Appendix J Stormwater and Flood Risk Assessment

Fast Track Approvals Act Application

Foxton Solar Farm

Genesis Energy Limited

SLR Project No.: 810.V14848.00001

13 February 2026

Hydrological and hydraulic modelling assessment

Foxton Solar Farm

Genesis Energy Limited

Prepared by:

SLR Consulting New Zealand Limited

SLR Project No.: 810.031065.00001

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Compliance with Environmental Court Practice Note 2023

Date	10 December 2025
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Code of Conduct	As an expert witness I have read, and am familiar with, the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2023. This report has been prepared in compliance with that Code. In particular, unless I state otherwise, this response is within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.
Signature	

Basis of Report

This report has been prepared by SLR Consulting New Zealand Limited (SLR), on the instruction of Genesis Energy (the Client), in accordance with the agreed scope of work. It is intended to support the Client's application under the Fast Track Approvals Act 2024 and may be relied upon by the Expert Panel and relevant administering agencies for the purposes of assessing the application. While SLR has exercised due care in preparing this report, it does not accept liability for any use of the report beyond its intended purpose. Where information has been supplied by the Client or obtained from external sources, it has been assumed to be accurate unless otherwise stated.

Executive Summary

Genesis Energy Limited (Genesis) are considering developing a solar farm 5km north-east of Foxton. As part of the consenting and design process, Genesis commissioned SLR Consulting to assess the flood risks to the site. This is to inform design to avoid placement of critical infrastructure in overland flowpaths.

To evaluate the potential flood risk to the site, a detailed flood assessment has been undertaken through fluvial (riverine) and pluvial (rainfall-driven) modelling in TUFLOW. To assess the fluvial risk from the Manawatū River, the estimated 0.5% Annual Exceedance Probability (AEP) peak flood flow was modelled. This model was high-level and designed to be conservative. To assess the pluvial flood risk, the estimated 20%, 10%, 5%, 2%, 1% and 0.5% AEP rainfall, using the critical (4-hour) duration rainfall and existing site terrain, were modelled. The model was validated using flows that were estimated for the onsite waterways using several methods.

Based on the existing topography and model assumptions, the flood hazard assessment concluded that:

- There is no modelled flood risk to the site from a 0.5% AEP or smaller flood event in the Manawatū River east of the site;
- The site is generally considered to be low risk, defined as flooding <250mm deep and velocity <0.5m/s. Hazardous floodwater (deep and/or high velocity) is typically confined to drains, except where it breaches the banks at two locations in the east;
- Flooding outside of drains generally occurs in isolated areas such as on the upgradient sides of farm access tracks or in topographic depressions. Most flooding outside of channels is relatively shallow (<250mm) and low velocity (<0.2m/s);
- Specific mitigation options for those areas modelled as high risk (depths exceeding 0.5m and/or velocity greater than 1m/s) include avoidance, terrain smoothing, increasing channel capacity, smoothing sharp bends in drains, modifying the terrain to prevent water spilling out from the drains or allow water to flow more easily toward drains, and maintenance of drains to remove excess vegetation. Increasing flow conveyance through drains may result in adverse effects elsewhere.
- In the small areas considered to have a moderate flood risk (depths exceeding 0.3m and/or velocity greater than 0.5m/s), or where the high risk encompasses a relatively small area, infrastructure should be raised to ensure it remains out of the predicted water level. In some areas, the panels could span areas of deeper water within channels with the height of the panels based on surrounding terrain, rather than the base of the channel.

Development should be avoided in areas of high risk. However, where this is not ideal, any changes to the landform to address flood risk may affect the hydrological response and risk classification at areas upstream and/or downstream of the intervention. These should be explicitly considered during detailed design. Further, new consents may have a hydraulic neutrality requirement to prevent increases in runoff that may worsen the flood risk to upstream or downstream users.

It is important to recognise that this assessment, and therefore the results, are affected by several assumptions and limitations. These must be acknowledged when using

these results. Following refinement of the design and sizing of stormwater infrastructure, the TUFLOW model could be rerun with these changes to reassess the risk to solar infrastructure.

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Appendices

1.0 Introduction

Genesis Energy Limited (Genesis) is seeking resource consents under the Fast-track Approvals Act 2024 ("FTA") to build and operate an approximately 180 MW solar facility that will generate approximately 345 GWh per year of renewable electricity. This will be enough to power the equivalent of 47,000 homes annually.

SLR Consulting have been engaged to undertake hydrodynamic modelling to determine flood risk (depth and velocities) to the site. SLR have built on the existing TUFLOW model developed during the initial desktop study to achieve the requested scope.

The scope of works to complete the hydrological and hydraulic analyses of the site included:

- A site visit to confirm dimensions for critical infrastructure where possible or in discussion with Council or landowners and gathering site specific information to ensure features modelled are representative.
- Obtaining additional elevation / terrain information and merging with site LiDAR to extend the model boundary to include upstream areas.
- Building on the existing model, expanding the model area to include the contributing area upstream of the site and any other catchment areas important for modelling the movement of water into and through the site.
- Derivation of design rainfalls for a range of events including 0.5%, 1%, 2%, 5%, 10% and 20% AEPs.
- Flood risk from the Manawatū River.

The following assessment report details the modelling undertaken and provides a flood risk assessment for each AEP event and recommendations for possible mitigation methods to address these risks.

1.1 Proposed development

The site for the proposed solar farm is located at 304 - 508 Wall Road and 447 Motuiti Road, Foxton. The site is situated approximately 4 km north of the Foxton town centre, on 436 hectares of a 488 hectare site currently used for dairy farming and runoff grazing. The solar farm will consist of solar panels and power generation equipment arranged in rows across the site with a battery energy storage system. The renewable electricity generated will be connected to the National Grid via a new on-site substation and connection assets.

The proposal includes 26ha of planting for the purposes of either boundary screening or the enhancement of dunelands, wetlands or drain margins. The enhancement planting will include some 1ha of natural inland wetland restoration planting concentrated at the area of the site with the greatest concentration of natural inland wetlands.

The solar farm will be owned and operated by the Genesis. The new substation and connection assets will be constructed by Genesis before being transferred to Transpower.

The site for the proposed solar farm is predominantly flat land having been historically flattened for agricultural use. A network of drains run through the properties, which are currently used as a dairy farm and as stock grazing.

The existing BPE-HAY A and B 220kV transmission line dissects the centre of the site in a north-easterly direction. The proposed solar farm will comprise of a panel arrays, BESS, substation, site office and storage buildings, inverters, cabling, vehicle crossings, internal access roads, security fencing and other associated activities.

Solar panels will be ground mounted with arrays up to 3.5m at the highest angle. Inverter units / STS units will be up to 2.7m in height. The proposed substation will be located by the existing BPE-HAY A and B 220kV transmission line.

No solar panels or earthworks will occur within the National Grid Transmission Corridor.

2.0 Manawatū River model build

To assess the potential flood risk to the site posed by overbank flow from the Manawatū River, a high-level hydraulic model was built. At its closest point, the site is approximately 2.8km from the main river channel. The plateau that the site sits on is approximately 20m above the Manawatū River channel. Horizons Regional Council (HRC) Flood Plain Mapping does not cover the area of interest. However, the mapped extent of the February 2004 flood event did not reach the site (pers. comm. HRC, Sep 2024).

Based on the topography of the floodplain for this reach of the Manawatū River, it was expected that floodwater would preferentially flow south-east of the River towards lower lying areas and paleochannels, although flooding on the western side (toward the site) would also occur but not reach the site. There is a significant stopbank along the true left bank (east of the Manawatū River) preventing inundation from smaller events. This model was intentionally created to be overly conservative to confirm this expectation and bolster confidence that the site would be unaffected.

2.1 Model overview

The two-dimensional (2D) hydraulic model was constructed using TUFLOW™, which is an industry standard hydrodynamic modelling software. A grid cell size of 5m was used in the hydraulic model. This cell size was considered appropriate for representing the Manawatū River channel, which is approximately 80m wide through this reach, as well as smaller tributaries and topographic features.

The sub-grid sampling (SGS) feature of TUFLOW was utilised with a resolution of 1m to increase the definition of the terrain across the modelled area. Specifically, this was used to ensure accurate representation of the Manawatū stopbanks.

The New Zealand Transverse Mercator 2000 coordinate reference system was selected.

2.2 Model inputs

2.2.1 Hydrological inputs

One annual exceedance probability (AEP) event was modelled, this being the 0.5% (1-in-200) AEP event. The model focused on fluvial flooding only, and excluded any additional inundation that might result from direct rainfall.

The nearest flow sites are the Manawatū River at Moutoa and Manawatū River at Teachers College gauges. The Moutoa gauge is tidally influenced and there are several periods of negative flows in the record. In addition, historically, the rating has only been applied at the top end of flows (pers. comm. Environmental Data Delivery Team Leader, October 2024). As a result, the Moutoa gauge is not appropriate for determining design flows. Conversely, the Teachers College gauge has a substantially longer and more reliable flow record and has been used in this study.

Frequency analysis was conducted using the Manawatū at Teachers College flow record. Three distributions were assessed, these being Gumbel, GEV, and Pearson’s Type III (PE3). A PE3 distribution was deemed to best fit the recorded high flows. From this frequency analysis, a 0.5% AEP design flow of 3968m^3/s was determined for the Manawatū River at Teachers College.

This design flow was scaled to just upstream of the Moutoa Floodway, downstream of the site. Scaling was based on the ratio of catchment area to the power of 0.8 ((McKerchar and Pearson, 1989). The scaled 0.5% AEP design flow was 5110m^3/s and was used as the inflow to the hydraulic model. The inflow was applied conservatively by inputting it to the Manawatū River channel upstream of the site as a steady state flow.

2.2.2 Hydraulic inputs

2.2.2.1 Model domain and boundaries

The model domain was limited by the extent of the provided digital elevation model (DEM). The domain was created to encompass the nearest edge of the proposed solar farm site and extended across the floodplain to east of the Manawatū River and upstream and downstream of the site.

An upstream boundary condition was used across the Manawatū River northeast of the site. This applied the hydrological inflow to the model domain. A downstream boundary condition was used to allow water to flow out of the model domain at the southern extent. The boundary slope condition was based on the hydraulic gradient of floodwater leaving the model.

2.2.2.2 Topography

A one metre resolution DEM for the wider area was provided by Horizons Regional Council (Horizons). This DEM was derived from several LiDAR surveys undertaken in 2009, 2013 and 2018 depending on the area. This data used Wellington Vertical Datum 1953 (WVD-53) as the reference level (m RL), with a vertical accuracy of +/-0.2m.

As LiDAR does not effectively penetrate water surfaces, the bathymetry of the Manawatū River was not accurately represented. Consequently, the design flow was applied on top of the water level (represented as the terrain surface) in the LiDAR. This approach is conservative as it assumes that the channel capacity is reduced.

2.2.2.3 Materials

Given the high-level nature of this modelling, a single Manning's n value was applied to all areas of the model domain. A Manning's n value of 0.03 was used, which is typical for pasture and was considered reasonable for this reach of the Manawatū River channel.

2.3 Model results

2.3.1 Overview

The TUFLOW hydraulic model was run for a design flow event with a 0.5% Annual Exceedance Probability (AEP). The decisions made in the setup and parameterisation for the model meant that results are expected to be overly conservative.

The 0.5% AEP peak flood water level across the model area were output from the model and used to establish whether the site is at risk of flooding from overbank flow from the Manawatū River.

2.3.2 Analysis

The cross-section presented in Figure 1 shows that in a 0.5% AEP flood event in the Manawatū River, the peak water level outside of the western riverbank and towards the site is between 11-12m (WVD-53). This is significantly below the eastern edge of the site that is nearest the river, which has a ground level of approximately 18m (WVD-53) at the lowest point. Although this is the closest area, it is still over 1.5km from any flooding. The cross-section alignment, as well as mapped results of modelled peak flood water levels are displayed in Figure 2. Sand dunes are visible in both the cross-section (Figure 1) and the topography shown in Figure 2. These will likely provide protection to the site in any events larger than a 0.5% AEP by blocking and diverting floodwater away from the site.

Due to the difference in levels, the distance between inundation and the site, and because of the conservative approach to the modelling, there is high confidence that flooding in the Manawatū River will not impact the site.

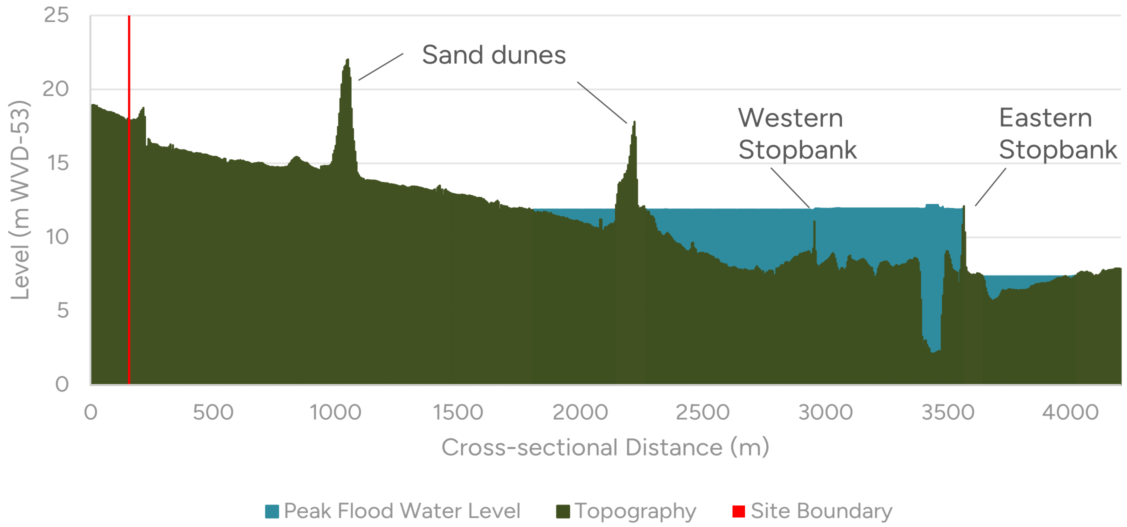

Figure 1. Cross-section showing topography and the modelled 0.5% AEP peak flood water level for the Manawatū River.

Figure 2. Modelled 0.5% AEP peak flood water levels for the Manawatū River.

3.0 Rain-on-grid model build

In the initial desktop assessment (SLR, 2024), a high-level two-dimensional TUFLOW™ hydraulic model (build 2020-10-AD) was developed for the site to provide an indication of potential development constraints with regard to flooding. The model domain was restricted by the extent of the high resolution (1m) survey digital elevation model (DEM) flown in 2024, that was used as the terrain for the model. This DEM excluded upstream areas that could potentially influence flooding onsite.

For this stage of the project, the model extent was increased to include upstream areas, from older regional LIDAR data. The model was run using a range of design rainfall scenarios to improve understanding of the flood risk to the site. The following sections provide an overview of the model development, parameterisation and validation.

3.1 Model overview

The two-dimensional (2D) hydraulic model was constructed using TUFLOW™. A grid cell size of 2m was used in the hydraulic model. This cell size was chosen as it provides a balance between computational run time and definition of the watercourses. A smaller cell size would have impaired model performance by increasing computational run-times, whilst a larger cell size would risk losing adequate definition of the channels. Figure 3 shows various key features of the model including the model domain and boundary condition locations.

The sub-grid sampling (SGS) feature of TUFLOW was also utilised to increase the definition of the model terrain and flow conveyance in critical areas. This enables model resolution to be improved without significant increases in computational runtimes. The SGS resolution was set to 1m, which was the highest possible resolution given the DEM grid cell size.

The New Zealand Transverse Mercator 2000 coordinate reference system was selected.

