Solar Flagships Program

PRELIMINARY HYDROLOGIC ANALYSIS

NYNGAN SOLAR PV PLANT (NORTHERN BLOCK)

- Revision 2
- 29 March 2011

Prepared for:

AGL Energy Limited

Solar Flagships Program

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Contents

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1. Introduction

1.1. Background to the Project

The Solar Flagships program is part of the Australian Government's $4.5 billion Clean Energy Initiative, announced in the May 2009 Budget. The Government has committed $1.5 billion to support the construction and demonstration of up to four large-scale solar power plants in Australia, using solar thermal and photovoltaic (PV) technologies. The Government's aim is to establish up to 1000 megawatts (MW) of large-scale solar power generation capacity. Round 1 for the Solar Flagships program will select one solar thermal project and one PV project, with a target of up to 400 MW of combined generation capacity.

AGL Energy Limited (AGL) has been shortlisted as one of four solar PV projects for funding under the Solar Flagships program. AGL is developing up to five solar PV projects with a total capacity of up to 200 MW AC at multiple properties across Australia. This approach offers the Commonwealth the opportunity to ensure that multiple stakeholders in multiple jurisdictions benefit from the Solar Flagships Program, providing jobs and economic growth and industry development across the country. Furthermore, the size of AGL's plants simplifies siting issues, allows easier and cheaper grid connections, and provides resource and time zone diversity.

1.2. Purpose of this Document

This preliminary hydrologic analysis has been prepared for AGL in support of a submission to the Commonwealth Solar Flagships Program.

This report assesses the hydrologic aspects for a property located near Nyngan in NSW. The proposed development site assessed within this report is north of the blocks previously studied and was selected by AGL due to its solar resource, proximity to existing electrical infrastructure, and availability of suitable land.

AGL has commissioned Sinclair Knight Merz (SKM) to undertake a preliminary hydrologic assessment for this property, with a particular focus on identifying any mainstream flooding or property drainage characteristics that could be prohibitive to the development of a solar photovoltaic (PV) plant and associated infrastructure.

This hydrology report provides outcomes from the preliminary flood assessment for the property, drawing on available data including:

- Property inspection and stakeholder consultation;
- Review of available data;
- Assessment of mainstream flooding;

- Property drainage; and
- Potential stormwater erosion.

A summary of the information contained within each section of this report is provided below.

Chapter 1 – introduces the proposal, its broad strategic context and provides a brief description of the property location.

Chapter 2 – describes property conditions on the basis of information gathered during property inspections, explains the legislative context based on a meeting with Council Officers and provides details on the data available for a preliminary flood assessment for the property.

Chapter 3 – identifies potential inundation of the property due to mainstream flooding.

Chapter 4 – identifies and discusses inundation due to local catchment drainage on the property.

Chapter 5 – presents stormwater erosion issues associated with the construction and operation of the project.

Chapter 6 – provides conclusions and recommendations.

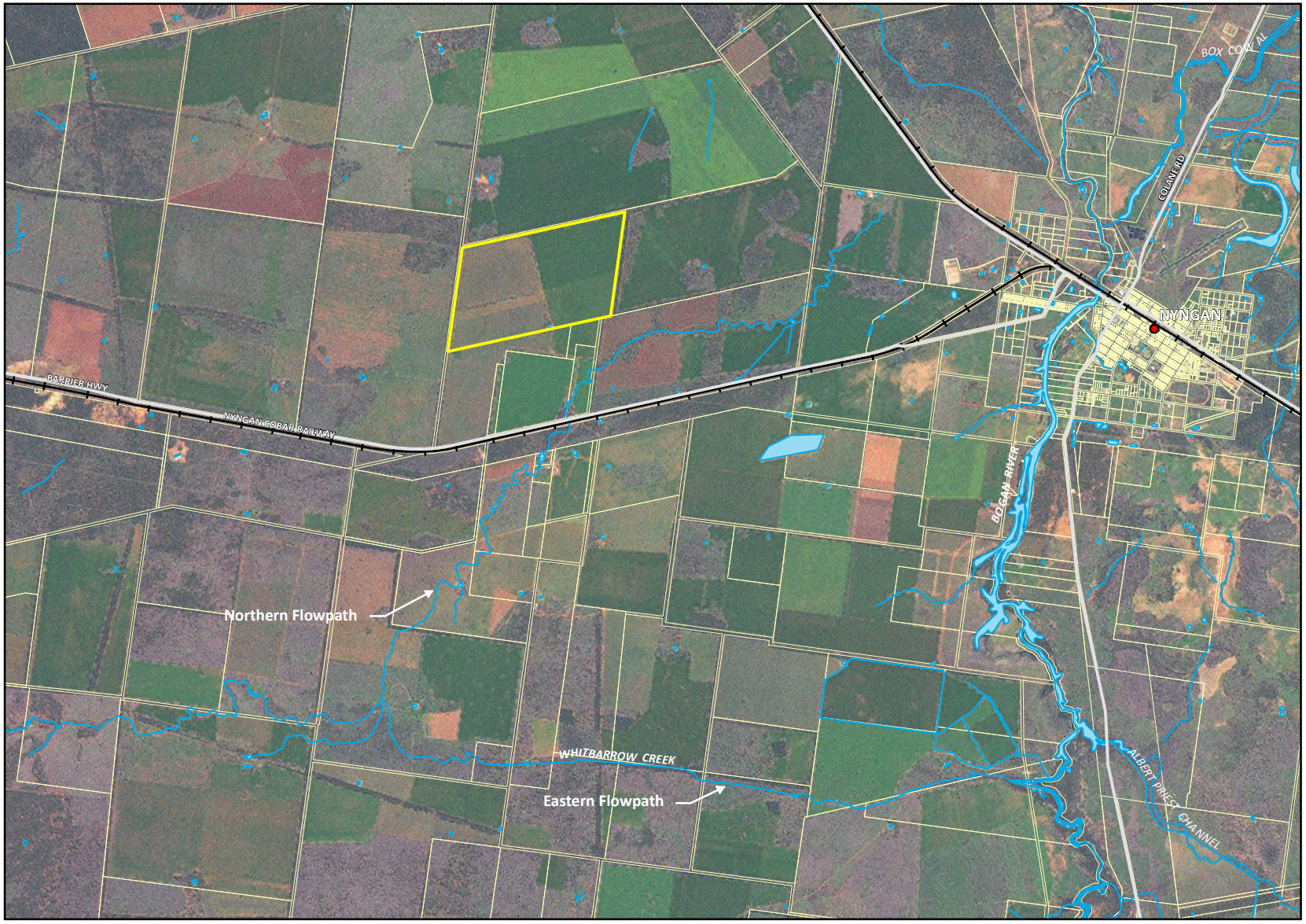
Chapter 7 – lists the references.

