REPORT

Tonkin+Taylor

Waihi Beach Stormwater Model

Model Build and System Performance

Prepared for
Western Bay of Plenty District Council

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Date
March 2017

Job Number
851969.101

Distribution:

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Executive summary

Tonkin & Taylor (T+T) were engaged by Western Bay pf Plenty District Council (WBoPDC) to update and extend the hydrological and hydraulic models for the Waihi Beach area.

A number of previous models have been developed for the Waihi Beach catchment. These models have been developed and run for different purposes from 2001 to 2015. T+T has developed two previous models, one for the entire area using TUFLOW software and the other for the north section of Waihi Beach using a 3-way coupled MIKE model.

The total catchment area included in the model covers some 49.4 km^2, and is located on the coast east of the township of Waihi.

A Mike Flood model comprising Mike 11, Mike 21 and Mike Urban was constructed for the FHM in accordance with the WBoPDC Model Build Guidelines (2014). The hydrological and hydraulic model build is detailed in this report.

The analysis undertaken has revealed very similar results to the 2013 modelling covering the northern part of Waihi Beach. The differences are attributable to changes in LiDAR (between 2013 and 2015) and changes to design tailwater (sea) level. In general the most recent modelling gives greater flood extent and larger flood depths than previous, in areas covered by both previous and current models.

Stormwater system capacity assessment revealed that a number of pipes in the 2, 5 and 10 year ARI events are under capacity and unable to convey the design flows. A number of pipes are also full due to being surcharged either by backwater effects or from stormwater ponding. Flooding caused by backwater surcharged pipes is not able to be mitigated without making significant changes to rest of the connected stormwater network. Sea level rise is likely to increase the effect of backwater surcharging.

1 Introduction

1.1 General

Tonkin & Taylor (T+T) were engaged by Western Bay of Plenty District Council (WBoPDC) to carry out the Waihi Beach Flood Hazard Mapping (FHM) study.

1.2 Objectives

The overall objectives of the Waihi Beach FHM are to:

- Develop hydraulic and hydrological models for the Waihi Beach catchment
- Complete floodplain mapping
- Undertake a stormwater system performance review for the catchment.

1.3 Scope

The services provided by T+T under the contract are to:

- Assess asset data from WBoPDC and identify surveys required to obtain sufficient quality asset data for model build
- Develop hydraulic and hydrological models of the catchment using the most up to date versions of appropriate modelling software
- Map inundation extents for design events
- Assess performance of the stormwater drainage system in the catchment and identify where levels of service requirements are not, or will not be, met

In this report the methodology, data sources and assumptions that have been adopted to build the hydraulic and hydrological models are summarised. The results of a system performance assessment are presented, together with the required flood hazard maps.

This Model Build and System Performance Report has been prepared for WBOPDC, in accordance with the Stormwater Modelling Guidelines (April 2014).

2 Catchment description

2.1 Location and topography

The Waihi Beach catchment covers approximately 49.4 km^2 and is located in the Western Bay of Plenty. It drains either directly to the Pacific Ocean or into the Tauranga Harbour. The catchment contains the townships of Waihi Beach, Athenree and Bowentown sub-catchments and can be seen in Figure 2.1 below.

Land use varies around the catchment with residential settlements and commercial land use generally nearer to the coastline, with upper catchment areas being largely in rural land use. In relatively recent times there has been residential development occurring further from the coast that contributes runoff towards the lower lying areas.

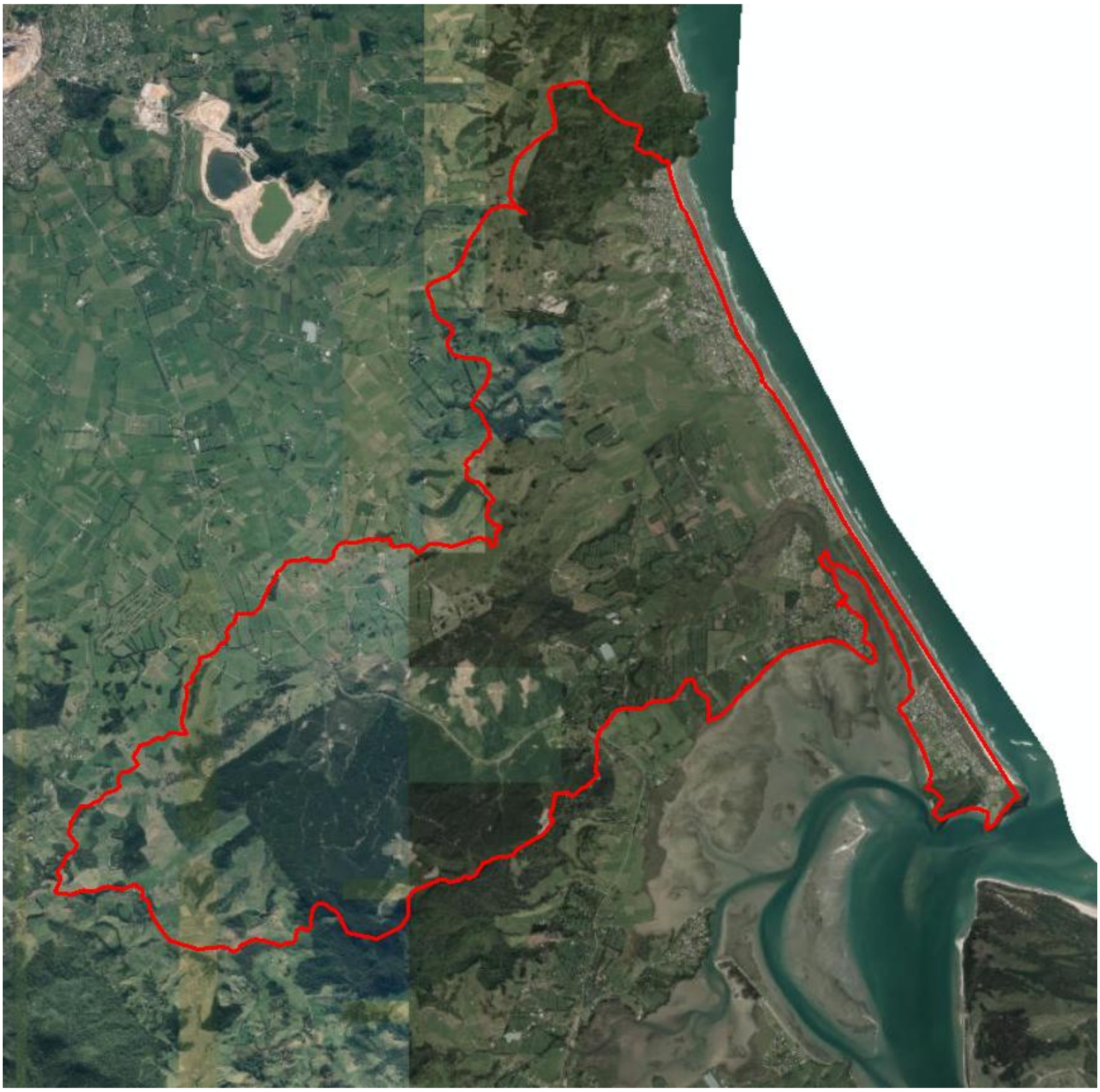

Figure 2.1: Outline of Waihi Beach, Athenree and Bowentown catchment extent

2.2 System description

The model covers Waihi Beach, Athenree and Bowentown. The stormwater systems differ for each area.

The majority of stormwater in Waihi Beach is outlet to the sea via three main creeks, namely One, Two and Three Mile Creeks. At the upstream of extent of One Mile Creek is Waihi Beach Dam, an earth dam which has a low flow culvert, a primary spillway and a secondary spillway. Broadlands block, an undeveloped low lying section of land, leads into Two Mile Creek and provides some attenuation of flood flows. A number of different open channels convey water from the piped network into three mile creek. Darley drain is an outlet located between One and Two Mile Creeks, it conveys flow received from the stormwater pipe network to the sea.

The stormwater in Bowentown is either outlet into the estuary on the west side of the peninsular, or pumped into the sand dunes on the eastern side and discharged by soakage.

Athenree consists of a number of small catchments with the pipe network outlets discharging to the estuary by gravity

2.3 System flood performance

Previous flood events which have been less than 10 year ARI have led to widespread flooding, predominantly through north Waihi Beach and Bowentown.

Future development and the effects of climate change and sea level rise are likely to lead to exacerbated flood levels if they are not adequately mitigated.

3 Modelling assessments

A number of previous models have been developed for the Waihi Beach catchment. These models have been developed and run for different purposes from 2001 to 2015. In recent years T+T has developed two previous models, one for the entire area using TUFLOW software and the other for the north section of Waihi Beach using a 3-way coupled MIKE Flood model.

3.1 TUFLOW simulated flood behaviour modelling

The model developed using TUFLOW software includes the same area as the 2016 MIKE Flood model. It includes rain on grid over the entire catchment with simulated pipes over 300 mm diameter. The tidal boundary levels used in this model are lower than those used in the 2016 model.

This model is used for comparison to the 2016 model.

3.2 MIKE Waihi Beach North Model

This model was developed in 2013 and only extends from the north of Waihi Beach south to Two Mile Creek. It is a 3-way coupled model developed using MIKE by DHI software. As there is flow over the southern boundary the main parts of the model have been incorporated into the 2016 model to develop an overall Waihi Beach Model.

The northern model was also used for comparison to the 2016 model results. The tidal boundaries for this model are lower than the ones used in the 2016 modelling.

3.3 Current Mike Flood Model

The current Mike Flood model is a 3 way coupled model using MIKE by DHI software. It covers the entirety of the Waihi Beach, Athenree and Bowentown catchments. The events to be run during the modelling process are outlined in Table 3.1 below.

Table 3.1: Design Runs

	Rainfall					Tide					ED/MPD
Event ARI	AEP %	ARI (years)	Duration	Time to peak	Horizon	AEP %	ARI (years)	Spring/Neap	Time of high	Horizon	
2	39%	2	24	12	2015	63%	1	Spring	12	2015	ED
5	18%	5	24	12	2015	63%	1	Spring	12	2015	ED
10	10%	10	24	12	2015	39%	2	Spring	12	2015	ED
50	2%	50	24	12	2115	5%	20	Spring	12	2115	MPD

4 Data quality

Data for the model came from a number of different sources. All of the data was received from WBOPDC.

4.1 Areas of interest

Due to the relatively small catchment area the whole of the catchment was able to be modelled. The 2D extent of the model was mostly focused on the built up urban areas and the directly contributing catchments. The model includes Waihi Beach, Athenree and Bowentown.

4.2 Review WBOPDC asset data

4.2.1 GIS Data

The Waihi Beach stormwater asset data provided by Western Bay of Plenty District Council (WBOPDC) was assessed and missing attribute data confirmed. The following table outlines the data received.

Table 4.1: Data provided for model build

Geographical Information System (GIS) stormwater asset data	Provided by WBOPDC
Asset data for pump stations	
1K DTM gridded LiDAR	
2K DTM gridded LiDAR	Sourced from Rotorua District Council (RDC)
5K DTM gridded LiDAR	
T+T Waihi Beach Model	T+T Ref 27863

The following assumptions were made when assessing the data:

- Asset data used in the previous Waihi Beach Model will supersede the GIS asset data provided by WBOPDC for the same sub-catchment area.
- Pipes less than 300 mm diameter will be excluded (unless connected to a pump station or providing other pipe to pipe connectivity).
- Catchpits, rodding eyes, soak holes and nodes without any connecting pipes will be excluded.
- Ten 'new nodes' were created at pipe connections, where a node would typically be expected.

A combination of visual checks, long section analysis and database assessments were used to review the asset data based on:

- Manhole ground level (lid level)
- Invert levels and ground levels
- Upstream pipe invert and diameter
- Downstream pipe invert and diameter
- Pipe diameter decreasing downstream
- Direction of slope of the pipe
- Missing pipes and connectivity issues

For some assets, missing data was inferred from available information, i.e.:

1 Where nodes are missing invert levels, or levels are above pipe inverts, they can be assumed from pipe levels, or interpolated from upstream and downstream level
2 Where lid levels are missing, they can be taken from the DEM
3 Missing manhole diameters can be assumed based on inlet and outlet pipes

4.2.2 Topography

The DEM did not provided accurate ground levels for open channels within the catchment. More information on open channels was required in order to model the channels in MIKE 11.

The LiDAR provided and therefore topography of the model was different than that used for previous modelling is shown the Figure below.

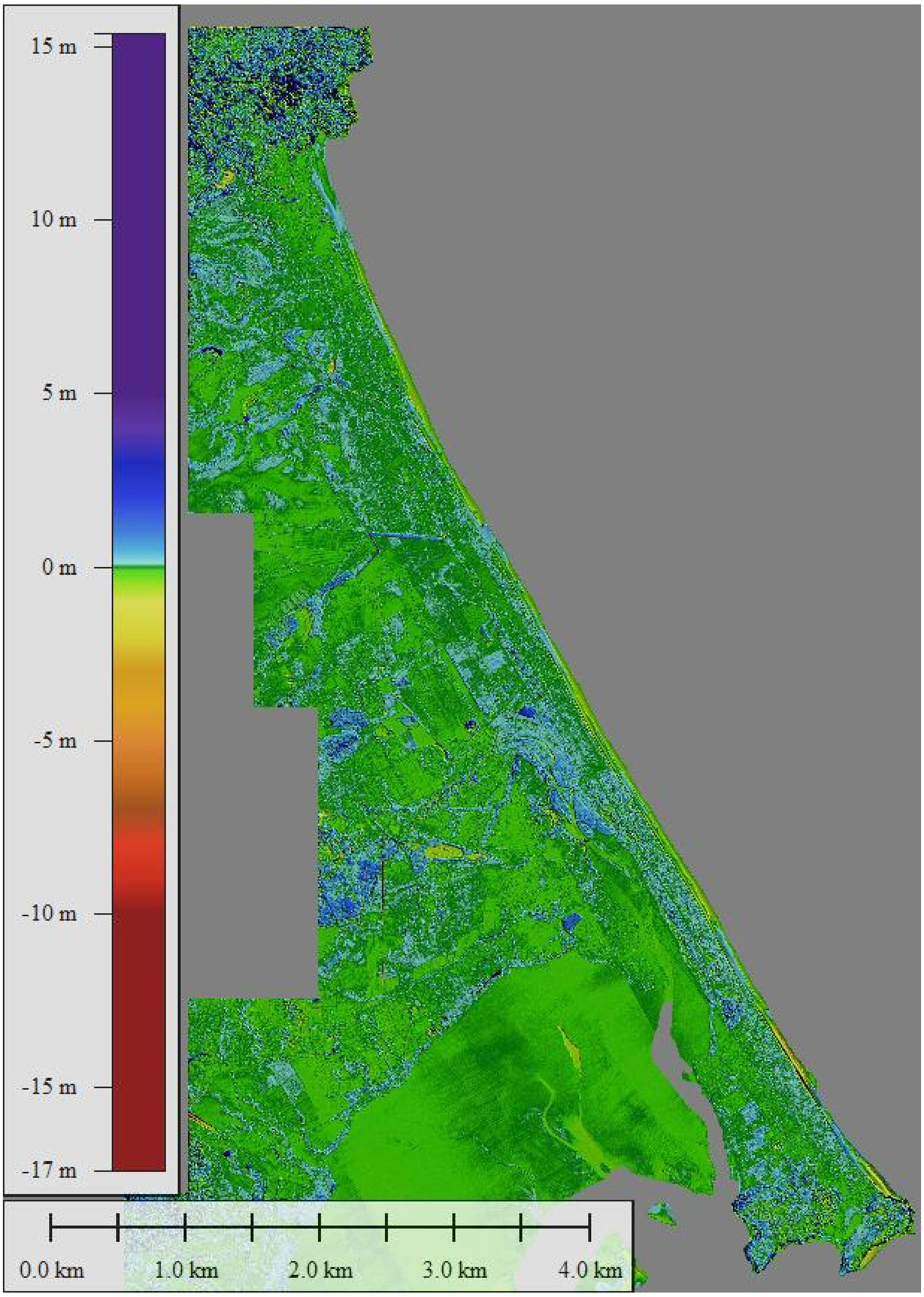

Figure 4.1: Differences in LiDAR (2015 LiDAR – 2010 LiDAR)

In this figure the ground elevation difference between the current (2015) LiDAR data and that used for the previous (2013) modelling is shown. The reasons for the differences can include earthwork and land development, but this does not explain all the differences. Other reasons are not known, but could include LiDAR survey method.