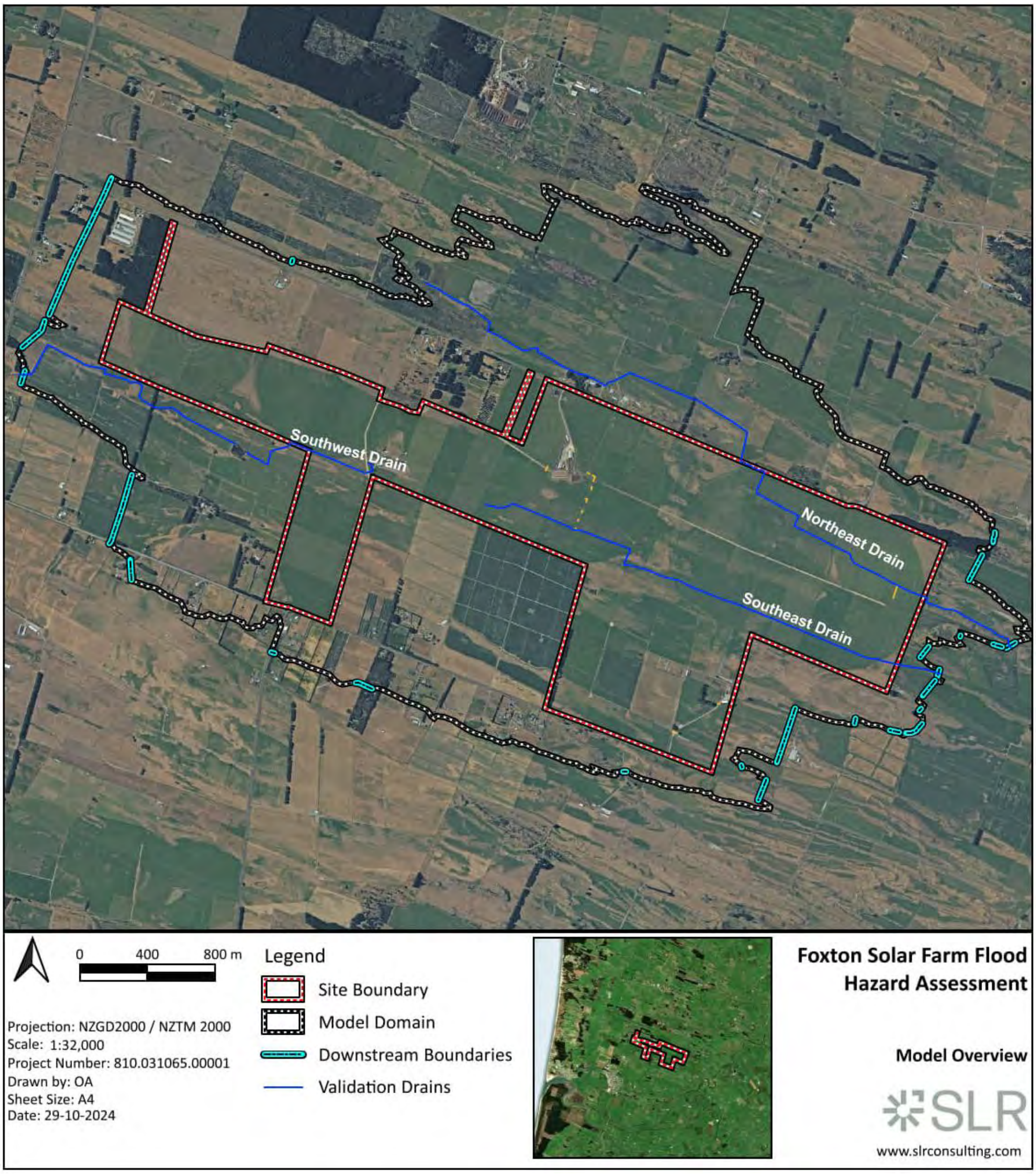

Figure 3. Model overview

3.2 Model inputs

3.2.1 Hydrological inputs

Six annual exceedance probability (AEP) events were modelled. These events were the 0.5% (1-in-200 year), 1% (1-in-100 year), 2% (1-in-50 year), 5% (1-in-20 year), 10% (1-in-10 year) and 20% (1-in-5 year) Annual Exceedance Probability (AEP).

The model focussed on pluvial (rainfall-driven) flooding only, since there were no major streams or waterways flowing through the catchment. The nearest major waterway is the Manawatū River which was modelled as not posing a flood risk to the site in events up to the

0.5% AEP (refer Section 2.0). Consequently, fluvial flooding has not been included in this more detailed modelling.

There are few rainfall gauges in the vicinity of the site. However, based on NIWA's mean annual rainfall data, rainfall across the model extent is believed to be relatively consistent. A global rain-on-grid approach was considered appropriate. This approach applied the same rainfall hyetograph equally to every cell in the model.

For input into the hydraulic model, the rainfall depths for the six design rainfall events and a temporal distribution for the rainfall are required. Rainfall depths were retrieved from NIWA's High Intensity Rainfall Design System (HIRDS v4). The critical duration was determined from running various design storms through the model to determine the storm duration that resulted in the largest flow.

As an initial indication of critical duration, the time of concentration for the model domain was estimated. Based on the Ramser-Kirpich and Bransby-Williams methods, the time of concentration for this site is estimated to be 2-3 hours for the model domain. Storm durations ranging from 1-hour to 6-hours were simulated for the 1% AEP event. The storm durations and corresponding rainfall depths are presented in Table 1. From the analysis, the 4-hour storm produced the highest peak flows in the three main drains (Table 1 and Figure 4 to Figure 6) and largest inundation extent across the site.

Table 1. 1% AEP design rainfall from NIWAs HIRDS database and corresponding modelled peak flows in the three main drains, downstream of the site.

Duration (hours)	Design Rainfall (mm)	Simulated peak flow (m^3/s)		
		Northeast Drain	Southeast Drain	Southwest Drain
1-hour	37.8	1.06	0.90	0.67
2-hours	49.3	1.62	1.78	0.89
3-hours	57.4	1.85	2.15	0.90
4-hours	63.7	1.88	2.23	0.93
6-hours	73.6	1.73	2.13	0.87

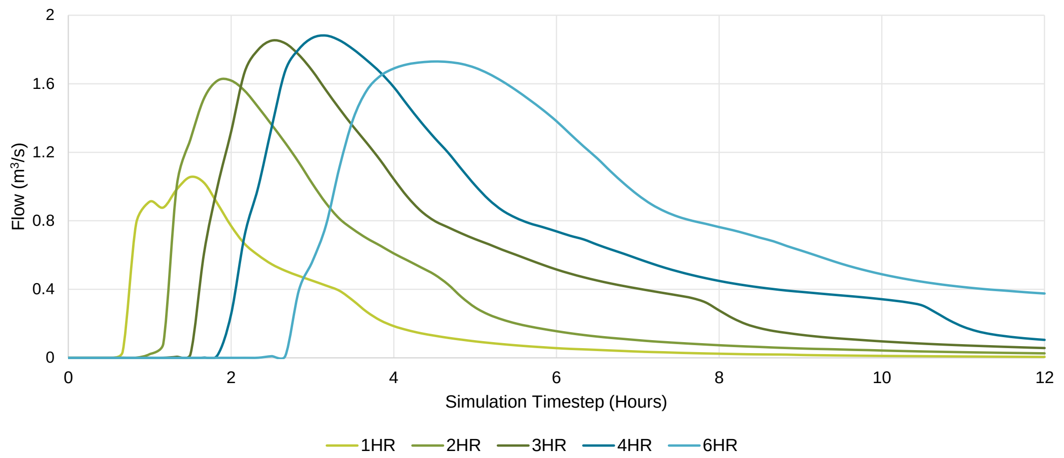

Figure 4. Comparison of peak flows for critical storm duration analysis (northeast drain).

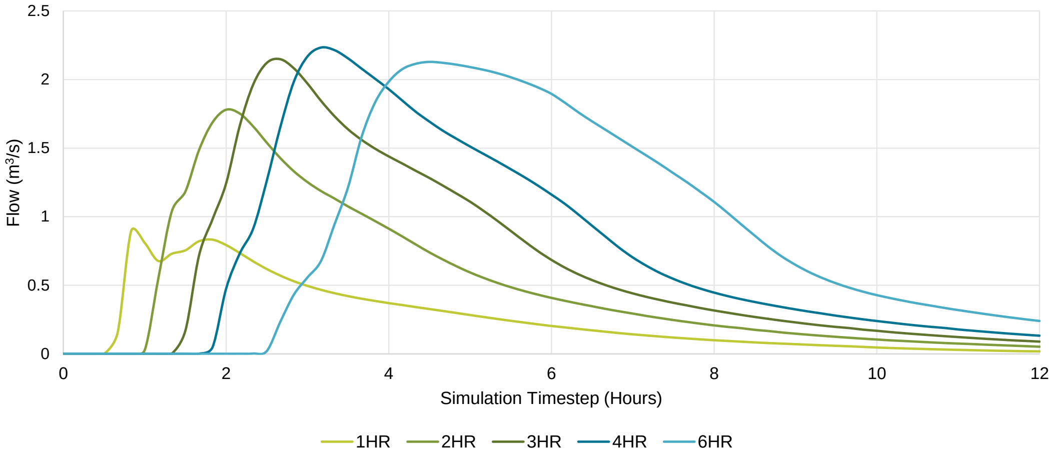

Figure 5. Comparison of peak flows for critical storm duration analysis (southeast drain).

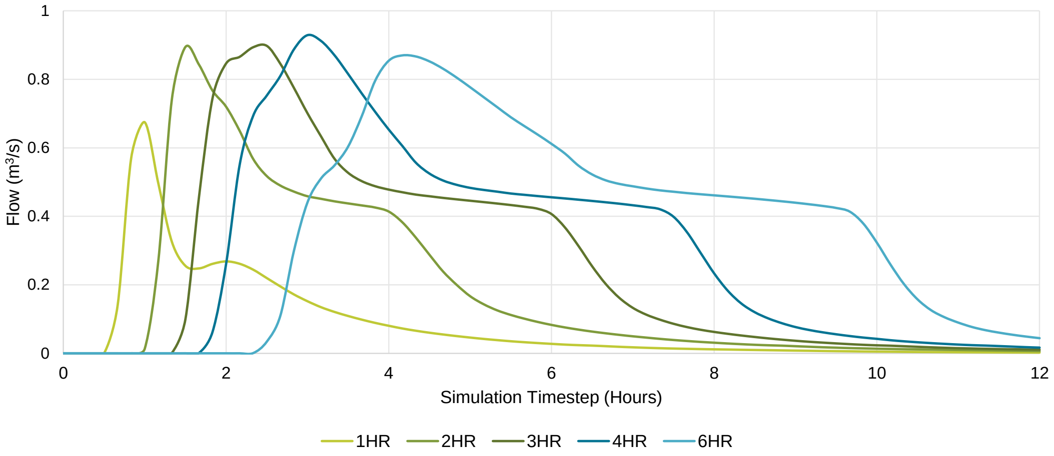

Figure 6. Comparison of peak flows for critical storm duration analysis (southwest drain)

For the purpose of this study, the HIRDS East of the North Island temporal distribution with a 4-hour duration was applied to each rainfall event. The design rainfall depths are shown in Table 2 and the associated hyetographs for the six AEP events are shown in Figure 4, Figure 5 and Figure 6.

Table 2. Rainfall depths for each design event for a 4-hour duration from NIWAs HIRDS database.

Duration	Design Rainfall Depth (mm)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
4-hours	35.3	41.4	47.8	56.6	63.7	71.0

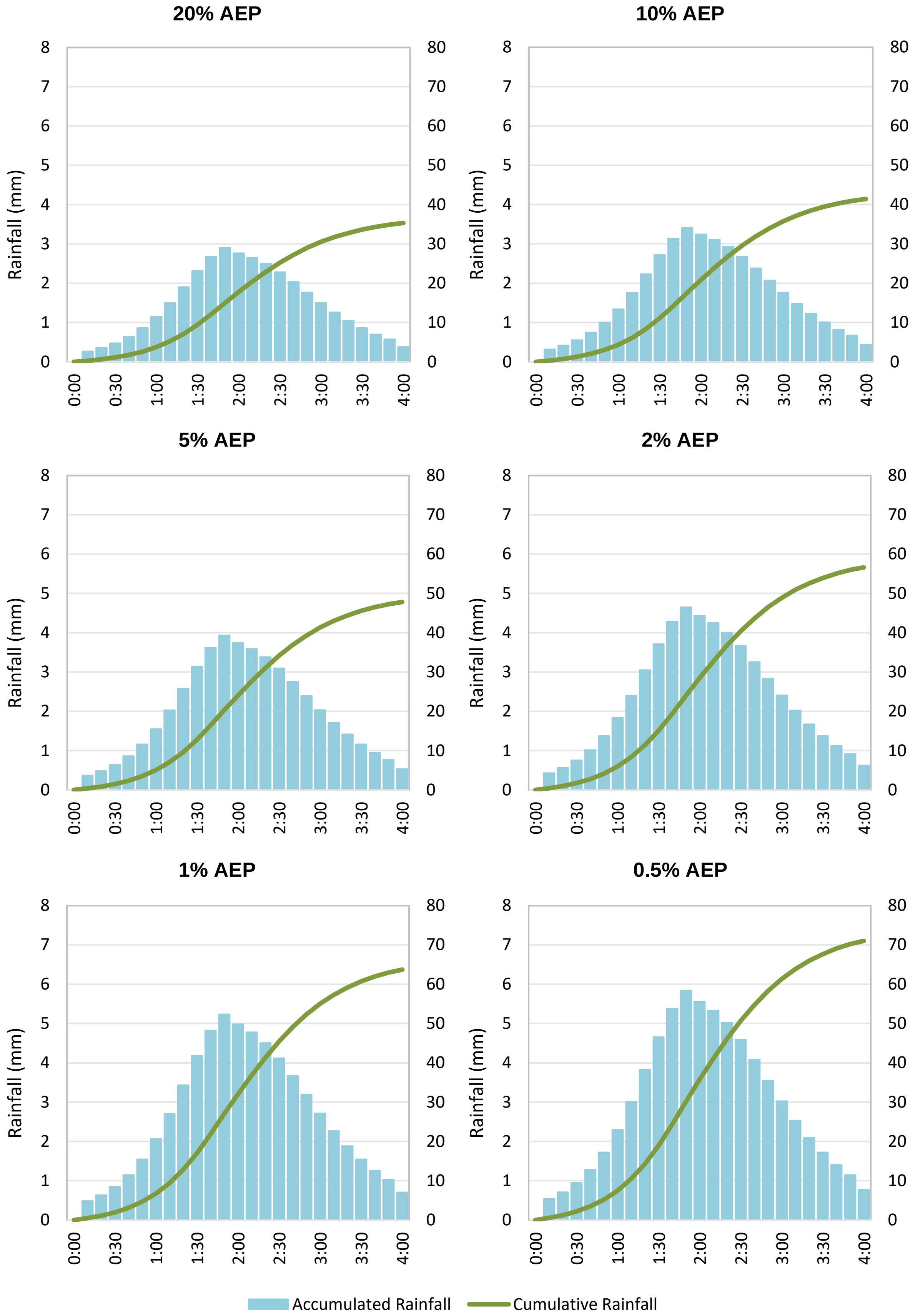

Figure 7. Rainfall hyetographs for the 4-hour duration events for all 6 AEP events modelling using the HIRDS WNI temporal distribution.

3.2.2 Hydraulic inputs

3.2.2.1 Model domain and boundaries

The model domain was created using topography (DEM and contours) and aerial imagery. Topography is essential for delineating catchments when using a rain-on-grid modelling approach, as rainfall is applied across every cell of the model domain. This means that 'glass-walling' can occur where water trying to leave the model is blocked by the model boundary. This results in potentially incorrect flood depths/extents along the boundary. Topography was used to ensure that the model boundary was created along ridgelines so that all rainfall contributing to the catchment would be captured. Aerial imagery was used for cross-referencing to verify the extent.

Downstream boundary conditions were used to allow water to flow out of the model domain at 24 locations. The boundary slope conditions were based on the hydraulic gradient of flowpaths leaving the model and were placed sufficiently far downstream of the site so that any minor inaccuracies that may be associated with the applied slope do not impact flooding onsite.

