2004	65500			INV	ABD	14/04/2004												N	N	N	N	Y	N
6028-2359	33M			WW, ENG					20	15/04/2004	0	15/04/2004	65500			INV	ABD	15/04/2004												N	N	N	N	Y	N
6028-2386				WW			14.8	25/11/2005	14.8	25/11/2005	14.8	25/11/2005	111692	8.3	125				3	3	21.55	25/11/2005	2397	4300	25/11/2005			1.25	25/11/2005	Y	Y	N	N	Y	N
6028-2429			SLE019	WW						25/09/2008		25/09/2008																		N	N	N	N	N	N
6028-2433				WW					12.4	8/04/2008	12.1	8/04/2008	145305	12.1	125				3	3	40.44	8/04/2008	4771	8420	8/04/2008			0.38	8/04/2008	Y	Y	N	N	Y	N
6028-3189				WW			50	4/06/2020	50	4/06/2020	50	4/06/2020	362920	45	50	MON														N	N	N	N	Y	N
6028-3188				WW			60	20/06/2020	60	20/06/2020	60	20/06/2020	362925	54	50	MON							5687	9980	7/09/2020					N	Y	N	N	Y	N

Unit_No	log_date	logger_name	depth_fro	depth_to	lith_code	description
6028-566	29/09/1961	BAUMANIS J	0	0.3	SOIL	dark
6028-566	29/09/1961	BAUMANIS J	0.3	4.27	LMST	and Sandstone boulders, light
6028-566	29/09/1961	BAUMANIS J	4.27	12.19	SDST	brown, bouldery
6028-566	29/09/1961	BAUMANIS J	12.19	17.07	CLYS	brown, sandy
6028-566	29/09/1961	BAUMANIS J	17.07	20.73	SAND	brown, with CLYS and LMST boulders in it, (v
6028-566	29/09/1961	BAUMANIS J	20.73	41.76	GRNT	decomposed
6028-566	29/09/1961	BAUMANIS J	41.76	42.06	GRNT	
6028-613	31/03/1999	MATTSSON N C	0	4	LMST	very hard limestone calcrete
6028-613	31/03/1999	MATTSSON N C	4	6	CAVE	large cave, some rocks
6028-613	31/03/1999	MATTSSON N C	6	10	LMST	hard limestone
6028-613	31/03/1999	MATTSSON N C	10	15	ROCK	soft layer with hard floating rocks
6028-613	31/03/1999	MATTSSON N C	15	18.5	CLYU	soft sandy caly with hard layers
6028-2210	14/04/1999	MATTSSON N C	0	1	TPSL	topsoil and limestone
6028-2210	14/04/1999	MATTSSON N C	1	3	LMST	limestone
6028-2210	14/04/1999	MATTSSON N C	3	10	CLYU	clay sand limestone
6028-2210	14/04/1999	MATTSSON N C	10	10.5	GRNT	clay sand with some granite rock and a few
6028-2234	3/09/1998	MATTSSON N C	0	11	LMST	hard limestone
6028-2234	3/09/1998	MATTSSON N C	11	12	CALC	hard calcrete
6028-2234	3/09/1998	MATTSSON N C	12	15	LMST	layers hard limestone/ base v hard limeston
6028-2269	8/01/2001	MATTSSON N C	0	1	SOIL	topsoil
6028-2269	8/01/2001	MATTSSON N C	1	2	LMST	limestone
6028-2269	8/01/2001	MATTSSON N C	2	4	LMST	hard limestone
6028-2269	8/01/2001	MATTSSON N C	4	16.14	LMST	limestone/sand
6028-2269	8/01/2001	MATTSSON N C	16.14	17	CLYU	clay
6028-2315	13/07/2003	MATTSSON N C	0	4	LMST	Limestone with sand layers
6028-2315	13/07/2003	MATTSSON N C	4	14	LMST	Limestone (brittle with water courses in stru
6028-2315	13/07/2003	MATTSSON N C	14	14.6	CLYU	Clay, base grey green
6028-2344	30/04/2004	MATTSSON N C	0	1	SAND	Sand, light brown with broken limestone
6028-2344	30/04/2004	MATTSSON N C	1	3	SAND	Sand, light brown
6028-2344	30/04/2004	MATTSSON N C	3	3.5	SAND	Sand, light brown, loose
6028-2344	30/04/2004	MATTSSON N C	3.5	9	SAND	Sand, light brown
6028-2344	30/04/2004	MATTSSON N C	9	15	SAND	Sand, light brown, dense to very dense
6028-2344	30/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2345	23/04/2004	MATTSSON N C	0	2	SAND	Sand, light brown with broken limestone
6028-2345	23/04/2004	MATTSSON N C	2	3	SAND	Sand with limey clay
6028-2345	23/04/2004	MATTSSON N C	3	8	SAND	Sand, light brown
6028-2345	23/04/2004	MATTSSON N C	8	9	SAND	Sand, pale brown
