HYDRO-METEOROLOGICAL
&
SURFACE WATER MANAGEMENT STUDY
TABBA TABBA
LITHIUM PROJECT

Prepared for

Wildcat Resources Limited

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EXECUTIVE SUMMARY

Wildcat Resources Ltd (Wildcat) proposes to develop the Tabba Tabba Lithium Project (TTLP), located approximately 50 km southeast of Port Hedland in the Pilbara region of Western Australia.

Wildcat engaged Carrick Consulting (WA) Pty Ltd to complete a baseline hydro-meteorological study and hydrological assessment to identify and ameliorate potential flood risks and develop preliminary engineering designs for the required surface water management measures. This report presents the findings from the subsequent desktop study and site visit.

The following key *hydro-meteorological* findings were made:

- The regional climate is one of extremes and droughts and major floods can occur in the same area within a few years of each other. The climate in this region is highly variable, both spatially and temporally, and this can make hydrologic analysis and the design of water management measures difficult.
- Although situated in the semi-arid Pilbara region with mean annual rainfalls in the order of 315 mm to 460 mm, significant short duration rainfall events can occur during the summer months when Tropical Cyclones and related low-pressure systems cross the Pilbara coast. Such events have delivered daily rainfall totals in excess of 300 mm locally.
- The mean annual rainfalls for local rainfall stations range from about 305 to 325 mm, while the median values range from some 288 to 337 mm. However, the Indee station, located some 37 km west-southwest of the TTLP site, remains open and has 105 years of relatively high quality (94.5% complete) data, and has mean and median annual rainfalls of 325 and 288 mm and is recommended for project use.
- Tropical cyclones bring heavy rains to the Pilbara region and although erratic in nature, occur relatively frequently and must therefore be considered in the design of infrastructure and surface water management measures. An analysis of cyclone path data for the last 52 years shows that, on average, one cyclone will pass within 200 km of the TTLP site every year or so and that one will pass within 100 km of the site every one to two years. Some 17 cyclones (most recently TC Joyce in January 2018) have passed within 50 km of the TTLP site over the 52-year period of record, or one cyclone every three years or so.
- Locally the wettest day on record occurred on 29 March 1988 when 354 mm was recorded at Indee, some 43 km northwest of the site. This rainfall was not attributed to a known tropical cyclone, but was obviously related to a very significant tropical low or depression event as it had an Annual Exceedance Probability (AEP) of between 1% AEP (1 in 100) and 0.5% AEP (1 in 200). The second and third wettest days recorded locally of 281 mm (recorded at Strelley on 24 March 1942) and 275 mm (recorded at Indee on 4 February 1938) were both as a result of tropical cyclones.
- A point rainfall intensity-frequency-duration (IFD) relationship was developed for Tabba Tabba using the updated data set produced by the Bureau of Meteorology (BoM) in 2016. In summary, the 1% AEP point rainfall intensities for 1, 3, 12, 24 and 72 hr duration events are 86.5, 44.8, 20.5, 13.2 and 5.3 mm/hr respectively (giving equivalent storm depths of some 86.5, 134, 246, 316 and 384 mm).
- Distance weighted average evaporation data for Port Hedland Airport and Marble Bar Comparison meteorological stations indicates that Tabba Tabba can expect a mean annual pan evaporation of some 3,305 mm, approximately 65% to 70% of which can be expected to evaporate from shallow freshwater ponds and dams on site.
- A review of Marble Bar Comparison temperature data indicates that typically there are in the order of 105 days each year with daily maximum temperatures in excess of 40°C, with approximately 45 such days occurring between October and January. Highest and lowest daily temperatures of 49.2°C and 1.1°C have been recorded in January and June respectively.
- The TTLP site is situated in the southern headwaters of Tabba Tabba Creek, which is located in the south-eastern part of DoWER's Coastal Catchment, which itself lies within DoWER's much

larger Port Hedland Coast Basin. There is a sparsity of flow gauging data across the regions and DoWER currently has no gauging stations on Tabba Tabba Creek or within the Coastal Catchment.

- Data for the three closest DoWER gauging stations (within 65 km of the TTLP site) indicates that annual and monthly flows are highly variable with a several orders of magnitude increase between minimum and maximum values. Median annual flows represent an average annual runoff yield of less than 10%. Typically, over three quarters of the annual streamflow occurs during January, February and March with the river usually drying up during the dry season around July or August.
- The Tabba Tabba Creek catchment (area = 440 km^2) is bounded by the Strelley/Shaw River catchment (area = 10,700 km^2) to the east, the Turner River catchment (area = 4,800 km^2) to the west and several smaller coastal creek catchments to the north, including Beebingarra Creek (area = 645 km^2) and Petermarer Creek (area = 403 km^2).
- The TTLP local watershed is formed by a range of north-south trending hills of up to about 75 m relief located some 3 to 4 km the south and west of the site and by gently sloping stony plains immediately to the south and east. Given the proximity of the local Tabba Tabba watershed, the catchment areas upstream of the proposed project facilities are relatively modest when compared to much larger regional catchments.
- All of the on-site creeks and drainages are ephemeral in nature. However, flows will occur periodically during the wet season months from December to March, when the potential exposure to high intensity cyclonic or tropical depression related rainfall is greatest. Consequently, on occasion, flows may be high and may cause asset damage or loss if appropriate measures are not in place.

The following key *surface water management* findings were made:

- Given the proximity of the local Tabba Tabba Creek watershed divide, catchment areas upstream of the proposed Mining and Processing Areas are relatively modest (33.8 and 14.4 km^2 respectively) and the surface water management measures required will be fairly limited.
- The presence of in-situ high ground (some 5-6 m above the channel bed) along the southern Pit crest provides a high degree of flood immunity from the Tabba Tabba Creek tributaries to the west and southwest of the Pit and no additional flood protection measures are currently envisaged for those tributaries. **Care should be taken to ensure that this high ground is left intact and is not disturbed by mining activities**.
- However, an approximately 850 m long Pit Diversion Channel and Flood Protection Bund will be required along the western side of the pit to direct runoff from the northwestern tributary into the western tributary. In order to manage the 1%AEP (1 in 100 year) event the channel will have a 40 m basewidth and be about 1.5 m deep. The parallel flood bund will be a minimum of 2 m high and have a 3 m crest width and constructed from select waste material placed and compacted in controlled layers.
- A minimum of four culverted floodway crossings of Tabba Tabba Creek and its tributaries will be required at the Mining Area (1 No.) and along the central HV/LV Road (3 No.). For preliminary design purposes all crossings have been assumed to comprise multiple corrugated metal pipe low-flow culvert barrels capable of passing events up to 50%AEP (1 in 2 year) and a depressed or lowered floodway section of roadway designed to pass 20%AEP (1 in 5 year) peak flows across the road surface up to a maximum depth of 0.25 m. For events greater than 20%AEP i.e. depths greater than 0.25 m, the crossing would be temporarily closed until the flood recedes.
- The design of the Processing Area and ancillary facility surface water management measures will be developed at the detailed design stage of the project, once the facility layout is better defined.
- Hydraulic modelling will be completed at the detailed design stage to determine potential impacts of the three proposed waste rock dumps on the Tabba Tabba Creek tributaries. It may

be necessary to shift and/or rock armour the toelines along the sides of the dumps adjacent to the Tabba Tabba Creek tributaries. **GLOSSARY OF HYDROLOGICAL TERMS**

Annual Exceedance Probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Antecedent Soil Moisture	Water present in the soil prior to a rainfall event.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random.
Australian Rainfall and Runoff (ARR)	National guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. Currently in its 4th edition it is commonly referred to as ARR2019.
Backwater	Water backed-up or retarded in its course as compared with its normal or natural condition of flow
Baseflow	The component of streamflow supplied by groundwater discharge
Basin	A tract of country, generally larger catchment areas, drained by a river and its tributaries.
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Channel	An artificial or constructed waterway designed to convey water. Often described as open channels to distinguish them from pipes.
Control	Physical properties of a cross-section or a reach of an open channel, either natural or artificial, that govern the relation between stage and discharge at a location in the open channel.
Dead Storage	In a water storage, the volume of water stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.
Discharge	Volume of liquid flowing through a cross-section in a unit time.
Drainage Division	Representation of the catchments of the 12-major surface water drainage systems across Australia, generally comprising a number of river basins.
Endorheic Basin	A closed surface water drainage basin that retains water and has no outflow to the sea.
Environmental Flow	The streamflow required to maintain appropriate environmental conditions in a waterway or water body.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evapotranspiration (ET)	The sum of evaporation and plant transpiration from the earth's land surface to the atmosphere.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding
Full Supply Level (FSL)	The normal maximum operating water level of a water storage when not affected by floods. This water level corresponds to 100% capacity.
Generalised Short-Duration Method (GSDM)	Appropriate for estimating probable maximum precipitation for durations up to six hours and for an area of less than 1000 square kilometres.
Generalised Tropical Storm Method – Revised (GTSMR)	Appropriate for estimating probable maximum precipitation in regions of Australia affected by tropical storms.

Intensity-Frequency-Duration (IFD)	Design rainfall intensities (mm/h) or design rainfall depths (mm) corresponding to selected standard probabilities, based on the statistical analysis of historical rainfall.
Minimum Supply Level (MSL)	The lowest water level to which a water storage can be drawn down (0% full) with existing outlet infrastructure; typically, equal to the level of the lowest outlet, the lower limit of accessible storage capacity.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP, and coupled with the worst flood producing catchment conditions.
Probable Maximum Precipitation (PMP)	The theoretically greatest depth of precipitation for a given duration under modern meteorological conditions for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Stage	The water level, typically measured at a water monitoring site
Storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
Surface Runoff	Water from precipitation or other sources that flows over the land surface. Surface runoff is the fraction of precipitation that does not infiltrate at the land surface and may be retained at the surface or result in overland flow toward depressions, streams and other surface water bodies
Sustainable Yield	The level of water extraction from a particular system that would compromise key environmental assets, or ecosystem functions and the productive base of the resource, if it were exceeded.
Total Suspended Solids (TSS)	The sum of all particulate material suspended (i.e. not dissolved) in water. Usually expressed in terms of milligrams per litre (mg/L). It can be measured by filtering and comparing the filter weight before and after filtration.
Transpiration	Evaporative loss of water from the leaves of plants through the stomata; the flow of water through plants from soil to atmosphere.
Watercourse	A river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time).
Wind Run	The product of the average wind speed and the period over which that average speed was measured

TABLE OF CONTENTS

SECTION PAGE

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

The Tabba Tabba Lithium Project (TTLP) is located about 50 km southeast of Port Hedland and straddles the boundary between the Town of Port Hedland and the Shire of East Pilbara in the Pilbara Region of Western Australia (Figure 1). Wildcat Resources Limited (Wildcat) has initiated a Feasibility Study (FS) for the TTLP to assess the economic viability of a mining operation, processing plant and associated infrastructure.

Wildcat has engaged Carrick Consulting (WA) Pty Ltd (Carrick) to complete a baseline hydro-meteorological study and hydrological assessment to identify and ameliorate potential flood risks and develop preliminary engineering designs for the required surface water management works. This report presents the findings from a desktop study of regional hydro-meteorological data and site visit that have been used in the preliminary design of surface water management measures at the TTLP.

