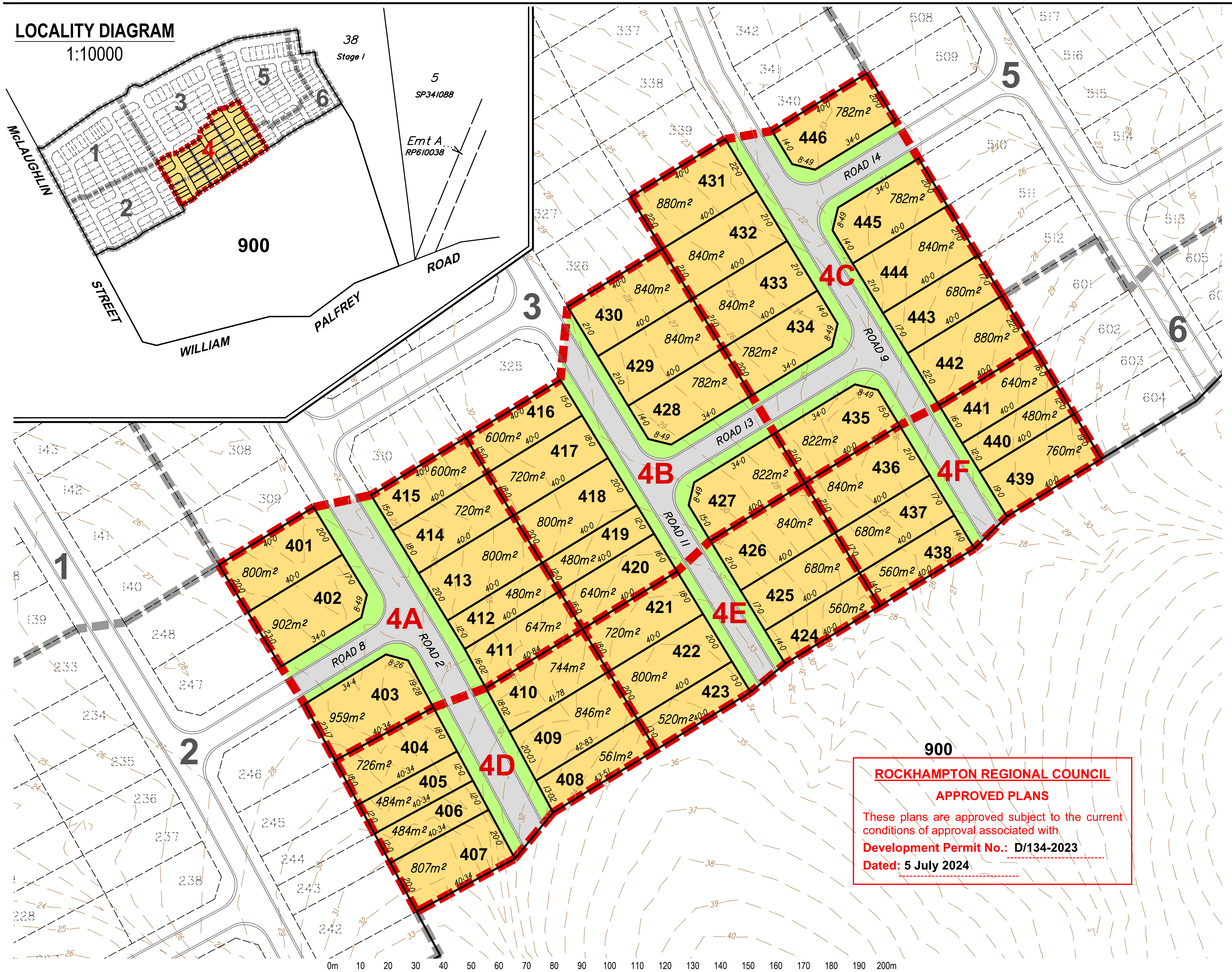

ROCKHAMPTON REGIONAL COUNCIL

APPROVED PLANS

These plans are approved subject to the current conditions of approval associated with

Development Permit No.: D/134-2023

Dated: 5 July 2024

# WESTERN PRECINCT

## IMPORTANT NOTE

This plan was prepared to accompany an application to Rockhampton Regional Council and should not be used for any other purpose.

The dimensions and areas shown hereon are subject to field survey and also to the requirements of council and any other authority which may have requirements under any relevant legislation.

In particular, no reliance should be placed on the information on this plan for any financial dealings involving the land.

This note is an integral part of this plan.

client

**MAAS Group Properties**
**Ellida Pty Limited**
**A.C.N. 657 243 233**

project

**Ellida Estate**
**23-27 William Palfrey Road,**
**Parkhurst**

plan of

**Reconfiguration Plan**
**Stage 4**
**(46 Residential Lots + Balance)**

rpd

**Lot 37 on SP341088**

lga

**Rockhampton Regional Council**

| issue | date | details | authorised |
|---|---|---|---|
| A | 4-09-2023 | Initial Issue | RJKF |
| B | 25-09-2023 | Layout amended, 1 lot added | RJKF |
| C | 17-01-2024 | Layout amended, 2 lots removed | RJKF |
| D | 6-02-2024 | Sub-staging added | RJKF |
| E | 23-05-2024 | Lot numbering amended | RJKF |

created

capricornsurveygroupcq
SURVEYING & PLANNING SOLUTIONS
07 4927 5199 | reception@csgcq.com.au | 132 Victoria Parade, Rockhampton QLD 4700

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ROCKHAMPTON REGIONAL COUNCIL

APPROVED PLANS

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**Development Permit No.:** D/134-2023

**Dated:** 5 July 2024

MAAS GROUP PROPERTIES PTY LTD

# ELLIDA, PARKHURST WESTERN STAGES 1-6

## STORMWATER MANAGEMENT PLAN AND HYDRAULIC IMPACT ASSESSMENT

Report No: MPG0001/R04
Rev: B
8 February 2024

| **DOCUMENT AUTHORISATION** | | | | | |
|---|---|---|---|---|---|
| **Revision** | **Revision Date** | **Report Details** | | | |
| A | 25/10/23 | Stormwater Management Plan and Hydraulic Impact Assessment | | | |
| B | 09/02/2024 | Stormwater Management Plan and Hydraulic Impact Assessment | | | |
| | | | | | |
| **Prepared By** | **Initial** | **Reviewed By** | **Initial** | **Authorised By** | **Signature** |
| Sina Iva | SI | Jeremy Cox | JC | Jeremy Cox | |

# CONTENTS

**1. AMENDMENTS INCLUDED IN THE STORMWATER MANAGEMENT PLAN ........ 1**

**3. INTRODUCTION ........ 3**

3.1 STUDY OBJECTIVES ........ 3

**4. DATA ........ 4**

**5. SITE CHARACTERISTICS ........ 4**

5.1 SITE AREA AND LOCATION ........ 4

5.2 EXISTING DRAINAGE AND TOPOGRAPHY ........ 5

5.3 PROPOSED DEVELOPMENT ........ 5

5.4 PROPOSED DRAINAGE ........ 5

**6. STORMWATER QUANTITY MANAGEMENT ........ 6**

6.1 LAWFUL POINT OF DISCHARGE ........ 6

6.2 HYDROLOGIC MODELLING APPROACH ........ 6

6.3 HYDROLOGIC MODEL RESULTS ........ 7

6.4 MANAGEMENT OF INCREASED RUNOFF ........ 8

**7. HYDRAULIC ASSESSMENT ........ 9**

7.1 MODEL CONSISTENCY ........ 9

7.2 MODEL TOPOGRAPHY ........ 10

7.3 HYDRAULIC MODEL ROUGHNESS ........ 10

7.4 POST-DEVELOPMENT MITIGATED SCENARIO ........ 11

7.5 HYDRAULIC ASSESSMENT RESULTS ........ 11

**8. STORMWATER QUALITY ........ 11**

8.1 WATERWAY STABILITY ........ 12

8.2 CONSTRUCTION PHASE ........ 12

8.3 STORMWATER QUALITY MODELLING ........ 12

8.1 STORMWATER QUALITY MODEL RESULTS ........ 15

**9. CONCLUSION ........ 16**

**10. QUALIFICATIONS ........ 17**

**11. RPEQ CERTIFICATION ........ 17**

**12. REFERENCES ........ 18**

# FIGURES

Figure 1: Aerial Image of Site Location (Source: QGIS) .......... 4
Figure 2: Location of Development within Ramsay Creek Regional Catchments .......... 7
Figure 3: MUSIC Model Schematic (Source: eWater MUSIC) .......... 15

# TABLES

Table 1: Summary of Sub-Catchment Characteristics .......... 7
Table 2: Peak Discharge Summary – Local Catchments .......... 8
Table 3. Detention Characteristics .......... 8
Table 5: Critical Storm Durations - Ramsay Creek Model .......... 9
Table 6:  Manning's Rougness Coefficients - Ramsay Creek Model .......... 10
Table 7: Typical Construction Phase Pollutants .......... 12
Table 8: MUSIC Model Catchment Parameters .......... 13
Table 9: Monthly Evapotranspiration Data at Rockhampton Aero Station .......... 13
Table 10: Treatment Device parameters – Bioretention Basin .......... 14
Table 11: Treatment Train Effectiveness at Receiving Node .......... 15

# APPENDICES

APPENDIX A PROPOSED LAYOUT PLAN
APPENDIX B CATCHMENTS
APPENDIX C MODEL DATA
APPENDIX D MODEL SETUP
APPENDIX E PRE-DEVELOPMENT HYDRAULIC MODEL RESULTS
APPENDIX F POST-DEVELOPMENT HYDRAULIC MODEL RESULTS
APPENDIX G HYDRAULIC MODEL IMPACT ASSESSMENT

# 1. AMENDMENTS INCLUDED IN THE STORMWATER MANAGEMENT PLAN AND HYDRAULIC IMPACT ASSESSMENT

2.2.1 Provide amended reconfiguration plans and technical drawings that consolidates the number of all stormwater basins (quality and quantity). The proposal is to capture and treat stormwater in four (4) separate locations for the stages of the development. Similarly, four (4) detention basins are proposed to mitigate impacts downstream. The number of basins to be contributed to Council would represent a maintenance burden.

**Response:**

**The detention basins have been consolidated into one detention basin (culvert crossing, 4 x ⌀1050mm RCP) located at the McLaughlin Street Crossing, refer to Appendix D (D002).**

2.2.2 Revise the Stormwater Management Plan and Hydraulic Impact Assessment and other relevant application material such that upstream catchments are developed catchments including a 60 percent (%) fraction impervious. The proposed post development catchment and drainage regime identifies stormwater runoff from upstream catchments RAM-18A, RAM-14D-1, RAM14C-1 and RAM-14B-1 discharging to the proposed four detention basins located adjacent to the major flow path via downstream catchments RAM-14E, RAM-14D-2, RAM-14C-2 and RAM-14B-2 respectively. However, the proposed fraction impervious of these upstream catchments for the post development is allocated as zero (0).

**Response:**

**The relevant upstream sub-catchments have been updated to include a fraction impervious of 60%, please refer to Table 1 of this report.**

2.2.3 Include catchment RAM-14E and all upstream catchments (RAM-14E, RAM-14D-2, RAM-14C-2, and RAM-14B-2) in the technical reporting to understand the impact of the development to the lawful point of discharge being LPD A. Please update Table 2 in the Stormwater Management Plan and Hydraulic Assessment and recalculate the volume accordingly.

**Response:**

**The development impacts (pre- and post-development (mitigated) scenarios) have been modelled in TUFLOW and the mapped results have been included in Appendix G of this report. These impact assessment results indicate that the velocity, hazard, and flood level impacts of the development have decreased at LPD A as a result of the proposed consolidated detention at the McLaughlin Street Crossing.**

2.2.4 The stormwater quality catchments must also include all the upstream catchments (RAM-14E, RAM-14D-2, RAM-14C-2 and RAM-14B-2) to calculate the bioretention basin details. The fraction impervious value used for the upstream catchments should be amended to reflect a developed catchment.

**Response:**

**The basin inlet will be designed to bypass the magnitude of upstream flows at the detailed design phase; however, the basin should not be designed to treat upstream catchment that is remaining undeveloped (as per the intent of the State Planning Scheme).**

2.2.5 Demonstrate the proposed works do not cause an actionable nuisance to downstream properties and infrastructure. It is noted the stormwater runoff from catchment RAM-18A will be diverted to catchment RAM-14D. No stormwater runoff will be discharged to the newly constructed channel located downstream of LPD B. Council is in favour of splitting the flows from catchment RAM-18A such that the proposed detention basin (adjacent to RAM-14E) can possibly be reduced in size and more flow is allocated to the newly constructed channel as originally intended.

**Response:**

**Stormwater from sub-catchment RAM-18-A is designed to discharge to the LPD B and not to be diverted through catchment RAM-14D. As per the impact assessment within Appendix G of this report, velocity, hazard, and flood level impacts to LPD A and LPD B have been reduced.**

# 3. INTRODUCTION

Premise Australia Pty Ltd (here within referred to as "Premise") has been commissioned by Maas Group Properties Pty Ltd to prepare a Stormwater Management Plan and Hydraulic Impact Assessment (SMP/HIA) in support of a development application for a Reconfiguration of Lot. The site is located within the Rockhampton Regional Council (RRC) Local Government Area (LGA) and is formally described as Lot 37 on SP341088.

This report has been developed to address the below planning framework:

- Rockhampton Region Planning Scheme (2015) - Version 2.2;
- Planning Act 2016 and the associated State Planning Policy (SPP, DILGP, 2017); and
- Environmental Protection Act 1994, Environmental Protection (Water) Policy 2009 (EP water).

The assessment has been undertaken following best practice guidelines recommended within

- RRC Planning scheme policies:
- SC6.10 Flood hazard planning scheme policy; and
- SC6.18 Stormwater management planning scheme policy
- Capricorn Municipal Development Guidelines;
- Queensland Urban Drainage Manual (IPWEA, 2017);
- Australian Rainfall and Runoff: A Guide to Flood Estimation (Babister et al, 2019) (ARR19); and
- MUSIC Modelling Guidelines (Water By Design, 2018)

## 3.1 Study Objectives

This SMP/HIA describes the assessment of stormwater quantity, quality and flood management undertaken to address the potential impacts caused by the development. The objectives of this report are as follows:

- Review existing information and studies for the subject site and adjacent catchment;
- Stormwater Quantity Management – quantify any changes in catchment hydrology resulting from the development, and the proposed mitigation infrastructure to manage adverse impacts.
- Hydrologic modelling of the catchment runoff using the XP-RAFTS rainfall-runoff modelling package and model files provided by RRC;
- Stormwater Quality Management – model and determine characteristics of a stormwater quality treatment train to achieve compliance with the relevant standards and guidelines.
- Water quality modelling of the development using the MUSIC modelling package to determine the adequacy of the proposed Stormwater Quality Improvement Devices (SQID's) in meeting the Water Quality Objective (WQO's) required under the SPP (2017)
- Flood Management – model and quantify any changes in flood characteristics resulting from the development, and the proposed mitigation infrastructure to manage adverse impacts
- Combined 1D/2D hydraulic modelling of the development using the TUFLOW hydraulic modelling package and model files provided by RRC;
- Propose mitigation measures for any impacts on stormwater quantity or flooding; and
- Analyse the pre and post-development scenarios for the 63.2%, 39%, 18%, 10%, 5%, 2% and 1% AEP events

# 4. DATA

In the preparation of this report, information about the site was gathered from the following sources:

- Aerial LiDAR data of the Anzlic Committee On Survey and Mapping (ELVIS, https://elevation.fsdf.org.au/);
- Ramsay Creek Flood Study data obtained from Rockhampton Regional Council;
- Detailed Survey;
- As constructed plans obtained from the Department of Transport and Main Roads (DTMR);
- Design inputs for hydrologic and hydraulic modelling from the Australian Rainfall and Runoff Data Hub;
- Rainfall and Meteorological data by the Australian Bureau of Meteorology; and
- Aerial Imagery and map data from Queensland Globe, Google and Nearmap (Accessed January-October 2023)

# 5. SITE CHARACTERISTICS

## 5.1 Site Area and Location

The development is located within Low density residential zoned land, and encapsulates an area of approximately 27ha, while the parent lot is 60.15ha. The site is generally bound by the unformed McLaughlin St to the west, the partially formed William Palfrey Rd to the south and vacant Low density residential allotments to the north and east. The site is shown in **Figure 1** in its local context.

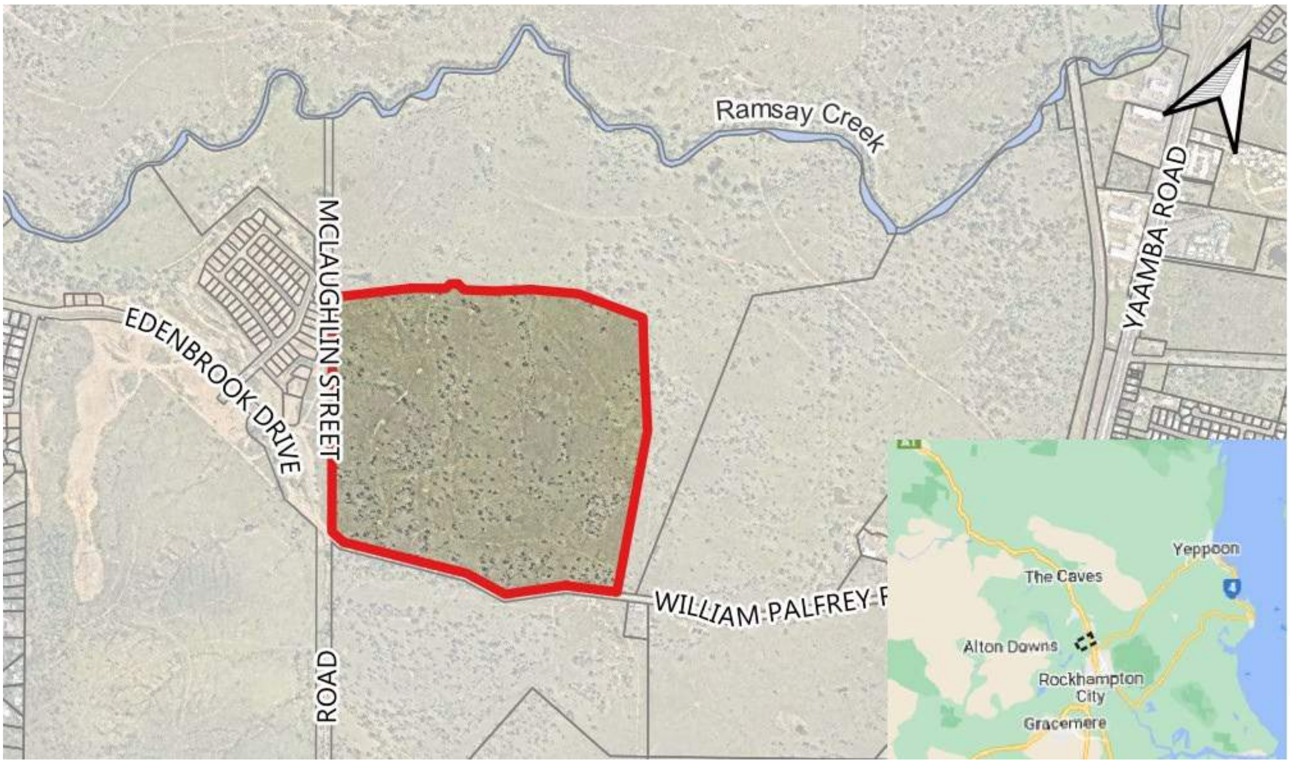


**Figure 1: Aerial Image of Site Location (Source: QGIS)**

## 5.2 Existing Drainage and Topography

The development site is located within the Ramsay Creek catchment. Ramsay Creek meanders along the northern border of the adjacent Lot 38 SP341088 to the north, generally flowing to the west. It eventually merges with the Fitzroy River approximately 2km south-west of the site. Based on the survey and LiDAR information, elevations within the development area range 14m to 42 m AHD. The gradient across the undulating topography has an approximate slope of 1-13%, with some steeper short slopes within forming the natural gullies up to 25%.

Local upstream catchments contribute to the development area, including a minor catchment upstream of William Palfrey Road to the south. Drainage lines are fairly well defined, with multiple discharge locations across the site boundary. The predominant drainage lines flow directly to the unnamed tributary of Ramsay Creek along the northern boundary, and across the western boundary. Both tributaries eventually merge at a convergence point within the adjacent Edenbrook development, then into Ramsay Creek approximately 1.2km along the main watercourse, to the west of the site. The entire catchment containing the area of the subject site discharging to Ramsay Creek via the convergence point of discharge has an area of 1,715ha.

The existing topography, drainage regime, and discharge locations for the pre-developed site are shown in **Appendix B**.

## 5.3 Proposed Development

The proposed development consists of 267 residential lots to be developed across six stages, with an internal network comprising fifteen local roads. Direct access to the development site will be provided from McLaughlin Street via the northwest corner. The proposed engineering works are as follows:

- Earthworks filling and excavation to achieve the development footprint;
- Roadworks to provide access and circulation for the development;
- Construction of services including drainage, sewer, water, electrical and telecommunications; and
- Provision stormwater infrastructure for management of stormwater quantity, quality and flooding.

The proposed development plan is included in **Appendix A**.

## 5.4 Proposed Drainage

Surface and roofwater runoff will from the residential lots will generally be discharged to stormwater infrastructure within the internal access roads, where it will be conveyed to quantity and quality management infrastructure at the outlets to the natural overland flow path. The minor drainage system will be designed with sufficient capacity to convey 0.5EY (2-year ARI) event runoff from the lots and 10% AEP event for the roads accordance with Table D05.04.1 of the CMDG – D5. Concept design of the drainage system can be seen on Premise drawings in **Appendix A**.

# 6. STORMWATER QUANTITY MANAGEMENT

## 6.1 Lawful Point of Discharge

In accordance with QUDM (2017) section 3.9, lawful discharge of stormwater is required. A Lawful Point of Discharge Test (LPD Test) is outlined in Section 3.9.1 to ensure the stormwater is discharged from the site lawfully and at lawful locations in addition to needing to meet other statutory requirements such as the SPP and Planning Act.

The test in Section 3.9.1 of QUDM is in sequential order. If a condition can be met, then subsequent items need not be tested. This should be read in full but is summarised here to provide context for this site. It can be summarised as:

| | |
|---|---|
| Test 1: | Will the proposed development alter the site’s stormwater discharge characteristics in a manner that may substantially damage a third-party property? (if yes go to Test 2, if not then LPD is satisfied) |
| Test 2: | Is the location of the discharge from the development site under the lawful control of the local government or other statutory authority from whom permission to discharge has been received? |
| Test 3: | An authority to discharge over affected properties will be necessary. |

The lawful point of discharge for Stages 1-6 is the existing overland flow path forming an unnamed tributary of Ramsay Creek along the northern boundary, as shown in **Appendix B**. This lawful point of discharge is considered appropriate as it currently receives runoff from the site, it allows for the development area to drain freely and management infrastructure will be constructed to mitigate adverse impacts.

## 6.2 Hydrologic Modelling Approach

RRC has supplied Premise a copy of the XP-RAFTS model used for the Ramsay Creek Flood Study. As per the supplied model, the regional subcatchments were reviewed to determine the relevant subcatchments with influencing flows over the site, to run the appropriate hydrological simulations, for critical duration adoption purposes. As seen in the Ramsay Creek catchment delineation data in **Figure 2**, the main subcatchments pertaining to the development area are RAM-14 and RAM-18.

### 6.2.1 SUB-CATCHMENT CHARACTERISTICS

The regional catchment delineation was further refined to ensure that all relevant local flows were adequately represented. For the pre-development case model, the catchment areas of RAM-14 and RAM-18 have been reduced and the development area has been represented as its own node within XP-RAFTS. Additional catchments were added to capture the portion of the site discharging over the northern boundary. A summary of model input parameters is provided in **Table 1**. The adopted pervious initial and continuing losses of 15mm and 1mm/hour respectively were retained for each design storm event.

**Table 1: Summary of Sub-Catchment Characteristics**

| Catchment | RRC Model | | Pre-Development | | Post-Development | |
|---|---|---|---|---|---|---|
| | Area (ha) | Fraction Imp (%) | Area (ha) | Fraction Imp (%) | Area (ha) | Fraction Imp (%) |
| RAM-14 | 134.053 | 0 | 73.986 | 0 | 73.986 | 0 |
| RAM-18 | 154.345 | 0 | 146.418 | 0 | 146.418 | 0 |
| RAM-14A-1 | | | 35.768 | 0 | 33.384 | 0 |
| RAM-14A-2 | | | - | - | 2.409 | 60 |
| RAM-14B-1 | | | 6.991 | 0 | 6.004 | 60 |
| RAM-14B-2 | | | 9.526 | 0 | 7.750 | 60 |
| RAM-14C-1 | | | 2.512 | 0 | 1.835 | 60 |
| RAM-14C-2 | | | 4.173 | 0 | 6.634 | 60 |
| RAM-14D-1 | | | 4.247 | 0 | 2.294 | 60 |
| RAM-14D-2 | | | - | - | 6.331 | 60 |
| RAM-18A | | | 7.927 | 0 | 0.607 | 60 |
| RAM-14E | | | - | - | 3.772 | 60 |

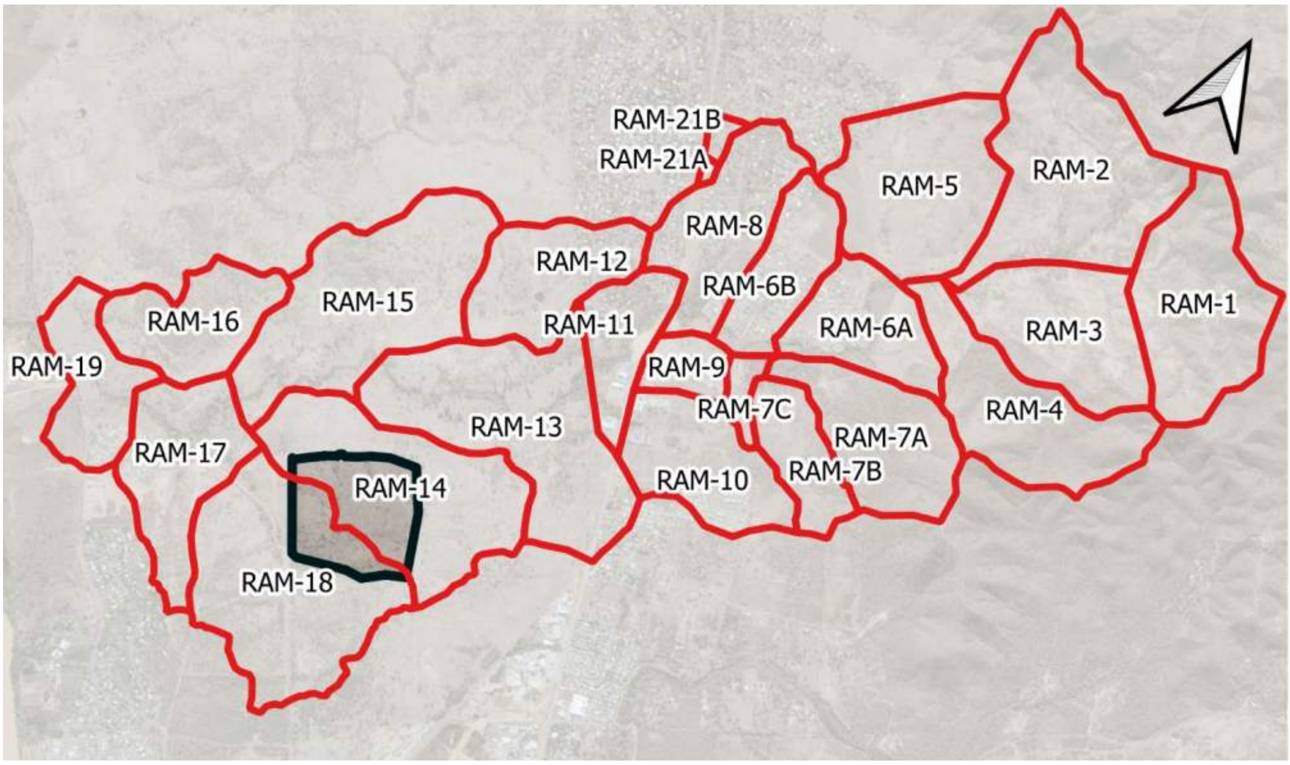


**Figure 2: Location of Development within Ramsay Creek Regional Catchments**

## 6.3 Hydrologic Model Results

To understand the impact of the development, peak discharges for pre and post-development have been assessed for lawful point of discharge. A comparison of peak discharges for the pre and post-development scenarios is shown in **Table 2**.

**Table 2: Peak Discharge Summary – Local Catchments**

| Annual Exceedance Probability (AEP) | Peak Discharge ($m^3/s$) | | Impact | |
|---|---|---|---|---|
| | Pre | Post | ($m^3/s$) | % |
| **LPD B (Catchment RAM-18A)** | | | | |
| 63.2% | 0.209 | 0.033 | -0.176 | -84% |
| 50% | 0.357 | 0.053 | -0.304 | -85% |
| 20% | 0.566 | 0.081 | -0.485 | -86% |
| 10% | 0.702 | 0.101 | -0.601 | -86% |
| 5% | 0.893 | 0.127 | -0.766 | -86% |
| 2% | 1.161 | 0.157 | -1.004 | -86% |
| 1% | 1.224 | 0.184 | -1.04 | -85% |

It can be seen in **Table 2** that the partial diversion of catchment RAM-18A results in reduced peak discharge and runoff volume to LPD B. The peak discharge to the LPD A will see an increase due to the development. This expected increase is due to the increase in both contributing catchment area and impervious area. It is proposed to provide detention at the proposed McLaughlin Street crossing to attenuate runoff from the site as part of the stormwater infrastructure design to manage the increase in peak discharges to LPD A. The pre and post- development (mitigated) scenarios have been modelled in TUFLOW and the results have been included in section 7 of this report.

## 6.4 Management of Increased Runoff

As mentioned above, it is proposed that detention be constructed as part of the stormwater quantity management system. The basin has been designed to maximise the volume of storage and attenuation of flow. This scheme is designed to meet the LPD Test referenced in Section 4.1 and ensure no increase in peak discharges downstream of the site.

A TUFLOW model was run for the post-development including the detention basin as the mitigated scenario. Characteristics of the proposed detention system can be seen in **Table 3.**

**Table 3. Detention Characteristics**

| Catchment & Basin ID | Outlet Configuration | LPD ID |
|---|---|---|
| RAM-14E | 4 x ⌀1050mm RCP, IL = 13.5 | A |

The mitigated impact maps for flood level, hazard and velocity are provided in Appendix G of this report which shows that the proposed detention basin attenuates the post-development peak discharges to below the pre-development levels for all events up to the 1% AEP event at LPD A. Due to the complex nature of the flow regime within the catchment, as well as the interaction of timing of local and regional runoff within the catchment, analysis has been undertaken in a 1D/2D combined hydraulic model to determine the impacts of the physical changes to the catchment on stormwater and flood behaviour within the wider catchment. The hydraulic assessment is outlined **Section 5** of this report.

# 7. HYDRAULIC ASSESSMENT

Analysis has been undertaken to demonstrate the adequacy of the stormwater management strategy in achieving no adverse impact on flooding or stormwater behaviour, or no actionable nuisance to downstream or adjacent properties or infrastructure as a result of the development.

The assessment has been undertaken using a combined 1D/2D hydraulic model to analyse both pre and post-development conditions. A comparison of the results of both scenarios demonstrates the effectiveness of the stormwater management strategy to ensure mitigation of flows before leaving the site. The Ramsay Creek Flood Study model provided by RRC was used as the base model for the assessment. The model was developed using the TUFLOW modelling package and is considered appropriate due the programs ability to model detailed 1D hydraulic structures in conjunction with the 2D terrain and allows for rapid interpretation of model results.

The hydraulic model was used to estimate the inundation extents and flow characteristics of the 1yr ARI (63.2% AEP), 2yr ARI (39% AEP), 5yr ARI (18% AEP), 10yr ARI (10% AEP), 20yr ARI (5% AEP), 50yr ARI (2% AEP) and 100yr ARI (1% AEP) critical design storm events.

## 7.1 Model Consistency

To ensure consistency between the model data supplied by RRC and this analysis, all TUFLOW inputs were based on the supplied information. The Ramsay Creek TUFLOW model was constructed using the Direct Rainfall (rain on grid) method for critical storms listed in **Table 5**. Direct rainfall was omitted from the development area and replaced with inflow hydrographs extracted from the XP-RAFTS model. This is considered appropriate, as the internal drainage network was not included in the model which would result in unrealistic surface storage at sag points. Temporal patterns and model losses have not been adjusted from those adopted by RRC.

Table 4: Critical Storm Durations - Ramsay Creek Model

| Annual Exceedance Probability (AEP) | Storm Duration (hr) |
|---|---|
| 63.2% | 1.5 |
| 39% | 1.5 |
| 18% | 1.5 |
| 10% | 1.5 |
| 5% | 1.5 |
| 2% | 1.5 |
| 1% | 1, 1.5, 2, 3, 4.5, 6 |

The supplied TUFLOW model has been setup to run utilising the TUFLOW Classic solver. To provide a much faster runtime, TUFLOW's Heavily Parallelised Compute (HPC) functionality with GPU processing has been adopted within the hydraulic modelling. A comparison of the maximum water surface elevations from the 1% AEP, 60-minute duration event between the TUFLOW classic and HPC results is shown in **Appendix C**. The comparison demonstrates the modelling outcomes are reasonably similar, and suitable for adoption for the hydraulic assessment.

## 7.2 Model Topography

A Digital Terrain Model (DTM) provided by RRC has been adopted for the model with a grid size of 3m, which is considered adequate for describing flooding behaviour for the purposes of this study. This resolution also adequately represents the main features of the site and major hydraulic structures. All stormwater pipes and culverts are expressed as 1D elements within the model. A minimum adaptive computational time step of 1.5 seconds has been adopted, which is appropriate for a model of this size and is consistent with TUFLOW recommendations.

Refer to **Appendix D** for an overview of the TUFLOW model topography.

## 7.3 Hydraulic Model Roughness

The model roughness of the streams and floodplains in the catchments was represented by the Manning's roughness coefficient, n, in the TUFLOW material file. The material file within the model holds all the information pertaining to the ground surface conditions for various areas, including the manning's "n" and infiltration losses at varying flow depths. The material type adopted for the development area in the Rasmsay Creek model is Long Grass.

This is considered appropriate to represent the development area in its pre-development state, being completely pervious and infiltrating rainfall. The remaining Manning's 'n' hydraulic roughness parameters have been maintained from the Ramsay Creek model and are outlined in **Table 6**.

Refer to **Appendix D** for an overview of the TUFLOW 2D Manning's 'n' roughness.

**Table 5: Manning's Rougness Coefficients - Ramsay Creek Model**

| Material | Manning's 'n' | Initial Loss (mm) | Continuing loss (mm/hr) |
|---|---|---|---|
| High Density Residential | 0.070-0.150 | 7.5 | 0.5 |
| Medium Density Residential | 0.060-0.120 | 7.5 | 0.5 |
| Low Density Residential | 0.050-0.090 | 7.5 | 0.5 |
| Commercial/Industrial | 0.030-0.060 | 7.5 | 0.5 |
| Dense Vegetation | 0.060-0.100 | 15.0 | 1.0 |
| Medium Vegetation | 0.050-0.080 | 15.0 | 1.0 |
| Light Vegetation | 0.045-0.080 | 15.0 | 1.0 |
| Channel | 0.050-0.060 | 0.0 | 0.0 |
| Riparian Corridor (sluggish areas) | 0.070-0.100 | 0.0 | 0.0 |
| Maintained Grass | 0.035 | 15.0 | 1.0 |
| Road Reserve | 0.025 | 0.0 | 0.0 |
| Rail Reserve | 0.030 | 15.0 | 1.0 |
| Fitzroy River Bed (at DS boundary) | 0.022 | 0.0 | 0.0 |
| Long Grass | 0.035-0.045 | 0.0 | 0.0 |
| Buildings | 0.018-0.500 | 0.0 | 0.0 |

## 7.4 Post-Development Mitigated Scenario

In the post-development scenario, the proposed earthworks were modelled using the modelling software package 12D. As mentioned in **Section 5.1**, the internal drainage network has been excluded from the model. Subsequently, the proposed detention basin has not been included explicitly in the model. This is considered appropriate as the 3m grid resolution does not provide as accurate a representation of the stage-storage-discharge relationship of the proposed basin as the hydrologic model. The basin has been 'represented' in the post-development scenario by using the mitigated hydrographs generated by the hydrologic model as inflow boundaries at the outlet locations.

The post-development TUFLOW model setup can be seen in **Appendix D**.

## 7.5 Hydraulic Assessment Results

Flood mapping has been produced for peak flood levels, depth, velocity, hazard, and flood afflux for the 63.2%, 18%, 10%, 5%, 2%, and 1%, AEP events for both the pre and post development scenarios. For the hydraulic model results, refer to:

- **Appendix E** for pre-development maps;
- **Appendix F** for post-development maps; and
- **Appendix G** for impact assessment maps.

### 7.5.1 HYDRAULIC IMPACT ASSESSMENT

As shown in **Appendix G**, the impact assessment demonstrates that the project results in minor variations to the existing flood regime within the site for all events up to the 1% AEP event, and no material change external to the site.

Overall, this assessment indicates that there are no actionable or adverse impacts to neighbouring properties or infrastructure as a result of the development.

### 7.5.2 DESIGNATED FLOOD PLANNING LEVELS

The Defined Flood (Event) Level (DFL) for the site is determined via the 1 in 100yr ARI (1% AEP) storm event as defined in the Rock-e-Plan, CMDG and QUDM. Given the topographical changes across the site and the flooding source, the post-development DFL for the site varies significantly across the site. Accordingly, the design floor levels of the future dwellings and other uses are to adhere to the minimum DFL level requirements as shown in the post-development modelling peak mapping results.

# 8. STORMWATER QUALITY

As the proposed development is a reconfiguration of lot for an urban purpose that involves premises greater than 2,500m$^2$ in size and will result greater than six lots, the management of stormwater quality is required to comply with the Queensland Government's State Planning Policy (SPP) (Queensland Government 2017), and in particular the outcomes of the SPP code: Water Quality (Appendix 2).

Performance Outcome PO1 in the SPP Code: Water Quality states that the development should be 'planned and designed considering the land use constraints of the site for achieving stormwater design objectives. Acceptable Outcome AO1.1 from the same appendix states the site stormwater quality management plan that is prepared needs to be "consistent with any local area stormwater management planning" and provide for “achievable stormwater quality treatment measures meeting design objectives or current best practice environmental management”. Table B contained within the SPP Code specifies the following minimum pollutant reductions in mean annual load from unmitigated development within Central Queensland:

| | |
|---|---|
| Total Suspended Solid (TSS) | 85% |
| Total Phosphorus (TP) | 60% |
| Total Nitrogen (TN) | 45% |
| Gross Pollutants (GP) | 90% |

## 8.1 Waterway Stability

Table B of the SPP Appendix 2 specifies the requirements for waterway stability management where a development drains to an unlined waterway downstream where a risk of increased erosion is caused by changes in hydrology. The design objectives outlined specify the peak 1-year ARI event discharge must be limited to the pre-development discharge. Stormwater quantity management infrastructure is proposed to attenuate peak discharges in the 63.2% AEP event (1-year ARI) at the point where the flows from the site are discharges to the waterway overlay is outlined in the hydrologic model results discussed in **Section 4**.

## 8.2 Construction phase

During the construction phase various pollutants are generated which can find their way into the stormwater runoff. These pollutants can affect the quality of the stormwater runoff and hence pollute both the site and the downstream receiving environment. **Table 7** below outlines the major sources of pollutants.

**Table 6: Typical Construction Phase Pollutants**

| **Construction Phase Pollutants** |
|---|
| Litter from construction packaging, paper, food packaging, off cuts, etc. |
| Sediment from erosion of exposed soils and stockpiles. |
| Hydrocarbons - from fuel and oil spills, leaks from construction equipment. |
| Toxic Materials - cement slurry, solvents, cleaning agents, wash waters. |
| pH altering substances - cement slurry, wash waters. |

Erosion and sediment control measures used during the construction phase of the development will be designed and installed in accordance with International Erosion Control Association (Australasia) - “Best Practice Erosion & Sediment Control – for building and construction sites” November 2008, and CDMG and RRC requirements for Erosion and Sediment Control.

## 8.3 Stormwater Quality Modelling

Stormwater Pollutant modelling for the development has been generated using the modelling program ‘Model for Urban Stormwater Improvement Conceptualisation’ (MUSIC), version 6.3, adhering to the Water by Design MUSIC modelling guidelines Version 1.0, 2010 (WBDMG) as outlined in the RRC SC6.18 planning scheme policy.

### 8.3.1 STORMWATER QUALITY CATCHMENTS

The catchment areas for water quality were determined based on the proposed development layout and are shown in **Appendix B**. A split catchment approach has been adopted for the residential catchments. Values for typical impervious fractions used in split catchments have been adopted from Table 3.5 in the WBDMG. Details of catchment parameters are listed in **Table 8**.

**Table 7: MUSIC Model Catchment Parameters**

| Catchment ID | Node Type | Area (ha) | Fraction Impervious |
|---|---|---|---|
| RAM-14A-2 | Road | 0.555 | 60% |
| | Roof | 0.555 | 100% |
| | Ground | 1.110 | 15% |
| RAM-14B | Road | 2.006 | 60% |
| | Roof | 2.006 | 100% |
| | Ground | 4.011 | 15% |
| RAM-14C | Road | 1.625 | 60% |
| | Roof | 1.625 | 100% |
| | Ground | 3.251 | 15% |
| RAM-14D | Road | 1.572 | 60% |
| | Roof | 1.572 | 100% |
| | Ground | 3.145 | 15% |
| RAM-14E | Road | 0.924 | 60% |
| | Roof | 0.924 | 100% |
| | Ground | 1.847 | 15% |

### 8.3.2 RAINFALL-RUNOFF AND POLLUTANT EXPORT PARAMETERS

The rainfall-runoff parameters have been based off the land use parameters set out in WBDMG Table 3.7. Pollutant export parameters for the split catchment have been based on the parameters set out in WBDMG Table 3.8.

### 8.3.3 RAINFALL AND EVAPOTRANSPIRATION DATA

Rainfall and evapotranspiration data were sourced from the Bureau of Meteorology (BoM) for Rockhampton (Station ID 39083) and covered the period from the 1st January 1991 to the 31st December 2001 with 6-minute rainfall data timestep, as recommended by RRC Guidelines. Monthly evapotranspiration data adopted for the MUSIC model is shown in **Table 9**.

**Table 8: Monthly Evapotranspiration Data at Rockhampton Aero Station**

| Month | Evapotranspiration (mm) |
|---|---|
| January | 205 |
| February | 160 |
| March | 170 |
| April | 125 |
| May | 95 |
| June | 80 |
| July | 80 |

| | |
|---|---|
| August | 105 |
| September | 125 |
| October | 170 |
| November | 185 |
| December | 200 |

### 8.3.4 TREATMENT NODES

Bioretention basins are proposed to provide tertiary treatment of stormwater runoff for each subcatchment. The bioretention basins will form part of, or discharge directly to the detention basins. The detention basins were not included in the MUSIC model, however in practice will provide further water quality benefits. The parameters for the treatment system are summarised in **Table 10**.

**Table 9: Treatment Device parameters – Bioretention Basin**

| **Component** | **RAM-14A-2** | **RAM-14B** | **RAM-14C** | **RAM-14D** | **RAM-14E** |
|---|---|---|---|---|---|
| Extended Detention Depth (m) | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| Surface Area ($m^2$) | 150 | 540 | 460 | 425 | 260 |
| Filter Area ($m^2$) | 150 | 540 | 460 | 425 | 260 |
| Unlined Filter Media Perimeter (m) | 60 | 128 | 122 | 125 | 72 |
| Saturated Hydraulic Conductivity (mm/hr) | 200 | 200 | 200 | 200 | 200 |
| Filter Depth (m) | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| TN Content of Filter Media (mg/kg) | 400 | 400 | 400 | 400 | 400 |
| Orthophosphate Content of Filter Media (mg/kg) | 30 | 30 | 30 | 30 | 30 |

The schematic MUSIC model setup can be seen in **Figure 3**.

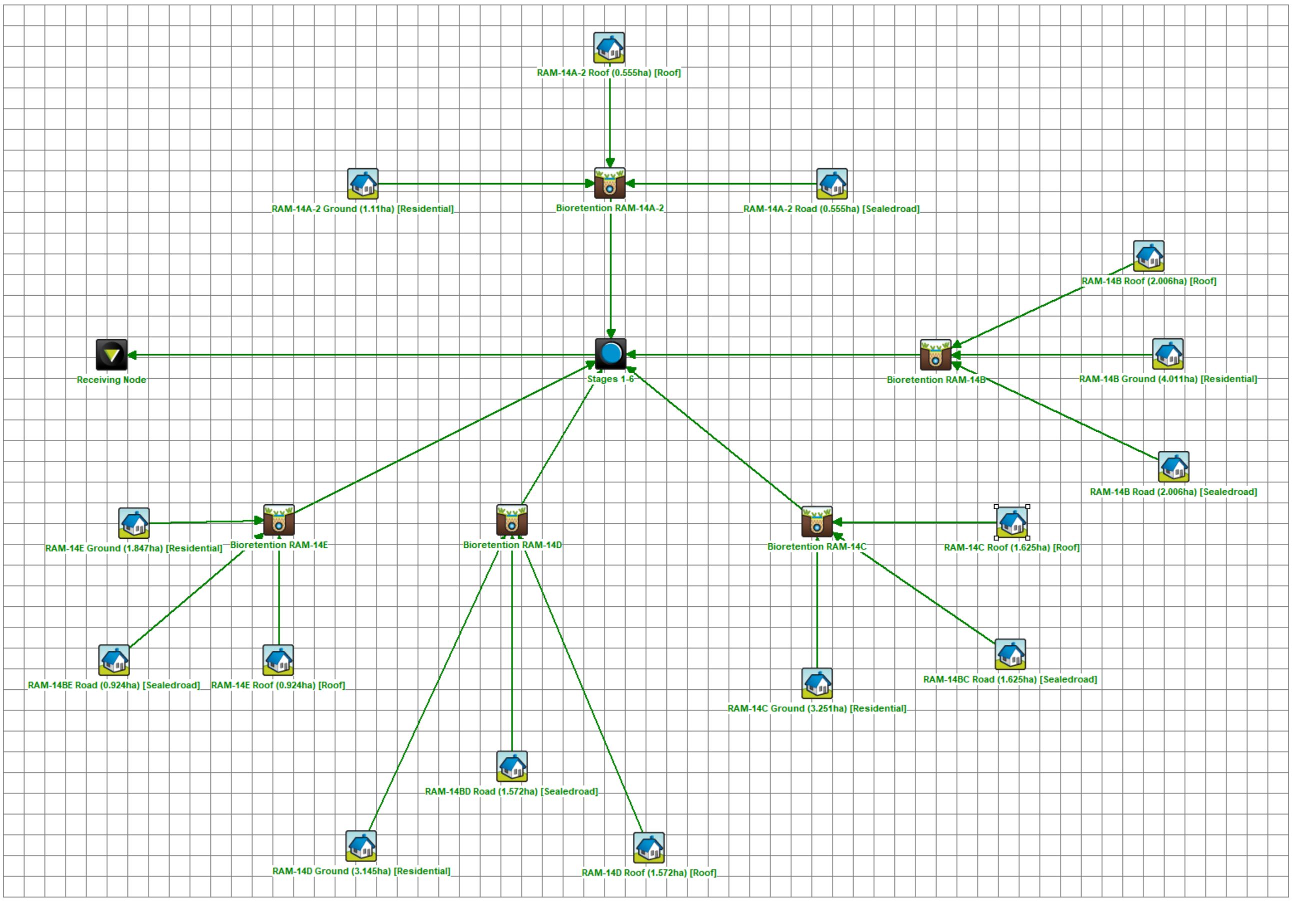


**Figure 3: MUSIC Model Schematic (Source: eWater MUSIC)**

## 8.1 Stormwater Quality Model Results

**Table 11** outlines the effectiveness of the MUSIC Model Treatment Train in achieving the set Stormwater Management Design Objectives (SMDO's) for pollutant reduction for the proposed development.

**Table 10: Treatment Train Effectiveness at Receiving Node**

| Pollutant | Unmitigated Load (kg/yr) | Mitigated Load (kg/yr) | Reduction (%) | Pollutant Reduction Target (%) | Reduction Target Achieved (Y/N) |
|---|---|---|---|---|---|
| Suspended Solids (TSS) | 14,000 | 2,070 | 85.2 | 85 | Y |
| Total Phosphorus (TP) | 28.4 | 6.57 | 76.9 | 60 | Y |
| Total Nitrogen (TN) | 166 | 79.3 | 52.3 | 45 | Y |
| Gross Pollutants > 5mm | 2,420 | 0 | 100 | 90 | Y |

The MUSIC results demonstrate that the SMDO's are met for the proposed development. Therefore, it is considered the stormwater quality improvement devices are sufficient to comply with the requirements of the State Planning Policy.

# 9. CONCLUSION

This Site Based Stormwater Management Plan and Hydraulic Impact Assessment Report details the proposed stormwater management strategy and infrastructure for the project in accordance with the Queensland Urban Drainage Manual, Australian Rainfall & Runoff 2019, Rockhampton Regional Council Guidelines and the State Planning Policy's Stormwater Management Design Objectives (SMDO's).

This report demonstrates that the proposed development is adequate to satisfy the 'lawful point of discharge'. It is demonstrated that the proposed stormwater infrastructure has sufficient capacity to convey the flows from the developed site catchment without causing an actionable nuisance to adjoining properties as peak discharges are to be attenuated through mitigation measures.

Hydrologic and hydraulic modelling was undertaken to demonstrate the development does not have an actionable nuisance impact on the external to the site.

The Stormwater Quality Improvement Devices (SQID's) proposed for the development include bioretention basins to comply with the State Planning Policy water quality Pollutant Load reductions for the site. As such, by implementing a SQID into the proposed development, stormwater runoff from the site will be treated to the satisfaction of RRC and the SPP.

# 10. QUALIFICATIONS

Our analysis and overall approach have been specifically catered for the requirements of Maas Group Properties Pty Ltd and may not be applicable beyond this scope. For this reason, any other third parties are not authorised to utilise this report without further input and advice from Premise.

Premise has relied on the following information as outlined in **Section 2** of this Report.

While Premise's report accurately assesses peak flows from design storms in accordance with current industry standards and guidelines, the sites future observed flows may vary from that predicted. For these reasons appropriate freeboards should be adopted.

# 11. RPEQ CERTIFICATION

As Registered Professional Engineer of Queensland (RPEQ) for this project, on behalf of Premise Australia Pty Ltd, I certify that the modelling undertaken as part of this assessment has been undertaken in accordance with current engineering best practice as recommended in the QUDM, ARR19, CMDG and Rockhampton Regional Council Guidelines.

Name: Jeremy Cox RPEQ No: 14732 Date: 09 February 2024

Signature: ______________________________

# 12. REFERENCES

1. Institute of Public Works Engineering Australasia (QLD Division), et al, 2016. *Queensland Urban Drainage Manual (QUDM), Fourth Edition*. Brisbane.
2. CRC for Catchment Hydrology, 2002. *Model for Urban Stormwater Improvement Conceptualisation (MUSIC)*. CRC for Catchment Hydrology, Melbourne.
3. Water by Design, 2010. *MUSIC Modelling Guidelines*, SEQ Healthy Water Ways Partnership, Brisbane
4. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), 2016, Canberra.
5. Bureau of Meteorology, *2016 IFDs – Rainfall Data.* Available at: http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016
6. Department of Infrastructure, Local Government and Planning, July 2017. *State Planning Policy (SPP),* Brisbane.

# APPENDIX A

## PROPOSED LAYOUT PLAN

## FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

**Premise**

ROCKHAMPTON OFFICE
21 EAST STREET
PO BOX 264
ROCKHAMPTON, QLD, 4700
PH: (07) 4829 3660
WEB: www.premise.com.au

DESIGNED
RAY STAER
CHECKED
CHRIS SHIELDS
PROJECT MANAGER
CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

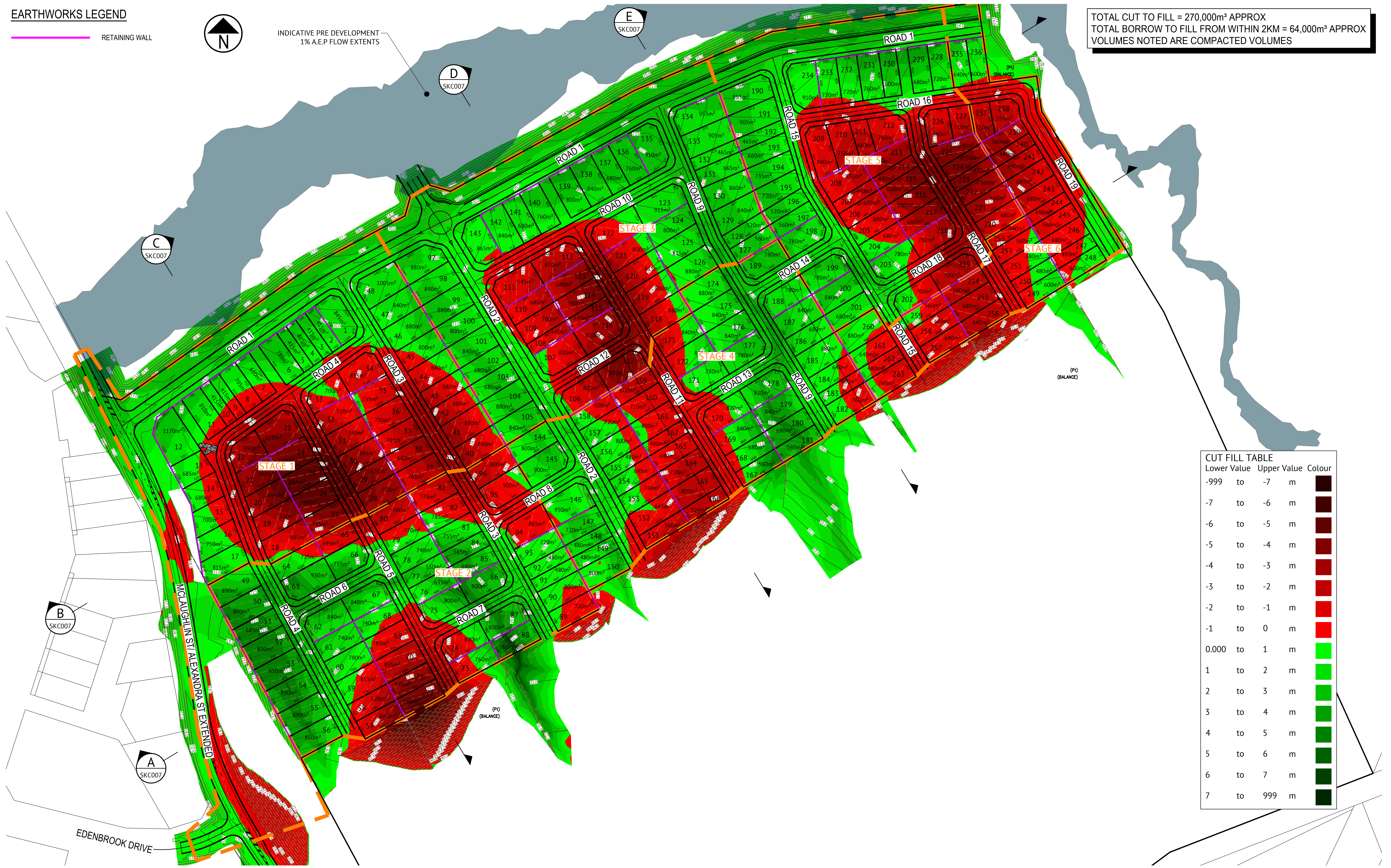
CLIENT: MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT: ELLIDA SUBDIVISION WEST
LOCATION: 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE: PRELIMINARY STORMWATER DRAINAGE

JOB CODE: MPG-0001
SHEET NUMBER: SKC002
REV: C

**EARTHWORKS LEGEND**

RETAINING WALL

TOTAL CUT TO FILL = 270,000m³ APPROX
TOTAL BORROW TO FILL FROM WITHIN 2KM = 64,000m³ APPROX
VOLUMES NOTED ARE COMPACTED VOLUMES



CUT FILL TABLE

| Lower Value | | Upper Value | | Colour |
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| -7 | to | -6 | m | 🟥 |
| -6 | to | -5 | m | 🟥 |
| -5 | to | -4 | m | 🟥 |
| -4 | to | -3 | m | 🟥 |
| -3 | to | -2 | m | 🟥 |
| -2 | to | -1 | m | 🟥 |
| -1 | to | 0 | m | 🟥 |
| 0.000 | to | 1 | m | 🟩 |
| 1 | to | 2 | m | 🟩 |
| 2 | to | 3 | m | 🟩 |
| 3 | to | 4 | m | 🟩 |
| 4 | to | 5 | m | 🟩 |
| 5 | to | 6 | m | 🟩 |
| 6 | to | 7 | m | 🟩 |
| 7 | to | 999 | m | 🟩 |

# FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
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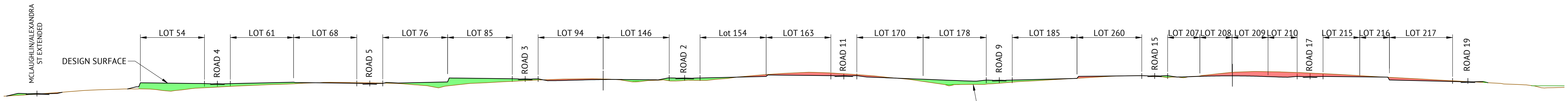
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT
MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT
ELLIDA SUBDIVISION WEST
LOCATION
23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE
PRELIMINARY EARTHWORKS

JOB CODE
MPG-0001
SHEET NUMBER
SKC006
REV
C



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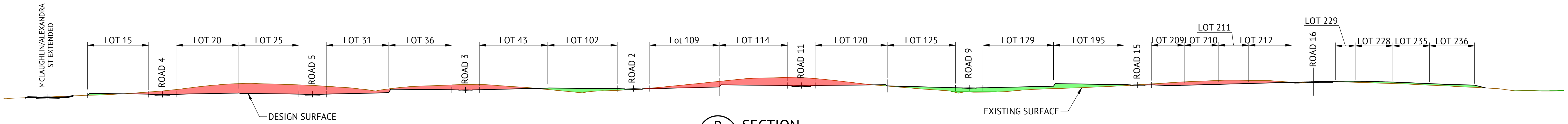

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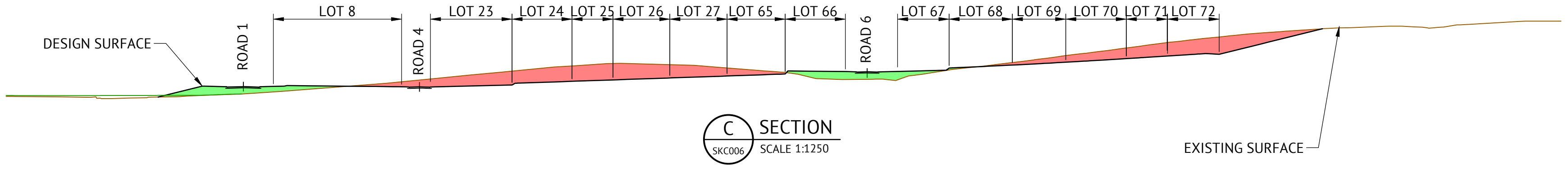
SKC006 SCALE 1:1250



C SECTION
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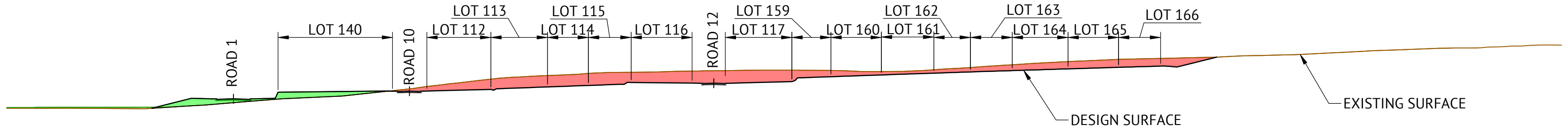

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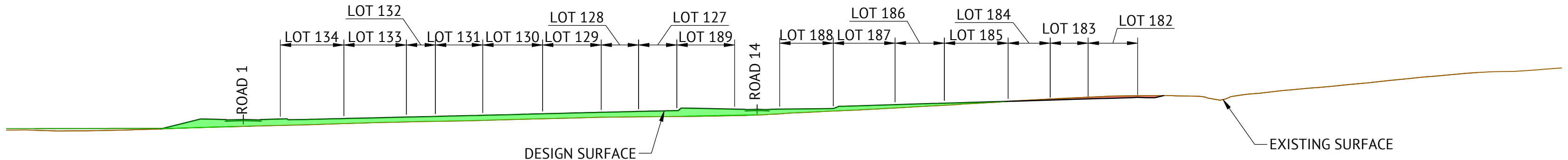

E SECTION
SKC006 SCALE 1:1250

## FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

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**Premise**

ROCKHAMPTON OFFICE
21 EAST STREET
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PROJECT MANAGER
CHRIS SHIELDS
ENGINEERING CERTIFICATION

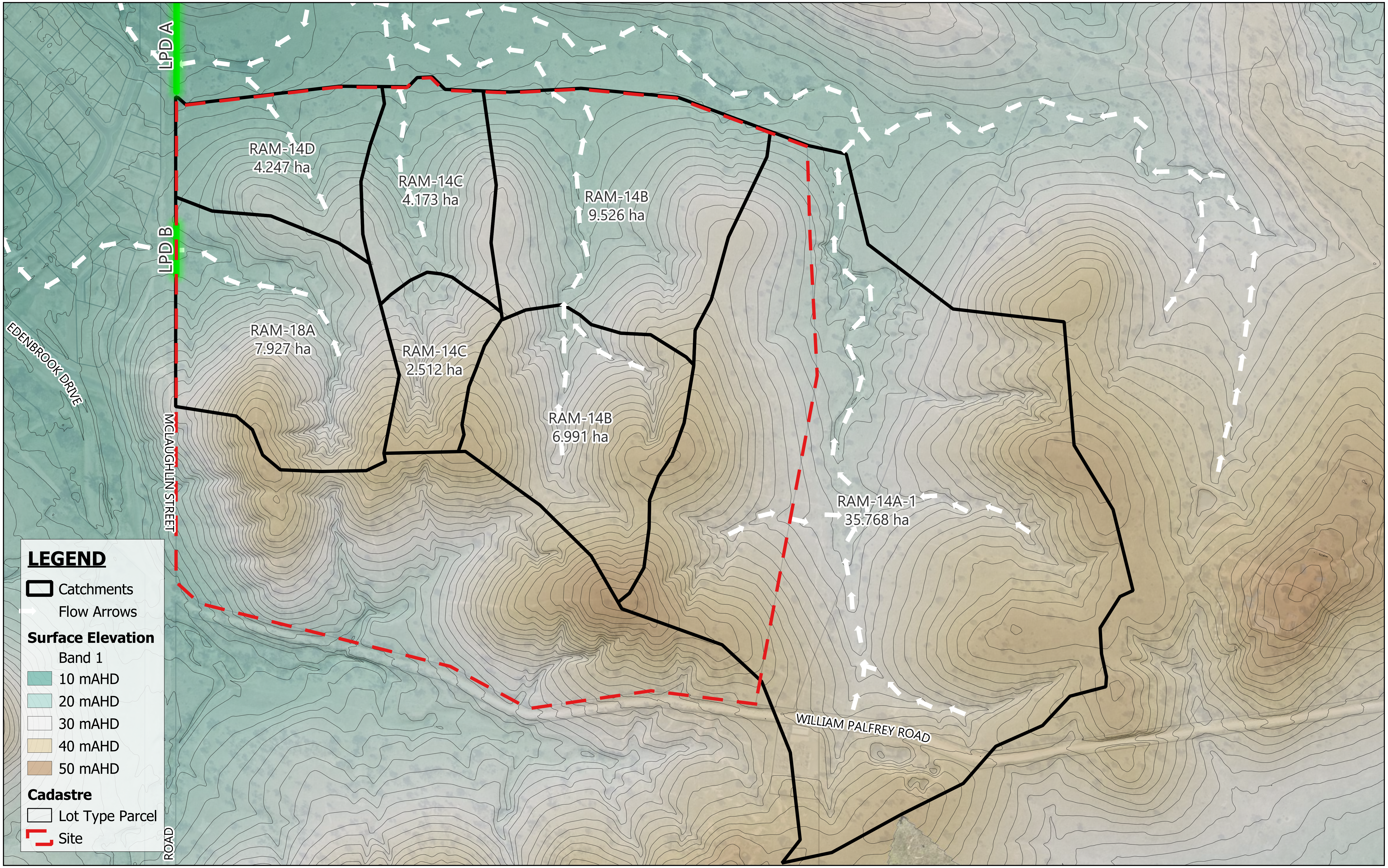
SCALE
0 25 50 75m
SCALE 1:1250 (A1)
ORIGINAL SHEET SIZE A1

CLIENT MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT ELLIDA SUBDIVISION WEST
LOCATION 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE PRELIMINARY EARTHWORKS SECTIONS

JOB CODE
MPG-0001
SHEET NUMBER
SKC007
REV
C

# APPENDIX B

## CATCHMENTS



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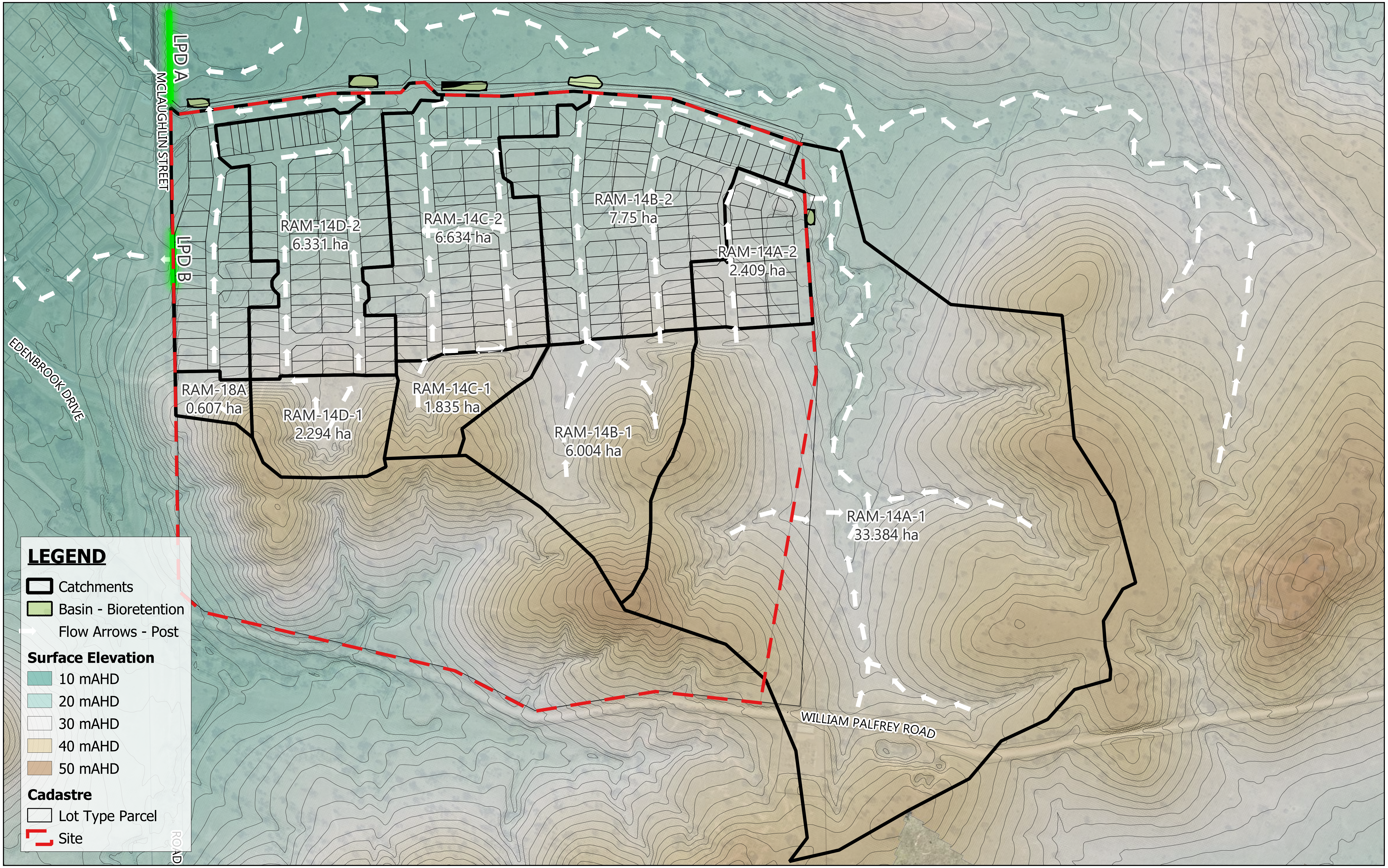
| **ELLIDA WEST STAGES 1-6, PARKHURST** | **MPG-0001** |
| Catchments and Drainage Regime - Pre-Development | **B001** |