3.2.2.2 Topography

Model terrain

An aerial survey undertaken in 2024 for the Foxton Site provided topographic data in the form of a digital elevation model (DEM). This is the most recent, readily available data that covers the entire site and provides high resolution (one metre) topographic data for the critical areas of the model. This data used New Zealand Vertical Datum (2016) as the reference level (m RL).

A one metre resolution DEM for the wider area was provided by Horizons Regional Council (Horizons). This DEM was derived from several LiDAR surveys undertaken in 2009, 2013 and 2018 depending on the area. This data used Wellington Vertical Datum (1953) as the reference level (m RL), with a vertical accuracy of +/-0.2m. It was converted to New Zealand Vertical Datum (2016) to be consistent with the site LiDAR. Following this conversion, the two datasets were merged to create a single DEM for the site and its contributing catchment. This was used as the underlying topography for the model domain.

Terrain modifications

LiDAR is not able to detect the ground level beneath water so does not pick up the invert of streams. Stream channels may also be poorly defined due to channel size and thick or poorly filtered vegetation cover. Consequently, gully lines were created across the model domain to ensure hydraulic connectivity of flowpaths. Gully lines interpolate elevation between two points and set all cells within the assigned gully a width and depth to those interpolated values.

Gully lines were used in place of culverts where it was assumed that a culvert exists, where no surveyed measurements/data were readily available and where absolute accuracy would not be critical to resulting flood extents. It is important that gully lines are only used for culverts that are not deemed critical as the lack of specifications may over or underestimate flow. Gully lines were also used throughout the catchment in the densely vegetated drains to ensure flow conveyance.

To effectively convey flow through the gully lines, it is necessary for them to be given widths of at least twice the models cell size. Therefore, the width of gully lines was 4m. Based on the size of the typical watercourses, a width of 4m is likely to overestimate flow conveyance.

3.2.2.3 Initial conditions

For the majority of the model domain, the initial conditions are dry. However, initial water levels were applied to two ponds in the wider catchment (both of which are outside of the site boundary). This allowed the pond water level to be set at full at the beginning of model simulations. This is considered conservative, as it eliminates the potential for storage in these areas.

3.2.2.4 Materials

Hydraulic roughness

Mannings n roughness values were applied to the model. These were variable across the model domain, with different roughness values associated with land cover classes. Land cover classes were determined using various layers available on the Land Information New Zealand (LINZ) Data Service and Maanaki Whenua Landcare Research's Land Cover Database (LCDB v5) layer for 2018. These layers were cross-referenced using aerial imagery and ground truthing during a site visit. It is likely that some inaccuracies persist, for example several buildings in the model domain are not represented. However, these are unlikely to impact the results. Roughness values were based on literature and professional judgement. The Manning's n values applied to the model are shown in Table 3.

Initial and continuing losses

Initial and continuing losses were applied to land cover classes to account for where there is potential for rainfall to be intercepted by vegetation. As the majority of the catchment is pasture, initial and continuing losses were predominantly 0mm. This is considered conservative; a higher initial loss (e.g. 5mm) would result in a slightly reduced flood extent. The initial and continuing loss values applied to the model are presented in Table 3.

Table 3. Applied roughness and rainfall loss parameters.

Land Cover Class	Manning's n	Initial Loss (mm)	Continuing Loss (mm/hr)
Pasture	0.03	0	0
Forest	0.07	20	2
Buildings	0.50	0	0
Roads	0.02	0	0
Surface Water	0.02	0	0
Drains	0.05	0	0

3.2.2.5 Soils

Maanaki Whenua Landcare Research's New Zealand fundamental soils layer (FSL) was used to represent the various soil types across the model domain. Soil type was used to determine initial and continuing losses of rainfall to infiltration.

Infiltration values were acquired from an investigation conducted by CLIMsystems, which took loss values for different soil classes from various literature and compiled them into a table providing a lower bound, median and upper bound for both initial and continuing infiltration losses (CLIMsystems, 2024). It should be noted that all sources used in the compilation are specific to the northern North Island of New Zealand, and although there is a lack of specific information for the lower North Island, it is assumed that these are appropriate for the site.

The local soils were identified as sandy recent, sandy brown and sandy gley. These soil types cross-over between typical properties of 'Hydrological Soil Group A' and 'Hydrological Soil Group B' (HSG A/HSG B). This group is characterized by high initial infiltration values and relatively low continuing infiltration and porosity. The higher initial infiltration value partly incorporates initial and continuing losses from pasture landcover. The values applied to the model for soil infiltration parameters are presented in Table 4. The low continuing infiltration loss value is representative of the drainage properties for the sandy brown/gley soils of the site, under which is a layer of Holocene Swamp Deposits (SLR, 2024). These deposits act to slow drainage of infiltrated rainfall and can lead to waterlogging in some parts of the site.

Table 4. Applied soil infiltration parameters.

Soil Class	Initial Infiltration (mm)	Continuing Infiltration (mm/hr)	Porosity
HSG A/B (Sandy Recent)	40	8	0.30
HSG A/B (Sandy Brown/Gley)	20	3	0.40
Impervious	0	0	0

3.2.2.6 Structures

Seventeen culverts were included in the model (Figure 8). The culverts were located within or in the immediate vicinity of the site. These culverts were observed during the site visit, and where accessible, the diameter was measured. Based on observations and measurements, the culverts were represented in the model 1D domain as structures with various parameters including shape, slope, roughness, size, blockage and form loss applied. The culverts were cylindrical, made of PVC (aside from one steel culvert) and had diameters ranging from 225-600mm.

3.2.3 Model limitations and assumptions

In developing the rain-on-grid model, several assumptions were necessary which may affect the results. These include:

- Rainfall depth and temporal distribution is assumed homogenous across the entire model domain. That is, the amount and timing of rainfall applied to each grid cell is the same.
- Rainfall has been limited to the model domain. Any rain that might fall outside of this boundary and might contribute to flooding of the site, has been excluded. However, any effect of this has been minimised through setting the model domain to the extent of the catchment boundary as determined by the DEM. Rain which falls outside of the domain and flows into the domain area is therefore reliant on being captured in the hydrologic inflows applied at the model upstream boundaries.
- Roughness, rainfall losses and infiltration values were assigned to layers derived from a combination of the Land Cover Database (LCDB) for 2018, Fundamental Soils Layer, Land Information New Zealand (LINZ) data, analysis of 0.3 metre aerial imagery for 2021-22, and ground truthing during a site visit. Inaccuracies may persist in the layers, and changes might have occurred since they were last updated. Aerial imagery is also not up to date and is limited as a tool by resolution. Despite the

potential for inaccuracies, this is a standard approach that provides an acceptable level of confidence that conditions are reasonably well represented.

- Some culverts were measured during the site visit to inform modelling. These structures were not surveyed. Where culverts exist but their dimensions could not be obtained, hydraulic connections were added to the model by simply burning channels into the DEM through gully lines. The gully lines are likely to overestimate flow through culverts. Furthermore, there are likely some hydraulic connections that were missed because of uncertainty regarding their existence. As such, flowpaths and areas of ponding may not accurately represent the existing conditions, though are considered representative based on the available information at hand.

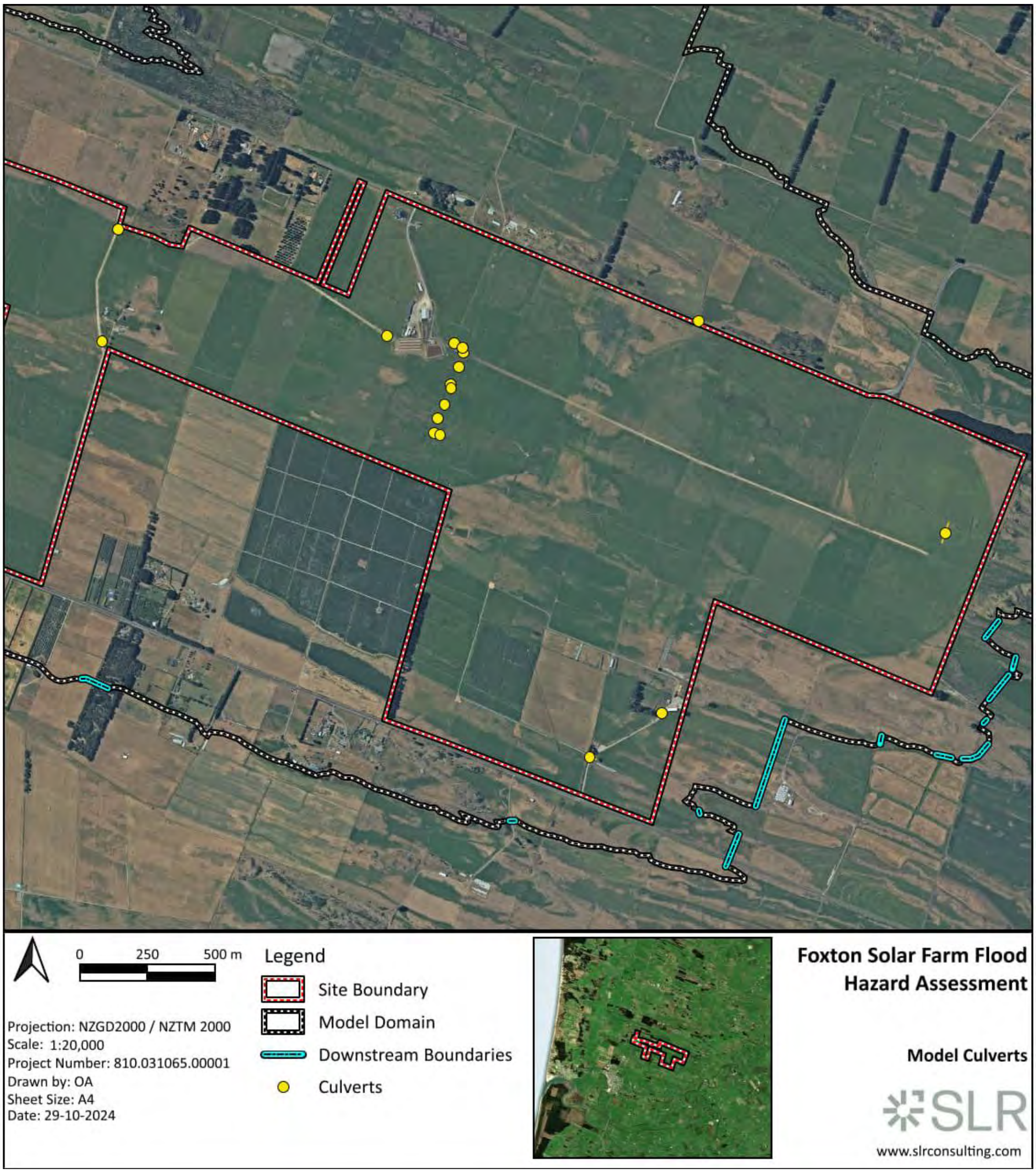

Figure 8. Model culverts.

3.3 Model sensitivity

During the development of the model, various parameters were modified and tested before values were finalized. The model was found to be sensitive to infiltration parameters, particularly initial infiltration which impacted the severity of flooding and changed the critical duration. High initial loss values were applied and compared to the moderate initial loss for the 1% AEP event. Continuing losses were kept the same. Using moderate initial losses increased depths slightly but flood extent was similar. Overall, the site still remains largely a low/moderate flood risk. High initial losses with low continuing losses were therefore used in the model as a result.

The model was also sensitive to culvert conveyance, with large open gully lines allowing more water through in initial model runs prior to the addition of culverts as 1-D structures. Hydraulic roughness did not appear to have a significant impact on flooding throughout the site.

It is important to recognise that development of the site has the potential to alter hydraulic characteristics and hydrodynamics, thereby impacting flood hazard.

3.4 Model validation

To validate the hydraulic model, the modelled 1% AEP peak flows for three drains downstream of the site were compared to flows estimated using the Rational Method calculation (Table 5). The Rational Method used the 1% AEP, 4-hour rainfall intensity, upstream catchment areas, with pasture grass cover and with a slope correction accounting for the flat terrain of less than 5%. Runoff coefficients to reflect high soakage (i.e. a runoff coefficient of 0.15) and moderate soakage (i.e. 0.25) have been compared. This comparison reflects the uncertainty in soakage rates of gravels and sands of the site.

Flows were also compared to estimates obtained from NIWA's River Flood Statistics for available reaches (Table 5).

The modelled 1% AEP peak flows aligned well with peak flows calculated using the Rational Method (+/-5% for each respective drain). Modelled flows were substantially higher than those generated by NIWA Flood Statistics, however, they were all within the upper limit of NIWA's standard errors associated with these values (Table 5). There is also some uncertainty inherent in the NIWA Flood Statistics flows, as inaccuracies in the delineation of catchments and connectivity of watercourses can often be found.

The modelled flows have been accepted based on their alignment with Rational Method calculations, and because they can be considered conservative with respect to NIWA's flood statistics.

Table 5. Model validation peak flow estimates. (Ranges represent values for high to moderate infiltration/soakage).

Site	Modelled (m^3/s)	Rational Method (m^3/s)	NIWA Flood Stats[1] (m^3/s)
Northeast Drain	1.88 – 2.19	1.79 –2.99	1.35 (+/-0.74)
Southeast Drain	2.23 – 2 .58	2.26 –3.76	1.51 (+/-0.83)
Southwest Drain	0.90 – 1.11	0.93 –1.49	0.81 (+/-0.45)

[1] NIWA Flood Statistics: https://niwa.maps.arcgis.com/apps/webappviewer/index.html?id=933e8f24fe9140f99dfb57173087f27d

To improve confidence in the validity and accuracy of results further information is necessary, though currently does not exist. This information could include real gauged and/or monitored data for flood events, and imagery of peak flood extents. Such data would allow for model calibration/validation to the observed flood extent.

4.0 Rain-on-grid model results

The TUFLOW rain-on-grid model was run for design rainfall depths for events with 20%, 10%, 5%, 2%, 1% and 0.5% Annual Exceedance Probability (AEP). A critical duration of 4-hours (established in Section 3.2.1) was applied.

For each design rainfall event, the peak flood depth and flow velocity across the solar farm site were mapped. These were used to identify areas and extents of pluvial flooding. Results have been output as 1m grids.

The model outputs, presented in Figure 9, Figure 10 and Appendix A, show the peak flood depths and flow velocities for each design rainfall event. As expected, because of the more extreme nature of the event, the greatest flood extent, depth and velocity results occur during the 0.5% AEP design rainfall. The subsequent analysis is thereby focused on this event, with the outputs shown in Figure 9 and Figure 10, but refers back to the smaller events presented in Appendix A.

The 0.5% AEP model results show widespread flooding across the site. The deepest and fastest flowing floodwaters onsite (ranging from depths of 0.5m to over 1m and from velocities of 0.2m/s to over 1m/s in the 0.5% AEP event) are typically contained within the various drains throughout the site.

Once floodwater is within one of the onsite drains, it typically remains within the banks. One significant breach, observed in all events larger than the 20% AEP, occurs at the downstream (eastern) end of the central drain (which runs along the southern side of the central access track) and connects to the northeastern drain via a culvert (see #8 in Figure 11). The drain overflows at this location due to increased water levels resulting from backwatering caused by the 90-degree bend in the drain and the limited capacity of the culvert which connects it to the northeastern drain. Floodwater coming out of the drain is, in places, over 0.5m deep and has a velocity exceeding 0.4m/s.

A second breach occurs in the drain in the north-eastern corner of the site where there is a natural depression in the topography along the course of the drain. Ponding occurs in all events at this location, with floodwaters in the larger events reaching ~0.6m.

Outside of the drains, flooding occurs as surface ponding in topographic depressions where no drainage paths exist to convey water away from these areas. In these areas, flooding is typically less than 250mm deep, though some areas have depths of between 250-500mm. These deeper areas of inundation exist where topographic depressions are more significant and on the upgradient sides of topographically raised features such as farm access tracks.

The timing of peak flood depths and velocities are reasonably consistent across the site and typically peak approximately three hours after the beginning of the storm event. This is logical as there is minimal floodwater attenuation within the catchment. Flooding is likely to come and go over a relatively short period of time.

