DENMAN ROAD SOLAR PARK

FLOOD STUDY &

STORMWATER MANAGEMENT PLAN

CLIENT: DPI AUSTRALIA PTY LTD

DOCUMENT NUMBER: 19-0155/R1155

VERSION: B

DATE: 12/02/2021

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1 INTRODUCTION

Topo were engaged by DPI Australia to prepare a Flood Study and Stormwater Management Plan for the proposed Denman Road Solar Park, located off Denman Road, Denman, NSW. The site is formally described as Lot 400 on DP791860.

1.1. GUIDELINES

This Flood Study has been prepared in accordance with:

+ *Best Practice Erosion and Sediment Control* (IECA 2008,2016), and
+ *Australian Rainfall and Runoff* (2016).

1.2. OBJECTIVE

The primary objective of this flood study is to identify the flood constraints, providing details in relation to flooding across the site and the management of stormwater during the operational phase of the project.

1.3. REVISION

VERSION	DATE	AUTHOR	APPROVED
DRAFT	17/02/20	STEVEN CHAMBERLAIN	STEVEN CHAMBERLAIN
A	6/04/20	STEVEN CHAMBERLAIN	STEVEN CHAMBERLAIN
B	12/02/21	STEVEN CHAMBERLAIN	STEVEN CHAMBERLAIN

2 PROJECT DESCRIPTION

2.1. LOCATION

The site is located on the southern side of Denman Road, within the Muswellbrook Shire Council area (NSW). The site covers approximately 40 ha of land and has been predominantly cleared, with some scattered trees remaining, and is surrounded by agricultural properties. Figure 1 presents the site and its surrounds, with the site shaded in orange.

Figure 1 – Site Location (Source: Google Maps)

2.2. PROJECT WORKS

The proposed solar farm development will include, but not be limited to:

- Installation of solar modules on frames,
- Construction of inverter housing, control rooms, and associated supporting infrastructure and facilities, and
- Formation of access maintenance tracks and perimeter fencing.

Due to the nature of solar farm developments where the solar panels are attached to raised platforms above vegetated ground, the increases in impervious areas are effectively minimal and very minor change to the existing landform is anticipated due to the construction/installation process.

3 SITE DESCRIPTION

3.1. CLIMATE

Based on historic rainfall data, the site is subject to an increased rainfall pattern over the summer period between November to March. Rainfall is reduced somewhat between April and October. The nearest Bureau of Meteorology (BoM) gauging station is located at Scone Airport and reports an annual average rainfall depth of 585.4 mm. The historic monthly rainfall for the region is presented below in Figure 3.

3.2. TOPOGRAPHY AND DRAINAGE

The site's northern boundary is formed by Denman Road. There are no defined drainage paths through the site and due to the flat grades, the flow lines are dominated by wide areas of shallow. Runoff is typically conveyed to the north towards Denman Road at grades of approximately 3 % in the upper portions of the site, decreasing to less than 1.5 % towards Denman Road. There is a table drain located along Denman Road, with three culverts identified that convey runoff to the north. These culverts have been included in the hydraulic model and a summary of the infrastructure is provided as Table 1 and their locations shown in Figure 4.

Based on the LIDAR data used for this assessment, the site's high point of approximately 160 m AHD occurs on the south eastern boundary at the ridgeline between Catchment 7 and 8. Elevations at Denman Road range between 127 m AHD and 127.5m AHD. Runoff from the southern western portion of the site is diverted to a dam located in the lower third of the site. External catchments to the south rise to a peak elevation of approximately 285 m AHD, however the majority of this runoff bypasses the site, impacting only the lower portion near Denman Road.

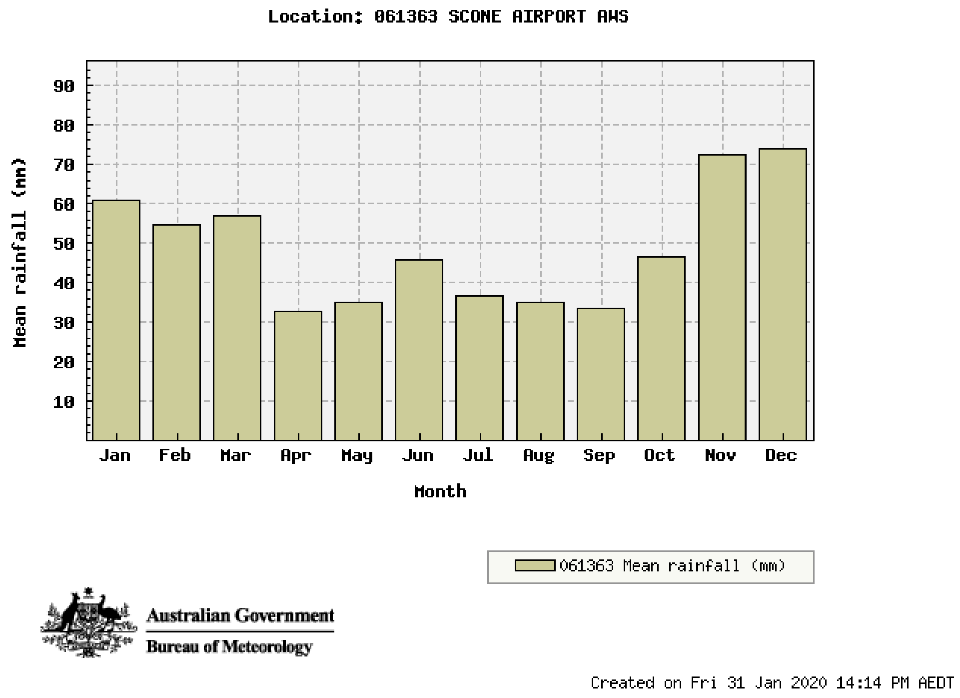


Figure 2 – Historic Monthly Rainfall (Source: BoM)

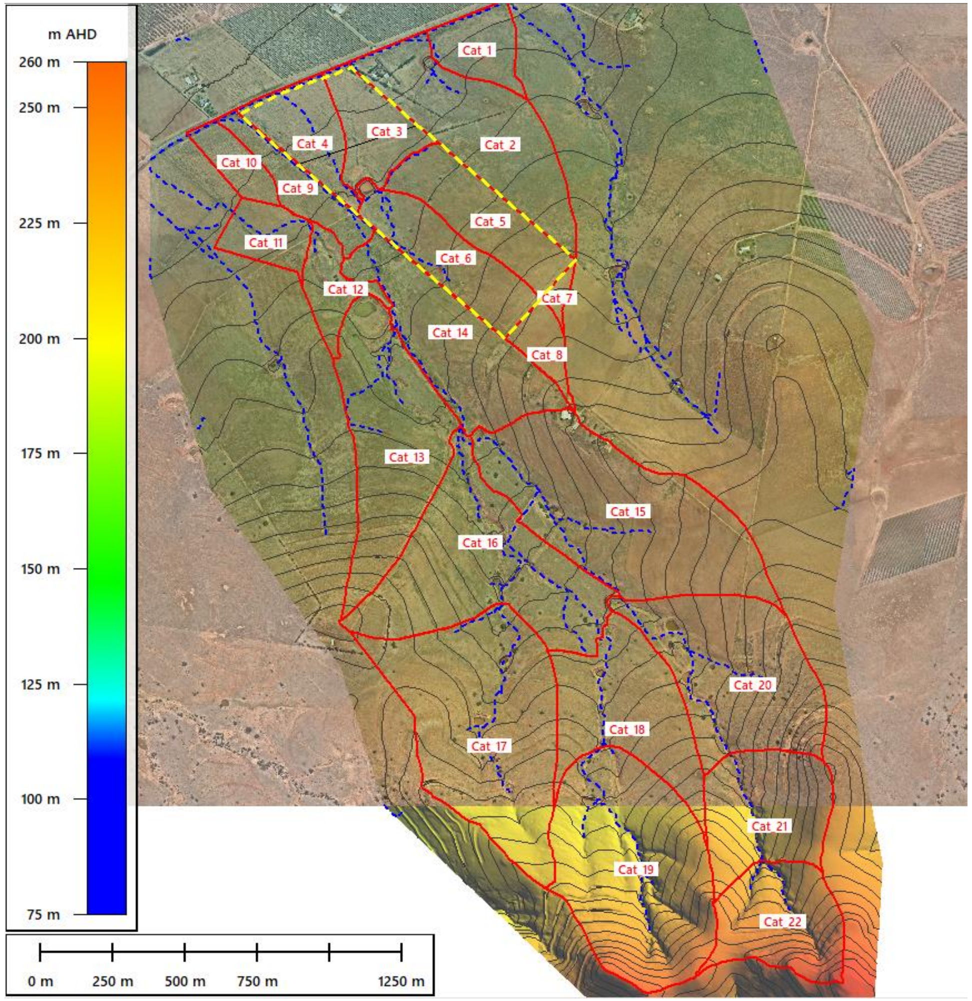


Figure 3 – Catchment Plan

Figure 4 – Denman Road Culvert Locations

Table 1 – Culvert Details

LOCATION	DRAINAGE INFRASTRUCTURE
1	4 x 600 mm RCP
2	2 x 2100 x 450 mm RCBC
3	4 x 2100 x 450 mm RCBC

4 HYDROLOGIC MODELLING

4.1. METHODOLOGY

An integrated hydrologic and hydraulic model was constructed for the catchment and site using the XP-Storm 2D software. The model represents the sub-catchments as a network of nodes linked to the 2D geometric base. Each node is defined by its fraction impervious and average catchment slope. The net rainfall is routed through the network after appropriate losses (initial and continuing) and roughness factors are applied, resulting in a surface runoff hydrograph for each sub-catchment.

4.2. HYDROLOGY

The XP-Storm runoff-routing model has been used to estimate design flood discharges within the study area. The XP-Storm model was used to estimate the 1 % Annual Exceedance Probability (AEP) storm event for the 15 minute to 6 hour storm durations. The modelling undertaken as part of this assessment applies the Australian Rainfall and Runoff (ARR) 2016 hydrology. The XP Storm Generator has been used, in conjunction with the Bureau of Meteorology (BOM) Intensity–Frequency–Duration (IFD) program and the ARR Data Hub to generate the rainfall intensities and temporal patterns for the site. By applying the ARR 2016 hydrologic methods, we have ensured this study is providing the best available information on design flood estimation.

4.3. RAINFALL DATA

Obtaining an estimated rainfall depth for a specified probability is an essential component of the design of infrastructure including. Design rainfalls are a probabilistic or statistically-based estimate of the likelihood of a specific rainfall depth being recorded at a particular location within a defined duration. This is generally classified by an AEP or Exceedances per Year (EY). Design rainfalls are therefore not real rainfall events, rather they are values that are probabilistic in nature.

The 2016 IFD design rainfalls are provided for use in conjunction with the 2016 edition of *Australian Rainfall and Runoff* (2016) http://arr.ga.gov.au/arr-guideline .

The rainfall intensities generated for the site and applied to the hydrologic modelling are summarised in Table 2.

Table 2 – BOM Intensity Frequency Duration Data (issued 14-1-2020)

DURATION	63% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
15 min	45.9	51.7	71.1	85.2	99.6	120.0	137.0
20 min	39.4	44.5	61.1	73.1	85.5	103.0	117.0
25 min	34.7	39.1	53.6	64.1	74.9	90.0	102.0
30 min	31.0	34.9	47.8	57.2	66.7	80.0	90.8
45 min	23.8	26.8	36.5	43.4	50.5	60.4	68.2
1 hour	19.5	21.9	29.7	35.3	41.0	48.8	55.0
1.5 hour	14.6	16.4	22.1	26.2	30.3	35.8	40.3
2 hour	11.9	13.3	17.9	21.1	24.4	28.8	32.3
3 hour	8.9	9.9	13.3	15.6	18.0	21.3	23.8
4.5 hour	6.7	7.5	9.9	11.7	13.5	15.9	17.9
6 hour	5.5	6.1	8.2	9.6	11.1	13.1	14.7

Location: Lat -32.3301, Long. 150.7685 Nearest Gauge: Lat -32.3375, Long. 150.7625

4.4. ROUTING

Hydrologic modelling has been undertaken using the Laurenson runoff routing method. The Laurenson method requires the catchment to be divided into a pervious (undeveloped) and an impervious (developed) portion. Due to the lack of development in the catchment, the fraction impervious is low. Based on aerial photography analysis, a fraction impervious has been calculated assuming 100 % impervious for water bodies, roadways and existing buildings.

4.5. CATCHMENT CHARACTERISTICS

The representation of a catchment in a flood hydrograph estimation model is, by necessity, highly conceptualised and aims to represent those features and characteristics that are most influential in determining the overall flood response of the catchment. The distribution of storm rainfall over different parts of the catchment and the flood response to it may vary considerably, depending on the details of topography, vegetation cover, land use and drainage network characteristics. The assessment undertaken has aimed to identify the features most likely to influence the flood hydrograph estimation and flood behaviour through the site. A catchment of approximately 365.5 ha has been identified as part of this assessment and has been further sub-divided to enable the flood regime of the site to be accurately determined. 22 sub-catchments have been delineated, as previously illustrated in Figure 3 and summarised in Table 3.

Table 3 – Catchment Details Applied to Hydrologic Assessment

CATCH ID	AREA (HA)	FRACTION IMPERVIOUS (%)	SLOPE (M/M)
1	6.55	2.9	0.039
2	21.93	1.9	0.028
3	8.41	0.9	0.021
4	8.74	3.1	0.017
5	12.49	0.0	0.032
6	12.20	1.9	0.032
7	1.02	0.0	0.037
8	3.62	0.0	0.045
9	6.77	0.7	0.016
10	4.10	2.3	0.016
11	5.70	0.0	0.025
12	5.45	0.0	0.020
13	25.69	4.4	0.034
14	20.35	0.0	0.030
15	38.42	0.6	0.057
16	31.64	1.2	0.045
17	37.87	0.9	0.055
18	20.26	1.1	0.051
19	35.66	0.3	0.109
20	27.19	1.3	0.055
21	16.74	0.1	0.124
22	14.73	0.0	0.136

4.5.1. ROUGHNESS COEFFICIENTS

Manning's n values have been applied to represent the catchment, and these values varied based on the degree of vegetation present. The roughness values have been varied and defined for the pervious and impervious portions of the catchment. The following values have been adopted:

+ Impervious area n = 0.015
+ Pervious areas n = 0.045

4.5.2. RAINFALL LOSSES

Rainfall loss rates are varied for the impervious and pervious areas, as summarised below:

+ Initial Loss 0 mm (impervious) 10 mm (pervious)
+ Continuing Losses 0 mm/hr (impervious) 2.5 mm/hr (pervious)

The ARR Data Hub recommends an initial loss of 40 mm. This loss rate is overly conservative and therefore has not been adopted for this assessment.

4.6. HYDROLOGIC MODELLING SCENARIOS

4.6.1. ARR 2016

The XP ARR Storm Generator enables input of the ARR data, with the rainfall global database, infiltration global database, and global storm definitions, into XP-Storm. Information such as the ARR Data Hub Text File, ARR Temporal Patterns Increments File, and BOM 2016 IFD Table File are used to generate rainfall files with the AEP and all of the durations for the given location. A rainfall global database, infiltration global database, and global storm definitions are all generated and used as part of the assessment. The XP Storm Generator report is included as Appendix A.