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09.02.2024

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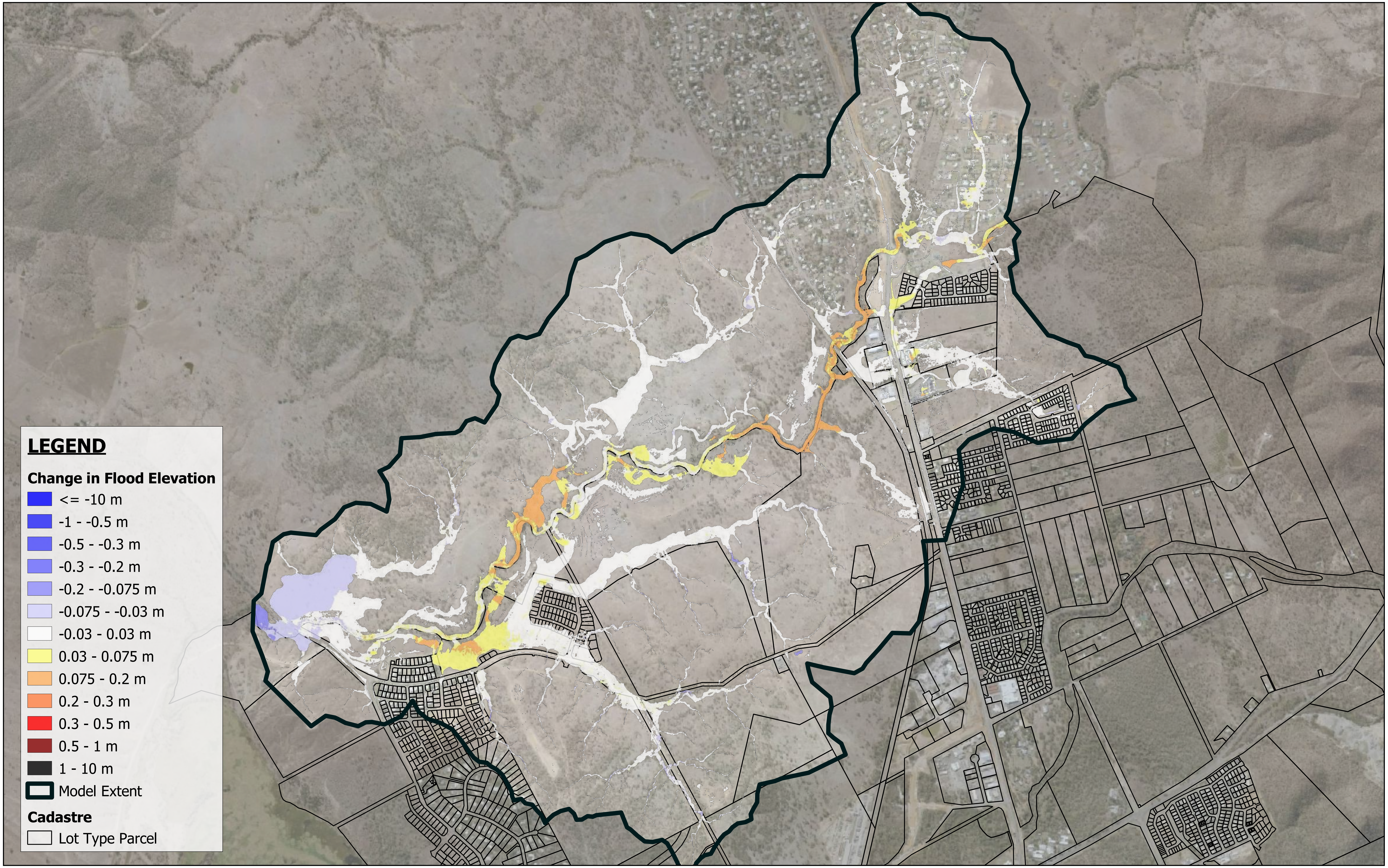
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| Catchments and Drainage Regime - Post-Development | B002 |

# APPENDIX C

## MODEL DATA



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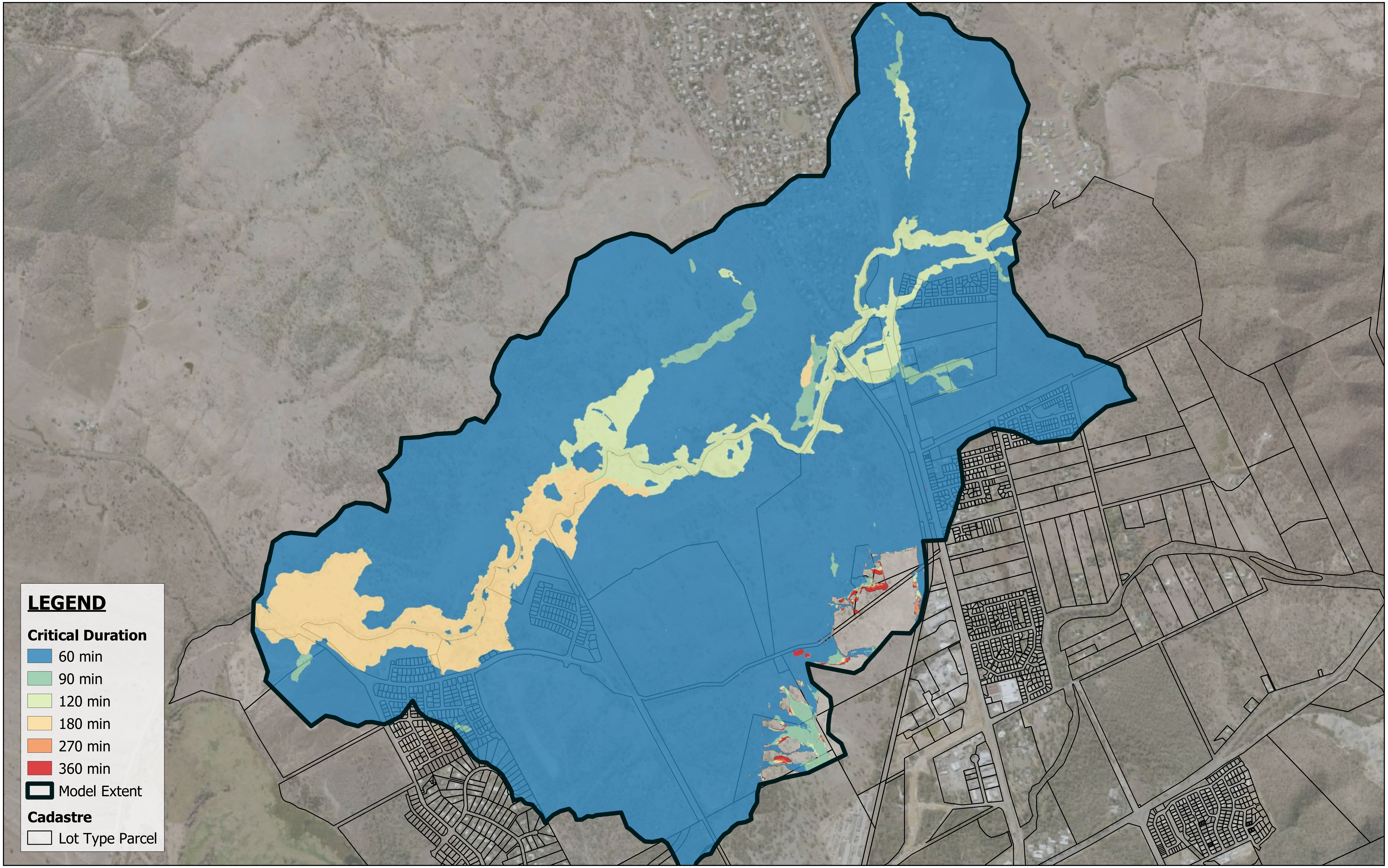
| Comparison of Flood Elevations - TUFLOW Classic vs. HPC (CPU vs. GPU) | **C001** |



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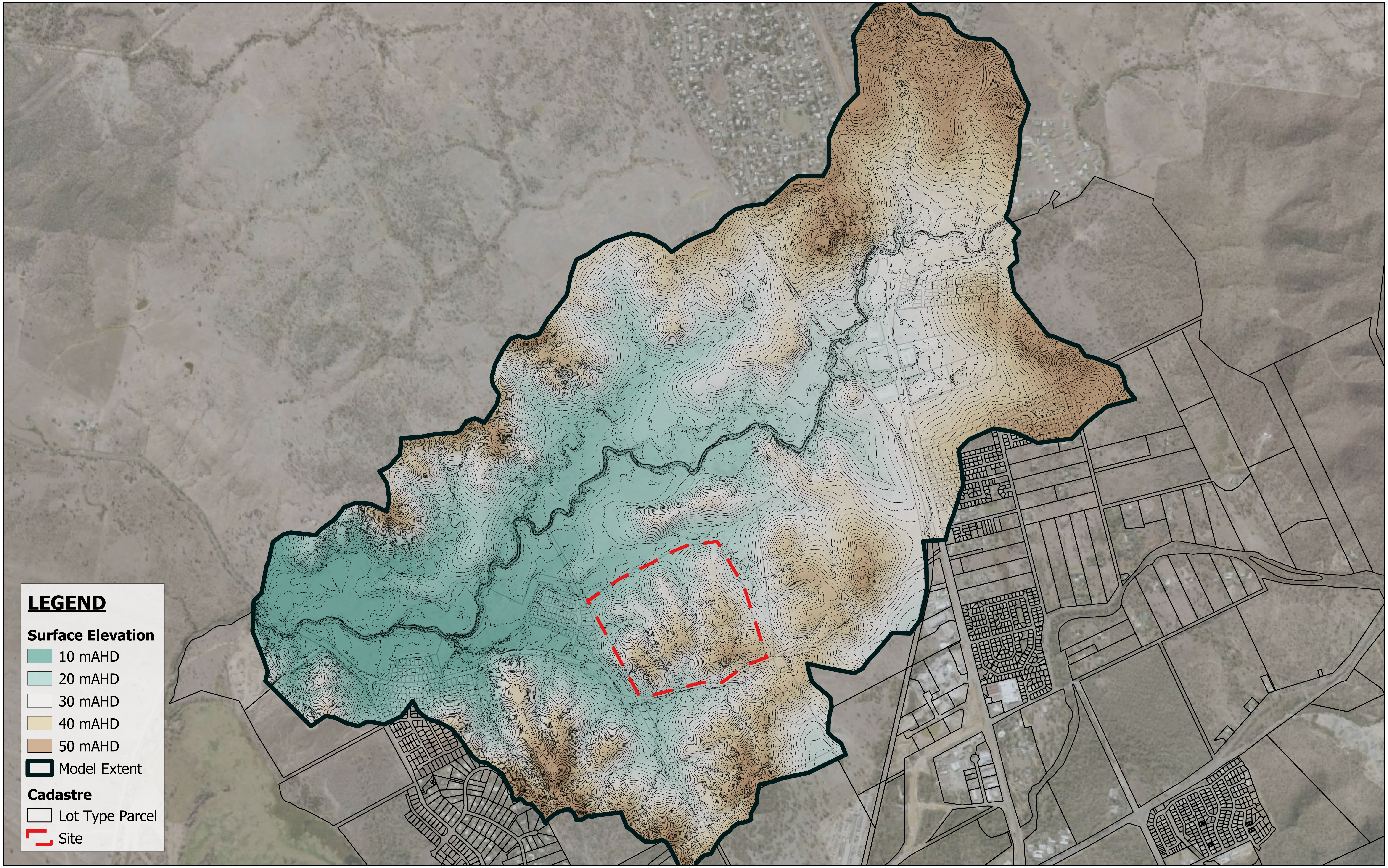
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Critical Duration - TUFLOW Model | C002 |

# APPENDIX D

## MODEL SETUP



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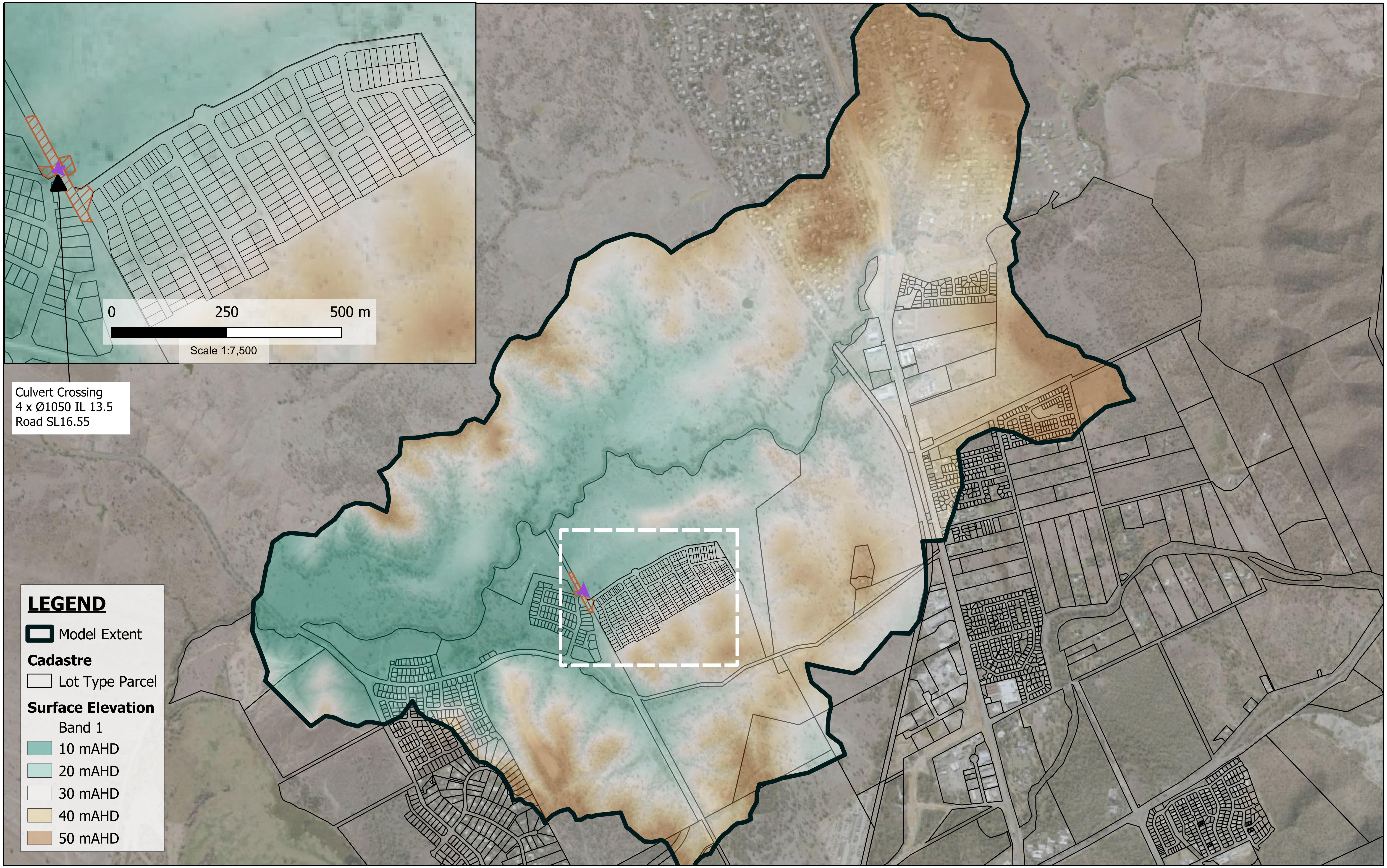
| TUFLOW Model Topography - Pre-Development | **D001** |



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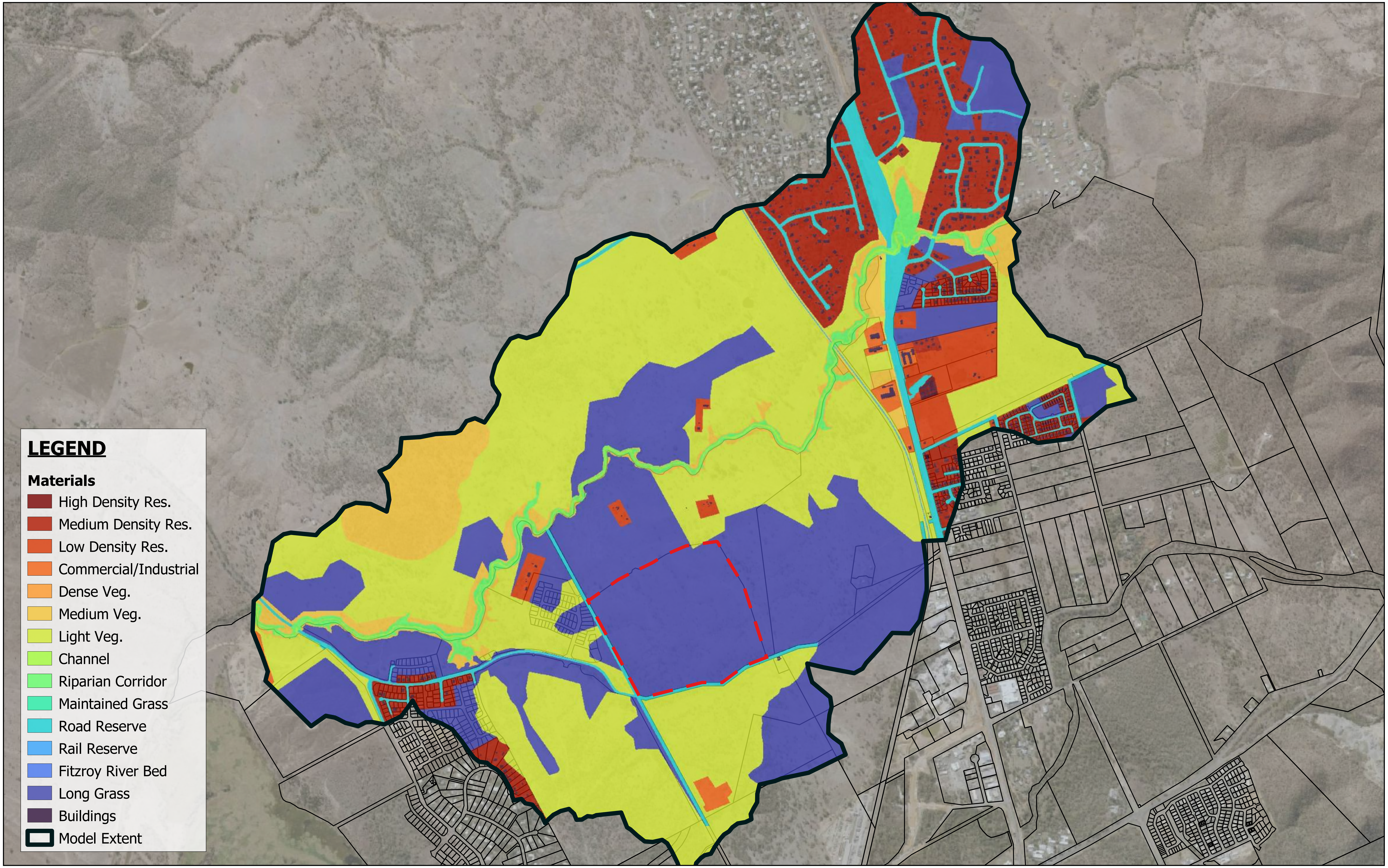
| TUFLOW Model Topography - Post-Development | **D002** |



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20.10.2023

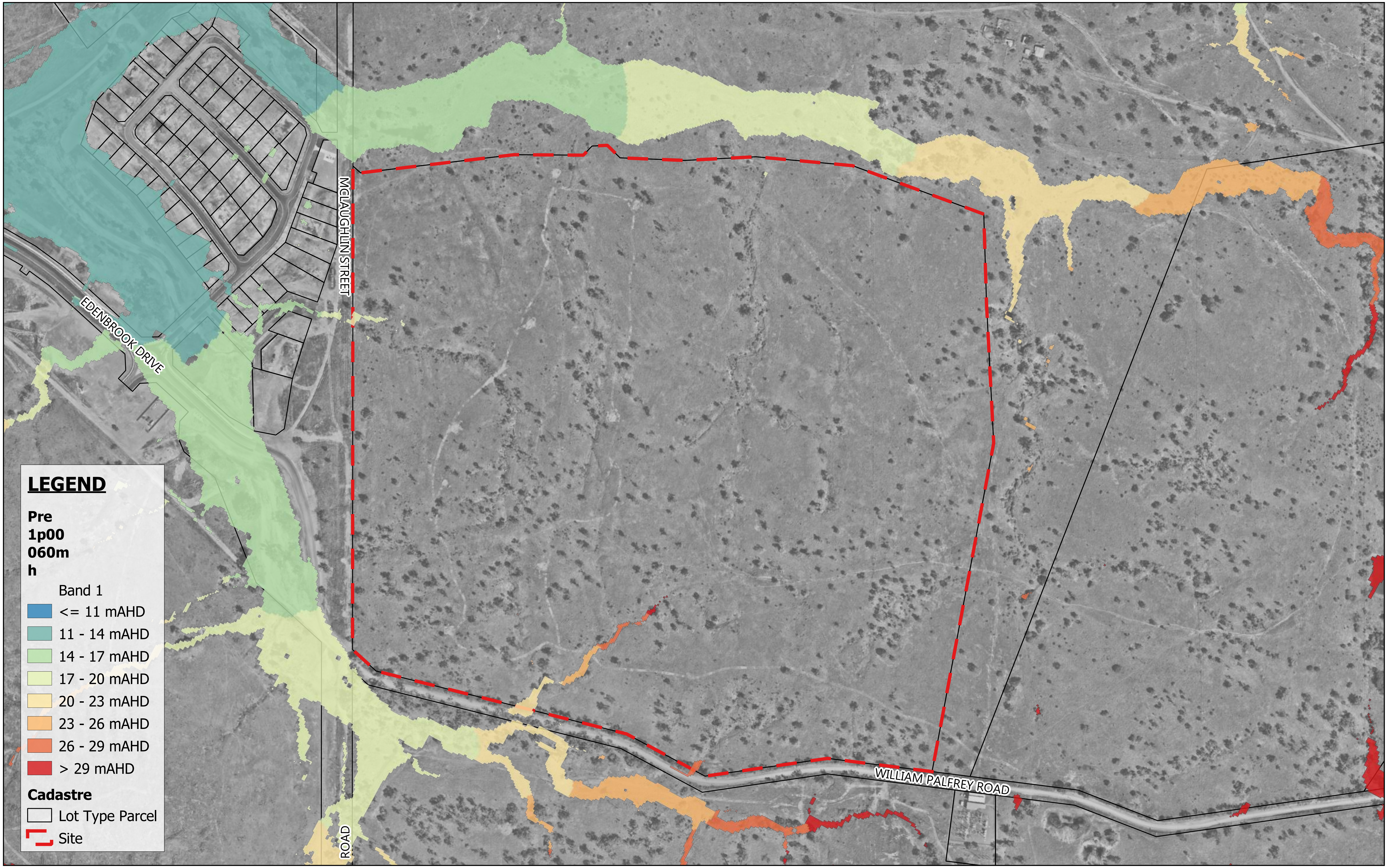
**MAAS GROUP PROPERTIES PTY LTD** | Oct 2023

**ELLIDA WEST STAGES 1-6, PARKHURST** | MPG-0001

TUFLOW Model Roughness Materials | D003

# APPENDIX E

## PRE-DEVELOPMENT HYDRAULIC MODEL RESULTS



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08.02.2024

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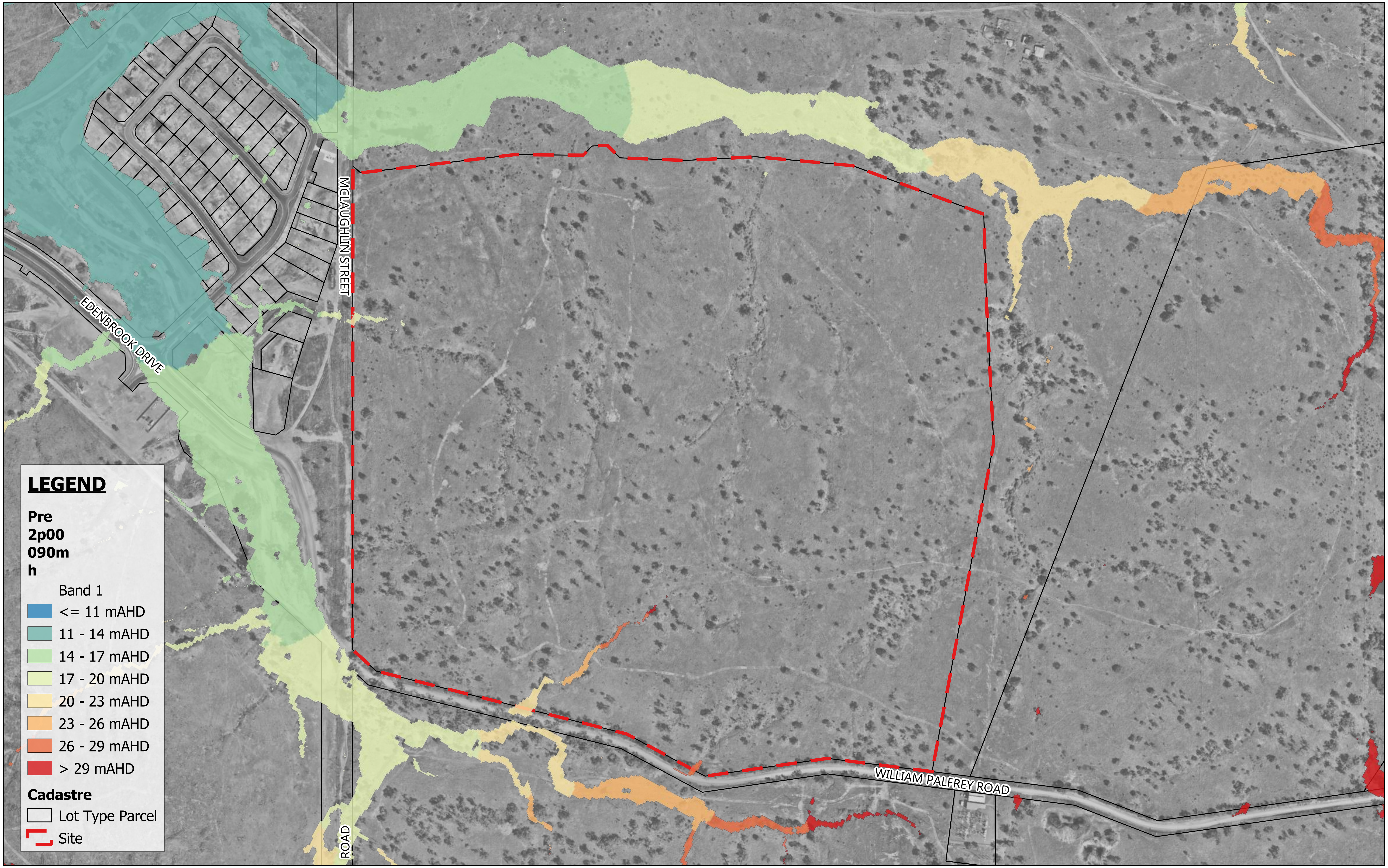
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Elevations - Pre-Development | E001 |



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08.02.2024

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|---|---|
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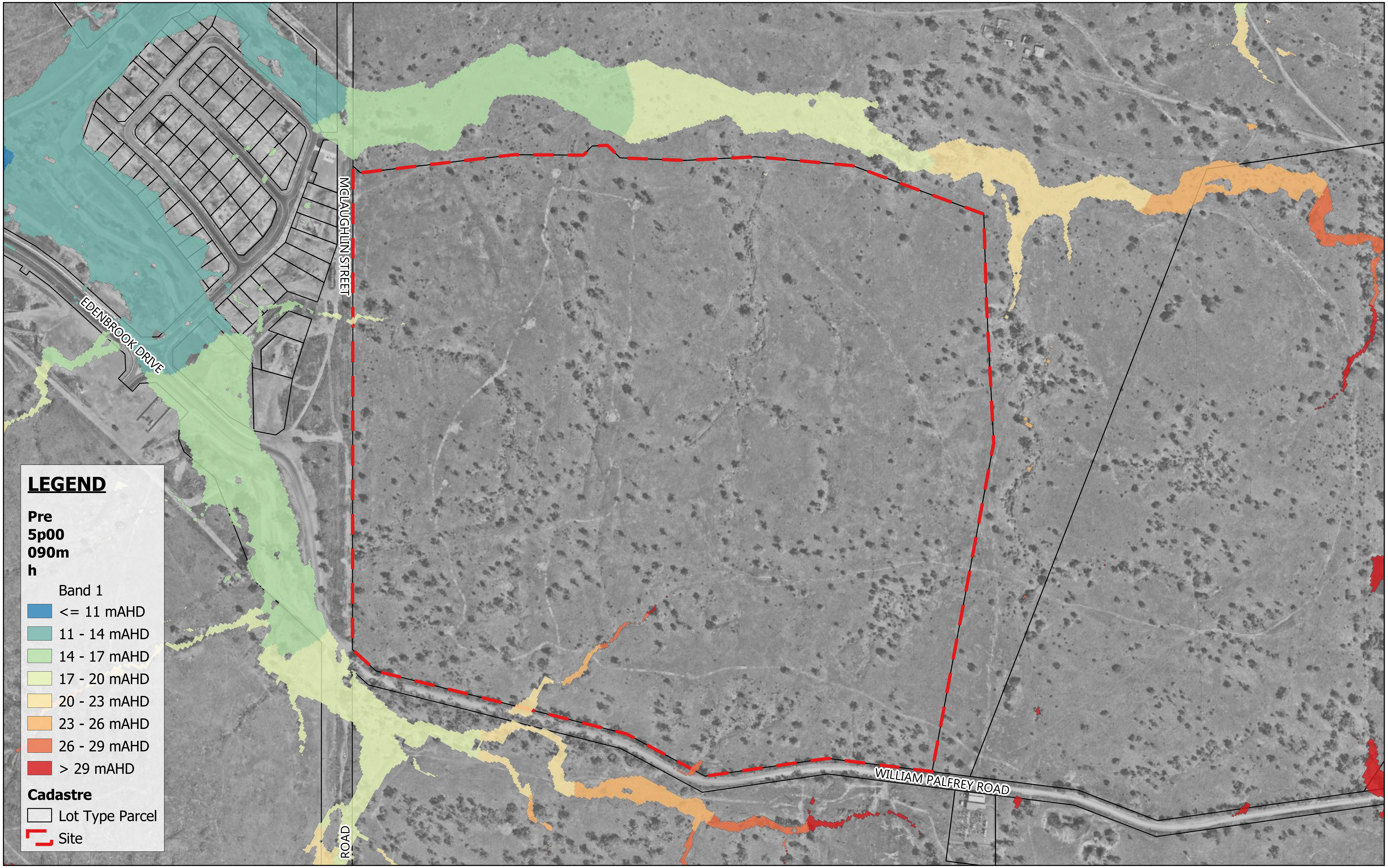
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Elevations - Pre-Development | E002 |



**Premise**

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Scale 1:4,500

08.02.2024

| | |
|---|---|
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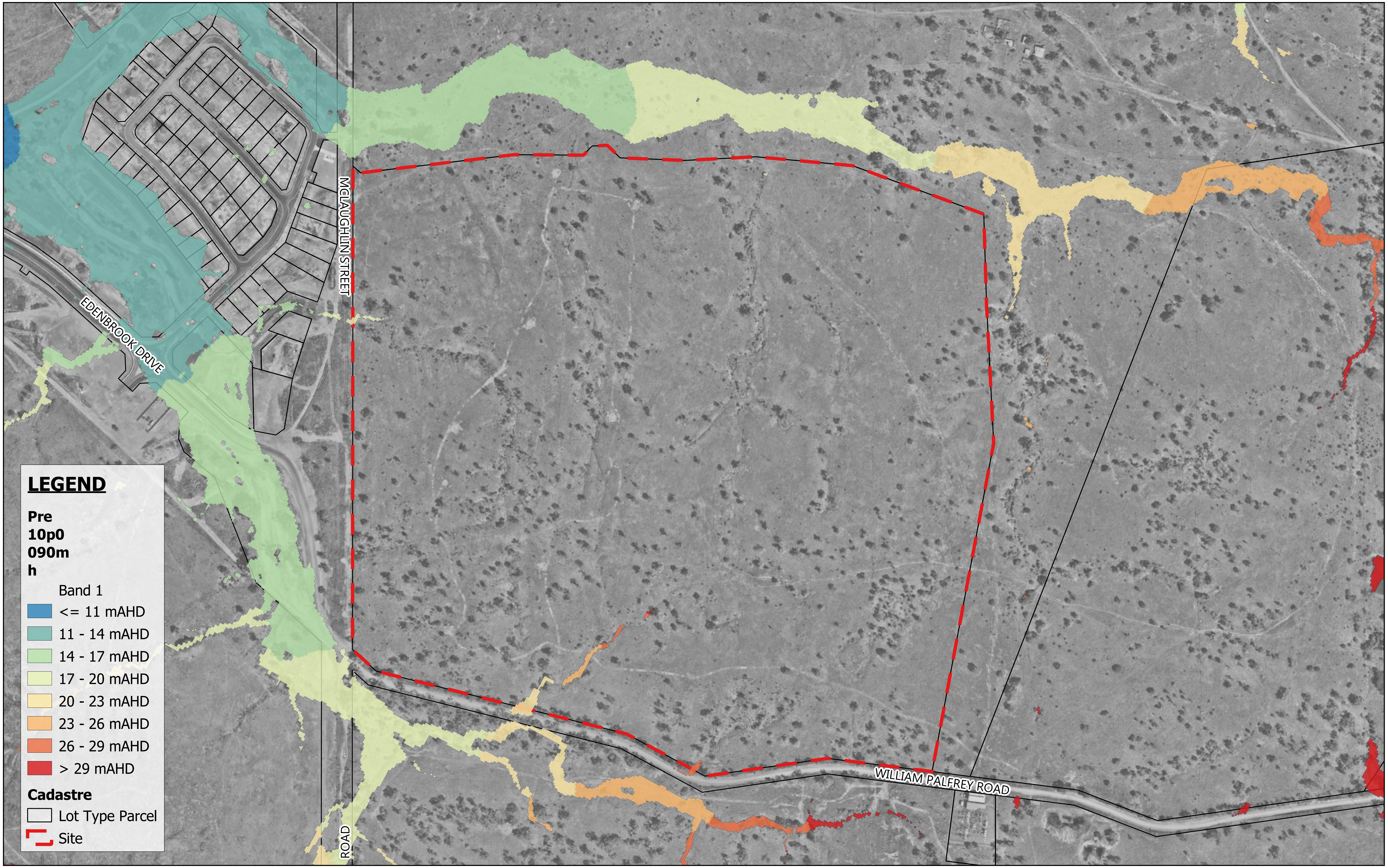
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Elevations - Pre-Development | E003 |



Premise

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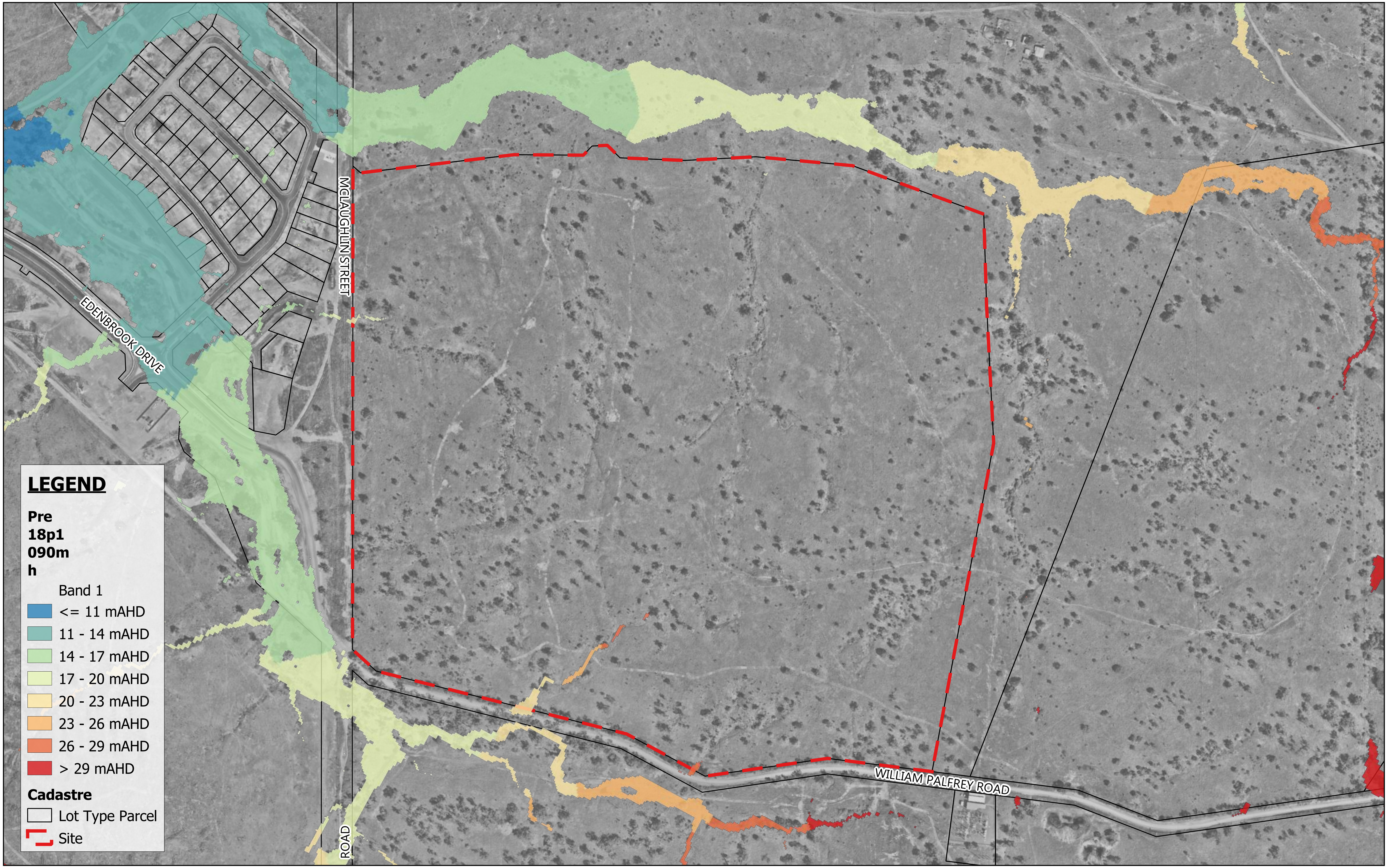
Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Elevations - Pre-Development | E004 |



Premise

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Scale 1:4,500

08.02.2024

| | |
|---|---|
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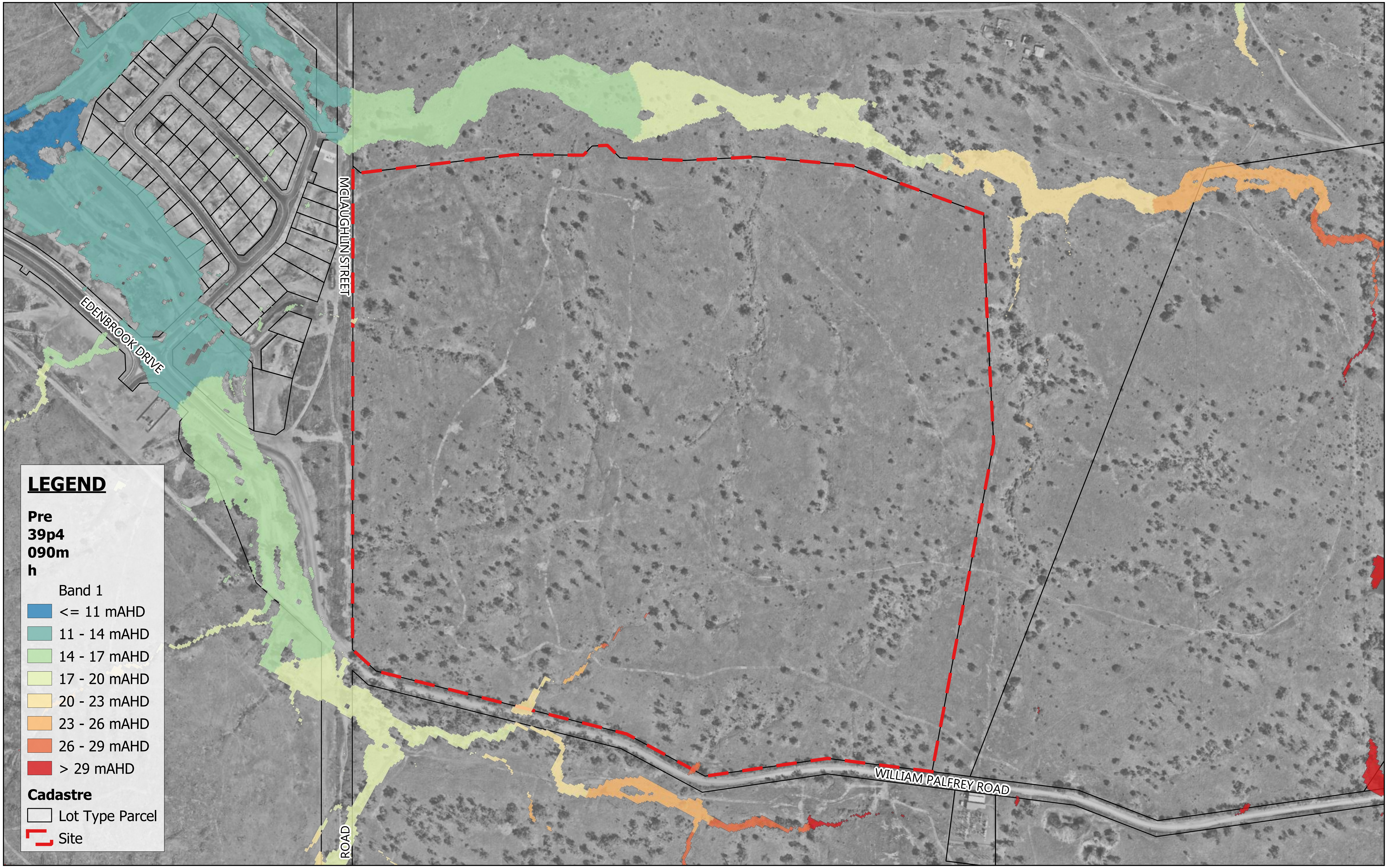
| 20% AEP Event Flood Elevations - Pre-Development | E005 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

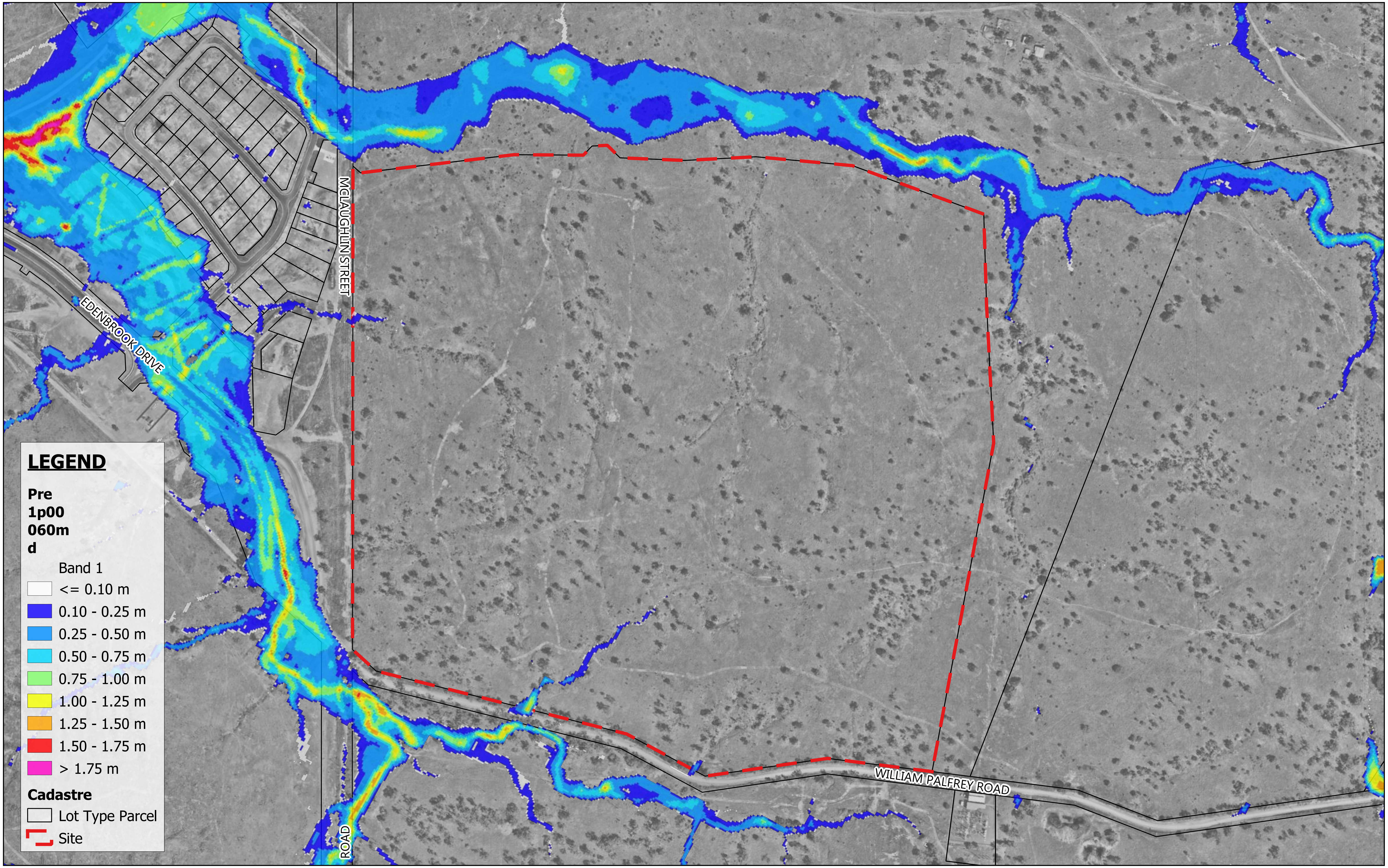
| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Elevations - Pre-Development | E006 |

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Elevations - Pre-Development | E007 |



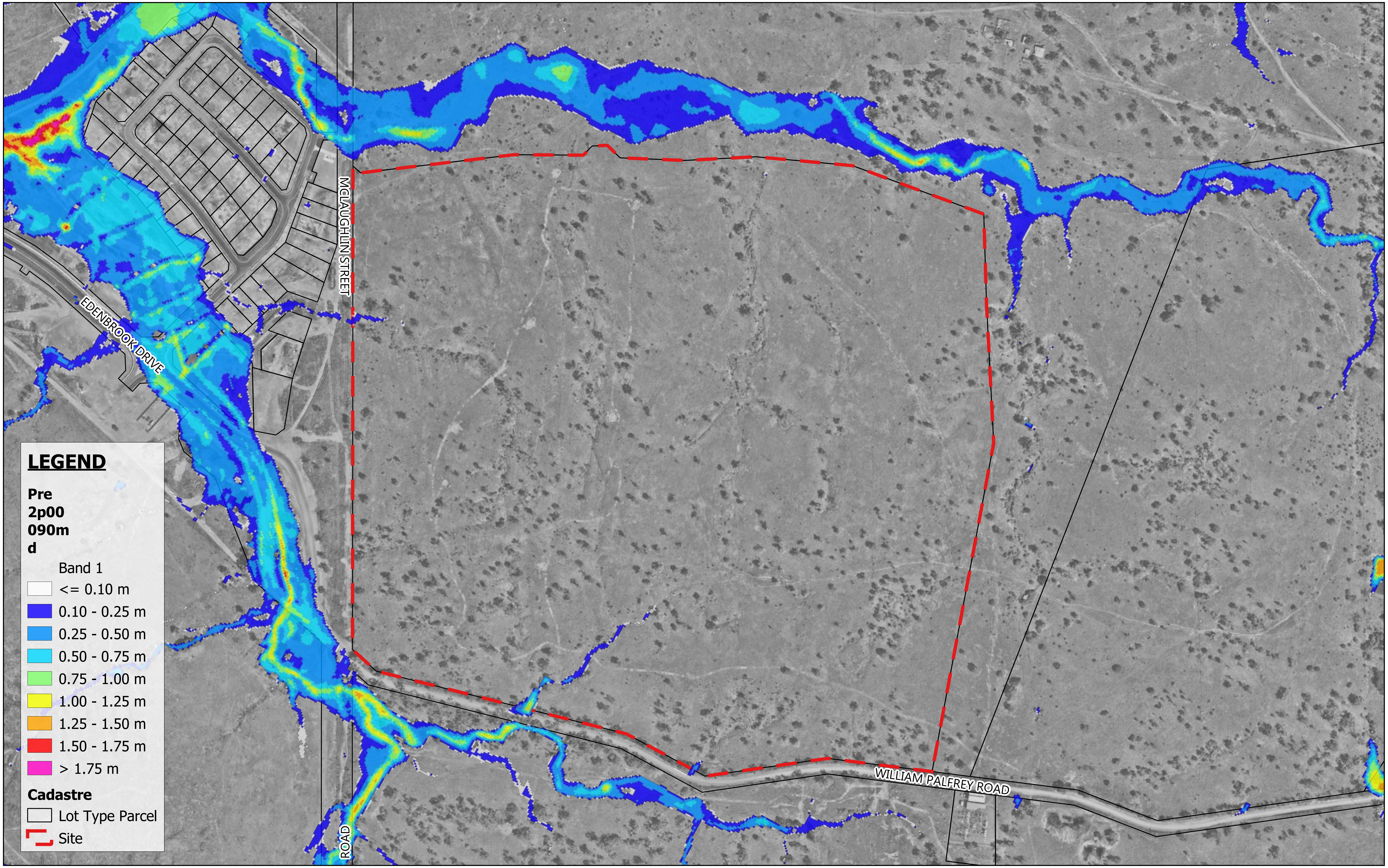
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Depth - Pre-Development | E008 |



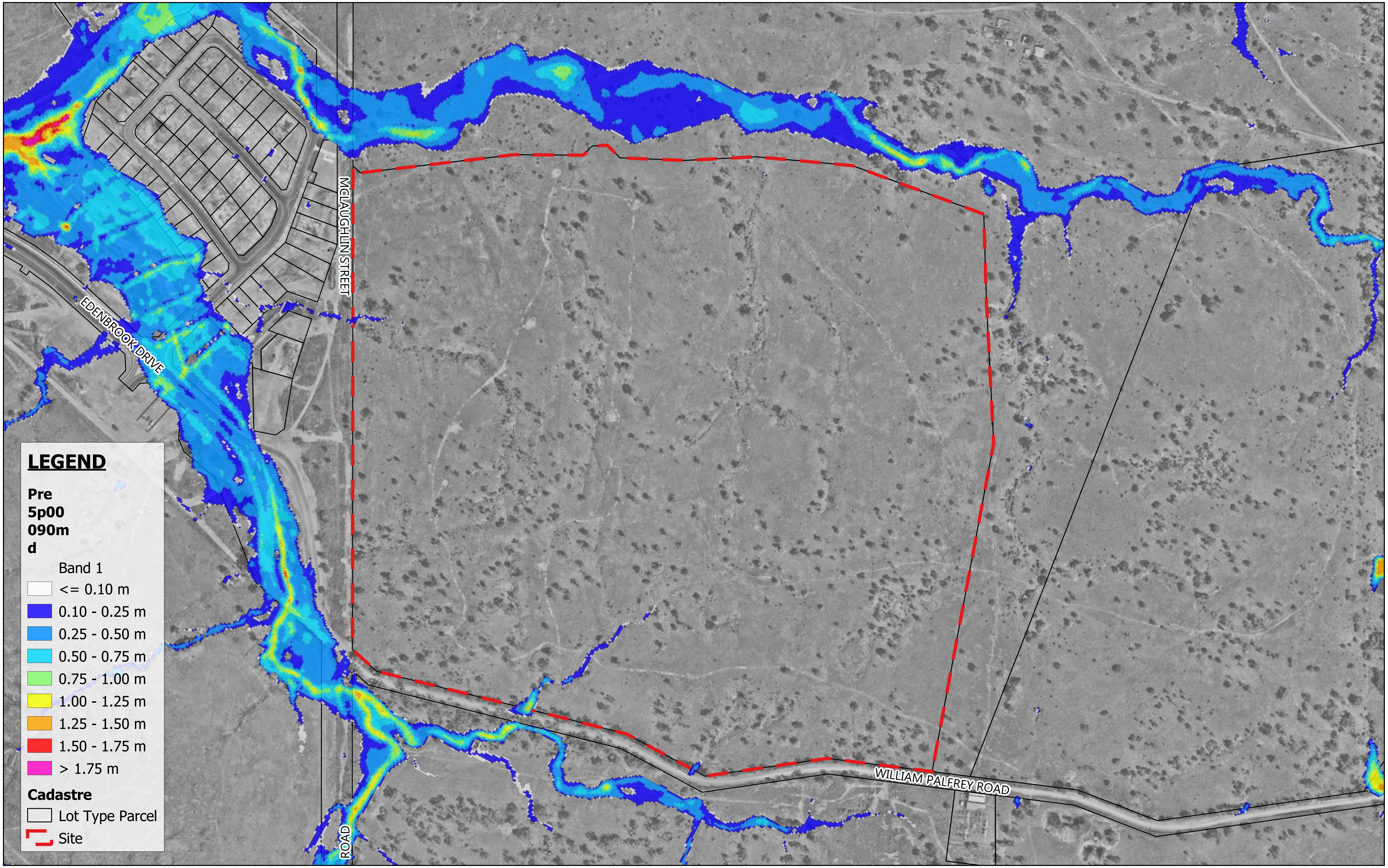
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Depth - Pre-Development | E009 |



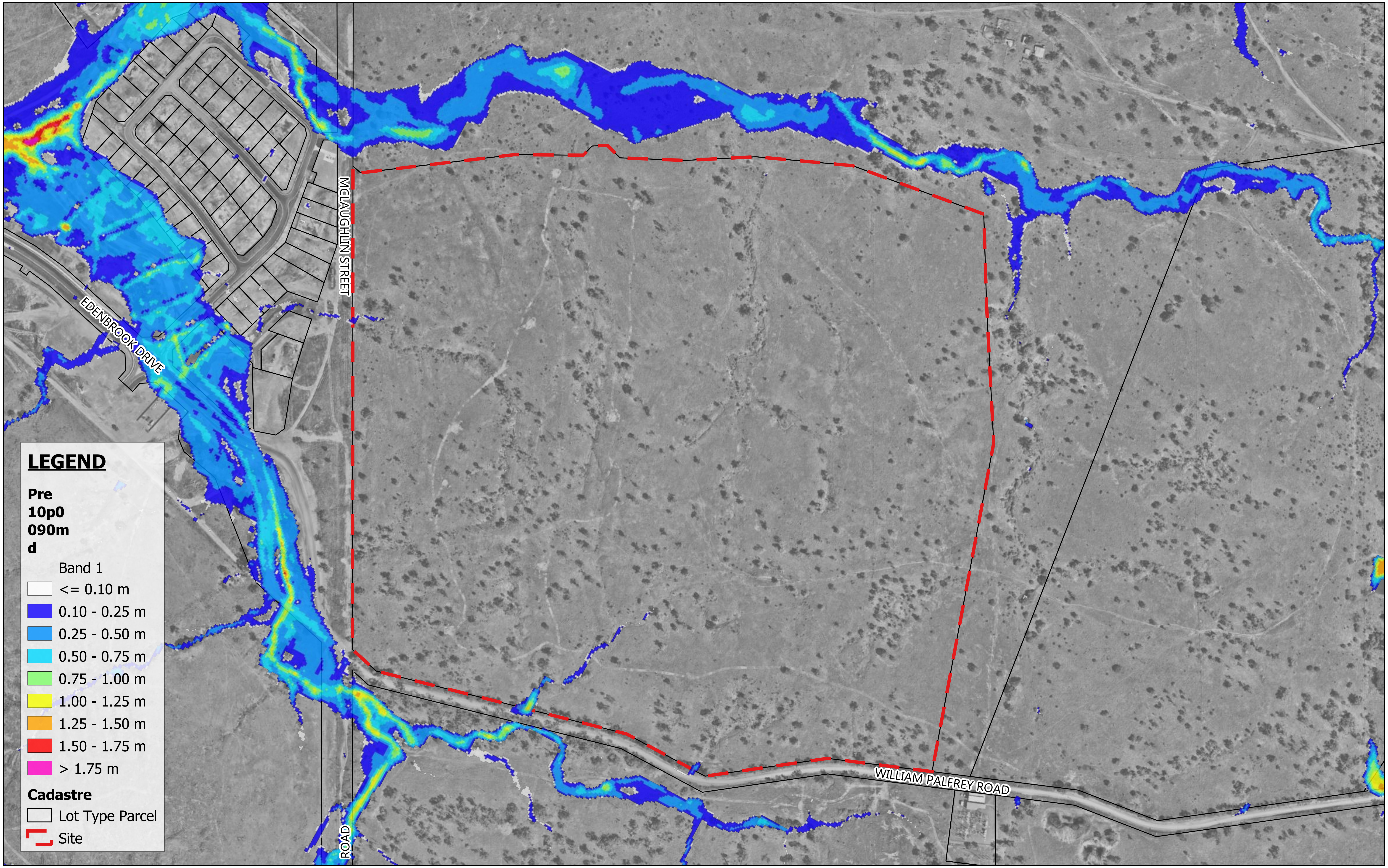
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Depth - Pre-Development | E010 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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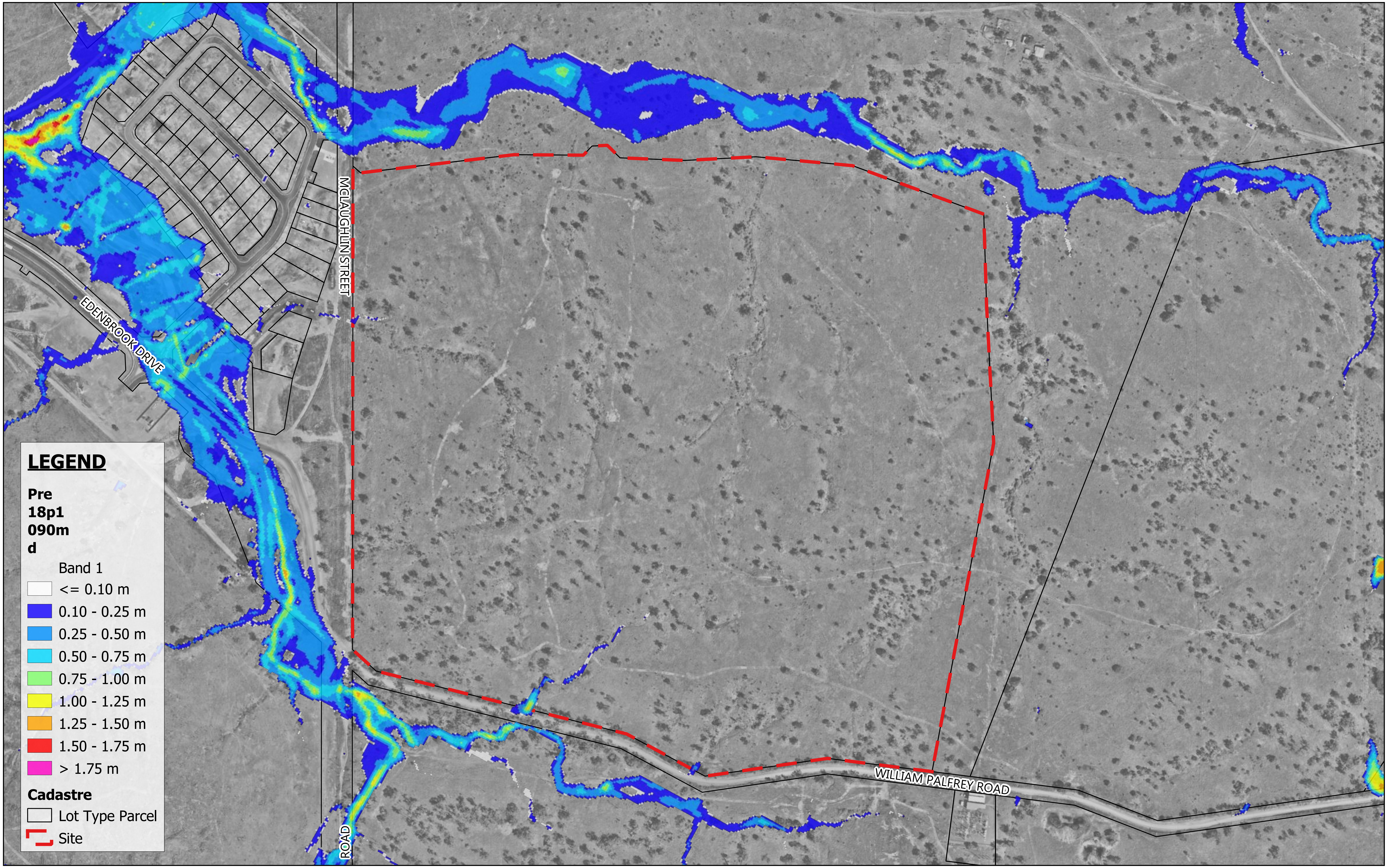
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Depth - Pre-Development | E011 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

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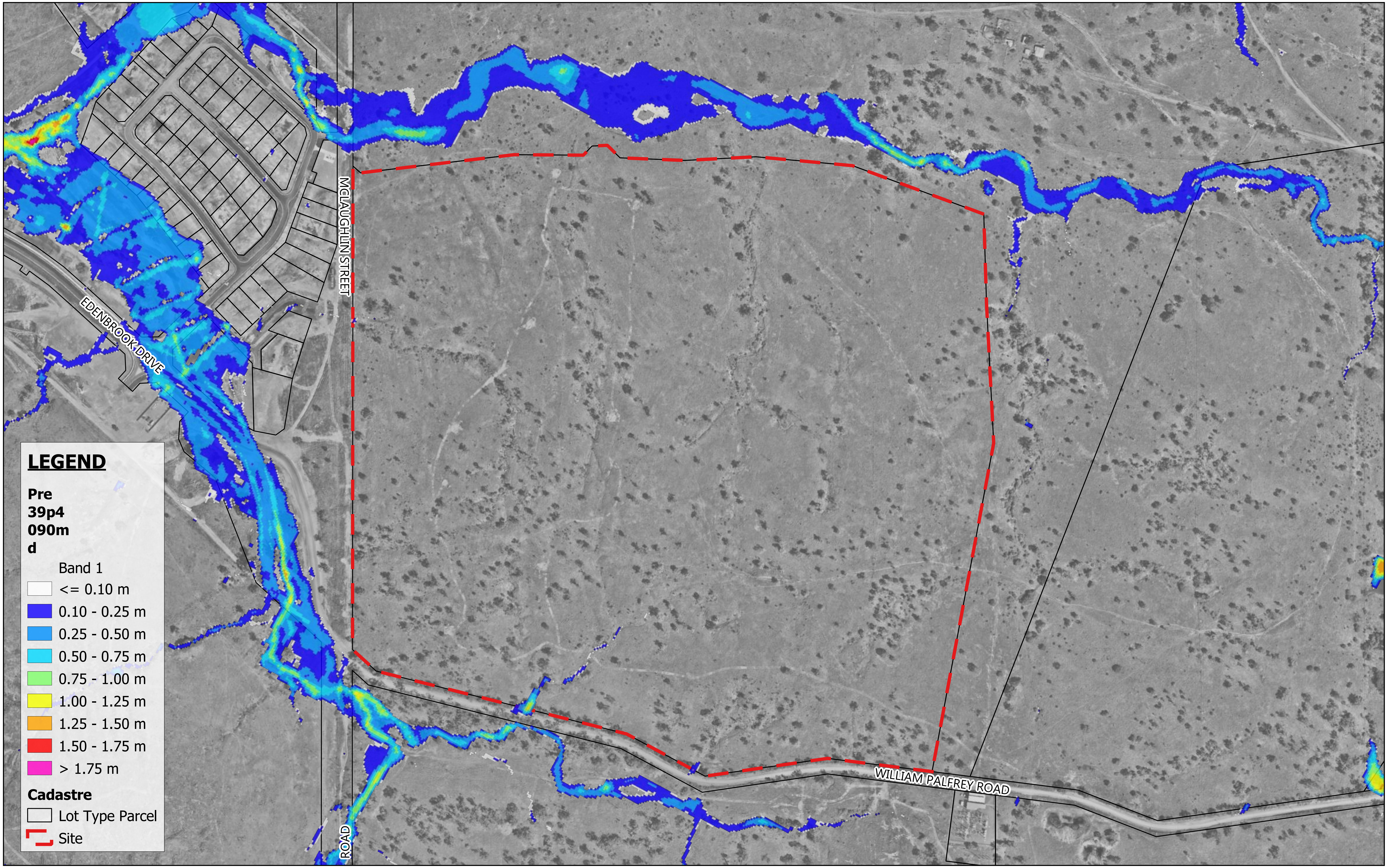
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Depth - Pre-Development | E012 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