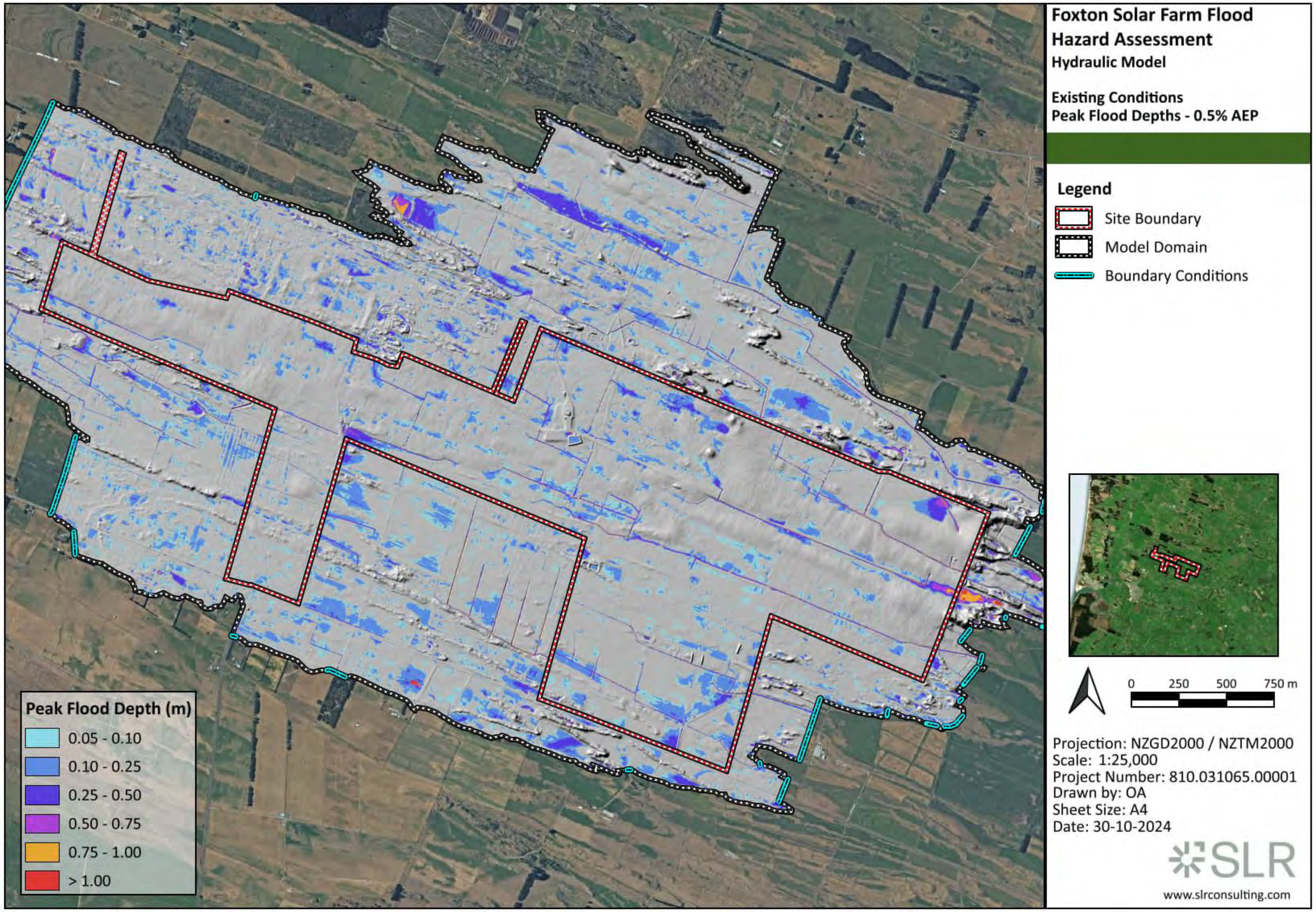

Figure 9. Modelled peak flood depths for the 0.5% AEP design rainfall event.

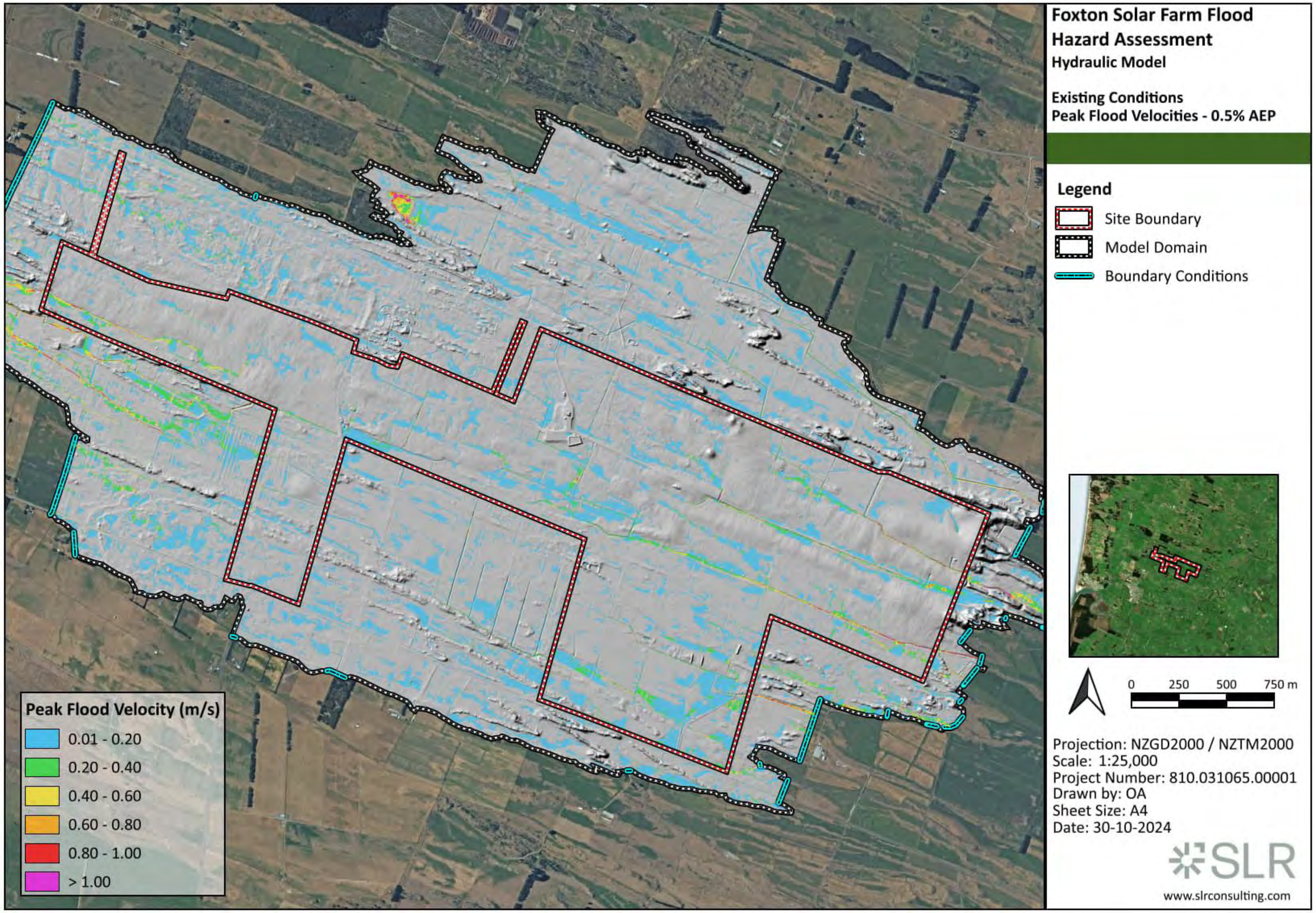

Figure 10. Modelled peak flood velocities for the 0.5% AEP design rainfall event.

5.0 Risk assessment

The risk criteria for the design of the solar farm, provided by Genesis, is based on the following flood depths and velocities:

- High risk – flood depths >0.5m or velocities >1m/s. Corrective actions would be required in these places.
- Moderate risk – flood depths are 0.3-0.5m or velocities of 0.5-1.0m/s. Although not specified by Genesis, SLR have applied this velocity for this risk class noting that they generally only occur within drains.
- Low risk – flood depths <0.3m or velocities <0.5m/s.

These criteria have been applied to the range of AEP events modelled to identify areas within the site with high, moderate or low flood risk. Figure 11 presents the outputs for this risk assessment for the 1% AEP event, with the remaining AEP events in Appendix B. Areas of moderate and high flood risk are denoted.

In the 20% AEP event, flood depths across the site are below 0.3m, i.e. low risk. There are some areas within the channels which have deeper floodwaters, but these are easily contained within the channel.

Flood risk increases at some locations as flood magnitudes increase, primarily in the north-eastern and eastern areas and around the dwelling in the central part of the site. These areas remain a moderate risk up to a 5% AEP (1 in 20-year) event.

From the 2% AEP event, the model results indicate a high flood risk in four locations, although the area of high risk is relatively small. The extent of the high risk areas at these four sites increases in a 1% AEP and 0.5% AEP event.

6.0 Mitigation options

Depending on the freeboard required for different infrastructure, some mitigation may be required. It is important to note that any change to the landform to address flood risk may affect overland flow paths and drainage upstream and/or downstream of intervention. In the first instance, areas of significant flood risk should be avoided. Where avoidance cannot be achieved, then interventions should be considered with respect to how they may impact hydrological response.

The proposed solar panels are expected to be mounted off the ground at a height of 1.762m when the panels are flat. At maximum tilt (60˚), the lowest edges of the panels would be 0.6m off the ground. Although most of the flood risk is below 0.3m in depth, smaller isolated areas indicate flooding could be up to 0.5m (#1 to #6 in Figure 11). In these areas, solar panels may need to be raised to ensure the lower edge of the panel at full tilt is clear of the predicted water level.

The inverter units and associated AC isolators are higher from the ground and therefore floodwaters pose a less significant threat, particularly since velocities are not fast.

There is a small narrow area (#6 in Figure 11) of deeper flood water (i.e. high risk) associated with a swale or minor drain. The water level in this location does not exceed 0.65m. Modelling has indicated this high risk zone is 50m long, though it is generally not wider than 5m. Therefore, the panels could potentially span this section. This deeper flooding is because the ground level is approximately 0.4m lower than the surrounding topography. Should the height of the panel be determined based on the elevation of the surrounding terrain rather than the elevation within the channel then it is less likely to be impacted by these floodwaters. Alternatively, it may be possible to infill this depression and remove the flood risk.

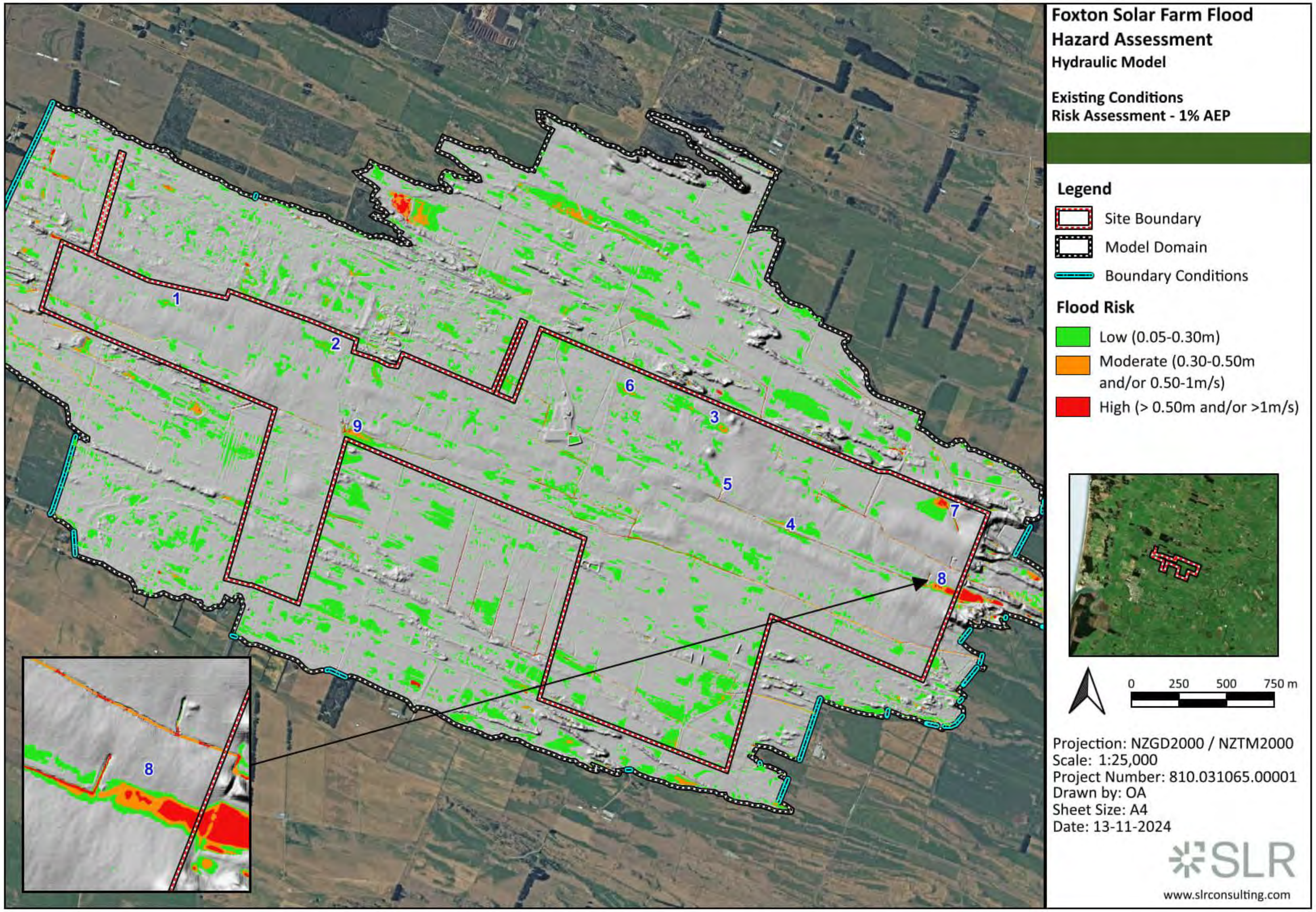

Figure 11. Risk assessment for the 1% AEP event, with areas of interest numbered.

The most significant areas of flooding are located in the eastern section of the site. Development should be avoided in these locations.

In the north-eastern corner of the site (#7 in Figure 11) a natural depression intersects with a drain. This is an area surrounded by higher elevation dunes with no natural overland flow path to drain water away. A potential mitigation option could include smoothing the terrain to enable water to flow more easily toward the drain. This could also include increasing the size of the drain to allow flow to be conveyed more quickly from this depression. However, it should be noted that this drain was not clearly evident in the terrain model and therefore some assumptions about its size and capacity had to be made. The capacity of this drain may be under- or over-estimated.

The drain along the southern margin of the central access track flows eastward before turning sharply (at 90˚) and discharging via the drain to the north. The drain overflows at this location due to increased water levels resulting from backwatering caused by the 90-degree bend in the drain and the limited capacity of the culvert (#8 in Figure 11). The area to which the drain overflows is a natural depression with no obvious overland flow path for water to discharge to. Therefore, ponding occurs at this location irrespective of the overflow from the drain. Further investigation to determine appropriate sizing of the culvert and mitigation measures is advised.

Mitigation options for this location include replacing the 90˚ bend with a more gradual curved bend to reduce flow resistance and allowing water to pass through more smoothly and reducing turbulence at that point in the drain. Increasing the size of the culvert to allow more water to be conveyed may also help. Additionally, a bund around the southern and eastern bank of the drain would help to contain water within the channel, however, there is a risk that it could spill out onto the western side of the drain. This bund would prevent water from spilling into the area which ponds to the east. Although modifications to the terrain could help reduce water level at this location, making it more suitable for solar panels, consideration would need to be given to the effect this would have on the neighbouring downstream property.

The final location is the area of moderate to high risk in the central part of the site (#9 in Figure 11). This area is within the exclusion zone so should have no impact of the placement or design of the solar farm.