8 standard duration storms between 20 minutes and 180 minutes for the 1 % AEP event have been assessed with a 10 storm ensemble being generated for each duration. The design storm hydrographs are illustrated as Figure 5. The maximum and median flow rate at outlet has been assessed and the critical duration determined. The results of the statistical analysis are summarised in Table 4 and presented as Figure 6 and Figure 7. The critical duration for the 1 % AEP storm ensemble is the 45 minute event, with the median and maximum storms being the 9th and 10th ensemble events respectively.

Table 4 – Summary of Peak Flow Rates for 1 % AEP Design Storms

Ensemble name	Storm 1	Storm 2	Storm 3	Storm 4	Storm 5	Storm 6	Storm 7	Storm 8	Storm 9	Storm 10	Average	Std. Dev.	Median
ECS_1pct_20min	35.6725	34.9465	34.0904	35.5882	34.8497	35.1317	35.3686	35.3511	35.7917	35.3287	35.2119	0.4705	35.3399
ECS_1pct_25min	40.0769	38.6384	39.5152	38.7509	40.1259	39.7405	40.2442	39.5488	39.8046	40.9281	39.7373	0.6490	39.7725
ECS_1pct_30min	44.2977	41.0751	40.6794	40.8286	42.7682	41.6687	44.0557	42.0984	43.9945	44.7513	42.6218	1.4788	42.4333
ECS_1pct_45min	44.6048	45.9208	45.1455	44.7594	47.8072	47.6848	45.0446	47.4307	46.6787	50.0956	46.5172	1.6687	46.2998
ECS_1pct_1hr	43.6557	44.0358	48.4734	43.6394	41.2242	50.0494	44.1763	47.5348	43.2584	53.0723	45.9120	3.5127	44.1061
ECS_1pct_1_5hr	38.8962	34.7932	34.2939	35.3969	36.3185	48.6687	32.6417	41.5909	37.8092	39.9585	38.0368	4.4013	37.0638
ECS_1pct_2hr	32.1580	39.8161	30.3289	43.5133	25.6694	44.3515	27.1887	41.1446	36.1547	43.2797	36.3605	6.7099	37.9854
ECS_1pct_3hr	24.4330	32.9275	31.7508	31.0731	20.6954	18.3142	29.3146	31.1379	27.2992	33.7127	28.0658	5.0234	30.1938

CRITICAL DURATION : The critical duration for the 1% AEP is the ensemble ECS_1pct_45min.
The median pattern for this ensemble is storm 9 (storm name : ECS_1pct_45min_9).
The pattern with the greatest <Max Flow> for this ensemble is storm 10 (storm name : ECS_1pct_45min_10).

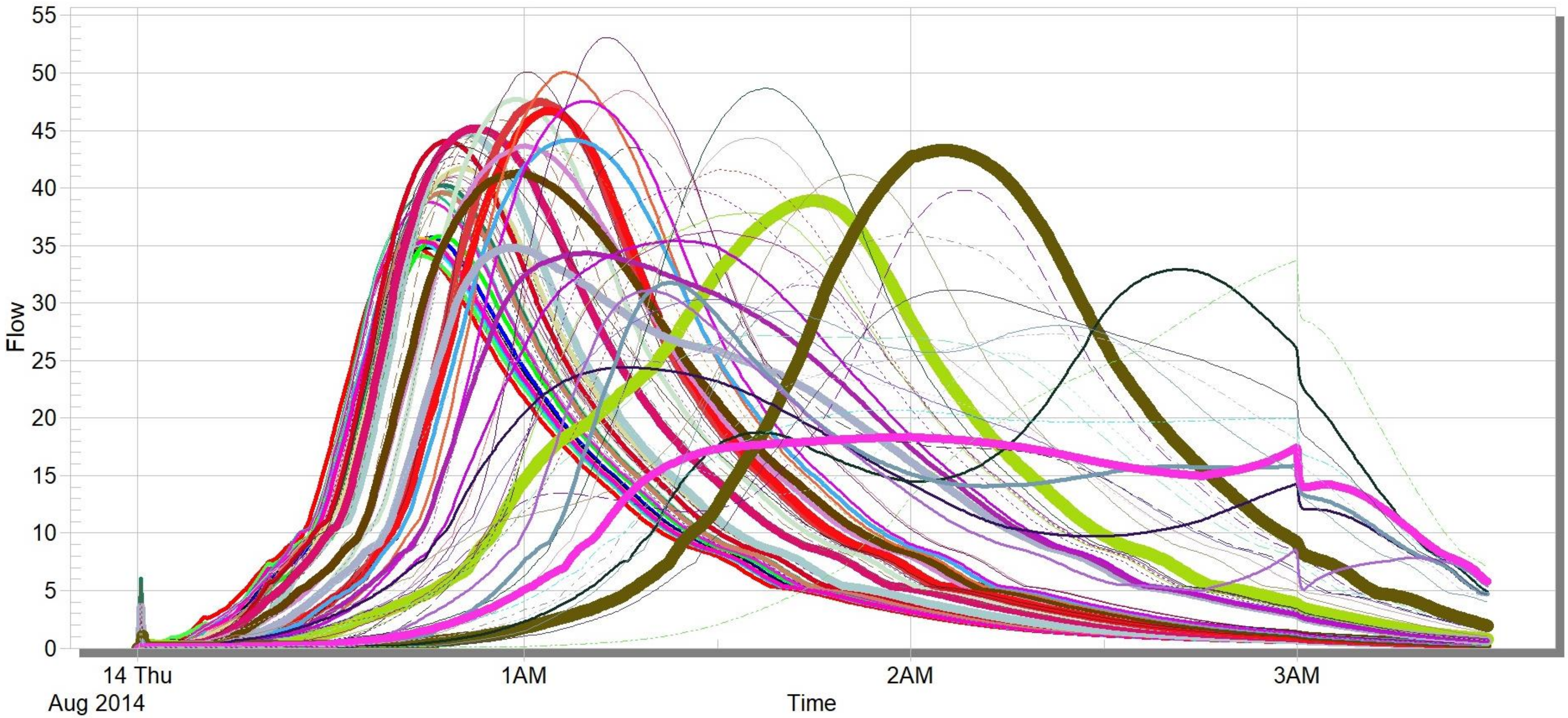


Figure 5 – Design Storm Hydrographs at Model Outlet – ARR 2016

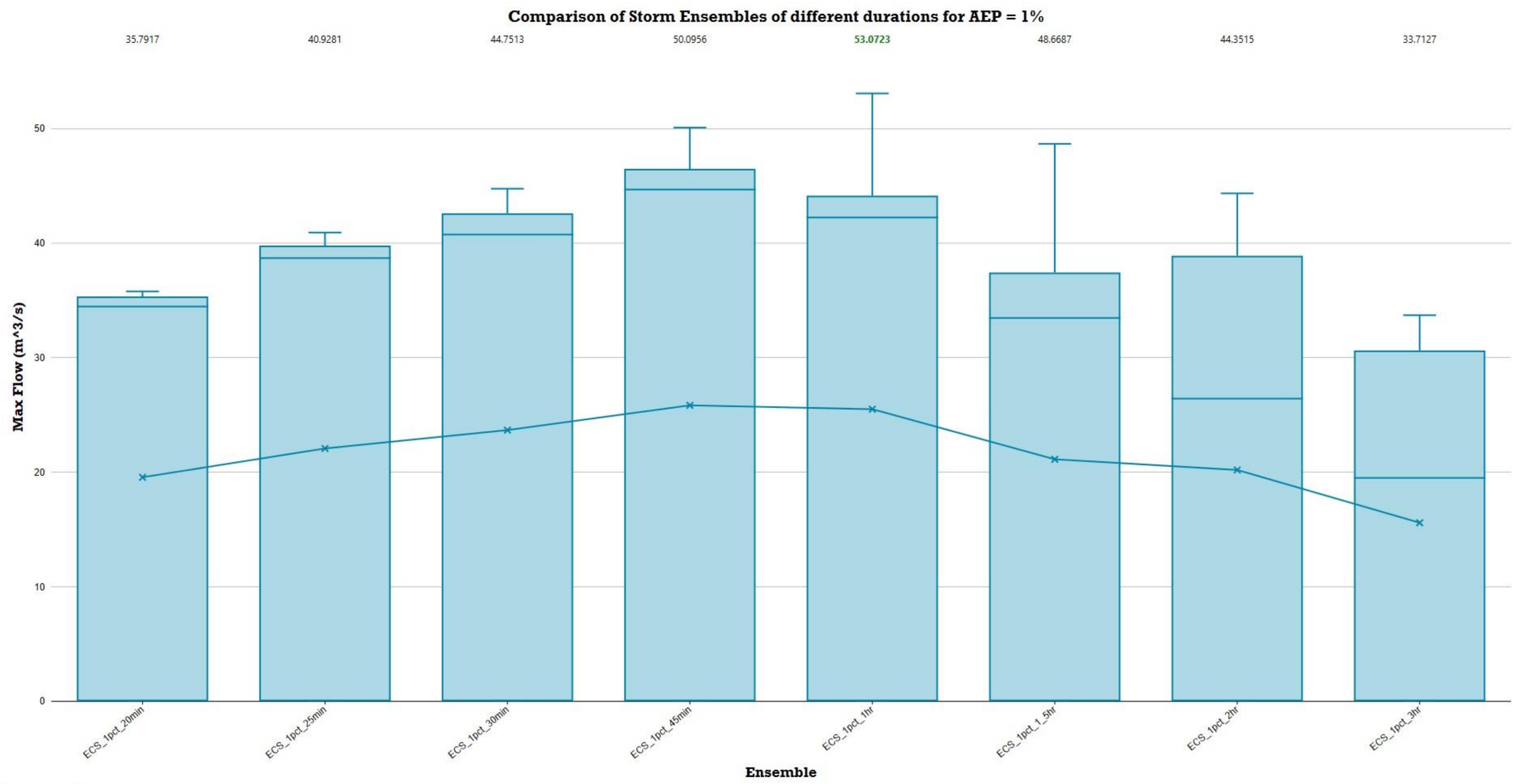


Figure 6 – Comparison of 1 % AEP Storm Ensembles with Maximum – Box and Whisker Plot

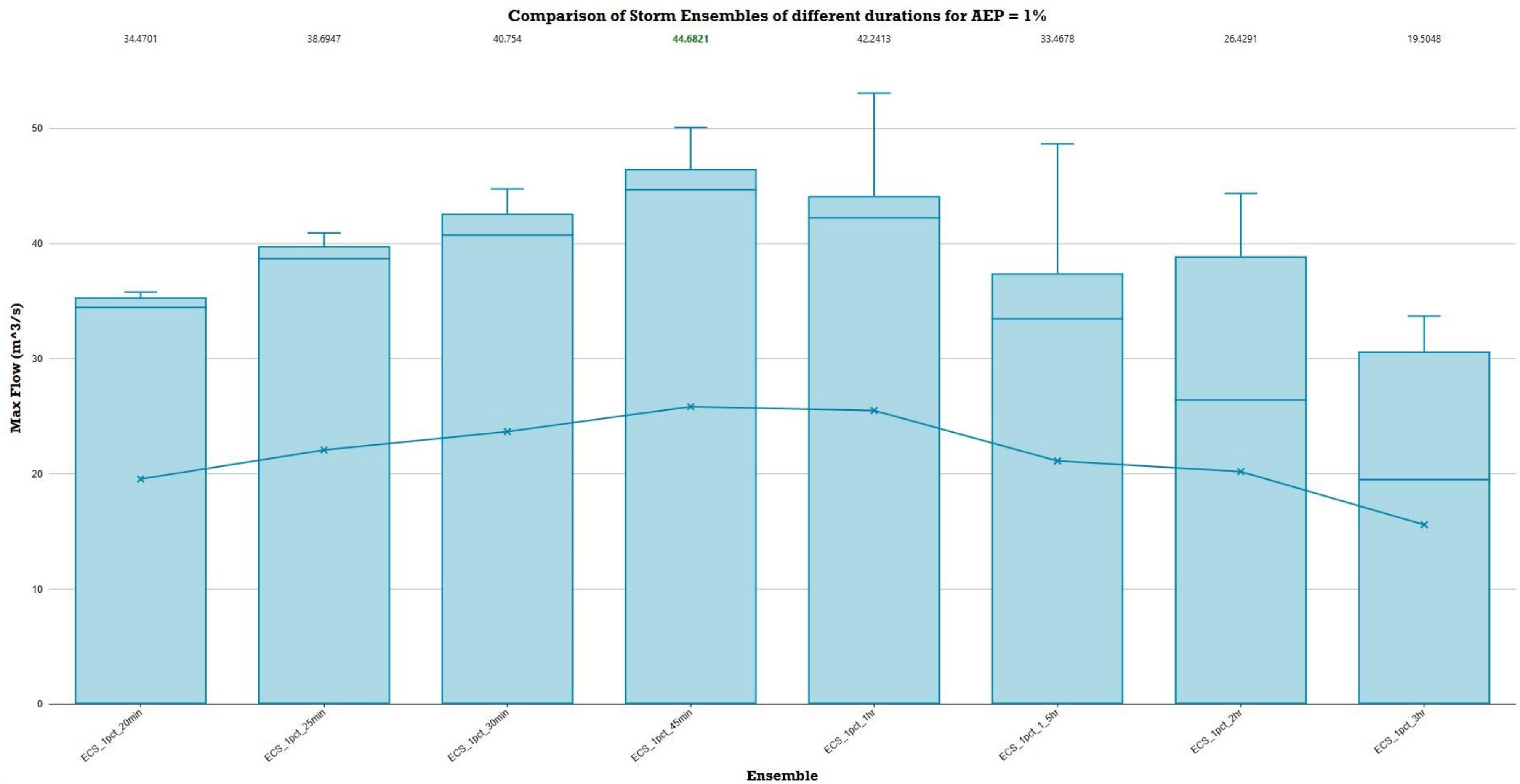


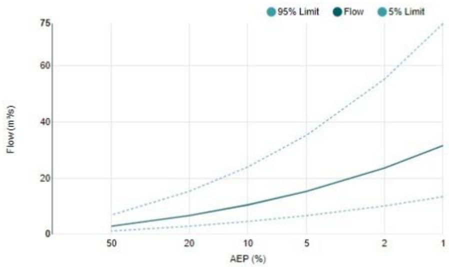
Figure 7 – Comparison of 1 % AEP Storm Ensembles with Median – Box and Whisker Plot

4.7. MODEL CALIBRATION / PEAK FLOW RATE COMPARISON

A comparison of the peak flow rates provided by the XP-Storm model and the results of the Regional Flood Frequency Estimation Model (RFFE) has been undertaken. The RFFE technique is based on data from 853 gauged catchments and transfers flood frequency characteristics from a group of gauged catchments to the location of interest. The method ensures that design flood discharge estimates are consistent with the gauged records and with results for other ungauged catchments in a region.