We have assumed in all cases that the more recent data is more accurate and supersedes the previous. This assumption necessitated significant rebuild of the previous model covering northern Waihi Beach.

4.3 Survey

Based on our assessment we required the following data to be captured by survey which was carried out by WBOPDC. Areas that required survey were determined using the TUFLOW simulated flood behaviour model.

Nodes (165 no.)

- Lid level and invert level
- Size of manholes and catchpits (grate size) to the nearest standard dimension
- Upstream and downstream pipe invert levels and soffit levels
- Pipe and culvert sizes to the nearest standard pipe diameter (or dimensions for box culverts)
- Annotated digital photographs

Pump Stations (7 no.)

- Wetwell lid levels and invert levels
- Size of wetwell to the nearest standard dimension
- Number of pumps, and model types
- Number of valves and types
- Annotated digital photographs

Open Channels

Cross sections at maximum 20 m spacings of the open channels shown on the location maps.

The pump station data was not provided to us during the model build process. Survey was undertaken by WBoPDC.

5 Model build

5.1 Modelling software

The software used to model the Waihi Beach catchment is shown in Table 1.

Table 1 Modelling software

Software Type	Mike 11 by DHI	Mike 21 by DHI	Mike Urban by DHI
Software Version	Version 2014	Version 2014	Version 2014
Service Pack	Service Pack 3	Service Pack 3	Service Pack 3
Method used for Runoff	n/a	UHM (Rain on Grid)	UHM (Lumped Catchment)

5.2 Schematisation

Taking into account the topography, stormwater networks, overland flowpaths and obstructions such as roads, the Waihi Beach catchment was delineated into a number of subcatchments. The lower subcatchments (urban area) are modelled as Rain on Grid (ROG) catchments and therefore the delineation of these subcatchments was not considered.

The upper subcatchments are modelled as Lumped Hydrology Catchments (LC) therefore overland flowpaths into the lower catchments were considered when delineating these catchments.

The 2-Dimensional (2D) extent was chosen to encompass all the area of interest and includes all the urban areas in Waihi Beach, Athenree and Bowentown. This extent is a contributing factor to model run time and was therefore kept to a minimum.

The 1-Dimensional (1D) model was used to represent major waterways as well as channels that are not well represented in the 2D DEM.

5.3 Hydrological model

5.3.1 Method used

The Soil Conservation Services (SCS) hydrological method was used to transform rainfall into runoff. The rainfall depths were determined from HIRDSv3. The hydrological processes were modelled using Unit Hydrograph Method (UHM) from Mike Urban and net effective rainfall was applied in MIKE 21.

5.3.2 Rainfall profile

The rainfall profile used is a 24 hour duration with the peak rainfall intensity occurring at 12 hours. Depth-Frequency-Duration Tables sources from HIRDS are shown below, climate adjusted Rainfall depths are shown in Table 5.2. Global Rainfall was applied to the extent of the model with no spatial variation between the catchments.

An example rainfall profile is shown in Figure 5.1 below.

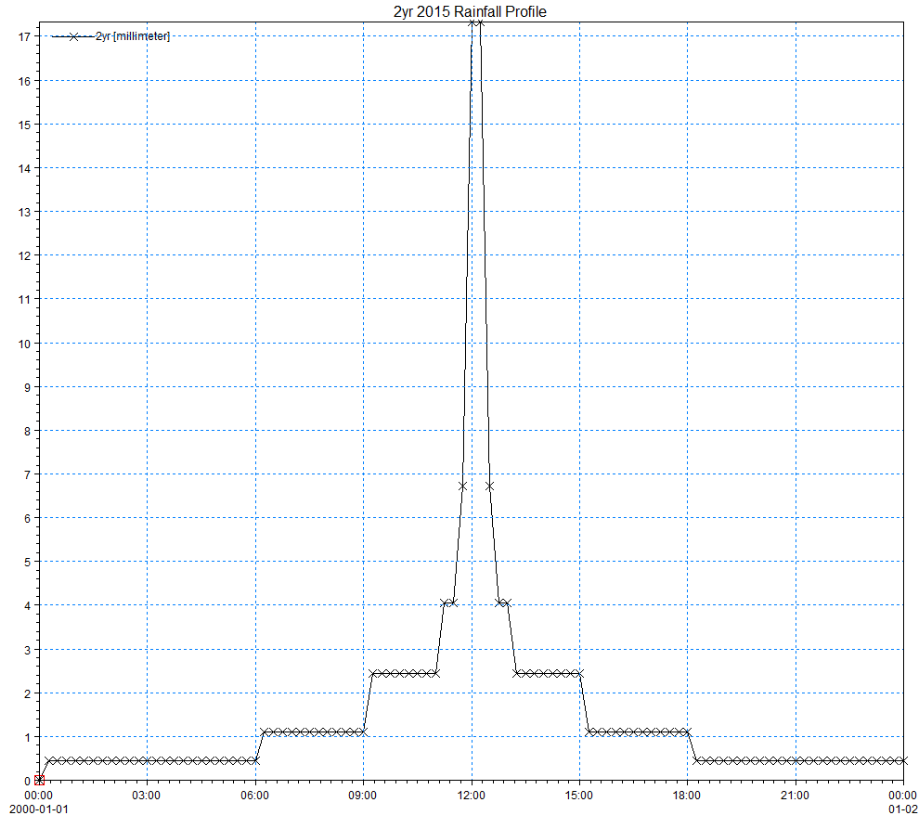

Figure 5.1: 2yr ARI Rainfall Profile

Table 5.1: Rainfall depths (mm)

Frequency		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	10.1	15.2	19.3	29.1	41	70.5	99.2	139.7	172.1	194.5
2	0.5	11	16.6	21.2	31.9	44.8	76.9	108	151.7	187	211.3
5	0.2	14.7	22.1	28.1	42.4	59.2	100.4	140.1	195.6	241.1	272.4
10	0.1	17.7	26.7	33.9	51.1	71.1	119.8	166.5	231.5	285.2	322.3
20	0.05	21.2	31.9	40.6	61.2	84.7	141.9	196.5	272	335.2	378.7
30	0.033	23.5	35.4	45	67.9	93.8	156.5	216.1	298.5	367.8	415.6
40	0.025	25.3	38.1	48.4	73	100.7	167.6	231.1	318.7	392.7	443.7
50	0.02	26.7	40.3	51.3	77.3	106.4	176.7	243.4	335.2	413.1	466.7
60	0.017	28	42.2	53.7	80.9	111.3	184.6	253.9	349.3	430.4	486.4
80	0.012	30.1	45.4	57.7	87	119.5	197.6	271.4	372.8	459.3	519
100	0.01	31.9	48	61.1	92	126.2	208.3	285.8	392	483	545.8

Table 5.2: Climate adjusted rainfall depths (mm)

Frequency		Duration									
ARI (y)	aep	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
1.58	0.633	11.8	17.7	22.2	33.2	46.3	78.3	109.2	152.3	185.8	208.8
2	0.5	12.8	19.3	24.4	36.4	50.6	85.5	118.9	165.4	201.9	226.8

5	0.2	17.2	25.7	32.5	48.7	67.5	113.3	157.2	217.8	266.4	299.9
10	0.1	20.7	31.1	39.3	59	81.9	136.9	189.2	262.1	321.7	362.2
20	0.05	24.8	37.3	47.3	71.1	98.2	164	226.6	313.1	385.2	434.4
30	0.033	27.4	41.3	52.6	79.3	109.6	182.8	252.4	348.6	428	482.8
40	0.025	29.6	44.5	56.5	85.3	117.6	195.8	269.9	372.2	457.8	516.8
50	0.02	31.2	47.1	59.9	90.3	124.3	206.4	284.3	391.5	482.5	545.1
60	0.017	32.7	49.3	62.7	94.5	130	215.6	296.6	408	502.7	568.1
80	0.012	35.2	53	67.4	101.6	139.6	230.8	317	435.4	536.5	606.2
100	0.01	37.3	56.1	71.4	107.5	147.4	243.3	333.8	457.9	564.1	637.5

5.3.3 Hydrological loss parameters

The hydrological losses are defined using the following:

i. Curve number

ii. Lag time

iii. Initial abstraction.

Each catchment has been represented with a curve number based on a weighted average. The curve number was determined using the land uses outlined in the Land Cover Database version 4 (LCDBv4) available on the Land Resource Information Systems (LRIS) online portal. To equate each landuse type to the appropriate curve number SCS soil group C was chosen to represent the Waihi Beach area. The weighted CN for each catchment can be seen in Table 5.3 below.

Lag time and initial abstraction was determined in accordance with the Auckland Council TP108 procedure, where lag time equals two-thirds of the time of concentration, and initial abstraction is 5mm. The catchments with Lag time listed as N/A in the table below are modelled as 'Rain on Grid' and therefore no lag time is needed.

The lag time was determined based on TP108 methodology, where the longest flow path for each sub-catchment was determined from LiDAR and an overland flowpath assessment. Catchment length and slope (by equal area method) were calculated based on identified longest flow path. The lag time for each sub-catchment was calculated based on catchment length, slope, curve number and channelization factor. A channelization factor of 0.6 was used.

Figure 5.2 shows an overview of the modelled catchments.

Table 5.3: Catchment parameters

Catchment ID	CN	Initial abstraction (mm)	Lag time (hrs)
Catch_01	71.77595	5	2.652908361
Catch_02	73.20147	5	0.565424797
Catch_03	73.72443	5	0.579557618
Catch_04	73.621	5	0.751765406
Catch_05	70.37163	5	0.354080257
Catch_06	73.83225	5	N/A
Catch_07	73.51132	5	N/A
Catch_08	70.00393	5	0.063796069
Catch_09	73.5129	5	N/A
Catch_10	72.89205	5	N/A
Catch_11	71.48057	5	N/A
Catch_12	74	5	N/A
Catch_13	73.77783	5	N/A
Catch_14	73.92622	5	N/A
Catch_15	73.06694	5	0.22452609
Catch_16	74	5	0.301891669
Catch_17	74	5	N/A
Catch_18	73.3755	5	N/A
Catch_19	73.78426	5	0.421833867
Catch_20	72.9453	5	0.161066186
Catch_21	73.24478	5	N/A
Catch_22	71.69292	5	0.247568823
Catch_23	72.32085	5	N/A
Catch_24	72.20399	5	N/A
Catch_25	73.19594	5	0.264414617

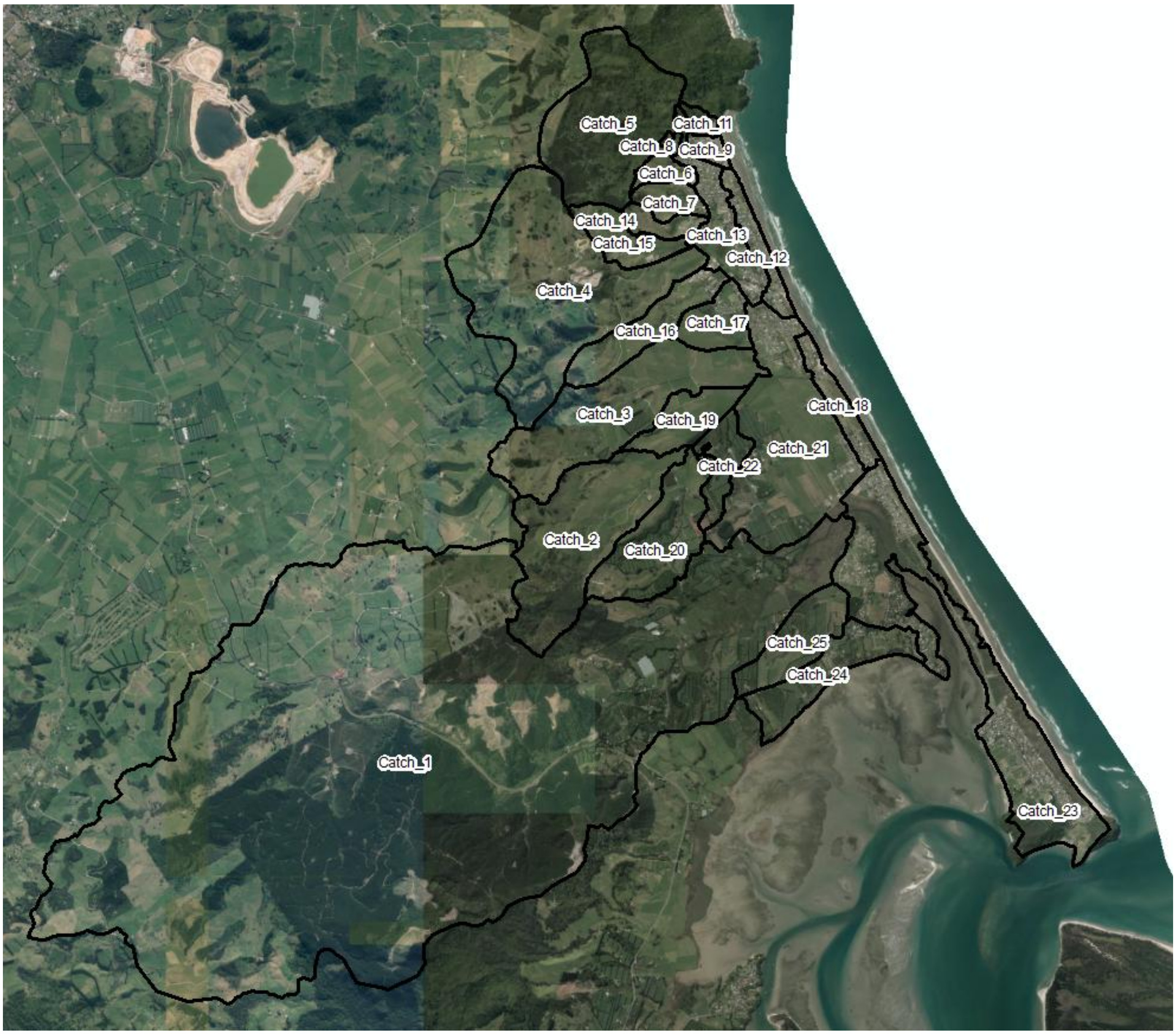

Figure 5.2: Modelled Catchments

5.3.4 Future land use

Land use varies around the catchment with residential settlements and commercial land use around the lower catchment, and more recent residential land development extending toward the upper catchment.

Future land use from the WBOPDC district plan shows some areas of residential development in the lower catchments.

For MPD Scenarios new weighted CN were calculated based on the updated Land Use. Due to the relatively small areas for development the CN changes were small.

5.3.5 Rain on grid

The rainfall in the lower (urban) catchments was represented as ROG (Catchments 6, 7, 9, 10, 11, 12, 13, 14, 17, 18, 21, 23, 24). Due to infiltration losses not being able to be applied with the ROG method a net effective rainfall was applied. Using the curve numbers and initial abstraction depths HEC HMS models for each ROG catchment were produced. The net rainfall from each catchment (for both ED and MPD) was then applied in the MIKE 21 model using a spatial and time varying distribution.

5.3.6 Lumped catchment

The upper catchments were represented with lumped catchment hydrology. Each catchment having the rainfall for the entire catchment loaded at one point in the catchment, then allowed to flow down into the area of interest. Care was taken to place loading points in overland flow paths and delineate catchments so that each major flow path was represented. The loading points were mainly placed at the extent of the 2D model, the exceptions being the smaller catchments which lie entirely within the 2D extent. For these subcatchments the loading points were placed approximately two thirds up the catchment.

5.3.7 Tidal boundaries

The open coast and inner harbour tidal levels used in the model were based on data provided by Bay of Plenty Regional Council (BOPRC) this data is summarised in Table 5.4. The tidal profile was generated using a sinusoidal curve with high tide corresponding to the peak rainfall. The amplitude of the tide was based on a spring tide range of 1.78 m.

Table 5.4: Tidal boundary values provided by BOPRC

ARI (yr)	1	2	20yrCC
High Tide level (open coast)	1.98	2.21	3.65
High Tide level (harbour coast)	1.62	1.76	3.25

A run matrix with the design runs shows how the tides were applied to each run. It can be viewed in Section 3.3.

5.4 Hydraulic model

5.4.1 Method used

A comprehensive hydraulic model was developed using DHI's Mike Flood software. The Mike Flood software dynamically couples three hydraulic models so that flows can pass from one model to another. The three models within the Mike Flood model are indicated below:

- In channel flow (Mike 11 model)
- Floodplains and overland flowpaths (Mike 21 model)
- Stormwater reticulation (Mike Urban model).

