Lake Way

Flood Modelling Report

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Executive Summary

Salt Lake Potash (SO4) propose to undertake sulphate of potash mining activities at Lake Way, Wiluna. SO4 have engaged Emerge Associates (Emerge) to prepare hydrological and hydraulic modelling of Lake Way and its contributing catchments. The primary purpose of the modelling is to provide a comparative assessment, and to measure the likely impact, of a number of proposed development scenarios (Demonstration Project with 691 ha of evaporation ponds and Full Project with 2,206 ha of evaporation ponds and stockpiles) on the peak flood elevation within Lake Way.

The modelling by Emerge has been conducted in consideration of key hydrological factors relevant to Lake Way. These include:

- Upstream catchment inflows (driven by catchment parameterisation and calibration)
- Rainfall on Lake Way
- Evaporation
- Infiltration (and the effects of development on infiltration capacity)
- Flow routing throughout Lake Way (2D surface water modelling)
- Infrastructure related to proposed development scenarios.

The 1D-2D modelling of Lake Way was conducted for the Pre-development, Demonstration Project and Full Project scenarios, for the 1% AEP, 20% AEP and 63.2% AEP design rainfall events. The resulting peak flood elevations are summarised in **Table E1**.

Table E1: Summary of peak flood elevation within Lake Way under various development scenarios and rainfall events

Modelling scenario	Peak flood elevation (m AHD)	Peak flood elevation relative to Pre-development (mm)
63.2% AEP design event		
Pre-development	490.445	-
Demonstration	490.445	0
Full Project	490.445	0
20% AEP design event		
Pre-development	490.579	-
Demonstration	490.578	-1
Full Project	490.579	0
1% AEP design event		
Pre-development	491.719	-
Demonstration	491.745	+26
Full Project	491.787	+68

As shown in **Table E1**, the modelling has identified that in the small and minor rainfall events (63.2% AEP and 20% AEP) there is no material change in the overall flooding elevations within Lake Way under any development scenario. There is however some minor localised redistribution of flooding due to the direct loss of flood storage within low-lying areas (western evaporation ponds and excess salt areas).

There are minor changes in peak flood elevation under the Demonstration and Full Project development scenarios in the 1% AEP event (an increase of 26 mm and 68 mm respectively). The rise in 1% AEP peak flood elevation in the post-development scenarios can be attributed to the direct loss of flood storage due to the development infrastructure, however is somewhat offset by the increase in infiltration capacity resulting from brine extraction.

The flood modelling has been based on the information available for Lake Way and surrounding catchments. It uses an approach consistent with the methodologies discussed in *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Ball J *et al.* 2019) and uses the latest investigative tools available (i.e. 1D-2D surface water modelling).

As a comparative assessment there is a high degree of confidence in the findings of this investigation. However, both the DEM and the calibration datum (derived from Cyclone Bobby, February 1995, the most recent major flood event for which rainfall and inundation data exists) have a broad accuracy of +/- 100 mm. Therefore, results of the modelling (i.e. flood elevation derived from observations made in 1995) assessed in isolation or against fixed points should be considered in the context of the reasonable accuracy of the aforementioned key modelling inputs. The relative change in flood elevation (i.e. the difference between development scenarios) is not expected to be impacted by these inputs as they remain consistent throughout all of the simulated scenarios.

The contributing catchment runoff assumptions could be further refined by monitoring of key locations within the relevant catchments, thus providing additional calibration data. However, this will provide little value to the assessment of peak flood inundation on the Lake Way playa, as this has been calibrated against an observed major rainfall/flood event. The approach adopted by Emerge is appropriate to the purposes of the modelling, the scale and location of the site and catchments, and provides an accurate comparative analysis tool that illustrates the potential impacts on the peak flood elevation in Lake Way under various development scenarios.

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Abbreviation Tables

Table A1: Abbreviations – Organisations

Organisations	
AR&R	Australian Rainfall and Runoff
BOM	Bureau of Meteorology

Table A2: Abbreviations – General terms

General terms	
AEP	Annual exceedance probability
AHD	Australian height datum
ARI	Average recurrence interval
CL	Continuing loss
DEM	Digital elevation model
GIS	Geographical information systems
IFD	Intensity, frequency and duration
IL	Initial loss
LiDAR	Light/Laser detection and ranging
PL	Proportional loss
RFFE	Regional flood frequency estimate
SRTM	Shuttle Radar Topography Mission
TWL	Top water level

Table A3: Abbreviations – units of measurement

Units of measurement	
ha	Hectare
km	Kilometre
m	Metre
m AHD	Metres in relation to the Australian height datum
m/day	Metres per day
m^2	Square metre
m^3	Cubic metre
m^3/ha	Cubic metre per hectare
m^3/s	Cubic metre per second
m^3/s/ha	Cubic metre per second per hectare
mm	Millimetre
mm/hr	Millimetres per hour
°C	Degrees centigrade
%	Percentage

Table A4: Terminology - design rainfall

Equivalent average recurrence interval (ARI) terminology	Average exceedance probability (AEP) terminology utilised
1 in 1 year ARI event	63.2% AEP event
1 in 1.5 year ARI event	50% AEP event
1 in 5 year ARI event	20% AEP event
1 in 10 year ARI event	10% AEP event
1 in 20 ARI event	5% AEP event
1 in 50 ARI event	2% AEP event
1 in 100 ARI event	1% AEP event
1 in 200 ARI event	1 in 200 AEP event
1 in 500 ARI event	1 in 500 AEP event

1 Introduction

1.1 Description of the site and project

Salt Lake Potash (SO4) propose to undertake sulphate of potash mining activities at Lake Way, Wiluna. Lake Way is situated within the Shire of Wiluna, and is approximately 15 km south of the town of Wiluna. Lake Way is approximately 36 km long and 10 km wide, with a surface area of approximately 245 km^2. The Lake contains a number of islands, most of which are located in the southern portion of the Lake. The location of Lake Way is shown in **Figure 1**.

SO4 have engaged Emerge Associates (Emerge) to prepare hydrological and hydraulic modelling of Lake Way and its contributing catchments. Emerge have adopted a 1D-2D flood modelling approach which aims to represent the key hydrological and hydraulic characteristics of the Lake, including catchment runoff, direct rainfall, infiltration and evaporation.

As a part of the project, Emerge has reviewed previous investigations undertaken on and around Lake Way, as well as any additional and relevant studies, guidelines or resources (these are discussed in **Section 2**). These, as well as the professional judgement of Emerge hydrologists has formed the basis of the modelling.

1.2 Purpose for this report

The primary and overarching objective of the modelling described in this report has been to investigate the changes in flooding within Lake Way due to proposed developments with respect to the existing (pre-development) condition. The modelling seeks to quantify the impact (direct and indirect) attributable to certain proposed development scenarios (i.e. Demonstration Project with 691 ha of evaporation ponds and Full Project with 2,206 ha of evaporation ponds and stockpiles). The findings of this investigation provide an improved understanding of the dynamic hydrologic processes within Lake Way and will ultimately contribute to the assessment of the SO4 Lake Way project.

1.3 Project rationale

The SO4 Lake Way project involves construction of solar evaporation ponds, brine extraction trenches and excess salt stockpiles within the lake surface (playa). The surface runoff catchments for Lake Way are large, and peak flood volumes within the Lake are significant. The proposed infrastructure is expected to remove some of the flood storage capacity within the Lake, which could potentially result in an increase in the peak flood elevation.

There has been some hydrological analysis undertaken for Lake Way by Knight Piesold (2018, 2019) which identified the peak flood levels within Lake Way following various rainfall events (see **Section 2.1**). This work has provided a simple but clear comparison of the difference that could occur due to the construction of approximately 700 ha of evaporation ponds within the Lake playa. This previous modelling adopts various assumptions regarding contributing catchments, however has no representation of other processes (e.g. infiltration, evaporation, direct rainfall on Lake Way, etc.) which could affect the flooding dynamics within the Lake.

There is no existing (known) stream flow gauging or formal ongoing measurement of Lake volumes for a major rainfall event, making model calibration problematic. This study seeks to collate the available information and use this to determine possible catchment characteristics, with a focus on improving the representation of Lake Way flood characteristics and overall hydrologic regime.

The study is not intended to determine the refined catchment characteristics from each contributing catchment, nor how rainfall is routed through the upstream catchments. Rather, it focusses on the interaction of runoff once it reaches Lake Way and the potential impacts that could result from construction of infrastructure within the Lake playa.

2 Background review

2.1 Previous studies

The hydrological and hydraulic model of Lake Way and contributing catchments (i.e. this study) have been informed by the previous work undertaken for the project by Knight Piesold (KP) (2018, 2019). In addition to the work completed by KP, Emerge have reviewed work supporting other projects nearby or with similar site context to form a basis for the pre-development modelling inputs, assumptions and methodology. A summary of the key inputs/methods/conclusions of relevance to this study are provided in the following sections.

2.1.1 Wiluna Uranium Project Surface Hydrology Studies (RPS 2015)

The following items from the RPS Wiluna Uranium Project Hydrology Studies are relevant to, and have informed, the approach taken in this study:

- Lake Way LiDAR data provided by Toro Energy was utilised.
- Hydraulic conductivity in Lake Way was measured between 3.1-37.4 mm/hour.
- The volume in the Lake was determined based on LiDAR data and aerial photography following Cyclone Bobby.
- Cyclone Bobby was determined to be approximately a 2% annual exceedance probability (AEP) event with a top water level of 491.6 m AHD.
- Flood elevation in response to a 1% AEP event based on a water balance was extrapolated to be 491.7 m AHD.
- Detailed hydraulic modelling of some creeks which contribute to Lake Way was presented.
- Channel and floodplain Manning's n of 0.06 was assumed, and a 32 mm/hr initial loss (IL) and 3 mm/hr continuing loss (CL) was adopted.

2.1.2 Lake Way Climatology and Hydrological Assessment (Knight Piesold 2018)

The following items from the KP Lake Way hydrological assessment are relevant to, and have informed, the approach taken in this study:

- Rainfall, pan evaporation and intensity frequency duration (IFD) tables were investigated and commented on.
- Previous RPS (2015) estimates of Lake Way flood level in response to a 1% AEP event were reviewed, with the conclusion that the 1% AEP Lake Way flood level is 491.7 m AHD.

2.1.3 Lake Way Project Demonstration Plant Flood Study (Knight Piesold 2019)

The following items from the KP Lake Way Flood Study are relevant to, and have informed, the approach taken in this study:

- Aerial imagery was used to assist with a catchment review, and determined some 'ineffective catchments'.
- RPS (2015) flood depths were extrapolated to derive 10% AEP flood levels and storage in Lake Way.
- Similar contributing catchments to previous work by RPS (2015) were determined.

- Australian Rainfall and Runoff: A Guide to Flood Estimation (AR&R) provided a methodology for Regional Flood Frequency Estimate (RFFE) to estimate peak flows from each catchment in the 1% AEP and 10% AEP events (for comparison).
- A triangular interpolation of estimated peak flows was used to create input catchment hydrographs. The time of concentration is determined by catchment size and not rainfall and routing.
- A 2D model of Lake Way in response to 1% AEP and 10% AEP events under pre-development and demonstration project scenarios was presented.
- The 1% AEP peak flood elevation was demonstrated to increase by 40 mm following construction of the demonstration project.
- Rainfall on the lake surface, losses to infiltration or evaporation were not accounted for.
- Uniform Manning's n of 0.025 was applied to the 2D modelled area.

2.1.4 Beyondie Sulphate of Potash Project Surface Water Assessment (Advisian 2018)

The following items from the Advisian Beyondie Sulphate of Potash Surface Water Assessment are relevant to, and have informed, the approach taken in this study:

- Sunshine Lake and Ten Mile Lake both have large contributing catchments, with similar attributes to those contributing to Lake Way.
- Upstream catchments were modelled using a 1D approach, similar to that proposed by this study of Lake Way.
- Observed flood elevation within Ten Mile Lake was used as calibration for upstream catchments.
- Catchment losses adopted 25 mm IL and 1.0-0.87 proportional loss (PL).

2.1.5 Laverton Flood Study (Worley Parsons 2014)

The following items from the Worley Parsons Laverton Flood Study are relevant to, and have informed, the approach taken in this study:

- TUFLOW 2D modelling was utilised to represent the lake surface and immediate surrounds
- Three regional peak flow estimate techniques were reviewed and compared: Rational Method, Index Flood Method (from AR&R) and Regional Flood Frequency Procedure (RFFP).
- RFFP peak flow estimates were comparable to previously published values produced by rainfall runoff modelling. The RFFP method was determined to be the most appropriate regional method to determine peak flow estimates for the relevant catchments.
- 1D Catchment losses adopted 16 mm/hr IL and 2 mm/hr CL; AR&R recommends 38 mm/hr IL and 3 mm/hr CL but this was deemed too high as it did not match observed flow/events when recreated in the model.
- 1D catchment assumptions varied Manning's n to calibrate to the 2011 flood event. The final Manning's values included 0.05 for floodplains (with limited vegetation), 0.04 for main channels 0.06 for light riparian vegetation.