1.3. Property Description

AGL is considering a property located near Nyngan in central NSW for the Solar PV project. The location of the property and immediate surrounds are shown in **Figure 1.1**. The property is 464 ha in area and located approximately 1.6 km north and 5 km west of the Nyngan-Cobar Railway line and the Mitchell Highway, respectively. The property is also located 8 km west of the Bogan River and lies on the floodplain of Whitbarrow Creek, which is a tributary of the Bogan River. This property is located on the northern boundary of the blocks previously studied.

Figure 1.2 shows the preliminary flow paths and key waterway structures in the area. Whitbarrow Creek passes approximately 500 m to the south-east of the property's south-eastern corner. The property is zoned private rural lands (1A General Rural).

Figure 1-1 | Location map



LEGEND

- Property boundary
- Watercourse
- Major road
- Railway
- Cadastre

DATA SOURCES
LPMA
Imagery: ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP

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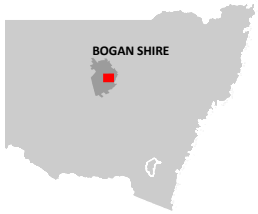

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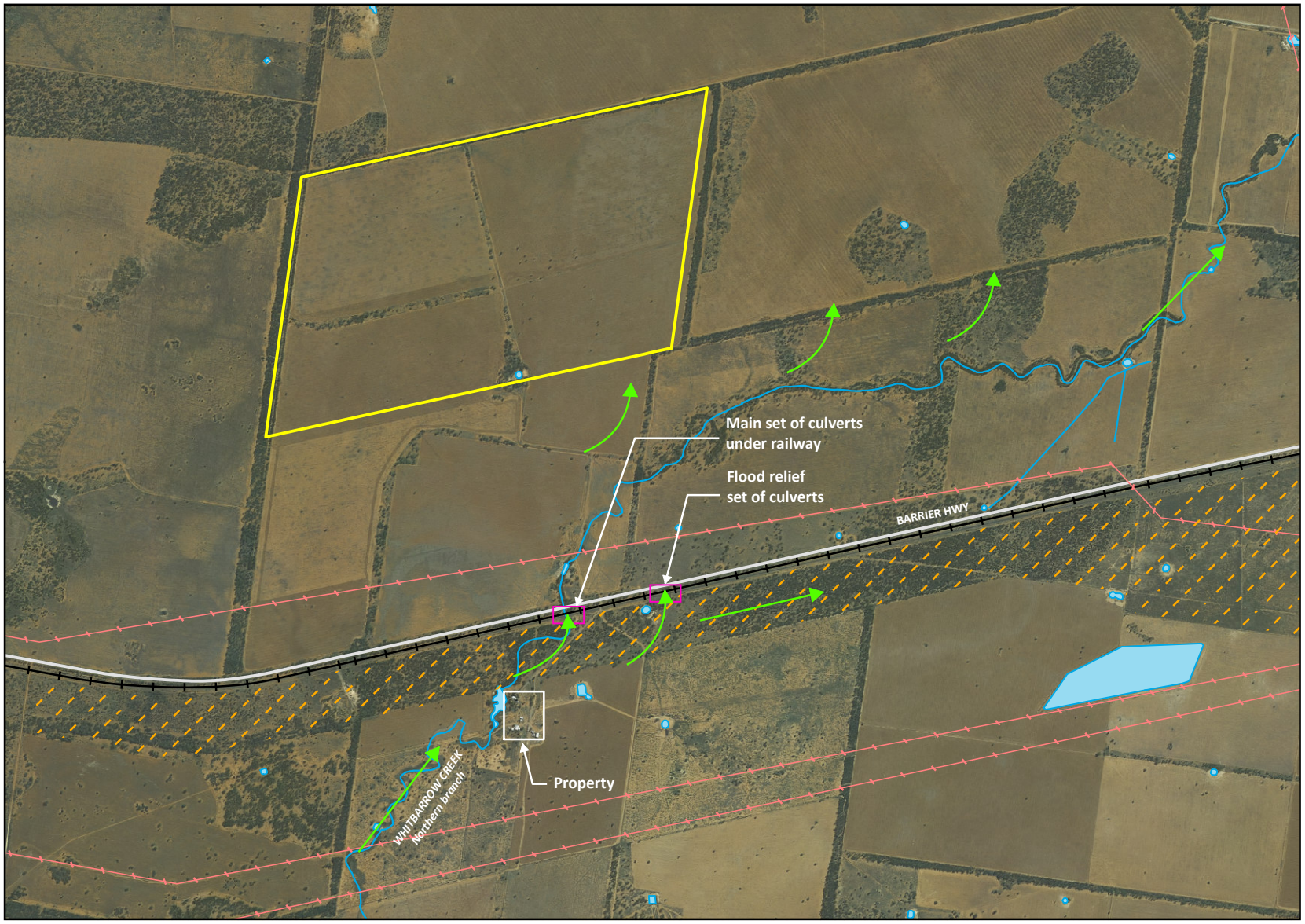
Sydney Spatial Team - Prepared by : DD
Checked by : JC

Figure 1-2 | Preliminary Flow Distribution for Whitbarrow Creek



LEGEND

- Property boundary
- Watercourse
- Assumed direction of overland flow
- Road
- Transmission line
- Railway
- Travelling Stock Route

DATA SOURCES
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Imagery: SPOT

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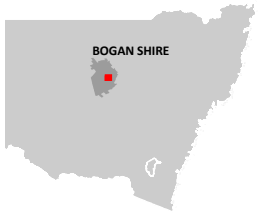

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Sydney Spatial Team - Prepared by : DD
Checked by : JC

2. Data Collection and Review

2.1. Property Visit Background

Three properties in Nyngan were inspected individually at different times. Site visits were conducted on 26th August 2010, 14th September 2010 and 24th February 2011 to collect information on hydrological issues for the three properties in Nyngan and their surroundings. The three properties are owned by the same family. One property is located on the southern side of the Nyngan-Cobar Railway line and the other two properties are located on the northern side of the Railway line. This report is concerned with the northern most block of the three.