6028-2345	23/04/2004	MATTSSON N C	9	9.5	CLYU	Slightly clayey layer and sand
6028-2345	23/04/2004	MATTSSON N C	9.5	13	SAND	Sand and clay, light brown
6028-2345	23/04/2004	MATTSSON N C	13	14	SAND	Sand light brown, dense
6028-2345	23/04/2004	MATTSSON N C	14	15	SAND	Sand, light brown, dense
6028-2345	23/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2346	13/04/2004	MATTSSON N C	0	8	SAND	Fine sand, broken, limestone, cemented, sa
6028-2346	13/04/2004	MATTSSON N C	8	10	SAND	Fine sand, gravelly with black gravel chips, d
6028-2346	13/04/2004	MATTSSON N C	10	12	SAND	Sand, fine, light brown
6028-2346	13/04/2004	MATTSSON N C	12	14.5	SAND	Sand, light brown
6028-2346	13/04/2004	MATTSSON N C	14.5	17	SAND	Sand, light brown, minor black gravel
6028-2346	13/04/2004	MATTSSON N C	17	17.45	SAND	SPT sample as above
6028-2347	21/04/2004	MATTSSON N C	0	3	SAND	Sand pale brown with limey fines
6028-2347	21/04/2004	MATTSSON N C	3	4	SAND	Light brown sand cemented layers

6028-2347	21/04/2004	MATTSSON N C	4	12.3	SAND	Light brown sand
6028-2347	21/04/2004	MATTSSON N C	12.3	13	SAND	Sand and clay, brown
6028-2347	21/04/2004	MATTSSON N C	13	15	SAND	Sand, fine cemented
6028-2347	21/04/2004	MATTSSON N C	15	15.45	SAND	SPT samples as above
6028-2348	20/04/2004	MATTSSON N C	0	7.5	LMST	Limestone with sand and dense layers
6028-2348	20/04/2004	MATTSSON N C	7.5	12	SAND	Sand, light brown
6028-2348	20/04/2004	MATTSSON N C	12	20	SAND	Sand, light brown, dense weakly cemented
6028-2348	20/04/2004	MATTSSON N C	20	20.45	SAND	SPT sample as above
6028-2349	9/04/2004	MATTSSON N C	0	4	SAND	Fine sand, light brown with thin calcrete lay
6028-2349	9/04/2004	MATTSSON N C	4	5	SAND	Sand with fine clay, slightly cemented at 5 m
6028-2349	9/04/2004	MATTSSON N C	5	8	SAND	Sand, fine white and slightly clayey
6028-2349	9/04/2004	MATTSSON N C	8	12	SAND	Sand, fine pale yellow with dense layers
6028-2349	9/04/2004	MATTSSON N C	12	13	CLYU	Clay and sand limey firm
6028-2349	9/04/2004	MATTSSON N C	13	15	SAND	Sand, light brown dense
6028-2350	20/04/2004	MATTSSON N C	0	0.6	SAND	Sand with calcrete layers
6028-2350	20/04/2004	MATTSSON N C	0.6	15	SAND	Sand, fine weakly cemented occasionally de
6028-2350	20/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2351	23/04/2004	MATTSSON N C	0	1	LMST	Limestone, calcrete
6028-2351	23/04/2004	MATTSSON N C	1	2.45	SAND	Sand and limestone, light brown
6028-2351	23/04/2004	MATTSSON N C	2.45	7	SAND	Sand, light brown, dense cemented layers
6028-2351	23/04/2004	MATTSSON N C	7	11	SAND	Thin crust of cemented sand and calcrete
6028-2351	23/04/2004	MATTSSON N C	11	11.45	CLYU	Thin layer of limey clay
6028-2351	23/04/2004	MATTSSON N C	11.45	15	SAND	Firm layers of sand and clay
6028-2351	23/04/2004	MATTSSON N C	15	15.45	SAND	SPT samples as above
6028-2352	18/04/2004	MATTSSON N C	0	1	LMST	Limestone and sand
6028-2352	18/04/2004	MATTSSON N C	1	9	SAND	Sand cemented layers, limey fines
6028-2352	18/04/2004	MATTSSON N C	9	10	SAND	Sand, light brown, slightly clayey (loose)
6028-2352	18/04/2004	MATTSSON N C	10	15	SAND	Sand, light brown layers of white fleck
6028-2352	18/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2353	16/04/2004	MATTSSON N C	0	2	LMST	Limestone and fine sand, pale grey calcrete
