REPORT

Western Bay of Plenty District Council

Waihi Beach
Flood Hazard Assessment

Tonkin & Taylor

ENVIRONMENTAL AND ENGINEERING CONSULTANTS

REPORT

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Flood Hazard Assessment

Report prepared for:

Western Bay of Plenty District Council

Report prepared by:

Tonkin & Taylor Ltd

Distribution:

Western Bay of Plenty District Council	4 copies
Tonkin & Taylor Ltd (FILE)	1 copy

December 2012

T&T Ref: 27863

Table of contents

Executive Summary

Western Bay of Plenty District Council (WBOPDC) commissioned Tonkin & Taylor (T&T) to carry out a flood hazard assessment of the northern Waihi Beach catchments. The assessment was required to define the flood hazard and subsequent studies will identify potential opportunities to reduce flood risk at northern Waihi Beach.

The assessment is based on a hydrological and hydraulic model of the area that was developed as part of the project.

In the absence of available data, the hydrological and hydraulic modelling was carried out in accordance with industry best practice. In the future, it may be possible to improve the accuracy of the model based on additional data sets as they become available. Therefore T&T recommend that WBOPDC develop a flood incident database of recorded flood levels, flow rates and flooded properties, so that a more detailed model calibration can be carried out in the future. The hydrological model was calibrated using rain gauges and flow gauges from nearby catchments, and the hydraulic model was validated for the 3rd July 2012 storm event based on surveyed flood levels

Scenarios representing the existing drainage system were developed for existing catchment land use and for maximum probable development land use in the catchment. The scenarios were assessed for design rainfalls for a range of return periods. The design rainfall events were all 24 hours duration, and incorporated an embedded storm approach where shorter duration storms are included within the long duration storm. This is an appropriate method for Waihi Beach where different areas flood either as a result of peak flows or runoff volume. For shorter duration storms the flood extents will be less.

The hydrological and hydraulic models were used to create flood hazard maps of the various design storm scenarios. The flood hazard maps are provided with this report. The model results were also analysed and the following characteristics were observed:

- Flooding in the catchments draining to One Mile Creek and Two Mile Creek were mainly affected by channel capacity and hydraulic controls at structures.
- However for the "Back dune" catchment where most habitable floor flooding occurs, the model results identified the following hydraulic characteristics:
    - Very limited flood conveyance through the piped drainage system, leading to significant retention of runoff volume and flows occurring overland
    - Low velocities with overland flow paths around the residential areas
    - High flood depths in low lying areas
    - In some areas, there was very little difference between the flood extents of storm events of differing return periods with only flood depths changing

Generally flooding in the "Back dune" sub-catchment is caused by limited capacity of the stormwater drainage system and "ponding" characteristics of the topography caused by the dune complex. Essentially the low lying areas fill with water and water cannot drain from the area (other than infiltration) before the "crest" of the pond is overtopped.

Based on current levels of development there are up to 140 habitable buildings at risk of flooding within the study extent at Waihi Beach for the existing catchment landuse and the 50 year ARI design storm event. Due to the effects of climate change to 2090, the number of buildings at risk increases to 150 and there are additional habitable buildings at risk from a 100 year ARI storm event. There are a large number of additional property owners that

will experience property flooding, without experiencing habitable floor level flooding (e.g. flooding of their gardens)

The study also showed that there are 70 habitable buildings at risk from flooding in a 24 hour duration, 2 year ARI design storm event.

In the future, if development is permitted to the maximum limits shown in the current District Plan, there will be a likely increase in the number of flooded buildings from 140 to 152 that are affected during a 24 hour, 50 year ARI storm event. For climate change scenarios, the number of flooded habitable buildings increases due to development to the District Plan limits from 150 to 156.

This report has highlighted that there is a significant flood risk at Waihi Beach and that there are a large number of residential properties at risk of inundation during design storm events. The results of the baseline assessment can be used to determine 50 year ARI flood levels, which WBOPDC require to help determine habitable floor level requirements. WBOPDC should give consideration regarding how to apply freeboard on top of the flood levels.

As part of the future works, a range of engineered flood mitigation works and management options can be assessed. The options can be assessed against the baseline flood scenarios represented in this report.

1 Introduction

1.1 General

Western Bay of Plenty District Council (WBOPDC) commissioned Tonkin & Taylor (T&T) to carry out a flood hazard assessment of the northern Waihi Beach catchments. The flood hazard assessment is required by WBOPDC to sustainably manage development and respond to development pressures in the Waihi Beach area. WBOPDC would also like to better understand current flooding issues and have the objective to reduce the impact of floods in the Waihi Beach area.

Historically, there have been a number of stormwater and option assessments that have been carried out in the Waihi Beach area. A review of these reports by T&T in May 2011 identified that assessment methodologies for both hydrology and hydraulics was not in accordance with current best practice and that new models for the catchments were required.

This report provides the results of the flood hazard mapping study that has been carried out.

The northern Waihi Beach catchments comprise the following sub-catchments:

- One Mile Creek
- Unnamed sub-catchment (referred to unofficially as the Maranui catchment)
- Two Mile Creek.

The catchment extents and general overview of North Waihi can be seen in Figure 1, Appendix A. The catchment extents provide the extent of reliability for the hydraulic model results.

1.2 Project objectives and scope of works

The overall project objective for WBOPDC is to define the flood hazard and to develop schemes that will reduce flood risk at northern Waihi Beach. A staged approach has been adopted by WBOPDC. The results, options and conclusions from each stage will then impact on the objectives of subsequent stages. This report details Stage 1.

The key stages are identified below:

- Stage 1 – Define flood extents using current best practices for hydraulic modelling (current study)

  This stage will provide baseline flood hazard maps and flood inundation maps from which future flood mitigation options can be assessed.
- Stage 2 – Identify flood mitigation options to reduce flooding at the Two Mile Creek and Maranui catchments (future study)

  This stage will consider a range of flood mitigation options to reduce existing flood hazards in the north Waihi Beach catchments. A rough order cost estimate for each of the flood mitigation options will be provided so that a comparative assessment of costs and benefits of each scheme can be carried out.
- Stages 3, 4, 5 – Development of preferred flood mitigation options from Preliminary Design (Stage 3) to Consent Level Design (Stage 4) and Construction Level Design (Stage 5).

  Stage 3 onwards will be focussed on the development of preferred solution/s from Stage 2. These stages will develop the preferred solution from concept design to consent and construction level designs. These stages can be arranged as appropriate.

In addition to the project objectives, the work can assist WBOPDC with developing a Catchment Management Plan, and may help with obtaining a Network Discharge Consent for the entire catchment. Currently we understand that the Network Discharge Consent applies only to the developed area of the catchment.

2 Modelling overview

This section provides an overview of model scenarios, hydrological model and the hydraulic model.

2.1 Model scenarios

The hydrological model and hydraulic model were used to carry out flood hazard mapping for a range of scenarios. The scenarios were developed in consideration of the Bay of Plenty Regional Council Hydrological and Hydraulic Guidelines (2001/04, and draft 2012). Additional model runs were developed to account for climate change effects on rainfall. The rainfall increase reflects the medium projections for climate change planning in accordance with Ministry for Environment (MfE) guidelines.

The model scenarios used for the flood hazard assessment are shown in Table 2-1.

Table 2-1 Stage 1 modelled scenarios

Scenario	Design return period		Catchment development	
	Rainfall	Sea level	Existing development	Maximum Probable Development
100 year ARI (Q_{100}:L_{20})	100 year ARI	20 year ARI	✓	✓
50 year ARI (Q_{50}:L_{20})	50 year ARI	20 year ARI	✓	✓
20 year ARI (Q_{20}:L_{2})	20 year ARI	2 year ARI	✓	✓
10 year ARI (Q_{10}:L_{2})	10 year ARI	2 year ARI	✓	✓
5 year ARI (Q_{5}:L_{2})	5 year ARI	2 year ARI	✓	✓
2 year ARI (Q_{2}:L_{2})	2 year ARI	2 year ARI	✓	✓
100 year ARI (Q_{100}:L_{20}) + climate change	100 year ARI + 16.8%	20 year ARI	✓	✓
50 year ARI (Q_{50}:L_{20}) + climate change	50 year ARI + 16.8%	20 year ARI	✓	✓
✓ Scenario modelled				

The sea levels used were in accordance with the EBOP guidelines for Open Coast West of Matata, as shown in Table 2-2.

Table 2-2 Sea level for open coast west of Matata (EBOP, 2001/04)

Return period	Sea level (Moturiki Datum)
2 year ARI	1.7
20 year ARI	2.1
50 year ARI	2.3
100 year ARI	2.5

2.2 Hydrological model

2.2.1 Methodology

T&T developed a hydrological model using the internationally recognised US Army Corp HEC-HMS model for the northern Waihi Beach catchments from calibrated parameters for the nearby catchments of Torrens Farm and Woodlands Road catchment. There are no flow gauges in the northern Waihi Beach catchments therefore it was not possible to calibrate the catchment directly. By calibrating to nearby catchments, we were able to make best use of available information.

The hydrological model was used to simulate the rainfall-runoff processes of the northern Waihi Beach catchments. The sub-catchments can be seen in Figure 2, Appendix A. The sub-catchment delineation was based on topography and location of hydraulic structures (e.g. culverts and bridges).

Hydrological characteristics are used in the rainfall-runoff modelling. Hydrological characteristics were determined for each sub-catchment for the existing development (ED) and for maximum probable development (MPD) in accordance with the zoning from the District Plan.

For MPD there are approximately 30 hectares of proposed residential zone land in areas identified for development. The consequence of this is to increase the impervious surface coverage which leads to greater runoff volumes and increased peak flows. The catchment areas and land use types for ED and MPD can be seen in Table 2-3.

Table 2-3 Sub-catchment land use areas (refer to Figure 2)

Catchment	Existing Development area (ha)						Maximum Probable Development area (ha)					
	Total area	Bush	Pasture	Residential	Road	Pond/lake	Total area	Bush	Pasture	Residential	Road	Pond/lake
A1	97.6	11.1	86.5	0	0	0	97.6	11.1	86.5	0	0	0
A2	38.3	1.7	36.7	0	0	0	38.3	1.7	36.7	0	0	0
A2b	4.4	0	4.4	0	0	0	4.4	0	4.4	0	0	0
A3	174.4	40.4	126.0	0	8.1	0	174.4	40.4	126.0	0	8.1	0
A4	23.9	0	22.6	0	1.3	0	23.9	0	20.4	1.6	1.9	0
A5	11.3	0	10.9	0	0.3	0	11.3	0	8.7	2.2	0.3	0
B1	29.0	0	28.2	0	0.8	0	29.0	0	28.2	0	0.8	0
B2	25.5	0	25.2	0	0.3	0	25.5	0	23.9	0.9	0.7	0
B3	19.8	0	14.7	3.8	1.3	0	19.8	0	0.1	13.8	5.9	0
C	49.3	11.2	37.1	0.1	1.0	0	49.3	8.8	34.6	3.5	2.4	0
D	18.6	9.3	6.0	2.5	0.7	0	18.6	8.1	2.9	5.3	2.3	0
E	22.2	7.7	10.6	3.1	0.8	0	22.2	5.3	0.4	11.6	5.0	0
F	17.8	0.8	12.2	4.3	0.5	0	17.8	0.8	7.3	6.8	2.9	0
G	5.4	0	1.0	2.8	0.9	0.8	5.4	0	1.0	2.8	0.9	0.8

Catchment	Existing Development area (ha)						Maximum Probable Development area (ha)					
	Total area	Bush	Pasture	Residential	Road	Pond/lake	Total area	Bush	Pasture	Residential	Road	Pond/lake
H	72.8	0	21.6	33.9	17.4	0	72.8	0	15.1	39.7	18.0	0
I	2.0	0	0	1.2	0.8	0	2.0	0	0	1.2	0.8	0
J	2.6	0	0	1.9	0.7	0	2.6	0	0	1.9	0.7	0

2.2.2 Rainfall

A design rainfall hyetograph was developed for 24 hour duration storm events from NIWA's High Intensity Rainfall Design System (HIRDS,v3). The design rainfall hyetograph uses an embedded storm duration approach (sometimes known as Chicago Method). This is when all rainfall intensities of shorter duration storms are embedded within the longer duration storm (i.e. a 24 hour rainfall hyetograph uses the intensity that occurs for a 10 minute duration, 20 minute duration, 30 minute etc.). This approach was considered appropriate for flood assessments of Waihi Beach where runoff volume as well as peak flows are a consideration.

The rainfall depths for varying durations and return period events can be seen in Table 2-4.

Table 2-4 Rainfall depth for Waihi Beach (HIRDS, v3)

ARI (y)	Rainfall depth (mm) for different storm durations							
	10 min	**20 min**	**30 min**	**60 min**	**2 hour**	**6 hour**	**12 hour**	**24 hour**
2	11.6	17.2	21.7	32.3	45.7	79.3	112.4	159.2
5	15.4	22.9	28.9	42.9	60.3	103.6	145.7	204.9
10	18.6	27.6	34.8	51.8	72.5	123.5	173	242.1
50	28.1	41.8	52.7	78.4	108.6	182.2	252.4	349.8
100	33.5	49.8	62.8	93.4	128.9	214.6	296.2	408.7

To represent scenarios that incorporate climate change, the rainfall was increased by 16.8% to allow for 2.1 degrees of warming to 2090 (note that the increase in rainfall does not correspond to the same increase in flow).

2.2.3 Results

The hydrological model was used to determine runoff hydrographs for each of the sub-catchments. The peak flows for each of the sub-catchments are summarised in Table 2-5.