The current indicative placement of the BESS and substation appear to be outside any significant flood risk, although a satisfactory buffer from the waterway is still recommended.

Some drains could potentially be infilled, which could mean that flooding exists as shallower, lower velocity sheet flow. However, it will alter the drainage dynamics of the site which could potentially transfer the flood hazard to other areas of the site or potentially downstream. Any changes to the landform to reduce flood risk should be carefully considered

For all drains, a maintenance schedule for routine and post-flood event clearing of drains and culverts should be implemented.

7.0 Conclusion

A flood hazard assessment has been conducted for a proposed solar farm near Foxton. This assessment involved the development of two TUFLOW computational hydraulic models. A high-level fluvial model was built to assess the potential for the site to impacted by overbank flow from a flood event in the Manawatū River, and a detailed rain-on-grid model was developed to assess the flood risk resulting from direct rainfall over the site and immediate catchment. The fluvial model assessed only the flood risk for a 0.5% AEP event in the Manawatū River while the rain-on-grid model provided information on the likely extent, depth and velocity of flooding resulting from 20%, 10%, 5%, 2%, 1% and 0.5% AEP design storm events.

Based on the existing topography and model assumptions, the flood hazard assessment concluded that:

- There is no modelled flood risk to the site from a 0.5% AEP or smaller flood event in the Manawatū River east of the site;
- The site is generally considered to be low risk, defined as flooding <250mm deep and velocity <0.5m/s. Hazardous floodwater (deep and/or high velocity) is typically confined to drains, except where it breaches the banks at two locations in the east;
- Flooding outside of drains generally occurs in isolated areas such as on the upgradient sides of farm access tracks or in topographic depressions. Most flooding outside of channels is relatively shallow (<250mm) and low velocity (<0.2m/s);
- Specific mitigation options for those areas modelled as high risk (depths exceeding 0.5m and/or velocity greater than 1m/s) include avoidance, terrain smoothing, increasing channel capacity, smoothing sharp bends in drains, modifying the terrain to prevent water spilling out from the drains or allow water to flow more easily toward drains, and maintenance of drains to remove excess vegetation. Increasing flow conveyance through drains may result in adverse effects elsewhere.
- In the small areas considered to have a moderate flood risk (depths exceeding 0.3m and/or velocity greater than 0.5m/s), or where the high risk encompasses a relatively small area, infrastructure should be raised to ensure it remains out of the predicted water level. In some areas, the panels could span areas of deeper water within channels with the height of the panels based on surrounding terrain, rather than the base of the channel.

Ideally, development should be avoided in areas of high risk. However, where this cannot be avoided, it should be noted that any changes to the landform to address flood risk may affect the hydrological response and risk classification at areas upstream and/or downstream of the intervention. These should be explicitly considered during detailed design. Further, new consents may have a hydraulic neutrality requirement to prevent increases in runoff that may worsen the flood risk to upstream or downstream users.

It is important to recognise that this assessment, and therefore the results, are affected by several assumptions and limitations. These must be acknowledged when using these results. Following refinement of the design and sizing of stormwater infrastructure, the TUFLOW model could be rerun with these changes to reassess the risk to solar infrastructure.

8.0 References

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9.0 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via https://www.slrconsulting.com/en/feedback. We recognise the value of your time and we will make a $10 donation to our Charity Partner - Lifeline, for every completed form.

Appendix A Rain-on-grid Model Results

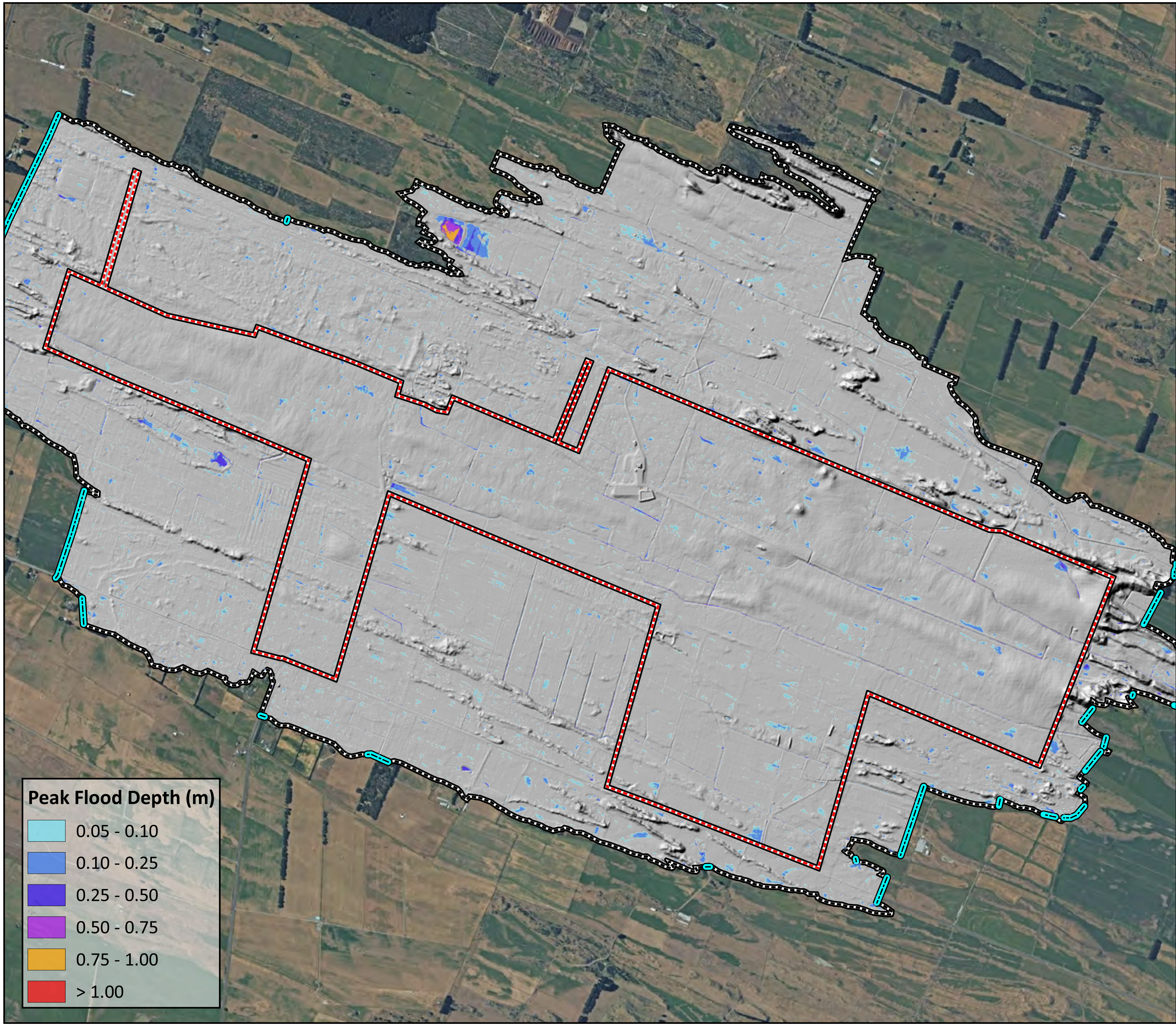
Hydrological and hydraulic modelling assessment

Foxton Solar Farm

Genesis Energy Limited

SLR Project No.: 810.031065.00001

8 December 2025



Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Depths - 20% AEP

APPENDIX A1

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
Date: 31-10-2024

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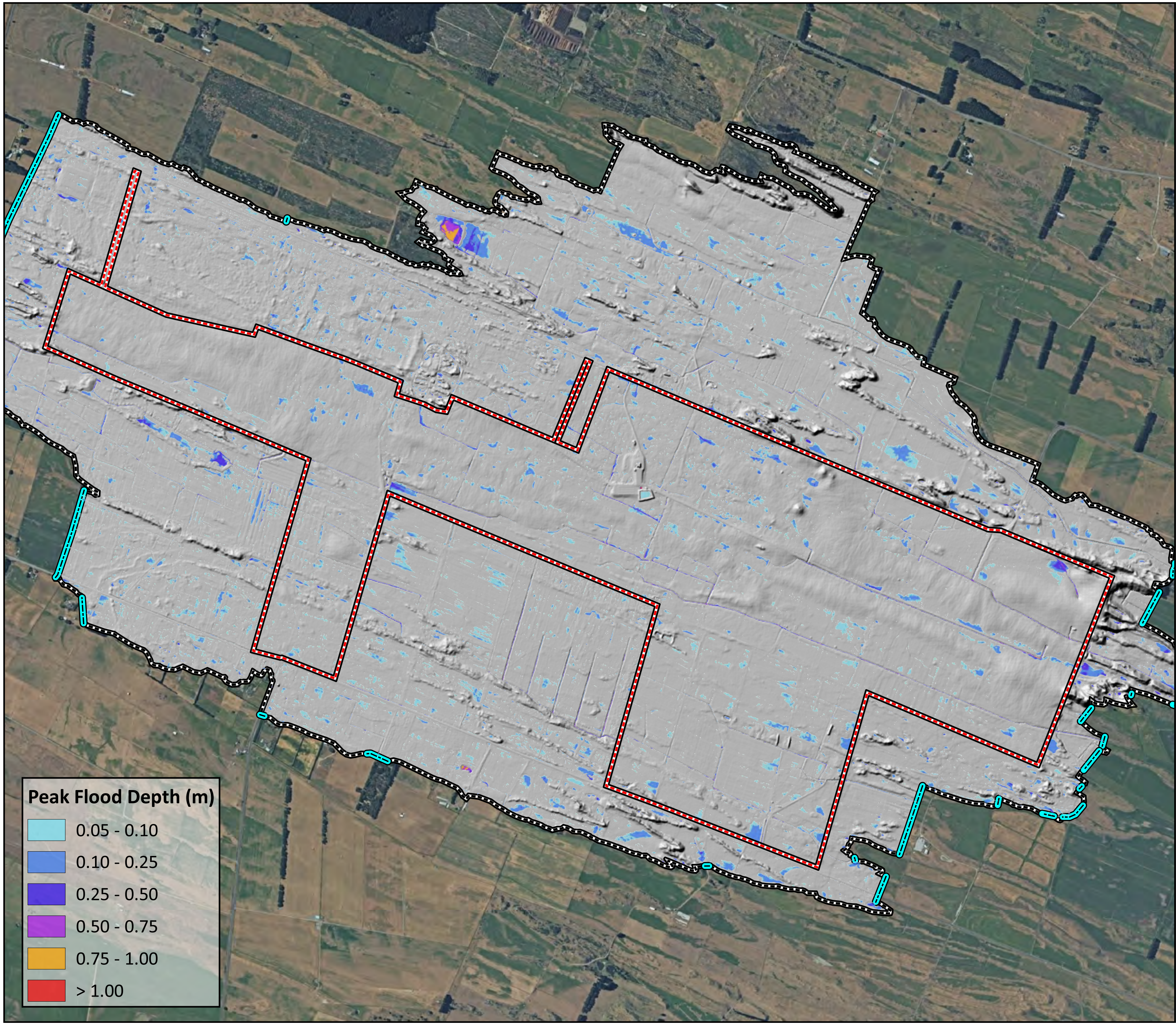
Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Depths - 10% AEP

APPENDIX A2



Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
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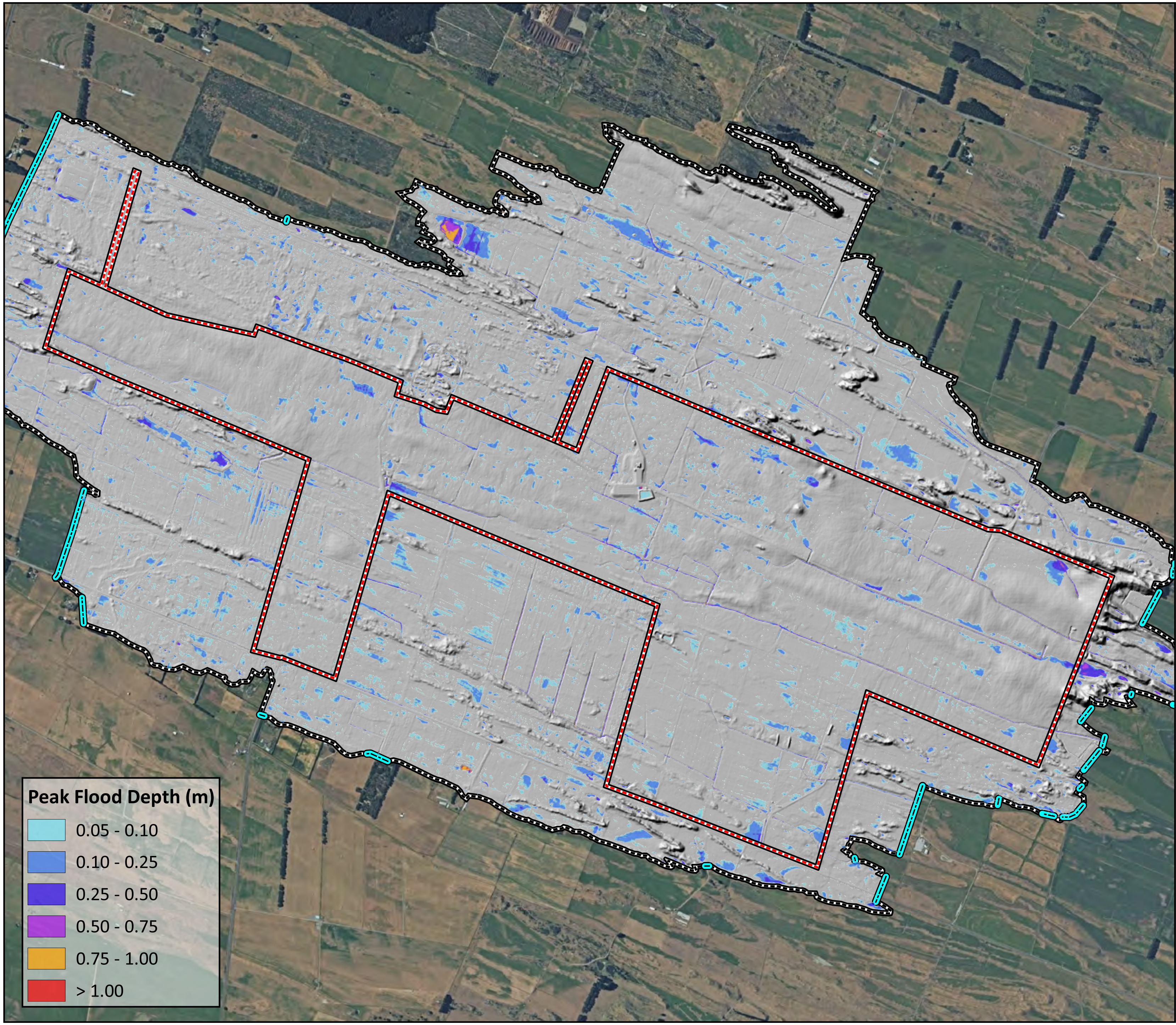