The following tasks were completed as part of the assessment:

- *Hydrological/meteorological Desktop Study* – we obtained hydro-meteorological data and mapping information from the relevant WA and Federal government bodies and completed a desktop review to define catchment areas and determine key catchment characteristics and regional and local meteorological conditions. This study yielded pertinent meteorological information e.g. rainfall intensity-frequency-duration (IFD), maximum daily rainfalls, tropical cyclone risk, critical historical wet/dry periods etc. and can be used in the future detailed design of surface water management works.
- *Site Visit* – Carrick's civil engineering hydrologist completed a one-day site visit in August 2024 in order to assess the existing surface water regime in the vicinity of the TTLP and to evaluate potential flood risks and impacts from proposed mining infrastructure on the local environment. During the visit upstream catchment areas were inspected in order to gauge land cover, ground slope, drainage density etc. as well as noting evidence of previous flood events.
- *Feasibility Level Surface Water Management Measure Design* - we have developed feasibility level designs for the surface water management works required at the TTLP including culverted flood way crossings, diversion channels, flood bunding etc. The designs are summarised in the text and shown on preliminary design figures to a level consistent with a Feasibility Study (FS).

The study findings and preliminary engineering designs are presented in the following sections.

2.0 HYDRO-METEOROLOGICAL STUDY

2.1 Data Sources

No on-site rainfall or steamflow data were available for the proposed TTLP site. The hydrological desktop study therefore made use of available local and regional data from the following sources (all distances measured from approximate central deposit location of 700,000 mE and 7,713,300 mN GDA94-MGA Zone 50):

2.1.1 Bureau of Meteorology (BoM) Data:

The BoM data summarised in Tables 1, 2 and 3 were obtained and used in the completion of the desktop study (refer to Figures 2 and 3 for locations):

Table 1: Daily Rainfall Records for Local BoM Stations

BoM Station Name	Station No.	Data Period	% Complete[2]	Distance from Site
Wallareenya	04038	1 Jul 1908 - 31 Mar 2023	74.2%	14.0 km SW
Tabba Tabba closed	04047	1 Dec 1924 - 30 Sep 1976	98.9%	18.5 km SSW
Strelley	04036	1 Jan 1907 - 31 Aug 2022	75.2	26.0 km NE
Lalla Rookh closed	04057	1 Jan 1917 - 30 Nov 1973[1]	89.9%	34.0 km SE
Indee	04016	1 Mar 1909 - 31 May 2023	91.7%	36.5 km WSW
Abydos closed	04000	1 Jul 1917 - 31 Dec 1974	69.6%	83.0 km S

Note 1: Lalla Rookh record comprises two discrete records from 1 Jan 1917 to 31 Aug 1925 (77.1 % complete) and 1 Aug 1946 to 30 Nov 1973 (93.9%). The combined record is 89.9% complete when the intervening period is ignored.
Note 2: % Complete = No. of Days Recorded ÷ (End Date of Record - Start Date of Record)

Table 2: Daily Evaporation for Regional BoM Stations

BoM Station Name	Station No.	Data Period	Distance from Site
Port Hedland Airport	04032	1967 - 2017	44.5 km NW
Marble Bar Comparison closed	04020	1968 - 1988	103.0 km SE

Table 3: Climate Summaries for Regional BoM Stations

BoM Station Name	Station No.	Recording Period	Distance from Site
Port Hedland Airport	04032	1942-2023	44.5 km NW
Yandee closed	04079	1971 - 1982	77.0 km S
Marble Bar Comparison closed	04020	1895-2006	103.0 km SE
Redmont closed	04043	1925 - 2012	147.0 km S
Wittenoom	05026	1949 - 2019	185.0 km SSW

Swept path data from the BoM's Southern Hemisphere Tropical Cyclone Data Portal for Australian cyclones from 1969/1970 season to 2021/2022 season were also used in the study.

2.1.2 Department of Water and Environmental Regulation (DoWER):

The DoWER data summarised in Table 4 were obtained and used in the completion of the desktop study:

Table 4: Flow Data Records for DoWER Gauging Stations

DoWER Site Name	Site No.	Data Period	Distance from Site
Pincunah (Turner River)	709010	1 Feb 1985 – 30 Nov 2023	63 km SSW
Jelliabidinia Well (Yule River)	709005	1 Oct 1973 – 30 Nov 2023	65 km WSW
North Pole Mine (Shaw River)	710229	1 Mar 1967- 30 Nov 2023	63 km SE

Note: Reliability of flow data varies from +/- 10% to > +/- 20%, particularly under high flow conditions.

2.1.3 Department of Agriculture (DoA):

Data presented in the Department's Evaporation Data for Western Australia, Resource Management Technical Report No. 65, October 1987.

2.1.4 Mapping Data

The following mapping data were used in the completion of the desktop study:

- 1:250,000 scale electronic topographic data for Marble Bar (SF 50-08) and Port Hedland Special (SF 50-04) map sheet.
- 1-second Hydro-Enforced SRTM data from Geoscience Australia.
- Landgate 5 m DEM dataset.
- ESRI World Imagery.
- Detailed topographic survey and imagery for TTLP, provided by Wildcat on 20 August 2024.
- Preliminary facility and infrastructure layout plan, provided by Wildcat on 30 August 2024.

2.2 Desktop Study Findings

2.2.1 General Location

The TTLP site is located some 50 km southeast of Port Hedland in the north-eastern Pilbara region of Western Australia (see Figure 1). The site lies approximately 32 km south of the Great Northern Highway/Marble Bar Road junction and some 26 km east of the Port Hedland-Wittenoom Road/Mount Newman Railway. The deposit is centred about approximate grid location 75,000 m E and 7,709,400 m N (GDA94-MGA Zone 51).

The TTLP site is situated within the headwaters of Tabba Tabba Creek and is bounded by the Strelley River catchment to the east and the Turner River catchment to the west. A small range of north-south trending hills of up to about 75 m relief are located several kilometres to the south and west of the site where the Tabba Tabba Creek system rises. Given the proximity of the local watershed, the catchment area upstream of the proposed mining area is relatively limited (i.e. less than about 40 km^2) compared to much larger regional catchments.

There are several relatively minor, unnamed watercourses that cross the TTLP site in a roughly southwest to northeast direction before reporting to Tabba Tabba Creek which continues northwards for some 50 km before discharging into the coastal marshlands located about 30 km east of Port Hedland. None of the creeks or watercourses in the vicinity of the TTLP site are perennial and only carry runoff following significant rainfall events. Nevertheless, periodic runoff will require careful consideration as flows may be significant on occasion and appropriate surface water management measures will be required to prevent asset damage or loss at the TTLP.

2.3 Meteorological Conditions

2.3.1 General

The Pilbara climate is one of extremes, with severe droughts and major floods occurring in the same area within a few years of each other. The climate in this region is highly variable, both spatially and temporally, and this can make hydrologic analysis and the design of water management facilities difficult.

Climatic conditions in the Pilbara are dominated, to a greater degree than in any other part of Western Australia, by tropical cyclones; and the coastal region between Broome and Karratha is considered the most cyclone-prone region of Australia[1] . Cyclones occur in all summer months, but predominantly in January to March and normally form over the Indian Ocean between northern Australia and Indonesia. They typically adopt a south-westerly course parallel to the Pilbara coast as far as the North West Cape, before continuing south. In the majority of cases cyclones will change direction towards the southeast, crossing the coast and bringing heavy rainfall to the arid interior, while gradually weakening. This change in direction, while parallel to the Pilbara coast, is the most likely means of generating high intensity rainfall in the vicinity of the TTLP site, causing runoff to report to local watercourses. On occasion runoff flows will be high, particularly along Tabba Tabba Creek and other on-site watercourses and diversion and flood protection measures will be required around the proposed mine facilities.

Alternatively, prolonged periods without significant rainfall or runoff can and frequently do occur in the Pilbara. For example, the Sherlock River located some 120 km to the southwest of the TTLP site drains a catchment area in excess of 5,000 km^2 and has, in the past, recorded no flow for periods in excess of two years. Given the spatial variability of the region's cyclonic rainfall it is likely that the duration of no-flow periods on rivers and creeks draining smaller areas could be considerably longer. Therefore, any proposed TTLP use of surface water drawn directly from local watercourses would be limited to opportunistic use only. If required, any impounding water supply dams would have to be designed for multi-year drought conditions. It is highly unlikely therefore that a surface water impoundment could be built in the vicinity of the site that could reliably supply the TTLP's entire water supply needs. At best, some form of seasonal runoff harvesting may be worthy of further investigation. Neither surface impounding nor runoff harvesting water supply sources have been considered as part of this study.

2.3.2 Regional Rainfall

The Pilbara region is semi-arid[2], with the mean annual rainfall varying from approximately 460 mm at Wittenoom to 315 mm at Port Hedland. The Pilbara becomes progressively wetter towards the northeast, with rainfall occurring mainly in the summer months, giving maxima from January to March as a result of tropical cyclones and related low-pressure events. There is almost no rainfall between July and October in the northeast Pilbara.

In the southern and western parts of the Pilbara, (around Onslow), not only is the average annual rainfall lower, but winter rains from the southwest are also a feature. This winter rainfall is usually due to low-pressure trough systems acting in conjunction with the northern component of large southerly frontal systems. This can lead to two rainfall maxima in the year, one in summer and the other in winter.

2.3.3 Local Rainfall

In order to analyse rainfall conditions local to the TTLP site daily rainfall data were obtained for six BoM rainfall stations, all of which fall within an 85 km radius of the site (see Figure 2 for station locations, summary data and charts are presented in Appendix A).

[1] "*Surface Hydrology of the Pilbara Region",* Ruprecht, J.K. and Ivansecu, S., Water and Rivers Commission, 1996.

[2] In the temperate zones of Australia, the classification of arid generally refers to areas with a mean annual rainfall of less than 250 mm.

It should be noted that three of the stations are currently closed i.e. Tabba Tabba, Lalla Rookh and Abydos. However, given their proximity to the TTLP site (all within 85 km of the site), their inclusion in the desktop study was considered useful. It should also be noted that only full or complete years of data were used in the annual rainfall analyses. This meant that length of some of the data sets was reduced significantly in order to remove incomplete years.

<u>Annual Rainfall</u>

Table 5 gives the maximum, minimum, mean and median annual rainfall for the local rainfall stations considered in the desktop review, while Table 6 gives the minimum, maximum and mean number of rain days per year and maximum duration without rain.

Table 5: Local Rainfall Stations Annual Rainfall

Station Name[1]	Minimum Annual Rainfall (mm)	Maximum Annual Rainfall (mm)	Mean Annual Rainfall (mm)	Median Annual Rainfall (mm)	No. of Complete Years
Wallareenya	20.3 (2022)	706.3 (1999)	323.4	318.7	68
Tabba Tabba [closed]	79.2 (1936)	550.8 (1942)	312.2	313.2	49
Strelley [2]	***5.3 (1924)***	769.3 (1921)	315.5	321.3	67
Lalla Rookh[3, closed]	86.6 (1972)	510.5 (1956)	305.3	306.9	25
Indee	22.9 (1924)	799.4 (1999)	324.5	288.4	96
Abydos [closed]	43.7 (1944)	***853.6 (1942)***	320.7	336.5	30

Notes:
1. Annual Rainfall values above calculated using complete years of data only.
2. Strelley recorded 807.6 mm in 1942 but that year was discarded due to being incomplete.
3. Lalla Rookh station was not operational between 1 September 1925 and 31 July 1946.

