BULLER RIVER

August 2015

Flood Mitigation Options Assessment

LANDRIVERSEA
PROFESSIONAL ENGINEERING

Report prepared for WCRC
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BULLER RIVER

FLOOD MITIGATION OPTIONS ASSESSMENT

EXECUTIVE SUMMARY

The existing hydraulic model of the Buller River has been refined and used to assess a range of flood mitigation options for Westport. The model has allowed for a more detailed representation of the main structures than in previous versions of the model and has also allowed for a degree of blockage on the Buller River Bridge and Nine Mile Road trestle bridge.

The options which have been assessed with the model are as follows and are presented in more detail in Section 2.

- Option A – Do Nothing (Existing Scenario)
- Option B – Extensive Stopbanks and Floodwalls
- Option C – Partial Stopbanks and Floodwalls
- Option D – Flood Relief Cut
- Option E – Extensive Stopbanks and Floodwalls combined with Flood Relief Cut
- Option F – Partial Stopbanks and Floodwalls combined with Flood Relief Cut

Results for each option have been presented in graphical format with maps of Flood Depth / Extent, Difference in Flood Depth and Flood Hazard being presented for each option in Appendix A, B and C.

Section 4 provides details of the flood damages assessment which was conducted using NIWAs RiskScape programme for each option. The results of which are summarised in the Table i below.

Table i - Estimated damages for options scenarios

	Damages ($Million)	
	50 year event (Current Climate)	**100 year event (Current Climate)**
Option A – Do Nothing	38	114
Option B –Extensive Stopbanks	6	8
Option C – Partial Banks	22	53
Option D – Flood Relief Cut	29	95
Option E – Extensive Banks and Cut	6	8
Option F – Partial Banks and Cut	12	29

Construction costs were also estimated for each option and are summarised in the Table ii. More details on the methods used to estimate the construction costs are presented in Section 5.

Table ii – Summary of estimated total construction costs for each option

	50 year cost ($Million)	**100 year cost ($Million)**
Option A – Do Nothing	0	0
Option B – Extensive Floodwalls	6.8	9.4

Option C – Partial Floodwalls	2.3	3.0
Option D – Flood Relief Cut	4.2	4.2
Option E – Extensive Floodwalls and Flood Relief Cut	10.5	13.0
Option F - Partial Floodwalls and Flood Relief Cut	6.5	7.3

Finally a general list of pros and cons for each option has been presented in Section 6.

It is recommended that these options are presented to the relevant council staff as well as taken to the general public in a refined form for consultation and general feedback.

TABLE OF CONTENTS

1. INTRODUCTION

The West Coast Regional Council recently commissioned Land River Sea Consulting to build a hydraulic model of the Buller River system, in order to identify the likely extent of flooding for a range of return period events, as well as to be able to use the model for investigating potential flood mitigation options. Details of this original model build are presented in the report "Buller River Hydraulic Modelling" (Gardner, 2015)

Further to the construction of the hydraulic model, a preliminary options assessment was carried out over a number of months in early 2015 (Gardner, 2015).

This report takes several of the options from the preliminary assessment in order to investigate them in more detail. This report analyses the effectiveness of each option by using a range of tools including flood extent and depth maps, flood hazard assessments, estimate of flood damages, estimate of construction costs as well as an analysis of the practical pros and cons of each option.

The version of the model which has been used for this assessment is more detailed than that used in previous assessments and takes into account all of the piers on the main bridge structures. The model has also allowed for blockage scenarios on both the Buller River Bridge (10% of waterway blocked by debris in addition to bridge piers and soffit lowered by 0.5m) as well as the main Nine Mile Road Bridge (5% of waterway blocked by debris in addition to bridge piers).

2. OPTIONS

Six options have been investigated as part of this analysis. For the purpose of this report the options to be assessed are labelled Option A to Option F. Details of each option are included below.

OPTION A – DO NOTHING

This option considers doing nothing and maintaining the status quo. The risks of doing nothing are outlined and the potential financial costs based on likely damages from a 50 and 100 year event are presented.

OPTION B – EXTENSIVE STOPBANKS AND FLOOD WALLS

This option involves constructing a series of stopbanks and concrete floodwalls, essentially ringbanking the main town area of Westport, as well as protecting the land adjacent to Snodgrass Rd as well as the Carter's Beach community. Stopbanks have been assumed to have a 2:1 batter slope and a top width of 6m down the Buller River to allow vehicle and pedestrian access, and a top width of 4m for all other banks.

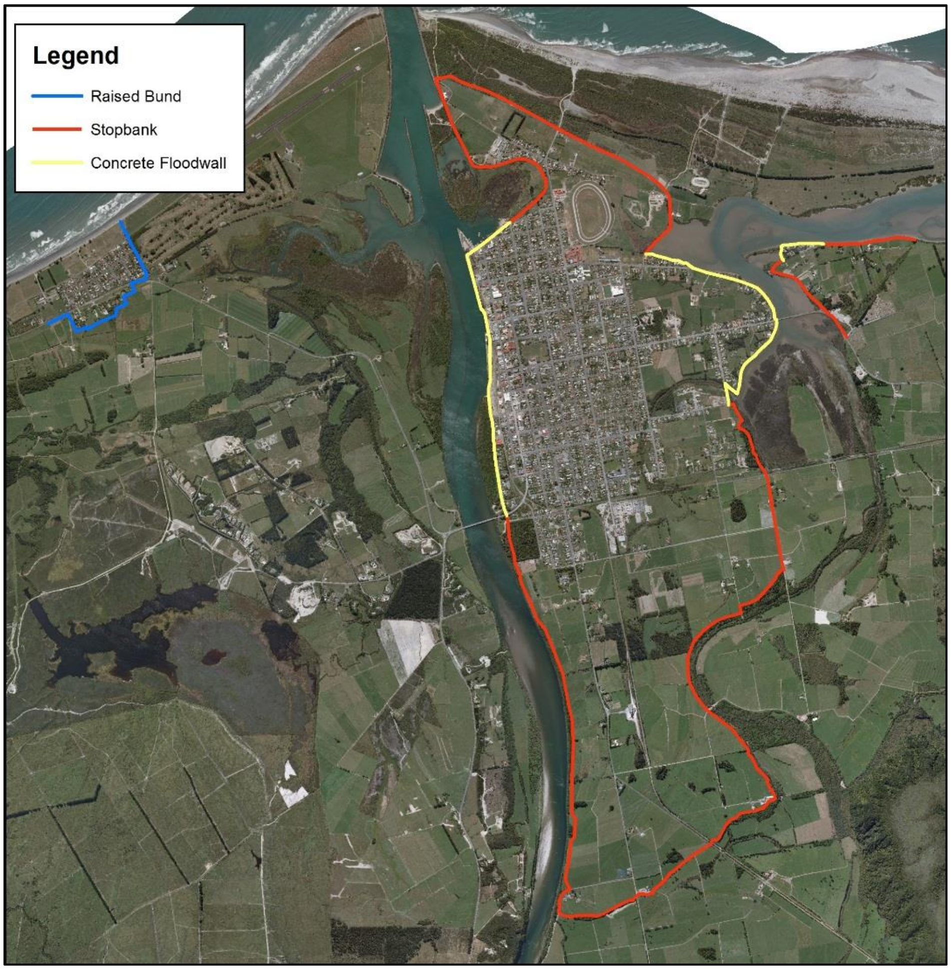

Figure 2-1 presents the basic concept below.

Figure 2-1 – Option B – Extensive stopbanks and flood walls

OPTION C – PARTIAL STOPBANKS AND FLOOD WALL

This option has investigated constructing stopbanks down the banks of the Buller River as well as at the top end of the Orowaiti overflow path. No banks down the Orowaiti overflow path have been allowed for, however protection for the Carters Beach community has been incorporated. Stopbanks have been assumed to have a 2:1 batter slope and a top width of 6m down the Buller River to allow vehicle and pedestrian access, and a top width of 4m for all other banks.

Figure 2-2 presents the basic concept below.

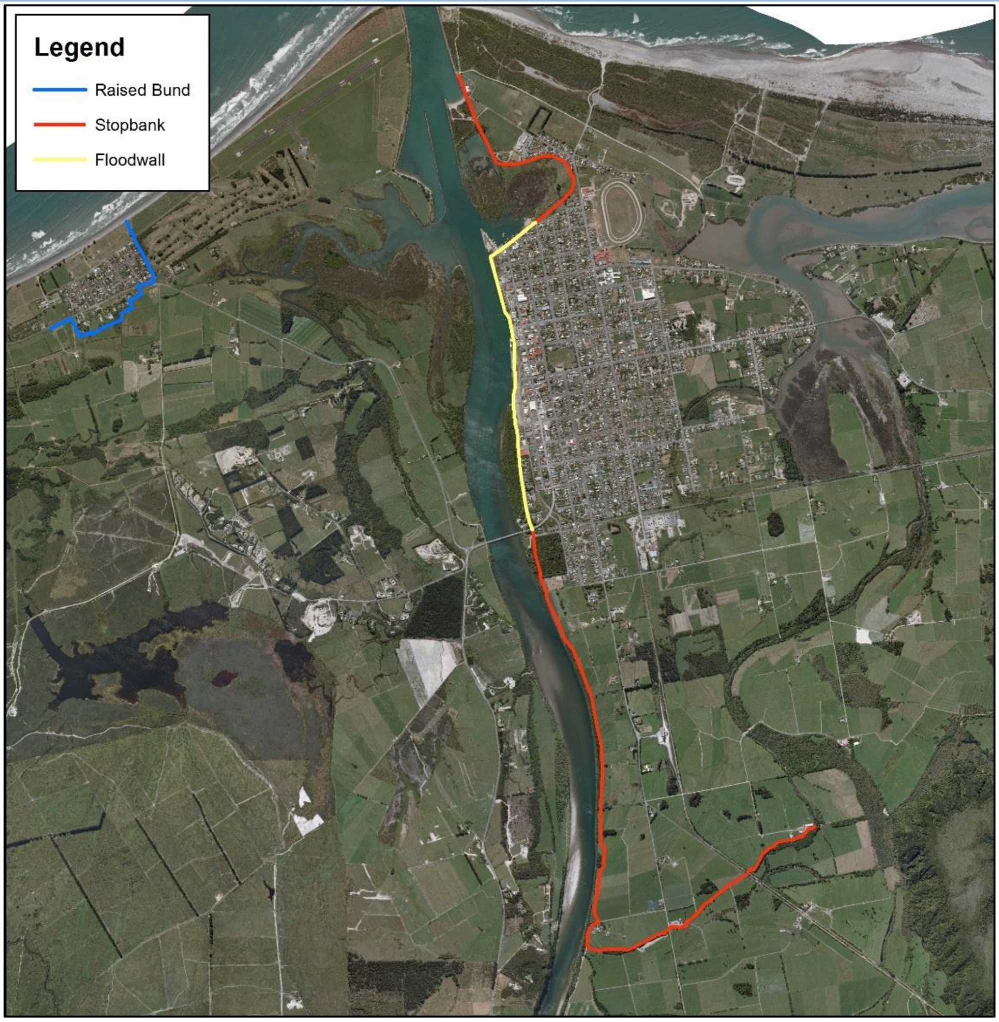

Figure 2-2 - Option C – Partial stopbanks and flood walls

OPTION D – FLOOD RELIEF CUT TO SEA FROM OROWAITI LAGOON

This option considers making a cut through the dune system from the Orowaiti Lagoon in order to allow water to exit to the sea more quickly. This option has adopted and invert level of 1m R.L sloping to an invert level of 0.5 at the sea. Lowering the invert level would significantly increase the effectiveness of the cut however would increase the risk to Westport from coastal inundation. Without more detailed further investigations it is not recommended to consider a lower invert level.

This option requires approximately 415,000 cubic metres of material to be excavated and is approximately 200 m wide. The option schematic is presented in Figure 2-3 below

Figure 2-3 – Option D – Flood Relief Cut

OPTION E – COMBINED STOPBANKS WITH OROWAITI CUT

This option considers the effectiveness of combining options B and D. A schematic of this option is presented in Figure 2-4 below.

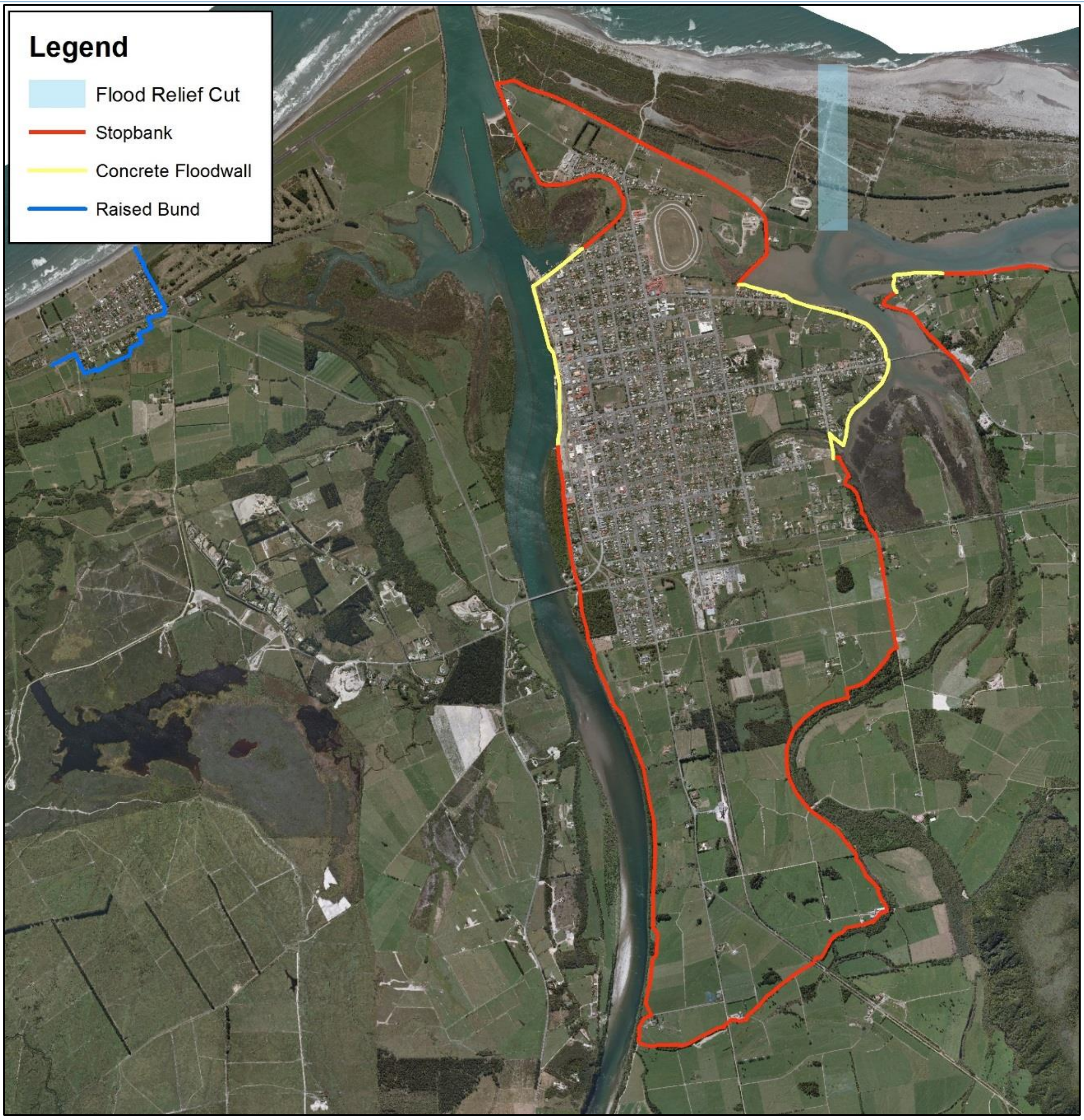

Figure 2-4 – Option E – Extensive Stopbanks combined with Flood Relief Cut

OPTION F – PARTIAL BANKS WITH OROWAITI CUT

This option considers the effectiveness of combining options C and D. A schematic of this option is presented in Figure 2-5 below.

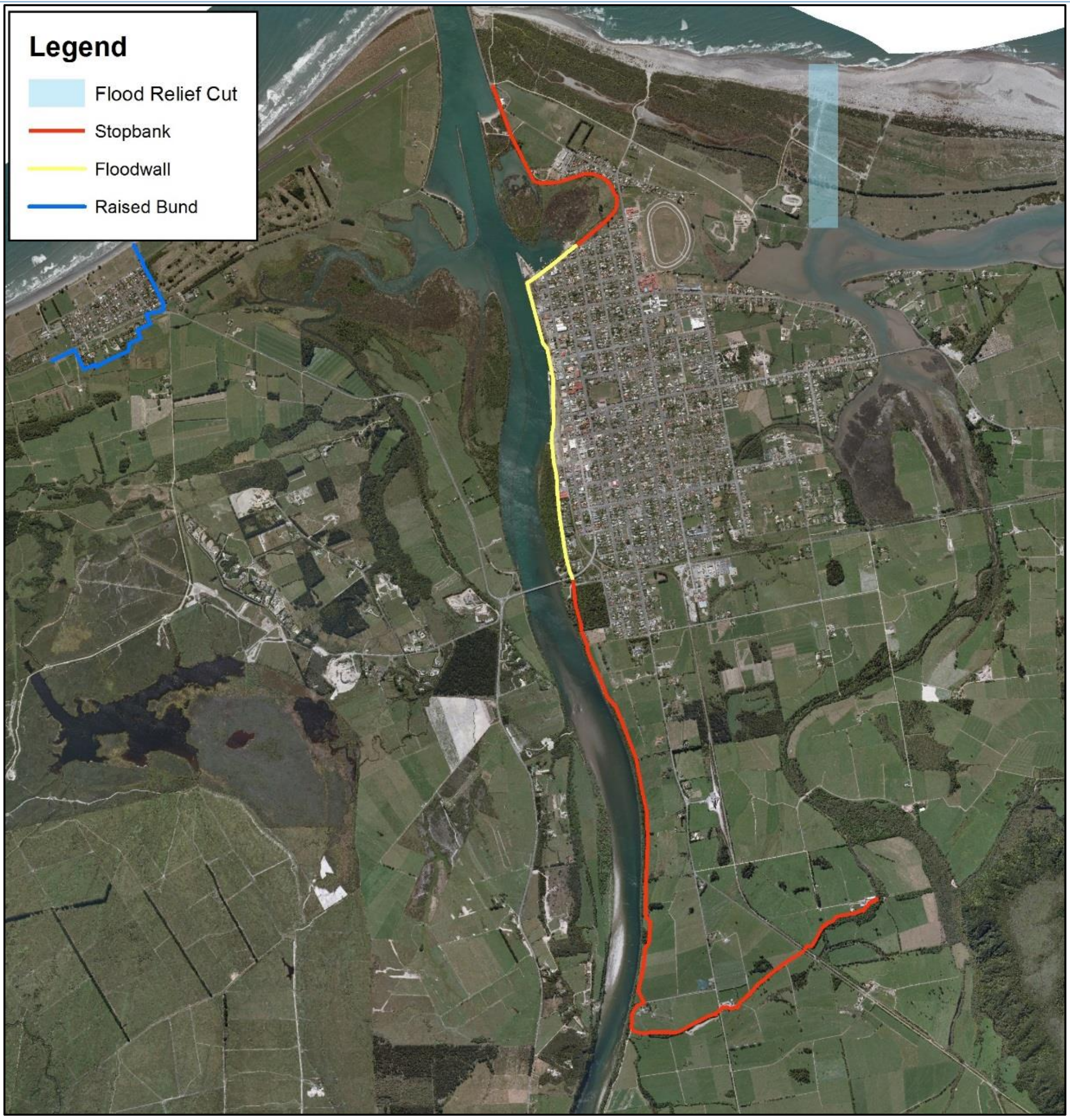

Figure 2-5 – Option F – Partial Stopbanks combined with Flood Relief Cut

3. RESULTS

FLOOD DEPTH / EXTENT

Maps showing the extent and depth of flooding for 50 and 100 year events have been produced for each option and are presented in Figure A-1 to Figure A-12 in Appendix A at the end of this document.