The RFFE predicts a peak discharge of 31.6m ^{3}/s, with a lower confidence limit (5 %) and upper confidence limit (95 %) of 13.4 m^3/s and 75.0 m^3/s respectively. The peak discharge for the critical duration (45 minute) median storm event of 46.7 m^3/s, is within the range predicated by the RFFE and is therefore considered acceptable for this assessment. A summary of the RFFE outputs is provided as Figure 8.

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	2.88	1.18	6.88
20	6.67	2.89	15.3
10	10.5	4.58	24.0
5	15.3	6.66	35.3
2	23.6	10.1	55.2
1	31.6	13.4	75.0

Statistics

Variable	Value	Standard Dev
Mean	1.075	0.532
Standard Dev	0.987	0.132
Skew	0.124	0.027

Note: These statistics come from the nearest gauged catchment. Details.

Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

Input Data	
Date/Time	2020-02-14 17:35
Catchment Name	Denman
Latitude (Outlet)	-32.32728
Longitude (Outlet)	150.7676
Latitude (Centroid)	-32.34332
Longitude (Centroid)	150.776
Catchment Area (km^2)	3.5438
Distance to Nearest Gauged Catchment (km)	13.58
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.179778
2% AEP 6 Hour Rainfall Intensity (mm/h)	13.155509
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	1.04
Interpolation Method	Natural Neighbour
Bias Correction Value	0.744

Figure 8 - Results of RFFE - Flow Rates and Confidence Limits

4.7.1. ARR 1987

The ARR 1987 Zone 1 temporal patterns have also been assessed and compared with the results of the ARR 2016 ensemble patterns. Standard duration storm events between 25 minutes and 120 minutes have been assessed, with the design hydrographs presented as Figure 9. As can be seen from this plot, the 60 minute storm event is the critical duration with a peak discharge of 47.8m ^{3}/s.

Table 5 – Summary of Design Storm Peak Flows

HYDROLOGY METHOD	STORM EVENT	PEAK DISCHARGE
ARR 2016	45 minute - median	46.7 m^3/s
ARR 2016	45 minute - maximum	50.1 m^3/s
ARR 1987 – Zone 1	60 minute	47.8 m^3/s

When applying ARR 2016 hydrology, the median storm event is typically chosen as the design storm. In this instance, the ARR 1987 Zone 1 temporal pattern results in a peak discharge greater than the median event and has therefore been chosen as the design storm for the hydraulic assessment. The flood extents using both hydrology methods have been compared. Refer to Section 6 for further details.

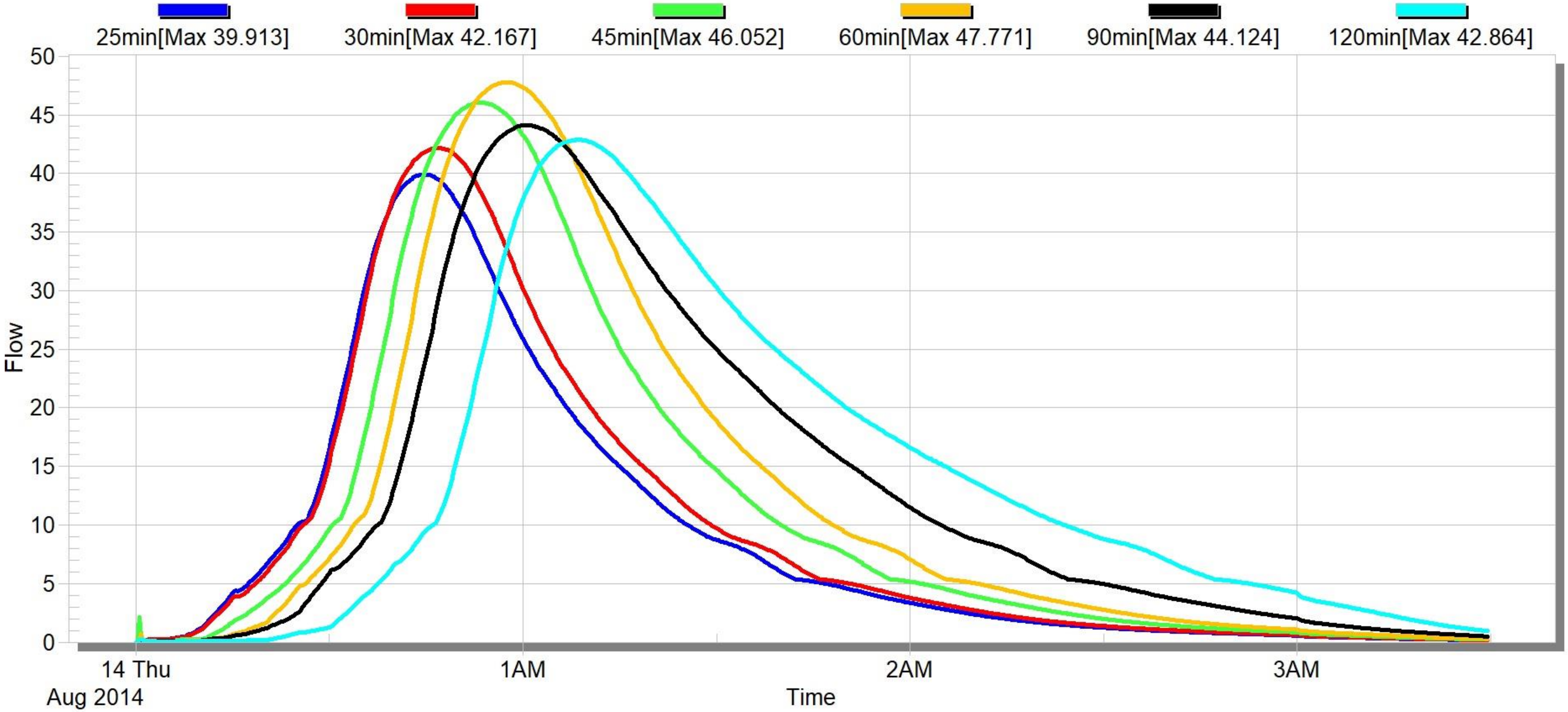


Figure 9 – Design Storm Hydrographs at Model Outlet – ARR 1987

4.8. RATIONAL METHOD COMPARISON

A comparison has been made between peak discharges provided by XP-STORM and those provided by Rational Method calculations. Although not formally a calibration process, it is an effective way to ensure roughness coefficients and loss rates are reasonable in the absence of recorded data. The comparison has been made against the results of the Australian Rainfall and Runoff (ARR) Zone 1 XP temporal pattern hydrologic model. The results of the comparison are summarised in Table 6. A summary of the time of concentration and Rational Method calculations is provided as Appendix B.

Table 6 – Summary of Rational Method Comparison

CATCH ID	RATIONAL METHOD (M^3/S)	XP-STORM (M^3/S)	DIFFERENCE (M^3/S)
Cat_1	0.97	1.10	0.13
Cat_2	2.44	2.52	0.08
Cat_3	1.07	1.05	-0.01
Cat_4	1.01	0.97	-0.04
Cat_5	1.51	1.73	0.22
Cat_6	1.55	1.70	0.15
Cat_7	0.17	0.23	0.06
Cat_8	0.60	0.72	0.12
Cat_9	0.77	0.78	0.01
Cat_10	0.55	0.53	-0.02
Cat_11	0.80	0.83	0.03
Cat_12	0.71	0.73	0.02
Cat_13	2.80	3.14	0.35
Cat_14	2.36	2.47	0.11
Cat_15	5.69	5.42	-0.27
Cat_16	4.11	4.22	0.11
Cat_17	5.04	5.28	0.24
Cat_18	3.16	3.09	-0.07
Cat_19	6.51	6.62	0.10
Cat_20	4.13	4.03	-0.10
Cat_21	3.26	3.69	0.43
Cat_22	2.51	3.45	0.94

As can be seen, the results of the hydrologic model compare well with those provided by the Rational Method and are therefore appropriate for use as part of this assessment. A negative value for difference indicates the XP-STORM peak flow rates are higher than the Rational Method.

5 HYDRAULIC MODELLING

The unsteady state, 1D/2D hydraulic model XP-STORM (incorporating TUFLOW as the model engine) was used to analyse the flood behaviour of the study area. LIDAR data from DNRM was utilised as part of this assessment and converted by XP-Storm to create a TIN for the study area, from which grid points (2D cells) were generated. Flows in excess of channel capacity break out and continue along the floodplain, as the topography dictates. Flood levels, discharge and velocity can be extracted from the model as functions of time at required locations. The XP-Storm model extent, outlet locations, and land use polygons are illustrated as Figure 10.

5.1. ROUGHNESS

Manning's n roughness values were estimated from aerial photography and included as 2D land use layers within XP-Storm. Much of the model area has been cleared and appears to have been used for grazing, and as such, a paddocks/grassland land use has been defined as the default for the model. There is some mature vegetation in the study area, and land use polygons have been defined based on the vegetation coverage of these areas which is typically along the drainage lines. A summary of adopted Manning's roughness values is provided in Table 7.

Table 7 – Manning's n Values

LAND USE	MANNING'S N VALUE
Paddocks/grazing/grass (default land use)	0.045
Medium Vegetation	0.055
Dense Vegetation	0.070
Water bodies/dams	0.025
Panel Area	0.060
Roads	0.015

5.2. BOUNDARY CONDITIONS

Hydrographs generated by the hydrologic model are applied as inputs to the hydraulic model and form the upstream boundary conditions. A 1D/2D interface is provided at the upstream extent of the active grid area. Additional catchment inflows are applied directly to the 2d model surface at points inside the model. Normal flow conditions are assumed for the downstream boundaries.

5.3. POST-DEVELOPMENT SCENARIO

The post-development scenario has been modified to include a higher Manning's roughness over the area of solar panel installation. A manning's n value of n = 0.06 has been adopted assuming support posts are spaced at 6m with little undergrowth in the panel areas. The extent of the increased roughness coefficient is illustrated in Figure 10.

In addition to this, the dam on the site has been filled by applying an elevation shape over the existing water body and flattening out the existing dam wall. Runoff is therefore conveyed as sheet flow over this area, rather than being concentrated into the dam.

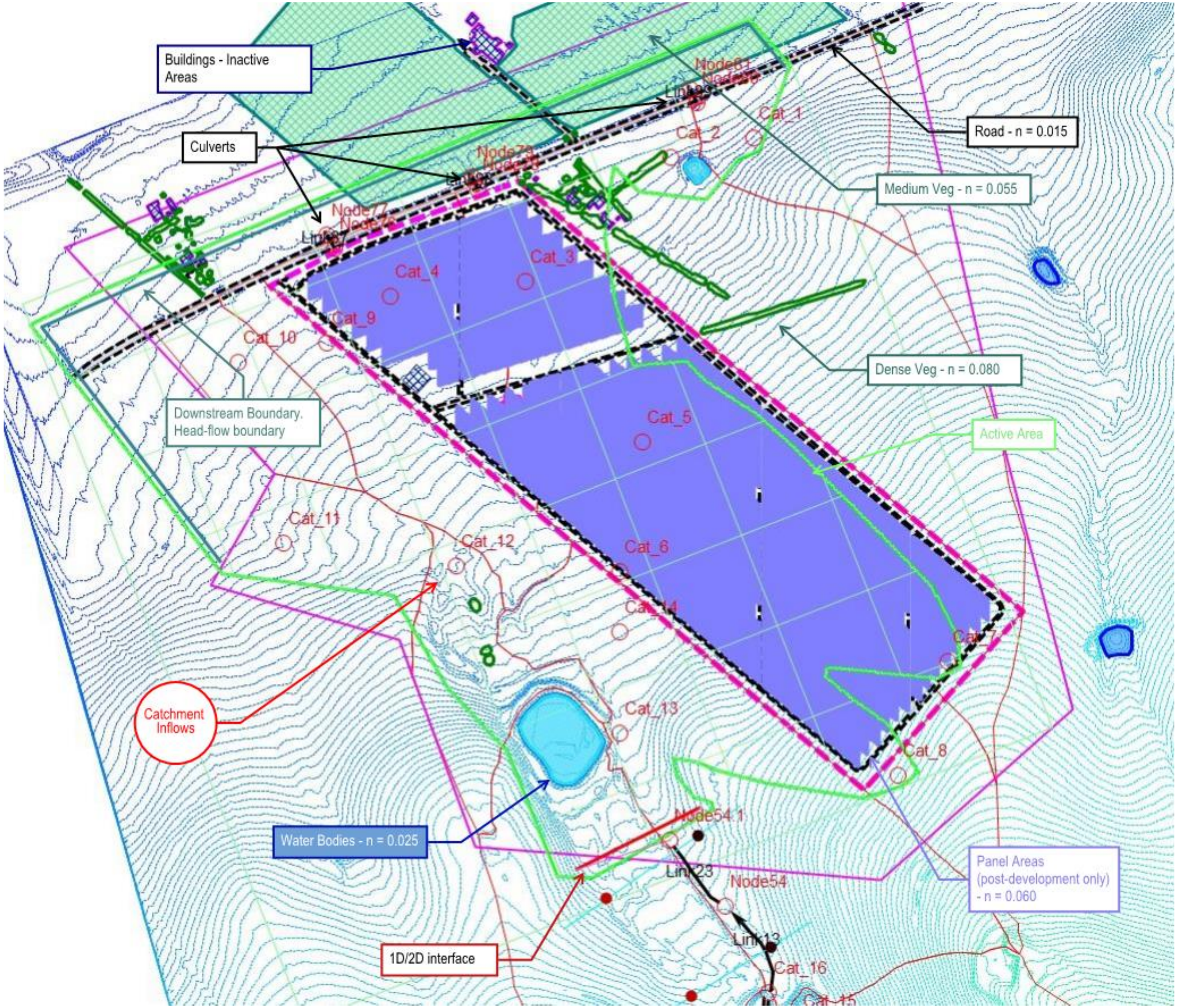


Figure 10 - Model Extents and Land Use Polygons

6 RESULTS

The results of the flood model have been extracted and presented as peak water level and maximum depth plots. The following plots are provided for the 1 % AEP critical duration (60 minute Zone 1 temporal pattern) maximum flow storm event:

+ Figure 11 – 1 % AEP Pre-Development Peak Water Level,
+ Figure 12 – 1 % AEP Pre-Development Maximum Depth Plot,
+ Figure 13 – 1 % AEP Pre-Development Maximum Depth Plot – Depths Greater than 100 mm,
+ Figure 14 – 1 % AEP Pre-Development Maximum Depth Plot – Depths Greater than 200 mm,
+ Figure 15 – 1 % AEP Pre-Development Maximum Depth Plot – Depths Greater than 300 mm,
+ Figure 16 – 1 % AEP Post-Development Peak Water Level,
+ Figure 17 – 1 % AEP Post-Development Maximum Depth Plot,
+ Figure 18 – 1 % AEP Post-Development Maximum Depth Plot – Depths Greater than 100 mm,
+ Figure 19 – 1 % AEP Post-Development Maximum Depth Plot – Depths Greater than 200 mm,
+ Figure 20 – 1 % AEP Post-Development Maximum Depth Plot – Depths Greater than 300 mm, and
+ Figure 21 - 1 % AEP Post-Development Maximum Depth – ARR 2016 Hydrology vs ARR 1987 Hydrology.

