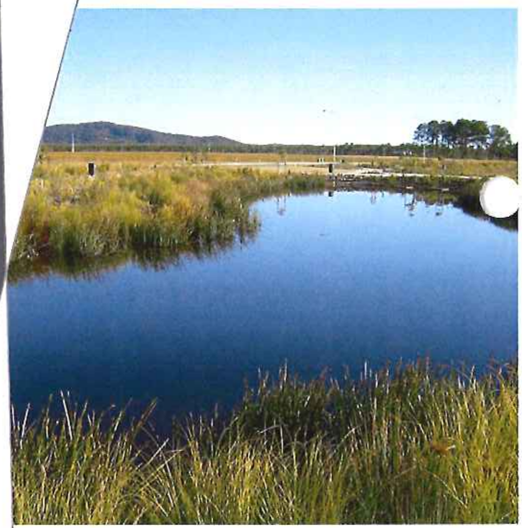
Peer Review

Moorabool Shire Flood Studies

V170467



Prepared for
Moorabool Shire Council

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Attachment 1: Peer Review – Moorabool Shire Flood Studies

Contact Information

Cardno Victoria Pty Ltd
Cardno Victoria Pty Ltd
47 106 610 913

Level 4
501 Swanston Street
Melbourne 3000
Australia

www.cardno.com
Phone +61 3 8415 7777
Fax +61 3 8415 7788

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Author(s):

Name Rob Swan
Principal Engineer

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Approved By:

Name Rob Swan
Manager, Water Engineering

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Executive Summary

Mooroabool Shire Council, in conjuction with Melbourne Water, has prepared proposed Land Subject to Inundation and Special Building Overlays for potential inclusion into the Moorabool Planning Scheme. This peer review has investigated the technical methodology used to determine the location and shape of the proposed planning overlays.

In our view, the flood models used have delivered results that are suitable for inclusion in the Moorabool Planning Scheme. With the exception of the lower Lerderderg study area, the flood extents used in the draft planning overlays are considered appropriate. The proposed flood extents and the resulting Special Building Overlay (SBO) shapes for the lower Lerderderg study area should be recreated, based on the model results using appropriate filtering techniques, such as those described in Melbourne Water's 2016 technical specifications.

Once the lower Lerderderg flood mapping extent and resultant SBO shape is amended, it is recommended that the planning scheme amendment process be recommenced.

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Glossary of Terms

Airborne Laser Scanning (ALS)	A form of survey that uses a laser to scan the shape of an object or surface from a plane or other point. Also known as LiDAR
Average Exceedance Probability (AEP)	The chance of a given discharge or level value being exceeded in a given year. A 1% AEP flood event has a 1% chance of occurring in any year (and is equivalent to the 1 in 100 year ARI event). The conversion from ARI to AEP is shown in the table below

ARI (years)	AEP (%)
1	63%
2	39%
5	18% (usually approximated as the 20% AEP)
10	10%
20	5%
50	2%
100	1%

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Australian Rainfall and Runoff (AR&R)	Australian Rainfall and Runoff is the industry standard resources for the estimation of flood flows in Australia.
Average Recurrence Interval (ARI)	The average or expected value of the period between exceedances of a given discharge or event. A 100-year ARI event would occur, on average, once every 100-years.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Council	The Moorabool Shire Council
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Difference Plot	A map showing the difference in flood depth between two flood events.
Digital Elevation Model (DEM)	A digital elevation model is an electronic representation of the land surface, usually derived from a combination of data sources, including ALS and ground survey.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
HEC-RAS	A 1d hydraulic model, used to estimate water behaviour in rivers and creeks. HEC-RAS is freely available and is developed by the United State Army Core of Engineers.
Hydraulics	The term given to the study of water flow in a river, floodplain, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

Land Subject to Inundation Overlay (LSIO)	This is an overlay in the Moorabool planning scheme that provides for control of the development of land in areas subject to flooding from open watercourses
LIDAR	See Airborne Laser Scanning above
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Melbourne Water Corporation (MW)	The regional floodplain management and drainage authority.
Pluviograph	A recording of the rainfall depths over time. Typically this is recorded in millimetres at 6 minute intervals.
RORB	RORB is an industry standard hydrological model developed in Victoria at Monash University in the 1970's. It is freely available and widely used in Victoria
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In this report, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Runoff Coeffcient	The proportion of rainfall that becomes runoff, usually estimated in a hydrological model. Typically runoff coeffcients will increase as rainfall intensity and/or the proportion of hard surfaces increases.
Special Building Overlay (SBO)	This is an overlay in the Moorabool Planning Scheme that provides for control of the development of land in areas subject to flooding from formal drainage networks, including underground drains..
Topography	A surface which defines the ground level of a chosen area.
TUFLOW	A 1d2d hydraulic model used to predict the flow of water over land and through drainage infrastructure. TUFLOW is a commercially available model.

1 Introduction

The purpose of this peer review is to determine the suitability of the flood modelling and mapping processes in deriving the proposed Land Subject to Inundation Overlay (LSIO) and Special Building Overlay (SBO) for the Moorabool Planning Scheme Amendment C73. The key questions explored as part of the document are:

1. Was the data sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping?
2. The LSIO and SBO maps were derived by using the hydrology model RORB and hydraulic models TUFLOW and HEC-RAS. Was the use of these models appropriate for the purpose of deriving planning scheme overlay maps?
3. Were the hydrology and hydraulic models set up with parameters that are within the normal range?
4. Have the hydrology results been incorporated correctly into the hydraulic model?
5. Are the model runs / results appropriate to produce fit for purpose flood extent mapping?
6. Have appropriate measures been used to produce the final flood extent mapping from the model results?

These questions can be answered through a thorough examination of the modelling processes used to derive the flood extents, a cross check of the methodology used to create the flood extents and assessment of the results against the community experience. We do note that for very severe flood events, especially around thunderstorm flooding, there may be no actual experience of this type of event.

1.1 Review procedure

The review has been completed to address the key queries above through the following methodology:

> Data Review
> Hydrological Modelling Review
> Hydraulic Modelling Review
> Flood Processing and Mapping Review.

For each section, any gaps and their expected impact in terms of accuracy of the overall flood shape and planning overlays have been highlighted

1.2 Projects Reviewed

There are a number of projects that form the inputs for the planning amendment. These projects utilised different hydraulic and hydrological modelling approaches and each will be assessed independently.

The three contributing flood mapping projects will for the main basis of the review plus additional mapping undertaken internally by Melbourne Water (known as the Planning Investigations studies.

The key documents to be reviewed as stated in the brief are:

- Report for Bacchus Marsh Area Floodplain Mapping (GHD, November 2010);
- Lower Lerderderg Catchments Flood Mapping Report (Engeny Water Management, December 2011);
- Ballan Township Flood Study, Final Report (Halcrow Pacific Pty Ltd, November 2011);
- Planning Investigations Methodology (Melbourne Water, 2015)
- Minutes of Special Meeting of Council – 22 June 2016; plus attachments to the agenda item.

The Planning Investigations Methodology is described in Appendix A.

2 Data Review

The three main projects that form the Overlay are:

- Bacchus Marsh Area Floodplain Mapping project (GHD, November 2010);
- Lower Lerderderg Catchments Flood Mapping project (Engeny Water Management, December 2011);
- Ballan Township Flood Study, (Halcrow Pacific Pty Ltd, November 2011);

These projects provide a detailed assessment of pre-existing data used for the purposes of the project. Cardno has undertaken a review of the datasets used in the derivation of the flood models to identify any gaps in the projects and their impact on flood mapping.

Melbourne Water's Planning Investigations team undertook flood analysis for a number of watercourses throughout the Moorabool Shire. The methodology and data used in these projects has been reviewed. These projects are collectively known as the Melbourne Water Planning Investigations models in this report.

2.1 Bacchus Marsh Area Floodplain Mapping Project

This project was undertaken by GHD after concerns were raised regarding the accuracy of an earlier study by WBM Oceanics Australia Pty Ltd (WBM), conducted for Council. The project used the following datasets:

> General MapInfo layers obtained from Melbourne Water during the course of the project:
  - Cadastral information (building footprints, properties, easements, road alignments);
  - Drainage data for Fisken St and Maddingley Park pipe drains;
  - 20 metre (m), 5 m, 1 m and 0.5 m contours of the Bacchus Marsh area;
  - Aerial photographs;
  - Bacchus Marsh Area flood extent (WBM Oceanics Australia Pty Ltd, 2006);
  - Bacchus Marsh Flood Risk Study (WBM Oceanics Australia Pty Ltd, 2006);
  - Data used to create the Digital Elevation Model (DEM) for the 2006 flood study, including surveyed cross-sections for the Werribee and Lerderderg Rivers;
  - TUFLOW model and GIS layers (WBM Oceanics Australia Pty Ltd, 2006);
  - RORB model and GIS layers(WBM Oceanics Australia Pty Ltd, 2006);
  - Thinned LiDAR data for the Bacchus Marsh area;
  - Survey drawings for bridges in the Bacchus Marsh Area; and
  - Benefit cost analysis model.