2.2 Australian Rainfall and Runoff

AR&R (Ball J *et al.* 2019) provides guidance on differing methods of estimating peak flow rates from regional ungauged catchments. These methods have been investigated and discussed in the previous studies listed. It notes that there is generally a lack of data available with which to estimate loss values within Arid regions. AR&R also provides a range of catchment loss rates from areas with similar context that could potentially be adopted or could guide catchment loss value selection at Lake Way. These are summarised in **Table 1**.

Table 1: Loss rates adopted for relevant flood studies described in AR&R (Ball J et al. 2019)

Location	Region	Initial loss rate	Continuing loss rate
Harding River	Pilbara	60	8.3
Emily Creek and Todd River	Central Australia	10-60	1.5-4.5
-	Pilbara	40-50	5

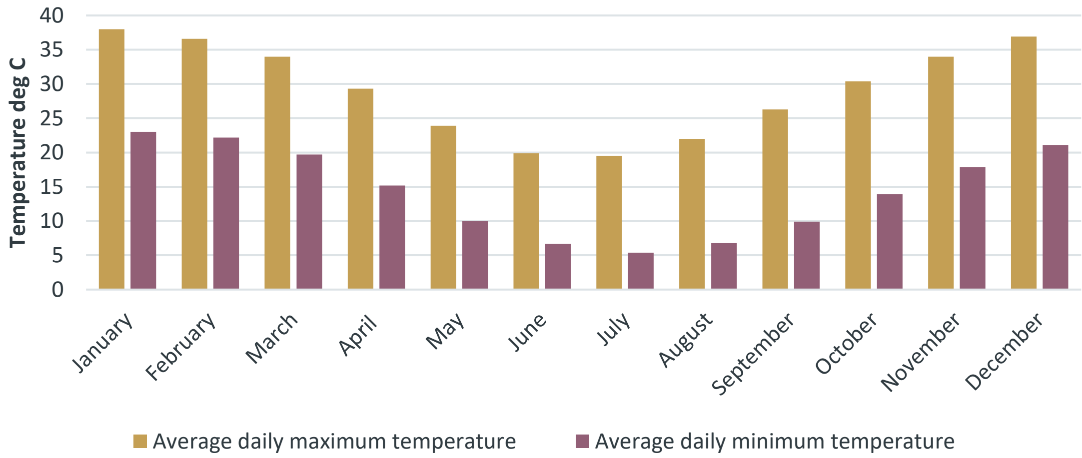
2.3 Climate and rainfall

The regional climate around Lake Way is semi-arid to arid. The region typically has low annual rainfall, hot dry summers and mild dry winters. Anti-cyclonic systems occur in summer, producing hot days and easterly winds. Thunderstorm activity can occur in association with these systems, and occasionally the remnant of tropical cycles can move across the region. Frontal systems move across the region producing the majority of rainfall from December to June.

2.3.1 Temperature

Average daily (minimum and maximum) temperatures can vary by 23^{0}C, with highest maximums generally recorded during December to February, and lowest minimums recorded July to August. A summary of average temperatures for Wiluna (BOM station 13012) is shown in **Chart 1**.

Chart 1: Average monthly maximum and minimum temperatures at Wiluna



2.3.2 Rainfall and evaporation

2.3.2.1 Annual rainfall

The mean annual rainfall at Wiluna is 261.7 mm (BOM 2019a). The majority of annual rainfall falls in the period December to June, with maximum rainfall (of 38 mm) typically occurring in January/February. Average monthly rainfall is summarised in **Table 2**.

2.3.2.2 Pan evaporation

Pan evaporation data based on average climatic conditions has been collected from the Wiluna weather station (BOM 2019a). Average monthly pan evaporation at Lake Way is summarised in **Table 2**.

Table 2: Average monthly rainfall and pan evaporation at Lake Way

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Average monthly rainfall (mm)	37.2	38.7	36.9	28.6	25.1	23.6	14.7	9.9	5	7.4	12.1	22.3
Pan evaporation (mm/month)	413	329	304	207	147	108	115	158	225	314	362	405

For the purposes of flood modelling and evaporative losses in Lake Way, an average daily evaporation rate of 10.7 mm/day has been adopted. Evaporation losses are further discussed in **Section 4.5**.

2.3.2.3 Intensity frequency and duration

The intensity, frequency and duration (IFD) of rainfall at Lake Way was obtained from the Bureau of Meteorology (BOM 2019b). The BOM IFD chart is shown in **Table 3**.

Table 3: IFD Chart for Lake Way

	Annual exceedance probability %						
Duration (hrs)	**63.2**	**50**	**20**	**10**	**5**	**2**	**1**
30 min	10.8 mm	13 mm	20.5 mm	26.3 mm	32.6 mm	41.8 mm	49.7 mm
1	13.7 mm	16.5 mm	26.1 mm	33.5 mm	41.6 mm	53.9 mm	65 mm
2	17.1 mm	20.4 mm	32.2 mm	41.5 mm	51.5 mm	66.9 mm	80 mm
3	19.4 mm	23.1 mm	36.4 mm	46.8 mm	58.1 mm	75.2 mm	90 mm
6	24.1 mm	28.8 mm	45.3 mm	57.9 mm	71.6 mm	91.3 mm	108 mm
9	27.5 mm	33 mm	51.6 mm	65.8 mm	81 mm	102 mm	120 mm
12	30.3 mm	36.3 mm	56.7 mm	72.1 mm	88 mm	111 mm	129 mm
18	34.4 mm	41.4 mm	64.7 mm	81.9 mm	100 mm	124 mm	144 mm
24	37.6 mm	45.3 mm	70.8 mm	89.3 mm	109 mm	134 mm	155 mm
36	42.1 mm	50.9 mm	89.6 mm	100 mm	121 mm	150 mm	172 mm
48	45.2 mm	54.8 mm	85.7 mm	108 mm	129 mm	160 mm	185 mm
72	49.2 mm	69.7 mm	93.5 mm	117 mm	140 mm	175 mm	203 mm

3 Catchment analysis

The overall approach to determining catchment rainfall inputs to Lake Way has been to identify the upstream catchments, determine their extents and features, then to find an appropriate way of representing them so that they can provide inputs to a more detailed 2D domain encompassing Lake Way. The Lake Way 2D domain is also treated as a catchment (with direct rainfall on the Lake) and not just an isolated storage area. This section describes the approach to identifying and characterising the upstream catchments.

3.1 Previous studies

The Wiluna Uranium Project Surface Hydrology Studies (RPS 2015) undertook an assessment of the catchments upstream of Lake Way. A total contributing catchment area of 11,000 km^2 was assumed. The overall catchment analysis was somewhat coarse, however a more detailed analysis of catchments relevant to the proposed uranium mine was undertaken (referred to as Kukububba, Abercrombie and Negrara catchments, which are 1,532 km^2, 1,296 km^2 and 311 km^2 in area respectively).

The Lake Way Climatology and Hydrological Assessment (Knight Piesold 2018) assessed all of the contributing catchments to Lake Way, however did not assess Lake Way itself as a catchment. KP assessed the catchment areas based on Shuttle Radar Topography Mission (SRTM) topography obtained from Geoscience Australia. KP identified eight catchments totalling 9,377 km^2, as summarised in **Table 4**.

Table 4: Lake Way contributing catchments determined by KP (2019)

Catchment	1	2	3	4	5	6	7	8
Area (km^2)	6,400	1,265	31	17	7	460	223	974

The KP analysis of contributing catchments assumed that two large areas were 'ineffective catchments' and would not contribute runoff to Lake Way under any rainfall event.

3.2 Contributing catchment areas

Emerge assessed the extent of catchments contributing to Lake Way. This assessment was undertaken based the SRTM-derived 1 Second Hydrologically Enforced Digital Elevation Model (DEM) (Geoscience Australia 2019), a 1m grid DEM of the Lake Way vicinity (produced from LiDAR) and analysis of aerial photography. The DEM is discussed further in **Section 4.1**. The upstream catchments were terminated at the boundary of Lake Way and immediate surrounds, which was modified to provide logical points for upstream catchments to enter the 2D domain (see **Section 4.2** for further discussion on the 1D-2D interface approach). The average catchment slope was estimated based on the average catchment lengths and elevation variation (headwater to discharge).

The contributing catchment boundaries and the extent of the 2D model domain are shown on **Figure 1** and **Figure 2** respectively. A summary of upstream catchment areas determined by Emerge is provided in **Table 5**.

Table 5: Lake Way contributing catchment areas determined by Emerge

Catchment	Lake Way	1	2	3	4	5	6	7	8	9	10	11
Area (km^2)	324	6537	1629	248	447	43	517	382	1248	9	17	34
Average slope (%)	0.05	0.15	0.29	0.39	0.41	0.74	0.34	0.36	0.28	1.17	0.92	1.01

The upstream catchment areas determined by Emerge differ slightly from the previous work undertaken by RPS (2015) and Knight Piesold (2019), however are considered appropriate for the inflow delineation identified in this study. The contributing catchments were defined using a GIS platform, and these were imported in to XPSWMM.

3.3 Catchment parameters

The upstream contributing catchments were represented in XPSWMM as 1D catchments while Lake Way (and immediate surrounds) was represented as a 2D domain (discussed further in **Section 4.3**). The catchments (and 2D domain) were parameterised with values for initial loss, continuing loss, Manning's n values and estimated average slopes. These were based on the review of previous studies and the available data (DEMs, aerial photography, geological mapping). The upstream catchments were generalised as a single land type. The parameterisation of this single land type was also applied to the margins and surrounds of the Lake playa within the 2D domain (2D domain parameterisation is discussed in **Section 4.3**).

The continuing loss parameter for the upstream catchments were varied until the 1% AEP peak flood elevation within Lake Way closely approximated the target elevation of 491.7 m AHD. The final land type parameterisation is provided in **Table 6**. The average catchment slopes are provided in **Table 5**.

The catchment loss parameters which provided the closest approximation to the 1% AEP pre-development flood depth resulting in Lake Way (491.7 m AHD) are summarised in **Table 6**. Note that the values presented in **Table 6** are the final calibrated values that were determined following coupling of the 1D-2D model, and inclusion of infiltration and evaporative losses (see **Sections 4.4** and **4.5**).

Table 6: Catchment loss parameters adopted for Lake Way contributing catchments

Catchment	Initial loss (mm)	Continuing loss (mm/hr)	Manning's n
All contributing catchments	40	6.8	0.06

It is noted that the adoption of the same catchment loss parameters for all contributing catchments is a simplification of the catchment dynamics that would occur differently across the catchments. However, the approach adopted is considered to be a reasonable representation of the upstream catchments given the scale and comparative nature of the investigations as well as the limited available information.

4 Lake Way 2D Domain and Model

Previous modelling undertaken to represent flood inundation in Lake Way have relied purely on the input from upstream catchments, which have 'filled' Lake Way as a static storage without temporal losses. The approach undertaken for this study seeks to account for the addition of:

- Rainfall falling directly on Lake Way
- Infiltration losses within the Lake Way playa during the rainfall event and thereafter
- Evaporation losses from the Lake immediately after cessation of rainfall and thereafter.

The above factors and other 2D modelling inputs are described in the following sections.

4.1 Digital elevation model

A DEM of Lake Way and surrounds was produced by surveyors AAM (2019) from captured LiDAR at a density of two points per square metre. The aerial survey was conducted between 7th December 2018 and 25th January 2019 by a fixed wing aircraft. The design accuracy of the survey was +/-100 mm.

The 1 m grid DEM produced by AAM was imported into XPSWMM to create the 2D domain. The actual resolution of the 2D domain is dependent on in-model triangulation and specified grid size. The grid size was varied depending on the required accuracy. Following AR&R (Ball J *et al.* 2019) methodology, a larger grid size (50 m x 50 m – 100 m x 100 m) was used for calibration and critical duration analysis. Finer resolution simulations subsequently confirmed that the accuracy of the coarser simulations was relatively uncompromised by the larger grid size, likely owing to the flat grades within most of the 2D domain. For the final simulations a grid size of 25 m x 25 m was adopted.

The location of the 2D domain extent was selected to provide logical and (where possible) defined upstream catchment input locations that would see runoff propagate through the 2D domain in a manner likely to be consistent with the overall hydrological regime. These were selected based on analysis of the topography, aerial photography and results from previous flood studies (catchment inflows are discussed in **Section 4.2**).