DIFFERENCE IN FLOOD DEPTH

Maps showing the difference in flood depth from the existing scenario (ie. Option A) have been produced in order to more easily visualise the effectiveness of each option in regards to reducing flood depths, as well as to visualise where depths have increased. Figure B-1 to Figure B-10 in Appendix B presents the flood difference maps for each option.

FLOOD HAZARD

Another useful tool for assessing the effectiveness of the various options on top of changes in flood depth / extent is to consider flood hazards based on a relationship between depth and velocity of the flood flows. There are a large number of flood hazard relationships which have been developed internationally however for this study, hazard maps have been produced for each option based on the UK Environment Agencies FD2320 method. This method is one of two methods which are required to be adopted in flood mapping studies in the UK and formulates flood hazard based on the following formula:

$$\mathbf{HR = d\ x(v + n) + DF}$$

Where:

HR: (flood) hazard rating

d: depth of flooding (m)

v: velocity of floodwaters (m/s)

DF: debris factor (if d>0.25 then DF = 1, else DF = 0.5)

n: constant (0.5)

Table 1 outlines the hazard categories which are adopted based on the above formula.

Table 3-1 – Hazard Categorisation based on UK Environment Authority FD2320/TR2

Threshold for Flood Hazard Rating	Degree of Flood Hazard	Description
<0.75	Low	**Caution –** "Flood zone with shallow flowing water or deep standing water"
0.75-1.25	Moderate	**Dangerous for some –** "Danger: Flood zone with deep or fast flowing water"
1.25-2.0	Significant	**Dangerous for most –** "Danger: Flood zone with deep fast flowing water"
>2.0	Extreme	**Dangerous for all –** "Extreme danger: Flood zone with deep fast flowing water

Figure C-1 to Figure C-12 in Appendix C present the flood hazard maps for each option.

4. FLOOD DAMAGES ASSESSMENT

A flood damages assessment has been carried out on each modelled scenario using NIWAs RiskScape package. This package incorporates recorded and measured data from Westport buildings in order to estimate damages in a number of potential hazard scenarios. More information about the RiskScape package can be found at https://riskscape.niwa.co.nz/

Damages have been calculated using the reinstatement cost option within the software package. The following assumptions were made when calculating damages:

- The flood event occurs during the day time
- No adequate flood warning is in place

The following costs are taking into consideration within the RiskScape damages assessment.

- Asset Repair
- Contents Repair
- Services Repair
- Plant Repair
- Stock Replacement
- Cleanup
- Disruption
- Vehicle

Table 4-1 presents the calculated damages for each option for the estimated 50 and 100 year events.

Table 4-1 – Estimated damages for options scenarios

	Damages ($Million)	
	50 year event (Current Climate)	**100 year event (Current Climate)**
Option A – Do Nothing	38	114
Option B –Extensive Stopbanks	6	8
Option C – Partial Banks	22	53
Option D – Flood Relief Cut	29	95
Option E – Extensive Banks and Cut	6	8
Option F – Partial Banks and Cut	12	29

5. OPTIONS COSTING

Preliminary cost assessments have been made for each option and are presented in the following section. Costs have been estimated based on rates from similar jobs in Canterbury and the West Coast. It should be noted that these costs should not be considered a detailed costing and have only been calculated for the purpose of making a comparison between each option.

OPTION A – DO NOTHING

Cost $0

OPTION B - EXTENSIVE STOPBANKS AND FLOOD WALLS

This option consists of two main components, a compacted gravel stopbank and concrete floodwalls.

Prices for the construction of the compacted gravel stopbank have been made based on discussions with West Coast Regional council staff and local contractors. Comparisons were also made with recent stopbank construction costs in the Canterbury region with ECan staff for similar projects.

Prices for the construction of the concrete floodwall have been made based on comparisons with costs for the recent construction of the floodwall in Greymouth.

Table 5-1 summarises the estimated costs for Option B below.

Table 5-1 – Estimated construction costs for Option B

	Estimated Costs ($ Million)	
	50 year event	**100 year event**
Buller River Compacted Gravel Bank	1.60	2.08
Buller River Concrete Floodwall	0.31	0.34
Orowaiti Overflow Compacted Gravel Bank	2.49	3.63
Orowaiti Overflow Floodwall	0.81	0.97
Easton's Road Culvert/Floodgate	0.3	0.3
Snodgrass Compacted Gravel Bank	0.60	0.86
Snodgrass Concrete Floodwall	0.16	0.18
Sea Front Compacted Gravel Bank	0.49	0.87
Carter's Beach Compacted Gravel Bank	0.08	0.18
Total Cost	**6.8**	**9.4**

OPTION C – PARTIAL BANKS

The costs for this option are calculated based on the same basis as for Option B. Table 5-2 summarises the estimated costs for Option C below.

Table 5-2 - Estimated construction costs for Option C

	Estimated Costs ($Million)	
	50 year event	**100 year event**
Buller River Compacted Gravel Bank	1.6	2.08
Buller River Concrete Floodwall	0.31	0.34
Orowaiti Overflow Compacted Gravel Bank	0.34	0.54
Carter's Beach Compacted Gravel Bank	0.08	0.18
Total Cost	**2.3**	**3.0**

OPTION D – OROWAITI FLOOD RELIEF CUT

Assumed costs of $10 / m³ allowing for removal and disposal of material. The price could be reduced if the material is able to be spread at site. The volume of material to be excavated is approximately 415,000 m³.

Estimated cost is in the order of **$4.15 million.**

OPTION E - EXTENSIVE STOPBANKS AND FLOOD WALLS AND FLOOD RELIEF CUT

The costs for this option are calculated based on the same basis as for Option B and C. Table 5-3 summarises the estimated costs for Option E below.

Table 5-3 - Estimated construction costs for Option E

	Estimated Costs ($Million)	
	50 year event	**100 year event**
Buller River Compacted Gravel Bank	1.60	2.08
Buller River Concrete Floodwall	0.31	0.34
Orowaiti Overflow Compacted Gravel Bank	2.49	3.62
Orowaiti Overflow Floodwall	0.74	0.89
Easton's Road Culvert/Floodgate	0.3	0.3
Snodgrass Compacted Gravel Bank	0.50	0.73
Snodgrass Concrete Floodwall	0.14	0.15
Sea Front Compacted Gravel Bank	0.19	0.48
Carter's Beach Compacted Gravel Bank	0.08	0.18
Flood Relief Cut	4.15	4.15
Total Cost	**10.5**	**12.9**

OPTION F – PARTIAL STOPBANKS AND FLOOD WALLS AND FLOOD RELIEF CUT

The costs for this option are calculated based on the same basis as for Option B and C. Table 5-4 summarises the estimated costs for Option F below.

Table 5-4 - Estimated construction costs for Option F

	Estimated Costs ($Million)	
	50 year event	**100 year event**
Buller River Compacted Gravel Bank	1.6	2.08
Buller River Concrete Floodwall	0.31	0.34
Orowaiti Overflow Compacted Gravel Bank	0.33	0.54
Carter's Beach Compacted Gravel Bank	0.08	0.18
Flood Relief Cut	4.15	4.15
Total Cost	**6.5**	**7.3**

SUMMARY OF CONSTRUCTION COSTS

A summary of the estimated construction costs for each option is presented in Table 5-5 below.

Table 5-5 – Summary of estimated total construction costs for each option

	50 year cost ($Million)	100 year cost ($Million)
Option A – Do Nothing	0	0
Option B – Extensive Floodwalls	6.8	9.4
Option C – Partial Floodwalls	2.3	3.0
Option D – Flood Relief Cut	4.2	4.2
Option E – Extensive Floodwalls and Flood Relief Cut	10.5	12.9
Option F - Partial Floodwalls and Flood Relief Cut	6.5	7.3

6. OPTIONS EVALUATION

COST ANALYSIS

Table 6-1 below presents the expected construction costs for each option alongside the estimated reduction in flood damages for a 50 and 100 year event.

Table 6-1 – Comparison of construction costs with flood damages reduction

	50 year event (Current Climate)		100 year event (Current Climate)	
	Construction Cost ($Million)	**Reduction in Damages ($Million)**	**Construction Cost ($Million)**	**Reduction in Damages ($Million)**
Option A – Do Nothing	0	0	0	0
Option B – Extensive Floodwalls	6.8	32	9.4	106
Option C – Partial Floodwalls	2.3	16	3.0	61
Option D – Flood Relief Cut	4.2	9	4.2	19
Option E – Extensive Floodwalls and Flood Relief Cut	10.5	32	12.9	106
Option F - Partial Floodwalls and Flood Relief Cut	6.5	26	7.3	85

PROS AND CONS

OPTION A – DO NOTHING

Pros

- No upfront costs
- No false sense of security created

Cons

- Potential for loss of life
- Large floods will cause significant damages

- Extensive evacuation likely at least temporarily and potentially for extended periods of time
- Flooding will likely be more common as sea levels rise

OPTION B – EXTENSIVE FLOOD WALLS

Pros

- Can be designed to prevent flood waters from inundating large number of properties in large events
- Reduced risk for loss of life
- Significant reduction in damages
- Stopbanks can have multiple purposes, ie. Cycle Path along the crest of the bank

Cons

- Unable to protect all properties in greater Westport area.
- Visually unappealing to some
- Can provide false sense of security (ie larger than design event always possible and may overtop) encouraging greater development and hence greater damages in over design event.
- If banks overtop, then difficult for the floodwaters to escape due to ringbank (can be remedied to some extent by sacrificing a section of the bank.)
- Constriction in flow in Orowaiti and Buller Rivers can have unintended consequences such as increasing scour and undermining existing structures
- Large outlay of capital required
- Some areas outside of banks have increased level of inundation

OPTION C – PARTIAL STOPBANKS

Pros

- Reduction in number of properties flooded in large events
- Reduction in flood levels to majority of properties
- Reduction in overall damages
- Stopbanks can have multiple purposes, ie. Cycle Path along the crest of the bank
- Significantly less capital outlay than extensive stopbank option

Cons

- Floodwalls may be visually unappealing to some
- Can provide false sense of security (ie larger than design event always possible and may overtop)
- Constriction in flow in Buller River can have unintended consequences in the river such as increasing scour
- Large outlay of capital required
- Properties near the Orowaiti Lagoon are still flooded in large events.

OPTION D – FLOOD RELIEF CUT

Pros

- Partial reduction in flood extent and depth
- Reduction in damages
- No raised structures to obstruct view
- No impact on Buller River flow dynamics

Cons

- Reduction in flood extent is only partial
- Potential for permanent realignment of cut during large events
- Increased risk of coastal inundation to Westport (Not quantified – however increasing over time as sea levels rise)
- Significant volume of material to excavate and hence high cost
- Is likely to contain stagnant water when tide exceeds level of channel invert
- Need to be opened to the sea prior to flood event – requirement for constant flood forecasting and monitoring
- May require ongoing maintenance

OPTION E – EXTENSIVE STOPBANKS AND FLOOD RELIEF CUT

Pros

- Can be designed to prevent flood waters from inundating large number of properties in large events
- Reduced risk for loss of life
- Significant reduction in damages
- Stopbanks can have multiple purposes, ie. Cycle Path along the crest of the bank
- Orowaiti flood walls are of a lower height than for Option B (see explanation below)
- Increase in flood depths in Orowaiti channel are less than for Option B

Cons

- Is unable to protect all properties in greater Westport area
- Flood walls may be visually unappealing to some
- Can provide false sense of security (ie larger than design event always possible and may overtop)
- If banks overtop, then difficult for the floodwaters to escape due to ringbank (can be remedied to some extent by sacrificing a section of the bank.)
- Constriction in flow can have unintended consequences in the river such as increasing scour and undermining existing structures
- Large outlay of capital required
- Some areas outside of banks have increased level of inundation
- Significantly more expensive than option B

In order to further demonstrate impact of the flood relief cut on the height of the concrete floodwalls for Option E, the figures below present approximate floodwall heights for a section of wall along the front of the Orowaiti Lagoon. Figure 6-1 presents the heights for Option B which is without the flood relief cut. Figure 6-2 presents the heights of the floodwall for Option E which includes the flood relief cut. It can be seen from these figures that the inclusion of the flood relief cut allows for the floodwall to be approximately 0.3m lower.

Figure 6-1 –Floodwall design heights along the Orowaiti Lagoon for a 50 year event with Option B

Figure 6-2 –Floodwall design heights along the Orowaiti Lagoon for a 50 year event with Option E

OPTION F – PARTIAL STOPBANKS AND FLOOD RELIEF CUT

Pros

- Reduction in number of properties flooded in large events
- Reduction in flood levels to majority of properties
- Reduction in overall damages from Option C
- Stopbanks can have multiple purposes, ie. Cycle Path along the crest of the bank
- Less capital outlay than extensive stopbank option

Cons

- Stopbanks/floodwalls may be visually unappealing to some
- Can provide false sense of security (ie larger than design event always possible and may overtop)
- Constriction in flow can have unintended consequences in the river such as increasing scour
- Large outlay of capital required
- Significant increase in cost from Option C

7. CONCLUSIONS / RECOMMENDATIONS

A number of flood mitigation options have been investigated for the Buller River using the existing MIKE Flood hydraulic model of the river system. Cost estimates have also been made for each option, as well as an estimate of likely flood damages using NIWAs RiskScape programme.

Each options has a number of advantages and disadvantages. This report has attempted to outlay the primary pros and cons as well as costs and benefits.

It is recommended that these options are presented to the Buller River Flooding working group as well as the respective councils for feedback and are then presented to the public for further feedback in a refined form.