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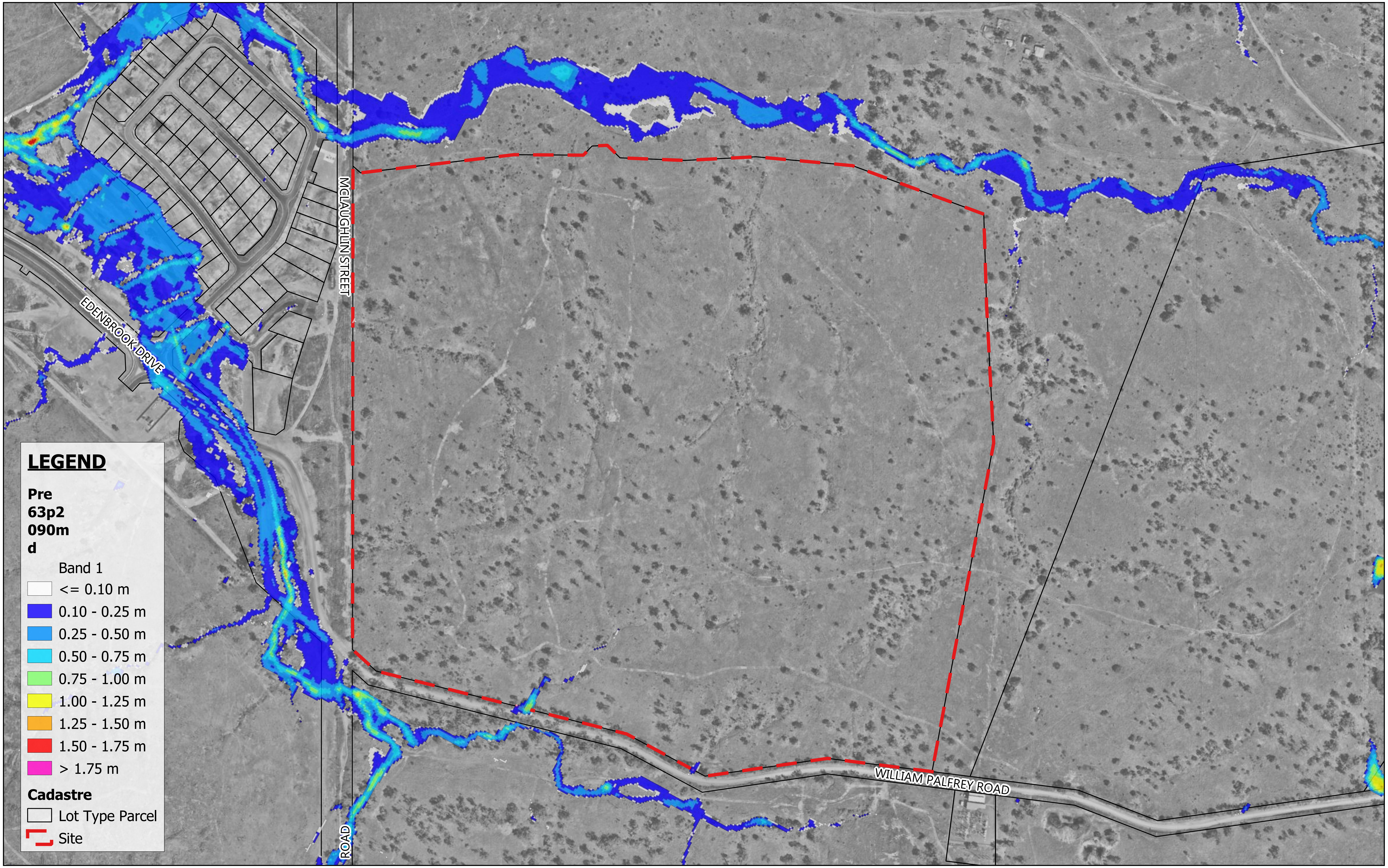
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Depth - Pre-Development | E013 |



0 150 300 450 m

Scale 1:4,500

08.02.2024

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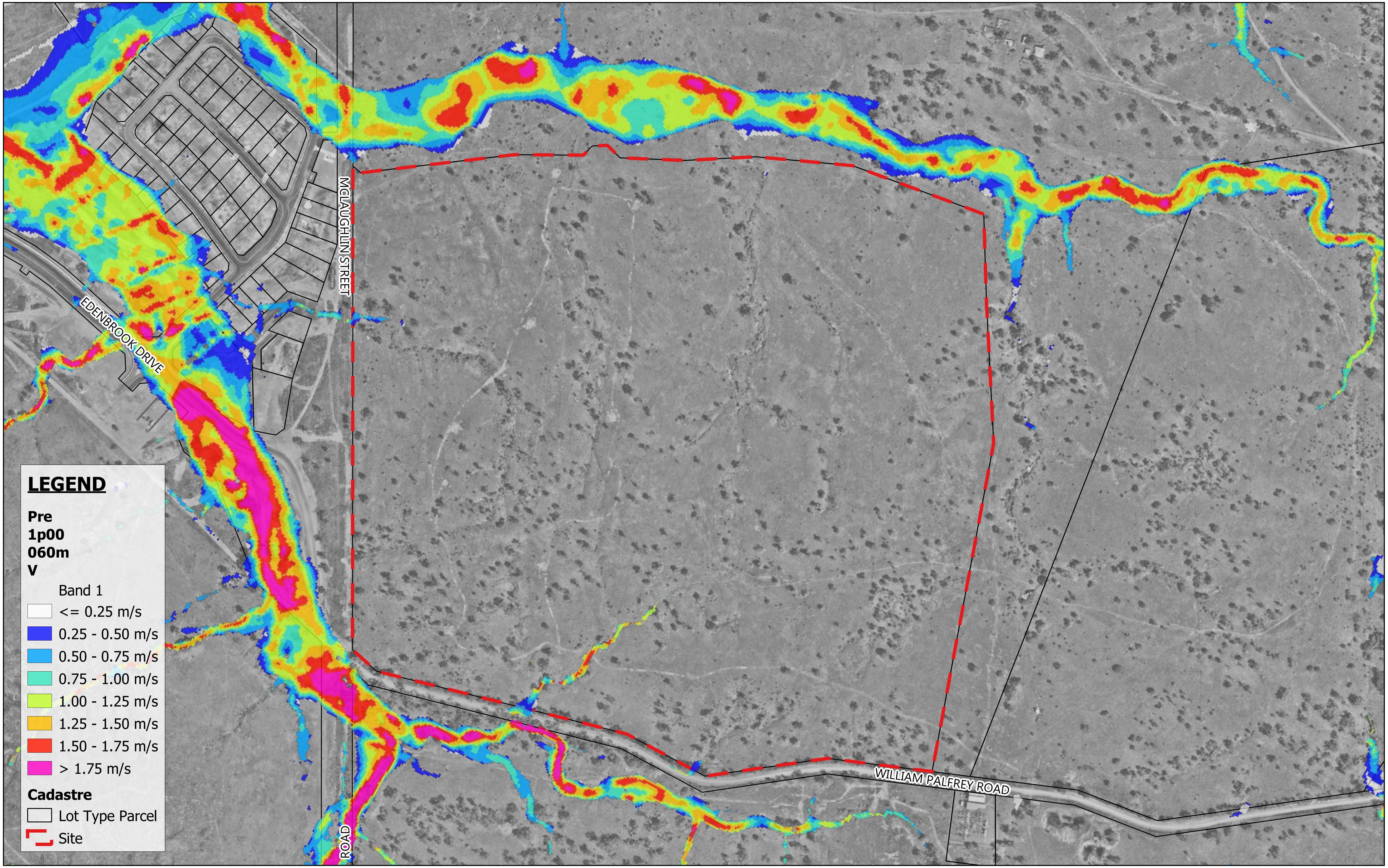
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Depth - Pre-Development | E014 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

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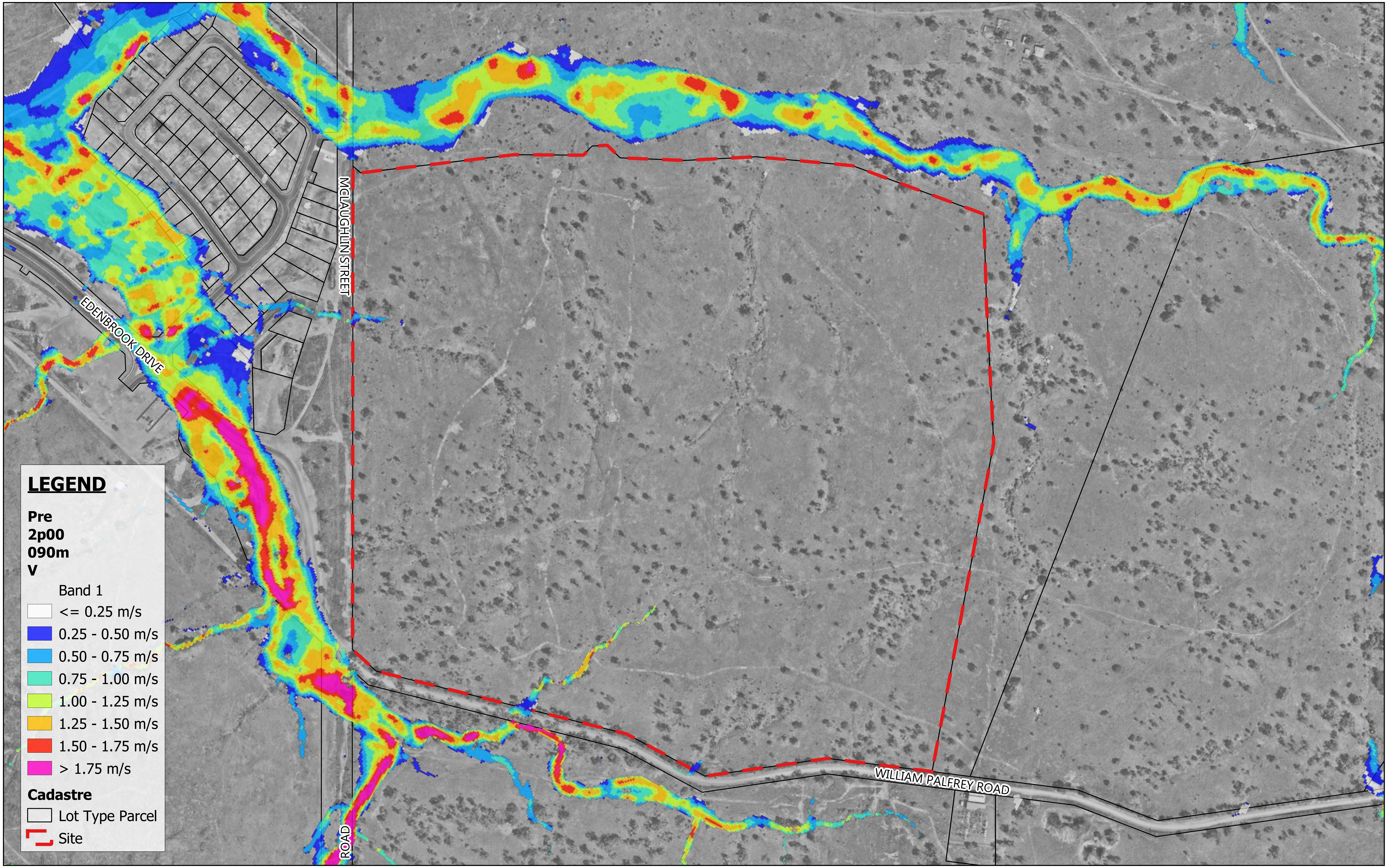
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Velocity - Pre-Development | E015 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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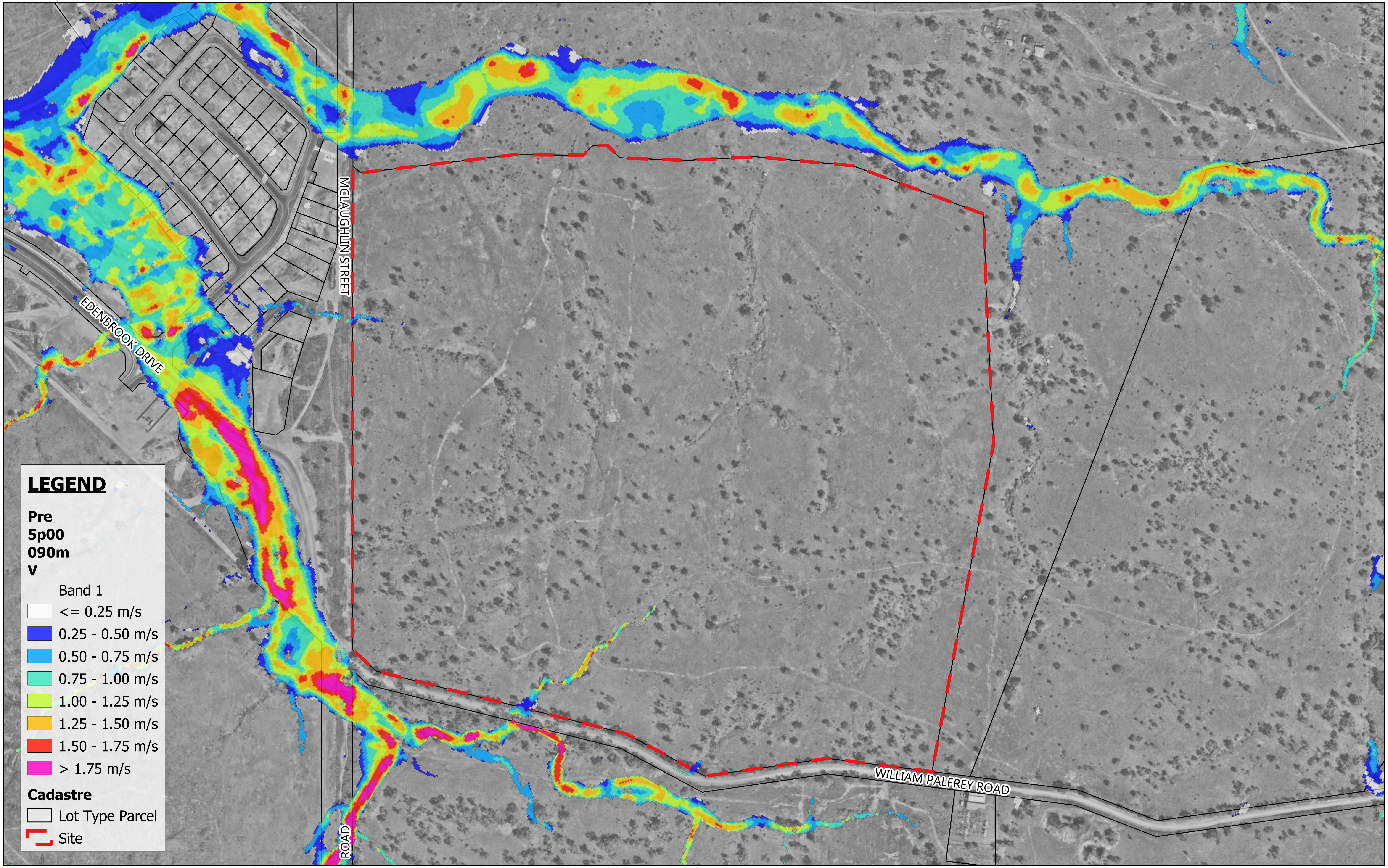
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Velocity - Pre-Development | E016 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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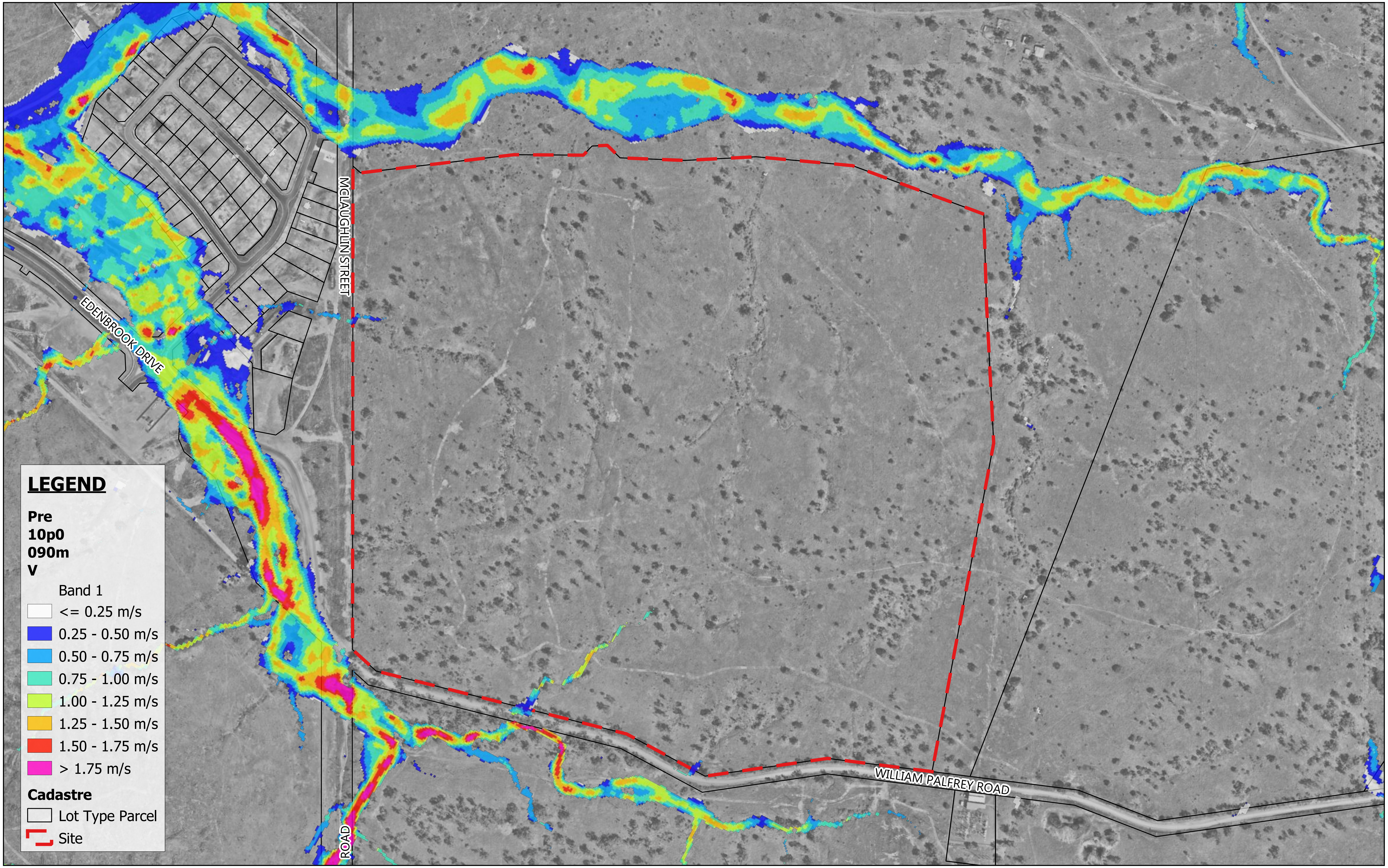
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Velocity - Pre-Development | E017 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

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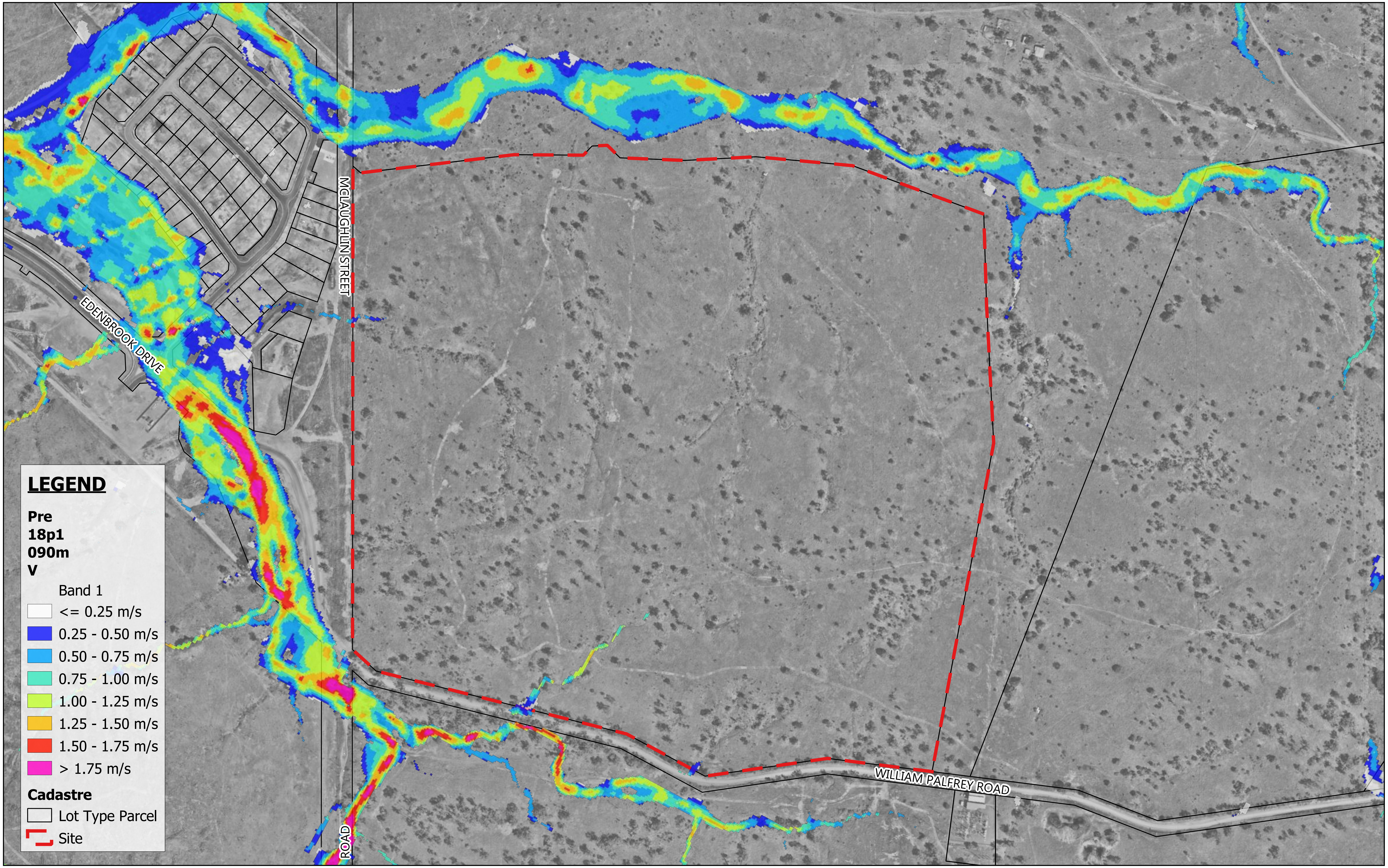
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Velocity - Pre-Development | E018 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

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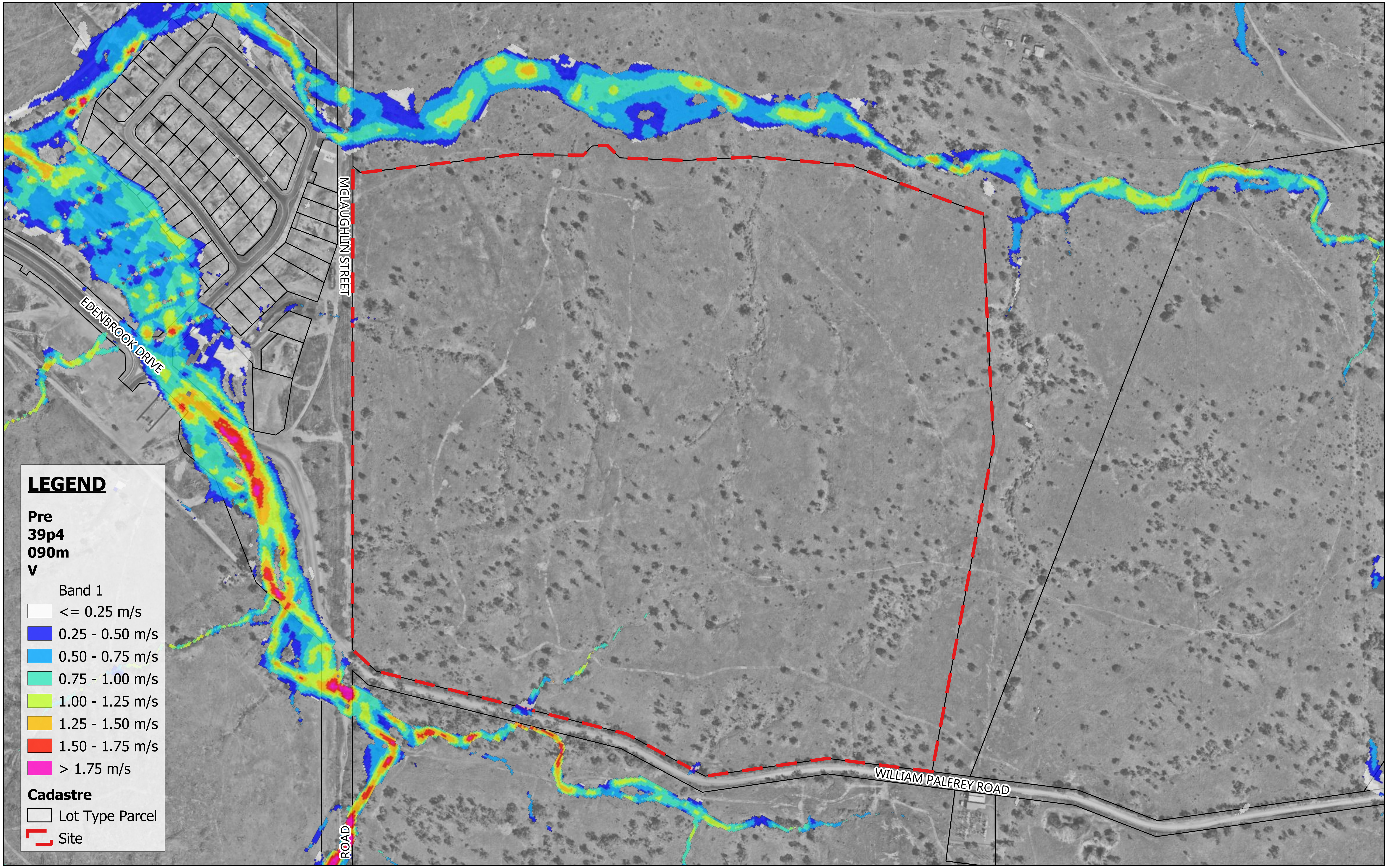
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Velocity - Pre-Development | E019 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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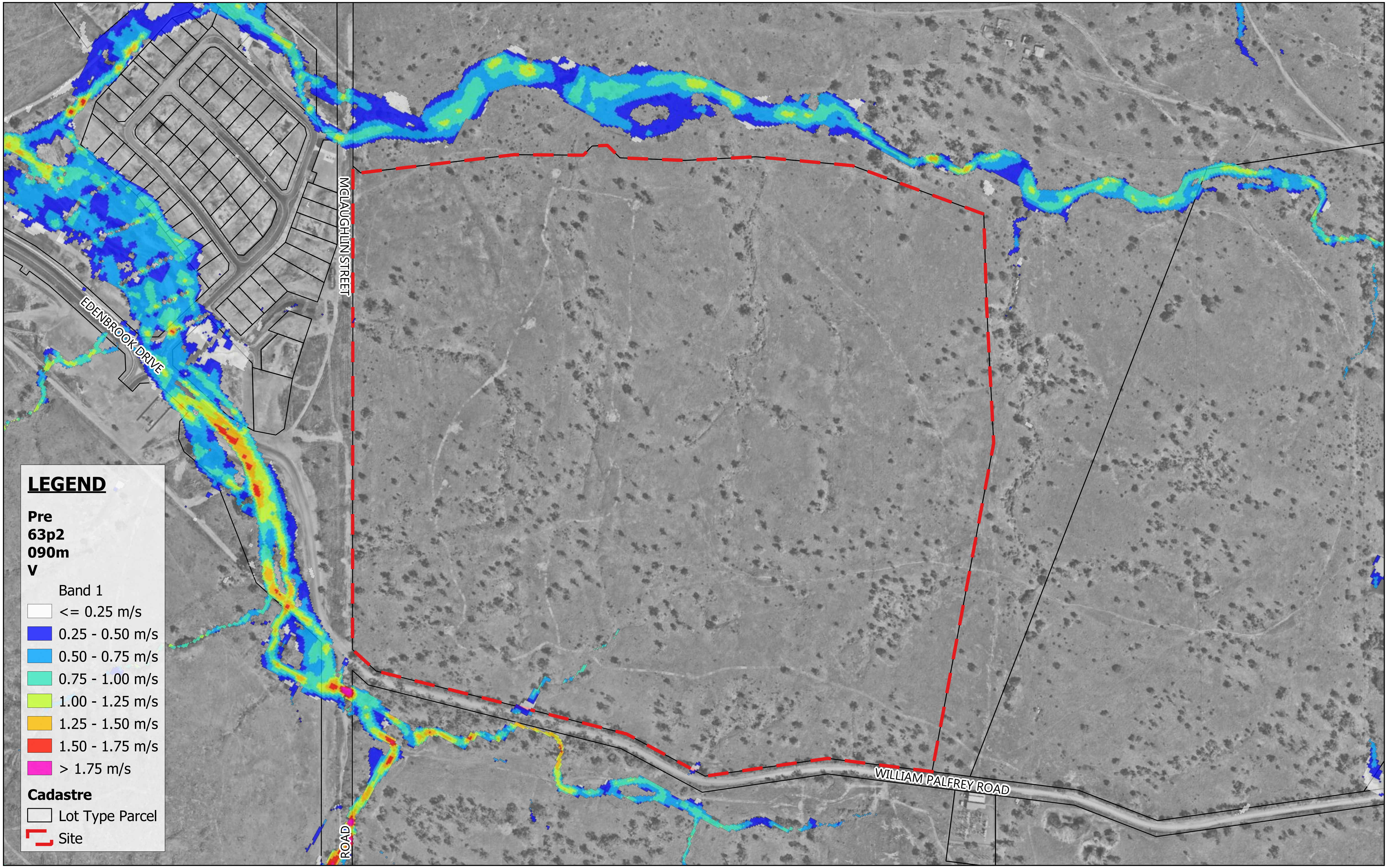
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Velocity - Pre-Development | E020 |



Premise

0 150 300 450 m

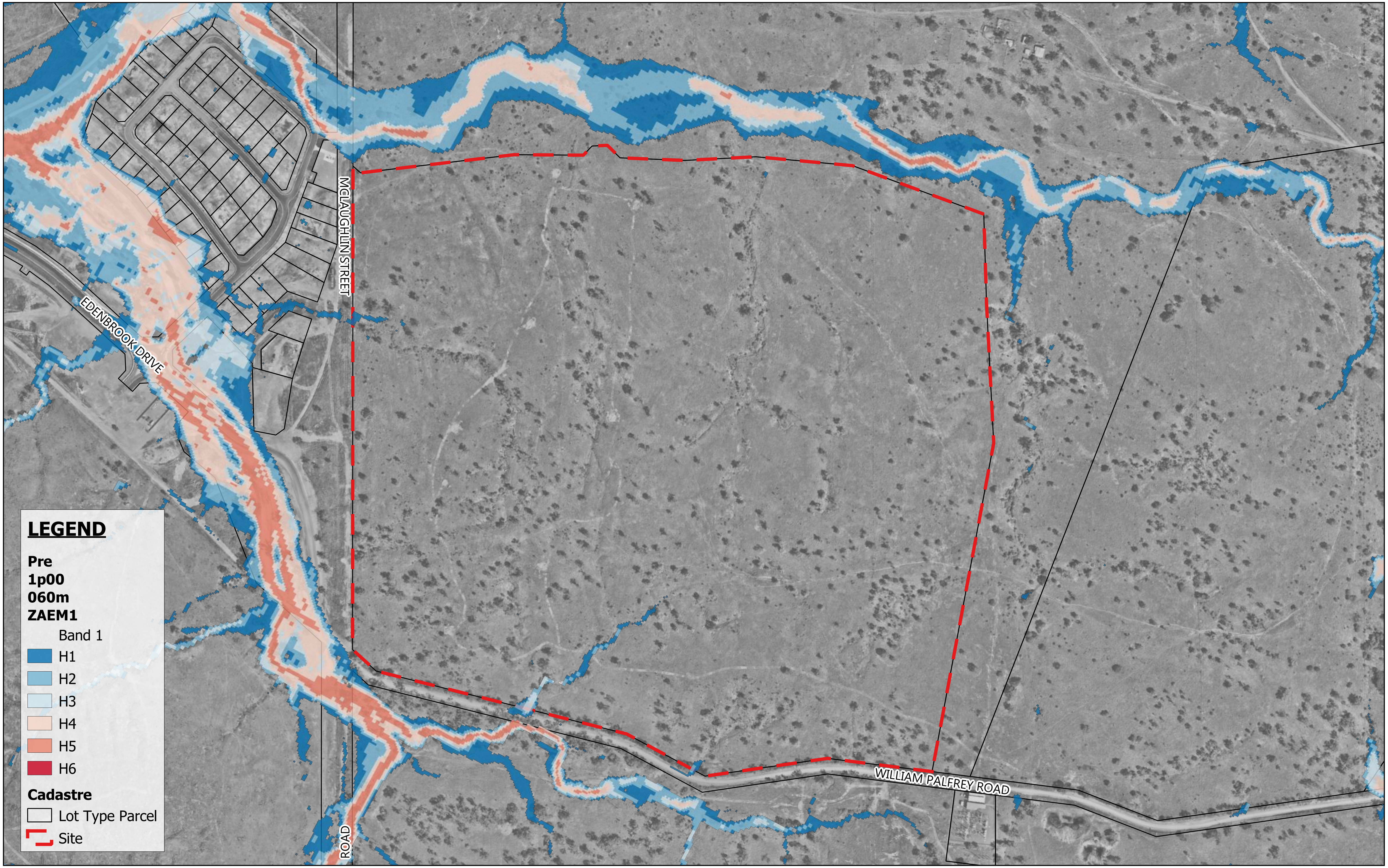
Scale 1:4,500

08.02.2024

MAAS GROUP PROPERTIES PTY LTD
Feb 2024

ELLIDA WEST STAGES 1-6, PARKHURST
MPG-0001

63.2% AEP Event Flood Velocity - Pre-Development
E021



0 150 300 450 m

Scale 1:4,500

08.02.2024

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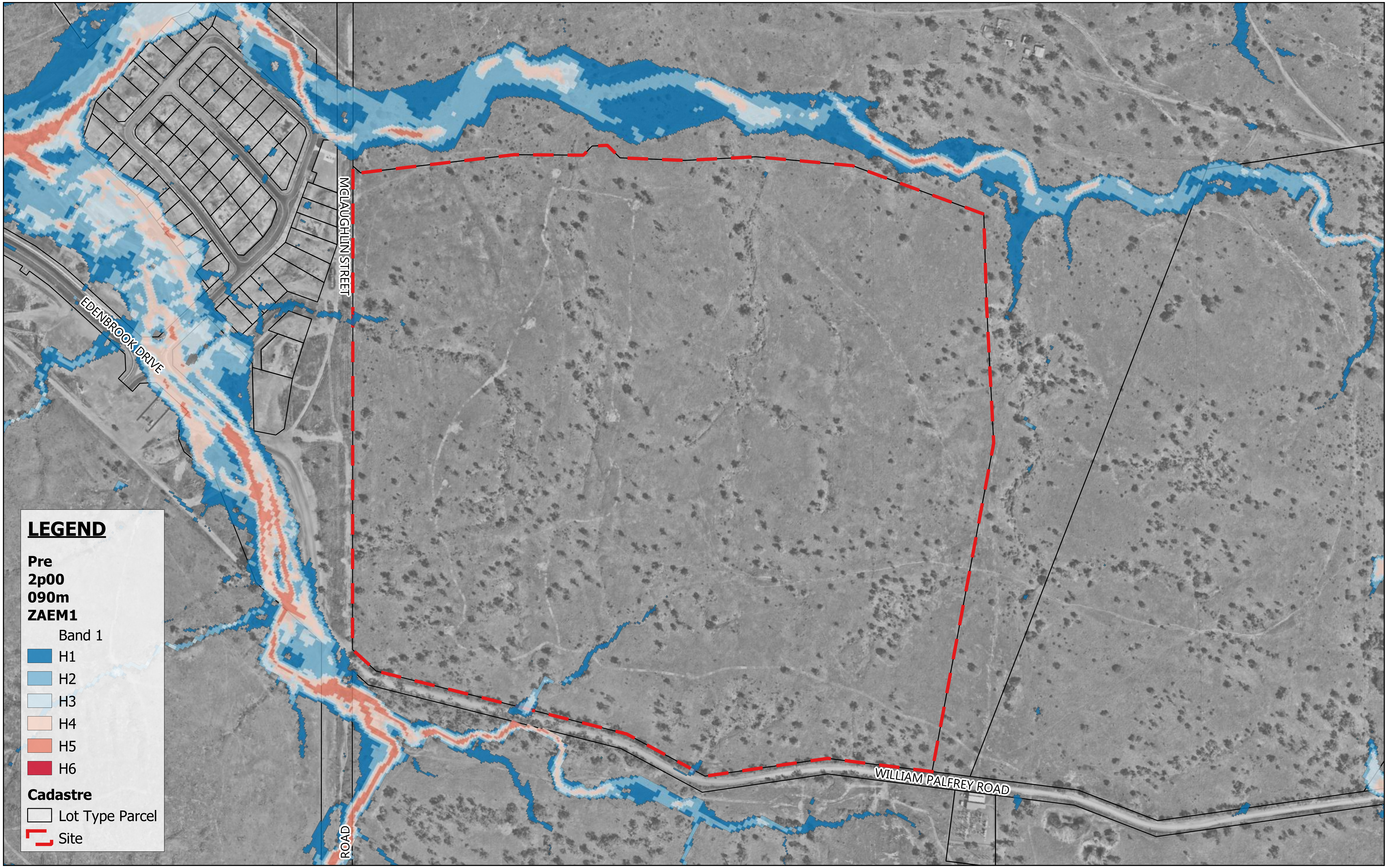
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Hazard - Pre-Development | E022 |



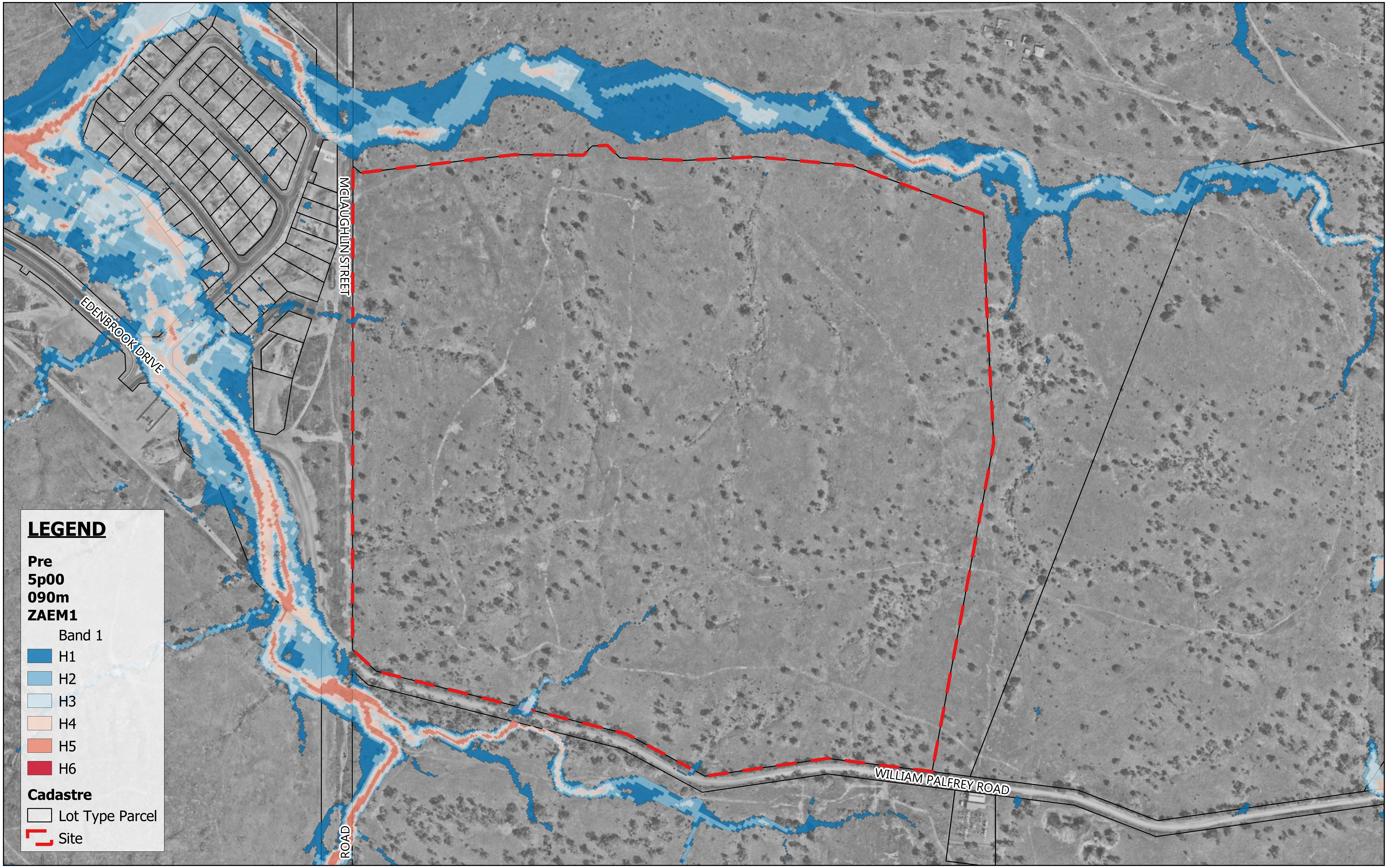
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Hazard - Pre-Development | E023 |



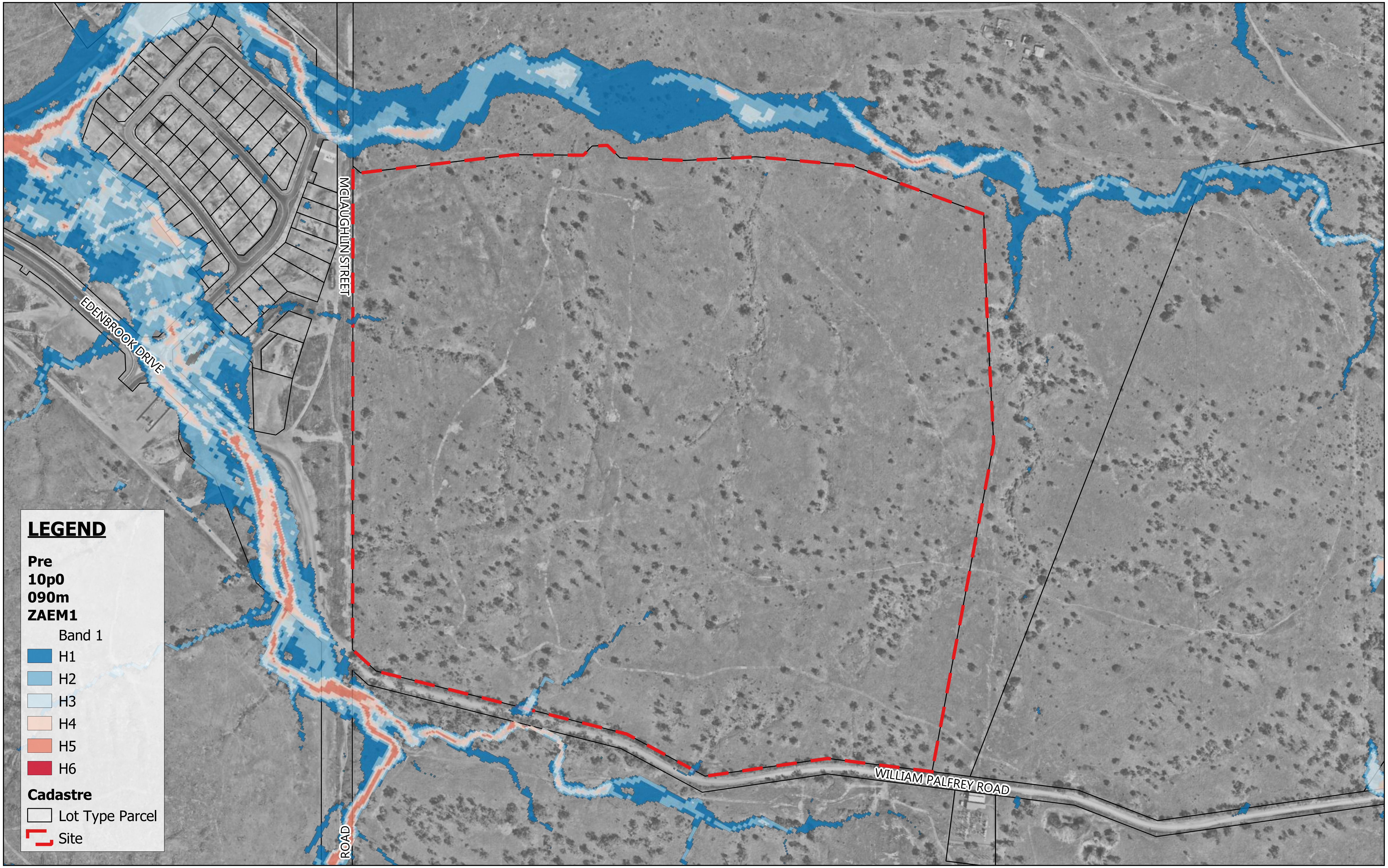
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Hazard - Pre-Development | E024 |



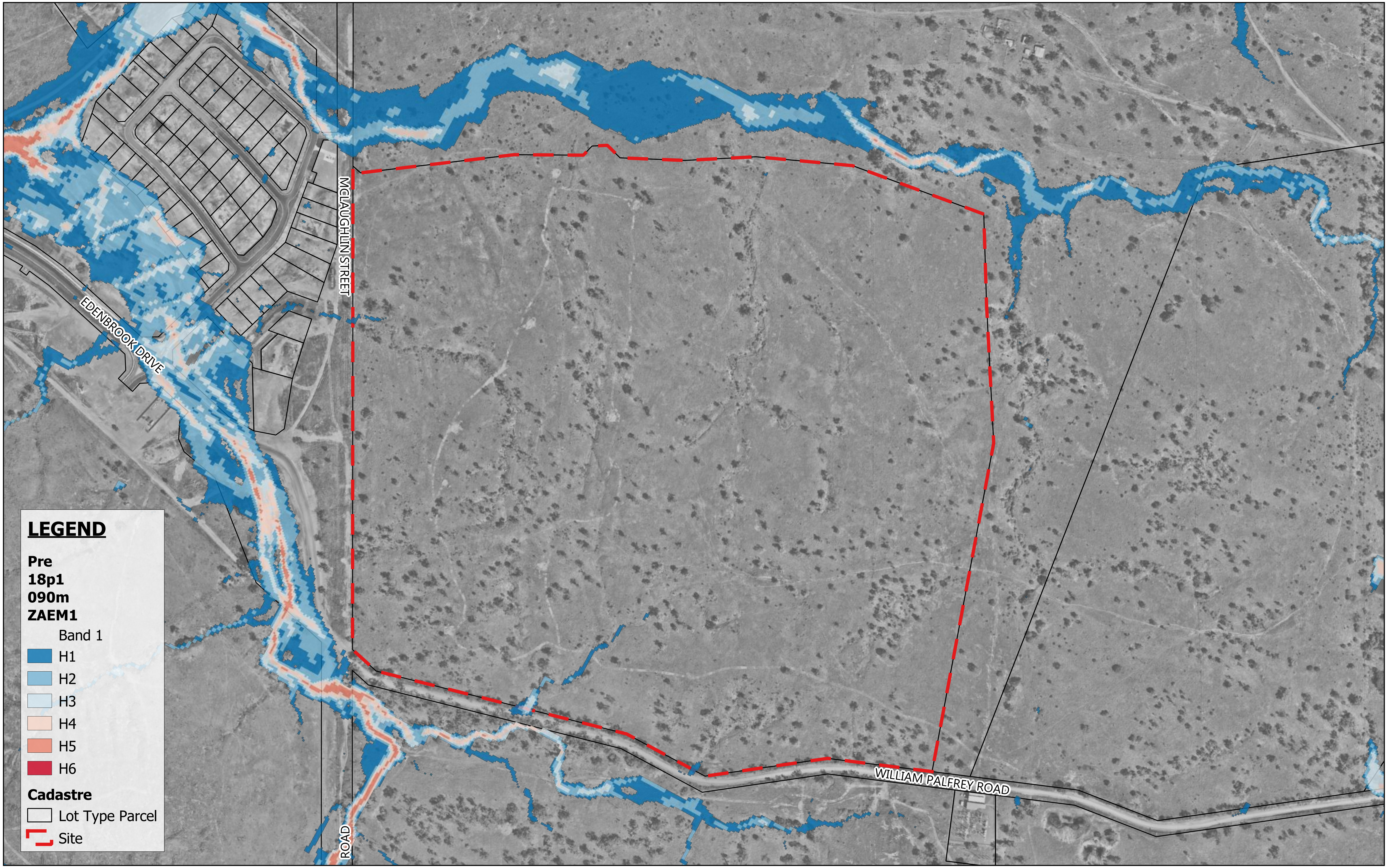
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Hazard - Pre-Development | E025 |



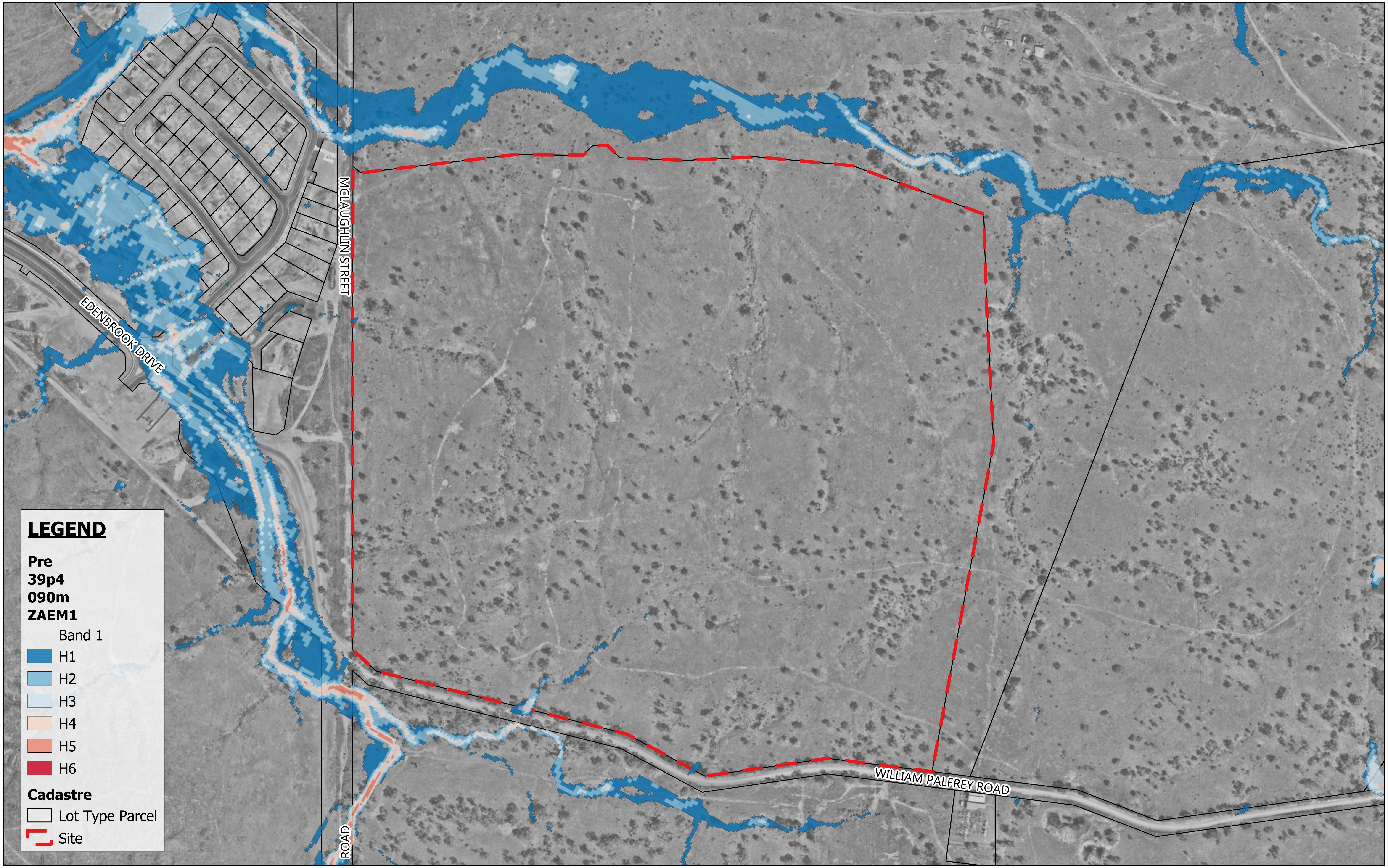
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Hazard - Pre-Development | E026 |



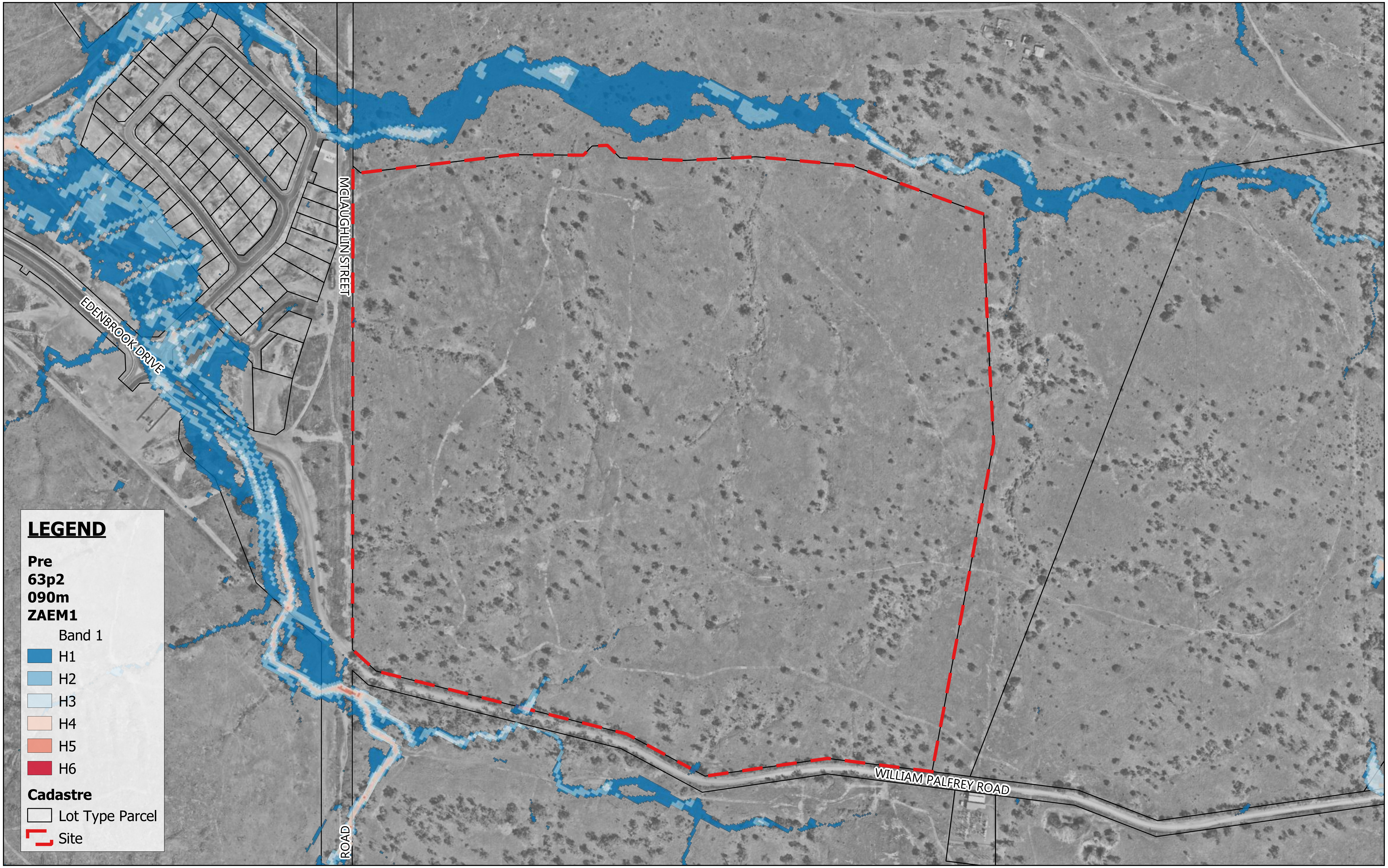
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Hazard - Pre-Development | E027 |



Premise

0 150 300 450 m

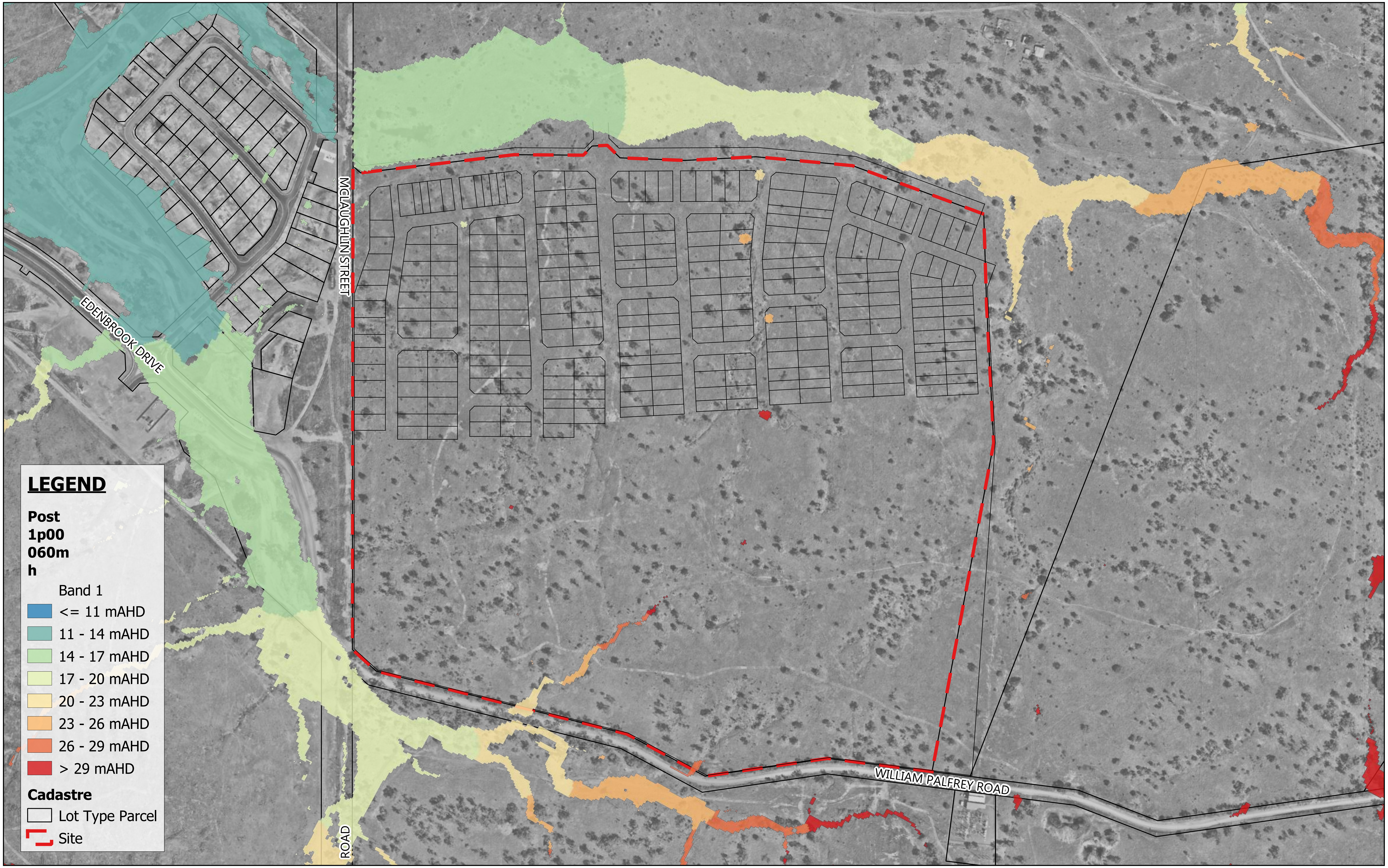
Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Hazard - Pre-Development | E028 |

# APPENDIX F

## POST-DEVELOPMENT HYDRAULIC MODEL RESULTS



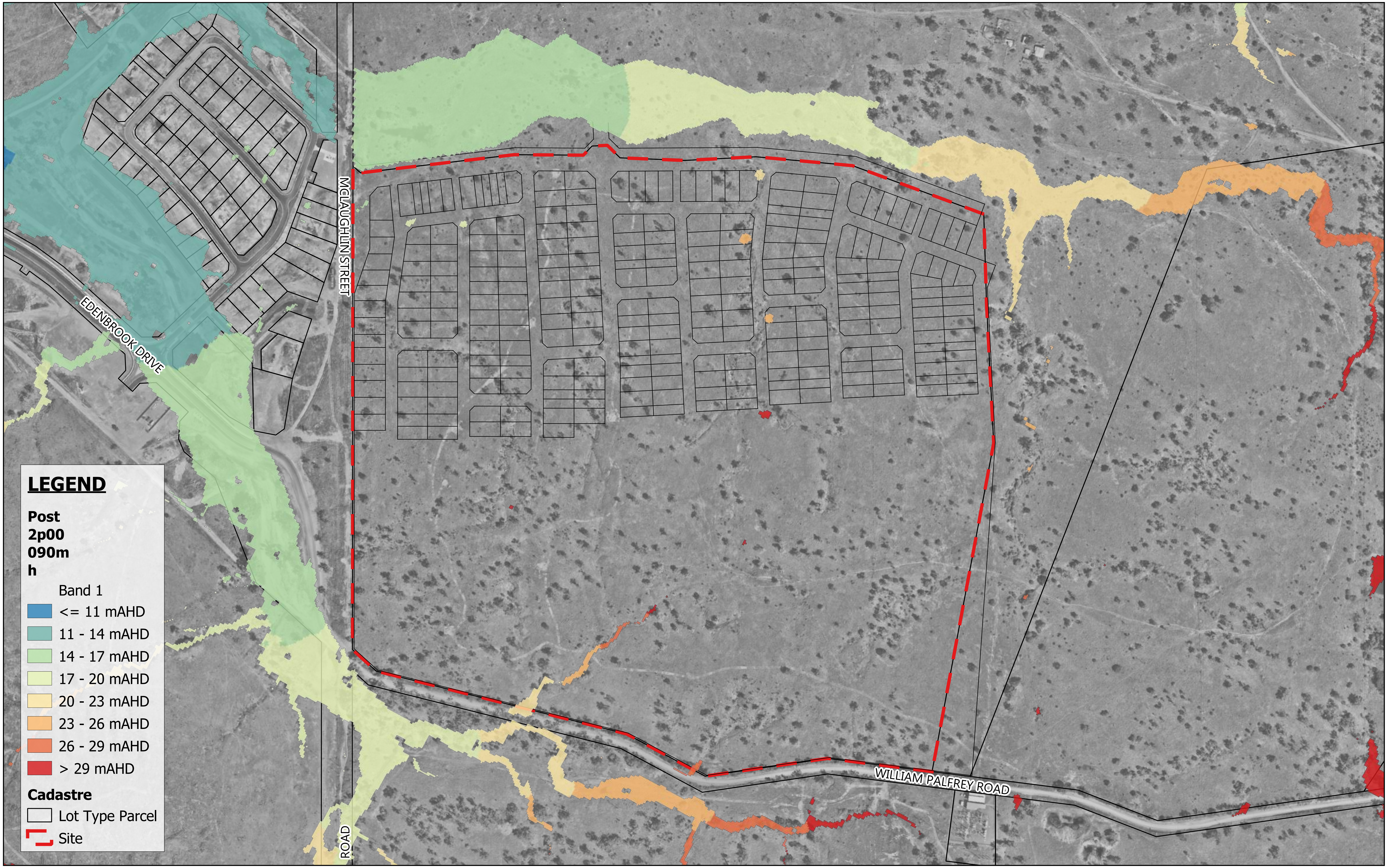
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Elevations - Post-Development | F001 |

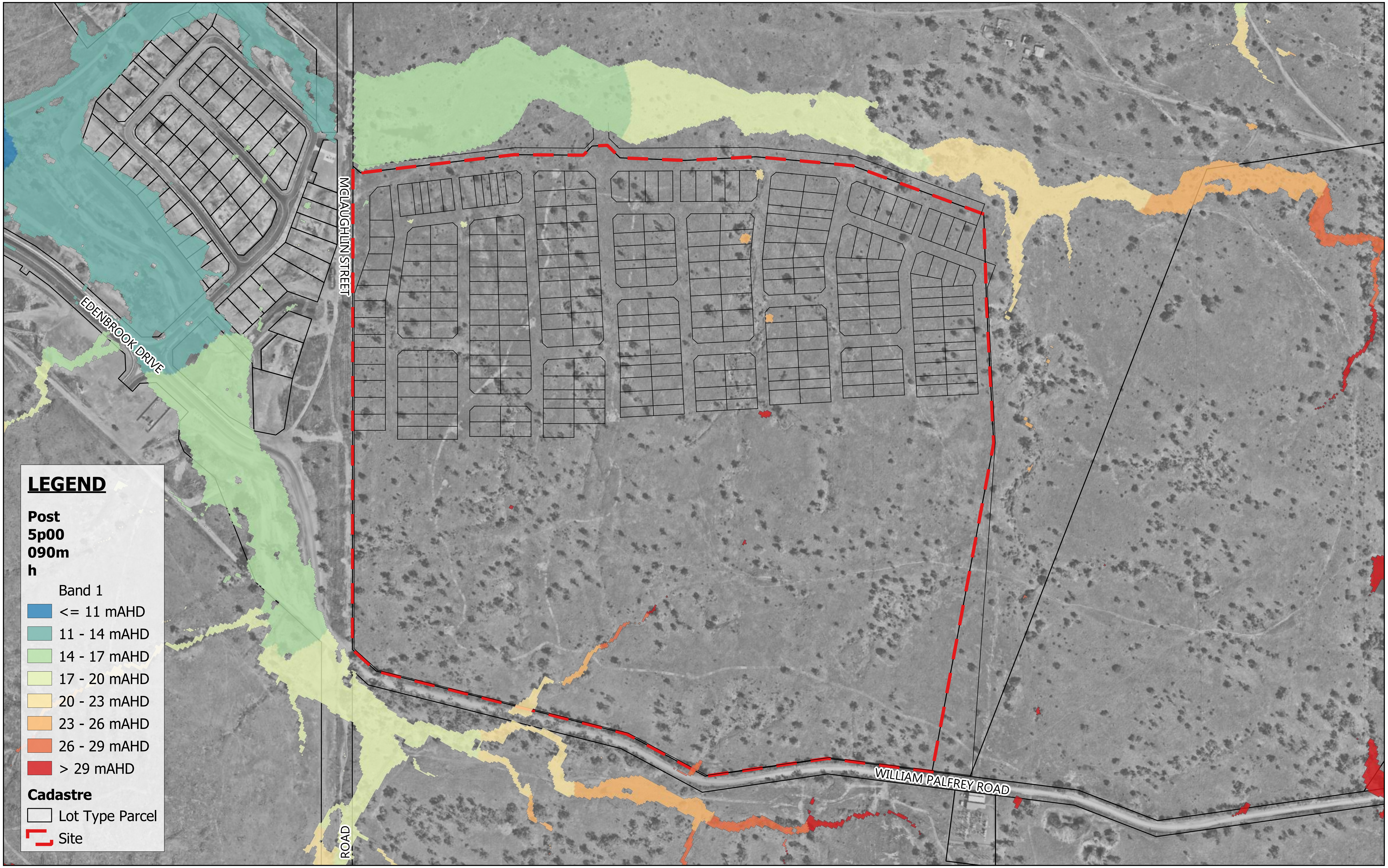


**Premise**

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Elevations - Post-Development | F002 |