> Other data:
  - Bureau of Meteorology pluviograph data for stations 87017, 87039 and 87075;
  - Theiss flow data for stations 231200, 231201, 231204, 231211, 231213, 231222, 231230, 231234; and
  - Southern Rural Water (SRW) rating tables for Pykes Creek Reservoir, Melton Reservoir and Merrimu Reservoir.

Cardno has not identified any additional data sources that would be required to complete flood mapping for this project or that would increase the accuracy of the modelled flood results. GHD also undertook significant analysis and review of the previous WBM models of the area and appear to have an excellent understanding of the catchment area.

2.2 Lower Lerderderg Catchments Flood Mapping Project

This project was undertaken by Engeny Water Management and assessed the Melbourne Water main drains flowing into the lower Lerderderg River through Bacchus Marsh. Primarily, this project is for urban flood mapping, with the GHD Bacchus Marsh Area Floodplain Mapping project dealing with the main river and creek systems.

The project used the following data sources:

> Aerial photography;

> Pit and pipe data (Melbourne Water assets and Council assets);

> LiDAR terrain data;

> Main catchment boundaries;

> Contours;

> Planning zones;

> Cadastre boundaries;

> Previous reports; and

> Design data for the Cairns Drive retarding basin and other assets.

Cardno is of the view that the data sources listed are suitable for the development of urban flood models. It is noted that no calibration data is available from the historical flood events. This is not unusual for urban areas as the majority of data is collected along main rivers and creeks. In our view, the datasets used are suitable for the derivation of urban flooding.

2.3 Ballan Township Flood Study

This project was undertaken by Halcrow for the main drainage and creek lines through the Ballan Township area. Halcrow used the following data sources:

> Survey data (supplied by MW) – Existing Connell-Wagner site survey data included manhole and pit locations and levels, and terrain cross sections;

> LiDAR information (supplied by MW) – Received in comma separated value (CSV) format. This was used to create the digital terrain model (DTM) and this information supplemented the site survey where data was not available;

> GIS Melbourne Water asset data (supplied by MW) – Pipe locations with diameters, inverts and types. Pit locations were available but invert levels were not supplied;

> GIS Council asset data (supplied by Moorabool Council) – Pipe locations with diameter, inverts and type. Pit locations with inverts, entrance levels and type.

> Aerial photography (supplied by MW) – Covering all of Catchments A and B, and most of Catchment C. Site visit by Halcrow revealed the small area not covered by aerial photography was not significantly different from adjacent areas;

> Design storm data (procedure sourced from Australian Rainfall and Runoff (AR&R) Volume 1 (1998 reprint)

- Intensity-Frequency-Duration (IFD) parameters for Ballan obtained from Australian Rainfall and Runoff, Volume 2 (1987), to develop the design storms used in the investigation;

> Probable Maximum Precipitation (PMP) design storm data (source -Generalised Short Duration Method (GSDM) 2003) – PMP parameter for the Ballan location obtained from the GSDM, to develop the design storms used in the investigation

> Hydrograph records of Werribee River (supplied by MW) - Flow gauge records, used to determine tailwater conditions.

Cardno is of the view that the data described above is suitable for the derivation of flood extents for the Ballan Township. Cardno is not aware of any additional data that would be useful for the Ballan Township modelling.

2.4 Melbourne Water Planning Investigations Models

These models were developed by Melbourne Water for the rural creeks in the Moorabool Shire. As the impacts of flooding on these creeks are usually limited to land inundation, they do not require the same level of information to develop reasonable flood extents for planning purposes. The Melbourne Water projects used the following information:

- Lidar Data to develop the model topography
- The existing Werribee River RORB model was used to derive overall catchments
- Land surface contours
- Melbourne Water Waterway alignment information.
- Storage information for major water storages including retarding basins and water reservoirs.

Cardno is of the view that these data sets are suitable for the derivation of indicative flood extents in rural areas of the Moorabool Shire.

2.5 Conclusions and recommendations

Based on our review, it is considered that the data used to derive the flood models in each project is suitable for the scale and type of project. Cardno is not aware of any additional data sources that would be required for accurate flood modelling of the Moorabool Shire.

3 Hydrological Modelling

Each project has used the RORB hydrological model to determine the catchment flows. RORB is an industry standard flood model developed in Victoria at Monash University in the 1970's. RORB is the most widely used hydrological model in Victoria and is the hydrological model required by Melbourne Water for flood mapping projects.

To estimate the expected catchment flows, RORB requires a number of inputs, including:

> Catchment and subcatchment sizes;

> The connectivity and flow lengths along streams, known as the model schematisation;

> An understanding of the river or stream form (stream, unlined channel,

> An empirical lag parameter, known as the k_c value, to modify how water is stored and routed through the model. It is important to note that this parameter is not determinable through the examination of the physical parameters of the catchment. K_c values can be determined by calibration and/or validation exercises or through the adoption of regional relationships;

> An estimate of the Fraction Impervious of each subcatchment.

The derivation of each of these parameters is discussed in the following sections for each project.

3.1 Catchment Delineation

For all projects, the catchment and subcatchment delineation has been undertaken based on land surface information. Cardno have reviewed the catchment delineation based on supplied catchment and subcatchment boundaries and available contour data.

For all models, the catchments used are consistient with the land surface contours and are appropriately sized for the nature of the project and the size of the catchments modelled. The subcatchment breakup is also appropriate. Some notes of importance include:

> The GHD model includes the entire Lerderderg River catchment. This is primarily a rural catchment and includes some significant storages.

> The model for the Lower Lerderderg area includes the Bacchus Marsh township. Subcatchment boundaries have been appropriately developed and are generally smaller than those used in the Bacchus Marsh Area Floodplain Mapping project. This allows a better definition of flows at the urban scale. Subcatchment boundaries are defined using appropriate topographical control, such as roads, railway lines and along property boundaries.

> The Ballan RORB model sub-catchments are appropriate. These catchments are generally relatively small in size, with clear delineation between existing rural and urban areas.

> The remaining rural area catchments, used by Melbourne Water to define rural stream flooding are subsets of the larger Werribee River model. These are considered to be appropriate for use.

Overall, Cardno considers the catchment and subcatchment delineation for all the RORB models is suitable for use in the derivation of floodway overlays and is consistent with best practice methods at the time of development.

3.2 RORB Model Schematisation

All the RORB models used in the project have been developed generally in accordance with Melbourne Water's technical specifications for flood mapping. Specifically:

> Reach types are consistent with on-ground conditions, including the use of natural, unlined, lined and drowned reaches.

> Diversions are appropriately considered

> Small farm dams are not specifically included in the model schematisations. This approach is considered to be conservative with regard to modelling and is consistent with normal flood modelling practice.

The schematisations of each model are suitable for the derivation of flood extents.

3.3 Derivation of Fraction Impervious Values

The fraction impervious value of a subcatchment is a measure of the hard surfaces that are directly connected to the drainage network as a proportion of the overall catchment area. This is one of the most important catchment characteristics in urban areas, as significantly more runoff is produced from impervious areas than from pervious areas. In general practice, the fraction imperviousness value of a subarea is based on the land use type, directly measured from aerial photography or a combination of these approaches.

Melbourne Water's technical specifications provide a guide for the expected fraction imperviousness value based on land use type. The values adopted in each project are shown in Table 3-1

Table 3-1 Fraction Impervious Values, Moorabool Shire Flood Projects

Land use	Bacchus Marsh	Lerderderg	Ballan	Melbourne Water
Residential Zones	0.5	0.5	Derived from Aerial photography indicatively 0.5	n/a
Road	0.6-0.7	0.6-0.7	0.6-0.7	0.6-0.7
Farm Zone	0.05	0.1	0.1	0.1
Schools	0.4-0.7 (site dependent)	0.7	0.5	n/a
Township Zones	0.3 (based on aerial photo)	0.2	0.3	0.2
Industrial/Commercial	0.9	0.9	0.9	n/a

Other areas were determined in all studies based on an examination of aerial photography. The values used in all studies are generally consistent and minor variations are to be expected. In our view, these values are consistent with the best practice approaches used at the time of the studies and are suitable for the derivation of flood extents.

3.4 Lag Parameter Kc

Each project has adopted a different method of determining the k_c factor, which is a lag parameter used in the model. This parameter accounts for local catchment storage and the speed of flow from the catchment. In general, for a catchment, lower k_c values means a fast response with a high peak flow, and higher k_c values indicate a slower catchment response with lower peak flows. The k_c parameter is also linked to the average flow length through a catchment, so a direct comparison of k_c values across catchments cannot be undertaken. K_c values are usually adopted based on calibration to known storm events, using regional methods based on a variety of catchments and/or comparison to other methods of flow estimation, usually the rational method.

3.4.1 <u>Bacchus Marsh Flood Study</u>

This project used recorded flow data for the Lerderderg and Werribee Rivers and recorded rainfall to estimate the k_c value based on real storm events. The model was assessed against three known storm events; November 1995, September 1993 and December 1987.