Foxton Solar Farm Flood Hazard Assessment
Hydraulic Model

Existing Conditions
Peak Flood Depths - 5% AEP

APPENDIX A3

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
Date: 31-10-2024

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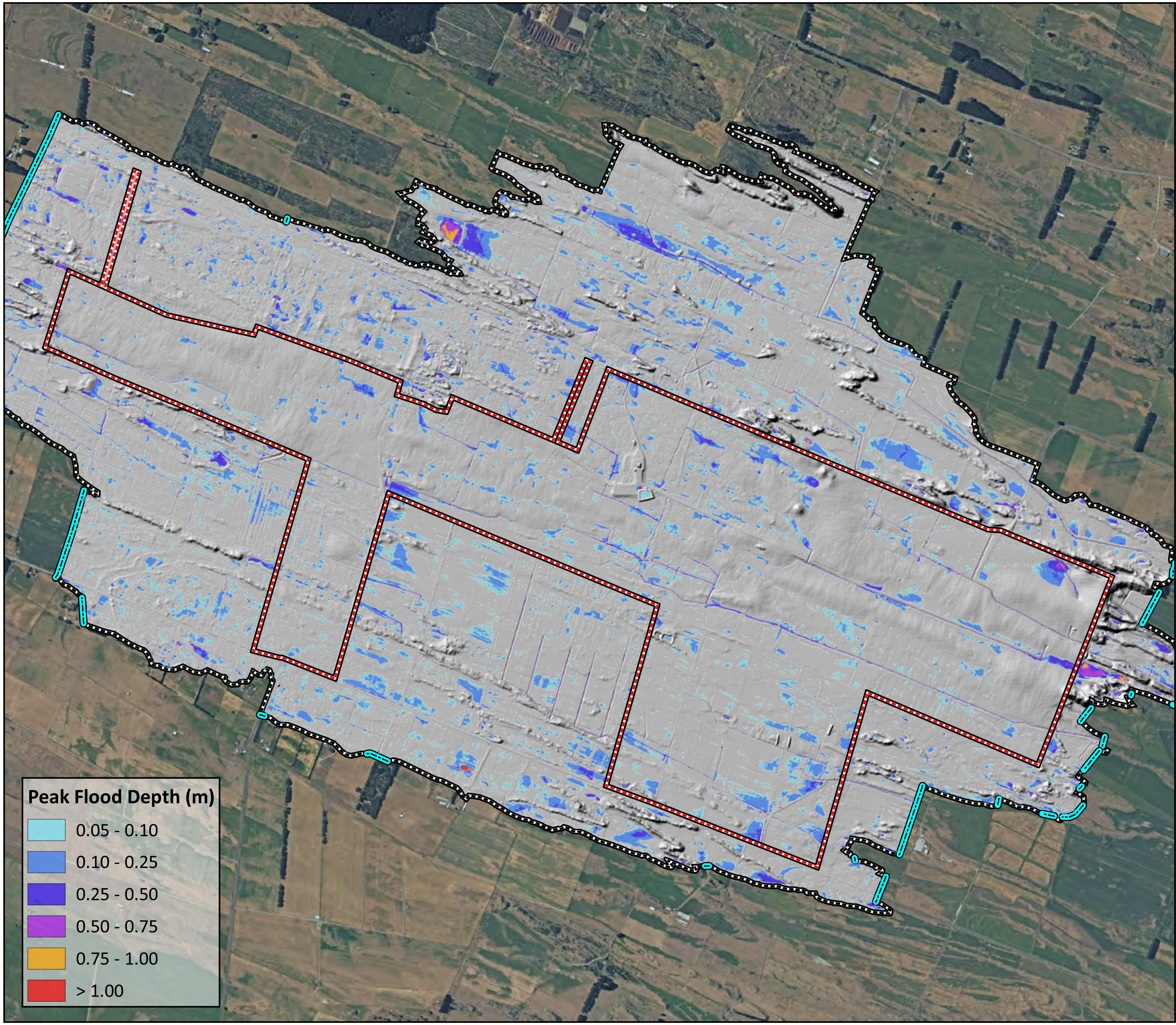
Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Depths - 2% AEP

APPENDIX A4



Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
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Date: 31-10-2024

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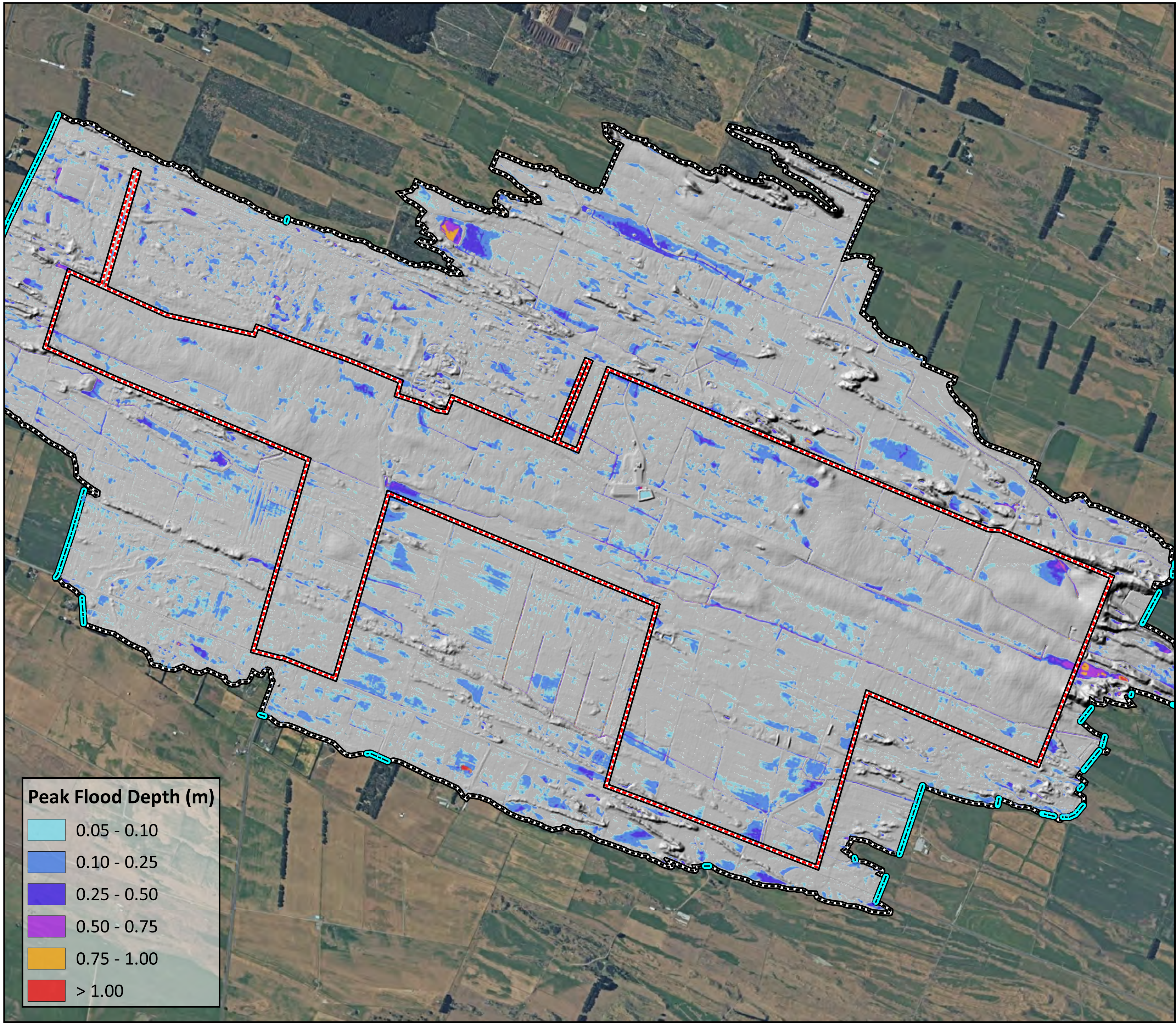


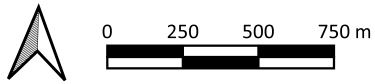
Foxton Solar Farm Flood Hazard Assessment
Hydraulic Model

Existing Conditions
Peak Flood Depths - 1% AEP

APPENDIX A5

Legend

- Site Boundary
- Model Domain
- Boundary Conditions



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Date: 31-10-2024

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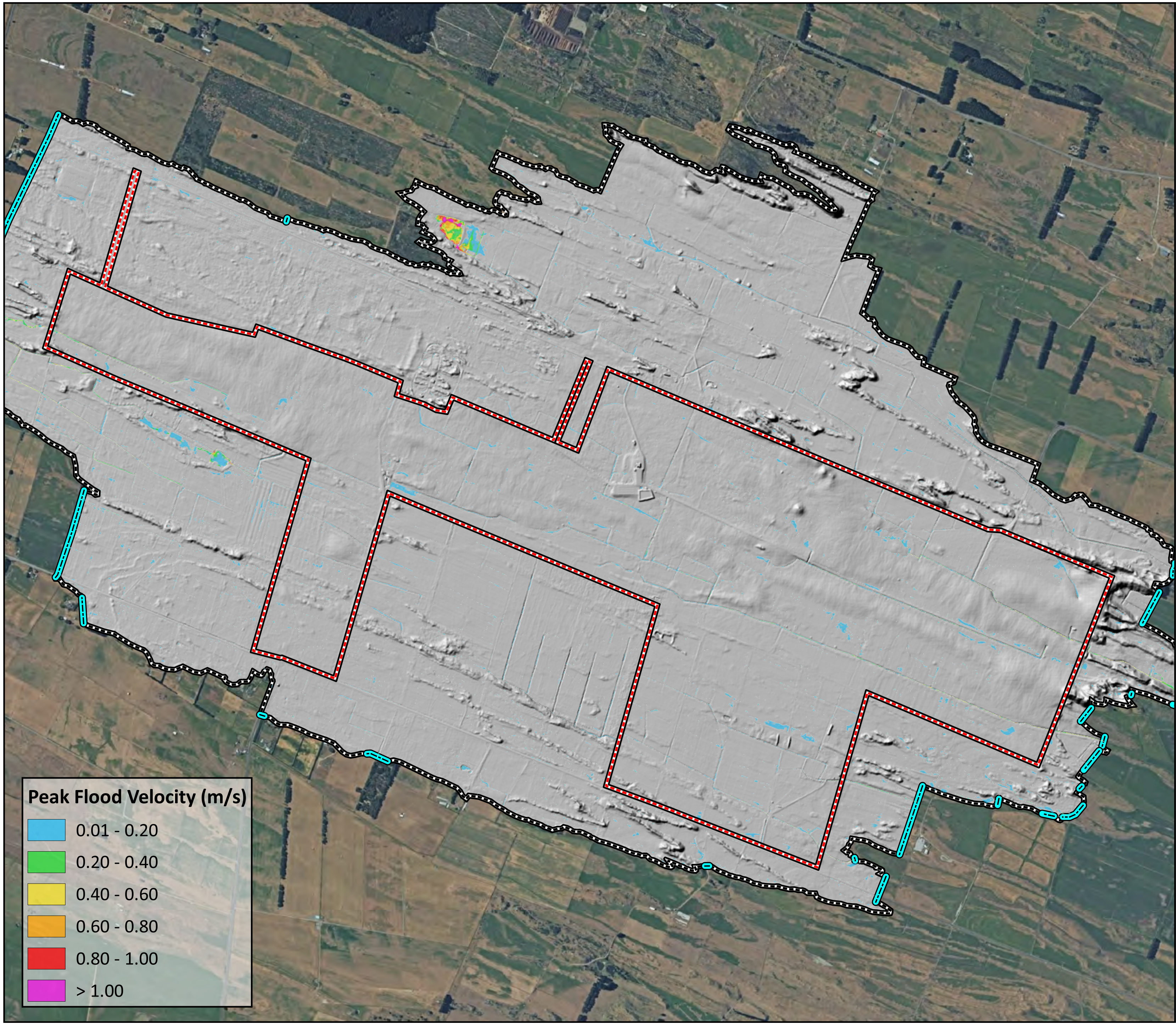
Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Velocities - 20% AEP

APPENDIX A6



Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
Date: 31-10-2024

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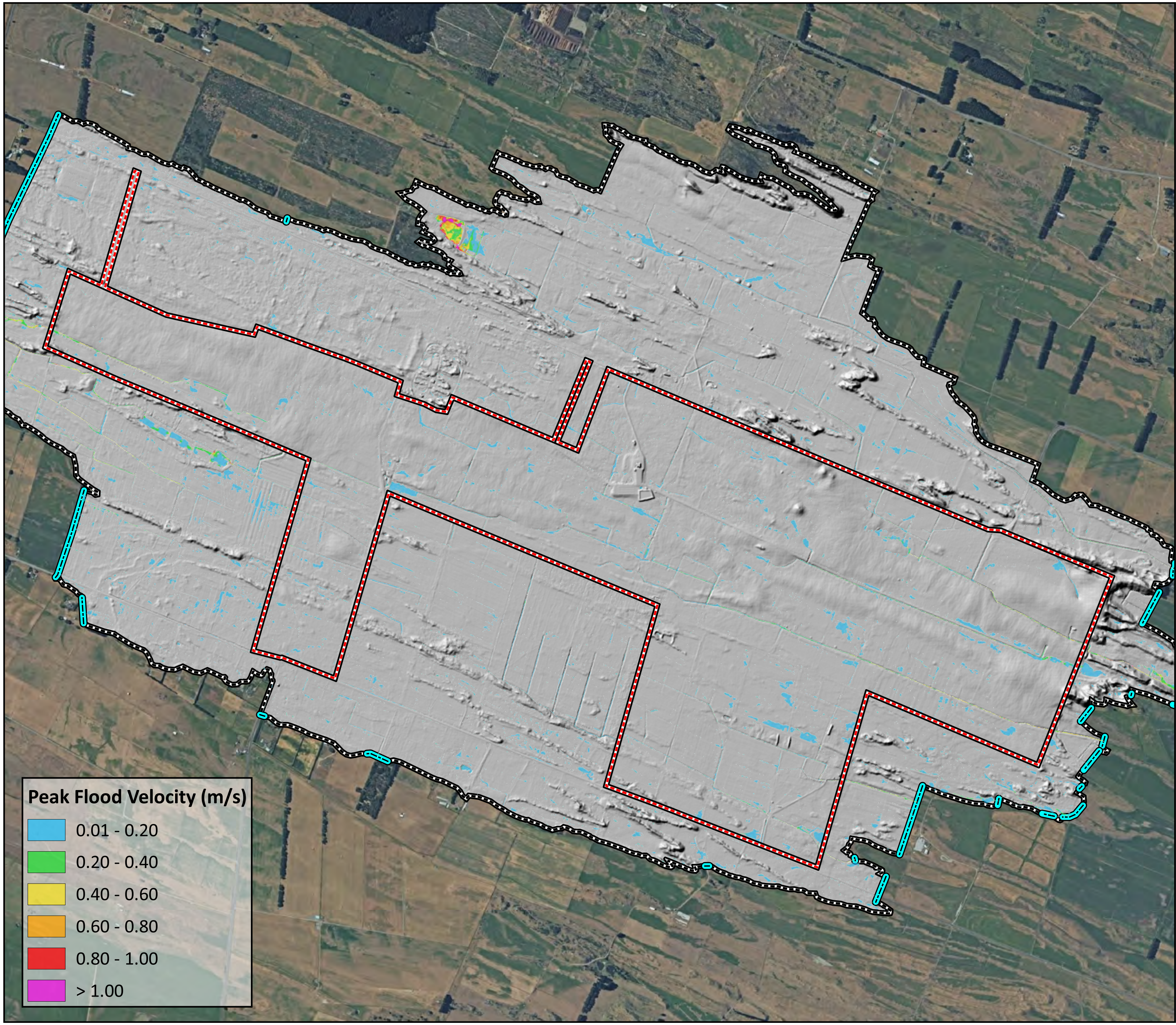
Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Velocities - 10% AEP

APPENDIX A7



Legend

- Site Boundary
- Model Domain
- Boundary Conditions

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Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
Date: 31-10-2024

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Foxton Solar Farm Flood Hazard Assessment