4.2 Upstream catchment inflows

Runoff from 1D upstream catchments (discussed in **Section 3**) were routed into the 2D domain through flow interface lines or flow areas depending on the expected catchment inflow characteristics. Flow areas (which spread flows out uniformly over a specified area) were used for catchments 4 and 5, where no significantly defined channels that directly flowed into Lake Way were identified. Elsewhere, flow interface lines (which prioritise routing flows at the lowest location along the interface) were used as catchment runoff was expected to predominately enter the 2D domain via defined channels. Flow areas and flow interface lines were located slightly upstream of the Lake boundary (where possible) to allow for concentration of flows prior to entering the Lake.

Catchment 8 was split between two streamlines as the upstream confluence was situated outside of the DEM extent. Hydraulic analysis undertaken by RPS (2015) determined that approximately 40% of the 100 year ARI (equivalent to the 1% AEP) flows are conveyed through the eastern streamline, while 60% is conveyed via the northern streamline. The catchment 8 area (and therefore runoff inflows) was split across the two inflow locations according to this delineation for all events. The location, type and extent of 1D catchment inflows are shown on **Figure 2**.

4.3 2D domain characteristics

The physical characteristics of the Lake Way 2D domain were represented in the model through parameterisation of IL and CL (rainfall abstraction) and surface roughness (Manning's n). Based on the regional geological mapping delineation (Geological Survey of Western Australia 1999), the 2D domain was divided into two broad land type categories, being the Lake Way playa (evaporite and clay areas) and the Lake Way margins/surrounds (generally sandy alluvium deposits). These land uses are shown on **Figure 2**.

The margins/surrounds of Lake Way were expected to be relatively similar to the upstream catchments and therefore share the same parameterisation (see **Section 3.3**). The calibration of the upstream catchment loss parameters is discussed in **Section 4.7**.

The IL and CL within the Lake playa are expected to be primarily attributable to the vertical infiltration of water, which is largely dependent on the sub-surface structure and soil characteristics. SO4 hydrogeologists have undertaken investigations into the Lake hydrogeology which have informed the representation of infiltration within the model (this is discussed further in **Section 4.4**). The application of infiltration within the model is provided through an infiltration rate (applied separately throughout the 2D domain), hence the CL attributable to the Lake playa is redundant. The Manning's n value for the playa was adopted from the KP Flood Study (2019).

The land type parameters for the 2D domain are summarised in **Table 7.**

Table 7: Lake Way 2D domain parameters

Land type	Rainfall abstraction - IL (mm)	Rainfall abstraction - CL (mm/hr)	Manning's n
Lake Way margins/ surrounds (alluvium)	40	6.8	0.06
Lake Way playa (playa and clay areas)	2	0*	0.025

Lake Way Playa continuing loss is primarily accounted for by infiltration (see **Section 4.4), which is applied separately.*

The land types for the Lake Way domain are shown on **Figure 2**.

4.4 Infiltration/groundwater recharge

The potential recharge to groundwater beneath Lake Way was assessed by SO4 hydrogeologists (Salt Lake Potash 2019). The assessment indicated that recharge to groundwater through vertical infiltration into playa sediments will occur at a rate of 40 mm/day for the Lake Way playa under all development scenarios. The amount of recharge that can occur is dictated by the storage volume in the vadose zone of the playa sediments and by the vertical hydraulic conductivity of the sediments. The XPSWMM model approach taken assumes that once the available pore space in the vadose zone has been filled with water infiltration effectively ceases. Excess water will remain ponded on the playa surface or it will evaporate. The total likely volume that would be recharged/infiltrated has been calculated by SO4 for each of the scenarios (Pre-development, Demonstration and Full Project), based on the porosity of the soils and changes to the available pore space in the vadose zone as a result of brine extraction (Salt Lake Potash 2019). The pore space available to accept infiltrating water differs between scenarios, however the rate of recharge/infiltration will remain approximately constant.

In order to demonstrate the relative effect on development on the observed Lake flood inundation levels, comparison can be made between the volume recharged/infiltrated and the total runoff and rainfall volume which enters Lake Way. A comparison of the recharge/infiltration volume and the peak runoff and rainfall volume (during the 1% AEP event) is provided in **Table 8**.

Table 8: Comparison between recharge volume and peak runoff and rainfall volume in Lake Way

Development scenario	Recharge volume (m^3)*	1% AEP runoff and rainfall volume (m^3)	Percentage of 1% AEP runoff and rainfall which recharges/infiltrates.
Pre-development	6,585,074	196,032,154	3.36%
Demonstration Ponds	9,566,822	195,879,215	4.88%
Full Project	17,820,224	195,438,524	9.12%

**Recharge volume has been calibrated in the model to reflect the infiltration storage capacity attributed to the vadose zone pore space for each development scenario.*

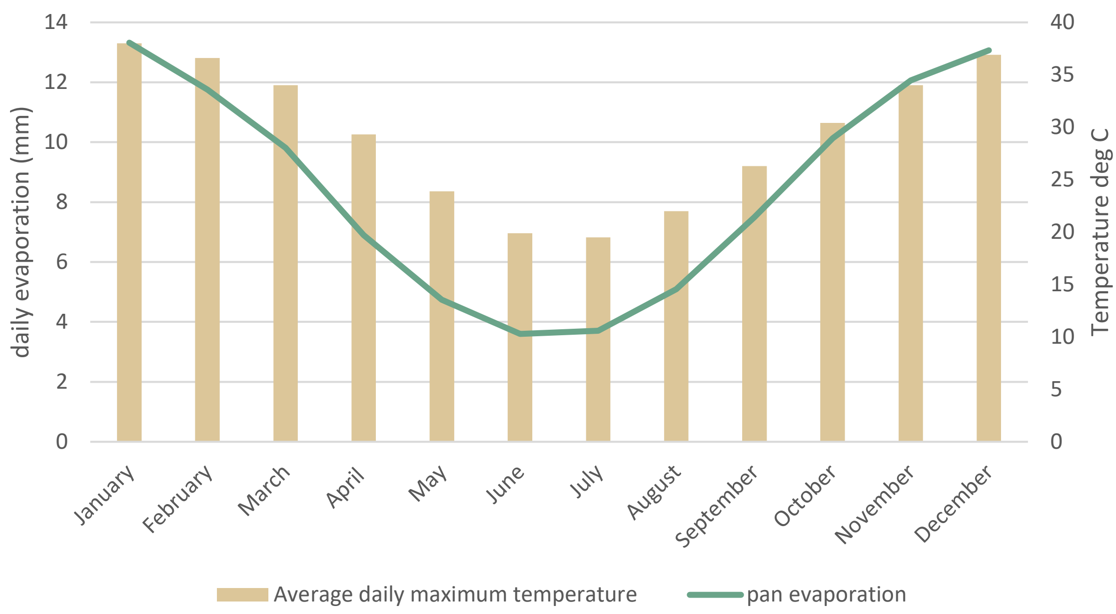
The modelling has incorporated the above methodology and advice and provides a simple accounting of the recharge/infiltration losses for the Pre-development scenario, and as a result of the different development scenarios. It does not account for the spatially variable nature of the drawdown and soil pore capacity, which would occur preferentially around the trenches, however given the duration of the 1% AEP storm event and the large flat nature of the Lake, the minor spatial variability will not have an appreciable effect on flood propagation or the peak flood elevation reached in the Lake.

A similar analysis was undertaken for more frequent rainfall events, and this shows that in the 62.3% and 20% AEP rainfall events the recharge capacity was not reached, indicating that most rainfall infiltrates at source during these rainfall events.

4.5 Evaporation losses

In order to incorporate evaporative losses, the daily pan evaporation rate measured at the Wiluna weather station was used to determine an average daily evaporation rate of 10.7 mm/day. The daily evaporation recorded and the annual variation of this plus average daily maximum temperature is shown in **Chart 2**.

Chart 2: Daily evaporative losses recorded at Wiluna



This average daily evaporation rate (10.7 mm/day) has been adopted as the evaporative loss in the modelling. Evaporation is applied as a constant rate throughout the 2D domain for the duration of the simulation and does not vary with time of day, with the exception that evaporation has not been applied during the modelled storm event (i.e. while it is raining on the Lake, as evaporation during this time will be limited). The model has been run for a duration significantly longer than the rainfall event, to allow for the time of concentration of the catchments and peak flood elevation in the Lake to eventuate. This also serves to show the combined effects that infiltration and evaporation have on the duration of inundation of various parts of the Lake and flood fringes.

4.6 Rainfall and critical duration analysis

The intensity of rainfall events were derived from the intensity, frequency and duration (IFD) charts produced by the Bureau of Meteorology (BOM) (2019b).

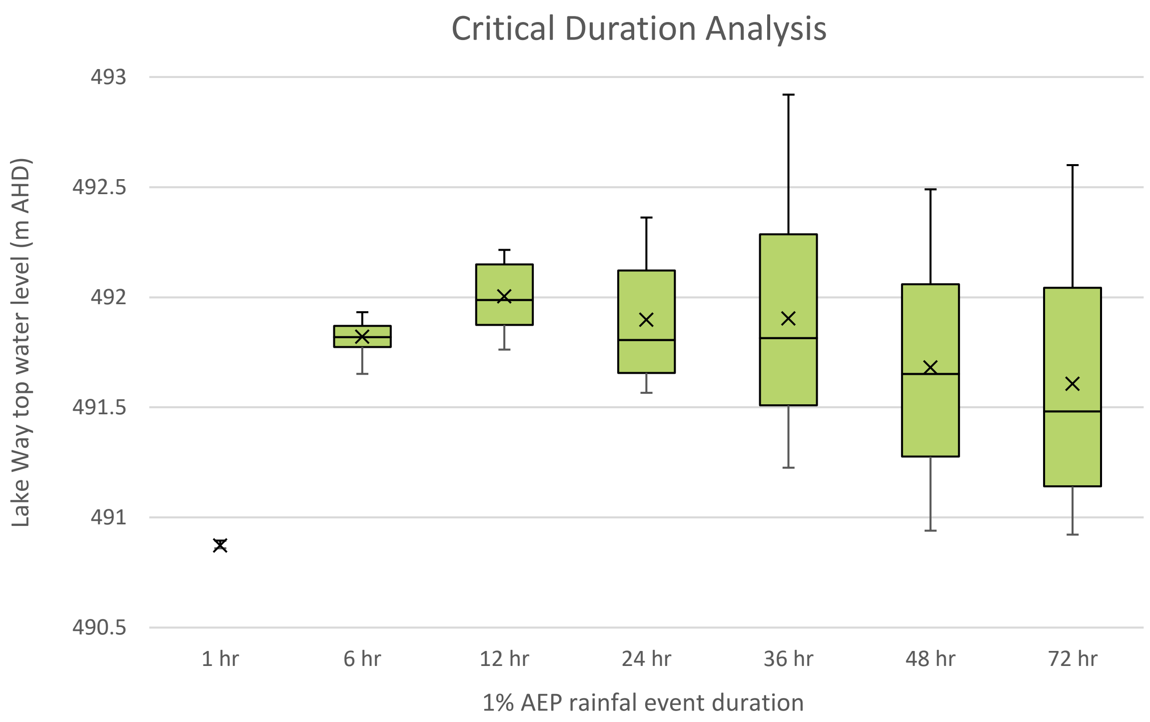
The Lake is located at the bottom of catchment, hence there are no significant discharges expected, other than through losses to groundwater or atmosphere. However, the inclusion of temporal losses (infiltration and evaporation) within the simulation results in dynamic relationships with respect to rainfall and key outputs such as peak flood elevation and lake volume. Therefore, a critical duration analysis was required. It is noted that the 1% AEP critical duration analysis is based upon an initial calibration loss rate (40 mm IL and 4.8 mm.hr^{-1} CL) and that these were subsequently updated following the results of the critical duration analysis and re-calibration (see **Section 4.7**). The 20% and 62.3% AEP critical duration analysis were conducted using the final losses, which are provided in **Table 6**.

The ensemble temporal patterns obtained from the AR&R Data Hub (AR&R 2019) were used for the analysis. The site is within the Rangelands temporal pattern region. The upstream catchments are situated within the Rangelands and Rangelands West regions. The temporal patterns from the Rangelands region were adopted throughout.

AR&R recommends that for computationally expensive 2D models a larger grid size may be used to enable practical assessment of the 10 ensembles associated with each duration. A grid size of 100 m x 100 m was used for the critical duration analysis. Finer resolution runs confirmed that the accuracy of the coarser runs was relatively uncompromised by the larger grid size, likely owing to the flat grades within most of the 2D domain.

Seven durations ranging between 1 hour and 72 hours were tested, with the peak flood elevation being assessed as the determining result. The results of the analysis are summarised in **Chart 3**, **Chart 4** and **Chart 5**.

Chart 3: 1% AEP critical duration analysis summary



Following the process suggested by AR&R (Ball J *et al.* 2019), the highest mean duration (the 12 hour duration for the 1% AEP) was selected as the critical duration (see **Chart 3**). AR&R also recommends that when it is not practical to run the entire ensemble array, the ensemble that produces the result closest to the mean (for the critical duration) should be adopted. Therefore, ensemble seven for the 12 hour duration 1% AEP storm was selected as the design rainfall event. Similarly, the design rainfall patterns for the smaller events were the ensemble five 12 hour duration pattern for the 20% AEP event and ensemble nine 4.5 hour duration pattern for the 63.2% AEP event (see **Chart 4** and **Chart 5**).