A good match was achieved for the recorded storm events and the model k_c was set based on these results. Validation was undertaken by running the design storm events for the model and comparing the results to a flood frequency analysis at each gauge using the design parameters. This approach is consistent with industry best practice.

3.4.2 Lower Lerderderg

The k_c parameter for the Lower Lerderderg RORB modelling was developed by estimating a peak flow rate using a rational method calculation and trialling k_c values until the flows at the catchment outlet in RORB matched. This approach is generally consistent with Melbourne Water's Flood Mapping Technical Specifications. The approach has been widely used in other studies across Melbourne. The k_c value was compared against the Dandenong Valley Authority Regional Method (which included Djerriwarrah Creek near Bacchus Marsh) and against the Department of Natural Resources and Environment (DNRE, now the Department of Environment, Land, Water and Planning) regression curves for catchments near the Great Dividing Range.

There are some minor issues with the approach adopted:

> Flow rates are only compared at the catchment outlet, however the hydraulic model area of interest starts well before the outlet. It would have been preferable to see some comparisons at the top of the Melbourne Water drainage network;

> The comparison to the DVA regional estimate is valid, although other estimates, such as Melbourne Water's Yarra values or the Victorian standard regional methods (e.g. Pearse, MAR <800, MAR >800) included in the RORB model may have been useful as a comparator.

> The models could have used a developed conditions case for the calculation of rational method flows, rather than a rural estimate.

Notwithstanding the above, the estimate of k_c is considered to be suitable for the development of the expected floodplain flows. It is possible that the flows estimated may be slightly lower than the actual 1% AEP flows based on the comparison with DNRE regional values.

3.4.3 Ballan Township

The k_c values in the Ballan Township RORB models were adopted by testing a range of regional methods for k_c generation and then comparing to a rational method calculation for each catchment. This provided a starting value for k_c. The method of Pearse was used as it provided the closest match to the 1% AEP flood event. The k_c value was then adjusted to provide the best match to this level, which included slightly increasing the estimate to lower the overall flow rates. As most of the catchments assessed in this study were rural, the comparison of RORB flows to the rational method is considered appropriate.

There are some minor issues with the analysis:

> Flow rates are only compared at the catchment outlet, however the hydraulic model area of interest starts well before the outlet. It would have been preferable to see some comparisons at the top of the Melbourne Water drainage network;

> It was noted that the RORB estimate of the critical storm event was much higher than that estimated by the rational method. This is likely due to the temporal pattern shapes of ARR 1987, where there are embedded bursts in the 9 hour pattern that are very close the those of the shorter durations. This is not an unexpected result.

> The adoption of runoff coefficients instead of continuous loss rates for rural catchments may also contribute to the longer storms being critical in RORB, but not in the estimates used in the Rational Method calculations. However, as the peak flow matches and the catchment flooding is not controlled by flood storage considerations this is considered minor.

Notwithstanding the above, the estimate of k_c is considered to be suitable for the development of the expected floodplain flows.

3.4.4 Melbourne Water Planning Investigations Models

The Melbourne Water RORB models have adopted k_c values based on the generalised regional equation found in the RORB manual. This is considered reasonable based on the rural nature of the catchments and tends to provide a higher value of k_c than some of the other regional methods. This would tend to result in a lower estimate of 1% AEP flows. The k_c values adopted are considered suitable for the assessment of floodplains in these rural areas.

3.5 Model Outputs

Each project has used the hydrograph outputs from the RORB model as inputs to their hydraulic model. This is standard practice in floodplain modelling. Our review indicates that model flows have been taken at appropriate locations in each hydrological model.

3.6 Conclusions

The hydrological modelling undertaken for each project in the Moorabool Shire is generally consistent with standard engineering practice for floodplain modelling. Our review has identified some potential minor issues with the assessment of RORB lag parameters in the Lower Lerderderg and Ballan model areas, however we consider that the impact on the results are very minor and would not lead to a significant change in the expected design flood hydrographs.

In our view, the hydrological models have been appropriately developed and are suitable for floodplain mapping in the Moorabool Shire.

4 Hydraulic Modelling and Flood Extents

In order to determine flood extents, hydraulic models are used. Hydraulic models calculate the water depth and flow velocity of water by solving the St Venant Equations for shallow water flow. The models used to determine the flood extents in the Moorabool Shire were:

> HEC-RAS – an industry standard one-dimensional (1D) hydraulic model developed by the US Army Core of Engineers. HEC-RAS is a well-established hydraulic model suitable for the analysis of flows in rivers and through floodplains where the flow direction is well understood (such as down a river valley). HEC-RAS can model both dynamic and steady state flows and mixed flow regimes. Branching flows are not allowed in standard versions of HEC-RAS
>
> HEC-RAS was used in all the projects undertaken by Melbourne Water's Investigations team and for two of the catchments in the Ballan Township Study where there were no underground drainage assets.

> XP-STORM – XP-STORM is a 1D hydraulic model developed by XP Software in Australia. XP-Storm is widely used for the analysis of drainage networks. In contrast to HEC-RAS, XP-STORM can model branched networks and include consideration of both piped underground drainage and overland flow paths simultaneously. The model is fully dynamic and can accurately calculate flood levels based on both storage and flow considerations
>
> XP-STORM was used in the Ballan Township Flood Mapping Project for catchment areas that included existing underground drainage networks

> TUFLOW (Including ESTRY1D) – The TUFLOW hydraulic model is widely used in Australia for the analysis of flood flows. TUFLOW is a two-dimensional (2D) model, meaning that the model calculates the flow directions based on the topography of the land surface, as opposed to a 1D model where the modeller must decide the flow direction. TUFLOW includes the ESTRY 1D model, allowing for the consideration of pipe and channel flows where the flow behaviour is inherently 1D in nature. This type of model represents industry best practice for the analysis of urban and rural floodplain flows. 2D models are particularly useful in the derivation of flood extents through complex flow areas, such as urban areas and branching floodplains.
>
> TUFLOW was used in the Bacchus Marsh and Lower Lerderderg flood mapping projects.

The models chosen are all used widely to derive floodplain flows. We have reviewed the overall schematisation of each flood model and found that they are generally well constructed and suitable for use. These models have been constructed in accordance with Melbourne Water's Technical Specification for Flood Mapping that was applicable at the time of each model being constructed. This specification is widely used around the Melbourne Metropolitan region and has been adopted by many municipalities as the standard specification for flood mapping. The specification ensures that all properties in the wider Melbourne area are treated equally in the provision of flood mapping services and that decisions made on the extent of the flood overlays are consistent.

Cardno has reviewed each model based on its schematisation, general model parameters, flow boundaries and downstream boundaries. This review has included the detailed examination of the model reporting and run files as appropriate.

4.1 Bacchus Marsh Flood Model

The Bacchus Marsh flood model is a large Tuflow model covering the riverine floodplains of the Lerderderg and Werribee Rivers, Parwan Creek and the floodplain of the Maddingley Park and Fisken Street Drains. The model did not include main drainage discharging to the Lerderderg River (covered by the Lower Lerderderg Flood Study).

We have reviewed the model and can advise that:

> It uses a topographic definition derived from LIDAR and river survey. The model adopted an 8m grid resolution, which is considered reasonable for the riverine flooding expected through the study area.

> The model included 1D sections for the main river channels and used a variety of structure types to represent channel features including bridges and weirs in the schematisation.

> The performance characteristics of some bridges were calculated using the HEC-RAS model and used in the TUFLOW model description. This is standard practice for some complex structure types.

> Mannings friction values are consistent with Melbourne Water's technical specification and are considered reasonable for the floodplain based on our experience. The model was calibrated to known storm events that provided some insight into the appropriate Mannings values

> Flows from upstream areas were introduced as hydrographs at appropriate locations. These matched the RORB output hydrographs.

> Where appropriate, local catchment inflows were introduced directly to the Melbourne Water Main Drains at each 'pit' along the length of the drain. This simulates the distribution inflow from local council drainage (that was not modelled) and is considered standard practice for these projects.

> Where there was no Melbourne Water drain, local inflows were introduced as 2D-sa boundaries. This type of boundary applies catchment flows to the lowest grid cells in an area specified by the modeller. The use of this boundary type is appropriate for the catchment.

> The model achieves a reasonable calibration to known storm events, especially adjacent to the township for both the Werribee and Lerderderg Rivers. The report provides valid examples of the errors in recorded data that can cause calibration to be a difficult process. In our view the calibration results appear to provide some certainty that the model is producing results that suitably replicate floodplain flows.

> An area not explored is the potential error in the gauging records. It is understood that the calibrated RORB model inflows are used in the input data. The accuracy of the gauged flow record, inferred from a rating curve) is not mentioned in the report. In our experience, the gauge records are often not well measured at very high stages. This may lead to some errors when calibrating as the modelled flow rates may not represent the actual flows at a certain stage. The effect of this is considered minor, as the calibration results are generally within 200 – 250 mm of the recorded levels at the key locations.