5.4.2 MIKE URBAN

Mike URBAN was used to model the LC Catchments as well as the stormwater reticulation. Information for the stormwater system was obtained from WBoPDC GIS or from survey.

5.4.2.1 Catchments

The lumped hydrology catchments were modelled in Mike Urban. The catchments were delineated using natural topography features as well as overland flow paths. The catchment parameters are outlined in Section 5.3.3. Figure 5.3 below shows the locations of the catchments.

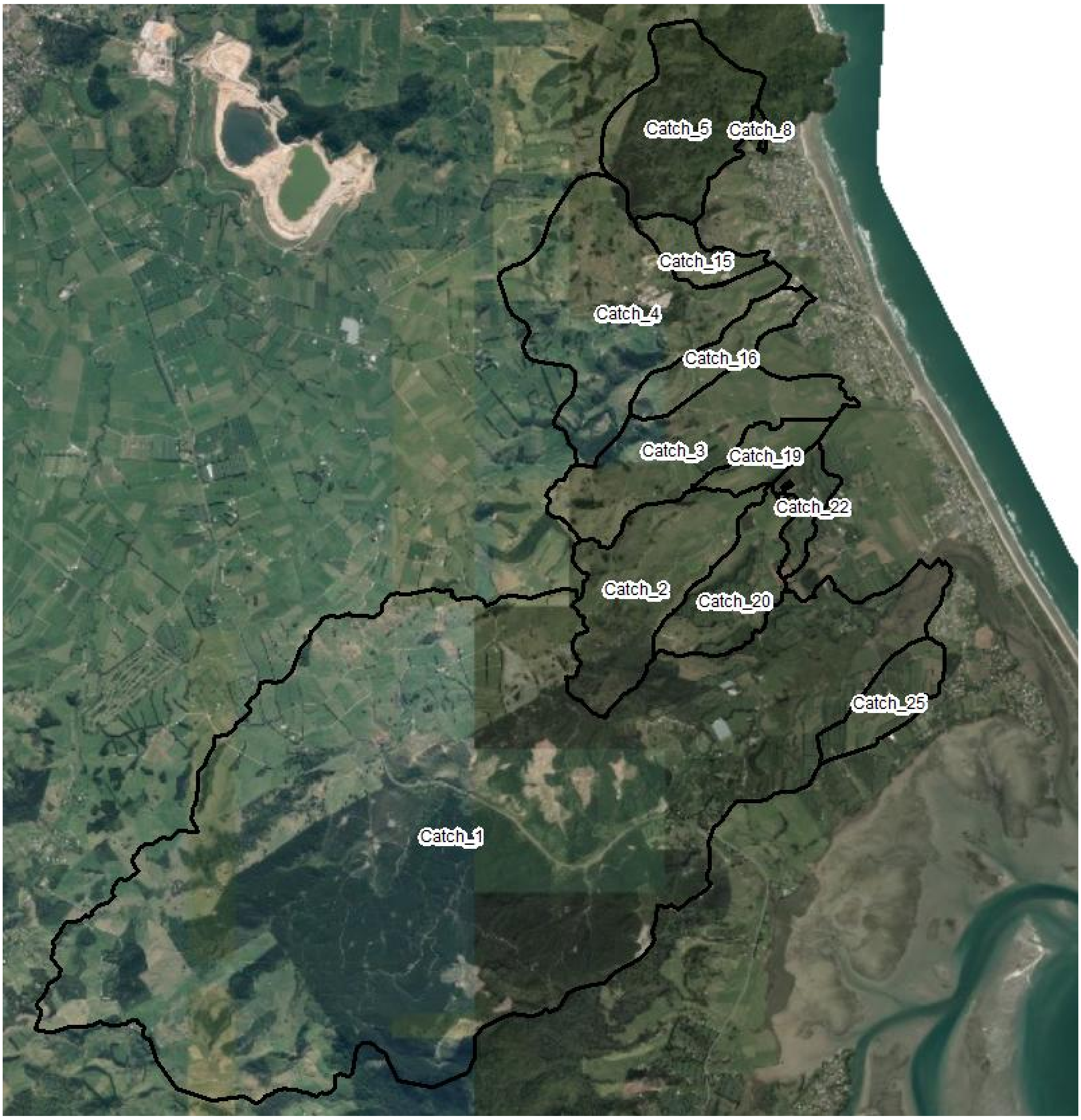

Figure 5.3: Lumped Hydrology Catchments modelled in Mike Urban

5.4.2.2 Manholes, outlets and Inlets

All manholes, inlets and outlets lying within the catchment boundary associated with pipes greater than 300 mm diameter that are located downstream of a hydrological loading node are included in the Mike Urban model. There are also a small number of pipes smaller than 300 mm that are included in the model to ensure connectivity between pipes.

Table 5.5 provides a summary of modelled manholes, inlets and outlets.

Table 5.5: Summary of modelled manholes, inlets and outlets

Hydraulic model components	ED and MPD
Total number of stormwater network system manholes (Mike Urban)	407
Total number of inlets and outlets (Mike Urban)	240

Note: This table does not include dummy manholes created for the purpose of distributing flows onto the Mike 21 grid

5.4.2.3 Pipes

All pipes and culverts located within the catchment boundary that are greater than 300 mm diameter and located downstream of a hydrological loading node are included in the Mike Urban model. There are also a small number of pipes smaller than 300 mm that are included in the model to ensure connectivity between pipes.

Table 5.6 provides a summary of modelled pipes, culverts and channels.

Table 5.6: Summary of modelled pipes, culverts and channels

Hydraulic model components	ED and MPD
Total number of stormwater network system links (Mike Urban)	524
Total number culverts (Mike 11)	24
Total number open channels (Mike 11)	17

5.4.2.4 Pumps

Pumps have been added into the MIKE Urban model and coupled to the MIKE 21 model. The pumps have been modelled as manholes and outlets with a flow-stage (Q-H) relationship based on a model pump curve. These pumps take water completely out of the system and essentially act as sinks.

5.4.3 MIKE 11

Mike 11 was used to model the 1D components of Waihi Beach. This includes creeks, open channels, bridges and culverts. Both surveyed cross sections and cross sections derived from the DEM were used to develop this model.

5.4.3.1 Existing model

The previous modelling completed by T+T of the north Waihi Beach catchments included Mike 11 models for One Mile Creek, Darley Drain and Two Mile Creek. These sections remain largely unchanged with minor adjustments carried out to apply them in the new model setting (particularly interfacing with new LiDAR data).

5.4.3.2 Model extent

The Mike 11 model includes sections for One, Two and Three Miles Creeks, Darley Drain, and open channels near Didsbury Drive and Emerton Road. Where the model extends to the ocean boundary the same tidal time series is applied as for the 2D Model.

5.4.3.3 Boundaries

Both upstream and downstream boundaries were added to each branch in Mike 11. The upstream boundaries consist of a 0.1 m^3/s initial inflow to ensure stability of the model at startup. The downstream boundaries are either the tidal time series outlined in Section 5.3.7 or a water level set at the same level as the adjacent DEM.

5.4.4 MIKE 21

Mike 21 was used to model the 2D component. This includes overland flow path and open channels not included in the Mike 11 model. The model was competed in a flexible mesh with maximum cell size off 100 m^2 in rural areas and 9 m^2 in urban areas.

5.4.4.1 Extent

The extent of the Mike 21 model was governed by the need to keep run times down while also making sure all the area of interest was covered. The 2D extent is shown in Figure 5.4 below.

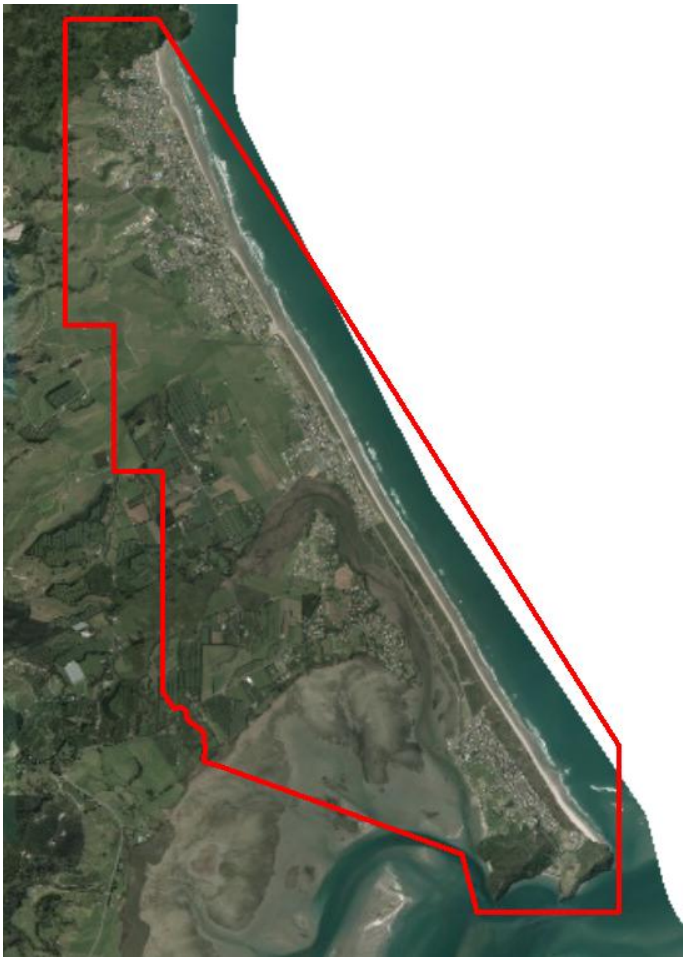

Figure 5.4: Mike 21 2D Model Extent

5.4.4.2 DEM and mesh

The DEM was derived from 2013 LiDAR provided by WBOPDC. This information was then converted into a flexible mesh, with smaller area elements in the urban area of interest and larger elements in the rural areas or in the ocean. This flexible mesh allowed for faster run times.

A number of localised changes had to be made to the LiDAR. These included lowering the level of the ground at stormwater outlets and lowering the invert of open channels that were not well represented in the LiDAR.

5.4.4.3 Roughness and viscosity

Manning's 'n' values have been applied to each cell in the 2D model. These values were derived from the land use type in the LCDBv4. The Manning's values were converted to Manning's 'M' values defined as 1/n for applying in the model. Figure 5.5 below shows the roughness layer applied.

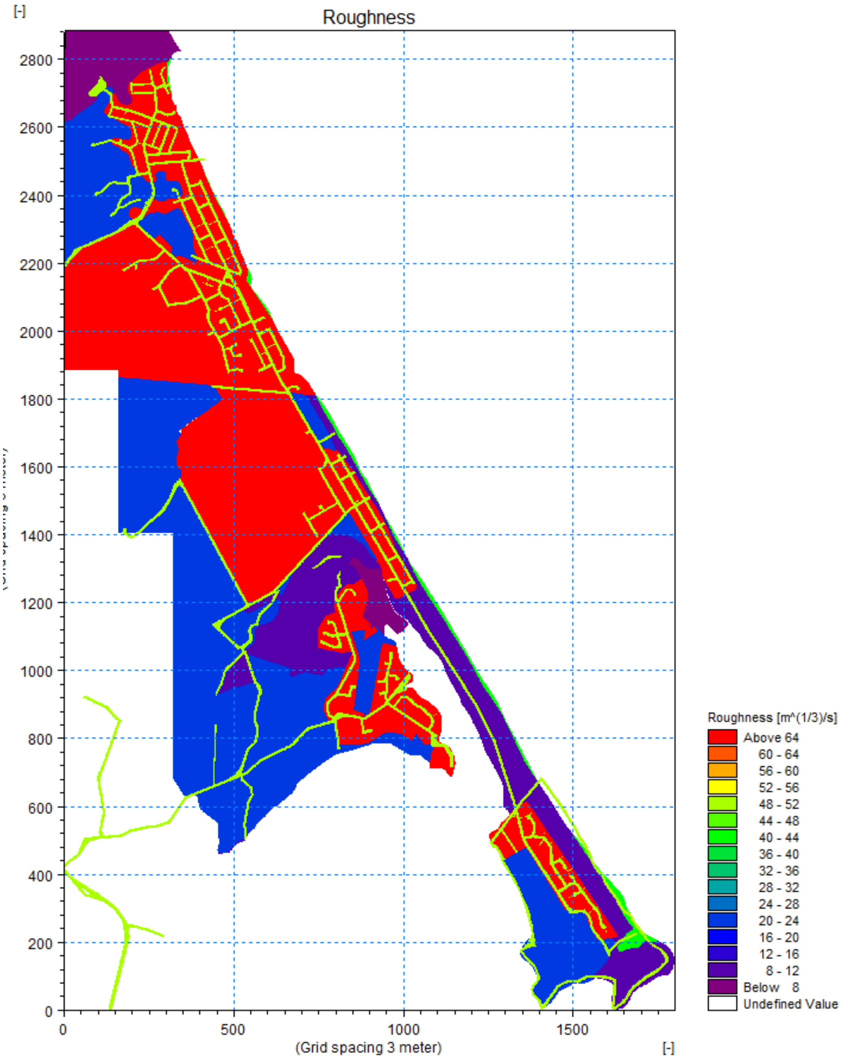

Figure 5.5: Manning's 'M' roughness values

The flux based eddy viscosity formulation was used in Mike 21 to represent the energy losses due to turbulence in Mike 21 (viscosity = $0.9m^2/s$).

5.4.5 MIKE flood

To allow flow between the three separate models, they were linked together in a number of different ways.

5.4.5.1 Lateral links (MIKE 21 to MIKE 11)

Grid cells in Mike 21 along both sides of the open channels were linked with Mike 11 branches. The link type used is "lateral link", the structure type is "weir", and the structure source is "M21".

To help stabilise the lateral links, adjustments were made to the Exponential smoothing factor, reducing all values to 0.4. The default weir coefficient (1.838) and friction (n = 0.05) were maintained.

5.4.5.2 MIKE Urban to MIKE 21

Manholes modelled in Mike Urban were divided into three categories:

i. Loading nodes
ii. Manholes
iii. Inlets and outlets.

All loading nodes are sealed manholes which were not coupled to the Mike 21 grid. A dummy weir was created for each loading node, sharing the same ID as the sealed manhole. All dummy weirs were linked to Mike 21 using the link type ‘weir to M21’.

Manholes are linked with Mike 21, by using the link type ‘inlet to M21’. The maximum inflow and outflow between the manhole and Mike 21 grid was set to 0.1 m^3/s. For flows less than 0.1 m^3/s, flows are calculated using the orifice equation was used.

Inlets and outlets are linked with Mike 21, by using the link type ‘outlet to M21’. Specific QH relationships were calculated for each inlet pipe. These were based on nomographs from the Culvert Manual (Ministry of Works and Development, 1978).

5.4.5.3 MIKE URBAN to MIKE 11

The link types used for discharge from Mike Urban to Mike 11 and vice versa are shown in Table 5.3.

Table 5.7: Linkage between Mike 11 and Mike Urban

Linkage	Link type
Mike Urban to Mike 11	Mike Urban outlets to Mike 11
Mike 11 to Mike Urban	Mike 11 water level boundary

5.4.6 Hydraulic model assumptions

The ponds, culverts and bridges are based on catchment understanding from the supplied GIS information, survey and knowledge of the area at the time of modelling. Due to the rate of development in the catchment modifications to the ponds, culverts and bridges since this time may not be represented in the model.

No blockage has been assumed in manholes, pipes, culverts and catchpits in the stormwater system.

No sedimentation has been allowed for in the pipes i.e. it is assumed that all pipes are capable of performing at full capacity.

No topographical changes, natural or otherwise have been allowed for in the modelling, including but not exclusive to geomorphological changes, volcanic activity and landslides.

The potential for change in asset condition over time is not represented.

Screens, orifice plates, control gates, valves, backflow preventers, choke points and other such obstructions and hydraulic controls are not modelled unless this data has been provided.

The bathymetry for modelling was developed using ground contours which were derived from LiDAR survey data. In urban areas the LiDAR data is stated to have an accuracy of ± 0.25 m with a 90% confidence interval.

Inlets were modelled as outlets in Mike Urban, with a QH relation assigned to each inlet based on nomographs from Culvert Manual (1978) by Ministry of Works and Development.

No account has been taken of the execution of any operations and maintenance works that may affect system performance (i.e. regular pipe cleaning may indicate a serious deficiency in the network affecting hydraulic conditions).