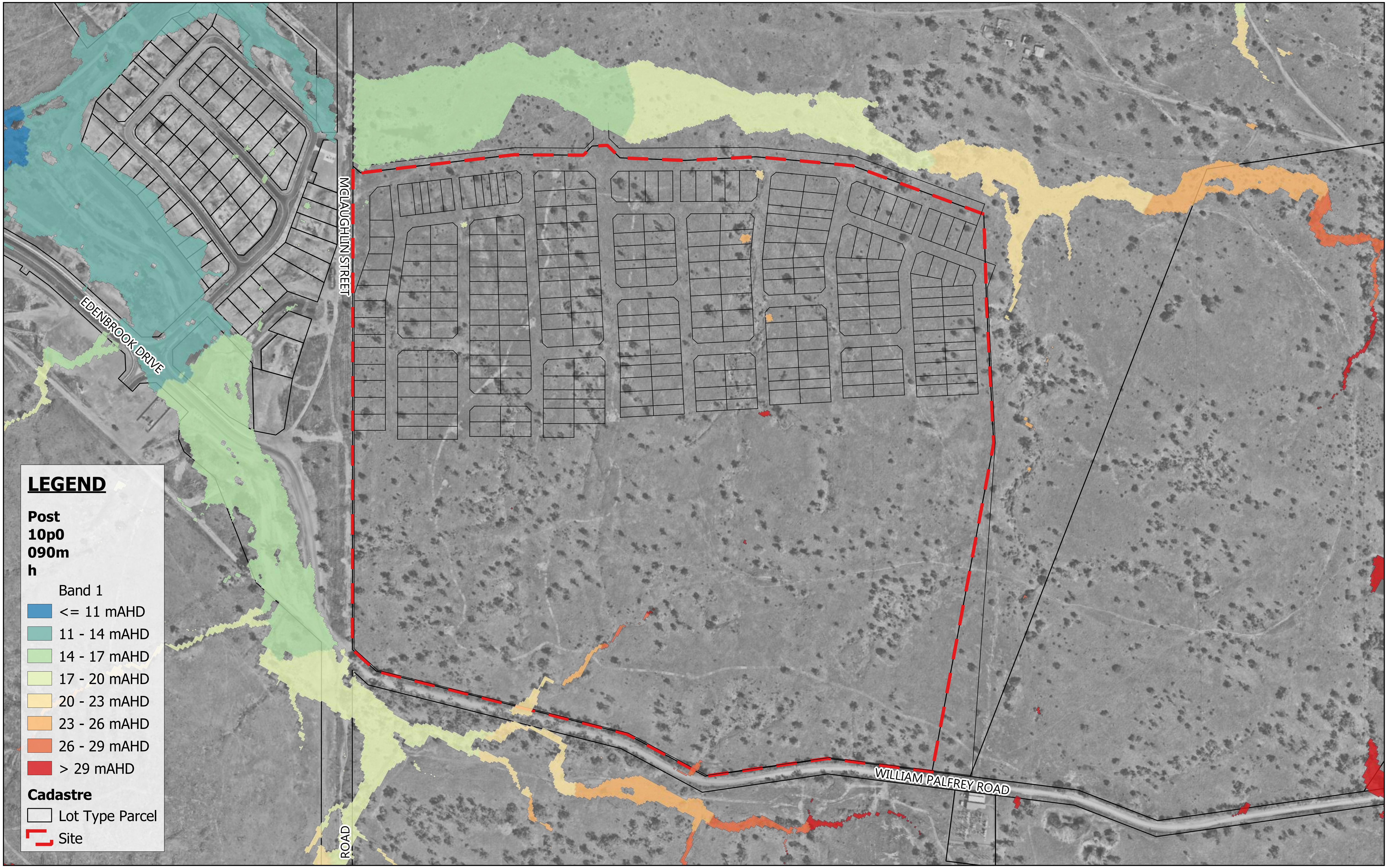
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Elevations - Post-Development | F003 |



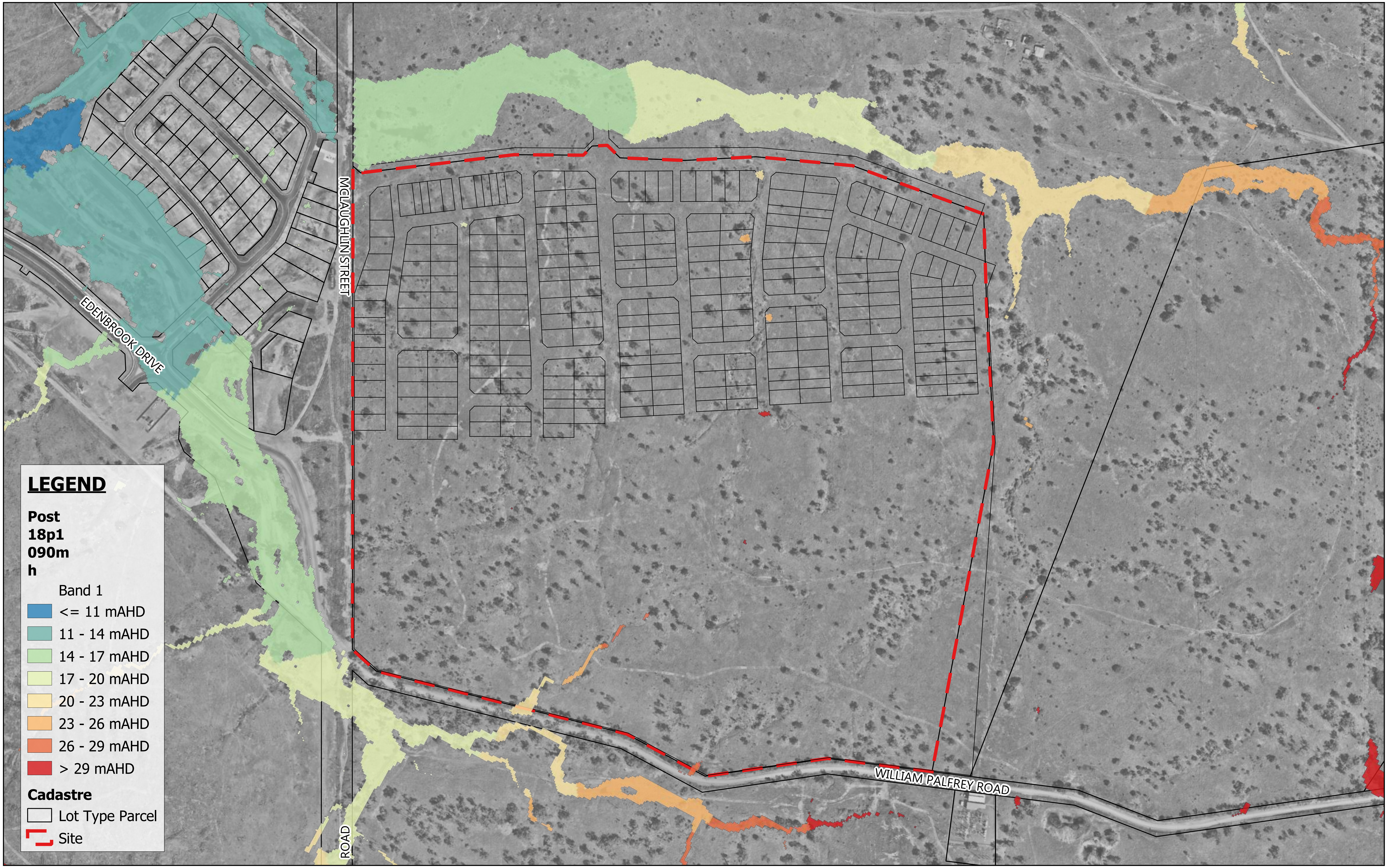
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Elevations - Post-Development | F004 |



0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Elevations - Post-Development | F005 |

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Elevations - Post-Development | F006 |

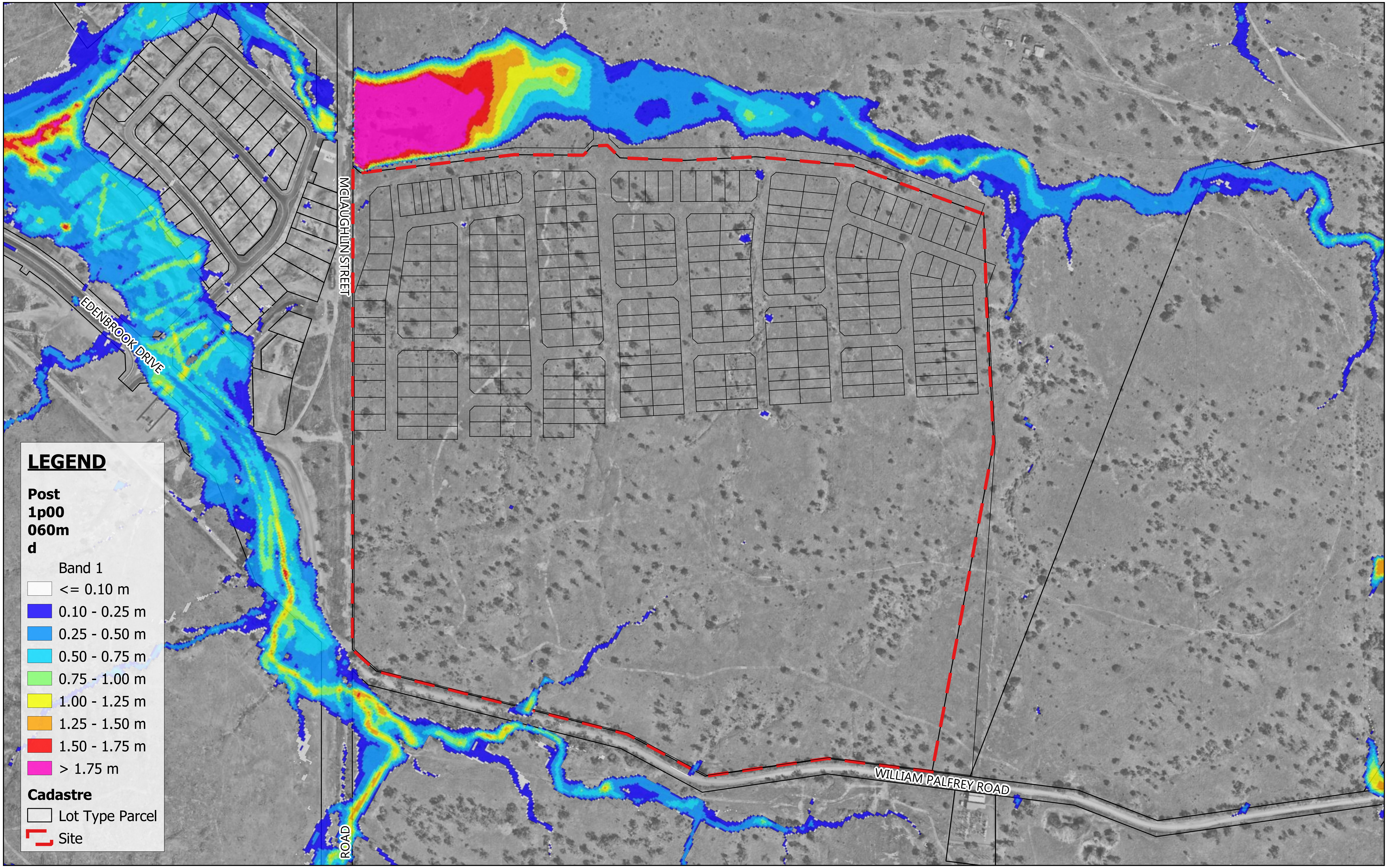
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Elevations - Post-Development | F007 |



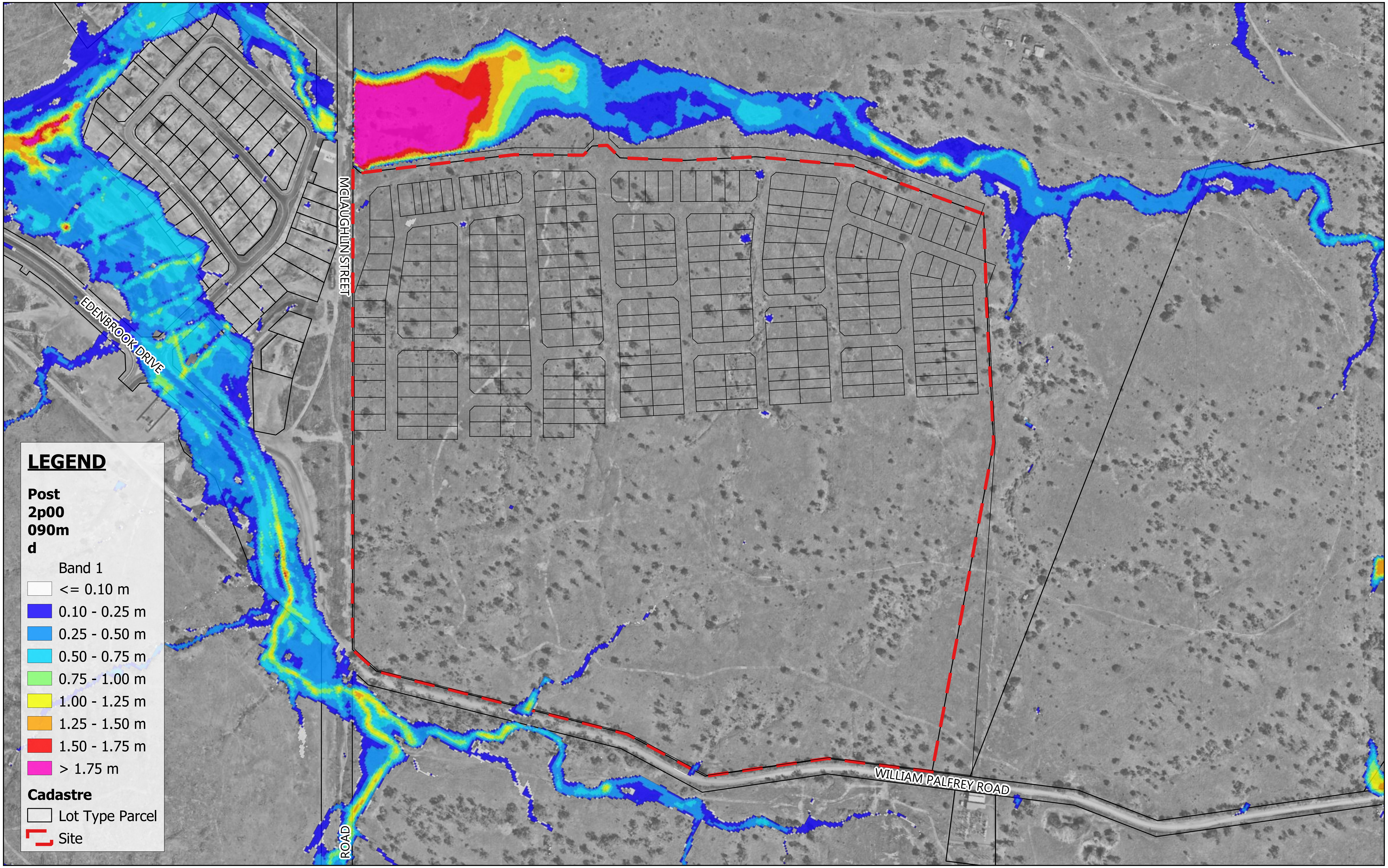
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Depth - Post-Development | F008 |



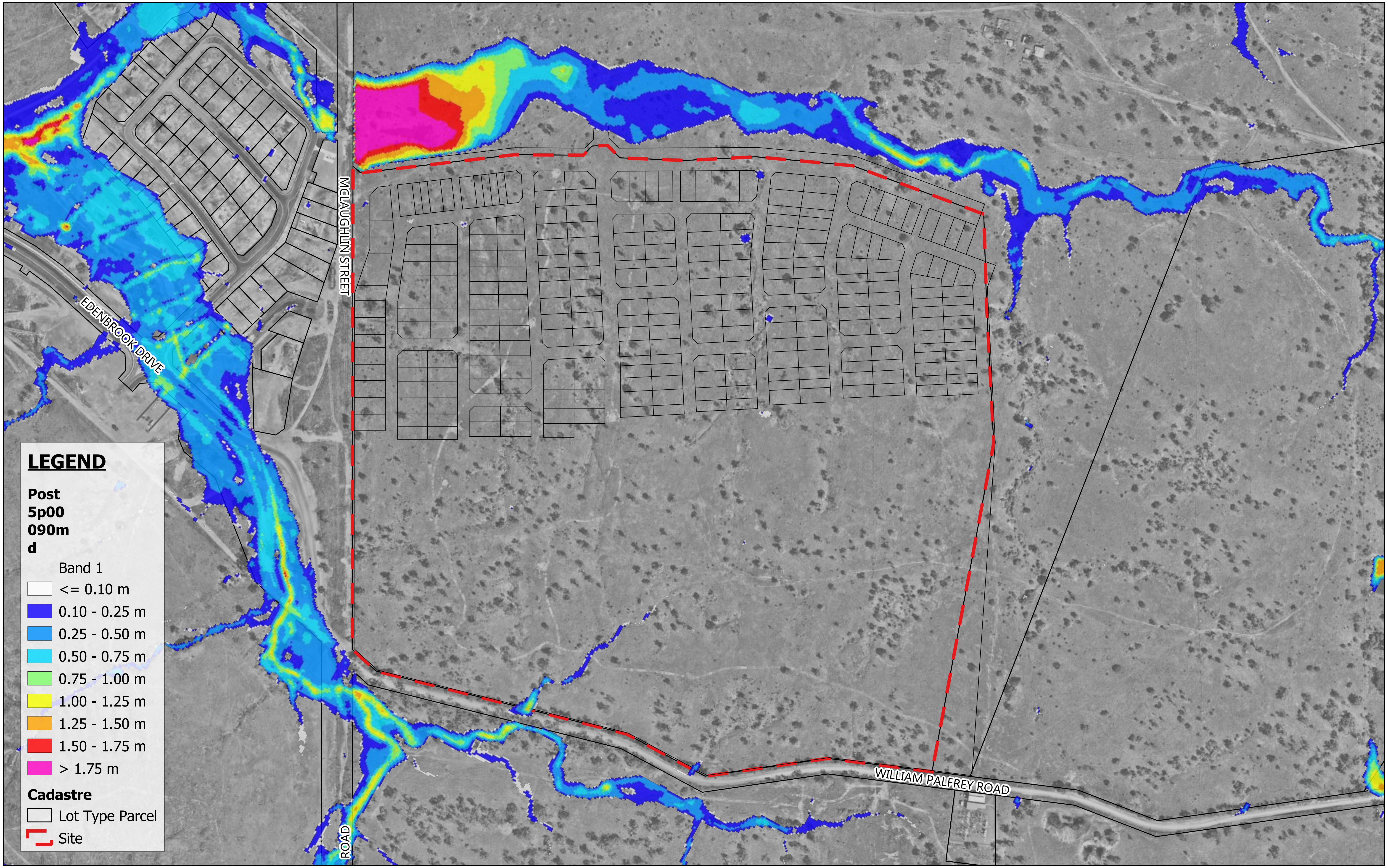
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Depth - Post-Development | F009 |



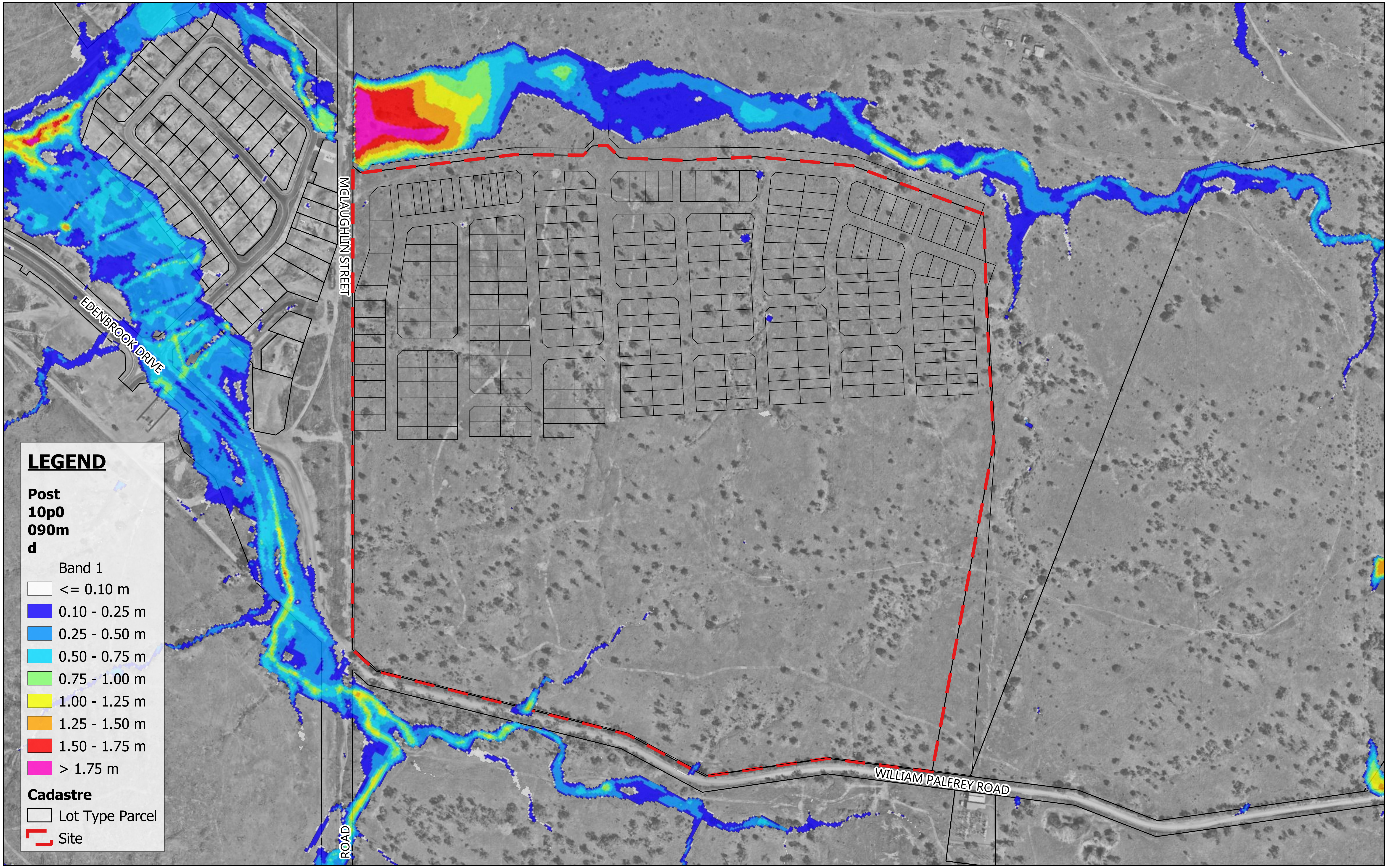
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Depth - Post-Development | F010 |



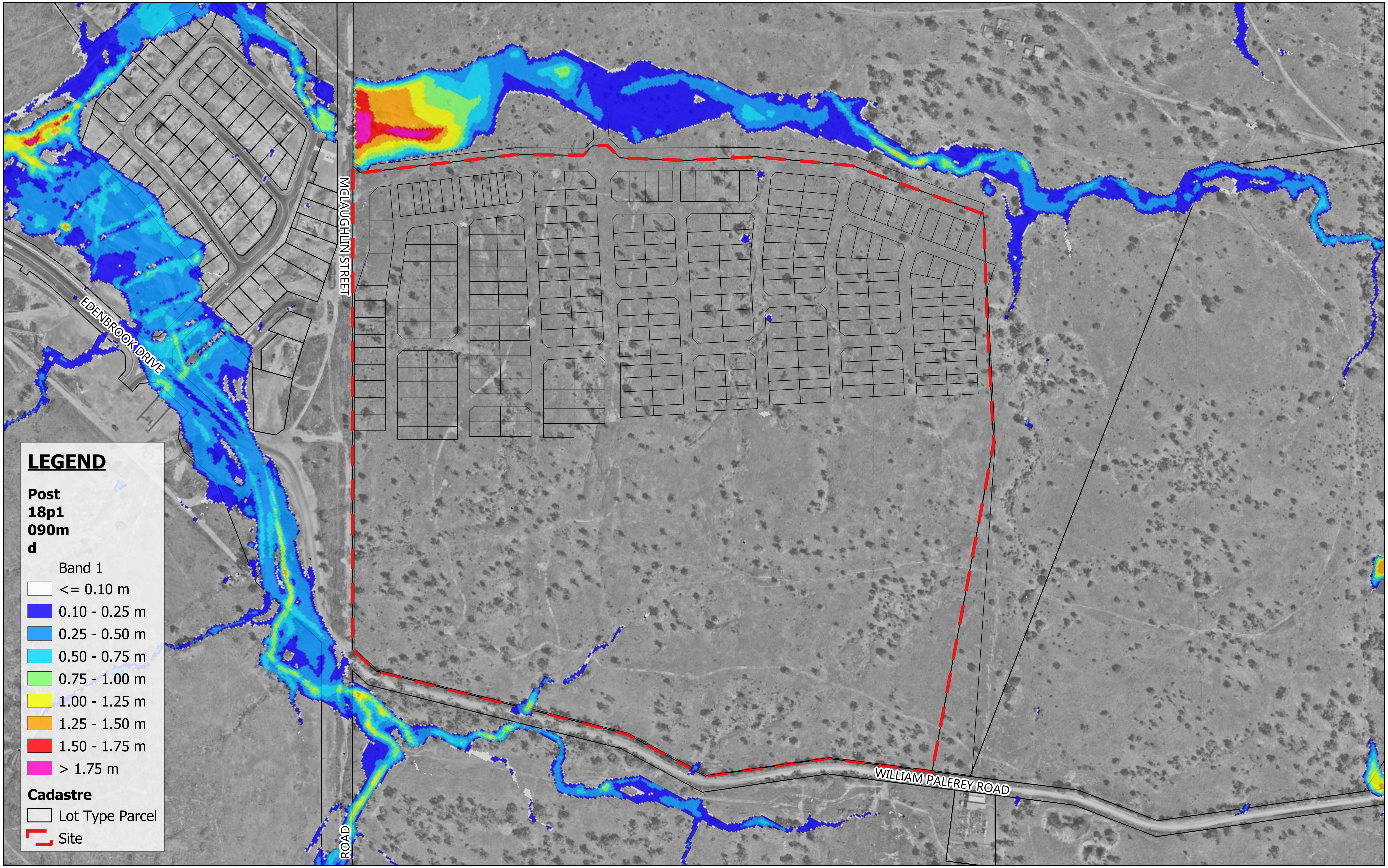
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Depth - Post-Development | F011 |



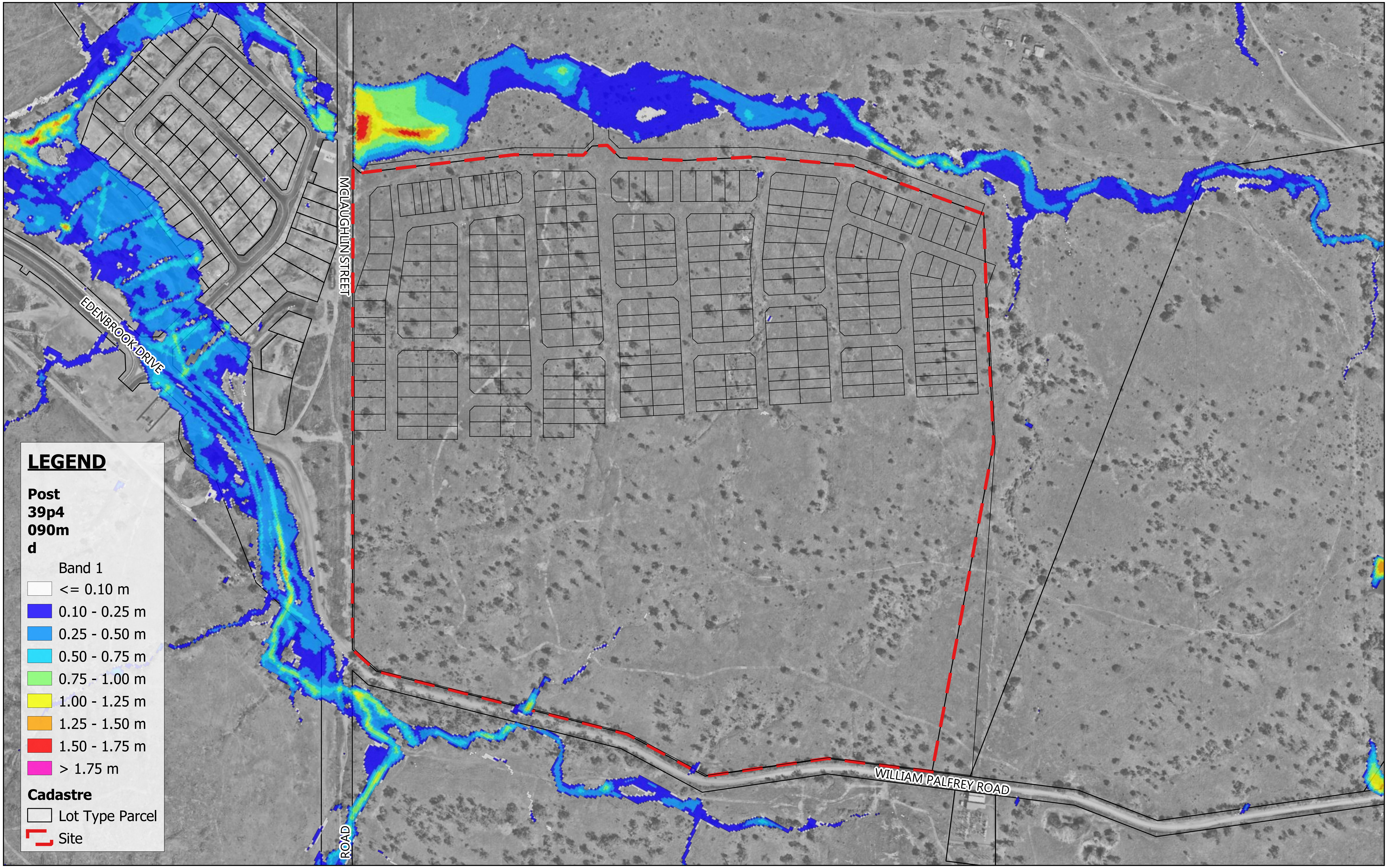
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Depth - Post-Development | F012 |



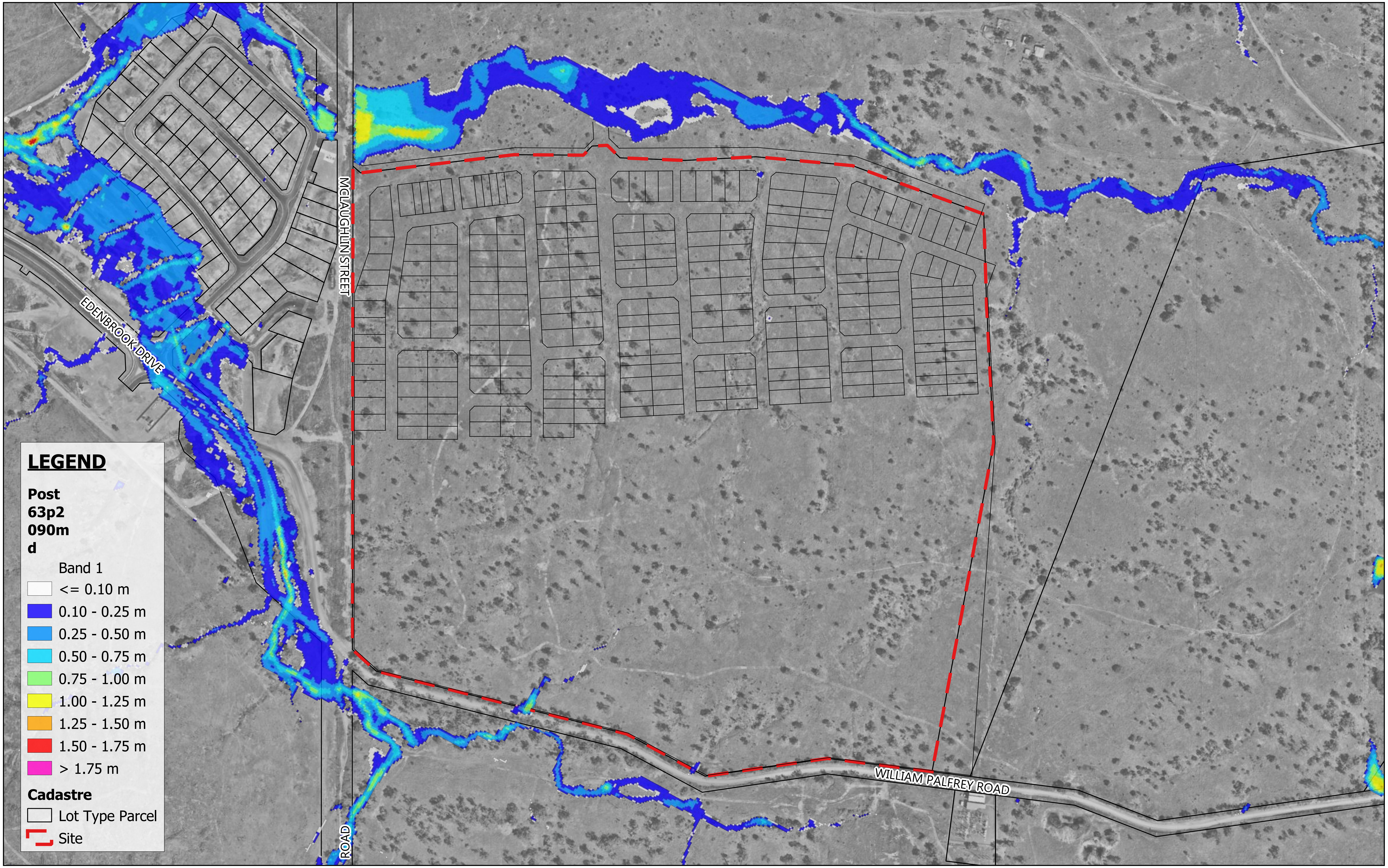
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Depth - Post-Development | F013 |



0 150 300 450 m

Scale 1:4,500

08.02.2024

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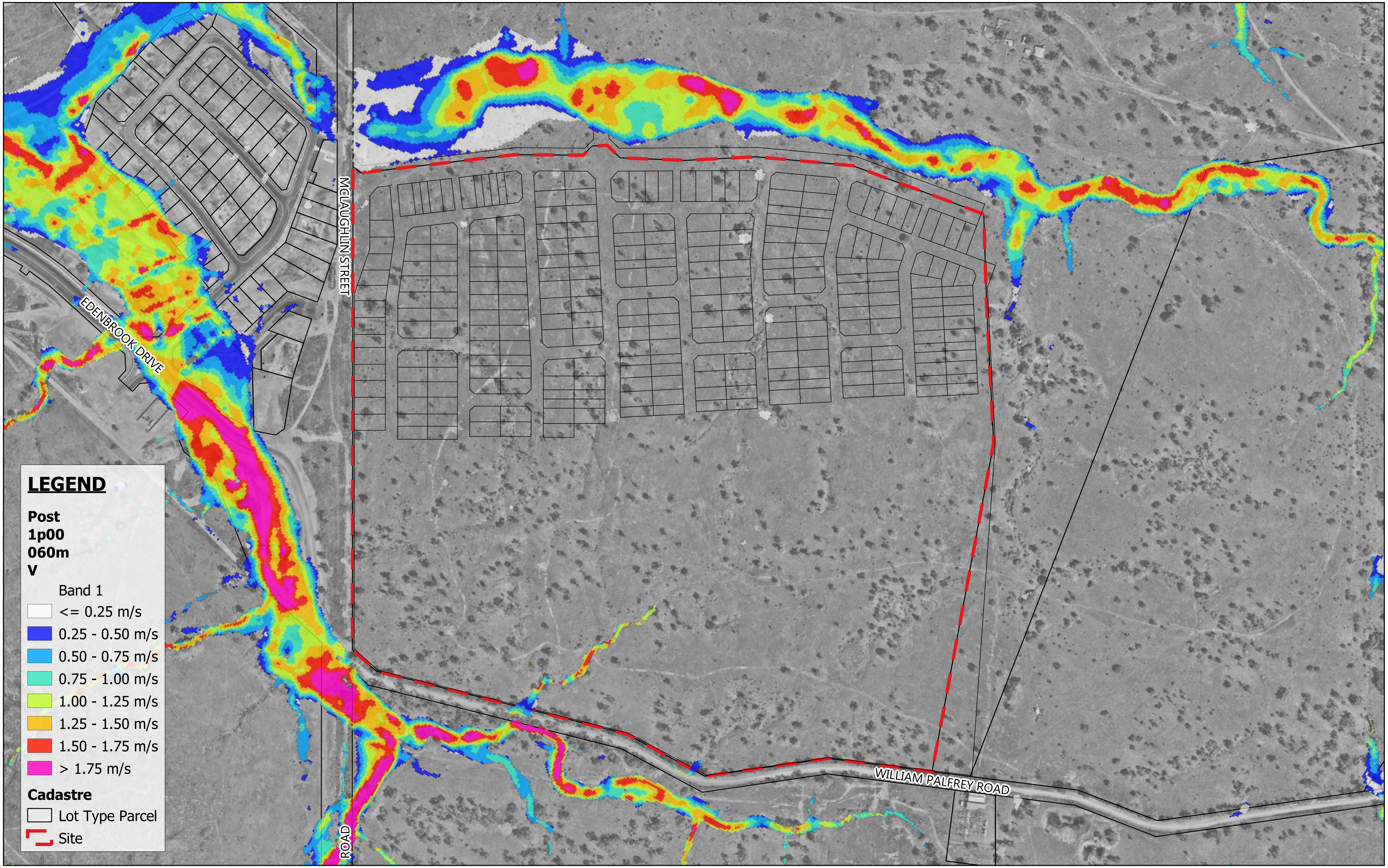
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Depth - Post-Development | F014 |



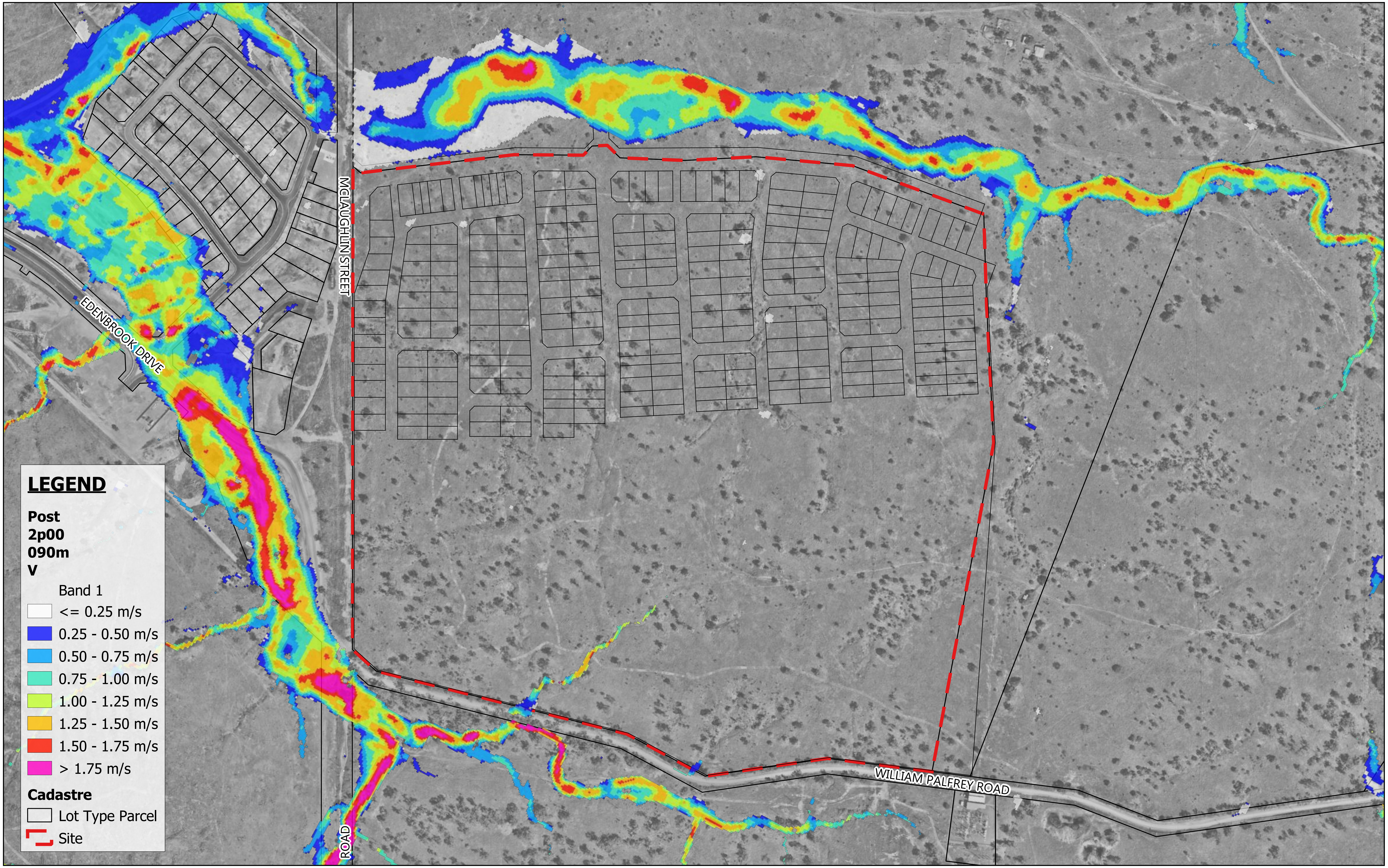
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Velocity - Post-Development | F015 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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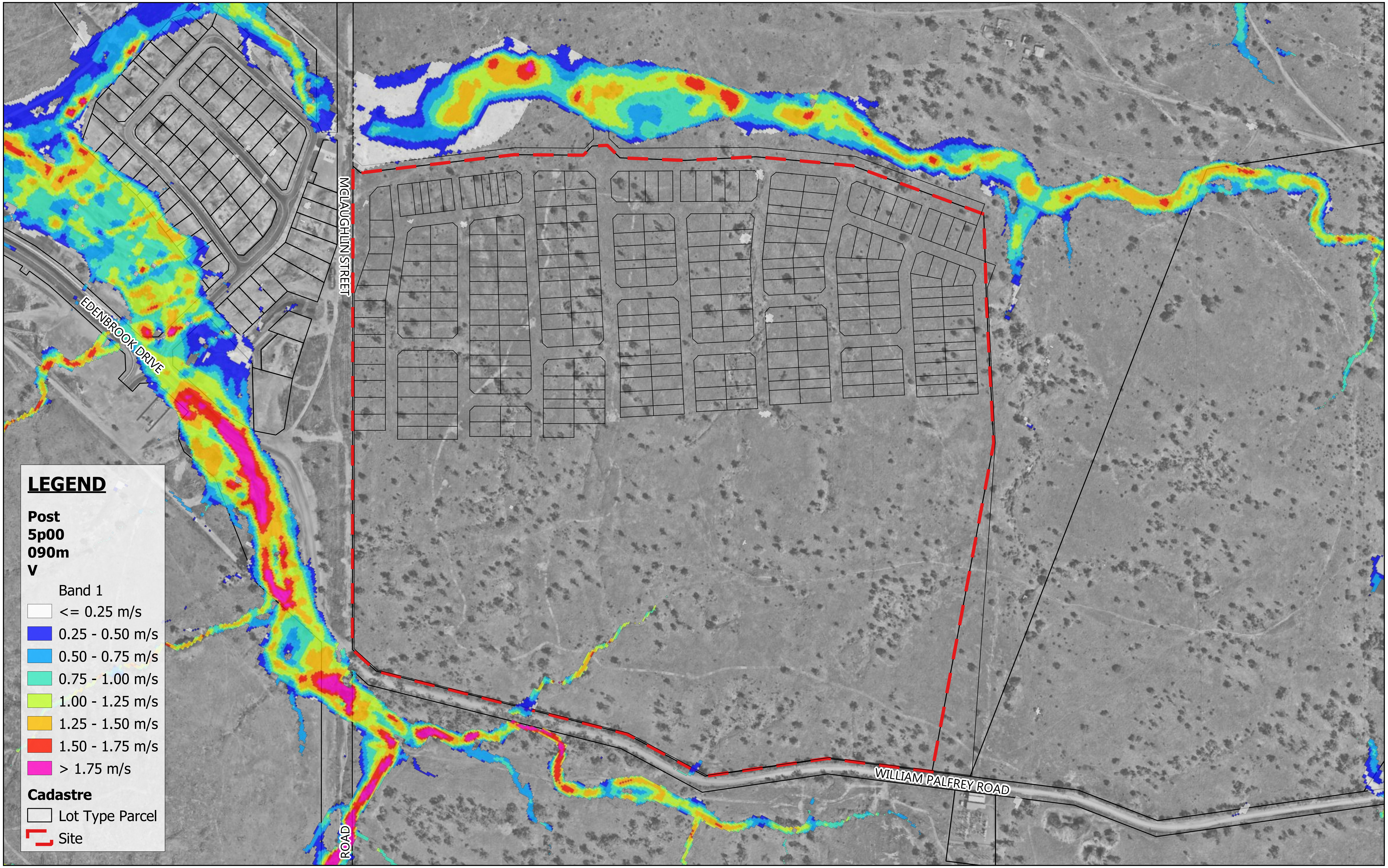
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Velocity - Post-Development | F016 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

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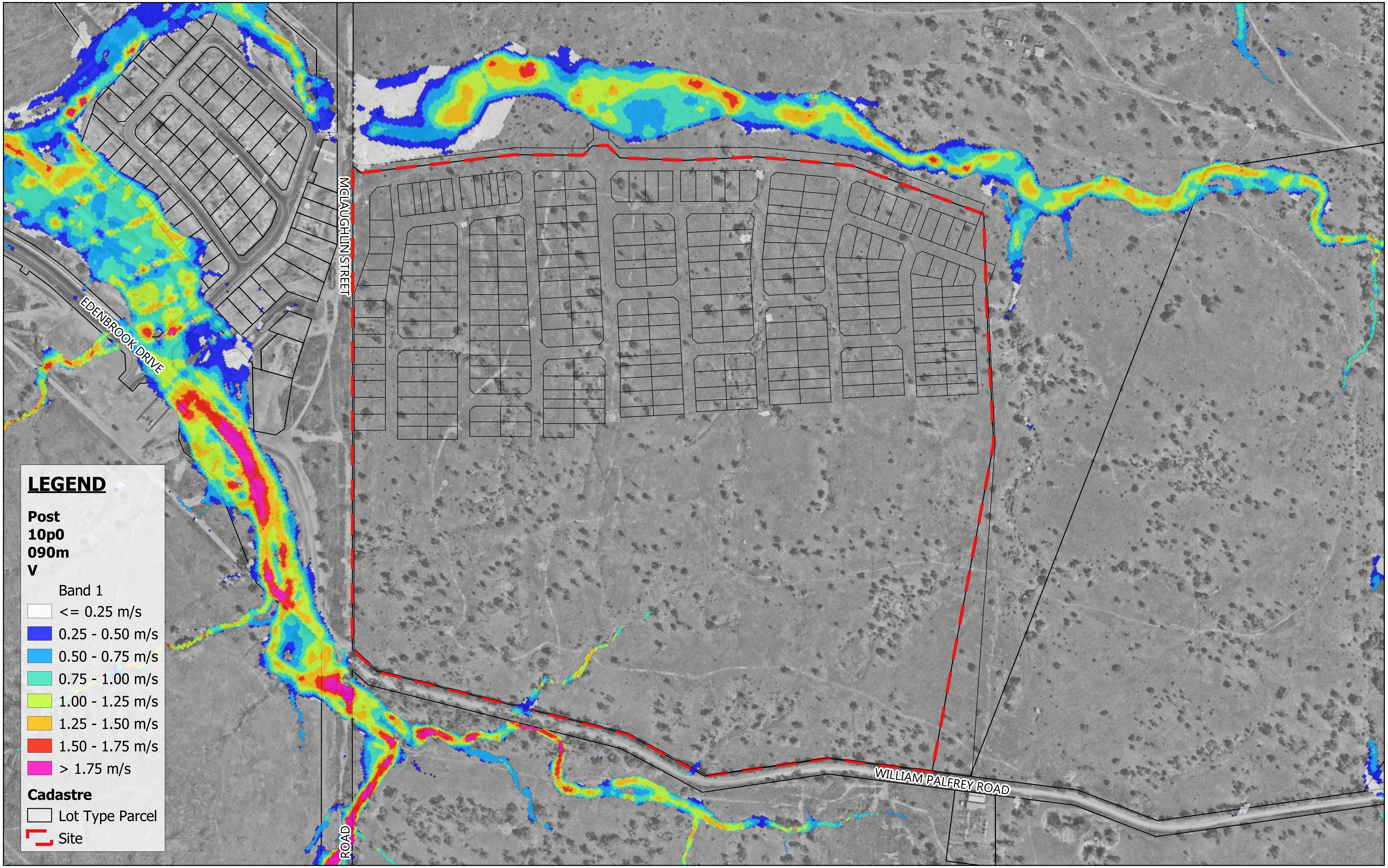
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Velocity - Post-Development | F017 |



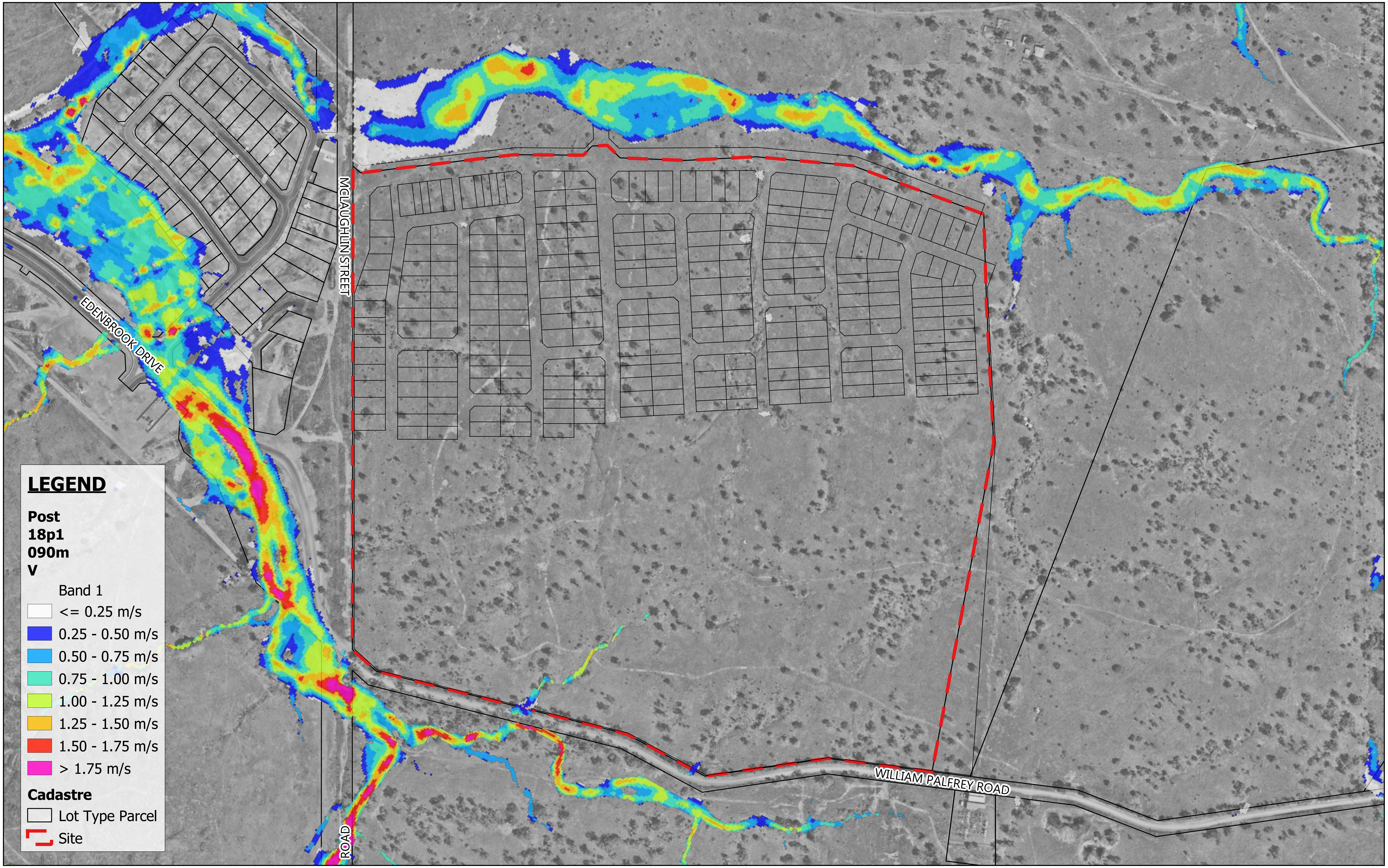
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Velocity - Post-Development | F018 |



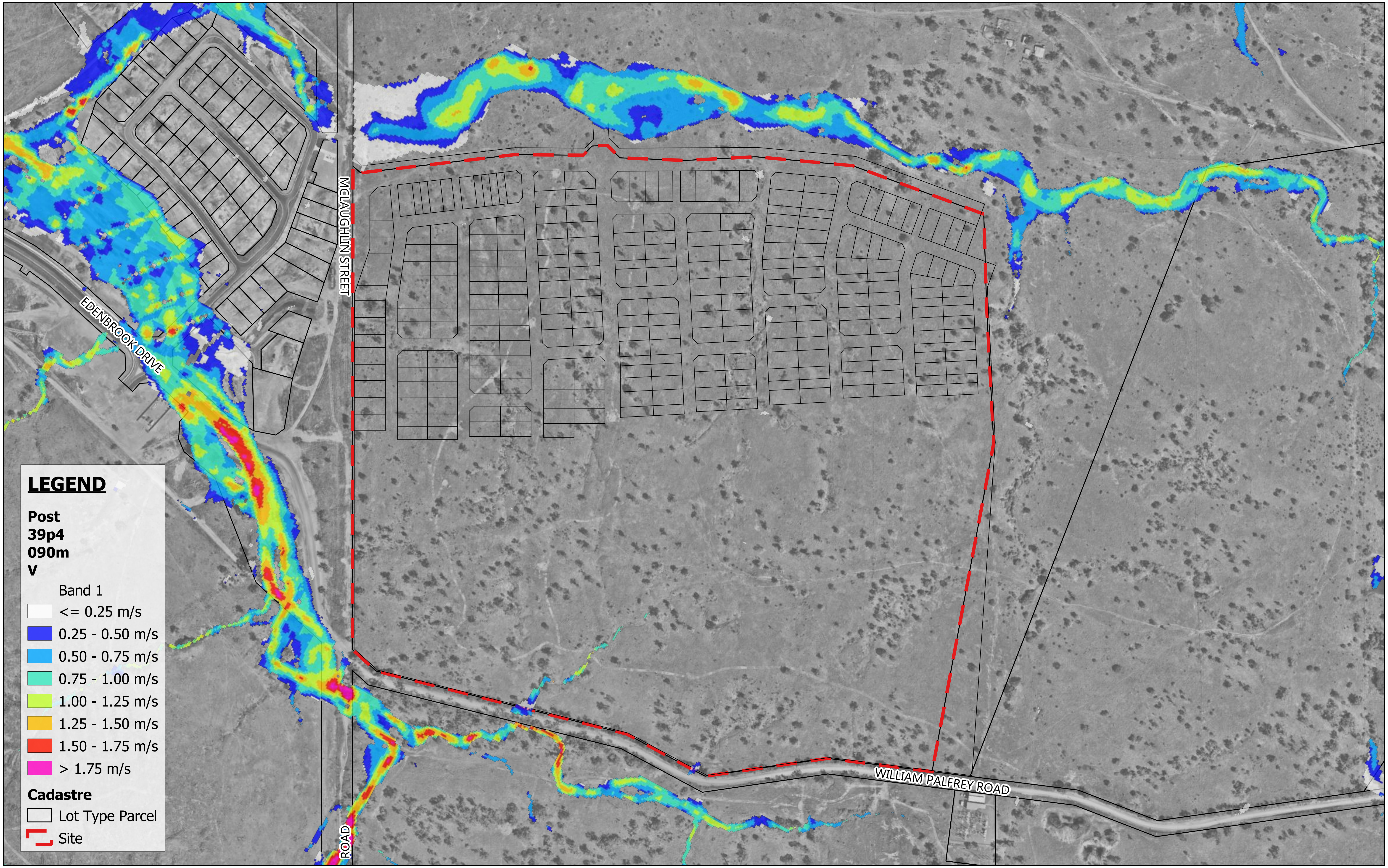
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Velocity - Post-Development | F019 |

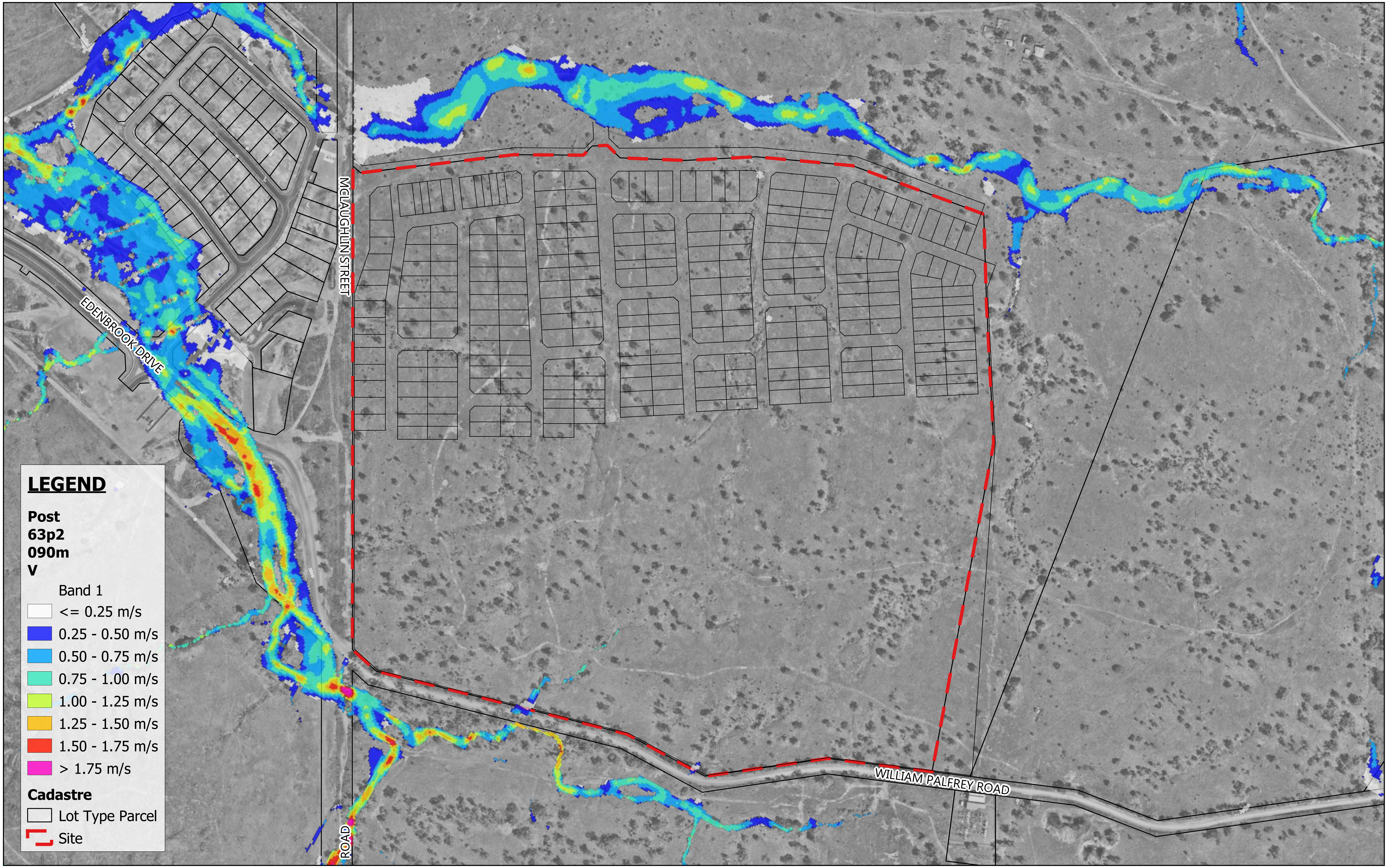


0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Velocity - Post-Development | F020 |



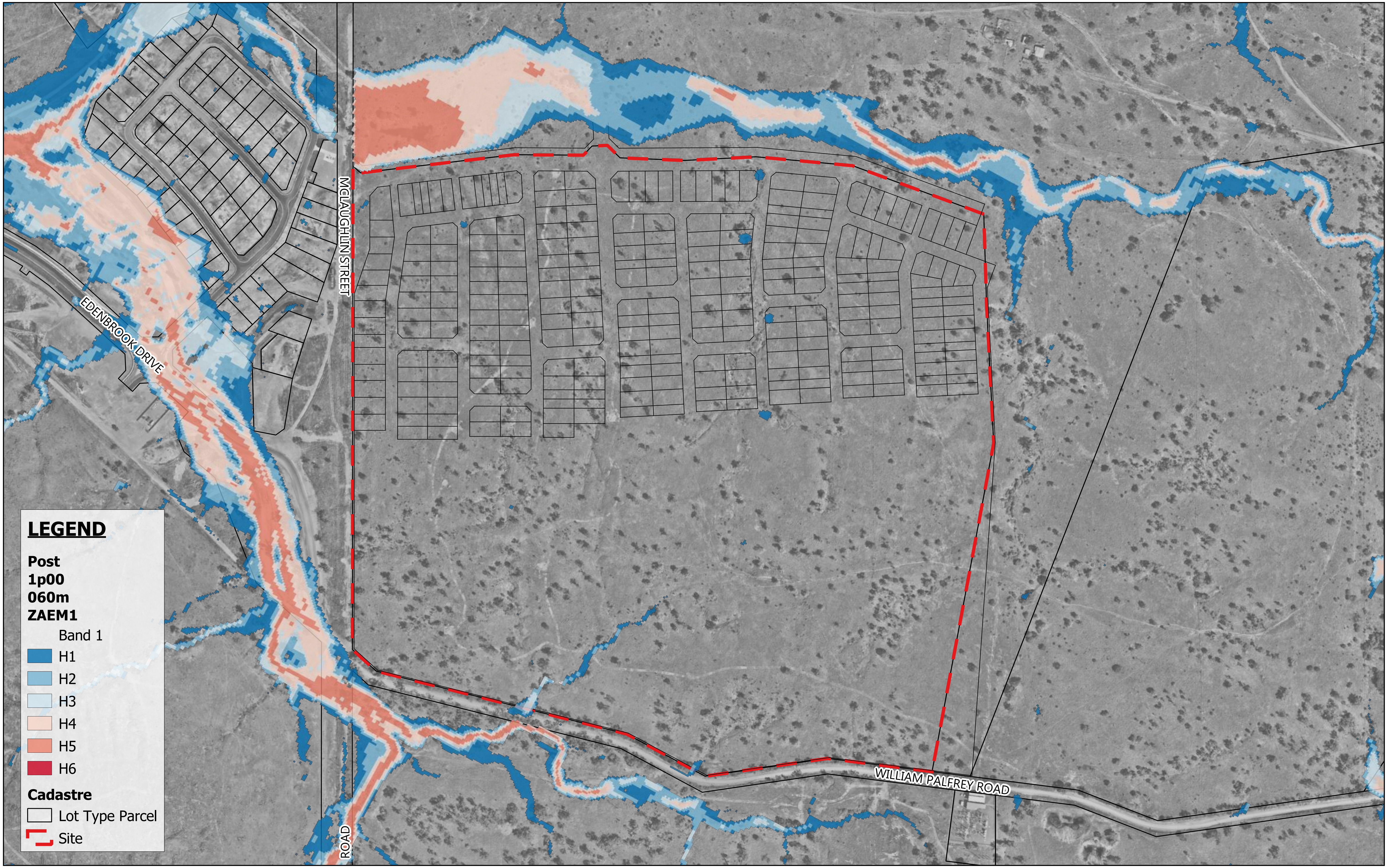
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Velocity - Post-Development | F021 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