> The results from the 8m model grid were interpolated to provide a 1m resolution output. While this provides a smooth surface, the actual flood behaviour may not be representative at every location. This is considered a minor issue as the interpolation distance is short and the floodplain flow widths are relatively wide. This limitation is appropriately acknowledged in the report.

> Flood extents created from the results of the flood mapping project are consistent with the expected flood shapes based on the topography of the Bacchus Marsh area.

The Bacchus Marsh flood model and the flood extents created are considered to be suitable for the creation of planning scheme overlays.

4.2 Lower Lerderderg Catchments Flood Mapping Project

The Lower Lerderderg Catchments Flood Mapping project includes the urban drainage networks of Bacchus Marsh, including Melbourne Water main drains flowing into the lower Lerderderg River. The model area covers the following main drainage catchments:

> Robertsons Road Drain

> Cairns Drive Drain

> Grey Street Drain

> Masons Lane Drain

> Lerderderg Street Drain

Our review of the model indicates that:

> The model adopts a 3m topographic grid definition, and extends beyond the Melbourne Water drainage network, including some areas of Council drainage;

> The model includes consideration of the Dickson Street retarding basin explicitly in the model definition

- The drainage network includes a number of Council and Melbourne Water pipes and open channels. It was noted that in two locations, the invert levels used in the model appeared to be incorrect, resulting in an uphill grade to the pipe. In the 1% flood event, these pipes are flowing under head and the water level on the land surface will control the actual pipe flow. It is considered that these minor issues would not result in any significant change in the flood extent.
- The pipes that have the incorrect slope occur in the council network and the flood extents used in the SBO start at the Melbourne Water drainage network. This further lessens the impact of the uphill pipe slope as floodwaters can re-enter the network downstream as capacity allows.
- Pits have been modelled as side entry pits with a limited opening at street level. As all pits and pipe in the network are not modelled, this may lead to the flood extent being larger than if a free flow of water was allowed between the underground and overland flow networks. For a 1% storm event, where flows are introduced directly to the pipe network, this is likely to have little or no impact on the expected flood levels.
- Pit losses were included in the model using the Engelhund method. This is considered appropriate for the catchment.
- The model includes 3 main methods of introducing catchment flows into the model:
  - Flow inputs at the upstream end of the models using 2d-sa boundaries.
  - Flow input directly to the pipe network, distributed evenly into the pits on a subcatchment basis.
  - Subcatchment flows in rural reaches, input to the model as direct rainfall boundaries.
- The flow boundaries for individual subcatchments are taken from the RORB model as unrouted flows. This means that no attenution of the flow is assumed prior to it being introduced to the hydraulic model, resulting in higher peak flows at each input location. In general, we would recommend that routed flows be used where subcatchment inflows are being introduced only to main drainage lines. This enables some attenuation to occur as would be expected as flows progress to the main drainage network.

  To examine the effect this has on the proposed overlays, Cardno ran the 1% AEP, 60 minute storm event with routed hydrographs extracted from the RORB mode outputs for the Lower Lerderderg model. The results of the assessment are shown in Figure 4-1 below, with blue areas showing the exhibited flood extent and green areas showing the flood extent with flow routing included.

  The effect of using the routed flows as input boundaries results in a small reduction in the overall flood extent in the 60 minute event. Our analysis indicated that out of approximately 450 impacted properties in the original flood extent, about 40 would no longer be considered flooded in this specific event. The original flood extent as exhibited could be considered a reasonable upper estimate of the 1% AEP flood extent as the differences are relatively minor. In some modelled catchments, there was no difference between the flood extents in this event. The effect of this change is expected to be less in longer storm events.

  As such, it is considered that although the extents exhibited are slightly conservative, they provide a reasonable estimate of the 1% AEP flood.

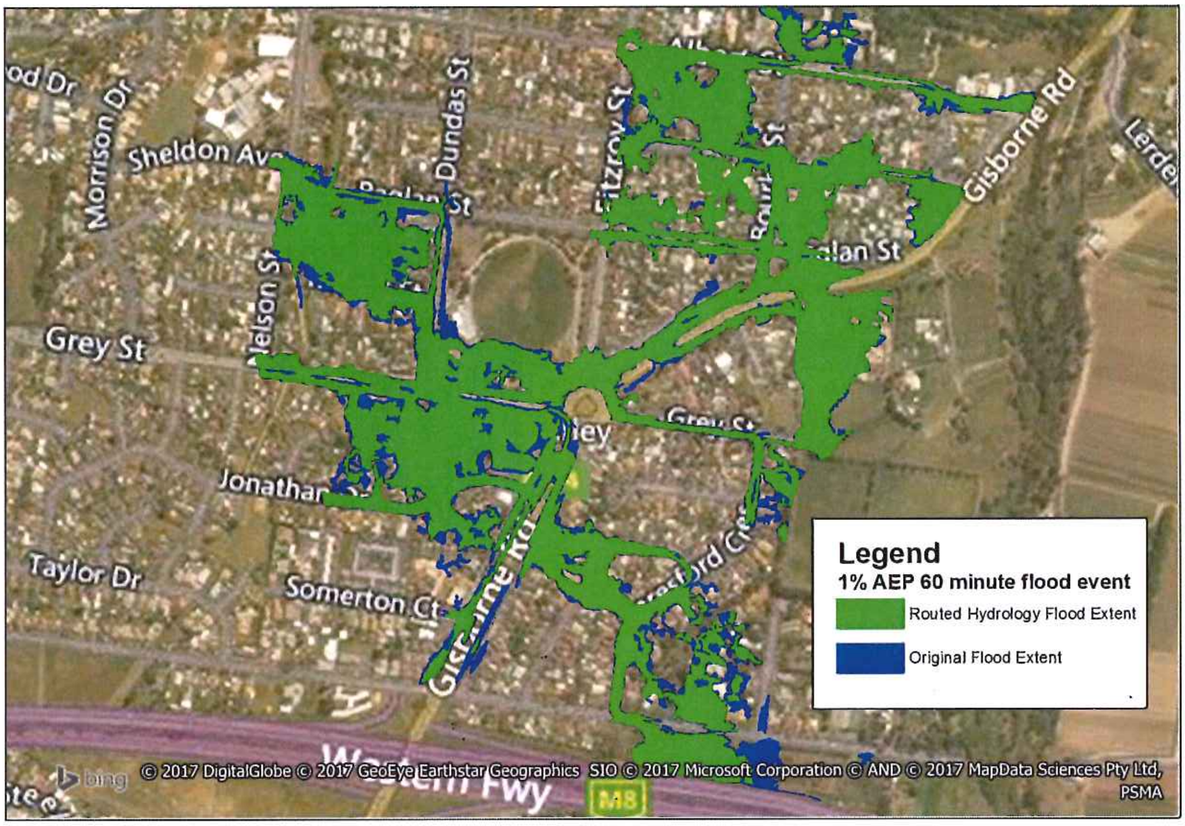


Figure 4-1 Flood Extent Comparison, Routed Hydrology inputs 1% AEP 60 minute flood event

> It was noted that the flood extent as exhibited, south of the Western Freeway, covers the entirety of the farming land between Mason's Lane and Lerderderg Street as shown in Figure 4-2. This flood shape does not match that shown in the Engeny report for this location (Figure 1 in the Engeny report, reproduced here as Figure 4-3). This is likely due to the flood extent in this area being created using a process that is now deprecated by Melbourne Water.

At the time of this project, Melbourne Water adopted a technique known as the 'point density method' to create flood extents based on the density of flooded areas predicted by a flood model. These extents did not appropriately take into account the actual hydraulic behaviour of the water and instead were used as they created a smooth boundary. As this location used a direct rainfall boundary, all grid cells in the area are 'wet' by the model and return a flow value. It appears that these shallow flood values were not appropriately filtered by Melbourne Water prior to creating the flood shape.

In our view, flood extents generated using the point density method should not be used in planning scheme overlays. It is recommended that the flood extents generated in the Lower Lerderderg catchments be re-examined and updated as necessary based on Melbourne Water's updated process to determine flood extents. The appropriate starting point would be the flood extents shown in the Lower Lerderderg Catchments Flood Mapping report, Figures 1 and 2.

It should be noted that this is not considered a modelling error but rather a data analysis error. We have noted other minor differences in the flood extents shown in the figures in the Lower Lerderderg report compared to the proposed SBO extent. This is likely due to the same issue.

Cardno considers that the proposed SBO extent does not appropriately reflect the results of the flood modelling for the Lower Lerderderg area. The proposed SBO should be modified to reflect the actual results of the flood modelling.

