Appendix I

Flood Study

A part of BMT in Energy and Environment

Sportsmans Creek Bridge Project

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Confidential

Sportsmans Creek Bridge Project

Prepared for:	KBR
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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BMT WBM Pty Ltd Level 1, 256-258 Norton Street Leichhardt NSW 2040 Australia PO Box 194, Leichhardt NSW 2040 Tel: +61 2 8987 2900 Fax: +61 2 8987 2999 ABN 54 010 830 421 www.bmtwbm.com.au	**Document:**	R.S20082.001.docx
	Title:	Sportsmans Creek Bridge Project
	Project Manager:	Paul Dunne
	Author:	Paul Dunne
	Client:	KBR
	Client Contact:	Wojtek Zborowski
	Client Reference:	

Synopsis:	**The Sportsmans Creek bridge project involves constructing a new bridge to the west of the existing Sportsman Creek bridge. This study provides an assessment of the impact of the proposed bridge on flood behaviour in the vicinity of Lawrence.**

REVISION/CHECKING HISTORY

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Destination	Revision										
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KBR	1	1									
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Contents

List of Figures

List of Tables

1 Introduction

The Sportsmans Creek bridge project involves constructing a new bridge to the west of the existing Sportsman Creek bridge as part of NSW Government's Bridges for the Bush program. The new bridge will replace the existing bridge and the existing bridge will be removed. These works are referred to as the proposed bridge scenario for the remainder of this report.

The primary objective of this study is to determine the impact of the proposed bridge scenario on flood behaviour in the vicinity of Lawrence and undertake an assessment of scour at the abutments and piers of the proposed bridge. The study has utilised the existing TUFLOW hydraulic model developed for the Lower Clarence River Flood Model Update (BMT WBM, 2013).

This report has been prepared to provide a summary of the assessment and the key finding of the study. The study has been undertaken in a staged approach as outlined below:

- Data collection and review (Chapter 2);
- Hydraulic modelling of the existing and proposed bridge scenarios (Chapter 3); and
- Analysis of results (Chapter 4).

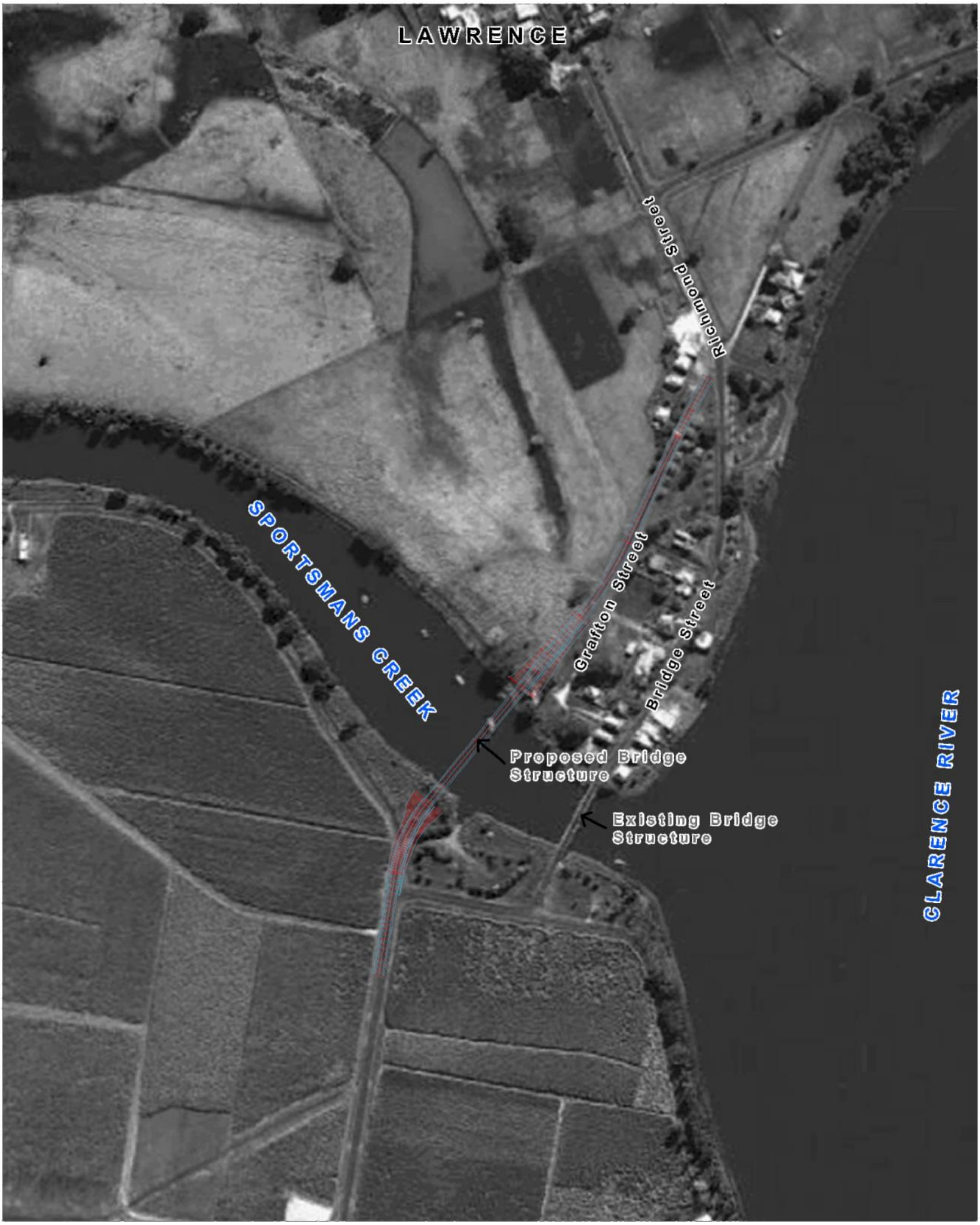
1.1 Study location

The Sportsmans Creek bridge project is located in Lawrence, NSW, a small town approximately 13km from Maclean. Lawrence is located on the banks of the Clarence River directly north of the confluence of Sportsmans Creek and the Clarence River. The existing bridge structure crosses Sportsmans Creek directly upstream of the Clarence River confluence with traffic passing along Bridge Street, Lawrence. The proposed bridge structure will be located approximately 130m upstream of the existing bridge on Sportsmans Creek with traffic diverted onto Grafton Street, Lawrence. Figure 1-1 shows the location of the existing and proposed bridge structures.

1.2 Lower Clarence River Flood Model Update

The Lower Clarence River Flood Model Update (BMT WBM, 2013) provides an assessment of the flood behaviour within the Lower Clarence Valley, and in particular the characteristics of the flood flow within Grafton and Maclean when the levee systems are overtopped.

The study is part of an ongoing process which aims to develop a greater understanding of the flood behaviour within the Lower Clarence Valley, aiding the management of flood risk within the greater catchment.



Title:

Proposed Upgrade of Sportsmans Creek Bridge Study Location

Figure: 1-1

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Approx. Scale

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Due to the size of the Clarence River catchment upstream of Grafton, relative to its various tributary catchments, the flooding behaviour of the Lower Clarence River floodplain is dominated by the flow originating from upstream of Grafton/Mountain View in terms of both peak flood levels and duration of inundation. The flow typically contributes 80% to 90% of the total volume of floodwaters that enters the lower floodplains, and flow can be sustained for several days to weeks. Clarence River floods typically occur from low rainfall intensity events that last several days or even weeks. On the Clarence River floodplain, the inflows from the smaller tributary catchments downstream play only a minor role in flood behaviour.

Acknowledging that the river flows originating from upstream of Grafton dominate flooding in the Lower Clarence Valley, the flood behaviour downstream of Grafton is quite complex. For Sportsmans Creek, river flows and elevated river levels in the Clarence River result in reverse/backflow up Sportsmans Creek for all of the design flood events. As the Clarence River floodplain flows peak, the flows reverse along the Sportsmans Creek channel with flows discharging from Sportsman Creek into the Clarence River.

Full details of the Lower Clarence River Flood Model Update (BMT WBM, 2013) can be found at the following link.

1.3 Technical requirements

The existing TUFLOW hydraulic model developed for the Lower Clarence River Flood Model Update (BMT WBM, 2013) has been further updated to assess the impact of the proposed bridge scenario to meet the following technical requirements of the study:

- Peak water levels for the 20% Annual Exceedance Probability (AEP) (1 in 5 year Annual Return Interval (ARI)), 2% AEP (1 in 50 year ARI) and 1% AEP (1 in 100 year ARI) design flood events for both the existing and proposed bridge scenarios;
- Peak flood velocities for the 20% AEP, 2% AEP and 1% AEP design flood events for the proposed bridge scenario;
- Peak climate change scenario water levels for the proposed bridge scenario assessing:
    - 10% increase in rainfall intensity combined with a 0.4m rise in sea levels;
    - 20% increase in rainfall intensity combined with a 0.9m rise in sea levels; and
- Undertake an estimation of scour at the abutments and piers of the proposed bridge using HEC 18, 2001 version for cohesive-less bed material. The scour assessment will be undertaken for the design flood event (20% AEP, 2% AEP and 1% AEP events) which produces the highest velocities at the location of the proposed bridge.

2 Data collection and review

2.1 Lower Clarence River flood model

The Lower Clarence flood model encompasses the Lower Clarence Valley floodplain from Mountain View, upstream of Grafton, to Yamba at the mouth of the Clarence River. The Lower Clarence River Flood Model Update (BMT WBM, 2013) represents an update to the Lower Clarence Flood Study Review (WBM, 2004) and Grafton and Maclean Flood Levee Overtopping: Hydraulic Assessment (BMT WBM, 2011). The model was refined such that it included multiple 2D domains, increasing the model resolution within and surrounding the urban areas of Grafton, South Grafton and Maclean. The model was updated to include newly available 1m resolution Airborne Laser Survey (ALS) topography data of the entire study area and revised Grafton and South Grafton levee survey data. This model was used to assess the flood behaviour in Grafton and Maclean when the levee systems surrounding these towns are overtopped. The model configuration is presented in Figure 2-1.

The flood model has been developed using TUFLOW, a fully 1D/2D hydraulic modelling software package.

All out-of-bank model topography is based on a DEM derived the ALS and topographic survey data. The in-bank bathymetry has been defined based on the Clarence River hydro-survey used by the original Lower Clarence River Flood Study (WBM 2004).

Land-use mapping is used by the hydraulic model to represent the associated hydraulic resistance or roughness within the floodplain. In total, nine areas of different land-use type based on aerial photography were used. These land-use values have been validated as part of the flood model calibration exercise.