6028-2353	16/04/2004	MATTSSON N C	2	10	SAND	Sand, fine, light brown
6028-2353	16/04/2004	MATTSSON N C	10	11	SAND	Sand, fine slightly clayey
6028-2353	16/04/2004	MATTSSON N C	11	15	SAND	Sand with pale grey limey fines
6028-2353	16/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2354	18/04/2004	MATTSSON N C	0	1	SAND	Sand
6028-2354	18/04/2004	MATTSSON N C	1	7	SAND	Sand with limestone
6028-2354	18/04/2004	MATTSSON N C	7	9	SAND	Sand and clay, some broken limestone
6028-2354	18/04/2004	MATTSSON N C	9	10	SAND	Fine sand some shell fragments
6028-2354	18/04/2004	MATTSSON N C	10	15	SAND	Sand, light brown with dense layers
6028-2354	18/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2355	10/04/2004	MATTSSON N C	0	1.5	LMST	Limestone, calcrete
6028-2355	10/04/2004	MATTSSON N C	1.5	7	SAND	Sand, fine, light brown small shell fragments
6028-2355	10/04/2004	MATTSSON N C	7	7.5	SAND	Cemented sand
6028-2355	10/04/2004	MATTSSON N C	7.5	9	SAND	Sand, light brown
6028-2355	10/04/2004	MATTSSON N C	9	15	SAND	Sand, light brown, fine shell fragments, mec
6028-2355	10/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2356	11/04/2004	MATTSSON N C	0	1	LMST	Limestone
6028-2356	11/04/2004	MATTSSON N C	1	10	SAND	Sand, light brown with cemented layers
6028-2356	11/04/2004	MATTSSON N C	10	11.5	SAND	Sand, fine and brown clay
6028-2356	11/04/2004	MATTSSON N C	11.5	15	SAND	Sand, fine, black grains, limey clay, dense

6028-2356	11/04/2004	MATTSSON N C	15	15.45	SAND	SPT sample as above
6028-2357	12/04/2004	MATTSSON N C	0	1	LMST	Limestone
6028-2357	12/04/2004	MATTSSON N C	1	14	SAND	Sand, fine to light brown to light grey, 11 m
6028-2357	12/04/2004	MATTSSON N C	14	17	SAND	Sand, light brown limey white clayey loose t
6028-2357	12/04/2004	MATTSSON N C	17	19.5	SDST	Sandstone, fine grained shell fragments
6028-2357	12/04/2004	MATTSSON N C	19.5	20.45	SDST	SPT sample as above
6028-2358	14/04/2004	MATTSSON N C	0	1	LMST	Limestone
6028-2358	14/04/2004	MATTSSON N C	1	4	SDST	Sandstone, with shell fragments, weakly cer
6028-2358	14/04/2004	MATTSSON N C	4	6	SAND	Sand, light brown
6028-2358	14/04/2004	MATTSSON N C	6	8	SDST	Sandstone, dense, shell fragments. Water lo
6028-2358	14/04/2004	MATTSSON N C	8	14	SDST	Sandstone, dense
6028-2358	14/04/2004	MATTSSON N C	14	15	SAND	Sand, fine, slightly clayey
6028-2358	14/04/2004	MATTSSON N C	15	20	SDST	Fine grained, sandstone, shell weakly cemer
6028-2359	15/04/2004	MATTSSON N C	0	6	LMST	Limestone to sandstone, water loss at 6 me
6028-2359	15/04/2004	MATTSSON N C	6	10.4	LMST	Limestone, red brown
6028-2359	15/04/2004	MATTSSON N C	10.4	14.3	SDST	Sandstone, light yellow, brown shelly
6028-2359	15/04/2004	MATTSSON N C	14.3	14.8	LMST	Limestone, red brown
6028-2359	15/04/2004	MATTSSON N C	14.8	15.45	SAND	Sand, fine, pale brown, loose. No recovery b
6028-2359	15/04/2004	MATTSSON N C	15.45	20	SDST	Sandstone fine grain shell fragments, loose
6028-2386	25/11/2005	MATTSSON N C	0	0.5	TPSL	Top soil
6028-2386	25/11/2005	MATTSSON N C	0.5	2	LMST	Hard limestone
6028-2386	25/11/2005	MATTSSON N C	2	8	CLYU	Sandy clay
6028-2386	25/11/2005	MATTSSON N C	8	13	CLYU	Sandy clay with hard layers
6028-2386	25/11/2005	MATTSSON N C	13	14.8	GRVL	Quartz gravel, tace of graphite with dark sar
6028-2433	8/04/2008	MATTSSON N C	0	1	TPSL	topsoil