2.1.1. Property Inspection 1 – 26th August 2010

This property visit was focussed on a visual assessment of the property located on the southern side of the Nyngan-Cobar Railway line and an interview with the landholder. Comments were generally related to the part of the property that the homestead is located on. Flooding experience obtained from the landholder included:

- Two floods have impacted the property in the last 50 years, 1980 (approximate) and 1992;
- The 1990 flood was not significant in Whitbarrow Creek catchment and thus did not cause inundation of their property;
- Inundation in the 1980 flood resulted in 300 mm depth of flooding above the floor of the house. Flooding is believed to be due to insufficient capacity of the railway culvert downstream of the property (twin 2.4 m box culverts at the time of the flood);
- The culverts under the railway (twin 2.4 m box culverts) were replaced by Australian Rail Track Corporation (ARTC) with seven 1.5 m diameter (refer to **Figure 2.1)** Armco pipes after the 1980s flood and prior to the 1992 flood;
- There was inundation in the property during the 1992 flood, but water did not enter the house. The owner estimated that the water level was about 0.4-0.5 m lower than the 1980 level; and
- The landholder was unaware if flows occurred in the flood relief culverts under the Railway during past flood events.

Observations during the site visit include:

- The formation of the Barrier Highway is located downstream of the Railway line and is lower than the rail embankment;
- Drainage under the highway is through a series of six 2 m x 1 m box culverts; and

- **Figure 2.1 Whitbarrow Creek northern branch culverts under the Nyngan-Cobar Railway line**

2.1.2. Property Inspection 2 - 14th September 2010

This property visit included a visual assessment of a property located on the northern side of the Nyngan-Cobar Railway line and an interview with the landholder. The property inspected on 14th September 2010 is located along the southern boundary of the current property (new northern block). Observations during the site inspection and comments from the landholder included:

- The property had not been subject to prolonged substantial inundation from upstream (to the west) local catchment flows;
- There are no defined creek channels though the property with runoff appearing to be mainly as sheet flow;
- Stormwater runoff from the property is drained relatively quickly or is readily absorbed into the sandy/loam soils (infiltration has been observed to be high from the landholder).

2.1.3. Property Inspection 3 - 24th February 2011

This property (new northern block) is the subject of this report. Observations made during the September 2010 visit to the adjoining property are also relevant to the current property. Additional observations and comments from the landholder are included:

- The property had not been subject to prolonged substantial inundation from Whitbarrow Creek overflows;
- No gullying or flow erosion features are present on the property indicating slow moving sheet flow;
- Runoff through, and from, the property is directed mainly in a easterly and north-easterly direction towards the Mitchell Highway;
- A farm dam is located mid way on the southern boundary and accepts inflows from the north-west and south-west, with no distinct overflow route to the east;
- Based on drainage structures in the Mitchell Highway, to the west of the property, drainage from the property is in a east-north-east direction, ultimately draining to the Bogan River;
    - There is an abandoned railway formation to the immediate east of the Mitchell Highway that would control flows to the Bogan River;
    - A major drainage point is present in the Mitchell Highway and abandoned railway that includes a series of four box culvert 1.2 m x 0.6 m in size and a 6 m wide collapsed timer bridge; and
    - The Mitchell Highway to the east of the property has numerous minor culverts, typically series of two box culverts 1.2 m x 0.6 m in size.
- Native vegetation is generally Box and Cyprus Pine denoting infrequent inundation; and
- There are no significant earthen banks that would redirect or obstruct the overland flows.

2.2. Stakeholders Consultation

Consultation was undertaken with Bogan Shire Council, RTA Western Region and Australian Rail Track Corporation (ARTC). The objective of the consultation was to obtain information related to flooding and drainage at and near the property.

Bogan Shire Council

The flood/drainage engineer at Council was contacted both at the time of the first property visit and subsequently by phone. Council do not have any flood related information for the property nor do they have specific drainage guidelines. Therefore estimation of design rainfall intensities, flows and water levels has been done in accordance with procedures in ARR (2001).

RTA Western Region

RTA was contacted to obtain drawings or survey for drainage structures under the Barrier Highway. No information was provided and RTA referred the consultant to Council.

Australian Rail Track Corporation (ARTC)

SKM requested drainage information for culverts under the railway embankment. ARTC provided asset information for the two sets of culverts downstream of the Nyngan South site . This included the size of culverts and the depth from invert to top of rail. No information was available to tie levels to a survey datum.

2.3. Review of Available Data

No streamflow gauging stations are located on Whitbarrow Creek. The review was limited to the relevant flooding/flood studies, topographic data, soils and rainfall data.

2.3.1. Reports, Plans and other documents

Macquarie Valley Flood Plain Atlas (1984, SKP)

The Water Resources Commission undertook investigations for floodplain management in the Macquarie Valley. Information used to prepare the maps included interviews with landholders, aerial photography obtained during floods and records from government authorities. Flood inundation extents are provided, which are largely based on inundation from the February 1955 event. The flood prone areas mapped did not include the Nyngan property.

Nyngan April 1990 Flood Investigation (1990, DWR)

The Department of Water Resources (DWR) undertook a detailed study following the 1990 flooding in Nyngan. This study included hydrologic analysis, hydraulic modelling and damage assessment. The study area considered did not include the proposed site. Other information was obtained from this study, such as historic hydrologic information and regional soil classifications. The investigation did not cover the Nyngan property.

Effect of Levee Height on Flooding Behaviour at Nyngan April 1990 (1993, Water Studies)

This study was done by Water Studies for the Department of Water Resources. It addressed issues related to the design and performance of the levees at Nyngan at the time of flooding (1990) and considered a range of mitigation design options. The Nyngan property was not included in the defined study area. Some mitigation options considered in this study resulted in increased flows west of the Bogan River, however, these are not considered to be able to impact on the Nyngan property.