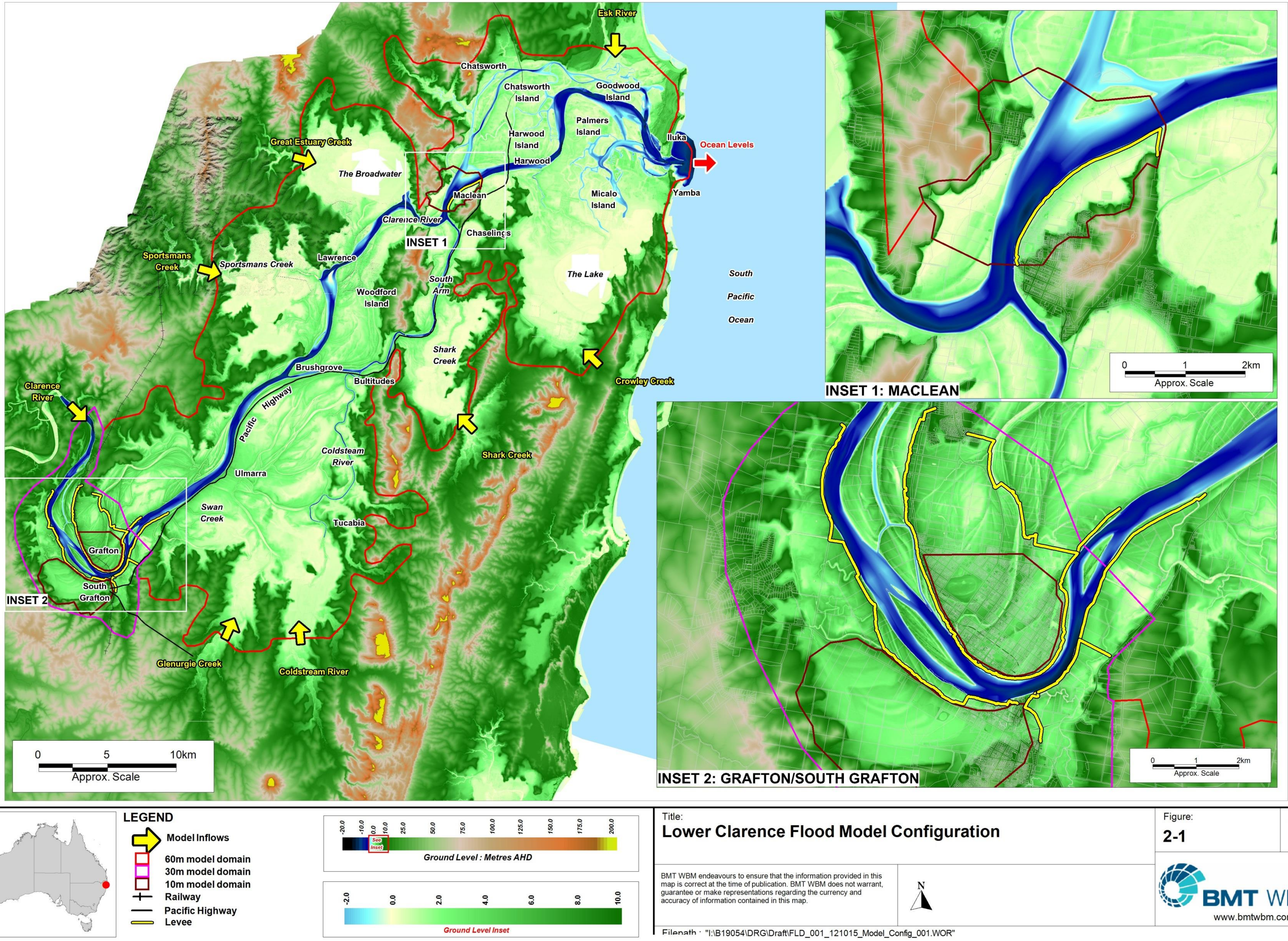
The Lower Clarence flood model uses various input boundary conditions including:

- Flood inflows for the Clarence River at Mountain View;
- Flood inflows for the Clarence River tributaries downstream of Mountain View;
- Floodplain rainfall runoff; and
- Ocean water levels.

Figure 2-1 shows the location of the catchment inflows and downstream boundary which have been included within the flood model.

The flood model has been successfully calibrated to the following historic flood events: 1967, 1968, 1980, 1988, 1996, 2001 and 2009. The calibrated model has been used to define the design flood behaviour within the catchment, including the 20%, 5%, 2%, 1% AEP events and the Probable Maximum Flood (PMF).

The model has also been used to assess the impact of climate change on flood behaviour through modelling increases in rainfall intensity and sea level rise.



Title:

Lower Clarence Flood Model Configuration

Figure: 2-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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2.2 Topographic data

2.2.1 Ground survey data

Ground and channel level survey data in the vicinity of both the existing and proposed structures has been provided by KBR. The survey data includes river channel survey data extending approximately 240m upstream existing Sportsman Creek bridge. The ground levels survey data includes details of the floodplain on the left and right banks of Sportsmans Creek and extends along Grafton Street, Bridge Street and Riverbank Road.

2.2.2 Bridge structures

Details of the existing Sportsman Creek bridge structure have been provided as structural drawings containing details of the elevations and chainages of components of the existing bridge structure.

Details of the proposed bridge structure have been provided as an AutoCAD drawing which contains the elevations and openings of the bridge deck. The AutoCAD drawing also provides details of the extent and elevations of the proposed approach road embankments as a Triangulated Irregular Network (TIN).

2.3 Media

Roads and Maritime Services (RMS) provided a video showing flood flows at the existing Sportsman Creek bridge (date of flood event unknown). The video shows flows in the Clarence River backing up through Sportsmans Creek as described in Section 1.2.

3 Flood Model Update

3.1 Model configuration

The Lower Clarence flood model developed as part of for the Lower Clarence River Flood Model Update (BMT WBM, 2013) has been used as the base model for this study. Two model configurations have been developed from this base model as part of this study:

(1) Existing scenario model; and

(2) Proposed scenario model.

The existing scenario model has been developed to form the baseline against which the proposed scenario model results have been assessed. The development of this existing scenario model has included the addition of a nested 2D model domain for Lawrence, adjustments to the model topography, updates to the existing Sportsmans Creek bridge and changes to the land-use delineation.

The proposed scenario model configuration has been developed from the existing scenario model and includes adjustments to the model topography, updates to the existing Sportsman Creek bridge, the inclusion of the proposed bridge and changes to the land-use delineation.

3.2 Nested 2D model domain at Lawrence

The Lower Clarence River Flood Model Update (BMT WBM, 2013) currently uses a 60m grid resolution, approximately equivalent to the width of Sportsmans Creek, in the vicinity of Lawrence. This resolution is too coarse to represent the flow patterns along Sportsmans Creek. Accordingly, a nested 2D model domain with a 15m grid resolution has been developed to represent the Lawrence area for both the existing scenario and proposed scenario models. Figure 3-1 shows the extent of the nested 2D domain for Lawrence.

3.3 Model topography

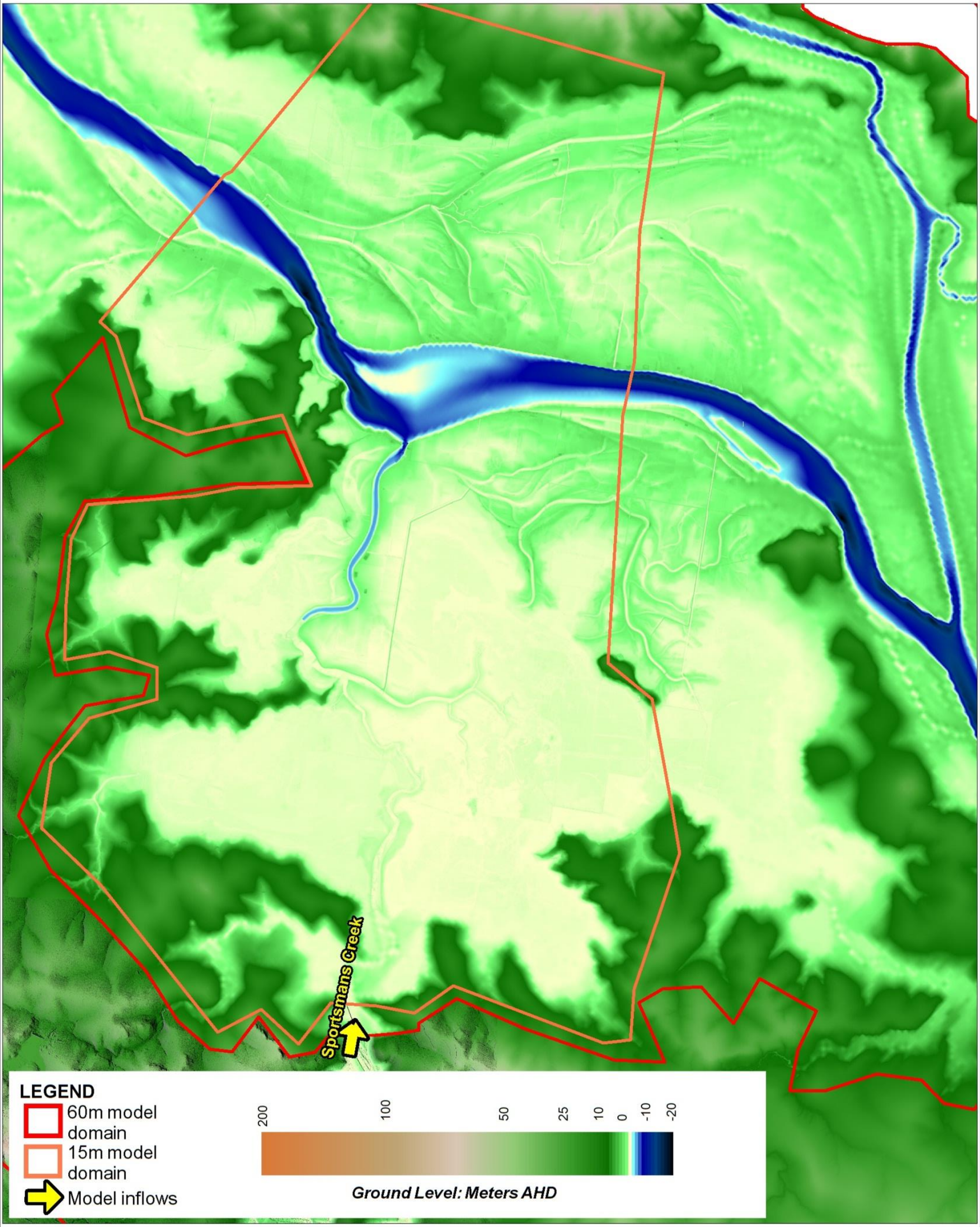
3.3.1 Existing scenario model

The existing model topography has been modified to include the following features:

- Ground level data in the vicinity of the existing and proposed structure based on the survey data provided by KBR; and
- Shape and elevation of the Sportsman Creek channel based on survey data provided by KBR.

The survey data provided by KBR for the Sportsmans Creek channel is limited to approximately 240m long reach of the channel extending from the existing Sportsman Creek bridge to west of the proposed bridge. In order to provide a smooth transition between the model topography and this is survey data, the survey data has been used to infer the Sportsmans Creek channel dimensions and elevations as follows:

- Downstream of the existing bridge to the confluence with the Clarence River; and
- For 2.7km upstream of the existing channel survey extent.



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Lower Clarence River Model Configuration - Lawrence

Figure: 3-1

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0 1.25 2.5km

Approx. Scale

BMT WBM

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Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigure3-1_ModelConfiguration_Lawrence.wor

3.3.2 Proposed scenario model

The topography in the proposed scenario model has been adjusted to include the road embankments which form the approach roads to the proposed bridge. Details of the extent and elevation of these road embankments have been based on the TIN data provided by KBR.

3.4 Model Structures

3.4.1 Existing scenario model

The structure representing the Sportsmans Creek Bridge within the Lower Clarence River Flood Model Update (BMT WBM, 2013) has been revised based on the structure details provided by KBR and the higher grid resolution of the 15m nested grid domain.

The structure has been modelled as a Flow Constriction (FC) within the TUFLOW model. An example of the application of a TUFLOW FC at a bridge structure is shown in Figure 3-2.