The asset data that was not captured or verified in the field as part of this project is assumed to be correct.

6 Testing and validation

Following the model design runs, comparisons were carried out against the previous models. For this comparison the 2013 North Waihi Beach District Plan 50 year results were used as well as results from TUFLOW simulated flood behaviour modelling.

6.1 Comparison to previous North Model (district plan)

Figure 6.1 below compares the 2016 MIKE max flood depth map to the 2013 district plan flood extent (for the north of Waihi Beach only), it should be noted that the modelled tide levels are higher in the 2016 model.

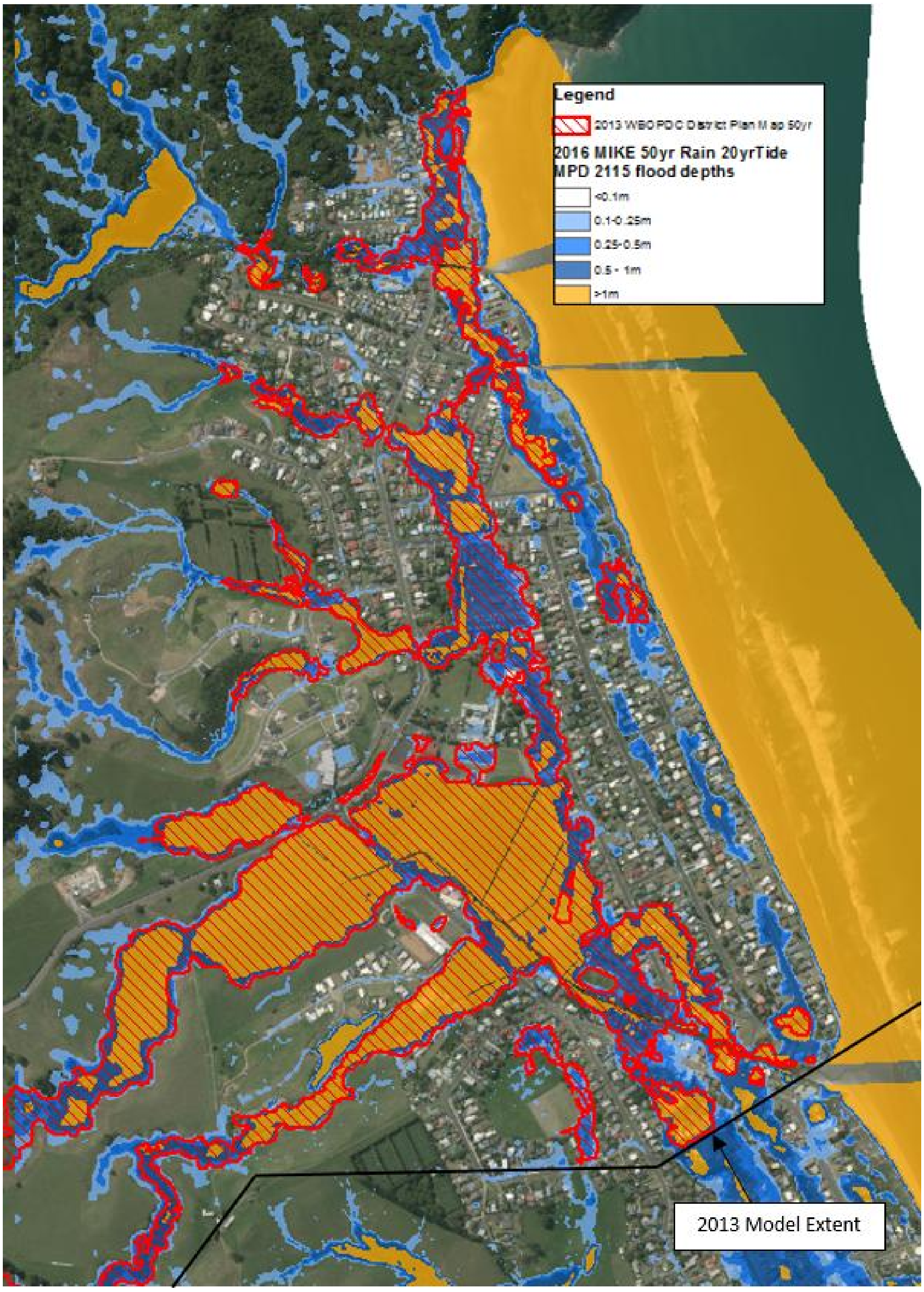

Figure 6.1: Comparison of 2016 model to 2013 district plan flood extent

The above figure shows that in the upper catchment areas in the model extent results are very similar. There are differences in the lower catchments close to the coast, these are due to the larger tide levels in the 2016 results.

6.2 Comparison to TUFLOW modelling

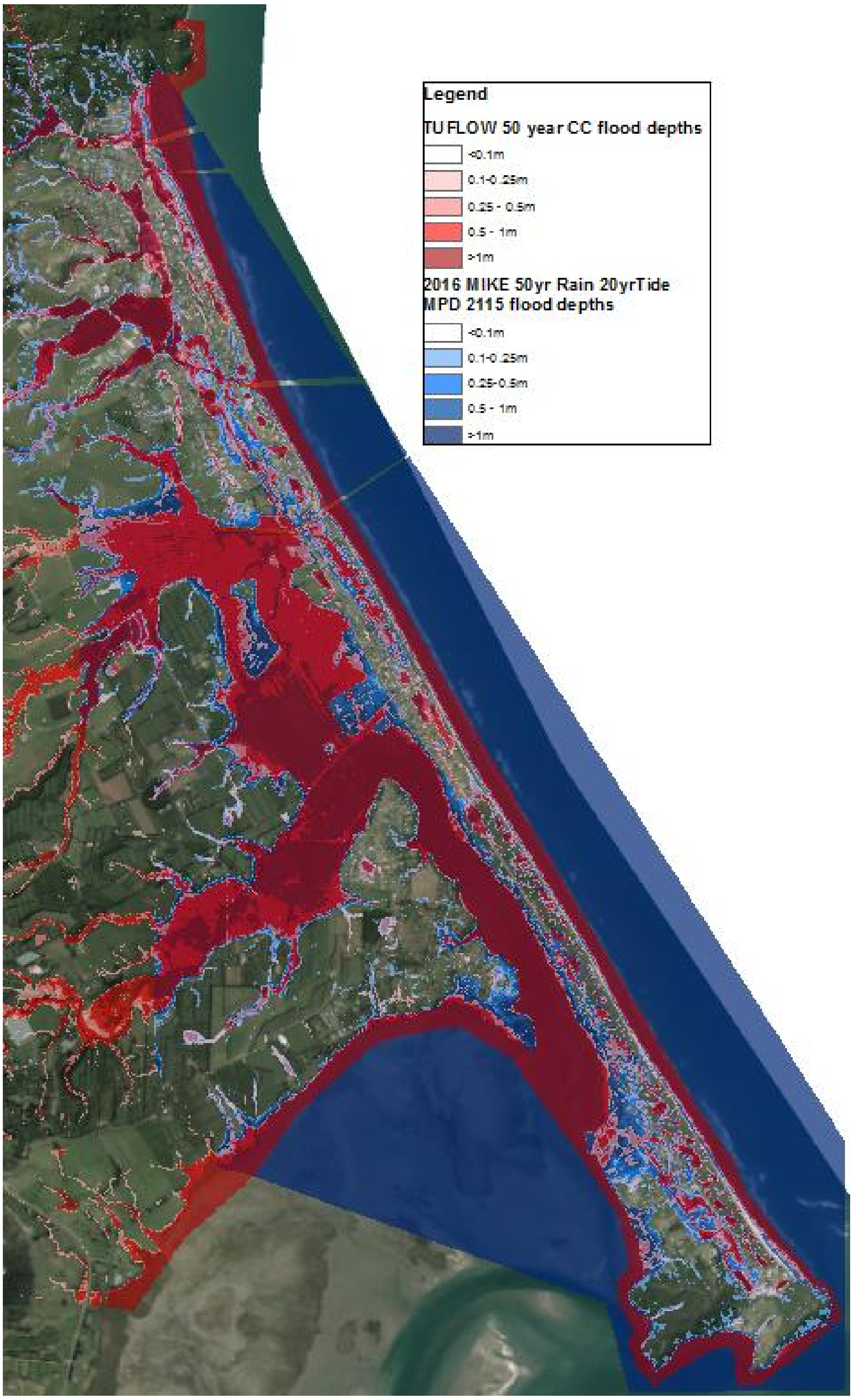

Figure 6.2: Comparison between 2016 MIKE 50yr flood depths and TUFLOW 50yr flood depths

Figure 6.2 shows the comparison between the 50yr climate change adjusted TUFLOW model result and the 2016 MIKE model 50yr climate change adjusted model. The models show the largest difference in the tidally affected areas. The 2016 MIKE model has a high tide level approximately 0.5m higher than the high tide in the TUFLOW model. This is evident in both the coastal areas as well as the estuary and surround areas.

6.3 Sensibility

Following the design runs, the preliminary results were presented to WBOPDC, comparison was made between the previously accepted Waihi Beach North model results and the 2016 results in the same areas. These comparisons showed sensible results, therefore the remaining model was accepted as sensible on the same basis.

7 Results

7.1 Floodplain mapping

The figures Appendix A show the flood depths for the four design runs. The results for depths greater than 100mm are shown.

The following figure numbers apply:

- Figure 1: 2-year ARI rain together with 1-year ARI tide, ED, northern part of Waihi Beach;
- Figure 2: 2-year ARI rain together with 1-year ARI tide, ED, Athenree and Pio Shores;
- Figure 3: 2-year ARI rain together with 1-year ARI tide, ED, Bowentown;
- Figure 4: 5-year ARI rain together with 1-year ARI tide, ED, northern part of Waihi Beach;
- Figure 5: 5-year ARI rain together with 1-year ARI tide, ED, Athenree;
- Figure 6: 5-year ARI rain together with 1-year ARI tide, ED, Bowentown;
- Figure 7: 10-year ARI rain together with 2-year ARI tide, ED, northern part of Waihi Beach;
- Figure 8: 10-year ARI rain together with 2-year ARI tide, ED, Athenree;
- Figure 9: 10-year ARI rain together with 2-year ARI tide, ED, Bowentown;
- Figure 10: 50-year ARI rain together with 20-year ARI tide, MPD, northern part of Waihi Beach;
- Figure 11: 50-year ARI rain together with 20-year ARI tide, MPD, Athenree;
- Figure 12: 50-year ARI rain together with 20-year ARI tide, MPD, Bowentown.

7.2 Pipe capacity assessment

A pipe capacity assessment was carried out on the 2, 5 and 10 year ED scenarios. The pipes were classified into three categories:

- Under capacity pipes
- Surcharged pipes
- Pipes without issue

Figures 13-18 in Appendix A show the pipes and the associated level of flooding.

8 Conclusions and recommendations

Tonkin + Taylor (T+T) were appointed by Western Bay of Plenty District Council to carry out stormwater flooding model build and analysis at Waihi Beach.

This report provides the methodology and outcomes of the model build, pipe capacity assessment and flood mapping. The flood plain and pipe capacity figures along with supporting information can be found in the Appendices of this report.

The analysis undertaken has revealed very similar results to the 2013 modelling covering the northern part of Waihi Beach. The differences are attributable to changes in LiDAR (between 2013 and 2015) and changes to design tailwater (sea) level. In general the most recent modelling gives greater flood extent and larger flood depths than previous, in areas covered by both previous and current models.

Stormwater system capacity assessment revealed that a number of pipes in the 2, 5 and 10 year ARI events are under capacity and unable to convey the design flows. A number of pipes are also full due to being surcharged either by backwater effects or from stormwater ponding. Flooding caused by backwater surcharged pipes is not able to be mitigated without making significant changes to rest of the connected stormwater network. Sea level rise is likely to increase the effect of backwater surcharging.

9 References

Auckland Council, 2011. Stormwater Flood Modelling Specification. November 2011.

WBOPDC, 2014. Stormwater Modelling Guidelines.

10 Applicability

This report has been prepared for the exclusive use of our client Western Bay of Plenty District Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Luke Dobney	Glen Nicholson
Water Resources Engineer	Project Director

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Mark Pennington

Senior Water Resources Engineer

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Appendix A: Results

- Flood depth maps
- Pipe capacity assessment

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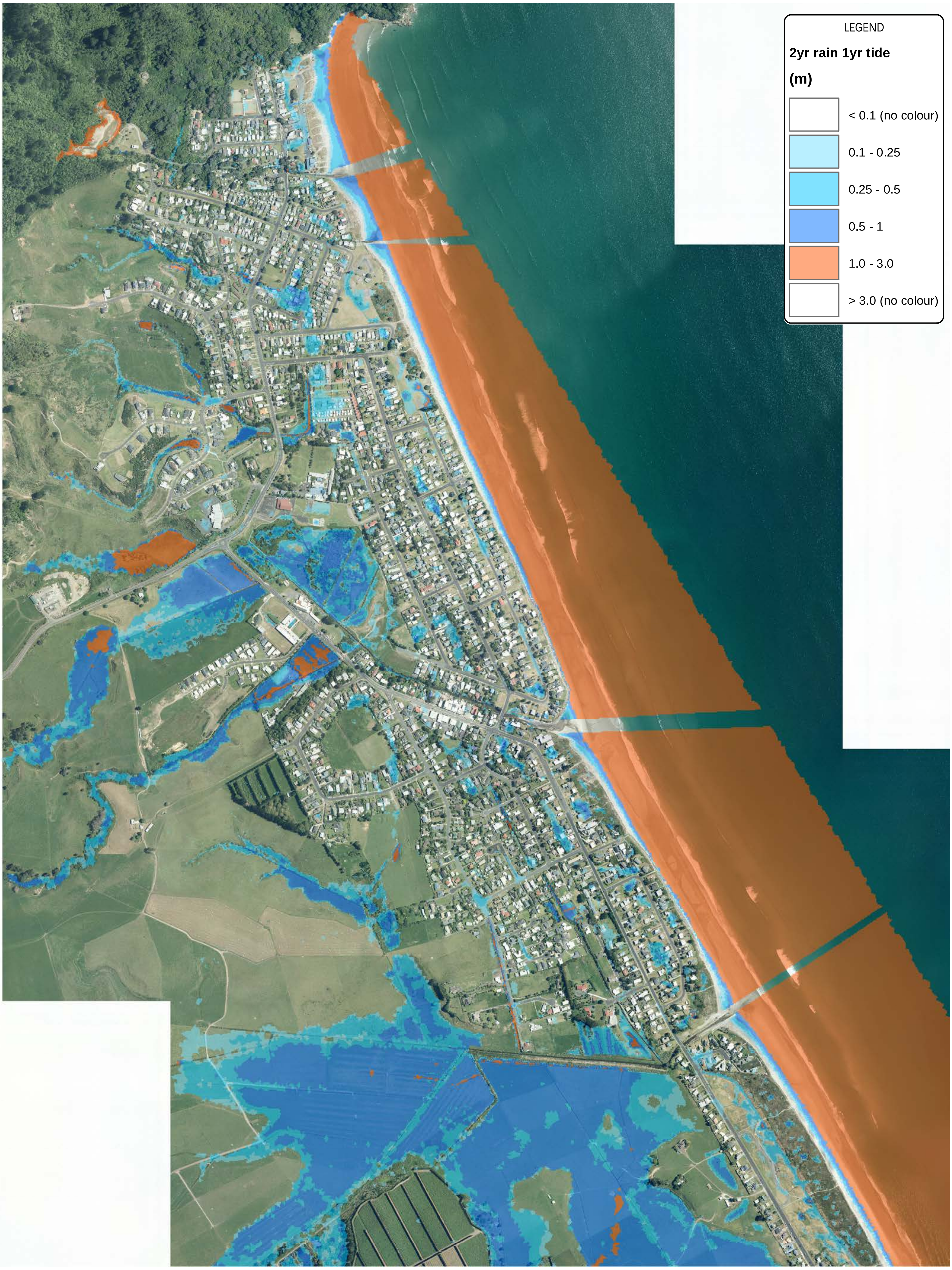