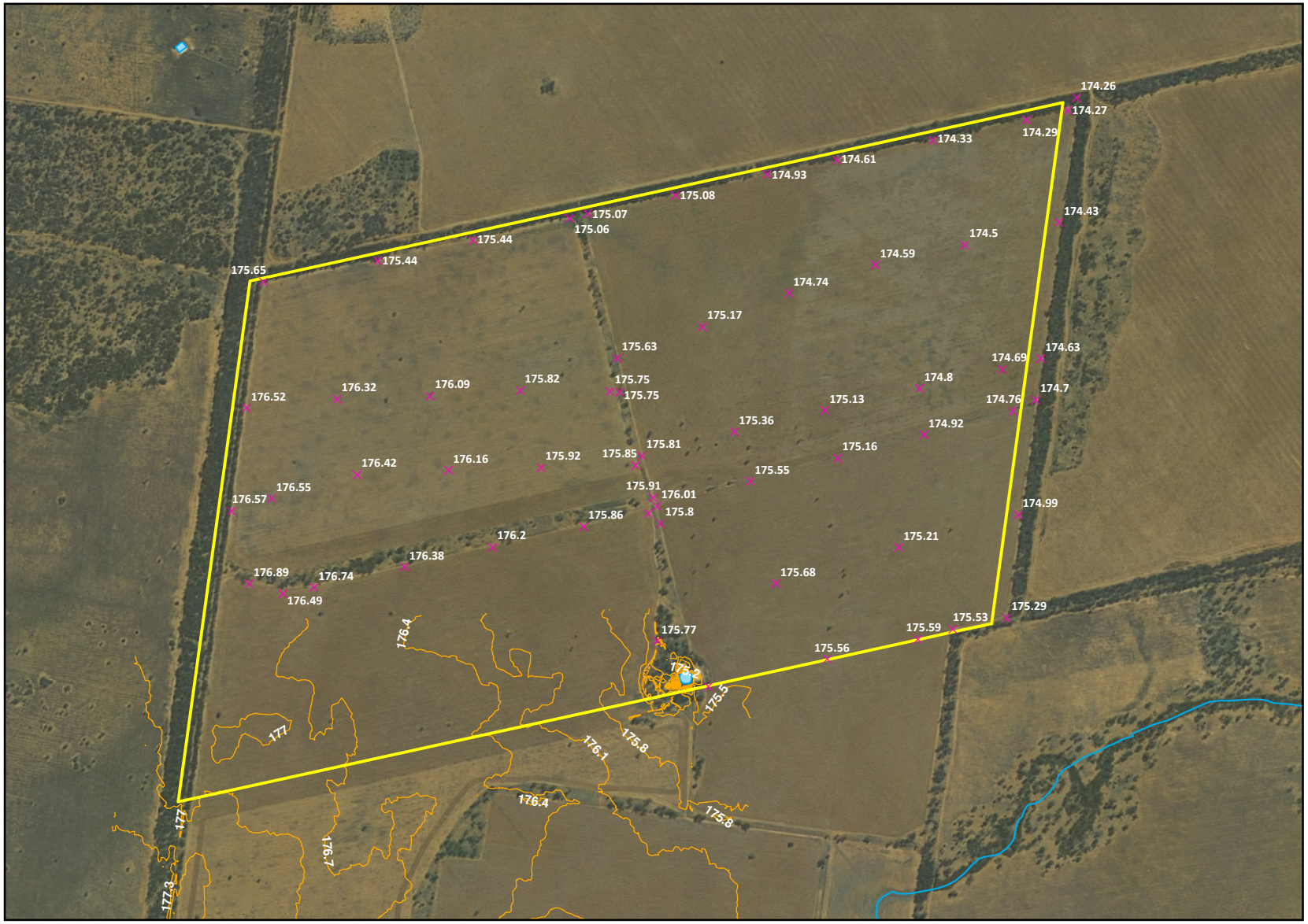
2.3.2. Topographic Data

Available topographic data for the Nyngan property includes 10 m contour data, spot levels, a 90 m x 90 m and a 25 m x 25 m Digital Terrain Models (DTM). Spot levels are indicated in **Figure 2.2**.

A 12 m x 12 m DTM and 0.3 m contour data covering a 250 m wide buffer around the paddock directly south from the property provides finer topographic data in the south-western corner of the current property.

The topographic data shows that the property is relatively flat and drains predominantly from the south-west to the north-east towards Mitchell Highway. Ground levels vary from 177 to 174.2 mAHD, with a longitudinal grade less than 0.1%. The farm dam located in the middle of the southern boundary forms a local depression at 175.2 mAHD and drains flows from the south-western corner.

Figure 2-2 | Spot Heights



LEGEND

- Property boundary
- Spot height
- 0.3m contour line
- Watercourse

DATA SOURCES
LPMA
Imagery: SPOT

GDA 1994 | MGA Zone 55
A4 1:20,000

0 0.5
Kilometre

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Sydney Spatial Team - Prepared by : DD
Checked by : JC

2.3.3. Soils

Soils within the catchment of Whitbarrow Creek include high rate infiltration loams in the headwater areas, medium rate infiltration soils over most of the catchment area and low rate infiltration along the lower reaches of the creek.

Classification for these soils was taken from the Nyngan Flood Investigation (NSW Department of Water Resources, 1990). The medium rate infiltration soils are defined as massive red and yellow earths in accordance with soils map of NSW. They are gradational soils with low to very low inherent fertility and include non-calcic desert loams.

The successive site visits confirmed that throughout the property the soils are red/brown earths with no evidence of floodplain related soils. The red/brown earths are evident in **Figure 2.3**.

- **Figure 2.3 Typical soils within the Nyngan property**

2.3.4. Rainfall Data

Rainfall stations in or near Whitbarrow Creek catchment include Nyngan Airport (51039), Hermidale (51026) and Nymagee (49036). Nyngan Airport is representative of rainfall in the lower section of Whitbarrow Creek catchment, Hermidale of the mid western portion and Nymagee of the headwaters of the catchment.

Records for the period 1973 to 2007 were obtained from the Bureau of Meteorology. Analysis of 3-day rainfall and 5-day rainfall intensities indicated that the recent major events are:

- January 1976, March 1983, January 1995, and December 1999/January 2000 at Nymagee
- February 1976, March 1983, February 1992 at Hermidale
- April 1989, February 1992, January 1995 at Nyngan Airport

This concurs with observations made by the property owner who identified the largest rainfall events in Whitbarrow Creek as being in the 1980s (assumed to be 1983) and 1992.

There are no stream gauge stations along Whitbarrow Creek. In the proximity to the study area, stream gauges are located on the Bogan River. However, due to differences in the catchment area size and location, the Bogan River data is not considered suitable for translation to the Whitbarrow Creek catchment.

3. Mainstream Flooding

3.1. Background

A review of the available topographic maps, satellite images and aerial photographs indicate that the property can potentially be subject to flooding from three sources:

- Flooding from the Bogan River,
- Flooding from Whitbarrow Creek, and
- Runoff from local catchments that drain through the property.

The first two sources are addressed in this section, with local catchment drainage presented in Section 4. This assessment has adopted the 100 year Average Recurrence Interval (ARI) event as a provisional flood planning level, referred to as design level in this study. A 100 year ARI event has a frequency of occurrence of once every hundred years or a 1% chance of occurring every year. This is usually the adopted level for residential areas due to potential flood damages and risk to life.