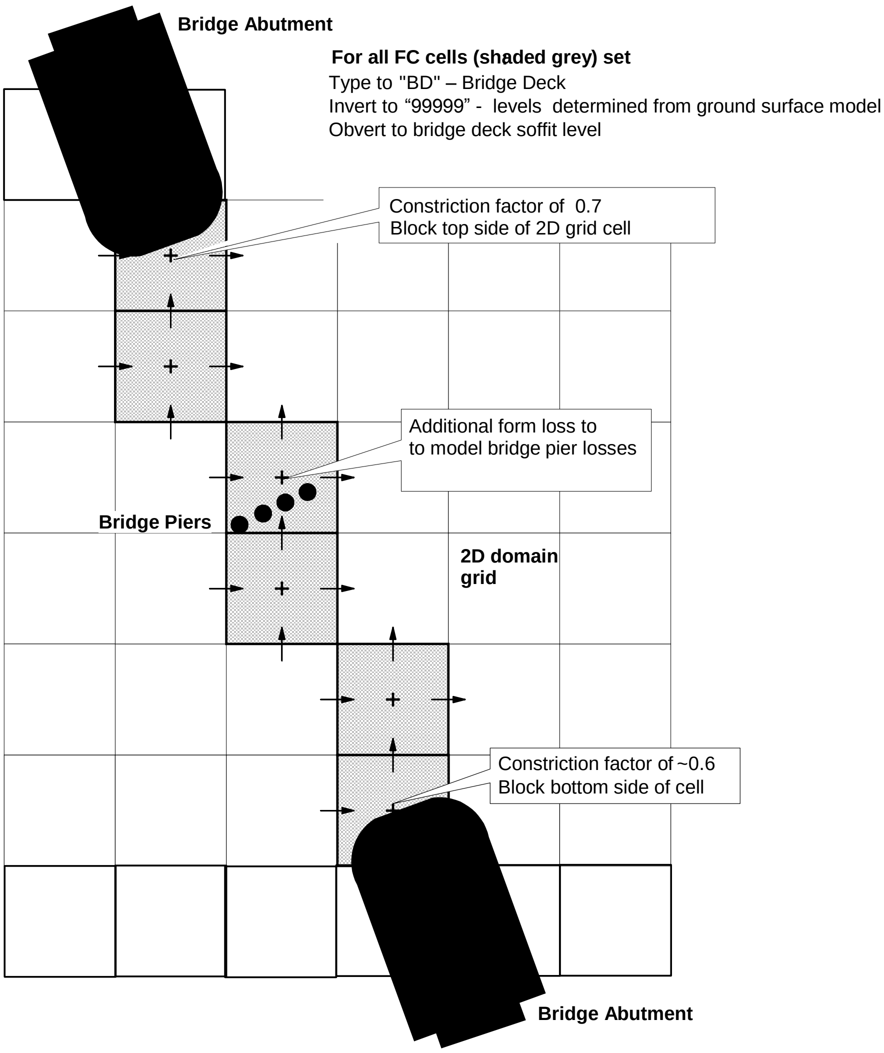


Figure 3-2 Setting FC Parameters for a Bridge Structure

The TUFLOW 2D solution automatically predicts the majority of “macro” losses due to the expansion and contraction of water through a constriction provided the resolution of the grid is sufficiently fine. Additional form loss coefficients and/or modifications to the 2D cells widths and flow height are added using TUFLOW FCs where the 2D model is not of fine enough resolution to simulate the “micro” losses (e.g. from bridge piers, vena contracta, losses in the vertical (3rd) dimension) (TUFLOW Manual, 2010).

Additional or “micro” losses for the bridge piers have been estimated using the techniques presented in Waterway Design (AustRoads 1994). Figure 5.7 from this document is reproduced in Figure 3-3 and has been used for determining the additional form losses (Δk_p) required to represent the bridge piers.

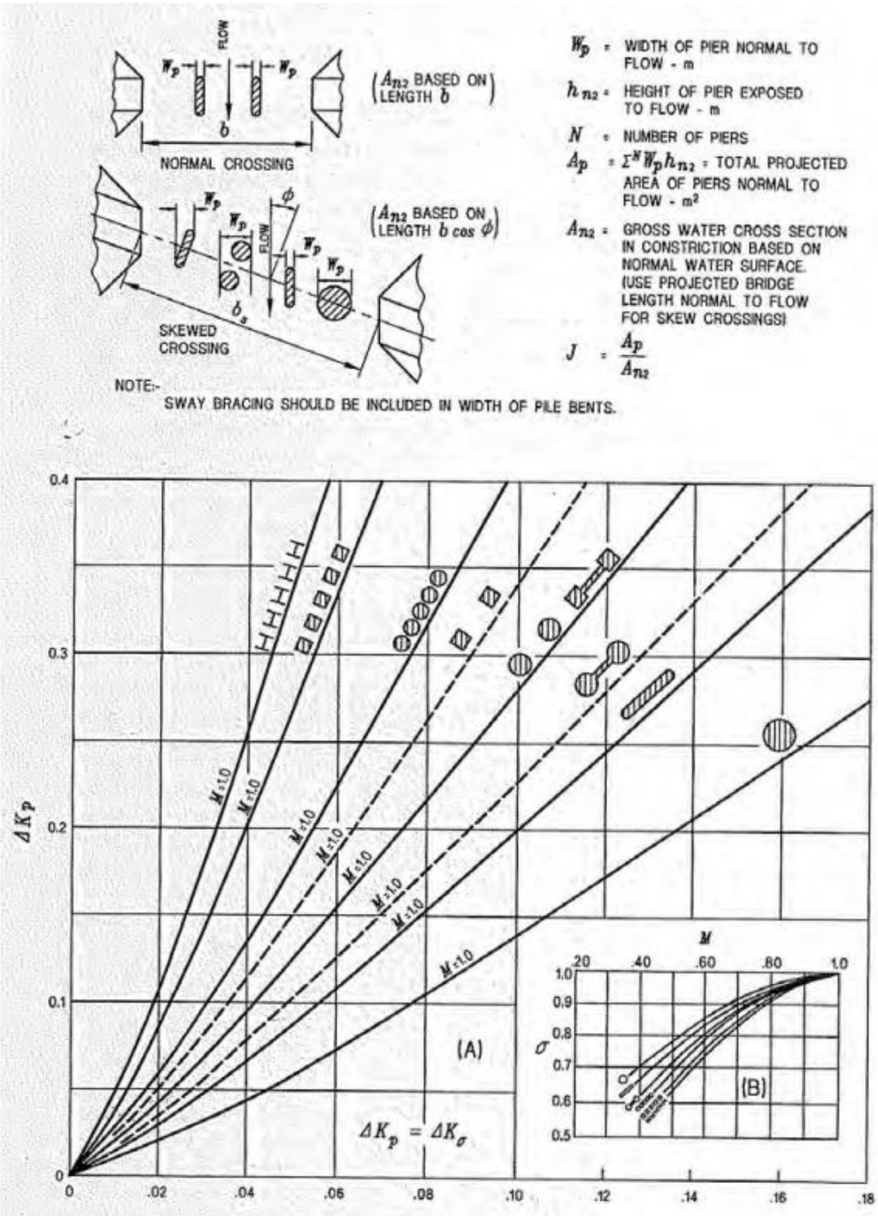


Figure 3-3 Pier Loss Coefficients (from Waterway Design, AustRoads, 1994)

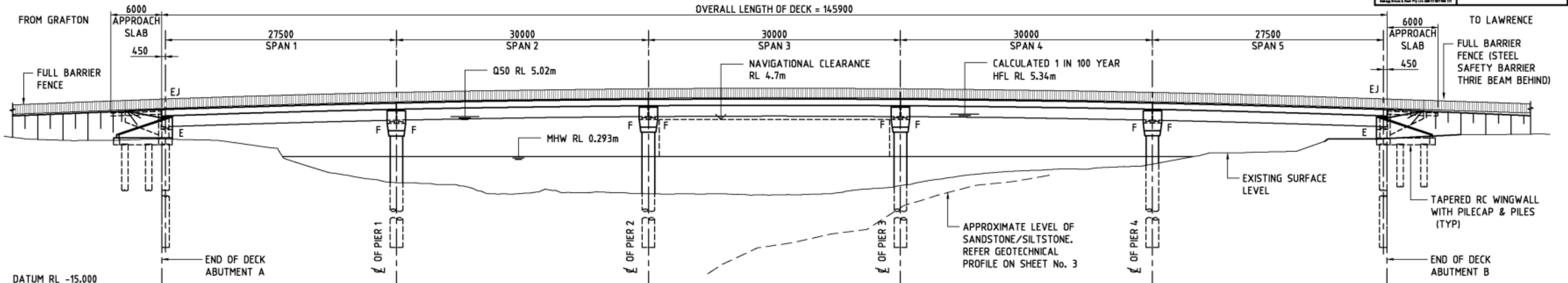
Figure 3-4 is a photograph of the existing bridge on Sportsmans Creek. For calculating the J value (fraction of the area blocked by piers), the entire bridge opening has been determined and one form loss value, Δk_p (refer to Figure 3-3), has been applied across all of the TUFLOW FC cells representing the bridge structure (refer to Figure 3-2). An average J value has been estimated based on the 20%, 2% and 1% AEP design event peak water levels at the bridge. Based on drawings of this bridge provided by KBR, Δk_p has an estimated value of 0.27 (i.e. normal crossing with three spill through vertical piers and two central circular columns connected by bracing).

Figure 3-4 Photograph of existing bridge on Sportsmans Creek

3.4.2 Proposed scenario model

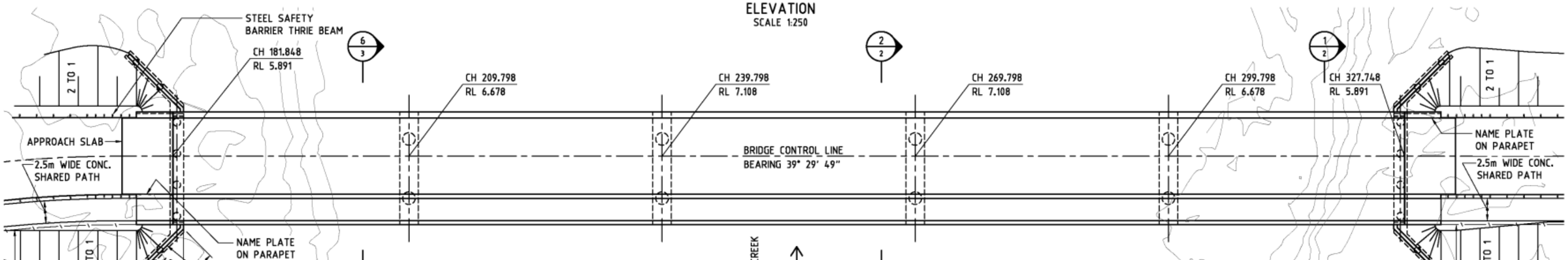
Details of the proposed bridge have been included in the model based on structure details provided by KBR (refer to Figure 3-5 on the next page). In addition to including the proposed bridge structure, the existing bridge structure has been modified to remove the bridge deck and piers with the exception of the north pier which has been retained.

The proposed bridge has been modelled as a TUFLOW FC within the model, with one form loss value, $\Delta k_{p,}$ applied across all TUFLOW FC cells representing the bridge structure. An average J value has been estimated based on the 20%, 2% and 1% AEP design event peak water levels at the bridge. The proposed bridge has an estimated Δk_p value of 0.28 (i.e. normal crossing with a total of 8 circular piers arranged in pairs perpendicular to the direction of flow).

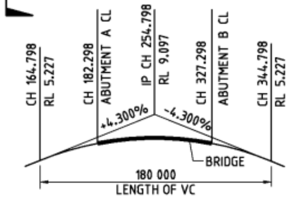


DESIGN SURFACE LEVEL ON BRIDGE CONTROL LINE RL	5.891	6.678	7.108	7.108	6.678	5.891
APPROXIMATE EXISTING SURFACE LEVEL ON BRIDGE CONTROL LINE RL	2.4	-2.8	-4.1	-3.1	-0.6	2.9
CHAINAGE ON BRIDGE CONTROL LINE	181.848	209.798	239.798	269.798	299.798	327.748

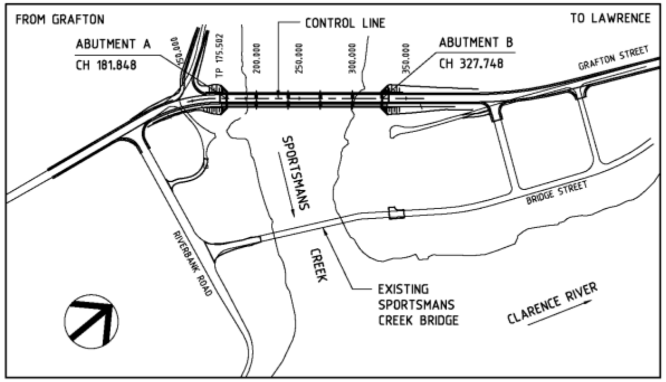
ELEVATION
SCALE 1:250



PLAN
SCALE 1:250



VERTICAL ALIGNMENT DIAGRAM
NOT TO SCALE



SITE PLAN
NOT TO SCALE

LOCALITY PLAN
THE BRIDGE SITE IS APPROXIMATELY 656km BY ROAD FROM SYDNEY

GENERAL NOTES

SCALE 0 5 10 15 20 25m

DIMENSIONS ARE IN MILLIMETRES.
CHAINAGES AND REDUCED LEVELS ARE IN METRES.
REDUCED LEVELS ARE RELATED TO AUSTRALIAN HEIGHT DATUM
E DENOTES EXPANSION BEARING
F DENOTES FIXED BEARING
EJ DENOTES EXPANSION JOINT
BH101 DENOTES BOREHOLE. REFER GEOTECHNICAL INVESTIGATION AND INTERPRETATION REPORT No. 137622029-005-R-Rev1 BY GOLDER ASSOCIATES FOR DETAILS
CONCRETE BRIDGE DECK WATERPROOFING MEMBRANE SHALL CONFORM TO ROADS AND MARITIME SERVICES SPECIFICATION B344 OR BPC2005/02.
WATERPROOFING MEMBRANE SHALL BE OVERLAYED WITH 75mm THICK ASPHALT.