6028-2433	8/04/2008	MATTSSON N C	1	6	LMST	sand, clay and limestone
6028-2433	8/04/2008	MATTSSON N C	6	7	LMST	ironstone, sandy clay and limestone
6028-2433	8/04/2008	MATTSSON N C	7	12.1	LMST	sand, clay and limestone
6028-3189	4/06/2020	STEVEN JAMES JUETT	1	2	SOIL	
6028-3189	4/06/2020	STEVEN JAMES JUETT	2	4	CALC	
6028-3189	4/06/2020	STEVEN JAMES JUETT	4	50	GRNT	
6028-3188	20/06/2020	STEVEN JAMES JUETT	0	2.5	CALC	sand/ clays
6028-3188	20/06/2020	STEVEN JAMES JUETT	2.5	10	GRNT	small breaks
6028-3188	20/06/2020	STEVEN JAMES JUETT	10	60	GRNT	extremely hard with no fractures or breaks

Unit_No	depth_from	depth_to	major_lith	minor_lith	Description
6028-566	0	0.3	SOIL		Dark brown sandy soil
6028-566	0.3	4.27	SAND	LMST	Cream fine grained calcareous sand with dense limestone
6028-566	4.27	12.19	SDST	LMST	Buff fine grained calcareous sandstone and limestone
6028-566	12.19	17.07	SAND	GRIT	Red brown clayey fine sand with fine quartz grit
6028-566	17.07	20.73	SAND	GRIT	Brown medium grained clayey sand with grit and coarse limestone gravel
6028-566	20.73	41.76	CLYW		White gritty kaolin with pockets of brown clay and mica
6028-566	41.76	42.06	GNSS		Light grey fine grained quartz felspar gneiss
6028-588	0	0.61	SAND	GRVL	Yellow brown clayey fine sand with abundant lateritic gravel
6028-588	0.61	4.27	SAND	GRIT	Yellow brown and grey clayey fine sand with quartz grit and lateritic gravel
6028-588	4.27	9.75	SAND	GRIT	Buff fine-medium grained sand and sub-angular grit
6028-588	9.75	14.94	SAND	GRIT	Yellow brown clayey fine sand with quartz grit mica and fine grey sand
6028-588	14.94	15.85	GNSS		Buff medium grained quartz felspar gneiss
6028-589	0	0.3	SOIL		Brown sandy soil
6028-589	0.3	0.91	GRVL		Red brown sub-angular lateritic gravel
6028-589	0.91	4.27	SAND	SILT	Yellow brown and grey clayey fine sand and silt with lateritic gravel
6028-589	4.27	7.62	SAND	GRIT	Buff fine sand with angular quartz grit
6028-589	7.62	9.14	SAND	GRIT	Light brown slightly clayey fine sand and grit
6028-589	9.14	10.36	SAND	SILT	Cream fine sand and silt with pockets of white clay, grit and angular quartz boulders
6028-589	10.36	13.11	SAND	SILT	Cream clayey fine sand and silt with lateritic gravel
6028-594	0	2.44	LMST		Cream sandy and friable limestone
6028-594	2.44	5.79	SAND	GRIT	Light grey fine sand and grit
6028-594	5.79	10.67	SAND	GRIT	Yellow sightly clayey fine-medium grained sand with rounded quartz grit
6028-594	10.67	12.8	CLYU	GRIT	White clay with abundant sub-angular quartz grit
6028-600	0	0.61	SOIL		Light grey very fine to fine sandy soil
6028-600	0.61	2.13	SAND		Light brown very clayey fine-medium sand, abundant smsll limestone fragments
6028-600	2.13	5.49	CLYU		Yellow-brown and grey slightly sandy very calcareous clay, abundant limestone fragments
6028-600	5.49	6.1	CLYU		White grey and brown calcareous fine sandy clay abundant mica
6028-600	6.1	9.75	GRNT		Decomposed gneissic granite
6028-601	0	4.88	CLYU	GRIT	Brown and red-brown sandy clay - abundant ferruginous grit
6028-601	4.88	9.14	SAND		Light yellow-brown slightly clayey fine to medium sand-rare ferruginous grit
6028-601	9.14	10.06	GRNT		Decomposed gneissic granite
6028-604	0	0.91	SOIL		Light brown fine to medium sandy soil
6028-604	0.91	4.88	CLYU		Grey and red-brown fine sandy clay - abundant ferruginous grit