MAAS GROUP PROPERTIES PTY LTD

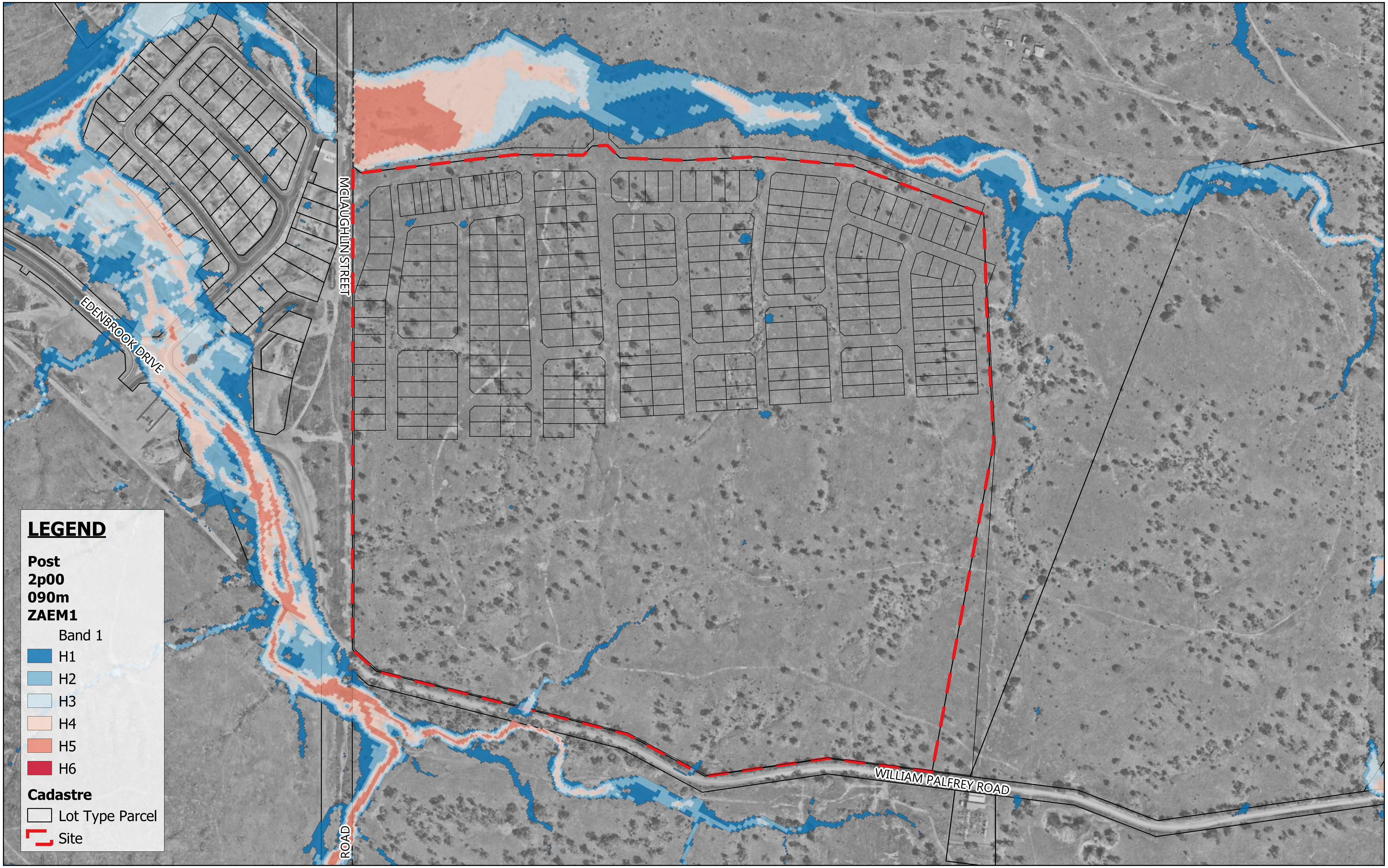
Feb 2024

ELLIDA WEST STAGES 1-6, PARKHURST

MPG-0001

1% AEP Event Flood Hazard - Post-Development

F022



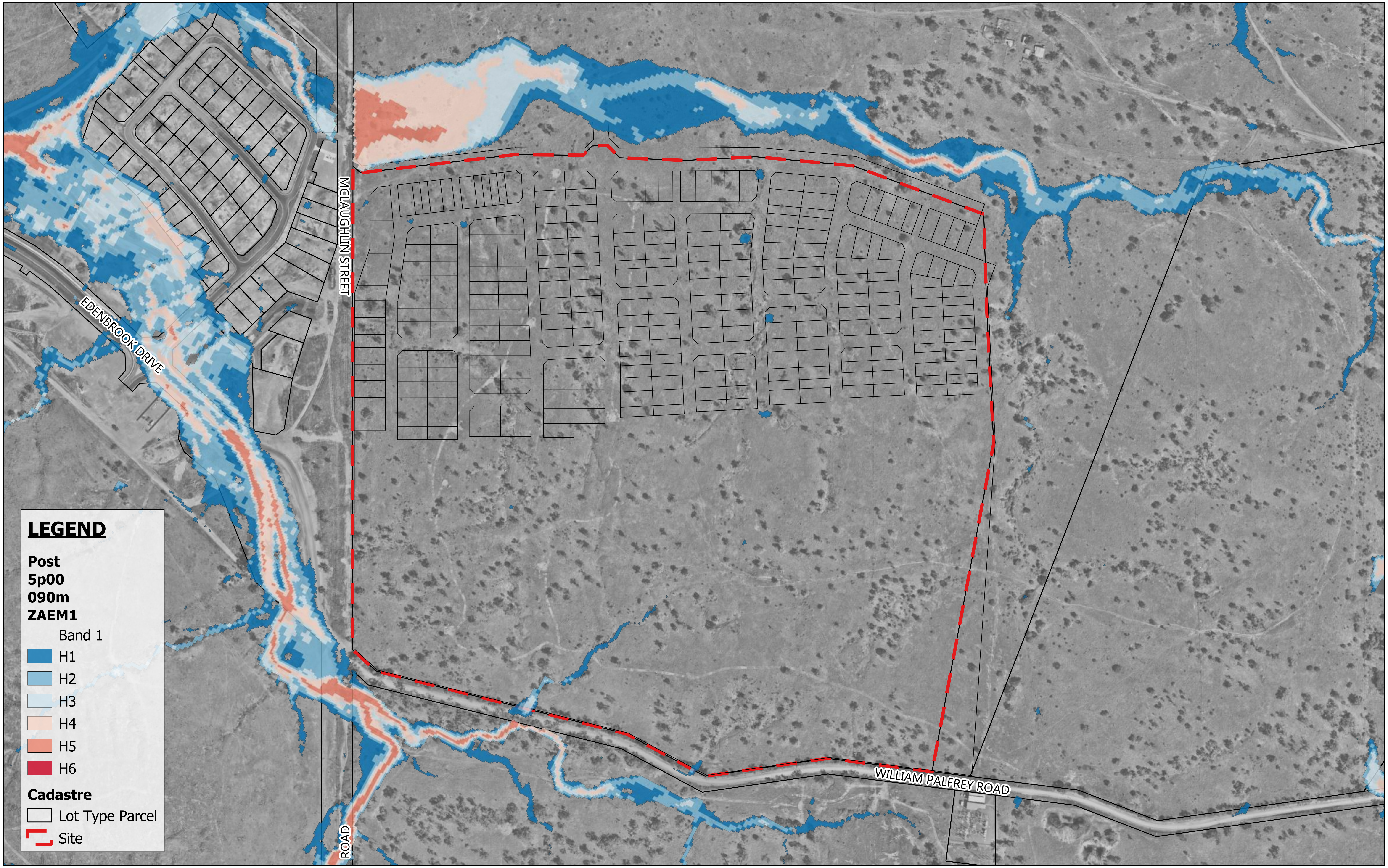
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Hazard - Post-Development | F023 |



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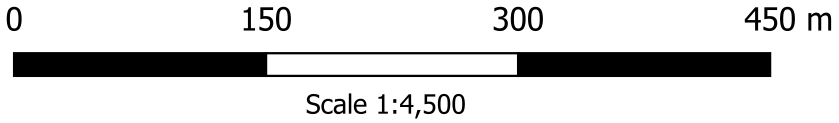
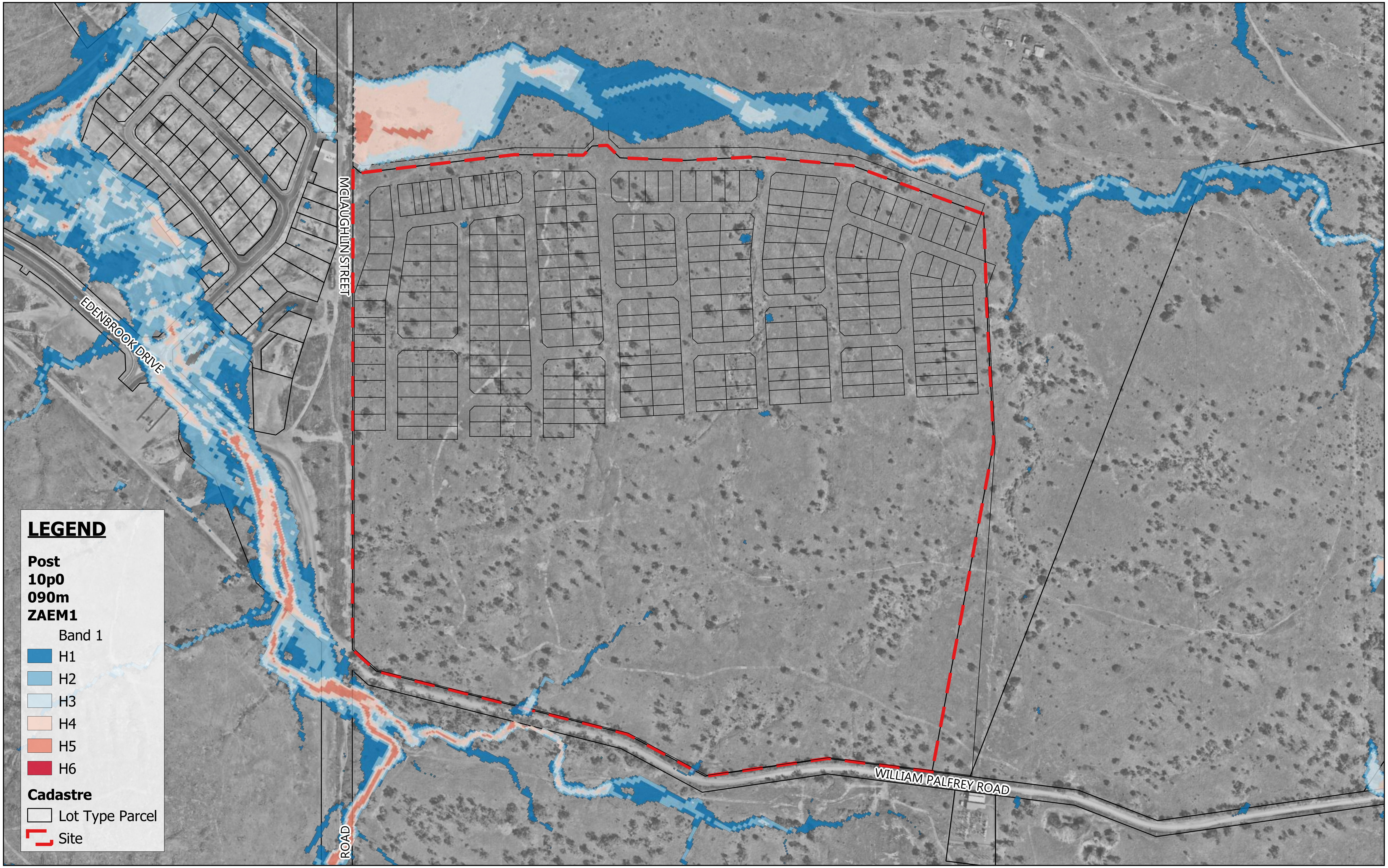


Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Hazard - Post-Development | F024 |



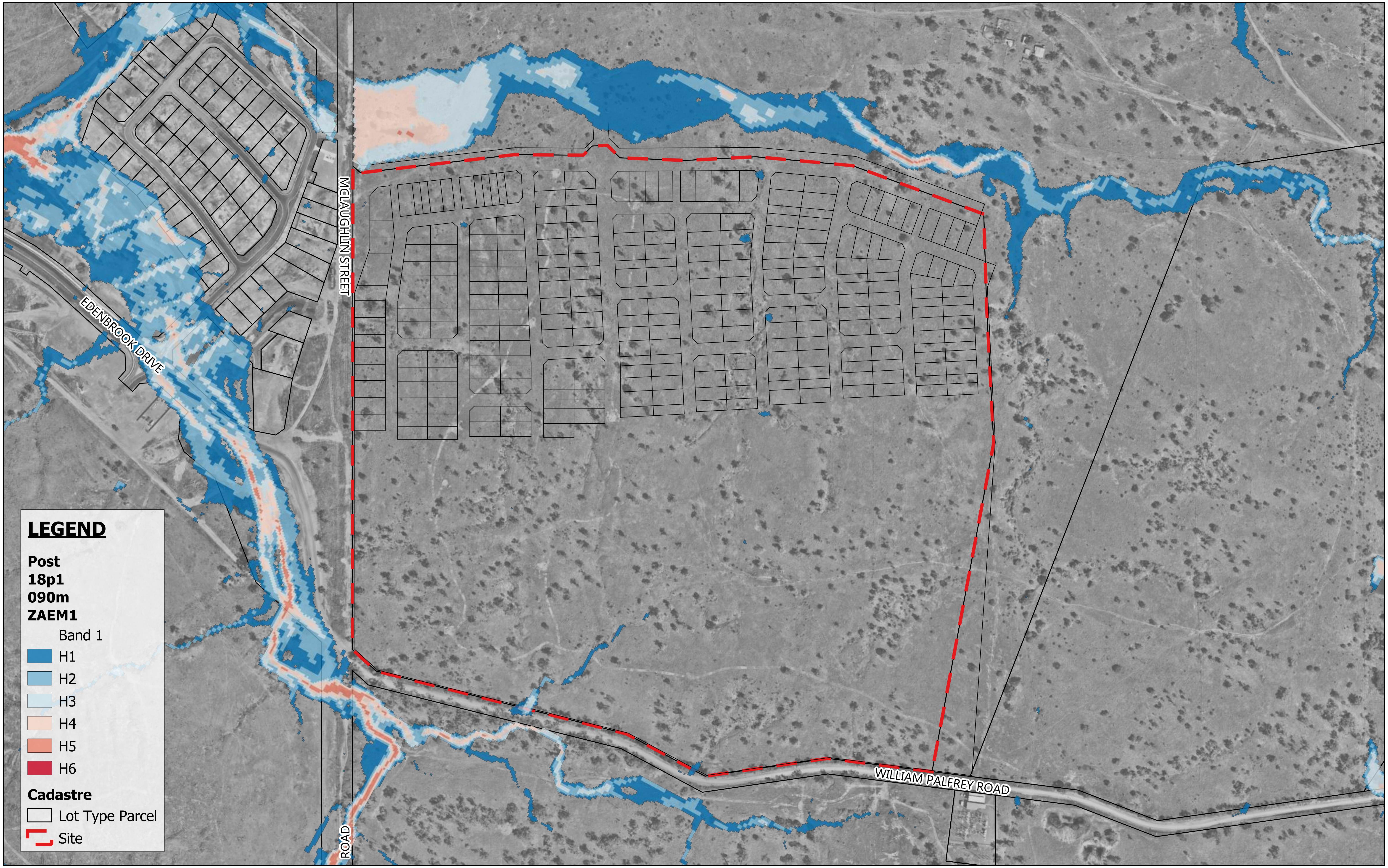
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Hazard - Post-Development | F025 |



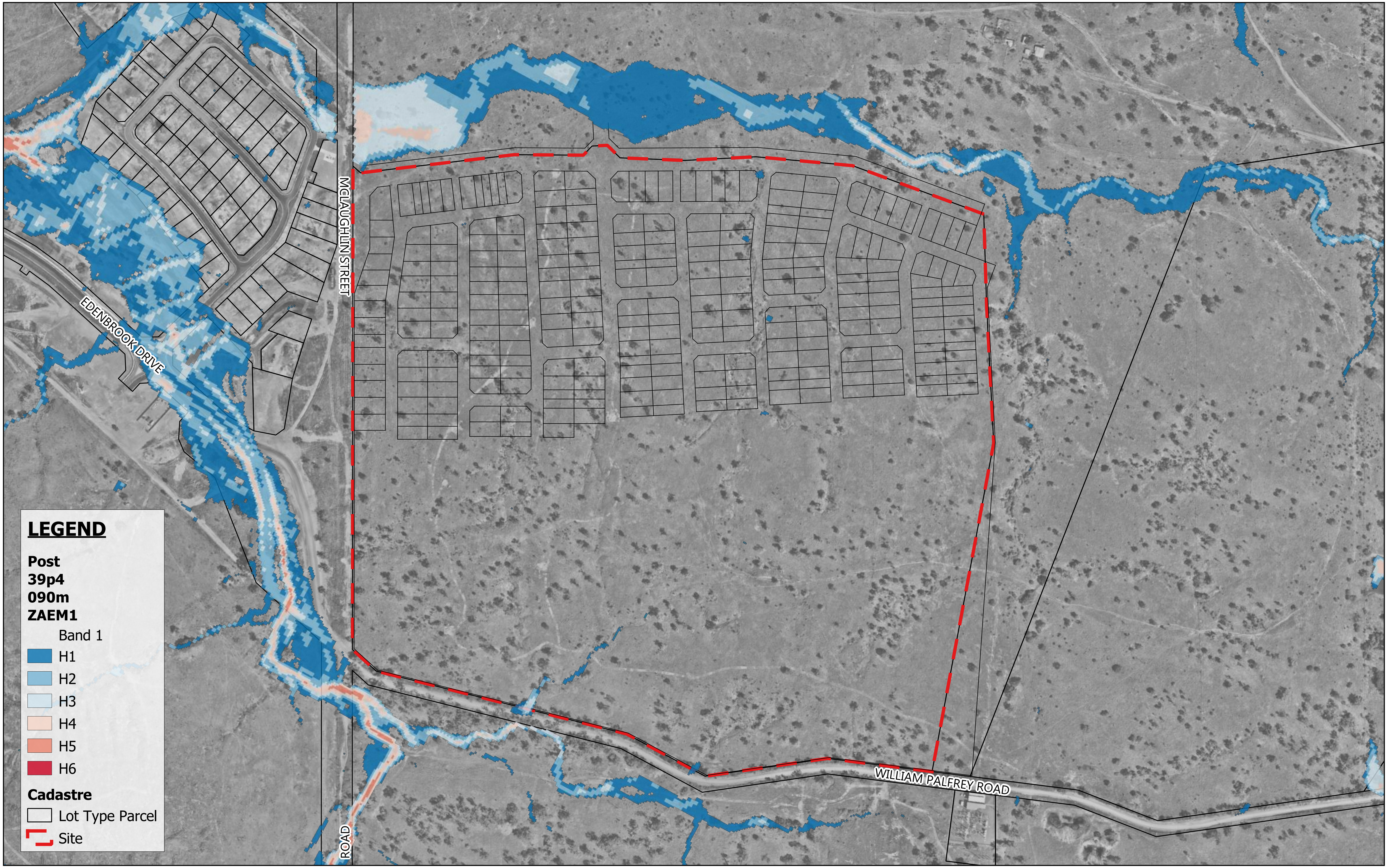
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Hazard - Post-Development | F026 |

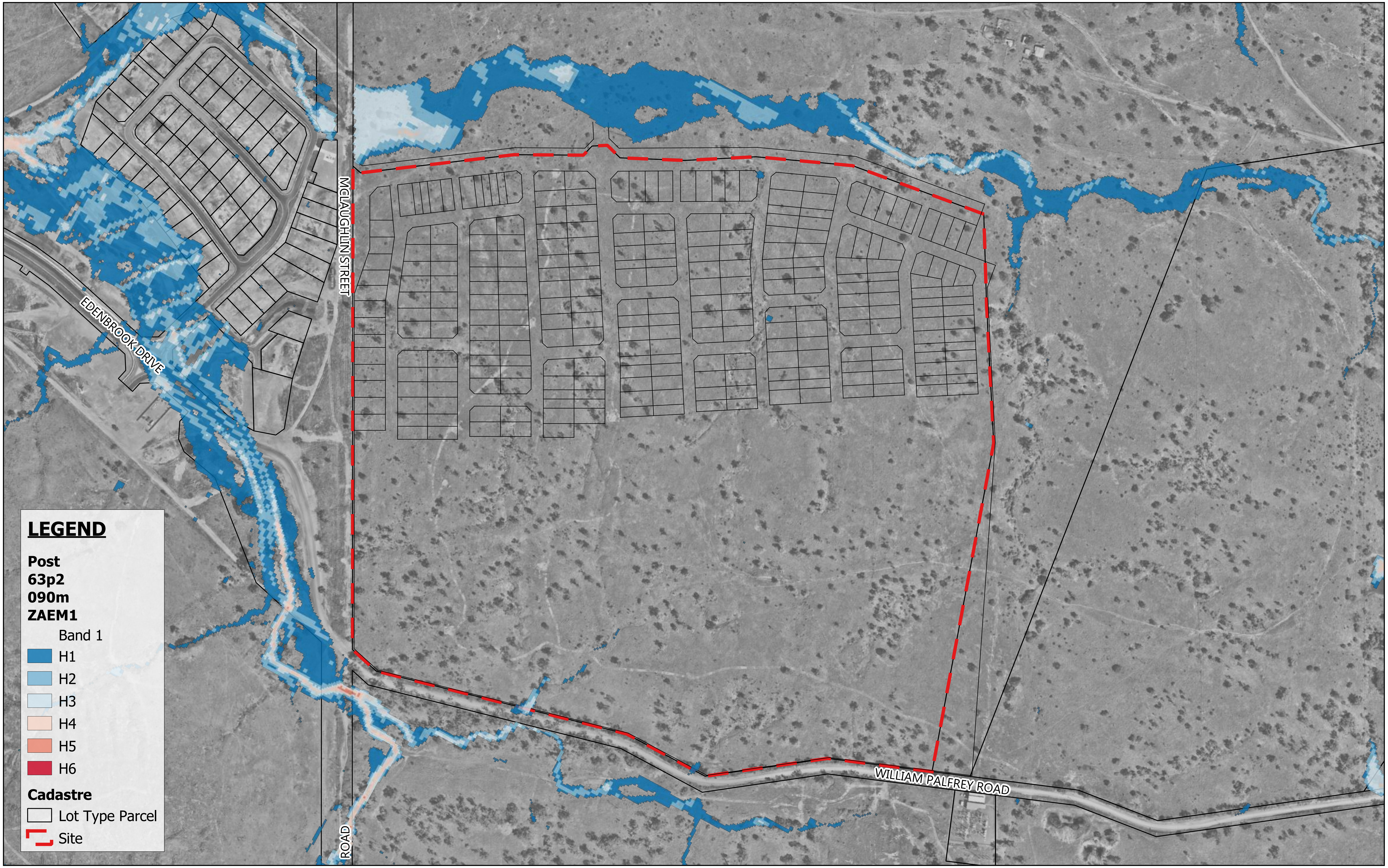


Premise

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Hazard - Post-Development | F027 |



0 150 300 450 m

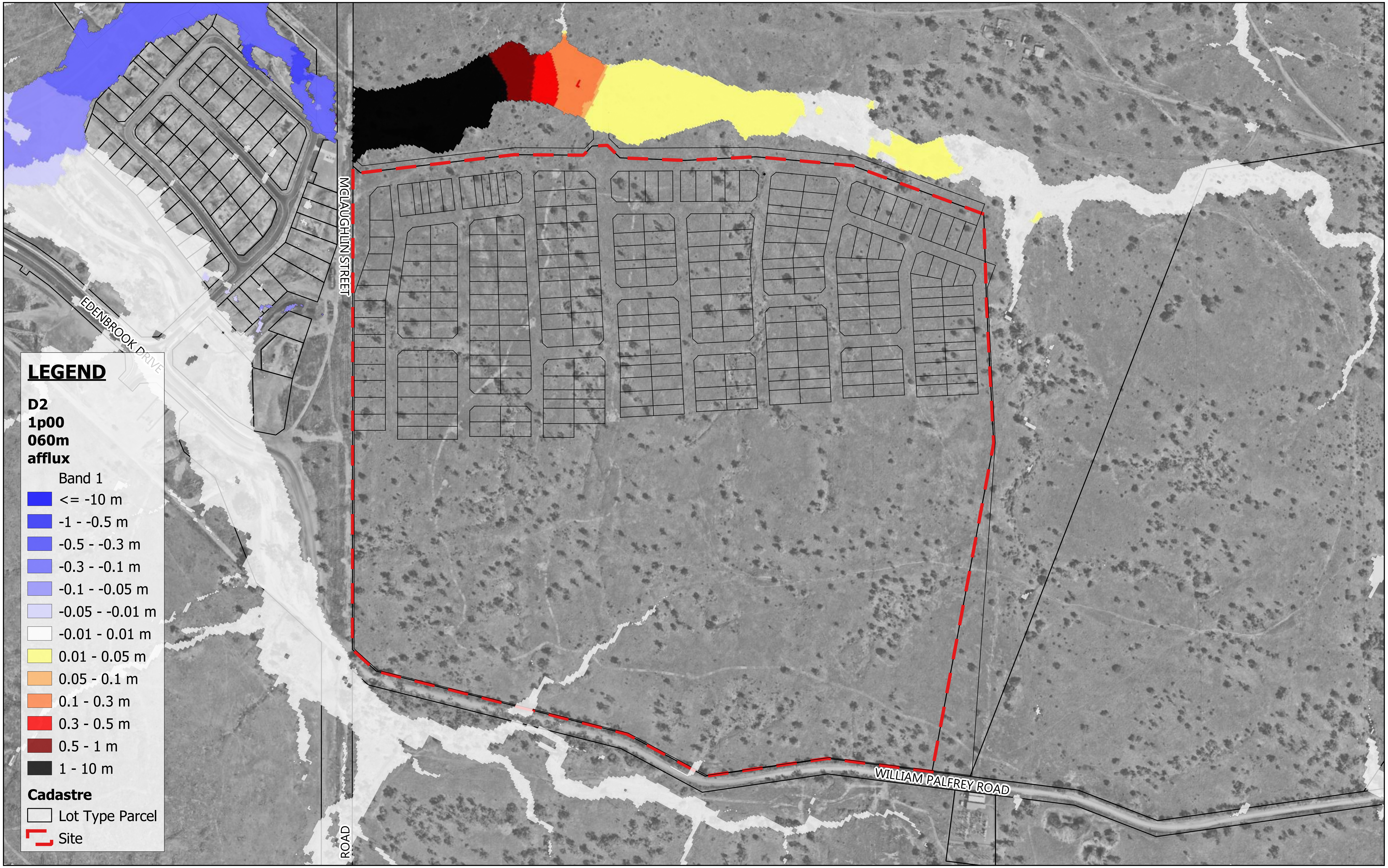
Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Hazard - Post-Development | F028 |

# APPENDIX G

## HYDRAULIC MODEL IMPACT ASSESSMENT



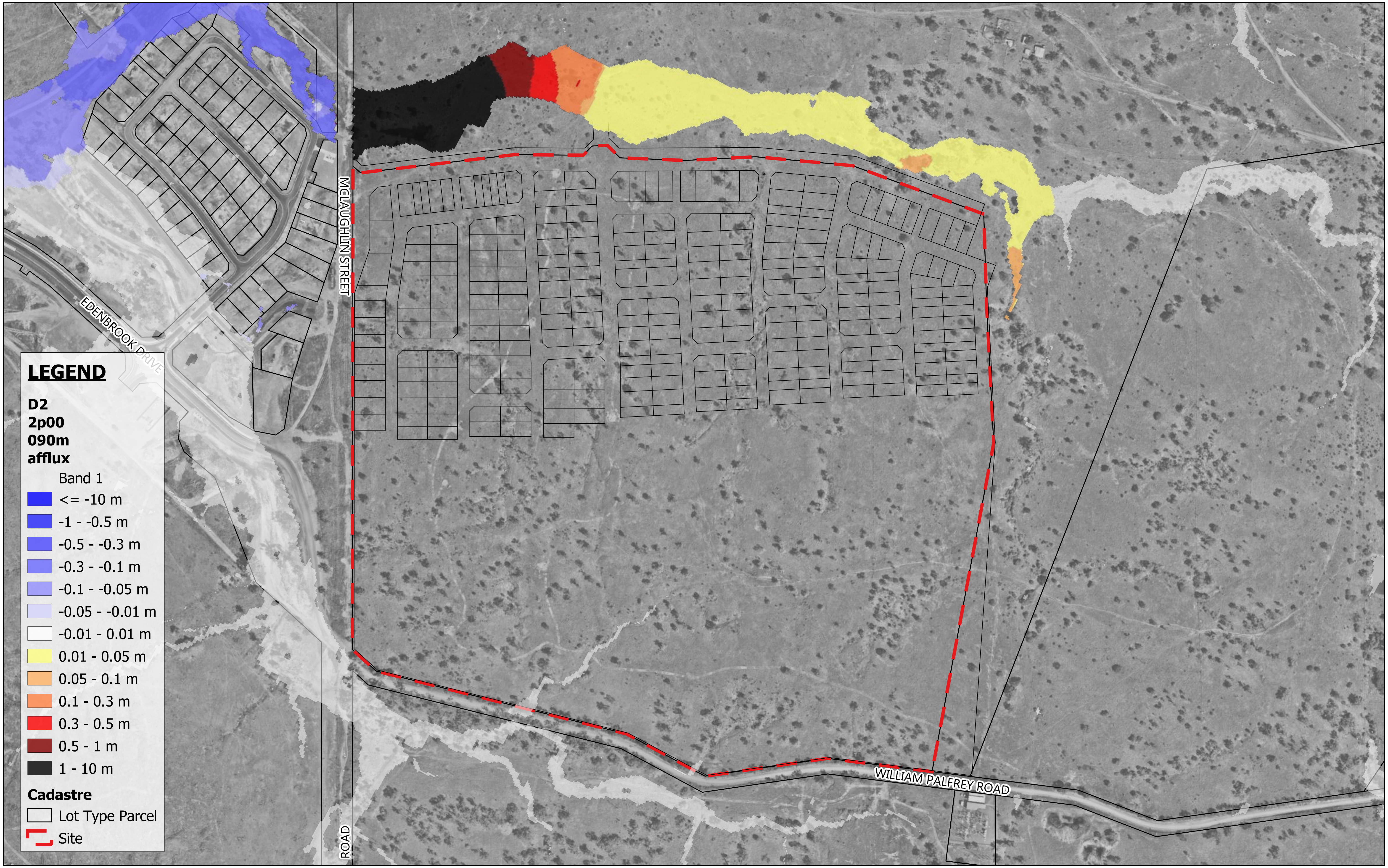
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Afflux | G001 |



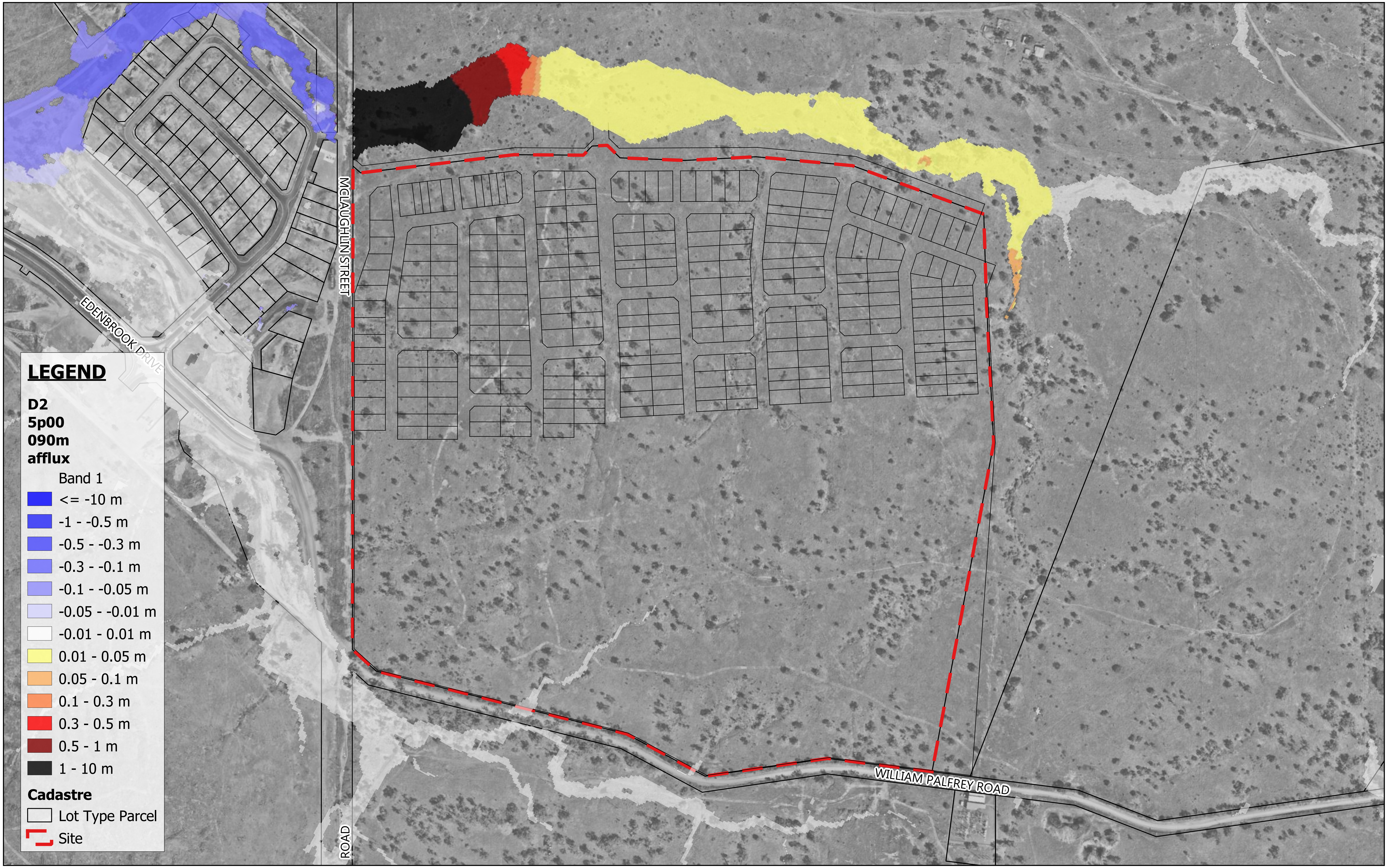
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Afflux | G002 |



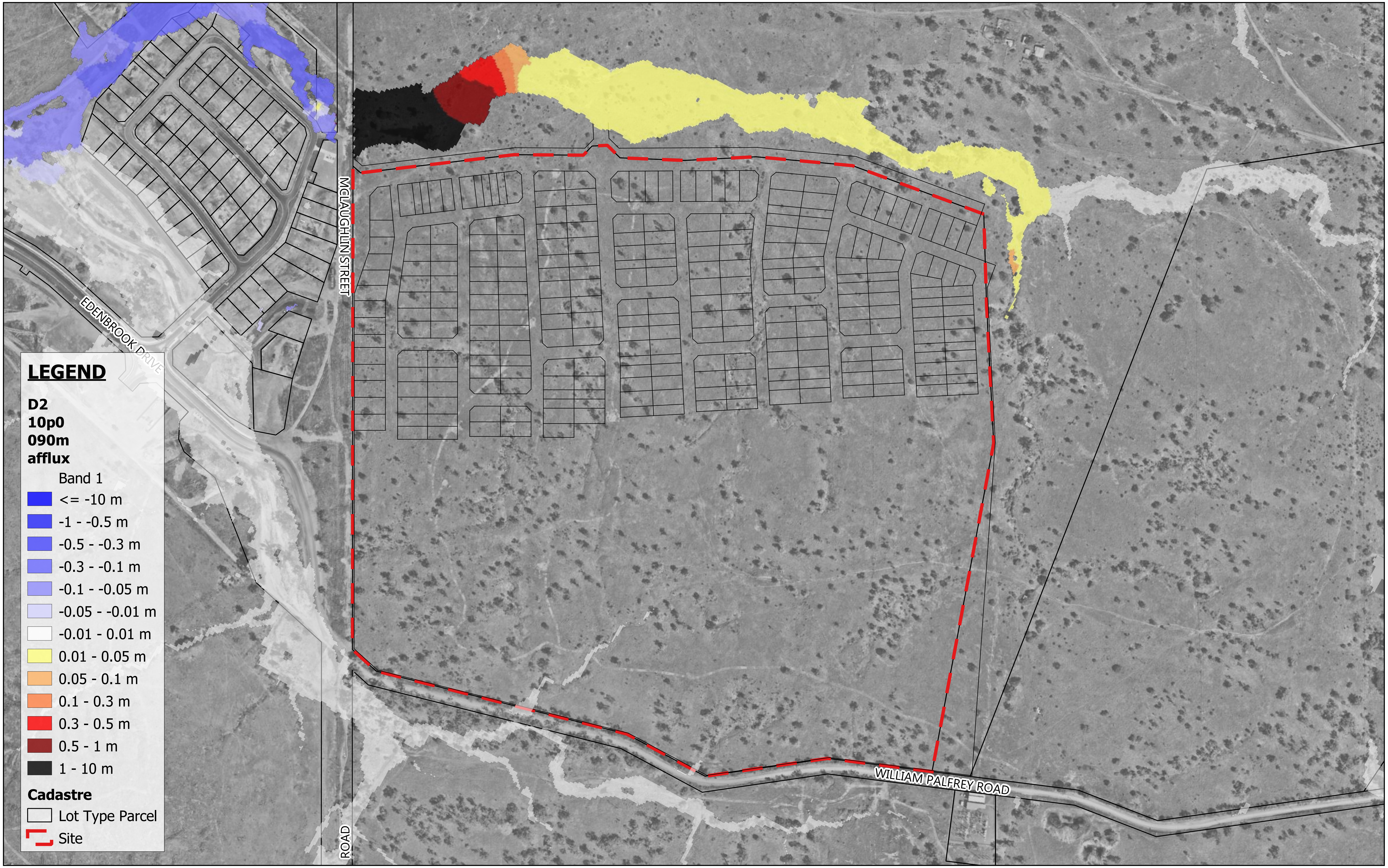
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Afflux | G003 |



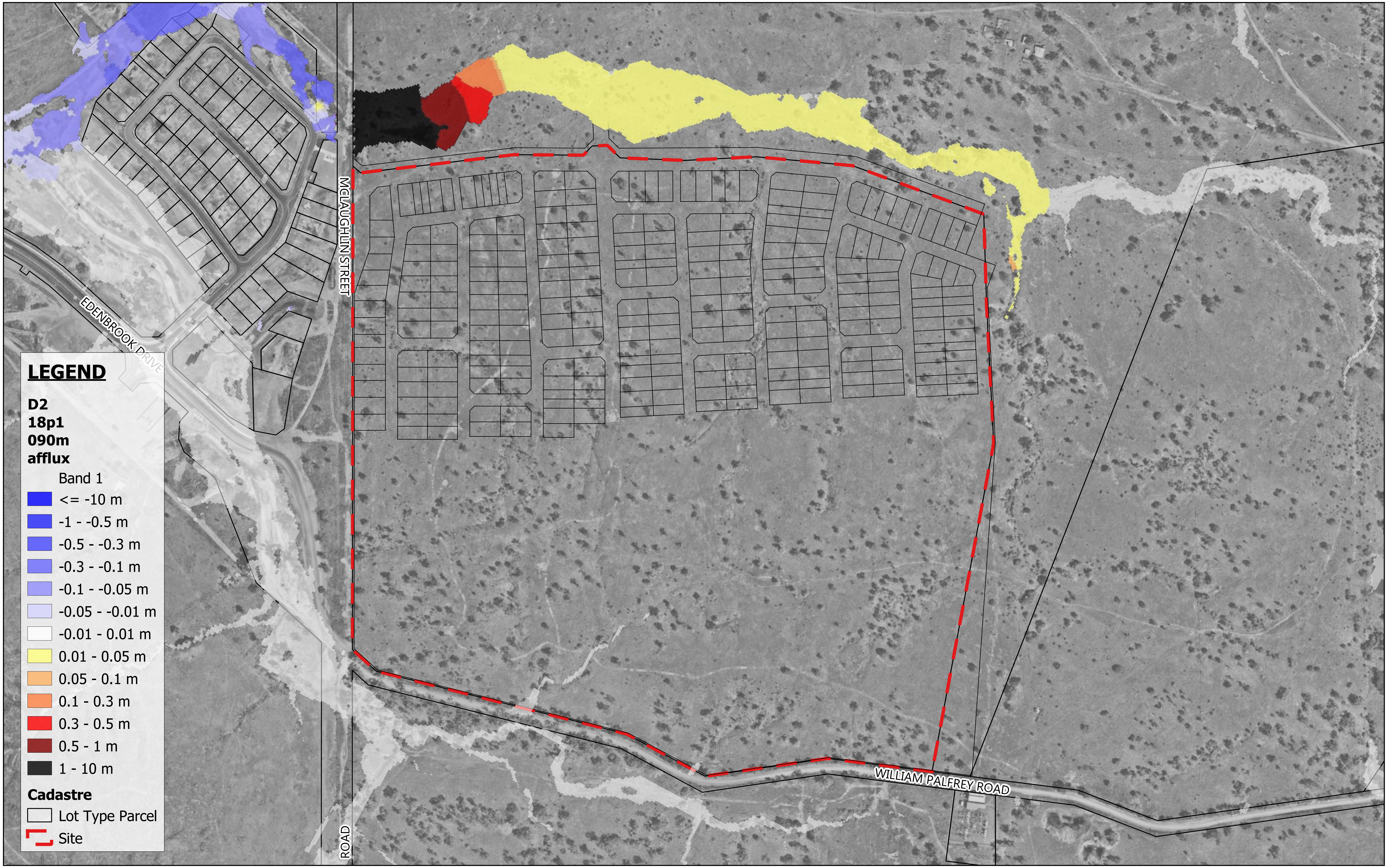
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Afflux | G004 |



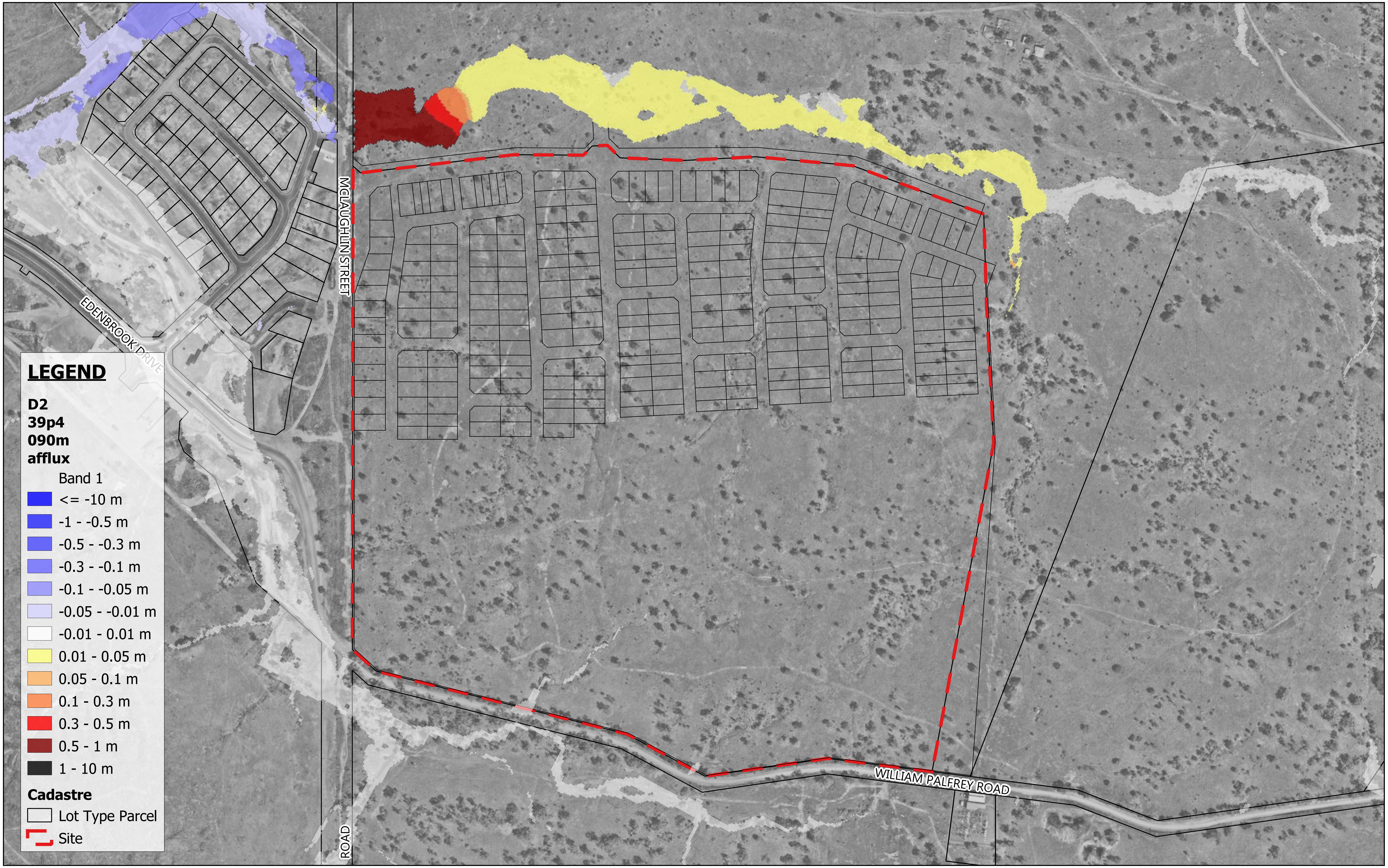
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Afflux | G005 |



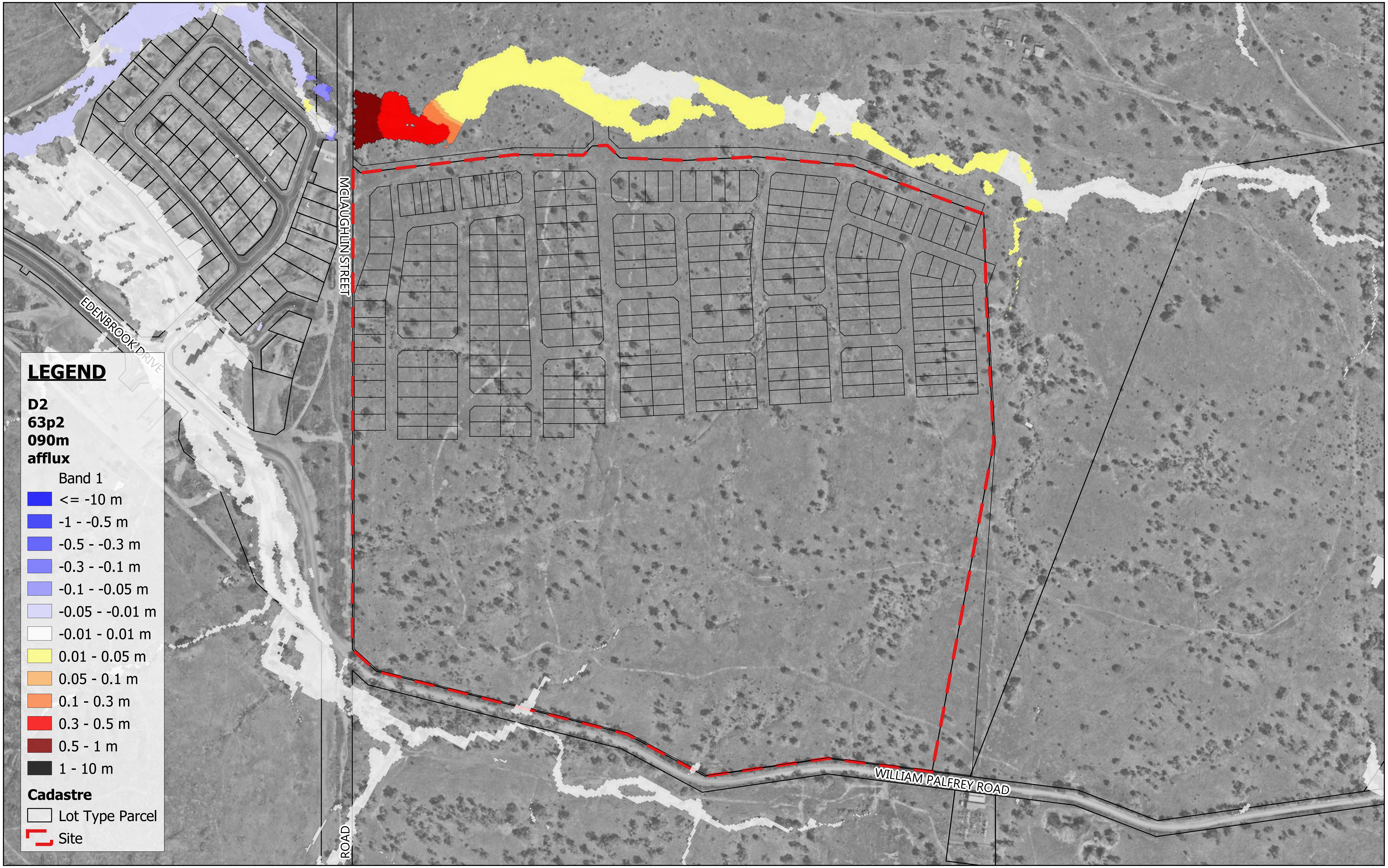
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Afflux | G006 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Afflux | G007 |

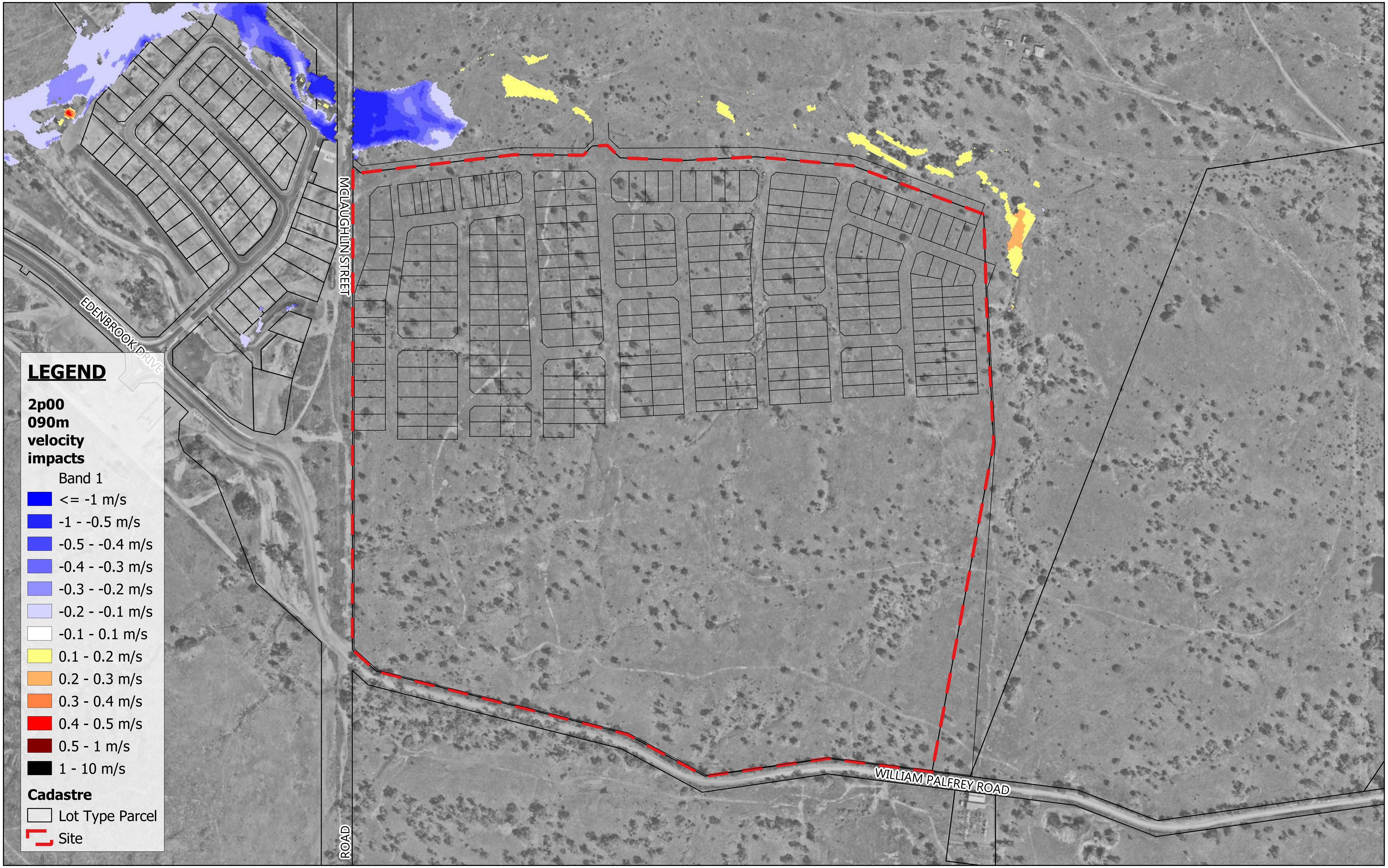
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Velocity Impact | G008 |

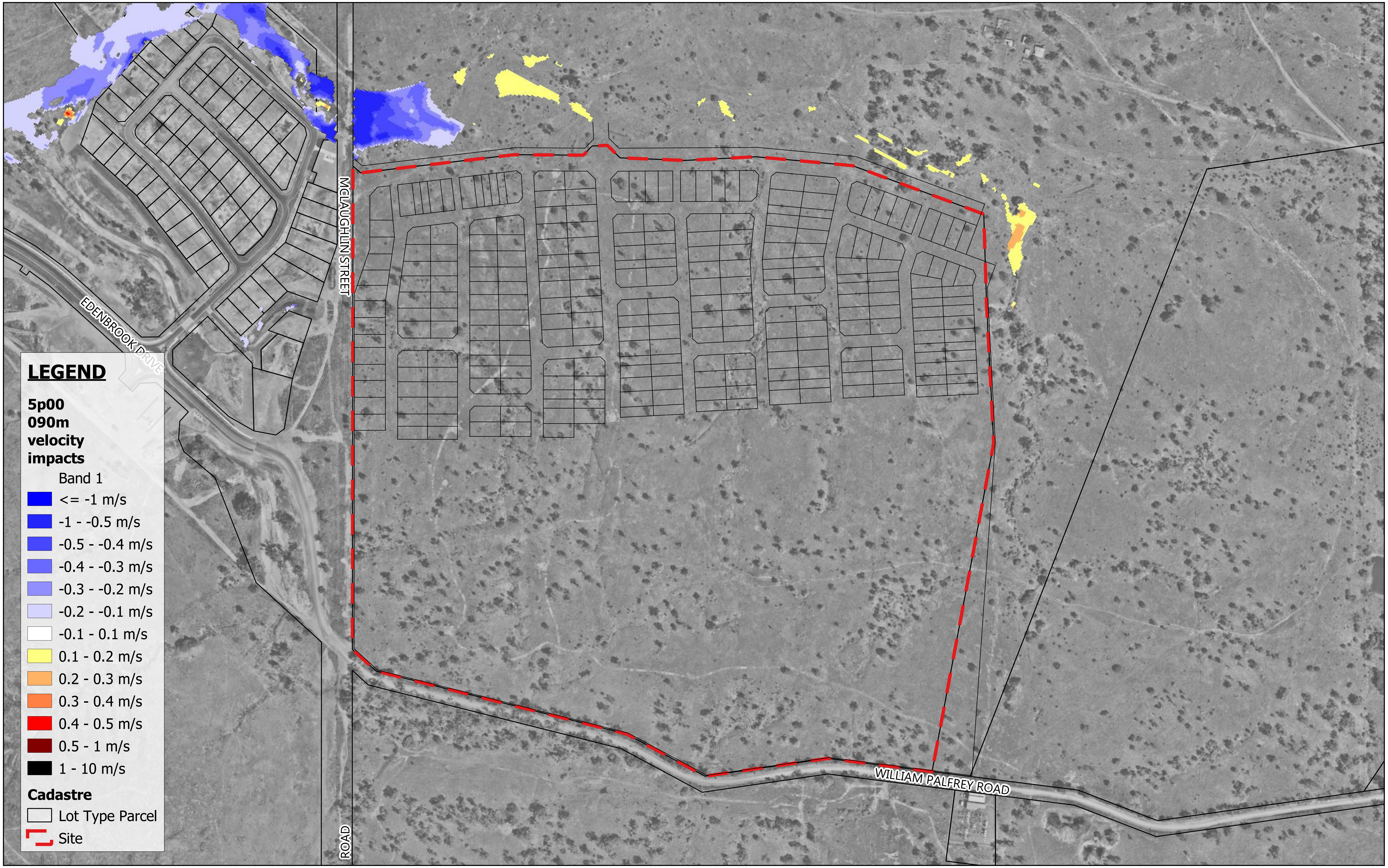


0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Velocity Impact | G009 |



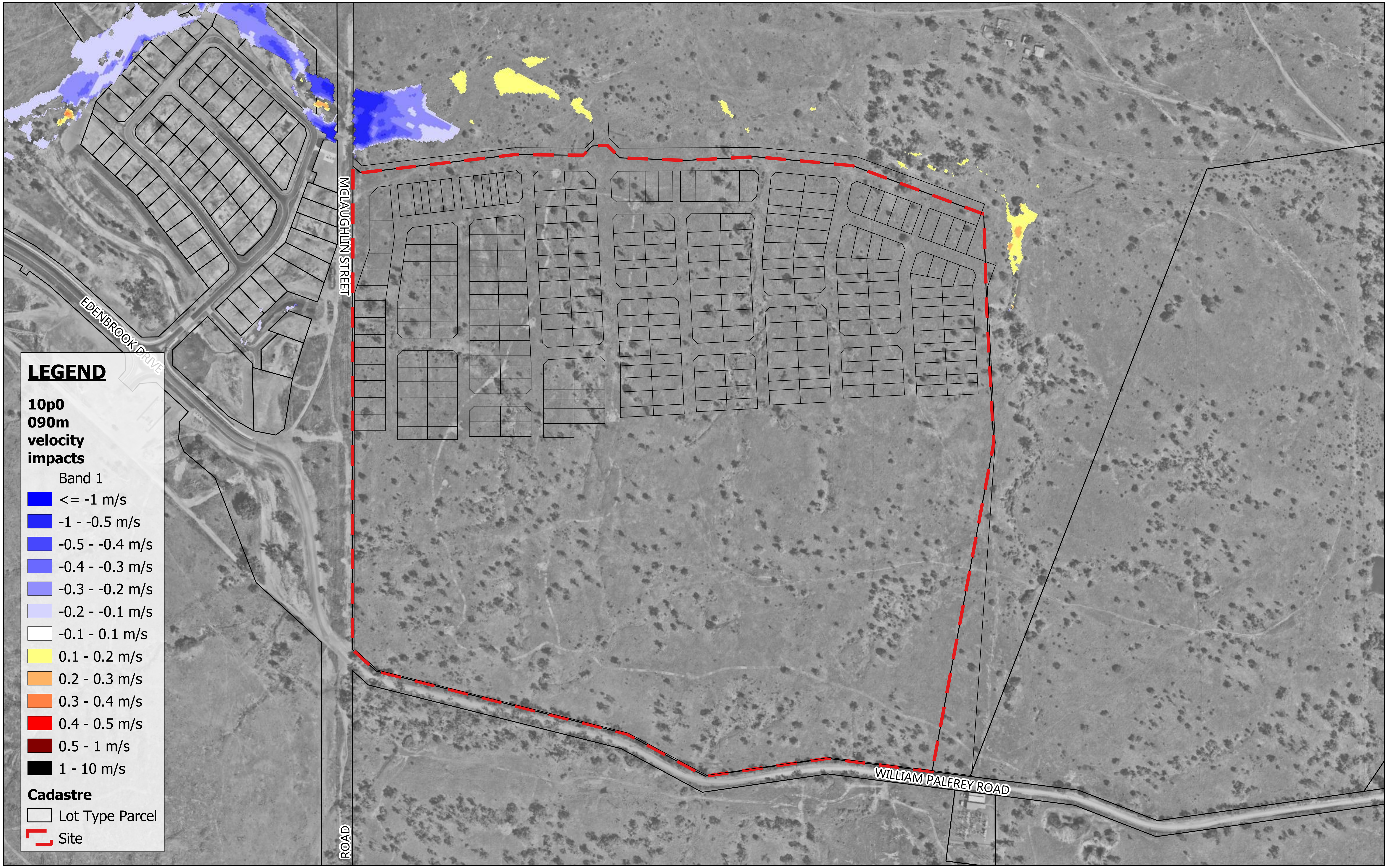
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Velocity Impact | G010 |



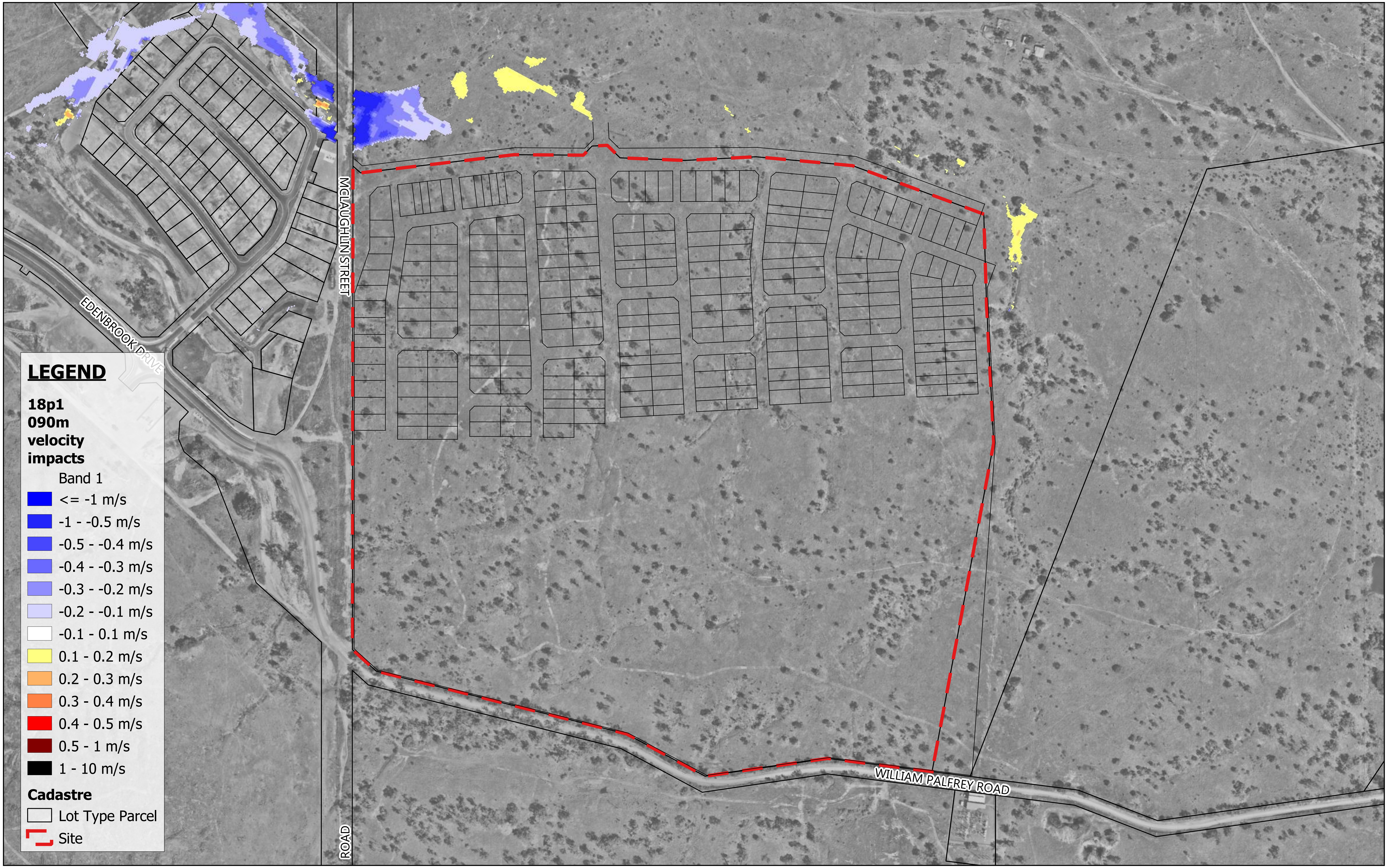
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Velocity Impact | G011 |

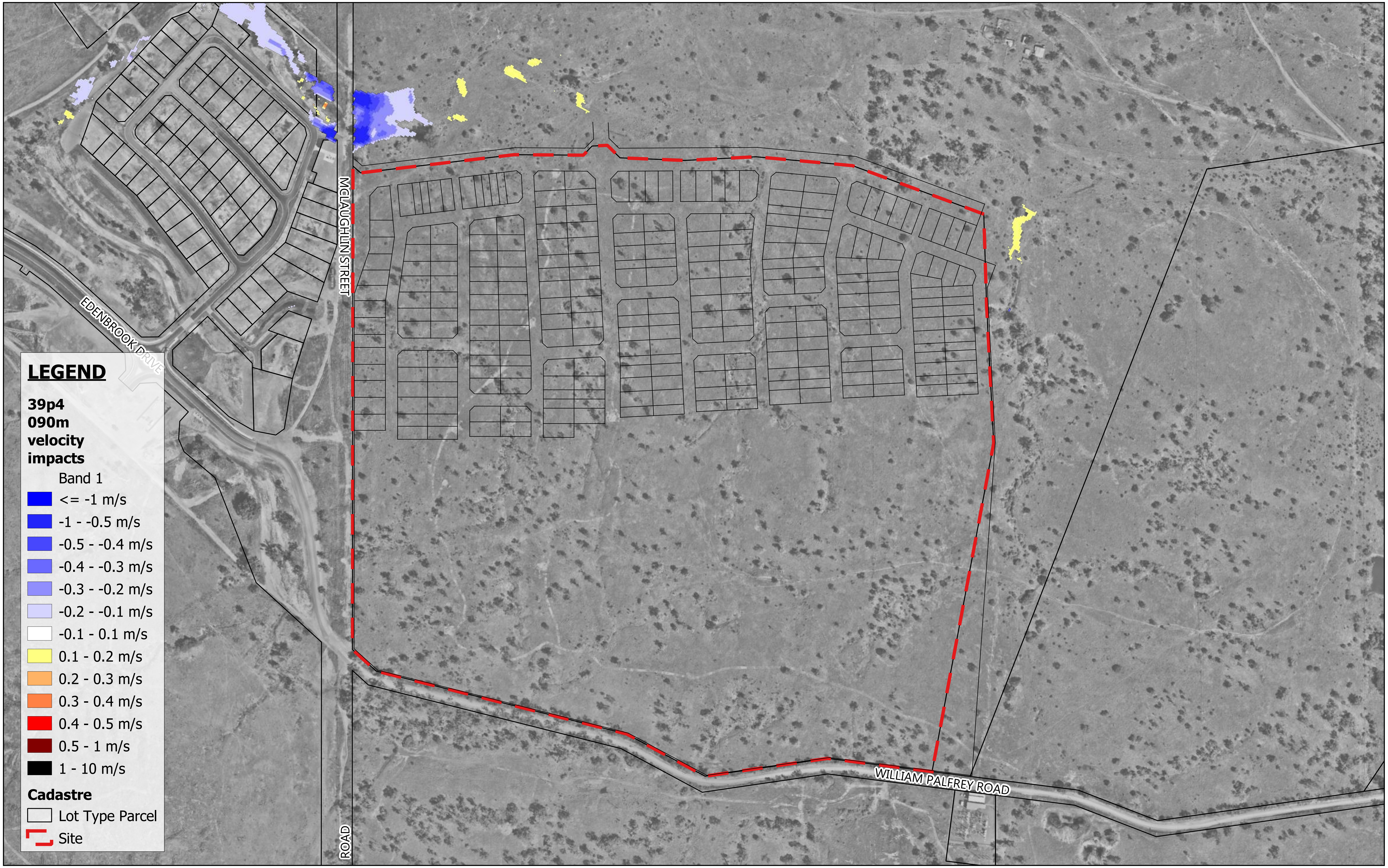


0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Velocity Impact | G012 |



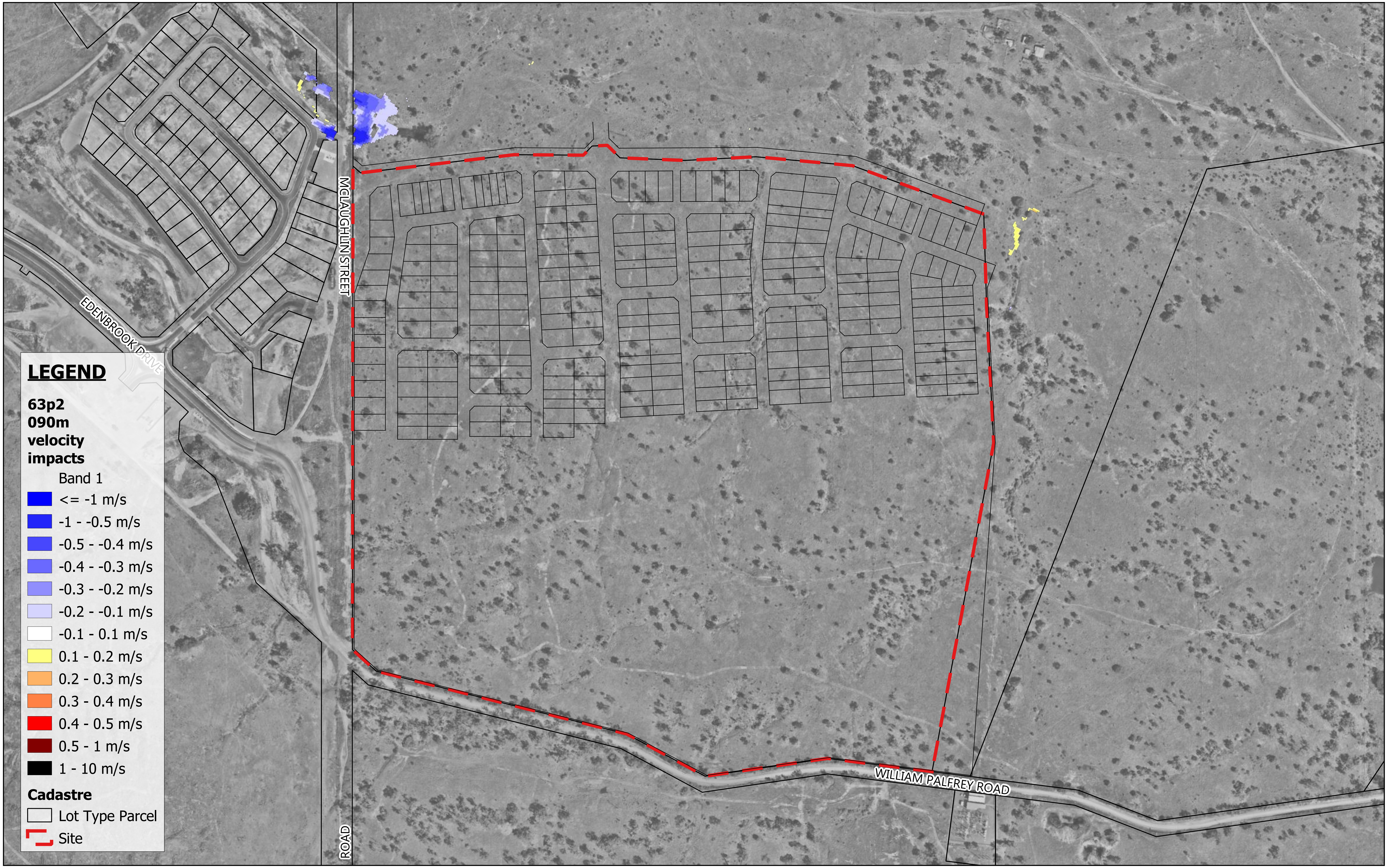
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Velocity Impact | G013 |