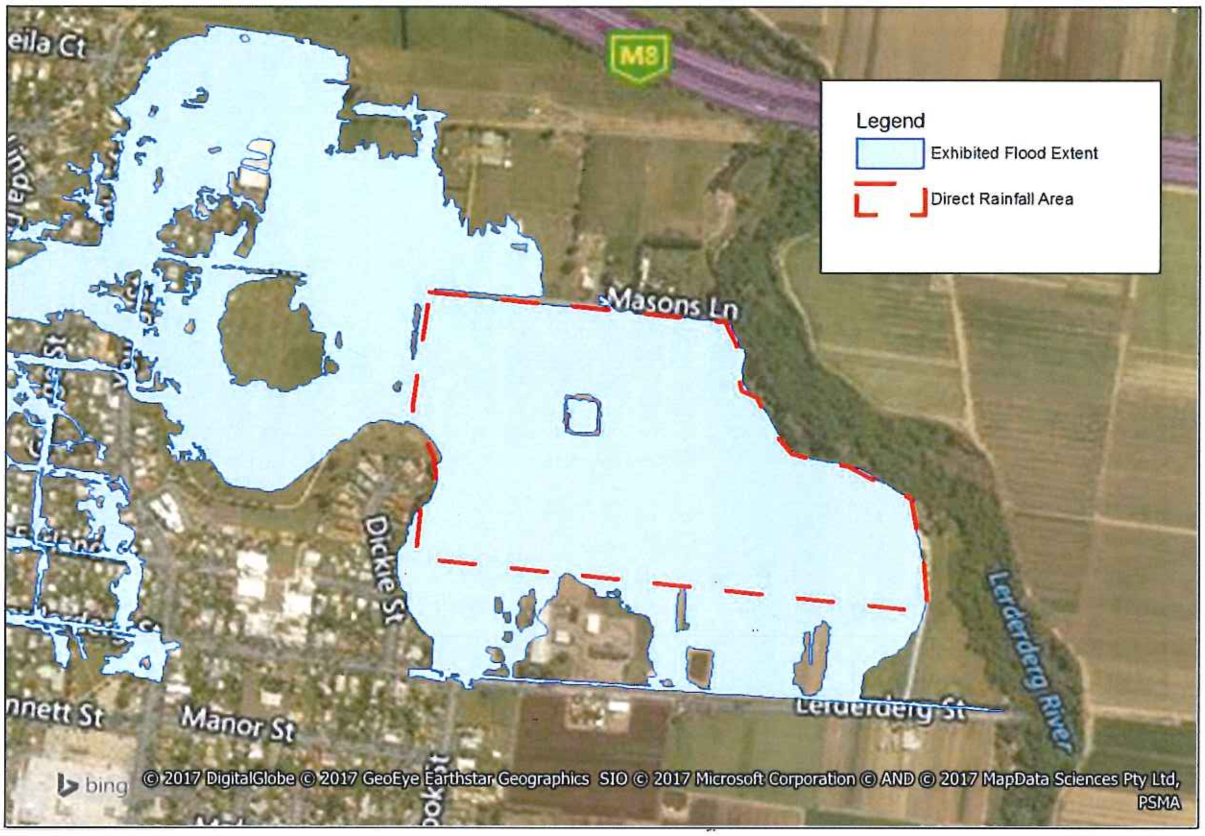


Figure 4-2 Exhibited SBO Extent, near Masons Lane

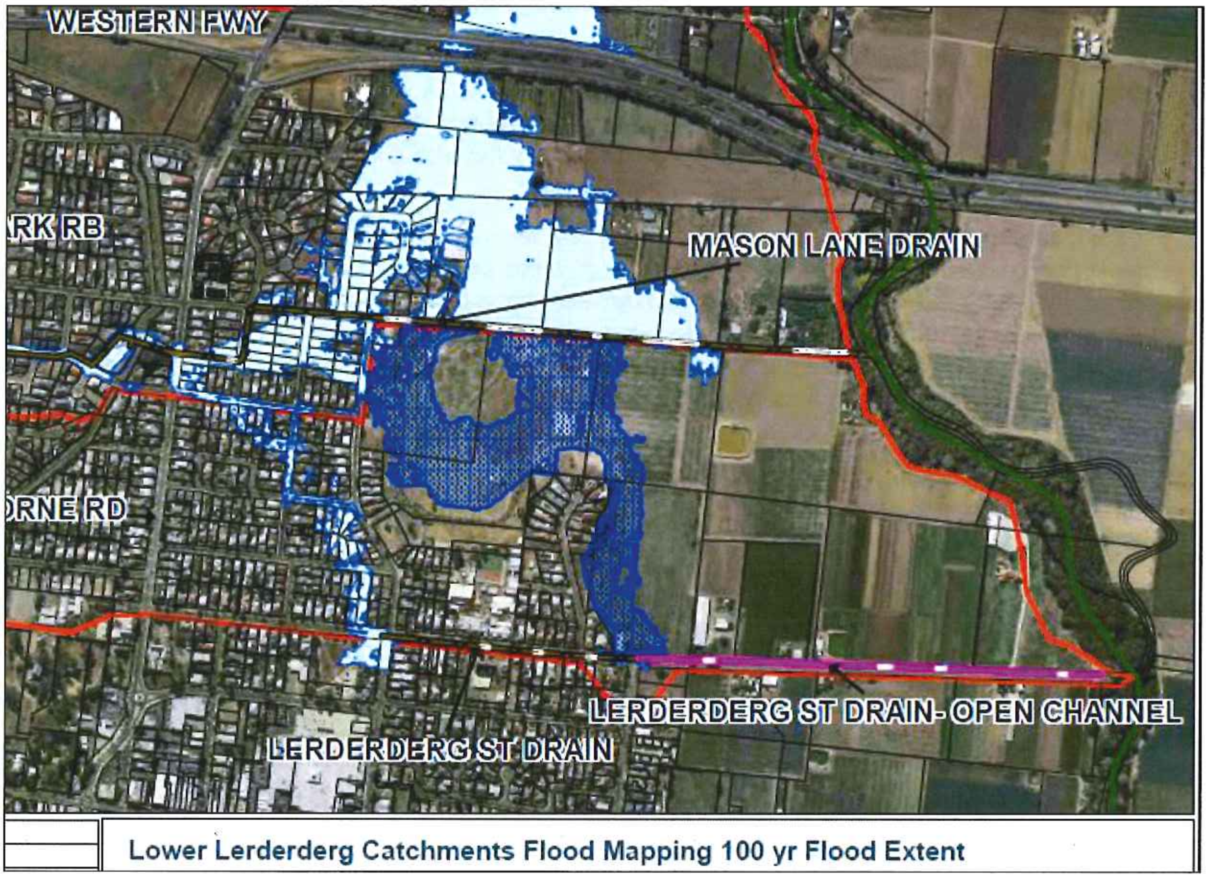


Figure 4-3 Model derived flood extent near Mason's Lane (after Engeny, 2011)

The modelling completed for the Lower Lerderderg study area likely provides a conservative flood extent, but is considered suitable for the derivation of flood extents for planning purposes. However, the exhibited shape does not appear to appropriately represent the results of the flood model, due to the algorithm adopted by Melbourne Water to smooth the flood extent. This algorithm is no longer used as it does not appropriately consider the hydraulic properties of the land. The flood extent needs to be recreated using the current Melbourne Water process.

4.3 Ballan Township Modelling

The Ballan township project used HEC-RAS and XP-STORM to model the flowpaths of three drainage catchments in the township. The catchments all ultimately drain to the Werribee River and primarily consist rural land with some township areas. Significant flow constrictions occur at road and rail formations, including the Western Highway and the Melbourne Ararat rail line.

Our review of the modelling indicates:

> For catchments A and C, modelling was completed using HEC-RAS. This model is considered to be suitable as there are no branching flowpaths and the floodplain is well defined by the creek valley.

> Catchment B uses the XP-STORM model as the catchment area includes the Gosling Street Drain and requires consideration of both underground and overland flow. The model chosen is suitable for the requirements of the project.

> In all models, the catchment cross sections are appropriately defined and are suitably spaced to define the flood behaviour. The extrapolation of cross sections using LIDAR is also considered appropriate as the ground survey contains the main creek channel, which can be difficult to capture using LIDAR. The floodplain shape will be well defined by the LIDAR data.

> The downstream boundary conditions adopted the 10% AEP river level for the Werribee River. This level provides a high tailwater condition without being too conservative. The use of the 10% AEP flood level as the downstream boundary is consistent with general industry practice.

> Manning's roughness values are consistent with industry standards for open channels and floodplains. The modelling has adopted the conservative approach of using the higher range of roughness values, thereby representing the maximum seasonal growth. This would raise the flood levels slightly compared to the average conditions, but is considered appropriate for large flood events.

> Flood extents were created by interpolating levels between model cross sections to develop a water surface. This surface was then intersected with the land surface to define the inundated area. This process is standard practice to derive flood extents from 1D flood models.

The models and flood extents produced in the Ballan Flood Study are suitable for use in planning scheme overlays.

4.4 Melbourne Water Planning Investigations

Melbourne Water's internal Planning Investigations team undertook HEC-RAS modelling of numerous creeks and rivers in the Moorabool Shire, including:

> Dale Creek

> Djerriwarah Creek

> Goodman Creek

> Korkuperrimul Creek

> The Lerderderg River (upstream of Bacchus Marsh)

> Myrniong Creek

> Stony Hut Creek

As part of this review we have not examined in detail every model provided by Melbourne Water. This is because the general methodology is consistent across the Melbourne Water projects.