Table 2-5 Sub-catchment peak flows

	Existing Development peak flow (m^3/s)						Maximum Probable Development peak flow (m^3/s)					
					Climate change						Climate Change	
	10yr	20yr	50yr	100yr	50yr	100yr	10yr	20yr	50yr	100yr	50yr	100yr
A1	15.5	19.5	26.0	32.1	28.4	38.5	15.5	19.5	26.0	32.1	28.4	38.5
A2	7.7	9.6	12.8	15.8	13.9	18.9	7.7	9.6	12.8	15.8	13.9	18.9
A2b	0.9	1.2	1.5	1.9	1.7	2.3	0.9	1.2	1.5	1.9	1.7	2.3
A3	26.2	33.1	44.1	54.4	48.0	65.3	26.2	33.1	44.1	54.4	48.0	65.3
A3b	2.4	3.1	4.1	5.1	4.5	6.1	2.4	3.1	4.1	5.1	4.5	6.1
A4	3.7	4.6	6.1	7.5	6.7	9.0	3.8	4.7	6.2	7.6	6.8	9.1
A5	1.9	2.4	3.2	3.9	3.5	4.7	2.0	2.5	3.3	4.1	3.6	4.8
B1	5.9	7.4	9.8	12.1	10.7	14.4	5.9	7.4	9.8	12.1	10.7	14.4
B2	4.1	5.2	6.9	8.5	7.5	10.2	4.2	5.3	7.0	8.6	7.6	10.3
B3	2.9	3.6	4.7	5.7	5.1	6.8	3.4	4.1	5.2	6.2	5.5	7.2
C	8.4	10.6	14.1	17.4	15.4	20.9	8.7	10.9	14.5	17.8	15.8	21.3
D	3.5	4.4	5.8	7.2	6.4	8.7	3.8	4.7	6.2	7.6	6.7	9.0
E	4.7	5.9	7.8	9.6	8.5	11.5	5.5	6.7	8.7	10.4	9.3	12.3
F	3.7	4.6	6.1	7.4	6.6	8.8	4.0	4.9	6.4	7.7	6.9	9.1
G	1.4	1.7	2.2	2.6	2.3	3.0	1.4	1.7	2.2	2.6	2.3	3.0

Catchment H, I and J are located on the flat back dune catchment. Due to the flat topography it was determined that the most appropriate method to represent these catchments was to add rainfall directly onto the 2D model grid (allowing for hydrological losses). Since the runoff from these sub-catchments does not become focussed to a particular point, it is not possible to provide peak flows from these sub-catchments.

2.3 Hydraulic model

2.3.1 Methodology

A comprehensive hydraulic model was developed of the Waihi Beach area using DHI Mike Flood software. The Mike Flood software dynamically couples three hydraulic models so that flows can pass from one model to another. The three hydraulic models are:

- Mike 11 model – in channel flow
- Mike 21 model - floodplains and overland flowpaths
- Mike Urban model - stormwater reticulation.

The hydraulic models were built based on a detailed survey of the northern Waihi Beach catchments during September and October 2011 by Harrison Grierson Ltd and Waihi Land Surveyors Ltd. The survey focussed on areas where asset data records were insufficient, or where there was uncertainty in the asset records. The survey recorded pipe and manhole geometry for stormwater assets important to drainage in the area. Minor stormwater assets that do not significantly affect catchment drainage were not included in the survey.

Cross section surveys of the open watercourses in the Two Mile Creek, One Mile Creek and Maranui catchments were also carried out to supplement the photogrammetric data.

The 2D model was built from LiDAR data (Light Detecting and Ranging), supplied by WBOPDC to T&T. The LiDAR data was captured following flights of the area, thought to be around 2008, but not confirmed.

The vertical datum used for all model builds and all results is Moturiki Datum.

Figure 3 in Appendix B shows the model schemetisation (i.e. which areas were covered by each model).

Roughness values were determined for different land uses based on the Terralink Land Cover layer (http://www.terralink.co.nz/gis-data/land-cover/). This layer was created from satellite images for the Ministry for the Environment. The roughness values used for different land use types are summarised in Table 2-6.

Table 2-6 Summary of roughness values used in the hydraulic model

Land use	Roughness (Mannings n)
Indigenous forest	0.09
Grassland	0.034
Manuka and or Kanuka	0.095
Urban parkland/open space	0.031
Built up area	0.016
Roads	0.015
Watercourse bed	0.033
Watercourse riparian margins	0.066

Flows into the hydraulic model were determined from the hydrological model and the downstream tailwater level (sea level) was determined in accordance with the EBOP guidelines shown in Table 2-2.

Soakage rates were applied to the hydraulic model in the sand geology areas. A soakage rate of 10^{-4} m/s (8640 mm/day) to represent constant losses from ponding areas.

2.3.2 Hydraulic model validation

A model validation of a storm event that occurred on 3 July 2012 was carried to determine confidence levels in the models. A model validation was carried out because a detailed model calibration was not possible due to the limited availability of flood flow or level data.

The 3 July 2012 storm event has been assessed as having a maximum return period of between 3 years and 4 years for a 3 hour duration (T&T, 2012), and caused flooding in the low lying areas of Waihi Beach. On the day following the 3 July 2012 storm event, T&T carried out a survey of debris levels to provide a means of validating the hydraulic and hydrological models. Ten houses were surveyed and an estimate of the flooded area was mapped on site by T&T. A copy of the field sketch of estimated flood areas is provided in Figure 4, Appendix B.

Rainfall records from the water treatment plant at Waihi Beach during the storm event were used in the hydrological model to determine catchment flows. The flows were then used as inflow boundaries for the hydraulic model. The results of the hydraulic model were then compared with the surveyed flood levels.

A comparison of the surveyed levels and the predicted flood levels from the model is shown in Table 2-7 and a flood map of the predicted flood extents is provided in Figure 5, Appendix B.

Table 2-7 Comparison of surveyed flood levels and predicted flood levels

Address	Surveyed flood level (Moturiki datum)	Modelled flood level (Moturiki datum)
4a Hillview	3.8	4.1
4 Hillview	3.8	4.1
6 Hillview	4.0	4.1
12 Leo	4.3	4.3
19 Brighton	3.8	4.3
23 Brighton	3.7	4.3
25 Brighton	3.6	4.3
55 Beach Road	5.3	5.1
56 Beach Road	4.1	4.3
27 Marine Ave	4.1	4.3

The results of the model validation show that the model is predicting water levels that are generally higher and range from -0.2 to +0.3m different to the observed flood levels. The exception is Brighton Road, where modelled water levels were up to 700mm higher than surveyed levels.

Overall, the flood extent recorded by the surveyor (shown in Figure 4a and 4b, Appendix B) is in general agreement with the modelled flood extents from the model validation event (shown in Figure 5, Appendix B).

Due to the limited availability of information it is not possible to determine the reason for the discrepancy in results, since we are unable to tell whether the inaccuracies lie in the hydrological model (i.e. over or under predicting runoff volume or peak flows) or the hydraulic model (i.e. over or under predicting levels based on correct or incorrect volumes/flows). It was also noted by the surveyor that a number of inlets to culverts and catchpits were blocked or partially blocked during the storm event. The model does not represent blockage of inlet structures.

3 Results

This section discusses the results of the flood study for the existing stormwater drainage network.

3.1 Flood inundation maps

The flood maps for the existing stormwater drainage for existing levels and maximum probable development levels of catchment development are included in Appendix C. Table 3-1 provides a summary of the figures and scenarios.

The flood maps show maximum water depths for each scenario. The maximum water depths are the greatest depths that occur at any period during the storm event.

Table 3-1 Modelled scenarios and figure numbers

Scenario	Existing Development	Maximum Probable Development
2 year ARI	Figure A01	Figure B01
5 year ARI	Figure A02	Figure B02
10 year ARI	Figure A03	Figure B03
20 year ARI	Figure A04	Figure B04
50 year ARI	Figure A05	Figure B05
50 year ARI + climate change	Figure A06	Figure B06
100 year ARI	Figure A07	Figure B07
100 year ARI + climate change	Figure A08	Figure B08

Flooding in the catchments draining to One Mile Creek and Two Mile Creek were mainly affected by channel capacity and hydraulic controls at structures.

However for the “Back dune” catchment (where most building flooding occurs), the model results identified the following hydraulic characteristics:

- Very limited flood conveyance through the piped drainage system, leading to significant retention of runoff volume and flows occurring overland
- Low velocities with overland flow paths around the residential areas
- High flood depths in low lying areas
- In some areas, there was very little difference between the flood extents of storm events of differing return periods with only flood depths changing
- There was only a small increase in flood extents and flood depth caused by climate change and in-fill development to the extent allowable in the current District Plan.

Overall flooding in the “Back dune” sub-catchments is caused by limited capacity of the stormwater drainage system and “ponding” characteristics of the topography caused by the dune complex. Essentially the low lying areas fill with water and water cannot drain from the area (other than infiltration) before the “crest” of the pond is overtopped.

3.2 Flood assessment

3.2.1 Flooded buildings

A survey of habitable floor levels of potentially flooded buildings in Waihi Beach was carried out during October to November 2011 to determine the number of buildings that may experience flooding of habitable floors from a 24 hour duration storm of differing return periods.

The buildings were included for survey if the building footprint (from aerial photograpahy) was within the flood extent from preliminary model runs. The damage to buildings can be used to identify the benefit of flood mitigation options which will be a key requirement under Stage 2 of the process. In total, the floor levels of 325 residential buildings were surveyed. Caravans, garages and a small number of non-residential buildings (e.g. the surf life saving club) were excluded from the survey.

The surveyed buildings are shown in Figure 6, Appendix D. The plot also shows whether the habitable floor level is flooded for different return period storms.

Table 3-2 provides a summary of the number of buildings that would experience habitable floor level flooding for a 24 hour storm duration of differing return periods. We note that shorter duration storms (of the same return period) will result in less flooding due to a reduction in runoff volume. There are additional properties (land) that are flooded that are not included inthese counts as habitable buildings are not included.

Table 3-2 Number of properties experiencing habitable floor flooding

Scenario	ED	MPD
2 year ARI	70	81
5 year ARI	77	90
10 year ARI	91	103
20 year ARI	112	118
50 year ARI	140	152
100 year ARI	157	165
50 year ARI + climate change	150	156
100 year ARI + climate change	182	187

The results shown in Table 3-2 indicate the following:

- That the effects of climate change will increase the number of habitable floor levels flooded during a 24 hour 50 year ARI storm event by 10 to 150 for the existing development
- That the effects of climate change will increase the number of dwellings flooded during a 24 hour 100 year ARI storm event by 25 to 182 for the existing development
- By developing impervious surfaces to the maximum limits shown in the current District Plan, the number of flooded dwellings affected during a 24 hour, 50 year ARI storm event with climate change will increase from 152 to 156, a difference of 4 dwellings.
- By developing impervious surfaces to the maximum limits shown in the current District Plan, the number of flooded dwellings affected during a 24 hour, 100 year ARI storm event with climate change will increase from 165 to 187, a difference of 22 dwellings.

4 Conclusions

Western Bay of Plenty District Council (WBOPDC) commissioned Tonkin & Taylor (T&T) to carry out a flood hazard assessment of the northern Waihi Beach catchments. The assessment was required to define the flood hazard.

The assessment is based on a hydrological and hydraulic model of the area that was constructed as part of this project. The hydrological model was developed based on calibrated models of nearby catchments, and the hydraulic model was validated for the 3rd July 2012 storm event based on surveyed flood levels. The hydrological and hydraulic models were used to create flood hazard maps of design storm scenarios and the flood hazard maps are provided with this report.

The model results were analysed and the following characteristics were observed:

- Flooding in the catchments draining to One Mile Creek and Two Mile Creek were mainly affected by channel capacity and hydraulic controls at structures.
- However for the "Back dune" catchment where most habitable floor flooding occurs, the model results identified the following hydraulic characteristics:
  - Very limited flood conveyance through the piped drainage system, leading to significant retention of runoff volume and flows occurring overland
  - Low velocities with overland flow paths around the residential areas
  - High flood depths in low lying areas
  - In some areas, there was very little difference between the flood extents of storm events of differing return periods with only flood depths changing

Generally flooding in the "Back dune" sub-catchment is caused by limited capacity of the stormwater drainage system and "ponding" characteristics of the topography caused by the dune complex. Essentially the low lying areas fill with water and water cannot drain from the area (other than infiltration) before the "crest" of the pond is overtopped.

Based on current levels of development there are up to 140 habitable buildings at risk of flooding within the study extent at Waihi Beach for a 50 year ARI design storm event. Due to the effects of climate change to 2090, the number of habitable buildings at risk increases to 150 and there are additional residential buildings at risk from a 100 year ARI storm event. There are a large number of additional property owners that will experience property flooding, without experiencing habitable floor level flooding (e.g. flooding of their gardens)

The study also showed that there are 70 habitable buildings at risk from flooding in a 24 hour duration, 2 year ARI design storm event.

In the future, if development is permitted to the maximum limits shown in the current District Plan, there will be a likely increase in the number of flooded habitable buildings from 140 to 152 that are affected during a 24 hour, 50 year ARI storm event. For climate change scenarios, the number of flooded habitable buildings increases due to development to the District Plan limits from 150 to 156.

This report has highlighted that there is a significant flood risk at Waihi Beach and that there are a large number of residential properties at risk of inundation during design storm events. The results of the baseline assessment can be used to determine 50 year ARI flood levels, which WBOPDC can use to help determine habitable floor level requirements. WBOPDC should give consideration regarding how to apply freeboard on top of the flood levels.