A. APPENDIX A – MAPS OF FLOOD DEPTH / EXTENT

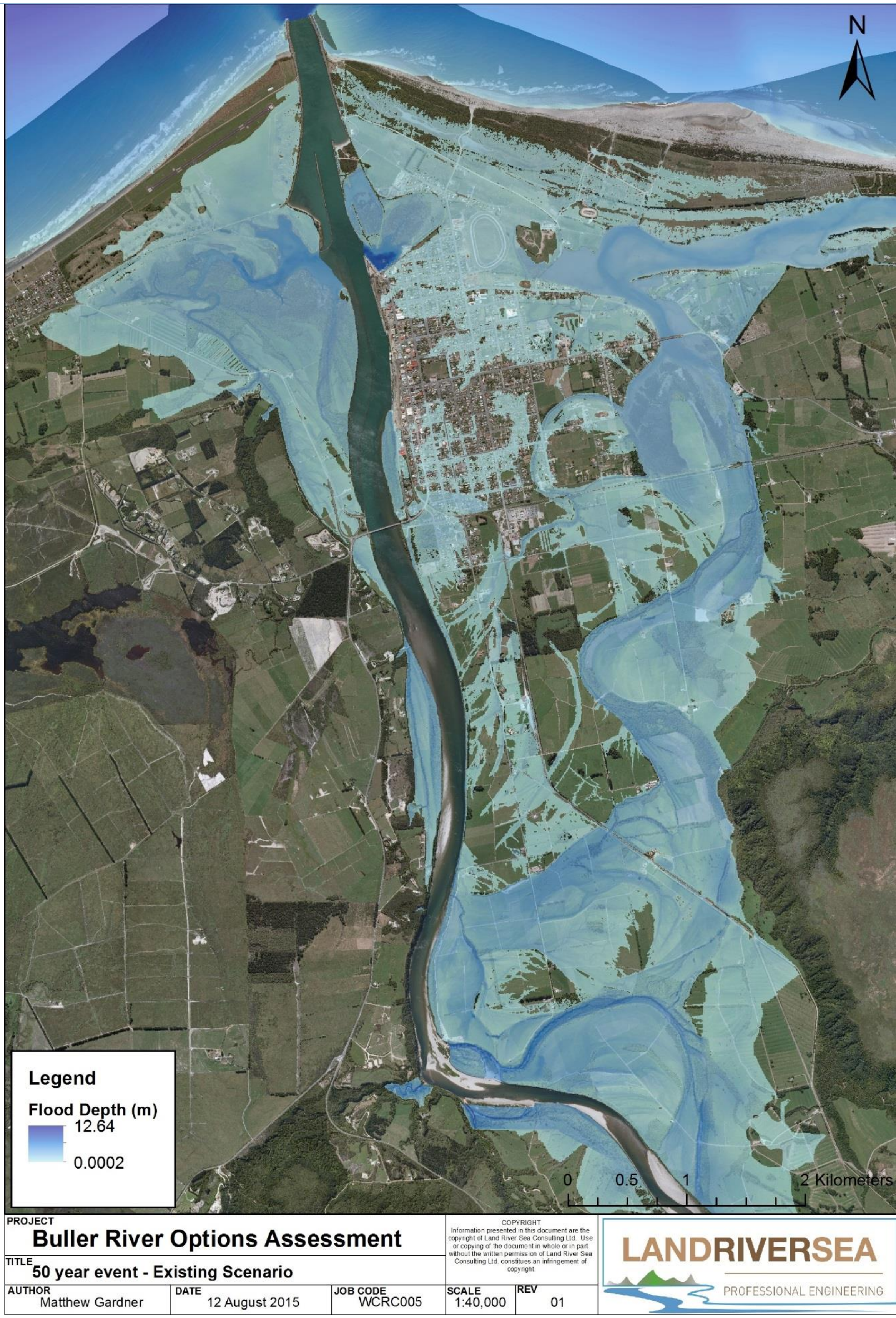

Figure A-1 - 50 year flood extent / depths - Option A – Existing Scenario

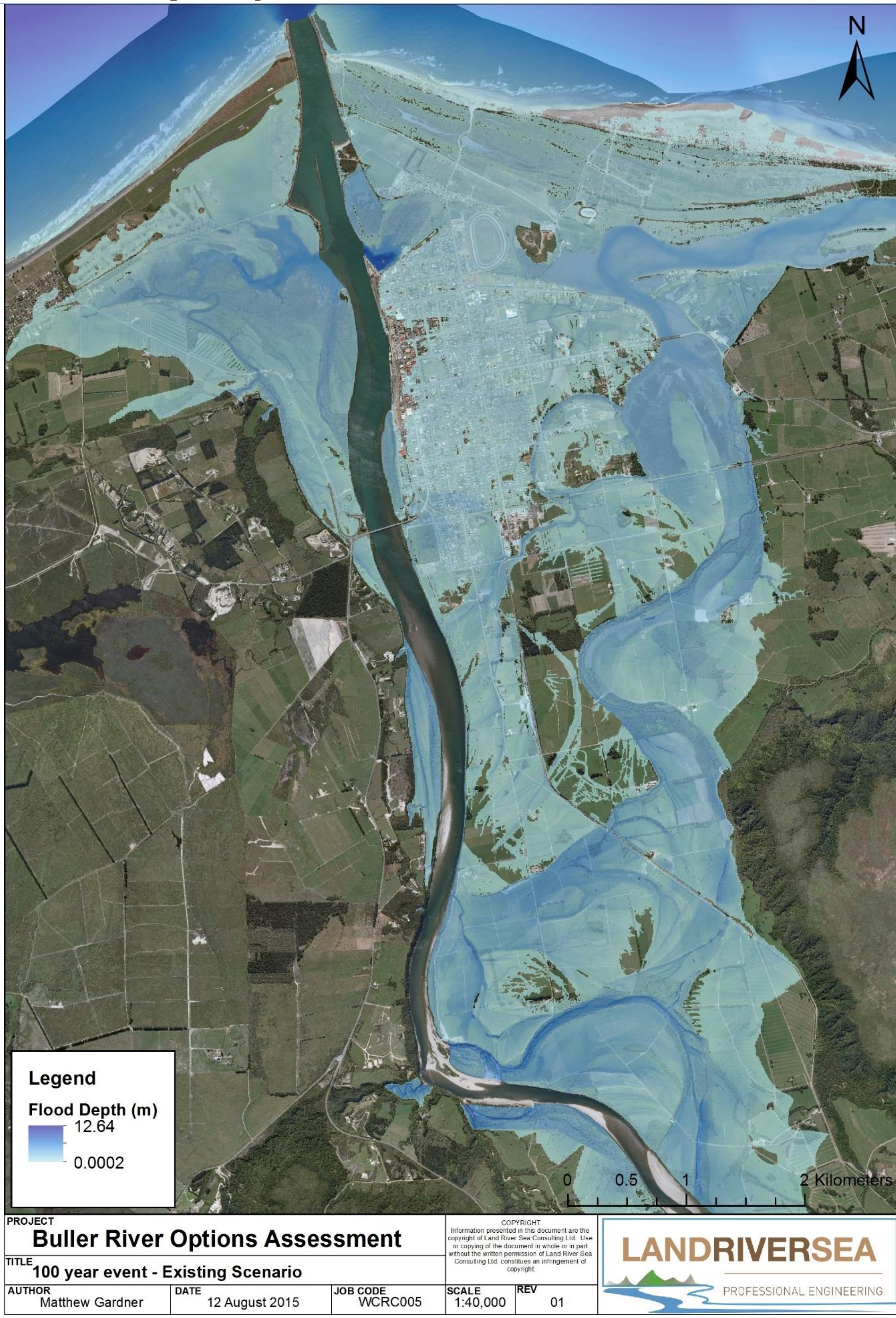

Figure A-2 - 100 year flood extent / depths - Option A – Existing Scenario

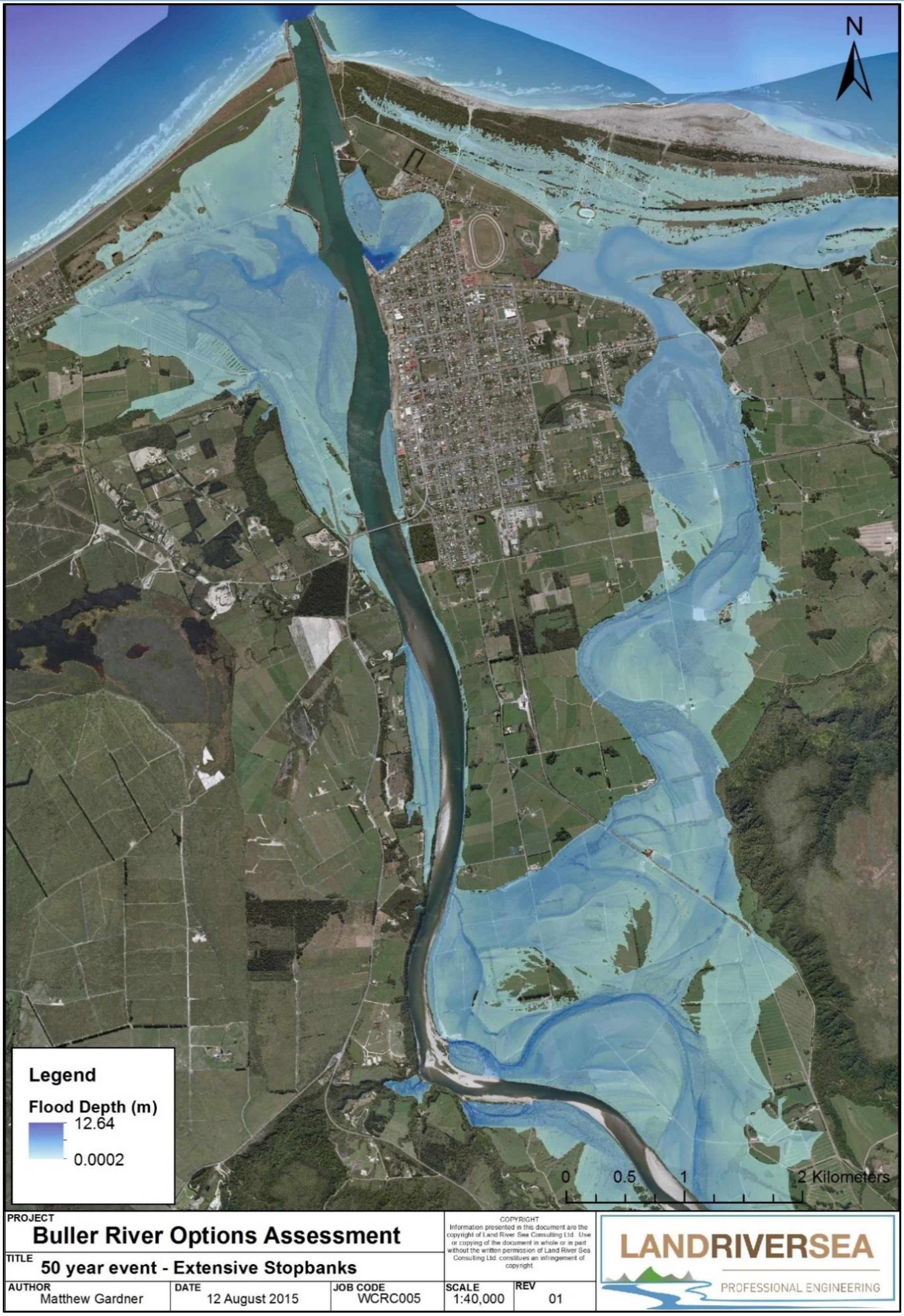

Figure A-3 – 50 year flood extent / depths - Option B – Extensive Stopbanks

Figure A-4 – 100 year flood extent / depths - Option B – Extensive Stopbanks

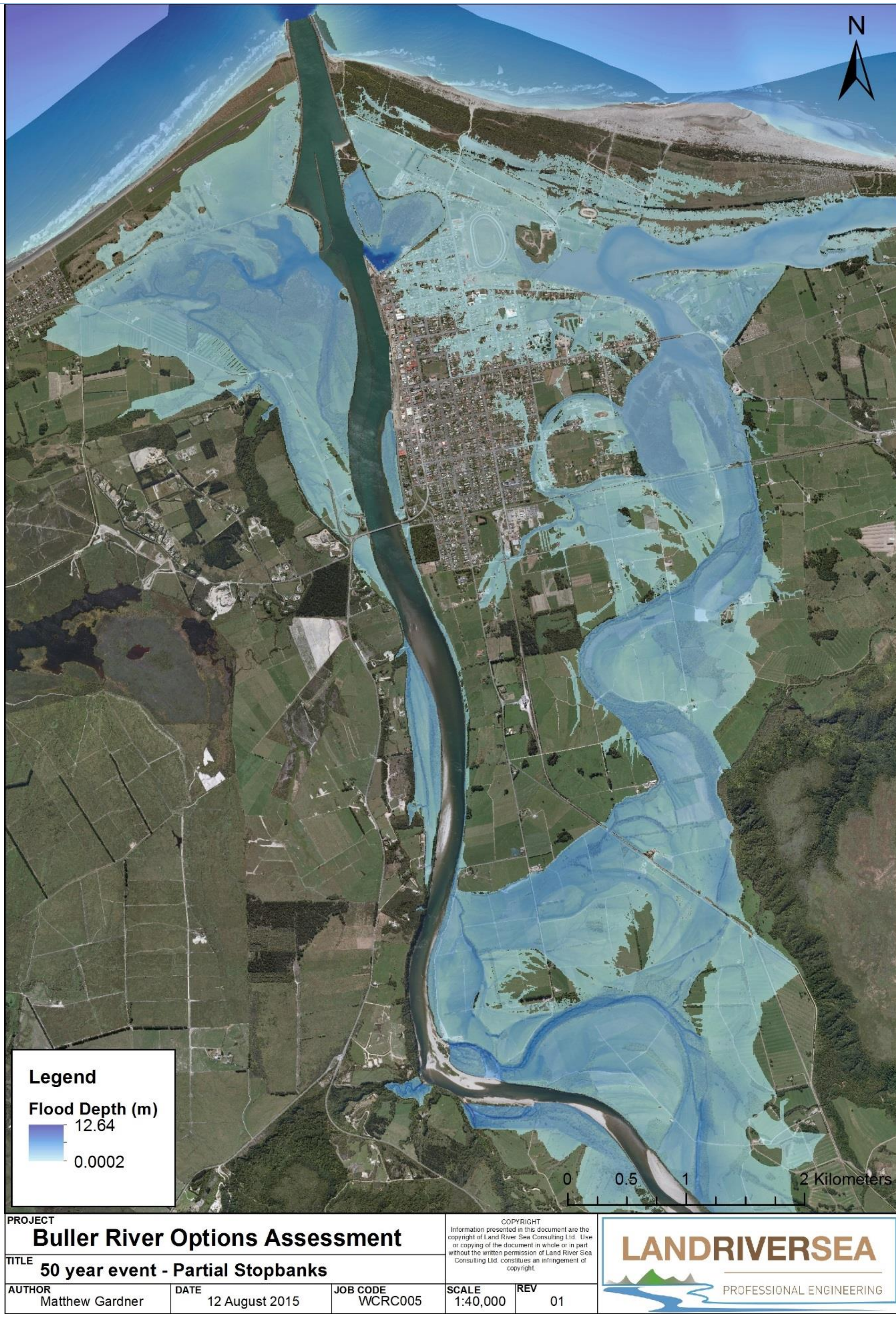

Figure A-5 - 50 year flood extent / depths - Option C – Partial Stopbanks

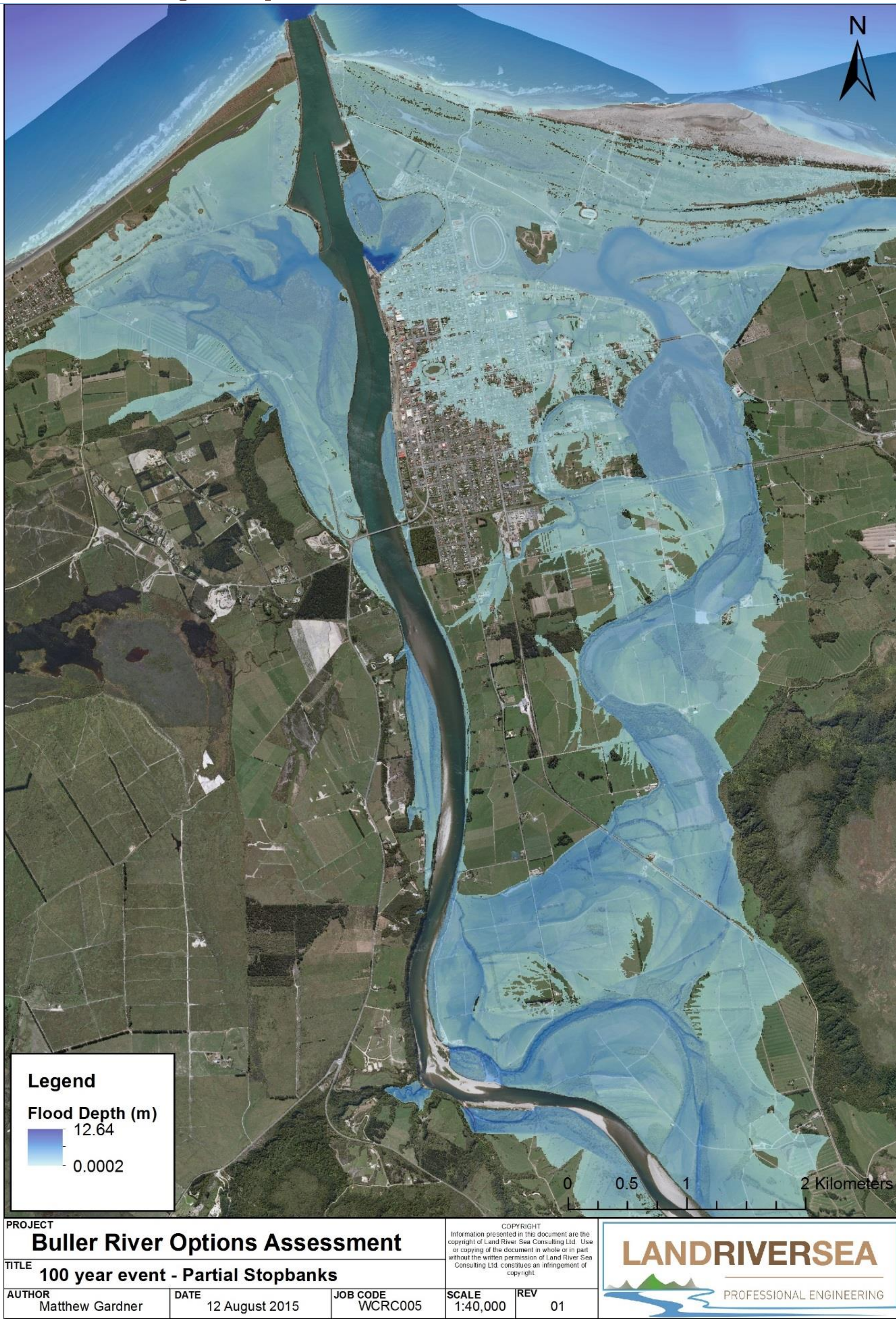

Figure A-6 - 100 year flood extent / depths - Option C – Partial Stopbanks