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 1

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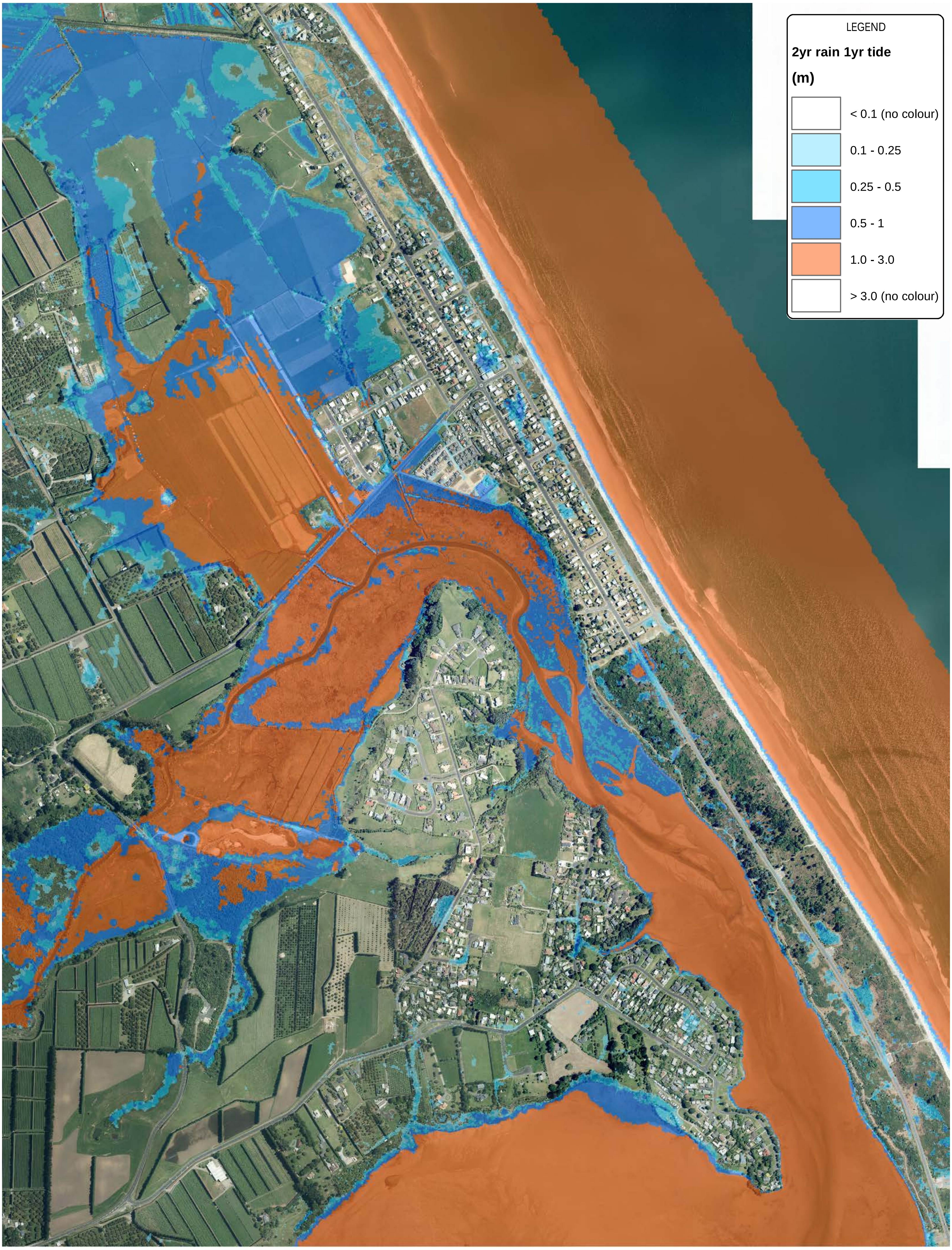

Notes: Aerial photograph sourced from BOPLASS 2015.
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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 2

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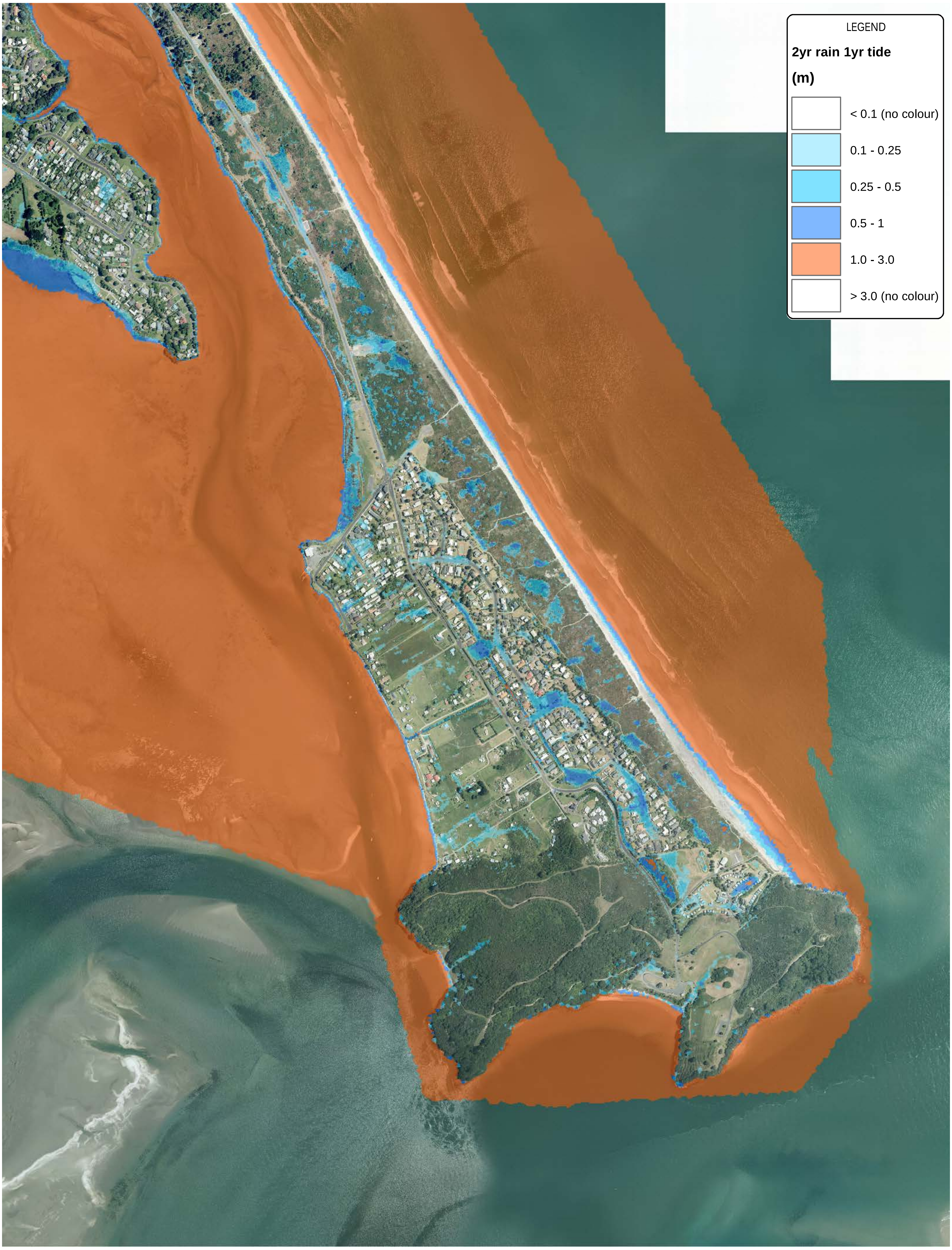

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

A3 SCALE 1:10,000

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 3

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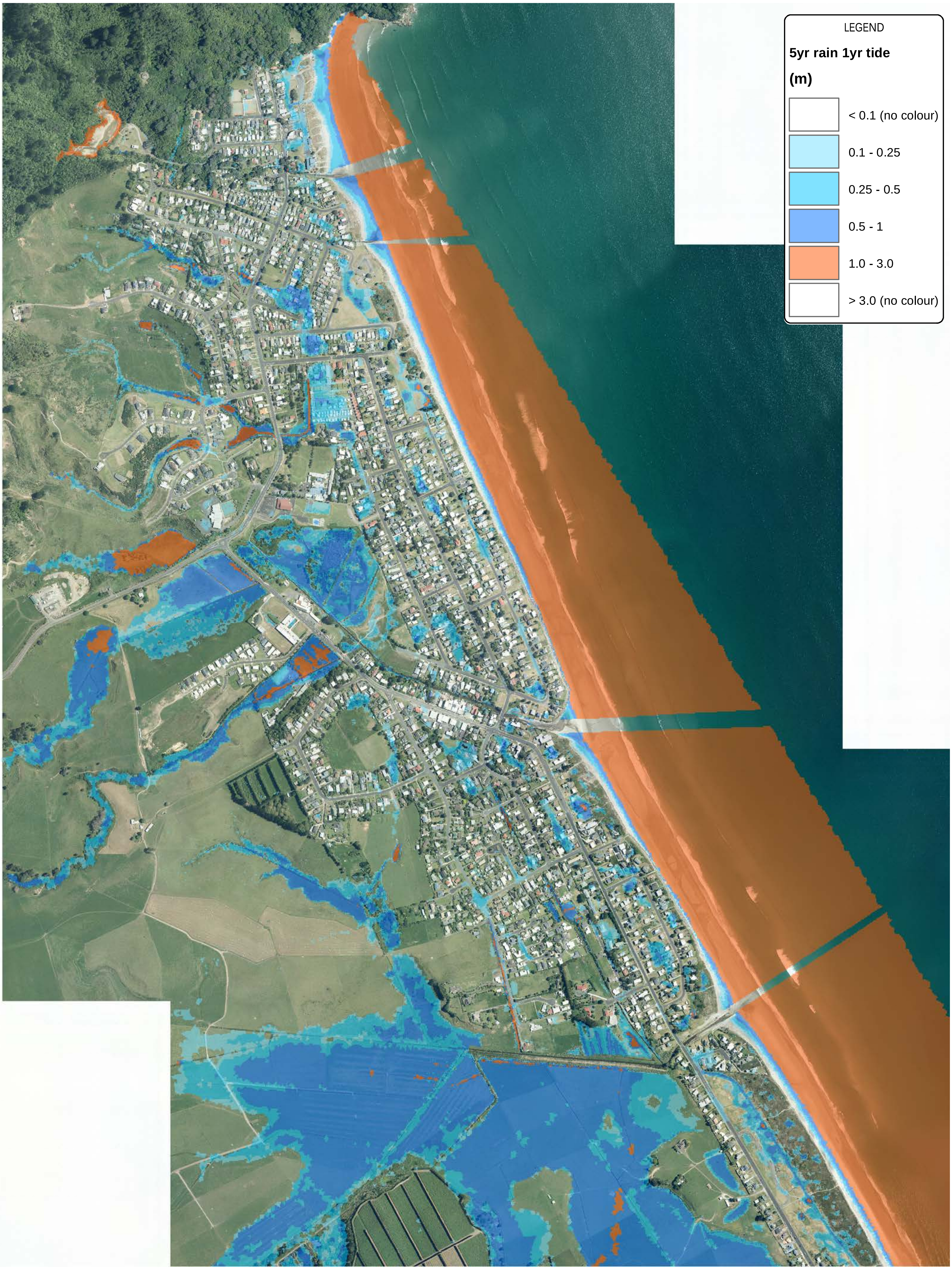

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 4

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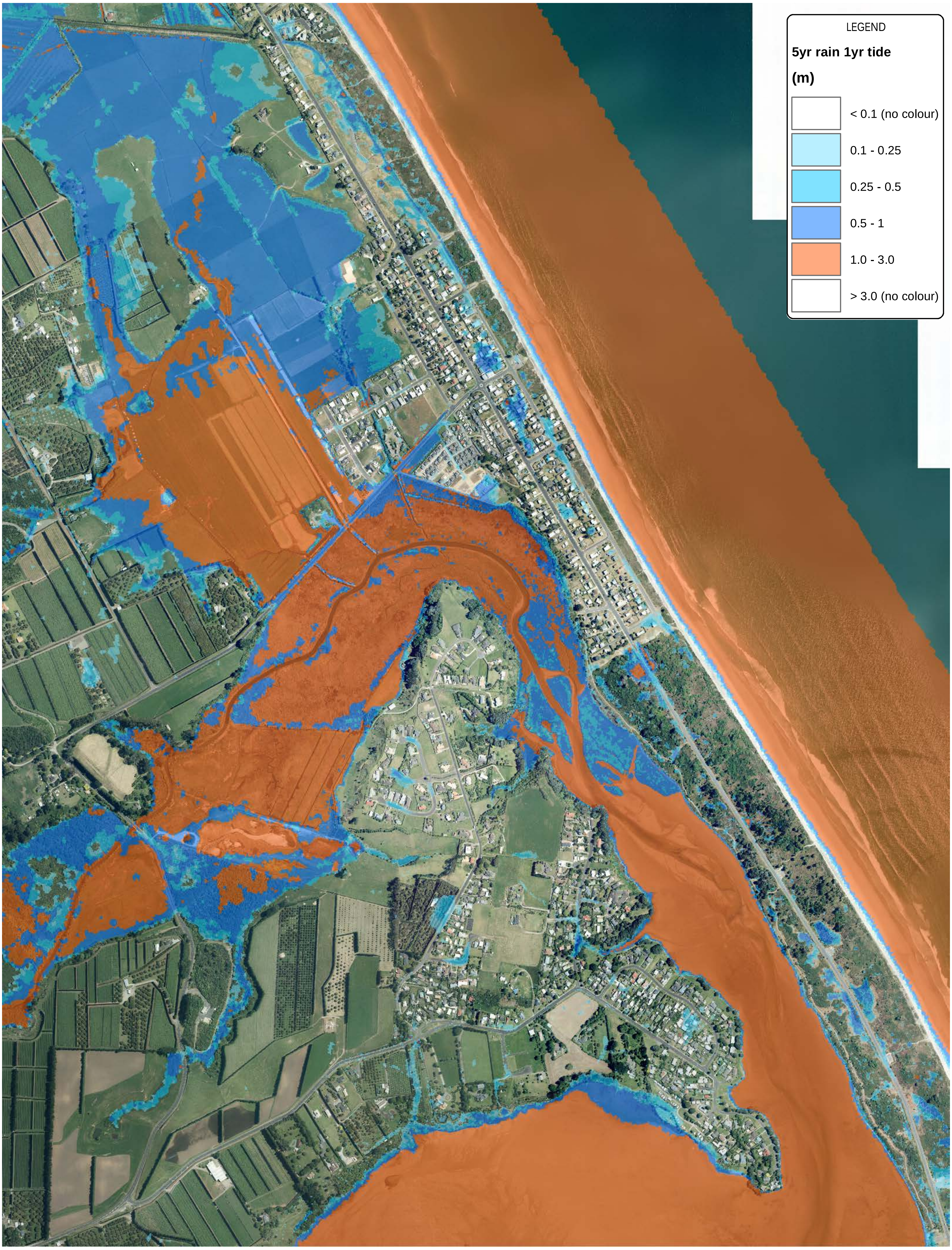