Table 6: Local Rainfall Stations Annual Rain Days and Duration Without Rain

Station Name[1]	No. of Rain Days per Year			Periods Without Rain		
	Min.	Max.	Mean	Maximum Duration	From	To
Wallareenya	***2***	***52***	24.7	280	8 Feb 2022	15 Nov 2022
Tabba Tabba [closed]	8	45	22.4	269	23 Mar 1940	17 Dec 1940
Strelley	***2***	51	19.8	321	22 Feb 1924	7 Jan 1925
Lalla Rookh [2, 3, closed]	8	41	21.0	316	1 Mar 1924	10 Jan 1925
Indee	5	45	25.2	313	4 Mar 1961	10 Jan 1962
Abydos [closed]	4	46	25.8	***322***	2 Feb 1940	19 Dec 1940

Notes:
1. All Annual Rainfall values above calculated using complete years of data only.
2. Lalla Rookh station was not operational between 1 September 1925 and 31 July 1946.
3. Drought at Lalla Rookh could actually have been longer than 316 days as data for February 1924 are missing.

All the annual rainfall data demonstrated right-hand or positive skewness typical of the region, particularly data for stations with 50 years or more gap-free data[3]. Median annual rainfall was therefore calculated (in addition to mean values) as it is generally considered to be a more representative reflection of rainfall central tendency for areas with skewed rainfall data. This is the

[3] The property of skewness is of questionable statistical value in hydrology when it must be estimated from less than 50 sample data points.

case in the Pilbara where exposure to a few, or even a single, extreme cyclonic rainfall event can have a disproportionate effect on the mean, but has much less effect on the median, given that it is based on ranked data.

Table 5 shows that the mean annual rainfalls for the local stations range from 305 to 325 mm, while the median values range from some 288 to 337 mm. For design purposes it is recommended that the data for the Indee station, with a mean and median annual rainfall of 325 and 288 mm respectively, be utilised given it remains open, is located some 36.5 km west-southwest of the TTLP site and has 96 years of complete annual data and 115 years of relatively high quality daily data (94.5% complete).

Points of note from the analysis of the complete annual rainfall data sets for Indee and the other local stations are as follows:

- Typically there is a one order of magnitude range between maximum and minimum annual rainfalls at all of the local stations. Minimum and maximum annual rainfalls of 5.3 mm and 853.6 mm were recorded at Strelley in 1924 and at Abydos in 1942 respectively. There is no obvious spatial rainfall distribution between the local rainfall stations and extreme rainfall values appear to be more closely related to the length of record.
- Local annual rainfalls are also highly temporally variable and significantly wet and dry years can occur in consecutive years. This temporal variation is reflected in the data for the local stations where three or four-fold year-on-year increases or decreases are common. The most extreme example of this year-on-year variability was noted in the data for Strelley which give an annual rainfall of 5.3 mm in 1924, followed by 525.4 mm in 1925 i.e. a near one hundred fold year-on-year increase.
- A frequency analysis of the 90 years of complete Indee rainfall data (using a Generalized Extreme Value Distribution) indicates that the 799.4 mm that occurred in 1999 had an annual exceedance probability (AEP) of around 2% (1 in 50), while the 22.9 mm that fell in 1924 was rarer than the 1% AEP (1 in 100) annual drought for the area. The 1% AEP (1 in 100) wettest year would see in the order of 880 mm of rainfall recorded locally.
- The local annual maximum of 853.6 mm recorded at Abydos in 1942 was due largely to tropical cyclone activity and depression related events in the first half of the year (748.2 mm were recorded in the six months to 30 June). Particularly heavy rainfalls were associated with Tropical Cyclone (TC) Unnamed #7[4] which brought 254 mm to Indee on 25 March (this event was also responsible for daily totals of 280.7 and 245.4 mm at Strelley and Wallareenya respectively). It should be noted that 1942 was also the wettest year on record at Tabba Tabba and also at Strelley (807.6 mm), ignoring the fact that data for November and December 1942 are missing for Strelley.
- Another significantly wet year also occurred locally in 1999 with both Indee and Wallareenya recording their highest annual rainfalls. Rainfalls in 1999 were largely attributable to TC's Vance and Gwenda in late March and early April respectively and to TC's Isla and John in December that year.
- The local minimum rainfall of 5.3 mm recorded at Strelley in 1924 is typical of conditions that year when there was no cyclone activity along the W.A. coast. Indeed many regional rainfall gauges recorded no measurable rain at all that year. These conditions led to what many consider the worst heatwave ever recorded when Marble Bar experienced 160 consecutive days when the maximum daily temperature reached or exceeded 37.8 °C (100.0 °F). Severe drought prevailed across the Western Australian tropics that year and stock losses were heavy. The 1924 rainfall is rarer than the 1% AEP (1 in 100) drought.

[4] Prior to 1964 Tropical Cyclones were unnamed and were instead assigned a sequential number by BoM according to the season of their occurrence.

- Locally, the longest continuously dry period was 322 days and was recorded at Abydos between 2 February and 19 December 1940. This exceeded the previous minimum number of rain days in one year of 321 and 316 days which been recorded previously at Strelley and Lalla Rookh in 1924. In all cases the maximum drought periods were broken by the on-set of the tropical cyclone season, typically in late December or early January.
- The average number of rain days per year recorded locally ranges consistently from between 20 and 26 days. However as many as 52 rain days per year (Wallareenya in 1963) and as few as 2 rain days per year (Strelley in 1924 and Wallareenya in 2022) have been recorded locally.

Monthly Rainfall

Mean, median, maximum and minimum monthly rainfall values were determined for Indee using all 1,237 complete months within the data set data, as shown in Table 7. It should be noted that this is a larger data set than the 96 year complete annual data set used for determination of the mean and median annual rainfall as some of the incomplete years contained complete months of data.

Table 7: Indee Monthly Rainfall

Month	Minimum Monthly Rainfall (mm)	Maximum Monthly Rainfall & Year (mm)	Mean Monthly Rainfall[1] (mm)	Median Monthly Rainfall (mm)	No. of Complete Months
January	0.0	316.8 (1997)	63.3	42.1	103
February	0.0	383.6 (1999)	78.0	67.8	103
March	0.0	***657.2 (2019)***	63.3	34.2	103
April	0.0	298.3 (1966)	19.7	2.2	106
May	0.0	211.8 (1929)	25.0	8.4	104
June	0.0	199.6 (1968)	22.9	6.4	103
July	0.0	86.6 (2005)	8.6	0.0	105
August	0.0	59.2 (1919)	4.9	0.0	103
September	0.0	43.9 (1937)	1.8	0.0	103
October	0.0	45.8 (1916)	1.4	0.0	103
November	0.0	57.4 (1943)	3.9	0.0	101
December	0.0	367.0 (1975)	20.4	4.8	100
Total no. of complete months in data set					**1,237**

Note 1: For the same data set, the sum of median monthly rainfalls does NOT equal the median annual rainfall, unlike the sum of mean monthly rainfalls, which does equal the mean annual rainfall. This is due to ranking of data required to obtain the median, rather than simple addition and division required for the mean.

Table 7 shows that locally the wettest months are from January to March, with the greatest amount of rainfall typically occurring in February with mean and median rainfall totals of 78.0 and 67.8 mm respectively. October is the driest month with mean and median rainfall totals of 1.4 and 0 mm respectively.

The monthly rainfall values show the effect that extreme cyclonic rainfall events can have on the mean rainfall values compared to median values, especially during the summer months. The difference between the mean and median monthly rainfall amounts is significantly less during the drier winter months. The increase in the median rainfall in early winter i.e. May and June, tends not to be due to cyclonic rainfall, but rather to low-pressure trough systems acting in conjunction with large southerly frontal systems.

The maximum monthly rainfalls for each of the local stations are presented in Table 8. The maximum monthly rainfall of 657.6 mm recorded at Indee in March 2019 was due to the passage of Severe Tropical Cyclone Veronica and comprised a three day total of 634 mm to 9:00 a.m. on 26 March. Severe TC Veronica was both very intense and physically large and was the most destructive cyclone to affect the Port Hedland area since TC George in March 2007, with wind gusts which were estimated to have reached in excess of 215 km/h. The Port Hedland port was closed from 22 to 26 March with estimated losses to iron ore exports in excess of $1 billion.

Table 8: Local Rainfall Stations Maximum Monthly Rainfall & Associated Event

Station Name	Maximum Monthly Rainfall (mm)	Date	Event
Wallareenya	379.0	February 1999	Tropical Low 18S
Tabba Tabba closed	330.2	February 1938	TC Unnamed #2 - 1938
Strelley	492.0	March 2007	Severe TC George
Lalla Rookh closed	303.0	April 1966	TC Shirley
Indee	***657.6***	***March 2019***	***Severe TC Veronica***
Abydos closed	348.9	March 1942	TC Unnamed #7 - 1942

Zero precipitation or dry months have been recorded at Indee throughout the year, with approximately 10% of the usually wetter January, February and March months recording no rainfall. Conversely, over 80% of the monthly records for October were dry.

A plot of the mean and median monthly rainfall data for the Indee station is included in Appendix A, along with those for the other five local BoM rainfall stations.

Daily Rainfall

A frequency analysis was carried out using Indee daily data to assess the typical duration of local rainfall events. As only daily data were available, a multiple day duration event was assumed to comprise two or more consecutive days of rainfall, resulting in 1,694 discrete rainfall events during the approximately 115 year Indee rainfall dataset. The results of the frequency analysis are presented in Table 9.

A review of the results of the rainfall duration frequency analysis shows that by far the greatest amount (about 66%) of rainfall events are discrete, single-day events. Two and three-day events represent some 21% and 7.5% of all rainfall events respectively. The longest period of consecutive daily rainfall was found to be 12 days and occurred between 8 and 19 February 1995 when TC Bobby was passing offshore along the Pilbara coastline.

Table 9: Rainfall Duration Frequency Analysis for Indee

Event Duration (days)	Frequency (No. of Events)	Frequency (%)	Cumulative Frequency (%)
1	1,118	66.00%	66.00%
2	349	20.60%	86.60%
3	127	7.50%	94.10%
4	56	3.31%	97.40%
5	24	1.42%	98.82%
6	13	0.77%	99.59%
7	2	0.12%	99.70%
8	3	0.18%	99.88%
9	1	0.06%	99.94%
10	0	0.00%	99.94%
11	0	0.00%	99.94%
12	1	0.06%	100.00%
Total	**1,694**	**100.00**	**-**

An analysis of daily rainfall data was carried out for the six local BoM stations. The ten wettest days are shown in Table 10 along with the recording station, date and tropical cyclone or tropical low name where known.

It should be noted that the top ranked daily event (354.0 mm) exceeds both the mean and median annual rainfall at Indee of 325 and 288 mm respectively. It should be noted that this maximum daily event cannot be attributed to a given tropical cyclone as no cyclones are known to have crossed the Pilbara coast during the 1987/88 season, which was one of least active Australian region tropical cyclone seasons on record. However, it was clearly a result of a very significant tropical low or depression event.

Table 10: Maximum Daily Rainfall

Station Name	Date	Precipitation to 09:00 hrs (mm)	Rank	Event Name
Indee	29 Mar 1988	354.0	1st	Unknown
Streeley	24 Mar 1942	280.7	2nd	TC Unnamed #7 - 1942
Indee	4 Feb 1938	274.8	3rd	TC Unnamed #2 - 1938
Streeley	2 Mar 1941	265.4	4th	TC Unnamed #1 - 1941
Indee	25 Mar 2019	263.4	5th	Severe TC Veronica
Indee	25 Feb 1989	258.0	6th	Tropical Low 16S
Abydos	25 Mar 1942	254.0	7th	TC Unnamed #7 - 1942
Streeley	29 Dec 1947	254.0	8th	TC Unnamed #1 - 1947
Wallareenya	25 Mar 1942	245.4	9th	TC Unnamed #7 - 1942
Streeley	4 Feb 1938	241.3	10th	TC Unnamed #2 - 1938

Note: Prior to 1964 Tropical Cyclones were unnamed and were instead assigned a sequential number by BoM.