ACCEPTED
PRINCIPAL BRIDGE ENGINEER
DATE

ISSUE	DATE	REVISION	PREP	CHECK	AUTH
C	22 AUGUST 2014	20%CONCEPT DESIGN FOR USE			
B	5 AUGUST 2014	RMS PM COMMENTS AMENDMENTS			
A	25 JULY 2014	20%CONCEPT DESIGN FOR COMMENT			

CLARENCE VALLEY COUNCIL
MR152 - GRAFTON TO YAMBA ROAD
BRIDGE OVER SPORTSMANS CREEK

CONCEPT DRAWINGS - SHEET 1

Kellogg Brown & Root Pty Ltd
KBR
ABN 91 007 660 317

TRANSPORT, ROADS AND MARITIME SERVICES
BRIDGE AND STRUCTURAL ENGINEERING BRANCH
110 GEORGE STREET PARRAMATTA NSW 2150
PHONE (02) 8837-0802 FACSIMILE (02) 8837-0055
CLIENT:

PREPARED	CHECKED	REGISTRATION No OF PLANS
DESIGN		
DRAWING D. CARTER	B. CONDON	BRIDGE NUMBER
SENIOR BRIDGE ENGINEER (NEW DESIGN)		ISSUE STATUS: PRELIMINARY
		SHEET No 1 ISSUE C

CAD No

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Sensitivity to changes in the form losses used to represent the bridge piers has been undertaken as discussed in Section 4.2.4.

3.5 Land-use Delineation

3.5.1 Existing scenario model

The land-use delineation within the Lawrence 2D model domain has been refined to more accurately define the land-uses for the 15m grid resolution. In addition to refining the land-uses used in the Lower Clarence River Flood Model Update (BMT WBM, 2013), the additional land-uses detailed in Table 3-1 have been introduced in the Lawrence 2D model domain based on a review of aerial photography (Google Earth, 2014).

Table 3-1 Additional Land-use Types Included in the Lawrence 2D Model Domain

Land-use type	Manning's n coefficient
Crops	0.1
Forest	0.2
Urban Blocks	0.3
Roads	0.02

3.5.2 Proposed scenario model

Minor adjustments to the roads land-use layer were included in the proposed scenario model to account for the proposed road and bridge alignment.

4 Model Results

4.1 Existing scenario model

4.1.1 Design model runs

The existing scenario model has been simulated for the 20% AEP, 2% AEP and 1% AEP events as per the Lower Clarence River Flood Model Update.

4.1.2 Peak water levels

The peak water levels from the existing scenario model have been checked against the model results from the Lower Clarence River Flood Model Update (BMT WBM, 2013) to ensure consistency between results from the existing model configuration and the Lower Clarence River Flood Model Update. The results indicate that there is a negligible difference in peak water levels between models.

4.2 Proposed scenario model

4.2.1 Design and climate change model runs

The proposed scenario model has been simulated for the 20% AEP, 2% AEP and 1% AEP design flood events as per the Lower Clarence River Flood Model Update.

Climate change model runs have been undertaken for the 1% AEP event for the following climate change scenarios:

- 10% increase in rainfall intensity combined with a 0.4m rise in sea levels; and
- 20% increase in rainfall intensity combined with a 0.9m rise in sea levels.

4.2.2 Peak water levels

Peak water levels from the proposed scenario model have been compared to existing scenario model results to determine the impact of the proposed structure on water levels in the vicinity of the proposed bridge. Appendix A4 to A6 presents a series of level difference maps showing both the differences in water levels across the 15m model grid and at seven specific markers along Sportsmans Creek. These markers are located upstream and downstream of the existing and proposed structures and along the left bank of Sportsmans Creek between Bridge Street and Grafton Street. The markers have been located to identify any localised changes in water levels as a result of the proposed bridge works. A table is included on the maps showing the peak water surface elevations for both the existing and proposed scenarios and the difference in peak water levels at the seven markers.

The results indicate that the peak flood levels are consistent in elevation across the seven flood markers and that that the proposed works have a negligible impact on peak water levels for each of the design flood events assessed. The consistency in peak flood levels across the seven flood markers corresponds with the peak Clarence River water levels which dominates flooding in Lawrence for the modelled design flood events.

Peak water level results of the climate change analysis are presented in Table 4-1.

Table 4-1 Peak Water Levels for 1% AEP Climate Change Analysis

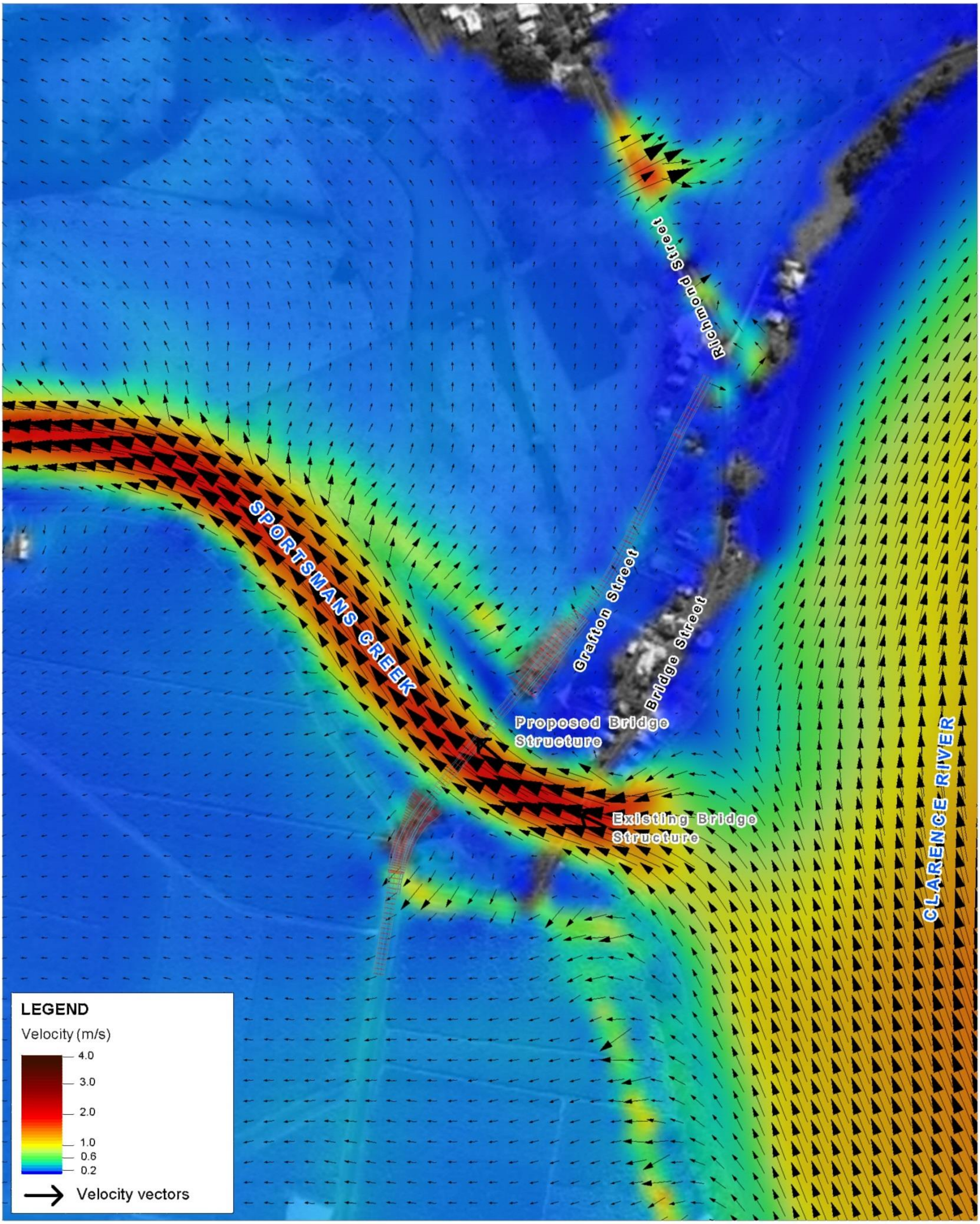
Flood level marker ID (refer to Figure A4)	Peak water levels (m AHD)	
	10% increase in rainfall intensity and 0.4m rise in sea levels	20% increase in rainfall intensity 0.9m rise in sea and levels
1	5.7	6.2
2	5.7	6.2
3	5.7	6.2
4	5.7	6.2
5	5.7	6.2
6	5.7	6.2
7	5.7	6.2

4.2.3 Peak velocities

Figure A-7 to Figure A-9 in Appendix A shows the peak velocities for each of the three design events assessed. The peak channel velocities at the location of the proposed structure range from 1.5 m/s for the 20% AEP event to 1.9 m/s for the 1% AEP event (note that velocities represent depth averaged conditions from the 2D model).

Of the three design flood events assessed, the peak channel velocities at the location of the proposed structure occur for the 1% AEP event. The peak velocities occur when flows in the Clarence River back up through Sportsmans Creek as indicated in Figure 4-1. These peak velocities occur in advance of the peak in the Clarence River flood wave. As discussed in Section 1.2, river flows originating from upstream of Grafton dominate flooding in the Lower Clarence Valley and reverse/backflows is a characteristic of flood mechanisms in the tributaries of the Lower Clarence River Valley.

The peak channel velocity profile at the location of the proposed bridge structure is presented in Figure 4-2. This velocity profile has informed the assessment of scour at the abutments and piers of the proposed bridge as detailed in Section 4.2.5.



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Velocity Vectors: 1% AEP Event

Figure: 4-1

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0 100 200m

Approx. Scale

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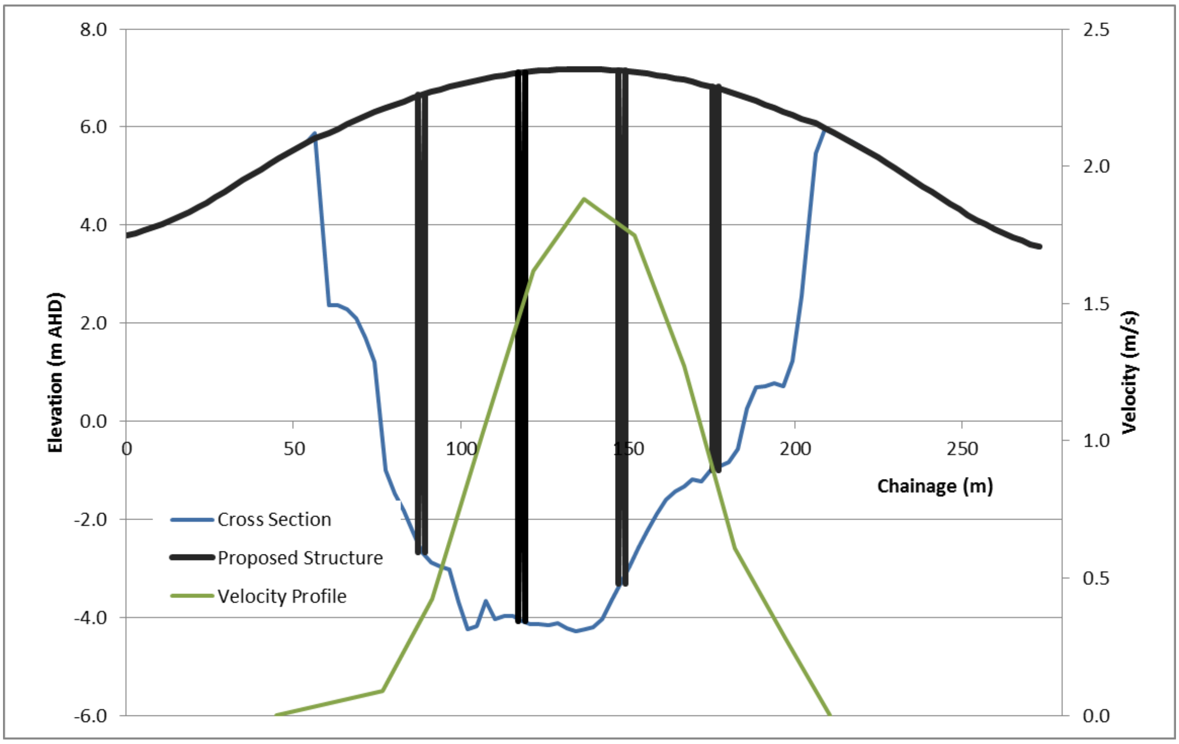

Figure 4-2 Channel Velocity Profile at the Location of the Proposed Bridge Structure for the 1% AEP Event

4.2.4 Sensitivity analysis

Sensitivity to the form loss adopted for the bridge piers (refer to Section 3.4.1) has been undertaken by increasing the form loss by 30%. The model has been run for the 1% AEP design event and the results indicate that changes to the form loss have a negligible impact on peak water levels and peak channel velocities at the location of the proposed bridge. This is not unexpected given the relatively minor pier area in relation to overall channel cross sectional area.