Our review of the modelling indicates:

> For the majority of the models, floodplain cross sections were created using LIDAR data. This will generally provide a conservative flood extent as the invert detail of the creek channel may not be fully captured in the survey. As the areas mapped by Melbourne Water are mostly rural in nature, the effect of this is considered to be low. It is unlikely that any additional properties would be identified as being at risk of flooding as a result of the cross section definitions. Using LIDAR to define cross sections in rural areas is a reasonable approach for these projects.

> The Lerderderg River HEC-RAS model used surveyed cross sections captured on site by Melbourne Water. This included capture of bridges and other flow structures

> For smaller creeks catchments, such as Dale Creek, road crossings and culverts were included only where information was available detailing their size and shape. For smaller creeks, this approach will still identify land that may be subject to inundation in rural areas as the models effectively follow the valley line. The exact flood shape may be over or underestimated near individual crossings, depending on the assumptions made regarding that crossing.

> Flood extents have been created in a similar manner to those in Ballan Flood Study. This is considered appropriate for the type of flooding that is expected to occur.

In our view, the Melbourne Water Planning Investigations models and the flood extents derived from them are suitable for the derivation of planning overlays.

4.5 Conclusions

Cardno has drawn the following conclusions based on our review of the hydraulic models and the derivation of flood shapes:

> All the hydraulic models used in the derivation of the proposed Moorabool LSIO and SBO are considered to be suitable for the purpose of developing flood extents and are consistent with good flood mapping practice.

> For the Lower Lerderderg model, the method of introducing the hydrological model flows into the hydraulic model is likely to result in a conservative determination of flood levels. Indicatively, the change in the flood extent impacts less than 10% of the total number of properties identified as subject to inundation. It is considered that remodelling is not required as conservative flood shapes fulfil the requirements of the planning scheme and provide a reasonable estimate of the area subject to flooding

> For the Ballan models, the choice of the high roughness to simulate the maximum seasonal growth of vegetation is considered an appropriate assumption and in line with best practice for the derivation of lands that may be subject to inundation in a 1% AEP flood event.

> The Melbourne Water Planning Investigations models provide suitable definition of the expected flood extents in rural areas and appropriately identify land that may be subject to flooding.

> For the Lower Lerderderg model area, the flood shape proposed in the SBO appears to have been derived using Melbourne Water's 'Point Density Method'. The shape does not match that shown in the Lower Lerderderg Catchments Flood Mapping report. Flood shapes derived using the Point Density Method cannot be supported for use in planning scheme overlays as they do not define the flood shape based on hydraulic properties. As a matter of urgency, the flood shapes should be recreated, based on the current Melbourne Water guidelines adopting standard filtering and smoothing parameters. This change is likely to remove some properties from the flood shape and include others, however the magnitude of the change is expected to be small.

5 Conclusions and Recommendations

Based on Cardno's review of the models, the key questions posed in the introduction can be answered.

5.1 Was the data sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping?

The data used in each project is sufficient in quantity and quality to achieve fit for purpose flood risk modelling and mapping. There were no major data sources identified that would have modified the results of the investigations.

5.2 The LSIO and SBO maps were derived by using the hydrology model RORB and hydraulic modes TUFLOW and HEC-RAS. Was the use of these models appropriate for the purpose of deriving planning scheme overlay maps?

The hydrological and hydraulic models used are suitable for the derivation of planning scheme overlay maps. The models chosen are widely used in Victoria for these purposes.

5.3 Were the hydrology and hydraulic models set up with parameters that are within the normal range?

All models were set up with parameters that are within the generally accepted ranges for models of this type in similar areas.

5.4 Have the hydrology results been incorporated correctly into the hydraulic model?

The hydrological model results have generally been incorporated correctly into the hydraulic models. Some subcatchment inflows in the Lower Lerderderg study area were incorporated into the hydraulic model without any routing, which may slightly overestimate the flood flows, however, they do not impact on flood volume. Cardno has tested adopting routed hydrographs in the Lower Lerderderg model area. For some subcatchments, this resulted in a slight reduction in the overall flood extent when compared to the results from the original project.

In a planning context, the model results from Lower Lerderderg Catchments Flood Planning project meet the objectives of the planning scheme and can be used to develop LSIO and SBO overlays. The results are considered to be a reasonable upper estimate of the likely flood extent.

5.5 Are the model runs / results appropriate to produce fit for purpose flood extent mapping?

The model runs and results in all hydraulic models are considered to be appropriate for the derivation of flood extent mapping

5.6 Have appropriate measures been used to produce the final flood extent mapping from the model results?

With the exception of the Lower Lerderderg study area, the flood extents used in the draft planning overlays are considered appropriate.

The flood extents created by Melbourne Water for Lower Lerderderg study area should not be used as the planning overlays. The proposed flood extents and the resulting SBO shapes in these areas should be recreated based on the model results using appropriate filtering techniques, such as those described in Melbourne Water's 2016 technical specifications.

5.7 Recommendations

In our view, the models used have delivered results that are suitable for inclusion in the Moorabool Planning Scheme. Once the Lower Lerderderg flood mapping extent and resultant SBO shape is amended, it is recommended that the planning scheme amendment process be recommenced.

Moorabool Shire Flood Studies

APPENDIX A

PLANNING INVESTIGATIONS METHODOLOGY

Cardno

Memo

To	Mike Kearney	**From**	Rushiru Kanakaratne
CC			
Date	19 February 2015	**Subject**	Werribee River Flood mapping

Dear Mike,

The flood mapping of Werribee River and its tributaries in the Moorabool Shire area was done using RORB and HEC-RAS models. The region was mapped using a series of these models in sequence; not a single large model what covered the whole area.

RORB

RORB models were used to estimate the flows for each of the mapping exercises. Werribee River had an existing RORB model that covered the entire catchment but smaller models were developed for the tributaries. The smaller models were necessary for better calibration. Lidar based surface contours were used to draw catchment boundaries and define reaches. All major storages (RBs and reservoirs) were included in these models but smaller storages (ponding upstream of road/rail embankments, farm dams) were not included.

HEC-RAS

The hydraulic modelling was done using HEC-RAS. The cross sections in HEC-RAS were generated from Lidar point data, not field survey. Crossings and culverts were included only where such information was available. Most crossings in this area are not modelled due to the lack of information. Downstream boundary levels were taken from exiting flood mapping.

Flood Extents

The results from HEC-RAS were used in conjunction with surface contours to generate the flood extents. Preliminary extents were generated using software such as 12d or Engage 3d and then refined manually.

In these models only the 100yr ARI flood event was considered.

Yours Sincerely

RUSHIRU KANAKARATNE
INVESTIGATIONS ENGINEER
FLOODPLAIN INVESTIGATIONS

Cardno Note: In many of the supplied Melbourne Water project files, there was additional model specific information provided. The general modelling approach was identical to that described in the Memo above.

Attachment 2: Responsibilities of Melbourne Water and Moorabool Shire Council

In Victoria, effective floodplain management is a responsibility of Melbourne Water and catchment management authorities (CMAs) in partnership with local government. For Moorabool Shire, the floodplain management authorities are Melbourne Water for the Port Phillip catchment area in the eastern half of the Shire, and Corangamite Catchment Management Authority for the western half of the Shire. This partnership is spelt out clearly in clause 13.2 of the Victorian Floodplain Management Strategy (DELWP, 2016) which states that *"the CMAs and Melbourne Water will work with LGAs to ensure that planning schemes use the planning controls that align with their flood risks"*.

Under Section 4(2) of the *Planning and Environment Act 1987*, one of the objectives of the planning framework established by the Act is *"to ensure sound, strategic planning and co-ordinated action at State, regional and municipal levels"*.

The State Planning Policy Framework (SPPF) of the Moorabool Planning Scheme includes a *'Floodplain Management'* policy under Clause 13.02-1, which has objectives for protecting life, property and community infrastructure, and for protecting natural flood carrying capacity, flood storage and floodplain areas of environmental significance. One of the strategies listed under Clause 13.02-1 is to *"identify land affected by flooding, including floodway areas, as verified by the relevant floodplain management authority, in planning scheme maps. Land affected by flooding is land inundate by the 1 in 100 year flood event or as determined by the floodplain management authority"*.

As a planning authority, Council has a legal obligation under Section 12(1) of the *Planning and Environment Act 1987* to implement the objectives of planning in Victoria. By introducing appropriate flood controls into the Moorabool Planning Scheme, Council would ensure that flood risk is considered in land development decisions, thereby implementing the following objectives of planning as set out under Section 4(1) of the Act:

- To provide for the fair, orderly, economic and sustainable use, and development of land;
- To provide for the protection of natural and man-made resources and the maintenance of ecological processes and genetic diversity;
- To secure a pleasant, efficient and safe working, living and recreational environment for all Victorians and visitors to Victoria; and
- To balance the present and future interests of all Victorians.