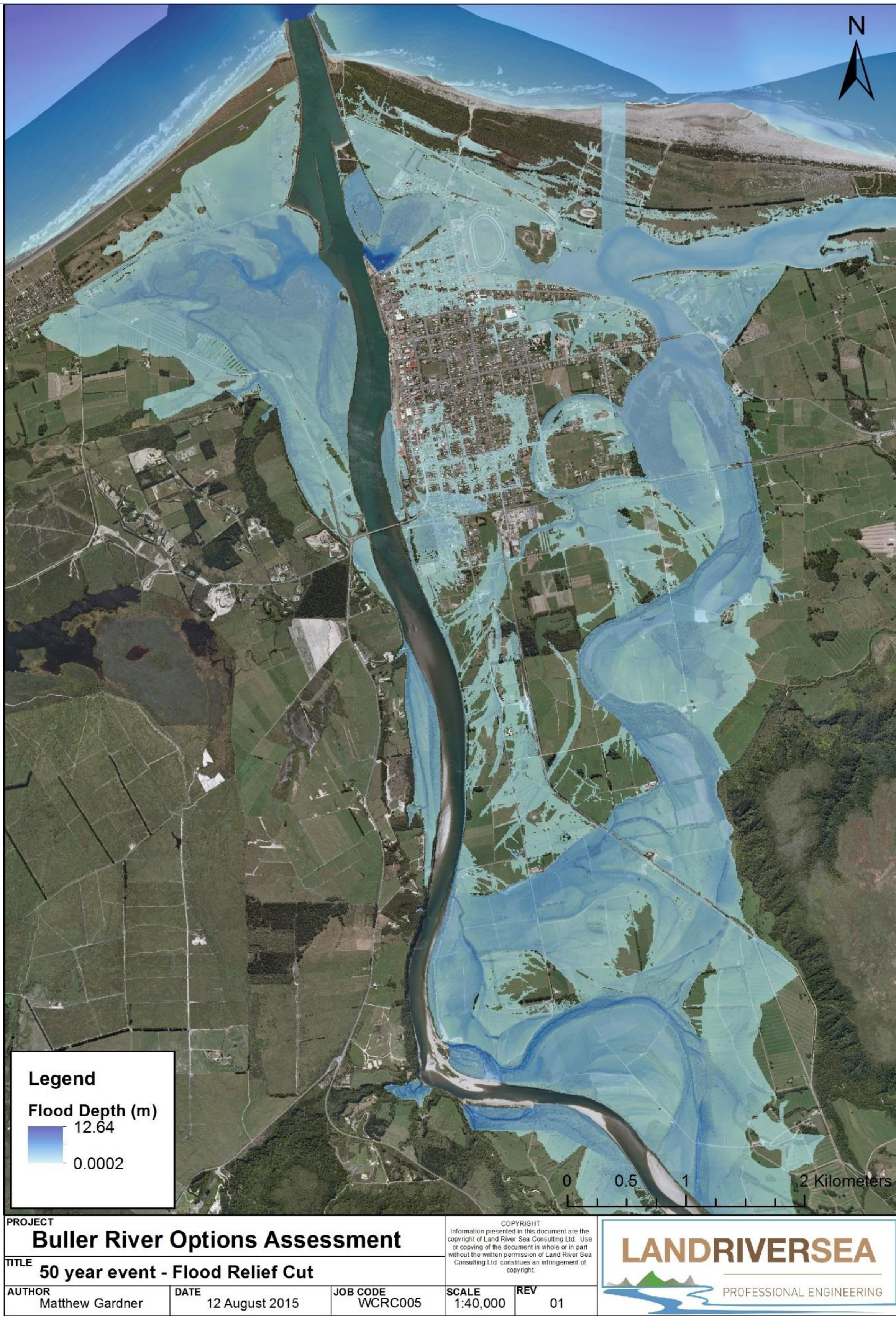

Figure A-7 - 50 year flood extent / depths - Option D – Flood Relief Cut

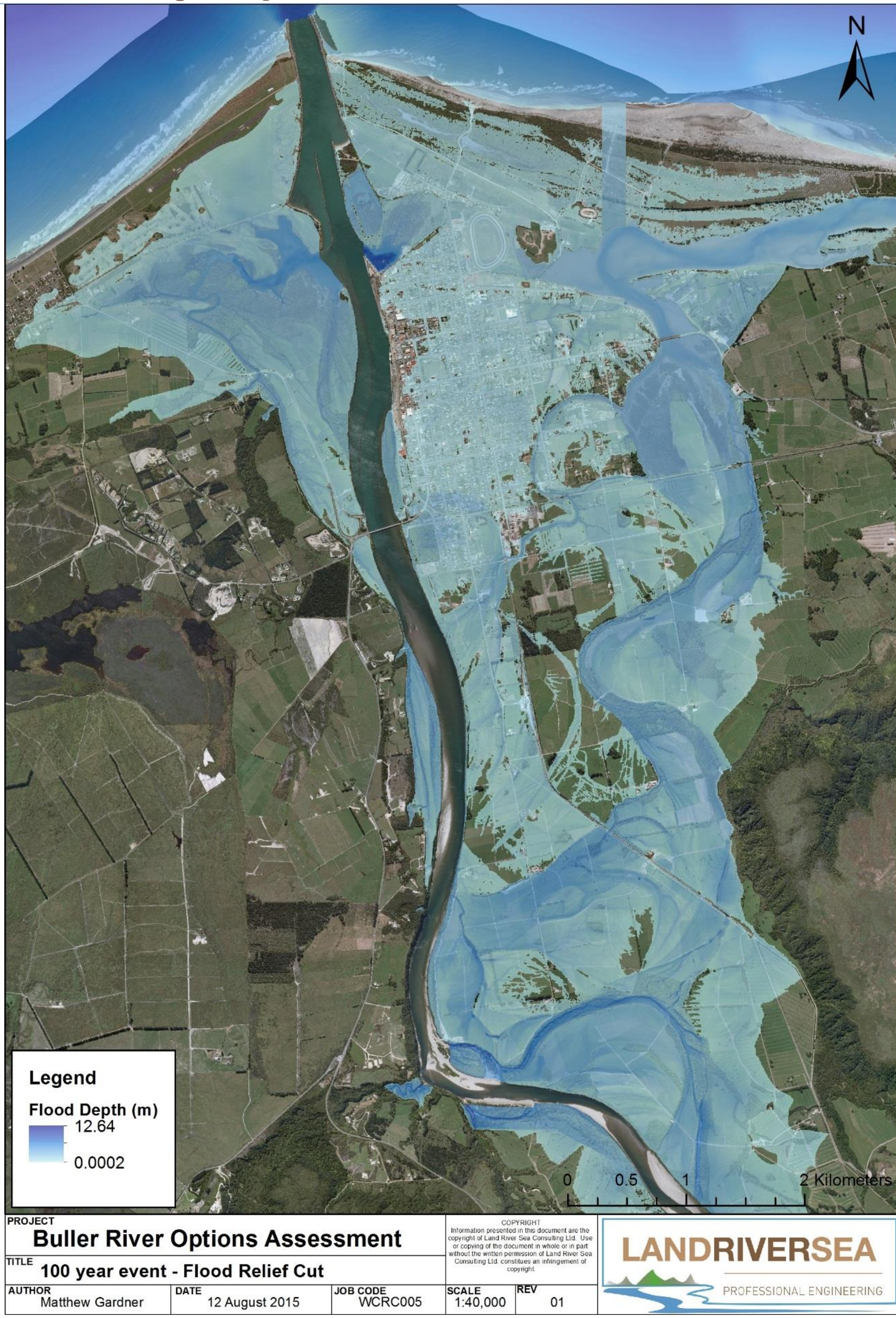

Figure A-8 - 100 year flood extent / depths - Option D – Flood Relief Cut

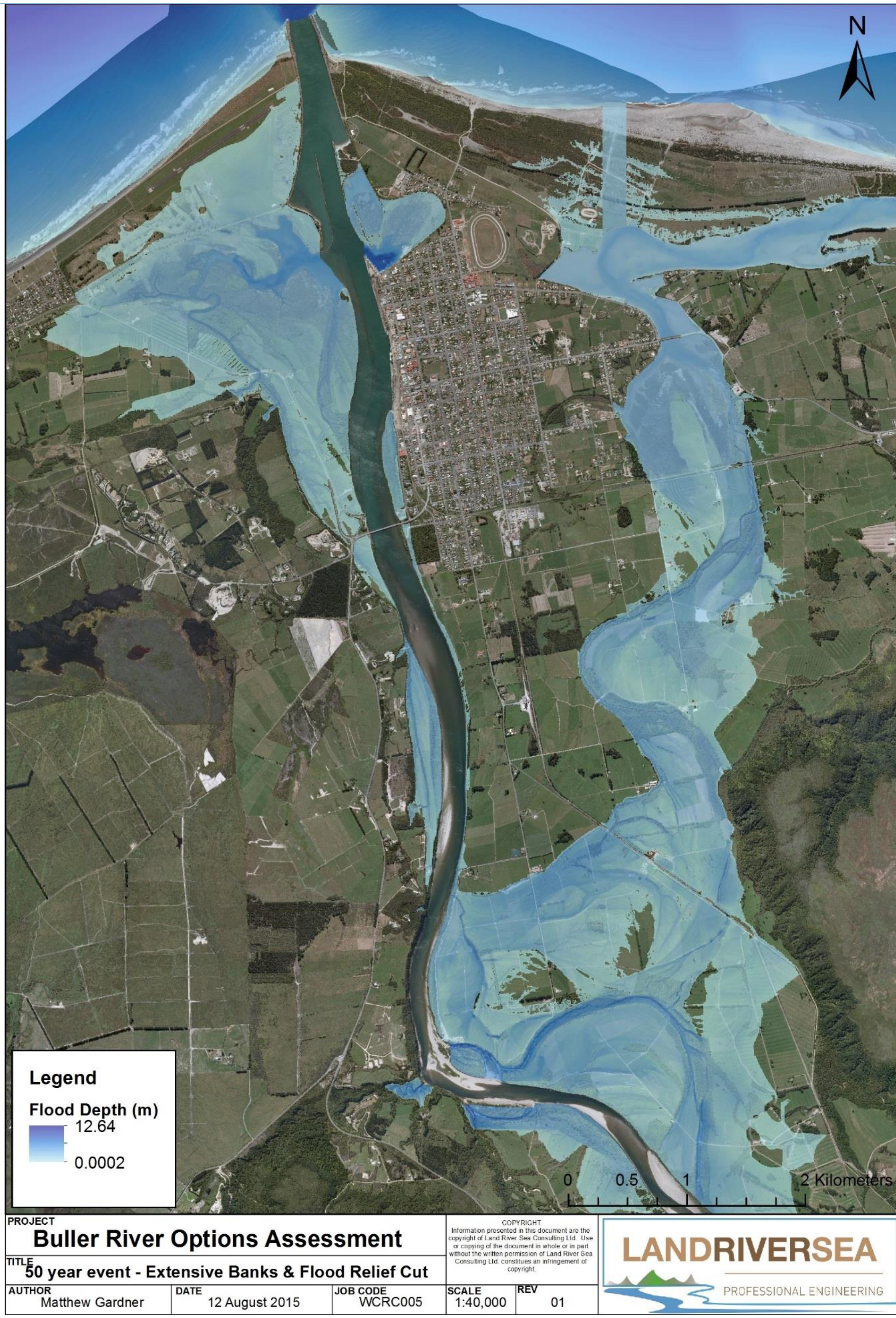

Figure A-9 - 50 year flood extent / depths - Option E – Extensive Stopbanks & Flood Relief Cut

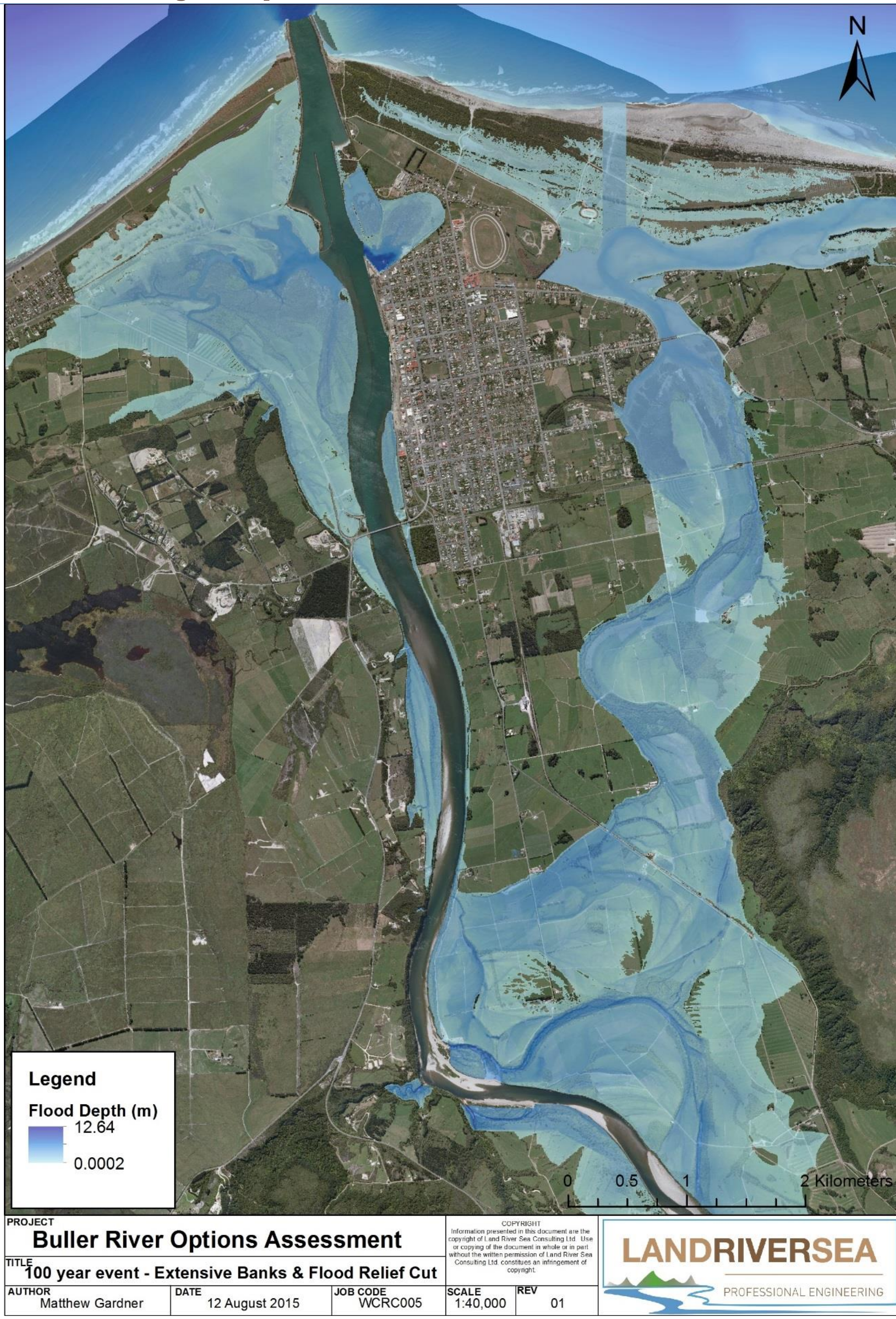

Figure A-10 - 100 year flood extent / depths - Option E – Extensive Stopbanks & Flood Relief Cut

Figure A-11 - 50 year flood extent / depths - Option F – Partial Stopbanks & Flood Relief Cut

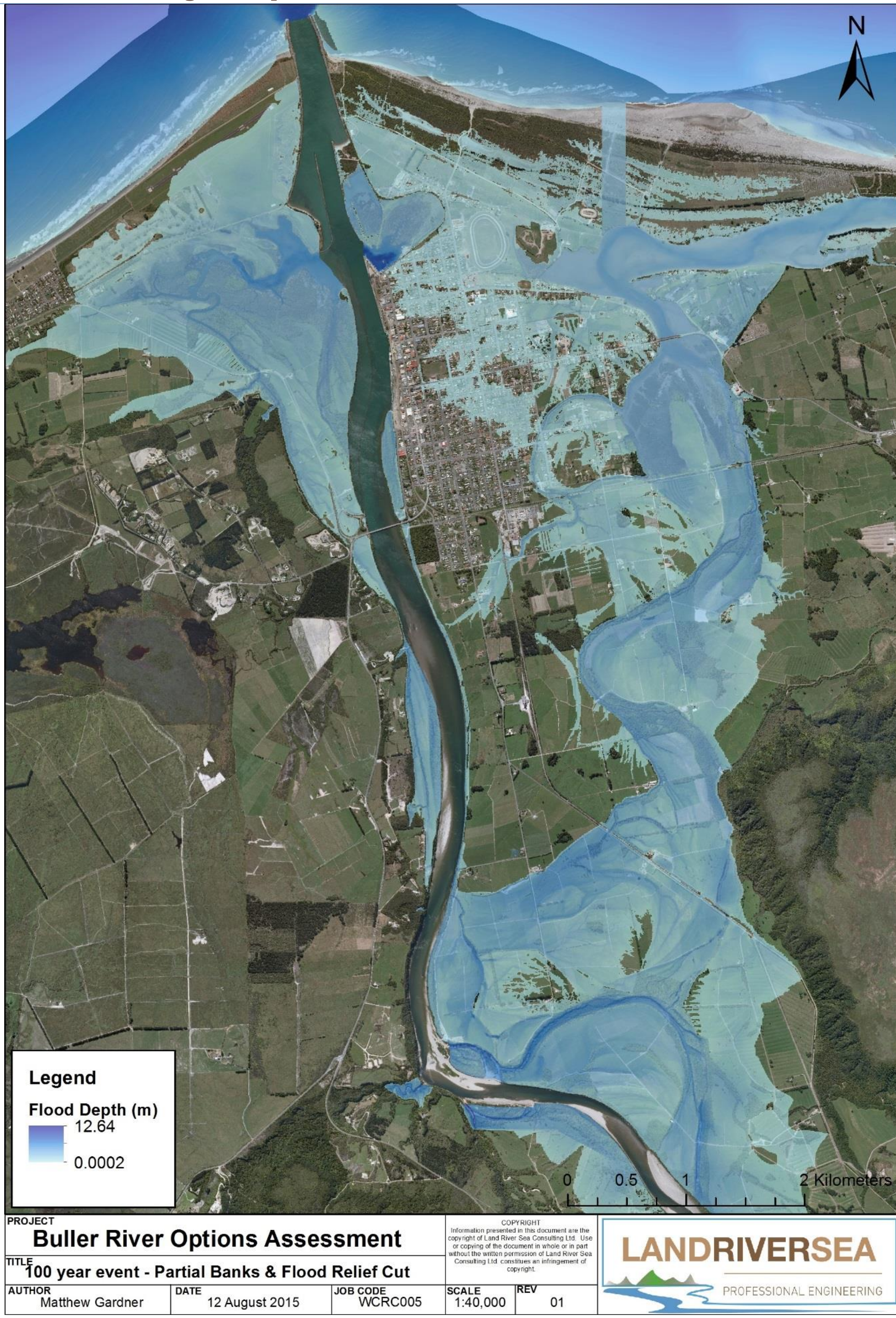

Figure A-12 - 100 year flood extent / depths - Option F – Partial Stopbanks & Flood Relief Cut