Review of the flood maps indicates large areas of shallow flooding across the site, with a minor increase in flood depths in the north western portion of the proposed panel array area. As demonstrated by the plots for depths greater than 100 mm, 200 mm and 300 mm, the inundation extent reduces considerably when these shallow flows are excluded from the mapping. Given the height above the ground at which the panels will be installed, it is reasonable to assume that panels could be located in these marginally affected flood areas and still remain operational while having no impact on flood levels.

6.1.1. AFFLUX ASSESSMENT

An afflux assessment was undertaken by comparing the pre- and post-development peak water levels and the results presented as Figure 22. As can be seen, the proposed development has minimal impact on the existing flood regime, with a minor increase in flood width observed within the site on the eastern flood fringe. It is noted however that this increase in flood width is contained within the site and <u>does not</u> impact the neighbouring property.

It is therefore considered there is no actionable nuisance for neighbouring properties as a result of the development.

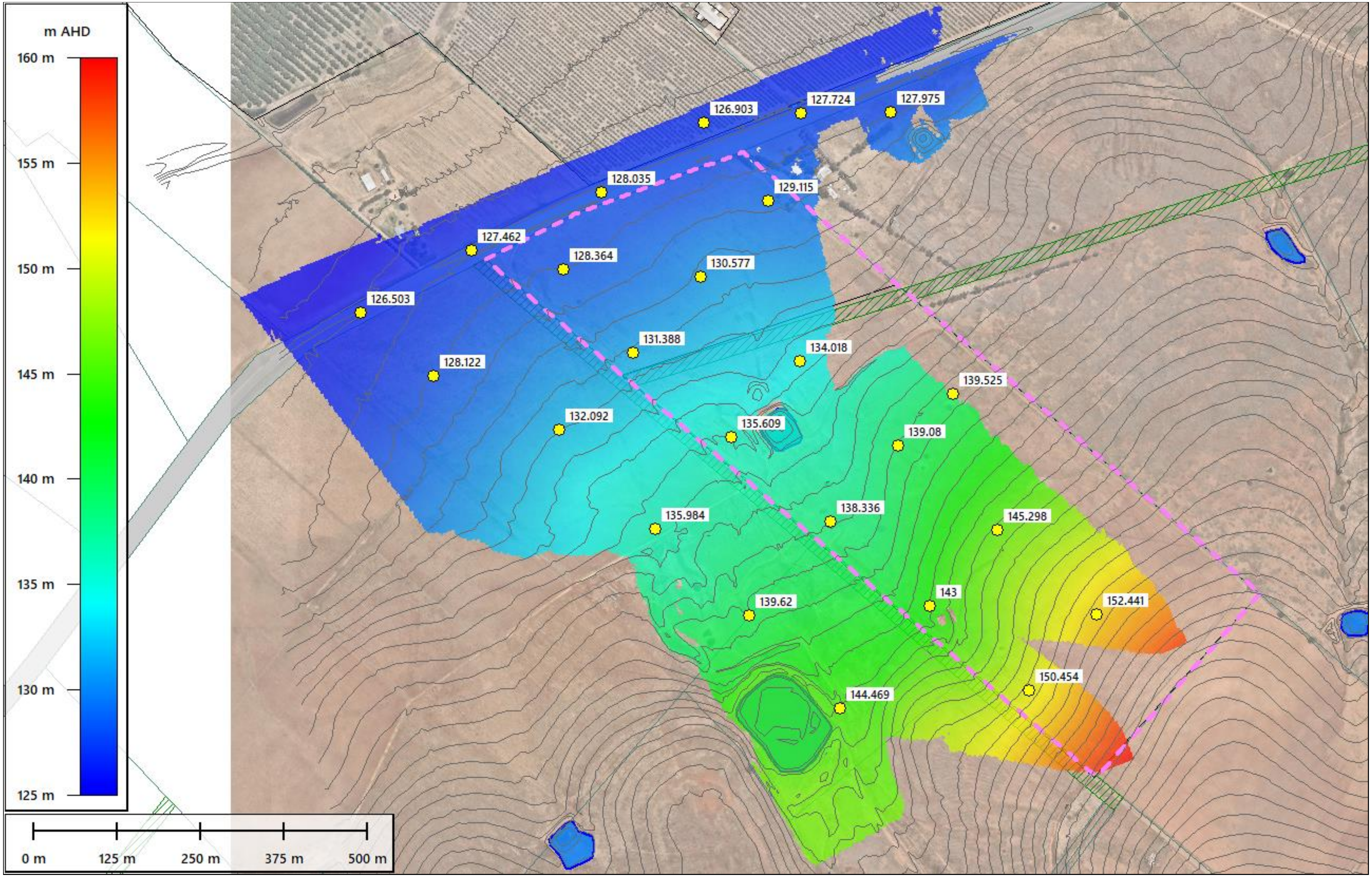


Figure 11 – 1 % AEP Pre-Development Peak Water Level

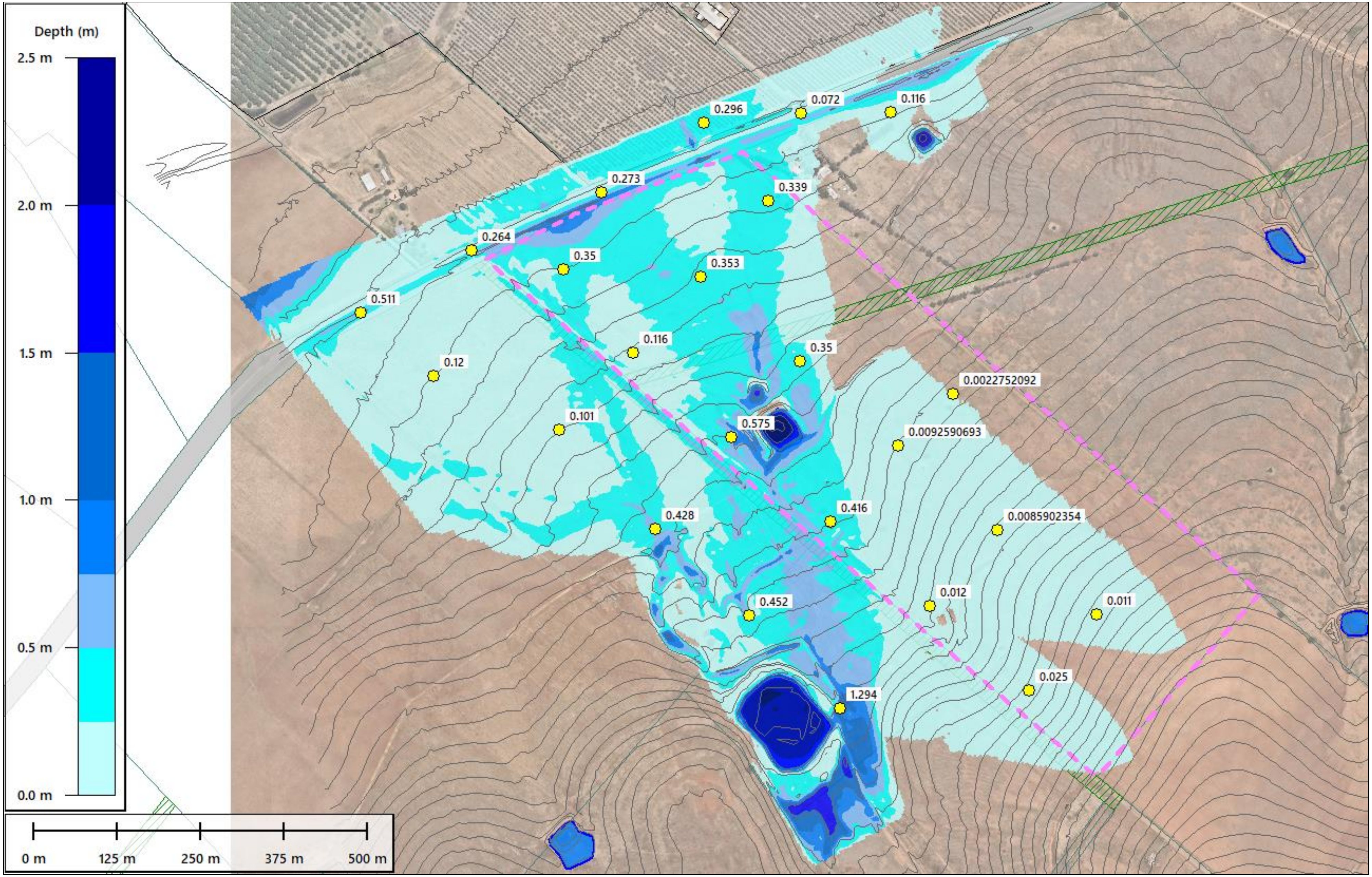


Figure 12 - 1 % AEP Pre-Development Peak Maximum Depth

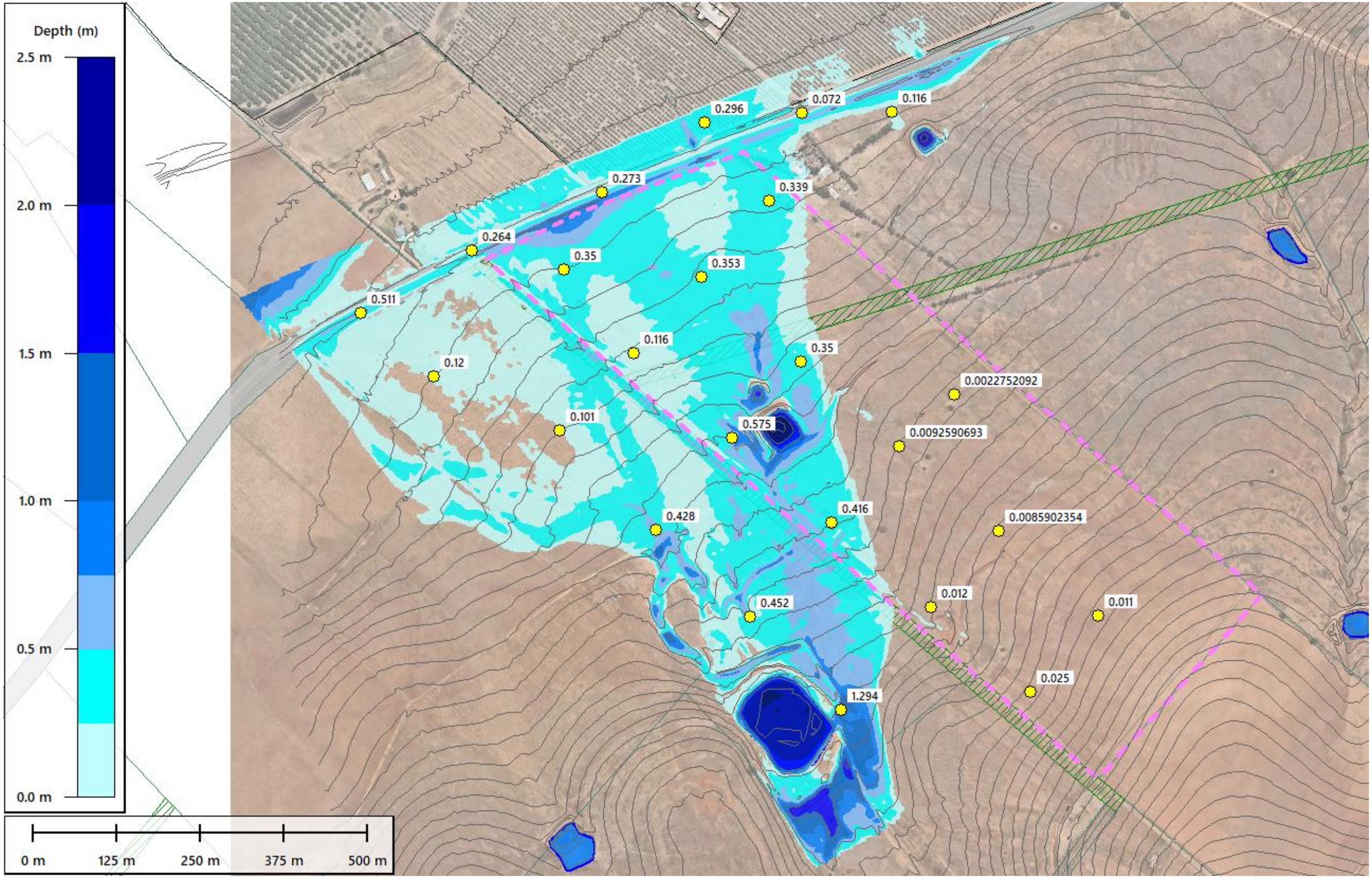


Figure 13 - 1 % AEP Pre-Development Peak Maximum Depth – Depths Greater than 100 mm

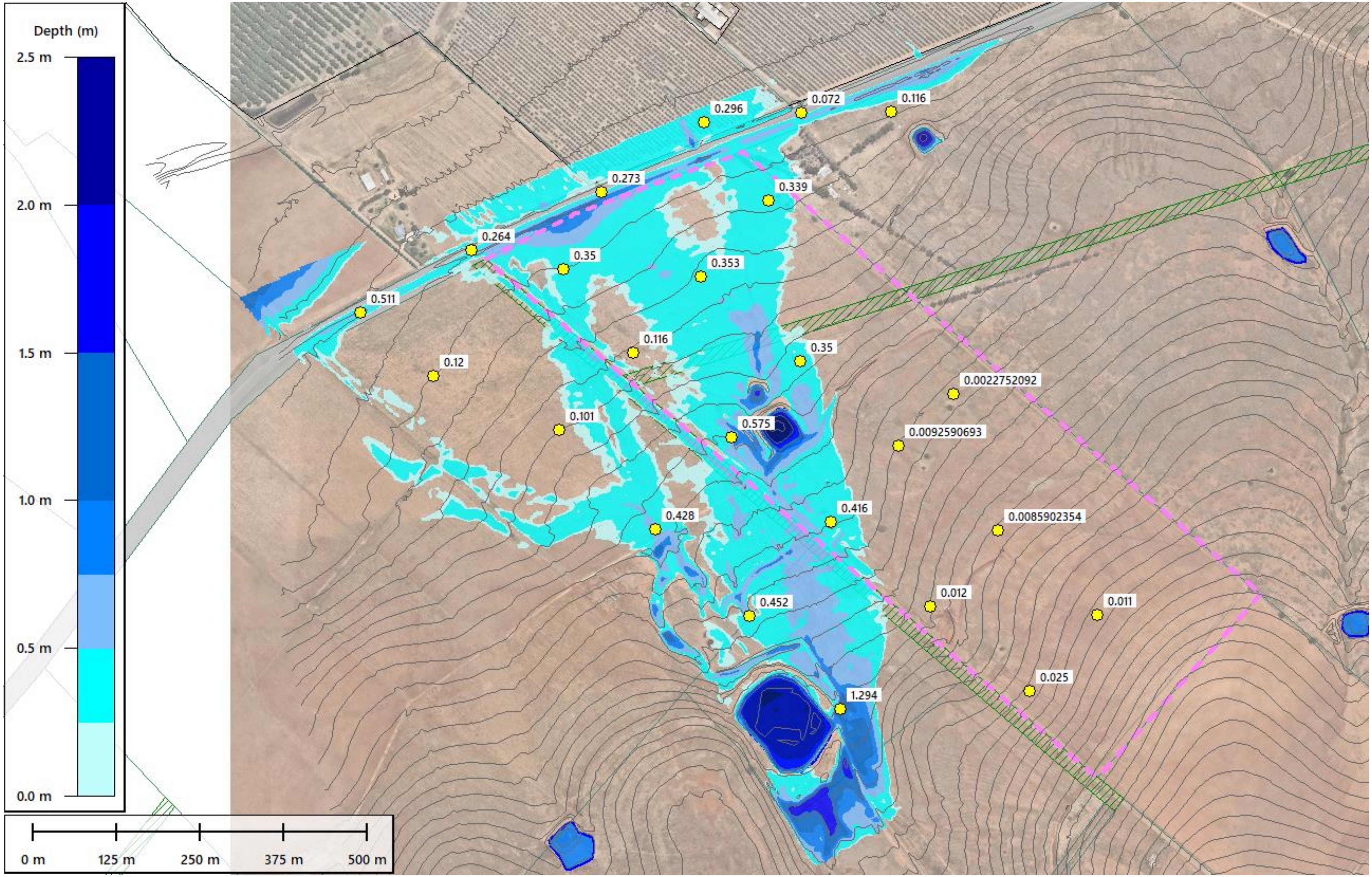


Figure 14 - 1 % AEP Pre-Development Peak Maximum Depth – Depths Greater than 200 mm