The above policies and statutory obligations provided the impetus for Melbourne Water to expend over $100,000 in modelling flood risk in Moorabool Shire, leading to the preparation of Amendment C73. Similar exercises were also carried out by Melbourne Water in partnership with City of Manningham (Amendment C109), City of Yarra (Amendment C201), City of Monee Valley (Amendment C151) and City of Port Phillip (Amendment C111) amongst others.

Attachment 3: Relevant Extracts from Moorabool Planning Scheme:

21.02 NATURAL ENVIRONMENT

10/11/2011
C57

21.02-1 Key Issues and Influences

26/02/2009
C34

Flood Management

- Large areas of the Moorabool Shire are prone to flooding as the Moorabool, Werribee, and Lerderderg Rivers flow through the Shire.

21.02-7 Implementation

26/02/2009
C34

Zones and Overlays

Specific application of zones and overlays to achieve the strategic objectives includes:

- Apply relevant overlays (VPO or ESO) to reflect biodiversity mapping of the Shire when completed;
- Apply Erosion Management Overlay (EMO) and Salinity Management Overlays (SMO) to reflect land capability across the Shire;
- Apply Floodway Overlay (FO) and Land Subject to Inundation Overlays (LSIO) to reflect relevant Council flood studies;
- Apply Significant Landscape Overlay (SLO) to ridgelines, escarpments, and hilltops; and
- Apply Wildfire Management Overlay to areas of fire risk.

21.02-8 Further Strategic Work

10/11/2011
C57

- Complete the biodiversity mapping project.
- Undertake studies to further identify areas subject to flooding and areas subject to poor drainage.
- Undertake erosion studies to inform the incorporation of the Erosion Management Overlay.
- Undertake salinity mapping to inform the incorporation of the Salinity Management Overlay.
- Investigate an appropriate buffer zone around the Ballan and Parwan Waste Water Plants in conjunction with the relevant Water Authorities, and develop ESO's within these buffers in conjunction with the Water Authorities and the EPA.

Attachment 4: Why flood extent mapping is urgently required in the Moorabool Planning Scheme

1. The Victorian Floods Review found that land use planning and building controls were generally more cost effective than flood mitigation infrastructure, flood warning systems, education or emergency responses.

2. As discussed above, Council has a legal obligation under Section 12(1) of the *Planning and Environment Act 1987* to implement the objectives of planning in Victoria. Section 6(2)(e) of the Act also provides for *"planning schemes to regulate or prohibit any use or development in hazardous areas or in areas which are likely to become hazardous areas"*. Because it is possible to predict which land is likely to be flooded, it is prudent to regulate development and building in those areas to ensure any impacts are known and managed. In so doing, the aim is to avoid or minimise the increase in future flood risks.

3. Enhanced effort in municipal planning, supported by increased knowledge of flood hazards, will go a long way towards securing resilience to floods. Flood overlays need to be introduced or updated as soon as possible after new flood maps are produced to maximise the returns on investment in flood information and help manage risk

4. The *Victorian Floodplain Management Strategy* (DELWP, 2016) sets the direction for floodplain management in Victoria. The Strategy supports communities by clarifying the roles and responsibilities of government, agencies and authorities involved in floodplain management for land use planning and infrastructure management. It also focuses on the development and sharing of high quality flood risk information that can be used for improved planning, flood warning and flood response. Key elements of the Strategy include:

   Policy 13c: *"LGAs with areas at risk of a 1% annual exceedance probability flood must ensure that their planning scheme contains:*
   - *the objectives and strategies for managing the risk in the Municipal Strategic Statement;*
   - *the appropriate zone and overlays."*

   Accountability 13a: *"LGAs are accountable for ensuring that their planning schemes correctly identify the areas at risk of a 1% annual exceedance probability flood, and contain the appropriate objectives and strategies to guide decisions in exercising land use controls in regard to flooding".*

5. Melbourne Water has legislative responsibilities as the floodplain management authority for the Port Phillip and Westernport catchments.

6. At present there is a lack of alignment between the planning scheme and building regulation system in Moorabool Shire. The Moorabool Planning Scheme currently does not contain any overlays to identify areas affected by flooding and overland drainage, despite State and local policies that suggest there should be flood extent mapping. Consequently, a planning permit is not required for many types of buildings and works and flood risk may not be identified until such time as the developer applies for a building permit.

Even if a planning permit is required for a particular development, without the appropriate flood overlays and permit triggers, flood risk may not be taken into consideration. Thus, there is currently potential for a planning permit to be issued for a development without due consideration of flood risk, and there have been cases where this has occurred. In such scenarios, the developer may subsequently have difficulty obtaining a building permit, or may be required to alter the design (e.g. reduce building footprint or raise floor levels). This may result in Council being accused of not fulfilling its duty as a planning authority or responsible authority under the *Planning and Environment Act 1987*. There is a high risk of litigation for building surveyors and Council staff, especially planners who may not even be aware of flood risk during pre-permit negotiations. Such risk would be alleviated if flood risk was identified and considered as early as possible in overall development concept design (i.e. the planning phase).

Upon application for a building permit or sale of property, Council issues a certificate under Regulation 326 of the Building Regulations 2006 (see Attachment 4), which requires identification of whether land is subject to flood risk. Council officers currently use the latest flood extent mapping prepared by Melbourne Water (i.e. the same mapping as exhibited under Amendment C73), to determine whether land is liable to flooding. Thus, the abandonment of Amendment C73 did not remove the mapping of flood risk or the obligation of landowners to comply with Melbourne Water requirements.

If the land is liable to flooding, a building permit applicant must obtain the 'report and consent' of Council prior to obtaining a permit. Council must not give its consent if it is of the opinion that there is likely to be a danger to the life, health or safety of the occupants of the building due to flooding of the site. In its report, Council may specify a minimum floor level for the building. Before specifying a floor level, Council *"must:*

a) consult with the floodplain management authority for that site; and
b) specify a level at least 300mm above any flood levels declared under the Water Act 1989 or otherwise determined by the floodplain management authority, unless the authority consents to a lower floor level."

7. Melbourne Water has no timeline or capital works programme to remove flooding risk from Bacchus Marsh, Ballan or other impacted areas. Melbourne Water is faced by many competing priorities – see point 1.

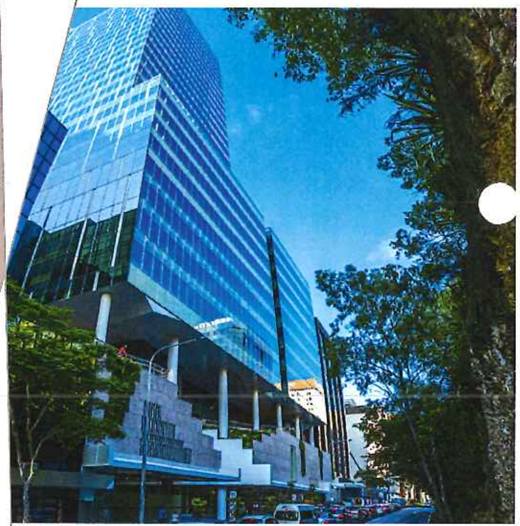
8. Reputation risk to Council in implementing M2041, all of which involves whole-of-government cooperation in data sharing, goal setting and infrastructure delivery. Land use planning starts with strategic planning which must consider threats from natural hazards such as bushfire and floods.

Attachment 5: **Revised flood extent mapping (SBO) for the lower Lerderderg study area**

Flood Related Planning Controls

Moorabool

V171604



Prepared for
Moorabool Shire Council & Melbourne Water

16 January 2018

Cardno

Contact Information

Cardno Victoria Pty Ltd
ABN 47 106 610 913

Level 4
501 Swanston Street
Melbourne 3000
Australia

www.cardno.com
Phone +61 3 8415 7777
Fax +61 3 8415 7788

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Author(s):

Name Ailsa Veldema
Job title Senior Flood Analyst

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Name Ailsa Veldema
Job title Senior Flood Analyst

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Table of Contents

Figures

1 Introduction

This has been prepared to accompany the proposed Special Building Overlay (SBO) for Moorabool, December 2017. It provides a background, describes what information has been used in the development and provides details of the overlay.

2 Background

Melbourne Water (MW) and Moorabool Shire Council (Council) prepared flood related planning overlays for potential inclusion into the Moorabool Planning Scheme. The overlays consisted of proposed Land Subject to Inundation Overlays (LSIO) and Special Building Overlays (SBO). MW and Council engaged Cardno to undertake an independent review of the technical methodology used to determine the location and shape of the proposed planning overlays. The report 'Peer Review Moorabool Shire Flood Modelling' (V170467, November 2017) documents the review.

It was concluded that the flood model from the Lower Lerderderg Catchments Flood Mapping project was suitable for use. However, the methodology adopted to convert the outputs to a planning overlay should be modified and the overlays be amended accordingly.

3 Information used and Methodology

Hydraulic modelling results from the Lower Lerderderg Catchments Flood Mapping project were used as inputs into the flood overlay and the process below followed.

> Step 1: Filter flood results to remove areas with shallow (less than 0.05 m) flooding;

> Step 2: Combine the above results into a single shape and remove both wet "puddles" or dry "islands" if the area is less than 100 m^2.

