VICTORIA RACING CLUB SUBMISSION TO THE MARIBYRNONG RIVER FLOOD REVIEW

17 MARCH 2023

1 MARIBYRNONG RIVER FLOOD REVIEW

1.1 In January 2023, Melbourne Water announced the Maribyrnong River Flood Review (**Flood Review**). The Victoria Racing Club Limited (**VRC**) acknowledges the important work that is being undertaken by the Flood Review and is pleased to have the opportunity to make a submission.

1.2 The VRC has prepared this submission in response to an invitation from Melbourne Water for the express purpose of assisting the Flood Review to discharge its terms of reference. The contents of this submission have been drawn from information within the knowledge of members of the current board and staff of the VRC together with enquiries made to date.

1.3 With the passage of time since the Flemington Racecourse flood protection was constructed, knowledge of the current board and staff is relatively limited and it has not been possible to undertake a thorough review of all potentially relevant documentation to this point in time.

1.4 Whilst there was significant flooding across Victoria in October 2022[1] it is the VRC's understanding that the focus of the Flood Review is technical matters that are relevant to the Maribyrnong River Flood Event that occurred on 14 October 2022 (**Flood Event**). This submission addresses factual matters concerned with the Flood Event.

2 INTRODUCTION

2.1 The VRC was founded in 1864 and registered in Victoria as a non-profit unlisted public company limited by guarantee on 10 April 2006. The VRC is a sports club operating in Australia and has members globally.

2.2 An overview of VRC's strategy and business operations is at **Annexure 2** of this submission, which is extracted pages 12-17 of the VRC's 2022 Annual Report. Surplus funds generated as a result of the VRC's business activities are invested in VRC's strategy and business operations.

2.3 The VRC is headquartered at Flemington Racecourse (**Racecourse**) which is located seven kilometres from the Melbourne CBD and occupies 320 acres. The Racecourse has four grandstands, ten training tracks, 18 resident trainers, an equine swimming pool and facilities for 600 horses in training. Annually, the VRC hosts around 500,000 racegoers across 25 race days at the Racecourse with 250,000 to 300,000 people attending the four-day Melbourne Cup Carnival, held in November annually. The Racecourse is operated 24 hours daily throughout 365 days a year.

2.4 The VRC is governed by a board of directors elected by its members. Current directors of the VRC's board are:

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[1] Which is the subject of the Victorian Environment and Planning Committee's Inquiry into the State's preparedness for and response to Victoria's major flooding event of October 2022.

(i) [redacted]

(ii) [redacted]

(iii) [redacted]

(iv) [redacted]

(v) [redacted]

(vi) [redacted]

(vii) [redacted]

(viii) [redacted]

(ix) [redacted]

(x) [redacted]

(xi) [redacted]

The VRC Company Secretary is [redacted]

2.5 At the time of writing this submission, the VRC has approximately 31,500 members and permanently employs 230 staff. An additional 650 casual staff members are employed on a Melbourne Cup Carnival race day.

2.6 The VRC works in cooperation with the Victorian Government, Minister for Racing and Minister for Tourism, Sport, and Major Events as both the racing industry and Melbourne Cup Carnival are major contributors to the Victorian economy. Despite attendance being capped due to COVID-19, the 2021 Melbourne Cup Carnival contributed $341 million in gross economic benefit to the Victorian economy. The 2022 Melbourne Cup Carnival contributed $422.1 million in gross economic benefit to the Victorian economy.

3 THE FLEMINGTON RACECOURSE FLOOD WALL

3.1 Between 2002 and 2003, the VRC, in consultation with relevant State Government Departments and Agencies, including the then Department of Sustainability and Environment (the **Department**) and Melbourne Water undertook feasibility and planning work to develop a Masterplan for redevelopment of Flemington Racecourse. The Masterplan was to include the development of a bund wall (**Floodwall**) spanning the southern edge of the Racecourse. Between 1974 and 2003, the Maribyrnong River broke its banks eight times.

3.2 The Floodwall was subsequently designed with a view to protecting the Racecourse and associated facilities, including the training facilities and stables for approximately 600 horses, from flooding levels up to the 100-year Average Recurrence Interval (**ARI**) for floods.

3.3 In or around May 2002, VRC instructed architect [redacted] to coordinate the investigation of the construction of a Floodwall. Also in or around May 2002, VRC engaged GHD Pty Ltd (**GHD**) (formerly Egis Consulting Engineers) as the engineers responsible for the Floodwall plans including managing flood risk and impacts of the Floodwall.

3.4 VRC engaged Young Consulting Engineers Pty Ltd (**Young Consulting Engineers**) as its representative for the planning process of the racetrack refurbishment, drainage and design of the Floodwall.

3.5 On 25 March 2003, Young Consulting Engineers applied to the Department for a planning permit (**Application 2003/86**) on behalf of VRC to carry out "racecourse track upgrade and flood protection works at Flemington Racecourse" (**Works**). This Application was one of a number of planning permit applications made in connection with the Masterplan, although it is the only application relevant to the construction of the Floodwall.

3.6 On or around 1 April 2003, GHD prepared the *Flemington Racecourse Flood Protection Investigation of Maribyrnong River Flood Protection – Draft Report* (**Draft Report**) (a copy of the Draft Report and Figure 1.1 and Appendix A are at **Annexure 3** to this submission).

3.7 On 30 April 2003, [redacted], at the request of GHD, completed his review of the Draft Report. His comments about it were provided to Melbourne Water (a copy of his comments are at Appendix D to **Annexure 4** of this submission).

3.8 In May 2003, GHD issued the *Flemington Racecourse Flood Protection Investigation of Maribyrnong River Flood Protection – Final Report* (**Final Report**) (a copy of the Final Report is at **Annexure 4** to this submission).

3.9 On or around June 2003, Environmental Resources Management Australia were appointed by the VRC as its town planners and landscape designers for the Floodwall project.

3.10 On 25 June 2003, the Masterplan was announced by the VRC. The objective of the Masterplan was to maintain the VRC's position at the forefront of the racing world. Stage One of the Masterplan incorporated references to measures to ensure the annual running of the Melbourne Cup would not be affected by the occurrence of one in 100 year ARI floods.

3.11 The Masterplan was made available to the public on the VRC website and there was capacity for questions to be submitted to allow the VRC to answer direct enquiries from interested parties.

3.12 Further, the VRC consulted with the community and held a public information meeting concerning five planning permit applications (including Application 2003/86) on 15 July 2003. Invitations to the public information meeting were sent to the 423 properties adjoining the Maribyrnong River in the City of Maribyrnong.

3.13 On 19 September 2003, Melbourne Water provided in-principle support for the Department to issue a planning permit for Application 2003/86, subject to 40 conditions.

3.14 On 5 February 2004, the then Minister for Planning, [redacted] issued a notice of decision to grant a permit in respect of Application 2003/86. An appeal to the Victorian Civil and Administrative Tribunal from the Minister's decision was subsequently initiated by objecting local councils and in around April 2004, the Minister exercised her power under clause 58 of Schedule 1 of the *Victorian Civil and Administrative Tribunal Act 1998* to call-in the appeal.

3.15 Subsequently, on 3 August 2004, the Minister issued planning permit 2003/86 to complete the Works. 49 conditions were attached to the Permit (**Permit Conditions**).

3.16 The Minister for Planning endorsed a number of different plans under the Permit. We assume that the Flood Review has or will obtain the full set of endorsed plans from the Department and so to avoid unnecessary duplication, we have not also provided them.

3.17 In around late August 2004, the VRC engaged PPM Group to provide project management services in connection with the Works.

3.18 In December 2005, following a competitive tender process, the VRC appointed Akron Roads Pty Ltd (**Akron**) to undertake the flood mitigation works required as a condition of the planning permit.

3.19 Compliance with each of the non-ongoing Permit Conditions was subsequently obtained, with the Department providing final confirmation of this in a letter to VRC dated 17 March 2008 (a copy of this letter is at **Annexure 5** to this submission). More detailed information as to the compliance with each of the Permit Conditions is set out in **Annexure 1** to this submission.

3.20 Construction of the Floodwall began in 2007 after the flood mitigation works required as a condition of the planning permit were completed in January 2006. To the best of the knowledge of current board members and employees of the VRC, the mitigation works were completed to the required standard.

3.21 In around September 2007, the construction of the Floodwall was substantially completed.

3.22 On 21 January 2009, GHD advised Akron of formal acceptance of the works under the Flemington Flood Wall Project and the site was handed over to the VRC.

We look forward to hearing the outcome of the Flood Review.

[redacted]

[redacted] | Victoria Racing Club Limited

[redacted]

List of Annexures:

1 Table of Planning Permit Conditions for Permit 2003/86

2 Extract of VRC's 2022 Annual Report, pages 12 to 17

3 GHD Draft Report, Flemington Racecourse Flood Protection – Investigation of Maribyrnong River Flood Protection, March 2003, including Figure 1.1 and Appendix A

4 GHD Final Report, Flemington Racecourse Flood Protection – Investigation of Maribyrnong River Flood Protection, May 2003

5 Letter from [redacted] (Department of Planning and Community Development) to [redacted] (Project Planning Management Pty Ltd), regarding Planning Permit No. 2003/86, 17 March 2006

Annexure 1 – Table of Planning Permit Conditions for Permit 2003/86

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
Condition 1	Prior to the commencement of works, amended plans to the satisfaction of the Responsible Authority must be submitted to and be approved by the Responsible Authority. When approved, the plans will be endorsed and then form part of the permit. The plans must be drawn to scale with dimensions and three copies must be provided. The plans must be generally in accordance with the submitted plans titled '*Flemington Racecourse Flood Wall Concept LS1-LS5* but modified to show: a) Design detail of the variety of fencing structures (including floodwall/gabion wall and security fence) including front and rear elevations of the entire fence, sections and the exact height of the fence at a scale of 1:200. b) Maximum height of the fencing structure reduced to 3.5 metres. c) Design detail and location of signage (including floodwall) proposed on the concrete wall, at a scale of 1:50. d) Detailed plan and section of the land between the floodwall and the bank of the Maribyrnong River, detailing the location of the pedestrian track. e) Details of external lighting, if proposed.	Yes	Yes – 20 December 2005
Condition 2	The works as shown on the endorsed plans must not be altered without the written consent of the responsible authority.	No - ongoing	

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
Condition 3	The amended plans, when approved to the satisfaction of the Responsible Authority, shall form part of the permit and must not be altered or modified in any way without the written consent of the Responsible Authority.	No - ongoing	
Condition 4	Prior to the commencement of all flood protection works (including racecourse upgrade and flood wall) and mitigation works, the Victoria Racing Club (VRC) (or its successor) as the user of the subject land must enter into a legally binding agreement with the Responsible Authority requiring: a) Agreement to be reached with the Society Temple of the Heavenly Queen Association (land owners of the Northern Railway embankment) and Vic Roads (owner of the Footscray Road Bridge) regarding the proposed mitigation works outlined in the GHD report 'Flemington Racecourse Flood Protection' dated May 2003; b) Mitigation works to be completed to the satisfaction of Melbourne Water and the Responsible Authority before any flood protection works commence; c) Mitigation works to be carried at the Northern Railway embankment and the Footscray Road Bridge to the satisfaction of Melbourne Water and the Responsible Authority. The VRC must pay all of the Responsible Authority's legal costs and expenses in the preparation, execution and registration on title of this agreement.	Yes	Yes – 19 August 2005

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
Condition 5	Prior to the commencement of the works, a scheme for landscape and planting showing all reduced levels (RL's) in connection with the proposed works must be submitted for the approval of the Responsible authority after consultation with the City of Melbourne and must be implemented immediately after the completion of the floodwall, or as otherwise may be agreed with the Responsible Authority. The areas concerned must be subsequently maintained to the satisfaction of the Responsible Authority.	Yes	Yes - 20 December 2005
Condition 6	Appropriate mitigation works must be undertaken along the Maribyrnong River flood plain to the satisfaction of Melbourne Water	No	
Condition 7	The cost of mitigation works to the Footscray Road Bridge and the Northern Railway shall be met entirely by the Victoria Racing Club and be undertaken to the satisfaction and at no cost to Vic Roads, Melbourne Water and the Responsible Authority	No	
Condition 8	a) Prior to the commencement of any works, including demolition, a detailed Construction Management Plan with the objective of minimising the impact of works associated with the Maribyrnong River pedestrian walking track and protection of existing native vegetation during construction must be submitted to and approved by the Responsible Authority after consultation with the City of Melbourne and the City of Maribyrnong.	Yes	Yes – 31 March 2006

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
	b) All development must be carried out in accordance with the Construction Management Plan.		
Condition 9	An annual survey of the apex level of the floodwall as compared with the design level to ensure that the apex level is not higher than the designed, must be submitted to the satisfaction of the Melbourne Water on an annual basis.	No - Ongoing	
Condition 10	Compensating works must be designed and constructed to offset any increase to Maribyrnong River flood levels for the 100-year ARI event, caused by works at Flemington Racecourse. A Design Certification Statement, signed by a suitably qualified hydraulic engineer, must accompany the design plans.	Yes	Yes - 20 December 2005
Condition 11	Unless otherwise agreed in writing by Melbourne Water, compensating works must be completed before starting works to erect the floodwall at Flemington Racecourse. This excludes site preparation, excavation and footings below existing ground level.	No	
Condition 12	Compensating works to any existing structures must be designed by a suitably qualified structural engineer and constructed to maintain structural integrity. A Design Certification Statement, signed by the suitably qualified structural engineer, must accompany the design plans	Yes	Yes - 20 December 2005

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
Condition 13	Before starting compensating works, evidence of agreement with landowners and/or authorities (if land or structure in public ownership) where compensating works are proposed, must be supplied to Melbourne Water and the Responsible Authority	Yes	Yes – 19 August 2005
Condition 14	Before starting compensating works, detailed design plans must be submitted to Melbourne Water and the Responsible Authority	Yes	Yes – 19 August 2005
Condition 15	Before starting compensating works, a Construction Site Management Plan (Compensating Works) must be to the satisfaction of Melbourne Water and the Responsible Authority. The plan must identify specific pollution and sediment control measures to be used and maintained, during the construction period, to mitigate runoff impacts upon the Maribyrnong River.	Yes	Yes – 19 August 2005
Condition 16	A suitably qualified practitioner must certify the Construction Site Management Plan (Compensating Works).	Yes	Yes - 20 December 2005
Condition 17	Before starting floodwall works at Flemington Racecourse, the following information regarding compensating works must be submitted to Melbourne Water and the Responsible Authority, for any:	Yes	Yes – for 17(a), obtained on 20 December 2005

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
	a) Works to structures - Construction Certification Statement, signed by a suitably qualified structural and hydraulic engineers, indicating that works have been completed in accordance with design. b) Changes to land levels - A Constructed Survey Level Plan, signed by a licensed land surveyor, with a statement indicating that any alterations to existing levels have been completed in accordance with design.		For 17(b), obtained on 1 March 2006
Condition 18	Before starting floodwall works, detailed design plans of the floodwall must be to the satisfaction of Melbourne Water and the Responsible Authority. A Design Certification Statement, signed by a suitably qualified hydraulic engineer, must accompany the design plans. The plans must provide for: a) Controlled over-topping of flood flows, to minimise on-site flood risks, for events greater than the 100- year ARI event. b) A floodwall apex level that provides an agreed freeboard margin above the 100-year ARI flood level.	Yes	Yes - 20 December 2005
Condition 19	Before starting floodwall works a geotechnical investigation of long-term vertical settlement must be completed by a qualified geotechnical engineer and submitted to Melbourne Water and the Responsible Authority	Yes	Yes - 20 December 2005
Condition 20	Before starting floodwall works, structural design details (including computations) must be submitted to Melbourne Water and the Responsible Authority. The details must show that the floodwall will:	Yes	Yes - 20 December 2005

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
	a) Meet the physical details and design parameters adopted in hydraulic modelling done by GHD Pty Ltd. b) Have an apex level that compensates for any long-term vertical settlement. c) Withstand Maribyrnong River flood forces (including debris impacts) and over-topping of flood flows. d) Be an impervious barrier to Maribyrnong River flood flows, for any event up to and including the 100- year ARI event. e) Integrate with any new vehicle connection (such as proposed at Smithfield Road), which intersects the floodwall's alignment, to achieve a continuous apex that is consistent with condition 9 above. A Design Certification Statement signed by a suitably qualified structural engineer must accompany the structural design details		
Condition 21	Before starting works a Floodwall Design Alignment Plan must be to the satisfaction of Melbourne Water and the Responsible Authority. The plan must dimension the location of the floodwall with respect nearby features that include, but not limited to, the following: a) The eastern bank of the Maribyrnong River. b) The northern side of Smithfield Road.	Yes	Yes - 20 December 2005

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
	The plan must accompany a statement from a hydraulic design engineer to confirm that the floodwall's design alignment and roughness corresponds to that used in flood modelling done by GHD Pty Ltd		
Condition 22	When floodwall works are finished the following must be submitted to Melbourne Water and the Responsible Authority to show the flood wall has been constructed in accordance to design plans: a) Floodwall As-Constructed Plan showing the floodwall's alignment and apex (reduced to AHD) signed by a licensed land surveyor. b) Construction Certification Statement signed by a suitably qualified structural and hydraulic engineers.	Yes	Yes – 2 January 2008
Condition 23	Before starting floodwall works, a Floodwall Maintenance Acceptance Statement must be submitted to Melbourne Water and the Responsible Authority. The statement must indicate that the racecourse owner (or their delegate) accepts full responsibility for the on-going care and maintenance of the floodwall	Yes	Yes - 20 December 2005
Condition 24	Before finishing floodwall works, a Floodwall Maintenance Plan must be submitted to Melbourne Water and the Responsible Authority. The plan must outline actions, carried out by and to the satisfaction of a suitably qualified structural engineer, to facilitate the ongoing care and maintenance of the flood wall.	Yes	Yes – 2 January 2008

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
Condition 25	The Flood wall Maintenance Plan must provide for inspections and maintenance on behalf of the racecourse owner (or their delegate), from within the racecourse, when Maribyrnong River flood-flow affects the floodwall	Covered by condition 24.	
Condition 26	Before starting floodwall works a separate application, direct to Melbourne Water, must be made for any new or modified stormwater outlets to the Maribyrnong River.	Yes	Yes - 20 December 2005
Condition 27	Before starting floodwall works, detailed design plans of all new and existing stormwater outlets must be to Melbourne Water's satisfaction. Plans must include detailed design of floodgates	Yes	Yes - 20 December 2005
Condition 28	Before starting floodwall works, a Stormwater Outlet Maintenance Acceptance Statement must be submitted to Melbourne Water and the Responsible Authority. The statement must indicate that the racecourse owner (or their delegate) accepts full responsibility for the ongoing care and maintenance of outlets and any floodgates	Yes	Yes - 20 December 2005
Condition 29	Before finishing floodwall works. Stormwater Outlet Maintenance Plan must be submitted to Melbourne Water and the Responsible Authority. The plan must be prepared by a suitably qualified engineer to describe actions to facilitate the ongoing care and maintenance of outlets and any floodgates	Yes	Yes - 2 January 2008

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
Condition 30	All stormwater outlets to the Maribyrnong River must be maintained by the racecourse owner (or their delegate) to the satisfaction of Melbourne Water.	No - Ongoing requireme nt	
Condition 31	Before finishing floodwall works, the site's Emergency Flood Response Plan must be reviewed to the satisfaction of a suitably qualified risk management practitioner. The plan must include actions to manage flood risks for any flood event where the floodwall is: a) A barrier to Maribyrnong River flood flows entering the site. b) Over-topped by Maribyrnong River flood flows. Copies of the plan must be submitted to Melbourne Water, the Responsible Authority and the City of Melbourne.	Yes	Yes – 14 January 2008
Condition 32	The Emergency Flood Response Plan must be reviewed to include actions that manage flood risks for racecourse activities within the waterway linear park	Yes	Yes – 28 February 2008
Condition 33	No pollution or sediment-laden runoff shall be discharged to the Maribyrnong River	No – Ongoing requireme nt	

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
Condition 34	Before starting works at Flemington Racecourse, a Construction Site Management Plan (Racecourse Works) must be provided to Melbourne Water's satisfaction. The plan must identify specific pollution and sediment s control measures to be used and maintained, during the construction period, to mitigate runoff impacts upon the Maribyrnong River	Yes	Yes – 16 February 2006
Condition 35	A suitably qualified practitioner must certify the Construction Site Management Plan (Racecourse Works).	Yes	Yes - 28 February 2008
Condition 36	Before starting works at Flemington Racecourse, a Stormwater Quality Management Strategy must be to the satisfaction of Melbourne Water and the Responsible Authority	Yes	Yes - 20 December 2005
Condition 37	The Stormwater Quality Management Strategy must provide for the design and construction of permanent stormwater quality works that meet the receiving water quality objectives outlined in State Environmental Protection Policy (Waters of Victoria).	Yes	Yes - 20 December 2005
Condition 38	Before finishing floodwall works at Flemington Racecourse, a Stormwater Quality Maintenance Plan must be provided to Melbourne Water's satisfaction.	Yes	Yes - 2 January 2008