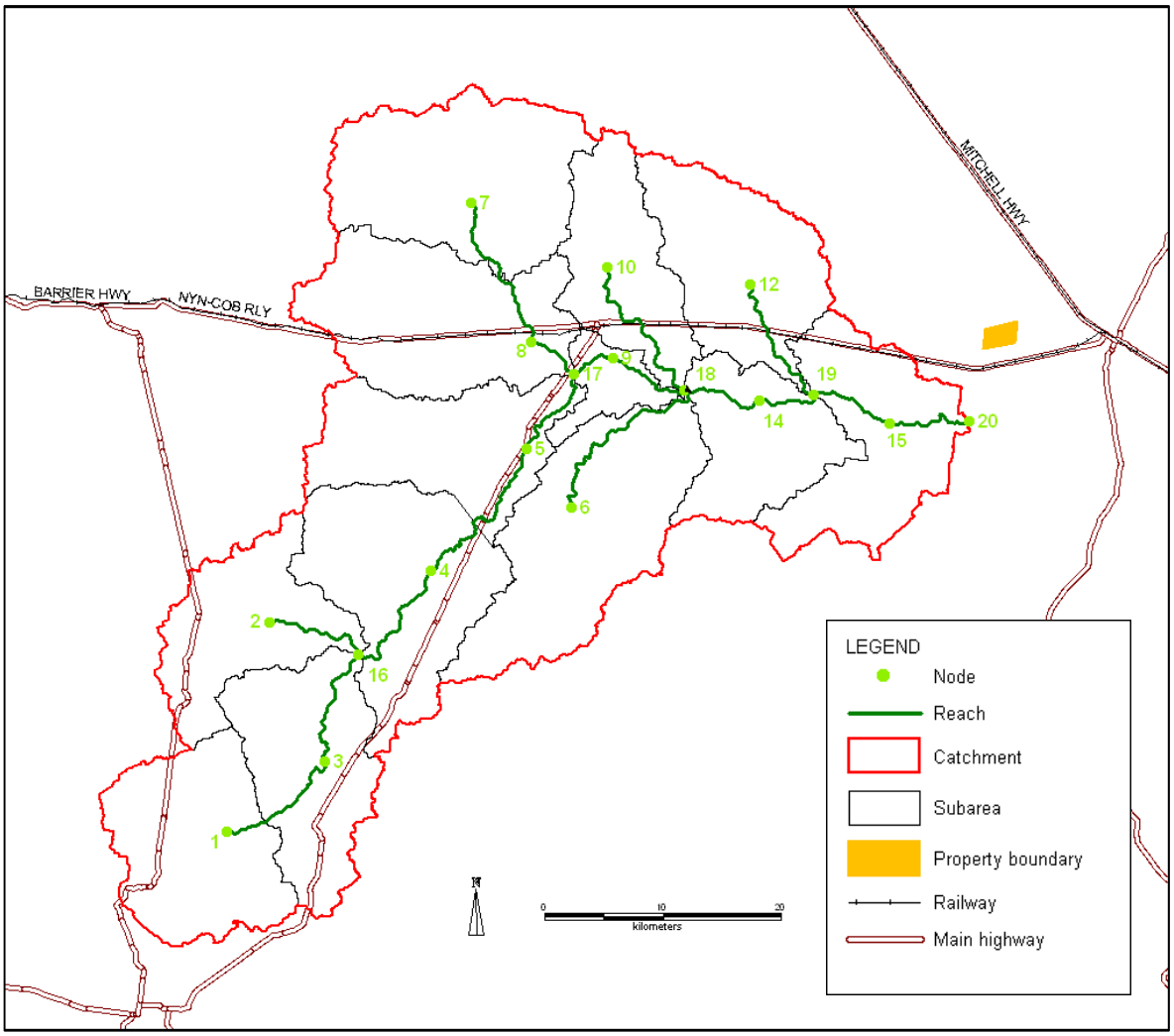
For this preliminary assessment, this flood level has been used to reflect the risks associated with expenditure and potential flood damage. A smaller event (higher frequency of occurrence) could be selected by AGL based on risk assessment, considering factors, such as, potential damage due to inundation, long term strategic planning and consequences of floods above the flood planning level. Similarly, if the PV plant is to be designed to achieve flood immunity against events rarer than a 100 year ARI event, then further flood assessment will be required.

3.2. Hydrologic Modelling

In the absence of any streamflow monitoring data for Whitbarrow Creek, a hydrologic model was developed for the Creek to estimate design discharges. Contributing design flows and associated water levels within the property were assessed using a rainfall runoff model, RORB version 6.15 (Laurenson et al., 2010). The RORB model is one of the most widely used models of its type in Australia, and consequently there is a good deal of information available on the value of the model parameters for a wide range of catchments. The model is able to simulate both linear and non-linear catchment behaviour, and exhibits many desirable modelling features, such as spatially distributed inputs and the ability to model flows at a number of points throughout the catchment.

3.2.1. Model Configuration

The 10 m contour data available from the NSW Department of Lands was used to delineate sub-areas for the RORB model. The sub-areas within the RORB model were defined to coincide with watershed boundaries and stream junctions. The catchment area of Whitbarrow Creek in the vicinity of the subject site was divided into thirteen sub-catchment areas (refer to **Figure 3.1**).



- **Figure 3.1 RORB Model Sub-catchments for Whitbarrow Creek**

3.2.2. Inputs Used in Design Flood Estimation

Rainfall Depths

Design rainfall depths for the creek catchment for all design events up to and including the 100 year ARI event for a range of storm durations were sourced from the Bureau of Meteorology's web site *http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtm*. As a result rainfall depths for all design events up to and including the 100 year ARI event were based on the standard Intensity-Frequency-Duration information provided in the current version of Australian Rainfall and Runoff.

Spatial Distribution of Rainfall

A uniform spatial distribution of design rainfall was assumed for events up to and including the 100 year ARI event. Point rainfall depths were converted to catchment average values using the Areal Reduction Factors (ARF) developed by the CRC for Catchment Hydrology (Siriwardena and Weinmann, 1996). The new areal reduction factors, based on daily rainfall data from Victoria, represent a significant improvement over the values presented in the current version of Australian Rainfall and Runoff, which were based on a limited USA study. ARFs adopted in this study are shown in **Table 3.1**.

Table 3.1 Adopted Areal Reduction Factors for Whitbarrow Creek

Storm Duration (Hour)	Areal Reduction Factors
3	0.65
4.5	0.68
6	0.70
9	0.74
12	0.76
18	0.79
24	0.80
30	0.82
36	0.83

Temporal Distribution of Rainfall

Temporal patterns for Zone II from the current version of Australian Rainfall and Runoff were used for events up to and including the 100 year ARI event for Whitbarrow Creek.

RORB Parameters

As there is no recorded flow data at the property, it is not possible to develop accurate, property-specific model parameters. Therefore, regional relationships have been used to determine appropriate design parameters for the catchment. These are based on the recommendations from Australian Rainfall Runoff Book II for ungauged catchments in central NSW (ARR, 2001).

3.2.3. Design Discharges

Estimated design discharges at the outlet for Whitbarrow Creek for a range of flood events are given in **Table 3.2**. Critical storm durations producing peak discharges for the design events are also shown in **Table 3.2**.