4.2.5 Scour assessment

An estimation of scour at the abutments and piers of the proposed bridge has been undertaken for the 1% AEP design flood event (i.e. the design flood event which produces the highest channel velocities at the location of the proposed bridge – refer to Section 4.2.2). The estimation of scour has been undertaken using Hydraulic Engineering Circular No. 18 “Evaluating Scour at Bridges” (FHWA, 2012) for non-cohesive bed material.

Contraction scour occurs when the flow area of the watercourse is reduced by the bridge constricting flow. Accordingly, the scour calculations are limited to the local scour at the abutments and pier.

The estimated scour depths at the abutments and piers are provided in Table 4-2. A summary of the local scour calculations at the abutments (based on HIRE equation) and piers (based on CSU equation) is provided in Appendix B.

Table 4-2 Estimated Scour Depths at the Abutments and Piers of the Proposed Bridge

Location (from left bank to right bank looking downstream – refer to Figure 3-5)						
	Left bank abutment	Pier 1 (pair of circular columns)	Pier 2 (pair of circular columns)	Pier 3 (pair of circular columns)	Pier 4 (pair of circular columns)	Right bank abutment
Scour depth (m)	1.8	0.9	1.7	1.9	1.3	2.5

5 Conclusions

The Lower Clarence flood model developed as part of for the Lower Clarence River Flood Model Update (BMT WBM, 2013) has been updated at Lawrence to include the addition of a nested 2D model domain, adjustments to the model topography, changes to the land-use delineation, updates to the existing bridge and the addition of the proposed bridge.

The updated model has been verified against model results from the Lower Clarence River Flood Model Update (BMT WBM, 2013). The impact of the proposed scenario on peak water levels has been assessed for the 20%, 2% and 1% AEP design flood events with the results indicating a negligible impact on peak water levels.

The peak channel velocities have been assessed for the design flood event (20% AEP, 2% AEP and 1% AEP events) which produced the highest channel velocities at the location of the proposed bridge. Analysis of model results indicates that the 1% AEP event produces the highest channel velocities at 2.1m/s. These results are based on critical duration flooding on the Clarence River and occur as a result of reverse/backflow up Sportsmans Creek.

Bridge scour calculations were undertaken in accordance with methods outlined in HEC-18 “Evaluating Scour at Bridges” (FHWA, 2012). Given the configuration of the proposed bridge structure and local approach flow conditions, no significant contraction scour is considered. Local abutment and pier scour depths for the 1% AEP design flood condition have been estimated to range from 0.9m up to 2.5m.

6 References

BMT WBM, 2011, Lower Clarence Flood Model Update 2013.

AUSTROADS, 1994, “Waterway Design”, A Guide to the Hydraulic Design of Bridges Culverts and Floodways, Austroads Publication AP-23/94, 1994.

BMT WBM, nd, Modelling Bridge Piers and Afflux in TUFLOW

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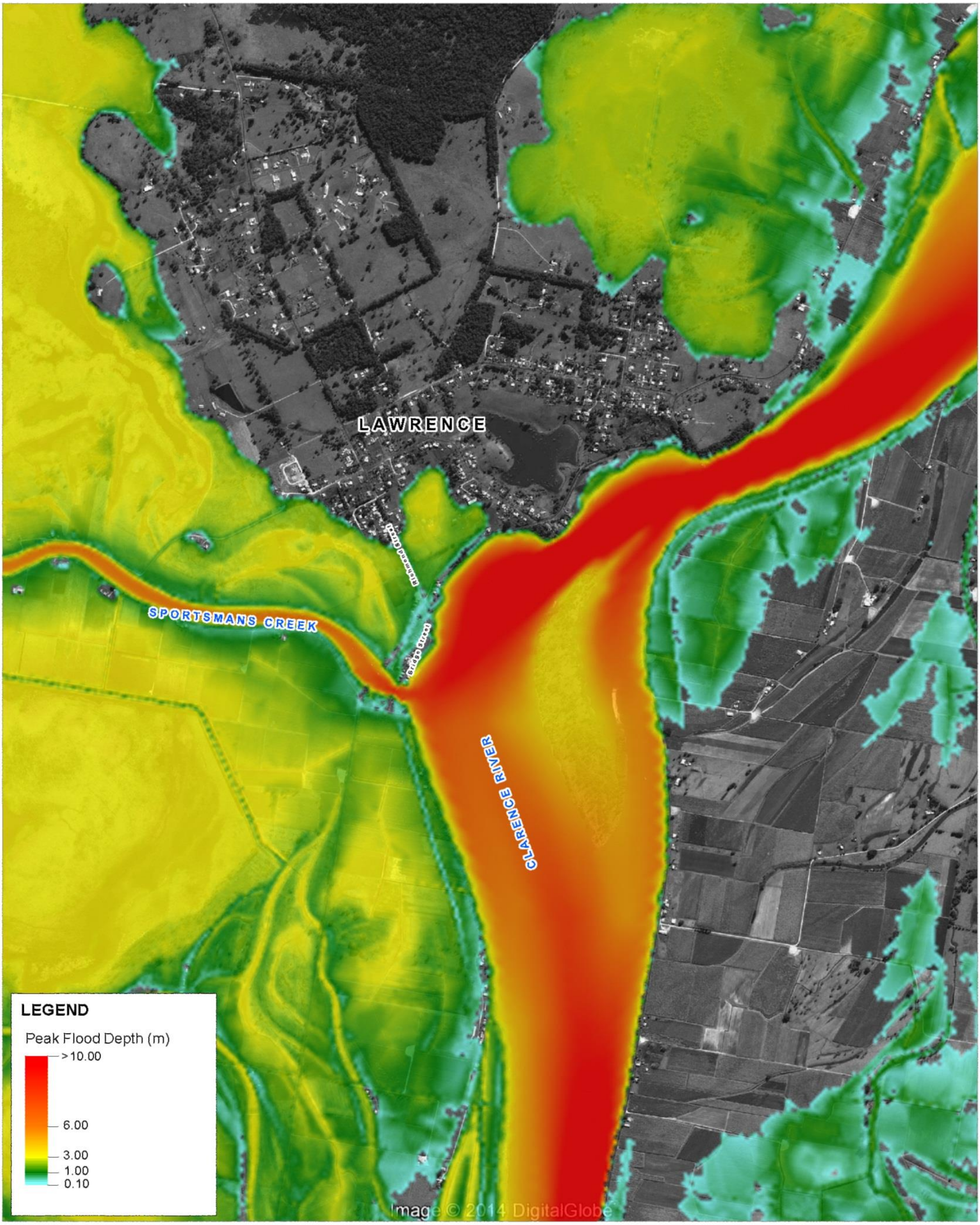
Appendix A Flood maps



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Depths: 20% AEP Event

Figure: A-1

Rev: -

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N

0 0.5 1km

Approx. Scale

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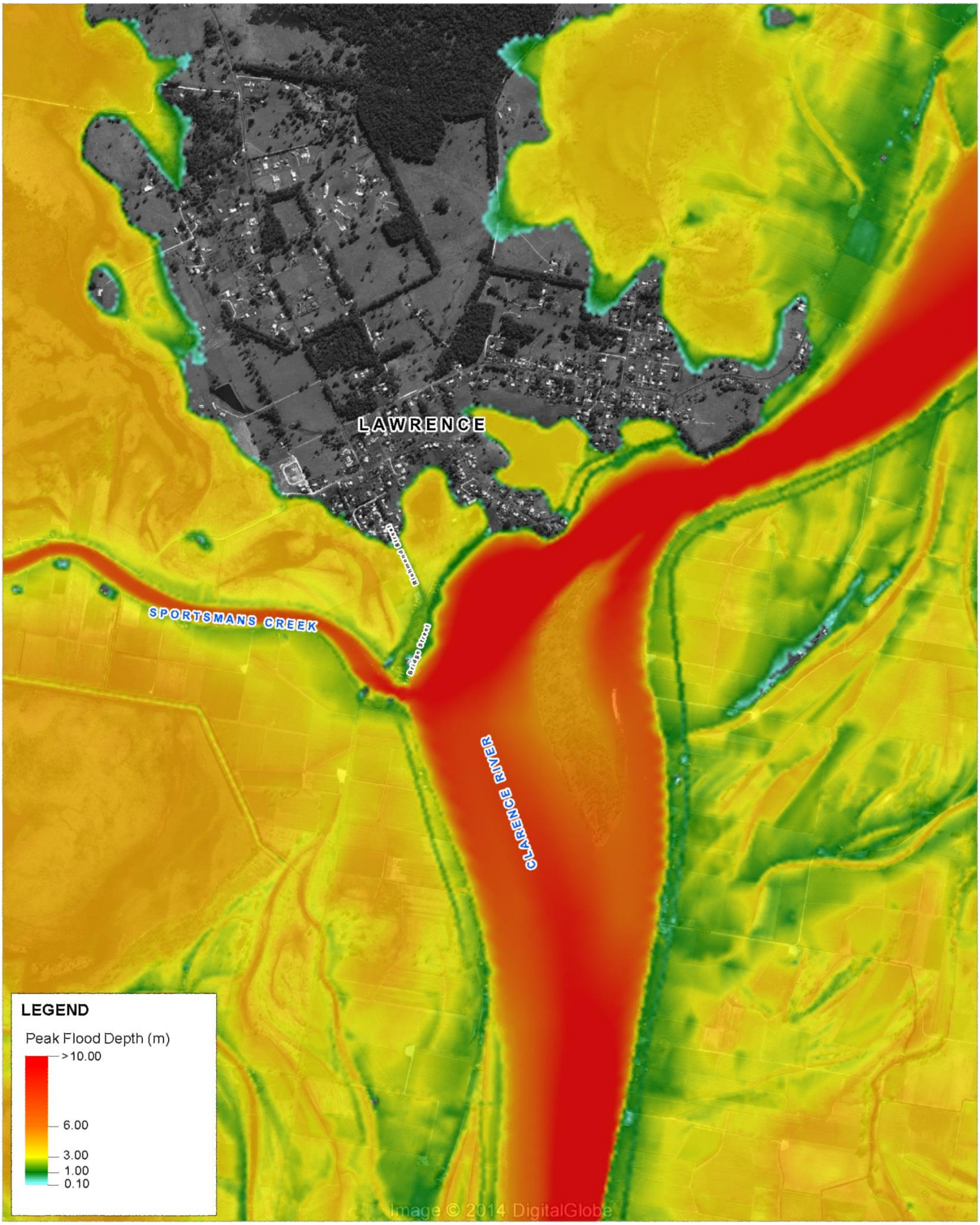
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-1_005YR_Depth.wor