As part of the future works, a range of engineered flood mitigation works and management options can be assessed. The options can be assessed against the baseline flood scenarios represented in this report.

5 References

EBOP, 2001/04. Hydrological and Hydraulic Guidelines;

Bay of Plenty Regional Council, 2012. Hydrological and Hydraulic Guidelines (DRAFT).

FHRC, 2010. The benefits of flood and coastal risk management: A handbook of Assessment Techniques;

GAB Robins, 2004. Whakatane Flood Plan Management Strategy. Stage 1, Flood damage costs for residential properties;

Metrowater, 2008. Flood damage assessment. Prepared by Phillip Johansen for Auckland City Council. October 2008;

NBR, 2004. National Business Review. Under Insurance Tackled, April 16, 2004, p10.

NSW Government, 2005. NSW Floodplain Development Manual;

NZIER, 2004. Economic impacts on New Zealand of climate change-related extreme events. Focus on freshwater floods. Report to the New Zealand Climate Change Office.

6 Applicability

This report has been prepared for the benefit of 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 without our prior review and agreement.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

....

Jon Rix
Project Manager

Dave Taylor
Project Director

Reviewed by

....

Tim Fisher
Technical Reviewer

JRRR

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Appendix A: Catchment drawings

- **Figure 1 Waihi Beach Overview**
- **Figure 2 Waihi Beach Sub-catchments**

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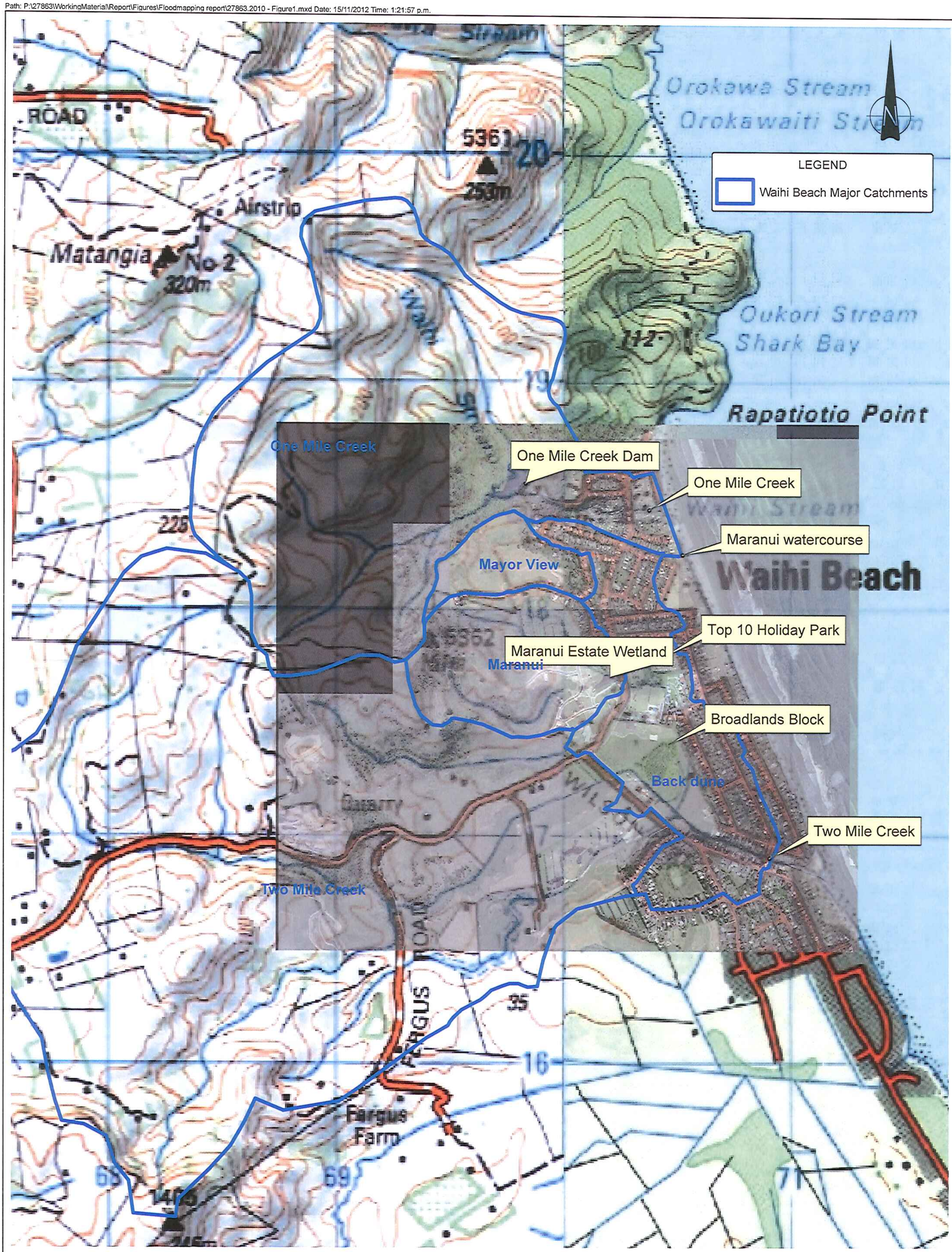

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:15,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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WBOPDC
Flood Hazard & Options Assessment
Waihi Beach Overview

FIGURE No. Figure 1

Rev. 0

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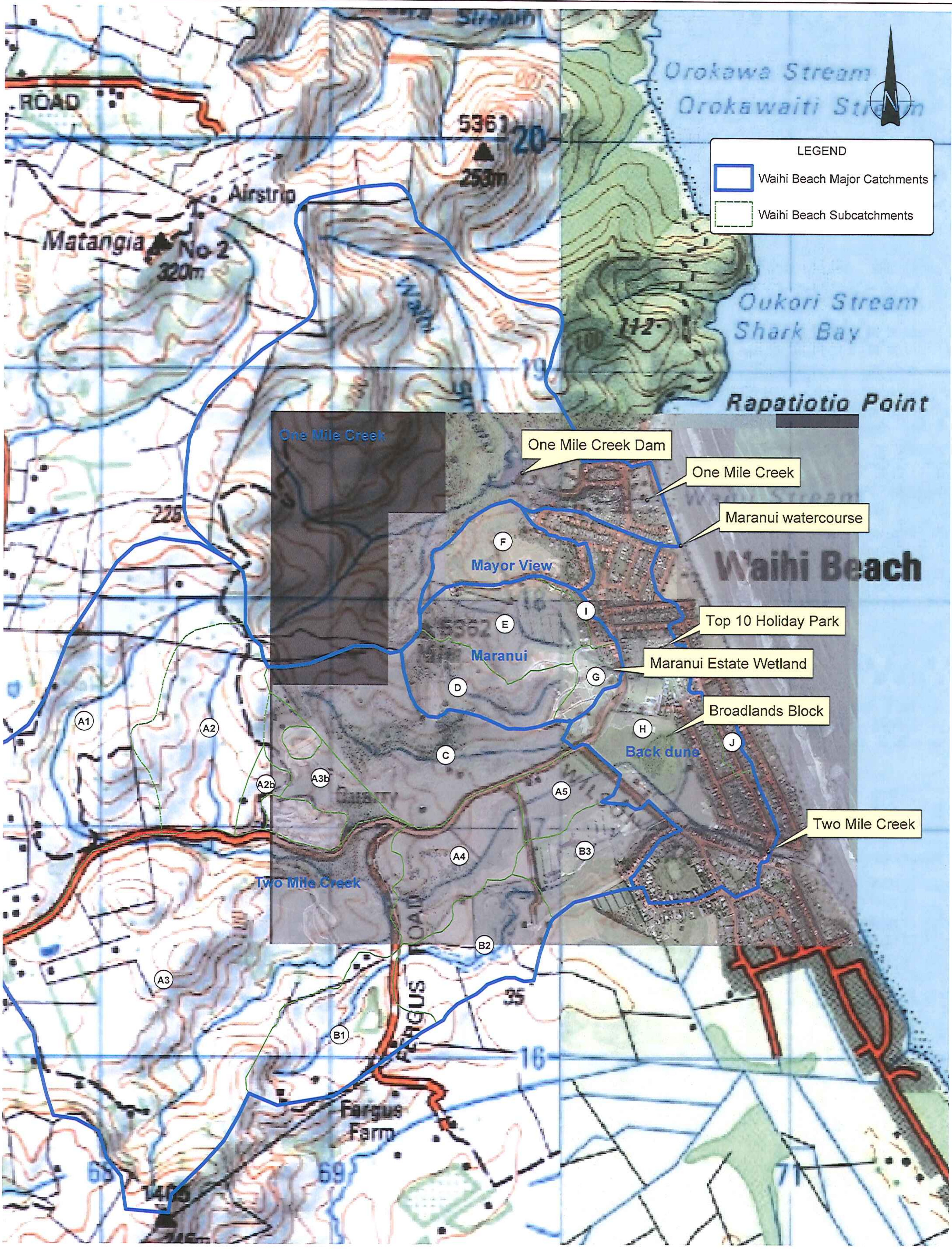

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:15,000

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Flood Hazard & Options Assessment
Waihi Beach Sub-catchments

FIGURE No. Figure 2

Rev. 0

Appendix B: Model Plots

- **Figure 3 Model Schemetisation**
- **Figure 4 Surveyors estimate of flood extents for 3/7/2012 storm event**
- **Figure 5 Model validation plot – Event 3/7/12**

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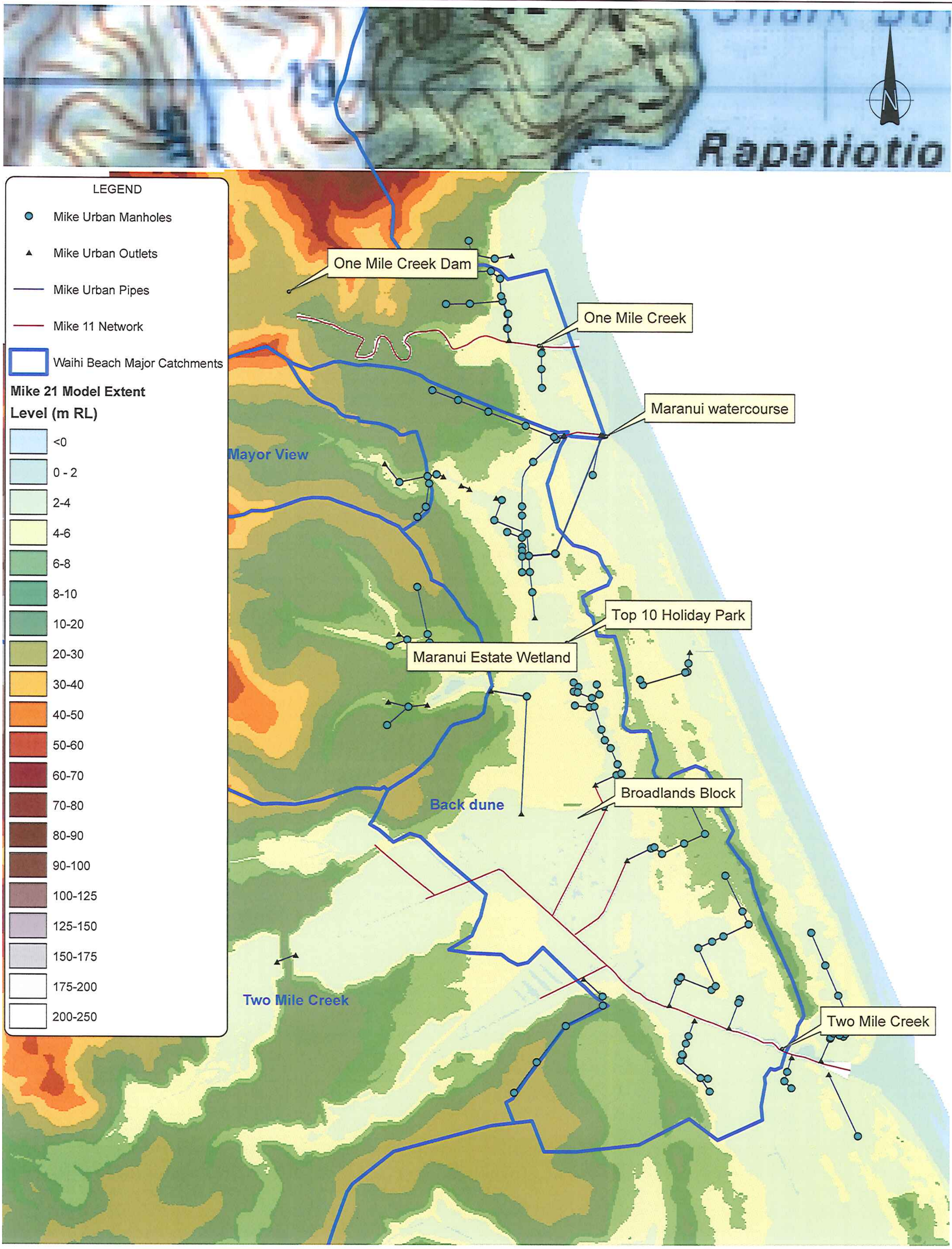

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

0 0.1 0.2 0.3 0.4 0.5 (km)

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WAIHI BEACH FLOOD OPTION
Model schemetisation

FIGURE No. Figure 3

Rev. 0

- **Figure 4 Surveyors estimate of flood levels for 3rd July 2012 flood event**

Waihi Beach

Western Bay of Plenty District Council

Date : Fri 06 Jul | Scale 1 : 8684 | Operator : External IVY | North

LOCATION OF SERVICES IS INDICATIVE ONLY. COUNCIL ACCEPTS NO LIABLITY FOR ANY ERROR.