6028-604	4.88	10.06	MARL		cream and yellow-brown slightly sandy marl - abundant hard limestone fragments
6028-604	10.06	15.54	CLYU		Grey and yellow-grey very micaceous and quartzitic clay
6028-604	15.54	16.15	GRNT		Decomposed gneissic granite
6028-606	0	0.61	SOIL	TRAV	Grey sandy soil and creamdense nodular travertine
6028-606	0.61	1.52	LMST		Buff dense nodular limestone
6028-606	1.52	4.57	SDST		White medium grained calcareous sandstone
6028-606	4.57	5.79	LMST		Cream soft sandy limestone
6028-606	5.79	7.92	SDST	LMST	Cream medium grained dense calcareous sandstone and limestone with brown fine sand
6028-606	7.92	10.97	CLYU		Greyish brown sandy clay with limestone nodules
6028-606	10.97	12.5	LMST		Cream dense limestone
6028-606	12.5	15.24	LMST	SAND	Buff dense limestone and cream fine sand
6028-606	15.24	15.85	SAND	GRIT	Yellow brown and grey clayey fine sand and grit with fragments of limestone
6028-607	0	0.91	SAND		Buff fine-medium grained sand
6028-607	0.91	8.23	SAND	GRIT	Yellow brown and grey clayey fine sand and grit with lateritic gravel
6028-607	8.23	10.36	SAND	GRIT	Yellow brown clayey fine sand with abundant sub-angular grit
6028-607	10.36	14.63	CLYU	GRIT	Light grey silty clay with grit and mica
6028-608	0	0.3	SAND		Grey fine-medium grained sand
6028-608	0.3	3.96	SDST	LMST	Cream medium grained friable calcareous sandstone and limestone
6028-608	3.96	7.92	SAND	LMST	Yellow-brown clayey fine sand with nodules of grey limestone and lateritic gravel
6028-608	7.92	8.23	GNSS		Grey fine grained quartz felspar gneiss
6028-609	0	1.52	SAND	GRIT	Yellow brown fine sand and grit
6028-609	1.52	3.35	SAND	GRIT	Brown clayey fine sand and grit with limestone gravel
6028-609	3.35	8.53	CLYU		Mottled pink, white and brown mottled clay
6028-609	8.53	18.59	CLYU	GRIT	Grey clay with abundant sub-angular grit and mica
6028-609	18.59	18.9	CLYU	GRIT	Brown and white clay with abundants mica and quartz grit
6028-609	18.9	38.1	CLYU		Brown grity clay with mica
6028-610	0	1.22	CLYU	GRIT	Brown sandy clay with quartz grit and limestone

6028-610	1.22	5.49	LMST		Cream dense sandy limestone
6028-610	5.49	9.45	SAND	GRIT	Red brown and grey clayey fine sand and grit
6028-610	9.45	10.36	SAND	GRIT	Yellow brown fine-medium grained sand and grit
6028-610	10.36	14.33	SAND	SILT	Light brown clayey fine sand and silt
6028-610	14.33	17.68	SAND		Buff fine sand
6028-610	17.68	19.2	QTZT		Light grey medium grained weathered feldspatic quartzite
6028-610	19.2	44.2	CLYU	GRIT	LIght brown and white clay with abundant quartz grit
6028-611	0	0.91	SOIL		Grey sandy soil
6028-611	0.91	4.88	SDST		Light grey friable calcareous sandstone
6028-611	4.88	7.01	LMST		Cream dense nodular limestone
6028-611	7.01	10.36	SAND	GRVL	Cream clayey fine sand with limestone gravel and quartz grit
6028-611	10.36	13.41	SAND	GRIT	Light brown fine coarse sand with limestone grit and fine gravel
6028-611	13.41	13.72	SAND	GRIT	Yellow-brown and grey clayey fine sand with grit and lateritic gravel
6028-612	0	0.3	SAND	GRVL	Brownish grey fine sand with oronstone gravel
6028-612	0.3	3.35	LMST		Grey and white sandy limestone, dense in parts
6028-612	3.35	4.57	SDST	SAND	Cream medium grained friable calcareous sandstone and sand
6028-612	4.57	5.18	SDST		Whit medium-coarse grained calcareous sandstone with shell fragments