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Depths: 2% AEP Event

Figure: **A-2**

Rev: **-**

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N

0 0.5 1km

Approx. Scale

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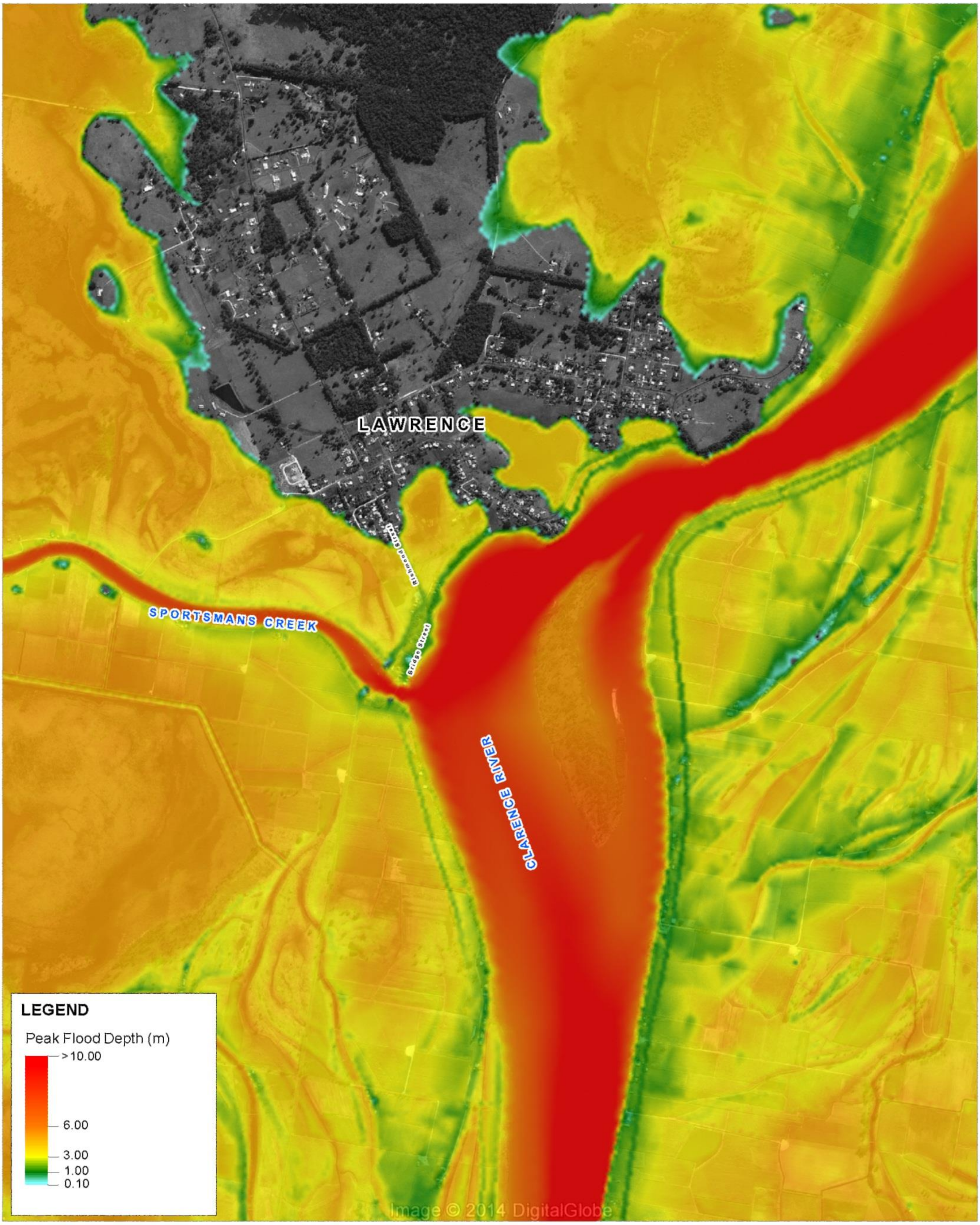
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-2_050YR_Depth.wor



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Depths: 1% AEP Event

Figure: **A-3**

Rev: **-**

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N

0 0.5 1km

Approx. Scale

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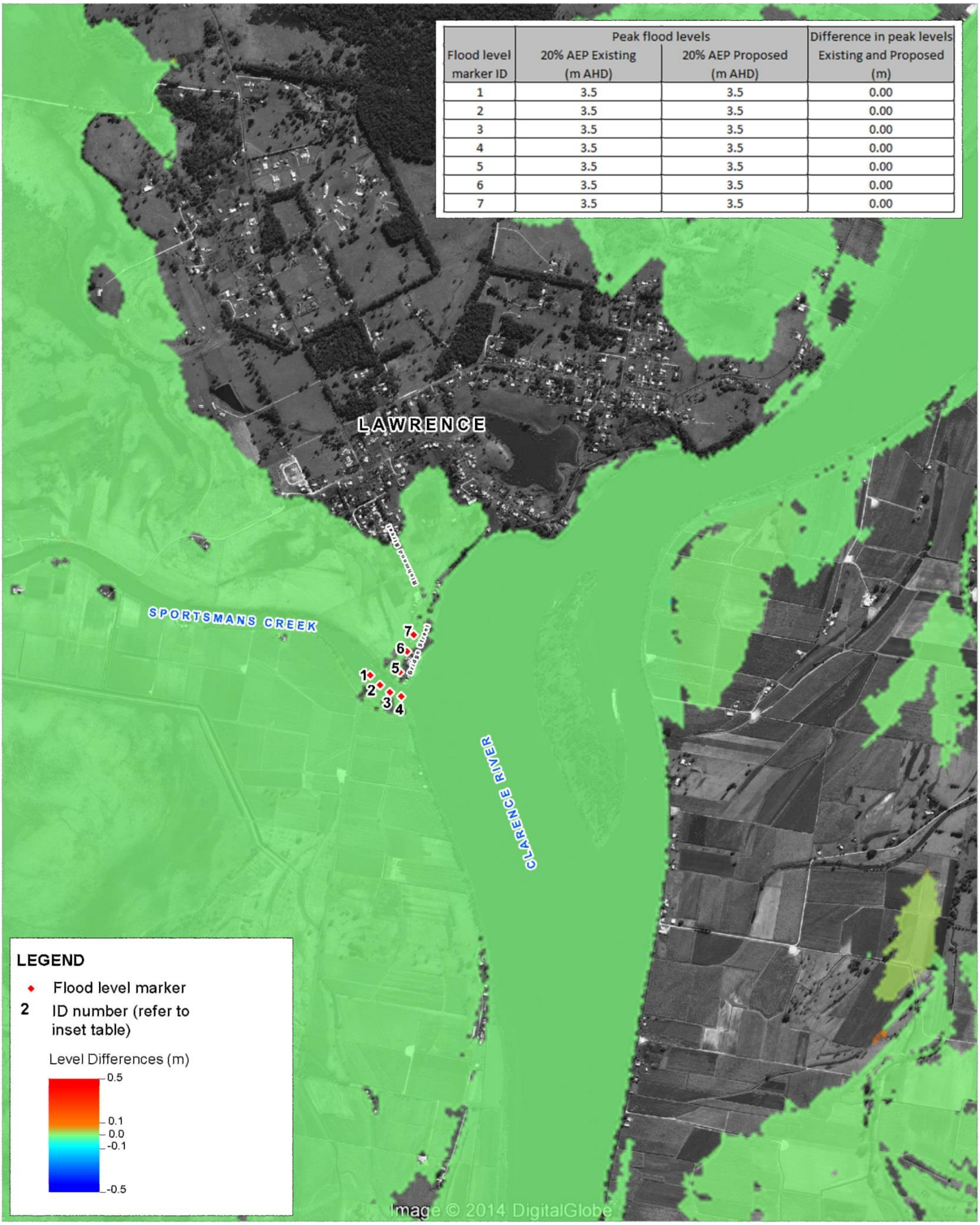
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-3_100YR_Depth.wor



Flood level marker ID	Peak flood levels 20% AEP Existing (m AHD)	Peak flood levels 20% AEP Proposed (m AHD)	Difference in peak levels Existing and Proposed (m)
1	3.5	3.5	0.00
2	3.5	3.5	0.00
3	3.5	3.5	0.00
4	3.5	3.5	0.00
5	3.5	3.5	0.00
6	3.5	3.5	0.00
7	3.5	3.5	0.00

Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Level Differences: 20% AEP Event

Figure: **A-4**

Rev: **-**

N

0 0.5 1km
Approx. Scale

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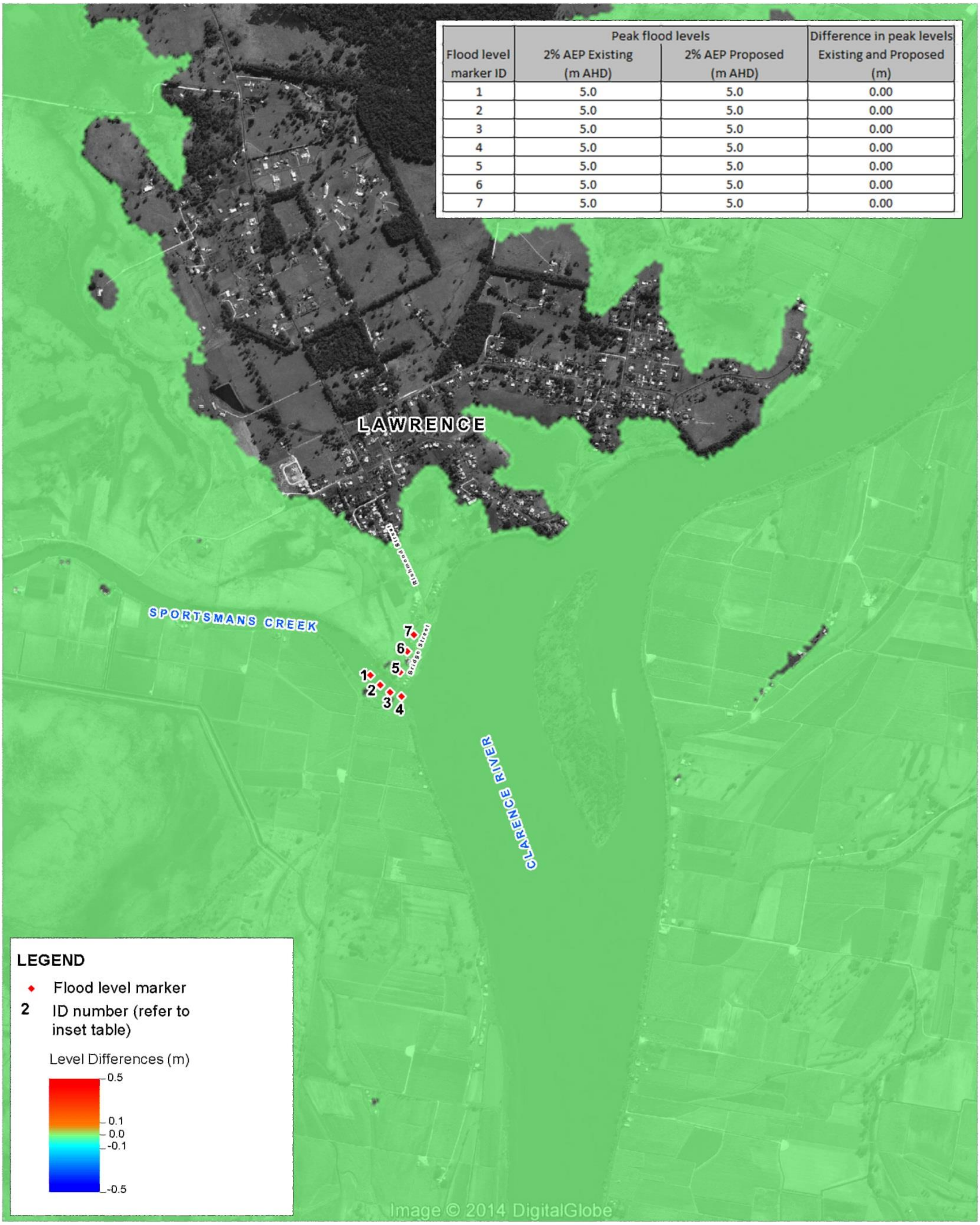
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-4_005YR_Level_Diff.wor



Flood level marker ID	Peak flood levels		Difference in peak levels
	2% AEP Existing (m AHD)	2% AEP Proposed (m AHD)	Existing and Proposed (m)
1	5.0	5.0	0.00
2	5.0	5.0	0.00
3	5.0	5.0	0.00
4	5.0	5.0	0.00
5	5.0	5.0	0.00
6	5.0	5.0	0.00
7	5.0	5.0	0.00

LEGEND

◆ Flood level marker

2 ID number (refer to inset table)

Level Differences (m)