ARCHAEOLOGICAL DATA SUPPLIED BY NZ ARCHAEOLOGICAL ASSOC./DEPT. OF CONSERVATION. DATA COPIED AS AT Jul 2005.

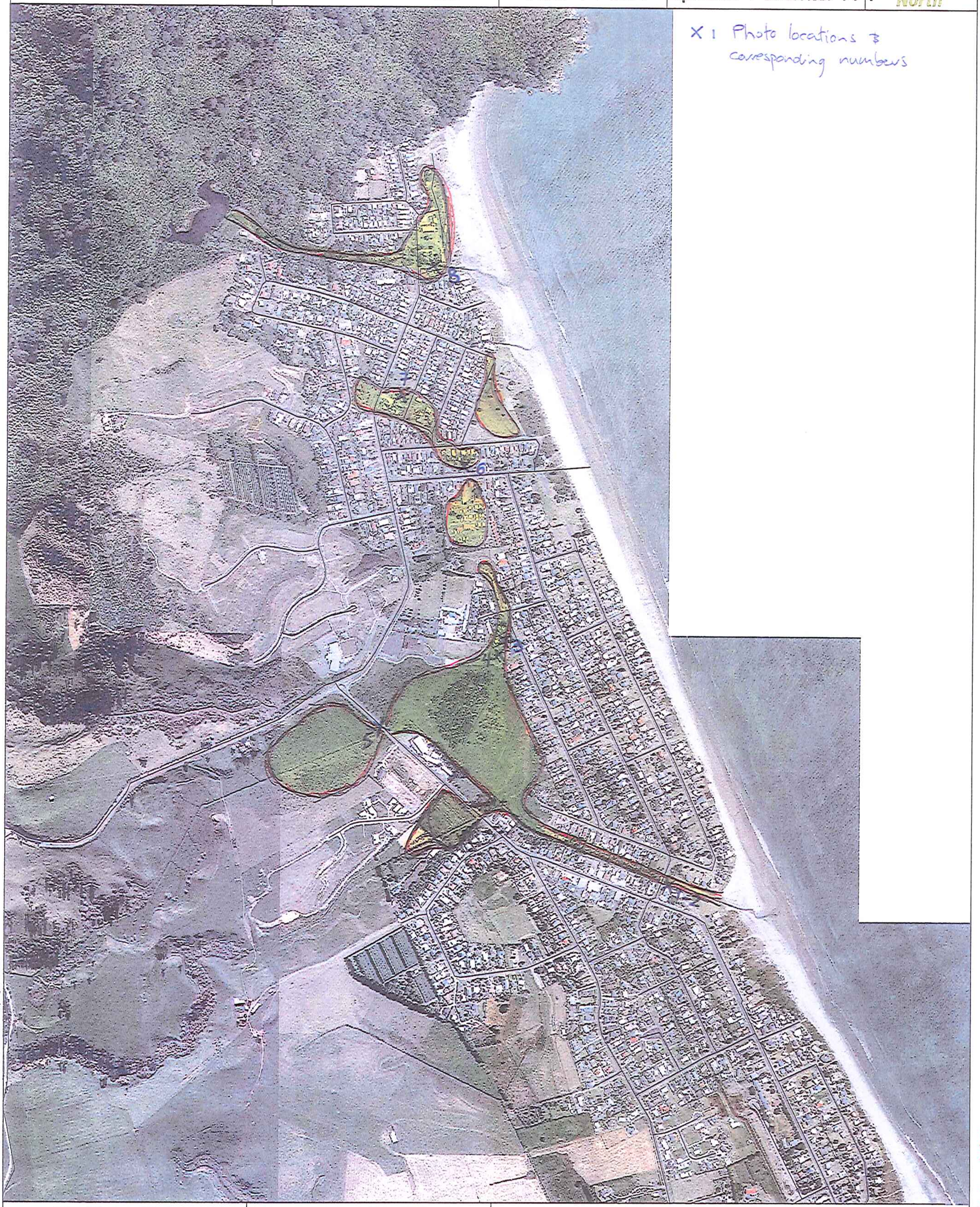
T&T Figure 4a

Western Bay of Plenty District Council

Waihi Beach

Date : Fri 06 Jul | Scale 1 : 8684 | Operator : External IVY | North

X 1 Photo locations & corresponding numbers



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T&T Figure 4b

Appendix C Flood maps – Baseline condition

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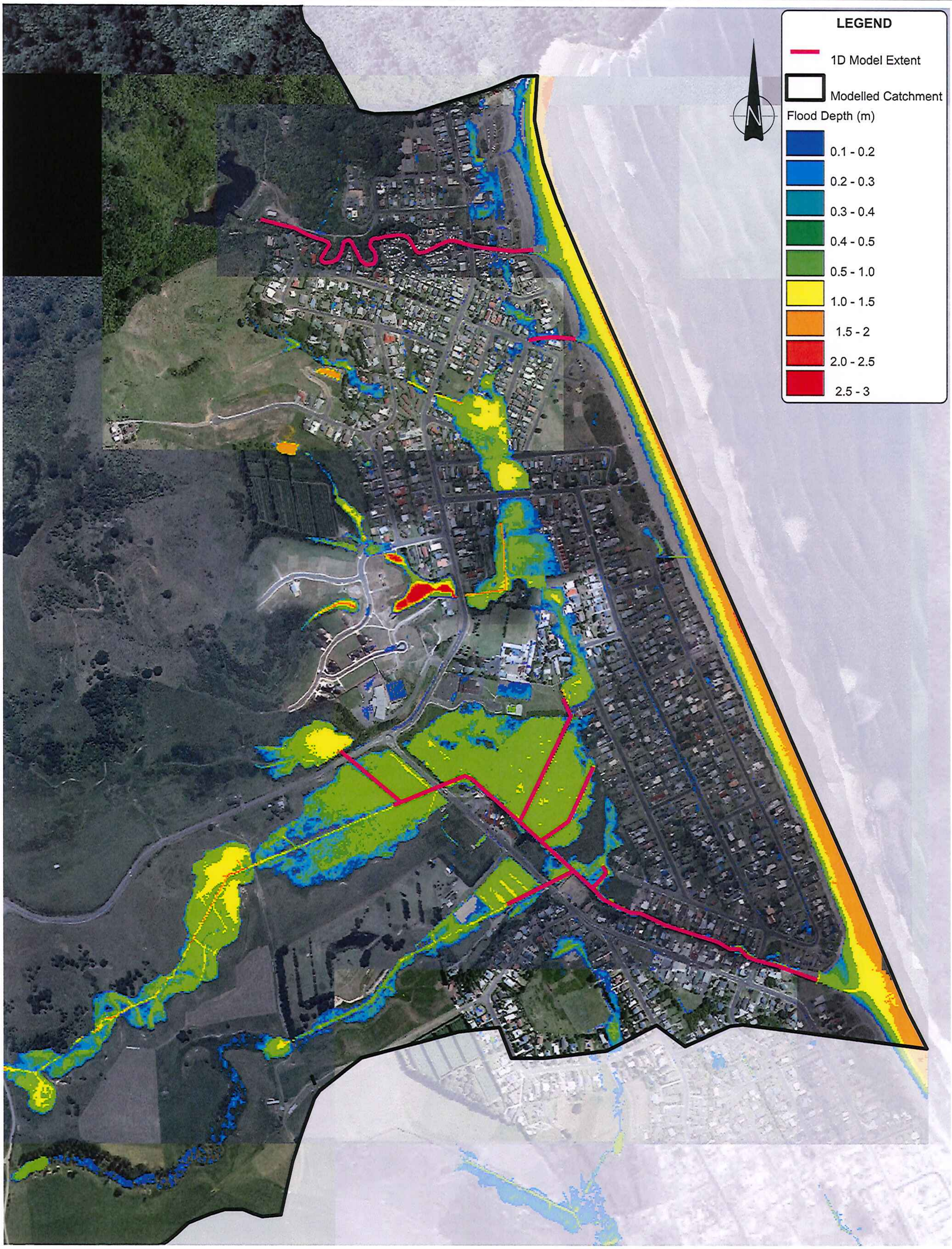

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

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WBOPDC
Flood Hazard & Options Assessment
2 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A01

Rev. 0

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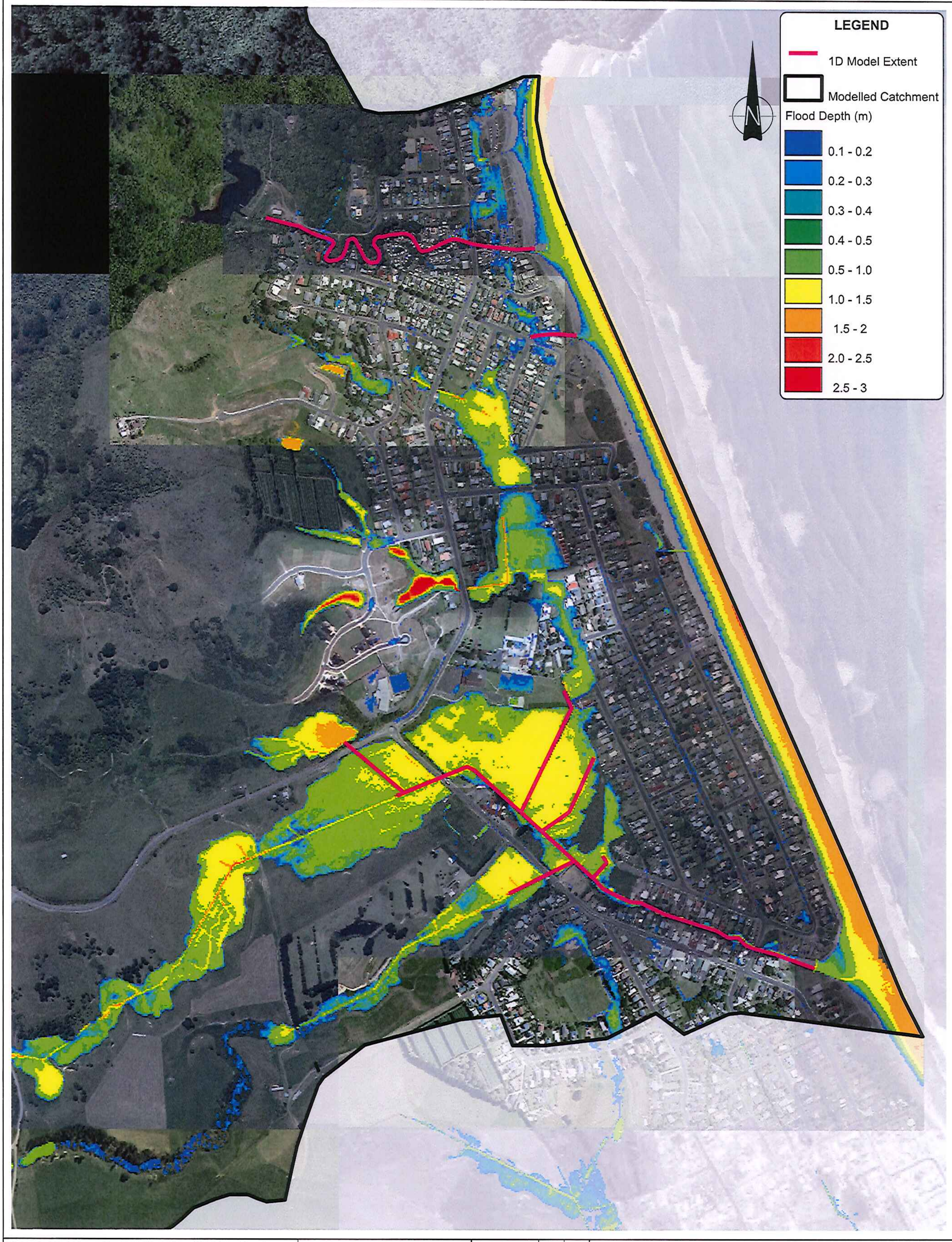

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

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WBOPDC
Flood Hazard & Options Assessment
5 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A02