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 5

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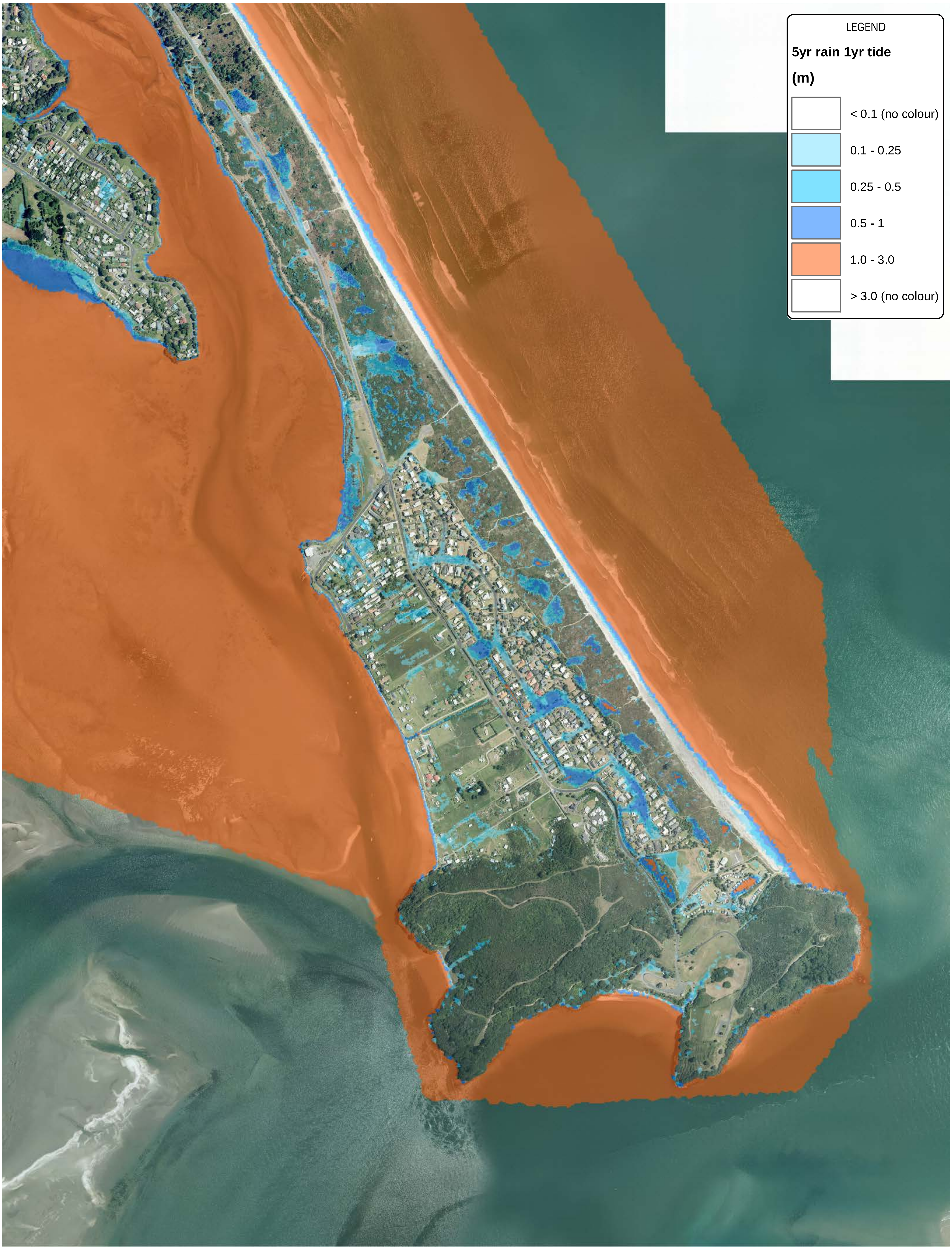

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 6

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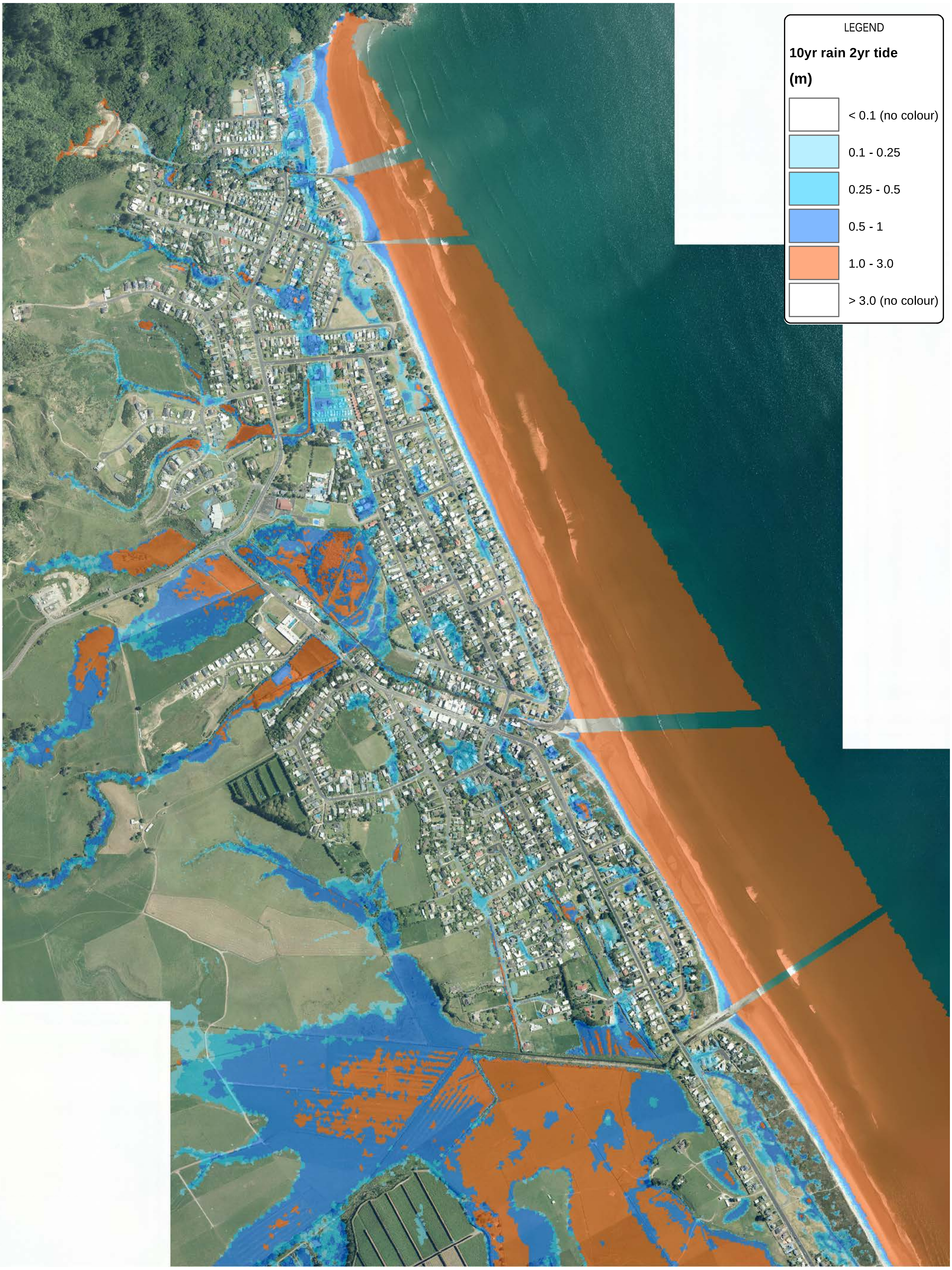

Notes: Aerial photograph sourced from BOPLASS 2015.
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A3 SCALE 1:10,000

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 7

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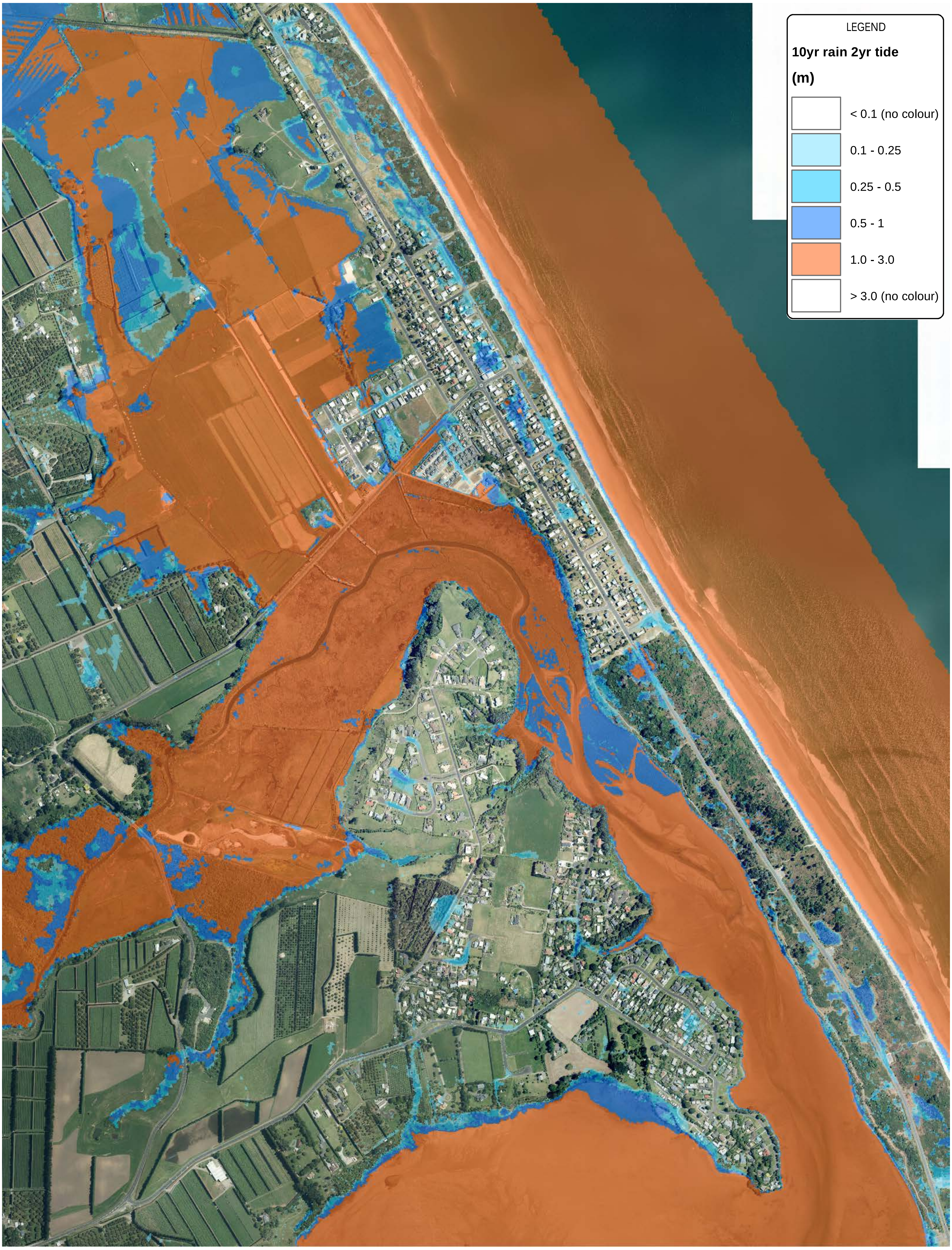

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

A3 SCALE 1:10,000

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 8

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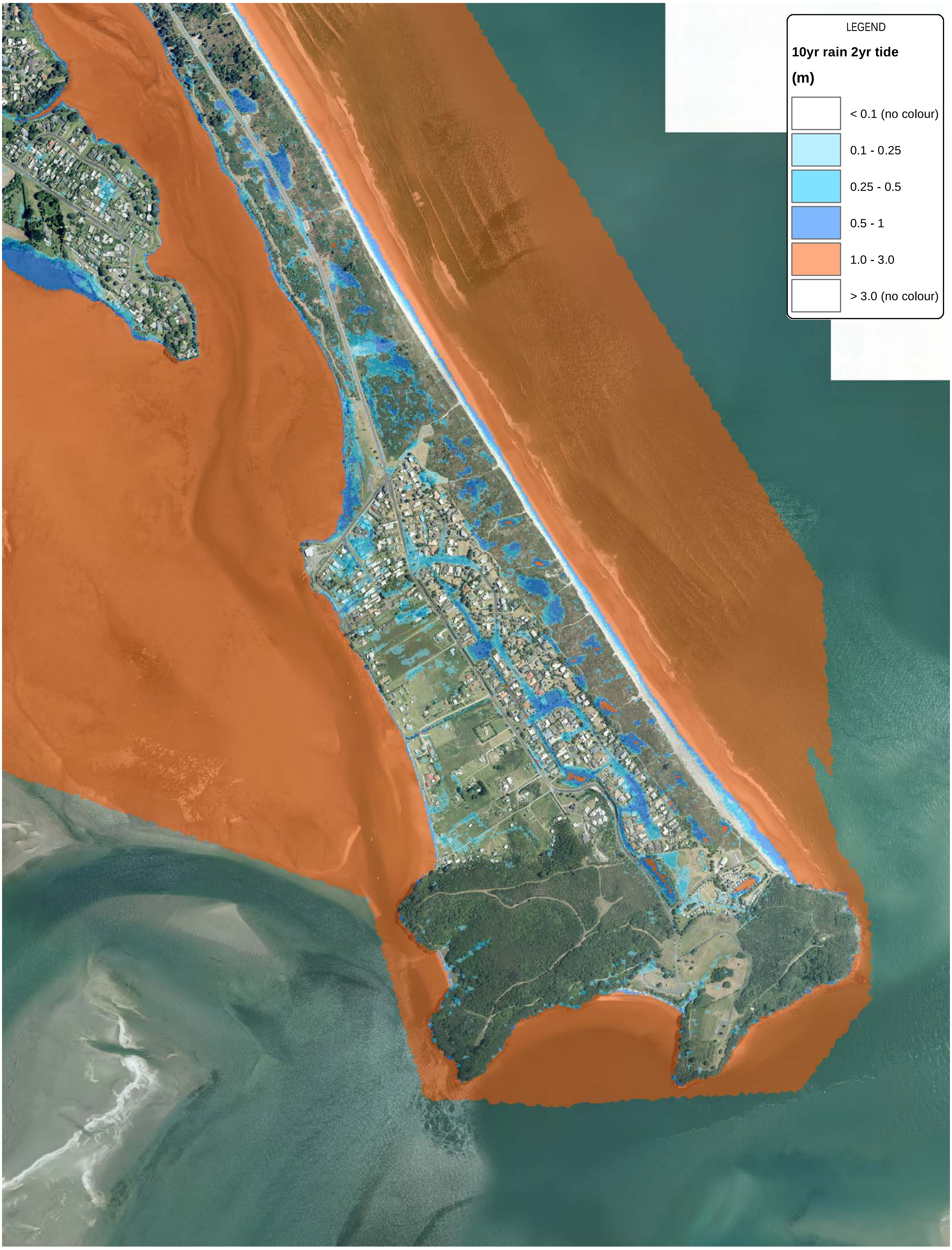

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 9

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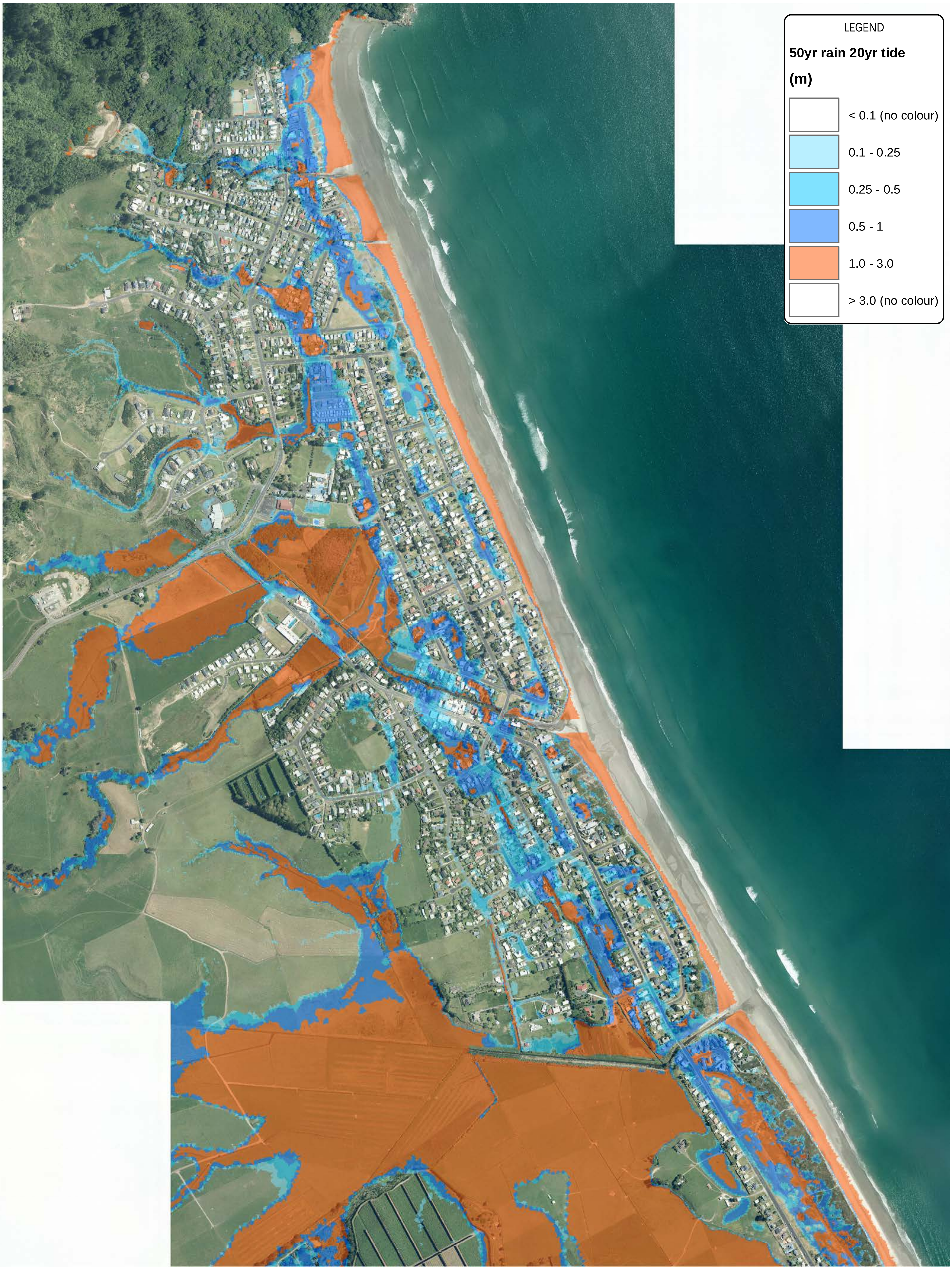

Notes: Aerial photograph sourced from BOPLASS 2015.
Model results to be read in conjunction with model build report.