Chart 4: 20% AEP critical duration analysis summary

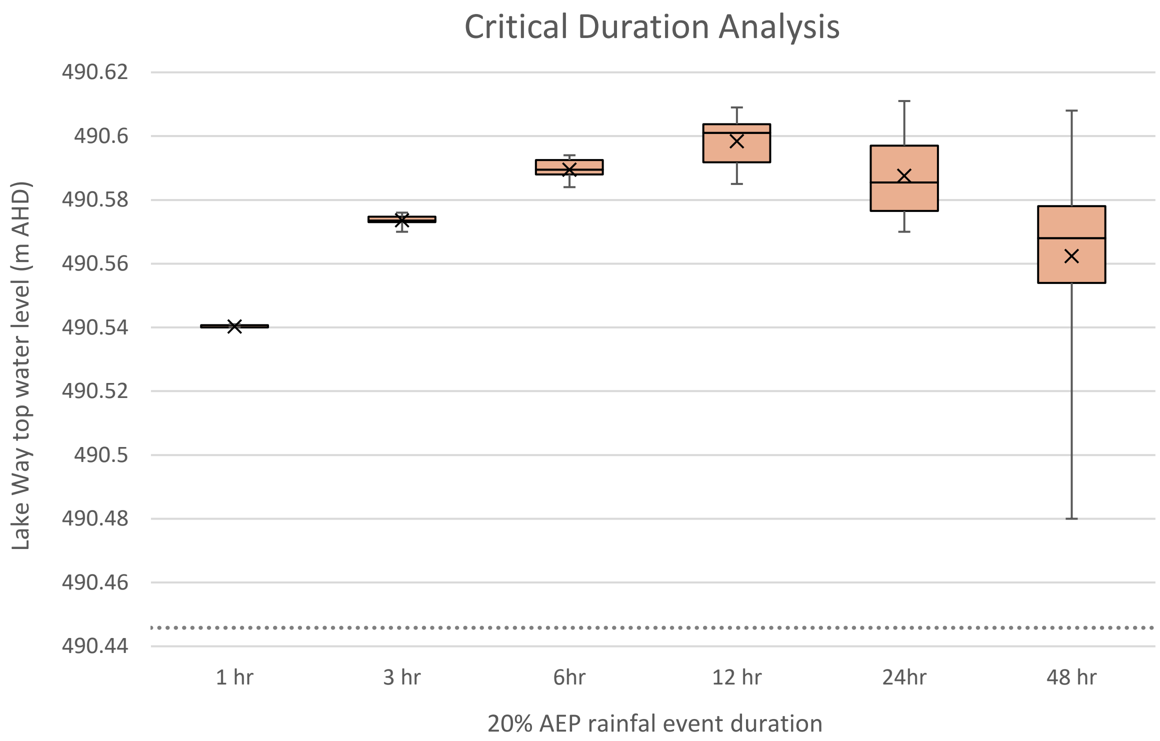
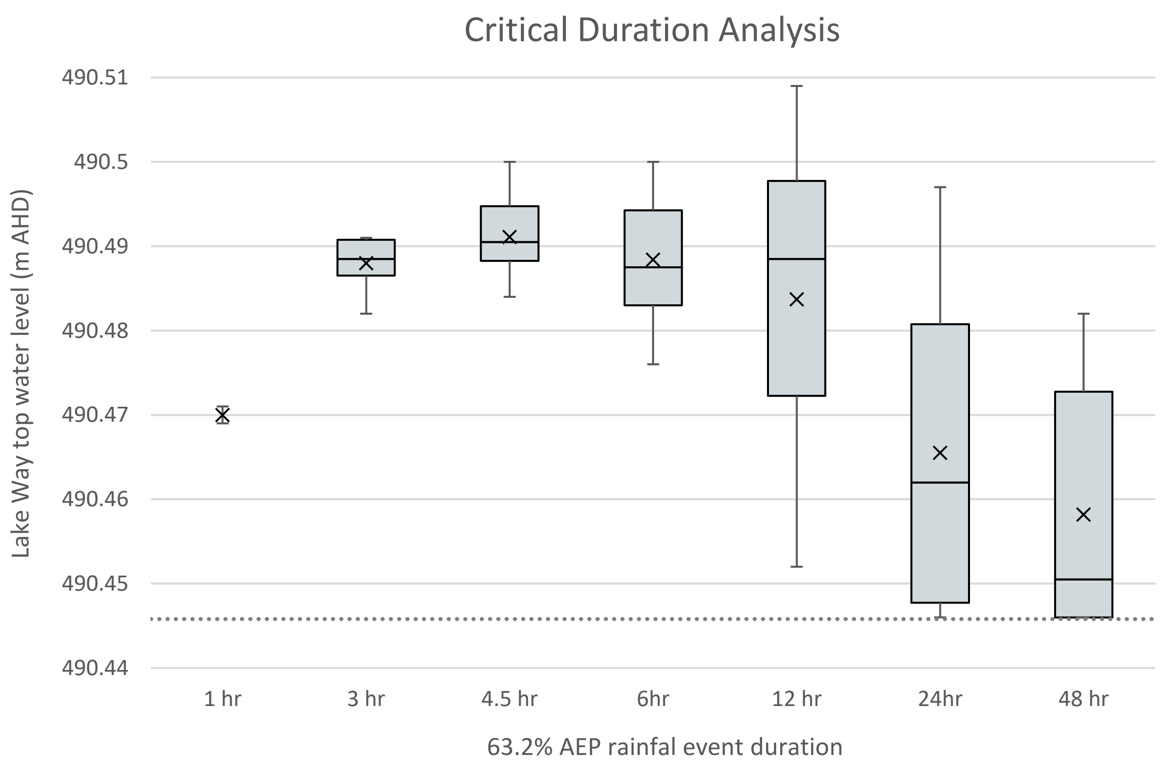


Chart 5: 63.2% AEP critical duration analysis summary



4.7 Model calibration

The 1D-2D model was calibrated in order to achieve the desired 491.72 m AHD peak flood elevation in Lake Way for the pre-development scenario, as determined by RPS (2015). The upstream catchment (and Lake Way margins/surrounds land type) CL value and the duration over which infiltration is applied (in order to reach a target recharge volume) in the 1% AEP event were varied throughout the process. As these processes are temporally interrelated, the calibration was conducted concurrently. The infiltration recharge volume (in the 1% AEP event) and calibrated CL rate for the upstream catchments are provided in **Table 8** and **Table 5** respectively. The achieved pre-development peak flood elevation within Lake Way following calibration is provided in **Table 10**.

4.8 Post-development infrastructure

Proposed infrastructure was introduced to the calibrated 1D-2D model in order to investigate the impact of various development scenarios on flooding within Lake Way; in particular any resultant change in peak flood elevation. Proposed developments included the construction of evaporation ponds, an array of excavated trenches and excess salt areas.

Evaporation ponds were represented in the model as nominally high (i.e. above the peak flood elevation) ridgelines, acting as exclusion bunds. This allows for rainfall to fall within the ponds and infiltrate or evaporate while keeping flooding in the pond areas hydraulically distinct from the remainder of the Lake. Excess salt stockpile areas were represented as vertically filled areas raised to a nominal height (i.e. above the peak flood elevation). Rainfall on excess salt stockpile areas is conveyed radially as sheet flow into the surrounding lake. Excess salt areas adopt the same loss rate as the Lake playa.

Development will also include construction of a series of trenches. However, as the excavated material will remain on the lake surface, any additional excavated volume (void space) will be largely offset when the excavated material is inundated as it will remain within the Lake playa. The trench infrastructure was therefore excluded from the model. For the purposes of this investigation it is expected that the trenches will have little to no direct impact on the final flood depth within the Lake (especially for large events such as the 1% AEP). It is expected however that the extraction of brine will have a significant indirect impact on the available infiltration capacity within the Lake (as discussed in **Section 4.4**).

Two development scenarios were investigated with varying infrastructure requirements. The recharge capacity and development infrastructure for each scenario are summarised in **Table 8** and **Table 9** respectively.

Table 9: Development infrastructure for modelled scenarios.

Modelling scenario	Evaporation ponds (ha)	Excess salt area (ha)
Pre-development	0	0
Demonstration	691	0
Full Project	1,270	936

5 1D-2D Model Results

Each development scenario was simulated with the critical duration rainfall events for the small, minor and major storms (63.2%, 20% and 1% AEP).

Due to the dynamics of the temporally varying inflows and losses, the flood elevation within Lake Way rises over a period of time, reaches a peak and subsequently declines. In the 1% AEP, this peak effectively occurs concurrently throughout all areas that are hydraulically connected to the main waterbody of the flooded Lake. In smaller events (63.2% and 20% AEP) the flooding is discontinuous and shallower flow paths restrict conveyance, resulting in differences in flood elevation between bodies of water or where flows are hydraulically constricted.

For purposes of comparison, the peak flood elevations and peak flood inundation areas were consistently derived from the peak water level taken at one location. This point was nominally positioned close to the centroid of the Lake and within a low-lying area to ensure the location was inundated in smaller events. The location is denoted as 'Data point' and is shown on **Figure 2**. Depth graduated flood mapping at the time of peak flood elevation is provided in **Figures 3** – **11**.

5.1 Pre-development environment

The pre-development environment model is intended to represent the Lake Way domain prior to any construction being undertaken by SO4 for the Lake Way sulphate of potash project. The pre-development model characteristics are discussed in **Section 3** and **Section 4** and are consistent (with a few notable exceptions) with post-development modelling.

5.1.1 Model results

The pre-development model was run for a number of design rainfall events (discussed in **Section 4.6**). The flood inundation extents and depths are summarised in **Table 10**, and shown graphically on **Figure 3**, **Figure 6** and **Figure 9** (at the time of peak flood elevation). As discussed, the peak elevation stated below is based on a reference location situated on the Lake playa, shown in **Figure 2**.

Table 10: Pre-development flood modelling summary and results

Rainfall event (AEP)	Design rainfall temporal pattern	Time of peak flood elevation	Peak flood elevation (m AHD)	Peak flood inundation area (ha)
63.2%	4.5 hours, ensemble 9	8.5 hours	490.445	950
20%	12 hours, ensemble 5	17.5 hours	490.579	4,234
1%	12 hours, ensemble 7	8 days 12 hours	491.719	20,247

5.1.2 Flooding regime

The overall flooding regime within Lake Way consists of an initial inundation due to rainfall and subsequent catchment inflows (in the 1% AEP event). The flooding in the small and minor events is predominantly due to rainfall directly onto the Lake surface. There are no flows contributed from upstream catchments in the small event (i.e. 63.2% AEP) and only very minor flows in some catchments in the minor event (i.e. 20% AEP).

Catchment inflows occur at many locations on the periphery of the Lake. This results in a gradual flooding of low-lying areas (not already inundated due to rainfall) and thereafter filling of the main body of the Lake. During larger rainfall events (i.e. 1% AEP) the existing causeway connecting the western bank of Lake Way and the Williamson Pit (located within the playa) will initially restrict flows from the larger northern catchments from reaching areas immediately to the south. However the difference in elevation dissipates prior to the peak flood elevation being reached. This is demonstrated by the lack of flood impediment shown in the pre-development flood mapping.

5.2 Demonstration Project

The Lake Way Demonstration Project involves the construction of infrastructure within the Lake playa including solar evaporation ponds. These ponds will effectively displace approximately 691 ha of potential flood storage area within Lake Way. It is expected that this will directly result in some measure of increase in peak flood elevation/depth. The Demonstration Project development will however also increase the amount of water that could be lost to infiltration via modification of the capacity of the soils beneath the Lake playa as a result of brine extraction (this is discussed in **Section 4.4**). It was found that the pre-development environment there were not sufficient inflows (rainfall and runoff) to meet the infiltration recharge capacity in the 63.2% AEP event or the 20% AEP event. Therefore, the increased infiltration capacity was only a factor in the 1% AEP event. In this case it is expected that the increase in infiltration capacity would somewhat offset the decrease in flood storage.

Excepting the increase in infiltration capacity and evaporations ponds, the Demonstration Project model adopts the same underlying assumptions as the Pre-development model. Post-development infrastructure is discussed in **Section 4.8** and the increased infiltration capacity is summarised in **Table 8**.

5.2.1 Model results

The resulting flood inundation extent, peak flood elevation and the time of peak flood elevation are summarised in **Table 11**. Flooding at the time of peak flood elevation is shown graphically on **Figure 4, Figure 7** and **Figure 10**.