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
Condition 39	The Stormwater Quality Maintenance Plan must outline actions, done on behalf of the racecourse owner, to facilitate the ongoing care and maintenance of all permanent stormwater quality works.	Covered by condition 38	
Condition 40	When all stormwater quality works are finished at Flemington Racecourse, a Construction Certification Statement must be submitted to Melbourne Water indicating works have been constructed in accordance to design. A suitably qualified practitioner must sign the statement	Yes	Yes - 2 January 2008
Condition 41	When all earthworks works are finished at Flemington Racecourse, a Site Survey Level Plan must be submitted to Melbourne Water and the Responsible Authority, showing all finished surface levels affected by the works. The plan must show levels reduced to AHD and signed by a licensed land surveyor.	Yes	Yes – 16 January 2009
Condition 42	Before starting landscape works, a Floodwall Landscape Report must be to the satisfaction of Melbourne Water and the Responsible Authority. The report must provide for the selection and siting of vegetation that does not affect the ongoing function and structural integrity of the floodwall (including berm).	Yes	Yes – 2 March 2007
Condition 43	Before starting landscape works, a qualified structural engineer and landscape designer must certify that landscaping identified within the Floodwall Landscape	Yes	Yes - 28 February 2008

Planning Permit 2003/86			
No.	**Condition**	**Secondary Approval required**	**Secondary Approval obtained**
	Report will not affect the ongoing structural integrity of the flood wall (including berm).		
Condition 44	Before starting landscape works, Detailed Landscape Plans must be submitted to the satisfaction of Melbourne Water and the Responsible Authority. The plans must provide for: a) Selection and siting of vegetation as outlined in the Floodwall Landscape Report. b) Vegetation within the river frontage area, tolerant to active flood flows and planted at a density that does not increase Maribyrnong River flood levels. c) Landscaping within the river frontage area that provides for maintenance access to the waterway. d) Any new or modified path within the river frontage area, designed in accordance with principles contained in Melbourne Water's guidelines for constructed paths. e) Landscaping within the river frontage area to soften the appearance of the waterway bank edge.	Yes	Yes – 20 December 2005
Condition 45	The Flood wall Maintenance Plan must outline actions, undertaken on behalf of the landowner, to ensure that maintenance of landscaping identified within the Floodwall Landscape Report will not affect the floodwall's ongoing structural integrity	Yes	Yes - 2 March 2007

Planning Permit 2003/86

No.	Condition	Secondary Approval required	Secondary Approval obtained
Condition 46	Before starting landscape works, a River Frontage Maintenance Plan must be to Melbourne Water's satisfaction. The plan must delineate Melbourne Water's waterway bank maintenance area from all other areas within the linear park and outline maintenance actions to provide for: a) No increase in Maribyrnong River flood levels. b) No increase in erosion potential of floodwaters within the linear park. c) Ongoing protection of waterway bank stability.	Yes	Yes - 2 March 2007
Condition 47	Before starting landscape works, landscape plan LS3 must be amended to show a floodwall apex level as outlined in conditions 18 and 20 and consistent with any issued planning permit for vehicle connections at Smithfield Road.	Yes	Covered by plans endorsed under other conditions
Condition 48	Before starting landscape works, landscape plans LS4 and LS5 must be amended to reflect the siting of trees in accordance Floodwall Landscape Report.	Yes	Covered by plans endorsed under other conditions
Condition 49	This permit will expire if one of the following circumstances applies: a) The development is not started within two years of the date of the permit. b) The development is not completed within four years of the date of this permit. The Responsible Authority may extend the periods referred to if a request is made in writing before the permit expires or within three months afterwards.	No	

In the 2021/22 Racing Season our Strategic Plan sought to strike a balance between our overall financial management and our ambition to position the Club for the future – post COVID19.

There have been a number of key outcomes achieved over the past twelve months and they include preparing for crowds returning to normal operation (with restrictions eased) post the 2021 Melbourne Cup Carnival where restricted crowds were permitted; growth in membership being achieved to 29,121; the Lexus partnership extended to 2024 and a new partnership with Penfolds; restructuring of the Executive Leadership Team; new strategic partnerships with Crown, Ticketmaster and Cirka; and significant outcomes actioned in the racing program and prizemoney to elevate the 2022/23 racing season.

Going forward, a key element of our vision is to continue to be a leader in world-class racing – in all aspects – from racing to facilities and experiences. To achieve this we must constantly review all aspects of our operation. We set the standard in equine welfare facilities and practices, and will continue to do so. It is a core strategic focus and an expectation of the community, and an integral element of our social license. We continue to introduce new technology and racing initiatives, and to innovate in the racing program, prizemoney and operations.

The Club has set an ambitious strategic plan for the period 2022 to 2024, to help to deliver on our vision for the future. We are always evolving, growing and building, to be recognised as outlined in each of the following areas.

RACING

We continue to develop our world-class facilities, ensuring that the quality of our track is the best in the world.

- From jump-outs to training to race days, our course has the highest safety standards and is one that people want to train and race at.
- We reward them with the best course, which attracts strong, competitive fields.
- It attracts competitors from all over the country and the world, offering the opportunity to win from any part of the track.
- Our prizemoney (total $70m) continues to attract these quality fields.
- We set the standard in equine welfare facilities and practices and strive for excellence in that area. The Equine Wellbeing Fund, which has supported multiple initiatives to date, was introduced by the Club in 2019. It was kickstarted with $1 million, which included 10% of proceeds from ticket sales from the 2020 Melbourne Cup Carnival, as well as 5% of membership fees each year. This ensures that members are supporting good equine welfare outcomes for thoroughbreds every time they renew their annual membership.
- The new synthetic surface delivers on the VRC's vision to provide an unrivalled experience for its equine athletes to train, perform and recover.
- Always looking to improve and elevate our race programming, the new TAB Champions Stakes Day on the final day of the Melbourne Cup Carnival is evidence. It offers three Group 1 races over a range of distances (sprint, mile and stakes).

ENGAGEMENT AND EXPERIENCE

- The Melbourne Cup Carnival remains the number-one economic benefit generator of any annual sporting event in Australia, with Melbourne Cup Day 2021 generating $340.98 million in economic activity across Australia despite restrictions (up by 7.8%, from $316.4 million in 2020).
- The Lexus Melbourne Cup is one of the most widely watched races globally, with an audience reach of over 750 million people and over 160 broadcast countries and territories.
- The VRC is the leading club and brand in racing and race-day events. When you are a visitor to Flemington, whether as a member, partner or guest, you know that you will get the best possible experience in events, hospitality and racing.
- The Club has an ever-evolving offering, catering to the needs of its members and racegoers.
- Going forward, we seek to evaluate and optimise opportunities to strategically grow our non-racing business, such as corporate and personal functions and business facilities.
- We look forward to establishing the next version of our Master Plan for Flemington.

CONTENT AND MEDIA

- Our development of VRC Media focuses on optimising the range, reach and engagement of our content and media assets.
- We are investing in the future while preserving our history with a new Media Asset Management system, which will catalogue and archive priceless footage, images, and content in broadcast quality for future generations to view.
- Striving to always be at the forefront of technology and digital offerings, we are evolving with our highly engaged community. Inside Run, a digital racebook that takes racing fans right inside the action with cameras that offer insights of the racing like never before is one such asset.
- Engaging members with the stories behind the racing is a crucial part of our business, and our member publications *Inside Headquarters* and *Carnival* magazines, along with regular stories online, do just this. The Club has its own point of view in the industry, and brings racing closer to our members through this content.

- Educating members and racegoers around the equine stars of the sport and the work done to care for them, pre, during and post racing is the focus of our Equine Welfare Bulletin, where experts in their fields offer their knowledge and expertise.

PEOPLE AND COMMUNITY

- The VRC wants to be a workplace of choice, and a valued and influential member of the racing industry and community.
- In 2021/22, the VRC continued its commitment to social responsibility and proactively engaged the local community in several community programs. The VRC generated more than $2 million in social impact through its community, charitable and equine welfare initiatives.
- The Club looks to increase the impact of both our and the Melbourne Cup Foundation's social responsibility activities. The Club has a proud heritage and history of supporting charities through a number of initiatives, including the 27-year-old Pin & Win program – a vital part of the Melbourne Cup Carnival. This initiative has raised $6.9 million since it began in 1995. Our previous partner, Very Special Kids, raised $1 million through the scheme, and we hope that our newest partner, Australian Childhood Foundation, benefits even more.
- The promotion of equine welfare is a major focus of the Club. We support Off The Track thoroughbreds and all rehoming options for retired racehorses and will continue to promote the wonderful work done in this space.
- Our partnerships with Racing Hearts and with Riding for the Disabled are testament to this dedication.
- To achieve our vision of being a world leader in racing and event entertainment while balancing the needs of the environment and community, the VRC aims to be a sustainable business, which manages and holds sustainable events that balances its operations with the needs of the community.
- By 2025, we will have 0% food waste to landfill and carbon neutrality, among many other initiatives. We aspire to attain the highest standards in environmental performance, assisted by partnerships with leading businesses and suppliers, integrating considerations of total value into procurement and all decision making.

HISTORY

Horse racing started at Flemington Racecourse in 1840, when Melbourne as a town was five years old. The Victoria Racing Club was established in 1864 and since 1871, with the establishment of the Victoria Racing Club Act, the racecourse has been managed by the VRC under a Crown land lease arrangement. The first race meeting at Flemington Racecourse was held on 3 March 1840, and the first Melbourne Cup, Flemington's most famous race, was run on Thursday 7 November 1861.

Born of a rivalry between the Victoria Turf Club and the Victoria Jockey Club, the Victoria Racing Club has had a long and rich history, and currently holds the largest membership of any race club in the world. The new body had set the standard for thoroughbred racing throughout Victoria, something that has never waned.

MEMBERSHIP

The Club is committed to recognising the importance of the legacy left by founding members of the Club. The introduction of Bagotville Race Day in 2020 was a nod to the great racecourse and the illustrious history of the VRC. It is due to visionaries such as Robert Cooper Bagot and Byron Moore that the VRC became Australia's premier race club and the custodian of one of the world's greatest races in the Lexus Melbourne Cup.

The VRC remains a leader by keeping the strategic focus on membership experience. With a membership base of more than 29,000 and growing in numbers from the previous years, the Club is proud to provide a place for members to share their passion and love for racing.

FACILITIES

Outside of the world-class Melbourne Cup Carnival, Flemington houses a number of dedicated event spaces, spread across three connected grandstands, which offer flexibility to cater to many types of events.

The venues at Flemington offer capacity for as many as 1,000 guests for breakfast, lunch or dinner, 1,300 delegates for a theatre-style conference, seminar or meeting, 2,500 guests for a cocktail reception or up to 60,000 for large-scale outdoor events.

From hosting thousands in The Atrium for functions, to more intimate gatherings in The Roof Garden with its unmatched city skyline views, there are a variety of spaces to suit any event.

The Nursery hosts music festivals and other outdoor events with crowds of up to 20,000 people.

Surrounded by the world-famous Flemington rose gardens, the iconic Front Lawn is not just where history is witnessed on the turf, but can also be hired as a space for an assortment of outdoor events.

Flemington Racecourse – Australia's oldest racecourse in continuous use – is approximately seven kilometres north-west of Melbourne CBD along the Maribyrnong River. Occupying an area of 320 acres, it is one of the largest racecourses and longest racetracks in Australia with a course proper 30 metres wide and a circumference of 2,312 metres with the famous 'Straight Six' – the six furlong (1200m) straight. There is also 10 kilometres of grass, sand and synthetic training tracks.

On the site are 18 resident trainers and facilities for 600 horses. The site is home to the largest public rose garden in the southern hemisphere (more than 16,000 rose bushes), The Heritage Centre, four grandstands, a gaming venue, park land, a nursery, wetlands, car parks, a train station, administration offices and an operational workshop, as well as a rich tapestry of heritage assets.

OPERATIONS

Governed by a board elected by its members, the Victoria Racing Club is a not-for-profit organisation. Surplus funds are reinvested into Flemington Racecourse and its operations.

A permanent workforce of around 220, in addition to the hundreds of staff employed by resident trainers, supports the VRC's management of the site that operates 24 hours a day, 365 days of the year. The VRC also employs more than 2,000 casual staff on a traditional Melbourne Cup Carnival race day (directly and through our catering operations). In pre-COVID-19 times, we host around 500,000 racegoers a year across 25 race days, with up to 250,000 to 300,000 attending the four days of the Melbourne Cup Carnival. Racing remains the second largest live-attended sport in Australia behind Australian Rules Football.

FLEMINGTON RACECOURSE IN NUMBERS

FACILITIES

7km from CBD

Occupies 320 acres

4 grandstands

10 training tracks

Equine swimming pool

Facilities for 600 horses in training

FACILITIES

Up to 31,500 in indoor spaces

Up to 64,000 on lawns and grounds

Up to 41,500 in car parks

OPERATIONS

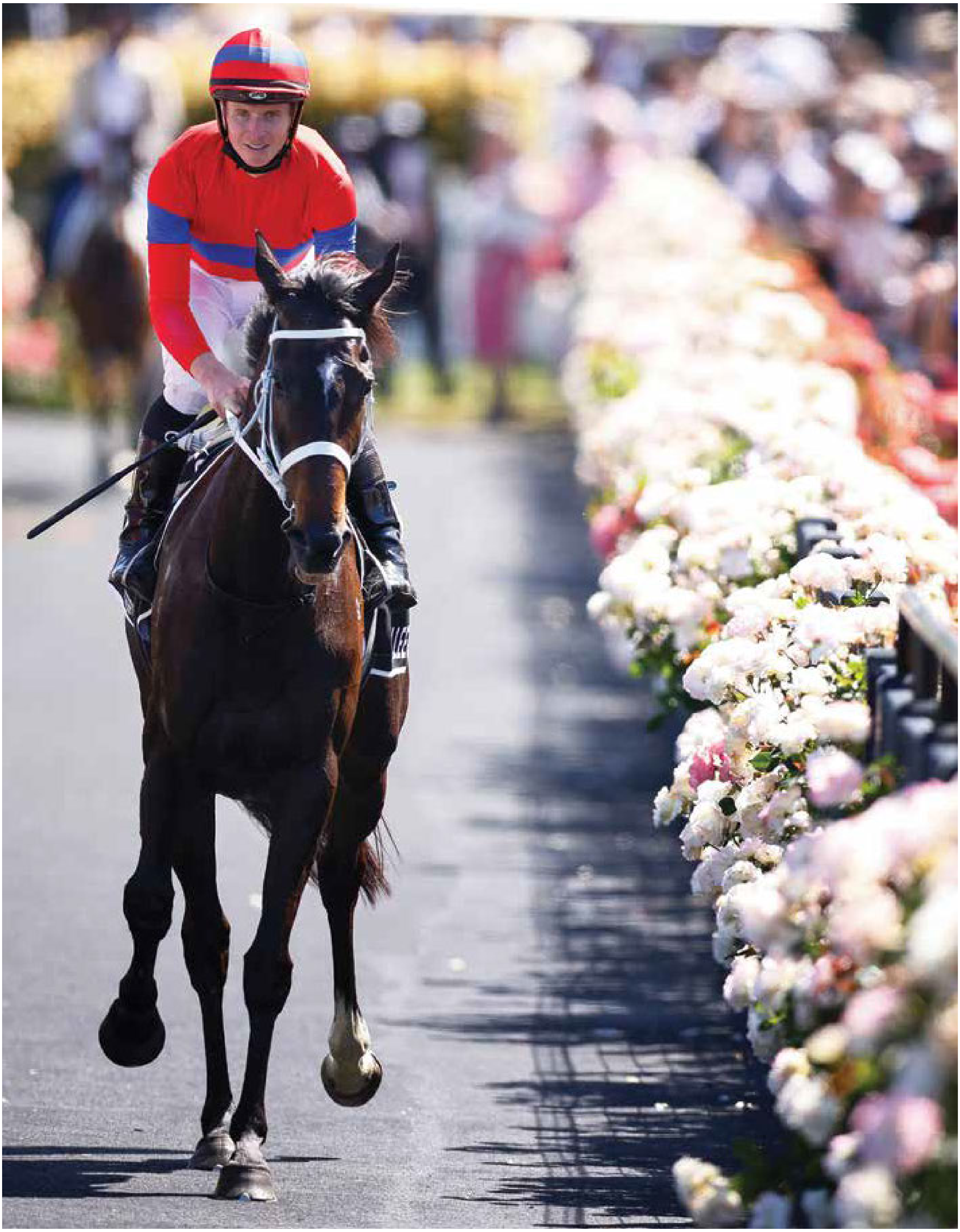
200+ staff

24 hours a day

365 days per year

18 resident trainers

16,500+ rose bushes



REACH

The VRC is a global sports club and business comprising racing, event entertainment and hospitality, aimed at a diverse customer base.

The Lexus Melbourne Cup is one of the most widely watched races in the world, with an audience reach of 750 million people across more than 160 broadcast countries and territories annually.

A general admission ticket allows patrons to view quality racing and access entertainment away from the track including Myer Fashions on the Field and renowned musical acts during the Melbourne Cup Carnival.

Our corporate clients are able to network with and entertain their clients in curated spaces that suit all industries and budgets.

Our sponsors receive year-round exposure during every race meeting, and are also able to invite their guests to experience the Melbourne Cup Carnival in the exclusive Birdcage enclosure.

And for our members, who are the backbone of our Club, we offer many venues ranging from casual outdoor areas, relaxed dining to fine dining to suit their needs, and those of their guests. We are pleased to provide diverse options all year round to match the race day requirements of our membership base.

The Melbourne Cup Carnival generates social and economic benefits on a large scale, and has a global reach that presents Melbourne, Victoria and Australia to the world in a positive way. In true reflection of our global vision, international reach is central to our business development and as a shop window for international investment in Australian racing, a $9 billion per annum industry.

The VRC remains a leader by keeping the strategic focus on membership experience. With a membership base of more than 29,000, the Club is proud to provide a place for members to share their passion and love for racing.

Victoria Racing Club

Flemington Racecourse Flood Protection

Investigation of Maribyrnong River Flood Protection

Draft Report

March 2003

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Glossary

100 year Average Recurrence Interval (ARI) flood
Commonly referred to as a flood with a 1% Annual Excedence Probability (1%AEP). A rare flood widely adopted as a design standard, this event has a 1 in 100 chance of being equalled or exceeded in any one year. While on average this event will occur only once in 100 years, it could occur several times or not at all during a given 100 year period.

1-dimensional (1-D) hydraulic model
Hydraulic models where levels are determined along a predefined flow path typically described by cross sections perpendicular to the predominant flow direction. 1-D models are computationally efficient at modelling of flows within a defined channel. Engineering judgement is required where 1-D models are applied to more complex flow mechanisms, such as flow transverse to the main flow direction.

2-dimensional (2-D) hydraulic model
2D models can model transverse flow. These models typically define the bathymetry or terrain as a regular grid and the flow path does not need to be predetermined. They require more data storage and run times are much longer, however they are useful for modelling rivers with extensive flood plains, i.e. where flow directions vary significantly in space and time.

Afflux
Change in flood level at a given location as a result of works, typically the difference in flood level between existing and proposed cases. Positive afflux is usually defined as an increase in flood levels.

Attenuation
the reduction in flood peak due to temporary storage associated with a floodplain, retarding basin or reservoir.

Conveyance
A measure of the capacity of a waterway to carry flows, especially flood flows. Conveyance is a function of geometry and roughness characteristics.

Hydrograph
a relationship defining the variation of flow with time, typically as a graph of flow versus time. Flood hydrographs may have multiple peaks, but typically rise to a peak before falling more gradually. Higher flows typically are reflected in higher water surface levels, hence the concept of a river rising and falling as the hydrograph (flood wave) passes through a given location over time.

Steady state
Used to describe a modelling approach in which flows and levels remain constant with time typically using peak flow values. Flood storage effects cannot be determined.

Unsteady state
A modelling approach using time varying flows and levels. Effects of flood storage are modelled.

Water Surface Level (WSL)
The surface of the water at a particular point, or the average water surface level when used

with respect to a 1D model cross section or particular river distance. Water surface levels can increase in a downstream direction when the flow velocity reduces.