Table 3.2 Estimated Peak Discharges

Design Flood (ARI)	Whitbarrow Creek	
	Peak Discharge (m^3/s)	Critical Storm duration (hr)
20 Year	280	30
50 Year	400	18
100 Year	500	18

3.2.4. Conclusions

The approach adopted in the estimation of design peak discharges for Whitbarrow Creek is consistent with the method advocated in Australian Rainfall and Runoff for ungauged catchments. A hydrologic model using RORB was set up for the catchment area of the Creek in the vicinity of the property. Model parameter values adopted for the RORB model were based on regional estimates of parameter values recommended in the Australian Rainfall and Runoff. Other input data used in the design flood estimation are also consistent with the recommendations made in the Australian Rainfall and Runoff. The design discharge in Whitbarrow Creek near the property upstream from the Nyngan-Cobar Railway line was estimated to be 500 m^3/s for the 100 year ARI event.

3.3. Flood Assessment

3.3.1. Flooding from the Bogan River

The "Nyngan April 1990 Flood Investigation" report prepared by DWR does not indicate that the property was inundated by the Bogan River. This agrees with comments from the landowner that noted that the April 1990 event did not flood their property.

The Nyngan April 1990 Flood Investigation (1990, DWR) reports that immediately downstream from the Nyngan-Cobar Railway line in the Nyngan township, approximately 8 km east from the property, water level reached 172.7 mAHD. This elevation recorded at the peak of the April 1990 flood, estimated to have a 200 year ARI, is lower than the lowest spot level measured, which is at 174.21 mAHD, at the property.

Based on the above information, it can be concluded that flooding from the Bogan River is not expected to impact the Nyngan property in a 100 year ARI event.

3.3.2. Flooding from Whitbarrow Creek

Overview of Flow Distribution

Whitbarrow Creek is a tributary of the Bogan River with a large catchment from the southwest of Nyngan (refer to **Figure 3.1**). Approximately 4 km south of the property, Whitbarrow Creek divides into two main branches that both ultimately join the Bogan River. The eastern flow path continues east to join the Bogan River approximately 10 km upstream of the Mitchell Highway Bridge, while the northern flow path first flows north to the Nyngan-Cobar Railway line and the Barrier Highway before turning east towards the Bogan River. The channel flowing north is considered by locals as the main carrier for Whitbarrow Creek flows. The estimated 100 year ARI flow, before the Creek splits, is approximately 500 m^3/s. Estimating the distribution of flow between Whitbarrow Creek northern and eastern branches would require extensive ground survey and assessment using a suitable hydraulic model. In the absence of this information, a conservative approach has been adopted that considers flows in the northern branch of 400 m^3/s.

Whitbarrow Creek's northern branch is intermittent and lacks definition in many areas. Approximately 6 km north from the main channel split, the Creek passes under the Nyngan-Cobar Railway line through seven 1.5 m diameter Armco pipes and a set of flood relief pipes (eight 0.9 m diameter) located 650 m east of the Creek. The Armco pipes are located approximately 1.6 km south from the Nyngan property (refer to **Figure 1.2**).

Downstream of the Railway, the Creek passes under the Barrier Highway through six 2 m x 1 m box culverts (size estimated during property visit). The Highway formation is lower than the Railway embankment. As the Railway line is elevated above ground level (2.6 m at the main culverts and 1.6 m at the flood relief culverts), water can pond against the upstream side of the Railway and flow both to the north through the Railway formation and east towards the Bogan River. For large events, the Railway would potentially be overtopped and flood waters would continue in the direction of Whitbarrow Creek towards the Bogan River. Water levels higher than the Railway level are expected to result in wide shallow flow over the Railway formation.

The capacity of the culverts (main channel and flood relief) under the railway is estimated to be 60 m^3/s for a water depth at the top of the railway formation. This assumes no blockage of culverts or elevated tailwater levels that may reduce capacity.

Ponding behind the railway formation is likely to result in flow being diverted east along the Railway line within a 350 m wide Travelling Stock Route (TSR). A hydraulic analysis provided an

estimate of this potential flow along the Railway formation. Available data was used where possible, other parameters were adopted as follows:

- Cross sections and longitudinal grade derived using the 0.3 m contours south of the Railway line provided estimates of railway levels; and
- Manning's value between 0.06 and 0.08, as suggested by the site photos, indicating that the area is vegetated with substantial shrubs and grass.