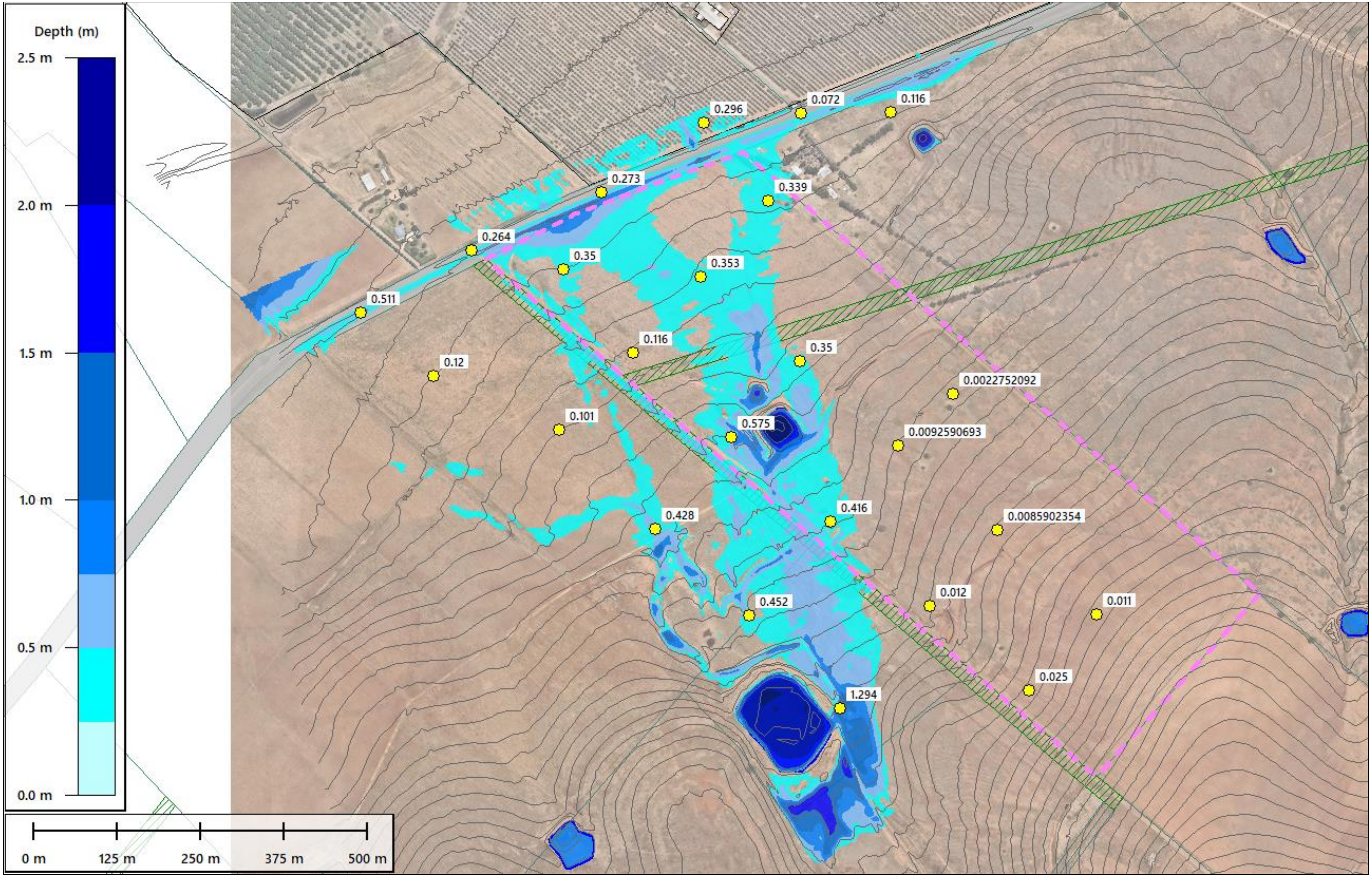


Figure 15 - 1 % AEP Pre-Development Peak Maximum Depth – Depths Greater than 300 mm

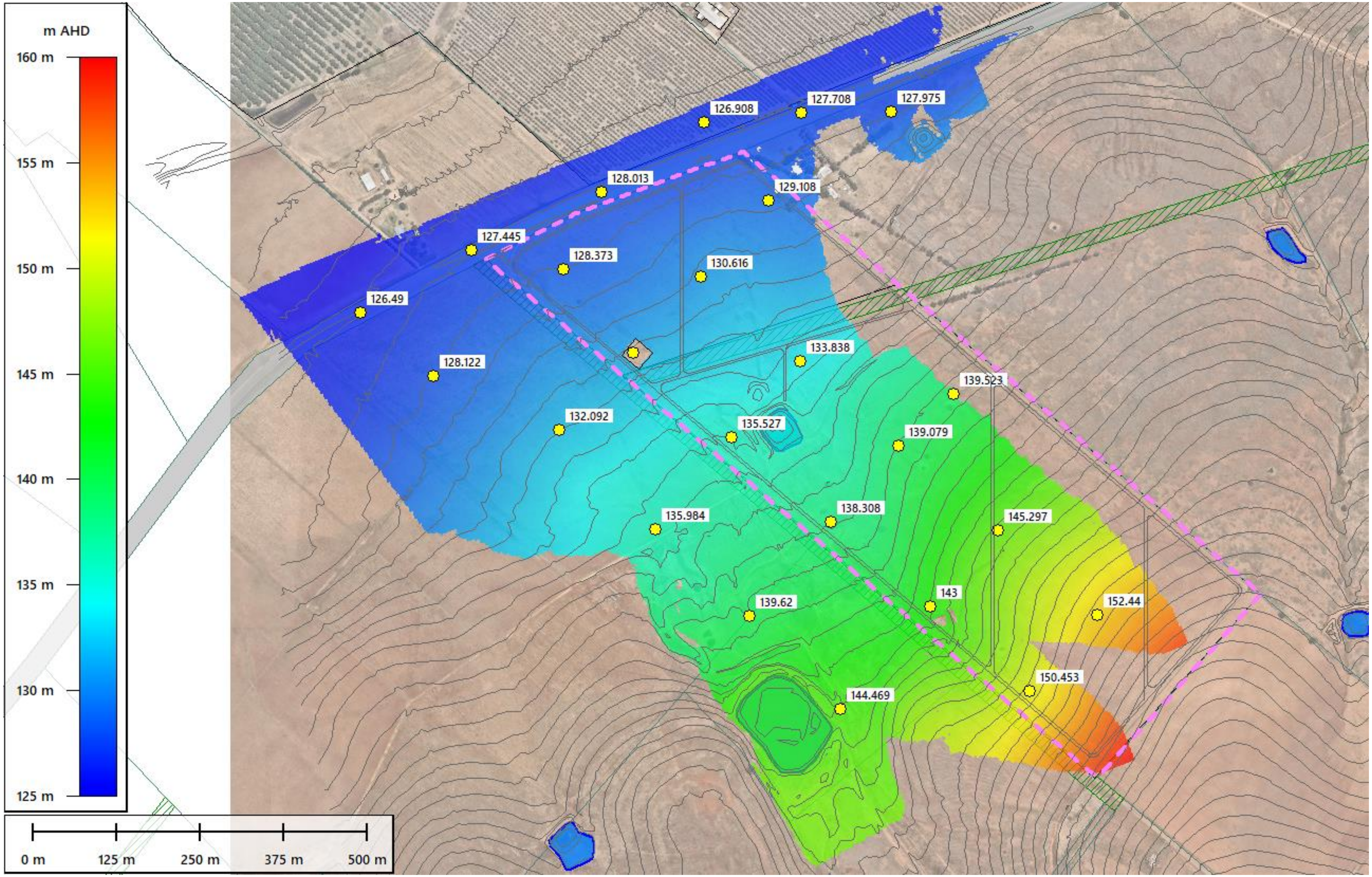


Figure 16 – 1 % AEP Post-Development Peak Water Level

TOPO.