Total Energy Level (TEL)
The level to which the water surface would rise if it were stationary. The TEL is above the water surface and always decreases in a downstream direction. The elevation difference between the WSL and TEL is known as the velocity head and is the square of the velocity divided by twice the accelation due to gravity

ie. $TEL = WSL + \frac{v^2}{2g}$

FFPW: Flemington (Racecourse) Flood Protection Works

Executive Summary

The reader is referred to Figure 1.1 for a map showing Flemington Racecourse and the Maribyrnong River.

The Victoria Racing Club engaged GHD to:

- Quantify the effects of the proposed Flemington Racecourse flood protection works on flood flows and flood levels in the Maribyrnong River;
- Identify and analyse appropriate mitigation measures which are likely to be acceptable to MW
- Prepare a report describing the analysis and results that will be suitable to support VRC's application with respect to floodplain issues.

A floodwall is proposed to protect Flemington Racecourse from flooding due to the 100 year ARI flood in the Maribyrnong River. The floodwall will block off almost 100 hectares of flood plain thereby reducing flood conveyance and floodplain storage. The loss of conveyance will cause a rise in upstream flood levels and the loss of floodplain storage will cause an increase in downstream flood flow, which in turn also causes the downstream flood levels to rise.

The 100 year ARI flow downstream of the site was found to increase by less than 1% from 838.4 m^3/s to 846.5 m^3/s (an increase of 8.2 m^3/s) due to loss of flood plain storage. This result was determined using a RORB model using input derived from a 2D model of Flemington. Unless works are implemented to mitigate against the increase in flood flow, the 100 year flood levels would increase by 30 to 35 mm between Footscray Road and Flemington. This increase in flood level (called "afflux") would reduce with distance upstream of Flemington. Following discussions with Melbourne Water it was decided to limit the study to upstream of Footscray Road

Afflux upstream of Flemington is caused by a combination of the downstream afflux and the loss of conveyance through the site. Unless mitigation works are implemented, the increase in flood level immediately upstream of the site, due to the loss of conveyance only, is approximately 20 mm at Fisher Parade. When combined with afflux due to the increase in flood flow (as described above) the total afflux would be approximately 55 mm at Fisher Parade. The afflux diminishes with distance upstream and, if mitigation works were not implemented, would be around 15 mm at Maribyrnong Village, an area which remains flood prone but has benefited from recent works.

Works to mitigate against the identified afflux were identified and analysed. A wide range of options was investigated but few options offered a suitable solution. The mitigation works proposed in this report involve providing additional conveyance and thereby "neutralising" the afflux.

Locations where conveyance could be most effectively improved were identified following a review of the flood profiles and site inspections. Mitigation works are proposed at two locations :

- Footscray Road Bridge, where streamlining of the left (eastern) bridge abutment will lower the flood level by approximately 55 mm; and
- Northern Rail Crossing, where a gravel access track located immediately downstream of the culverts that were installed in 1991 will be removed and lower the flood level by approximately 44 mm.

The lower flood levels, or "benefits", tend to taper off with distance upstream. However, the combined effect of mitigation works at both locations is for the afflux due to the flood protection works to be “neutralised”. In some locations the mitigation works over-compensate and 100 year ARI flood levels are slightly lower than under existing conditions.

The estimated capital cost of the proposed mitigation works is approximately $2 M. This order of cost figure is based on the current concept design with no allowance for any compensation which may be required. This estimate is based on a preliminary mitigation concept and will be refined during the detailed design phase. The detailed design phase will involve further negotiation with authorities and landholders and additional survey, analysis and design.

The current concept has been investigated to establish the viability of the project from a hydraulic perspective. While the approval process has the potential to restrict the impact of the mitigation works, preliminary indications are that the proposed mitigation works will provide a cost effective solution of benefit to the wider community.

1. Introduction

1.1 Scope of Investigation

Victoria Racing Club (VRC) commissioned GHD to undertake hydraulic investigations to determine the effects on Maribyrnong River flood levels of proposed flood protection works. The proposed flood protection works include the construction of a floodwall to protect the Flemington Racecourse from a 100 year ARI Maribyrnong River flood. This investigation also determined the extent and nature of the mitigation works required to compensate for the portion of flood plain effectively removed from the Maribyrnong River by the proposed floodwall. This report describes these investigations.

1.2 Background

Flemington Racecourse is located on the left (eastern) flood plain of the Maribyrnong River upstream of Smithfield Road ref Figure 1.1. The site has undergone substantial development over a considerable period of time and further development is planned. Planning is currently well underway for a major track reconstruction and associated works.

Flemington Racecourse is the location of Australia's biggest and richest horse racing carnival. The Spring Racing Carnival is an internationally recognised event; its four days of racing include the legendary Melbourne Cup. Derby Day, Cup Day, Oaks Day and Emirates Day generate significant economic and social benefits for the state of Victoria.

Flemington racecourse has been inundated several times by floodwaters from the Maribyrnong River. Such flooding has the potential to require substantial remediation works and if it were to occur within two months of the Melbourne Cup could lead to cancellation of the carnival. The Victoria Racing Club (VRC), in recognising the risks which flooding presents to the racecourse, its patrons and the Spring Racing Carnival, decided to investigate ways of reducing these risks.

1.3 Description of Proposed Flemington Racecourse Flood Protection Works

The concept of a floodwall around the racecourse has been developed during a series of discussions with Melbourne Water, the VRC it's Course development consultants and GHD. The floodwall will protect racecourse assets and events from a 100 year ARI Maribyrnong River flood. The proposed level of protection should enable a revision of the planning scheme to reflect that the racecourse is no longer part of the floodplain thus simplifying future development at the racecourse.

As the racecourse is located on the Maribyrnong flood plain, the site currently provides conveyance and attenuation of Maribyrnong River flood flows. In the absence of appropriate mitigation works the proposed floodwall will reduce currently available flood plain storage and conveyance leading to increased flood levels downstream and upstream of the site. Melbourne Water, as the flood plain referral authority, require that the 100 year ARI design flood levels are not increased by the proposed flood protection works at Flemington.

Figure 1.1 Locality Plan

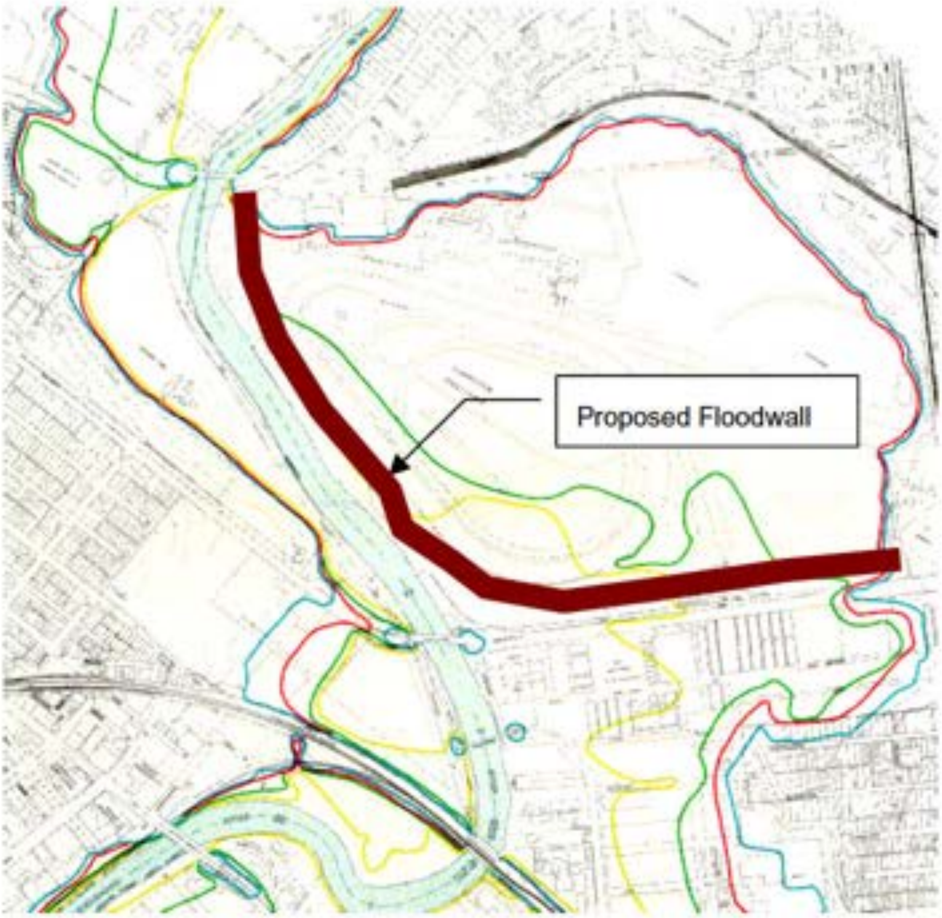
g:\31\12638\tech\gis\Figure 1-1 A3 portrait.wor

The proposed works include:

- A floodwall to protect the racecourse and events held there from the 100 year ARI Maribyrnong River flood.
- Associated mitigation works in the Maribyrnong River to compensate for the reduced floodplain storage and conveyance resulting from the proposed floodwall.
- Other associated works with little or no impact on the Maribyrnong River are not dealt with in this report and include:
  - Modification to the internal drainage system (ie inside or behind the flood wall)
  - A complete track reconstruction.
  - Construction of an underpass beneath the track for access to the central portion of the track
  - Water reuse facilities

The extent of flooding on the Maribyrnong River was mapped in 1986 by the MMBW, an extract is included as Figure 1.2. The general concept is to protect the racecourse from a 100 year ARI Maribyrnong River flood. The 1986 extent of flooding for the 100, 50 ,30 and 20 year ARI events are shown in Figure 1.2 as blue, red, green and yellow lines respectively.

Figure 1.2 Existing Flood Extents (1986) and Proposed Floodwall



2. Methodology

2.1 Introduction

This section describes the overall investigation approach, establishes some of the adopted terminology, and describes the data and models used for this investigation.

2.2 Overview of the Assessment Methodology

The effects of the proposed floodwall can be split into two related components; a loss of attenuation and a loss of conveyance. The process for evaluating and designing mitigation works was developed with an understanding of how these effects interact. In simple terms, loss of attenuation causes an increase in downstream flows. Loss of conveyance and or increased flows result in higher upstream flood levels. The following summarises the assessment tasks in the order they were undertaken:

1. Review of the existing conditions HEC-RAS model of the Maribyrnong River as supplied by Melbourne Water in January 2003.
2. Assessment of flow attenuation at Flemington Racecourse for existing and proposed conditions using detailed local models.
3. Extension of the HEC-RAS model downstream to include Footscray Road
4. Assessment of afflux due to loss of conveyance associated with proposed floodwall.
5. Determination of flood levels for existing and unmitigated proposed conditions using HEC-RAS in Steady State adopting the flows determined in task 2 above.
6. Investigation of bridging improvements to mitigate against the impacts of the proposed flood wall.
7. Modelling of the proposed works, ie the flood wall and associated mitigation works to determine flood levels and afflux in the Maribyrnong River.

2.3 Nomenclature

The following section describes the specific meanings given to various terms and expressions used in this report. Definitions for many of the more widely used technical terms are included in a glossary of generic terms at the front of this report.

Flemington: used to refer to the region of the Maribyrnong River adjacent to Flemington Racecourse between Fisher Parade and Lynchs Bridge.

Flood Wall: refers to the perimeter flood wall at the Flemington Racecourse Site designed to protect the racecourse from a 100 year ARI Maribyrnong River flood

Flood Protection Works: refers to the flood wall and associated mitigation works on the Maribyrnong River including proposed bridge modifications as required.

Existing Conditions: January 2003 conditions as detailed in the Melbourne Water Report (ref 1)

Base Case: the existing conditions model extended downstream to include Footscray Road, and minor amendments to flows and structure details, refer to Section 4.2. Revised flow estimates were developed for the base case to enable an appropriately conservative assessment of the effects of the proposed floodwall, refer to section 3.

Unmitigated Case: The “Base Case” with the floodwall. It includes the effects of loss of conveyance and flood plain storage but with no mitigation works.

Proposed Case: The “Unmitigated Case” with mitigation works that remove all positive afflux upstream of Footscray Road.

Flood Level: For consistency with previous Melbourne Water and MMBW Maribyrnong River investigations all flood levels produced in this report are Total Energy Levels (TEL) unless noted otherwise. The total energy level being the level to which water would rise if brought to rest.

2.4 Existing Conditions

Melbourne Water has provided the existing conditions model on which this investigation is based. The existing conditions model was created in HEC-RAS version 3.1, which is a one dimensional hydraulic model well suited to determining flood flows and levels for planning purposes on the Maribyrnong River from Footscray Road to Maribyrnong Village. It represents January 2003 conditions and is a suitable starting point for the impact assessment of the proposed flood wall on flood flows in the Maribyrnong River.

Details of the existing conditions model are published in Melbourne Water Corporations report, “Maribyrnong River Hydraulic Model, Final Report”, February 2003, by GHD (ref 1). Some key features of the existing conditions model are summarised below.

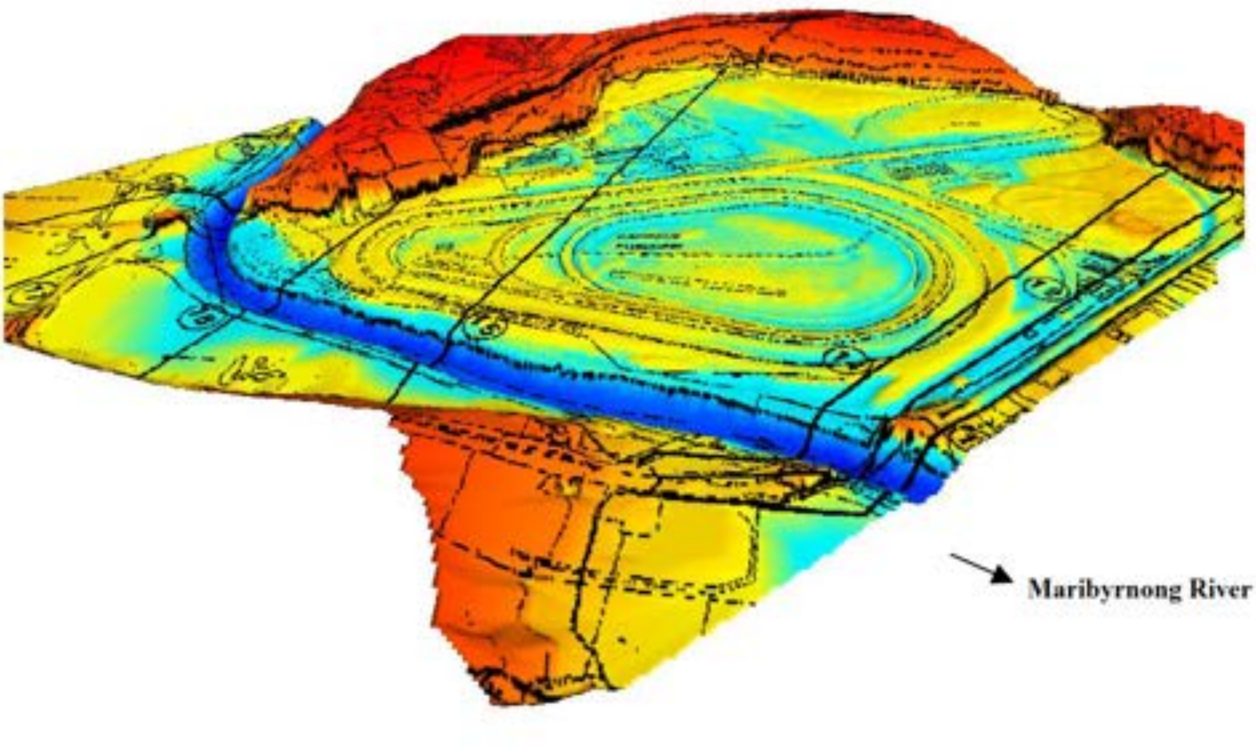
- The existing flood levels are total energy levels and are derived from a steady state HEC-RAS model.
- The model extends from Maribyrnong Village downstream to immediately upstream of Footscray Road. The cross sections are based on a variety of sources including bathymetric soundings, detailed photogrammetric and field survey and Melbourne Water one meter contours.
- The model was calibrated to the flood levels published in the “Maribyrnong River Flood Mitigation Report” MMBW 1986 (ref 6). The resultant calibrated steady state model has Manning’s ‘n’ values that are generally smoother than theory would suggest.
- The calibrated model was subsequently altered to incorporate three post 1986 developments:
    - Construction of 12 monolithic culverts adjacent to the northern railway bridge
    - Construction of Kensington Banks Development downstream of Lynchs Bridge
    - Construction of Edgewater Development upstream of Fisher Parade
- The existing condition models include an unsteady state HEC-RAS model used to determine the attenuated flows and a steady state HEC-RAS model that uses the attenuated flows to determine flood levels for planning purposes.
- Scour was not explicitly modelled although is implicitly accounted for at the Northern Railway Bridge as a result of the calibration process.
- The report identifies that it may be appropriate to use local models to more precisely determine local effects.

The last of these bullet points warrants some further explanation:

In all one dimensional hydraulic models flood levels are based on representative cross sections and cross sectionally averaged properties. Water surface levels and flow velocities typically vary significantly across a wide flood plain. This type of variation is beyond the ability of a one dimensional model to resolve and can be significant in determining the impact of floodplain modifications. The use of a one dimensional model with its inherent assumptions is generally considered appropriate for setting flood levels along a river such as the Maribyrnong. When detailed assessment of the flow distribution and the effect of flood plain works is required, such as for analysis of the current proposal, a two dimensional model will typically provide more confidence in the findings.

On this basis a two dimensional model of the site was developed using the same bathymetric soundings, detailed photogrammetric survey and Melbourne Water one meter contours as used for Melbourne Water's existing conditions model. The extent and relief of the two dimensional model is illustrated in Figure 2.1. More detailed information on the two dimensional model is included in Appendix A.

Figure 2.1 The existing site as represented in the two dimensional model



3. Change in Peak Flood Flow due to Loss of Flood Plain Storage

3.1 Introduction

The reduction in peak flows due to the temporary storage of floodwater is known as attenuation. This section describes:

- the existing attenuation estimates and why they need to be revised for the current investigation;
- the way existing attenuation estimates were revised and attenuation for the proposed case determined; and
- compares the revised flow estimates with existing attenuation estimates for existing and proposed conditions.

3.2 Existing Attenuation Estimates

The existing conditions model provided by Melbourne Water includes an estimate of flow attenuation under existing conditions, which was based on a one dimensional unsteady state HEC-RAS model. The primary purpose of the Melbourne Water model was determining flood levels for planning purposes.

All modelling involves some uncertainty and when deriving attenuation estimates for the purposes of setting planning levels it is generally conservative to underestimate attenuation because overestimating flows results in conservatively high flood levels. Such an approach is not appropriately conservative for determining the effect of loss of flood plain storage as required for the current investigation.

For the current investigation it is appropriate to revise the existing condition attenuation estimates for two reasons:

1. to ensure that the attenuation estimate is appropriately conservative ie to provide increased confidence that it is not underestimated; and
2. to examine the effects of the floodplain in more detail using local models as recommended in the MW existing report (ref 1)

3.3 Assessment of Attenuation

A detailed two dimensional model of Flemington (refer to Figure 2.1) was created and calibrated to enable assessment of conveyance and storage effects. Examination of flow attenuation estimated using the unsteady 2D model identified some limitations, and an alternate methodology using RORB was devised. While the RORB analysis was ultimately adopted as being the most reliable, it includes a stage storage relationship derived using the unsteady state FLS model runs. The following sections chronologically describe the process undertaken to determine the effect of loss of flood plain storage.

3.3.1 Unsteady State Simulation of Attenuation

Dynamic (Unsteady state, having flow varying with time) FLS runs to determine the attenuation due to the reach between Fisher Parade and Lynches Bridge were undertaken for the existing and with flood wall conditions. The difference in attenuation in this reach is the effect of loss of floodplain storage. The effect was larger than expected and careful review of these runs identified two limitations to the FLS model that affect the attenuation estimates. These limitations are due to a "levee effect" and a "boundary condition effect". Details of the unsteady state FLS model and its limitations are discussed in greater detail in Appendix A.