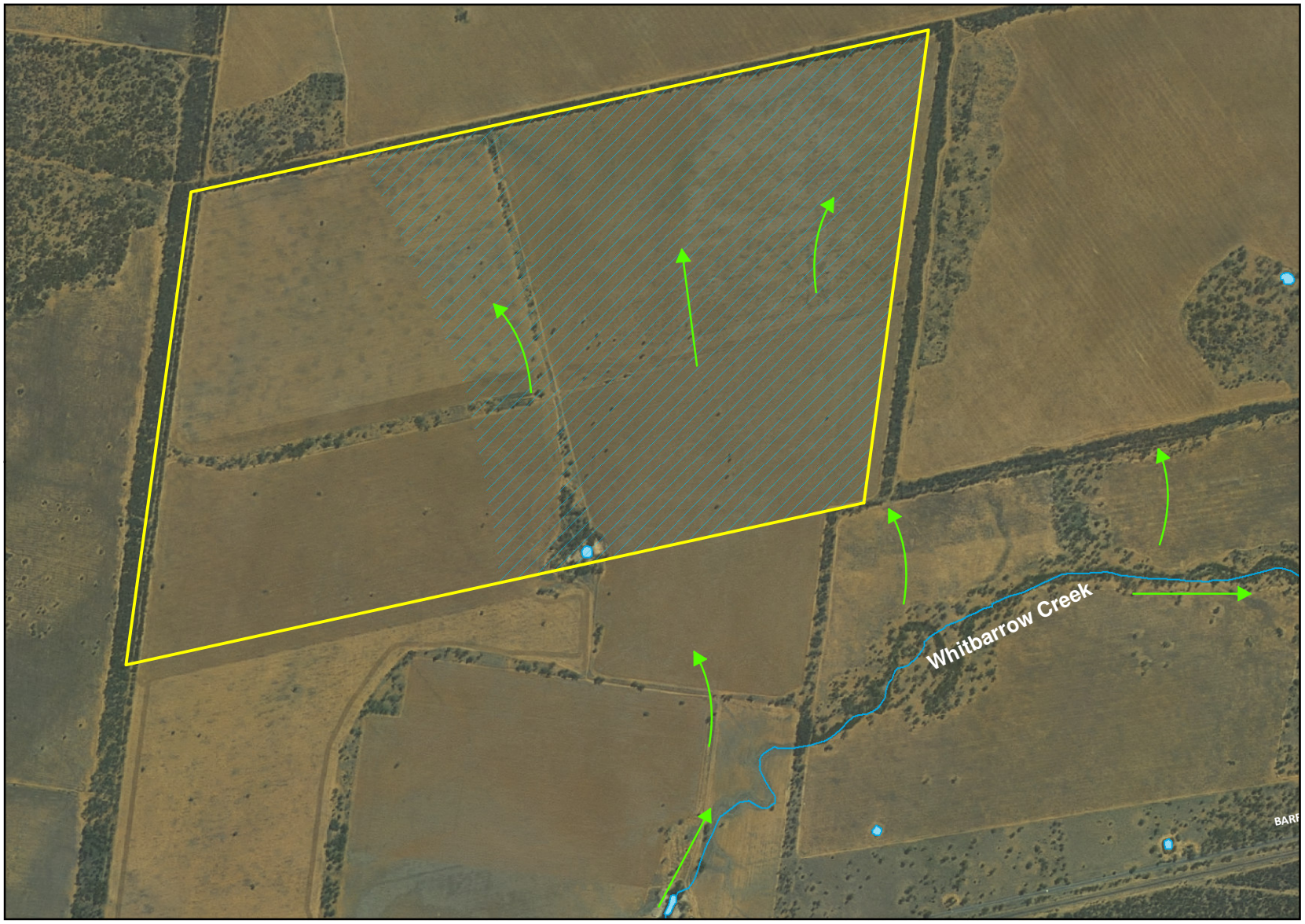
For flow depth up to the top of the Railway formation (depth assumed to be between 0.8 and 1 m), it is estimated that the flow along the TSR is approximately 110 m^3/s. Therefore, the combined flow capacity through the railway culverts and conveyance east along the rail alignment, is approximately 170 m^3/s. Considering flood flows in Whitbarrow Creek northern branch of 400 m^3/s, there is an unaccounted flood flow of 230 m^3/s. It is assumed that this flow would be conveyed over the Railway line. The estimated overflow is dependent on the length of the rail, against which water is ponded. As the Railway has a very gradual longitudinal grade (less than 0.05%), flow over the formation is assumed to be shallow, wide flow. Preliminary calculations indicate that overtopping depths are around 0.2 m in a 100 year ARI event. This assumes no breaching of the rail formation.

Preliminary Hydraulic Calculations for the Property

The property can potentially be subject to inundation due to overflows from Whitbarrow Creek, particularly in the eastern areas. To estimate the potential inundation, a HEC-RAS model was established. HEC-RAS (Hydrologic Engineering Center's River Analysis System) is a widely used computer program used to model hydraulics of water flow through natural waterways and channels. The model was run for the 100 year ARI flow, considered to be 290 m^3/s, which corresponds to the flow in Whitbarrow Creek northern branch carried through the Railway, either by the culverts or by flowing over the formation.

During a 100 year ARI event, the flow in Whitbarrow Creek floodplain is constrained on its southern bank by the Railway line, however, from the available topographic and flood modelling data, the Creek will break its northern bank approximately 1 km downstream of the Railway line. The breakout flow moves overland towards the north-east and through the property. It is estimated that approximately 100 m^3/s is conveyed through the property in a 100 year ARI event. Due to the relatively flat terrain and the absence of gullies (erosion due to fast concentrated flows), the water moves as shallow sheet flow along the eastern part of the property. Based on hydraulic calculations, flood depths and velocities within the property are estimated at 0.3 m and 0.2 m/s, respectively. The shallow sheet flow would cover approximately 60% of the property (refer to **Figure 3.2**). Hence, the property isn't subject to flooding from Whitbarrow Creek above a depth of 0.3 m in a 100 year ARI event.

Figure 3-2 | Potential 100 year ARI inundation in the Nyngan property due to flooding in Whitbarrow Creek



LEGEND

- Property boundary
- Expected extent of flood inundation
- Watercourse
- Assumed direction of flood flow in Whitbarrow Creek

DATA SOURCES
LPMA
Imagery: SPOT

GDA 1994 | MGA Zone 55
A4 1:22,000

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Sydney Spatial Team - Prepared by : DD
Checked by : JC

3.3.3. Conclusions

The property is unlikely to be flooded from the Bogan River up to a 200 year ARI event. However, it can potentially be subject to inundation due to flooding in Whitbarrow Creek. A HEC-RAS model was used to estimate the flood extent within the property resulting from a 100 year ARI flooding in Whitbarrow Creek. A preliminary hydraulic assessment shows that Whitbarrow Creek breaks its northern bank approximately 1 km downstream of the Railway line and approximately 100 m^3/s of flood flow is conveyed overland in the eastern areas of the property in a 100 year ARI event. The depth and velocity of flooding is estimated at 0.3 m and 0.2 m/s, respectively. This shallow sheet flow would cover approximately 60% of the property.

The property can be protected from flooding in Whitbarrow Creek through construction of a small levee along the southern and eastern boundaries of the property. A detailed assessment needs to be undertaken in future design phases if there is a need to protect the property from flooding in Whitbarrow Creek.

4. Property Drainage

4.1. Identification of Drainage Areas

Available topographic data, consisting of the 25 m x 25 m DTM and of the spot levels, was used to define overland flow paths and drainage areas within the property. External catchments draining through the property were identified with the DTM. The spot levels indicated no defined floodways within the property suggesting that local drainage is mainly sheet flow following the gentle grade from south-west to north-east. This is in agreement with the site inspection which did not identify any gullies. The north-eastern corner which has the lowest elevation appears to be the outlet to any water draining through the property.

The local catchment draining through the north-eastern corner was defined by aggregating information from the two datasets. It includes the whole property, assuming that all of the property area is contributing to the flow as a conservative approach due to the limited topographic data. This catchment is approximately 8 km^2 and subsequently flows east-north-east towards Mitchell Highway.

4.2. Estimation of Design Discharges

In the absence of any streamflow monitoring data that could be used to derive design flows by flood frequency analysis, design flow for the local catchments draining to the Nyngan property was estimated using the Probabilistic Rational Method in accordance with procedures in Australian Rainfall & Runoff (ARR). This method is appropriate for estimating peak discharge in catchments less than 250 km^2. The rainfall intensity-frequency-duration (IFD) data used in the calculation was sourced from the Bureau of Meteorology's web site;
http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtm.