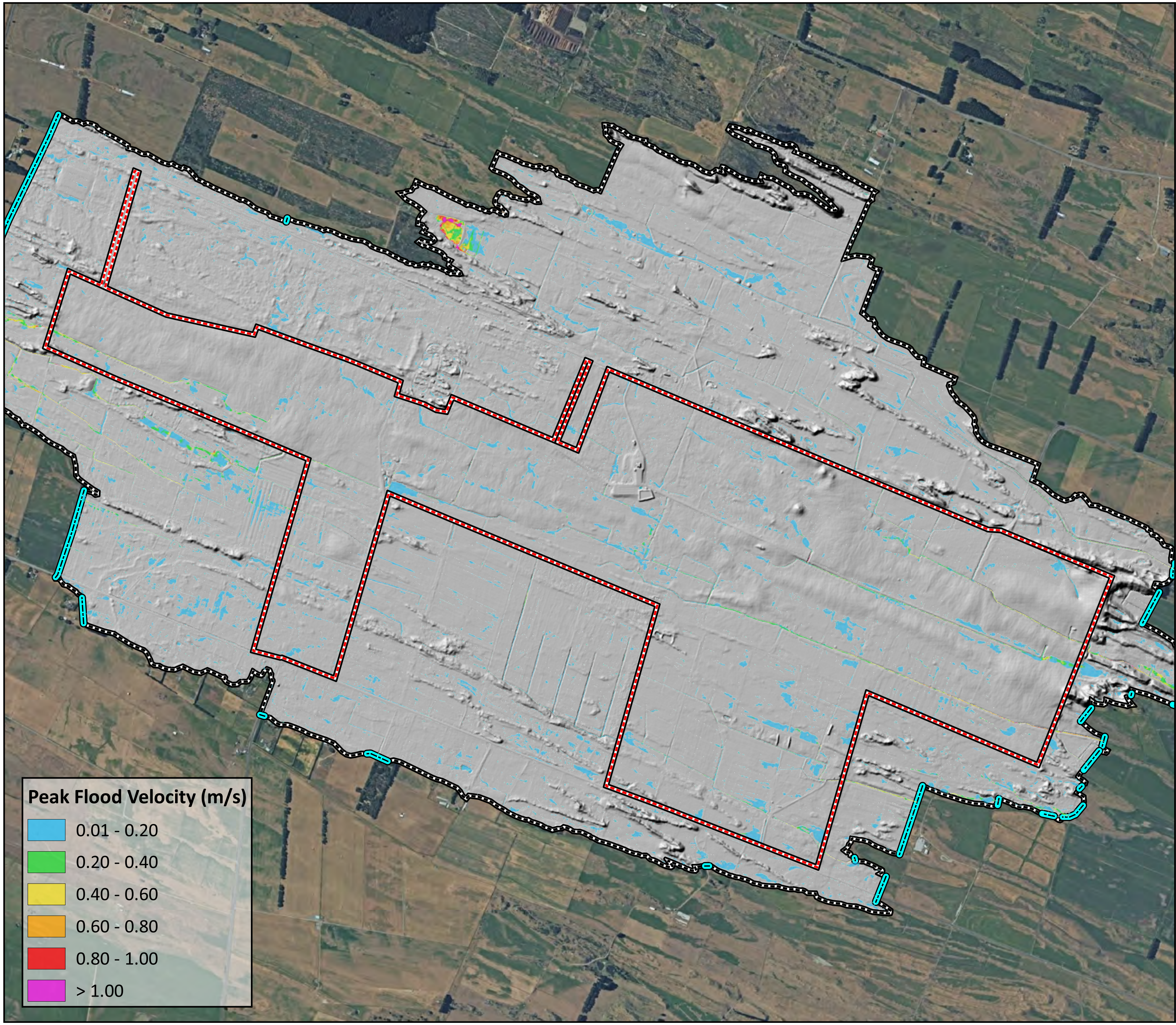
Hydraulic Model

Existing Conditions
Peak Flood Velocities - 5% AEP

APPENDIX A8

Legend

- Site Boundary
- Model Domain
- Boundary Conditions



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Scale: 1:25,000
Project Number: 810.031065.00001
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Date: 31-10-2024

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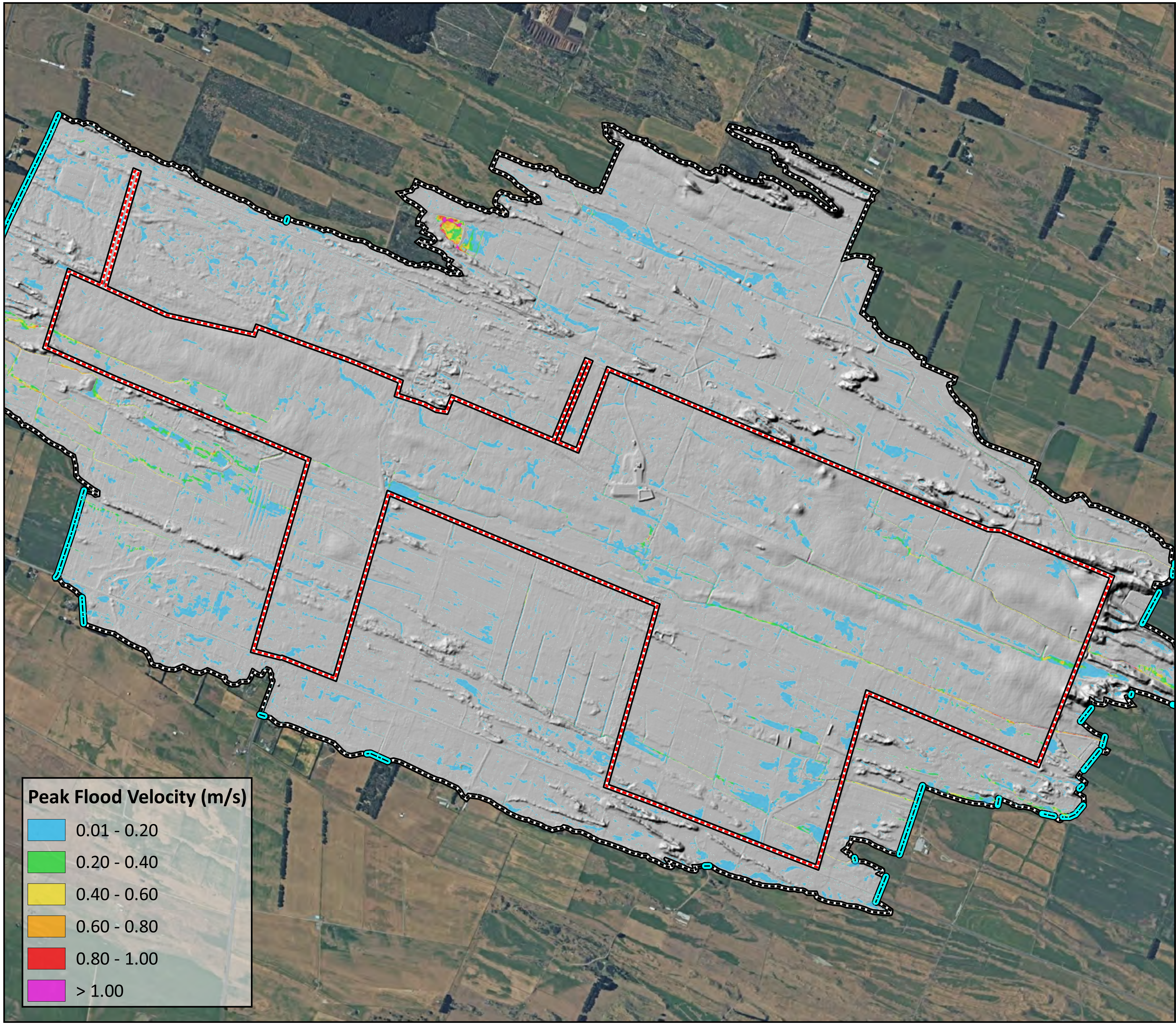
Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Peak Flood Velocities - 2% AEP

APPENDIX A9



Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
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Project Number: 810.031065.00001
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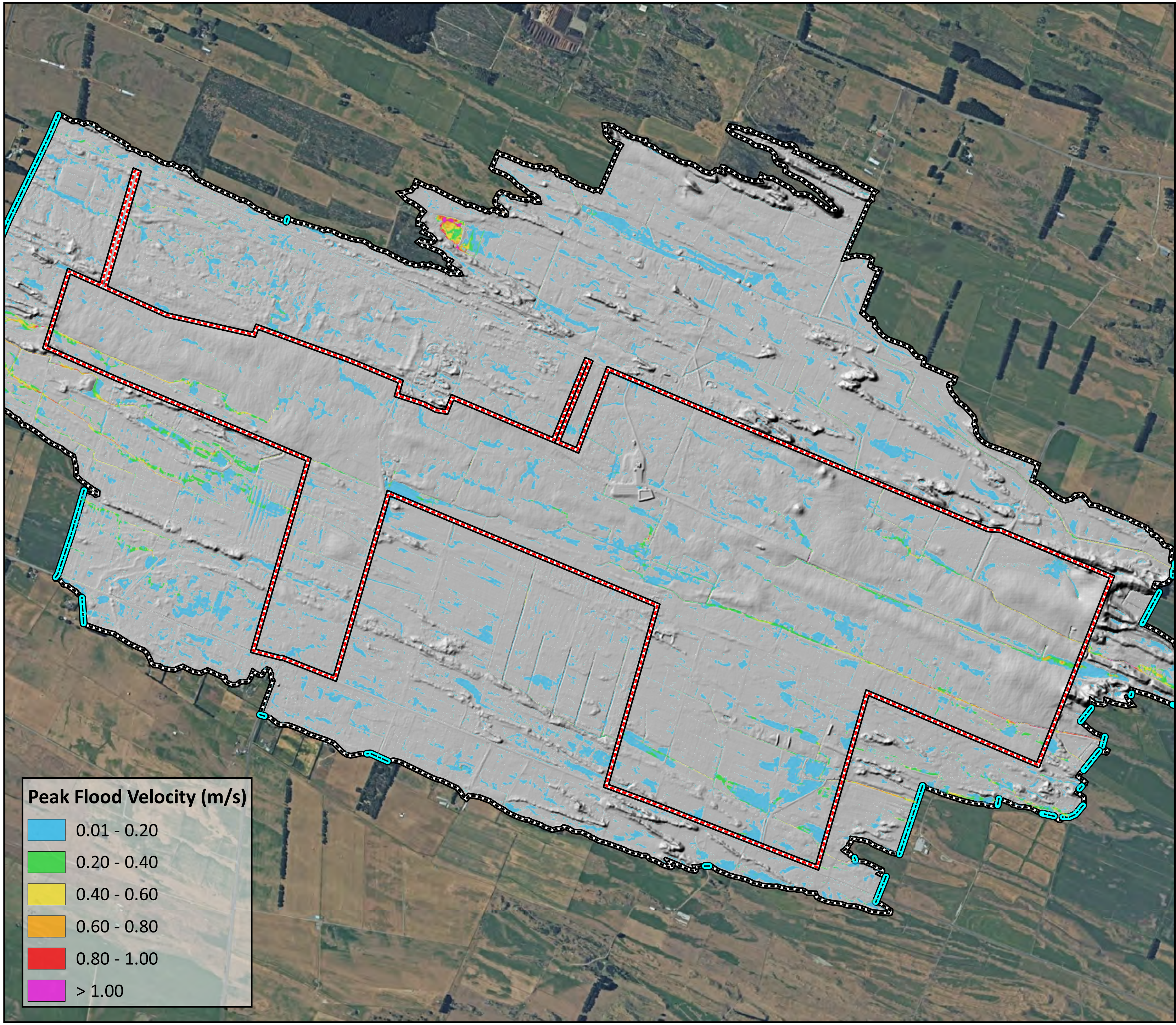

Foxton Solar Farm Flood Hazard Assessment
Hydraulic Model

Existing Conditions
Peak Flood Velocities - 1% AEP

APPENDIX A10

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
Date: 13-11-2024

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Appendix B Risk Assessment

Hydrological and hydraulic modelling assessment

Foxton Solar Farm

Genesis Energy Limited

SLR Project No.: 810.031065.00001

8 December 2025

Foxton Solar Farm Flood Hazard Assessment
Hydraulic Model

Existing Conditions
Risk Assessment - 20% AEP

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

Flood Risk

- Low (0.05-0.30m)
- Moderate (0.30-0.50m and/or 0.50-1m/s)
- High (> 0.50m and/or >1m/s)

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
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Date: 11-11-2024

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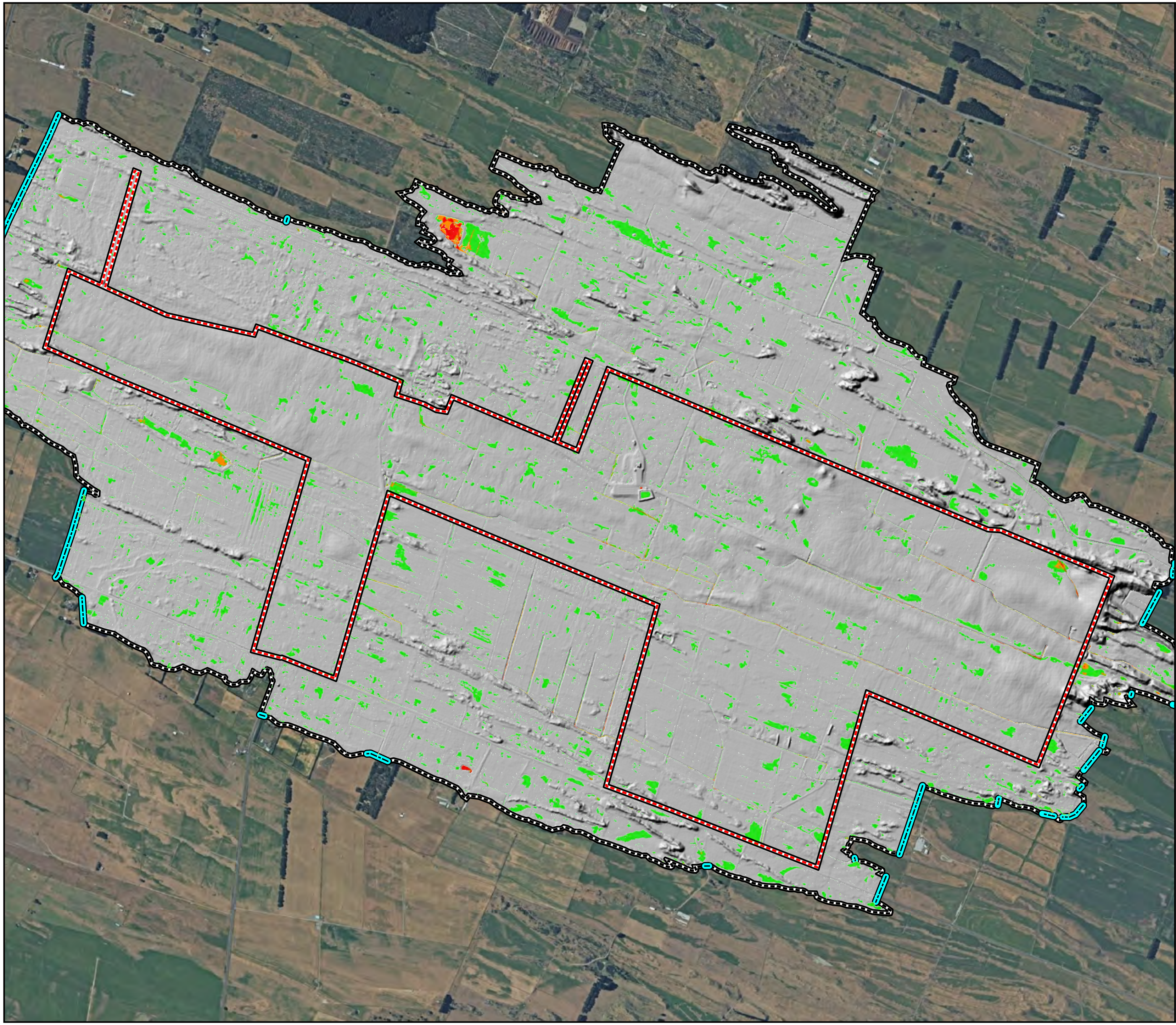

Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Risk Assessment - 10% AEP

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

Flood Risk

- Low (0.05-0.30m)
- Moderate (0.30-0.50m and/or 0.50-1m/s)
- High (> 0.50m and/or >1m/s)

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
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Sheet Size: A4
Date: 11-11-2024