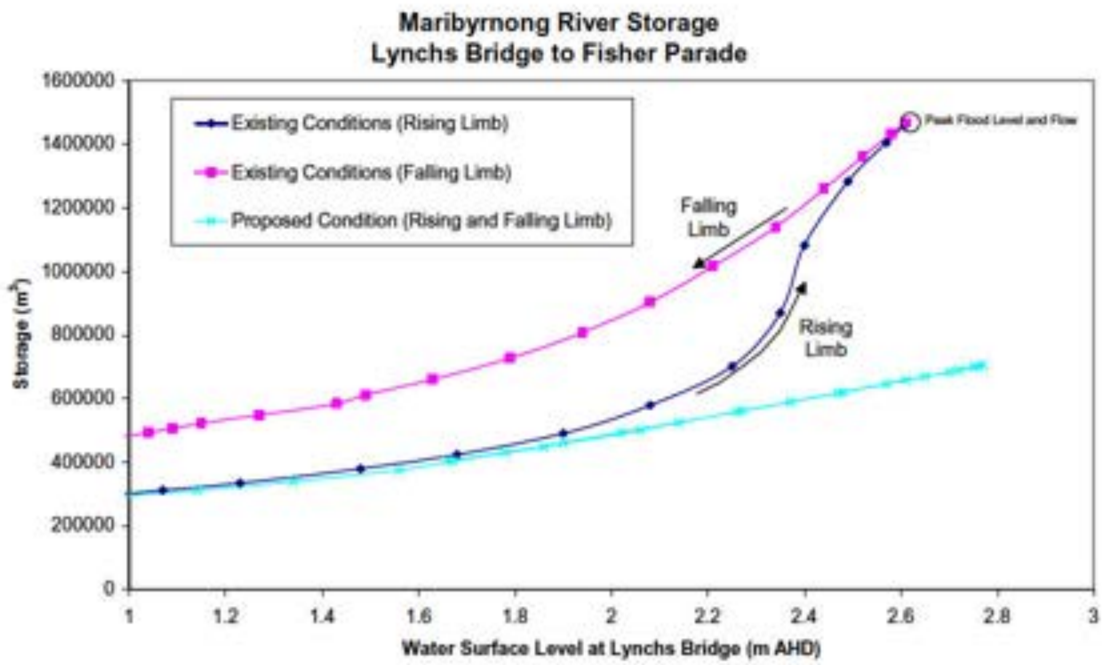
3.3.2 RORB model with inputs from FLS

RORB is a widely used hydrologic model with runoff, stream flow routing and storage modelling capabilities. In general the routing capabilities of hydraulic models such as FLS are more detailed and hence more reliable than hydrologic models, however with accurately defined stage storage and stage discharge relationships hydrologic models can provide relatively simple and reliable results. The use of RORB's retarding basin routines in the current investigation enabled the two FLS modelling limitations (ref Appendix A) to be addressed. The "levee effect" can be adjusted to an appropriate degree and the FLS boundary condition assumptions isolated from the analysis. The

Stage Storage Relationship at Flemington Racecourse

The FLS model flood levels are considered generally reliable between Fisher Parade and Lynches Bridge (refer more detailed discussion in Appendix A). An accurate stage storage relationship was determined by post processing the results from the unsteady state simulations. Grided flow depths between Fisher Parade and Lynches Bridge were processed at hourly intervals on the rising and falling limbs of the design flood to determine storage for a range of levels at Lynches Bridge. The resultant relationships for the existing and with flood wall conditions are depicted in Figure 3.1

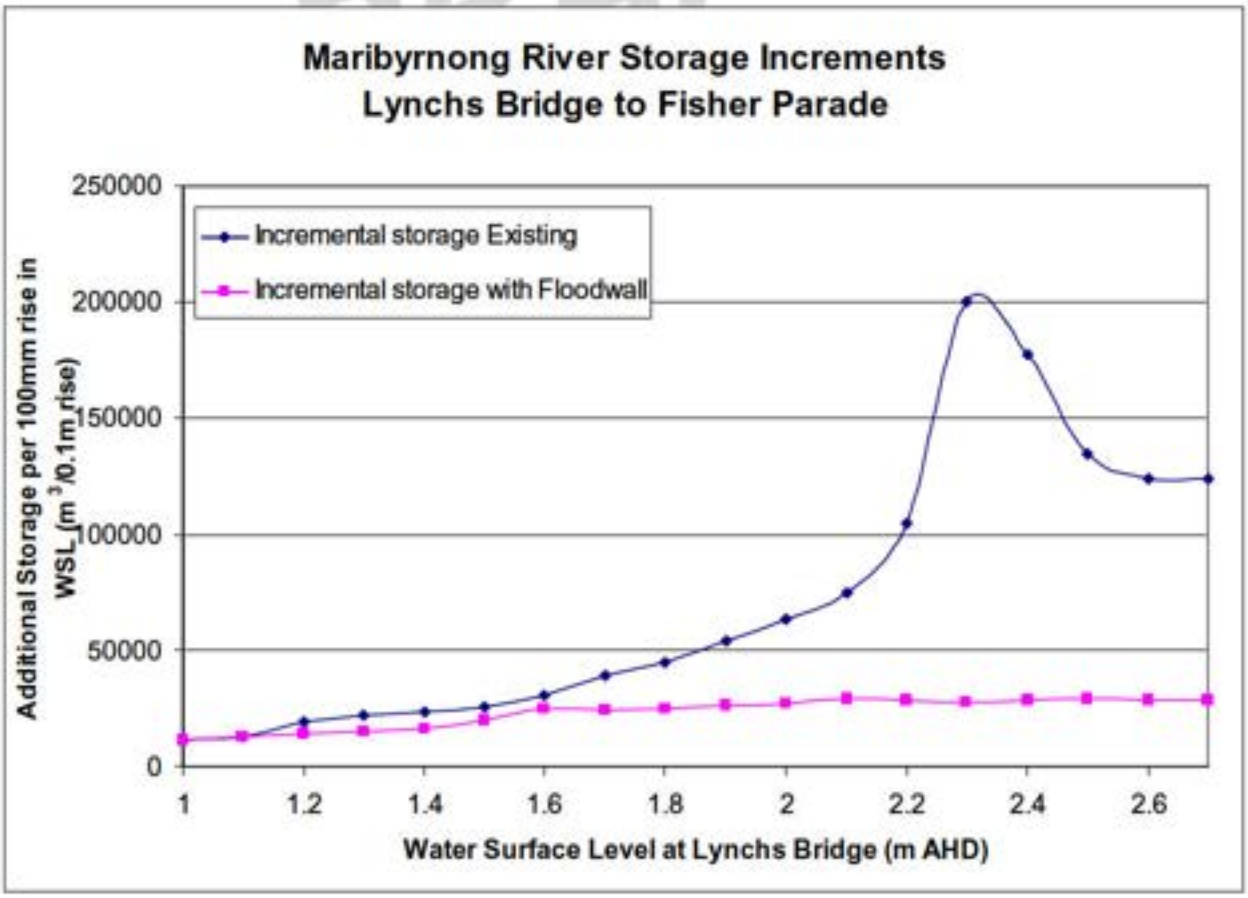
Figure 3.1 Post Processed Storage from FLS Results



The variation in the rising and falling limbs of the existing stage storage relationship is primarily due to the "levee effect", refer Appendix A. Adopting the rising limb relationship in RORB would produce excessive attenuation because the storage remains "levied off", until nearer the flood peak. Unlike the

FLS representation, much of this 'reserved' storage is expected to fill progressively during a real flood event. Similarly, adopting the falling limb relationship in RORB would underestimate the attenuation in a real flood. The reason FLS exaggerates the "levee effect" is because small drainage paths are not well represented in the 5m grid. Given that the 100 year ARI flow rises gradually it is expected that reverse flow along drains will be sufficient to progressively fill substantial areas which remain artificially dry in FLS. On this basis it is expected that the actual incremental storage curve is more closely represented by the falling limb curve. It was therefore considered appropriately conservative to adopt a storage relationship midway between the rising and falling limbs of the FLS based stage storage curves. The adopted relationship is summarised in Figure 3.2. This figure clearly indicates the effect of the proposed works on available storage for a range of levels.

Figure 3.2 Storage Characteristics



Stage Discharge Relationship

The stage discharge relationship used in RORB was obtained using the existing conditions steady state HEC-RAS model provided by Melbourne Water (ref 1). This HEC-RAS model was run for a range of flows using the downstream rating table from the unsteady state HEC-RAS model also provided by Melbourne Water (ref 1). Flows and levels at Lynchs Bridge from each of these runs were tabulated and adopted for the RORB analysis.

3.4 Flow Attenuation Estimates

The RORB model was run using the stage storage and discharge relationships described in the previous sections with an input hydrograph at Fisher Parade extracted from the existing conditions unsteady state HEC-RAS model provided by Melbourne Water.

The existing and proposed RORB models differed only in their stage storage relationships. The input hydrograph and stage discharge relationship remained identical. This is a slight approximation for the proposed situation (with flood wall and mitigation works) when in fact the downstream rating curve will change as a result of mitigation works. As there is little attenuation between Fisher Parade and Lynches Bridge under proposed conditions (0.2m^3/s ref Table 3.1) this approximation will have little or no impact on mitigation requirements and is considered appropriate.

Estimates of flow attenuation through the site from the Melbourne Water existing conditions model and as revised for this investigation are summarised in Table 3.1. The peak 100 year ARI flow estimates for the entire reach are plotted in Figure 3.3 and selected values tabulated in Table 3.2.

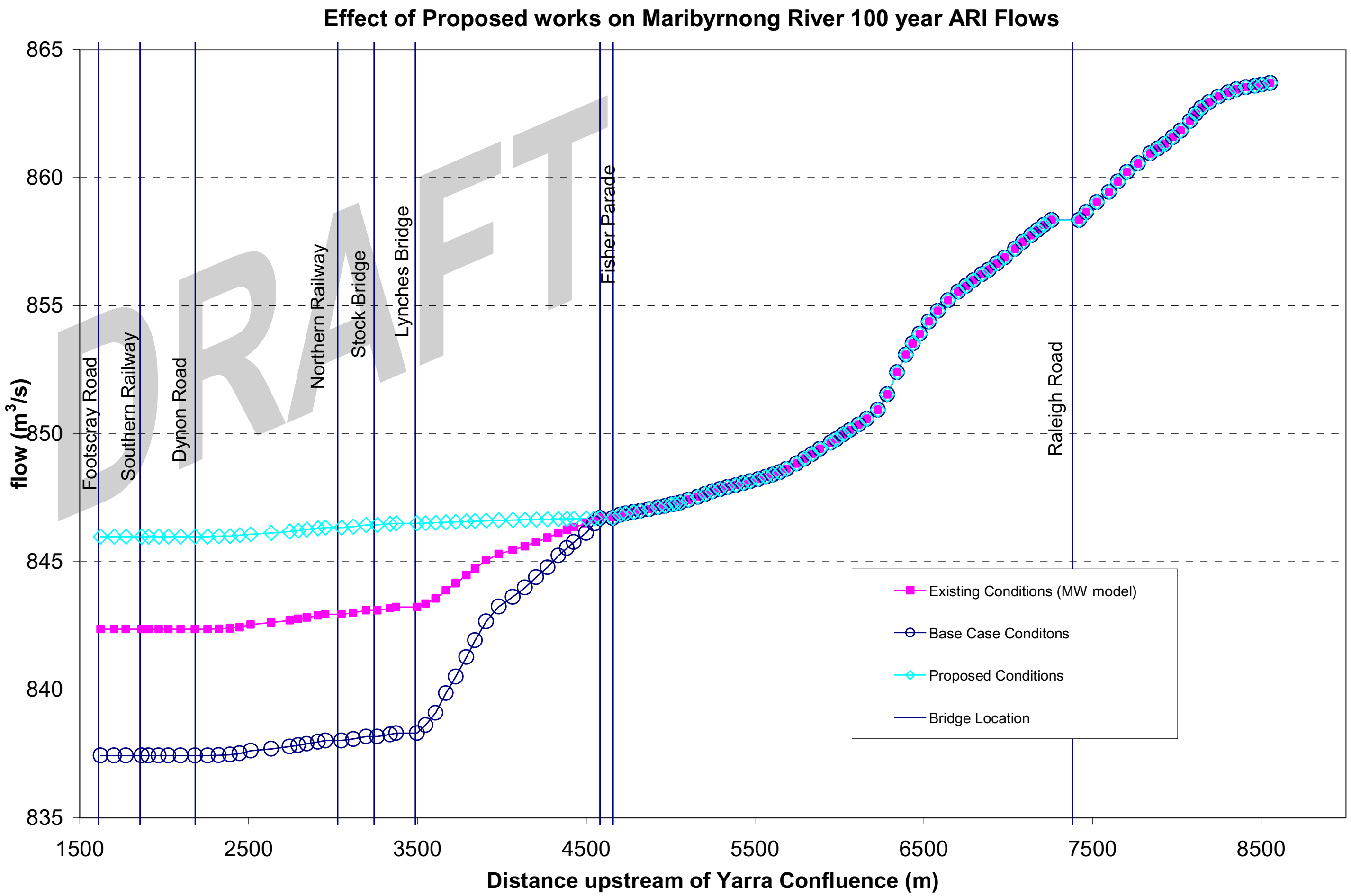
Table 3.1 Flow Attenuation Estimates (m^3/s)

Description	Melbourne Water Model of Existing Conditions (from HEC-RAS version 3.1)	RORB modelling with inputs from FLS
Base case February 2003		
Fisher Parade	846.7	846.7
Lynches Bridge	843.2	838.3
Attenuation through site	3.5	8.4
Proposed Conditions (with Flood Wall and no Mitigation Works)		
Fisher Parade	Not analysed	846.7
Lynches Bridge	Not analysed	846.5
Attenuation through site	Not analysed	0.2
Net effect of Proposed Works (with Flood Wall and Mitigation Works)		
Reduction in attenuation (increase in flood flow)	< 3.5	8.2

Table 3.2 100 year ARI attenuated flows from Maribyrnong Village to Footscray Road

River Station (km)	Description	MW Existing Conditions (m^3/s)	Base Case (Revised Existing Conditions) (m3/s)	Proposed Conditions (m3/s)
8.614	upstream model boundary	863.7	863.7	863.7
7.481	u/s raleigh road	858.3	858.3	858.3
5.899	Jack's Magazine	849.2	849.2	849.2
4.719	u/s Fisher Parade	846.7	846.7	846.7
3.559	u/s Lynchs Bridge	843.2	838.3	846.5
3.324	u/s Stock Bridge	843.1	838.2	846.4
3.112	u/s Northern Railway Bridge	842.9	838.0	846.3
2.319	u/s Dynon Road	842.4	837.4	846.0
1.928	u/s Southern Railway Bridge	842.4	837.4	846.0
1.685	u/s Footscray Road	842.4	837.4	846.0

Figure 3.3 Flow Attenuation



4. Unmitigated Effect on Flood Levels

4.1 Introduction

The effect of the proposed flood wall on flood levels in the Maribyrnong was determined using a steady state HEC-RAS model appropriately adjusted to incorporate the effects of the works as determined by more detailed local models.

The process involved establishing the base case model, and determining the downstream and upstream impacts of the proposed flood wall without mitigation works. It is essential to first quantify the unmitigated effects so that mitigation works can be located and designed to address the effects.

4.2 Base case Hydraulic Model

4.2.1 Introduction

The base case HEC-RAS model incorporates the following changes to the existing conditions model provided by Melbourne Water:

- extension of model downstream to include Footscray Road
- review and update of select bridge modelling parameters.
- Revised flows as detailed in the previous section

Details of these changes are outlined in the following sections.

4.2.2 Extension of model to include Footscray Road

The existing conditions model provided by Melbourne Water extends downstream to the upstream side of Footscray Road. The model was extended a further 95 m downstream to include a representation of Footscray Road based on design drawings and the cross section immediately upstream of Footscray Road with minor adjustments to better reflect conditions downstream. These minor adjustments comprised a 5m widening of the cross sections downstream of Footscray Road to reflect the widening on the left (east) bank and the addition of details including the Ports and Harbours wharf and the moored craft on the right (west) bank. The model parameters were chosen using engineering judgement to reflect our understanding of the reach and, with respect to the main channel roughness parameters, to be consistent with the existing conditions model.

The downstream boundary condition was adjusted so that the base case levels match the published Melbourne Water existing levels (ref 1) using both existing conditions flows and the revised (lower) flows. The adopted downstream boundary conditions result in levels which are generally within 10 mm of the Melbourne Water existing conditions levels, refer Table 4.2. A normal depth based on an energy slope of 0.00096 was used to achieve this fit and was adopted for all subsequent runs.

4.2.3 Bridge (and Culvert) Modelling Parameters

It was noted that the Melbourne Water existing conditions model was calibrated to the published MMBW 1986 flood profile. This process focussed on achieving realistic flood levels using reasonable bridge modelling parameters. It did not however seek to investigate each bridge in detail and while the overall bridge losses may be appropriate they were not necessarily achieved using a representative set of parameters.

When designing mitigation works it is important that the works provide real hydraulic improvements to flow conditions rather than apparent ones. Hence it is essential that the parameter set used to determine the bridge losses is an accurate representation based on a detailed assessment.

A review of Manning's 'n' roughness values, contraction and expansion coefficients, and pier loss coefficients in the exsiting conditions model identified a high Manning's 'n' value within the Northern Railway Bridge of 0.055. Following a careful reassessment of the bridge it was decided to reduce the internal bridge roughness to a more realistic Manning's 'n' of 0.03 and to increase the pier width to account for the flow direction as it impacts on the bridge pier from the real width of 5m to the projected width of 8.9m. The modelling approach for The Northern Railway culverts was changes from a series of 12 culverts to a second bridge opening with 11 blade piers and the same characteristics as the culverts. This change was undertaken because with dry soffits in the 100 year ARI event, the culverts are better represented as a bridge with piers. The net bridge loss in the base case remains approximately the same as under existing conditions ref Table 4.1.

Table 4.1 Changes to Bridge modelling approach

Northern Railway Bridge	MW Existing conditions model	Base Case
Manning's 'n'	0.055	0.03
Contraction Loss Coefficient	0.3	0.3
Expansion Loss Coefficient	0.5	0.5
Pier Drag Coefficient	2.0	2.0
Yarnell Pier Coefficient	1.25	1.25
Pier Width	5	8.9
Energy loss across bridge (m)	0.22	0.217

A summary of the minor flood level changes associated with the establishment of the base case geometry and flows is presented in Table 4.2. The subsequent assessment of proposed works and mitigation measures are all undertaken with respect to the revised base case model as described in the preceding sections.

Table 4.2 Flood Level Changes in Maribyrnong River due to establishment of Base Case - Base Case Model relative to the Existing Conditions provided by Melbourne Water

	Revised modelling approach, flows as per MW existing conditions model (ref 1)	Base Case revised geometry and flows.
Average afflux* (mm)	7	-5
Change at Fisher Parade (mm)	5	-8
Change at Lynchs Bridge (mm)	7	-9
Change upstream of Footscray Road (mm)	15	-3

* Average afflux is the arithmetic mean of afflux values from Footscray Road to Maribyrnong Village.

4.3 Downstream Impact Only (due to loss of floodplain storage only)

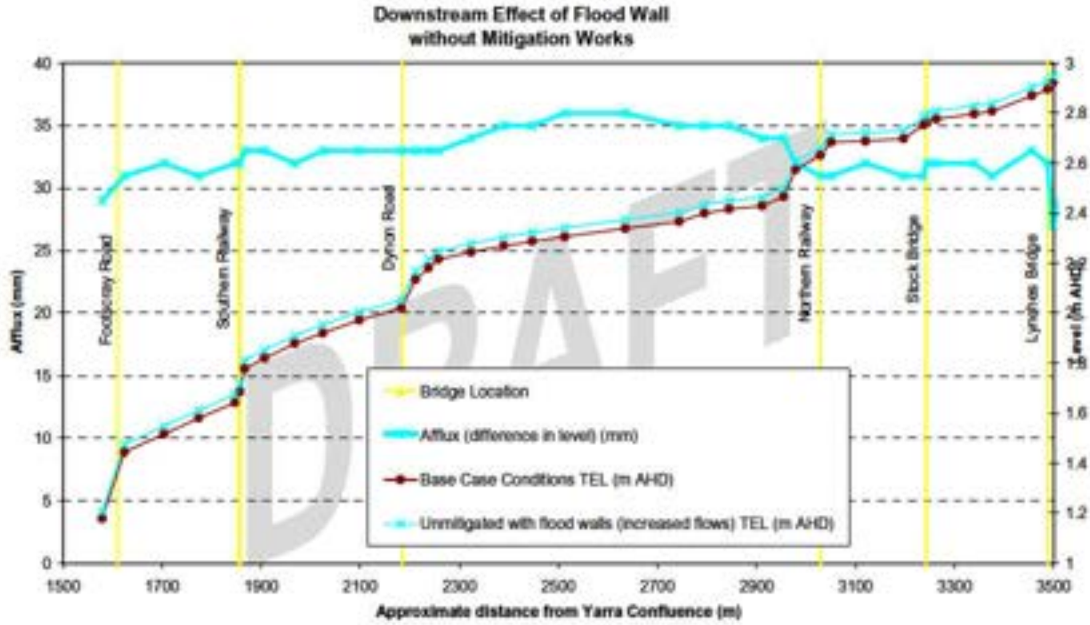
4.3.1 Introduction

The base case steady state HEC-RAS model was modified to include the proposed flood wall thus forming the unmitigated model. Both the existing and unmitigated models were then run with attenuated peak flows determined as described in Section 3. The flood levels from these two runs were compared downstream of Lynchs Bridge to provide an estimate of the increase in peak 100 year ARI flood levels (afflux), which would occur downstream in the event that the flood wall was constructed without mitigation works. The higher flood levels result from the loss of flood plain storage and the consequent increase in downstream flows and flood levels relative to the base case.