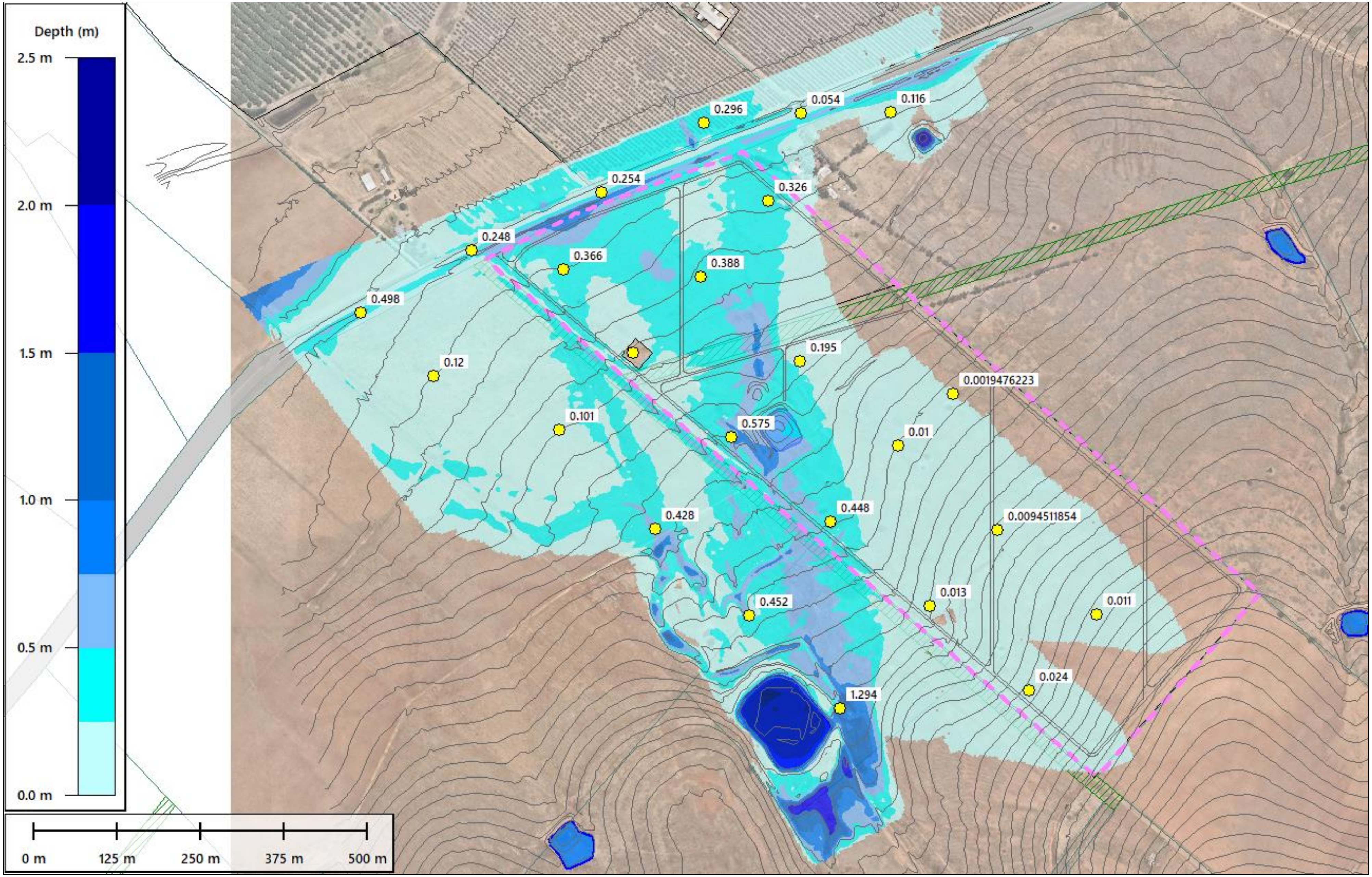


Figure 17 - 1 % AEP Post -Development Peak Maximum Depth

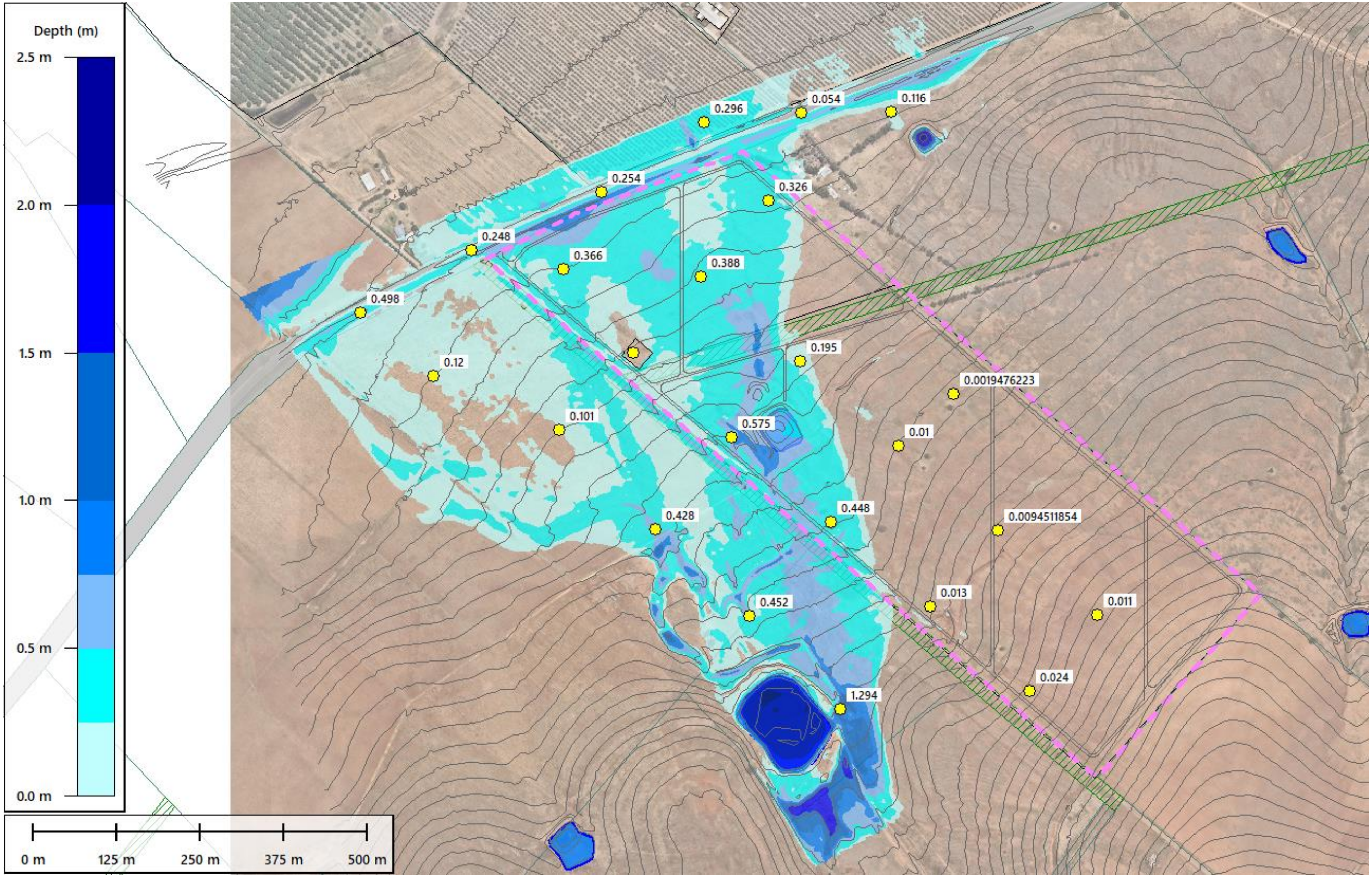


Figure 18 - 1 % AEP Post -Development Peak Maximum Depth – Depths Greater than 100 mm

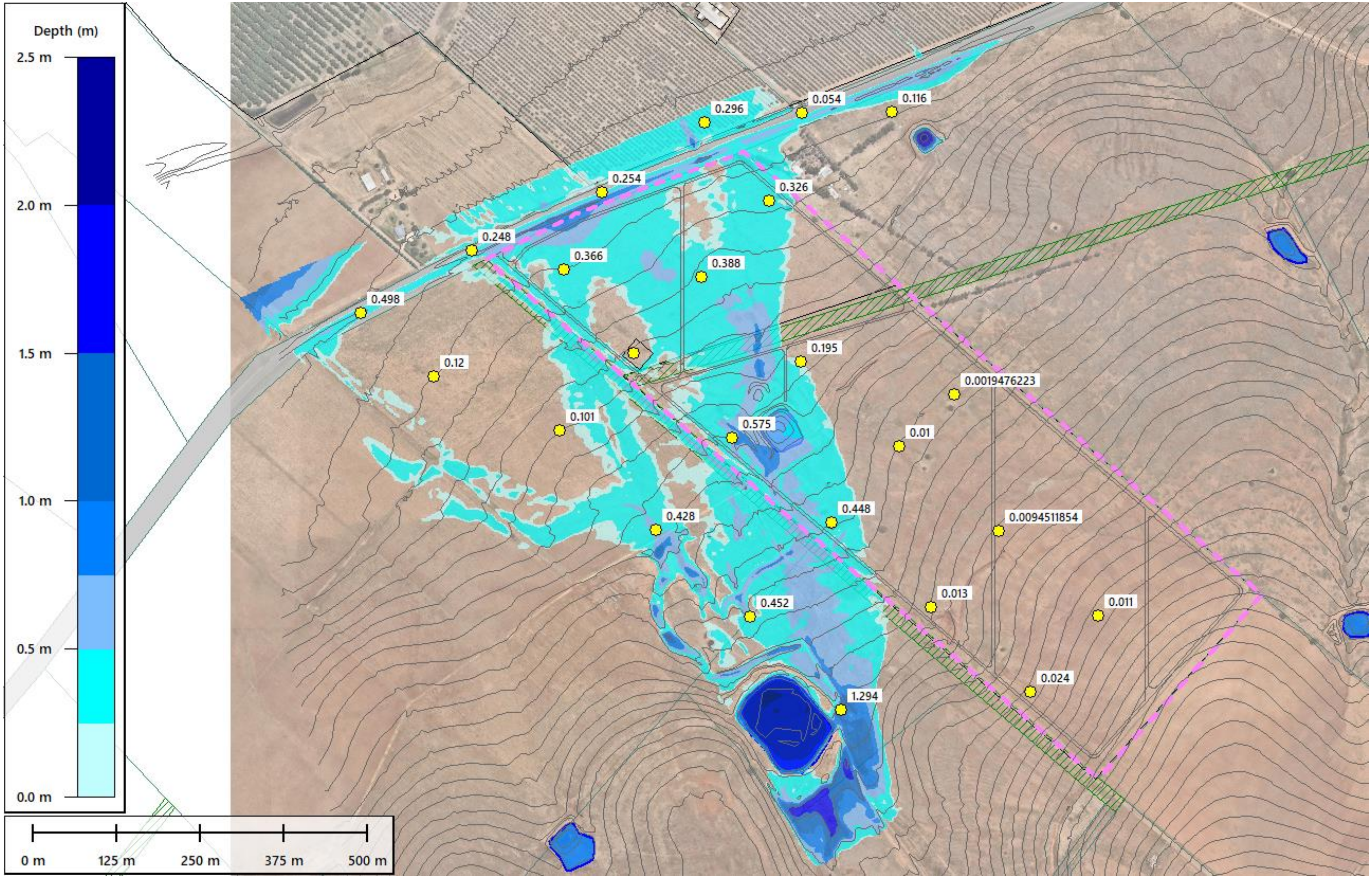


Figure 19 - 1 % AEP Post -Development Peak Maximum Depth – Depths Greater than 200 mm

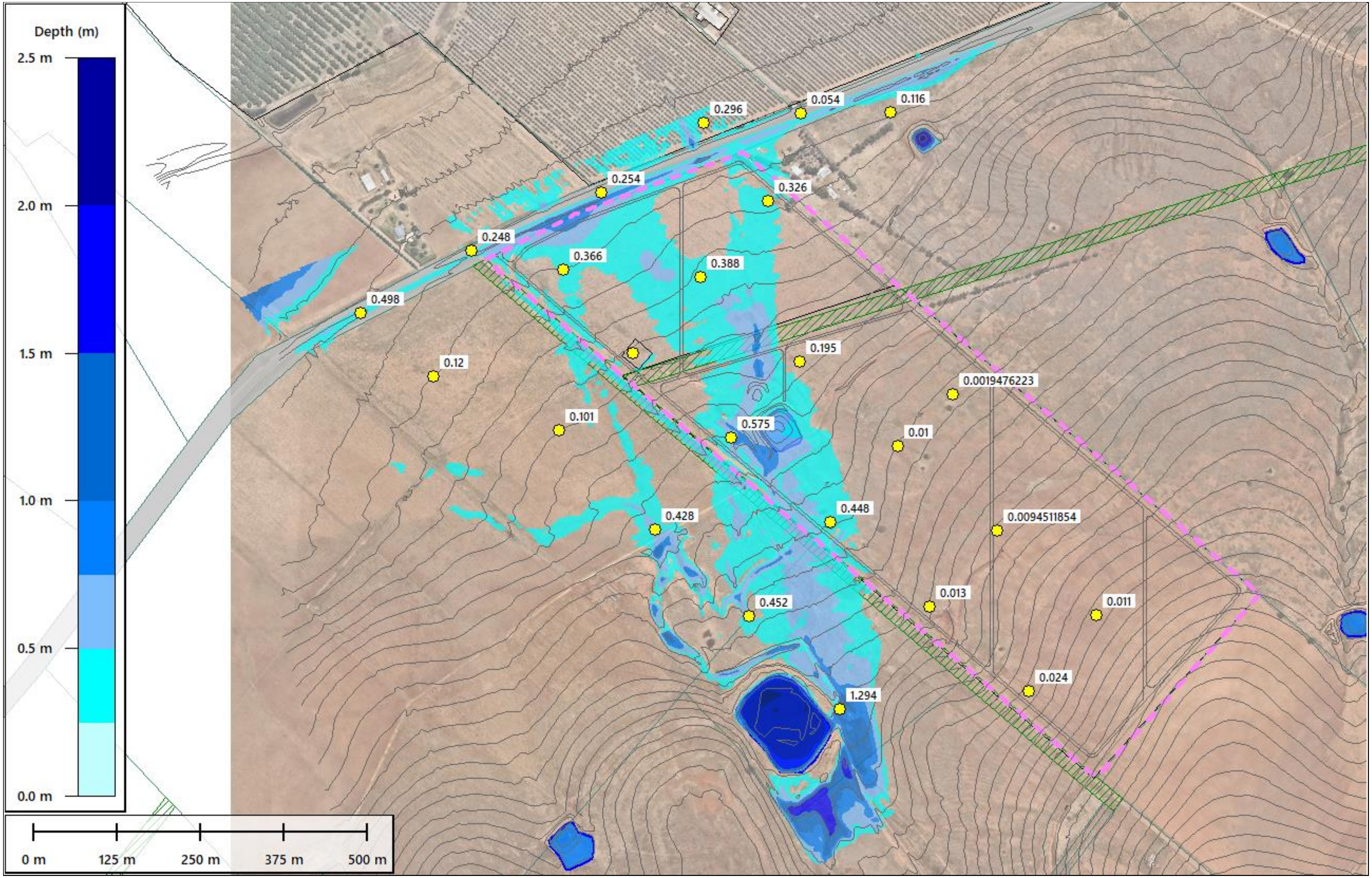


Figure 20 - 1 % AEP Post -Development Peak Maximum Depth – Depths Greater than 300 mm

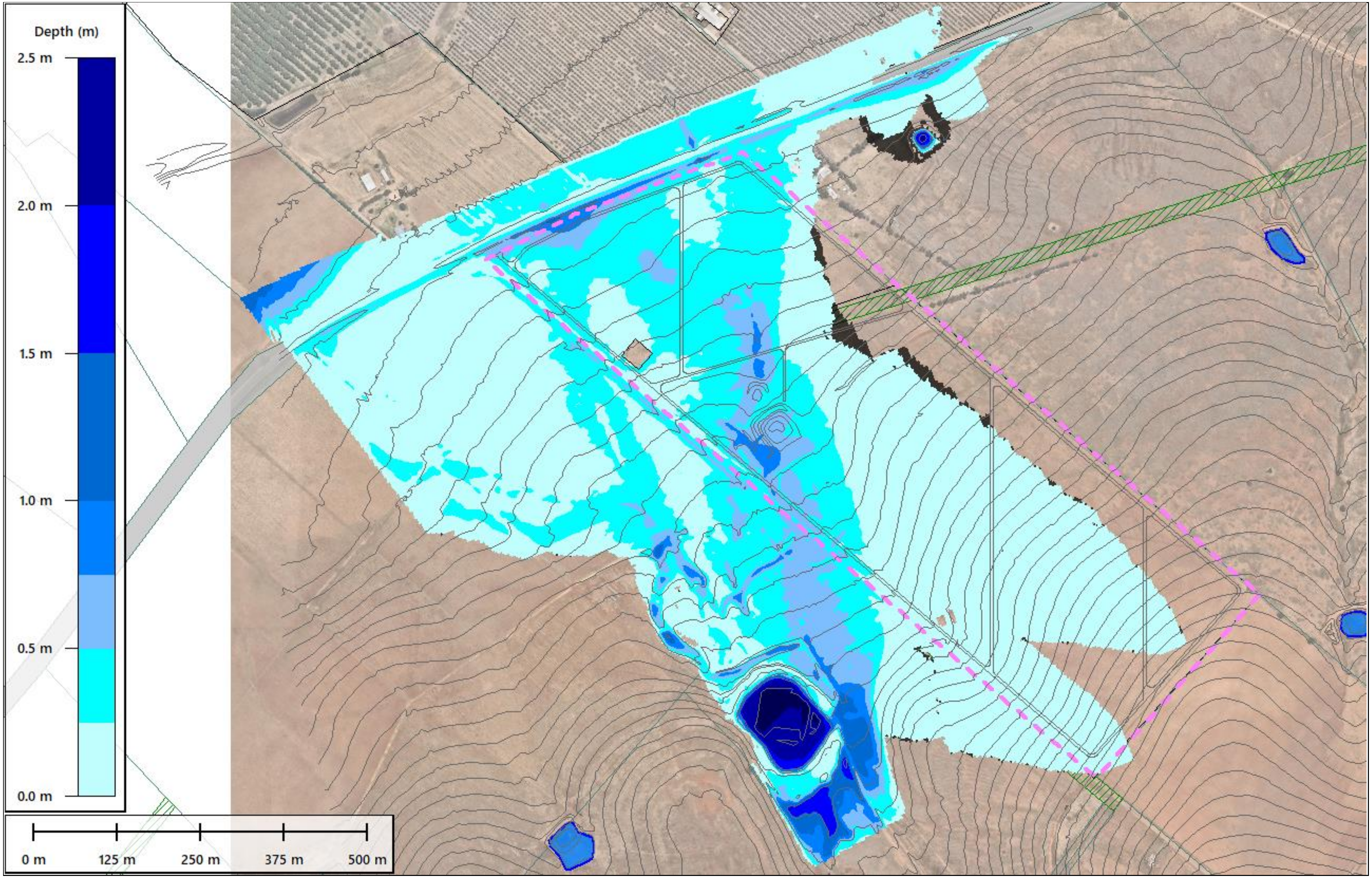


Figure 21 - 1 % AEP Post-Development Peak Maximum Depth – ARR 2016 Hydrology vs ARR 1987 Hydrology (shown in black)