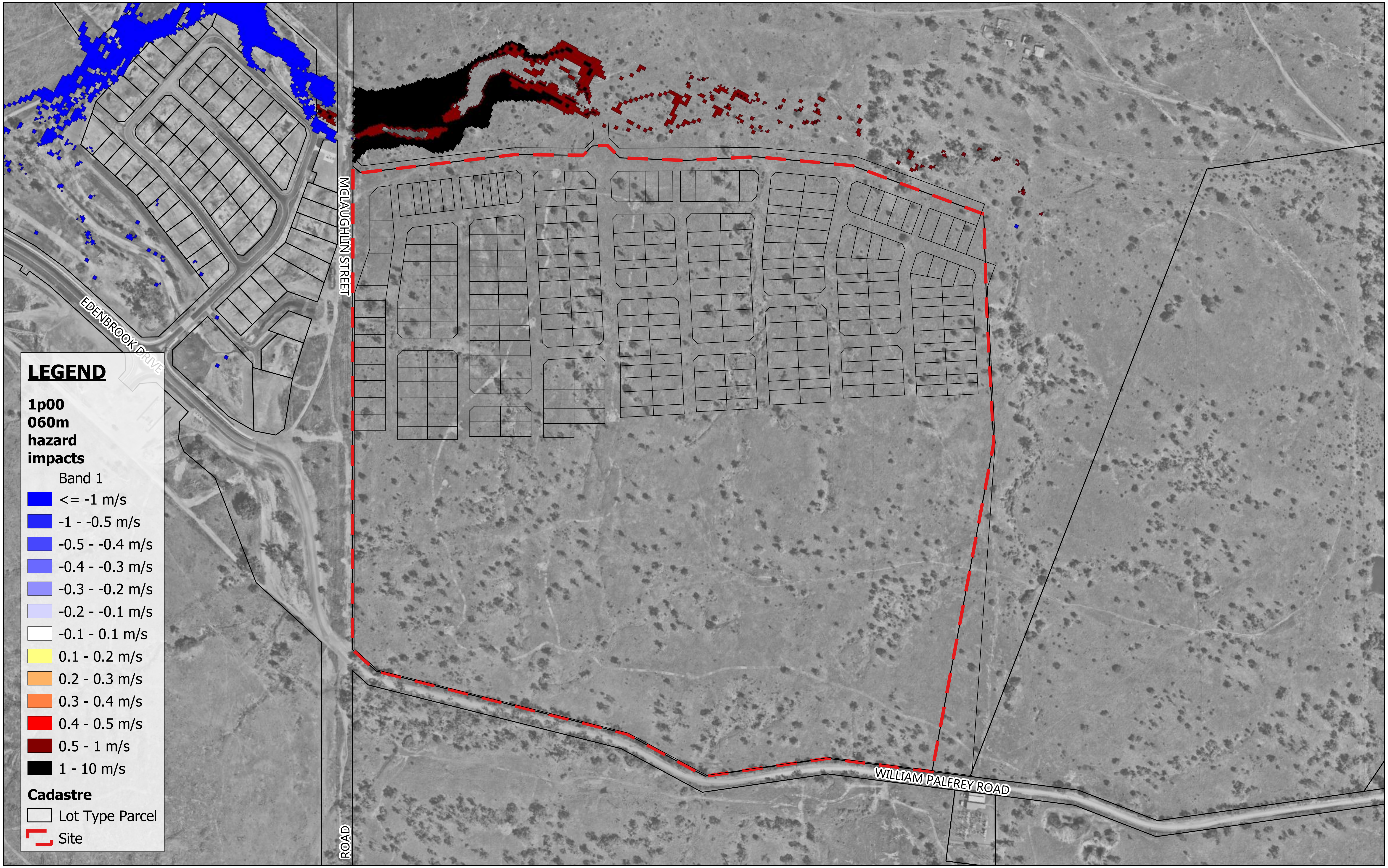
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Velocity Impact | G014 |



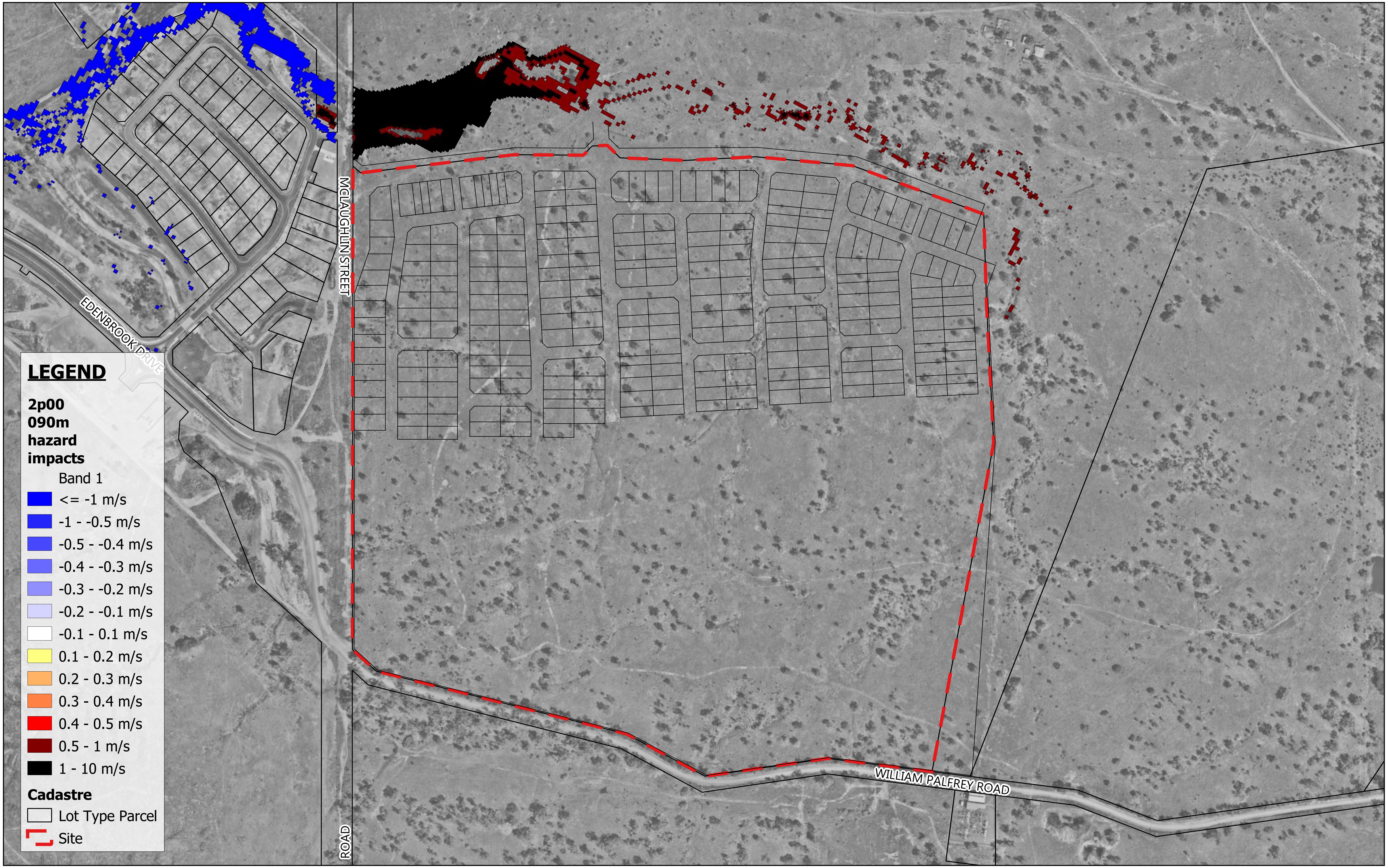
**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 1% AEP Event Flood Hazard Impact | G015 |



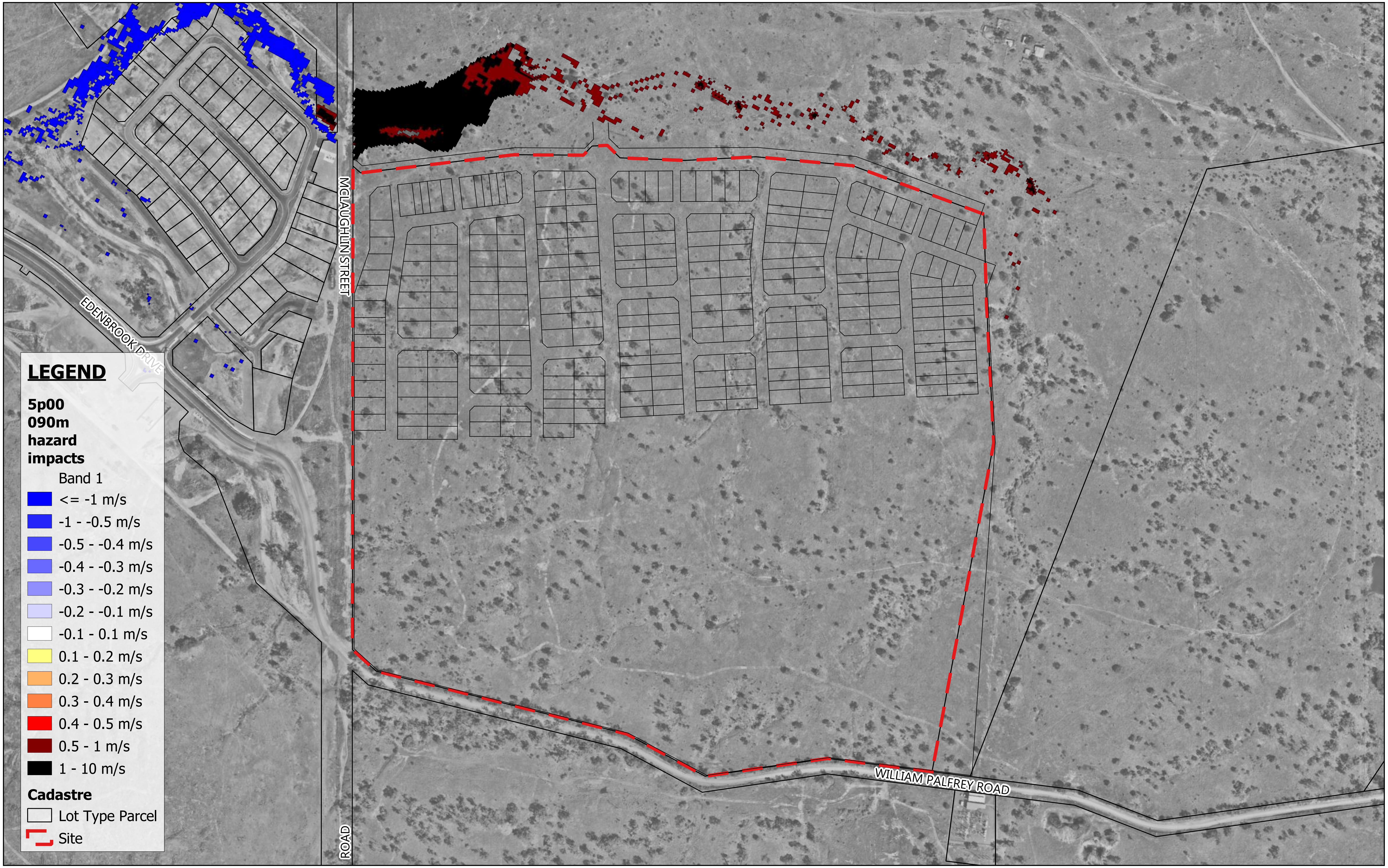
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 2% AEP Event Flood Hazard Impact | G016 |



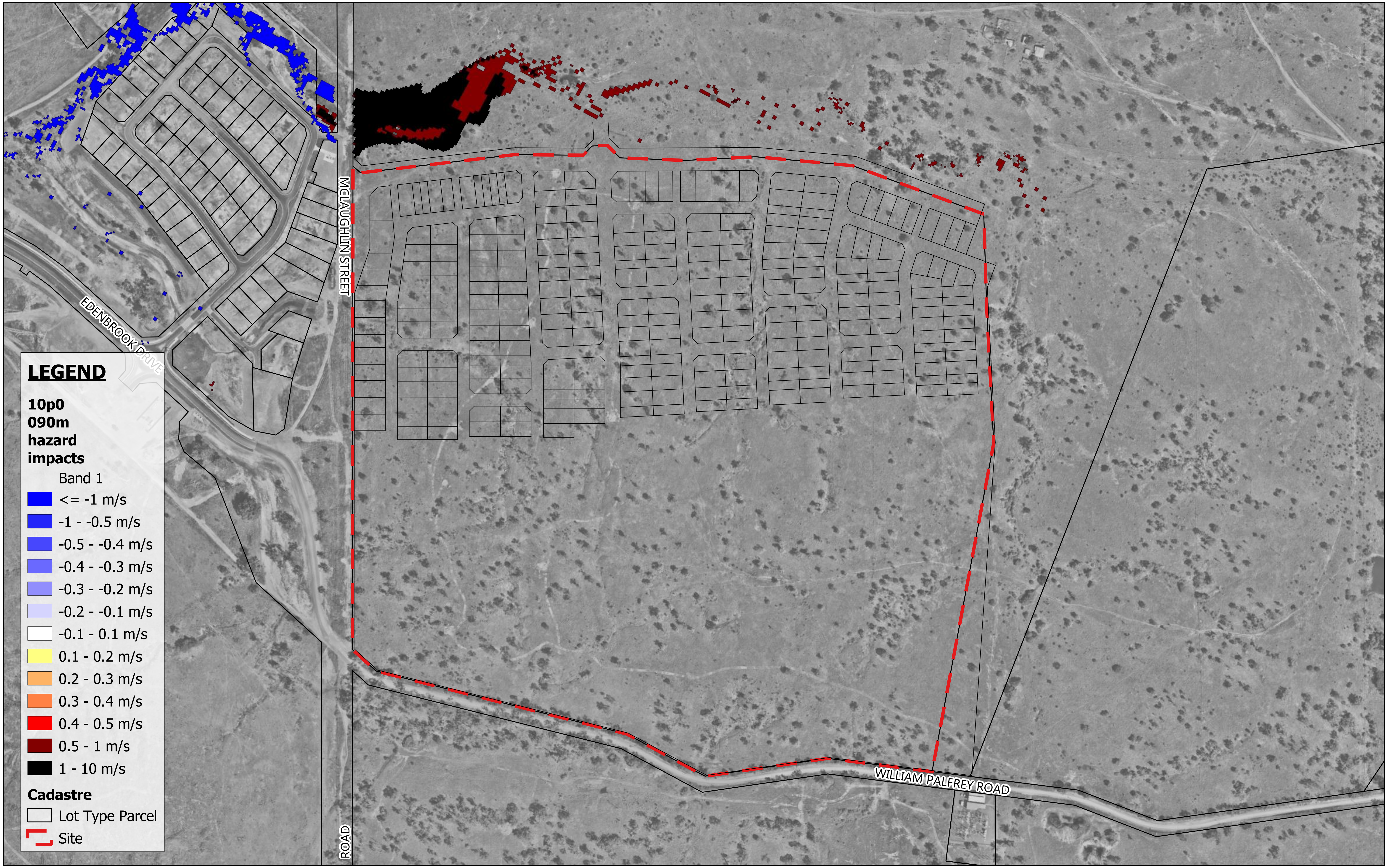
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 5% AEP Event Flood Hazard Impact | G017 |



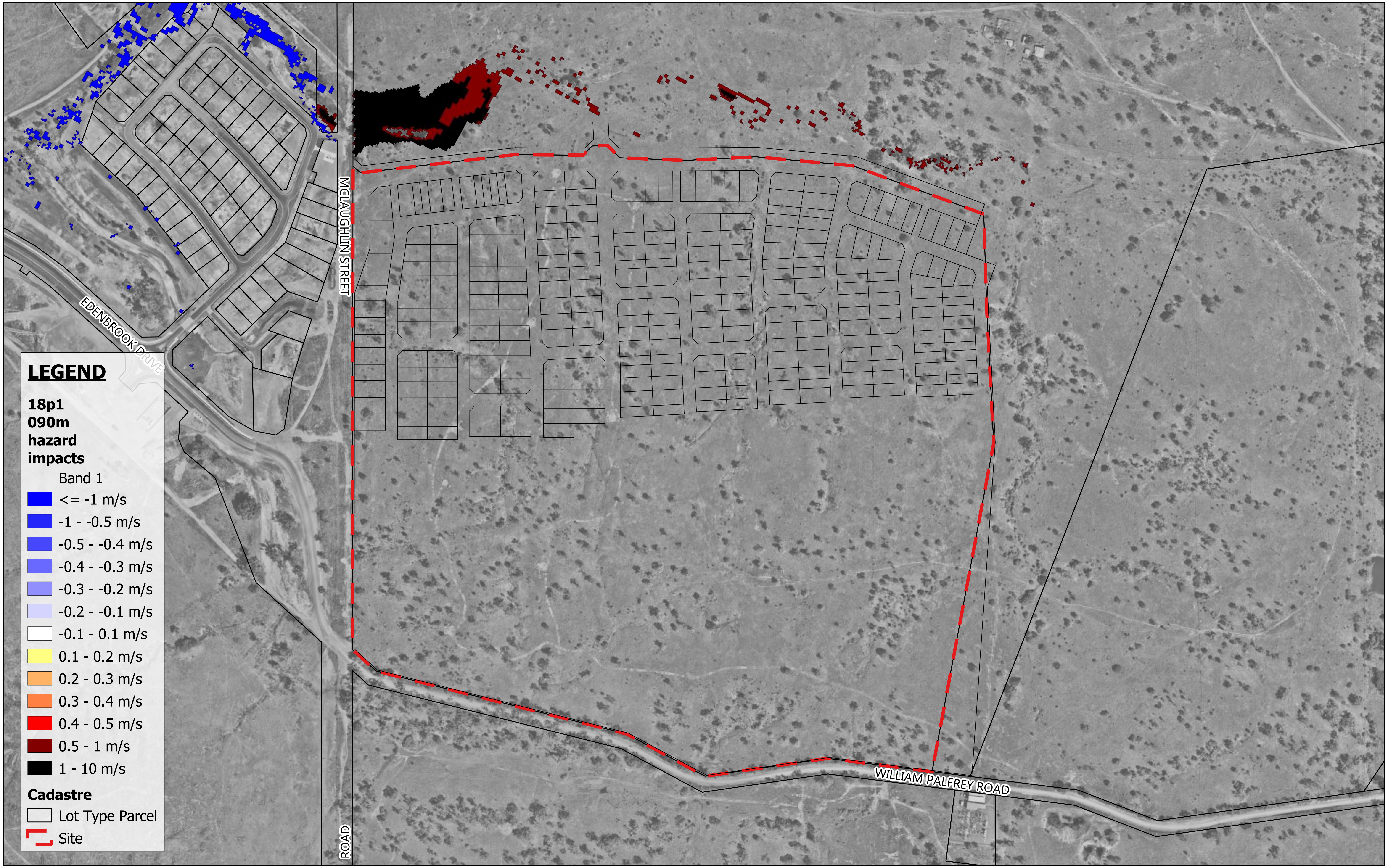
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 10% AEP Event Flood Hazard Impact | G018 |



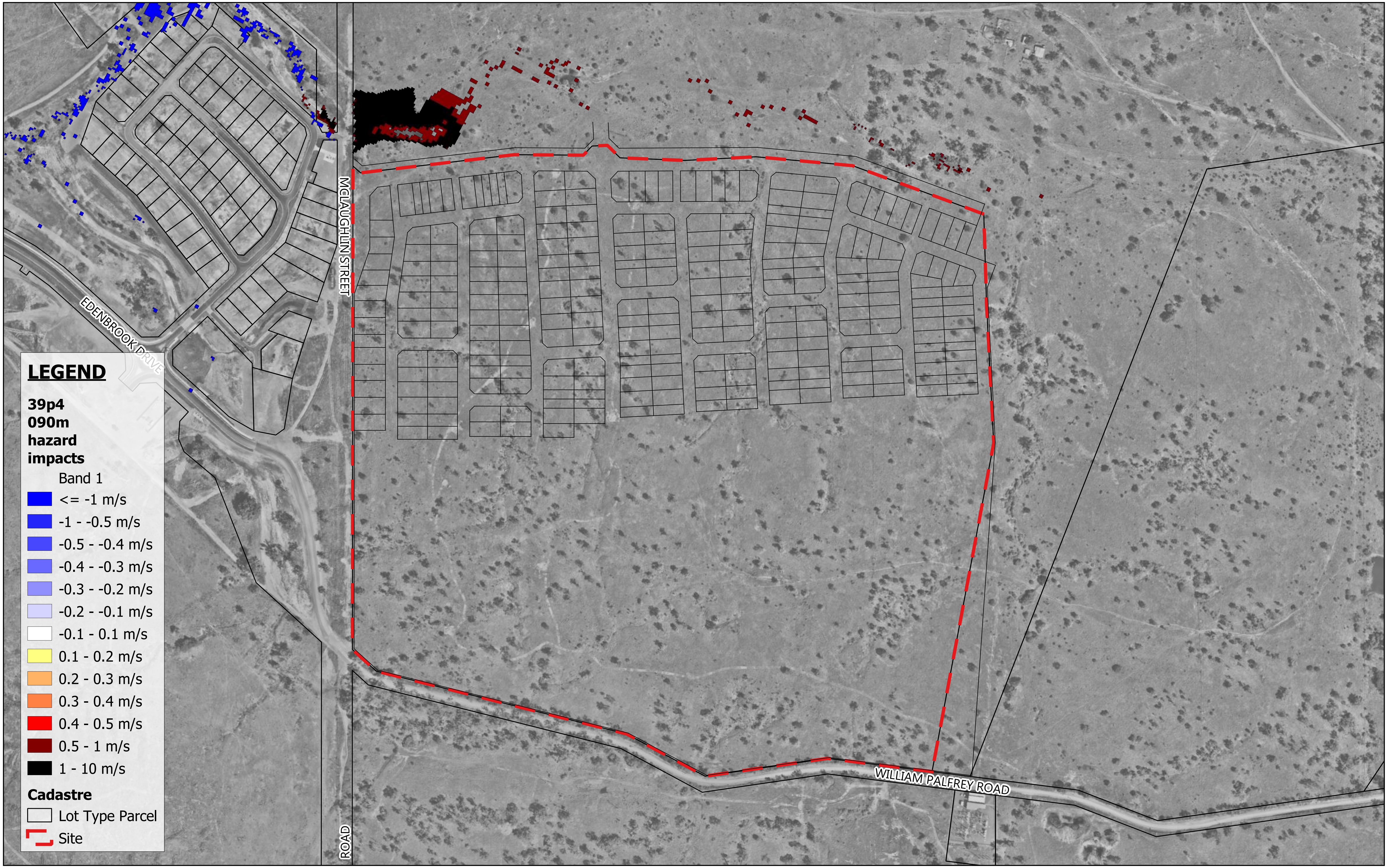
Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 20% AEP Event Flood Hazard Impact | G019 |



**Premise**

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
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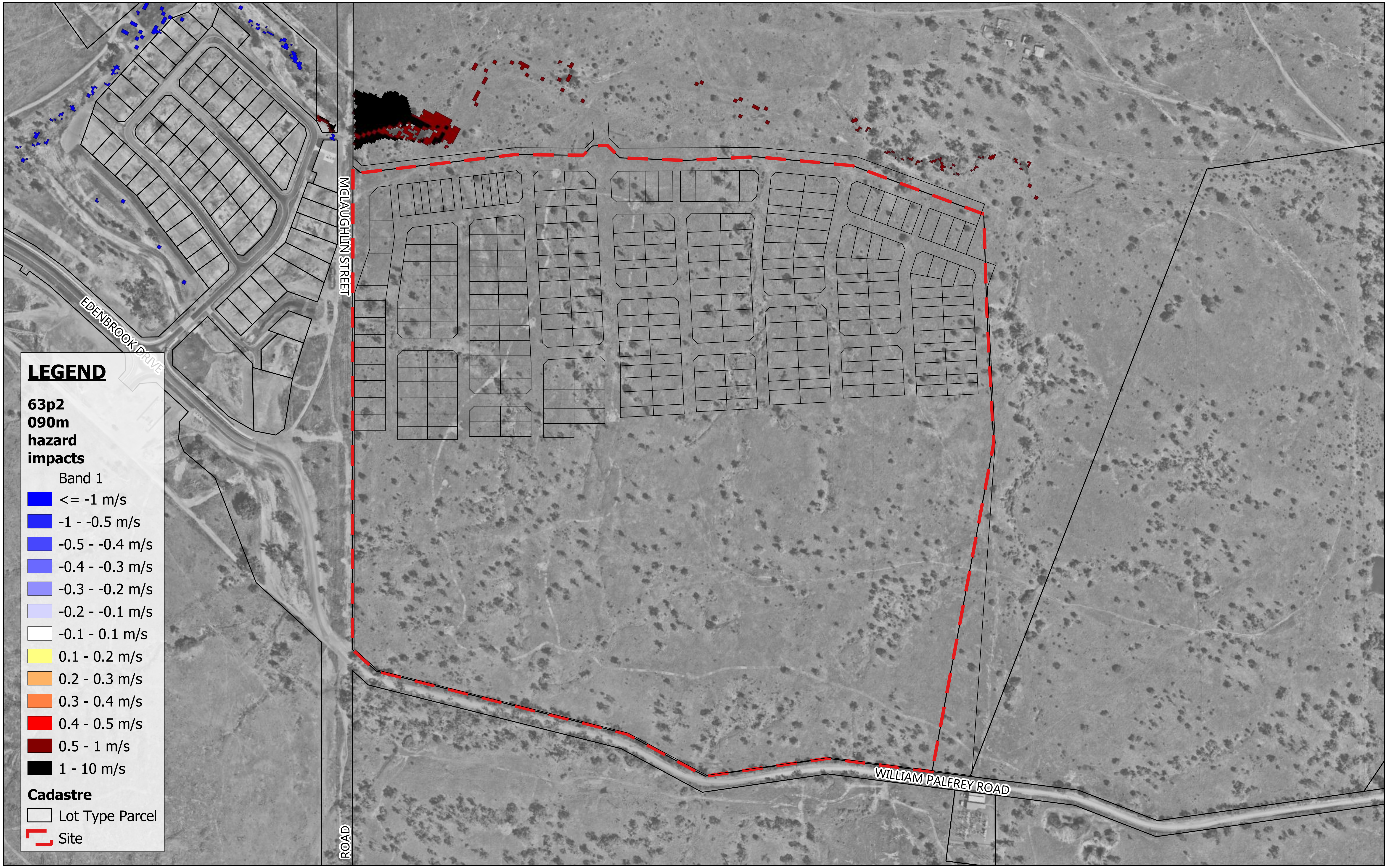
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 50% AEP Event Flood Hazard Impact | G020 |



Premise

0 150 300 450 m

Scale 1:4,500

08.02.2024

| | |
|---|---|
| MAAS GROUP PROPERTIES PTY LTD | Feb 2024 |
| ELLIDA WEST STAGES 1-6, PARKHURST | MPG-0001 |
| 63.2% AEP Event Flood Hazard Impact | G021 |

Premise

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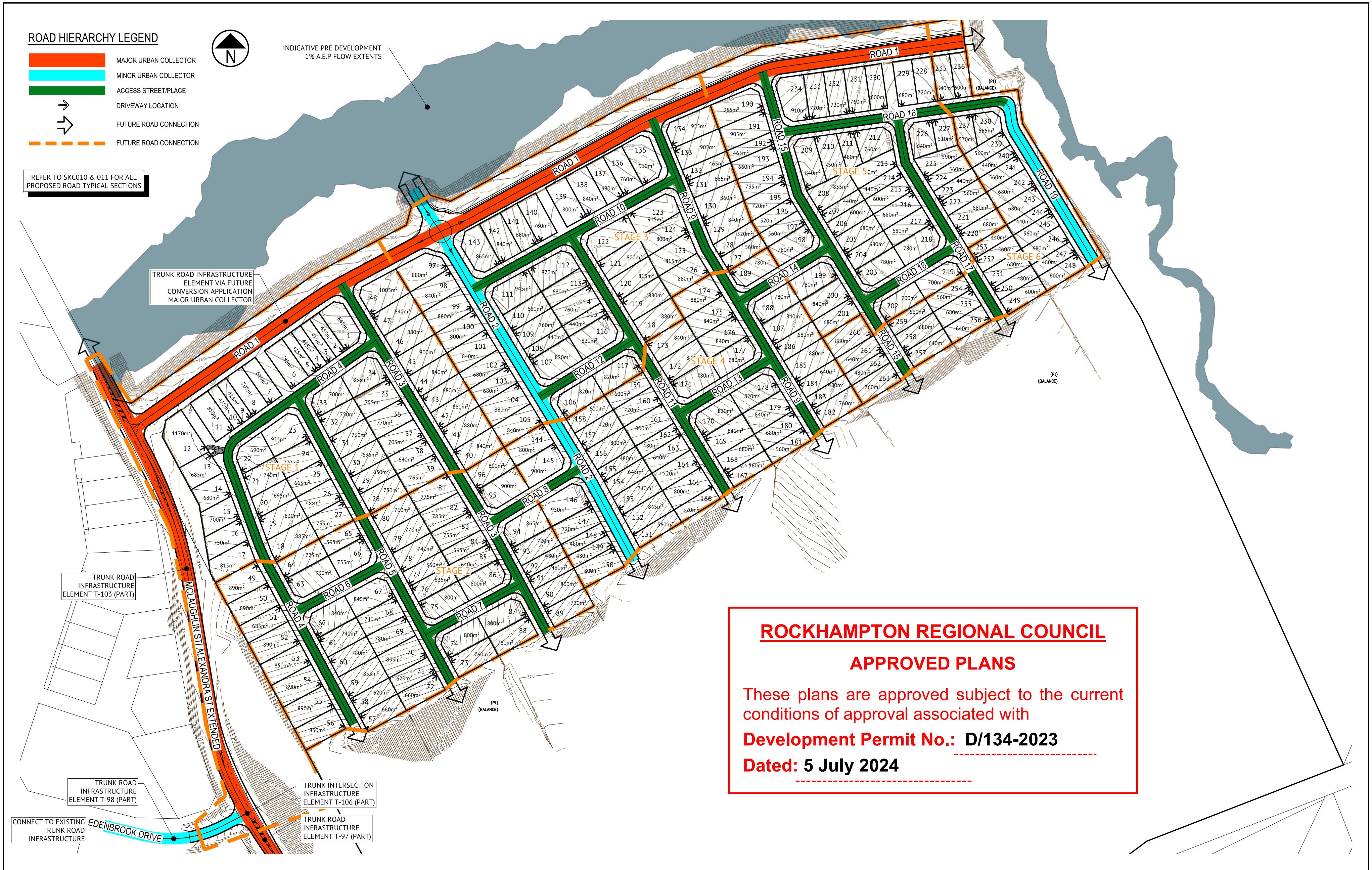


# ROCKHAMPTON REGIONAL COUNCIL

## APPROVED PLANS

These plans are approved subject to the current conditions of approval associated with

**Development Permit No.:** D/134-2023

**Dated:** 5 July 2024

FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

Premise

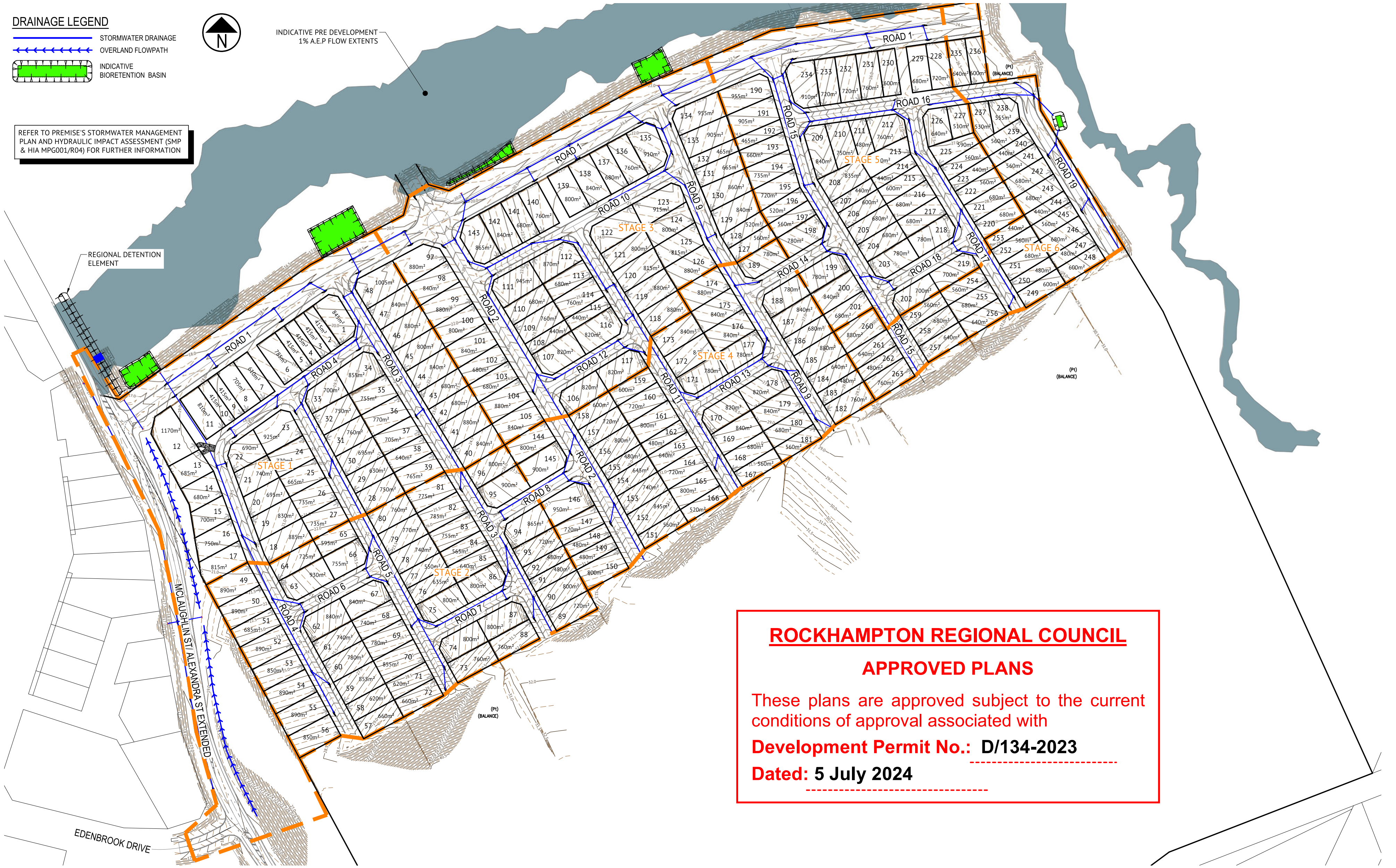
ROCKHAMPTON OFFICE
21 EAST STREET
PO BOX 264
ROCKHAMPTON, QLD, 4700
PH: (07) 4829 3660
WEB: www.premise.com.au

DESIGNED RAY STAER
CHECKED CHRIS SHIELDS
PROJECT MANAGER CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT ELLIDA SUBDIVISION WEST
LOCATION 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE PRELIMINARY ROAD HEIRARCHY

JOB CODE MPG-0001
SHEET NUMBER SKC001
REV C



**ROCKHAMPTON REGIONAL COUNCIL**

**APPROVED PLANS**

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**Development Permit No.: D/134-2023**

**Dated: 5 July 2024**

## FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

Premise

ROCKHAMPTON OFFICE
21 EAST STREET
PO BOX 264
ROCKHAMPTON, QLD, 4700
PH: (07) 4829 3660
WEB: www.premise.com.au

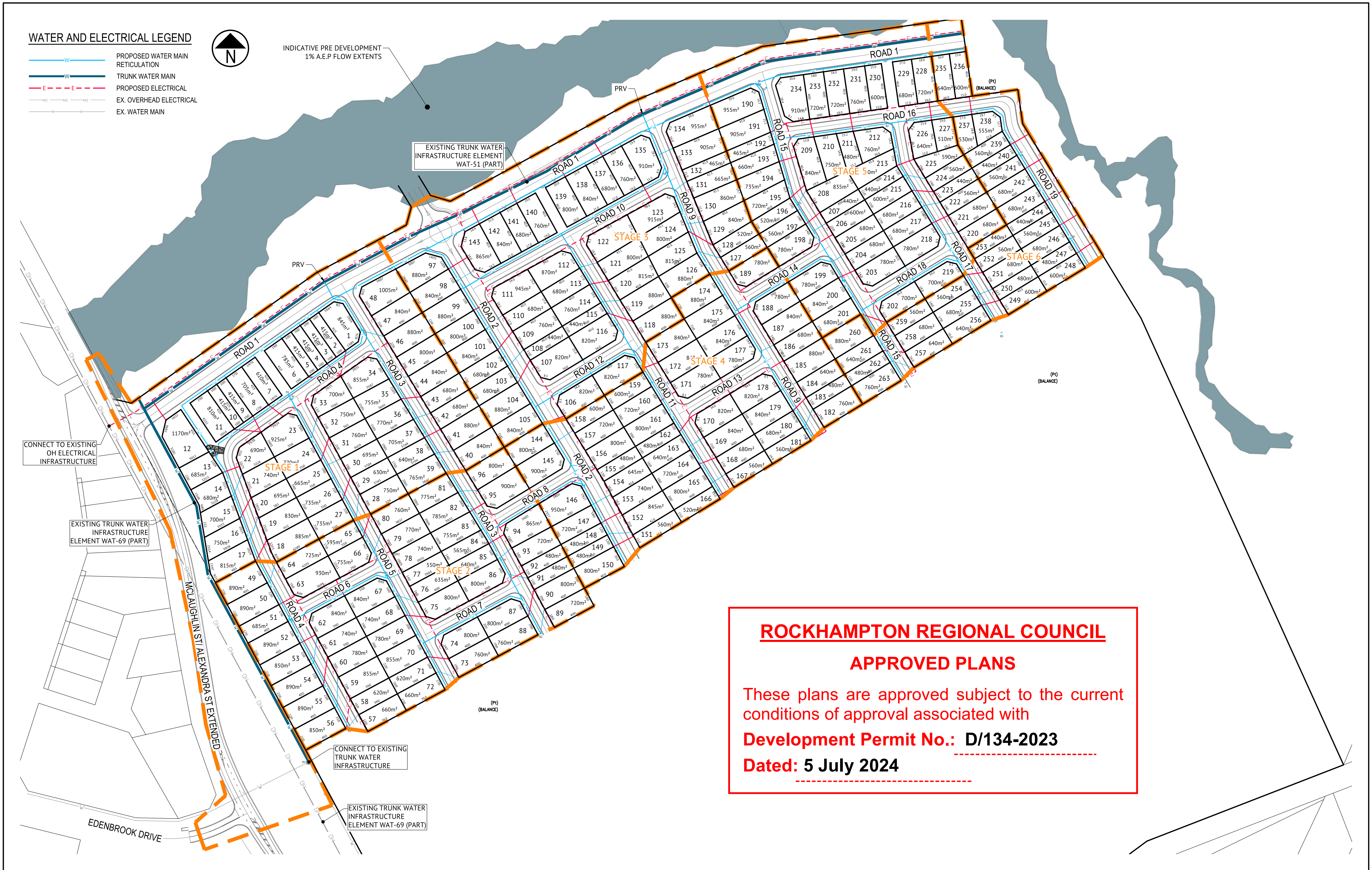
DESIGNED: RAY STAER
CHECKED: CHRIS SHIELDS
PROJECT MANAGER: CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT: MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT: ELLIDA SUBDIVISION WEST
LOCATION: 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE: PRELIMINARY STORMWATER DRAINAGE

JOB CODE: MPG-0001
SHEET NUMBER: SKC002
REV: C

Document Set ID: 40744359
Version: 1, Version Date: 15/02/2024



## ROCKHAMPTON REGIONAL COUNCIL

## APPROVED PLANS

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**Development Permit No.:** **D/134-2023**

**Dated:** **5 July 2024**

# FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

Premise

ROCKHAMPTON OFFICE
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PO BOX 264
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PH: (07) 4829 3660
WEB: www.premise.com.au

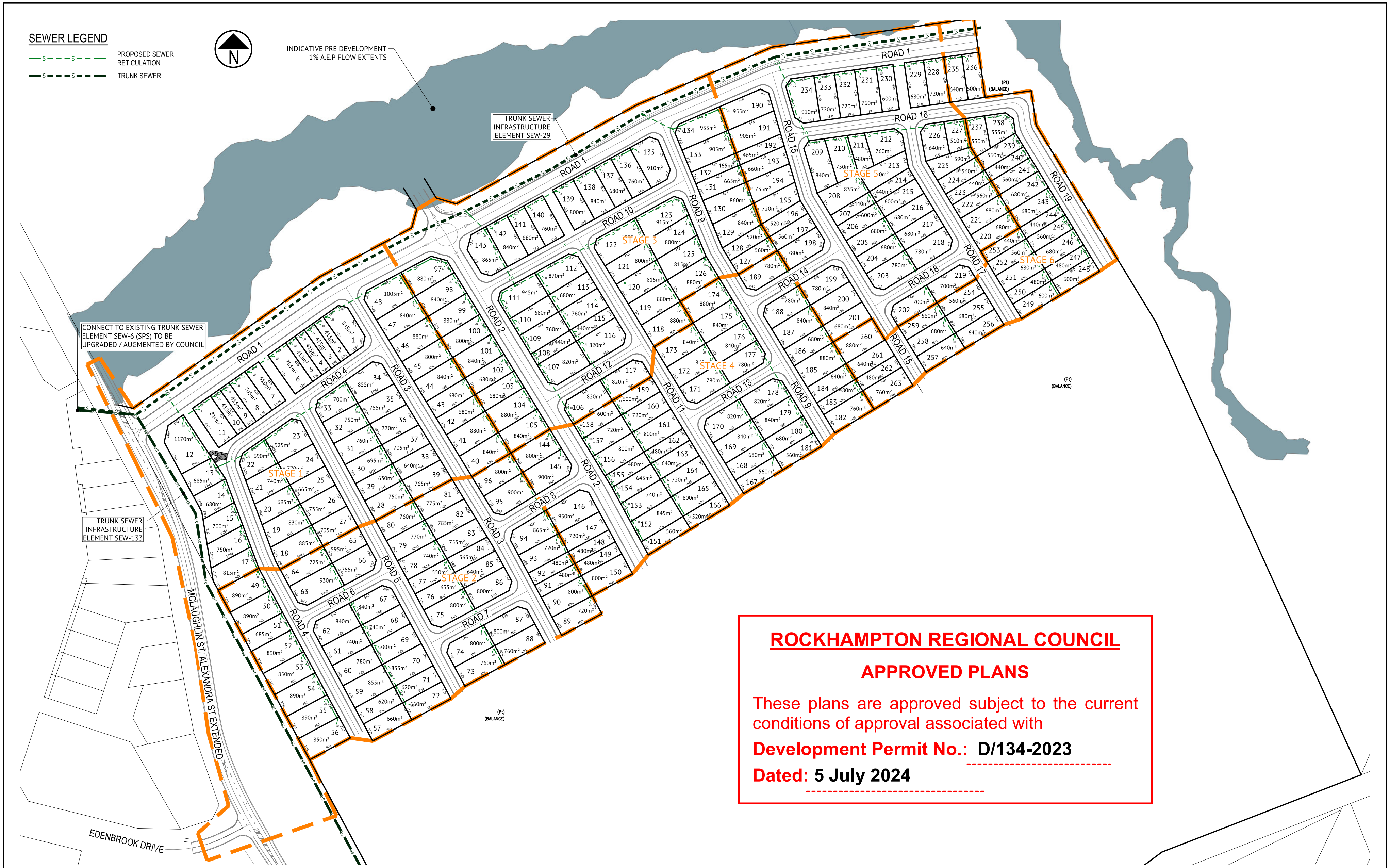
DESIGNED
RAY STAER
CHECKED
CHRIS SHIELDS
PROJECT MANAGER
CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT: MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT: ELLIDA SUBDIVISION WEST
LOCATION: 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE: PRELIMINARY WATER & ELECTRICAL RETICULATION

JOB CODE
MPG-0001
SHEET NUMBER
SKC003
REV
C

Document Set ID: 40744359
Version: 1, Version Date: 15/02/2024



## ROCKHAMPTON REGIONAL COUNCIL

## APPROVED PLANS

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**Development Permit No.: D/134-2023**

**Dated: 5 July 2024**

## FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

Premise

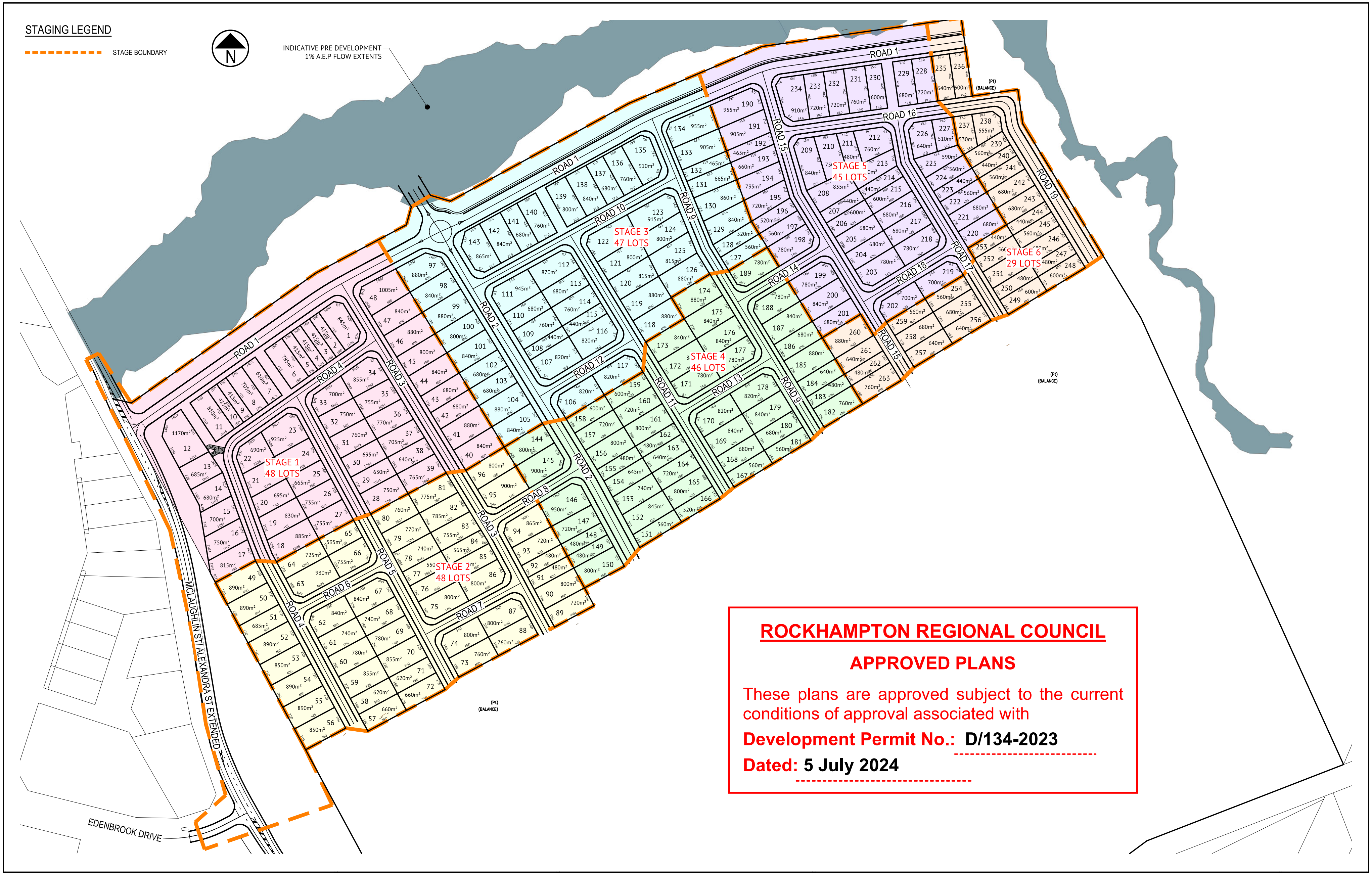
ROCKHAMPTON OFFICE
21 EAST STREET
PO BOX 264
ROCKHAMPTON, QLD, 4700
PH: (07) 4829 3660
WEB: www.premise.com.au

DESIGNED: RAY STAER
CHECKED: CHRIS SHIELDS
PROJECT MANAGER: CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT: MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT: ELLIDA SUBDIVISION WEST
LOCATION: 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE: PRELIMINARY SEWER RETICULATION

JOB CODE: MPG-0001
SHEET NUMBER: SKC004
REV: C



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**Development Permit No.: D/134-2023**

**Dated: 5 July 2024**

## FOR DA APPROVAL

| DATE | REV | DESCRIPTION | REC | APP |
|---|---|---|---|---|
| 08/02/2024 | C | DA RFI RESPONSE | AB | CWS |
| 10/10/2023 | B | FOR COUNCIL DA ASSESSMENT | AB | CWS |
| 4/10/2023 | A | PRELIMINARY - NOT FOR CONSTRUCTION | JJ | CWS |

REVISIONS

Premise
ROCKHAMPTON OFFICE
21 EAST STREET
PO BOX 264
ROCKHAMPTON, QLD, 4700
PH: (07) 4829 3660
WEB: www.premise.com.au

DESIGNED RAY STAER
CHECKED CHRIS SHIELDS
PROJECT MANAGER CHRIS SHIELDS
ENGINEERING CERTIFICATION

SCALE
0 30 60 90m
SCALE 1:1500 (A1)
ORIGINAL SHEET SIZE A1

CLIENT MAAS GROUP PROPERTIES ELLIDA PTY LTD
PROJECT ELLIDA SUBDIVISION WEST
LOCATION 23-27 WILLIAM PALFREY ROAD, PARKHURST, QLD
SHEET TITLE PRELIMINARY STAGE DESIGN
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MACQUARIE GEOTECH

# Ellida West, Parkhurst – Slope Assessment

Job No.: G23920

Submitted to:

MAAS

PO Box 4921

Dubbo NSW 2830

Attn: Dominic Wilson

ROCKHAMPTON REGIONAL COUNCIL

APPROVED PLANS

These plans are approved subject to the current conditions of approval associated with

**Development Permit No.:** D/134-2023

**Dated:** 5 July 2024

Ellida West, Parkhurst - Slope Assessment

Report No.: G23920

Client – MAAS

Ellida West, Parkhurst – Slope Assessment

REVISION CONTROL

| Revision | Date | Details | Prepared By | Reviewed By |
|---|---|---|---|---|
| 00 | 25 January 2024 | Draft | M.Williams | - |
| 01 | 29th January 2024 | Final | M.Williams | C. Green |
| | | | | |

## Contents

1 INTRODUCTION .......... 5
2 SCOPE OF WORKS .......... 5
3 SITE DESCRIPTION .......... 5
  3.1 Topography .......... 6
4 DESK STUDY .......... 6
  4.1 Regional Geology .......... 6
  4.2 Previous Investigations .......... 7
5 FIELDWORK .......... 7
  5.1 Service Location .......... 7
  5.2 Test Pits .......... 7
  5.3 Sampling .......... 8
6 EXISTING SUBSURFACE CONDITIONS .......... 8
  6.1 Exploratory Hole Summary .......... 9
  6.2 Groundwater .......... 9
7 PROPOSED DEVELOPMENT .......... 9
8 SLOPE STABILITY ASSESSMENT .......... 9
  8.1 Sign of Slope Instability .......... 10
  8.2 Failure Mechanisms .......... 10
  8.3 Potential Landslide Risks .......... 10
  8.4 Risk to Property .......... 10
  8.5 Quantitative Risk Estimation – Loss of Life .......... 11
9 Discussion and Recommendations .......... 12
  9.1 Summary of Landslide Risk Assessment .......... 12
  9.2 Earthworks .......... 12
    9.2.1 Site Preparation .......... 12
    9.2.2 Re-use of Site Material .......... 13
    9.2.3 Residual Slopes .......... 13
    9.2.4 Storm Water Control .......... 14
  9.3 Footing Design .......... 14
  9.4 Further Geotechnical Input .......... 14
10 CONCLUSION .......... 15

## Figures

Figure 1: Site Location .......... 6
Figure 2: Test Pit Locations .......... 8

## Tables

Table 1: Summary of Ground Conditions .......... 9
Table 2: Possible Failure Mechanisms .......... 10
Table 3: Summary of Post Development Slope Instability Hazards .......... 11
Table 4: Summary of Risk Estimation of Annual Probability of Loss of Life .......... 12

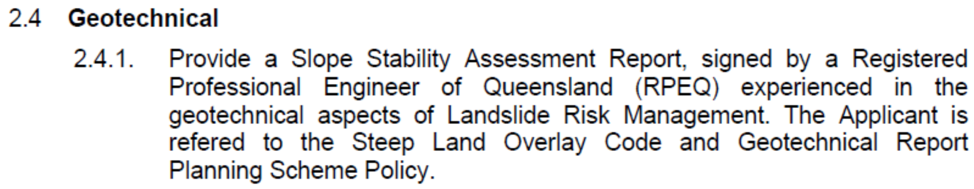
## Appendices

Appendix A – Geotechnical Explanatory Notes
Appendix B – Exploratory Hole Logs
Appendix C – AGS 2007 Guidelines

# 1 INTRODUCTION

At the request of MAAS, Macquarie Geotechnical (MG) has carried out a qualitative slope stability assessment for the proposed Ellida West, Parkhurst, subdivsion.

A development application (DA) has been submitted to Rockhampton Regional Council, who have responded with an RFI Item 2.4.1 as per below, requiring a Slope Stability Assessment Report:



2.4 **Geotechnical**

2.4.1. Provide a Slope Stability Assessment Report, signed by a Registered Professional Engineer of Queensland (RPEQ) experienced in the geotechnical aspects of Landslide Risk Management. The Applicant is refered to the Steep Land Overlay Code and Geotechnical Report Planning Scheme Policy.

The objective of this report is to provide the required slope stability assessment.

The client has provided the following documents to MG:

- Groundwork Plus, Preliminary Resource Assessment and Quarry Development Plan, reference 2694_230_001, dated August 2022
- Premise, Engineering Infrastructure Report No: MPG-0001/R01Rev: B dated 25 October 2023

# 2 SCOPE OF WORKS

The agreed scope of works are as follows:

- Undertake a desk study and review existing investigation information to assess the likely geological conditions of the site and to develop a geological model for the site.
- Undertake additional test pit investigation.
- Provide a qualitative assessment of existing and post development slope instability risk based on AGS (Australian Geotechnical Society) 2007 guidelines.
- Review proposed development and earthworks plans.
- Provide indicative earthworks and outline foundation recommendations.

# 3 SITE DESCRIPTION

The project is located at Parkhurst approximately 7km north of Rockhampton, Queensland within the Rockhampton Regional Council (RRC) area.

Figure 1: Site Location

## 3.1 Topography

The site is an area of undulating hills. The site is bounded by William Paffrey Road to the south, McLaughlin Street and the Edenbrook subdivision to the west, open vacant ground near to Ramsey Creek to the north and open vacant ground to the east.

Elevations range from around RL 18 mAHD in the northern part of the site to a maximum of around RL 35 mAHD in the south.

Portions of the subject site are subject to the 'Steep Land' overlay in the RRC Planning Scheme, with some segments having a slope greater than 25%, mostly towards the south.

# 4 DESK STUDY

A brief desk study was undertaken using readily available geological and geotechnical information and included the following:

## 4.1 Regional Geology

The geological map of the area indicates the site to be underlain by Rockhampton Group/Alma Formation sedimentary rocks, with Alluvium in the lower ground towards Ramsey Creek in the north.

## 4.2 Previous Investigations

Investigations have previously been carried out at the site.

Groundwork Plus undertook test pit investigations in July 2022. Twelve test pits were excavated to a maximum depth of 3.0m. The locations are indicated on Figure 2. The previous Groundwork Plus logs are attached in Appendix B.

The pits generally encountered Alluvial and Residual soils overlying relatively shallow weathered rock, predominantly comprising siltstone. No groundwater was encountered.

Having reviewed our data library; MG have also previously investigated the site. Nine test pits were excavated in May 2022. Unfortunately, the previous logs cannot be located, however the locations are shown on Figure 2 and the generalised description of the site by the former MG Principal Engineering Geologist (Robert Cox) at the time was:

'Test pits mainly comprised topsoil to 200mm overlaying 200-300mm Sandy CLAY/Sandy CLAY (weathered shale) & overlaying extremely weathered low strength weathered shale. TP05 & TP09 had 200mm topsoil layer then 500mm layer of Sandy Clay, then into extremely weathered low strength weathered shale.' No groundwater appears to have been encountered.

# 5 FIELDWORK

To confirm the previous investigation findings, additional Fieldwork was undertaken on 24th January 2024 by a team of geo-technicians from our Rockhampton laboratory. The fieldwork was undertaken in accordance with our proposal and AS1726 Geotechnical Site Investigation.

## 5.1 Service Location

MG obtained underground services and utility plans through 'Before You Dig (BYDA)' services. No risk from buried services was indicated in our proposed investigation locations.

## 5.2 Test Pits

An excavator was used to excavate nine test pits to maximum depth of 2.2m.

On completion of each test pit the excavation and spoil was photographed. Groundwater was not encountered in any of the test pits.

Upon completion of test pitting, excavations were backfilled with the excavated spoil material. Backfilled material was compacted as much as practicable by tamping with the excavator bucket and trafficked over with the excavator tracks.

Test pit logs are presented in Appendix B. Test pit locations are indicated in Figure 2, below. Yellow pins (GW) are Groundwork Plus test pits. Blue pins (MG) are MG pits 2002. Green pins (MGR) are MG Rockhampton pits January 2024.

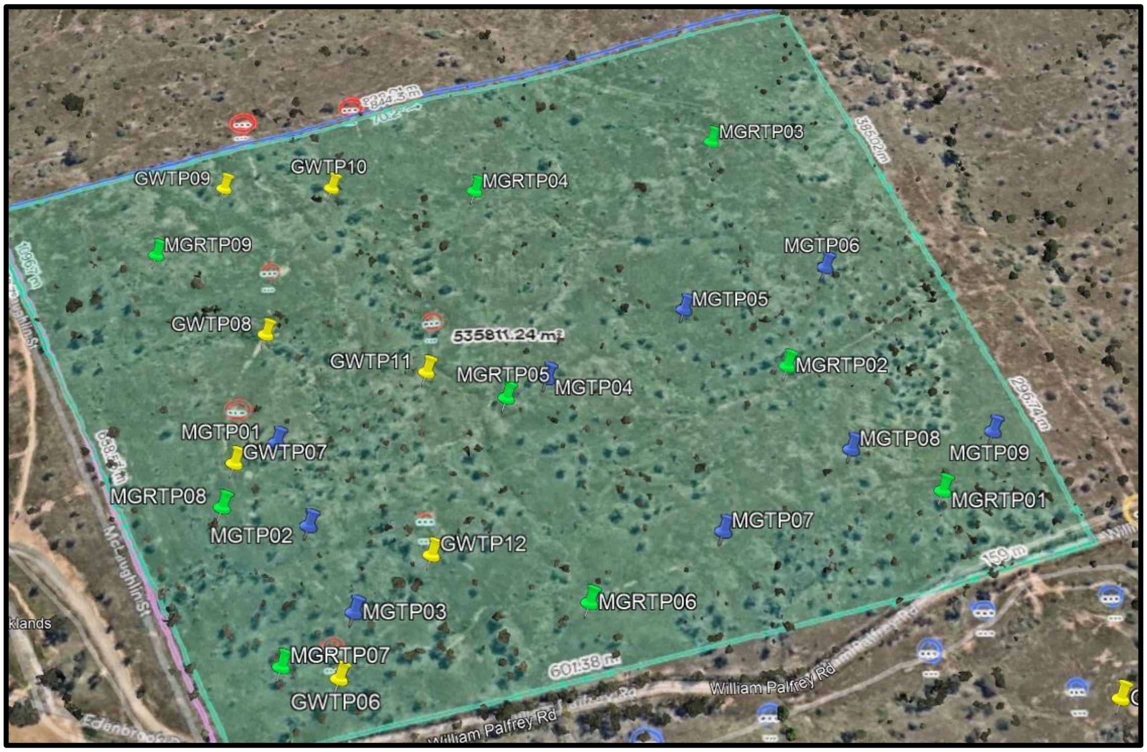


**Figure 2: Test Pit Locations**

## 5.3 Sampling

Sampling was undertaken in general accordance with AS1289 1.2.1 and based on that defined in MG's proposal. Laboratory testing will be reported separately and is not directly relevant to this current report.

# 6 EXISTING SUBSURFACE CONDITIONS

The subsurface conditions encountered in the boreholes are presented in detail in the attached borehole logs (refer Appendix B). The subsurface conditions encountered in all boreholes are broadly summarised in Table 1 below.

## 6.1 Exploratory Hole Summary

**Table 1: Summary of Ground Conditions**

| Unit | Name | Depth Range (m) | Maximum Thickness (m) | Material Description |
|---|---|---|---|---|
| 1 | Topsoil | GL - 0.20 | 0.2 | Clay with grass roots |
| 2 | Clay | Generally <1.2m but locally deeper | Not determined | Alluvial and/or Residual |
| 3 | Rock | 0.2 to >3.00 | Not determined | Generally Siltstone/Shale/Chert |

## 6.2 Groundwater

The comments on groundwater are based on the observations made at the time of the investigation. Groundwater was not encountered in any of the test pits at the time of investigation. It is possible that elevated groundwater levels may occur during wet periods.

Seasonal variation in groundwater may occur and should be considered as part of design process.

# 7 PROPOSED DEVELOPMENT

It is understood that the site is to be subdivided. Significant 'cut and fill' earthworks are proposed by the developer to form a relatively level platform.

MG has reviewed preliminary earthworks plans in the Premise report and later emails from Premise which show earthworks extending further south than indicated in the original Premise report. The approximate development platform level appears to around RL 22m, which requires cuts of up to around 12m and filling up to around 8m. Estimated volumes of 'cut to fill' of 260,000 m$^3$ and 'cut to excess' of 609,000 m$^3$ have been indicated.

MAAS have also confirmed that cut / fill batters have been limited to a maximum slope angle of 1V:3H within the development.

# 8 SLOPE STABILITY ASSESSMENT

A geotechnical landslide risk assessment has been undertaken in accordance with the risk assessment method described in Appendix C of the journal, Australian Geomechanics, Vol. 42, No. 1, dated March 2007 (attached in Appendix C of this report).

Assessment of landslide risk considers the frequency and consequences of particular failure events. The landslide risks considered herein, are those that could directly impact on the development and its occupants. The risk to property and the 'Risk to Life' and are assessed in the following sections.

## 8.1 Sign of Slope Instability

Signs of slope instability can include, but are not limited to:

- Creep-observed from tilting of trees, movement of structures including buildings, retaining walls, swimming pools and fences or by soil/rock encroaching onto roads or over drains, gutters etc.
- Hummocky disturbed ground over or at the base of the slopes.
- Tension cracks in or at the top of slopes.

No obvious signs of the above indicators of instability were observed within the proposed subdivision site at the time of walkover by our geotechnicians.

## 8.2 Failure Mechanisms

The possible landslide hazards considered applicable to the property are assessed in Table 2 below:

**Table 2: Possible Failure Mechanisms**

| Failure Type | Description of Failure Mechanism |
|---|---|
| Rotational Landslide<br>Or<br>Translational Landslide | This mode of failure is characterised by a curved or relatively flat failure surface, which would most likely be on the contact between topsoil and residual soil or within residual soils depending on groundwater conditions prevailing at the time of the failure. |
| Creep | Slow downhill movement of the landmass |

## 8.3 Potential Landslide Risks

The assessed potential slope failure types considered for this site are:

- Large-scale slope instability;
- Localised slope instability within or downslope of the site and
- Localised soil creep due to steep slopes, groundwater conditions and other factors.

## 8.4 Risk to Property

Risk is assessed initially based on the existing conditions, which locally due to some of the higher gradients could be perceived to be elevated and therefore leads to the site’s inclusion in the RRC Planning Scheme, ‘Steep Land’ overlay.

Due to the relatively shallow bedrock, MG consider that deep seated failures would be unlikely due to the rock strength and failures would likely occur as ‘translational’ failures along the soil/rock interface, particularly if saturated during intense and prolonged wet weather. Consequently MG would assess the localised instability risk to be ‘low to moderate’.

However significant earthworks are to be undertaken and the critical risk is ‘post development’ including and allowing for any mitigations and implementation.

Risk assessment for property loss was undertaken using the Risk Matrix from AGS (2007). The Risk Matrix defines qualitative terminology for likelihood, consequence and risk. The frequency estimate is expressed as an annualised probability, considering the probability of spatial impact and is expressed qualitatively as a likelihood.