4.3.2 Results

The downstream afflux due to the loss of flood plain storage only (and consequent increase in flows) was determined to be approximately 30 to 35 mm, refer to Figure 4.1

Figure 4.1 Effect of loss of Floodplain Storage only, without mitigation works



4.4 Upstream Impact (due to loss of conveyance)

4.4.1 Introduction

The previous analysis using HEC-RAS, (section 4.3), provides an estimate of the upstream impact of the proposed flood wall due to both loss of conveyance and residual afflux from the increased downstream flows. However, this approximation is subject to uncertainties. The uncertainties arise because the one dimensional HEC-RAS model is unable to suitably resolve the distribution of flow across the flood plain at Flemington. The flow distribution is critical to the assessment of upstream afflux since the larger the proportion of the total flow conveyed by the floodplain at Flemington, the larger the upstream impact and conversely.

The previously established two dimensional hydraulic model using FLS provides a detailed analysis of the flow distribution within the floodplain and is hence better able to quantify the local effects of the proposed flood walls. As a result, the afflux due to the loss of conveyance was determined using FLS and the HEC-RAS model adjusted as required to reproduce the same result and enable the effects to be assessed beyond the bounds of the local two dimensional model.

4.4.2 2D Hydraulic Modelling of Conveyance effects

Two Steady State (flow constant with time) FLS model runs were undertaken to quantify the upstream impact of the proposed flood walls, ie. no floodwall and with floodwall. A tail water level of 2.60 m AHD was adopted as the downstream level at Lynchs Bridge and a constant inflow of 846.7 m^3/s was used for the upstream boundary condition. The existing and proposed geometry and roughness files were as adopted for the unsteady state flow attenuation analysis.

It is considered appropriate to use the constant tail water level adopted on the basis that the proposed conditions are to incorporate mitigation works to bring 100 year flood levels down to match the base case, ie. there will be no residual afflux due to the increased flows.

The adoption of a constant flow rate equal to the flow at Fisher Parade as per the Melbourne Water Existing Conditions HEC-RAS model is appropriately conservative for the current analysis. The use of smaller or attenuated flows would lead to a slightly smaller estimate of upstream afflux.

Results of the FLS runs are summarised in Table 4.3. Given identical flows and downstream boundary conditions, the afflux at the downstream end of the site is zero. Hence the difference in flood levels at the upstream end of the works, immediately downstream of Fisher Parade, is an estimate of the afflux due to the loss of conveyance resulting from the proposed flood wall. Being a two dimensional model, values at these locations vary slightly across the river, mean values have been tabulated.

Table 4.3 Flood Level downstream of Fisher Parade

Condition	Water Surface Level (m AHD)	Total Energy Line (m AHD)
Existing	2.982	3.226
Proposed	3.002	3.242
Afflux (m)	0.020	0.016

4.4.3 Adjustment of HEC-RAS model to match FLS result

To enable direct comparison with the FLS analysis of afflux due to loss of conveyance only, the base case model was rerun with geometry modified to include the floodwall (no mitigation works). These results were compared with the results for the base case to determine the afflux due to the loss of conveyance. The afflux derived using FLS as discussed in section 4.4.2 was slightly in excess of the HEC-RAS estimate. Conveyance in the base case with floodwall model was reduced to match the FLS result. Given that the model is already very smooth the alternate approach of increasing conveyance in the base case model was considered unrealistic. The Manning's 'n' value for the main channel was increase from 0.015 to 0.0155 between Lynchs Bridge and Fisher Parade to match the FLS afflux estimates, as shown in Table 4.4.

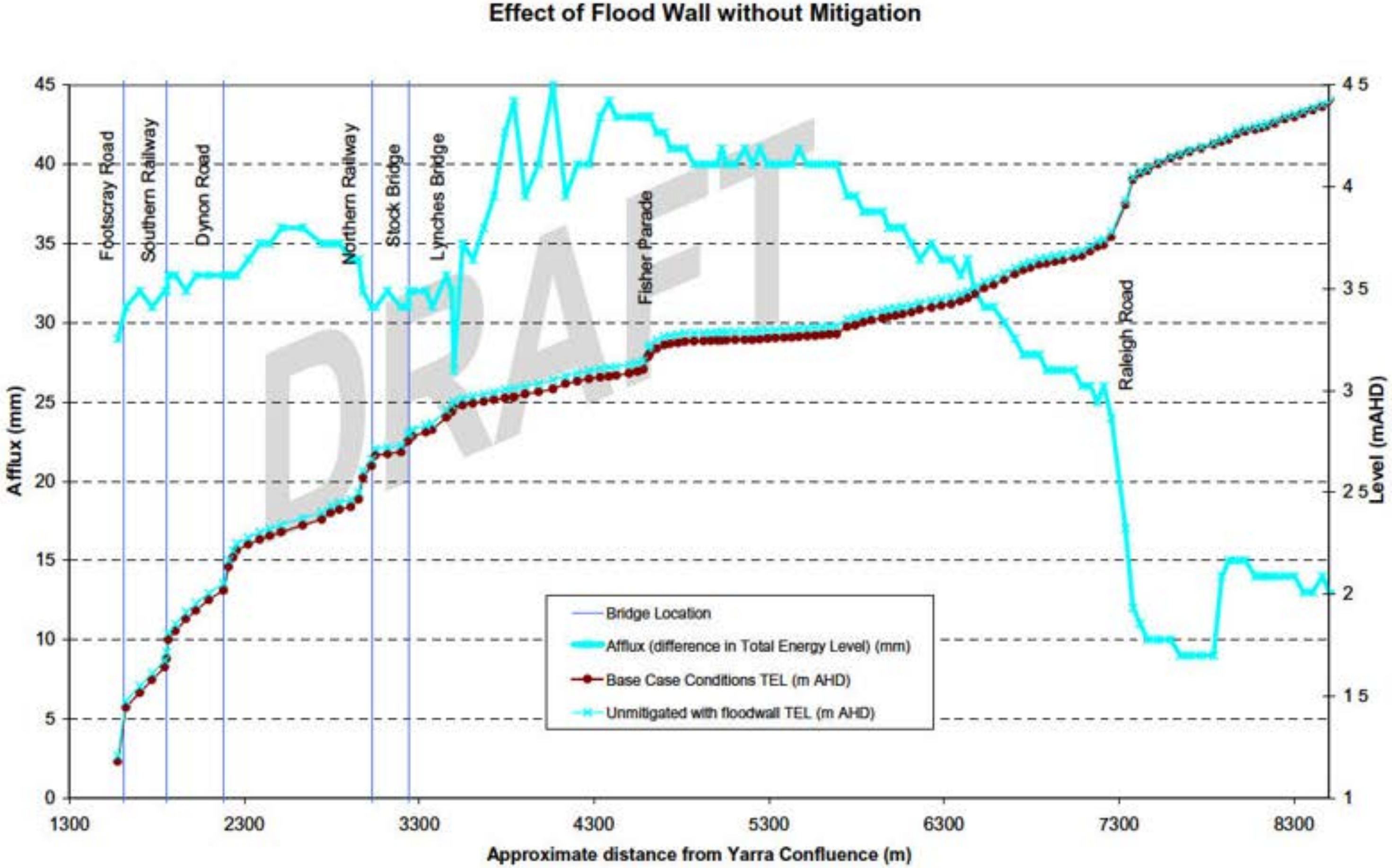
Table 4.4 Afflux due to loss of conveyance only, results from adjusted HEC-RAS model

	WSL Afflux (mm)	TEL Afflux (mm)
Maximum (at upstream end of works immediately downstream of Fisher Parade)	20	15
Afflux at Lynches Bridge	0	0
Difference (estimate of afflux due to loss of conveyance)	20	15
FLS estimate of afflux due to loss of conveyance (for comparison from Table 4.3)	20	16
Comparison of HEC-RAS and FLS results (mm)	0	-1

4.4.4 Results

The unmitigated effect of the floodwall on flood levels in the Maribyrnong River including both downstream and upstream effects is summarised in Figure 4.2. The maximum afflux is 45 mm at Flemington and this tapers off to 15mm at the upstream end of the Maribyrnong Village

Figure 4.2 Effect of works without Mitigation



5. Mitigation Works

5.1 Introduction

As detailed in the previous sections the proposed reduction in flood plain storage and conveyance leads to an increase in downstream flows, and increased flood levels downstream and upstream of Flemington. Without mitigation these higher flood levels have the potential for increased flood damage.

Short of large scale retarding basin works similar in concept to those proposed by the MMBW in 1986 (ref 6) it is not practical to provide compensating storage sufficient to compensate for the proposed removal of flood plain storage. As a result mitigation works have been aimed at increasing the capacity of the Maribyrnong River to cope with the increased flows. The mitigation works have been tailored to address Melbourne Water requirements with respect to 100 year ARI flood levels. The mitigation works will provide some benefit for a range of events however their performance for floods greater or smaller than the 100 year ARI event has not been assessed.

5.2 Mitigation Works

There are few practical opportunities to mitigate against the effects of the proposed flood wall. Given the flood prone nature of much of the early development along the Maribyrnong River opportunities to lower flood levels are extremely valuable and until recently practical solutions In fact if opportunities to lower flood levels were abundant Following numerous site visits and analysis of flood profiles the following mitigation opportunities were identified:

- Footscray Road Bridge potential to reduce upstream flood levels with modifications to left abutment by
    - Increasing waterway area
    - Reducing expansion and contraction losses with flow training walls
- Northern Railway Culvert potential to increase culvert capacity by removing downstream road embankment. Removing this obstruction will:
    - Increase culvert capacity;
    - Reduce flow through the rail bridge; and
    - Lower flood levels upstream of the Northern Railway embankment.

Specialist interpretation and judgement is required to appropriately and confidently model the relatively small changes to bridge structures such as those proposed. We sought advice from [redacted] of R J Keller and Associates with respect to design and modelling of these improvement works. The conceptual design of the mitigation works and their modelling has been undertaken in conjunction with [redacted] to ensure that the modelled effects are a realistic assessment of the performance improvements which will be achieved by the mitigation works.

The proposed bridge works and the associated HEC-RAS bridge parameter changes are as summarised in Table 5.1. Details of the works themselves are documented in the following sections and in Appendix B.

Table 5.1 Proposed Hydraulic Improvements

	MW Existing conditions model	Base case	Proposed Conditions	Comment
Footscray Road				
Manning's 'n'		0.02	0.02	No change
Contraction Loss Coefficient		0.15	0.10	Construction of flow training walls on left bank with alignment based on Fargue Spiral
Expansion Loss Coefficient		0.35	0.15	
Pier Drag Coefficient		1.33	1.33	No change
Yarnell Pier Coefficient		0.9	0.9	
Other works			Removal of internal bluestone abutments on left bank	
Energy loss across bridge (m)	Not modelled	0.266	0.211	Reduction of 55 mm
Northern Railway				
Manning's 'n'	0.055	0.03	0.03	Modelling refinement Wider piers and smoother Manning's n relative to MW existing
Contraction Loss Coefficient	0.3	0.3	0.3	None
Expansion Loss Coefficient	0.5	0.5	0.5	
Pier Drag Coefficient	2.0	2.0	2.0	
Yarnell Pier Coefficient	1.25	1.25	1.25	
Other works				Remove road embankment on downstream side of railway culverts.
Energy loss across bridge (m)	0.22	0.217	0.200	Reduction of 17 mm

5.2.1 Hydraulic Improvements to Footscray Road

When the Footscray Road Bridge was redesigned in the 1950s, the existing bluestone abutments were partially retained. The original bluestone abutments are still evident projecting out into the river from within the new concrete abutments, refer Figure 5.1 and Figure 5.2. The proposed mitigation strategy is to remove the bluestone abutment from the left (eastern) bank and construct flow training walls upstream and downstream of this location, thus improving the flow beneath the bridge and thereby lowering the total loss across the bridge from 266 mm to 211 mm. No works are proposed for the right (Western) abutment since the effect of similar changes would be minimal given the upstream jetty and downstream wharf structures.

The details of the flow training walls are important to achieving the desired improvements. A curvilinear vertical wall is proposed with a horizontal alignment smoothly transitioning between the bank and the abutment based on a Fargue spiral to minimise the contraction and expansion losses. The curves will be approximated by a series of straights such that the maximum deflection angle between adjacent straights is 6^{o}. The height of the walls will be approximately 600 mm above the water surface level, which is approximately equal to the total energy level. The expected order of cost for the Footscray Road mitigation works is around $1.1M. Preliminary details and cost estimates are included in Appendix B.

Preliminary discussions with Vic Roads and our structural engineers indicate that it will be feasible to undertake works to safely remove the projecting bluestone and maintain the structural integrity of the abutment. Vic Roads have looked at their data base and the Footscray Road Bridge does not appear on either the heritage Victoria or National trust Registers. Archaeological issues are yet to investigated.

Figure 5.1 Footscray Road Bridge (photograph from upstream on the left bank)

Figure 5.2 Downstream end of Bluestone Abutment to be removed

5.2.2 Hydraulic Improvements to the Northern Railway

The railway tracks between South Kensington and Footscray Stations cross the Maribyrnong River and its flood plain on a substantial embankment. The following structures convey floodwater through this embankment:

1. A 60 m long single span bridge over the main channel dating back to the 1850s. This bridge is listed on the Victorian Heritage Register as the "Rail Bridge over the Maribyrnong between South Kensington, Footscray Stations Footscray", and as such is legally protected under the Heritage Act 1995. The registration relates to the extent of all the bridge structure including the abutments and wing walls as defined by the Heritage Council.
2. A second newer bridge located parallel and immediately upstream comprises two 40m spans with a central rectangular pier. The bridges are located on a reasonably sharp bend, this combined with their differing geometries produces significant hydraulic losses across the structures.
3. The "Railway Culverts" constructed as part of Lynchs Bridge Project in the 1990s significantly reduced upstream flood levels. In a 100 year ARI design flood the 12 rectangular flood plain culverts each 5 m wide with high soffits above the flood level reduce the flow through the bridges by over 30%.

The proposed works are to lower a road embankment located immediately downstream of the railway culverts thus increasing the capacity of the railway culverts. Removing this obstruction increases the capacity of the culverts and the waterway immediately downstream, reducing the flow through the railway bridges and lowering upstream flood levels by 44 mm. The net bridge loss reported by HEC-RAS reduces from 217 mm to 200 mm, the other 27 mm reduction occurring as a result of the improved conveyance immediately downstream of the culverts.

Figure 5.3 The road embankment downstream of the Northern Railway Culverts

The works have been designed for minimal impact particularly with respect to the downstream heritage listed bridge and other railway structures. The roadway was constructed during the 1990s and is located on land owned by the Temple of Heavenly Queen Association who at the time held a planning permit for the construction of a temple downstream of the railway embankment. It is understood that the planning permit has subsequently lapsed. The road embankment is understood to have two functions:

- As a means of access to the bridge abutment, culverts and power transmission tower. It is expected that constructing a downstream road to connect to the existing bike path could provide this function.
- As a separating weir between the upstream and downstream lake systems. There is currently no apparent need for this function however the Temple of the Heavenly Queen may have some future requirement for this functionality.

Subject to approvals this option is hydraulically very promising and is expected to cost in the order of \$0.9M. Preliminary details and cost estimates have been produced are included in Appendix B.

Given the uncertainties with regarding approval to remove the road embankment it was considered appropriate to analyse the mitigation works with and without the works at the northern railway.

5.3 Net Effect of Proposed Works

As the differences in flood levels due to the Flemington Racecourse Flood Protection works are relatively small it is difficult to see the difference on a plot of flood levels. Plotting the difference in flood levels (afflux) provides a much clearer indication of the changes. Afflux plots showing the effect of the Flemington Racecourse floodwall with and without the mitigation works are presented as Figure 5.4. In accordance with normal practise positive afflux represents an increase in flood level and negative afflux represents a reduction. The following sections briefly describe the two Proposed Condition Afflux curves.

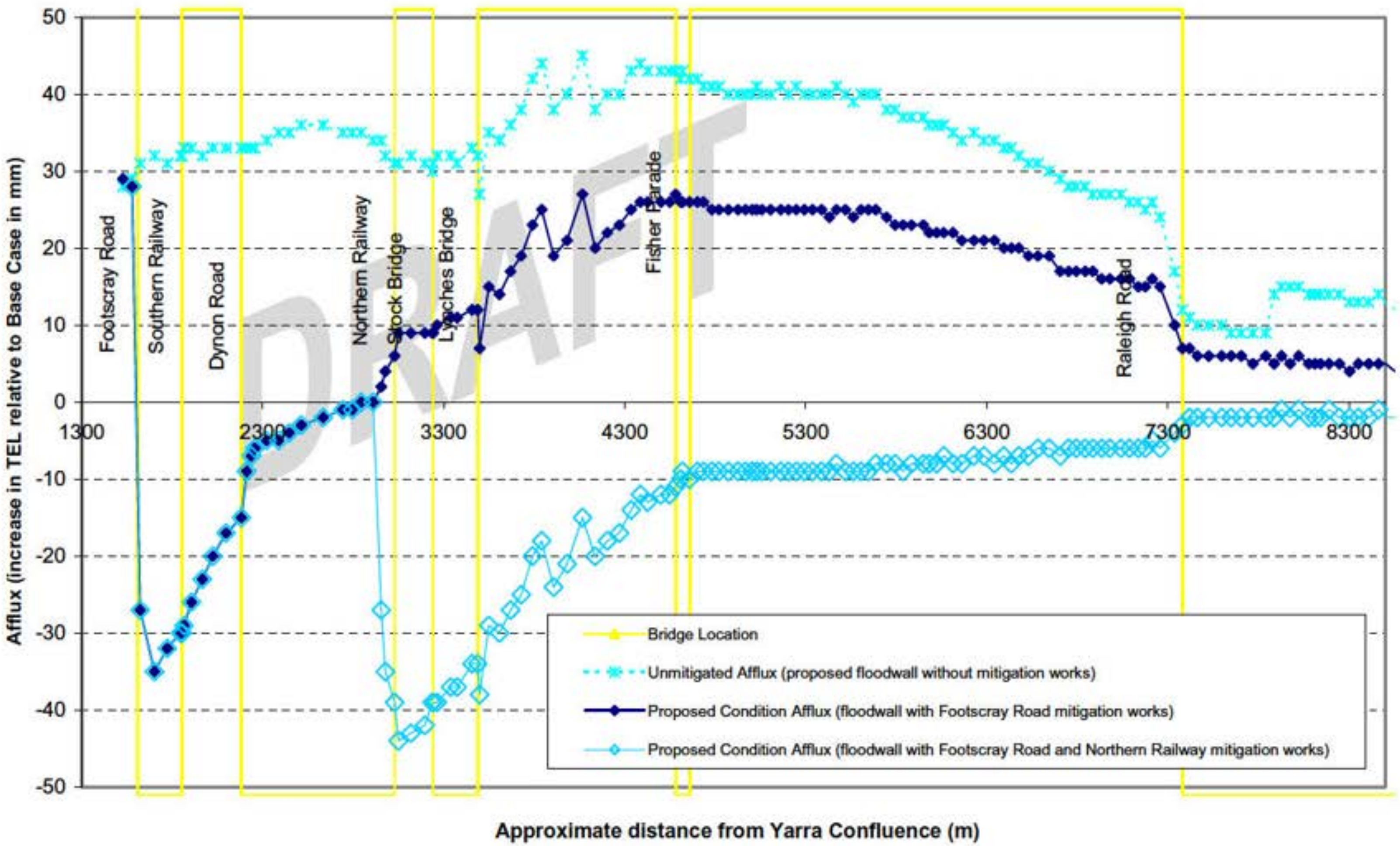
5.3.1 Floodwall with Footscray Road Mitigation Works

This proposal relies on the proposed works at Footscray Road to lower flood levels downstream of the Northern Railway. Upstream of the Northern Railway increases in flood levels due to the floodwall do occur however these are small in comparison with the reduction in flood levels which was achieved in the 1990s with the construction of the railway culverts.