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 10

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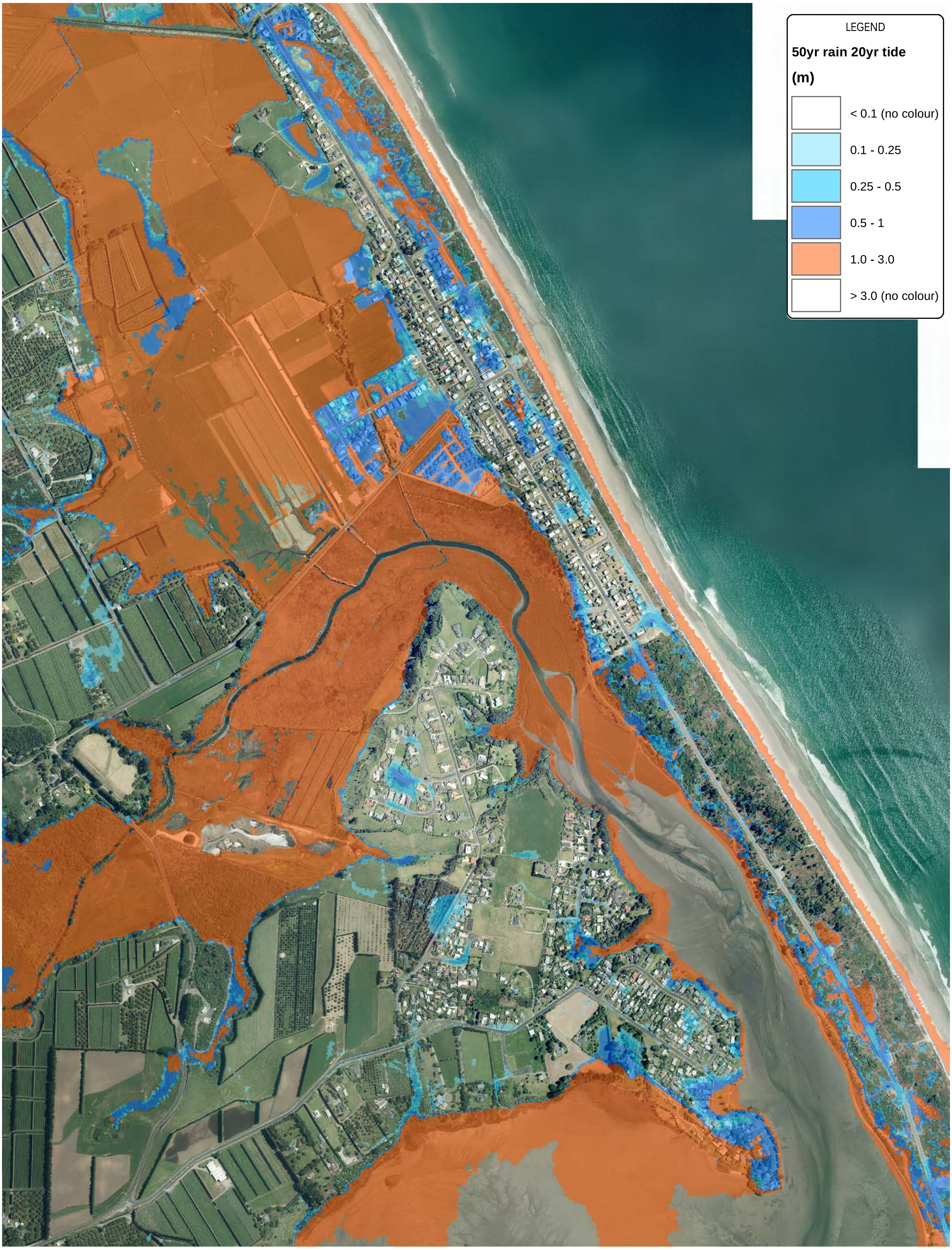

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 11

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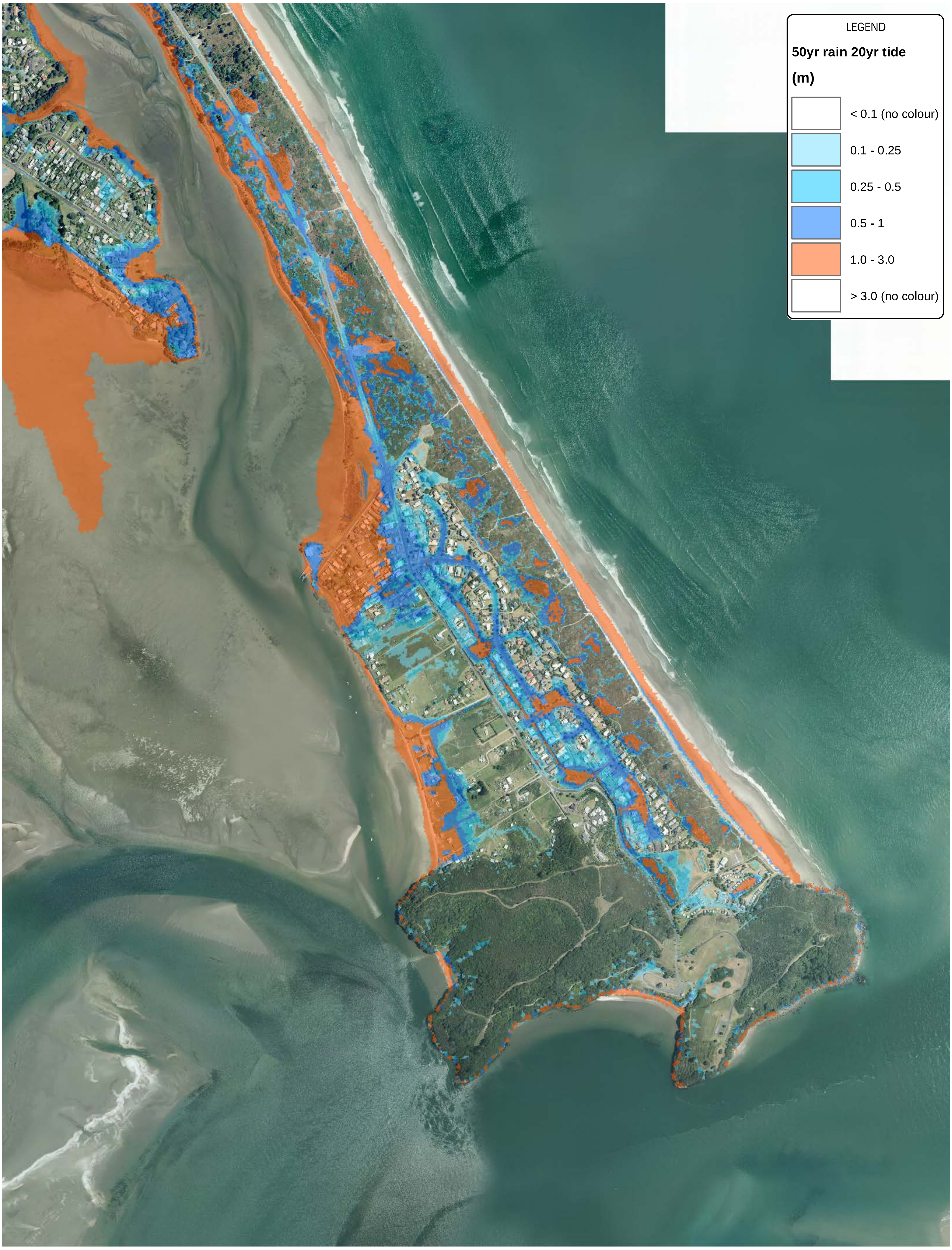

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Waihi Beach Stormwater Model

Maximum Flood Depth

FIGURE No. Figure 12

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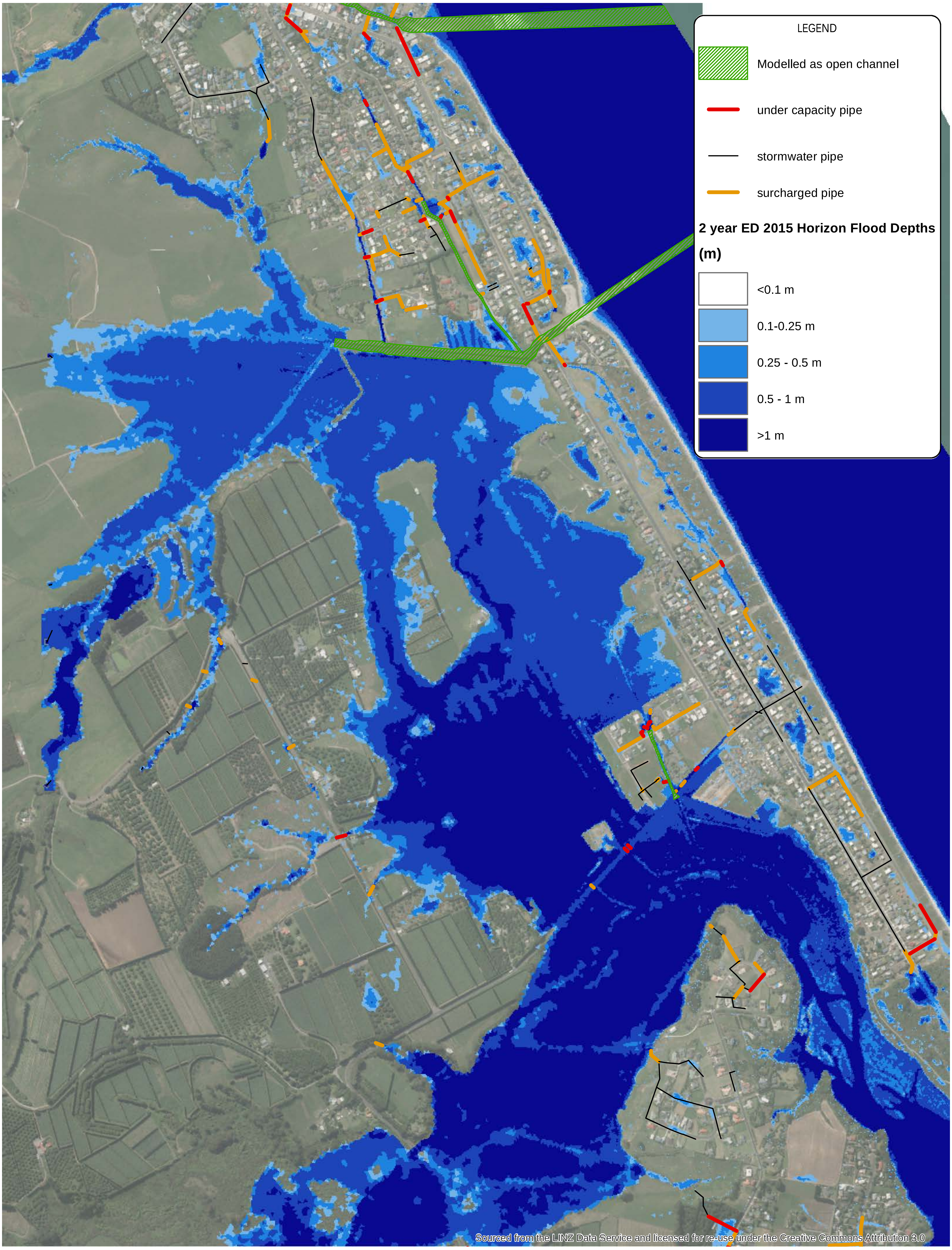

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A3 SCALE 1:10,000

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Waihi Beach South
Pipe Capacity Assessment
2 year Rainfall - 1yr Tide - ED - 2015 Horizon

FIGURE No. Figure 13

Rev. 0

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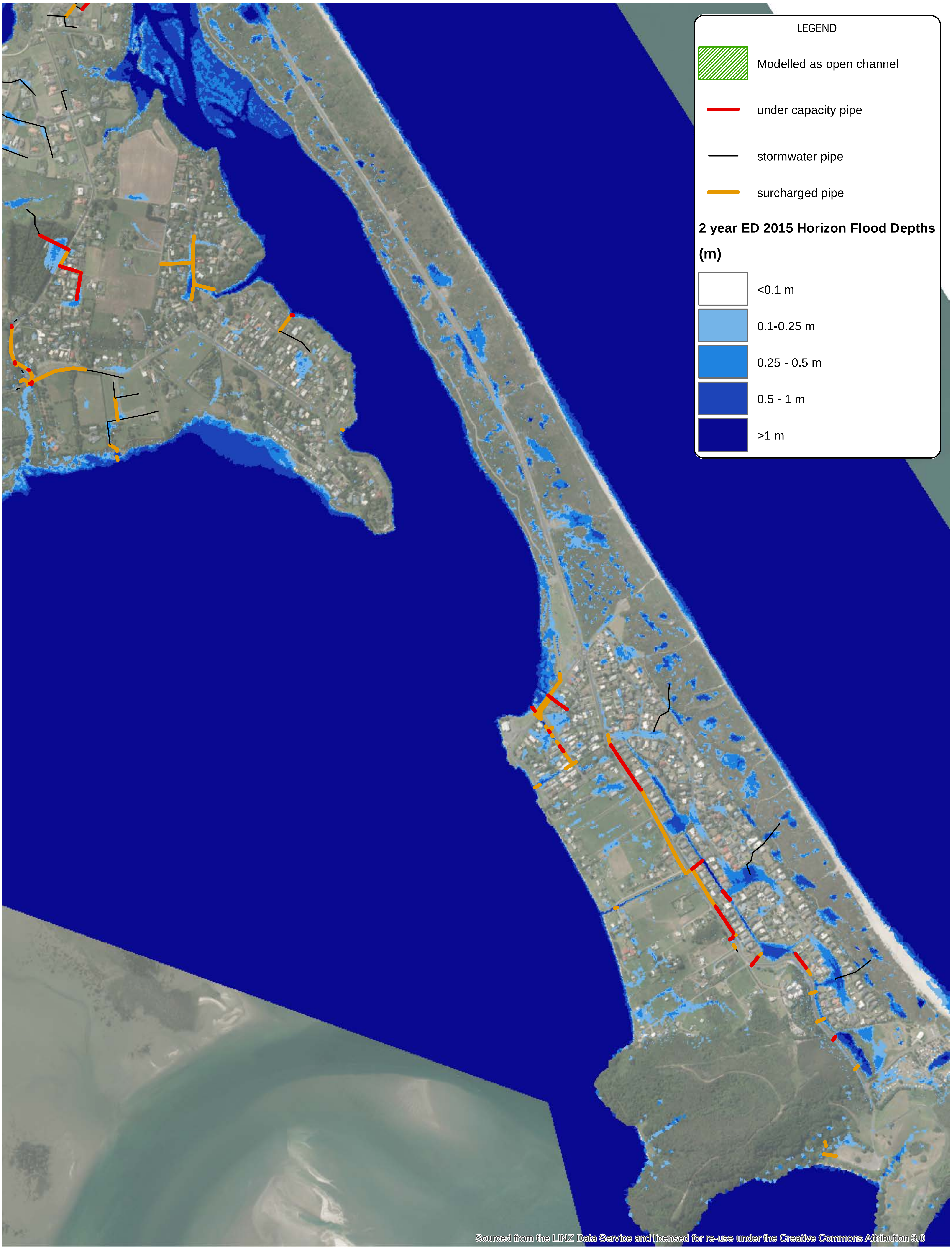