0.5
0.1
0.0
-0.1
-0.5

Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Level Differences: 2% AEP Event

Figure: **A-5**

Rev: **-**

N

0 0.5 1km
Approx. Scale

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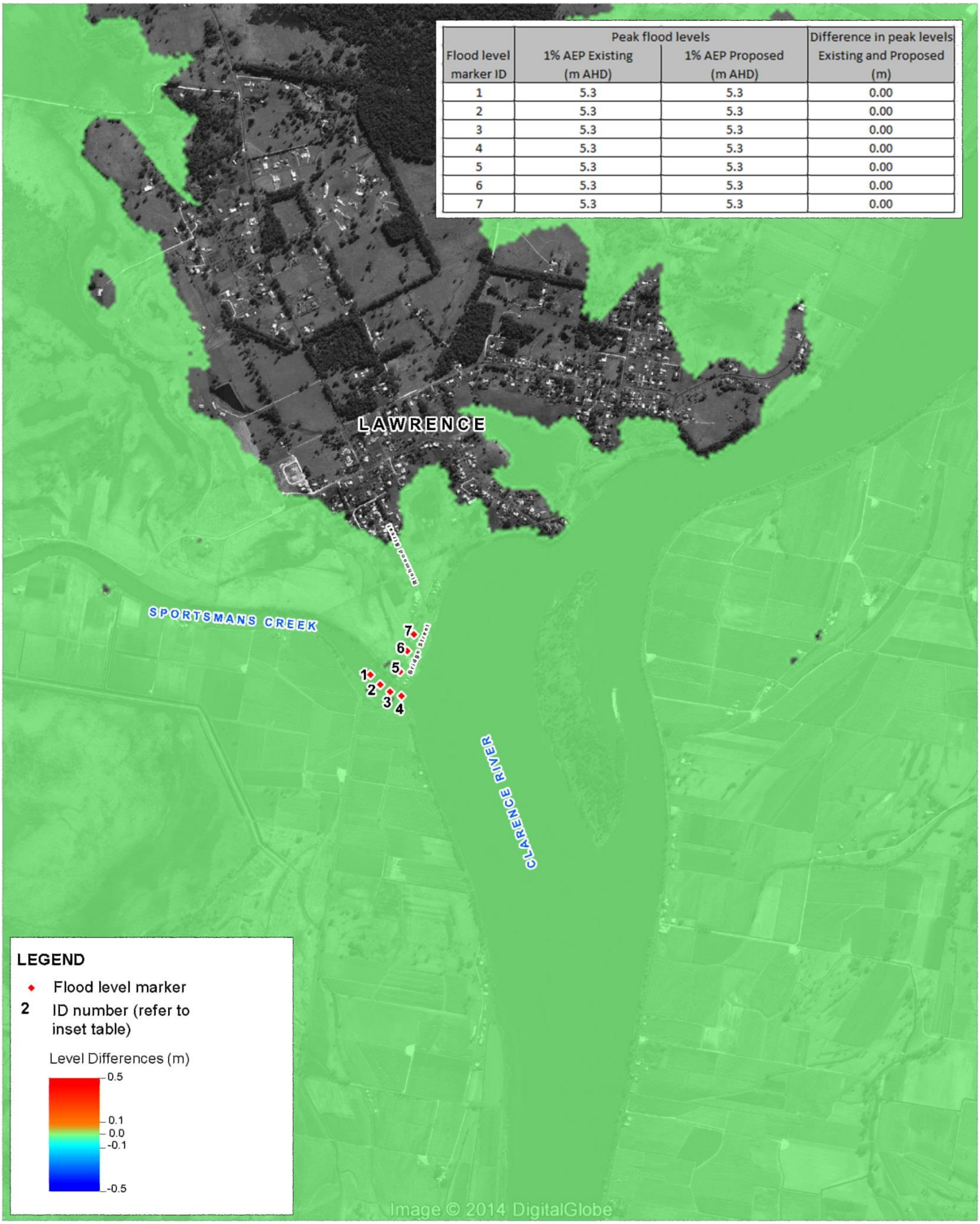
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-5_050YR_Level_Diff.wor



Flood level marker ID	Peak flood levels: 1% AEP Existing (m AHD)	Peak flood levels: 1% AEP Proposed (m AHD)	Difference in peak levels Existing and Proposed (m)
1	5.3	5.3	0.00
2	5.3	5.3	0.00
3	5.3	5.3	0.00
4	5.3	5.3	0.00
5	5.3	5.3	0.00
6	5.3	5.3	0.00
7	5.3	5.3	0.00

Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Level Differences: 1% AEP Event

Figure: **A-6**

Rev: **-**

N

0 0.5 1km
Approx. Scale

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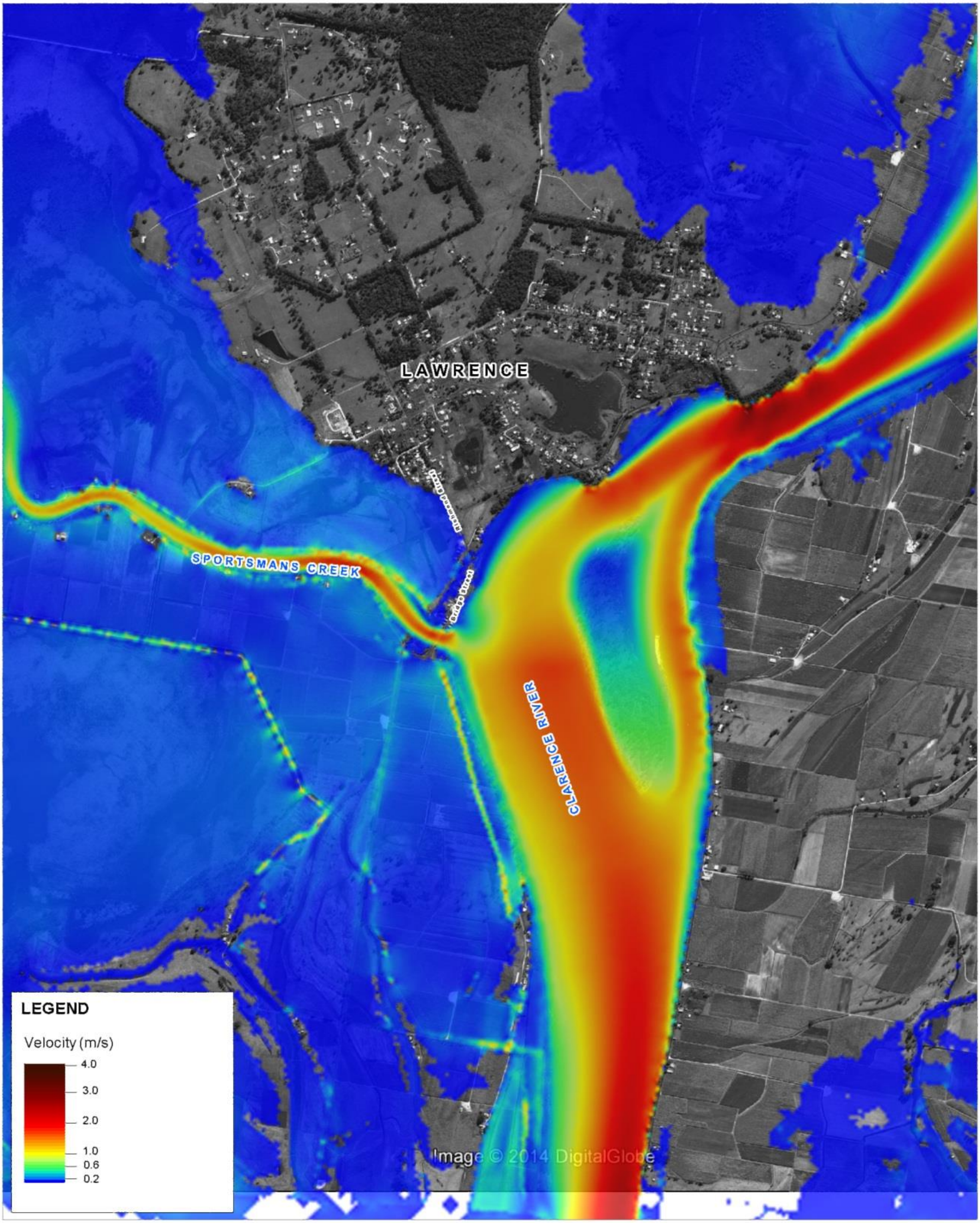
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-6_100YR_Level_Diff.wor



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Velocities: 20% AEP Event

Figure: **A-7**

Rev: **-**

N

0 0.5 1km

Approx. Scale

BMT WBM

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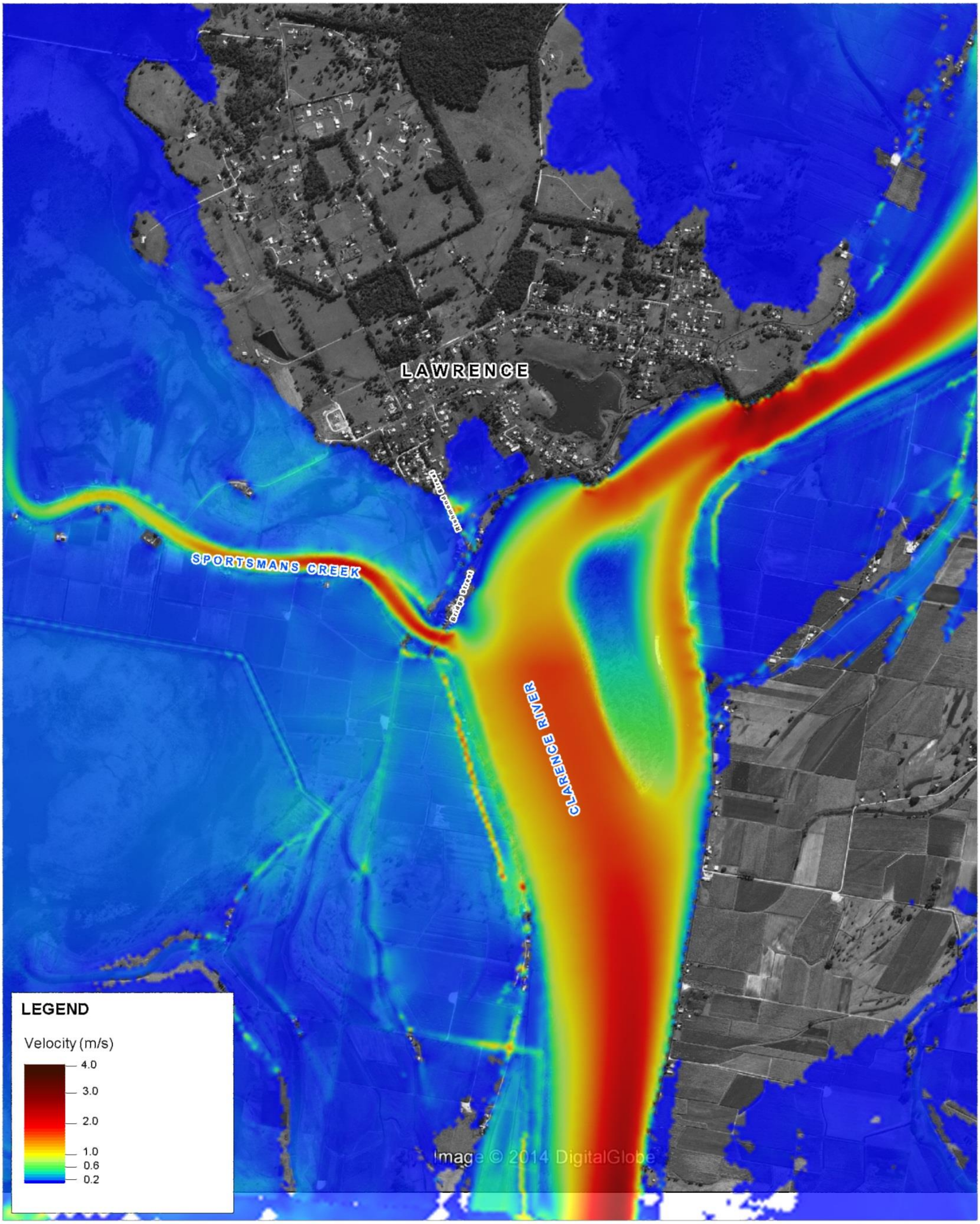
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-7_005YR_Velocity.wor