5.3.2 Floodwall with Footscray Road and Northern Railway Mitigation Works

The proposed works, which include the mitigation works at Footscray Road and the Railway Culverts are effective in lowering flood levels upstream of Footscray Road. In fact a slight benefit remains as shown by the negative afflux values, which extend all the way to Maribyrnong Village.

Figure 5.4 Effect of Proposed Flood Protection Works



6. Recommendations

This draft report has been prepared to facilitate further discussions between the VRC, its consultants, Melbourne Water and other stakeholders.

Following a review by the VRC it is recommended that this report be presented to Melbourne Water for their comment. It is expected that presentation of this report will:

- Enable Melbourne Water to assess the VRC's proposal with respect to the Maribyrnong River;
- Facilitate further comment with respect to required mitigation works; and
- Assist with obtaining approval in principle for the proposed floodwall and associated mitigation works.

Once approval of the concepts is received from Melbourne Water, the concepts should be progressed through a detailed design process prior to construction. The following issues will need to addressed prior to and or during detailed design phase:

- Detailed discussions with relevant authorities and asset managers should be undertaken with a view to obtaining required approvals for the works;
- Additional survey to enable accurate computation of quantities and set out;
- Refine cost estimates; and
- Detailed Design.

7. References

1. Melbourne Water Corporation: “Maribyrnong River Hydraulic Model, Final Report, February 2003”, by GHD
2. Manual Delft-FLS 2.55 July 2001 WL | Delft Hydraulics
3. E.M. Laurenson and R.G. Mein Monash University Department of Civil Engineering, ”RORB – Version 4 Runoff Routing Program, User Manual” May 1988.
4. US Army Corp of Engineers, Hydrologic Engineering Centre: “HEC-RAS, River Analysis System. Hydraulic Reference Manual Version 3.1 November 2002.
5. Les Hamill, “Bridge Hydraulics” University of Plymouth 1999
6. Melbourne Metropolitan Board of Works: “Maribyrnong River Flood Mitigation Study, March 1986, MMBW-D-0040”.

Appendix A

2D Hydraulic Modelling

A1 Overview

A2 Unsteady State Modelling

A3 Model Reliability and Limitations

A4 Model Figures

Appendix B

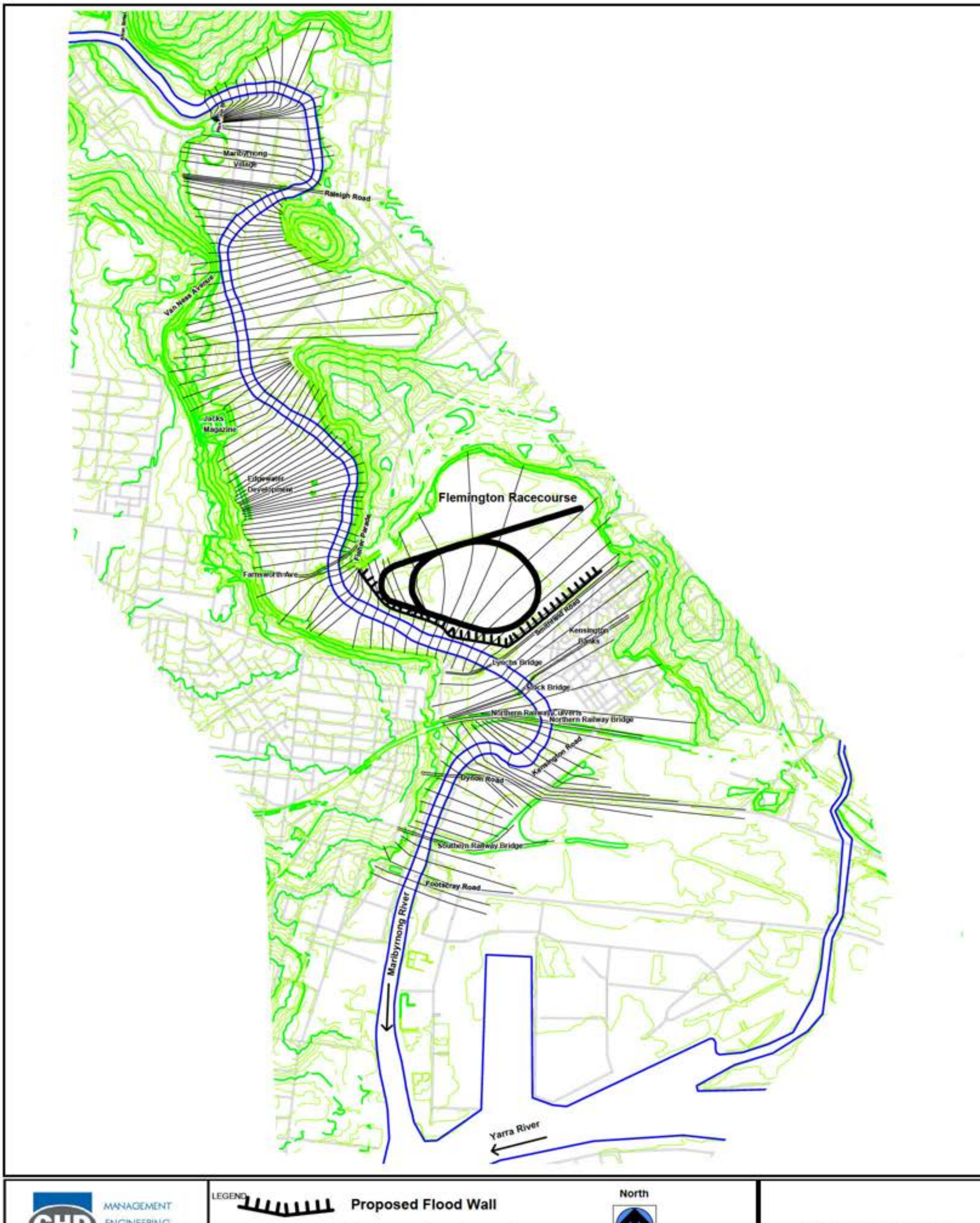
Proposed Works

GHD Pty Ltd ABN 39 008 488 373

[redacted]

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	[redacted]	[redacted]		[redacted]		26/03/03



GHD MANAGEMENT ENGINEERING ENVIRONMENT

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LEGEND

- Proposed Flood Wall
- Cross section alignment
- Road alignments
- 1m contours
- Direction of Flow

North

SCALE 1 : 20,000 at A3

200 100 0 200 400 600 800 1000 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

Maribyrnong River

Locality Plan

Figure 1.1

A. 2D Hydraulic Modelling

A.1 Overview

Unlike one dimensional hydraulic models which use a cross section based flow representation which assumes flow is travelling in one direction, two dimensional hydraulic models work on a grid structure enabling far more accurate representation of geometry and more realistic flow behaviour. Their structure allows the modelling of real life flow characteristics such as lateral flows, eddying etc. They provide far greater resolution of flood flow behaviour and are less subject to modelling judgement and interpretation. The downside of two dimensional models is their intensive data and computational requirements.

A two dimensional model extending from upstream of Fisher Parade to downstream of Lynches Bridge was developed to model the effects of the proposed flood wall. The model uses a rotated rectilinear grid of 103,875 cells (277 rows by 375 columns), each cell measuring 5 m by 5 m square. The model was created and run using Delft FLS version 2.47.

Delft FLS (Delft Flooding System) is a 2D Hydrodynamic simulation package developed at Delft Hydraulics in the Netherlands. It is suitable for the simulation of dynamic behaviour over initially dry land and is based on the full 2D shallow water equations. The model requires good topographic data, roughness parameters and upstream and downstream boundary conditions. Direct outputs from the model include water surface levels, depths, velocities (magnitude and direction), and flows at specified time intervals and locations.

A.1.1 Terrain Data

Topographic data for the Flemington model is consistent with that adopted for the Melbourne Water existing conditions HEC-RAS model and includes a combination of detailed photogrammetry over the Eastern floodplain, river bathymetry from depth soundings and lower reliability information from the MW 1 m contours primarily for the western flood plain. The effect of this lower quality data from the 1m contours is expected to be insignificant given that the western flood plain remains unchanged.

A proposed model incorporating the effect of the proposed floodwall was established by raising the terrain levels for the area to be protected above the 100 year flood level as bounded by the proposed wall alignment.

A.1.2 Calibration of Two Dimensional Hydraulic Model

The 2D model was calibrated to the January 2003 1% profile from the Melbourne Water existing conditions model using a constant flow rate of 845 m^3/s, being the average flow from Fisher Parade to Lynchs Bridge flows ie 846.7 and 843.2 as determined for the Melbourne Water Existing conditions modelling (ref Table 4.2 of Ref 1). A downstream level of 2.60 mAHD was adopted. This level is the downstream water surface level published in the Appendix of the Melbourne Water existing conditions modelling report. The adopted Manning's n values are displayed in Figure A.3

It is noted that these values are smoother than normally expected however this is consistent with the Melbourne Water existing conditions model. Just as important is the relative roughness of the main channel and flood plain, which is considered to have an appropriate balance.

A.2 Unsteady State Modelling

The FLS model was run with time varying boundary conditions for both existing and proposed geometries with a view to refining attenuation estimates between Fisher Parade and Lynchs Bridge. These unsteady state runs are very time consuming (approx 12 hours). FLS automatically adjusts its time step to minimise run time within the maximum time step which was set to 10 seconds. The modelling of the 100 year hydrograph was started at $45m^3/s$ (t=0) and peaked at around t=26hrs. Computations were continued until the desired results were obtained up to a maximum of 62 simulation hours.

A.2.1 Boundary Conditions

The 100 year ARI hydrograph at Fisher Parade was used as the upstream boundary condition for all unsteady state runs. This hydrograph was extracted from the Existing Conditions unsteady state HEC-RAS model provided by Melbourne Water.

The downstream boundary condition for existing condition unsteady state runs was a rating table (flow versus elevation) for Lynchs Bridge. This relationship was obtained using the existing conditions steady state HEC-RAS model provided by Melbourne Water. The HEC-RAS model was run for a range of flows using the downstream rating table used for the unsteady state HEC-RAS runs. Flows and levels at Lynchs Bridge from each of these runs were tabulated and used as the downstream boundary condition for FLS.

A.3 Model Reliability and limitations

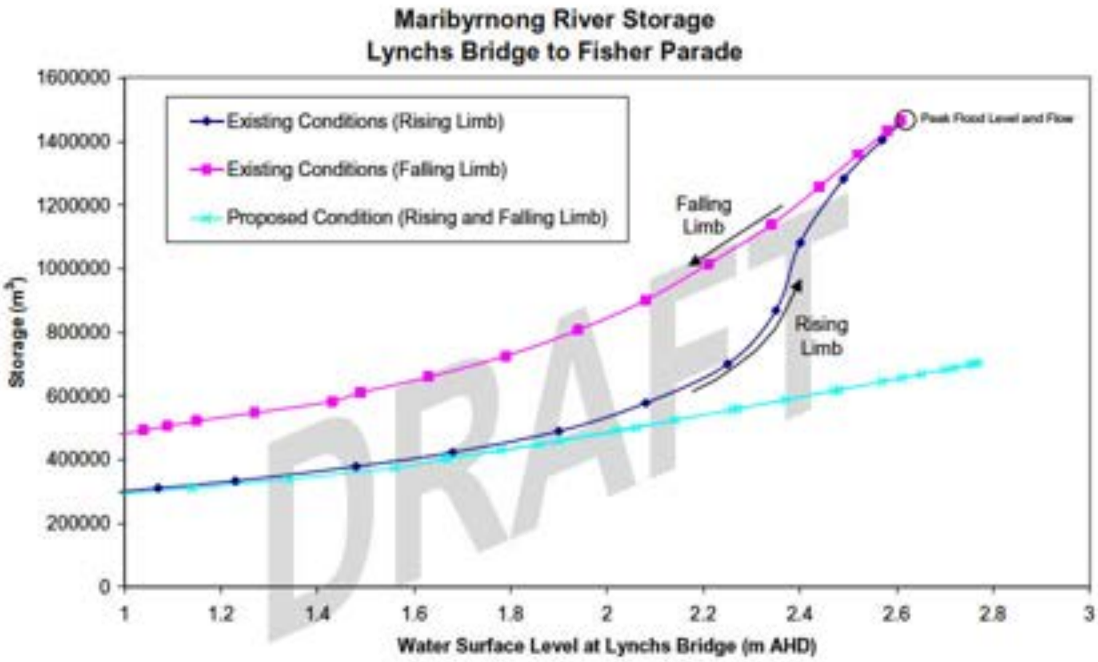
The model is generally considered reliable for modelling of flood levels and velocities between Lynchs Bridge and Fisher Parade. In unsteady state runs the model is capable of determining attenuation however as with all modelling some interpretation and understanding of the underlying simplifications is required. With respect to attenuation estimates from the unsteady state FLS model two effects have been identified and are discussed in the following sections.

A.3.1 The ‘Levee’ Effect

The floodplain storage in the Flemington site (1,440,000 m^3) is small compared to the volume of the 100 year ARI hydrograph (89,700,000 m^3) ie 1.6%. In such situations, attenuation of the peak flow is dominated by the storage available near the peak of the flood. Storage volume filled well before the peak flow does almost nothing to reduce the flood peak. If a region is levied off so that it overtops near the peak of a particular flood event, the storage behind this levee is effectively reserved to store flood water from the peak of the hydrograph, thus maximizing the attenuation benefit provided by this region for that particular event. This ‘levee’ effect can occur as a result of natural or man made banks in a flood plain however the integrity of natural banks are typically less than for a constructed levee. Leakage into the storage area reduces storage available when the bank is overtopped. Ignoring the effect of leakage will lead to an overestimate of attenuation. At Flemington, numerous drains, culverts and ditches enable the storage to fill progressively. These features are too small to be modelled in the FLS model with its 5m grid, as a result the model tends to overestimate the attenuation.

This effect is significant for the analysis of the 100 year ARI flood and is best understood by looking at the storage relationship derived from the FLS unsteady state results refer to Figure A.1. The base case results clearly show a difference in storage available at a given level between the rising and falling limbs, this difference is due to the ‘levee’ effect.

Figure A.1 The Stage Storage relationship extracted from FLS model results



A.3.2 Boundary Condition Effects

The FLS model extends upstream of Fisher Parade and downstream of Lynchs Bridge to enable establishment of a realistic flow distribution. The boundary conditions are applied at the upstream and downstream limits of the model, ie upstream and downstream of Fisher Parade and Lynchs Bridge respectively.

For example the model shows some attenuation between the upstream model boundary where flow enters the model and Fisher Parade (846.7 to 845.4m3/s). This attenuation occurs within a section of the model that is primarily designed to establish the correct distribution of flow upstream of Fisher Parade. The levels and attenuation modelled within this reach are based on an incomplete geometric representation of the actual topology with an establishing flow distribution; hence attenuation upstream of Fisher Parade should not be relied upon.

Likewise downstream of Lynches Bridge the model is not expected to produce accurate levels and attenuation. The Downstream rating curve obtained from HEC-RAS results inside of Lynchs bridge was applied downstream of Lynchs Bridge and an overly smooth connecting channel used to connect the boundary to Lynchs Bridge. The smooth connecting channel is kept at the same dimensions as the bridge cross section to avoid expansion losses and the smoothness reduces friction losses to a small amount. This small amount is none the less a source of error, leading to slightly higher levels through the site.

A.4 FLS Model Figures

Figure A.2 Terrain Model without Floodwall

Figure A.3 Adopted Manning's 'n' values for FLS Model

Figure A.4 Steady State 100 year ARI Water Surface Level Contours Without Floodwall

Figure A.5 Steady State 100 year ARI Water Surface Level Contours With Floodwall

Figure A.6 Steady State 100 year ARI Velocity Vectors Without Floodwall

Figure A.7 Steady State 100 year ARI Velocity Vectors With Floodwall

Figure A.8 Steady State 100 year ARI Afflux (WSL with – WSL without Floodwall)

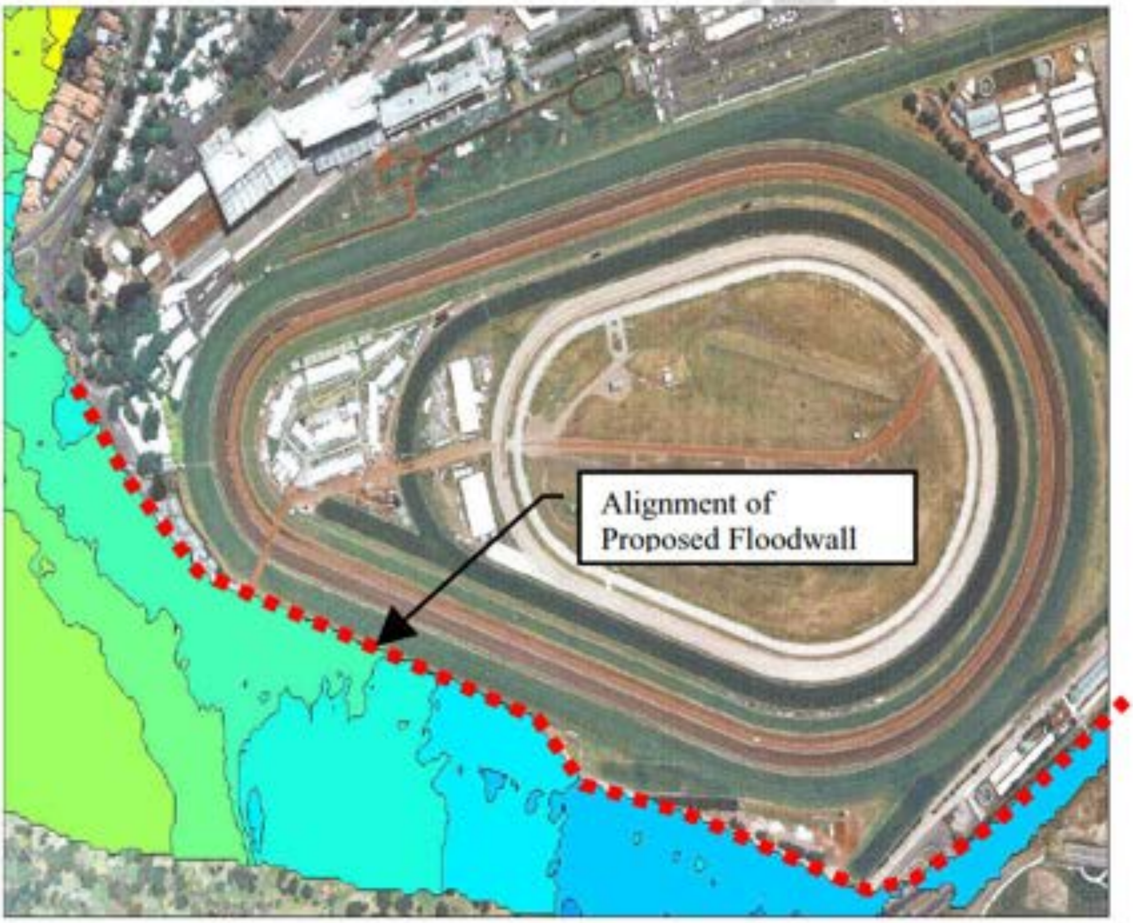
Figure A.9 Non-Steady State 100 year ARI Innundation Extent Progression Without Floodwall

B. Proposed Works

B.1 Proposed Floodwall Alignment

A vertical floodwall is proposed to separate the Maribyrnong River and the racecourse. The proposed wall will extend from high ground near Fisher Parade to high ground along Smithfield Road. The proposed floodwall alignment shown as ■ ■ ■ ■ in Figure B.1 follows the northern boundary between the proposed flood extent and the aerial photo.

Figure B.1



B.2 Proposed Mitigation Works at Footscray Road

The Footscray Road mitigation concept involves removal of the bluestone abutment and flow training walls for the left abutment.

B.2.1 Removal of Bluestone Abutment

Preliminary assessment of this task has identified the likely need for a temporary cofferdam to work behind, a monorail gantry to remove the slabs, cutting equipment and temporary propping prior to permanent stabilisation works which may be integrated into the flow training wall. A detailed structural analysis is yet to be undertaken.

B.2.2 Flow Training Walls

The conceptual horizontal alignments of the flow training walls are displayed in Figure B.2 with flow from left to right. Detailed survey will be undertaken as part of the detailed design process at which time the alignment will be revised as required.