> Step 3: Smooth the shape to remove the 'staircase' effect associated with modelling grid cells.

> Step 4: Split the shape into MW and Council controlled areas based on the splits adopted in the previous overlays and on the source of flooding (i.e. if inundation emanates from a MW asset then is classified as MW flooding). Remove the Council areas as the amendment is for MW controlled areas only.

> Step 5: Based on MW's document 'Finalising Flood Extents for Inclusion in Planning Schemes' review the overlay at the property scale. In summary, properties which had less than 2% of their total area inundated were considered for removal. If more than 25% of their frontage was affected or the area is considered at risk based on the various flood depths experienced, the overlay was retained on the property.

The draft overlay produced using the above process was supplied to MW for review. During this review an area (at Cairns Drive DS) was updated by MW to be more reflective of the topography which had recently been significantly modified as part of development works.

4 Overlays

The revised Special Building Overlay is shown on Figure 4-1 overleaf.

Figure 4-2 shows this proposed overlay alongside the previously exhibited overlay. Whilst there are a number of changes, the key area of change is in the rural land south of Masons Lane. The proposed overlay is significantly reduced from that which was previously exhibited.

It is recommended that the proposed SBO is adopted and the planning scheme amendment process be recommenced.

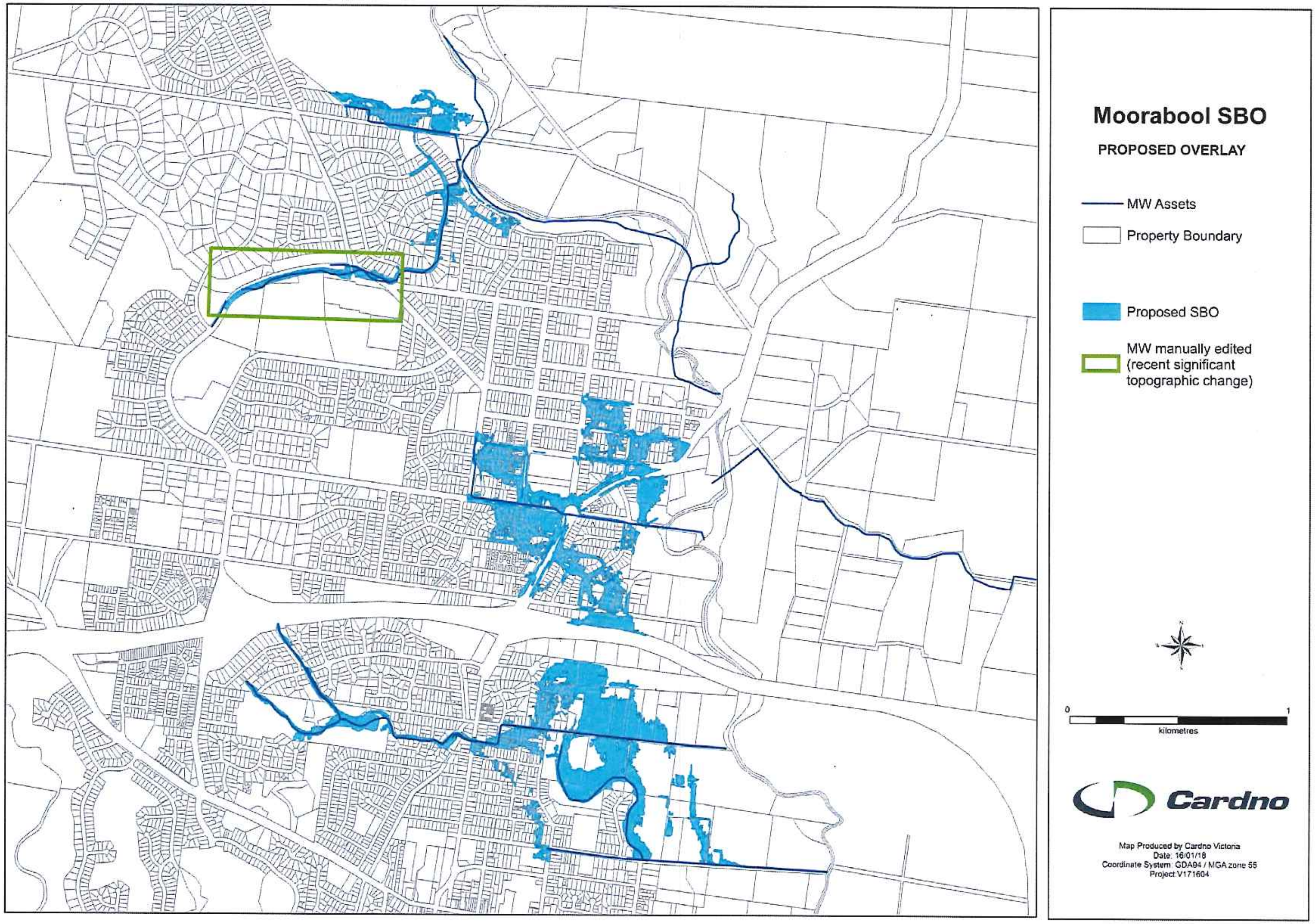

Figure 4-1 Proposed Overlay

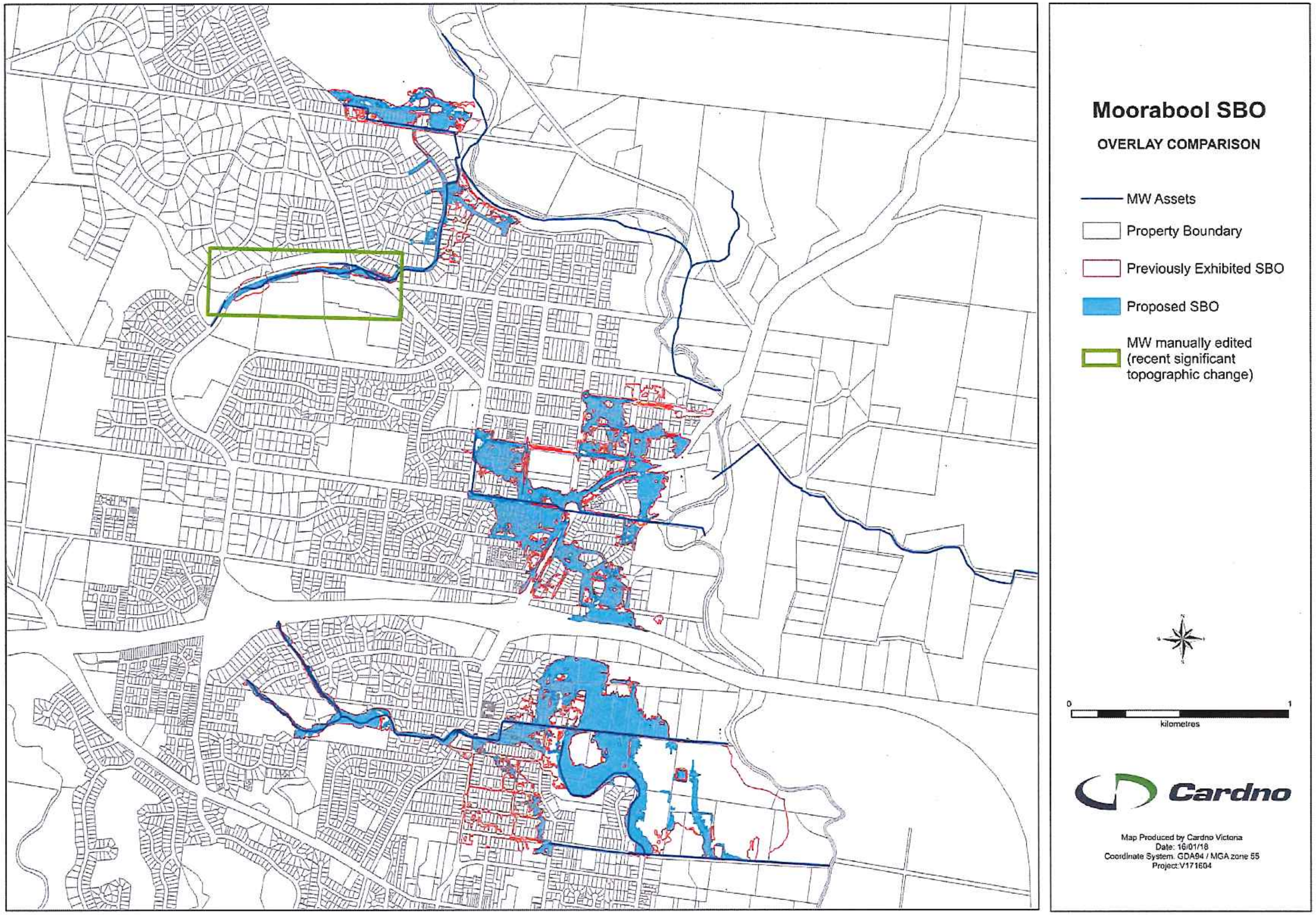

Figure 4-2 Overlay Comparison