B. APPENDIX B – MAPS OF DIFFERENCE IN FLOOD LEVEL

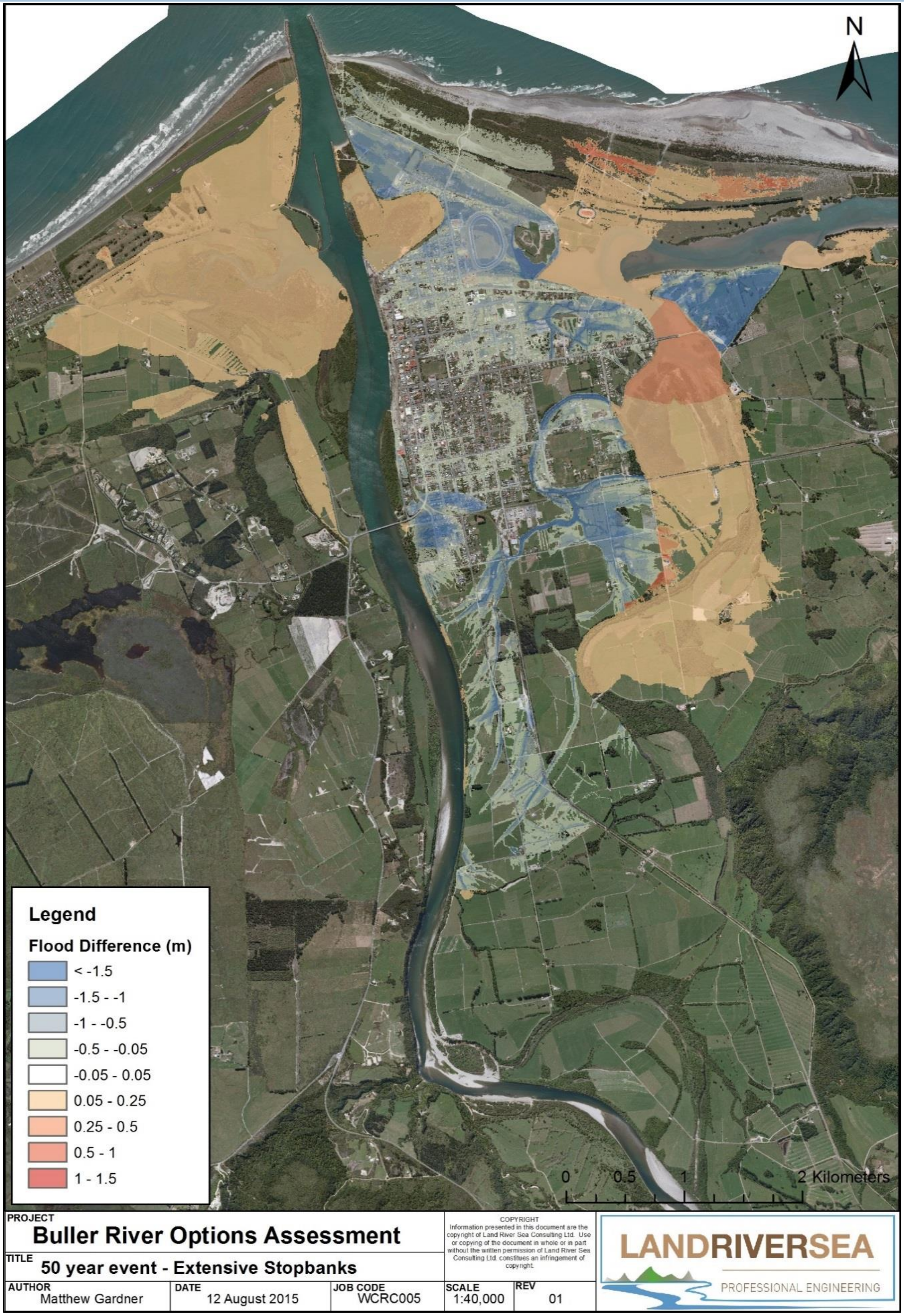

Figure B-1 - 50 year flood level differences - Option B – Extensive Stopbanks

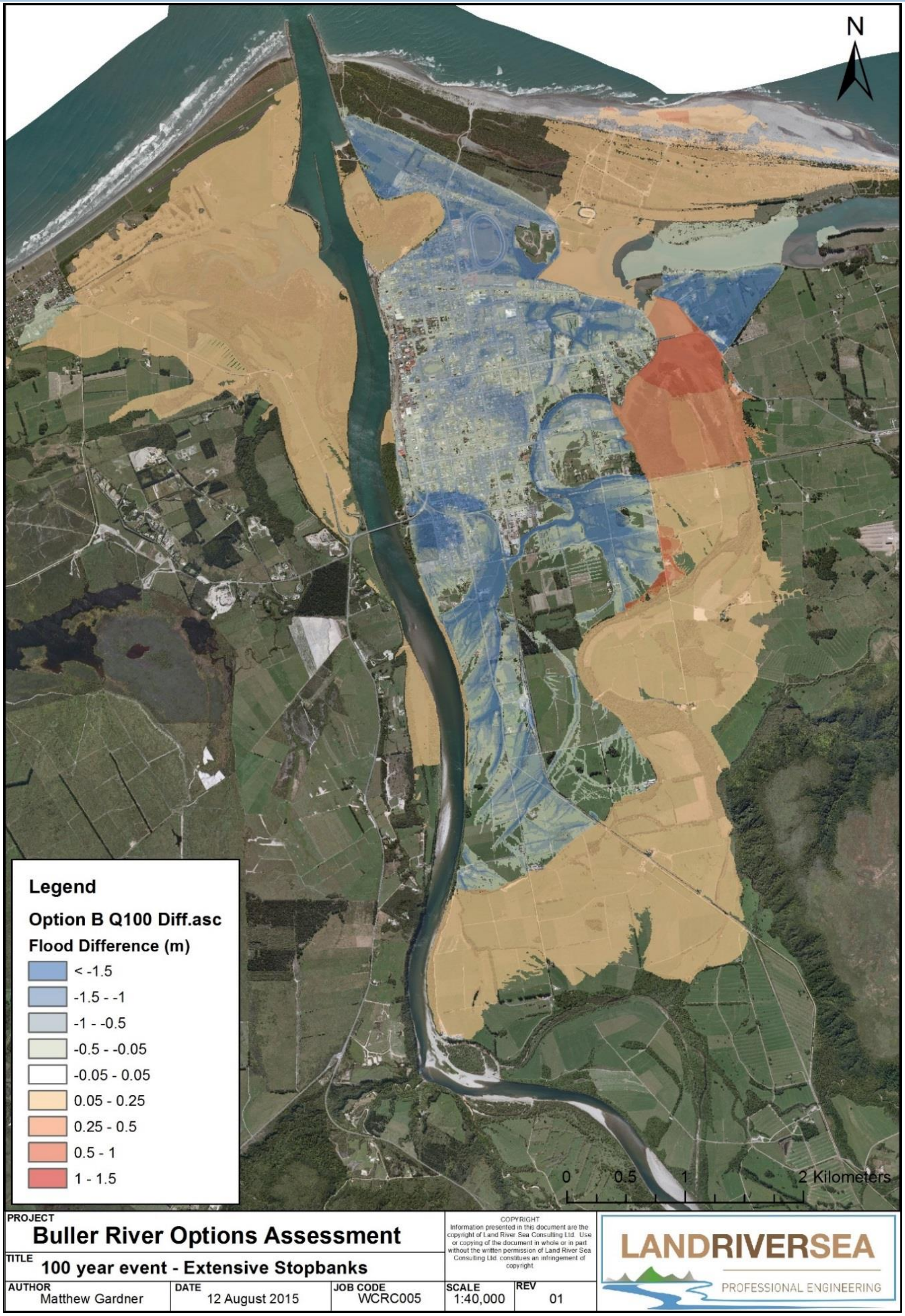

Figure B-2 - 100 year flood level differences - Option B – Extensive Stopbanks

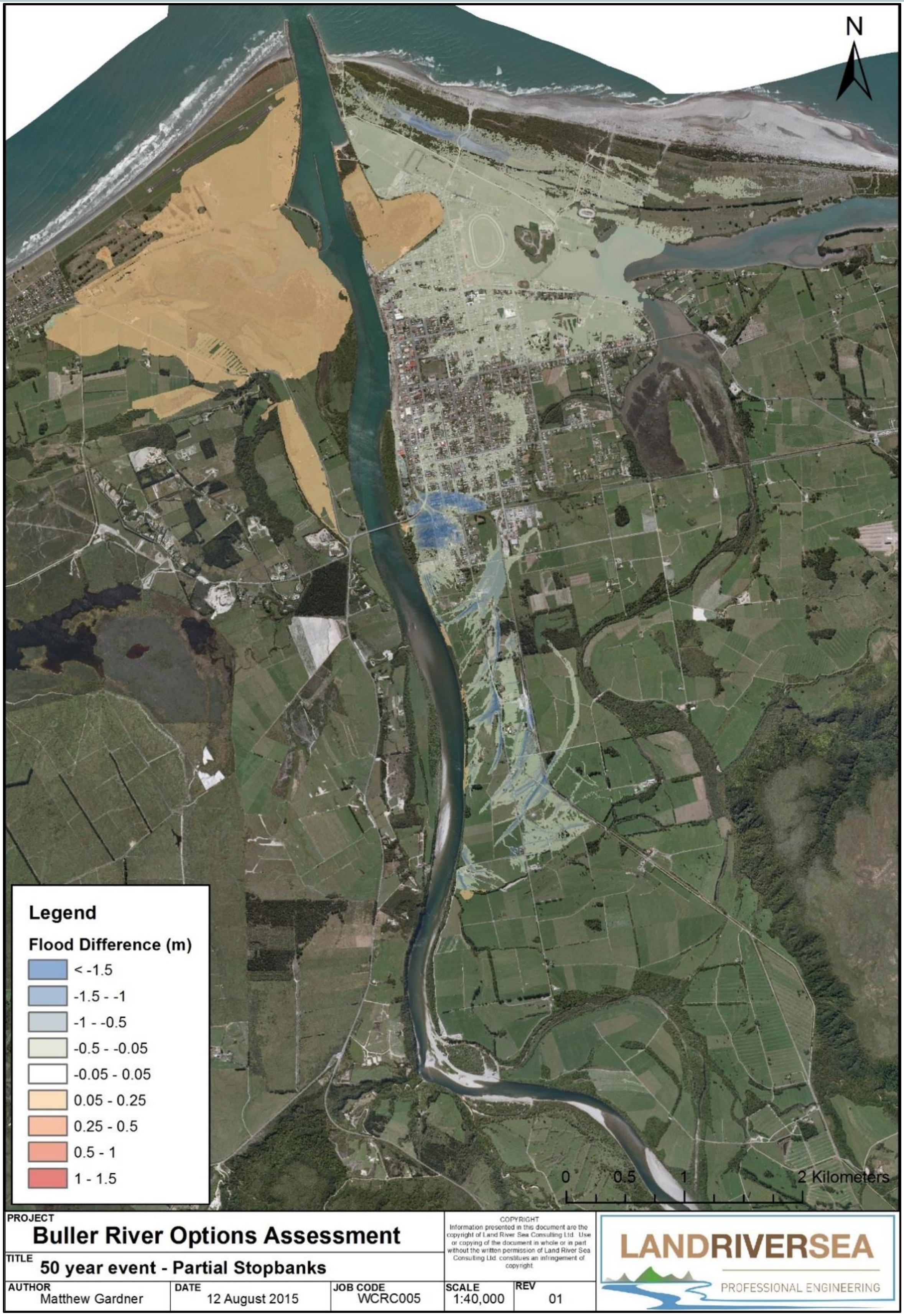

Figure B-3 - 50 year flood level differences - Option C – Partial Stopbanks

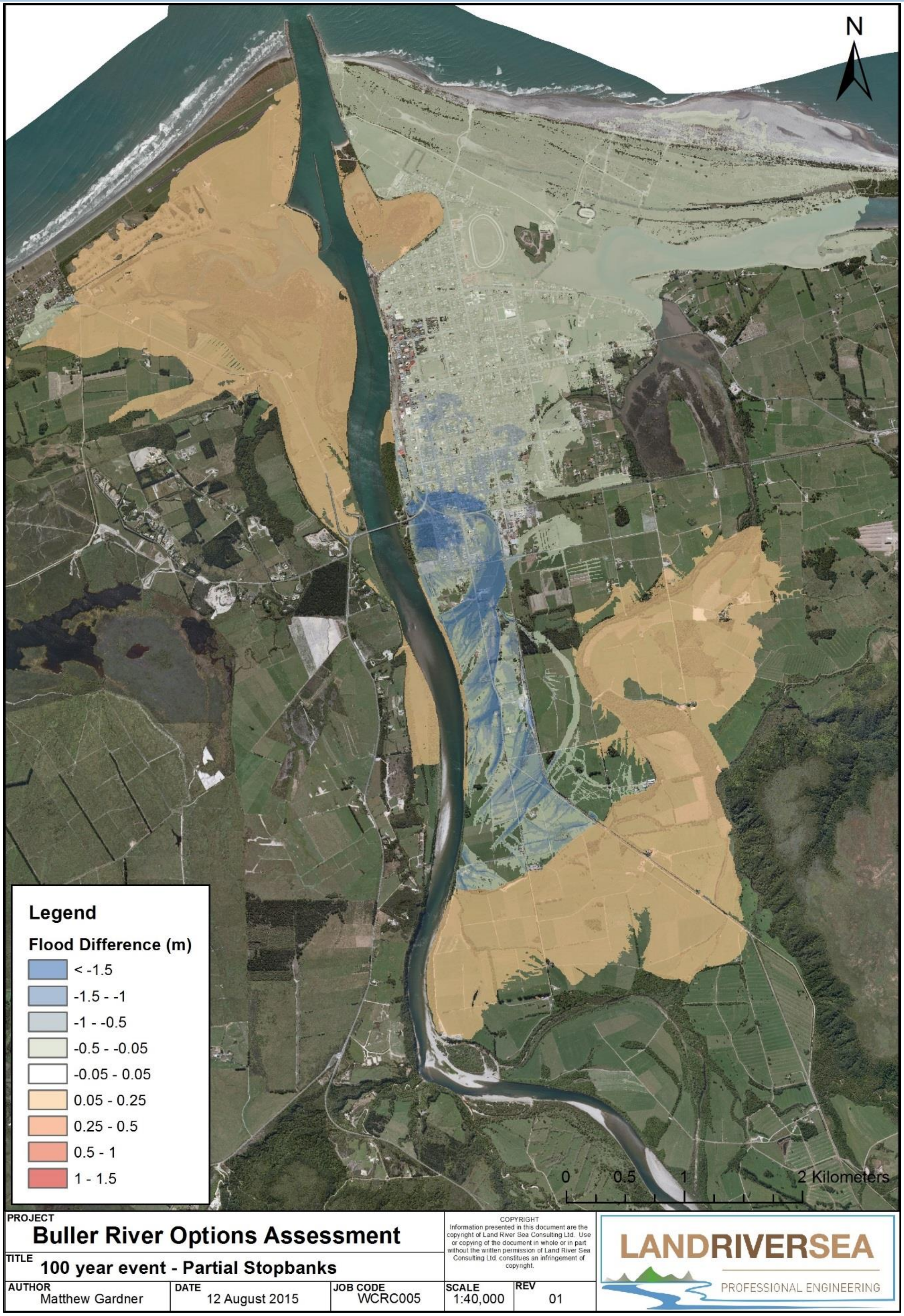

Figure B-4 - 100 year flood level differences - Option C – Partial Stopbanks

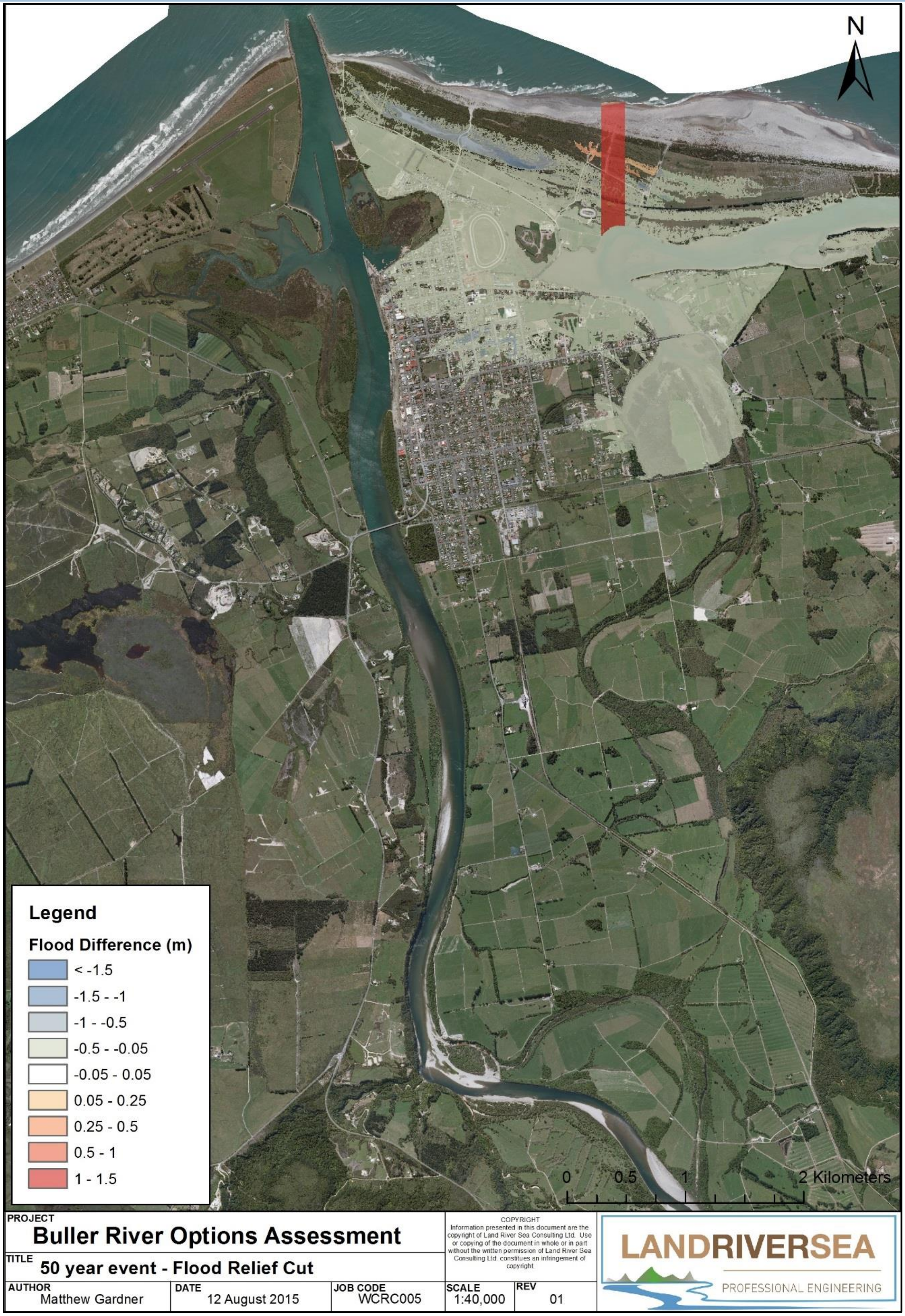

Figure B-5 - 50 year flood level differences - Option D – Flood Relief Cut

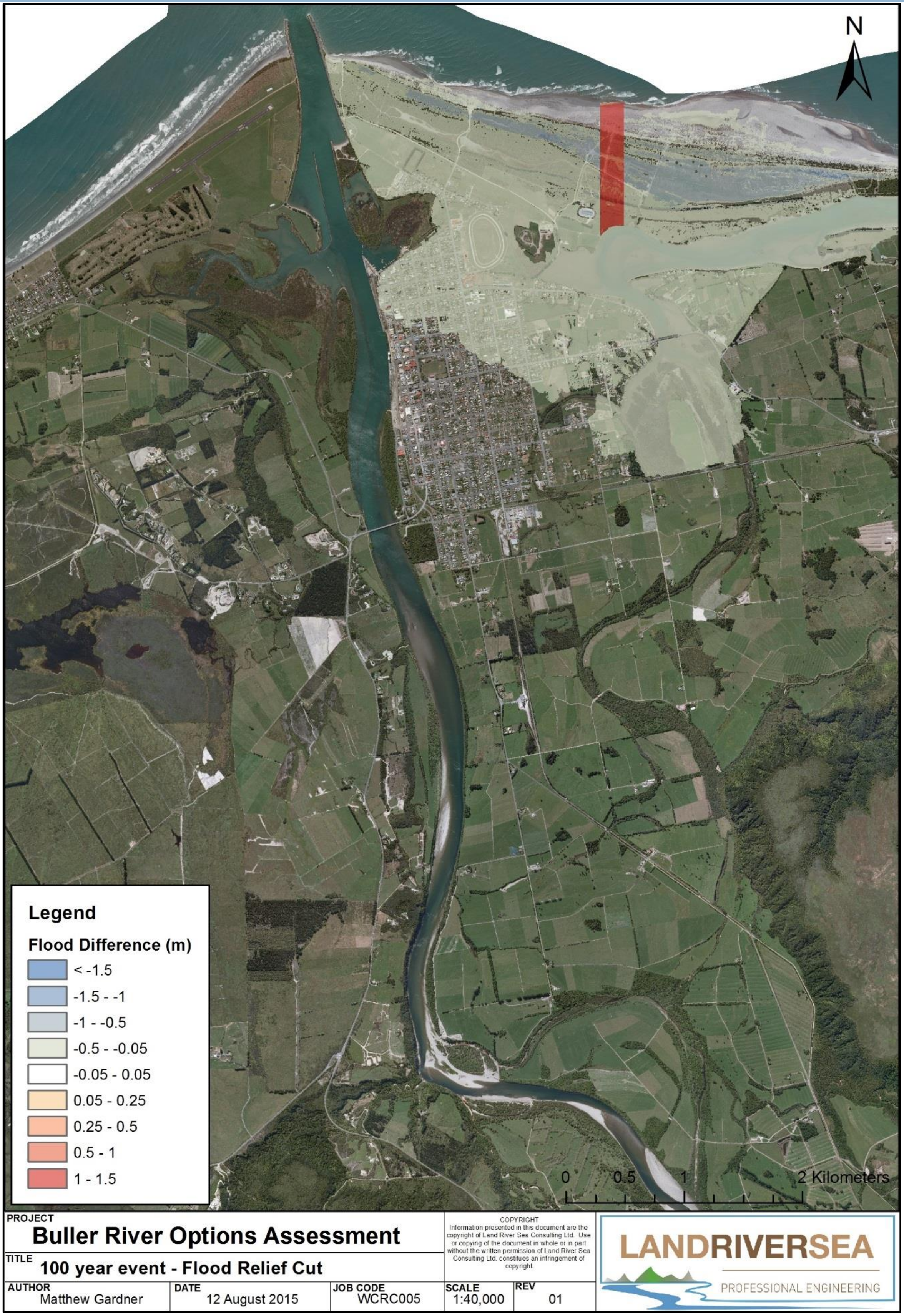

Figure B-6 - 100 year flood level differences - Option D – Flood Relief Cut

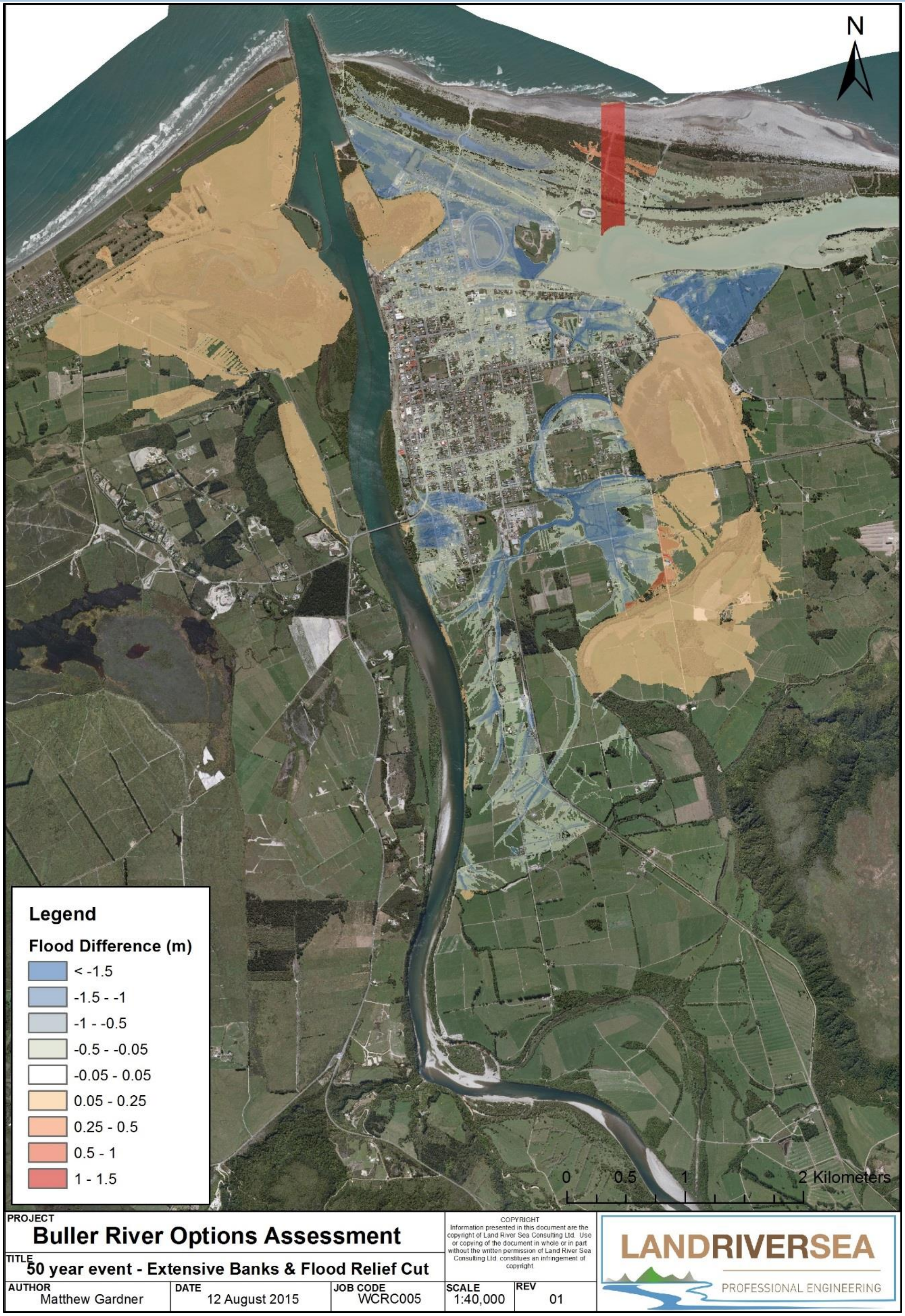

Figure B-7 - 50 year flood level differences - Option E – Extensive Stopbanks & Flood Relief Cut