A frequency analysis was carried out on the Indee daily rainfall record (using a Wakeby Distribution) which showed that the 354 mm event which was recorded on 29 March 1988 was between 1% AEP (1 in 100) and 0.5% AEP (1 in 200). The local 1% AEP (1 in 100) daily rainfall is estimated to be in the order of 320 mm.

A listing of the ten wettest days at each of the local rainfall stations is provided in Appendix A.

Maximum two, three and seven day rainfalls recorded at each of the local rainfall stations are shown in Table 11.

Table 11: Local Stations Maximum Two, Three and Seven Day Rainfalls

Station Name	Maximum Two-Day Rainfall (mm)	Maximum Three-Day Rainfall (mm)	Maximum Seven-Day Rainfall (mm)
Wallareenya	349.3 (Feb 1938)	350.6 (Feb 1938)	350.6 (Feb 1938)
Tabba Tabba closed	330.2 (Feb 1938)	330.2(Feb 1938)	330.2 (Feb 1938)
Strelley	324.1 (Feb 1938)	327.1 (Feb 1938)	408.0 (Mar 2007)
Lalla Rookh closed	186.5 (Feb 1969)	204.9 (Mar 1956)	273.1 (Jan 1917)
Indee	***467.8 (Mar 2019)***	***634.2 (Mar 2019)***	***648.2 (Mar 2019)***
Abydos closed	254.0 (Mar 1942)	255.3 (Mar 1942)	285.8 (Mar 1942)

The local maximum two, three and seven day rainfall depths of some 468, 634 and 648 mm were recorded at Indee in late March 2019 due to Severe TC Veronica. The significance of this event is highlighted when compared to the totals for the other stations.

Sub-Daily Rainfall

Pluviograph data from the four closest pluviographic stations at Port Hedland (44.5 km NW), Marble Bar Comparison (103.0 km SE), Abydos (81 km S) and Whim Creek (115 km WSW) were assessed. Table 12 shows the maximum six-minute and sixty-minute duration rainfall intensities recorded at each of the pluviograph stations.

Table 12: Regional Stations Maximum Recorded Six & Sixty-Minute Rainfall Intensity

Station Name	Max. Six-Minute Intensity (mm/hr)	Date	Max. Sixty-Minute Intensity (mm/hr)	Date
Port Hedland Airport	140.0	22 Mar 2007	79.8	22 Mar 2007
Marble Bar Comparison closed	110.0	5 Jan 2000	44.4	31 Dec 2005
Abydos closed	123.2	29 Apr 1966	69.5	29 Apr 1966
Whim Creek	130.0	23 Jan 2000	99.4	23 Jan 2000

Notes:
1. Port Hedland Airport values based on approximately 63 years of data collected between 1953 and 2015 (71% complete).
2. Marble Bar Comparison values based on approximately 8 years of data collected between 1997 and 2006 (54% complete).
3. Abydos values based on approximately 3 years of data collected between 1963 and 1968 (22% complete).
4. Whim Creek values based on approximately 16 years of data collected between 1997 and 2015 (27% complete).

The maximum recorded six-minute and one-hour intensities shown above compare well with the calculated 10% AEP (1 in 10) to 5% AEP (1 in 20) six-minute duration rainfall intensities summarised in the following section.

Intensity-Frequency-Duration Relationship

Table 13 shows the point rainfall IFD relationship developed for the TTLP using the most recent national dataset (updated by BoM in 2016).

Table 13: TTLP Point Rainfall IFD Relationship

Duration (hours)	Rainfall Intensity (mm/hr)						
	10% AEP (1 in 10)	5% AEP (1 in 20)	2% AEP (1 in 50)	1% AEP (1 in 100)	0.5% AEP (1 in 200)	0.2% AEP (1 in 500)	0.1% AEP (1 in 1,000)
0.083	156	184	224	256	296	353	399
0.5	80.9	95.4	115	130	151	180	204
1	52.8	62.4	75.7	86.5	99.9	119	135
2	33.7	40.1	49.3	56.8	65.8	78.4	88.7
3	26.1	31.3	38.7	44.8	52.1	62.2	70.4
6	17.1	20.8	26.1	30.4	35.6	42.6	48.3
12	11.2	13.9	17.6	20.5	24.1	28.9	32.8
24	7.13	8.9	11.3	13.2	15.3	18.3	20.7
48	4.21	5.22	6.58	7.7	8.69	10.2	11.4
72	2.96	3.63	4.55	5.34	5.93	6.94	7.73

The full IFD relationship is presented in Appendix B of this report.

Cyclone Swept Path Analysis

The TTLP site is located about 45 km south of the Pilbara coast which experiences more cyclones than any other part of Australia. On average Port Hedland is impacted by at least one significant cyclone about every one to two years usually between mid-December and April, with the peak typically occurring in February. Such events cause flooding, road closures and operational interruptions and other problems at existing mines in the region and require careful planning to mitigate their effects.

In order to estimate the frequency that cyclones might be expected in the region the swept paths of all cyclones from the 1969/70 to 2021/22 seasons were examined and those that passed within a 200 km radius of the proposed TTLP site were noted. This radius of influence was arbitrarily chosen as the width within which a cyclone would cause some operational impact to the proposed TTLP, even if only minor.

This initial assessment showed that some 54 tropical cyclones entered the 200 km radius during the approximately 52-year period of record, or that the long-term regional average is approximately one cyclone within 200 km every year or so.

A second assessment was carried out to determine the number of cyclones crossing closer to or within 100 km of the TTLP site. It was considered that cyclones crossing within this tighter radius would have more significant impacts on the proposed TTLP, likely leading to lost time and possible asset damage or loss. This assessment showed that 25 cyclones crossed within a 100 km radius over the approximately 52-year period of record, or one every two years or so.

A final assessment showed that 17 cyclones (most recently TC Joyce in January 2018) passed within 50 km of the TTLP site over the 52 year period of record, or one every three years or so.

The results of the cyclone swept path analyses are provided in Appendix C.

It should be noted that the above analyses are somewhat subjective as they only considered the cyclone frequency and not intensity. Cyclone intensity varies from a gale force category 1 with wind speeds up to 125 km/hr to severe category 5 cyclones with gusts of more than 280 km/hr (the maximum wind gust at Port Hedland is 208 km/h which was recorded during TC Joan on 8 December 1975). Obviously a more intense cyclone passing further away may cause greater damage than a less intense cyclone in the immediate vicinity of the TTLP site.

Probable Maximum Rainfall Estimate

In order to estimate the probable maximum rainfall (PMP) that might be experienced at the TTLP site the BoM's GSDM and GTSMR Coastal methods were applied (refer to Appendix D for calculations). The resulting PMP rainfall depths and intensities are summarised in Table 14. It should be borne in mind that the estimated PMP rainfall depths and intensities are some five to six times greater than those for the 1% AEP event.

Table 14: Tabba Tabba Lithium Project - PMP Rainfall Depth & Intensity Estimates

Duration (hours)	PMP Rainfall Depth (mm)	PMP Rainfall Intensity (mm/hr)
1	450	450.0
2	670	335.0
3	810	270.0
4	920	230.0
5	1010	202.0
6	1080	180.0
12	1160	96.7
24	1270	52.9
36	1550	43.1
48	1820	37.9
72	2290	31.8
96	2570	26.8
120	2700	22.5

Note: Refer to Appendix D: Tabba Tabba Lithium Project – Probable Maximum Precipitation Estimate for details.

2.3.4 Evaporation

Evaporation data show that evaporation is highest in the summer months from November to February. The mean monthly Class A bird-guarded pan evaporation measured at Port Hedland Airport and Marble Bar Comparison (the closest reliable evaporation gauging sites) is listed in Table 15.

The mean annual pan evaporation measured at Port Hedland Airport and Marble Bar Comparison is very similar at 3,367 mm and 3,379 mm respectively, which is approximately one order of magnitude greater than the median annual rainfall for the region. Mean monthly evaporation typically exceeds mean monthly rainfall throughout the year. The evaporation data show that evaporation is highest in the summer months, with November and December having the highest values.

Table 15: Mean Monthly Pan Evaporation

Month	Mean Monthly Pan Evaporation (mm)		
	Port Hedland Airport[1]	Marble Bar Comparison[2]	Tabba Tabba Estimated[3]
January	322	353	332
February	271	294	278
March	288	301	292
April	264	258	262
May	229	202	221
June	195	162	185
July	205	167	193
August	233	195	221
September	267	261	265
October	329	341	332
November	345	381	356
December	353	400	367
Mean Annual Pan Evaporation (mm)	**3,301**	**3,315**	**3,305**

Notes:
1. Port Hedland Airport values based on BoM's analysis of data collected between 1967 and 2017.
2. Marble Bar Comparison values based on BoM's analysis of data collected between 1968 and 1988.
3. Tabba Tabba estimated based on 70%/30% weighted average of Port Hedland and Marble Bar stations.

Given that the TTLP site is located approximately 44.5 km from Port Hedland Airport and 103 km from the Marble Bar station, and in the absence of any local evaporation data, the 70%/30% weighted average of pan evaporation data for both stations shown in the table above is considered suitable for current design purposes. This indicates that the annual evaporation rates at the TTLP will be in the order of 3,305 mm/year.

The Department of Agriculture's (DoA) Technical Report No. 65 referenced earlier states that a 7% coefficient of variation can be applied to mean annual evaporation rates in WA. Applying this coefficient to the TTLP mean annual evaporation of 3,305 mm gives a standard deviation of some 231 mm. Assuming that evaporation data are normally distributed, estimates of annual pan evaporation with 10, 50 and 100 year ARI will be about of 3,690 mm, 3,770 mm and 4,000 mm respectively.

The DoA report also states that a "pan to dam" coefficient in the order of 65-70% is appropriate for use for shallow dams and ponds (less than 4 m deep) storing freshwater in the Pilbara. Consequently mean annual evaporative rates in the order of 2,150 mm to 2,315 mm might be expected from freshwater storage ponds at the TTLP site.

2.3.5 Temperature

The climate summary data for the Marble Bar Comparison station, some 103 km to the southeast of the TTLP site, provides the following information regarding temperature:

- Mean daily maximum temperatures range from 41.6°C in December to 26.8°C in July.
- Mean daily minimum temperatures range from 26.1°C in January to 11.7°C in July.
- Highest and lowest daily temperatures of 49.2°C and 1.1°C respectively have been recorded at Marble Bar on 3 January 1922 and 30 June 1935 respectively.

- Typically Marble Bar will have in the order of 105 days each year with daily maximum temperatures in excess of 40°C, approximately 45 of which will occur in December and January.

Monthly temperature data for Marble Bar Comparison Station are shown in Table 16 below.