Rev. 0

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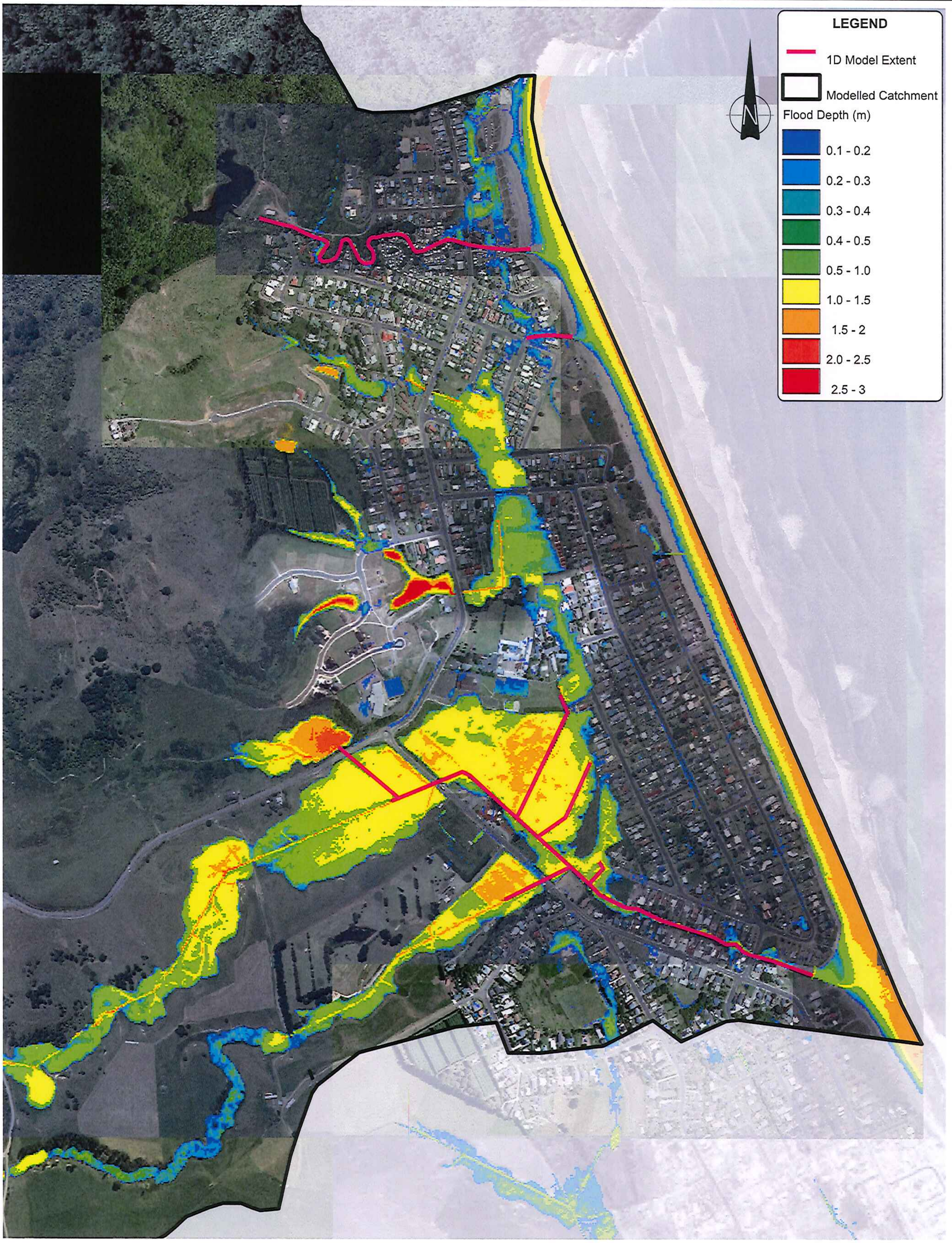

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

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10 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A03

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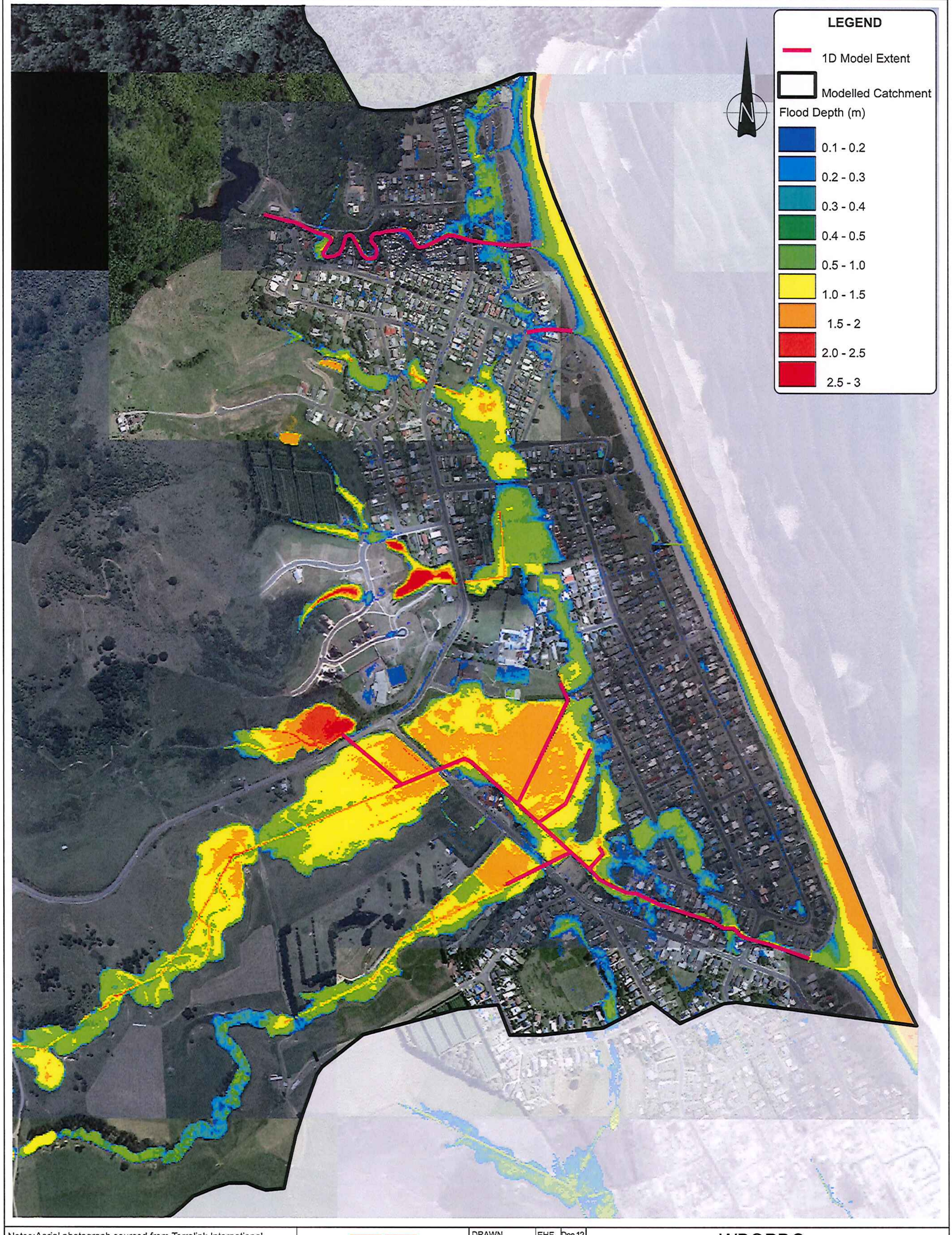

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

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WBOPDC
Flood Hazard & Options Assessment
20 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A04

Rev. 0

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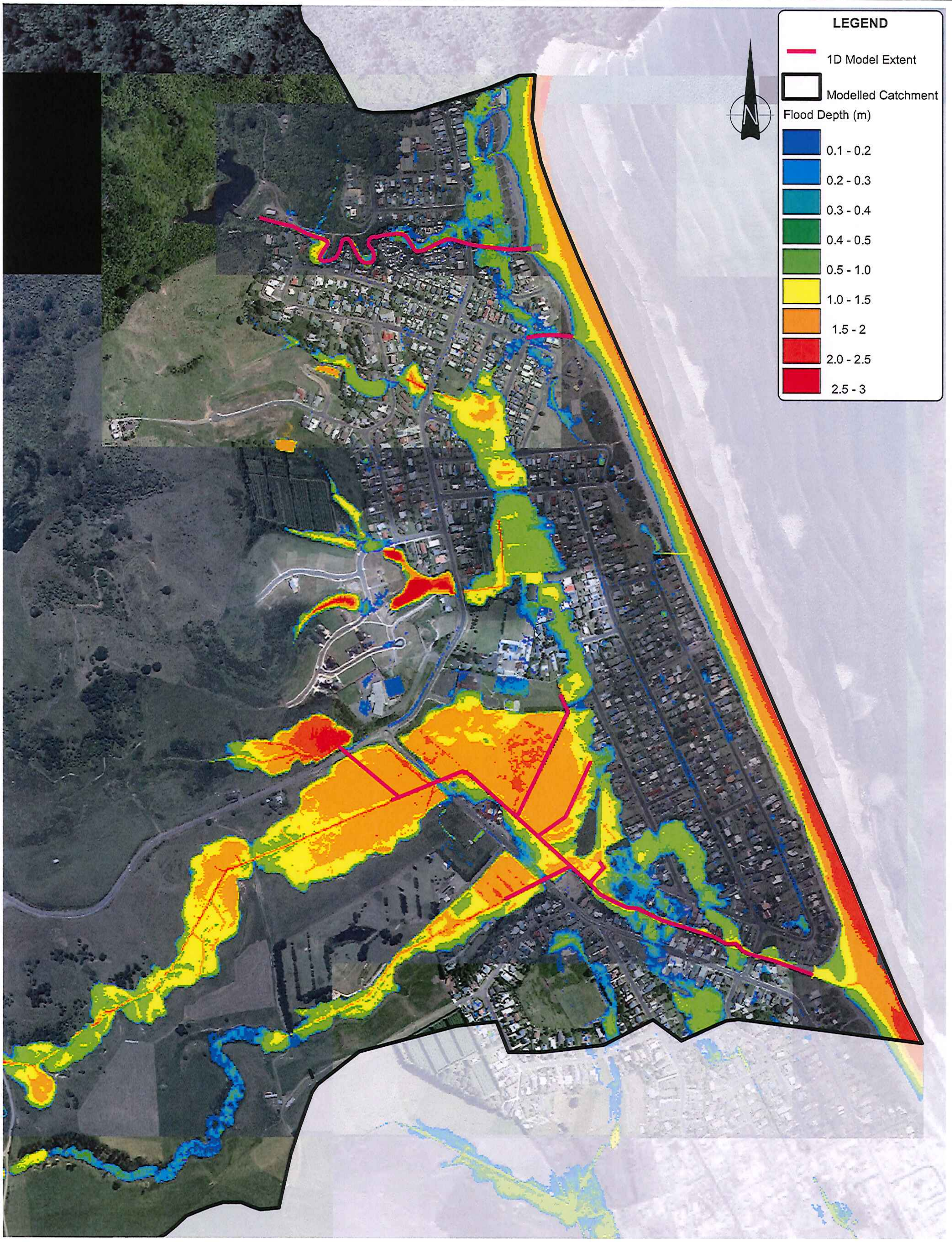

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

0 0.1 0.2 0.3 0.4 0.5 (km)

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50 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A05 | Rev. 0

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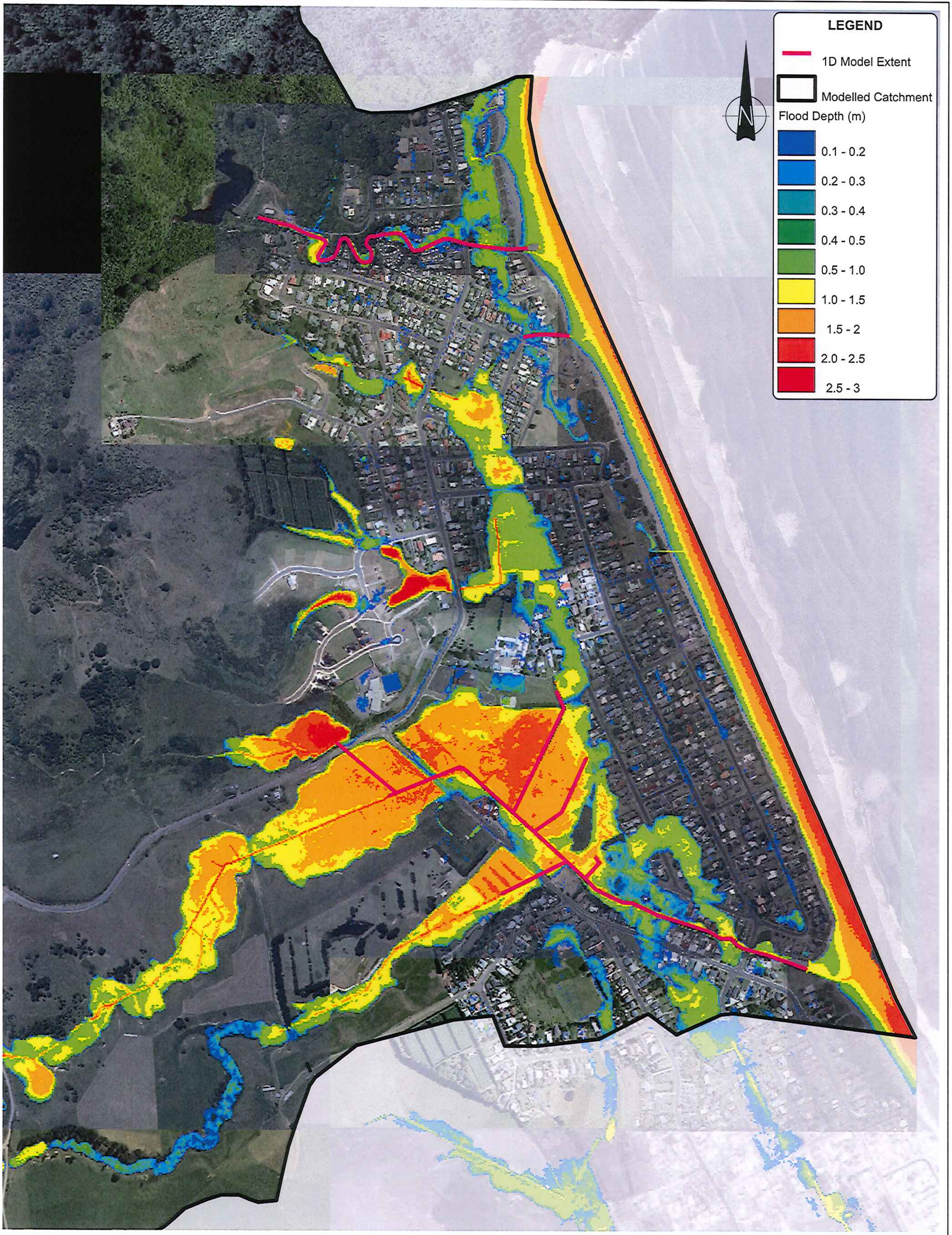