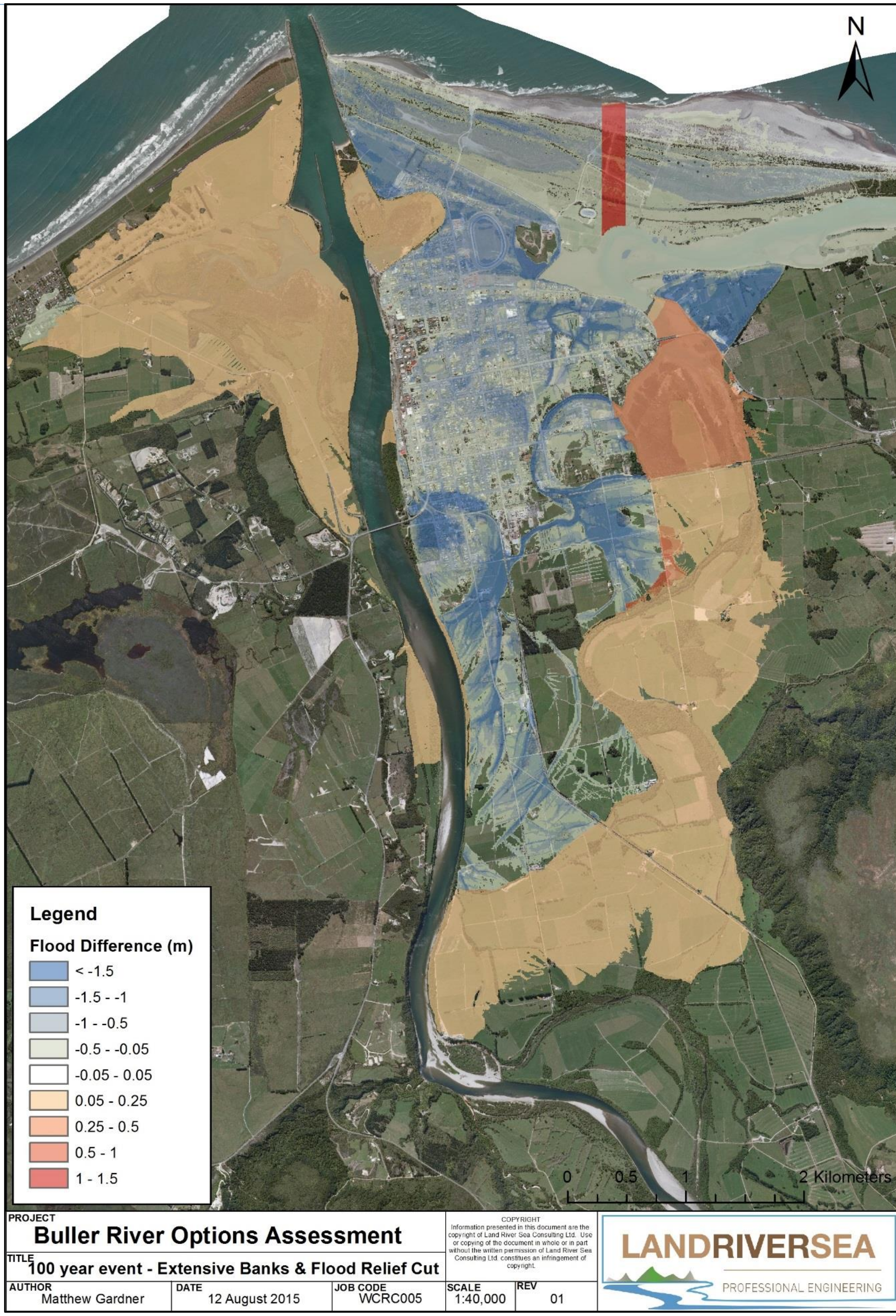

Figure B-8 - 100 year flood level differences - Option E – Extensive Stopbanks & Flood Relief Cut

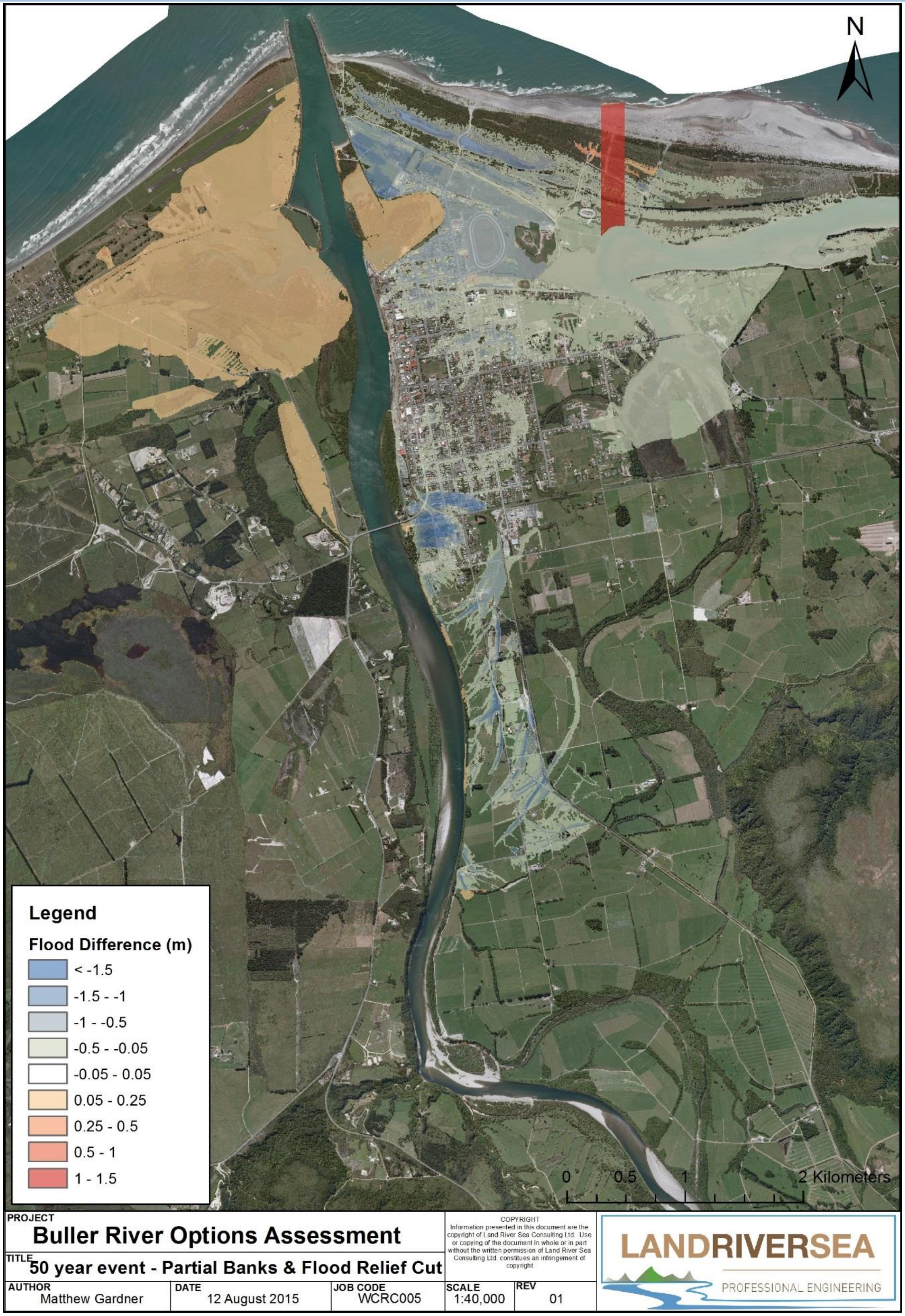

Figure B-9 - 50 year flood level differences - Option F – Partial Stopbanks & Flood Relief Cut

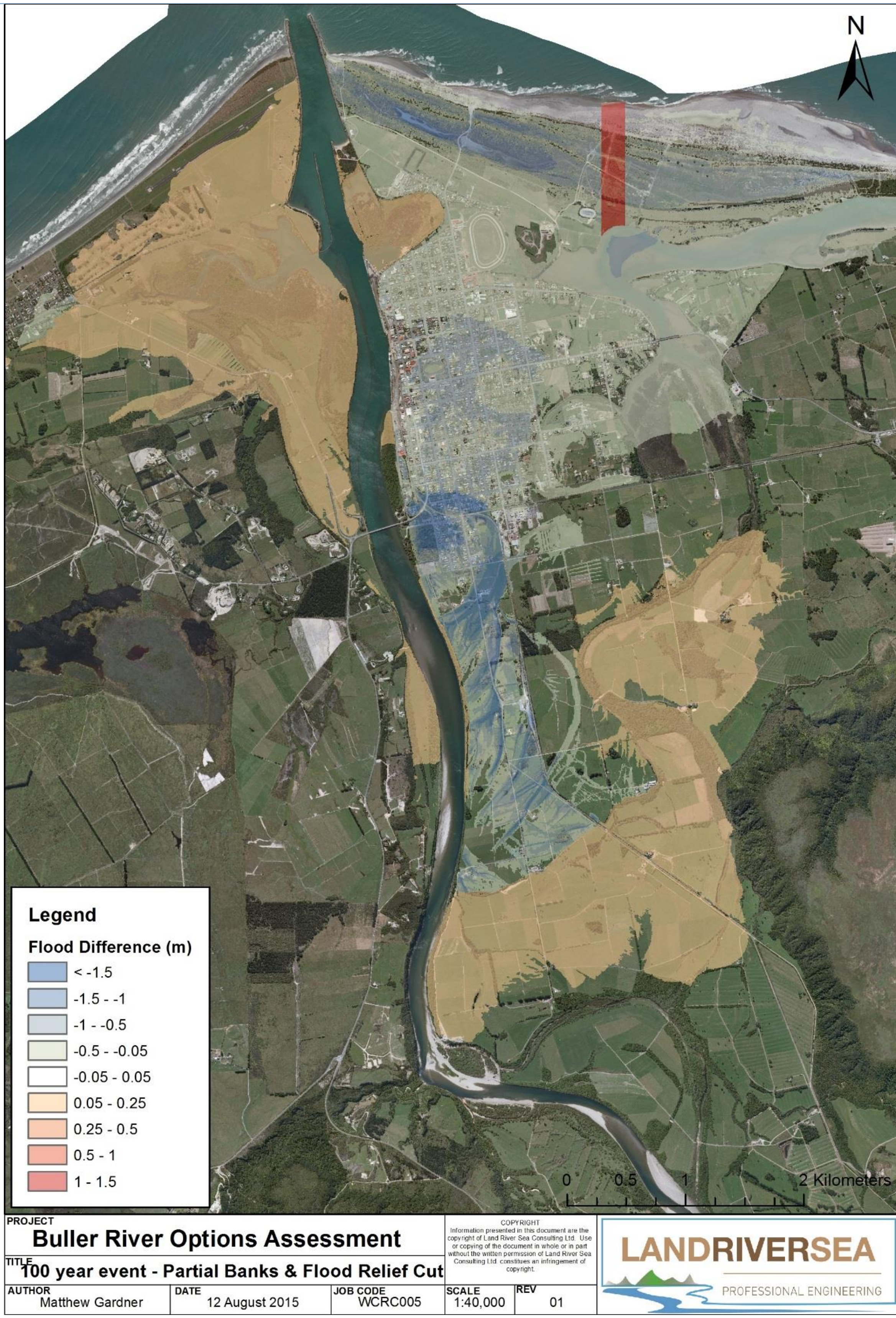

Figure B-10 - 100 year flood level differences - Option F – Partial Stopbanks & Flood Relief Cut