Table 16: Monthly Temperature Data for Marble Bar Comparison Station (°C)

Month	Mean daily maximum Temp	Mean daily minimum Temp	Highest daily Max Temp	Lowest daily Min Temp	Mean no. of days where Max Temp ≥ 30.0 deg C	Mean no. of days where Max Temp ≥ 40.0 deg C
Jan	41.0	26.1	***49.2***	18.9	30.3	21.3
Feb	39.8	25.6	48.3	13.9	27.3	15.9
Mar	39.0	24.7	46.7	15.0	30.0	14.2
Apr	36.0	21.4	45.0	10.0	28.0	3.0
May	30.7	16.6	39.5	5.6	19.5	0.0
Jun	27.1	13.2	35.8	***1.1***	5.6	0.0
Jul	26.8	11.7	35.0	2.2	5.2	0.0
Aug	29.6	13.3	37.2	3.9	14.6	0.0
Sep	33.9	16.7	42.6	5.6	26.3	0.4
Oct	37.6	20.3	45.6	10.0	30.5	7.6
Nov	40.5	23.6	47.2	14.4	29.7	18.6
Dec	41.6	25.5	48.3	17.0	30.5	23.7

Note: Marble Bar Comparison mean daily maximum and minimum temperature values based on approximately 105 years of data between 1901 and 2006.

2.3.6 Wind Speed and Direction

The Port Hedland Airport station, some 44.5 km northwest of the site, is the nearest BoM station that records mean daily wind speed and direction, along with maximum instantaneous wind gust speed.

The monthly 9 am and 3 pm mean wind speeds and maximum wind gusts for Port Hedland Airport are shown in Table 17.

Mean annual wind roses for the 9 am and 3 pm observations at the Port Hedland Airport station are provided in Appendix A. These show that easterly's and south-easterly's predominate in the morning, but by the afternoon north-westerly's and northerly's prevail. For the morning observation time it was noted that it was calm for about 6% of the year, while afternoons are nearly always windy with calm conditions noted less than 0.5% of the time.

Table 17: Mean Monthly 9 am and 3 pm Wind Speed and Maximum Wind Gusts for Port Hedland Airport Station

Month	Mean 9 am Wind Speed (km/h)	Mean 3 pm Wind Speed (km/h)	Highest Recorded Wind Gust (km/h)
Jan	14.6	25.6	170.6 (19 Jan 1987)
Feb	14.4	23.6	192.6 (1 Feb 1980)
Mar	15.1	21.6	200.2 (27 Mar 1977)
Apr	16.9	19.6	153.7 (8 Apr 1983)
May	19.9	18.3	85.3 (19 May 1996)
Jun	20.8	17.9	76.0 (25 Jun 2013)
Jul	20.8	18.7	81.7 (13 Jul 1984)
Aug	20.2	20.1	85.3 (14 Aug 1995)
Sep	18.4	22.3	81.7 (27 Sep 1990)
Oct	17.9	25.3	92.5 (17 Oct 1969)
Nov	16.0	26.5	81.7 (14 Nov 1972)
Dec	15.2	26.8	207.7 (8 Dec 1975)

Note: Port Hedland mean values based on approximately 69 years of data recorded between 1942 and 2012, while wind gust values based on approximately 67 years of data recorded between 1954 and 2023.

2.4 Hydrological Conditions

2.4.1 Regional Hydrologic Setting

As shown in Figure 4, the TTLP is situated in the southern headwaters of Tabba Tabba Creek, which is located in the south-eastern part of DoWER's Coastal Catchment (area = 7,443 km^2), within DoWER's much larger Port Hedland Coast Basin (area = 35,172 km^2).

The Tabba Tabba Creek catchment (area = 440 km^2) is bounded by the Strelley/Shaw River catchment (area = 10,700 km^2) to the east, the Turner River catchment (area = 4,800 km^2) to the west and several smaller Coastal Catchment creeks to the northwest, including Beebingarra Creek (area = 645 km^2) and Petermarer Creek (area = 403 km^2), as shown in Figure 5 (the catchment areas of Tabba Tabba, Beebingarra and Petermarer Creeks have been measured to where the salt flats commence, within about 10 km of the Pilbara coastline).

Although there is a sparsity of flow gauging data for the Strelley and Turner rivers (DoWER currently only has one surface water gauging station on the Turner River and none on the Strelley River), they are both typical of major rivers in the Pilbara in that they are ephemeral and highly variable with flows increasing from zero to up to thousands of cubic metres per second in a matter of days following major storm events.

Typically, over three quarters of the annual streamflow occurs during January, February and March with the river usually drying up during the dry season around July or August and leaving a series of disconnected permanent pools which are recharged by groundwater. There is strong interaction between the surface water and groundwater hydrology at the catchment scale but little is known at a more localised scale. Surface water flow in the river and flood plain recharges the alluvium through the river bed during the wet season. During the dry season, river flow is initially maintained by groundwater discharge, until declining levels drop below the river bed.

2.4.2 Review of Regional Flow Data

Daily flow data were obtained for DoWER's closest flow monitoring stations at Pincunah on the Turner River, Jelliabidina Well on the Yule River and North Pole Mine on the Shaw River as summarised in Table 4 earlier and shown on Figure 4. These data were analysed and the key results are presented in Tables 18 and 19 on the following pages (DoWER data are provided in Appendix E).

It should be noted that water years i.e. 1 July to 30 June were used in the flow data analyses as flow in the local rivers generally results from runoff tropical cyclones and other depression related events that usually straddle the calendar year end of 31 December.

Inspection of the flow data indicates the following:

- Annual flows are highly variable with a several order of magnitude increase between minimum and maximum values.
- Months with zero flow have been recorded at all stations during all months of the year.
- Using median annual flows at the three gauging stations and applying the Indee median annual rainfall of 288 mm/year across each catchment results in average annual runoff yields of less than 10% for each of the catchments.
- The highest flow recorded at Pincunah was 2,118 m^3/s recorded on 25 February 1989 following heavy rainfalls earlier in the month (Indee recorded its third wettest day on record with a rainfall of 285 mm on the same day).
- The highest flow recorded at Jelliabidina was 6,763 m^3/s recorded on 26 February 1995 and was likely associated with the passage of TC Bobby along the Pilbara coast over the preceding week.
- The highest flow recorded at North Pole Mine was 5,035 m^3/s recorded on 29 March 1988 following heavy rainfalls earlier in the month (Indee recorded its wettest day on record with a rainfall of 354 mm on the same day).

Table 18: Total Annual Flow (ML) and Annual Maximum Daily Flow (m^3/s) at Pincunah, Jelliabidina Well and North Pole Mine 1984/85 to 2022/23

Water Year[1]	Pincunah (Turner River)[2]		Jelliabidina Well (Yule River)[3]		North Pole Mine (Shaw River)[4]	
	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)
1984-85	Incomplete	Incomplete	137,930	492.2	59,677	296.2
1985-86	284	14.8	0	0	0	0.0
1986-87	5,573	245.8	13,857	143.0	31,827	225.6
1987-88	63,663	834.6	537,288	4,208.0	-	5,035.0
1988-89	96,247	2,118.0	441,270	3,705.0	-	2,150.0
1989-90	0	0.0	667	2.2	768	2.2
1990-91	0	0.0	0	0	0	0.0
1991-92	4,353	42.8	0	0	7,018	47.6
1992-93	21,708	66.8	96,850	1,299.0	50,391	267.9
1993-94	2,679	29.1	0	0	12,887	33.2
1994-95	69,166	416.0	912,347	6,763.0	475,045	3,041.0
1995-96	0	0.0	0	0	97,239	1,320.0
1996-97	61,570	577.5	789,612	3,080.0	483,732	1,394.0
1997-98	6,848	111.9	0	0	1,706	37.6
1998-99	31,434	200.1	708,039	843.9	761,079	3,035.0
1999-00	208,224	1,941.0	2,382,380	3,468.0	2,381,050	4,956.0
2000-01	66,251	151.5	359,210	84.2	177,699	603.3
2001-02	0	0.0	0	0.4	260,111	2,234.0
2002-03	84,060	1,828.0	Missing	1,236.0	467,634	3,476.0
2003-04	8,320	110.2	Missing	Missing	288,665	832.4
2004-05	3,337	49.0	Missing	Missing	465	48.4
2005-06	54,923	214.0	764,121	1,479.0	642,757	937.2
2006-07	95,534	775.2	366,353	2,514.0	552,872	2,954.0

Table 18: Contd.

Water Year[1]	Pincunah (Turner River)[2]		Jelliabidina Well (Yule River)[3]		North Pole Mine (Shaw River)[4]	
	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)	Total Annual Flow (ML)	Max. Daily Flow (m^3/s)
2007-08	7,165	167.8	18,676	83.7	889	6.8
2008-09	4,978	49.6	109,779	397.8	226,146	1,031.0
2009-10	0	0.0	0	0	748	82.1
2010-11	6,012	40.6	173,097	300.5	382,284	775.9
2011-12	5,922	28.1	309,838	5,038.0	556,402	3,080.0
2012-13	1,344	13.2	70,256	1,476.0	22,900	213.6
2013-14	24,442	162.2	153,507	526.3	500,153	1,712.0
2014-15	0	0.0	51,050	98.7	51,418	213.3
2015-16	947	9.9	3,732	14.61	39,200	386.5
2016-17	20,369	54.9	255,088	276.9	734,429	810.0
2017-18	6,286	101.8	21,083	57.1	270,787	960.8
2018-19	82,903	1,308.0	588,825	3,954	405,256	4,793.0
2019-20	14,349	197.3	56,665	1,564	494,617	3,212.0
2020-21	29,158	690.0	174,043	255.4	374,521	4,439.0
2021-22	146	0.5	833	6.5	63,259	361.0
2022-23	1,690	9.9	160	2.8	12,383	170.3
Minimum	**0**	**0**	**0**	**0**	**0**	**0**
Maximum	**208,224**	**2,118**	**2,382,380**	**6,763**	**2,381,050**	**5,035**
Mean	**28,681**	**331**	**263,793**	**1,172**	**294,271**	**1,415**
Median	**6,567**	**84**	**83,553**	**277**	**177,699**	**810**

Notes:

1. Water years assumed to run from 1 July to 30 June.
2. Pincunah Catchment Area = 885 km^2
3. Jelliabidina Well Catchment Area = 8,430 km^2
4. North Pole Mine Catchment Area = 6,500 km^2.

Table 19: Monthly Flow Parameters (GL) for Pincunah, Jelliabidina Well and North Pole Mine DoWER Flow Monitoring Stations

Month	Minimum Monthly Flow (GL)			Maximum Monthly Flow (GL)			Mean Monthly Flow (GL)			Median Monthly Flow (GL)		
	Pincunah[1]	Jellia-bidina[2]	North Pole[3]	Pincunah[1]	Jellia-bidina[2]	North Pole[3]	Pincunah[1]	Jellia-bidina[2]	North Pole[3]	Pincunah[1]	Jellia-bidina[2]	North Pole[3]
Jan	0	0	0	78,068	298,683	510,329	5,292	95,854	57,873	471	63,572	603
Feb	0	0	0	88,247	811,831	594,766	8,898	163,754	81,904	760	71,341	15,068
Mar	0	0	0	90,866	800,933	1,276,491	9,176	142,440	84,007	466	32,880	5,478
Apr	0	0	0	15,618	459,289	413,293	1,167	67,947	24,264	-	14,080	1
May	0	0	0	4,195	93,904	30,439	174	24,127	2,224	-	-	-
Jun	0	0	0	4,870	29,861	106,993	241	10,486	3,740	-	-	-
Jul	0	0	0	2,206	16,207	13,367	75	5,425	440	-	-	-
Aug	0	0	0	1,558	32,358	22,738	40	8,450	598	-	-	-
Sep	0	0	0	420	2,918	168	11	2,918	4	-	-	-
Oct	0	0	0	25	371	-	1	371	-	-	-	-
Nov	0	0	0	2,162	0	257	55	0	6	-	-	-
Dec	0	0	0	77,182	1,219,912	344,548	2,867	326,041	22,487	-	-	-

Notes:
1. Pincunah results based on data recorded between February 1985 and November 2023. (Catchment Area = 885 km^2).
2. Jelliabidina Well results based on data recorded between March 1973 and November 2023. (Catchment Area = 8,430 km^2).
3. North Pole Mine results based on data recorded between March 1967 and November 2023. (Catchment Area = 6,500 km^2).