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

0 0.1 0.2 0.3 0.4 0.5 (km)

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Flood Hazard & Options Assessment
50 year ARI Flood Extent
ED + Climate Change - Baseline

FIGURE No. Figure A06

Rev. 0

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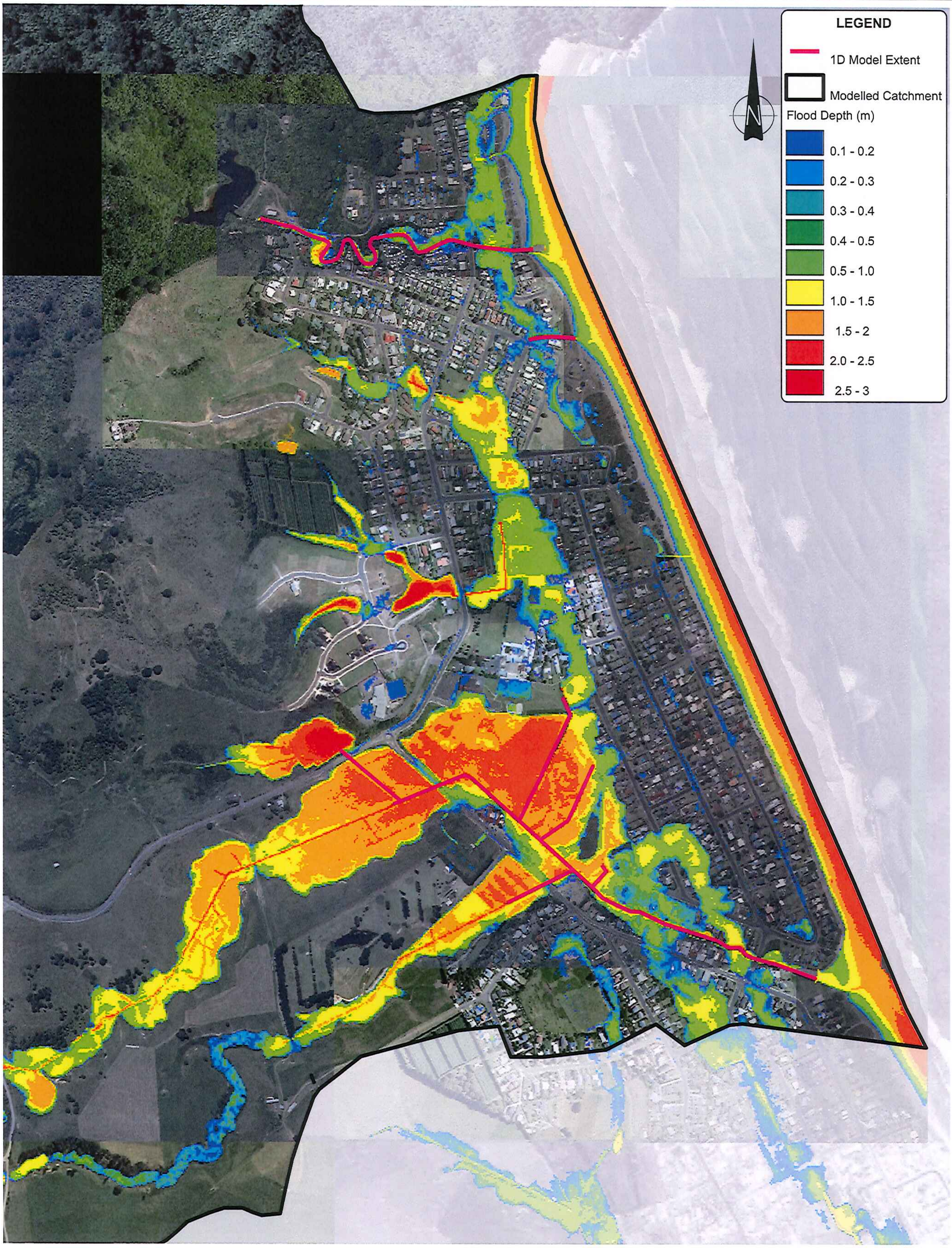

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A3 SCALE 1:7,500

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Flood Hazard & Options Assessment
100 year ARI Flood Extent
ED - Baseline

FIGURE No. Figure A07

Rev. 0

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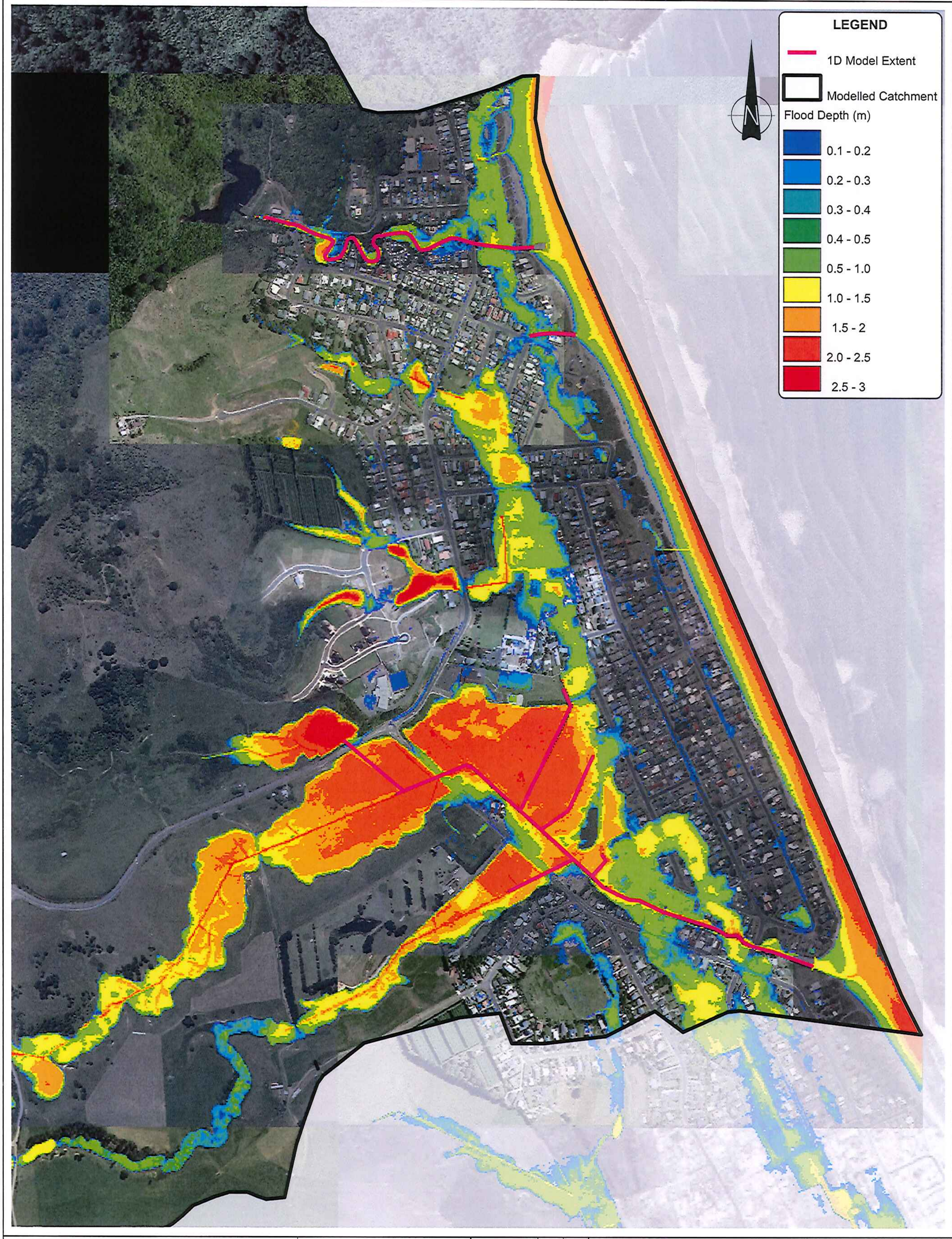

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

0 0.1 0.2 0.3 0.4 0.5 (km)

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100 year ARI Flood Extent
ED+ Climate Change - Baseline

FIGURE No. Figure A08

Rev. 0

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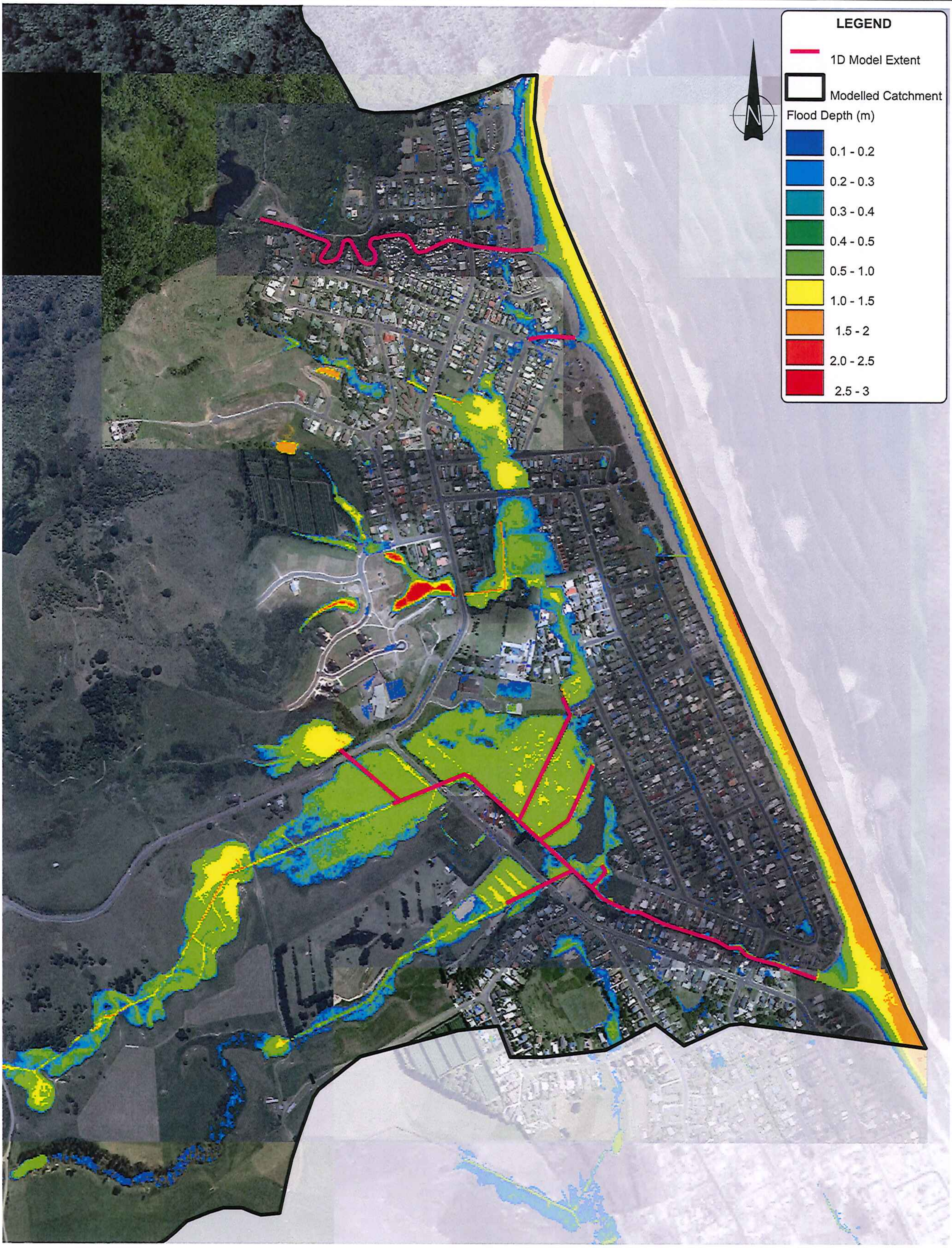

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A3 SCALE 1:7,500

0 0.1 0.2 0.3 0.4 0.5 (km)

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Flood Hazard & Options Assessment
2 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B01