6028-612	5.18	7.32	LMST		Cream dense nodular sendy limestone
6028-612	7.32	8.84	SAND		Grey fine sand with fragments of grey clay and nodules of limestone
6028-613	0	2.44	CLYU		Grey very calcareous clay and white limestone rubble
6028-613	2.44	4.88	LMST	CLYU	Light grey broken limestone and clay
6028-613	4.88	7.62	SAND		Off-white lime sand with abundant fine to medium quartz sand
6028-614	0	0.3	SOIL		Light brownish grey fine to medium sandy soil
6028-614	0.3	1.83	LMST		Light brownish grey slightly sandy limestone rubble with pockets of clay
6028-614	1.83	3.05	CLYU		Grey and yellow-brown calcareous and sandy clay - abundant limestone fragments up to 6mm
6028-614	3.05	7.92	LMST		Yellow brown crystalline limestone
6028-614	7.92	8.53	GRIT		Light-brown slightly sandy limestone grit
6028-615	0	2.74	SAND		Light grey calcareous sand with shell frgments and limestone boulders
6028-615	2.74	5.18	CLYU	GRVL	Yellow brown and grey sandy clay with ironstone gravel
6028-615	5.18	6.1	SILT	GRVL	Mottled white and red brown fine silt with ironstone gravel
6028-616	0	0.3	SOIL		Greyish brown sandy soil
6028-616	0.3	1.22	LMST		Cream dense nodular limestone
6028-616	1.22	3.66	SAND		Cream medium grained calcareous sand
6028-616	3.66	7.01	SAND	CLYU	Brown clayey medium grained sand with grey clay, quartz grit and lateritic gravel
6028-617	0	0.61	LMST	SOIL	Cream dense nodular limestone and grey sandy soil
6028-617	0.61	1.83	LMST		Cream fine grained dense nodular limestone
6028-617	1.83	4.88	SAND	SDST	Cream fine-medium grained calcareous sand and friable sandstone
6028-617	4.88	10.97	SAND	SILT	Light grey and brown clayey fine sand and silt
6028-617	10.97	12.19	GNSS		Grey coarse grained highly weathered gneiss
6028-618	0	2.74	CLYU	GRIT	Red brown sandy clay with grit and lateritic gravel
6028-618	2.74	8.53	SAND	GRIT	Yellow brown clayey fine sand with grit, limestone and lateritic gravel
6028-618	8.53	12.8	CLYU	SAND	White gritty clay and clayey fine sand
6028-618	12.8	16.76	SAND	SILT	Greyish brown clayey fine sand and silt with grit, mica and pockets of white clay
6028-619	0	0.61	SAND		Light brown fine to medium sand
6028-619	0.61	5.18	CLYU	GRIT	Grey and red-brown sandy clay - abundant ferruginous grit
6028-619	5.18	6.71	CLYU		Light greenish grey very sandy clay - some milky quartz grit
6028-619	6.71	12.8	CLYU		Grey and light brown micaceous clay
6028-619	12.8	13.72	GRNT		? Very acid gneissic granite - little dark mineral present
6028-621	0	0.3	SOIL		Greyish brown sandy soil
6028-621	0.3	1.52	SDST		Cream medium grained dense calcareous sandstone with shell fragments
6028-621	1.52	4.57	SAND	SDST	Cream medium grained calcareous sand and friable sandstone
6028-621	4.57	6.4	CLYU	GRVL	Yellow brown and grey sandy clay with abundant lateritic gravel
6028-621	6.4	7.92	SAND	GRIT	LIght grey clayey fine sand and grit
6028-621	7.92	9.14	SAND	GRIT	Pink fine-medium grained sand and sub-angular grit
6028-630	0	4.57	SDST		Grey sandsotne highly calcareous composed of both dark and light grains
6028-630	4.57	7.62	LMST		LIght cream and grey sandy limestone
6028-630	7.62	11.28	LMST		Light grey fine sandy limestone
6028-630	11.28	12.19	SAND		Light creamy grey calcareous sand
6028-630	12.19	13.72	MARL		Light greenish sandy marl with limestone fragments