2.4.3 Local Hydrological Setting

As mentioned above, the bulk of the proposed TTLP facilities are situated within the southern headwaters of Tabba Tabba Creek catchment which is bounded by the Strelley River catchment to the east and the Turner River catchment to the west and several smaller coastal creek systems to the northwest. The only exception to this is a portion of the proposed TSF (~120 ha) which straddles the eastern regional catchment boundary with the Strelley River catchment, as shown in Figure 7.

Given the relatively small areas concerned and the preliminary nature of the current site layout, the hydrological analyses and discussions presented in the following sections only relate to the Tabba Tabba Creek catchment. Once the site layout plan has been finalised the hydrological effects of facilities located outside of the Tabba Tabba Creek catchment (if any) will be considered.

The TTLP local watershed is formed by a range of north-south trending hills with a maximum relief of about 75 m located some 3 to 4 km the south and west of the proposed mining area and by gently sloping stony plains immediately to the south and east of the proposed processing area. Given the proximity of the local Tabba Tabba watershed, the catchment areas upstream of the proposed mining and processing areas are relatively modest when compared to much larger regional catchments.

A selection of photographs showing typical catchment conditions at the TTLP is shown in Photograph Nos. 1 to 3 (a complete set of site visit photographs is provided in Appendix F). The land surfaces in the vicinity of the TTLP are typical of the De Grey lowlands with mostly erosional surfaces comprising gently undulating stony plains and interfluves with closely spaced tributary drainage lines and minor granite hills, tor fields and quartz ridges, typically up to 25 m relief. These plains and low hills support hummocky grasslands of hard and soft spinifex and other scattered acacia shrubs. Creek channels typically have fringing grassy wood/shrublands with eucalypts and acacias.

Photograph No. 1: View South From Proposed Pit Area with Pit Western Tributary in Mid-ground

Photograph No. 2: Typical Tabba Tabba Creek Tributary Channel with Fringing Vegetation

Photograph No. 3: Typical Gently Undulating Plain with Hummocky Grassland

2.4.4 Tabba Tabba Local Catchment Delineation

As discussed earlier, the TTLP is situated within the southern headwaters of the Tabba Tabba Creek catchment which covers a total area of approximately 440 km^2 measured to where the salt flats commence, within about 10 km of the Pilbara coastline.

This total Tabba Tabba Creek catchment area was further delineated into the following six sub-catchment areas which are relevant to the currently proposed TTLP facilities, as shown on Figure 6 (N.B. additional sub-catchments may be added once the site layout is finalised):

1. *Pit Northwestern Sub-Catchment* – area northwest of proposed Stage 4 pit shell;
2. *Pit Western Sub-Catchment* – area west of proposed Stage 4 pit shell;
3. *Pit Southwestern Sub-Catchment* – area southwest of proposed Stage 4 pit shell;
4. *Haul Road Sub-Catchment No. 1* – area to southwest of proposed HV/LV corridor;
5. *Haul Road Sub-Catchment No. 2* – area to southwest of proposed HV/LV corridor; and,
6. *Haul Road Sub-Catchment No. 3* – area to southwest of proposed HV/LV corridor.,

The hydrological parameters for each of the sub-catchments above were estimated using GIS tools applied to the available Landgate 5 m DEM dataset and are summarised in Table 20.

Table 20: TTLP Sub-Catchment Hydrological Parameters

Sub-Catchment ID	Area (km^2)	Perimeter (km)	Main Stream Length (km)	Main Stream Equal Area Slope (m/km)
1. Pit Northwestern	5.161	16.98	4.26	3.3
2. Pit Western	8.756	25.83	6.15	4.5
3. Pit Southwestern	19.882	33.55	9.28	2.4
4. Haul Road No. 1	4.579	16.33	4.50	3.6
5. Haul Road No. 2	30.170	45.56	12.53	2.8
6. Haul Road No. 3	25.049	35.19	9.86	2.5

Peak flow estimates were developed for each of these sub-catchments areas using a regional hydrologic estimation method, as presented in the following section.

2.4.5 RFFE Peak Flow Estimates

For preliminary design purposes peak flow estimates were developed for the Tabba Tabba Creek sub-catchments identified above using the Regional Flood Frequency Estimation (RFFE) method as presented in Book 3 of Australian Rainfall and Runoff 2019 (ARR19)[5]. Hydrological modelling techniques using RORB or other similar appropriate modelling techniques should be adopted at the detailed design stage.

RFFE peak flow estimates for the Tabba Tabba Creek sub-catchments are summarised in Table 21 (results are provided in Appendix G).

Table 21: Tabba Tabba Creek RFFE Method Peak Flow Estimates

Sub-Catchment ID	Hydrological Event/Peak Flow Estimates (m^3/s)					
	50%AEP	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP
1. Pit Northwestern	9.2	26.2	42.7	62.1	90.3	113.0

[5] "*Australian Rainfall and Runoff: A Guide to Flood Estimation*", Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), Commonwealth of Australia, 2019.

2. Pit Western	12.3	35.3	57.5	83.7	122.0	152.0
3. Pit Southwestern	19.1	54.6	88.8	129.0	188.0	234.0
4. Haul Road No. 1	8.6	24.7	40.1	58.5	84.9	106.0
5. Haul Road No. 2	24.2	69.3	113.0	164.0	238.0	297.0
6. Haul Road No. 3	21.6	51.7	100.0	146.0	212.0	264.0

These peak flow estimates are used later in this report (refer to Section 4.0) as input to the preliminary design of surface water management measures for each of the sub-catchments.

3.0 SURFACE WATER MANAGEMENT

3.1 Flood Risk & Hydrological Design Criteria

Runoff will only occur in the various Tabba Tabba Creek tributaries following significant rainfall events, particularly during the summer months from January to March, when the potential exposure to high intensity tropical cyclone related rainfall is greatest. The hazard that such events pose to on-site facilities depends, amongst other things, on the following:

- the magnitude of the flood event;
- the proximity of the facility to the watercourse in flood;
- the sensitivity of the facility to flooding; and,
- the level of protective flood measures provided to the facility.

While the latter three factors can be controlled or engineered to some degree, the magnitude of the naturally occurring rainfall-runoff events may lead to flooding that cannot be controlled.

Although significant rainfall-runoff events do not occur cyclically, especially in a climatic region as variable as the Pilbara, their probability of occurrence within any given period can be estimated. This probability is typically expressed as an AEP.

Table 22 shows the percentage probability for a range of different AEP flood events that could occur during an assumed ten year operational life of the TTLP.

Table 22: Rainfall Event Probability of Occurrence During Ten Year Operational Life

Annual Exceedance Probability (AEP)	50%	20%	10%	5%	2%	1%
Probability of Occurrence	99.3%	86.5%	63.2%	39.3%	18.1%	9.5%

It is therefore recommended that a 1%AEP (1 in 100 year) design criterion is adopted for the design of the Mining Area flood protection measures during operations, while a 10%AEP (1 in 10 year) criterion should be adopted for the design of all Processing Area drainage measures. It is further recommended that "*balanced criteria*" be adopted for the proposed all road crossings with a 50%AEP (1 in 2 year) event adopted for culvert design below floodways, while the floodways are designed to safely pass the 20%AEP (1 in 5 year) flood peak over the road surface, prior to temporary closure.

3.2 Surface Water Management Strategy

The proposed facility layout is shown on Figure 7 along with the local catchment boundaries and inferred drainages.

3.2.1 Mining Area

The proposed TTLP Mining Area is located immediately north of the confluence of three Tabba Tabba Creek tributaries with a combined upstream catchment area of about 33.8 km^2. Runoff from these tributaries pose the greatest potential flood risk to mining activities and require careful consideration.

Inspection of the available topographic data and findings from the site visit indicate the following:

- Runoff from the Pit Northwestern sub-catchment (5.16 km^2) will require the construction of a diversion channel and adjacent flood protection bund along the western crest of the pit to direct runoff southwards and into the Pit Western tributary.
- The existing "high ground" at the southern crest of the proposed pit (typically 5-6 m above the channel bed) provides a high degree of flood immunity from runoff from both the Pit Western and Pit Southwestern tributaries and no additional flood protection measures are currently envisaged. However, all reasonable measures should be taken to ensure that this high ground is left intact and is not disturbed by mining activities.
- An engineered floodway crossing will be required within the Mining Area for the Haul Road crossing to the south of the open pit. This crossing will be located downstream of the confluence

of the Pit Northwestern, Western and Southwestern tributaries with a combined upstream catchment area of approximately 33.8 km^2.

The preliminary design of the Mining Area surface water management measures is presented in Section 4.0 of this report.

3.2.2 Haul Road/LV Access Road Corridor

The approximately 5 km long proposed HV/LV Road corridor between the Mining Area and Processing Area crosses three Tabba Tabba Creek tributaries i.e. Haul Road sub-catchments Nos. 1, 2 and 3 identified earlier, with a combined upstream catchment area of approximately 59.8 km^2. Given the importance of maintaining access along this corridor it is critical that the proposed crossings are designed to provide an acceptable level of serviceability.

The preliminary design of the Haul Road/LV Access Road Corridor crossing is provided in Section 4.0.

3.2.3 Waste Rock Dumps

Three waste rock dumps (WRD's) are proposed for the TTLP. These will be located immediately south of the central HV/LV Road corridor, one east and one west of the two main Tabba Tabba Creek tributaries and a third WRD straddling the local watershed between the two tributaries, as shown in Figure 7.

Hydraulic modelling to determine potential impacts of these dumps on the Tabba Tabba Creek tributaries will be completed at the detailed design stage to ensure impacts are minimised. It may be necessary to shift and/or rock armour the toelines along the sides of the dumps adjacent to the two tributaries.

3.2.4 Processing Area and Ancillary Facilities

As shown earlier, the proposed TTLP Processing Area and ancillary facilities are located in the uppermost headwaters of Tabba Tabba Creek, with most of the proposed facilities situated some 3-4 m above the existing channel beds. Given that much of the existing catchment area will be modified to accommodate the proposed TSF/ROM landforms, Processing Area and ancillary facilities, each of which will have their own specific surface water management measures, they are considered to be at relatively low risk from large flood events. Surface water management measures for the Processing Area and ancillary facilities are therefore likely to be fairly modest and designed solely for drainage of runoff from internal areas, rather than needing to consider flows from large upstream catchment areas.

The design of Processing Area and ancillary facility surface water management measures will be developed at the detailed design stage of the project, once the facility layout is better defined.

3.2.5 General Surface Water Management

Suitable management of runoff from more common rainfall events will also be required in order to protect project infrastructure, minimise erosion and reduce the potential loss of sediment laden or other contaminated runoff from the TTLP site. This should include the segregation of drainage from the various project facilities as follows:

- Plant Area (wet processing areas);
- Mine Yard/Laydown Area.
- Hazardous Material Storage Areas.
- Disturbed Mine Areas.
- Undisturbed Mine Areas.

3.2.6 Plant Area

Rain falling within wet processing areas will be collected within bunded areas and returned to the process. Provision should be made for the return of such flows to the process by means of drains, launders, sumps, pumps etc. Alternatively such water may be used for dust suppression within the processing area if of acceptable quality.