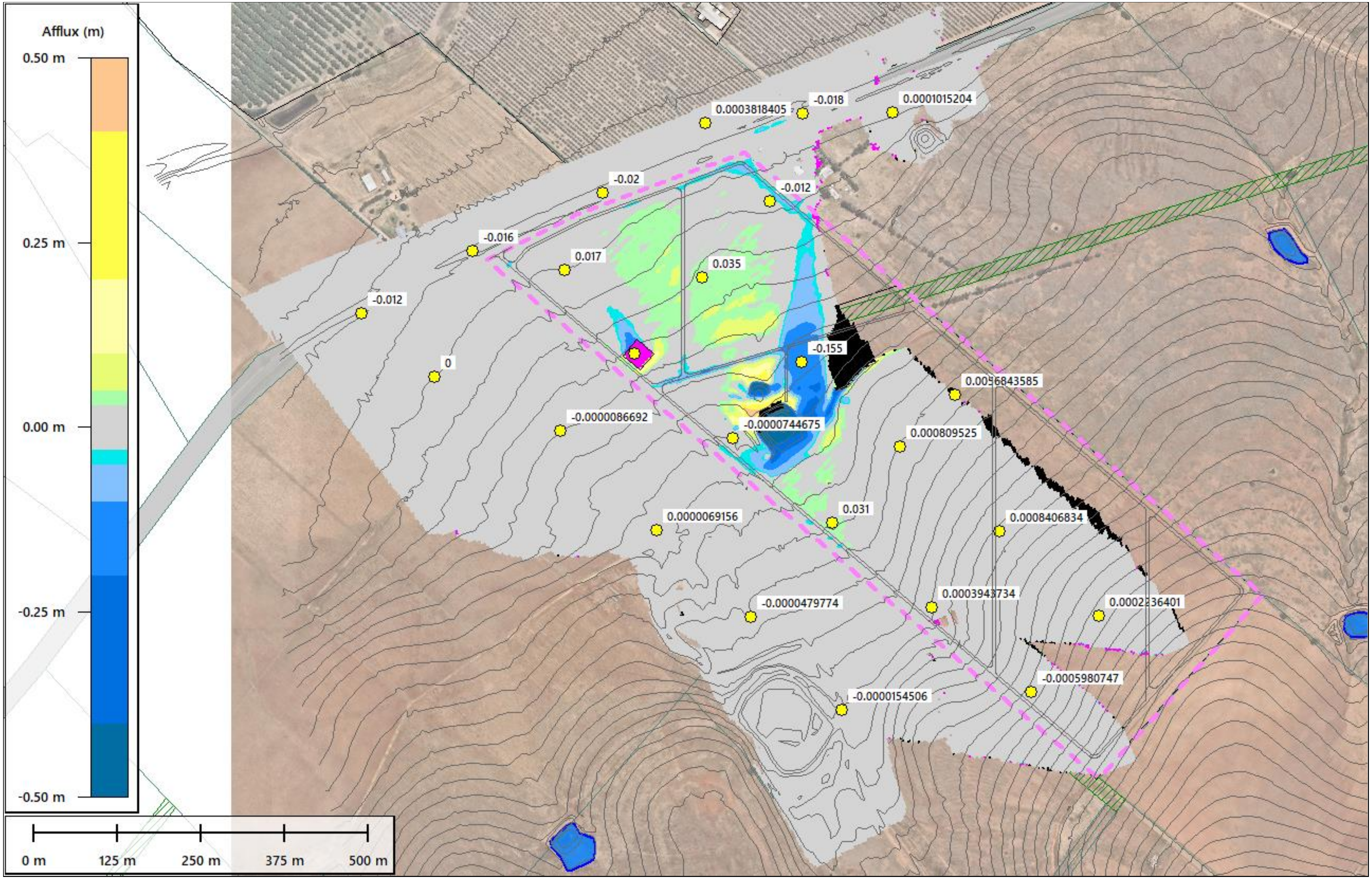


Figure 22 - 1 % AEP Afflux Assessment

7 STORMWATER QUALITY

7.1. CONSTRUCTION PHASE

The proposed works will involve only minor disturbance across the site during the construction phase, associated with trenching for services and driving of support piles for the panels. Additional works for the construction of the sub-station, inverter housings and formation of access roads will result in localised disturbance.

The effective management of stormwater runoff via the implementation of Erosion and Sediment Control (ESC) measures will be required during the construction phase to limit any impacts associated with erosion on the receiving flow paths.

It is recommended that an ESC plan be prepared prior to construction and in accordance with *Soils and Construction – Managing Urban Stormwater* (Landcom, 2004) and the *Best Practice Erosion and Sediment Control* guideline (IECA, 2008 & 2016), which specifies sediment and erosion control requirements based on assessed erosion risk and estimated soil loss. Given the nature of the site and the proposed works the erosion risk is expected to be very low to low. Failure to manage the site carefully and restrict the areas of disturbance will require additional stormwater treatment systems to be implemented and will potentially require the use of sediment basins to capture and treat runoff prior to it being released from the site.

7.2. OPERATIONAL PHASE

During the operational phase of the development, the site topography will be virtually unchanged from the pre-development scenario. It is proposed that internal roadways/access tracks and the sub-station will be gravel sheeted, with the remainder of the site remaining grassed. The solar panels will be raised off the ground and will not present any impediment to vegetative growth. Therefore, the increase in effective impervious surfaces as a result of the development will be negligible as runoff will fall from the panels to a grassed surface.

Adverse effects of increased impervious surfaces can be reduced by minimising those areas that have a direct connection to an impervious drainage system. For the proposed development, there is no direct connection of impervious surfaces to an impervious drainage system. Conveyance of runoff overland or within grassed swales reduces pollutant runoff, increases stormwater infiltration, and improves the quantity and quality of dry weather flows within streams through improved groundwater inflows.

The objective of this report is to assess the stormwater quality measures required to ensure the water quality of the receiving environment is not adversely impacted as a result of the development. Due to the minimal change in topography and negligible increase in impervious surfaces, it is considered any increase in pollutant loads will also be negligible. Conveyance of runoff over vegetated areas (i.e. buffer zones) will be sufficient to remove any entrained pollutants. If there is any chance that runoff may be concentrated by the formation of the access tracks, it should be conveyed by a swale drain and discharged via a level spreader to reduce the risk of erosion occurring along the tracks.

7.3. DESIGN OBJECTIVES

The *Muswellbrook Shire Development Control Plan Section 25 Storm Water Management* identified the following objective for pollutants:

> To ensure that stormwater generated from development does not result in pollution of water courses or receiving waters.

Given the nature of the development, the generation of gross pollutants will eb negligible, as will the generation of hydrocarbons as vehicle movement across the site, once operational, will be minimal. As previously noted, runoff will fall from the solar panels back onto a grassed/vegetated surface as occurs in the existing scenario, so the flow regime and generation of pollutants remains essentially unchanged from the pre-development scenario.

7.4. MODELLING & TREATMENT STRATEGY

7.4.1. SOFTWARE

An assessment has been made of the pre-and post-development pollutants loads using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) – Version 6.2.1. The modelling undertaken looks at the pollutant removal rates by conveying runoff through the site in vegetated swales.

7.4.2. CATCHMENTS

Modelling has been undertaken using a "split" catchment modelling approach. Therefore, the site has been divided into sub-catchments representing the roof, road and ground areas of the proposed development. The MUSIC catchment plan is included as Figure 23 and summarised in Table 8.

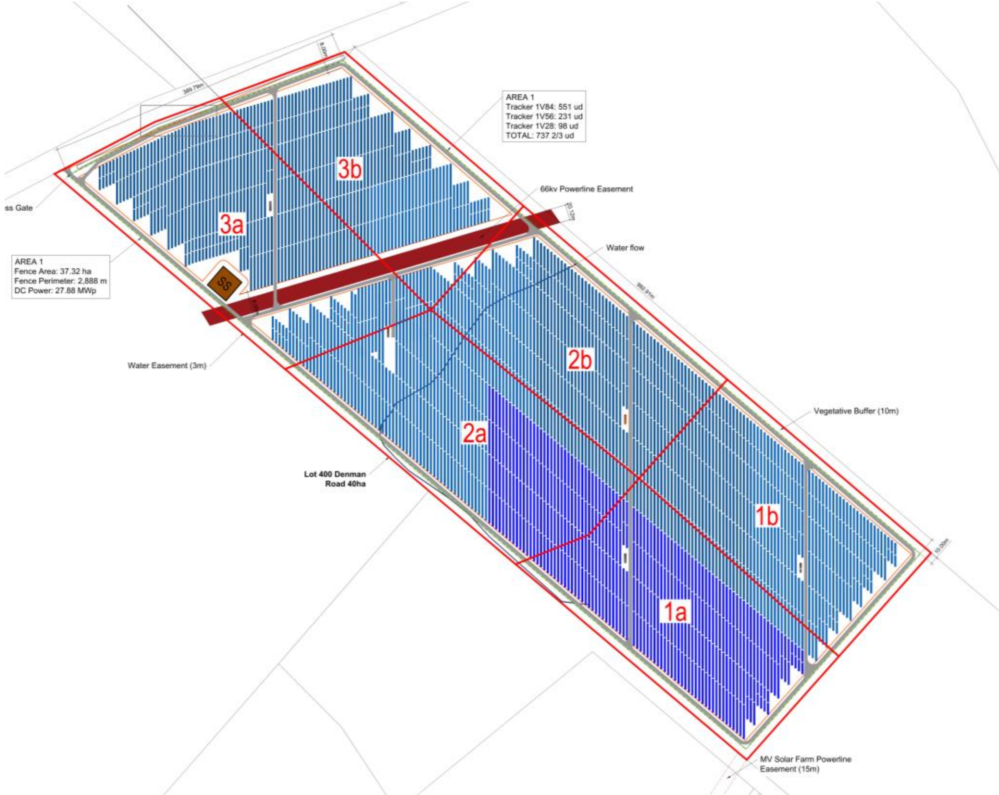


Figure 23 - MUSIC Catchment Plan

Table 8 – Catchment Definition

CATCHMENT ID	AREA (HA)	LAND USE	FRACTION IMP.
Inverter 1	0.006	Roof	100%
Inverter 2	0.006	Roof	100%
Inverter 3	0.003	Roof	100%
Substation	0.102	Ground	100%
Road 1a	0.314	Road	50%
Road 1b	0.314	Road	50%
Road 2a	0.214	Road	50%
Road 2b	0.214	Road	50%
Road 3a	0.361	Road	50%
Road 3b	0.361	Road	50%
Ground 1a	6.141	Ground	0%
Ground 1b	6.141	Ground	0%
Ground 2a	6.463	Ground	0%
Ground 2b	6.463	Ground	0%
Ground 3a	6.571	Ground	0%
Ground 3b	6.571	Ground	0%
TOTAL	**40.246-**	-	-

7.4.4. MUSIC MODEL PARAMETERS

The parameters utilised in the MUSIC model are provided in Table 9 to Table 12. Rainfall runoff and pollutant export parameters have been sourced from *Using MUSIC in Sydney Drinking Water Catchment* (WaterNSW, 2019).

7.4.5. TREATMENT TRAIN

Runoff from the site will be directed to a bioretention system. The details of the treatment elements are provided in Table 12.

Table 9 – Meteorological and Rainfall Runoff Data

INPUT	DATA USED IN MODELLING
Rainfall station	Tamworth Oxley Lane
Time step	6 minutes
Modelling period	1-1-1994 to 31-12-2009
Mean annual rainfall (mm)	598
Evapotranspiration (mm)	1,334
Rainfall runoff parameters	Rural Residential
Pollutant export parameters	Rural Residential

Table 10 – Rainfall Runoff Parameters

PARAMETER	SOURCE NODES
Landuse	Rural Residential
Rainfall threshold (mm)	1.5
Soil storage capacity (mm)	97
Initial storage (% capacity)	25
Field capacity (mm)	79
Infiltration capacity coefficient a	135
Infiltration capacity coefficient b	4.0
Initial depth (mm)	10
Daily recharge rate (%)	10
Daily baseflow rate (%)	10
Daily deep seepage rate (%)	0

Table 11 – Rural Residential Pollutant Export Parameters

LAND USE	FLOW TYPE	TSS (LOG_{10} MG/L)		TP (LOG_{10} MG/L)		TN (LOG_{10} MG/L)	
		MEAN	ST. DEV.	MEAN	ST. DEV.	MEAN	ST. DEV.
Ground	Baseflow	1.15	0.17	-1.22	0.19	-0.05	0.12
	Stormflow	1.95	0.32	-0.66	0.25	0.30	0.19
Road	Baseflow	1.20	0.17	-0.85	0.19	0.11	0.12
	Stormflow	3.0	0.32	-0.30	0.25	0.34	0.19
Roof	Baseflow	N/A	N/A	N/A	N/A	N/A	N/A
	Stormflow	1.30	0.32	-0.89	0.25	0.30	0.19

Table 12 – Swale Parameters

PARAMETER	VALUE
Length (m)	Varies (typically 175)
Bed Slope (%)	2.0
Base Width (m)	2.0
Top Width (m)	6.0
Depth (m)	1.0
Vegetation Height (m)	0.25
Exfiltration Rate (mm/hr)	0.0

Table 13 – Buffer Parameters

PARAMETER	VALUE
Percentage upstream area buffered (%)	100
Buffer Area (% of upstream impervious area)	50
Exfiltration Rate (mm/hr)	0.0

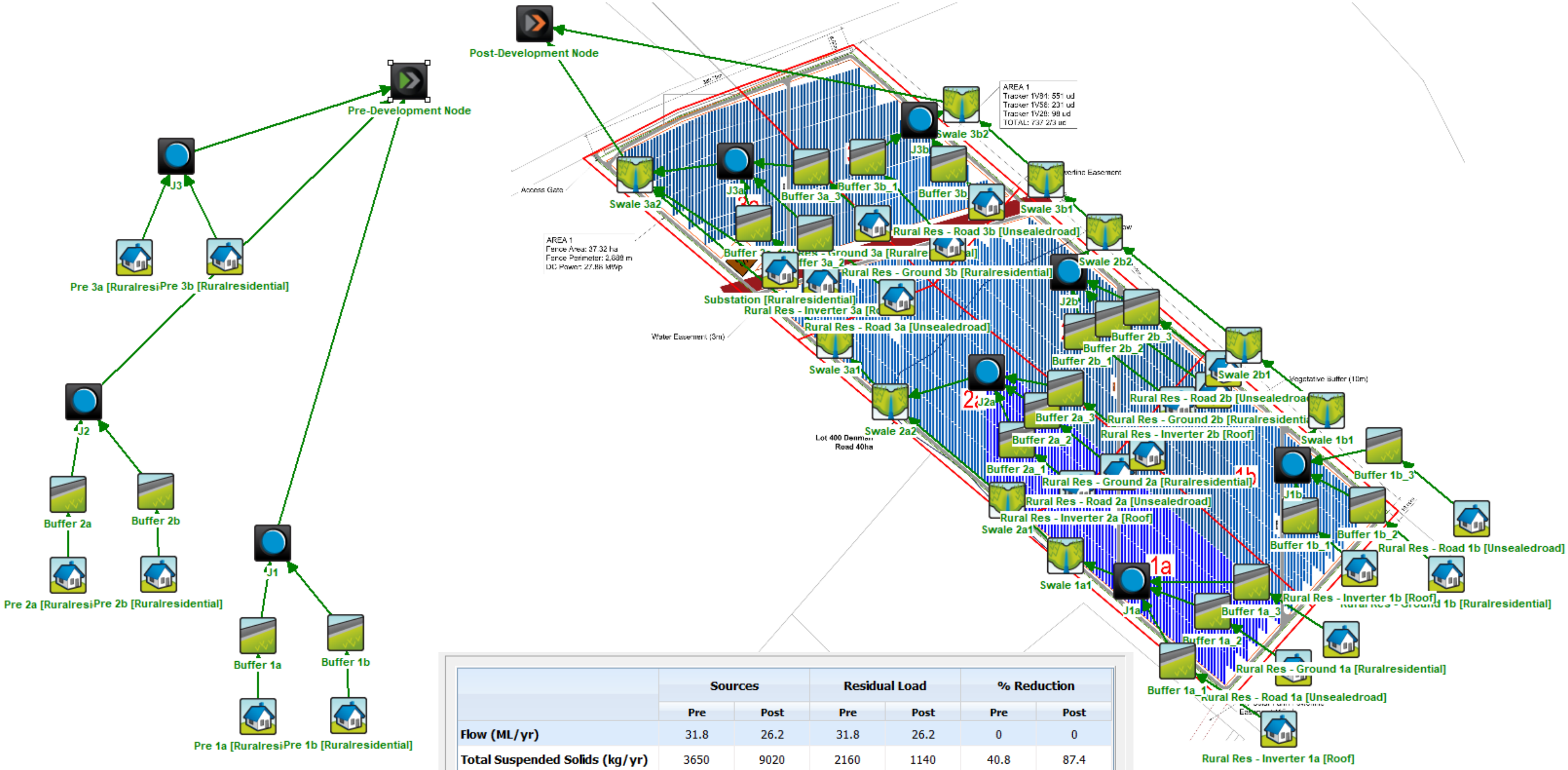
7.4.6. RESULTS

The results of the MUSIC model indicate the treatment train achieves the required design objectives, as summarised in Table 13 and Figure 7.