Table 11: Demonstration Projects flood modelling and results (and Pre-development for reference)

Rainfall event (AEP)	Time of peak flood elevation	Peak flood elevation (m AHD)	Peak flood inundation area (ha)
Demonstration Project			
63.2%	8.5 hours	490.445	929
20%	17.5 hours	490.578	4,268
1%	8 days 12 hours	491.745	19,762
Pre-development			
63.2%	8.5 hours	490.445	950
20%	17.5 hours	490.579	4,234
1%	8 days 12 hours	491.719	20,247

5.2.2 Flooding regime

As discussed in **Section 5.1**, flood propagation within the Lake occurs gradually due to direct rainfall on the surface and from many catchment inflows located along the periphery (in the 1% AEP event). The existing causeway leading to the Williamson Pit provides some initial restriction of northern catchment inflows, which is subsequently dissipated. As the proposed infrastructure is located alongside the road, there is expected to be no significantly increase in impediment of flood propagation. The consistency of time of peak flood elevation compared with the pre-development illustrates this (see **Table 11**).

There is however some redistributing of flooding due to the removal of flood storage (evaporation ponds). The western ponds are located within low-lying areas that would have otherwise received flows from concentrating rainfall or initial catchment inflows. Therefore flooding is reapportioned due to these ponds in all events. In the 63.2% AEP and 20% AEP events additional flooding occurs along the outer boundaries of the western ponds within low-lying areas. Changes in flooding in these events are localised and do not impact the remainder of the Lake. There is a small change to the overall flooding depth and extent in the 1% AEP event due to the slight (26 mm) rise in peak flood elevation throughout the connected Lake Way flood body.

5.3 Full Development Project

The Full Development project involves construction of 1,270 ha of solar evaporation ponds and 936 ha of excess salt stockpiles within the Lake playa. These ponds and stockpiles will effectively displace a combined 2,206 ha of potential flood storage area within Lake Way (although some inundation occurs within evaporation ponds due to direct rainfall). It was expected that inclusion of the development infrastructure would result in some measure of increase in peak flood elevation/depth. The Lake Way Full Development will also however greatly increase the amount of water that could be lost to infiltration via modification of the available vadose zone storage volume beneath the Lake playa as a result of brine extraction. This increase in infiltration/recharge capacity is expected to be significantly more than the Demonstration Projects (this is discussed in **Section 4.8**, with the infiltration capacities summarised in **Table 8**).

With the exception of the increase in infiltration capacity, evaporations ponds and excess salt areas, the Full Project model adopts the same underlying assumptions as the Pre-development model.

5.3.1 Model results

The resulting flood inundation extents, flood elevation and the time of peak flood elevation are summarised in **Table 12**. Flooding at the time of peak flood elevation is shown graphically on **Figure 5**, **Figure 8** and **Figure 11.**

Table 12: Lake Way Project at Full Development flood modelling results

Rainfall event (AEP)	Time of peak flood elevation	Peak flood elevation (m AHD)	Peak flood inundation area (ha)
Full Project			
63.2%	8.2 hours	490.445	926
20%	17.5 hours	490.579	4,303
1%	8 days 11 hours	491.787	18,191*
Pre-development			
63.2%	8.5 hours	490.445	950
20%	17.5 hours	490.579	4,234
1%	8 days 12 hours	491.719	20,247

**Note that the peak flood inundation area would also include an additional 2,206 ha that will be taken up by the Full project evaporation ponds and stockpiles. The comparative total area taken up by inundation and infrastructure combined would be 20,397 ha.*

5.3.2 Flooding regime

Flood propagation within the Lake under the Full Development Project occurs similarly to the pre-development regime (as discussed in **Section 5.1**). The time of peak elevation is reached at a slightly earlier time (following the commencement of the rainfall event), which indicates that the overall flooding regime within the Lake is not impacted.

As with the Demonstration Projects, there is some redistribution of flooding due to the removal of flood storage areas (evaporation ponds and salt excess stockpiles) occurring to the north of the infrastructure in the 63.2% and 20% AEP events. However, the loss in flood storage is only fully realised in the 1% AEP event with the additional ponds and salt excess areas being mostly dry at the time of peak flood elevation. The loss of flood storage is somewhat offset by the increase in infiltration capacity in the 1% AEP event, resulting in an increase in peak flood elevation (of 68 mm.

5.4 Summary and discussion

Modelling has identified that in the smaller rainfall events (63.2% AEP and 20% AEP) there is no material change in the overall flooding regime within Lake Way under any development scenario. There is however some minor localised redistribution of flooding due to the direct loss of flood storage within low-lying areas (the western evaporation ponds and excess salt areas).

There is an increase in peak flood elevation under the Demonstration and Full Project development scenarios in the 1% AEP event (of 26 mm and 68 mm respectively). The rise in 1% AEP peak flood elevation in the post-development scenarios can be attributed to the direct loss of flood storage due to the development infrastructure, however is somewhat offset by the increase in infiltration capacity resulting from brine extraction.

The peak flood elevation/inundated area is compared to the pre-development condition in **Table 13**.

Table 13: Pre-development and development scenario comparison

Rainfall event (AEP)	Peak flood elevation variance from pre-development (mm)		Peak inundation area variance from pre-development (%)	
	Demonstration	Full Project	Demonstration	Full Project
63.2%	0	0	-2.22%	-2.46%
20%	-1	0	+0.81%	+1.64%
1%	+26	+68	-2.39%	-10.15%

5.5 Reasonable accuracy of results

It is noted that informed, but broad generalisations have been made relating to the modelling inputs and approach discussed in **Section 3** and **Section 4**. As such, there is inherent uncertainty associated with the modelling (and indeed all modelling). However, as the generalisations and base assumptions are consistent throughout the modelling scenarios there can be confidence in the comparative difference in peak flood elevations, which is the primary objective of the modelling.

The level of confidence in certain modelling assumptions and approaches may become relevant when results are assessed in isolation or against fixed points. In particular, the catchment parameterisation and calibration has been conducted against an extrapolation of the only known available datum (the flood elevation achieved by Cyclone Bobby). In this respect, the reasonable accuracy of calibration datum (which was derived from satellite photography of flooding with a broad accuracy of +/- 100 mm) should be considered when assessing the results of the modelling.

Similarly, the reasonable accuracy of the extent and depth of flooding should be assessed in context of the accuracy range of the DEM (which is +/- 100 mm as discussed in **Section 4.1**). This should be considered when reviewing location specific flood extents, depths and elevations. As such, the flood mapping provided has not displayed the first 50 mm of inundation. The primary reason for doing so is to remove the noise created within this range of accuracy and the associated flooding of resulting depressions. A figure displaying the 20% Pre-development flood mapping with inundation > 1 mm shown, versus inundation > 50 mm shown is provided in **Figure 12**. The value of 50 mm was selected as the most appropriate display value as lower values than this show the level of variance in the underlying DEM, and does not provide an accurate indicator of inundated areas.

Furthermore, the modelling is not intended to be used as detailed hydraulic assessment of streamlines or flow routing throughout upstream catchments. Notwithstanding, the modelling does provide an accurate representation of flood propagation within Lake Way itself and immediate surrounds (within the 2D domain).

6 Conclusions

6.1 Summary

The modelling by Emerge has been conducted in consideration of key hydrological factors pertaining to the overall flood regime within Lake Way. These include:

- Upstream catchment inflows (driven by catchment parameterisation and calibration)
- Rainfall on Lake Way
- Evaporation
- Infiltration (and the effects of development on recharge capacity)
- Flow routing throughout Lake Way (2D surface water modelling)
- Infrastructure related to proposed developments.

The approach adopted by Emerge, as outlined in this report, is considered appropriate given the purposes of the modelling and scale of the investigations. The primary purpose being to provide a comparative assessment, and to measure the likely impact of a number of proposed development scenarios, on the peak flood elevation within Lake Way.

The 1D-2D modelling of Lake Way was conducted under the Pre-development, Demonstration and Full Project scenarios, for the 1% AEP, 20% AEP and 63.2% AEP design rainfall events. The peak flood elevation in each scenario is provided in **Table 14**. The flooding at the moment when the peak flood elevation is reached is shown in **Figures 3 - 11**.

Table 14: Lake Way top water top peak flood elevations under various scenarios

Modelling scenario	Peak flood elevation (m AHD)	Change in peak flood elevation relative to Pre-development (mm)
63.2% AEP design event		
Pre-development	490.445	-
Demonstration	490.445	0
Full Project	490.445	0
20% AEP design event		
Pre-development	490.579	-
Demonstration	490.578	-1
Full Project	490.579	0
1% AEP design event		
Pre-development	491.719	-
Demonstration	491.745	+26
Full Project	491.787	+68

6.2 Assessment of potential impact

Modelling has identified that in the small and minor rainfall events (63.2% AEP and 20% AEP) there is no material change in the overall flooding regime within Lake Way under any development scenario. There is however some minor localised redistribution of flooding due to the direct loss of flood storage within low-lying areas (western evaporation ponds and excess salt areas).

There are minor changes in peak flood elevation under the Demonstration and Full Project development scenarios in the 1% AEP event (an increase of 26 mm and 68 mm respectively). The rise in 1% AEP peak flood elevation in the post-development scenarios can be attributed to the direct loss of flood storage due to the development infrastructure, however is somewhat offset by the increase in infiltration capacity resulting from brine extraction.

As a comparative assessment there is a high degree of confidence in the findings of this investigation. However, both the DEM and the calibration datum (derived from Cyclone Bobby) have a broad accuracy of +/- 100 mm. Therefore, results of the modelling (i.e. flood elevations) assessed in isolation or against fixed points should be considered in the context of the reasonable accuracy of the aforementioned key modelling inputs.

6.3 Recommendations

There is a lack of hydrological data (monitoring or observed) within the study area or surrounds. As a result of this, there is a reduced degree of confidence in the model calibration datum. However, the methodology adopted in this study focuses on relative differences so the results are deemed to be suitable for assessing any impacts attributable to the proposed development. If further accuracy regarding individual catchment inputs is required it would be recommended to undertake monitoring of key catchment input locations to provide peak flow and rainfall data that could be used for further calibration of catchment assumptions.

7 References

The references listed below have been considered as part of preparing this document.

7.1 General references

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Figures

Figure 1: Upstream Catchments

Figure 2: 2D Model Domain, Land Types and Catchment Inflows

Figure 3: Pre-development 63.5% AEP Flood Inundation of Lake Way

Figure 4: Post-development (Demonstration) 63.5% AEP Flood Inundation of Lake Way

Figure 5: Post-development (Full Project) 63.5% AEP Flood Inundation of Lake Way

Figure 6: Pre-development 20% AEP Flood Inundation of Lake Way

Figure 7: Post-development (Demonstration) 20% AEP Flood Inundation of Lake Way

Figure 8: Post-development (Full Project) 20% AEP Flood Inundation of Lake Way

Figure 9: Pre-development 1% AEP Flood Inundation of Lake Way

Figure 10: Post-development (Demonstration) 1% AEP Flood Inundation of Lake Way

Figure 11: Post-development (Full Project) 1% AEP Flood Inundation of Lake Way

Figure 12: Flood Inundation Mapping Comparison (20% AEP Pre-development)