ARR recommends the Western NSW method for the region of Nyngan. However, the Western NSW method does not provide peak discharge parameters for a 100 year ARI. It provides values for extrapolation up to the 50 year ARI event. In order to provide an estimate for the impact of a 100 year ARI event, being the usual design event, an application of a 50% increase in the 50 year ARI flows was used. This is considered to be a reasonable guide for an estimated 100 year ARI event, and appropriate for this concept design.

In future detailed design development, a rainfall runoff model could be developed to more accurately calculate a flow for a 100 year ARI event.

The Western NSW method gives a 50 year ARI peak flow for the property drainage of 10 m^3/s at the outlet of the property. An estimate for the impact of a 100 year ARI event, or 50% increase in the 50 year ARI flows, results in a flow of 15 m^3/s.

4.3. Flood Depths

The land use for the area draining through the property is rural. Vegetation cover over the property reflects agricultural activities with mainly grass or crops and occasional trees. The property is relatively flat (approximately 0.1% longitudinal grade) and does not have well defined drainage channels. Drainage within the property is typically wide shallow sheet flow, initiated when the soil profile is saturated, when rainfall intensities exceed soil infiltration rates or when flows from external catchments flow into the properties.

Based on hydraulic calculations and given the flat topography, it is expected that most areas within the Nyngan property would experience shallow sheet flow up to a maximum depth of 0.25 m in an estimated 100 year ARI event. The velocity of flow through the property is expected to be slow due to the flat nature of the terrain. At this preliminary stage of assessment, the potential flow path has been described qualitatively. To quantify the impacts, a more detailed approach would be required.

4.4. Conclusions

An external local catchment, drains through the western boundary into the property and in large events is expected to flow north-east through the property towards the Mitchell Highway. Preliminary hydraulic assessment indicates that the property will experience only marginal flooding from local catchment drainage; with the maximum depth not exceeding 0.25 m. All flows within the property are expected to have a low flow velocity.

5. Potential Stormwater Erosion

The PV plant construction would involve PV panels supported by posts that are thrust into the ground. Some vegetation cover is expected to be retained, which will protect the soil from erosion. Access roads and buildings will be minimal. Any potential soil erosion and sediment impacts during construction can be mitigated through procedures in the construction environment management plan (EMP).

A preliminary appraisal of soil and erosion issues for operational phase is provided for guidance in development of concept designs for the property. This is not prescriptive of all issues to be considered. Appraisal is based on observations from site visits and SKM's experience on other projects.

It is expected that the change of land use on the property would result in less vegetation cover than currently exists. This has the potential to result in increased soil and water erosion. A full appraisal of the impacts and mitigation measures would be included in ongoing design. Some suggestions include:

- adopt vegetation types suitable for soil types, climatic conditions and shaded areas under the panels;
- ensure works maintain sheet flow and do not concentrate flow which potentially would increase erosion; and
- develop monitoring and maintenance program.

6. Conclusions and Recommendations

6.1. Conclusions

A preliminary flood assessment for the property was undertaken to determine the impact flooding would have on the proposed PV plant. The Nyngan property is located north of the Nyngan-Cobar Railway line and approximately 8 km west of the Bogan River. It also lies 500 m west from Whitbarrow Creek, which is a tributary of the Bogan River.

The property has no history of prolonged overland flooding, as noted by the current landowner during the property inspection. Information provided in a previous flood study (NSW Department of Water Resources, 1990) did not identify the property as being flood prone from the Bogan River. Due to the lack of stream gauge data along Whitbarrow Creek, the flood assessment undertaken has been based on the available data. The 100 year ARI event was used to assess the flood risk to the property from both mainstream and local catchment runoff.

For the mainstream flooding, the property is not expected to experience flooding from the Bogan River in a 100 year ARI. To assess mainstream flooding from Whitbarrow Creek, a hydrologic rainfall-runoff model was set up using RORB. The Creek's northern branch is considered to be the main flow carrier and the modelling estimated that, in a 100 year ARI event, water is likely to pond against the Railway embankment and is anticipated to overtop the formation, conveying a peak flow of 290 m^3/s north of the Railway line. Approximately 1 km downstream (north) of the Railway line, Whitbarrow Creek breaks its northern bank and a portion of the flood flow escapes the Creek's floodplain and moves in a northerly direction. It is estimated that in a 100 year ARI flood event, a flow of approximately 100 m^3/s is conveyed overland through the eastern part of the property resulting in shallow flooding up to a depth of 0.3 m. The velocity of flow within the property is estimated at 0.2 m/s. Approximately 60% of the property is affected by this shallow sheet flow in a 100 year ARI flood in Whitbarrow Creek.

The impact of localised site drainage on the property in a 100 year ARI event is considered minor. Local drainage will consist of sheet flow where maximum water depths are expected to be less than 0.25 m in a 100 year ARI event.

There is potential to substantially mitigate the impacts of local drainage and mainstream flooding by siting the PV plant equipment at least 0.3 m above the ground plus freeboard.

This preliminary flooding assessment is based on limited property specific information and various assumptions, therefore, a detailed flood impact assessment will be required to determine flood depths with more accuracy. Also, if any additional changes to land use occur during development that lead to significantly increased imperviousness, then additional hydrological analysis would be required.

6.2. Limitations and Assumptions

Limitations for this study and the associated assumptions made include:

- No streamflow gauge available to enable RORB model to be calibrated. Parameter values used are based on the RORB Manual and regional estimates recommended in Australian Rainfall and Runoff;
- No topographic information suitable to determine flow split between Whitbarrow Creek northern and eastern branches. Method adopted assumed a range of potential flows into the northern branch between 50 and 100% of the total catchment flow. This study adopted the 100 year ARI as the flood design level. This event should be confirmed in the detailed design phase;
- Topographic data was not suitable to develop a hydraulic model to quantify the distribution of flow passing along the rail versus flow surcharging over the rail formation. It was assumed no attenuation of flow occurred upstream of the rail line, that overflow over the rail formation would be wide (over 2 km) and that the rail formation would not breach; and
- No observed data was suitable to validate the preliminary hydraulic assessment. Assumed parameter values from similar applications were made with reference to photos taken during the property visit.

6.3. Recommendations

It is recommended that a detailed hydraulic model be used to define flow paths into Whitbarrow Creek's northern branch. This model should extend sufficiently downstream of the Railway line along the northern branch and include the full extent of the overland flow path through the property. This would require survey (ground or ALS (Airborne Laser Scanning)) of the Creek and its floodplain and key features within the study area such as top of rail level, Barrier Highway level, creek and culvert invert levels, and floor levels of the house adjacent to the property. Preferably, model parameters would be calibrated using flood inundation information provided by the owner for the property located on the southern side of the Railway line. Subsequently, the model would be used to assess design flow distribution and water levels within the property.

7. References

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