3.2.7 Mine Yard/Laydown Areas

Mine Yard/Laydown areas should comprise surface water runoff and wash down water drainage and recovery systems. Rainfall runoff from the Mine Yard/Laydown areas including roads, building roofs, laydown yards etc. should be captured in open drains, prior to pumping to a water management pond for re-use.

Mine Yard/Laydown area drains should be sized for the peak of the 10%AEP event as a minimum with a freeboard of at least 250 mm. Flow velocities along such drains should be limited to minimise erosion and the generation of sediment.

3.2.8 Disturbed Areas

Outside the Processing and Mine Yard/Laydown areas proposed project facilities with significant land disturbance will comprise the open pit, WRD/TSF/ROM landform, access and haul roads and various stockpiles. Source controls should be used to improve the quality of runoff from these facilities. Runoff from these facilities should be directed to a water management pond prior to re-use.

For runoff within the proposed open pit, source controls should comprise practices such as mining from upper benches or processing stockpiled material following significant rainfall events. In-pit sumps should be used to settle out sediment from collected runoff prior to pumping to surface for re-use.

3.2.9 Undisturbed Areas

Run-off from undisturbed areas within the project limits should be diverted around proposed project facilities into existing natural watercourses or drainage lines by providing diversion drains typically sized for the 10% AEP event with a minimum 250 mm freeboard. Flow velocities along all diversion drains should be limited to minimise erosion and the generation of sediment.

Where active mining and processing areas or other sensitive facilities require protection from runoff from undisturbed areas the 1% AEP event should typically be used for the design of flood protection bunds.

3.3 Drainage and Sediment Control Design Criteria

The following design criteria will be applied to drainage measures for the proposed TTLP facilities:

3.3.1 Peak Flow Estimation

Peak discharges from catchment areas of less than 10 hectares will be estimated using the Rational Method (i.e. Q = CIA). The average run-off coefficient (C) will be based on the values presented in Table 23.

Table 23: Run-off Coefficients

Catchment Type	Run-off Coefficient
Undisturbed areas	0.20
Gravel roads and yard areas	0.50
Asphalt, concrete and roof areas	0.90

Rainfall intensity (I) for the event duration will be interpolated from the rainfall Intensity Duration Frequency (IDF) relationship developed for the TTLP provided in Appendix B. The time of concentration of each catchment area will be determined in accordance with the Kirpich Equation as follows:

$T_c = 0.00032 \times L^{0.77} \div S^{0.385}$

Where:

T_c = Time of concentration (hours).

L = Maximum length of water travel (m).
S = Average Slope (m/m).

The minimum time of concentration to be used for design purposes will be 5 minutes. Catchment areas (A) will either be measured directly in the field or calculated using CAD tools and the latest field survey data.

Peak discharge estimates from areas larger than 10 hectares will be obtained by using hydrologic modelling methods such as those presented in ARR19.

3.3.2 Channel Design

Channel design parameters will be determined using Manning's Equation as follows:

$Q = (A\ R^{2/3}\ S^{1/2})/n$

Where:

Q = flow rate (m^3/s).
A = cross-sectional area of channel (m^2).
n = roughness coefficient, as per values presented below (dimensionless).
R = hydraulic radius, i.e. cross-sectional area, A, divided by wetted perimeter, P (m)
S = channel slope (m/m).

Roughness coefficients will be based on the values presented in Table 24 below:

Table 24: Roughness Coefficients

Channel Type	Roughness Coefficient
Unlined Earth, Clean, recently completed	0.016-0.018
Unlined Earth, With short grass, few weeds	0.022-0.027
Unlined Rock, Smooth and uniform	0.035-0.040
Unlined Rock, Jagged and irregular	0.040-0.045
Lined, Formed concrete	0.017-0.020
Lined, Random stone mortar	0.020-0.023
Lined, Dry rubble (rip-rap)	0.023-0.033

3.3.3 Drainage Design

Open Drain Construction

Open drain construction will be based upon the following criteria:

- Minimum self-cleansing velocity of 0.7 m/s for a 50%AEP event;
- Maximum velocity of 1.0 m/s for a 10%AEP event for unlined earth channels with no specific erosion protection;
- Minimum 250 mm freeboard on open drains; and,
- Channel erosion control protection in the form of appropriate drop structures, rock check dams, rock-lined channels or concrete lined channels.

Culvert Installation

The minimum culvert diameter will be 450 mm. Culverts and underground stormwater drainage pipes will be installed at slopes that provide self-cleansing minimum velocities of 0.7 m/s for one-third depth of full-flow.

Hardstand Area Drainage

Hardstand area drainage will be designed with a minimum surface grade of 0.5% in open yard areas and a minimum grade of 2% for a distance of 25 m away from structures. Hardstand areas with finished elevations 1 m or greater above natural surface elevations will have a safety bund constructed along their outside edge. Suitably spaced breaks will be placed along the bund to allow runoff to escape. Rock or geomembrane lined slope drains will be constructed at these breaks to minimise erosion of fill material.

3.3.4 Water Management/Sedimentation Pond Design

For preliminary design purposes water management/sedimentation ponds will be designed to store runoff from the 10%AEP-24-hour rainfall event i.e. 171 mm rainfall, without discharge.

The detailed design of sedimentation ponds will be based on removing the settleable fraction down to a selected minimum design particle size based on an analysis of the sediment particle size distribution reporting to the pond. The adopted design particle size will correspond to 25% of the sample passing by weight or an absolute minimum particle size of 20 micron (unless chemical coagulant dosing is used). The required pond surface area will be estimated using the peak inflow rate and design particle settling velocity according to Stokes Law and applying published sedimentation efficiency factors[6].

Sedimentation ponds will have a minimum live settling depth of 1 m and an aspect ratio (length: width) of not less than 3:1 and preferably 5:1. Sufficient provision for dead (sediment) storage and freeboard will also be made.

3.3.5 Oily Water Separator Design

All potentially hydrocarbon impacted water from wash-down and re-fuelling facilities will be directed to a suitable gravity type oily water separator prior to collection and re-use.

[6] *The Constructed Wetlands Manual (Vols 1 & 2)*, Dept of Land and Water Conservation, NSW, 1998.

4.0 PRELIMINARY ENGINEERING DESIGN

The preliminary design of the TTLP surface water management measures is described in the following sections and shown on the accompanying figures. An order of magnitude materials take-off (MTO) has also been provided based on preliminary earthworks models. The layout of the measures has been based on the topographic data, aerial imagery and mine infrastructure design provided by Wildcat in August 2024.

4.1 Mining Area

4.1.1 General

As discussed earlier, the proposed TTLP Mining Area is located immediately north of the confluence of three Tabba Tabba Creek tributaries (Northwestern Pit, Western Pit and Southwestern Pit).

Although runoff from these tributaries pose a significant potential flood risk to mining activities, the presence of in-situ high ground (some 5-6 m above the channel bed) along the southern pit crest provides a high degree of flood immunity from runoff from both the Pit Western and Pit Southwestern tributaries. Consequently no additional flood protection measures are currently envisaged for those tributaries; however, **care should be taken to ensure that this high ground is left intact and is not disturbed by mining activities**.

Mining Area surface water management measures are therefore likely to be limited to the following:

- *Pit Northwestern Diversion Channel and Flood Protection Bund;*
- *Haul Road Road Tabba Tabba Creek Crossings;* and,
- *Ancillary Mining Area Surface Water Management Measures.*

The PFS level design of these measures is presented in the following sections and preliminary quantities and earthworks volumes have been provided in the MTO in Section 4.8.

4.1.2 Pit Northwestern Diversion Channel and Flood Protection Bund

In order to divert runoff from the approximately 5.16 km^2 Pit Northwestern sub-catchment area upstream of the open pit (identified earlier) it will be necessary to construct an approximately 850 m long diversion channel and parallel flood protection bund, as shown in Figure 8. The flood bund will be offset from the western pit crest and aligned in a roughly north to south direction to direct runoff into the Pit Western tributary.

The RFFE method 10% and 1% AEP peak flow estimates developed earlier for the Pit Northwestern sub-catchment were used in the preliminary design with the diversion channel designed to pass the 10% AEP peak flow with 0.6 m freeboard and checked for the 1% AEP peak flow with zero freeboard. The flood bund constructed along the downstream (east) side of the channel will have a minimum height of 2.0 m and will provide protection for events of greater magnitude than 1%AEP.

The preliminary design parameters for the Pit Northwestern Diversion Channel and Flood Protection Bund have been summarised in Table 25 (channel sizing calculations have been provided in Appendix G). Preliminary earthworks modelling indicates that in the order of 24,000 m^3 of cut will be required for the channel and approximately 22,300 m^3 of fill will be required for the bund. It may therefore be possible to construct the flood bund from material excavated from the diversion channel, subject to geotechnical suitability.

The flood protection bund should be a minimum of 2 m high, with 2H:1V sideslopes and a 3 m wide crest. It should not be constructed by end dumping of waste materials in piles, but instead the bund footprint should be cleared and it should be built from select waste material (300 mm maximum size), placed and compacted in layers (500 mm maximum thickness) and dozer-compacted. The upstream face of the bund should be protected with a 750 mm thick layer of riprap with a median rock size (D_{50}) of 300 mm and a maximum rock size (D_{100}) of 450 mm. The riprap should be manufactured from fresh (non-PAF), hard, angular rock and installed over a heavy-duty non-woven geotextile layer.

Table 25: Pit Northwestern Diversion Channel and Flood Bund - Preliminary Design Parameters

Design Parameter	Units	Value
Length	m	850
Average Gradient	%	0.15
Base Width	m	40.0
Channel Depth	m	1.5
Side Slopes (Bund & Channel)	H:V	2H:1V
Channel Design Top Width	m	46.0
10% AEP Peak Flow	m^3/s	42.7
10% AEP Peak Flow Depth[1]	m	0.8
1% AEP Peak Flow	m^3/s	113.0
1% AEP Peak Flow Depth[1]	m	1.4
Minimum Bund Height	m	2.0
Minimum Bund Crest Width	m	3.0
Minimum Bund Base Width	m	11.0

Notes 1: Hydraulic design assumes Manning Roughness "n" = 0.025.

4.1.3 Haul Road Tabba Tabba Creek Crossings

An engineered floodway crossing will be required within the Mining Area to the south of the proposed open pit where the Haul Road crosses downstream of the confluence of the Pit Northwestern, Western and Southwestern tributaries with a combined upstream catchment area of approximately 33.8 km^2 as shown earlier on Figure 6.

For preliminary design purposes the new Haul Road floodway crossing has been assumed to comprise multiple corrugated metal pipe (CMP) low-flow culvert barrels capable of passing events up to the 50%AEP (1 in 2 year) peak flow and a depressed or lowered floodway section of roadway designed to pass 20%AEP (1 in 5 year) peak flows across the road surface up to a maximum depth of 0.25 m. For events greater than 20%AEP i.e. depths greater than 0.25 m, the crossings would be temporarily closed until the flood recedes.

The resulting 50%AEP and 20%AEP peak flow estimates and preliminary culvert selection has been summarised in Table 26 where MA1 refers to the Haul Road crossing (refer to Appendix G for calculations).

Table 26: Mining Area Proposed Floodway Crossing - Preliminary Design Parameters

Crossing I.D.[1]	Area[2] (km^2)	50%AEP Peak Flow[3] (m^3/s)	Culvert Selection	20%AEP Peak Flow[3] (m^3/s)	Floodway Length (m)
MA1	33.8	25.8	6 No. 1500 Dia	74.0	350

Notes:
1. MA1 = Haul Road crossing.
2 Peak flow estimates from RFFE method applied to combined pit catchment area 33.8 km^2.