Table 14 – MUSIC Results

POLLUTANT	SOURCES		RESIDUAL LOAD		% REDUCTION	
	PRE	POST	PRE	POST	PRE	POST
Total Suspended Solids (kg/yr)	3,650	9,020	2,160	1,140	40.8	87.4
Total Phosphorus (kg/yr)	8.21	8.37	6.39	4.27	22.2	49
Total Nitrogen (kg/yr)	68.9	58.9	60.6	49.7	12	15.6
Gross Pollutants (kg/yr)	419	187	419	0	0	100

The results of this assessment show no increase in pollutant loads exiting the site in the post-development scenario. The MUSIC modelling suggests the incorporation of vegetated swales into the development will result in post-development load reductions of 87 %, 49 % and 16 % for TSS, TP and TN, which reduces the loads to less than the pre-development scenario.



	Sources		Residual Load		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	31.8	26.2	31.8	26.2	0	0
Total Suspended Solids (kg/yr)	3650	9020	2160	1140	40.8	87.4
Total Phosphorus (kg/yr)	8.21	8.37	6.39	4.27	22.2	49
Total Nitrogen (kg/yr)	68.9	58.9	60.6	49.7	12	15.6
Gross Pollutants (kg/yr)	419	187	419	0	0	100

Figure 24 - Screen Shot of Results and MUSIC Model

8 STORMWATER QUANTITY

During the detailed design phase, the additional impervious surfaces will be assessed and hydraulic modelling undertaken to assess the change in peak flow rate due to the development. It is not expected that any increase in peak flow rates will be observed due to the increase in fraction impervious being negligible. Therefore, no mitigation measures are proposed for maintaining pre-development peak flow rates from the site. Similarly, there will be no increase in peak flood levels for neighbouring properties as no earthworks are proposed that will result in the re-direction of flows or loss of floodplain storage.

As previously noted, the increase in fraction impervious is negligible as a result of the development. The construction of roadways and supporting infrastructure (i.e. sub-station) may have the potential to result in a minor increase in impervious surfaces, but due to the size of the catchment and magnitude of the existing flow rates it is considered highly unlikely the additional runoff will result in any change to the peak discharges for the site.

8.1.1. OPERATIONAL PHASE DRAINAGE

During the operational phase, it is recommended that slope lengths be limited by providing cross drainage bunds that divert runoff to a stable drain at the property boundary. Spacing of these bunds will be determined based on the recommendations of Table 4.3.2 (IECA, 2008). Based on the site topography, cross drainage structures will be required approximately every 50 m. Further assessment will be undertaken for these drainage features during the detailed design phase when access track and solar panel array locations are finalised.

9 SUMMARY

The primary objective of this flood study is to identify the flood constraints of the site. Review of the flood maps indicates the inundation extents are predominantly areas of shallow flooding. As demonstrated by the plots for depths greater than 100 mm, 200 mm and 300 mm, the inundation extents reduces considerably when these shallow flows are excluded from the mapping. Given the height above the ground at which the panels will be installed, it is reasonable to assume panels could be located in these marginally affected flood areas and still remain operational while having no impact on flood levels.

Rainfall landing on the solar panels will run off, falling onto a vegetated surface. The drip line at the base of the panels will vary as a result of their tracking movements. IT is therefore considered there will be no increase in impervious area because of the solar panels.

Due to the minimal increase in effective impervious surfaces across the site and the magnitude of the contributing external catchment, there will be an insignificant increase in peak flow rate in the post-development scenario. Therefore, there will be no adverse impacts for adjacent properties or roadways.

Due to the nature of the development, minimal change in topography and insignificant increase in impervious surfaces, it is considered pollutant loads exiting the site will remain essentially unchanged from the pre-development scenario. Conveyance of runoff over vegetated areas (i.e. buffer zones) will be sufficient to remove any entrained pollutants. Conveyance of runoff overland or within vegetated swales reduces pollutant loads, increases stormwater infiltration, and improves the quantity and quality of dry weather flows within streams through improved groundwater inflows. The water quality modelling undertaken in MUSIC supports this conclusion.

If there is any chance that runoff may be concentrated by the formation of the access tracks, it should be conveyed by a swale drain and discharged via a level spreader to reduce the risk of erosion.

No earthworks that divert, channelise or otherwise adversely impact the stormwater overland flows from or into neighbouring properties will be permitted. Cross drainage structures will be provided to ensure slope lengths and therefore the chance of rilling and gully erosion are reduced. These structures will also maximise the potential for infiltration. Any formalise drainage will be discharged across scour protection and level spreaders prior to it reaching Denman Road to ensure the pre-development flow regime is maintained.

10 CERTIFICATION

This report and associated modelling have been prepared by Steven Chamberlain of Topo (RPEQ 15,545).

Signature: Date: 12-2-2021

11 REFERENCES

Ball, J. et al., 2016. *Australian Rainfall and Runoff: A Guide to Flood Estimation).* [Online] Available at: http://arr.ga.gov.au/home [Accessed 03 07 2018].

IECA, 2008. *Best Practice Erosion and Sediment Control.* Picton, NSW: International Erosion Control Association (Australasia).

Landcom, 2004. *Soils and Construction - Managing Urban Stormwater,* s.l.: New South Wales Government.

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APPENDIX A

XP ARR STORM GENERATOR OUTPUT SUMMARY

APPENDIX B

RATIONAL METHOD

TIME OF CONCENTRATION

Table B1 – Overland Flow/Standard Inlet Time

CATCHMENT	ESTIMATED LENGTH OF SHEET FLOW (TABLE 4.06.3)	HORTONS ROUGHNESS VALUE	SLOPE (%)	TC (MINUTES)
Cat_1	100	0.045	2	19.43
Cat_2	100	0.045	3	17.91
Cat_3	100	0.045	2	19.43
Cat_4	100	0.045	1	22.31
Cat_5	100	0.045	5	16.17
Cat_6	100	0.045	5	16.17
Cat_7	100	0.045	4	16.91
Cat_8	100	0.045	6	15.59
Cat_9	100	0.045	2	19.43
Cat_10	100	0.045	2	19.43
Cat_11	100	0.045	3	17.91
Cat_12	100	0.045	3	17.91
Cat_13	100	0.045	7	15.12
Cat_14	100	0.045	7	15.12
Cat_15	100	0.045	6	15.59
Cat_16	100	0.045	5	16.17
Cat_17	100	0.045	7	15.12
Cat_18	50	0.045	11	10.97
Cat_19	50	0.045	16	10.17
Cat_20	50	0.045	10	11.18
Cat_21	50	0.045	19	9.83
Cat_22	100	0.045	8	14.72

Table B2 – Channel Flow Time

CATCHMENT	LENGTH OF CHANNEL FLOW (M)	VELOCITY (M/S)	TC (MINUTES)
Cat_1	276	1.5	3.07
Cat_2	879	0.9	16.28
Cat_3	340	0.7	8.10
Cat_4	395	0.7	9.40
Cat_5	570	0.7	13.57
Cat_6	653	0.9	12.09
Cat_7	45	1.5	0.50
Cat_8	240	1.5	2.67
Cat_9	560	0.7	13.33
Cat_10	284	0.7	6.76
Cat_11	250	0.7	5.95
Cat_12	395	0.7	9.40
Cat_13	1053	0.9	19.50
Cat_14	925	0.9	17.13
Cat_15	1190	3	6.61
Cat_16	990	1.5	11.00
Cat_17	970	1.5	10.78
Cat_18	830	1.5	9.22
Cat_19	850	3	4.72
Cat_20	900	1.5	10.00
Cat_21	530	3	2.94
Cat_22	365	3	2.03

Table B3 – Total Time of Concentration

CATCHMENT	TC (MINUTES)
Cat_1	22.49
Cat_2	34.19
Cat_3	27.52
Cat_4	31.72
Cat_5	29.74
Cat_6	28.27
Cat_7	17.41
Cat_8	18.26
Cat_9	32.76
Cat_10	26.19
Cat_11	23.87
Cat_12	27.32
Cat_13	34.62
Cat_14	32.25
Cat_15	22.21
Cat_16	27.17
Cat_17	25.90
Cat_18	20.19
Cat_19	14.90
Cat_20	21.18
Cat_21	12.78
Cat_22	16.75

Table B4 – Rational Method

Catchment	Area	I100	C100	Q100	I50	C50	Q50	I20	C20	Q20	I10	C10	Q10	I5	C5	Q5	I2	C2	Q2	I1	C1	Q1
Cat_1	6.55	111.0	0.48	0.97	97.3	0.46	0.81	80.9	0.42	0.62	69.2	0.40	0.50	59.0	0.38	0.41	46.8	0.34	0.29	37.3	0.32	0.22
Cat_2	21.93	83.4	0.48	2.44	73.6	0.46	2.06	61.4	0.42	1.57	52.6	0.40	1.28	45.0	0.38	1.04	35.8	0.34	0.74	28.6	0.32	0.56
Cat_3	8.41	95.1	0.48	1.07	83.8	0.46	0.90	69.7	0.42	0.68	59.7	0.40	0.56	51.0	0.38	0.45	40.5	0.34	0.32	32.4	0.32	0.24
Cat_4	8.74	86.9	0.48	1.01	76.7	0.46	0.86	63.9	0.42	0.65	54.8	0.40	0.53	46.8	0.38	0.43	37.2	0.34	0.31	29.8	0.32	0.23
Cat_5	12.49	90.8	0.48	1.51	80.0	0.46	1.28	66.7	0.42	0.97	57.2	0.40	0.79	48.8	0.38	0.64	38.8	0.34	0.46	31.0	0.32	0.34
Cat_6	12.20	95.1	0.48	1.55	83.8	0.46	1.31	69.7	0.42	0.99	59.7	0.40	0.81	51.0	0.38	0.66	40.5	0.34	0.47	32.4	0.32	0.35
Cat_7	1.02	128.0	0.48	0.17	113.0	0.46	0.15	93.4	0.42	0.11	79.9	0.40	0.09	68.0	0.38	0.07	53.9	0.34	0.05	43.0	0.32	0.04
Cat_8	3.62	124.0	0.48	0.60	109.0	0.46	0.50	90.6	0.42	0.38	77.5	0.40	0.31	66.0	0.38	0.25	52.3	0.34	0.18	41.7	0.32	0.13
Cat_9	6.77	85.1	0.48	0.77	75.1	0.46	0.65	62.6	0.42	0.49	53.7	0.40	0.40	45.9	0.38	0.33	36.5	0.34	0.23	29.2	0.32	0.18
Cat_10	4.10	99.8	0.48	0.55	87.8	0.46	0.46	73.1	0.42	0.35	62.6	0.40	0.29	53.4	0.38	0.23	42.4	0.34	0.16	33.8	0.32	0.12
Cat_11	5.70	105.0	0.48	0.80	92.3	0.46	0.67	76.8	0.42	0.51	65.7	0.40	0.42	56.0	0.38	0.34	44.4	0.34	0.24	35.5	0.32	0.18
Cat_12	5.45	97.4	0.48	0.71	85.7	0.46	0.60	71.4	0.42	0.45	61.1	0.40	0.37	52.1	0.38	0.30	41.4	0.34	0.21	33.1	0.32	0.16
Cat_13	25.69	81.7	0.48	2.80	72.1	0.46	2.37	60.2	0.42	1.80	51.6	0.40	1.47	44.1	0.38	1.20	35.1	0.34	0.85	28.1	0.32	0.64
Cat_14	20.35	86.9	0.48	2.36	76.7	0.46	1.99	63.9	0.42	1.52	54.8	0.40	1.24	46.8	0.38	1.01	37.2	0.34	0.71	29.8	0.32	0.54
Cat_15	38.42	111.0	0.48	5.69	97.3	0.46	4.78	80.9	0.42	3.63	69.2	0.40	2.95	59.0	0.38	2.39	46.8	0.34	1.70	37.3	0.32	1.27
Cat_16	31.64	97.4	0.48	4.11	85.7	0.46	3.46	71.4	0.42	2.64	61.1	0.40	2.15	52.1	0.38	1.74	41.4	0.34	1.24	33.1	0.32	0.93
Cat_17	37.87	99.8	0.48	5.04	87.8	0.46	4.25	73.1	0.42	3.23	62.6	0.40	2.63	53.4	0.38	2.13	42.4	0.34	1.52	33.8	0.32	1.14
Cat_18	20.26	117.0	0.48	3.16	103.0	0.46	2.67	85.5	0.42	2.02	73.1	0.40	1.65	62.3	0.38	1.33	49.3	0.34	0.94	39.4	0.32	0.71
Cat_19	35.66	137.0	0.48	6.51	120.0	0.46	5.47	99.6	0.42	4.14	85.2	0.40	3.38	72.5	0.38	2.73	57.4	0.34	1.93	45.9	0.32	1.45
Cat_20	27.19	114.0	0.48	4.13	100.0	0.46	3.47	83.1	0.42	2.64	71.1	0.40	2.15	59.4	0.38	1.70	43.3	0.34	1.11	38.3	0.32	0.93
Cat_21	16.74	146.0	0.48	3.26	129.0	0.46	2.76	107.0	0.42	2.09	91.2	0.40	1.70	77.7	0.38	1.37	61.5	0.34	0.97	49.1	0.32	0.73
Cat_22	14.73	128.0	0.48	2.51	113.0	0.46	2.13	93.4	0.42	1.60	79.9	0.40	1.31	68.0	0.38	1.06	53.9	0.34	0.75	43.0	0.32	0.56