Figure B.2 Conceptual Flow Training Walls

Plan of Proposed Abutment Works - Concept Sketch **NOT FOR CONSTRUCTION**

Footscray Road Left (East) Abutment

Set out points for new vertical flow training walls

Upstream wing wall (minimum crest height 1.5m AHD)

river distance (m)	offset (m)
-12.04	3.21
-11.50	2.71
-10.88	2.24
-10.18	1.79
-9.37	1.37
-8.44	0.98
-7.35	0.64
-6.02	0.35
-4.27	0.12
0.00	0.00

Downstream wing wall (minimum crest height 1.3m AHD)

river distance (m)	offset (m)
60.14	6.23
51.72	5.99
48.26	5.54
45.64	4.96
43.48	4.29
41.65	3.53
40.05	2.70
38.22	1.94
36.06	1.27
33.44	0.69
29.98	0.24
21.56	0.00

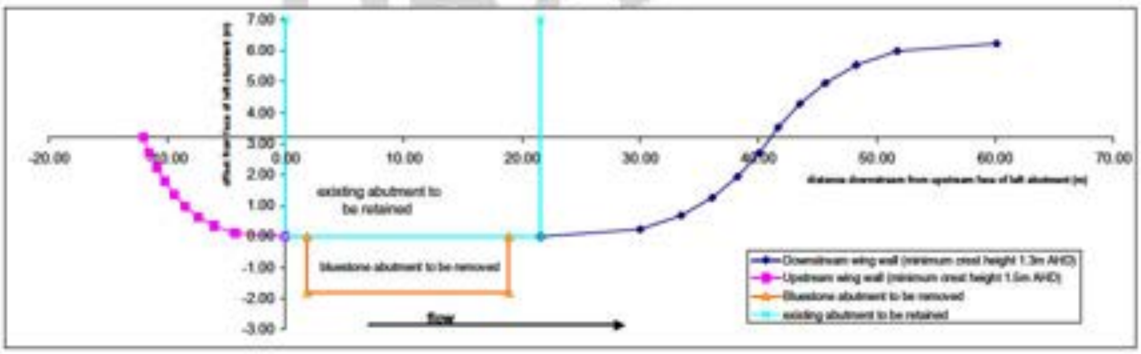
Notes

Curves can be constructed as straights between nominated points

Bank to be reinstated to match walls

walls to be tappered into existing banks

coordinates subject to revision following detailed survey



B.2.3 Cost Estimate

Preliminary “order of cost” estimates have been prepared for the Footscray Road mitigation concept and are presented in Table B.1. No allowance has been made for any compensation, which may be required.

Table B.1 Footscray Road left abutment Improvements – Indicative Schedule of Costs

Item	Description	Order of Cost ($1,000)
1.	Site Establishment / Environmental	100
2	Survey, Detailed Structural Assessment, Design and Approvals	150
3a	Remove Bluestone Abutment (cofferdam, labour and mechanical)	200
3b	Construction of wingwalls and support to facia	300
4	Site reinstatement	50
5	Service Relocations (provisional)	100

	Contingency (22%)	200
	TOTAL	1,100

B.3 Northern Railway Culverts

The Northern Railway mitigation concept involves removal of the road embankment immediately downstream of the railway culverts. Approximately 70 m of earth roadway embankment is to be removed, lowering levels from approximately 0.8 mAHD to 0 mAHD to match the invert level of the culverts. It is expected that the earth embankment will need to be disposed of as contaminated fill. There is potential for approval difficulties with this mitigation concept.

B.3.1 Cost Estimate

Preliminary “order of cost” estimates have been prepared for the Northern Railway mitigation concept and are presented in Table B.2. No allowance has been made for any compensation, which may be required.

Table B.2 Northern Railway Culvert Improvements - Indicative Schedule of Costs

Item	Description	Order of Cost ($1,000)
1.	Site Establishment / Environmental	100
2	Survey, Design and Approvals	100
3a	Lowering Road Works	50
3b	Disposal to Contaminated Fill	75
3c	Construction of Alternate Access 500m x $600	300
4	Site reinstatement	75
5	Service Relocations (provisional)	20
	Contingency (25%)	180
	TOTAL	900

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Victoria Racing Club

Flemington Racecourse Flood Protection

Investigation of Maribyrnong River Flood Protection

Final Report

May 2003

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Glossary

100 year Average Recurrence Interval (ARI) flood
Commonly referred to as a flood with a 1% Annual Excedence Probability (1%AEP). A rare flood widely adopted as a design standard, this event has a 1 in 100 chance of being equalled or exceeded in any one year. While on average this event will occur only once in 100 years, it could occur several times or not at all during a given 100 year period.

1-dimensional (1-D) hydraulic model
Hydraulic models where levels are determined along a predefined flow path typically described by cross sections perpendicular to the predominant flow direction. 1-D models are computationally efficient at modelling of flows within a defined channel. Engineering judgement is required where 1-D models are applied to more complex flow mechanisms, such as flow transverse to the main flow direction.

2-dimensional (2-D) hydraulic model
2D models can model transverse flow. These models typically define the bathymetry or terrain as a regular grid and the flow path does not need to be predetermined. They require more data storage and run times are much longer, however they are useful for modelling rivers with extensive floodplains, i.e. where flow directions vary significantly in space and time.

Afflux
Change in flood level at a given location as a result of works, typically the difference in flood level between existing and proposed cases. For consistency flood levels and hence afflux in this report are based on the Total Energy Level (TEL) unless noted otherwise. Positive afflux is usually defined as an increase in flood levels.

Attenuation
the reduction in flood peak due to temporary storage associated with a floodplain, retarding basin or reservoir.

Conveyance
A measure of the capacity of a waterway to carry flows, especially flood flows. Conveyance is a function of geometry and roughness characteristics.

FFPW
Abbreviation for Flemington (Racecourse) Flood Protection Works

FLS
FLS stands for Delft Flood Level System, which is a 2-dimensional floodplain modelling software package.

Hydrograph
a relationship defining the variation of flow with time, typically as a graph of flow versus time. Flood hydrographs may have multiple peaks, but typically rise to a peak before falling more gradually. Higher flows typically are reflected in higher water surface levels, hence the concept of a river rising and falling as the hydrograph (flood wave) passes through a given location over time.

Steady state
Used to describe a modelling approach in which flows and levels remain constant with time typically using peak flow values. Flood storage effects cannot be determined.

Unsteady state
A modelling approach using time varying flows and levels. Effects of flood storage are modelled.

Water Surface Level (WSL)
The surface of the water at a particular point, or the average water surface level when used with respect to a 1D model cross section or particular river distance. Water surface levels can increase in a downstream direction when the flow velocity reduces.

Total Energy Level (TEL)
The level to which the water surface would rise if it were stationary, eg. At the nose of a pier. The TEL is above the water surface and always decreases in a downstream direction. The elevation difference between the WSL and TEL is known as the velocity head and is the square of the velocity divided by twice the accelation due to gravity

ie. $TEL = WSL + \frac{v^2}{2g}$

Executive Summary

The reader is referred to Figure 1.1 for a map showing Flemington Racecourse and the Maribyrnong River.

The Victoria Racing Club (VRC) engaged GHD to:

- Quantify the effects of the proposed Flemington Racecourse flood protection works on flood flows and flood levels in the Maribyrnong River;
- Identify and analyse appropriate mitigation measures which are likely to be acceptable to Melbourne Water
- Prepare a report describing the analysis and results that will be suitable to support VRC's application with respect to floodplain issues.

A floodwall is proposed to protect Flemington Racecourse from flooding due to the 100 year ARI flood in the Maribyrnong River. The floodwall will block off almost 100 hectares of floodplain thereby reducing flood conveyance and floodplain storage. Without the proposed mitigation works, the loss of floodplain storage would increase downstream flood flows, which in turn would increase flood levels, and the loss of conveyance would raise upstream flood levels.

The 100 year ARI flow downstream of the site was found to increase by less than 1% from 838.3 m^3/s to 846.5 m^3/s (an increase of 8.2 m^3/s) due to loss of floodplain storage. This result was determined using a RORB model with input derived from a 2D model of Flemington. Unless works are implemented to mitigate against the increase in flood flow, the 100 year flood levels would increase by 30 to 35 mm between Footscray Road and Flemington. This increase in flood level (called "afflux") would reduce with distance upstream of Flemington. Following discussions with Melbourne Water it was decided to limit the study to upstream of Footscray Road.

Afflux upstream of Flemington is caused by a combination of the downstream afflux and the loss of conveyance through the site. Unless mitigation works are implemented, the increase in flood level immediately upstream of the site, due to the loss of conveyance only, reaches a maximum value of approximately 15 mm at Fisher Parade. When combined with afflux due to the increase in flood flow (as described above) the total afflux would be approximately 45 mm at Fisher Parade. The afflux diminishes with distance upstream and, if mitigation works are not implemented, would be around 10 to 15 mm at Maribyrnong Village. This region remains flood prone despite lowering of flood levels (relative to 1990 flood levels) due to the installation of culverts at the Northern Railway Bridge and the Edgewater development, both of which were completed prior to February 2003.

Works to mitigate against the effects of the floodwall were identified and analysed. A wide range of options was investigated but few options offered a suitable solution. The mitigation works proposed in this report involve providing additional conveyance and thereby "neutralising" the afflux. Dr Bob Keller has been engaged to review the hydraulic analysis and has been involved in the hydraulic analysis to date.

Locations where conveyance could be most effectively improved were identified following a review of the flood profiles and site inspections. Mitigation works are hydraulically feasible at two locations :

- Footscray Road Bridge, where streamlining of the left (eastern) bridge abutment will lower the 100 year ARI flood level by approximately 55 mm; and

- Northern Rail Crossing, where removal of a gravel access track, located immediately downstream of the culverts that were installed in 1991, would lower the 100 year ARI flood level by approximately 44 mm.

The lower flood levels, or "benefits", tend to taper off with distance upstream.

It is proposed to construct the Flemington floodwall with mitigation works at Footscray Road. This proposal will lower flood levels between Footscray Road and the Northern Railway Bridge. The reach upstream of the Northern Railway benefited from a substantial lowering of flood levels (by around 300mm) in 1991 due to the construction of the Railway Culverts. Within this reach the proposal results in an increase in flood levels of up to 30 mm relative to January 2003 conditions with the maximum afflux experienced at the upstream end of Flemington Racecourse. The afflux decreases with distance upstream to around 5 mm at Maribyrnong Village. As the proposed increases in flood level within this reach are an order of magnitude smaller that the lowering achieved by the construction of the railway culverts, the net effect is a substantial reduction since 1990.

The estimated capital cost of the proposed mitigation works at Footscray Road is approximately $1.1 M. This order of cost figure is based on the current concept design with no allowance for any compensation, which may be required. This estimate is based on a preliminary mitigation concept and will be refined during the detailed design phase. The detailed design phase will involve further negotiation with authorities and landholders and additional survey, analysis and design.

If additional mitigation works at the Railway culverts were implemented the effect would be to over-compensate for the Flemington floodwall, ie to lower 100 year ARI flood levels between Footscray Road and Maribyrnong Village. This would be a desirable outcome. However, the gravel access road is located on private property over which the VRC have no control. Unless agreement with the landowners is forthcoming it is suggested that Melbourne Water make a record of the potential benefits associated with lowering the gravel road so that at some stage in the future when the opportunity arises, Melbourne Water could implement these works, estimated to cost approximately $0.9M.

The current concept has been investigated to establish the viability of the project from a hydraulic perspective. While the approval process has the potential to restrict the benefit of the mitigation works, preliminary indications are that the proposed mitigation works will provide an effective solution.

The way forward from here includes:

- Submission of this report and the associated hydraulic models to Dr Bob Keller for review;
- Submission of this report to Melbourne Water with a view to obtaining approval in principal for the proposed works; and
- Finalising the report upon receipt of comments from Melbourne Water.

1. Introduction

1.1 Scope of Investigation

Victoria Racing Club (VRC) commissioned GHD to undertake hydraulic investigations to determine the effects on Maribyrnong River flood levels of proposed flood protection works. The proposed flood protection works include the construction of a floodwall to protect the Flemington Racecourse from a 100 year ARI Maribyrnong River flood. This investigation also determined the extent and nature of the mitigation works required to compensate for the portion of floodplain effectively removed from the Maribyrnong River by the proposed floodwall. This report describes these investigations.

1.2 Background

Flemington Racecourse is located on the left (eastern) floodplain of the Maribyrnong River upstream of Smithfield Road ref Figure 1.1. The site has undergone substantial development over a considerable period of time and further development is planned. Planning is currently well underway for a major track reconstruction and associated works.

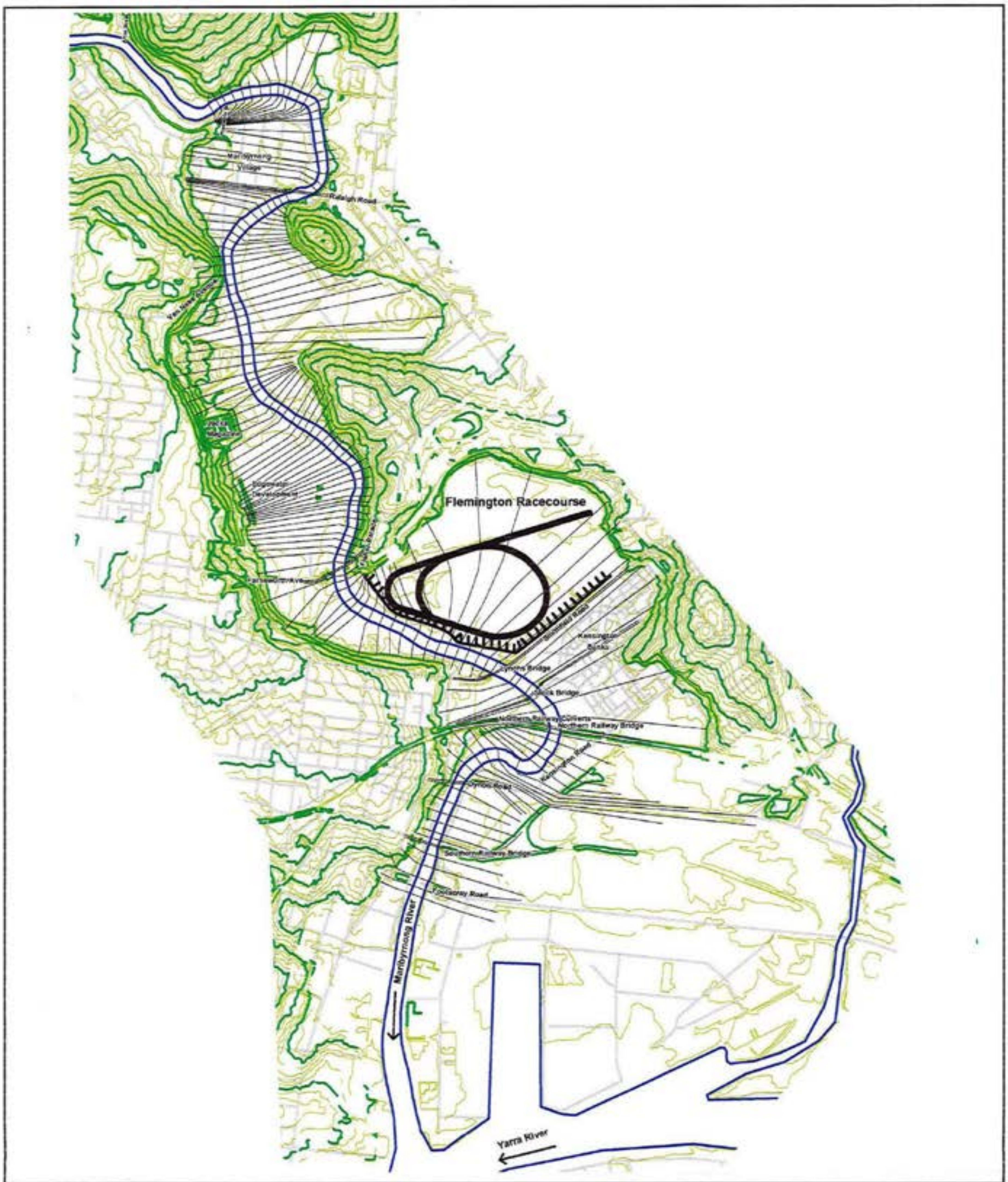
Flemington Racecourse is the location of Australia's biggest and richest horse racing carnival. The Spring Racing Carnival is an internationally recognised event; its four days of racing include the legendary Melbourne Cup. Derby Day, Cup Day, Oaks Day and Emirates Day generate significant economic and social benefits for the state of Victoria.

Flemington racecourse has been inundated several times by floodwaters from the Maribyrnong River. Such flooding has the potential to require substantial remediation works and if it were to occur within two months of the Melbourne Cup could lead to cancellation of the carnival. The Victoria Racing Club (VRC), in recognising the risks which flooding presents to the racecourse, its patrons and the Spring Racing Carnival, decided to investigate ways of reducing these risks.

1.3 Description of Proposed Flemington Racecourse Flood Protection Works

The concept of a floodwall around the racecourse has been developed during a series of discussions with Melbourne Water, the VRC, it's Course development consultants and GHD. The floodwall will protect racecourse assets and events from a 100 year ARI Maribyrnong River flood. The proposed level of protection should enable a revision of the planning scheme to reflect that the racecourse is no longer part of the floodplain thus simplifying future development at the racecourse.

As the racecourse is located on the Maribyrnong floodplain, the site currently provides conveyance and attenuation of Maribyrnong River flood flows. In the absence of appropriate mitigation works the proposed floodwall will reduce currently available floodplain storage and conveyance leading to increased flood levels downstream and upstream of the site. Melbourne Water, as the floodplain referral authority, require that the 100 year ARI design flood levels are not increased by the proposed flood protection works at Flemington.



MANAGEMENT
ENGINEERING
ENVIRONMENT

G:\31\12638\tech\GIS\Figure1-1.WOR

LEGEND

	Proposed Flood Wall
	Cross section alignment
	Road alignments
	1m contours
	Direction of Flow

North

SCALE 1 : 20,000 at A3

200 100 0 200 400 600 800 1000 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

Maribyrnong River

Locality Plan

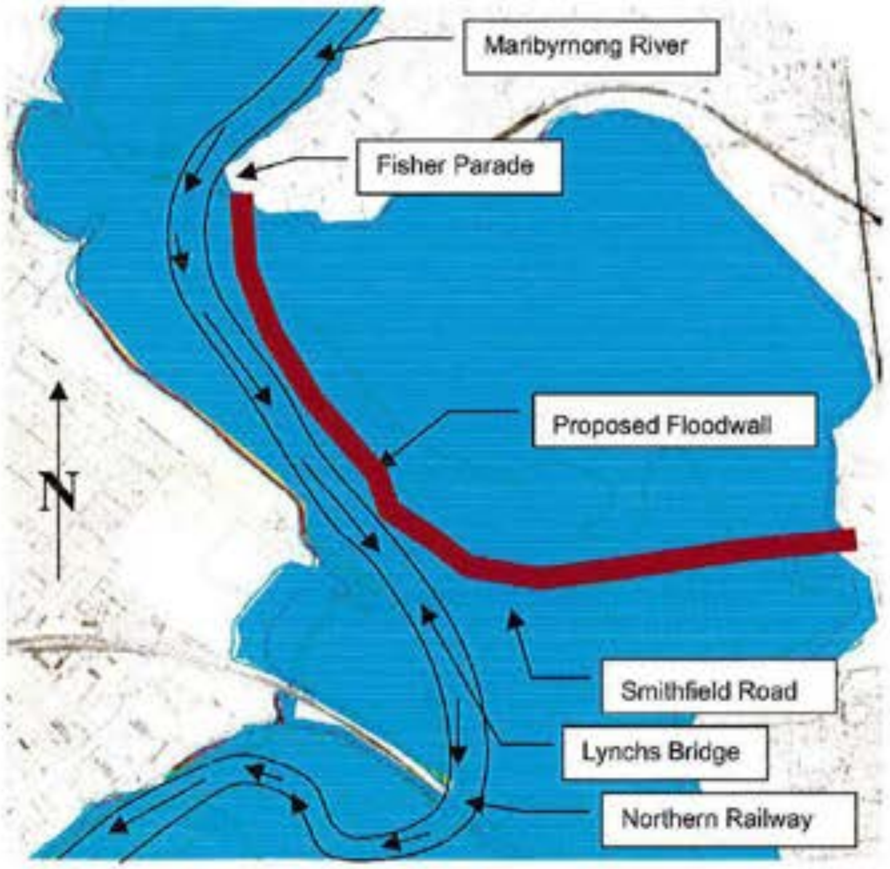
Figure 1.1

The proposed works include:

- A floodwall to protect the racecourse and events held there from the 100 year ARI Maribyrnong River flood.
- Associated mitigation works in the Maribyrnong River to compensate for the reduced floodplain storage and conveyance resulting from the proposed floodwall.
- Other associated works with little or no impact on the Maribyrnong River are not dealt with in this report and include:
  - Modification to the internal drainage system (ie inside or behind the floodwall)
  - A complete track reconstruction.
  - Construction of an underpass beneath the track for access to the central portion of the track
  - Water reuse facilities

The extent of flooding on the Maribyrnong River was mapped in 1986 by the MMBW, an extract is included as Figure 1.2. The general concept is to protect the racecourse from a 100 year ARI Maribyrnong River flood. The 1986 extent of flooding for the 100 year ARI event is shown in Figure 1.2 as the shaded region.