The culvert selection summarised above was based on passing the design peak flows using a standardised 1500 mm diameter CMP (to be confirmed/optimised following completion of road design at detailed design stage). The capacity of the culverts was based on manufacturer's nomographs, assuming inlet control with a maximum headwater:diameter (H_w/D) ratio of 1.5:1 and a k_e of 0.9 i.e. square-ended culverts projecting from the road fill.

This results in an assumed minimum road construction depth of 2.25 m at the crossing location. Where this is not achievable it may be necessary to install a greater number of smaller diameter culverts due to limited cover between the top of the barrel and the road surface. Given that heavy traffic will traverse the Haul Road it is recommended that an absolute minimum cover of 600 mm be adopted between the road surface and the top of the CMP.

Assuming that the new haul road will be 24 m wide overall (i.e. 18 m between safety bunds plus two 3 m base width bunds) , a standard culvert length of 33 m was adopted. This includes a 4.5 m allowance for 2H:1V side slopes on both sides of the 2.25 m high road embankment.

The floodway lengths were estimated assuming that the road embankment acts like a broad-crested weir (weir coefficient = 1.69) and adopting a design water depth of 0.25 m overtop the road surface. It has been assumed that a 300 mm thick cement-stabilised road base will be installed along the full length of each floodway, along with riprap protection on the downstream road embankment. Signage and depth gauge boards should also be provided at all floodway crossings.

4.1.4 Ancillary Mining Area Surface Water Management Measures

In addition to the Pit Northwestern Diversion Channel and Flood Bund and haul road floodway crossing discussed above, flood risks to the proposed TTLP open pit should be further ameliorated and flood protection provided by a combination of the following measures:

- Pit crest/safety bunding placed as close as geotechnically possible to the pit crest to minimise runoff from adjacent areas;
- Road “hump” at the top of the pit ramp; and,
- Haul road grading and drainage to direct runoff away from the pit.

Even with the provision of these surface water management measures some runoff will report in-pit from direct precipitation falling within the pit crest and runoff from the relatively small catchment area between the pit crest and adjacent bunding. This rainfall-runoff will report to in-pit sump pumps before being pumped back to surface.

The proposed 10-year LOM pit crest area of 715,500 m^2 was measured directly from the pit shell provided and a 10% allowance was added for the surface area between the pit crest and the adjacent pit bund. Rainfall depths for a range of 72-hour duration events (refer to Rainfall IFD values in Appendix B) were then applied to this area assuming a conservative 100% runoff factor. This resulted in the in-pit runoff volumes and approximate water depths on the ultimate pit floor shown in Table 27.

Table 27: In-Pit Runoff Volume & Depth Estimates

Rainfall Event	Rainfall Depth (mm)	In-Pit Volume[1] (m^3)	In-Pit Water Depth[2] (m)
50%AEP-72 hour	102	80,300	14.5
20%AEP-72 hour	166	130,600	19.5
10%AEP-72 hour	213	167,600	22.0
5%AEP-72 hour	262	206,200	24.5
2%AEP-72 hour	328	258,100	27.5
1%AEP-72 hour	384	302,200	30.0

Notes:

1. 100% runoff coefficient assumed and pit crest area increased by 10% to allow for area between crest and bunding.
2. Assuming ultimate pit floor at -320 mAHD is dry at start of rainfall event.

4.2 HV/LV Road Corridor

As discussed earlier, the approximately 5 km long proposed central HV/LV Road corridor between the Mining Area and Processing Area crosses three separate Tabba Tabba Creek tributaries (Haul Road sub-catchments Nos. 1, 2 and 3), with a combined upstream catchment area of approximately 59.8 km^2. Given the importance of maintaining access along this corridor it is critical that the proposed crossings are designed to provide an acceptable level of serviceability. It has been assumed that the road corridor will be constructed as a single landform with a safety/divider bund down the middle to separate HV and LV traffic.

For preliminary design purposes the HV/LV Road corridor floodway crossings have been assumed to comprise multiple corrugated metal pipe (CMP) low-flow culvert barrels capable of passing events up to the 50%AEP (1 in 2 year) peak flow and a depressed or lowered floodway section of roadway designed to pass 20%AEP (1 in 5 year) peak flows across the road surface up to a maximum depth of 0.25 m. For events greater than 20%AEP i.e. depths greater than 0.25 m, the crossing would be temporarily closed until the flood recedes.

The catchment areas upstream of the three proposed crossings were delineated as shown earlier on Figure 6. The catchment areas, resulting 50%AEP and 20%AEP peak flow estimates and preliminary culvert selections have been summarised in Table 28 (refer to Appendix G for calculations).

Table 28: Haul Road/LV Access Road Corridor Floodway Crossings - Preliminary Design Parameters

Crossing No.	Area (km^2)	50%AEP Peak Flow[1] (m^3/s)	Culvert Selection	20%AEP Peak Flow[1] (m^3/s)	Floodway Length (m)
HR1	3.5	8.6	2 No. 1500 mm	24.7	120
HR2	28.9	24.2	5 No. 1500 mm	69.3	330
HR3	8.7	21.6	5 No. 1500 mm	51.7	240

Note 1: Peak flow estimates from Tabba Tabba Creek RFFE method presented earlier.

The preliminary culvert selections summarised above were based on passing the design peak flows using a standardised 1500 mm diameter CMP (to be confirmed/optimised following completion of road design at detailed design stage). The capacity of the culverts was based on manufacturer's nomographs, assuming inlet control with a maximum headwater:diameter (H_w/D) ratio of 1.5:1 and a k_e of 0.9 i.e. square-ended culverts projecting from the road fill.

This results in an assumed minimum road construction depth of 2.25 m at the crossing locations. Where this is not achievable it may be necessary to install a greater number of smaller diameter culverts due to limited cover between the top of the barrel and the road surface. Given that heavy traffic will traverse the road corridor it is recommended that an absolute minimum cover of 600 mm be adopted between the road surface and the top of the CMP.

Assuming that the new haul road will be 24 m wide overall (i.e. 18 m between safety bunds plus two 3 m base width safety bunds) and that the LV Road will comprise a 12 m wide unsealed carriageway (i.e. 10 m wide plus two 1.0 m wide shoulders), a standard culvert length 39 m was adopted. This includes a 4.5 m allowance for 2H:1V side slopes on both sides of the 2.25 m high road embankment.

The floodway lengths were estimated assuming that the road embankment acts like a broad-crested weir (weir coefficient = 1.69) and adopting a design water depth of 0.25 m overtop the road surface. It has been assumed that a 300 mm thick cement-stabilised road base will be installed along the full length of each floodway, along with riprap protection on the downstream road embankment. The HV/LV splitter/divider bund should be replaced at floodways with steel posts or bollards to permit the periodic passage of floodwater over the road surface.

Signage and depth gauge boards should also be provided at all floodway crossings.

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4.3 Preliminary Quantity Estimation

Preliminary construction quantities for the proposed water management measures identified above are summarised in Table 29. These quantities have been measured directly from preliminary earthworks models and are only suitable for PFS level cost estimating purposes by Wildcat.

Table 29: Water Management Measures - Preliminary Quantity Estimate

Description	Quantity	Unit

Haul Road Tabba Tabba Creek Crossing (1 No.)		
Corrugated metal pipe culverts 1500 mm dia. (6 barrels)	198	m
Rock Lined Outlet Apron Rip-rap, 750 mm thick (D_{50} = 450 mm)	180	m^2
Cement-stabilised road base at Floodways, 300 mm thick (350 m Long x 18 m wide running surface)	6,300	m^2
Rip-rap protection at Floodways, 750 mm thick (D_{50} = 450 mm)	1,175	m^2
Haul Road/LV Access Road Corridor Floodway Crossings (3 No.)		
Corrugated metal pipe culverts 1500 mm dia. (12 barrels)	540	m
Rock Lined Outlet Aprons Rip-rap, 750 mm thick (D_{50} = 450 mm)	360	m^2
Cement-stabilised road base at Floodways, 300 mm thick (690 m Long)	31,050	m^2
Rip-rap protection at Floodways, 750 mm thick (D_{50} = 450 mm)	3,450	m^2
Pit Northwestern Diversion Channel & Flood Protection Berm (850 m Long)		
Diversion Earthworks (cut)	24,000	m^3
Rip-rap at inlet/outlet, 750 mm thick (D_{50} = 450 mm)	400	m^2
Flood Protection Bund Foundation Preparation	9,350	m^2
Flood Protection Bund Earthworks (fill)	22,300	m^3
Flood Protection Bund Riprap, 750 mm thick (D_{50} = 450 mm)	3,825	m^2

5.0 CLOSING REMARKS

A desktop study was completed to develop hydro-meteorological information that was then used in the analysis and preliminary design of water management measures for the proposed TTLP. Key surface water management findings include the following:

- Given the proximity of the local Tabba Tabba Creek watershed divide, catchment areas upstream of the proposed Mining and Processing Areas are relatively modest (33.8 and 59.8 km^2 respectively) and the surface water management measures required will therefore be fairly limited.
- The presence of in-situ high ground (some 5-6 m above the channel bed) along the southern Pit crest provides a high degree of flood immunity from the Tabba Tabba Creek tributaries to the west and southwest of the Pit and no additional flood protection measures are currently envisaged for those tributaries. **Care should be taken to ensure that this high ground is left intact and is not disturbed by mining activities**.
- However, an approximately 850 m long Pit Diversion Channel and Flood Protection Bund will be required along the western side of the pit to direct runoff from the northwestern tributary into the western tributary. In order to manage the 1%AEP (1 in 100 year) event the channel will have a 40 m basewidth and be about 1.5 m deep. The parallel flood bund will be a minimum of 2 m high and have a 3 m crest width.
- A minimum of four culverted floodway crossings of Tabba Tabba Creek and its tributaries will be required at the Mining Area (1 No.) and HV/LV Road corridor (3 No.). For preliminary design purposes all crossings have been assumed to comprise multiple corrugated metal pipe low-flow culvert barrels capable of passing events up to the 50%AEP (1 in 2 year) peak flow and a depressed or lowered floodway section of roadway designed to pass 20%AEP (1 in 5 year) peak flows across the road surface up to a maximum depth of 0.25 m. For events greater than 20%AEP i.e. depths greater than 0.25 m, the crossing would be temporarily closed until the flood recedes.
- The design of the Processing Area and ancillary facility surface water management measures will be developed at the detailed design stage of the project, once the facility layout is better defined.
- Hydraulic modelling will be completed at the detailed design stage to determine potential impacts of the three proposed waste rock dumps on the Tabba Tabba Creek tributaries. It may be necessary to shift and/or rock armour the toelines along the sides of the dumps adjacent to the Tabba Tabba Creek tributaries.

We trust that this report satisfies Wildcat Resources Limited's current requirements and we look forward to discussing the future development of the Tabba Tabba Lithium Project with you.

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APPENDIX A

Meteorological Data

APPENDIX B

Intensity Frequency Duration Relationship for TTLP Site

APPENDIX C

Cyclone Swept Path Analysis

APPENDIX D

TTLP Probable Maximum Precipitation Estimate

APPENDIX E

DoWER Hydrological Data

APPENDIX F

Site Visit Photographs
(19 September 2024)

APPENDIX G

Tabba Tabba Creek RFFE Method Results
& Preliminary Engineering Design Calculations