Rev. 0

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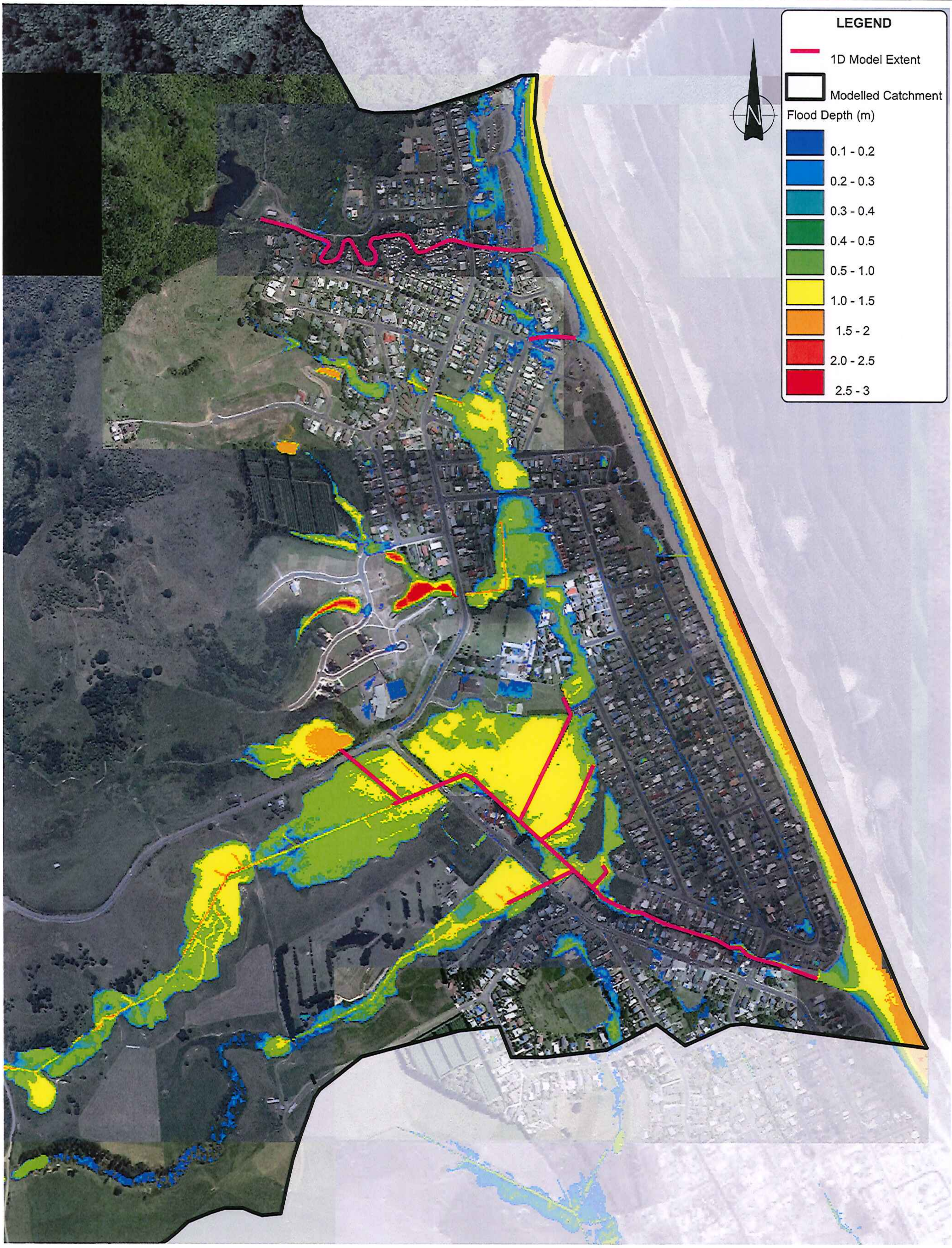

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A3 SCALE 1:7,500

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WBOPDC
Flood Hazard & Options Assessment
5 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B02

Rev. 0

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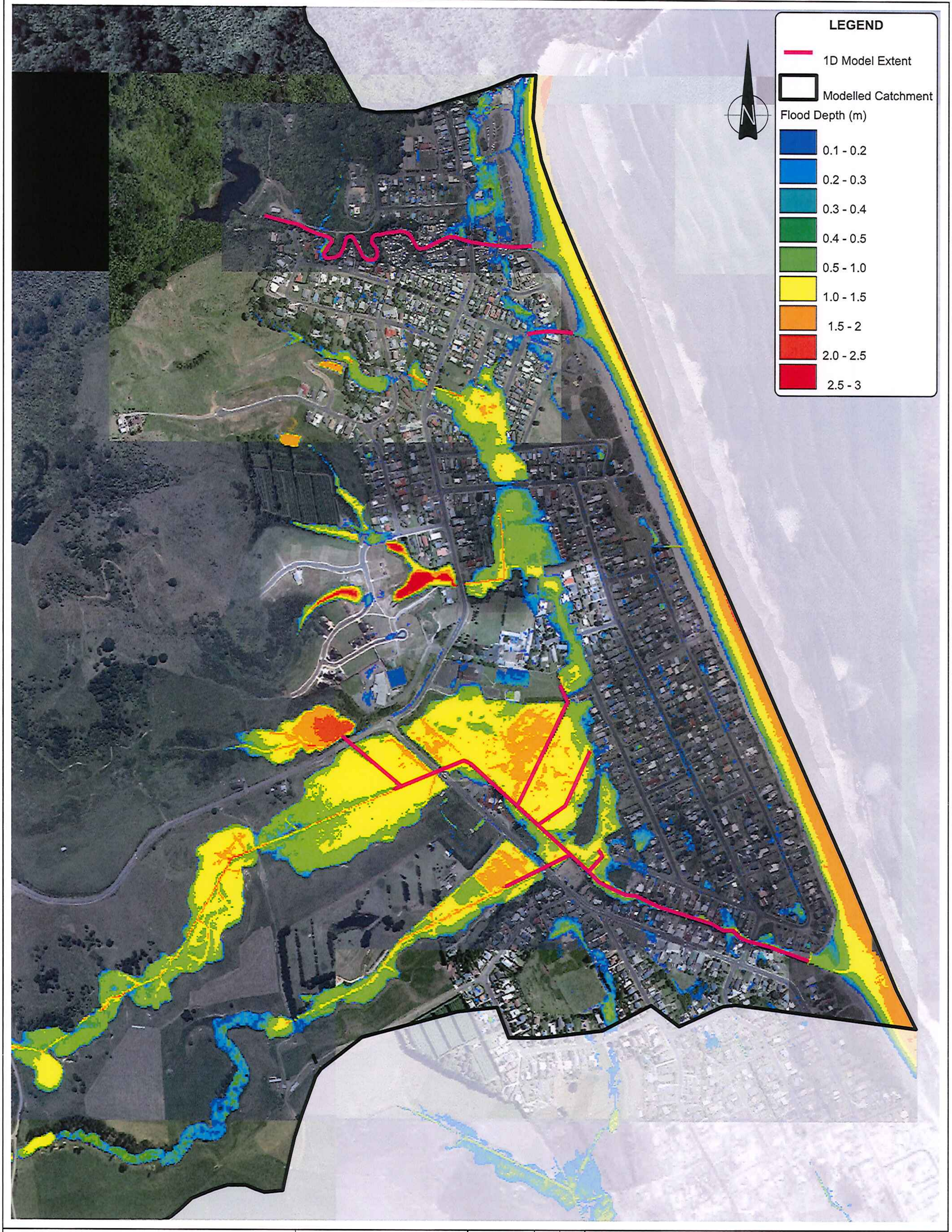

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A3 SCALE 1:7,500

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Flood Hazard & Options Assessment
10 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B03

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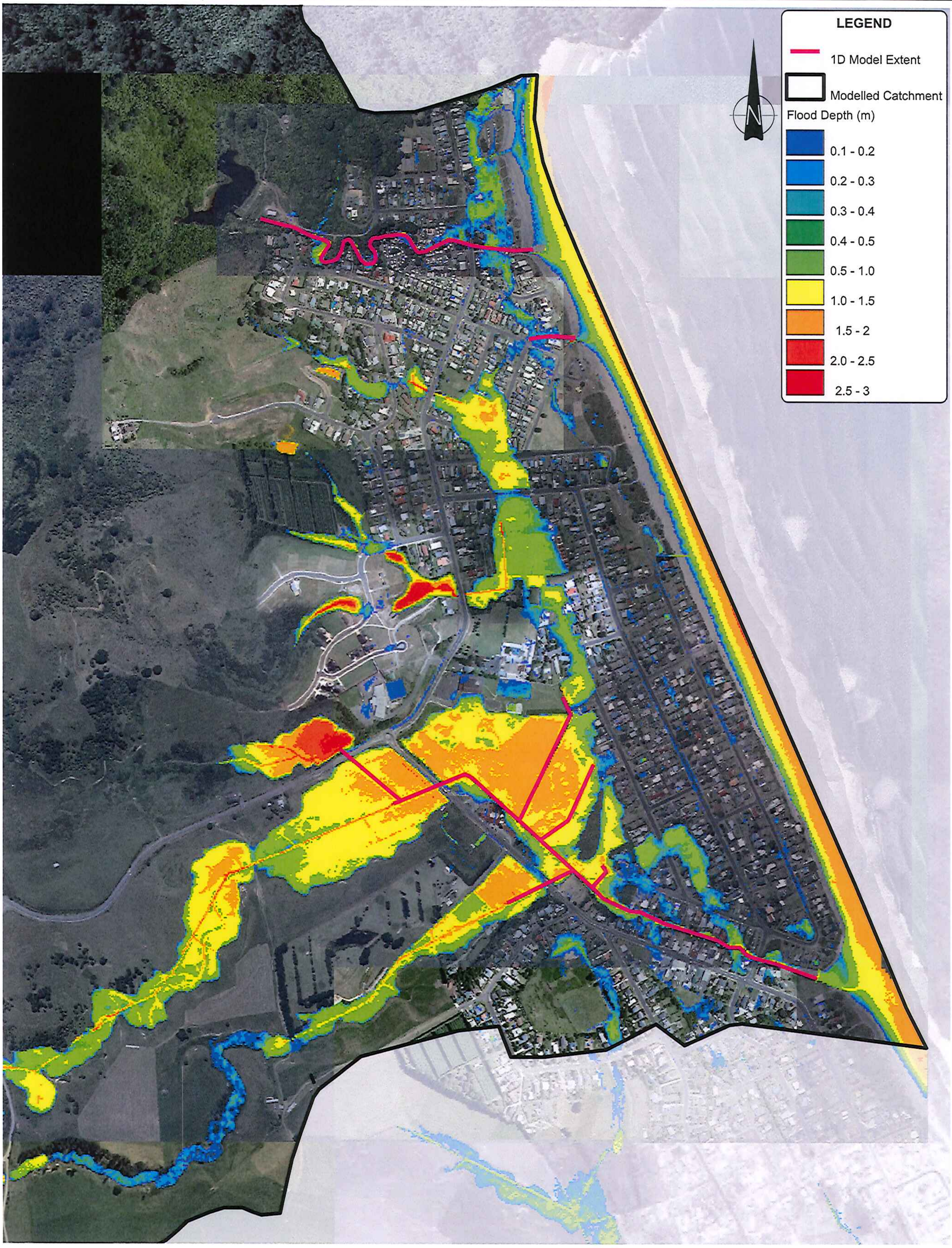

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A3 SCALE 1:7,500

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20 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B04

Rev. 0

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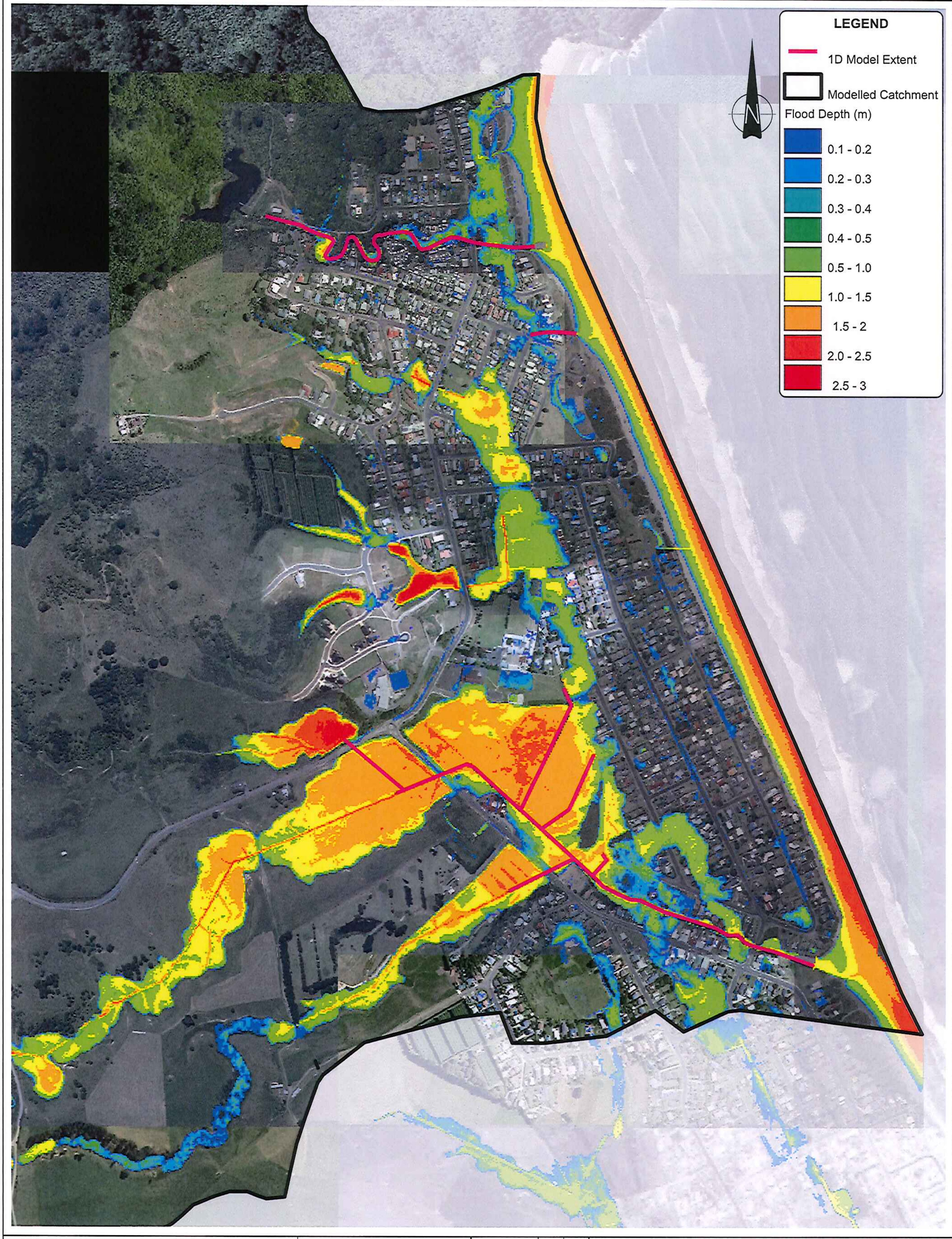