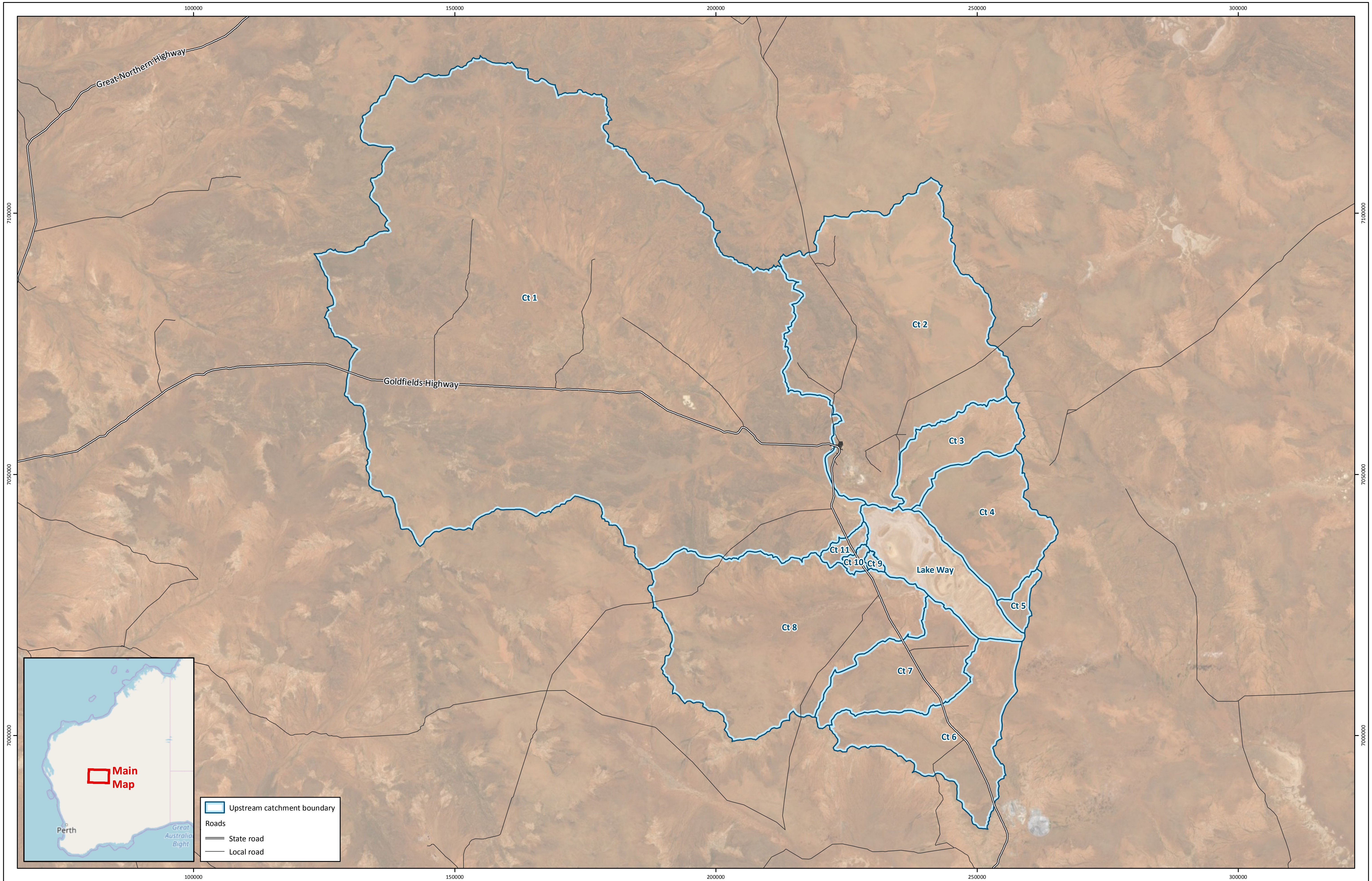

Figure 1: **Upstream Catchments**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F10
Drawn: KNM
Date: 05/11/2019
Checked: MGB
Approved: DPC
Date: 08/11/2019

N

0 5 10 15 20
Kilometres
Scale: 1:650,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

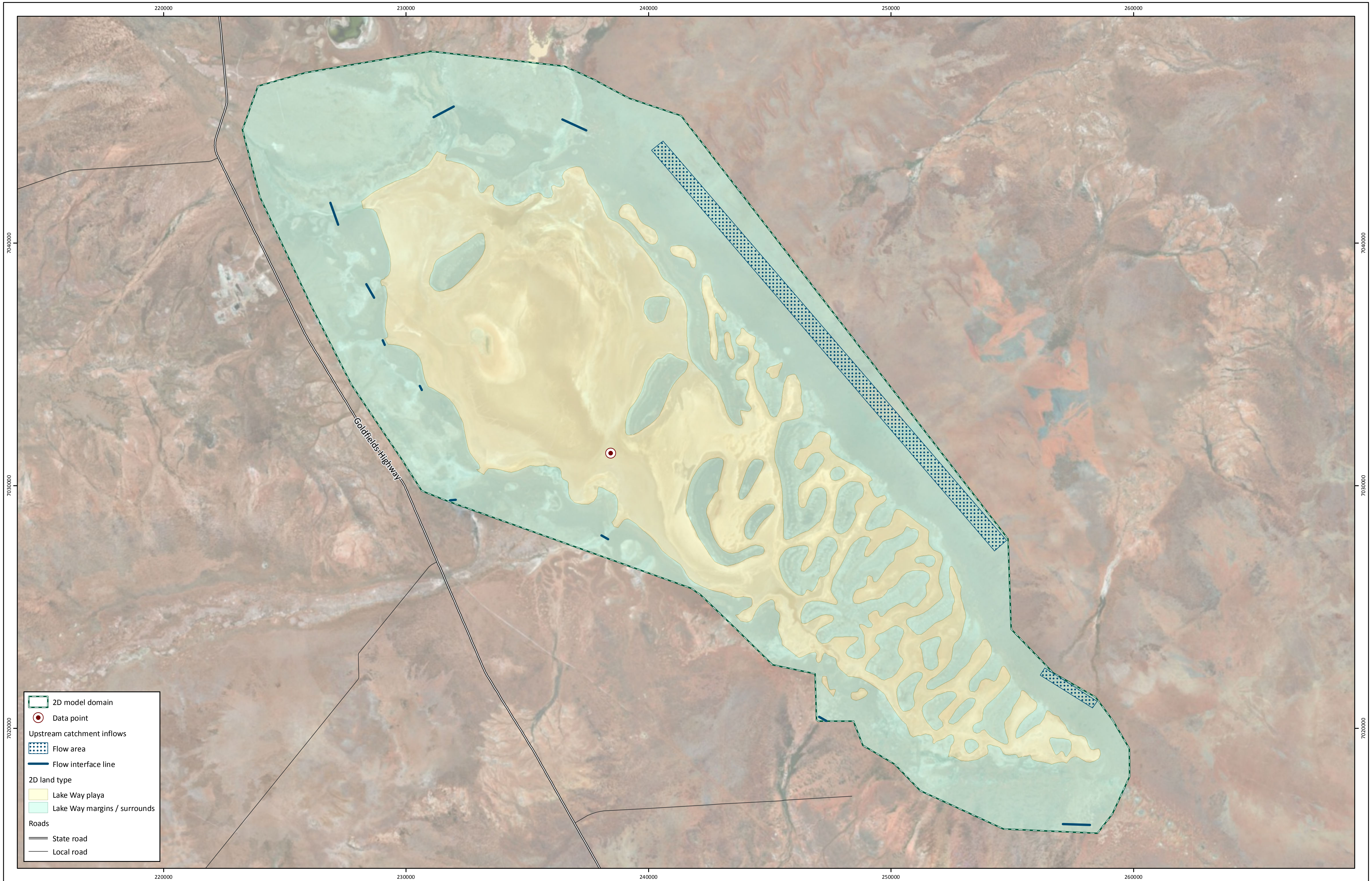

Figure 2: **2D Model Domain, Land Types and Catchment Inflows**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number: EP19-056(02)--F11
Drawn: KNM
Date: 05/11/2019
Checked: MGB
Approved: DPC
Date: 08/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:140,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

Figure 3: **Pre-development 63.5% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F12
Drawn: KNM
Date: 05/11/2019
Checked: MGB
Approved: DPC
Date: 08/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

Figure 4: Post-development (Demonstration) 63.5% AEP Flood Inundation of Lake Way

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F15a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

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Figure 5: **Post-development (Full Project) 63.5% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F21a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

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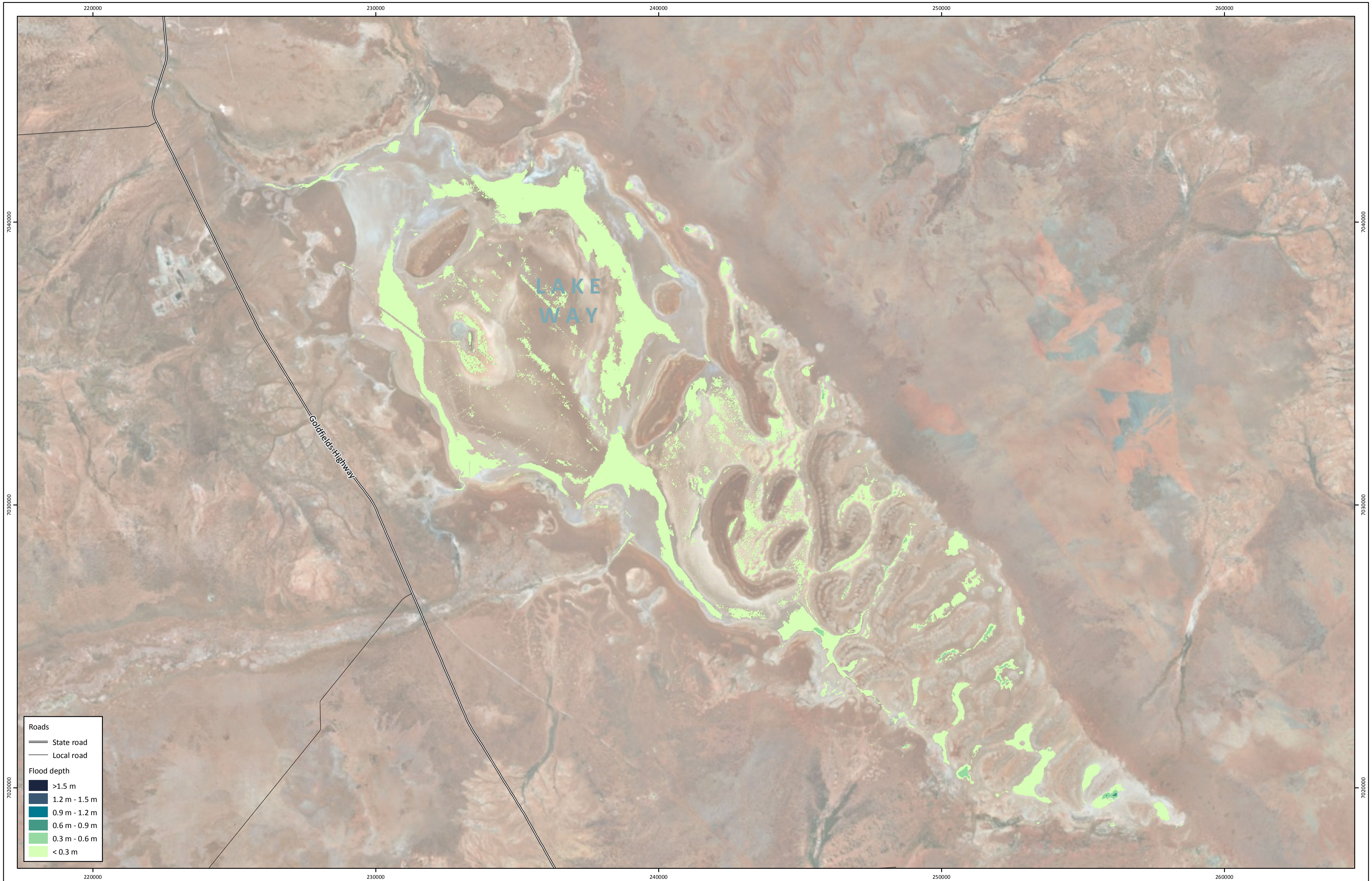


Figure 6: **Pre-development 20% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F13a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

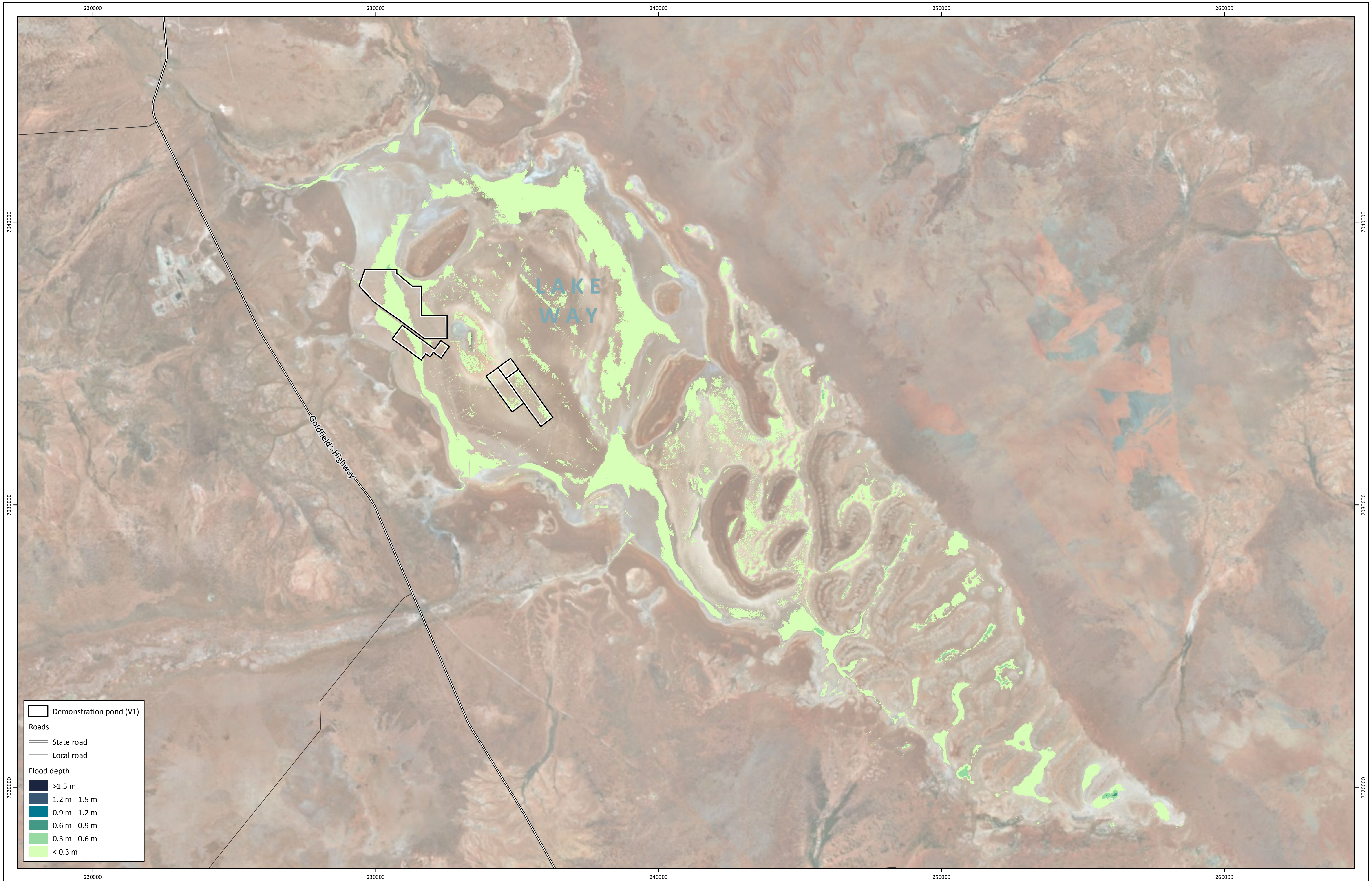


Figure 7: **Post-development (Demonstration) 20% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F16a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