C. APPENDIX C – FLOOD HAZARD MAPS

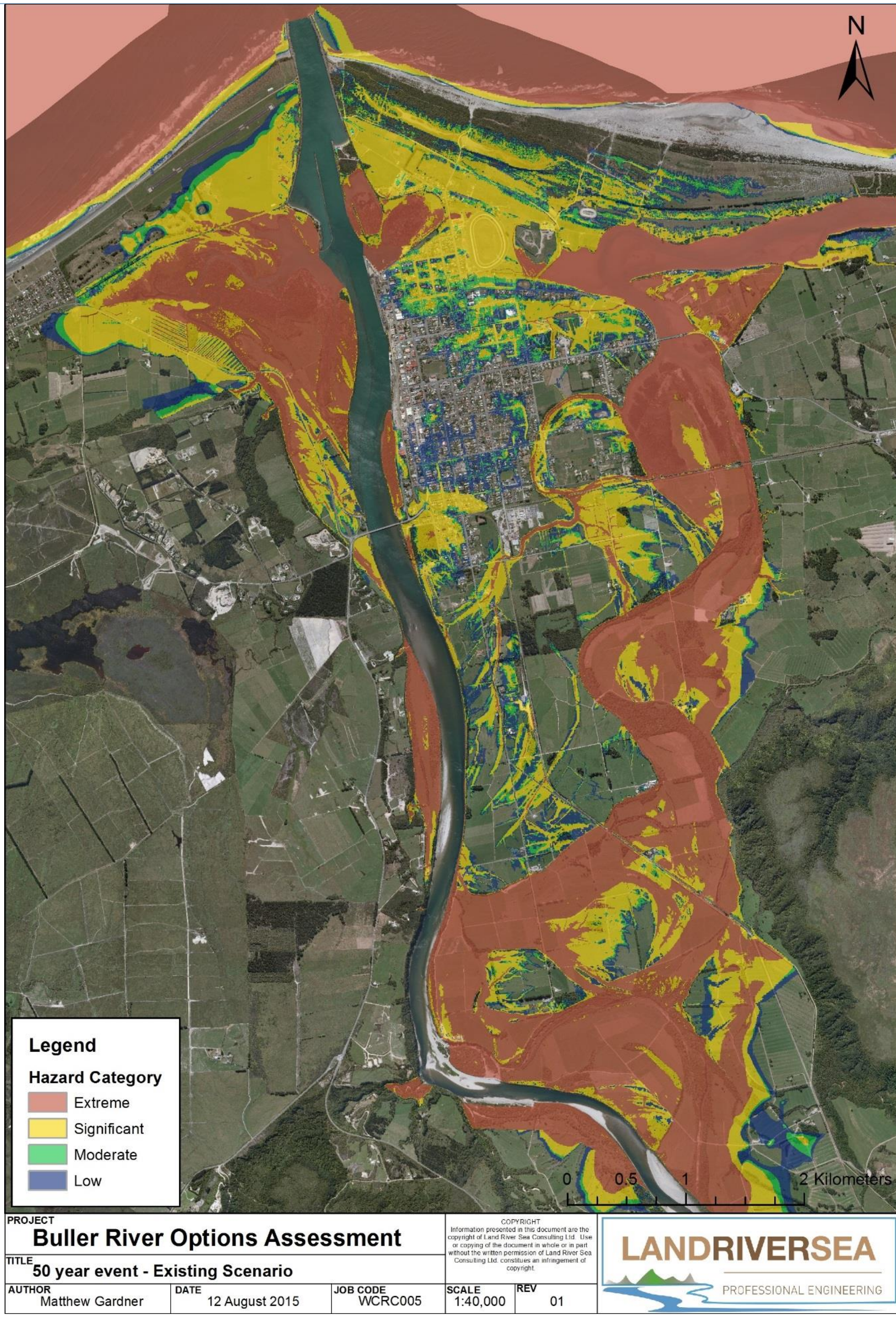

Figure C-1 - 50 year flood hazard - Option A – Existing Scenario

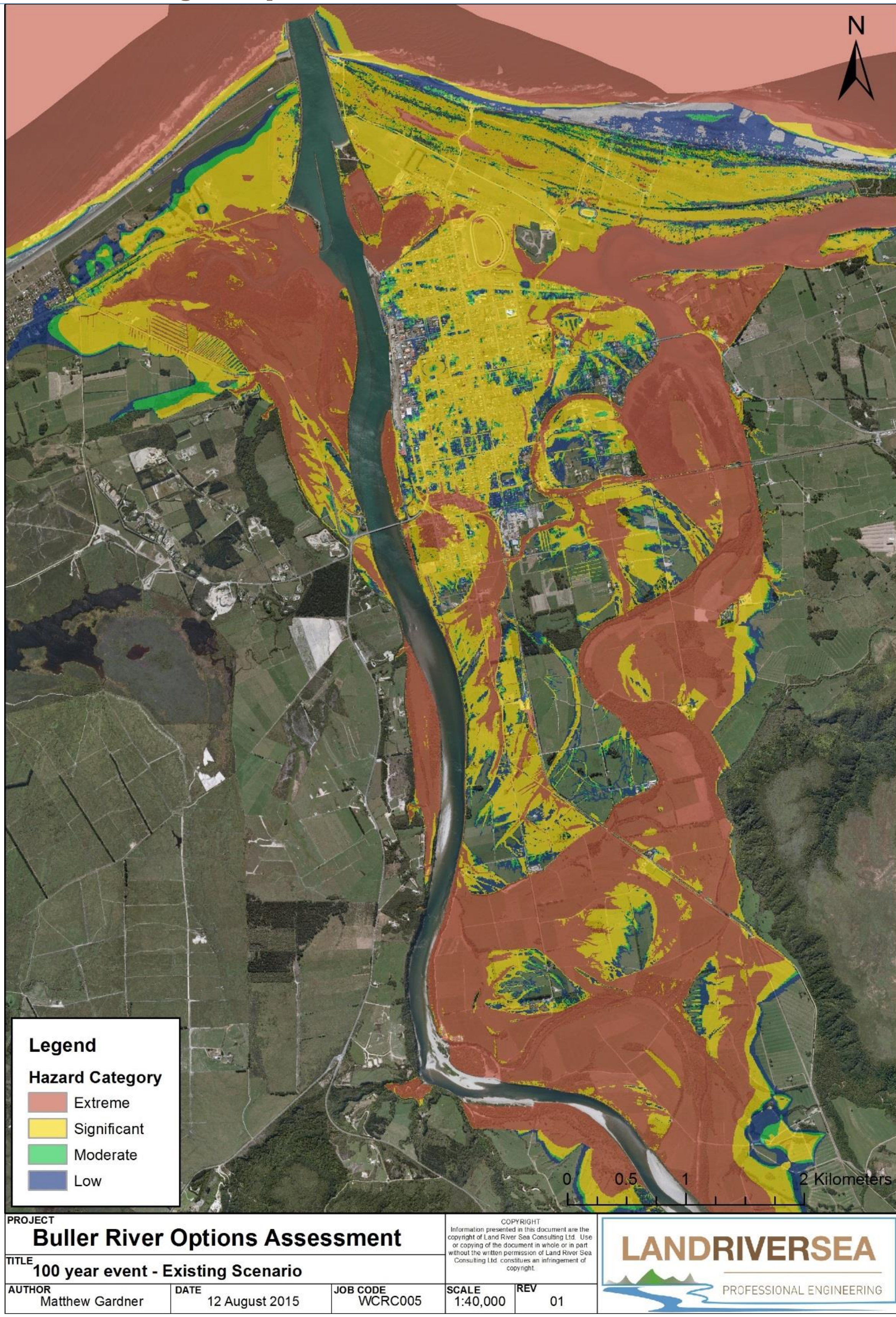

Figure C-2 - 100 year flood hazard - Option A – Existing Scenario

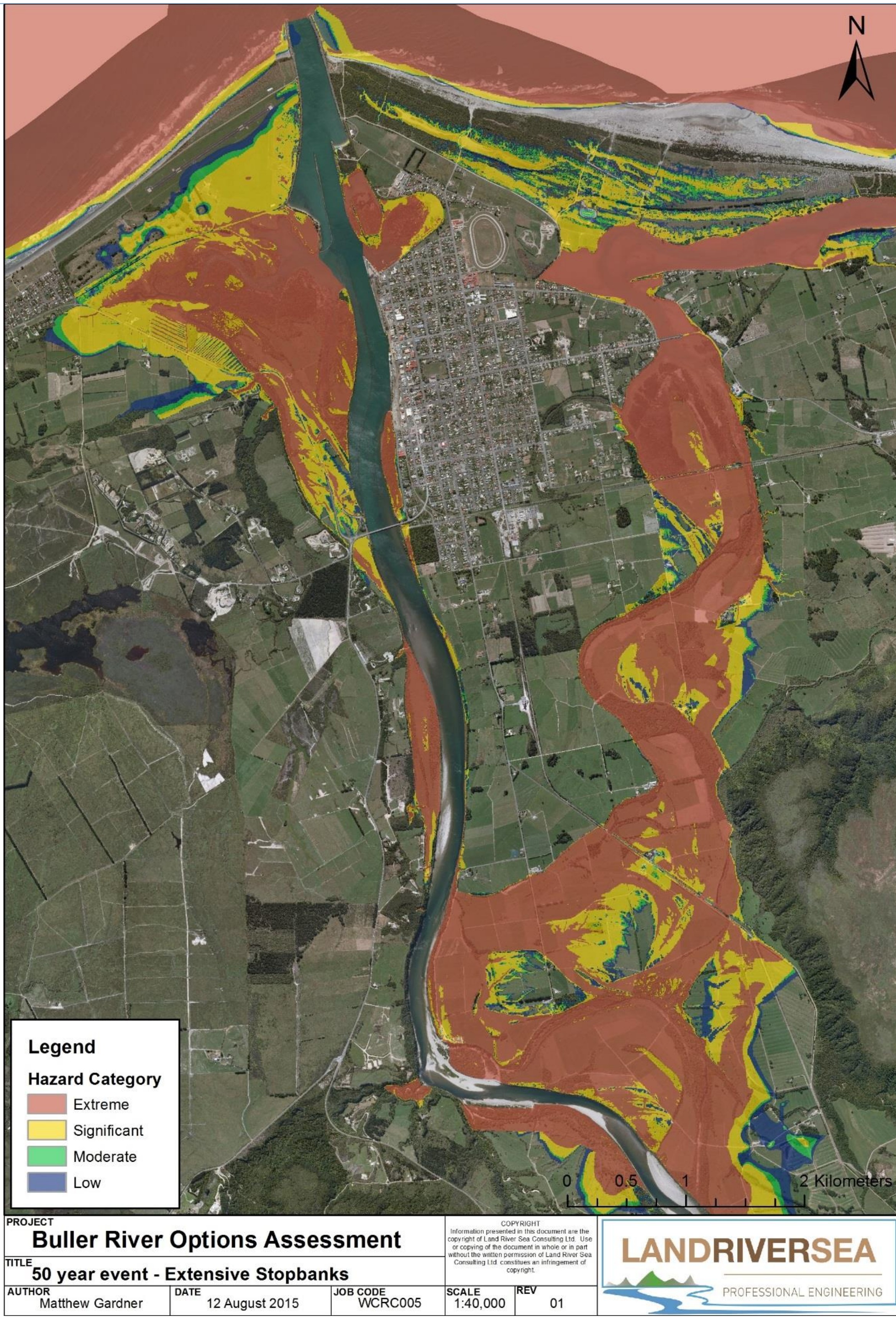

Figure C-3 - 50 year flood hazard - Option B – Extensive Stopbanks

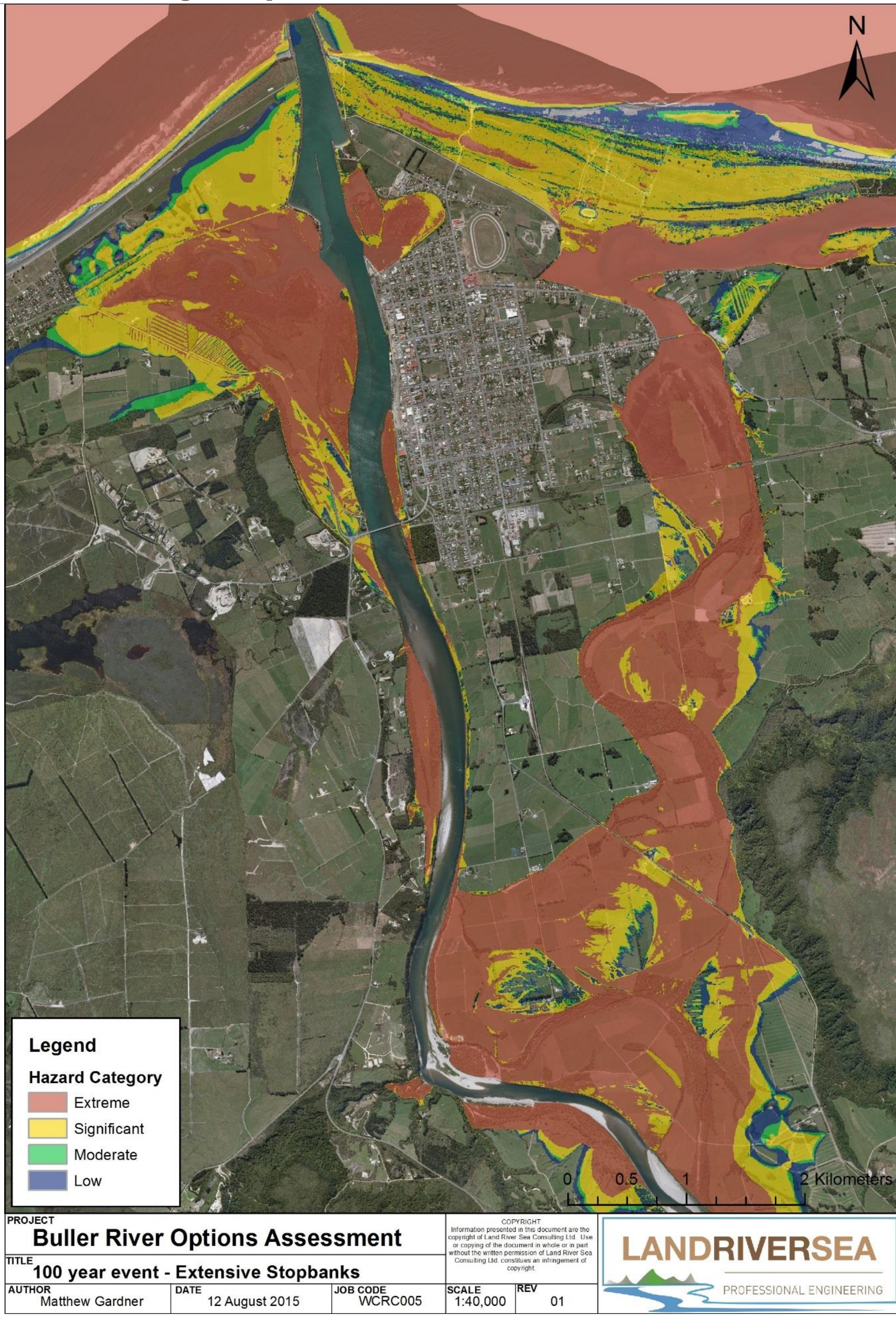

Figure C-4 - 100 year flood hazard - Option B – Extensive Stopbanks

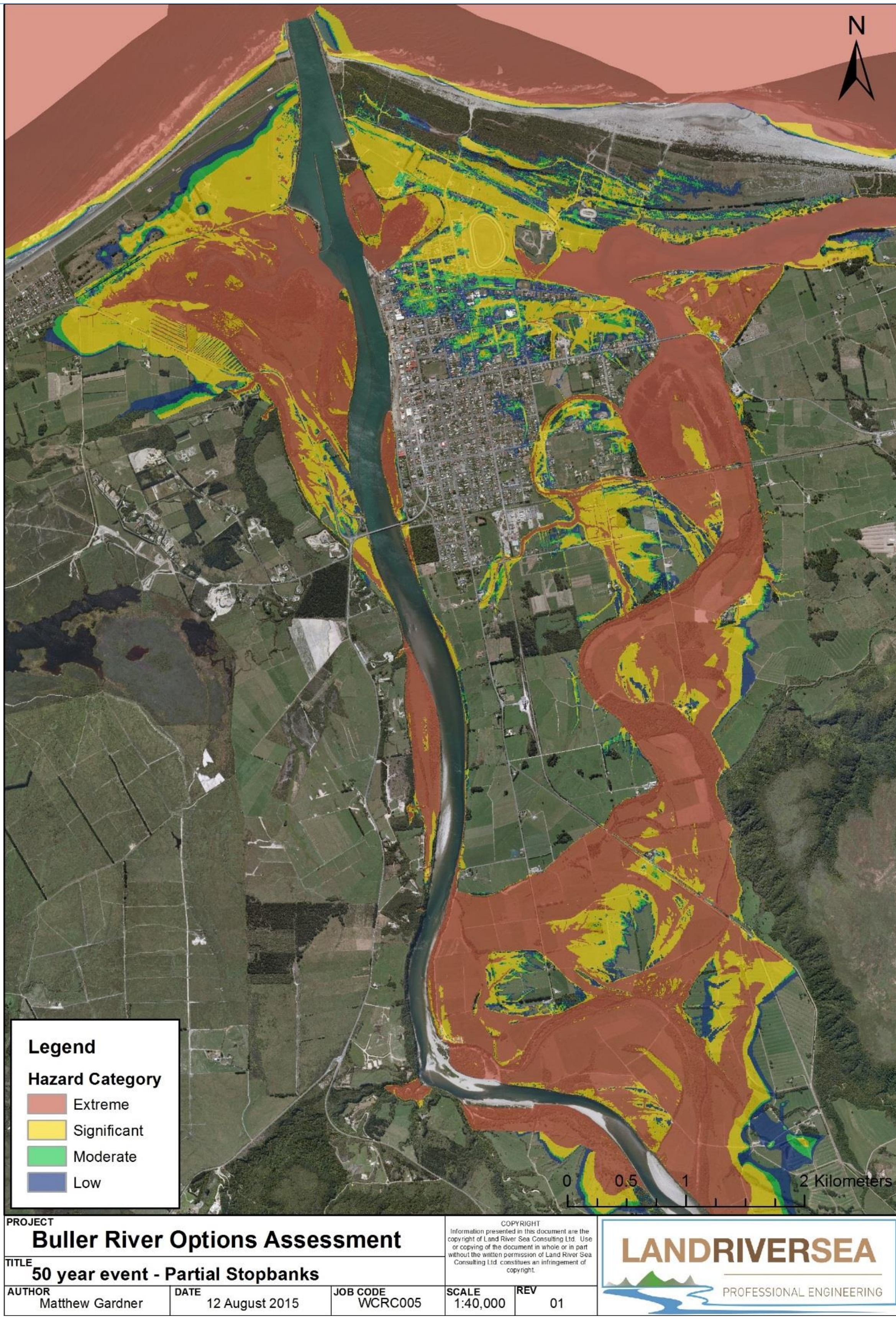

Figure C-5 - 50 year flood hazard - Option C – Partial Stopbanks

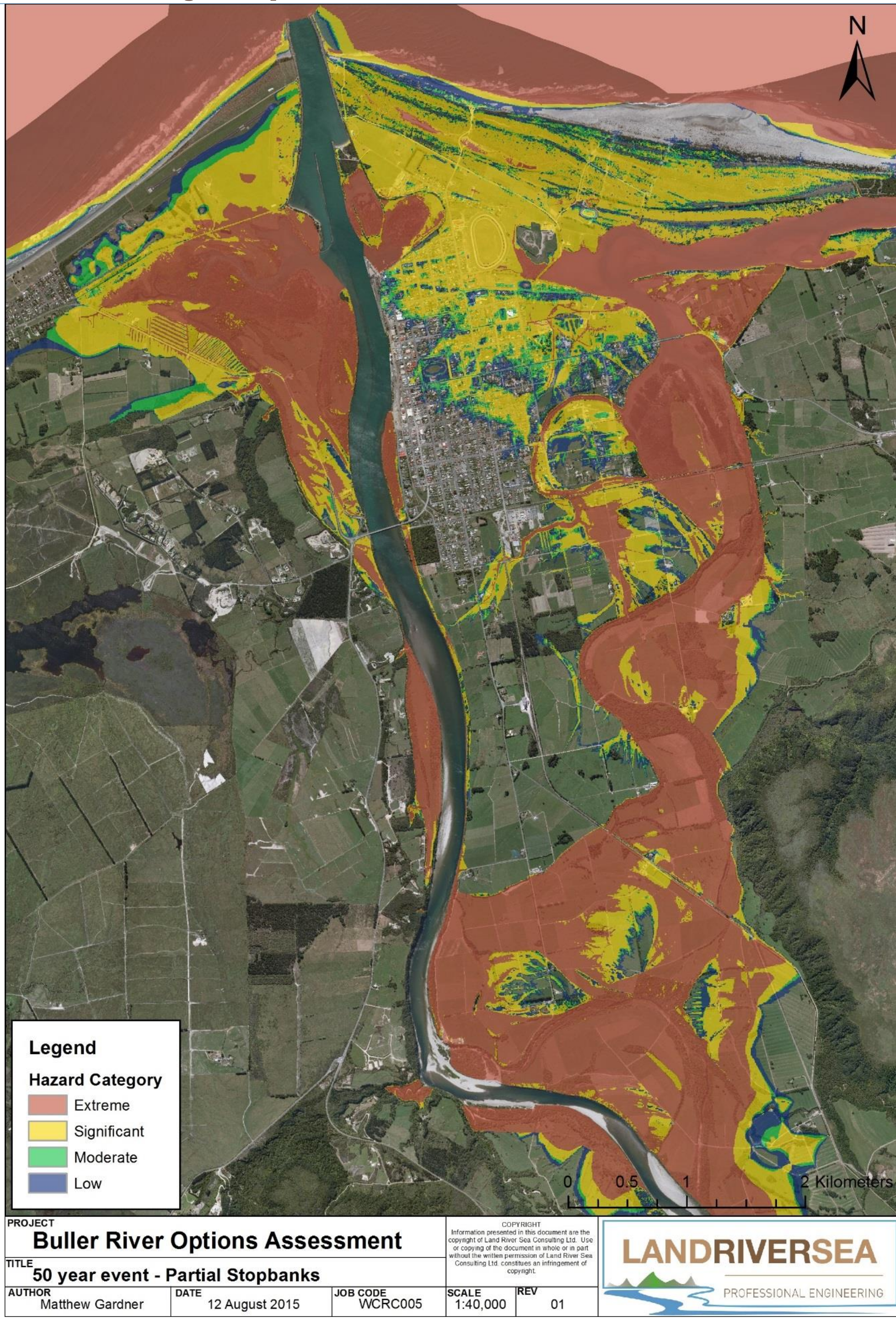

Figure C-6 - 50 year flood hazard - Option C – Partial Stopbanks

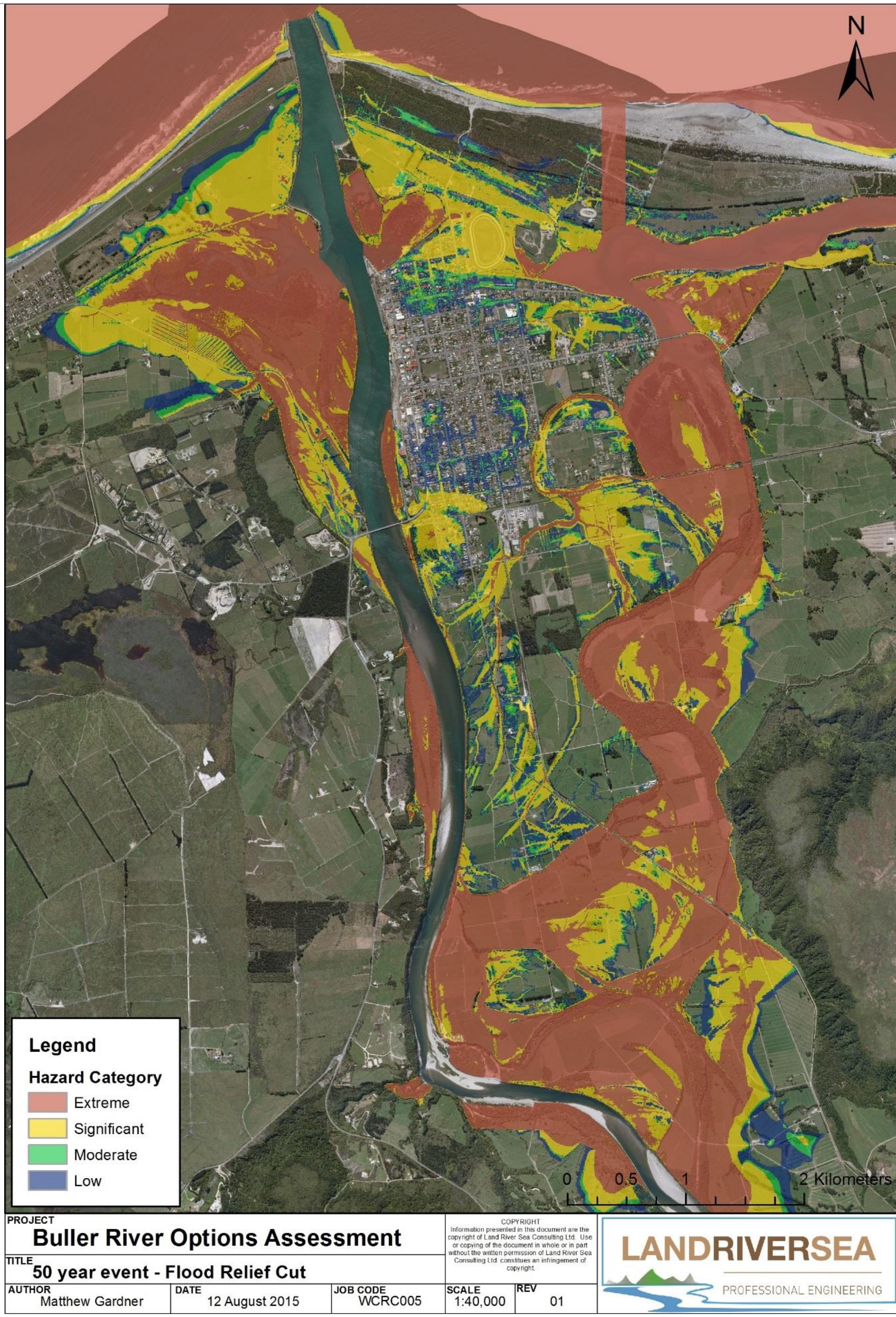