Notes:

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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Waihi Beach South
Pipe Capacity Assessment
2 year Rainfall - 1yr Tide - ED - 2015 Horizon

FIGURE No. Figure 14

Rev. 0

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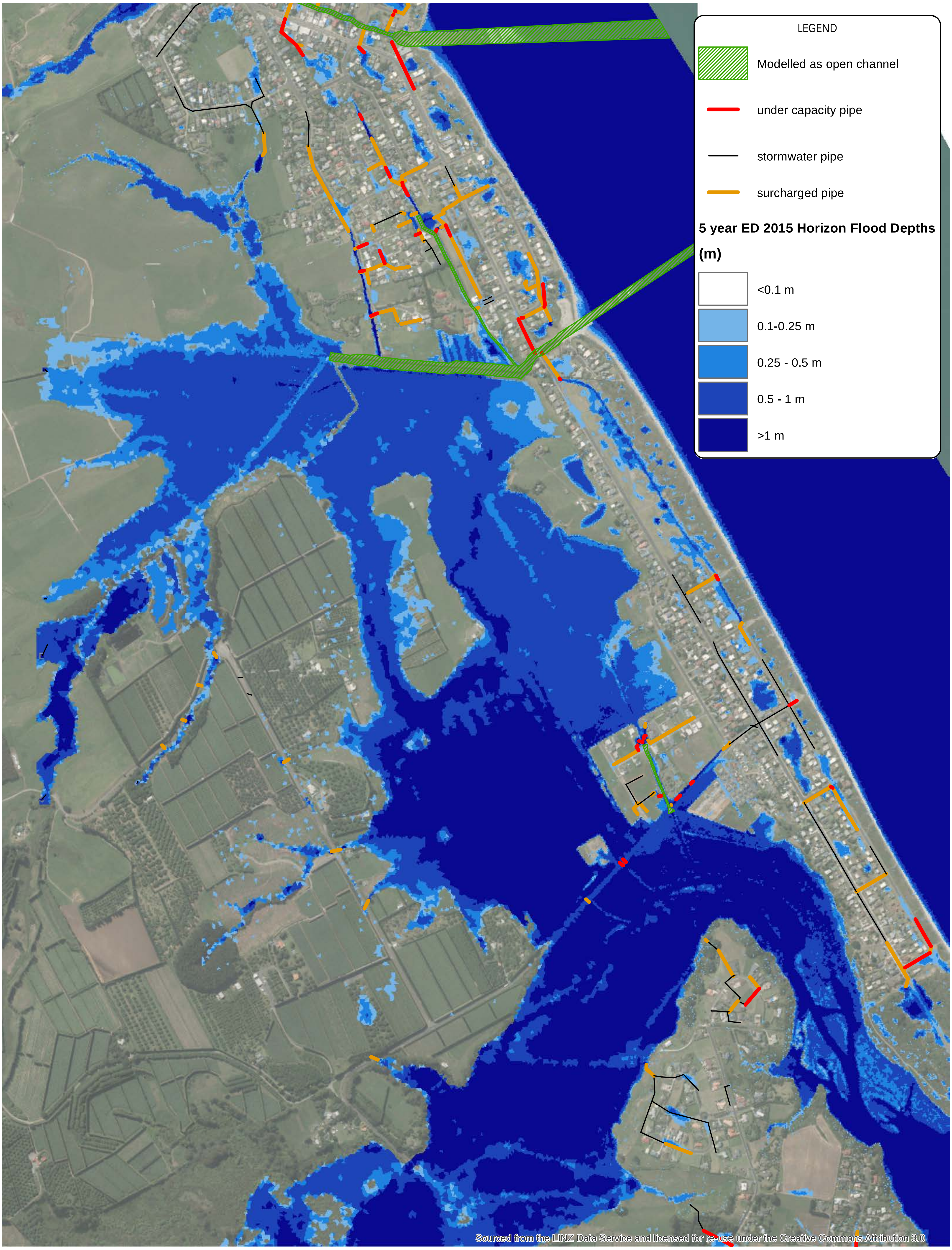

Notes:

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE Figure11-5yrPipeCapacity.mxd		
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Waihi Beach South
Pipe Capacity Assessment
5 year Rainfall - 1yr Tide - ED - 2015 Horizon

FIGURE No. Figure 15

Rev. 0

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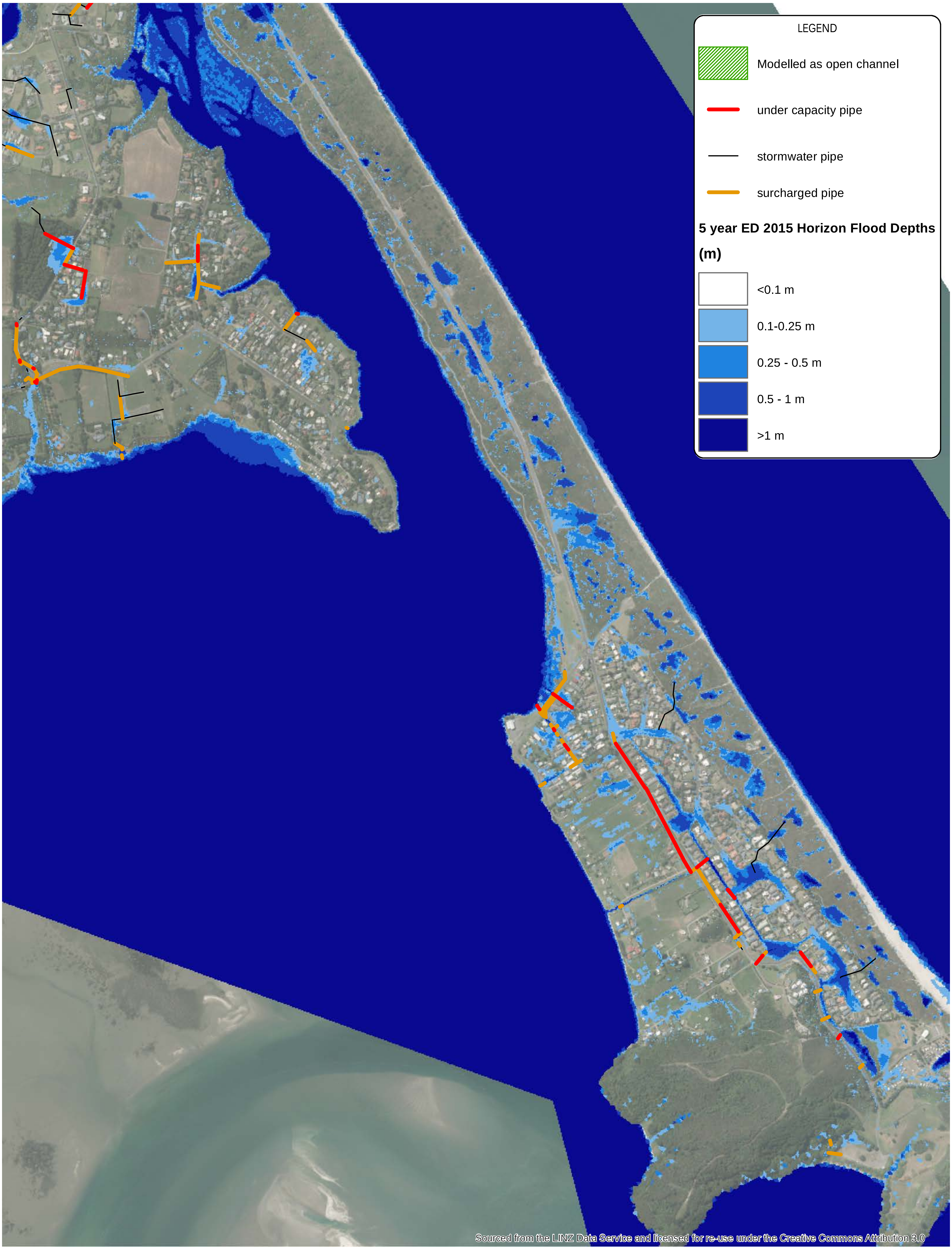

Notes:

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE	Figure12-5yrPipeCapacity.mxd	
SCALE (AT A3 SIZE)	1:10,000	
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Waihi Beach South

Pipe Capacity Assessment

5 year Rainfall - 1yr Tide - ED - 2015 Horizon

FIGURE No. Figure 16

Rev. 0

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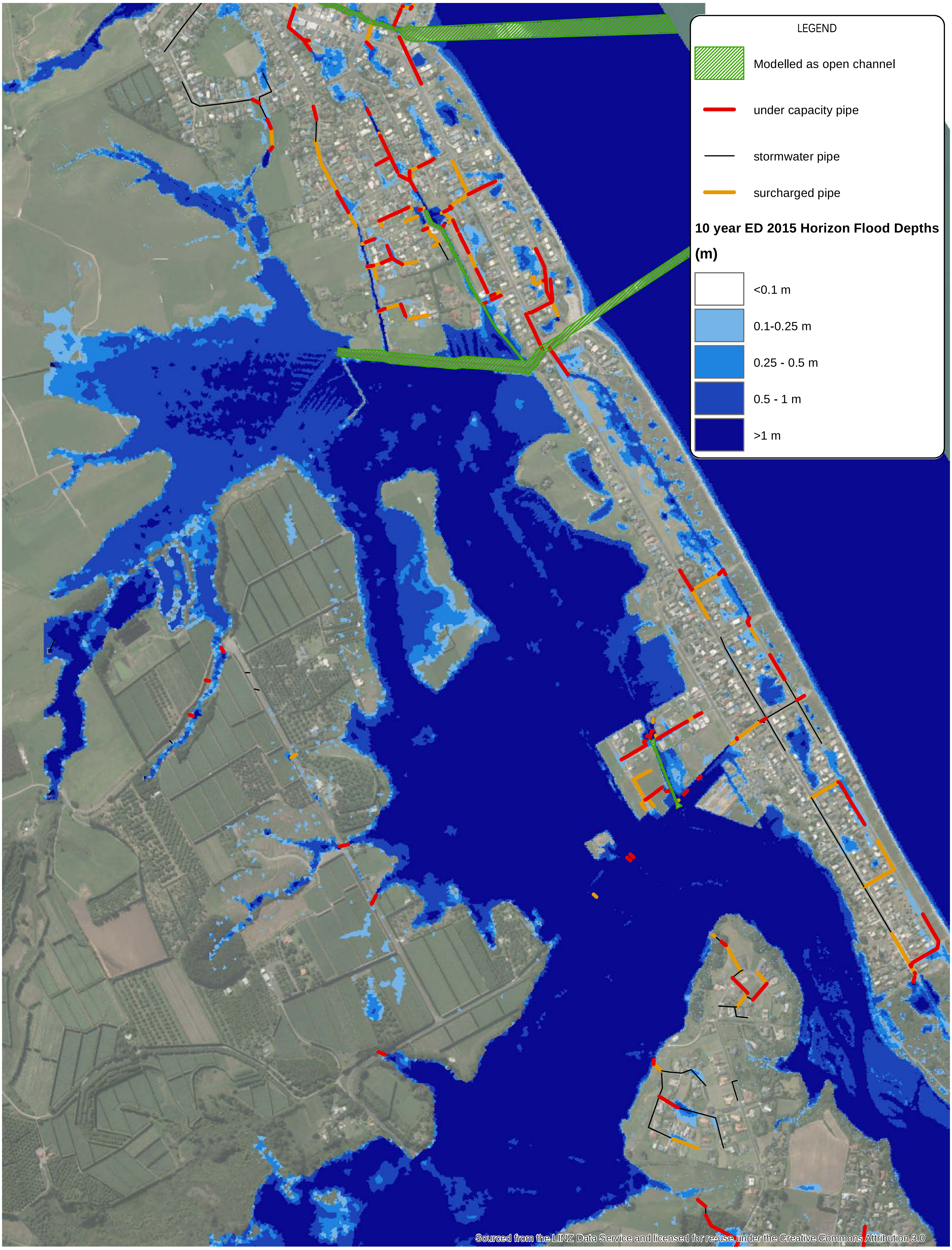

Notes:

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE Figure13-10yrPipeCapacity.mxd		
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Waihi Beach South

Pipe Capacity Assessment

10 year Rainfall - 2yr Tide - ED - 2015 Horizon

FIGURE No. Figure 17

Rev. 0

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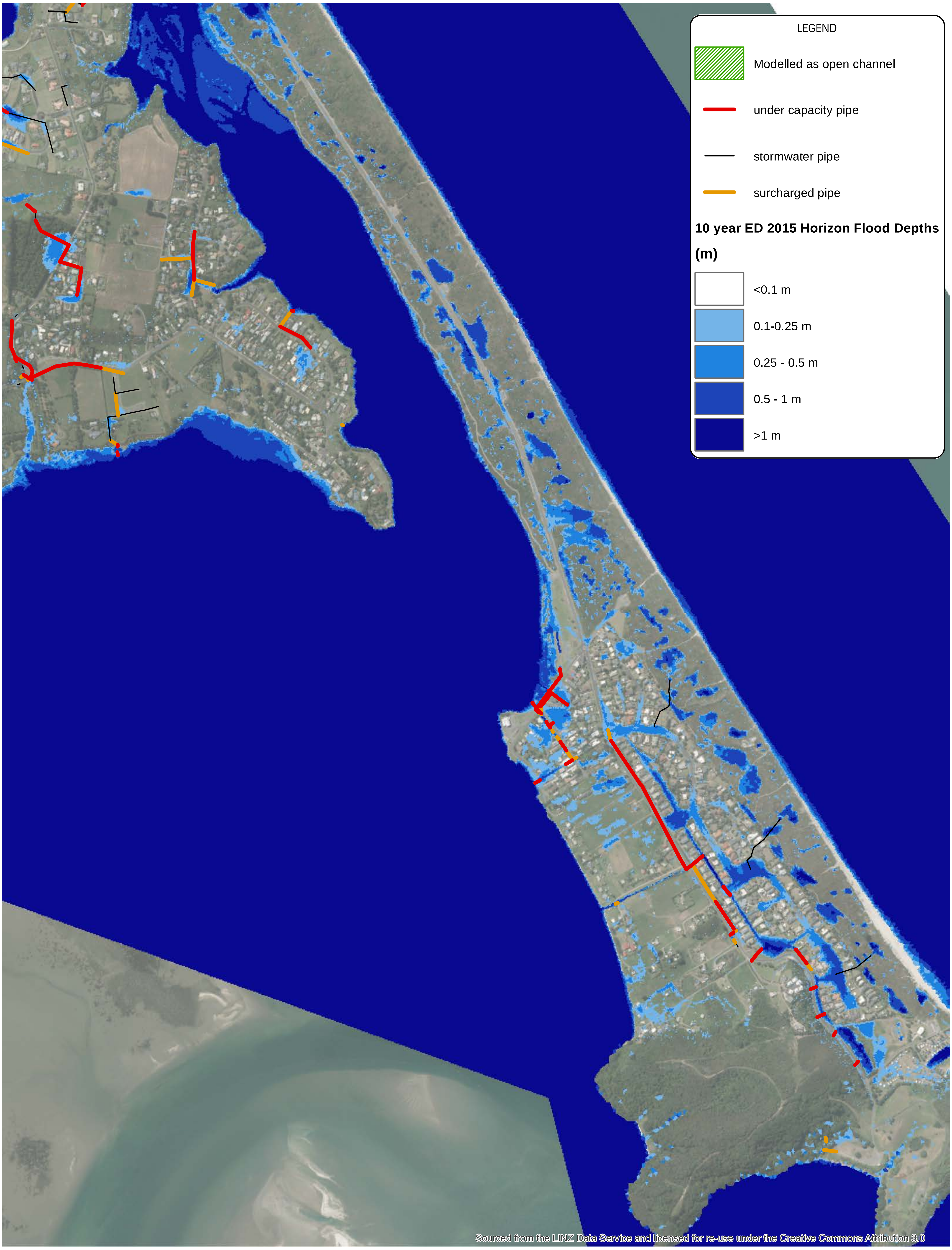

Notes:

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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ARCFILE Figure14-10yrPipeCapacity.mxd

SCALE (AT A3 SIZE) 1:10,000

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Waihi Beach South

Pipe Capacity Assessment

10 year Rainfall - 2yr Tide - ED - 2015 Horizon

FIGURE No. Figure 18

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