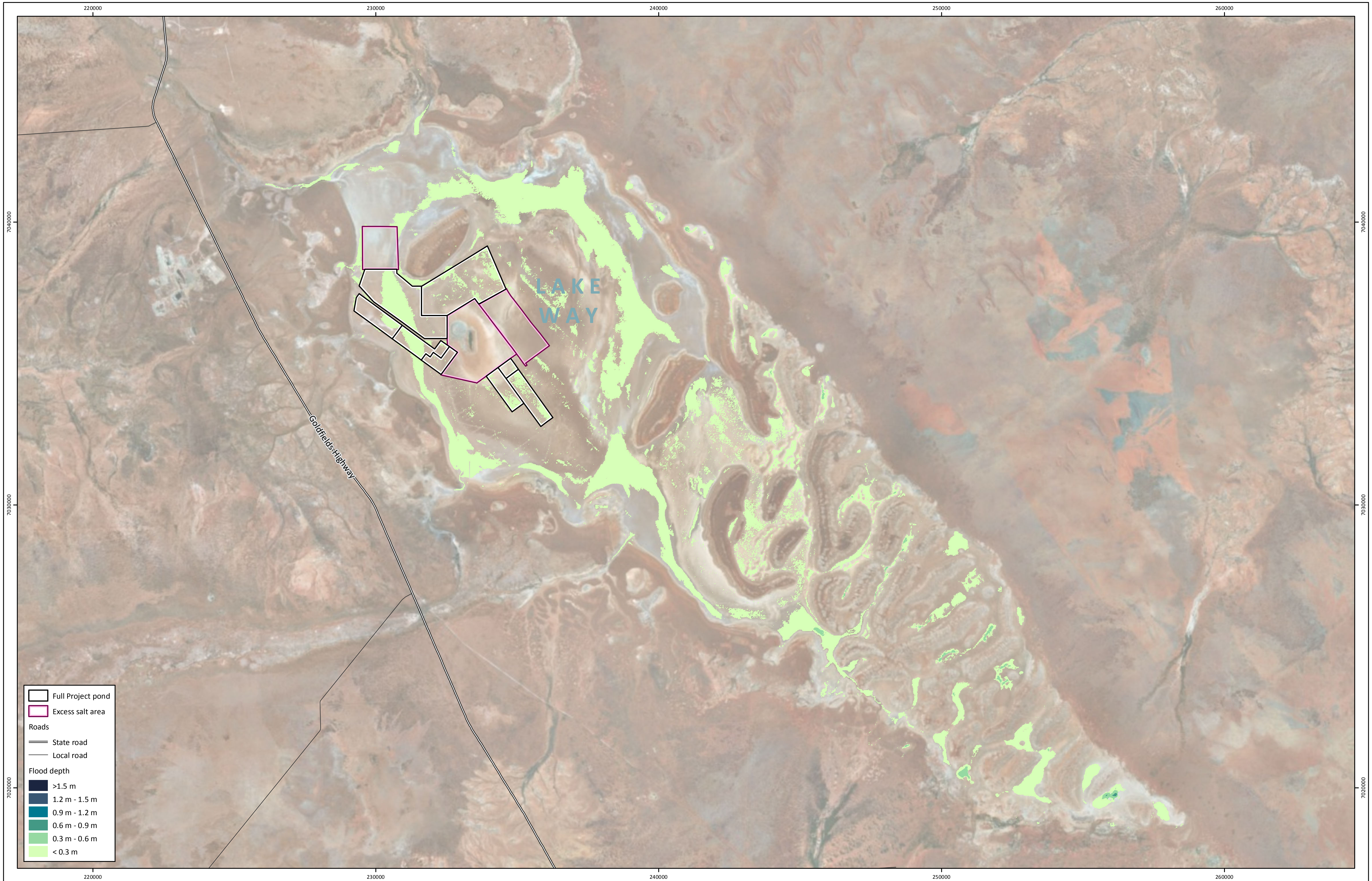


Figure 8: **Post-development (Full Project) 20% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number: **EP19-056(02)--F22a**
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

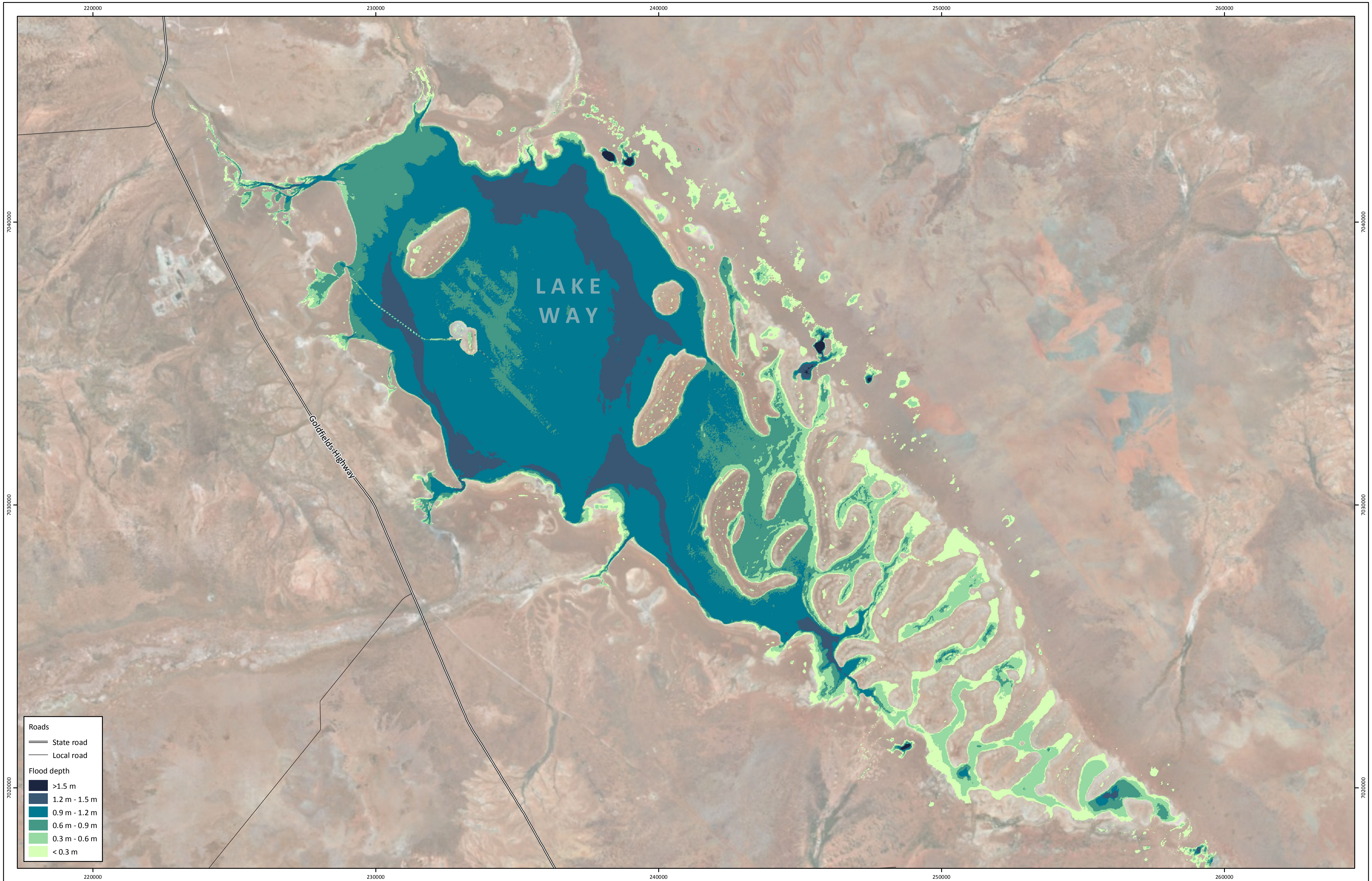


Figure 9: **Pre-development 1% AEP Flood Inundation of Lake Way**

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F14a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

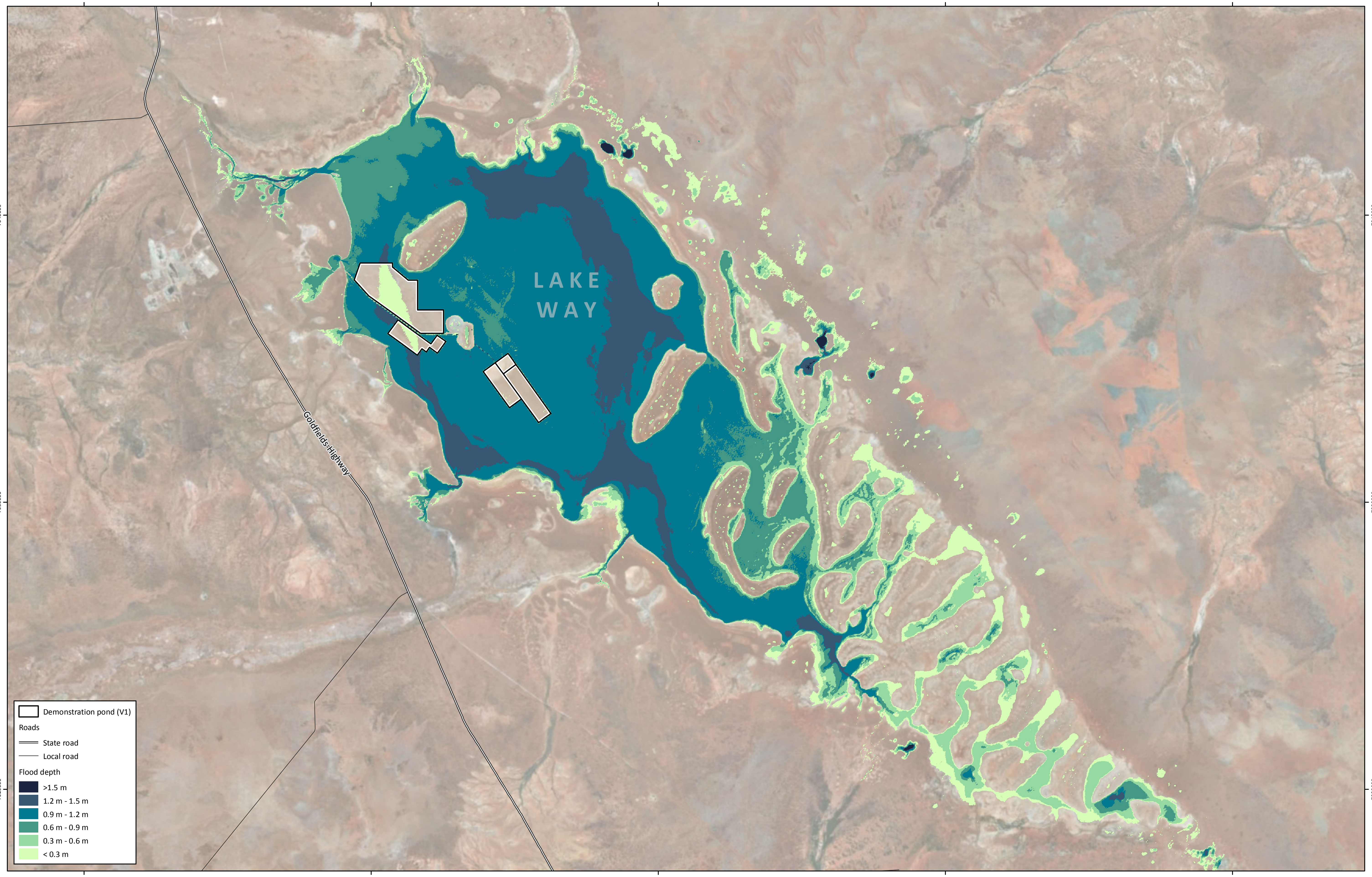


Figure 10: Post-development (Demonstration) 1% AEP Flood Inundation of Lake Way

Project: Flood Study
Lake Way

Client: Salt Lake Potash Ltd

Plan Number: EP19-056(02)--F17a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES

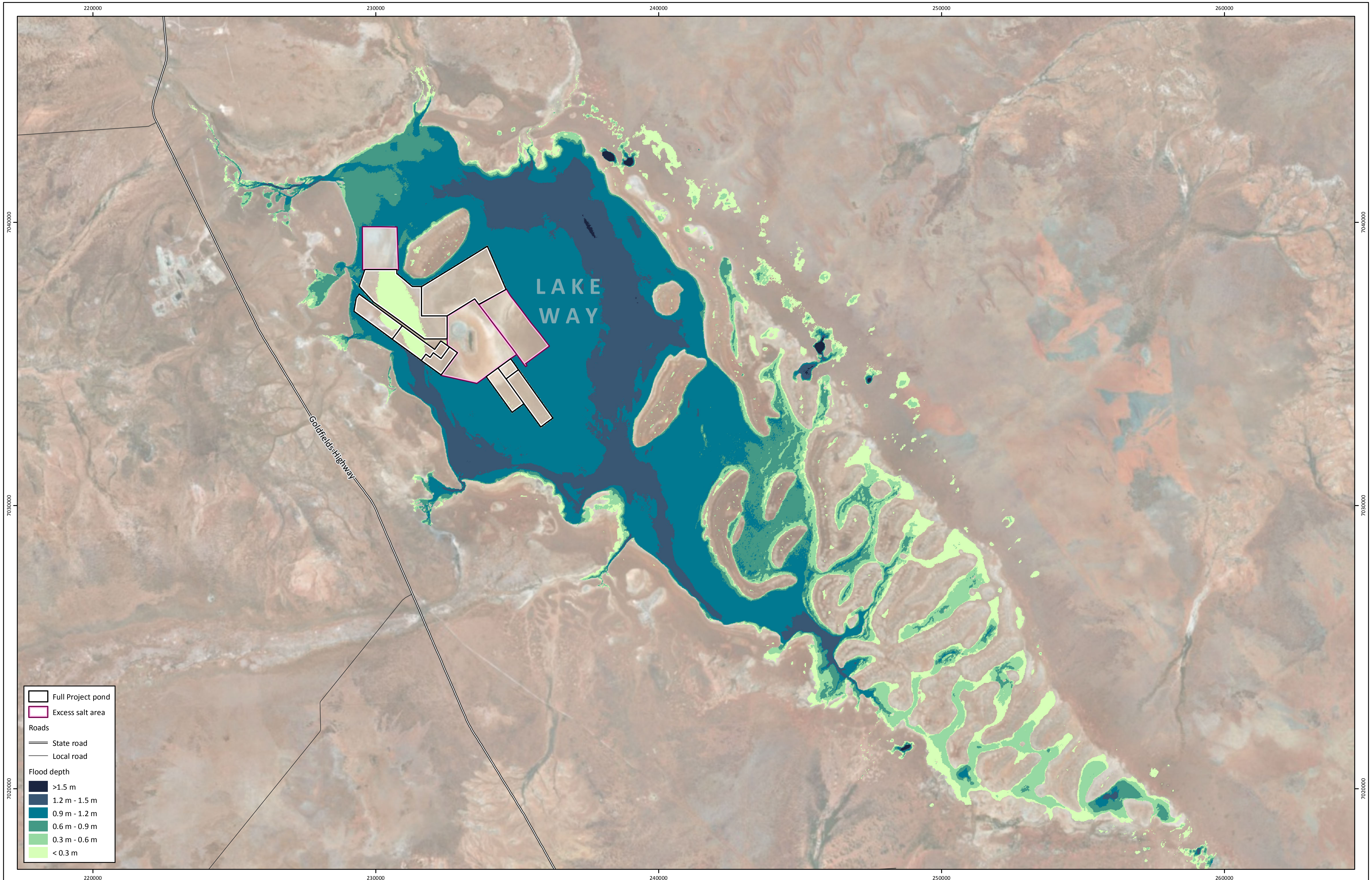


Figure 11: Post-development (Full Project) 1% AEP Flood Inundation of Lake Way

Project: Flood Study
Lake Way

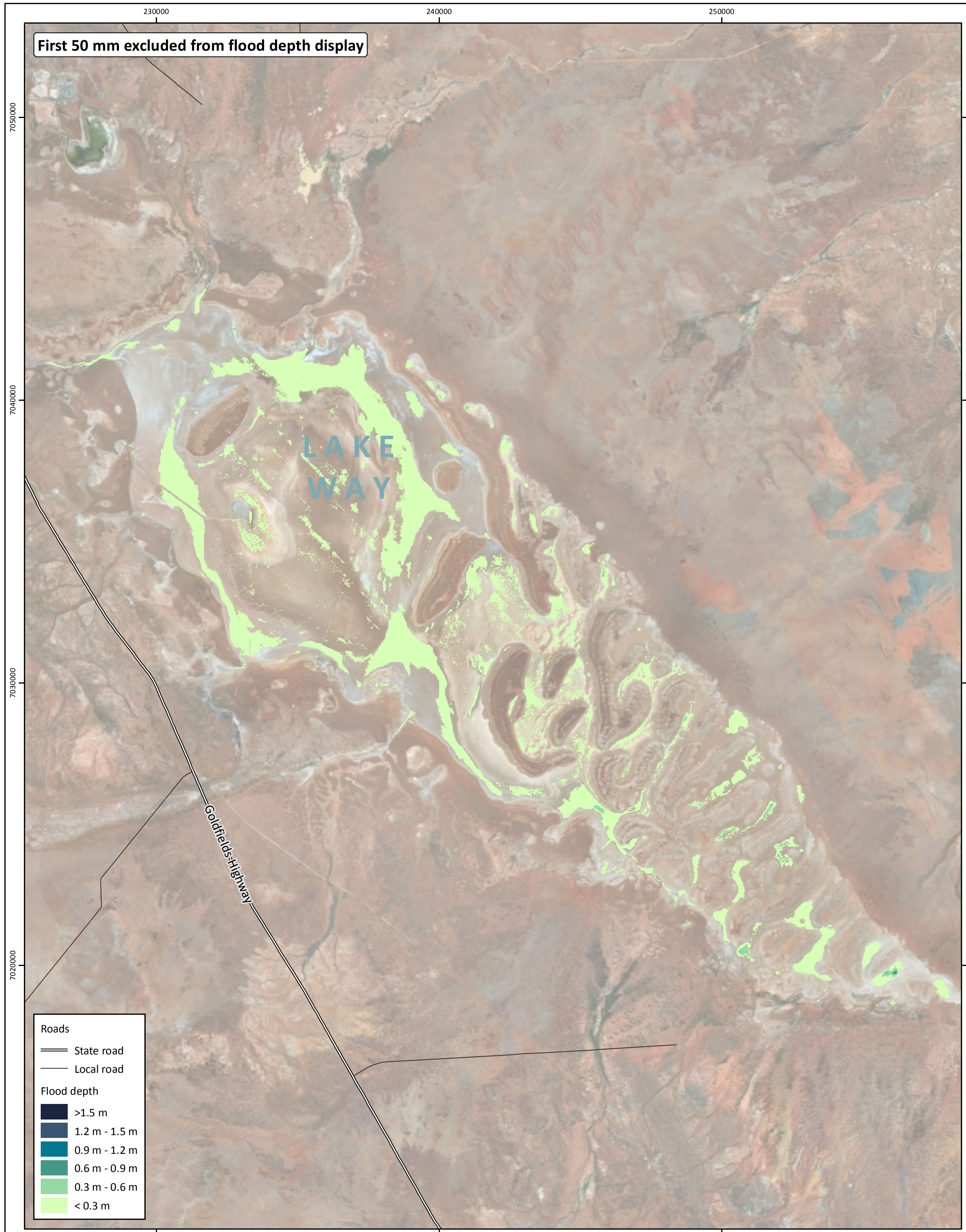
Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F23a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 1 2 3 4
Kilometres
Scale: 1:120,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES



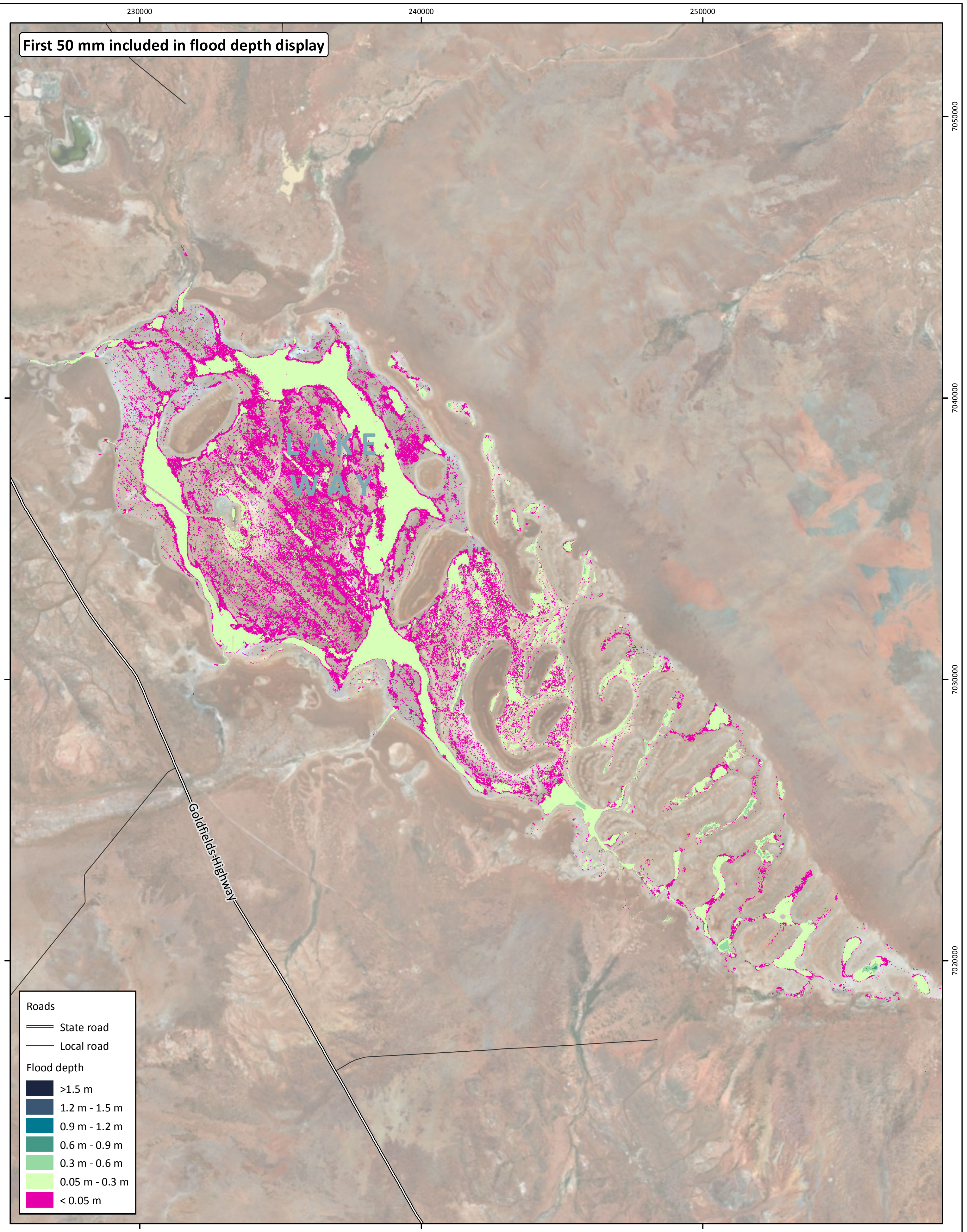


Figure 12: **Flood Inundation Mapping Comparison (20% AEP Pre-development)**

Project: Flood Study
Lake Way
Client: Salt Lake Potash Ltd

Plan Number:
EP19-056(02)--F24a
Drawn: KNM
Date: 19/11/2019
Checked: MGB
Approved: DPC
Date: 19/11/2019

N

0 2 4 6
Kilometres
Scale: 1:170,000@A3
GDA 1994 MGA Zone 51

emerge ASSOCIATES