Figure C-7 - 50 year flood hazard - Option D – Flood Relief Cut

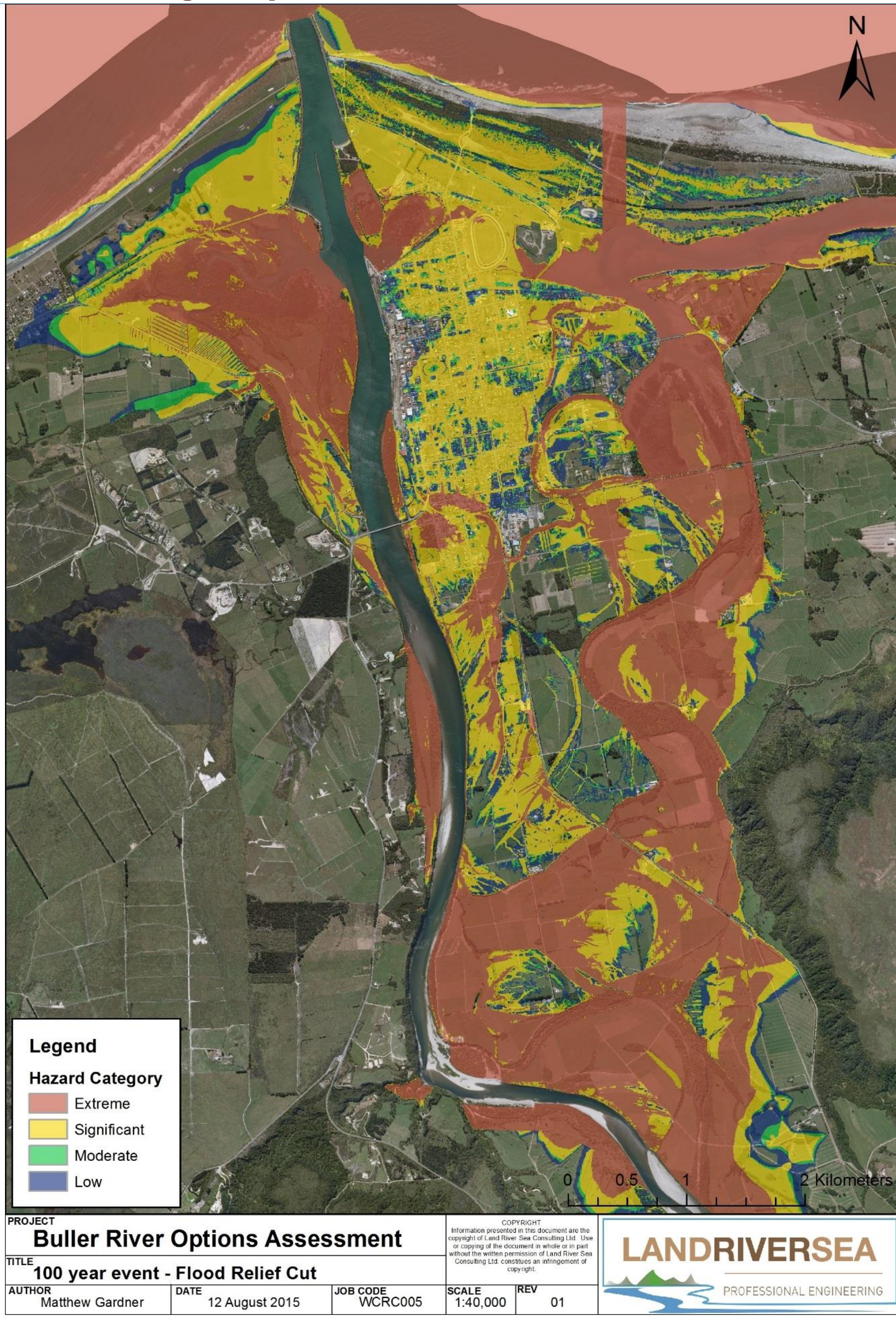

Figure C-8 - 100 year flood hazard - Option D – Flood Relief Cut

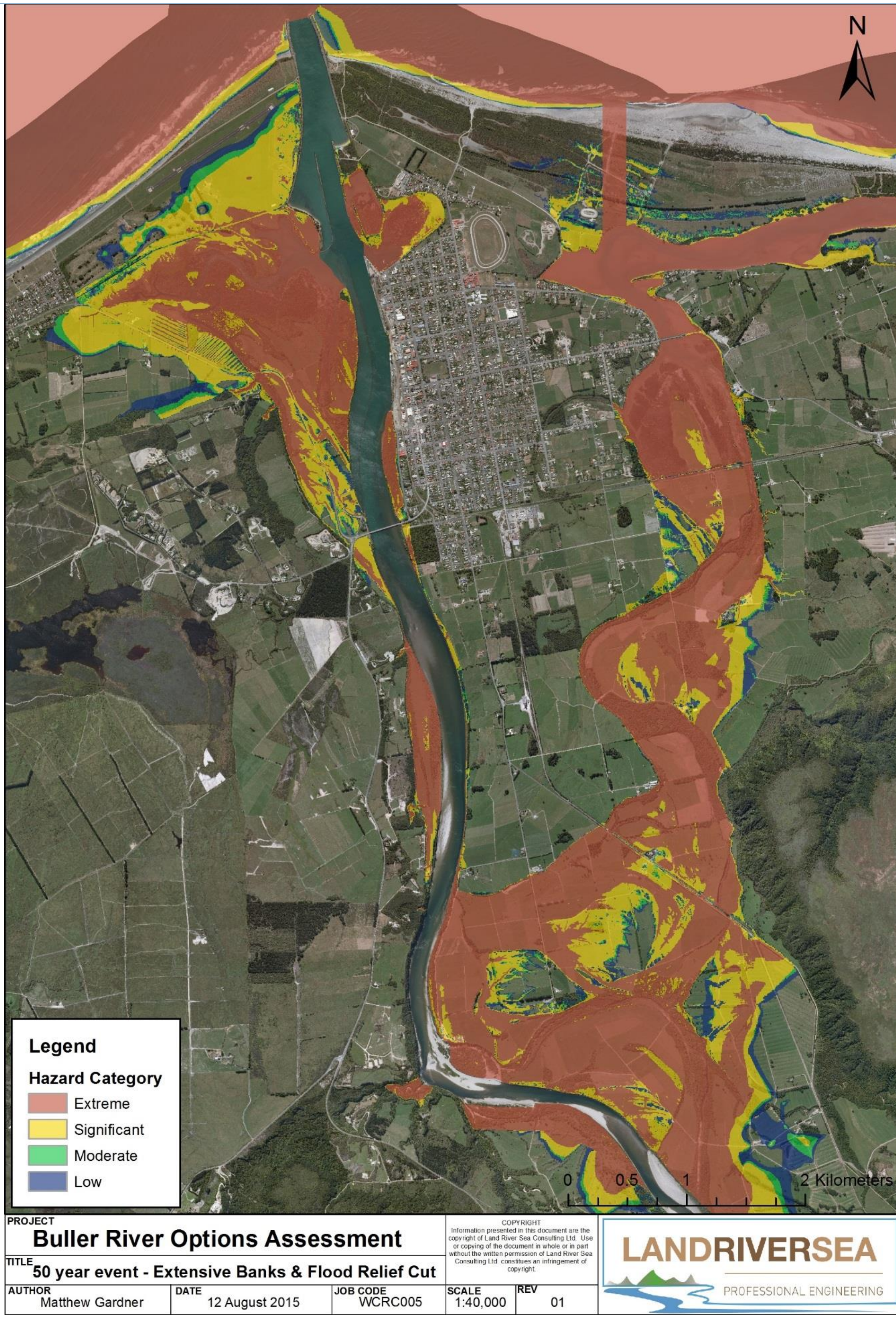

Figure C-9 - 50 year flood hazard - Option E – Extensive Stopbanks and Flood Relief Cut

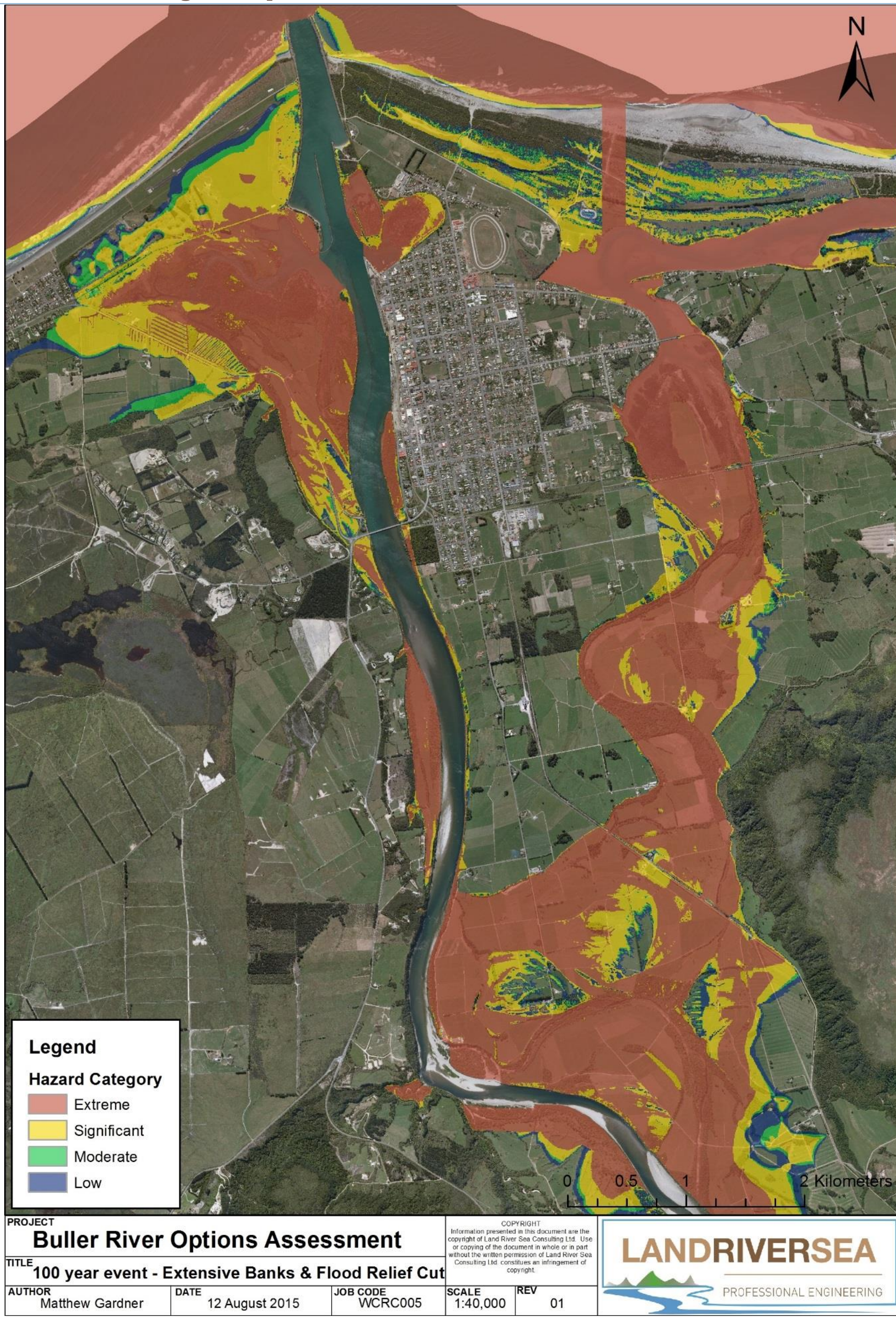

Figure C-10 - 100 year flood hazard - Option E – Extensive Stopbanks and Flood Relief Cut

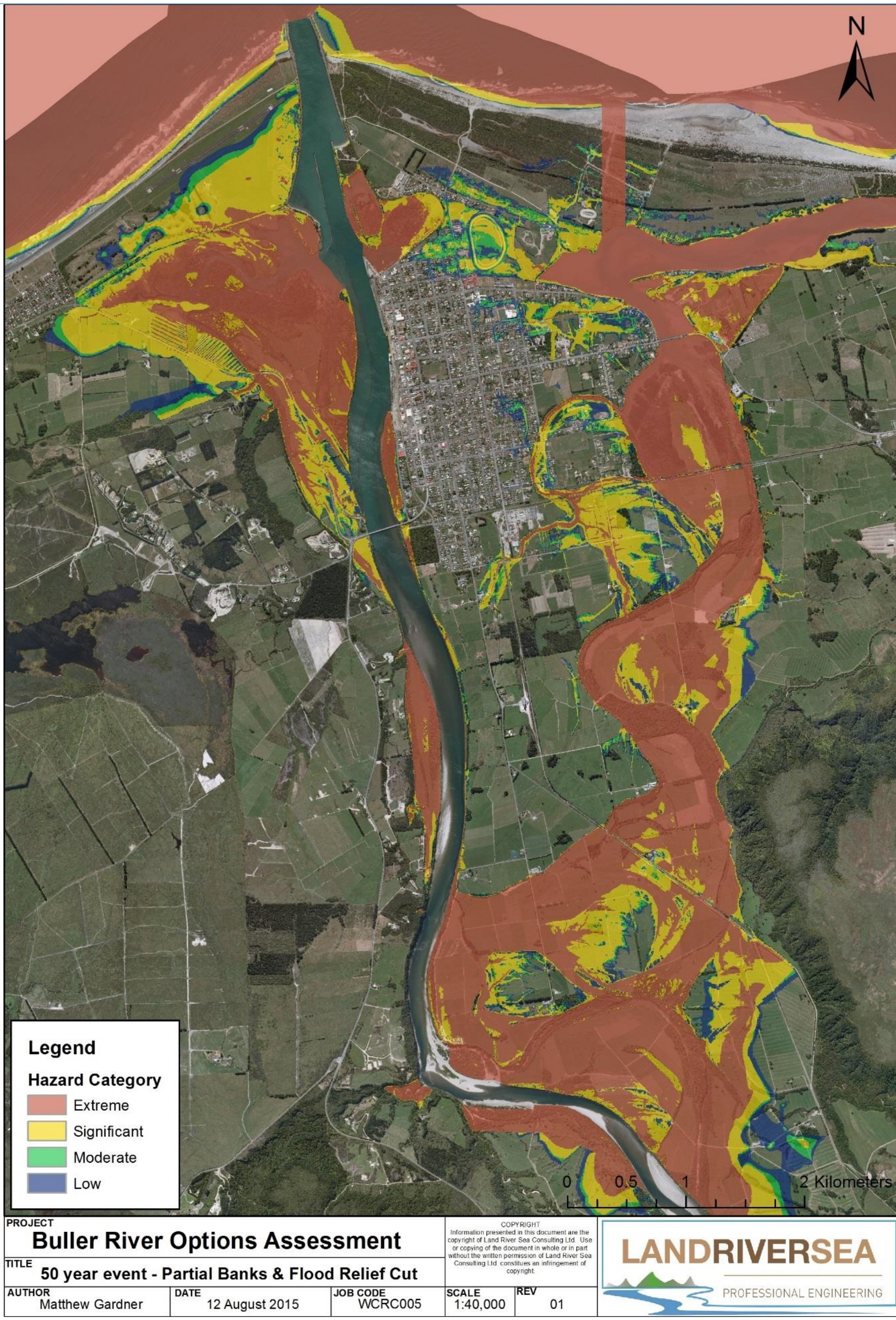

Figure C-11 - 50 year flood hazard - Option F – Partial Stopbanks and Flood Relief Cut

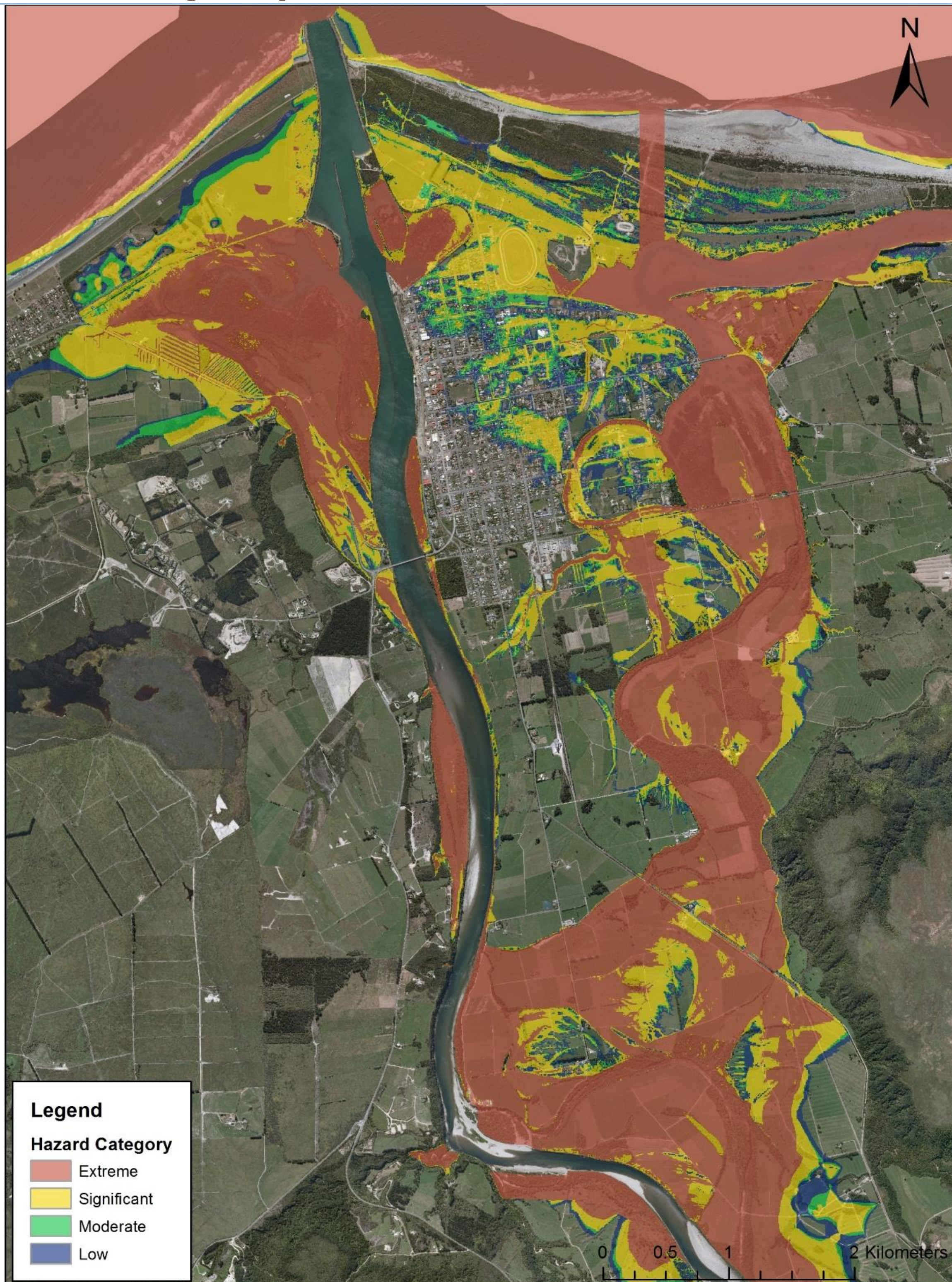

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Figure C-12 - 100 year flood hazard - Option F – Partial Stopbanks and Flood Relief Cut