The result of this assessment is summarised in the following Table 3:

**Table 3: Summary of Post Development Slope Instability Hazards**

| Hazard | Likelihood | Consequence | Risk |
|---|---|---|---|
| Large-scale slope instability | Rare | Major | Low |
| Failure of slope within and downslope of the site | Unlikely | Minor | Low |
| Localised soil creep | Possible | Insignificant | Very Low |

Table 3 above is based on an assigned Importance Level 2 structure described as low-rise residential construction in accordance with AGS, 2007. The assessed level of risk following the proposed development is based on the advice provided within this report (section 9) being implemented on the site.

Our assessment indicates ‘post development’ and having undertaken earthworks as per our recommendations (Section 9), the instability risk would be mitigated to ‘low’

## 8.5 Quantitative Risk Estimation – Loss of Life

The risk to ‘Loss of Life’ was considered for ‘post development’ landslide events detailed in section 8.3. The annual probability of loss of Life, R(LOL) following the proposed development, is assessed as follows:

$$R_{(LOL)} = P_{(H)} \text{ x } P_{(S:H)} \text{ x } P_{(S: T)} \text{ x } V_{(D: T)}$$

Where $P_{(H)}$ is the annual probability of landslide

$P_{(S:H)}$ is the probability of spatial impact which considers the potential travel distance, size of the slide and the geometry of the site.

$P_{(T:S)}$ is the temporal spatial probability which considers the time a person may be on site and the time they may occupy the part of the site impacted by the landslide.

$V_{(D:T)}$ is the vulnerability of the individual on the site.

Table 4: Summary of Risk Estimation of Annual Probability of Loss of Life

| Case | Hazard | $P_{(H)}$ | $P_{(S:H)}$ | $P_{(S:H)}$ | $V_{(D:T)}$ | $R_{(LoL)}$ |
|---|---|---|---|---|---|---|
| 1 | Large scale slope instability | $1 \times 10^{-5}$ | 0.8 | 0.5 | 0.8 | 3.2E-06 |
| 2 | Failure of slope within and down slope of the site | $1 \times 10^{-4}$ | 0.2 | 0.1 | 0.5 | 1.0E-06 |
| 3 | Localised soil creep | $1 \times 10^{-3}$ | 0.2 | 0.1 | 0.05 | 1.0E-06 |

# 9 Discussion and Recommendations

## 9.1 Summary of Landslide Risk Assessment

In summary, the risks to the properties 'post development' are assessed as 'low' while the risks against loss of life are considered to be 'acceptable' in accordance with AGS 2007 provided the proposed housing is limited to low rise building construction (two storeys).

Acceptable Risk for Loss of Property is taken as 'low' as defined in the Practice Note issued by AGS in 2007. Generally, the risk for loss of human life induced by the slope hazards was assessed to be acceptable on the 'post development' implementation of the advice given in this report. AGS suggests the individual life loss risk criteria for the person most at risk of $10^{-6}$ per annum for acceptable risk and $10^{-5}$ per annum for tolerable risk.

It should be noted that our assessment is based on 'post development' conditions and does not cover the earthworks construction period for which earthworks contractors should prepare their own risk assessments for temporary works.

## 9.2 Earthworks

The correct implementation of earthworks is critical to reducing the slope instability risk to an acceptable low level.

### 9.2.1 Site Preparation

The following scope of work is required as a minimum to prepare the site prior to filling:

- Prior to construction and placement of any fill, the proposed areas should be stripped to remove all vegetation, topsoil, uncontrolled fill, organic, root affected or other potentially deleterious material;
- Subsoil drains should be considered within any natural drainage channels proposed for filling, to allow any infiltration within the subsequent fill to escape the excavation profile.
- Where the ground slopes at more than 1V:10H (6°), the ground profile should be benched in 300mm vertical steps to create near-level platforms for filling. The platforms should be

graded with a cross fall no steeper than 2% downslope to allow drainage of any infiltration to the fill and to prevent pooling of subsurface moisture.

- Following stripping to design level, the exposed subgrade materials should be proof rolled in the presence of a suitably qualified and experienced Geotechnical Engineer to identify any wet or excessively deflecting material.
- Proof rolling should involve compacting the site with an 8-ton roller, trimming the rolled surface to level and clean finish; where there are areas indicating excessive deflection then these may require over-excavation and backfilling with an approved select material.
- Fill batters should be overfilled and then trimmed back, to allow adequate compaction of the batter finished surface.
- An earthworks specification will be required and as a minimum, compaction should achieve 95% of the standard maximum dry density.

### 9.2.2 Re-use of Site Material

Careful extraction and stockpile management will be required to optimise the potential volume of site won materials. Where feasible, material should be trucked directly to the placement site to avoid double handling and associated time and cost implications.

Screening and blending of raw materials won from the rock cuttings will be required to comply with Specification grading requirements for particular material types.

With the exception of the topsoil, the majority of the site won soil material from the cuttings is considered suitable for use as general fill material. If the material is proposed to be used as engineered fill within the permanent works then some blending of the material with coarser particle sizes may be required to comply with Specification grading requirements.

The majority of the site won material from the rock cuttings (moderately weathered rock or stronger) is likely to be suitable for use as general fill and selected material zone fill. Screening and processing of the raw material will be required to comply with earthwork specification and design requirements.

### 9.2.3 Residual Slopes

Slope angles no steeper than 1V:3H are considered appropriate for compacted embankment fill materials in the temporary and permanent conditions respectively.

Cut batters, less than 3m in height, in moderately weathered or stronger rock material can be up to 1V:2H.

Consideration must be given to any residual cut or fill batters at the boundaries of the development. In principle the subdivision site should grade to adjacent land at no steeper than 1V:3H to 1V:2H, and no higher than 3m.

Any slopes, not meeting the above specifications, will require retention.

Site filling should be undertaken to the provisions of AS3798-2007: "Earthworks for Residential and Commercial Developments". Fill for support of structures or equipment should be placed to Level 1 inspection and testing requirements as per the standard.

### 9.2.4 Storm Water Control

All storm water across the site both during construction and after development should be controlled and should not be allowed to flow over or saturate the ground as this may increase the risk of localised instability.

## 9.3 Footing Design

All topsoil must be removed prior to commencing the building footing/platform constructions.

Based on the results of the investigation and the proposed post development topography, shallow foundations would be anticipated.

Provided the earthworks are supervised appropriately, fill materials are placed in accordance with AS3798-2007 and an appropriate earthworks specification is followed, MG would anticipate the site materials to classify as an 'engineered fill' for which an allowable bearing pressure of 100kPa can be anticipated.

A geotechnical consultancy should be engaged to supervise earthworks, inspect and certify all foundation excavations to confirm the bearing strata meets the engineering design requirements.

Lot/site classification in accordance with AS2870 will be required post earthworks.

In conclusion, the site is considered suitable for the proposed development subject to undertaking the recommendations provided in this report.

## 9.4 Further Geotechnical Input

The following summarises the further geotechnical input which have been discussed in the preceding sections of this report:

- Geotechnical review of finalised earthworks drawings;
- Earthworks supervision and certification; and
- AS2870 site classification.

# 10 CONCLUSION

The findings of our report were based on our fieldwork, technical assessment and local knowledge for this site.

We trust the foregoing is sufficient for your present purposes, and if you have any questions please contact the undersigned.

Martin Williams
Principal Geotechnical Engineer
BSc MSc CPEng
RPEQ - 30303

| | |
|---|---|
| Attached: | Limitations of Geotechnical Site Investigation |
| References: | AGS 2007 |

# LIMITATIONS OF GEOTECHNICAL SERVICES

## Scope of Services

This report has been prepared for the Client in accordance with the Services Engagement Form (SEF), between the Client and Macquarie Geotechnical.

## Reliance on Data

Macquarie Geotechnical has relied upon data and other information provided by the Client and other individuals. Macquarie Geotechnical has not verified the accuracy or completeness of the data, except as otherwise stated in the report. Recommendations in the report are based on the data.

Macquarie Geotechnical will not be liable in relation to incorrect recommendations should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed.

## Geotechnical Investigation

Findings of Geotechnical Investigations are based extensively on judgment and experience. Geotechnical reports are prepared to meet the specific needs of individual clients. This report was prepared expressly for the Client and expressly for the Clients purposes.

This report is based on a subsurface investigation, which was designed for project-specific factors. Unless further geotechnical advice is obtained this report cannot be applied to an adjacent site nor can it be used when the nature of any proposed development is changed.

## Limitations of Site investigation

As a result of the limited number of sub-surface excavations or boreholes there is the possibility that variations may occur between test locations. The investigation undertaken is an estimate of the general profile of the subsurface conditions. The data derived from the investigation and laboratory testing are extrapolated across the site to form a geological model. This geological model infers the subsurface conditions and their likely behavior with regard to the proposed development.

The actual conditions at the site might differ from those inferred to exist.

No subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

## Time Dependence

This report is based on conditions, which existed at the time of subsurface exploration. Construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report.

Macquarie Geotechnical should be kept appraised of any such events, and should be consulted for further geotechnical advice if any changes are noted.

## Avoid Misinterpretation

A geotechnical engineer or engineering geologist should be retained to work with other design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issues.

No part of this report should be separated from the Final Report.

## Sub-surface Logs

Sub-surface logs are developed by geoscientific professionals based upon their interpretation of field logs and laboratory evaluation of field samples. These logs should not under any circumstances be redrawn for inclusion in any drawings.

## Geotechnical Involvement During Construction

During construction, excavation frequently exposes subsurface conditions. Geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed.

## Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendations and should make their own enquiries and obtain independent advice in relation to such matters

Macquarie Geotechnical assumes no responsibility and will not be liable to any other person or organisations for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisations arising from matters dealt with or conclusions expressed in the report.

## Other limitations

Macquarie Geotechnical will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

## Other Information

For further information reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, 1987.

# Appendix A – Geotechnical Explanatory Notes

# Geotechnical Explanatory Notes

## Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer as follows:

### UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

| USC Symbol | Description |
|---|---|
| GW | Well graded gravel |
| GP | Poorly graded gravel |
| GM | Silty gravel |
| GC | Clayey gravel |
| SW | Well graded sand |
| SP | Poorly graded sand |
| SM | Silty sand |
| SC | Clayey sand |
| ML | Silt of low plasticity |
| CL | Clay of low plasticity |
| OL | Organic soil of low plasticity |
| MH | Silt of high plasticity |
| CH | Clay of high plasticity |
| OH | Organic soil of high plasticity |
| Pt | Peaty Soil |

### MOISTURE CONDITION

Dry – Cohesive soils are friable or powdery
Cohesionless soil grains are free-running

Moist – Soil feels cool, darkened in colour
Cohesive soils can be moulded
Cohesionless soil grains tend to adhere

Wet – Cohesive soils usually weakened
Free water forms on hands when handling

For cohesive soils the following codes may also be used:

| | |
|---|---|
| MC>PL | Moisture Content greater than the Plastic Limit. |
| MC~PL | Moisture Content near the Plastic Limit. |
| MC<PL | Moisture Content less than the Plastic Limit. |

### PLASTICITY

The potential for soil to undergo change in volume with moisture change is assessed from its degree of plasticity. The classification of the degree of plasticity in terms of the Liquid Limit (LL) is as follows:

| Description of Plasticity | LL (%) |
|---|---|
| Low | <35 |
| Medium | 35 to 50 |
| High | >50 |

### COHESIVE SOILS – CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by the pocket penetrometer values and by resistance to deformation to hand moulding.

A Pocket Penetrometer may be used in the field or the laboratory to provide approximate assessment of unconfined compressive strength of cohesive soils. The values are recorded in kPa, as follows:

| Strength | Symbol | Pocket Penetrometer Reading (kPa) |
|---|---|---|
| Very Soft | VS | < 25 |
| Soft | S | 20 to 50 |
| Firm | F | 50 to 100 |
| Stiff | St | 100 to 200 |
| Very Stiff | VSt | 200 to 400 |
| Hard | H | > 400 |

## COHESIONLESS SOILS – RELATIVE DENSITY

Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

The Standard Penetration Test (SPT) is carried out in accordance with AS 1289, 6.3.1. For completed tests the number of blows required to drive the split spoon sampler 300 mm are recorded as the N value. For incomplete tests the number of blows and the penetration beyond the seating depth of 150 mm are recorded. If the 150 mm seating penetration is not achieved the number of blows to achieve the measured penetration is recorded. SPT correlations may be subject to corrections for overburden pressure and equipment type.

| Term | Symbol | Density Index | N Value (blows/0.3 m) |
|---|---|---|---|
| Very Loose | VL | 0 to 15 | 0 to 4 |
| Loose | L | 15 to 35 | 4 to 10 |
| Medium Dense | MD | 35 to 65 | 10 to 30 |
| Dense | D | 65 to 85 | 30 to 50 |
| Very Dense | VD | >85 | >50 |

## COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

| Name | Subdivision | Size |
|---|---|---|
| Boulders | | >200 mm |
| Cobbles | | 63 mm to 200 mm |
| Gravel | coarse | 19 mm to 63 mm |
| | medium | 6.7 mm to 19 mm |
| | fine | 2.36 mm to 6.7 mm |
| Sand | coarse | 600 μm to 2.36 mm |
| | medium | 210 μm to 600 μm |
| | fine | 75 μm to 210 μm |

# Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

## ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$\text{RQD (\%)} = \frac{\text{Sum of Axial lengths of core} > \text{100mm long}}{\text{total length considered}}$$

$$\text{TCR (\%)} = \frac{\text{length of core recovered}}{\text{length of core run}}$$

## ROCK STRENGTH

Rock strength is described using AS1726 and ISRM - Commission on Standardisation of Laboratory and Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials and the Point Load Index", as follows:

| **Term** | **Symbol** | **Point Load Index $Is_{(50)}$ (MPa)** |
|---|---|---|
| Very Low | VL | 0.03 to 0.1 |
| Low | L | 0.1 to 0.3 |
| Medium | M | 0.3 to 1 |
| High | H | 1 to 3 |
| Very High | VH | 3 to 10 |
| Extremely High | EH | >10 |

## ROCK MATERIAL WEATHERING

Rock weathering is described using the following abbreviation and definitions used in AS1726:

| **Abbreviation** | **Term** |
|---|---|
| RS | Residual soil |
| XW | Extremely weathered |
| DW | Distinctly weathered |
| HW | Highly weathered |
| MW | Moderately weathered |
| SW | Slightly weathered |
| FR | Fresh |

## DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

| Term | Defect Spacing | Bedding |
|---|---|---|
| Extremely closely spaced | <6 mm | Thinly Laminated |
| | 6 to 20 mm | Laminated |
| Very closely spaced | 20 to 60 mm | Very Thin |
| Closely spaced | 0.06 to 0.2 m | Thin |
| Moderately widely spaced | 0.2 to 0.6 m | Medium |
| Widely spaced | 0.6 to 2 m | Thick |
| Very widely spaced | >2 m | Very Thick |

## DEFECT DESCRIPTION

| Type: | Description |
|---|---|
| B | Bedding |
| F | Fault |
| C | Cleavage |
| J | Joint |
| S | Shear Zone |
| D | Drill break |

**Planarity/Roughness:**

| Class | Description |
|---|---|
| I | rough or irregular, stepped |
| II | smooth, stepped |
| III | slickensided, stepped |
| IV | rough or irregular, undulating |
| V | smooth, undulating |
| VI | slickensided, undulating |
| VII | rough or irregular, planar |
| VIII | smooth, planar |
| IX | slickensided, planar |

The inclination if defects are measured from perpendicular to the core axis.

## WATER

▽ Water level at date shown

◁ Partial water loss

▷ Water inflow

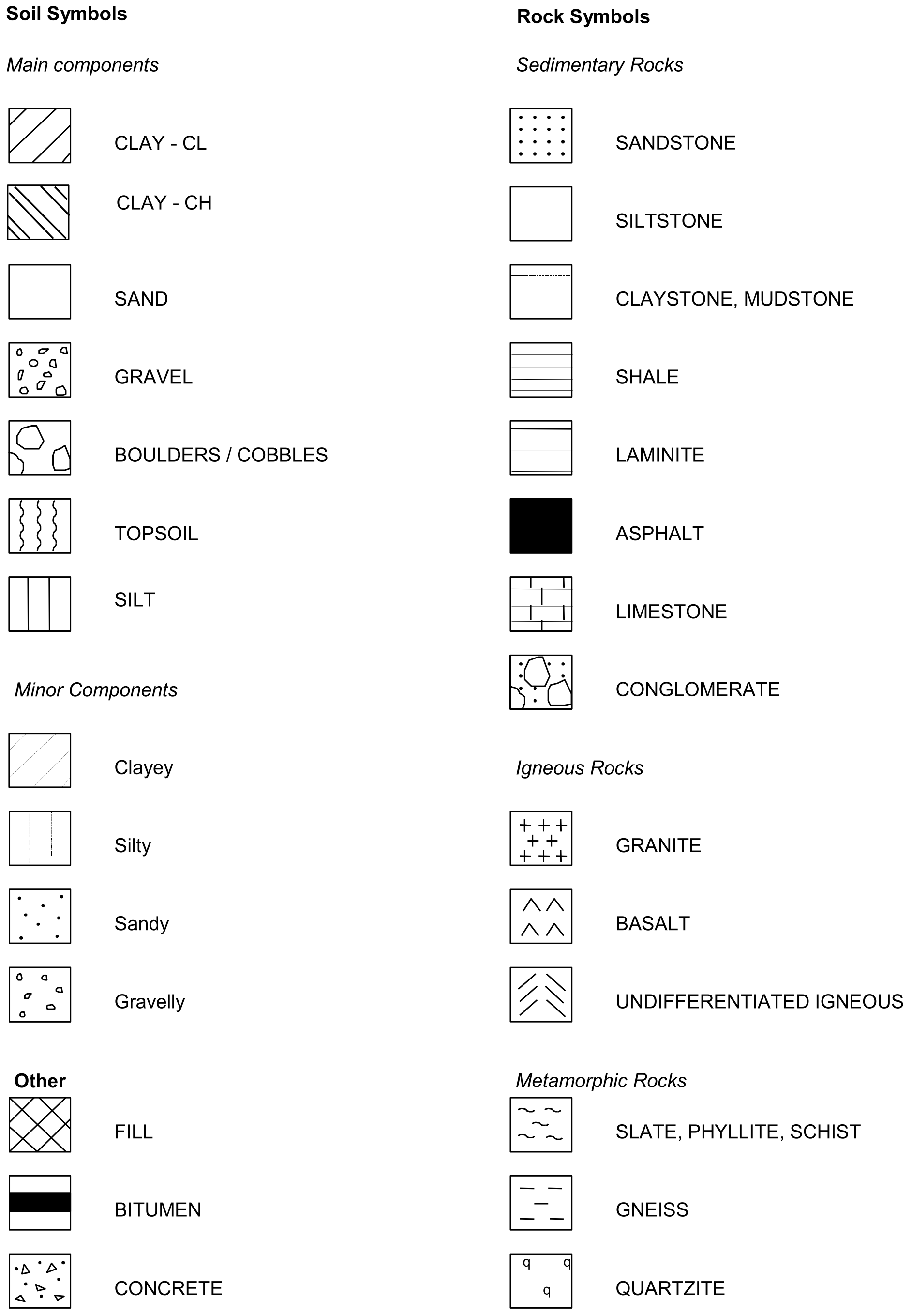
◀ Complete water loss

*Groundwater not observed:* The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

*Groundwater not encountered:* The borehole/test pit was dry soon after excavation, however groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

## Graphic Symbols for Soils and Rocks

Typical symbols for soils and rocks are as follows. Combinations of these symbols may be used to indicated mixed materials such as clayey sand.



**Soil Symbols**

*Main components*

- CLAY - CL
- CLAY - CH
- SAND
- GRAVEL
- BOULDERS / COBBLES
- TOPSOIL
- SILT

*Minor Components*

- Clayey
- Silty
- Sandy
- Gravelly

**Other**

- FILL
- BITUMEN
- CONCRETE

**Rock Symbols**

*Sedimentary Rocks*

- SANDSTONE
- SILTSTONE
- CLAYSTONE, MUDSTONE
- SHALE
- LAMINITE
- ASPHALT
- LIMESTONE
- CONGLOMERATE

*Igneous Rocks*

- GRANITE
- BASALT
- UNDIFFERENTIATED IGNEOUS

*Metamorphic Rocks*

- SLATE, PHYLLITE, SCHIST
- GNEISS
- QUARTZITE

# Engineering Classification of Shales and Sandstones in the Sydney Region – A Summary Guide

The Sydney Rock Class classification system is based on rock strength, defect spacing and allowable seams as set out below. All three factors must be satisfied.

## CLASSIFICATION FOR SANDSTONE

| Class | Uniaxial Compressive Strength (MPa) | Defect Spacing (mm) | Allowable Seams (%) |
|---|---|---|---|
| I | >24 | >600 | <1.5 |
| II | >12 | >600 | <3 |
| III | >7 | >200 | <5 |
| IV | >2 | >60 | <10 |
| V | >1 | N.A. | N.A. |

## CLASSIFICATION FOR SHALE

| Class | Uniaxial Compressive Strength (MPa) | Defect Spacing (mm) | Allowable Seams (%) |
|---|---|---|---|
| I | >16 | >600 | <2 |
| II | >7 | >200 | <4 |
| III | >2 | >60 | <8 |
| IV | >1 | >20 | <25 |
| V | >1 | N.A. | N.A. |

## UNIAXIAL COMPRESSIVE STRENGTH (UCS)

For expedience in field/construction situations the uniaxial (unconfined) compressive strength of the rock is often inferred, or assessed using the point load strength index ($Is_{50}$) test (AS 4133.4.1 – 1993). For Sydney Basin sedimentary rocks the uniaxial compressive strength is typically about 20 x ($Is_{50}$) but the multiplier may range from about 10 to 30 depending on the rock type and characteristics. In the absence of UCS tests, the assigned Sydney Rock Class classification may therefore include rock strengths outside the nominated UCS range.

## DEFECT SPACING

The terms relate to spacing of natural fractures in NMLC, NQ and HQ diamond drill cores and have the following definitions:

| Defect Spacing (mm) | Terms Used to Describe Defect Spacing[1] |
|---|---|
| >2000 | Very widely spaced |
| 600 – 2000 | Widely spaced |
| 200 – 600 | Moderately spaced |
| 60 – 200 | Closely spaced |
| 20 – 60 | Very closely spaced |
| <20 | Extremely closely spaced |

[1] After ISO/CD14689 and ISRM.

## ALLOWABLE SEAMS

Seams include clay, fragmented, highly weathered or similar zones, usually sub-parallel to the loaded surface. The limits suggested in the tables relate to a defined zone of influence. For pad footings, the zone of influence is defined as 1.5 times the least footing dimension. For socketed footings, the zone includes the length of the socket plus a further depth equal to the width of the footing. For tunnel or excavation assessment purposes the defects are assessed over a length of core of similar characteristics.

Source: Based on Pells et al (1978), as revised by Pells et al (1998).
Pells, P.J.N, Mostyn, G. and Walker, B.F. – Foundations on Sandstone and Shale in the Sydney Region. Australian Geomechanics Journal, No 33 Part 3, December 1998.

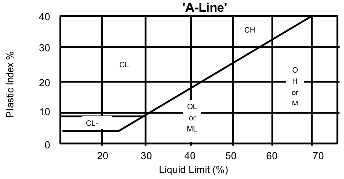
# Summary of Soil Logging Procedures

**Coarse Material:** grain size - colour - particle shape - secondary components - minor constituents - moisture condition - relative density - origin - additional observations.

**Fine Material:** plasticity - colour - secondary components - minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

## Guide to the Description, Identification and Classification of Soils

| Major Divisions | | | | SYMBOL | Typical Names |
|---|---|---|---|---|---|
| > 200mm | BOULDERS | | | | |
| 60 to 200mm | COBBLES | | | | |
| COARSE GRAINED SOILS | More than 65% by dry mass less than 63mm is greater that 0.075mm | GRAVEL | More than 50% of coarse fraction > 2.36mm | GW | Well-graded gravels, gravel-sand mixtures, little or no fines. |
| | | | | GP | Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels. |
| | | Gravelly Soils | | GM | Silty gravels, gravel-sand-silt mixtures. |
| | | | | GC | Clayey gravels, gravel-sand-clay mixtures |
| | | SANDS | More than 50% of coarse fraction < 2.36mm | SW | Well-graded sands, gravelly sands, little or no fines. |
| | | | | SP | Poorly graded sands and gravelly sands; little or no fines, uniform sands. |
| | | Sandy Soils | | SM | Silty sands, sand-silt mixtures. |
| | | | | SC | Clayey sands, sand-clay mixtures. |
| FINE GRAINED SOILS | More than 35% by dry mass less than 60mm is less than 0.076mm | Liquid Limit < 50% | | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts |
| | | | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays. |
| | | | | OL | Organic silts and organic silty clays of low plasticity. |
| | | Liquid Limit > 50% | | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts. |
| | | | | CH | Inorganic clays of high plasticity, fat clays. |
| | | | | OH | Organic clays of medium to high plasticity, organic silts. |
| HIGHLY ORGANIC SOILS | | | | Pt | Peat and other highly organic soils. |



| Grain sizes | | | |
|---|---|---|---|
| Gravel | | Sand | |
| Coarse - | 63 to 19mm | Coarse - | 2.36 to 0.6mm |
| Medium - | 19 to 6.7 mm | Medium - | 0.6 to 0.21mm |
| Fine - | 6.7 to 2.36mm | Fine - | 0.21 to 0.075mm |

**GEOLOGICAL ORIGIN:-**

**Fill** - artificial soils / deposits

**Alluvial** - soils deposited by the action of water

**Aeolian** - soils deposited by the action of wind

**Topsoil** - soils supporting plant life containing significant organic content

**Residual** - soils derived from insitu weathering of parent rock.

**Colluvial** - transported debris usually unsorted, loose and deposited

**Field Identification of Fine Grained Soils - Silt or Clay?**

**Dry Strength** - Allow the soil to dry completely and then test its strength by breaking and crumbling between the fingers. High dry strength - Clays; Very slight dry strength - Silts.

**Toughness Test** - the soil is rolled by hand into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly until it has dried sufficiently to break into lumps. In this condition inorganic clays are fairly stiff and tough while inorganic silts produce a weak and often soft thread which may be difficult to form and readily breaks and crumbles.

**Dilatancy Test** - Add sufficient water to the soil, held in the palm of the hand, to make it soft but not sticky. Shake horizontally, striking vigorously against the other hand several times. Dilatancy is indicated by the appearance of a shiny film on the surface of the soil. If the soil is then squeezed or pressed with the fingers, the surface becomes dull as the soil stiffens and eventually crumbles. These reactions are pronounced only for predominantly silt size material. Plastic clays give no reaction.

## Descriptive Terms for Material Portions

| COARSE GRAINED SOILS | | FINE GRAINED SOILS | |
|---|---|---|---|
| *% Fines* | *Term/Modifier* | *% Coarse* | *Term/Modifier* |
| ≤ 5 | Omit, or use "trace" | ≤ 15 | Omit, or use "trace" |
| > 5, ≤ 12 | "with clay/silt" as applicable | > 15, ≤ 30 | "with sand/gravel" as applicable |
| > 12 | Prefix soil as "silty/clayey" | > 30 | Prefix as "sandy/gravelly" |

## Moisture Condition

*for non-cohesive soils:*

| | |
|---|---|
| Dry - | runs freely through fingers. |
| Moist - | does not run freely but no free water visible on soil surface. |
| Wet - | free water visible on soil surface. |

*for cohesive soils:*

| | |
|---|---|
| MC > PL | Moisture content estimated to be greater than the plastic limit. |
| MC ~ PL | Moisture content estimated to be approximately equal to the plastic limit. The soil can be moulded |
| MC < PL | Moisture content estimated to be less than the plastic limit. The soil is hard and friable, or powdery. |

The plastic limit (PL) is defined as the moisture content (percentage) at which the soil crumbles when rolled into threads of 3mm dia.

## Consistency - For Clays & Silts

| *Description* | *UCS(kPa)* | *Field guide to consistency* |
|---|---|---|
| Very soft | < 25 | Exudes between the fingers when squeezed in hand |
| Soft | 25 - 50 | Can be moulded by light finger pressure |
| Firm | 50 - 100 | Can be moulded by strong finger pressure |
| Stiff | 100 - 200 | Cannot be moulded by fingers. Can be indented by thumb. |
| Very stiff | 200 - 400 | Can be indented by thumb nail |
| Hard | > 400 | Can be indented with difficulty by thumb nail |
| Friable | - | Crumbles or powders when scraped by thumbnail |

## Relative Density for Gravels and Sands

| *Description* | *SPT "N" Value* | *Density Index (ID) Range %* |
|---|---|---|
| Very loose | 0 - 4 | < 15 |
| Loose | 4 - 10 | 15 - 35 |
| Medium dense | 10 - 30 | 35 - 65 |
| Dense | 30 - 50 | 65 - 85 |
| Very dense | > 50 | > 85 |

# Summary of Rock Logging Procedures

**Description order:** constituents - rock name - grain size - colour - weathering - strength - minor constituents - additional observations.

- minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.

## Definition - Sedimentary Rock

| | |
|---|---|
| Conglomerate | more than 50% of the rock consists of gravel (>2mm) sized fragments |
| Sandstone | more than 50% of the rock consists of sand (0.06 to 2mm) sized grains |
| Siltstone | more than 50% of the rock consists of silt sized granular particles and the rock is not laminated |
| Claystone | more than 50% of the rock consists of clay or mica material and the rock is not laminated |
| Shale | more than 50% of the rock consists of clay or silt sized particles and the rock is laminated |

## Weathering

| | | |
|---|---|---|
| Residual Soil | RS | Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a change in volume but the soil has not significantly transported. |
| Extremely Weathered | EW | Rock is weathered to such an extent that it has 'soil' properties; ie. it either disintegrates or can be remoulded, in water. |
| Distinctly Weathered | DW | **Highly Weathered (HW)** - Rock is wholly discoloured and rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals<br>**Moderately Weathered (MW)** - The whole of the rock is discoloured, usually by iron staining and bleaching. Shows little or no change in rock strength. |
| Slightly Weathered | SW | Rock is slightly discoloured but shows little or no change of strength from fresh rock. |
| Fresh | FR | Rock shows no sign of decomposition or staining. |

## Stratification

| | | | |
|---|---|---|---|
| thinly laminated | <6mm | medium bedded | 0.2 - 0.6m |
| laminated | 6 - 20mm | thickly bedded | 0.6 - 2m |
| very thinly bedded | 20 - 60mm | very thickly bedded | >2m |
| thinly bedded | 60mm - 0.2m | | |

## Discontinuities

**order of description:** depth - type - orientation - spacing - roughness / planarity - thickness - coating

| | Type | Class | Roughness/Planarity | Class | Roughness/Planarity |
|---|---|---|---|---|---|
| B | Bedding | I | rough or irregular, stepped | VI | slickensided, undulating |
| F | Fault | II | smooth, stepped | VII | rough or irregular, planar |
| C | Cleavage | III | slickensided, stepped | VIII | smooth, planar |
| J | Joint | IV | rough or irregular, undulating | IX | slickensided, planar |
| S | Shear Zone | V | smooth, undulating | | |
| D | Drill break | | | | |

## Rock Strength

| Term | | Is (50) | Field Guide |
|---|---|---|---|
| | | 0.03 | |
| Very low | VL | | Material crumbles under firm blows with sharp end of pick; can be peeled with knive. Pieces up to 30mm thick can be broken by finger pressure. |
| | | 0.1 | |
| Low | L | | A piece of core 150 mm long x 50 mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling. |
| | | 0.3 | |
| Medium | M | | A piece of core 150 mm long x 50 mm dia. can be broken by hand with considerable difficulty. Readily scored with knife. |
| | | 1 | |
| High | H | | A piece of core 150 mm long x 50 mm dia. core cannot be broken by unaided hands, can be slightly scratched or scored with knife. |
| | | 3 | |
| Very High | VH | | A piece of core 150 mm long x 50 mm dia. May be broken readily with hand held hammer. Cannot be scratched with pen knife. |
| | | 10 | |
| Extremely High | EH | | A piece of core 150 mm long x 50 mm dia. Is difficult to break with hand held hammer. Rings when struck with a hammer. |

* - rock strength defined by point load strength (Is 50) in direction normal to bedding

## Degree of fracturing

| | |
|---|---|
| fragmented | The core is comprised primarily of fragments of length less than 20mm, and mostly of width less than the core diameter |
| highly fractured | Core lengths are generally less than 20mm - 40mm with occasional fragments. |
| fractured | Core lengths are mainly 30mm - 100mm with occasional shorter and longer lengths |
| slightly fractured | Core lengths are generally 300mm - 1000mm with occasional longer sections and shorter sections of 100mm -- 300mm. |
| unbroken | The core does not contain any fracture. |

# - spacing of all types of natural fractures, but not artificial breaks, in cored bores.

The fracture spacing is shown where applicable and the Rock Quality Designation is given by: RQD (%) = sum of unbroken core pieces 100 mm or longer

# Appendix B – Borehole Logs

**Table 1** – Test Pit Summary

**TP01**

**Sample No.** S-252A

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.15 | Soil | Grey Gravelly Clayey |
| 0.15 | 3 | Siltstone | Orange Brown Highly weathered. |

**Photographs**:

## TP02

**Sample No.** S-252B

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.15 | Soil | Grey Gravelly Clayey |
| 0.15 | 3 | Siltstone minor chert | Orange Brown Highly weathered. |

**Photographs**:

## TP03

**Sample No.** S-252C

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.15 | Soil | Black Brown Gravelly Clayey |
| 0.15 | 0.4 | Gravel | Orange Brown Clayey |
| 0.4 | 3 | Chert | Brown Grey Extremely Weathered |

**Photographs**:

## TP04

**Sample No.** S-252D

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.2 | Soil | Grey Gravelly Clayey |
| 0.2 | 3 | Clay | Orange Brown Highly Weathered |

**Photographs**:

## TP05

**Sample No.** S-252E

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.2 | Soil | Grey Gravelly Clayey |
| 0.2 | 0.4 | Clay | Orange Brown Gravelly |
| 0.4 | 3 | Chert | Orange Brown Extremely Weathered |

**Photographs**:

## TP06

**Sample No.** S-252F

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.3 | Clay | Red Brown Gravelly |
| 0.3 | 1 | Gabbro / Diorite | Light Brown Extremely Weathered |
| 1 | 3 | Gabbro / Diorite | Light Brown Highly Weathered |

**Photographs**:

## TP07

**Sample No.** S-252G

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.25 | Clay | Dark Grey Gravelly |
| 0.25 | 3 | Siltstone | Orange Brown, Extremely Weathered, Clayey |

**Photographs**:

## TP08

**Sample No.** S-252H

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.15 | Soil | Light Grey Gravelly Clayey |
| 0.15 | 0.5 | Chert | Extremely Weathered Gravelly Clayey |
| 0.5 | 3 | Chert | Orange Cream Highly Weathered |

**Photographs**:

## TP09

**Sample No.** S-252I

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.3 | Clay | Grey Black Gravelly |
| 0.3 | 3 | Chert / Siltstone | Orange Brown Highly Weathered |

**Photographs**:

## TP10

**Sample No.** S-252J

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.3 | Clay | Grey Brown Gravelly |
| 0.3 | 3 | Siltstone | Grey Gravelly |

**Photographs**:

## TP11

**Sample No.** S-252K

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.25 | Soil | Grey Brown Gravelly Clayey |
| 0.25 | 0.65 | Clay | Orange Brown |
| 0.65 | 3 | Siltstone | Highly Weathered |

**Photographs**:

## TP12

**Sample No.** S-252L

| Depth From (m) | Depth To (m) | Lithology | Description |
|---|---|---|---|
| 0 | 0.2 | Clay | Grey Gravelly |
| 0.2 | 0.6 | Chert | Grey Brown Highly Weathered Extremely Fractured |
| 0.6 | 3 | Chert | Orange Brown Highly Weathered Extremely Fractured Iron Stained |

**Photographs**:

PGID: TP1{LOG_001}
PUB: 24012516

MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

**PIT NO : TP1**
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

| EXCAVATION INFORMATION | | | | MATERIAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PENETRATION<br>VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION<br>Soil Type, Colour, Plasticity or Particle Characteristic<br>Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa<br>100 200 300 400 | STRUCTURE<br>& Other Observations |
| | Not Observed | B-1<br>1.20m | 0.0<br>0.5<br>1.0 | | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular.<br>1.20m | D | H | | Possibly ALLUVIAL SOIL becoming RESIDUAL SOIL |
| | | | 1.5<br>2.0<br>2.5<br>3.0<br>3.5 | | | Hole Terminated at 1.20 m<br>Target depth | | | | |

PHOTOGRAPHS
NOTES ☐

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**
VE E F H VH — No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

See Explanatory Notes for details of abbreviations & basis of descriptions.

MG 4.02 LIB_MAINBRANCH.GLB Log MG TEST PIT EXCL. DCP/RL G23920.GPJ <<DrawingFile>> 25/01/2024 16:26 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: DGDT-P 4.01.2 dpt 3.04 2018-07-02 Prj: DGDT-P 4.00.6 2017-11-25

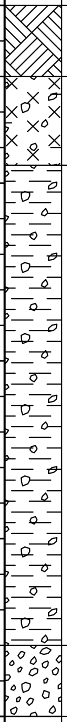
MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

**PIT NO : TP2**

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :



| EXCAVATION INFORMATION | | | | MATERIAL | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PENETRATION (VE E F H) | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa (100 200 300 400) | STRUCTURE & Other Observations |
| | Not Observed | | 0.0 – 0.20m | NA | TOPSOIL CLAY: medium plasticity. | NA | NA | | TOPSOIL |
| | | | 0.20m – 0.45m | ML | Clayey Gravelly SILT: low plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | D | H | | ALLUVIAL SOIL |
| | | 0.50m B-1 | 0.45m – 1.80m | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | | | | ALLUVIAL SOIL becoming RESIDUAL SOIL |
| | | 1.80m | 1.80m – 2.00m | GP | Clayey GRAVEL: fine to coarse grained, sub-angular, dark brown. | | VD | | RESIDUAL SOIL |
| | | | 2.00m | | Hole Terminated at 2.00 m<br>Target depth | | | | |

DEPTH (M): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PHOTOGRAPHS NOTES ☐

**METHOD**
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper

**SUPPORT**
- T Timbering

**PENETRATION**
VE E F H VH — No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

**SAMPLES & FIELD TESTS**
- U - Undisturbed Sample
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- MC - Moisture Content
- PP - Pocket Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
- D - Dry
- M - Moist
- W - Wet

**CONSISTENCY/ RELATIVE DENSITY**
- VS - Very Soft
- S - Soft
- F - Firm
- St - Stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

See Explanatory Notes for details of abbreviations & basis of descriptions.

PGID: TP3{LOG_001}
PUB: 24012516

MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

PIT NO : TP3
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

| EXCAVATION INFORMATION | | | | MATERIAL | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
| | Not Observed | | 0.0 – 0.25m | NA | TOPSOIL Clayey GRAVEL: fine to coarse grained, sub-rounded to sub-angular, brown. | | | | TOPSOIL |
| | | | 0.25m – 0.60m | CI | CLAY: medium plasticity, brown. | | | | ALLUVIAL SOIL |
| | | 0.60m<br>B-1<br>2.20m | 0.60m – 2.20m | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded. | | | | ALLUVIAL SOIL possibly RESIDUAL SOIL |
| | | | 2.20m | | Hole Terminated at 2.20 m<br>Target depth | | | | |

DEPTH (M): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PHOTOGRAPHS ☐
NOTES

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**
VE E F H VH — No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

See Explanatory Notes for details of abbreviations & basis of descriptions.

MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

**PIT NO :** **TP4**
FILE / JOB NO : G23920
SHEET : 1 OF 1

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

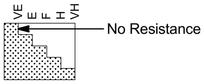
| EXCAVATION INFORMATION | | | | MATERIAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | CLASSIFICATION SYMBOL | | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
| | Not Observed | | 0.0 | NA | 0.20m | TOPSOIL SILT: low plasticity, brown. | | | | TOPSOIL |
| | | | | CI | 0.60m | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | | | | ALLUVIAL SOIL |
| | | | 0.5<br>1.0<br>1.5 | CI | 1.60m | Gravelly CLAY: shale, medium plasticity, brown; gravel fine to coarse, sub-rounded. | | | | ALLUVIAL SOIL possibly RESIDUAL SOIL |
| | | | 2.0<br>2.5<br>3.0<br>3.5 | | | Hole Terminated at 1.60 m<br>Target depth | | | | |

PHOTOGRAPHS
NOTES ☐

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**



**WATER**
10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

PGID: TP5{LOG_001}
PUB: 24012516

MACQUARIE GEOTECH

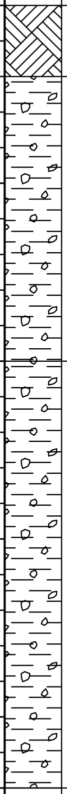
# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

**PIT NO : TP5**
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

EXCAVATION INFORMATION | MATERIAL



| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
|---|---|---|---|---|---|---|---|---|---|
| | Not Observed | | 0.0–0.20m | NA | TOPSOIL SILT: low plasticity, brown. | NA | NA | | TOPSOIL |
| | | | 0.20m–1.00m | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | D | H | | ALLUVIAL SOIL |
| | | | 1.00m–2.20m | CI | Gravelly CLAY: shale, medium plasticity, red-brown; gravel fine to coarse, sub-rounded. | | | | RESIDUAL SOIL |
| | | | 2.20m | | Hole Terminated at 2.20 m<br>Target depth | | | | |

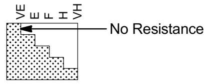
0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PHOTOGRAPHS ☐
NOTES

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**



**WATER**
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

MG 4.02 LIB_MAINBRANCH.GLB Log MG TEST PIT EXCL. DCP/RL G23920.GPJ <<DrawingFile>> 25/01/2024 16:26 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: DGDT-P 4.01.2 dpt 3.04 2018-07-02 Prj: DGDT-P 4.00.6 2017-11-25

PGID: TP6{LOG_001}
PUB: 24012516

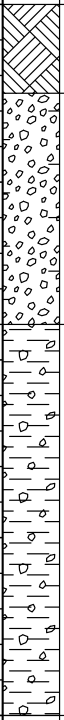
MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

**PIT NO : TP6**
FILE / JOB NO : G23920
SHEET : 1 OF 1

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

| EXCAVATION INFORMATION | | | | MATERIAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
| | Not Observed | | 0.0 |  | NA | TOPSOIL SILT: brown. | NA | | | TOPSOIL |
| | | | 0.25m | | GP | Clayey GRAVEL: fine to coarse grained, sub-rounded to sub-angular, granite, brown. | D | | | ALLUVIAL SOIL possibly RESIDUAL SOIL |
| | | 0.95m B-1 | 0.90m | | CL | Clayey CLAY: medium plasticity, red-brown; clay fine to coarse, sub-rounded. | | | | RESIDUAL SOIL |
| | | 2.00m | 2.00m | | | Hole Terminated at 2.00 m<br>Target depth | | | | |

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PHOTOGRAPHS
NOTES ☐

**METHOD**

| | |
|---|---|
| N | Natural Exposure |
| X | Existing Excavation |
| BH | Backhoe Bucket |
| B | Bulldozer Blade |
| R | Ripper |

**SUPPORT**

| | |
|---|---|
| T | Timbering |

**PENETRATION**

VE E F H VH — No Resistance

**WATER**

10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow

**SAMPLES & FIELD TESTS**

| | |
|---|---|
| U | - Undisturbed Sample |
| D | - Disturbed Sample |
| B | - Bulk Disturbed Sample |
| MC | - Moisture Content |
| PP | - Pocket Penetrometer (UCS kPa) |
| VS | - Vane Shear; P-Peak, R-Remouded (uncorrected kPa) |
| PBT | - Plate Bearing Test |

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**

| | |
|---|---|
| D | - Dry |
| M | - Moist |
| W | - Wet |

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

PGID: TP7{LOG_001}
PUB: 24012516

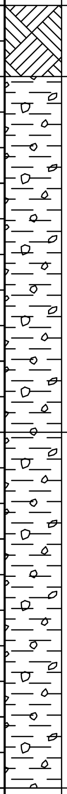
**MACQUARIE GEOTECH**

# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

**PIT NO : TP7**
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :



| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
|---|---|---|---|---|---|---|---|---|---|
|  | Not Observed |  | 0.0–0.20m | NA | TOPSOIL SILT: low plasticity, brown. | NA | NA |  | TOPSOIL |
|  |  | 0.20m<br>B-1<br>2.20m | 0.20m–1.20m | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | D | H |  | ALLUVIAL SOIL |
|  |  |  | 1.20m–2.20m | CI | Gravelly CLAY: medium plasticity, red-brown; gravel fine to coarse, sub-rounded. |  |  |  | ALLUVIAL SOIL possibly RESIDUAL SOIL |
|  |  |  | 2.20m |  | Hole Terminated at 2.20 m<br>Target depth |  |  |  |  |

Depth scale: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PHOTOGRAPHS
NOTES ☐

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**
VE E F H VH
No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

MG 4.02 LIB_MAINBRANCH.GLB Log MG TEST PIT EXCL. DCP/RL G23920.GPJ <<DrawingFile>> 25/01/2024 16:26 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: DGDT-P 4.01.2 dpt 3.04 2018-07-02 Prj: DGDT-P 4.00.6 2017-11-25

MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

**PIT NO : TP8**
FILE / JOB NO : G23920
SHEET : 1 OF 1

| | |
|---|---|
| POSITION : | SURFACE ELEVATION : |
| EQUIPMENT TYPE : Excavator | METHOD : refer excavation information column |
| DATE EXCAVATED : 24/01/2024 | LOGGED BY : J Hamilton    CHECKED BY : |

| EXCAVATION INFORMATION | | | | MATERIAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
| | Not Observed | | 0.0 | | NA | TOPSOIL SILT: brown. (0.10m) | NA | NA | | TOPSOIL |
| | | 0.20m B-1 | | | CI | Gravelly CLAY: medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. (0.40m) | | | | ALLUVIAL SOIL |
| | | | 0.5 | | CI | Gravelly CLAY: medium plasticity, red-brown; gravel fine to coarse, sub-rounded to sub-angular. (0.80m) | | | | ALLUVIAL SOIL possibly RESIDUAL SOIL |
| | | | 1.0<br>1.5 | | CI | Gravelly CLAY: medium plasticity, red-brown; gravel fine to coarse, sub-rounded. (2.00m) | H | H | | RESIDUAL SOIL |
| | | 2.00m | 2.0<br>2.5<br>3.0<br>3.5 | | | Hole Terminated at 2.00 m<br>Target depth | | | | |

PHOTOGRAPHS
NOTES ☐

**METHOD**
N Natural Exposure
X Existing Excavation
BH Backhoe Bucket
B Bulldozer Blade
R Ripper

**SUPPORT**
T Timbering

**PENETRATION**
VE E F H VH
No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
water inflow
water outflow

**SAMPLES & FIELD TESTS**
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
D - Dry
M - Moist
W - Wet

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

MACQUARIE GEOTECH

# EXCAVATION - GEOLOGICAL LOG

CLIENT : Premise
LOCATION : Ellida Estate
PROJECT : Ellida Estate GI

**PIT NO : TP9**
FILE / JOB NO : G23920
SHEET : 1 OF 1

POSITION :
SURFACE ELEVATION :
EQUIPMENT TYPE : Excavator
METHOD : refer excavation information column
DATE EXCAVATED : 24/01/2024
LOGGED BY : J Hamilton
CHECKED BY :

| EXCAVATION INFORMATION | | | | MATERIAL | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| PENETRATION VE E F H | GROUND WATER LEVELS | SAMPLES & FIELD TESTS | DEPTH (M) | GRAPHIC LOG | CLASSIFICATION SYMBOL | MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components | MOISTURE CONDITION | CONSISTENCY RELATIVE DENSITY | POCKET PENETRO-METER kPa 100 200 300 400 | STRUCTURE & Other Observations |
| | | | 0.0 | | NA | TOPSOIL SILT: brown. | NA | NA | | TOPSOIL |
| | Not Observed | 0.20m<br>B-1 | | | | 0.20m<br>Gravelly CLAY: shale, medium plasticity, brown; gravel fine to coarse, sub-rounded to sub-angular. | | | | ALLUVIAL SOIL possibly RESIDUAL SOIL |
| | | | 0.5 | | | | | | | |
| | | | | | CI | | D | H | | |
| | | | 1.0 | | | | | | | |
| | | | 1.5 | | | | | | | |
| | | 1.60m | | | | 1.60m<br>Hole Terminated at 1.60 m<br>Target depth | | | | |
| | | | 2.0 | | | | | | | |
| | | | 2.5 | | | | | | | |
| | | | 3.0 | | | | | | | |
| | | | 3.5 | | | | | | | |

PHOTOGRAPHS
NOTES ☐

**METHOD**
- N Natural Exposure
- X Existing Excavation
- BH Backhoe Bucket
- B Bulldozer Blade
- R Ripper

**SUPPORT**
- T Timbering

**PENETRATION**
VE E F H VH
No Resistance

**WATER**
10 Oct., 73 Water Level on Date shown
▶ water inflow
◀ water outflow

**SAMPLES & FIELD TESTS**
- U - Undisturbed Sample
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- MC - Moisture Content
- PP - Pocket Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
- PBT - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**
Based on Unified Classification System

**MOISTURE**
- D - Dry
- M - Moist
- W - Wet

**CONSISTENCY/ RELATIVE DENSITY**

| | |
|---|---|
| VS | - Very Soft |
| S | - Soft |
| F | - Firm |
| St | - Stiff |
| VSt | - Very Stiff |
| H | - Hard |
| VL | - Very Loose |
| L | - Loose |
| MD | - Medium Dense |
| D | - Dense |
| VD | - Very Dense |

See Explanatory Notes for details of abbreviations & basis of descriptions.

# Appendix C – AGS 2007

Australian
Geomechanics
Society

Extract from

# Australian Geomechanics

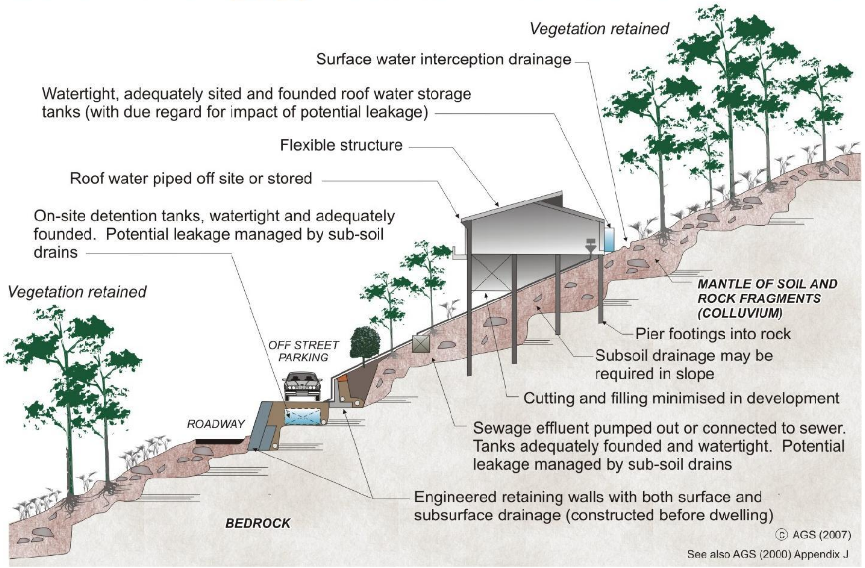
Journal and News of the Australian Geomechanics Society
Volume 42 No 1 March 2007

Extract containing:

## "Practice Note Guidelines for Landslide Risk Management 2007"

Ref: AGS (2007c)

EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



## Landslide Risk Management

ENGINEERS AUSTRALIA

AusIMM
AUSTRALASIAN INSTITUTE OF MINING & METALLURGY

ISSN 0818-9110

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

**Australian Geomechanics Society Landslide Taskforce,**

**Landslide Practice Note Working Group**

## TABLE OF CONTENTS

**PART A: BACKGROUND** ........ **64**
**1** INTRODUCTION........ **64**
**2** RISK TERMINOLOGY ........ **65**
**PART B GUIDELINES FOR REGULATORS** ........ **66**
**3** GUIDELINES FOR REGULATORS ........ **66**
**PART C GUIDELINES FOR PRACTITIONERS** ........ **69**
**4** SCOPE DEFINITION........ **69**
**5** HAZARD ANALYSIS ........ **69**
**6** CONSEQUENCE ANALYSIS ........ **74**
**7** RISK ESTIMATION ........ **75**
**8** RISK ASSESSMENT ........ **77**
**9** RISK MANAGEMENT........ **78**
**10** REPORTING STANDARDS ........ **81**
**11** SPECIAL CHALLENGES ........ **81**
**12** ACKNOWLEDGEMENTS ........ **82**
**13** REFERENCES........ **83**
APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK........ **84**
APPENDIX B - LANDSLIDE TERMINOLOGY ........ **87**
APPENDIX C - QUALITATIVE TERMINOLOGY........ **91**
APPENDIX D -EXAMPLE FORMS ........ **93**
APPENDIX E - GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING SYMBOLS........ **110**
APPENDIX F- EXAMPLE OF VULNERABILITY VALUES........ **112**
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION........ **113**

# PART A: BACKGROUND

## 1 INTRODUCTION

### 1.1 PREAMBLE

Slope instability occurs in many parts of urban and rural Australia and often impacts on housing, roads, railways and other development. This has been recognised by many local government authorities, and others, and has led to the requirement by many local government councils for stability assessments prior to allowing building development.

In 2000, the Australian Geomechanics Society (AGS) published "Landslide Risk Management Concepts and Guidelines" (AGS 2000). Since then there have been many published papers and discussion which have progressed Landslide Risk Management (LRM) in particular and risk management in general. As a consequence, AGS considered it appropriate to develop more comprehensive guidelines for practitioners and regulators involved in LRM.

This Practice Note Guidelines for Landslide Risk Management (the Practice Note) and its Commentary (AGS 2007d) are one part of a series of three guidelines related to LRM that have been prepared by AGS with funding under the National Disaster Mitigation Programme (NDMP). That programme has been introduced by the Australian Government to fund disaster mitigation, addressing hazards such as flooding, bushfires and landslides.

The associated guidelines which should be read in conjunction with the Practice Note are:-

- AGS (2007a) *"Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning".*
- AGS (2007e) *"Australian GeoGuides for Slope Management and Maintenance".*

### 1.2 PURPOSE

The purpose of this Practice Note is to:

1. Review the Australian Geomechanics Society (AGS) Landslide Risk Management Concepts and Guidelines (AGS 2000) in the light of usage since publication and update accordingly and in addition, to take the opportunity to establish a formal revision process/documentation. Accordingly, a Revision Table is included in the Practice Note.

2. Provide guidance and recommendations on tolerable risk criteria, minimum reporting standards and assessment criteria/options to Local Government and Government bodies who as the regulator, receive Landslide Risk Management (LRM) reports and decide on levels of Tolerable Risk.

3. Provide guidance of a technical nature in relation to the processes and tasks undertaken by geotechnical practitioners who prepare LRM reports including appropriate methods and techniques. The Practice Note is a statement of what constitutes good practice by a competent practitioner for LRM, including defensible and up to date methodologies.

4. Provide guidance on the quality of assessment and reporting, including the outcomes to be achieved and how they are to be achieved. It sets out the functions and responsibilities of the professional carrying out the assessment.

5. Be a reference document for legislative purposes, which has been subject to nation-wide peer review.

### 1.3 SCOPE

This Practice Note supersedes AGS (2000) as the guideline for good practice and is accompanied by a Commentary (AGS 2007d) which discusses various aspects and gives appropriate references, and which should be read in conjunction with this Practice Note.

AGS (2000) contains much useful and relevant commentary which can (and should) be read in conjunction with the Practice Note. It is not the intention of the Practice Note to supersede this valuable commentary, rather to complement it. AGS (2000) should be regarded as "companion literature". Unless specifically discussed or revised in the Practice Note, the Working Group considers the commentary, examples and references provided in AGS (2000) to constitute appropriate background for the use of the Practice Note.

The emphasis of the Practice Note is on residential subdivision and development, particularly when considering the requirements for assessment on a lot-by-lot basis for either existing or proposed development.

The recommendations are however applicable to all classes of urban and rural building development or the environment.

The risk analysis principles could be adopted for short term risks associated with trenches or excavations during construction projects and for quarries and open cut mines. For such cases, risk tolerance criteria are controlled by occupational health and safety requirements and are not covered here.

The Practice Note can be applied to roads and railways. However, special consideration has to be given to the number of users, their temporal spatial probability and the summation of the risk along the route. This is discussed further in the Commentary.

### 1.4 CONVENTIONS USED

The Practice Note includes imperative verbs, such as 'establish', 'use', 'identify' and so on. These are to be understood as meaning; *"AGS recommends that you establish…"*, or *"…that you use…."* or *"…that you identify….."* and so on as the case may be. This form of expression has been used to avoid unnecessary repetition of wording in the sense of 'plain English'.

Paragraphs presented in **bold type** constitute the guideline statement and subsequent sub paragraphs provide discussion of the guideline topic. Further discussion is provided in the Commentary.

In the following, use of the word 'landslide' implies both existing (or known landslides) and potential landslides which a practitioner might reasonably predict based on the relevant geology, geometry and slope forming processes. Such potential landslides may be of varying likelihood of occurrence. 'Landslide' also includes 'landslip' (as used in Victorian legislation), 'slump' and the various landslide forms (see Appendix B).

### 1.5 STAKEHOLDERS

The various stakeholders who may be affected by landslide risk include:-

- The **landowner** who will frequently be the client in terms of a commission to prepare a LRM report for a site or a development proposal.
- The **occupier** who would most often also be the land owner.
- The **financier** who would often be a financial institution having an interest in the land and any development thereon.
- The **regulator** (Appendix A) who would have responsibility for setting risk acceptance criteria, administering planning controls and approving development proposals as being within the requirements of planning controls, or a policy.
- The **practitioner** (Appendix A) who would have the required expertise for and responsibility of preparing a LRM report and recommending suitable risk control measures, when needed, to achieve the risk acceptance criteria.
- The **design professional** (such as architect or structural engineer) who would be one of the advisors to the client with responsibility for integration of risk control measures recommended by the practitioner into the development scheme, where possible, within the design brief from the client.
- The **insurer** where appropriate may have an interest in providing insurance cover against nominated insurable risks.

Although there is no section in the Practice Note dealing with the Client, clearly the Client is an essential stakeholder in relation to the practitioner. The Client will be relying on unbiased, sound technical advice from the practitioner as to the risk that a development proposal poses to the client and /or his interests. It will be the responsibility of the client to accept the risks involved, subject to the approvals of the regulator.

## 2 RISK TERMINOLOGY

**The framework for the LRM process, as shown in Figure 1 in a simplified flow chart form, should be adopted.**

**Adopt the recommended terminology for ease of communication and clarity as defined in Appendix A.**

As with most areas of expertise, there is a technical jargon associated with LRM. Specialist terminology is used to convey succinct ideas or facts. This cannot be avoided and by necessity is of a technical nature. The relevant terminology is defined in Appendix A. The lay reader is also referred to the Commentary for further discussion and to the GeoGuides (AGS 2007e).

This Practice Note, and the companion AGS guidelines (AGS 2007a, 2007e), use the term 'landslide' rather than 'landslip' or 'slump' or similar, to cover a wide range of failure mechanisms in soil, rock (as discussed in Appendix B) and man made structures such as retaining walls, as implied by the definition in Appendix A.

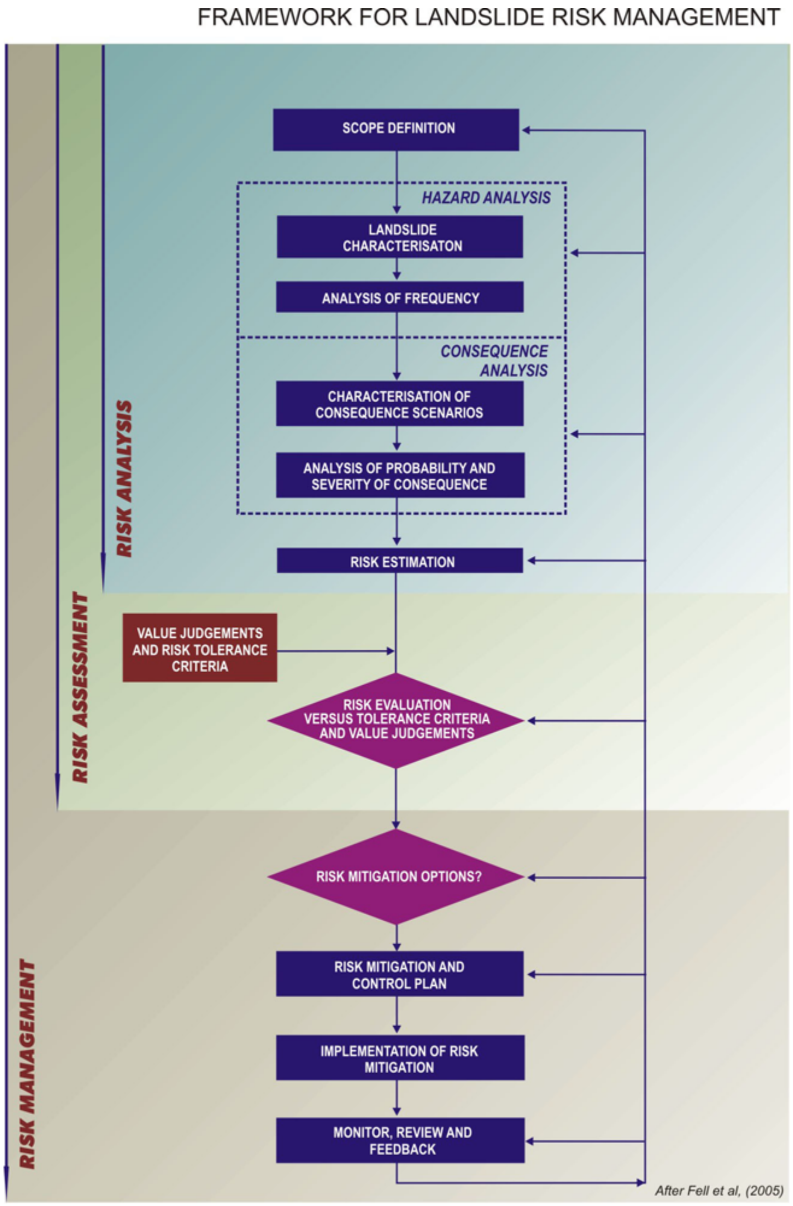


Figure 1.

The Framework for LRM presented in Figure 1 is similar to the flow chart in AGS (2000). However, it has been simplified in presentation and has been amended slightly from AGS (2000) to reflect the inclusion of Frequency Analysis as part of Hazard Analysis (in accordance with the abovementioned definition of hazard and as defined in AGS 2000).

Definitions for associated terminology have also been included in Appendix A together with an explanation of Landslide Risk as presented in AGS Australian GeoGuide LR7.

# PART B GUIDELINES FOR REGULATORS

## 3 GUIDELINES FOR REGULATORS

### 3.1 BACKGROUND

The term landslide denotes *"the movement of a mass of rock, debris or earth down a slope"*. The phenomena described as landslides are not limited to either "land" or to "sliding" and usage of the word has implied a much more extensive meaning than its component parts suggest. The rates of movement cover the full range from very rapid to extremely slow. The size, similarly, can vary enormously. The combination of type of landslide, size and rate of movement can determine the destructive power, and hence potential consequences of the landslide in terms of damage to property, loss of life, economic costs and impact on the environment. Subsidence, as a mechanism, is excluded from consideration, though it may be similar in consequence and appear to be of a similar form. Appendix B presents a summary of the terminology used to classify and describe landslides.

Landslides can impact on human development and activity as well as natural areas / features. It is the potential impact on human development which becomes of concern to the planners, regulators and disaster management authorities. Landslides can be just one of a number of threats which have to be considered, others being for example flooding, bush fires, and seismicity.

Examples of where landsliding is potentially an issue include:-

a) Where there is a history of landsliding.
b) Where there is no history of sliding but the topography dictates sliding may occur.
c) When there is no history of landslides but geological and geo-morphological conditions are such that sliding is possible.
d) Where there are constructed features which, if they fail, may travel rapidly.
e) Forestry works and agricultural land clearing which can lead to landslides causing damage to the environment.

Specific examples of the above are given in the AGS Guidelines for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning (AGS 2007a). AGS (2007a) also provides detailed guidance to the regulator in relation to landslide zoning for planning purposes.

### 3.2 RELEVANCE TO APPROVALS PROCESS

Details of the approvals process may vary in detail from state to state. It is understood that in all States and Territories of Australia, the regulator has a statutory responsibility to consider the impact of a number of hazards, including landslides, on potential development of land as a ‘duty of care’ exercise. The regulator is usually the local government, but may be a State Government department or body. The actual mechanism and regulatory context for dealing with planning controls, building controls and approval process varies from state to state. However, the outcome should be that areas having a landslide risk are properly considered in relation to land use and development proposals.

In order to develop planning controls and building regulations, local government (or other regulators) must ensure that it has the statutory means to:

a) Through a planning scheme and using the principles in AGS (2007a), identify the areas that are susceptible to or at risk from landslides.
b) Require planning and/or building approvals for all land use and development within the areas zoned as susceptible to landslides.
c) Ensure there is a proper process for assessment in relation to existing and proposed development, including the requirement for completion of LRM reports in accordance with this Practice Note.
d) Provide appropriate risk tolerance criteria for loss of life and property so that there is a means to determine whether it is appropriate for development to occur or the required land use to proceed.
e) Apply, if necessary, consent conditions on the land use and/or development approval, including conditions requiring maintenance that will appropriately manage the landslide risk for that use and/or development.

It can be seen from the above that zoning in accordance with AGS (2007a) becomes the ‘initiator’ under the planning scheme and building approvals process to determine whether LRM controls are required and whether more detailed LRM consideration is required.

### 3.3 POLICY REQUIREMENTS

**The regulator should have a specific policy which sets out the requirements for LRM assessments as part of the development application documentation and process**.

The need for such a policy should be determined by zoning studies in accordance with AGS (2007a). Essential components of such a policy will include:

**3.3.1** **When a LRM assessment is required.** This may be related to a Susceptibility or Hazard Zoning Study or some other plan or criteria defining areas or types of development included or excluded.

**3.3.2** **The necessary competencies of practitioners undertaking LRM assessments**. **Such practitioners should be required to have LRM as a core competency.** A method of demonstrating core competency in LRM is being addressed by the Australian Geomechanics Society and Engineers Australia as a specific area of practice within the National Professional Engineers Register (NPER). Some regulators may choose to define another method of demonstrating competency.

**3.3.3** **The basic requirements of LRM reports** which should be based on compliance with the requirements of this Practice Note.

3.3.4 **Require assessment of risk to life as part of a LRM report** which, as discussed below, should be completed in a quantitative basis.

3.3.5 **Suggest adoption of the preferred qualitative terminology given in Appendix C of this Practice Note for risk to property** so that the regulator can become accustomed to the terminology adopted and implications arising there from. If alternative terminology is to be adopted for LRM, the regulator should only accept non standard schemes where the terms have been clearly defined, the terms have been explained in relation to the preferred terminology and it can be reasonably demonstrated by the practitioner that the alternative is better suited to the particular circumstances of the assessment.

3.3.6 **Provide the required forms** to control the submissions and approvals process.