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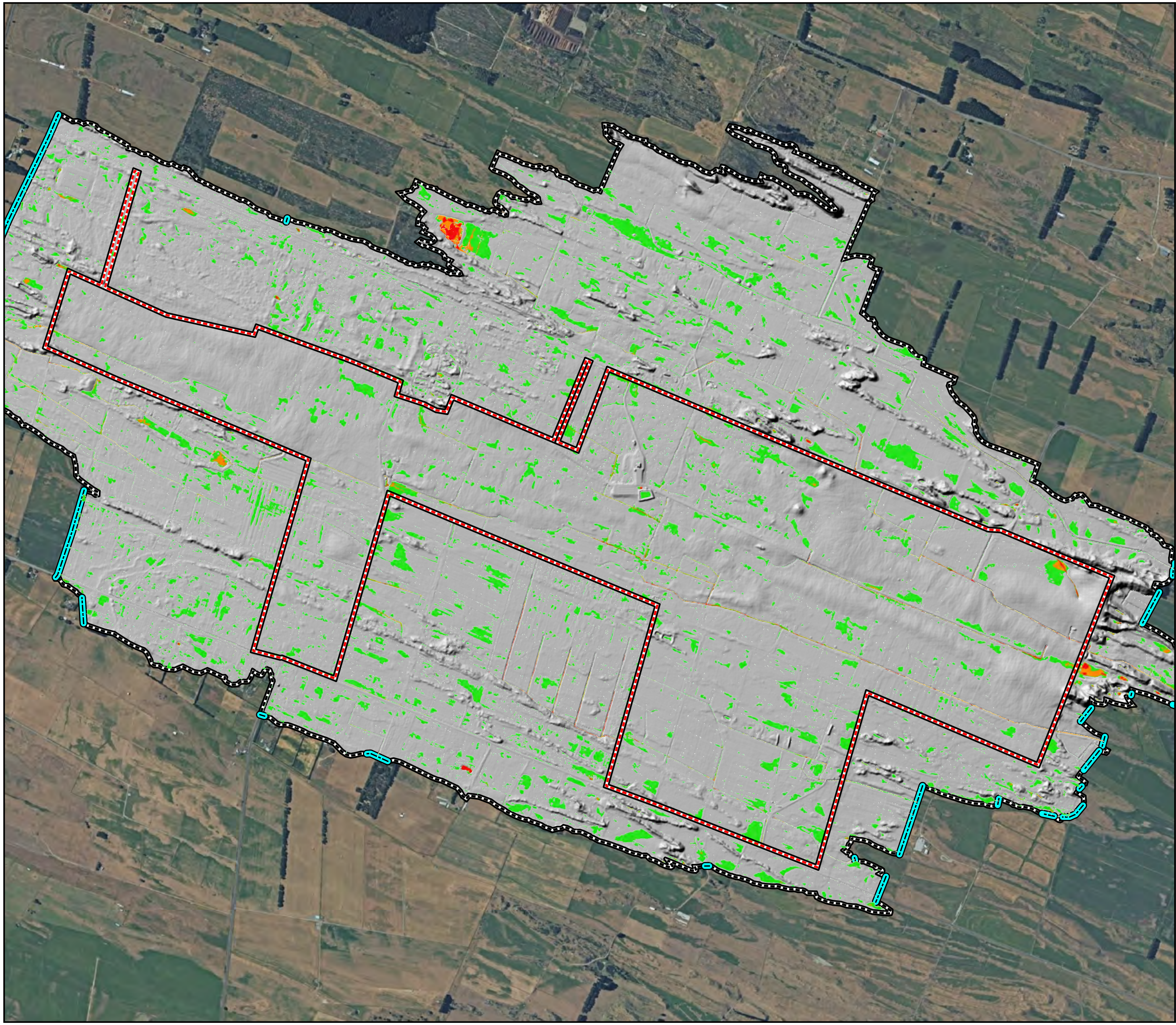

Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Risk Assessment - 5% AEP

Legend

Site Boundary
Model Domain
Boundary Conditions

Flood Risk

Low (0.05-0.30m)
Moderate (0.30-0.50m and/or 0.50-1m/s)
High (> 0.50m and/or >1m/s)

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
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Date: 11-11-2024

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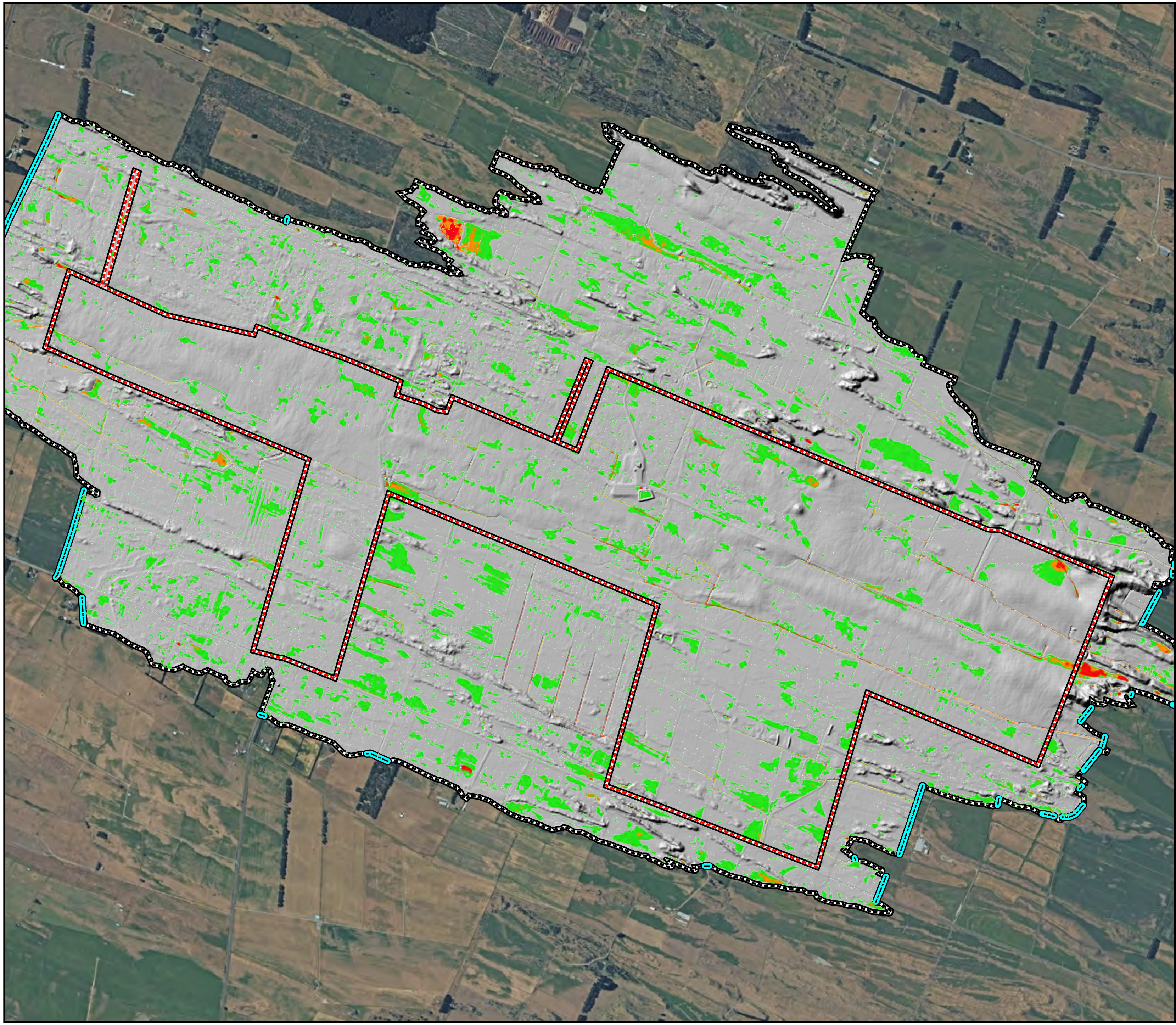

Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Risk Assessment - 2% AEP

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

Flood Risk

- Low (0.05-0.30m)
- Moderate (0.30-0.50m and/or 0.50-1m/s)
- High (> 0.50m and/or >1m/s)

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
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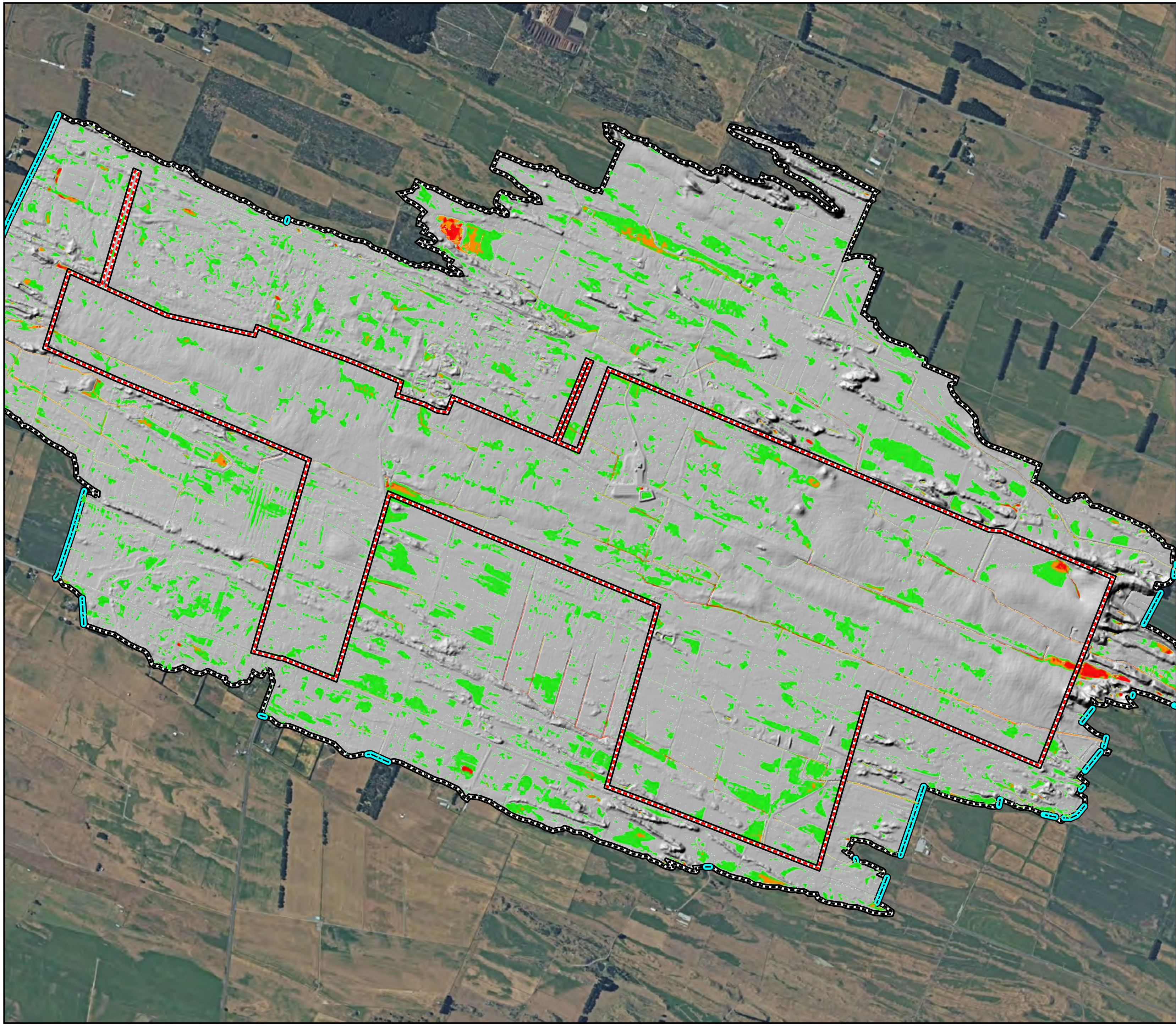

Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions
Risk Assessment - 1% AEP

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

Flood Risk

- Low (0.05-0.30m)
- Moderate (0.30-0.50m and/or 0.50-1m/s)
- High (> 0.50m and/or >1m/s)

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
Scale: 1:25,000
Project Number: 810.031065.00001
Drawn by: OA
Sheet Size: A4
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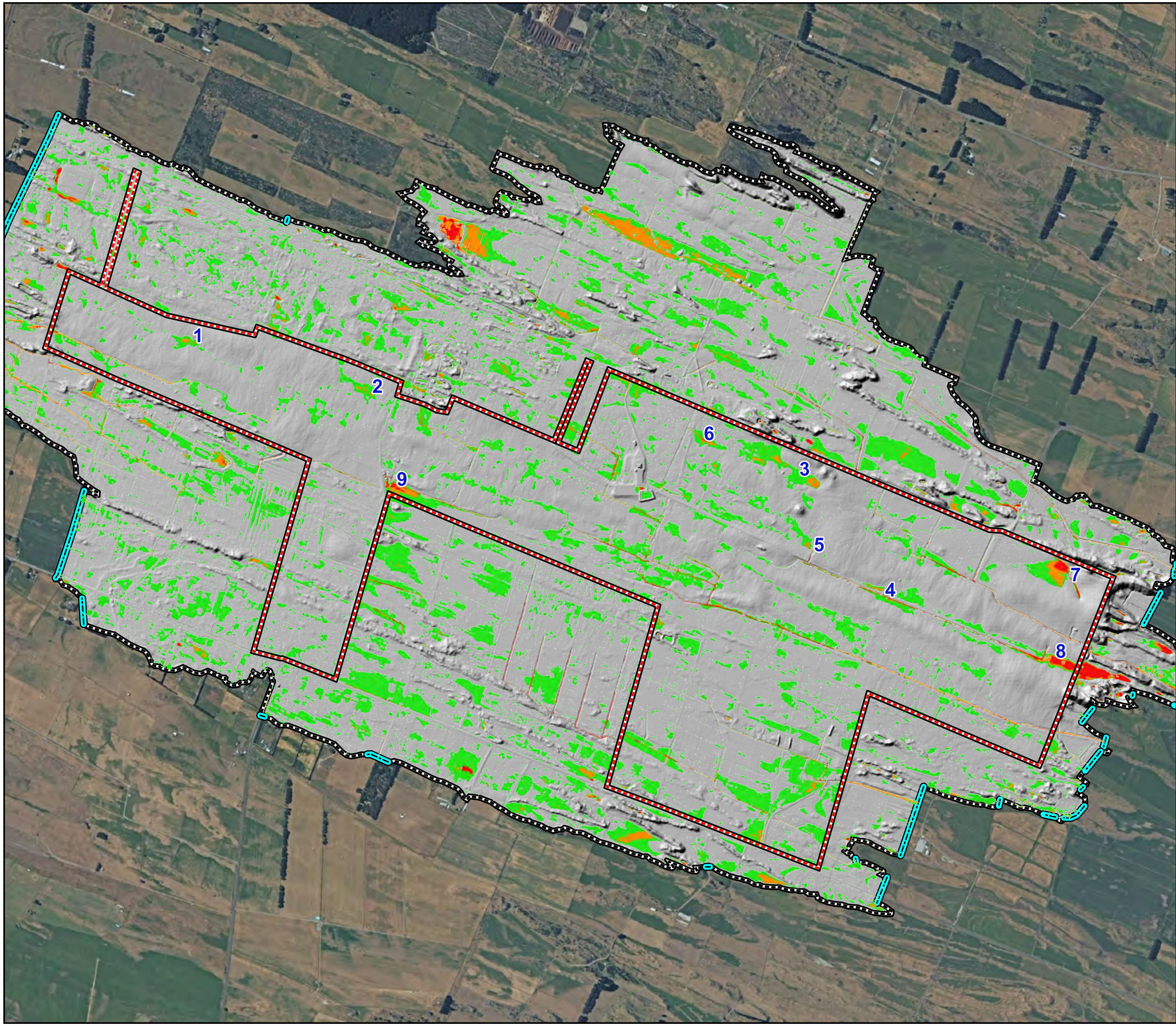

Foxton Solar Farm Flood Hazard Assessment

Hydraulic Model

Existing Conditions

Risk Assessment - 0.5% AEP

Legend

- Site Boundary
- Model Domain
- Boundary Conditions

Flood Risk

- Low (0.05-0.30m)
- Moderate (0.30-0.50m and/or 0.50-1m/s)
- High (> 0.50m and/or >1m/s)

0 250 500 750 m

Projection: NZGD2000 / NZTM2000
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