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Flood Hazard & Options Assessment
50 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B05

Rev. 0

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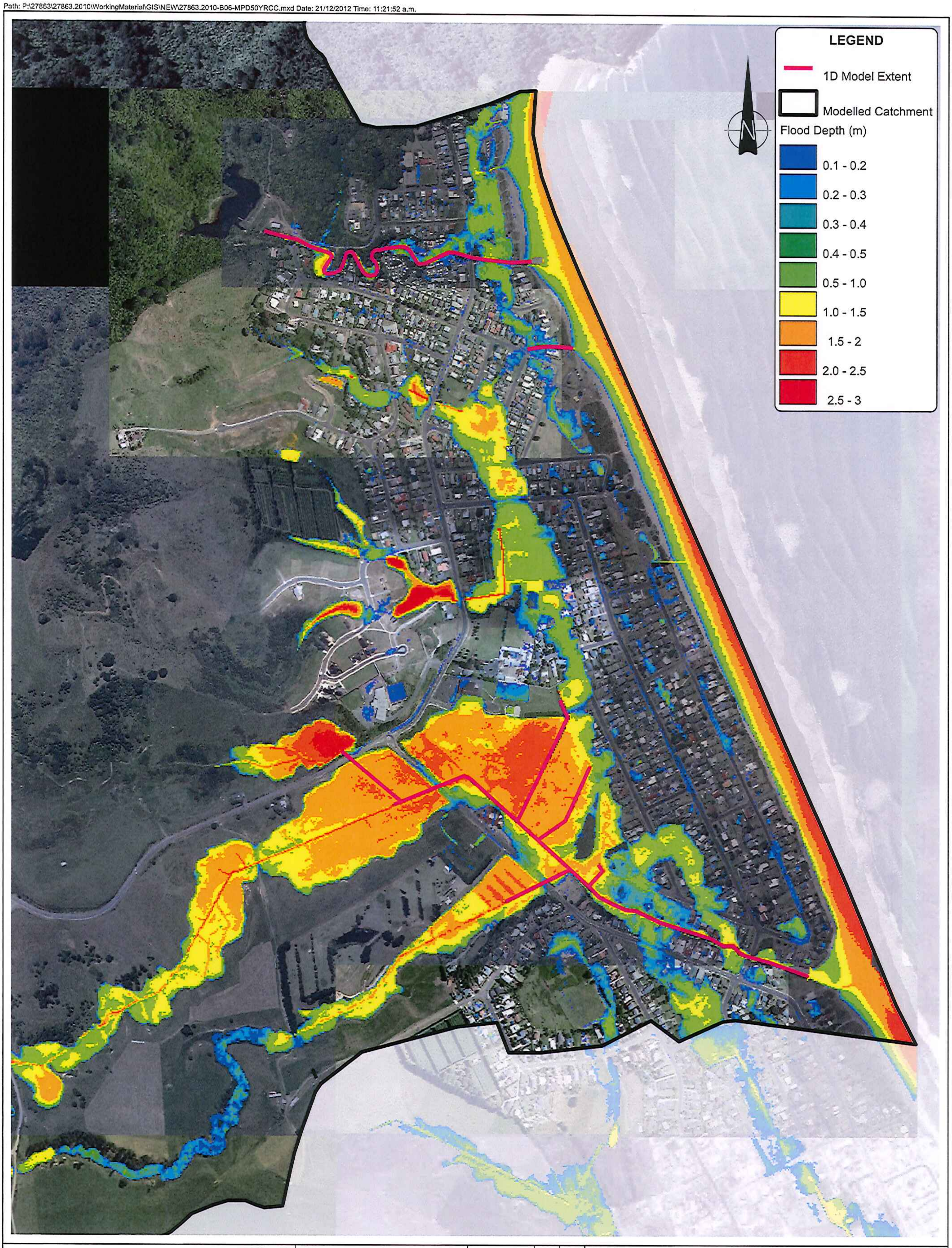

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A3 SCALE 1:7,500

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50 year ARI Flood Extent
MPD + Climate Change - Baseline

FIGURE No. Figure B06

Rev. 0

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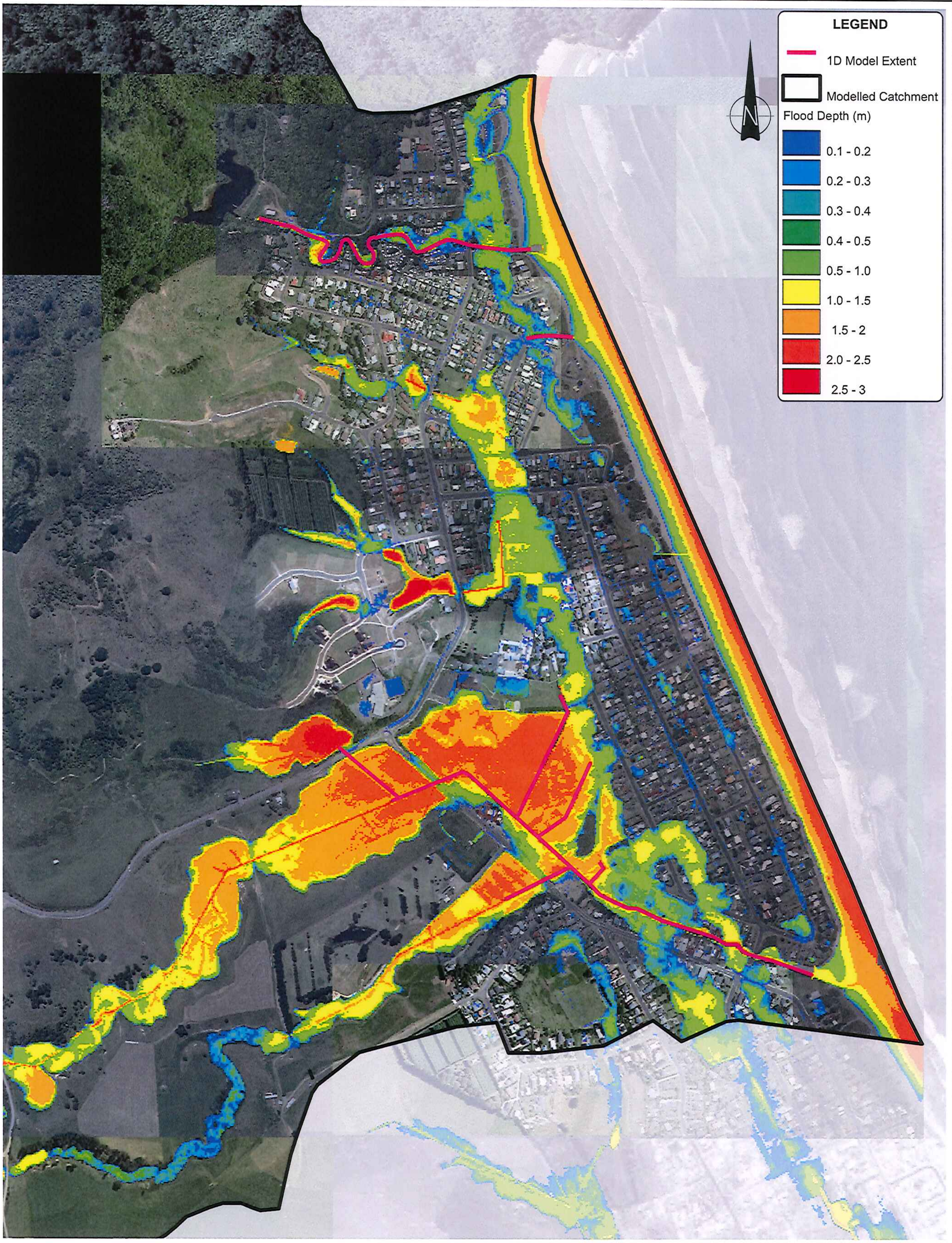

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A3 SCALE 1:7,500

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Flood Hazard & Options Assessment
100 year ARI Flood Extent
MPD - Baseline

FIGURE No. Figure B07

Rev. 0

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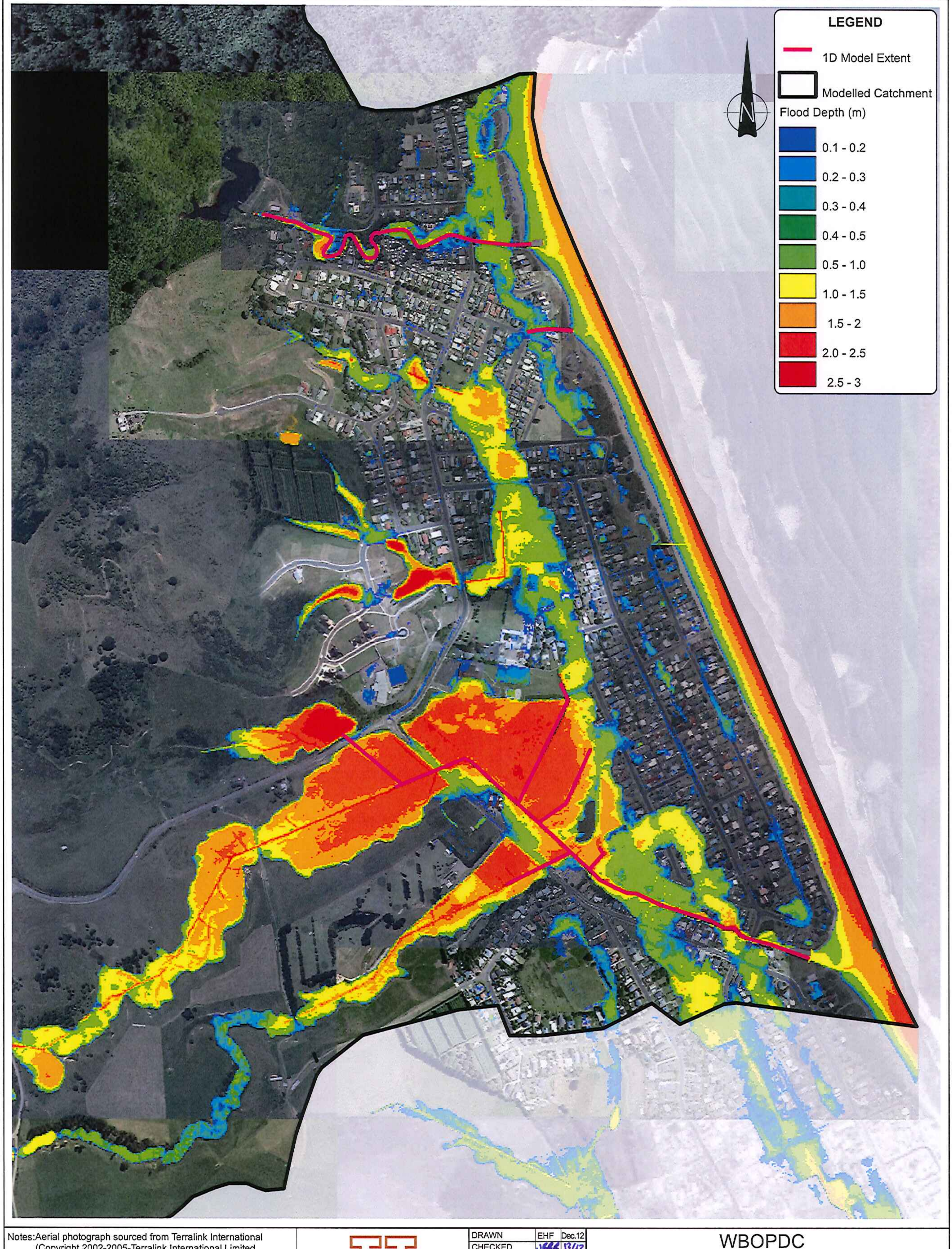

Notes: Aerial photograph sourced from Terralink International (Copyright 2002-2005-Terralink International Limited and its licensors. Approximate date 2001-2003).

A3 SCALE 1:7,500

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Flood Hazard & Options Assessment
100 year ARI Flood Extent
MPD + Climate Change - Baseline

FIGURE No. Figure B08

Rev. 0

Appendix D Surveyed floor levels and flood damage

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A3 SCALE 1:5,000

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SCALE (AT A3 SIZE) 1:5,000		
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WBOPDC
Flood Hazard & Options Assessment
Habitable Floor Level Flooding
2 year ARI, Existing Development

FIGURE No. Figure 6a

Rev. 0

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A3 SCALE 1:5,000

0 0.1 0.2 0.3 (km)

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5 year ARI, Existing Development

FIGURE No. Figure 6b

Rev. 0

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A3 SCALE 1:5,000

0 0.1 0.2 0.3 (km)

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SCALE (AT A3 SIZE) 1:5,000		
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Habitable Floor Level Flooding
10 year ARI, Existing Development

FIGURE No. Figure 6c

Rev. 0

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A3 SCALE 1:5,000

0 0.1 0.2 0.3 (km)

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20 year ARI, Existing Development

FIGURE No. Figure 6d

Rev. 0

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A3 SCALE 1:5,000

0 0.1 0.2 0.3 (km)

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SCALE (AT A3 SIZE) 1:5,000		
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50 year ARI, Existing Development

FIGURE No. Figure 6e

Rev. 0

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A3 SCALE 1:5,000

0 0.1 0.2 0.3 (km)

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SCALE (AT A3 SIZE) 1:5,000		
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100 year ARI, Existing Development

FIGURE No. Figure 6f

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