3.3.7 **Specify the criteria under which a decision will be made for both the scope/nature of developments and the appropriate tolerable risk criteria being adopted.**

## 3.4 PROCESSING REQUIREMENTS

### 3.4.1 The regulator should use a number of forms to provide appropriate QA process control and documentation records of the submitted LRM assessment and subsequent compliance with the approval conditions.

The forms need to be appropriate to each stage of the development application, approval, detailed design, construction and maintenance of the development. Essential contents will include:

1. Name and qualification of the practitioner responsible for the LRM assessment.
2. A list of supporting documents including the architectural, civil design and structural engineering design drawings, as appropriate, to fully define the extent and scope of the proposed development.
3. A statement of compliance with the requirements of this Practice Note. In some cases the statements will be required to include details of how compliance is achieved.
4. Document reference details (date, reference number, report title) for the relevant LRM assessment submission.

A suite of example forms is given in Appendix D for modification by each regulator to be consistent with their policy. The aim of the forms is to provide appropriate documentary control of the stages required through to completion of a development.

Processing of the application by the regulator should include, amongst other aspects, confirmation that the submission is in accordance with policy requirements, and that the nature of the development complies with the requirements of the LRM assessment.

Where the regulator has specific concerns in relation to the adequacy of a submission, or the conclusions reached, or if required by a Hazard Zoning study, the submission may be subject to peer review or independent specialist advice to the regulator as an audit process or as part of mediation for an agreement. The reviewer should independently review the LRM assessment report in terms of adequacy of compliance with this Practice Note and the reasonableness of the assessment conclusions and risk control measures specified. The review should also consider the specific development proposals as defined by the design drawings.

### 3.4.2 Where the recommendations of this Practice Note have not been followed, then the regulator should <u>either</u> reject the application <u>or</u> require provision of further information before approval is given.

It is anticipated that the forms in Appendix D will, in part, constitute a checking template for the regulator. Further discussion is given in the Commentary.

### 3.4.3 Where construction is completed but all aspects of the Approval Conditions have not been completed with appropriate documentation or justification, then the final approval by the regulator should not be given until sufficient information is provided to demonstrate compliance.

It is anticipated that completion of Forms F and G with suitable annotation would help identify where non compliance exists. If the regulator does not have a strong procedure for enforcement of, or auditing of, compliance with consent conditions, then there may be subsequent liability issues for the regulator if non-compliance becomes an issue at a later date.

## 3.5 ESTABLISHMENT OF TOLERABLE RISK CRITERIA

**The regulator is responsible for setting the Tolerable Risk Criteria for loss of life and property loss. Discussion of the considerations and world practice are given in the Commentary together with the AGS recommendation for consideration by the regulator.**

## 3.6 LANDSLIDE INVENTORY

**The local Council, or other regulator, should maintain an inventory of past landslide events as discussed in AGS (2007a) and make this information available to all practitioners.**

### 3.7 ROLE AND RESPONSIBILITY OF THE PRACTITIONER

**The practitioner has the role of providing technical input in relation to the specialized aspect of LRM.** Such input will be subject to the specific requirements of any policy instituted by the regulator. The regulator may require specific levels of qualification and competence of practitioners providing the regulator with advice in relation to compliance with the risk acceptance criteria.

The qualifications and experience of suitable practitioners are as discussed in Paragraph 3.3.2.

It is the responsibility of the practitioner to carry out LRM assessments in accordance with this Practice Note and within the requirements of his/her professional Code of Ethics. The practitioner must provide advice to the client and regulator in an unbiased manner.

# PART C GUIDELINES FOR PRACTITIONERS

## 4 SCOPE DEFINITION

**Establish the purpose and scope of the risk assessment study.**

The practitioner needs to take into account the initial brief from the client and the requirements of the regulator. Usually these will be sufficient for the practitioner to decide on the appropriate scope and level of the study which should then be advised to the client as a “reverse brief”. In the LRM process, the practitioner will have a role to advise the client as to how the landslide risk can be reduced, avoided or otherwise controlled including options or alternatives.

## 5 HAZARD ANALYSIS

### 5.1 DATA GATHERING / DESK STUDY

**Assemble relevant data and record their sources.**

Often there is a body of local experience which becomes invaluable for the assessment process. Such experience includes published papers, geological maps, aerial photographs and general studies such as Hazard Zoning studies completed for the regulator. Local experience can include previous assessments and knowledge of problematic areas which should be available from the regulator’s landslide inventory. Practitioners new to an area should discuss with locals their knowledge and experience.

Preferred data for the assessment will include site specific data, such as survey plan showing existing features, spot heights, contours and location and nature of services. Initial design proposals are required so that the risk assessment may be completed and appropriate risk control measures specified. (It is a necessary requirement in the performance of a risk assessment for there to be an element at risk, hence the need for a preliminary design or for an assumed development which should be defined in the LRM report).

### 5.2 FIELD INVESTIGATION REQUIREMENTS

#### 5.2.1 Complete investigations sufficient to establish a geotechnical model, identify geomorphic processes and associated process rates.

The investigation may involve a number of methods and may be completed in stages, with each stage sufficiently detailed to provide a model appropriate to the level of study being undertaken. Further discussion is given in the Commentary.

#### 5.2.2 Inspect the site and surrounds including field mapping of the geomorphic features.

This must be completed by the practitioner for every assessment. The field mapping is to document the observations and to enable formulation of the geotechnical model.

Mapping should be completed to scale on an available survey plan and must include the surrounds (above, below and adjacent) to the site as appropriate to define the landslides and the geotechnical model.

Where a survey plan is not available, then simple survey using hand held tape and clinometer methods should be used to draw up a plan, to scale, using standard mapping symbols and terminology to represent the geological and geomorphic features. (Examples of geological and geomorphic mapping symbols are presented in Appendix E.)

#### 5.2.3 Determine the subsurface profile from exposures or subsurface investigation such as by boreholes and/or test pits.

This is necessary as part of the geotechnical model. Often exposures or knowledge from a nearby site may be sufficient.

Where such data is not available or not appropriate, subsurface investigation is required to enable formulation of the model and must include determination of the depth to rock or to below the depth of potential failure surfaces if this is greater.

Where pre-existing landslides are expected or suspected, then where practical, use should be made of either test pits (to enable sufficient sample/material to be seen for identification of shear planes or other relevant structure) or boreholes (with appropriate sampling and installation of inclinometers for monitoring for evidence of movements).

#### 5.2.4 Assess likely groundwater levels and responses to trigger rainfall events.

Consideration of the likely ground water response will enable assessment of response to rainfall trigger events. Use may be made of experience in the area, as observation of site specific data will frequently require prolonged periods of monitoring to enable formulation of a groundwater response model taking into account the statistical significance of rainfall events during the monitoring period. For relatively straightforward projects with low to moderate risks, a basic qualitative estimate of groundwater levels and responses may be appropriate when there is a lack of data. However, other more complicated projects, or where risk levels are higher, will require a greater level of understanding of groundwater levels and responses.

For more detailed analysis, particularly of possible stabilisation measures by subsurface drainage, observation of groundwater levels and their response to significant rainfall events is advisable to enable subsequent assessment of the effectiveness of subsurface drainage measures. Careful consideration must be given to the location of piezometers and their construction details.

#### 5.2.5 Prepare a cross section drawing (to scale) through selected parts of the site to demonstrate the geotechnical model of site conditions and on which landslides may be identified.

The resulting geotechnical model should integrate all the data obtained from the mapping and investigations.

The section should demonstrate the likely variation in subsurface conditions on the section including groundwater levels. On large or complex sites, more than one section may be required. All sections are to be drawn to natural scale. If exaggerated vertical scale is required for clarity, then a summary section at natural scale should also be included.

Adequate investigation has been completed when the geotechnical model is sufficiently defined to understand the slope forming processes relevant to the site and surrounds, the form and extent of landslides, likely triggers for the landslides and process rates associated with the landslides. The report should include explanation of uncertainties associated with the model.

#### 5.2.6 Take into account slope forming process rates associated with the geotechnical model and landslides.

An understanding of the slope forming process relevant to the landslides and associated process rate is fundamental for evaluation of likelihood.

#### 5.2.7 Identify landslides types/locations appropriate to the geotechnical model based on local experience and general experience in similar circumstances.

The types of landslides will be dependent on the geotechnical model and to some extent on the nature of existing and/or proposed development. The expected characteristics of the landslides (such as the size, type of material involved, rate of failure and travel distance) need to be assessed. The range of landslide sizes can vary from the very large landslides, which may encompass a whole hillside or region, to a small site specific landslide. The model should include assessment of the fundamental cause as well as likely trigger events. The report must document the hazard assessment which will include the estimated likelihood for each landslide type.

The hazard assessment must address areas upslope from the site, downslope from the site and across the slope adjacent to the site where these may affect the site.

#### 5.2.8 If required, further detailed investigations should be completed to better define the model, the landslides, the triggers, the frequency (likelihood) or design of stabilisation measures to control the risk.

Such additional investigation is most likely to be required on sites where the risk is judged to be intolerable and/or where further input is required to resolve uncertainties**.**

## 5.3 LANDSLIDE CHARACTERISATION

**Characterise the landslides based on the desk study and field investigations. Use Appendix B for terminology to describe the landslides.**

The characterization should include the classification, volume, location and potential travel distance of all landslides which may occur on the site or travel on to or regress into the site.

## 5.4 FREQUENCY ANALYSIS

### 5.4.1 Techniques for Frequency Analysis

#### a) Adopt a frequency analysis technique appropriate to the level of study and complexity of the geotechnical model and slope forming process.

The appropriate technique may change with different levels of study, or for different stages of a project, or with the project brief and available budget. For example, techniques and level of detail may be different for:

- Subdivision stage LRM
- Residential dwellings LRM
- Infrastructure and utilities LRM
- Natural resource and environmental LRM

It is essential that the assessment be based on the best estimates available and that expert judgment be applied to answers so derived.

It is essential to understand the slope forming process before moving on to the frequency assessment.

The assessment must document the reasoning in a transparent manner.

**b) Gather local and historical knowledge of slope performance and landslide characteristics and occurrence. The resulting inventory enables assessment of frequency.**

This technique is a basic starting point and essential for all studies. However, a common shortcoming is that "local knowledge" is often poorly documented and difficult to collate and assess. Local Council records and experience should be accessed via a landslide inventory made available to practitioners. Analysis of aerial photographs and possibly maps may provide additional data.

Documentation of events by local newspapers may also be a useful source, depending on the quality of reporting and what events are judged at the time to be of local interest.

**c) Empirical methods based on slope instability ranking systems.**

These methods are often devised by expert groups to assist with prioritisation of treatment measures.

The methods are usually based on subjective judgment of the relative importance of contributory factors. The results obtained may be difficult to calibrate or it may be difficult to obtain consistent results and hence may be inaccurate. The methods do not usually allow assessment of frequencies.

**d) Relationship to geomorphology and geology.**

This method is based on the principle put forward by Varnes (1984) that the past and present are guides to the future. Hence, this leads to the assumptions that:

1. it is likely that landsliding will occur where it has occurred in the past and
2. landslides are likely to occur in similar geological, geomorphologic and hydrological conditions as they have in the past.

The use of historic records and landslide inventories of past performance are likely to be required to enable frequency values to be assessed. However, it should be noted that landslide frequency, size and intensity may differ from past performance where altered trigger events are introduced, e.g. due to man made changes or climate change. In addition, other factors (such as periodic or seasonal wetting and drying cycles resulting in soil creep, cyclic degradation and strength loss) can also result in failures after relatively "normal" rainfall events.

The use of other slope attribute factors (such as slope angle, slope drainage, slope age, presence of groundwater, slope orientation) may assist with assessment of particular slopes relative to the broad geomorphic model.

**e) Prepare a statistical evaluation of rainfall and relate to history of landsliding and population of slopes within area of similar slope type.**

Rainfall, and the consequent effect on groundwater levels, is widely recognized as a main trigger event for landsliding. Therefore, indicative frequency values may be related to the frequency of rainfall provided there is sufficient historical data to enable the relationship between rainfall frequency, antecedent rainfall and landslide events to be correlated.

A similar approach may be adopted for other forms of triggering events such as earthquakes.

**f) Consider use of simulation models and Monte Carlo sampling analyses to derive a frequency of failure.**

These methods (including simulation modelling of groundwater response to rainfall, evapotranspiration, and ground water flows) can be difficult to carry out reliably. Picarelli *et al.* (2005) outline some of the difficulties with these methods. Simulation modelling is most likely to be applicable only to medium to large, deep seated landslides where extensive monitoring data is available to enable calibration over a range of rainfall and piezometric responses.

Experience shows that full probabilistic analysis is difficult and time consuming (Robin Fell personal comm.). Therefore this method should only be carried out for special cases where sufficient data is available to enable the results to be meaningful.

**g) Use knowledge based expert judgment or 'degree of belief' method which combines experience, expertise and general principles.**

For most assessments this may be the only suitable option to estimate frequency due to the lack of objective data. The assessment relies to a large degree on subjective assessment of available data where other more rigorous methods are not available or viable. The method still requires some degree of research to obtain relevant data and an understanding of the geological model to qualify the judgment of likelihood. Nonetheless, the approach requires the proposition of various possible scenarios followed by the systematic testing and elimination of options as a result of investigation, discussion and judgment to develop an estimate of frequency (Lee and Jones 2004).

The result is conditioned by the 'degree of belief' of the practitioner. Typically, the resulting accuracy for a frequency assessment and, perhaps, a consequence assessment could vary from half an order of magnitude at best, to one order of magnitude or perhaps two orders of magnitude. As a result, the risk assessment should clearly display its sensitivity to the input parameters and, unless justified by further investigations, a conservative outcome should be adopted.

**h) Where appropriate, use event trees to provide a structur**

**i) ed and auditable approach for the use of expert judgment and subjective probability assessment.**

An event tree analysis uses a graphical construct to show the logical sequence of events or considerations that can be used to analyse the system leading to a particular outcome. It can be used for evaluation of probability of failure of a landslide, or consequence of failure, or risk. The logical sequence within the system is mapped as a branching network with conditional probabilities assigned to each branch of a node. The frequency of achieving a certain outcome is the product of the conditional probabilities leading to that outcome times the frequency of the initiating "trigger" such as rainfall.

**i) Other methods.**

The above may not be an exhaustive list but covers the principal methods/approaches. Specific circumstances of a particular area or project may enable other approaches or combinations of approaches to be used. Field techniques may develop to offer alternatives, for example remote sensing by satellite.

Further comment is given in the Commentary together with some guidance on different site investigation methods.

### 5.4.2 Estimation of Annual Probability (Frequency) ($P_{(H)}$) of Each Landslide

**a) Use 'best estimates' for frequency but consider range / uncertainty / sensitivity.**

Suitable methods are outlined in Section 5.2.

It is important not to infer greater accuracy than is reasonably possible. Evaluation of the sensitivity arising from uncertainty is part of the consideration.

A best estimate is to be derived for each landslide which is then applied to both risk to property and risk to life assessments. The estimate may be related to the size of the landslide and/or the expected amount of movement as part of the hazard assessment. The appropriate qualitative term is chosen from the estimated probability based on the frequency assessment. Note that the reverse, the adoption of a probability value from a qualitative term, should not be undertaken as it has been demonstrated that this results in a range of estimates of frequency several orders of magnitude apart depending on the practitioner.

**b) Estimates of frequency may be derived by partitioning the problem to (Annual probability of trigger event) x (Probability of sliding given the trigger event) over the range of trigger events.**

Landslides of the one 'type', but having varying possible scales (magnitude/travel distance/velocity etc.) need to be assessed separately. Each could well have a different frequency of occurrence. The landslide inventory of performance for an area will provide some basis for the assessment.

A trigger event for a particular locality (e.g. a certain intensity/duration or recurrence interval of rainfall) will not necessarily cause each potential landslide event in that locality to occur. There will be a finite probability (value) that the landslide under consideration may not be set off by the trigger event.

The frequency of landsliding should be assessed over the full range of the triggering events, and the total frequency carried forward in the risk analysis. In practice this process may be simplified to consider only the highest frequency triggering events. An example is presented in the Commentary.

**c) Complete a review of the assessed frequency in relation to the implied cumulative frequency of the event occurring within the design life and known performance within the area.**

This is a 'sanity check' on the result of the assessment. It is import to apply judgment or bias on the final outcome only, not on the input estimates.

Values of the cumulative probability are shown on Figure 2 for different annual probability values as a function of time over usual design life intervals. The resulting cumulative probabilities should be checked to confirm they are reasonable in relation to experience. The implications of the cumulative probability values shown in Figure 2 are discussed further in the Commentary.

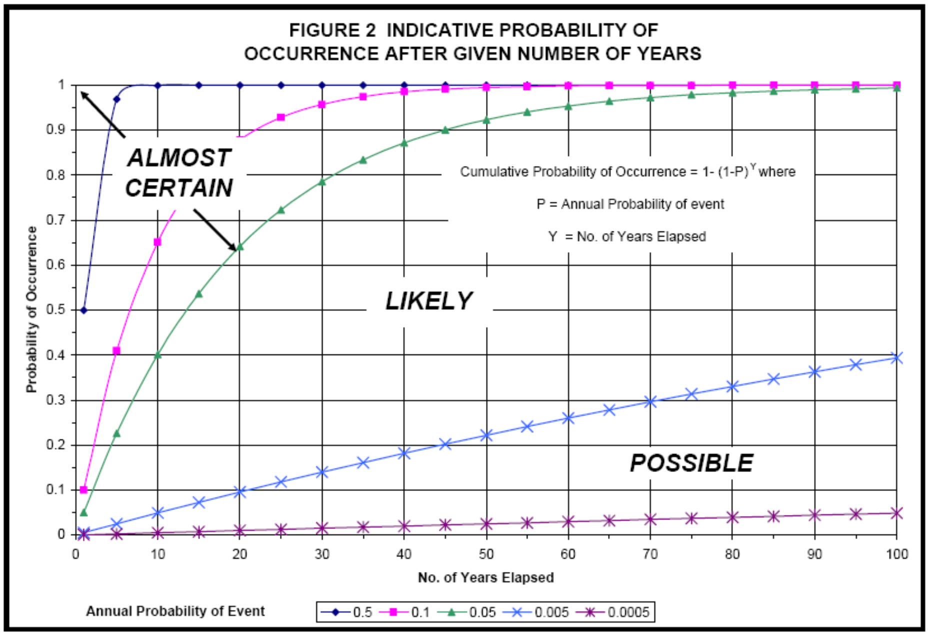


FIGURE 2 INDICATIVE PROBABILITY OF OCCURRENCE AFTER GIVEN NUMBER OF YEARS

### 5.4.3 Assess the Travel Distance and the Probability of Spatial Impact ($P_{(S:H)}$) of the Elements at Risk

When assessing risk arising from landsliding, it is important to be able to estimate the distance the slide mass will travel and its velocity. These factors determine the extent to which the landslide will affect property and persons downslope and the ability of persons to take evasive action.

The travel distance depends on:

- Slope characteristics
    - Height
    - Slope
    - Nature of material
- Mechanism of failure and type of movement such as
    - Slide, fall, topple etc.
    - Sliding, rolling, bouncing, flow
    - Strain weakening or not
    - Collapse in undrained loading (static liquefaction)
    - Influence of surface water and groundwater
    - Comminution of particles
- Characteristics of the downhill path
    - Gradient and gradient direction
    - Channelisation
    - The potential for depletion/accumulation
    - Vegetation

Information on travel distance from previous events on or near the site may be collected during the site inspection. Predictions of travel distance and travel direction should be based on the assessed mechanism of future events and site characteristics.

For rotational landslides which remain essentially intact, the method proposed by Khalili *et al* (1996) or experience with landslides in similar geological, topographic and climatic conditions can be used to estimate the displacement. Further discussion is given in the Commentary.

For slides which break up, and in some cases become flows, and slides from steep cuts, the travel distance is usually estimated from empirical methods, such as Hunter and Fell (2002) and Corominas (1996). These methods are only approximate, and the wide scatter of data on travel distance angles reflects the range of topographical, geological and climatic environments, different slide mechanisms and limited quality of data from which the methods are derived.

If the empirical methods are to be used for predictions of travel distance and the probability of spatial impact of the elements at risk, much judgement will be required and it is important to try to calibrate the methods with landslide behaviour in the study area. It is often useful to allow for a range of travel distances in the calculation and express that range in probabilistic terms as discussed in the Commentary.

The annual probability of the landslide and probability of spatial impact may be considered together in qualitative terms as likelihood of impact on the element at risk being considered.

# 6 CONSEQUENCE ANALYSIS

## 6.1 ELEMENTS AT RISK

The elements at risk will include:

- Property, which may be subdivided into portions relative to the hazard being considered.
- People, who either live, work, or may spend some time in the area affected by landsliding.
- Services, such as water supply or drainage or electricity supply.
- Roads and communication facilities.
- Vehicles on roads, subdivided into categories (cars, trucks, buses).

These should be assessed and listed for each landslide hazard.

For some cases, other risks may also have to be considered. For example:

- Environmental, where the elements at risk are environmental (rather than man made), such as forests or water bodies.
- Social, where the consequences of the landslide may have an impact on social conditions, such as the cost of disruption to traffic where roads are affected.
- Political, where the consequences may not be acceptable in political terms.

## 6.2 TEMPORAL SPATIAL PROBABILITY ($P_{(T:S)}$)

When the elements at risk are mobile (e.g. persons on foot, in cars, buses and trains) or where there is varying occupancy of buildings (e.g. between night and day, week days and weekends, summer and winter), it is necessary to make allowance for the probability that persons (or a particular number of persons) will be in the area affected by the landslide. This is called the Temporal Spatial Probability**.**

For where the elements at risk are mobile it is proportion of a year (between 0 and 1.0) in which a person, car or bus will be below or on the landslide when it occurs. For occupancy of buildings it is a calculation of the proportion of a year (between 0 and 1.0) which the number of persons being considered occupy the building, or the area of the building likely to be impacted.

These calculations should allow for the possibility that the persons may have warning of trhe impending landslide and may evacuate the area. Each case should be considered by taking account of the details of the situation. Generally persons on a landslide are more likely to observe the initiation of movement and move off the slide, than those who are below a slide which falls or flows onto them unless the rates of movement are slow.

## 6.3 EVALUATION OF CONSEQUENCE TO PROPERTY

### 6.3.1 Estimate the extent of damage likely to property arising from each of the landslides.

This requires an understanding of the landslide characteristics and experience in assessing the likely impact on property. The consequences are often calculated using the vulnerability ($\mathbf{V}_{(\mathrm{Prop:S})}$) of the elements at risk to the landslide.

The factors which most affect vulnerability of property are:

- The volume of the slide in relation to the element at risk.
- The position of the element at risk, e.g. on the slide, or immediately downslope.
- The magnitude of slide displacement, and relative displacements within the slide (for elements sited on the slide).
- The rate of slide movement.

It should be noted that the vulnerability refers to the degree of damage (or damage value in absolute or relative terms) which is judged to be likely if the landslide does occur.

As discussed below, the assessment should be based on a quantitative estimate to enable clarification of the judgment which for a qualitative assessment may be subject to considerable interpretation.

### 6.3.2 Estimate the indicative cost of the damage.

This requires use of indicative costs of building and remedial works. Frequently, broad brush ‘guesstimates’ will suffice, but the ‘guesstimate values’ and basis should be documented. Some guidance is given in the Commentary. It should not be necessary to use a quantity surveyor to establish a more accurate estimate as usually the broad brush guesstimate will suffice for allocation of a consequence term in a qualitative scheme such as in Appendix C.

The indicative cost of damage is to be the Total Cost as this is the most relevant to the owner. Components to be considered comprise:-

- Direct costs related to reinstatement works for damaged portions of the property (structures and the land).
- Stabilization works required to render the site to an tolerable risk level for the landslide.
- Professional and approvals fees.
- Consequential costs (such as legal fees and alternative temporary accommodation).

It does not include additional stabilisation works to address other landslides which may affect the property.

#### 6.3.3 Estimate the market value.

This may be achieved by reference to property sale values within the local area which will reflect the value of the land plus structures. The client is likely to have some knowledge of the local market values. Again, a broad-brush guesstimate should often suffice.

#### 6.3.4 Consider the resulting Consequence classification, such as using Appendix C, and implied accuracy of the above estimates.

It is not expected that the assessor will be a quantity surveyor or have similar experience, but that sensible estimates, possibly as a range, can be made and documented. Statement of limits of accuracy or uncertainty are appropriate for sensitivity and appraisal analysis.

### 6.4 EVALUATION OF CONSEQUENCES TO PERSONS

The following factors influence the likelihood of deaths and injuries or vulnerability ($\mathbf{V}_{(D:T)}$) of persons who are impacted by a landslide:

- Volume of slide.
- Type of slide, mechanism of slide initiation and velocity of sliding.
- Depth of slide.
- Whether the landslide debris buries the person(s).
- Whether the person(s) are in the open or enclosed in a vehicle or building.
- Whether the vehicle or building collapses when impacted by debris.
- The type of collapse if the vehicle or building collapses.

Persons are very vulnerable in the event of complete or substantial burial by debris, or the collapse of a building. It should be noted that even small slides, and single boulders, can kill people.

Appendix F provides some indicative examples of vulnerability values. The Commentary provides some more detailed discussion.

## 7 RISK ESTIMATION

### 7.1 QUANTITATIVE RISK ESTIMATION

Quantitative risk estimation involves integration of the frequency analysis and the consequences.
For property, the risk can be calculated from:

$$\mathbf{R}_{(Prop)} = \mathbf{P}_{(H)} \text{ x } \mathbf{P}_{(S:H)} \text{ x } \mathbf{P}_{(T:S)} \text{ x } \mathbf{V}_{(Prop:S)} \text{ x } \mathbf{E} \qquad \textbf{(1)}$$

Where

| | |
|---|---|
| $\mathbf{R}_{(Prop)}$ | is the risk (annual loss of property value). |
| $\mathbf{P}_{(H)}$ | is the annual probability of the landslide. |
| $\mathbf{P}_{(S:H)}$ | is the probability of spatial impact by the landslide on the property, taking into account the travel distance and travel direction. |
| $\mathbf{P}_{(T:S)}$ | is the temporal spatial probability. For houses and other buildings $\mathbf{P}_{(T:S)}$= 1.0. For Vehicles and other moving elements at risk1.0< $\mathbf{P}_{(T:S)}$ >0. |
| $\mathbf{V}_{(Prop:S)}$ | is the vulnerability of the property to the spatial impact (proportion of property value lost). |
| $\mathbf{E}$ | is the element at risk (e.g. the value or net present value of the property). |

For loss of life, the individual risk can be calculated from:

$$\mathbf{R}_{(LoL)} = \mathbf{P}_{(H)} \text{ x } \mathbf{P}_{(S:H)} \text{ x } \mathbf{P}_{(T:S)} \text{ x } \mathbf{V}_{(D:T)} \qquad \textbf{(2)}$$

Where

| | |
|---|---|
| $\mathbf{R}_{(LoL)}$ | is the risk (annual probability of loss of life (death) of an individual). |
| $\mathbf{P}_{(H)}$ | is the annual probability of the landslide. |
| $\mathbf{P}_{(S:H)}$ | is the probability of spatial impact of the landslide impacting a building (location) taking into account the travel distance and travel direction given the event. |
| $\mathbf{P}_{(T:S)}$ | is the temporal spatial probability (e.g. of the building or location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence. |
| $\mathbf{V}_{(D:T)}$ | is the vulnerability of the individual (probability of loss of life of the individual given the impact). |

A full risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landsliding, smaller slides, boulder falls, debris flows) and all the elements at risk.

For comparison with tolerable risk criteria, the individual risk from all the landslide hazards affecting the person most at risk, or the property, should be summed.

The assessment must clearly state whether it pertains to ‘as existing’ conditions or following implementation of recommended risk mitigation measures, thereby giving the ‘residual risk’.

## 7.2 SEMI-QUANTITATIVE AND QUALITATIVE RISK ESTIMATION FOR RISK TO PROPERTY

When considering the risk to property, it may be useful to use qualitative terms to report the results of the analysis, rather than quantitative values. The risk calculation may be completed quantitatively or by the use of qualitative terms.

A semi quantitative analysis (where the likelihood is linked to an indicative probability) or a qualitative analysis may be used:

- As an initial screening process to identify hazards and risks which require more detailed consideration and analysis.
- When the level of risk does not justify the time and effort required for more detailed analysis.
- Where the possibility of obtaining numerical data is limited such that a quantitative analysis is unlikely to be meaningful or may be misleading.

Section 7.3 describes a suitable and preferred terminology.

## 7.3 RISK MATRIX FOR PROPERTY LOSS

### a) Adopt a defined qualitative terminology for likelihood, consequence and risk.

Qualitative terminology is presented in Appendix C for property loss. The terminology has been developed from Appendix G in AGS (2000) taking into account the experience and comments as discussed in the Commentary.

For ease of use, the frequency estimate, expressed as an annualized probability and taking into account the probability of spatial impact, is expressed qualitatively as likelihood.

The terminology is aimed primarily at residential development but may also be used for other situations. It is noted that provision of specific numerical values at the Notional Boundaries for the terms adopted does not reduce the uncertainty that may be associated with assessment of appropriate numerical values.

Where sufficient data is available, the risk should be determined from a quantitative analysis. The results can then be objectively compared, especially with quantified allowable risk criteria.

Where there is insufficient data or the study is at a walk over or preliminary design level, then use of qualitative methods or terms may be more appropriate. Use of risk ranking schemes, where component inputs are assigned relative ranks, may be suitable for initial screening. In other cases, it is likely that expression of the likelihood, consequence and risk using qualitative terms is preferable for communication purposes; (for example using terminology as in Appendix C). Selection of the appropriate term should be based on an appropriate evaluation of likelihood or consequence ranges.

Semi-quantitative methods may be a combination of both, for example considering risk to property qualitatively, and risk to life quantitatively based on the appropriate best estimates of likelihood.

### b) The practitioner should adopt the preferred risk matrix presented in Appendix C.

The terminology presented in Appendix C of this Practice Note has addressed the shortcomings identified with the scheme in Appendix G AGS (2000). Appendix G of AGS (2000) is now superseded and should no longer be used. Adoption of Appendix C as a preferred risk matrix will assist with uniformity of assessment and interpretation. This is discussed further in the Commentary.

The regulator should only accept non standard schemes where the terms have been clearly defined, the terms have been explained in relation to the preferred terminology, and it can be reasonably demonstrated by the practitioner that the alternative is better suited to the particular circumstances of the assessment.

## 7.4 ESTIMATION OF RISK OF LOSS OF LIFE

### a) Estimate the risk of loss of life quantitatively for the person most at risk.

The annual probability of loss of life for the person most at risk from the landslide(s) should be estimated using the equations in Section 7.1. The person most at risk will often but not always be the person with the greatest spatial temporal probability.

The individual risk, as determined by summing the risk, for the person most at risk, from all the landslide hazards, is used for comparison with the tolerable risk criteria.

**b) For situations where there is a potential for large numbers of lives to be lost in a single landslide event, estimate the frequency (f) –number (N) of lives lost pairs and total annual risk.**

If the possible loss of large numbers of lives from a landslide incident is high, society will generally expect that the probability that the incident might actually occur should be low. This accounts for society's particular intolerance to incidents that cause many simultaneous casualties and is embodied in the criteria for tolerable societal risk. Societal Risk is discussed further in the Commentary.

In many cases there will be more than one landslide hazard (e.g. rockfall, which may lead to one or two lives lost; medium volume rapid landslide which may lead to several lives lost; and large rapid landslide which may lead to many lives lost). The frequency (annual probability, "f") of the "event" and the number of lives lost (N) should be estimated for each landslide hazard.

The total annual risk = $\sum$ (f x N) should also be estimated.

## 8 RISK ASSESSMENT

### 8.1 RISK EVALUATION

**Evaluate the risks against Tolerable Risk Criteria for loss of life and property loss.**

**Accept the risks if tolerable, or seek to reduce risks to tolerable levels by risk mitigation.**

The main objectives of risk evaluation are usually to decide whether to accept or treat the risks and to set priorities. The Tolerable Risk Criteria are usually imposed by the regulator, unless agreed otherwise with the owner/client

Non- technical clients may seek guidance from the practitioner on whether to accept the risk. In these situations, risk comparisons, discussion of treatment options and explanation of the risk management process can help the client make his decision.

It is desirable, if not essential, that the practitioner who prepared the risk assessment be involved in the decision making process because the process is often iterative, requiring assessment of the sensitivity of calculations to assumptions, modification of the development proposed and revision of risk mitigation measures.

Risk evaluation involves making judgements about the significance and tolerability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to finance, loss of life or other values. Risk evaluation may include consideration of issues such as environmental effects, public reaction, politics, business or public confidence and fear of litigation.

In a simple situation where the client/owner is the only affected party, risk evaluation may be a simple value judgement. In more complex situations, value judgements on acceptable risk appropriate to the particular situation are still made as part of an acceptable process of risk management.

### 8.2 TOLERABLE RISK CRITERIA

**The regulator is to establish the Tolerable Risk Criteria for loss of life and property loss.**

As discussed in Section 3.5, the regulator is the appropriate authority to set standards for tolerable risk which may relate not only to perceived safety in relation to other risks, but also to government policy. Implementation of a tolerable risk level has implications to the community at large, both in terms of relative risks or safety and in terms of economic impact on the community.

The Commentary provides discussion and gives the AGS recommendations in relation to tolerable risk for loss of life. These are summarized in Table 1

Table 1: AGS Suggested Tolerable loss of life individual risk.

| Situation | Suggested Tolerable Loss of Life Risk for the person most at risk |
|---|---|
| Existing Slope (1) / Existing Development (2) | $10^{-4}$ / annum |
| New Constructed Slope (3) / New Development (4) / Existing Landslide (5) | $10^{-5}$ / annum |

Notes:

1. "Existing Slopes" in this context are slopes that are not part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
2. "Existing Development" includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
3. "New Constructed Slope" includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).
4. "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope / Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.
5. "Existing Landslides" have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of "public safety".

Acceptable risks are usually considered to be one order of magnitude lower than the Tolerable Risks.

It is important to distinguish between "acceptable risks" and "tolerable risks".

*Tolerable Risks* are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable.

*Acceptable Risks* are risks which everyone affected is prepared to accept. Action to further reduce such risk is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort.

AGS suggests that for most development in existing urban area criteria based on Tolerable Risks levels are applicable because of the trade-off between the risks, the benefits of development and the cost of risk mitigation.

The Commentary discusses Individual and Societal risk to loss of life. Usually Societal risk need not be considered for a risk evaluation in relation to a single dwelling. Societal risk should be evaluated for buildings having high numbers of occupants, such as schools, hospitals, hotels or motels where many lives are at risk. This then addresses society's aversion to loss of many lives from single landslide events.

The Tolerable Risk Criteria for property loss may be determined by the Importance Level of the development (Appendix A) as discussed in the Commentary.

# 9 RISK MANAGEMENT

## 9.1 RISK MITIGATION PRINCIPLES

### 9.1.1 Feasible options for risk mitigation for each risk assessment are to be identified and discussed including the reduced risk by adoption of those options.

Alternative methods to be explored include:

a. ***Accept the risk***, which is only an option subject to the criteria set by the regulator. Where the risk is not tolerable then risk mitigation measures are required.

b. ***Avoid the risk***, such as relocation of the site of proposed development, or revise the form of the development, or abandon the development (though this may still require some risks to be controlled due to possible effect on third parties adjacent or nearby).

c. ***Reduce the frequency of landsliding***, by stabilisation measures to control the initiating circumstances, such as by re-profiling the surface geometry where existing slopes are 'over steep', by provision of improved surface water drainage measures, by provision of subsurface drainage scheme, by provision of retaining structures such as retaining walls, anchored walls or ground anchors.

d. ***Reduce the consequences***, by provision of defensive stabilisation measures or protective measures such as a boulder catch fence, or amelioration of the behaviour of the landslide, or by relocation of the development to a more favourable location.

e. ***Manage the risk by establishing monitoring and warning systems,*** such as by regular site visits, or by survey, which enable the risks to be managed as an interim measure in the short term or as a permanent measure for the long term by alerting persons potentially affected to a change in the landslide condition. Such systems may be regarded as a method of reducing the consequences provided it is feasible for sufficient time to be available between the alert being raised and appropriate action being implemented.

f. ***Transfer the risk,*** such as by requiring another authority to accept the risk (possibly via a court appraisal) or by provision of insurance to cover potential property damage.

g. ***Postpone the decision,*** where there is sufficient uncertainty resulting from the available data, provided that additional investigations or monitoring are likely to enable a better risk assessment to be completed. Postponement is only a temporary measure and implies the risks are being temporarily accepted, even though they may not be acceptable or tolerable.

Adoption of particular risk mitigation measures needs to be documented so that the decisions are transparent to future land owners and to the regulator. The documentation will need to make it clear whether there is ongoing maintenance required or not. Responsibility for implementation of the risk mitigation measures (including auditing and reporting) resides with the land owner, particularly where ongoing maintenance is required.

It should be recognized that there may be situations where the risk is such that either no development should occur, or that very strict conditions and/or extensive investigations and implementation of risk control measures will be required. Such risk control measures may render the proposed development unworkable.

### 9.1.2 Wherever possible the recommended options should be engineered to reduce the uncertainties.

It is not possible to remove risk, but it can be reduced.

Risk mitigation options should include robust engineering design to reduce uncertainties and hence the risk.

Guidance on good engineering practice for hillside design and construction is given in Appendix G which has been reproduced from AGS (2000).

It is necessary that the options considered lower the risk to at least tolerable levels. In many cases, the ALARP principle (“As Low As Reasonably Practicable” as discussed in the Commentary) may apply so that reduction to a tolerable level is a pragmatic result since reduction to acceptable levels is not viable in the context of the cost to the individual or community. In other cases, good practice may suggest that risk reduction be applied since it is relatively cheap or cost effective to implement even though risk levels are assessed to already be at acceptable levels. In other words, risk minimization should be a governing feature or tenet of LRM.

Evaluation of mitigation options may take into account relative costs and effectiveness of the measures and inherent uncertainties. Combinations of mitigation measures may be appropriate.

The options should be reassessed if there is a need to reduce uncertainties or if suitable engineering options cannot be adopted.

An issue will be who decides on what level of risk reduction is appropriate. This is dependent on the risk tolerance criteria set by the regulator. The owner is likely to input into selection of the options, subject to approvals by the regulator. For some cases, there may be discussion between the stakeholders to select a suitable scheme of risk mitigation measures.

### 9.1.3 The adopted risk mitigation measures are to be detailed in a mitigation plan to explain and document the implementation of the measures.

The mitigation plan should identify responsibilities for each stakeholder during and after implementation. It may also include cost estimates, programme, required inspection regime, performance measures and expected outcomes. The level of detail will depend on the priority for the option and stage of the evaluation and implementation process.

The mitigation plan may include an emergency plan which should establish from the outset the sequence of events or monitoring results that will activate this plan. The plan may include a number of warning levels and consequent actions. The plan must be carefully reviewed to confirm it is workable and will achieve the desired risk mitigation.

The existence of the mitigation plan needs to be readily known to subsequent land owners. The most readily available method for this is to register the mitigation plan details on the land title.

### 9.1.4 The risk should be subject to monitoring and review during the assessment of options, during implementation of the risk mitigation measures and during the on going monitoring.

Further data may come to light during the management process which enables the risks to be reassessed. Such data may be adverse, requiring more stringent risk mitigation measures, or alternatively may be positive by demonstrating satisfactory slope performance under adverse conditions. It is anticipated that the practitioner would have a primary role in the monitoring and review process and particularly to confirm the requirements of the approval conditions had been fulfilled.

## 9.2 SITE SPECIFIC DEVELOPMENT CONDITIONS

**Identify appropriate site specific development conditions to provide good practice and control the risks to acceptable levels.**

In the context of advice from a technical expert (the practitioner) acting in a consultant capacity, development controls would usually constitute ‘recommendations’, but as they will be integral with the risk assessment of the final development they may not be optional to the client. The practitioner should provide a statement as to the appropriateness of the development proposals in relation to the risk management requirements.

If ‘certification’ of the completed development is required (by the planning scheme or regulator’s approval conditions), then the development conditions and associated inspections and documentation must be sufficient to enable this to be provided at the later date.

The development conditions should be subdivided into those required at each of the stages of detailed design, construction (including appropriate sequencing and temporary works), and for maintenance. The development conditions must address all the factors relevant to controlling the landslide risk.

## 9.3 DESIGN LIFE

### 9.3.1 Design of the risk mitigation measures is to be suitable for the time frame of the life of the structure - the design life. The design life is to be clearly stated on the design drawings.

Often the design life will be that specified by relevant design codes such as 40 to 60 years for AS3600 Concrete Code, 50 years for AS2870 Residential Slabs and Footings, or for 5 years to 120 years for temporary site works to major public works respectively for AS4678 Earth Retaining Structures.

A design life of at least 50 years would be considered to be reasonable for permanent structures used by people. Some local government policies may require a longer design life as discussed in the Commentary. However, for some structures, such as timber retaining walls, inherent performance of the materials will limit the effective performance life to less than the required design life.

### 9.3.2 Where the effective performance life is less than the required design life, then the effective life should be extended by a maintenance regime designed to overcome the limitations and to enable the performance to be assessed throughout the required design life. This is likely to require more extensive repair and replacement as determined by regular maintenance inspections.

For example, experience shows the longevity of timber crib walls is less than for a concrete structure, due to faster degradation of timber with time. Therefore, a more frequent inspection and maintenance / repair / replacement regime will be required for timber crib walls to enable suitable repair and replacement so that a reasonable design life can be achieved. Similar considerations will apply to subsoil drains and stressed anchors.

## 9.4 MAINTENANCE REQUIREMENTS

### 9.4.1 The design is to include details of required inspections and maintenance to enable the risk mitigation measures to remain effective for at least the design life of the structure.

Risk mitigation is not just an exercise in LRM documentation, design of the works and construction of the risk mitigation measures. The owner, including all owners subsequent to those responsible for commissioning the risk mitigation measures, has a responsibility to inspect and maintain the risk mitigation measures.

### 9.4.2 Refer to the AGS Australian GeoGuide LR111 which provides advice on record keeping.

The other GeoGuides (AGS, 2007e) also provide advice on the frequency of maintenance tasks.

**9.4.3 Implementation of the maintenance plan may require 'enforcement' by annotation on the land title so that subsequent purchasers become aware of the requirements and that relevant documents are available for the maintenance plan. Such 'enforcement' will be a benefit to subsequent owners as they will be better informed as to their required input responsibilities.**

# 10 REPORTING STANDARDS

**10.1 The report on the risk assessment is to document the data gathered, the logic applied and conclusion reached in a defensible manner.**

The practitioner will gather relevant data, will assess the relevance of the data and will reach conclusions as to the appropriate geotechnical model and basic assessment of the slope forming processes and rates. Full documentation of these results provides evidence of completion, provides transparency in the light of uncertainty, enables the assessment to be re-examined or extended at a later date and enables the assessment to be defended against critical review. The process often identifies uncertainties or limitations of the assessment which also need to be documented and understood.

**10.2 The data to be presented includes:**

a. List of data sources.
b. Discussion of investigation methods used, and any limitations thereof.
c. Site plan (to scale) with geomorphic mapping results.
d. All factual data from investigations, such as borehole and test pit logs, laboratory test results, groundwater level observations, record photographs.
e. Location of all subsurface investigations and/or outcrops/cuttings.
f. Location of cross section(s).
g. Cross section(s) (to scale) with interpreted subsurface model showing investigation locations.
h. Evidence of past performance.
i. Local history of instability with assessed trigger events.
j. Identification of landslides, on plan or section or both, and discussed in terms of the geomorphic model, relevant slope forming process and process rates. Landslides need to be considered above the site, below the site and adjacent to the site.
k. Assessed likelihood of each landslide with basis thereof.
l. Assessed consequence to property and life for each landslide with basis thereof.
m. Resulting risk for each landslide.
n. Risk assessment in relation to tolerable risk criteria (e.g. regulator's published criteria where appropriate).
o. Risk mitigation measures and options, including reassessed risk once these measures are implemented.

Where any of the above is not or cannot be completed, the report should document the missing elements, including an explanation as to why.

The report needs to clearly state whether the risk assessment is based on existing conditions or with risk treatment measures implemented. In some cases, the assessment for both existing and after treatment should be documented to demonstrate the effect of risk control measures on reducing risk.

A report which does not properly document the assessment is of limited value and would appear to have no reasonable basis.

# 11 SPECIAL CHALLENGES

## 11.1 MINOR WORKS

**Adoption of all the provisions of the Practice Note for minor works may not be appropriate or reasonable. However, the basic principles still need to be considered. Although some policies may make provision for less onerous consideration for minor works, the practitioner will still have a duty of care to advise on all aspects and may have other landslides not connected with the proposed works that will still need to be considered.**

Minor works should be evaluated on a site by site basis but are likely to comprise proposed works of relatively low monetary value (such as may be completed by an owner builder with appropriate approvals and insurances) or those which do not change the existing risk, provided the existing risk has been assessed to be within the tolerable range. In some cases, the risk to life may be much higher than the risk to property and may dictate the need for risk mitigation to achieve tolerable risk levels.

### 11.2 PART OF THE SITE NOT ACCEPTABLE

**Existing or proposed development may not involve the full site area. Nonetheless, the practitioner's report must address all risks and advise the client and/or regulator of necessary works to control risks on other parts of the site or adjacent/nearby sites upslope or down slope as appropriate (as a primary duty of care issue)**.

Where additional development is proposed, it may be found that risks associated with the proposed development are tolerable but that landslide risks on other parts of the site are not. These other risks still must be addressed.

### 11.3 ADJOINING AREAS NOT UNDER RESPONSIBILITY OF THE SITE OWNER

In some cases, the risk posed by landslides in areas beyond the control of the land owner may be intolerable.

**The LRM assessment report must identify these landslides and provide a preliminary assessment of appropriate risk mitigation measures, which may require further investigation to better assess the risk.**

**The regulator may then implement appropriate orders (as appropriate to the legal/regulatory framework) to enforce appropriate risk mitigation measures and/or investigations. Alternatively, it may not be appropriate for development to proceed in such cases.**

### 11.4 COASTAL CLIFFS

**LRM reports on coastal cliffs should include consideration of the existing slope profile, evidence of past instability, geology, defects, ground water, degradation cycles, and degradation rates and possible effects of wave attack, wave run-up and sea spray. The cliff areas should be examined from the face side as well as from the land side.**

Assessment of coastal cliffs is likely to require special expertise to consider the combined effects associated with recession rates, rock mechanics and wave environment. The LRM assessment may require some input from coastal engineers to address possible effects from storm events in terms of wave heights, run-up and frequency. The most frequent hazard is often boulder falls which will have risk determined by the temporal spatial probability.

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The preparation of this Practice Note and Commentary has been carried out under the auspices of the AGS by a Working Group comprising:

Bruce Walker, Working Group Convenor, Jeffery and Katauskas Pty Ltd
Grahame Wilson, Douglas Partners Pty Ltd
Warwick Davies, Davies Geotechnical Pty Ltd.

with assistance from Robin Fell and Andrew Leventhal.

The documents prepared by the Working Group have been subject to peer review and discussion by the AGS Landslides Taskforce. The Steering Committee comprised:

Robin Fell, Emeritus Professor, University of New South Wales
Andrew Leventhal, GHD Geotechnics (chair)
Tony Phillips, Tony Phillips Consulting Pty Ltd
Bruce Walker, Jeffery and Katauskas Pty Ltd
Geoff Withycombe, Sydney Coastal Councils Group.

Other representatives on the Taskforce have comprised:

Laurie de Ambrosis, GHD Geotechnics
Mark Eggers, Pells Sullivan Meynink Pty Ltd
Max Ervin, Golder Associates Pty Ltd
Angus Gordon, former General Manager, Pittwater Council
Greg Kotze, GHD Geotechnics
Arthur Love, Coffey Geotechnics Pty Ltd
Alex Litwinowicz, GHD Geotechnics

Tony Miner, As Miner Geotechnical
Fiona MacGregor, Douglas Partners Pty Ltd
Garry Mostyn, Pells Sullivan Meynink Pty Ltd
Grant Murray, Sinclair Knight Merz Ltd
Garth Powell, Coffey Geotechnics Pty Ltd
Ralph Rallings, Pitt & Sherry Pty Ltd
Ian Stewart, Roads & Traffic Authority NSW
Peter Tobin. Wollongong City Council
Graham Whitt, Shire of Yarra Ranges.

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# APPENDIX A - DEFINITION OF TERMS AND LANDSLIDE RISK

## RISK TERMINOLOGY

**Acceptable Risk** – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

**Annual Exceedance Probability (AEP)** – The estimated probability that an event of specified magnitude will be exceeded in any year.

**Consequence –** The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

**Elements at Risk** – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

**Frequency** – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

**Hazard** – A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

**Individual Risk to Life** – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

**Landslide Activity** – The stage of development of a landslide; pre failure when the slope is strained throughout but is essentially intact; failure characterised by the formation of a continuous surface of rupture; post failure which includes movement from just after failure to when it essentially stops; and reactivation when the slope slides along one or several pre-existing surfaces of rupture. Reactivation may be occasional (eg seasonal) or continuous (in which case the slide is "active").

**Landslide Intensity** – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

**Landslide Risk** - The AGS Australian GeoGuide LR7 (AGS, 2007e) should be referred to for an explanation of Landslide Risk.

**Landslide Susceptibility** – The classification, and volume (or area) of landslides which exist or potentially may occur in an area or may travel or retrogress onto it. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

**Likelihood** – Used as a qualitative description of probability or frequency.

**Probability** – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

(i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an "objective" or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.

(ii) Subjective probability (degree of belief) – Quantified measure of belief, judgment, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgment regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.

**Qualitative Risk Analysis** – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

**Quantitative Risk Analysis** – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

**Risk** – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

**Risk Analysis** – The use of available information to estimate the risk to individual, population, property, or the environment, from hazards. Risk analyses generally contain the following steps: Scope definition, hazard identification and risk estimation.

**Risk Assessment** – The process of risk analysis and risk evaluation.

**Risk Control** or **Risk Treatment** – The process of decision making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

**Risk Estimation** – The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.

**Risk Evaluation** – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.

**Risk Management** – The complete process of risk assessment and risk control (or risk treatment).

**Societal Risk** – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.

**Susceptibility – see Landslide Susceptibility**

**Temporal Spatial Probability** – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

**Tolerable Risk** – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

**Vulnerability** – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

## ASSOCIATED TERMINOLOGY

**Importance Level** – of a building or structure is directly related to the societal requirements for its use, particularly during or following extreme events. The consequences with respect to life safety of the occupants of buildings are indirectly related to the Importance Level, being a result of the societal requirement for the structure rather than the reason *per se* of the Importance Level.

**Authority** or **Council** having statutory responsibility for community activities, community safety and development approval or management of development within its defined area/region.

The **Regulator** will be the responsible body/authority for setting Acceptable/Tolerable Risk Criteria to be adopted for the community/region/activity, which will be the basis for setting levels for Acceptable and Tolerable Risk in the application of the risk assessment guidelines.

| Importance Level of Structure | Explanation | Examples<br>(Regulatory authorities may designate any structure to any classification type when local conditions make such desirable) |
|---|---|---|
| 1 | Buildings or structures generally presenting a low risk to life and property (including other property). | Farm buildings.<br>Isolated minor storage facilities.<br>Minor temporary facilities.<br>Towers in rural situations. |
| 2 | Buildings and structures not covered by Importance Levels 1, 3 or 4. | Low-rise residential construction.<br>Buildings and facilities below the limits set for Importance Level 3. |
| 3 | Buildings or structures that as a whole may contain people in crowds, or contents of high value to the community, or that pose hazards to people in crowds. | Buildings and facilities where more than 300 people can congregate in one area.<br>Buildings and facilities with primary school, secondary school or day-care facilities with capacity greater than 250.<br>Buildings and facilities for colleges or adult education facilities with a capacity greater than 500.<br>Health care facilities with a capacity of 50 or more residents but no having surgery or emergency treatment facilities.<br>Jails and detention facilities.<br>Any occupancy with an occupant load greater than 5,000.<br>Power generating facilities, water treatment and waste water treatment facilities, any other public utilities not included in Importance Level 4.<br>Buildings and facilities not included in Importance Level 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond property boundaries. |
| 4 | Buildings or structures that are essential to post-disaster recovery, or with significant post-disaster functions, or that contain hazardous materials. | Buildings and facilities designated as essential facilities.<br>Buildings and facilities with special post-disaster functions.<br>Medical emergency or surgery facilities.<br>Emergency service facilities: fire, rescue, police station and emergency vehicle garages.<br>Utilities required as back-up for buildings and facilities of Importance Level 4.<br>Designated emergency shelters.<br>Designated emergency centres and ancillary facilities.<br>Buildings and facilities containing hazardous (toxic or explosive) materials in sufficient quantities capable of causing hazardous conditions that extend beyond property boundaries. |

(from BCA Guidelines)

**Practitioner** – A specialist Geotechnical Engineer or Engineering Geologist who is degree qualified, is a member of a professional institute and who has achieved chartered professional status – being either Chartered Professional Engineer (CPEng) within the Institution of Engineers Australia, Chartered Professional Geologist (CPGeo) within the Australasian Institute of Mining & Metallurgy, or Registered Professional Geoscientist (RPGeo) within the Australian Institute of Geoscientists – specifically with Landslide Risk Management as a core competency.

A Practitioner will include persons qualified under the Institution of Engineers Australia NPER – LRM register.

It would normally be required that the Practitioner can demonstrate an appropriate minimum period of experience in the practice of landslide risk assessment and management in the geographic region, or can demonstrate relevant experience in similar geological settings.

**Regulator** – The regulatory authority [Federal Government/ State Government/ Instrumentality/ Regional/Local.

# APPENDIX B - LANDSLIDE TERMINOLOGY

The following provides a summary of landslide terminology which should (for uniformity of practice) be adopted when classifying and describing a landslide. It has been based on Cruden & Varnes (1996) and the reader is recommended to refer to the original documents for a more detailed discussion, other terminology and further examples of landslide types and processes.

### Landslide

The term ***landslide*** denotes "the movement of a mass of rock, debris or earth down a slope". The phenomena described as landslides are not limited to either the "land" or to "sliding", and usage of the word has implied a much more extensive meaning than its component parts suggest. Ground subsidence and collapse are excluded.

### Classification of Landslides

Landslide classification is based on Varnes (1978) system which has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are ***Rock***, ***Earth*** and ***Debris***, being classified as follows:-

The material is either rock or soil.

| | |
|---|---|
| ***Rock***: | is "a hard or firm mass that was intact and in its natural place before the initiation of movement." |
| ***Soil:*** | is "an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil." |
| ***Earth***: | "describes material in which 80% or more of the particles are smaller than 2 mm, the upper limit of sand sized particles." |
| ***Debris***: | "contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2 mm and the remainder are less than 2 mm." |

The terms used should describe the displaced material in the landslide before it was displaced.

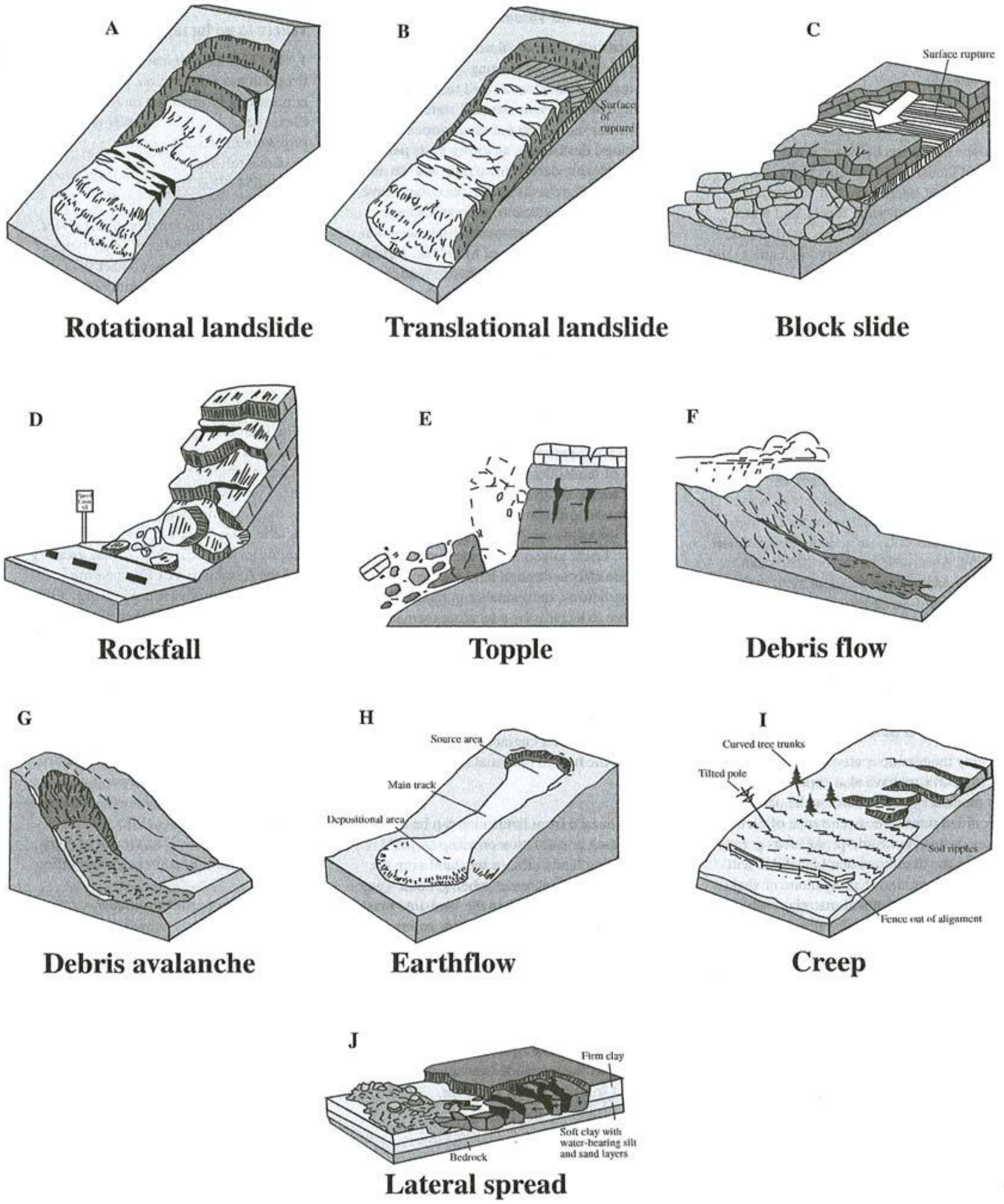
The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence ***fall***, ***topple***, ***slide***, ***spread*** and ***flow***.

The following table shows how the two terms are combined to give the landslide type:

Table B1: Major types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

| **TYPE OF MOVEMENT** | | **TYPE OF MATERIAL** | | |
|---|---|---|---|---|
| | | **BEDROCK** | **ENGINEERING SOILS** | |
| | | | **Predominantly Coarse** | **Predominantly Fine** |
| FALLS | | Rock fall | Debris fall | Earth fall |
| TOPPLES | | Rock topple | Debris topple | Earth topple |
| SLIDES | ROTATIONAL | Rock slide | Debris slide | Earth slide |
| | TRANSLATIONAL | | | |
| LATERAL SPREADS | | Rock spread | Debris spread | Earth spread |
| FLOWS | | Rock flow | Debris flow | Earth flow |
| | | (Deep creep) | (Soil creep) | |
| COMPLEX | Combination of two or more principle types of movement | | | |

Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at http://landslides.usgs.gov.



**Rotational landslide** **Translational landslide** **Block slide**

**Rockfall** **Topple** **Debris flow**

**Debris avalanche** **Earthflow** **Creep**

**Lateral spread**

Figure B1: These schematics illustrate the major types of landslide movement.
*(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)*

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Second or subsequent movements in complex or composite landslides can be described by repeating, as many times as necessary, the descriptors used in Table B2. Descriptors that are the same as those for the first movement may then be dropped from the name.

For example, the very large and rapid slope movement that occurred near the town of Frank, Alberta, Canada, in 1903 was a *complex, extremely rapid, dry rock fall – debris flow*. From the full name of this landslide at Frank, one would know that both the debris flow and the rock fall were extremely rapid and dry because no other descriptors are used for the debris flow.

The full name of the landslide need only be given once; subsequent references should then be to the initial material and type of movement; for the above example, "the rock fall" or "the Frank rock fall" for the landslide at Frank, Alberta.

Table B2: Glossary for forming names of landslides.

**Activity**

| State | Distribution | Style |
|---|---|---|
| Active | Advancing | Complex |
| Reactivated | Retrogressive | Composite |
| Suspended | Widening | Multiple |
| Inactive | Enlarging | Successive |
| Dormant | Confined | Single |
| Abandoned | Diminishing | |
| Stabilised | Moving | |
| Relict | | |

**Description of First Movement**

| Rate | Water Content | Material | Type |
|---|---|---|---|
| Extremely rapid | Dry | Rock | Fall |
| Very rapid | Moist | Earth | Topple |
| Rapid | Wet | Debris | Slide |
| Moderate | Very Wet | | Spread |
| Slow | | | Flow |
| Very slow | | | |
| Extremely slow | | | |

Note: Subsequent movements may be described by repeating the above descriptors as many times as necessary. These terms are described in more detail in Cruden & Varnes (1996) and examples are given.

**Landslide Features**

Varnes (1978, Figure 2.1t) provided an idealised diagram showing the features for a *complex earth slide – earth flow*, which has been reproduced here as Figure B2. Definitions of landslide dimensions are given in Cruden & Varnes (1996).

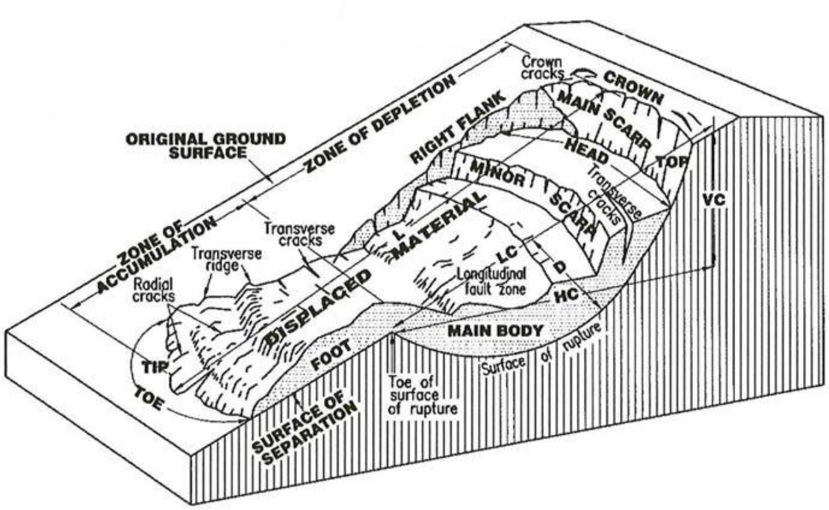


Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(*Varnes, D J (1978,)Slope Movement Types and Processes. In Special Report 176: Landslides: Analysis and Control(R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33).*

**Rate of Movement**

Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term "creep" has been omitted due to the many definitions and interpretations in the literature.

| Velocity Class | Description | Velocity (mm/sec) | Typical Velocity | Probable Destructive Significance |
|---|---|---|---|---|
| 7 | Extremely Rapid | | | Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely |
| | | 5 x $10^{3}$ | 5 m/sec | |
| 6 | Very Rapid | | | Some lives lost; velocity too great to permit all persons to escape |
| | | 5 x $10^{1}$ | 3 m/min | |
| 5 | Rapid | | | Escape evaluation possible; structures; possessions, and equipment destroyed |
| | | 5 x $10^{-1}$ | 1.8 m/hr | |
| 4 | Moderate | | | Some temporary and insensitive structures can be temporarily maintained |
| | | 5 x $10^{-3}$ | 13 m/month | |
| 3 | Slow | | | Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase |
| | | 5 x $10^{-5}$ | 1.6 m/year | |
| 2 | Very Slow | | | Some permanent structures undamaged by movement |
| | | 5 x $10^{-7}$ | 15 mm/year | |
| | Extremely **SLOW** | | | Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS** |

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

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# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

## APPENDIX C: LANDSLIDE RISK ASSESSMENT

## QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

### *QUALITATIVE MEASURES OF LIKELIHOOD*

| **Approximate Annual Probability** | | **Implied Indicative Landslide Recurrence Interval** | | **Description** | **Descriptor** | **Level** |
|---|---|---|---|---|---|---|
| **Indicative Value** | **Notional Boundary** | | | | | |
| $10^{-1}$ | $5x10^{-2}$ | 10 years | 20 years | The event is expected to occur over the design life. | ALMOST CERTAIN | A |
| $10^{-2}$ | $5x10^{-3}$ | 100 years | 200 years | The event will probably occur under adverse conditions over the design life. | LIKELY | B |
| $10^{-3}$ | $5x10^{-4}$ | 1000 years | 2000 years | The event could occur under adverse conditions over the design life. | POSSIBLE | C |
| $10^{-4}$ | $5x10^{-5}$ | 10,000 years | 20,000 years | The event might occur under very adverse circumstances over the design life. | UNLIKELY | D |
| $10^{-5}$ | $5x10^{-6}$ | 100,000 years | 200,000 years | The event is conceivable but only under exceptional circumstances over the design life. | RARE | E |
| $10^{-6}$ | | 1,000,000 years | | The event is inconceivable or fanciful over the design life. | BARELY CREDIBLE | F |

**Note:** (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

### *QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY*

| **Approximate Cost of Damage** | | **Description** | **Descriptor** | **Level** |
|---|---|---|---|---|
| **Indicative Value** | **Notional Boundary** | | | |
| 200% | 100% | Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage. | CATASTROPHIC | 1 |
| 60% | 40% | Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage. | MAJOR | 2 |
| 20% | 10% | Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage. | MEDIUM | 3 |
| 5% | 1% | Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works. | MINOR | 4 |
| 0.5% | | Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.) | INSIGNIFICANT | 5 |

**Notes:** (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

# PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

## APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

### *QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY*

| **LIKELIHOOD** | | **CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)** | | | | |
|---|---|---|---|---|---|---|
| | **Indicative Value of Approximate Annual Probability** | **1: CATASTROPHIC 200%** | **2: MAJOR 60%** | **3: MEDIUM 20%** | **4: MINOR 5%** | **5: INSIGNIFICANT 0.5%** |
| **A – ALMOST CERTAIN** | $10^{-1}$ | VH | VH | VH | H | M or **L** (5) |
| **B - LIKELY** | $10^{-2}$ | VH | VH | H | M | **L** |
| **C - POSSIBLE** | $10^{-3}$ | VH | H | M | M | **VL** |
| **D - UNLIKELY** | $10^{-4}$ | H | M | **L** | **L** | **VL** |
| **E - RARE** | $10^{-5}$ | M | **L** | **L** | **VL** | **VL** |
| **F - BARELY CREDIBLE** | $10^{-6}$ | **L** | **VL** | **VL** | **VL** | **VL** |

**Notes**: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

### *RISK LEVEL IMPLICATIONS*

| **Risk Level** | | **Example Implications** (7) |
|---|---|---|
| VH | VERY HIGH RISK | Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property. |
| H | HIGH RISK | Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property. |
| M | MODERATE RISK | May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable. |
| **L** | LOW RISK | Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required. |
| **VL** | VERY LOW RISK | Acceptable. Manage by normal slope maintenance procedures. |

**Note:** (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.