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Velocities: 2% AEP Event

Figure: **A-8**

Rev: **-**

N

0 0.5 1km

Approx. Scale

BMT WBM

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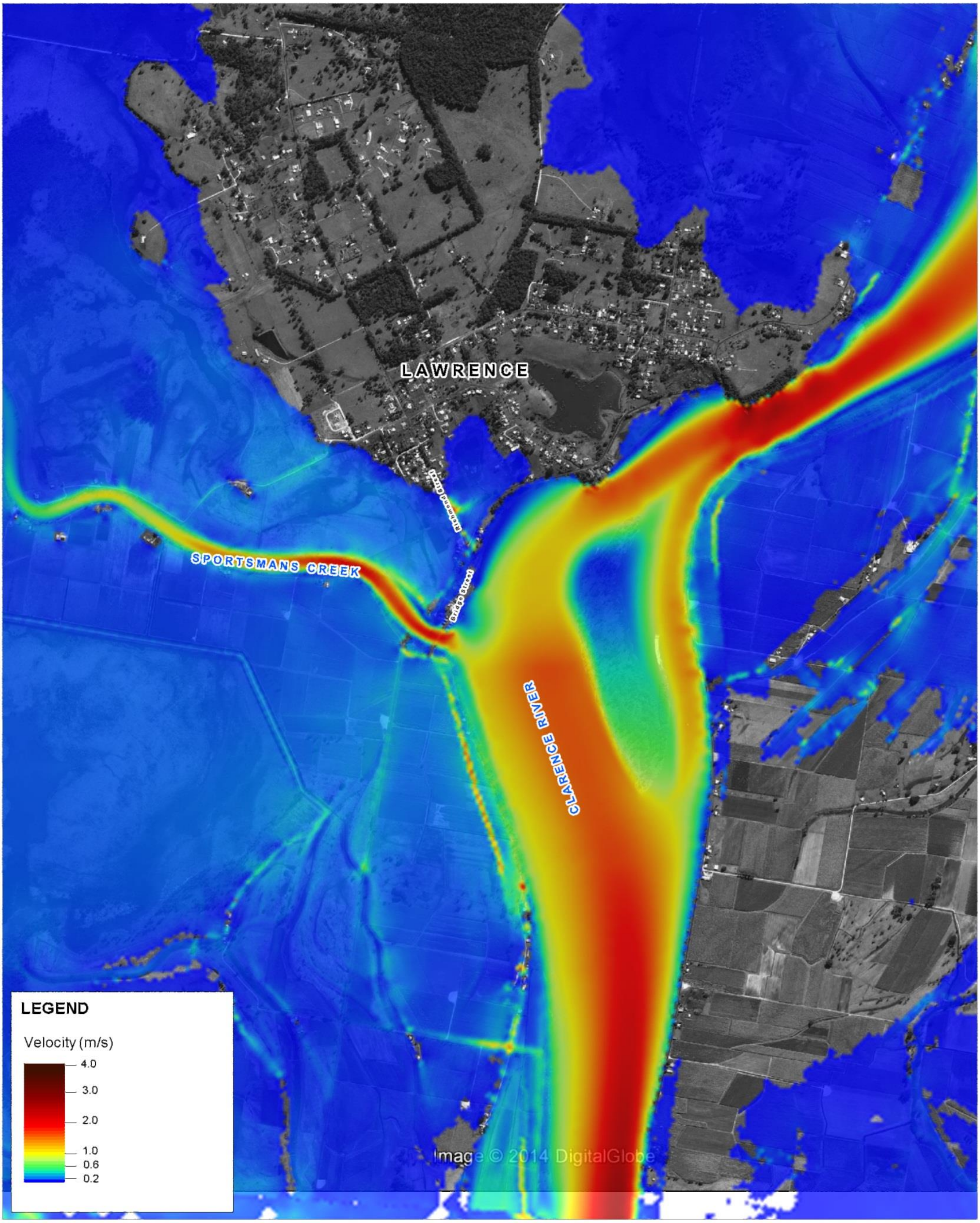
Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-8_050YR_Velocity.wor



Title:

Proposed Upgrade of Sportsmans Creek Bridge
Maximum Flood Velocities: 1% AEP Event

Figure: **A-9**

Rev: **-**

N

0 0.5 1km

Approx. Scale

BMT WBM

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Filepath : S:WATERPROJECTSS20082 - Sportsman Creek Bridge ProjectDraftingWORFigureA-9_100YR_Velocity.wor

Appendix B Bridge Scour Calculations

B.1 Abutment scour

8.6.2 HIRE Abutment Scour Equation

An equation based on field data of scour at the end of spurs in the Mississippi River (obtained by the USACE) can also be used for estimating abutment scour (FHWA 2001). This field situation closely resembles the laboratory experiments for abutment scour in that the discharge intercepted by the spurs was a function of the spur length. The modified equation, referred to herein as the HIRE equation, is applicable when the ratio of projected abutment length (L) to the flow depth (y_1) is greater than 25. This equation can be used to estimate scour depth (y_s) at an abutment where conditions are similar to the field conditions from which the equation was derived:

$$\frac{y_s}{y_1} = 4\,Fr^{0.33}\,\frac{K_1}{0.55}\,K_2 \qquad (8.2)$$

where:

- y_s = Scour depth, ft (m)
- y_1 = Depth of flow at the abutment on the overbank or in the main channel, ft (m)
- Fr = Froude Number based on the velocity and depth adjacent to and upstream of the abutment
- K_1 = Abutment shape coefficient (from Table 8.1)
- K_2 = Coefficient for skew angle of abutment to flow calculated as for Froehlich's equation (Section 8.7.1)

If L'/y1 >25, HIRE equation is appropriate (where L' is the length of active flow obstructed by the abutment)

L' (m)	150		
	LEFT	RIGHT	
y1	1.3	2.95	*depth of flow at abutment in the main channel
V1	0.1	0.4	*velocity at abutment in main channel
Fr	0.03	0.07	=V/((g.y)^(1/2))
K1	0.82	0.82	vertical abutment with wingwalls
theta (deg	90	90	
K2	1.00	1.00	= (theta/90deg)^0.13
ys	1.84	2.53	

TOTAL SCOUR DEPTH AT ABUTMENT

Total scour depth (yt) = Contraction scour + Abutment scour

NOTE: Contraction scour was calculated for the main channel section

yt (m)	1.84	2.53

B.2 Pier scour

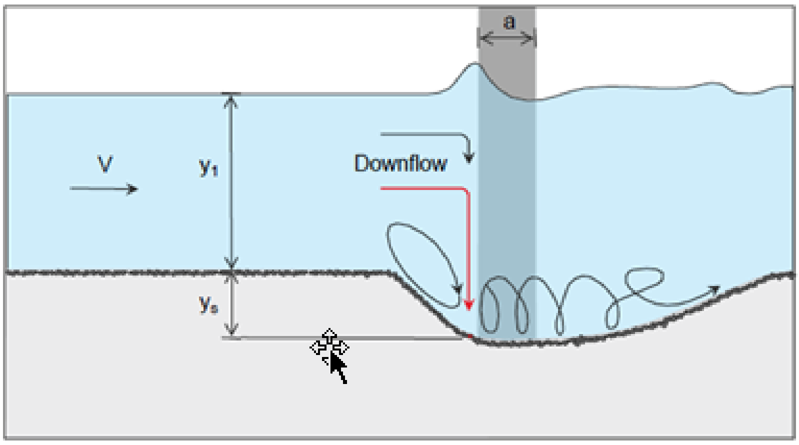

Figure 7.2. Definition sketch for pier scour.

The HEC-18 equation is:

$$\frac{y_s}{y_1} = 2.0\ K_1\ K_2\ K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{0.43} \qquad (7.1)$$

As a Rule of Thumb, the maximum scour depth for round nose piers aligned with the flow is:

$y_s \leq 2.4$ times the pier width (a) for $Fr \leq 0.8$ (7.2)
$y_s \leq 3.0$ times the pier width (a) for $Fr > 0.8$

In terms of y_s/a, Equation 7.1 is:

$$\frac{y_s}{a} = 2.0\ K_1\ K_2\ K_3 \left(\frac{y_1}{a}\right)^{0.35} Fr_1^{0.43} \qquad (7.3)$$

where:

y_s = Scour depth, ft (m)
y_1 = Flow depth directly upstream of the pier, ft (m)
K_1 = Correction factor for pier nose shape from Figure 7.3 and Table 7.1
K_2 = Correction factor for angle of attack of flow from Table 7.2 or Equation 7.4
K_3 = Correction factor for bed condition from Table 7.3
a = Pier width, ft (m)
L = Length of pier, ft (m)
Fr_1 = Froude Number directly upstream of the pier = $V_1/(gy_1)^{1/2}$
V_1 = Mean velocity of flow directly upstream of the pier, ft/s (m/s)
g = Acceleration of gravity (32.2 ft/s^2) (9.81 m/s^2)

Pier No. 1 – Pair of cylinders (FROM LEFT BANK)

#	2	number of peirs
a	1.5	
L	3	for circular peirs, L = (# . a)
y1	6.35	depth corresponding to peak velocity
V1	0.29	
Fr	0.04	
theta	90	angle of attack of flow i.e. angle the velocity vector makes to the peir
K1	1	
K2	0.63728	
K3	1.1	
ys	0.84	

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Pier No. 2 – Pair of cylinders

#	2	number of peirs
a	1.5	
L	3	for circular peirs, L = (# . a)
y1	7.75	depth corresponding to peak velocity
V1	1.48	
Fr	0.17	
theta	90	angle of attack of flow i.e. angle the velocity vector makes to the peir
K1	1	
K2	0.63728	
K3	1.1	
ys	1.74	

Pier No. 3 – Pair of cylinders

#	2	number of peirs
a	1.5	
L	3	for circular peirs, L = (# . a)
y1	6.95	depth corresponding to peak velocity
V1	1.78	
Fr	0.22	
theta	90	angle of attack of flow i.e. angle the velocity vector makes to the peir
K1	1	
K2	0.63728	
K3	1.1	
ys	1.86	

Pier No. 4 – Pair of cylinders

#	2	number of peirs
a	1.5	
L	3	for circular peirs, L = (# . a)
y1	4.65	depth corresponding to peak velocity
V1	0.86	
Fr	0.13	
theta	90	angle of attack of flow i.e. angle the velocity vector makes to the peir
K1	1	
K2	0.63728	
K3	1.1	
ys	1.29	

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BMT WBM Brisbane	Level 8, 200 Creek Street, Brisbane 4000 PO Box 203, Spring Hill QLD 4004 Tel +61 7 3831 6744 Fax +61 7 3832 3627 Email bmtwbm@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Denver	8200 S. Akron Street, #B120 Centennial, Denver Colorado 80112 USA Tel +1 303 792 9814 Fax +1 303 792 9742 Email denver@bmtwbm.com Web www.bmtwbm.com
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BMT WBM Mackay	PO Box 4447, Mackay QLD 4740 Tel +61 7 4953 5144 Fax +61 7 4953 5132 Email mackay@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Melbourne	Level 5, 99 King Street, Melbourne 3000 PO Box 604, Collins Street West VIC 8007 Tel +61 3 8620 6100 Fax +61 3 8620 6105 Email melbourne@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Newcastle	126 Belford Street, Broadmeadow 2292 PO Box 266, Broadmeadow NSW 2292 Tel +61 2 4940 8882 Fax +61 2 4940 8887 Email newcastle@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Perth	Level 3, 20 Parkland Road, Osborne, WA 6017 PO Box 1027, Innaloo WA 6918 Tel +61 8 9328 2029 Fax +61 8 9486 7588 Email perth@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Sydney	Level 1, 256-258 Norton Street, Leichhardt 2040 PO Box 194, Leichhardt NSW 2040 Tel +61 2 8987 2900 Fax +61 2 8987 2999 Email sydney@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Vancouver	Suite 401, 611 Alexander Street Vancouver British Columbia V6A 1E1 Canada Tel +1 604 683 5777 Fax +1 604 608 3232 Email vancouver@bmtwbm.com Web www.bmtwbm.com