Figure 1.2 Existing Flood Extents (1986) and Proposed Floodwall



2. Methodology

2.1 Introduction

This section describes the overall investigation approach, establishes some of the adopted terminology, and describes the data and models used for this investigation.

2.2 Overview of the Assessment Methodology

The effects of the proposed floodwall can be split into two related components; a loss of attenuation and a loss of conveyance. The process for evaluating and designing mitigation works was developed with an understanding of how these effects interact. In simple terms, loss of attenuation causes an increase in downstream flows. Loss of conveyance and or increased flows result in higher upstream flood levels. The following summarises the assessment tasks in the order they were undertaken:

1. Review of the existing conditions HEC-RAS model of the Maribyrnong River between upstream of Footscray Road and the Maribyrnong Village, as supplied by Melbourne Water in January 2003.
2. Assessment of flow attenuation at Flemington Racecourse for existing and proposed conditions using detailed local models.
3. Extension of the HEC-RAS model to include the Footscray Road bridge.
4. Assessment of afflux due to loss of conveyance associated with proposed floodwall.
5. Determination of flood levels for existing and unmitigated proposed conditions using HEC-RAS in Steady State adopting the flows determined in task 2 above.
6. Investigation of options to mitigate against the impacts of the proposed floodwall.
7. Modelling of the proposed works, ie the floodwall and associated mitigation works to determine flood levels and afflux in the Maribyrnong River.
8. On-going discussions with Dr Bob Keller who will review the hydraulic modelling undertaken on this project.

2.3 Terminology

The following section describes the specific meanings given to various terms and expressions used in this report. Definitions for many of the more widely used technical terms are included in a glossary of generic terms at the front of this report.

Flemington: used to refer to the region of the Maribyrnong River adjacent to Flemington Racecourse between Fisher Parade and Lynchs Bridge.

Floodwall: refers to the perimeter floodwall at the Flemington Racecourse Site designed to protect the racecourse from a 100 year ARI Maribyrnong River flood

Flood Protection Works: refers to the floodwall and associated mitigation works on the Maribyrnong River including proposed bridge modifications.

Existing Conditions: January 2003 conditions as detailed in the Melbourne Water Report (ref 1)

Base Case: this includes the Footscray Road Bridge, minor amendments to structure details, refer to Section 4.2. Revised flow estimates were developed for the base case to enable an appropriately conservative assessment of the effects of the proposed floodwall, refer to section 3.

Unmitigated Case: Includes the floodwall, but no mitigation works, i.e. it includes the effects of loss of conveyance and floodplain storage but with no mitigation works.

Proposed Case: The proposed combination of works, i.e. the floodwall, changes to flows associated with the floodwall, and the proposed mitigation works at Footscray Road Bridge.

Flood Level: For consistency with previous Melbourne Water and MMBW Maribyrnong River investigations all flood levels produced in this report are Total Energy Levels (TEL) unless noted otherwise. The total energy level is the level to which water would rise if brought to rest.

2.4 Existing Conditions

Melbourne Water has provided the existing conditions model on which this investigation is based. The existing conditions model was created in HEC-RAS version 3.1, which is a one dimensional hydraulic model well suited to determining flood flows and levels for planning purposes on the Maribyrnong River from just upstream of Footscray Road to Maribyrnong Village. It represents January 2003 conditions and is the agreed starting point for the impact assessment of the proposed floodwall on flood flows in the Maribyrnong River.

Details of the existing conditions model are published in Melbourne Water Corporations report, "Maribyrnong River Hydraulic Model, Final Report", February 2003, by GHD (ref 1). Some key features of the existing conditions model are summarised below.

- The existing flood levels are total energy levels and are derived from a steady state HEC-RAS model.
- The model extends from Maribyrnong Village (upstream boundary) to immediately upstream of Footscray Road (the downstream boundary). The cross sections are based on a variety of sources including bathymetric soundings, detailed photogrammetric and field survey and Melbourne Water one metre contours.
- The model was calibrated to the flood levels published in the "Maribyrnong River Flood Mitigation Report" MMBW 1986 (ref 6). The resultant calibrated steady state model has Manning's 'n' values that are generally smoother than theory would suggest.
- The calibrated model was subsequently altered to incorporate three post 1986 developments:
    - Construction of 12 monolithic culverts through the embankment adjacent to the northern railway bridge
    - Construction of Kensington Banks Development downstream of Lynchs Bridge
    - Construction of Edgewater Development upstream of Fisher Parade
- The existing condition models include an unsteady state HEC-RAS model used to determine the attenuated flows and a steady state HEC-RAS model that uses the attenuated flows to determine flood levels for planning purposes.
- Scour was not explicitly modelled although is implicitly accounted for at the Northern Railway Bridge as a result of the calibration process.

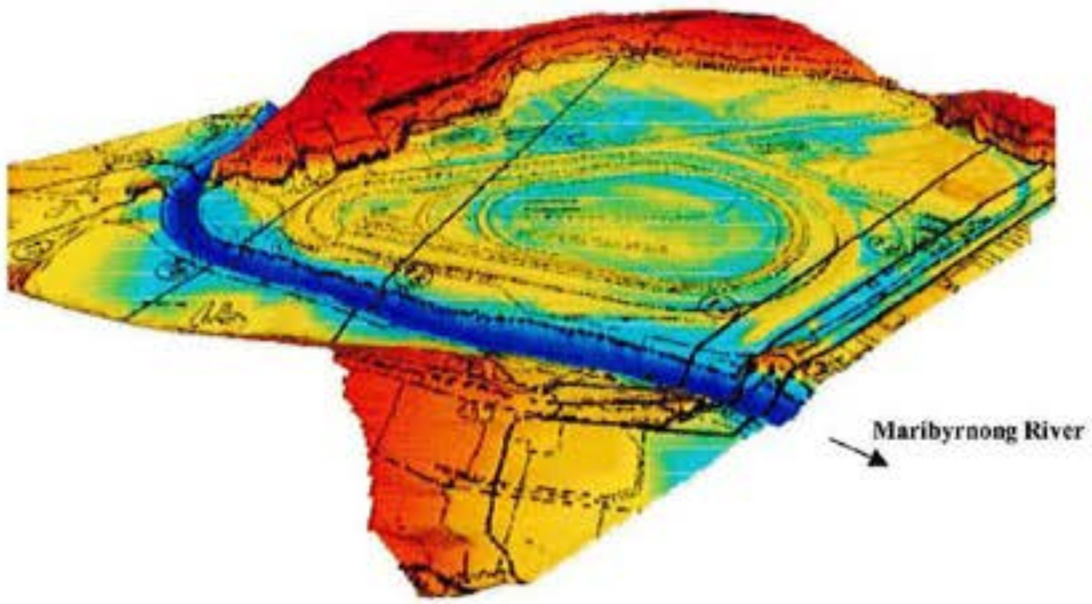
- The report identifies that it may be appropriate to use local models to more precisely determine local effects.

The last of these bullet points warrants some further explanation:

In one dimensional hydraulic models flood levels are based on representative cross sections and cross sectionally averaged properties. Water surface levels and flow velocities typically vary significantly across a wide floodplain. This type of variation is beyond the ability of a one dimensional model to resolve and can be significant in determining the impact of floodplain modifications. The use of a one dimensional model with its inherent assumptions is generally considered appropriate for setting flood levels along a river such as the Maribyrnong. When detailed assessment of the flow distribution and the effect of floodplain works is required, such as for analysis of the current proposal, a two dimensional model will typically provide more confidence in the findings.

On this basis a two dimensional model of the site was developed using Delft FLS software based on the same bathymetric soundings, detailed photogrammetric survey and Melbourne Water one metre contours as used for Melbourne Water's existing conditions model. The extent and relief of the two dimensional FLS model is illustrated in Figure 2.1. Essentially, the FLS model was used to determine the hydraulic conveyance of floods through the Flemington site under existing conditions and the effects of the floodwall on upstream flood levels. It was also used to obtain the elevation-volume relationship for the site which was used to model the effect of the loss of floodplain storage. More detailed information on the two dimensional model is included in Appendix A.

Figure 2.1 The existing site as represented in the two dimensional model



3. Change in Peak Flood Flow due to Loss of Floodplain Storage

3.1 Introduction

The reduction in peak flows due to the temporary storage of floodwater is known as attenuation. This section describes:

- the existing attenuation estimates and why they need to be revised for the current investigation;
- the way existing attenuation estimates were revised and attenuation for the proposed case determined; and
- compares the revised flow estimates with existing attenuation estimates for existing and proposed conditions.

3.2 Existing Conditions Attenuation Estimates

The existing conditions model provided by Melbourne Water includes an estimate of flow attenuation under existing conditions, which was based on a one dimensional unsteady state HEC-RAS model. The primary purpose of the Melbourne Water model was to determine flood levels for planning purposes.

All modelling involves some uncertainty and when deriving attenuation estimates for the purposes of setting planning levels it is generally conservative to underestimate attenuation because the consequently overestimated flows result in conservatively high flood levels. Such an approach is not appropriately conservative for determining the effect of loss of floodplain storage as required for the current investigation.

For the current investigation it is appropriate to revise the existing condition attenuation estimates for two reasons:

1. to ensure that the attenuation estimate is appropriately conservative, i.e. to provide increased confidence that it is not underestimated; and
2. to examine the effects of the floodplain in more detail using local models as recommended in the Melbourne Water existing conditions report (ref 1)

3.3 Assessment of Attenuation

A two dimensional model of Flemington (refer to Figure 2.1) was created using a 5m rectangular grid and calibrated to enable assessment of conveyance and storage effects. Examination of flow attenuation estimated using the unsteady 2D model (called Delft Flood Level System, or FLS) identified some limitations, and an alternate methodology using RORB was devised. While the RORB analysis was ultimately adopted as being the most reliable, it includes a stage storage relationship derived using the unsteady state FLS model runs. The following sections chronologically describe the process undertaken to determine the effect of loss of floodplain storage.

3.3.1 Unsteady State Simulation of Attenuation

Dynamic (Unsteady state, having flow varying with time) FLS runs to determine the attenuation due to the reach between Fisher Parade and Lynchs Bridge were undertaken for the existing and with floodwall conditions. The difference in attenuation in this reach is the effect of loss of floodplain storage. Review of these runs identified two limitations to the FLS model that affect the attenuation estimates. These limitations are due to a "levee effect" and a "boundary condition effect". Details of the unsteady state FLS model and its limitations are discussed in greater detail in Appendix A.

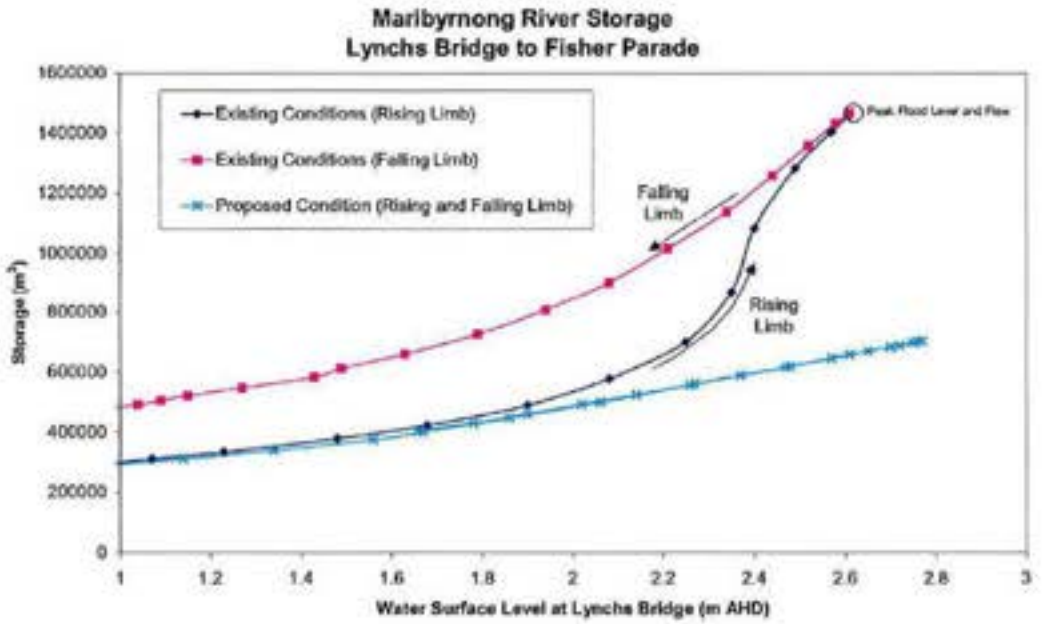
3.3.2 RORB model with inputs from FLS

RORB is a widely used hydrologic model with runoff, stream flow routing and storage modelling capabilities. In general the routing capabilities of hydraulic models such as FLS are more detailed and hence more reliable than hydrologic models, however with accurately defined stage storage and stage discharge relationships hydrologic models can provide relatively simple and reliable results. The use of RORB's retarding basin routines in the current investigation enabled the two FLS modelling limitations (ref Appendix A) to be addressed. The "levee effect" can be adjusted to an appropriate degree and the FLS boundary condition assumptions isolated from the analysis.

Stage Storage Relationship at Flemington Racecourse

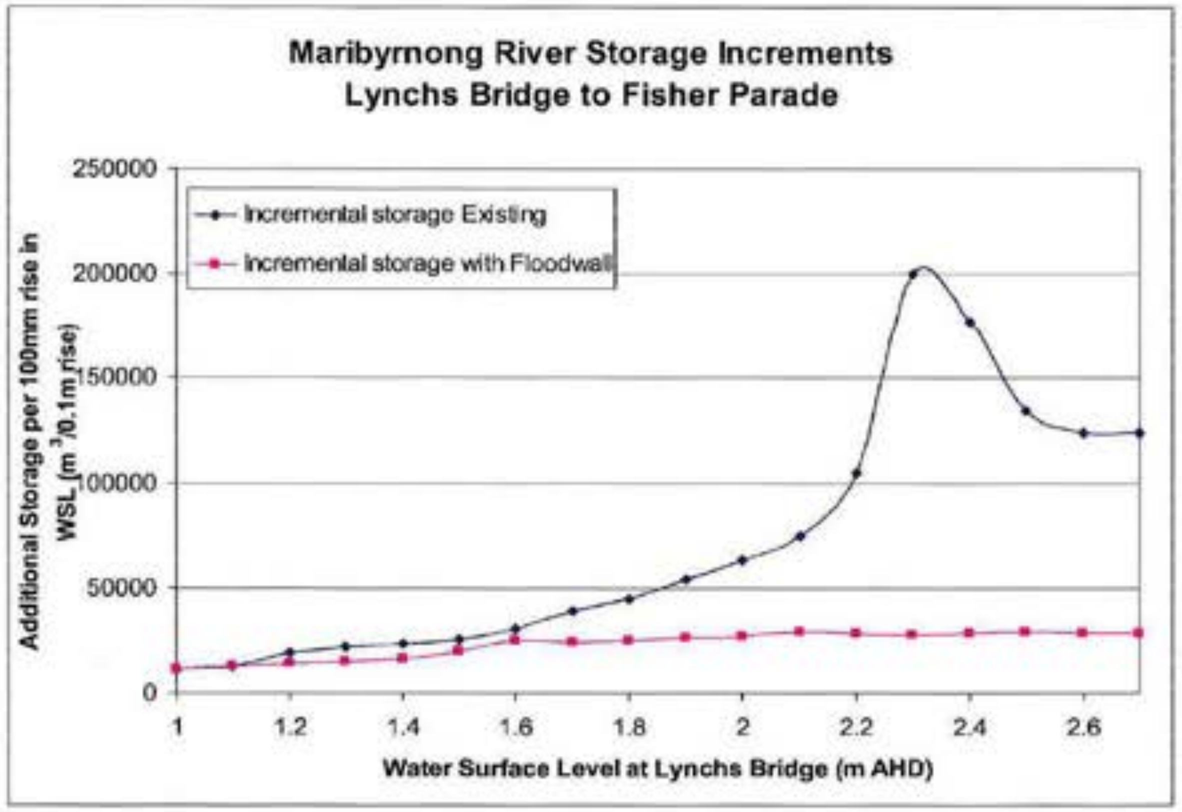
The FLS model flood levels are considered generally reliable between Fisher Parade and Lynchs Bridge (refer more detailed discussion in Appendix A). An accurate stage storage relationship was determined by post processing the results from the unsteady state simulations. Flow depths from the FLS model's 5 m grid between Fisher Parade and Lynchs Bridge were processed at hourly intervals on the rising and falling limbs of the design flood to determine storage for a range of levels at Lynchs Bridge. The resultant relationships for the existing and with floodwall conditions are depicted in Figure 3.1

Figure 3.1 Post Processed Storage from FLS Results



The variation in the rising and falling limbs of the existing stage storage relationship is primarily due to the "levee effect", refer Appendix A. Adopting the rising limb relationship in RORB would produce excessive attenuation because the storage remains "leveed off", until nearer the flood peak. Unlike the FLS representation, much of this 'reserved' storage is expected to fill progressively during a real flood event. Similarly, adopting the falling limb relationship in RORB would underestimate the attenuation in a real flood. The reason FLS exaggerates the "levee effect" is because small drainage paths are not well represented in the 5m grid. Given that the 100 year ARI flow rises gradually it is expected that reverse flow along drains will be sufficient to progressively fill substantial areas which remain artificially dry in FLS. On this basis it is expected that the actual incremental storage curve is more closely represented by the falling limb curve. Based on engineering judgement and discussion with [redacted] it was therefore considered appropriately conservative to adopt a storage relationship midway between the rising and falling limbs of the FLS based stage storage curves. The adopted relationship is summarised in Figure 3.2, a brief explanation of the two curves follows.

Figure 3.2 Storage Characteristics



The Incremental Storage curves in Figure 3.2 show the rate of increase in floodplain storage for various elevations at Lynches Bridge for the following conditions:

"Existing" conditions - the rate at which storage increases begins to increase above bank full conditions (RL 1.6 mAHD) as more of the floodplain becomes inundated. At the 100 year ARI extent there should be approximately 125,000m^3 of storage for every 100 mm rise in flood level ie. total floodplain area of 1.25 km^2 x 100 mm depth. The rate of increase in storage is higher than this between RL 2.2 and 2.5 as "reserved" storage is flooded.

"With Floodwall" conditions - the floodplain storage increases at a relatively constant rate due to the vertical sides of the floodwall.

Stage Discharge Relationship

The stage discharge relationship used in RORB was obtained using the existing conditions steady state HEC-RAS model provided by Melbourne Water (ref 1). This HEC-RAS model was run for a range of flows using the downstream rating table from the unsteady state HEC-RAS model also provided by Melbourne Water (ref 1). Flows and levels at Lynchs Bridge from each of these runs were tabulated and adopted for the RORB analysis.

3.4 Change in Attenuation Results

The RORB modelling was undertaken using the inputs described above and an input hydrograph at Fisher Parade extracted from the existing conditions unsteady state HEC-RAS model provided by Melbourne Water (ref. 1). Peak flows from this unsteady state HEC-RAS model are referred to as "MW Existing Conditions" in Table 3.1.

Two RORB models were established: a "Base Case" which represents existing conditions at Flemington; and a "Proposed Conditions" model which includes the proposed floodwall at Flemington.

The two RORB models differed only in their stage storage relationships, i.e. the input hydrograph and stage discharge relationship remained identical. A small approximation is therefore built into the analysis because under proposed conditions, the stage discharge relationship will change slightly. This approximation will have little or no impact on mitigation requirements given the attenuation between Fisher Parade and Lynchs Bridge is small (0.2 m^3/s) under proposed conditions, refer to Table 3.1).

The adopted peak inflows and outflows from the RORB models of the Base Case and Proposed conditions are shaded in Table 3.1. Downstream of the Flemington Site the flow estimates are based on Unsteady State HEC-RAS modelling. The peak 100 year ARI flow estimates for the entire reach are plotted in Figure 3.3 and selected values tabulated in Table 3.1.

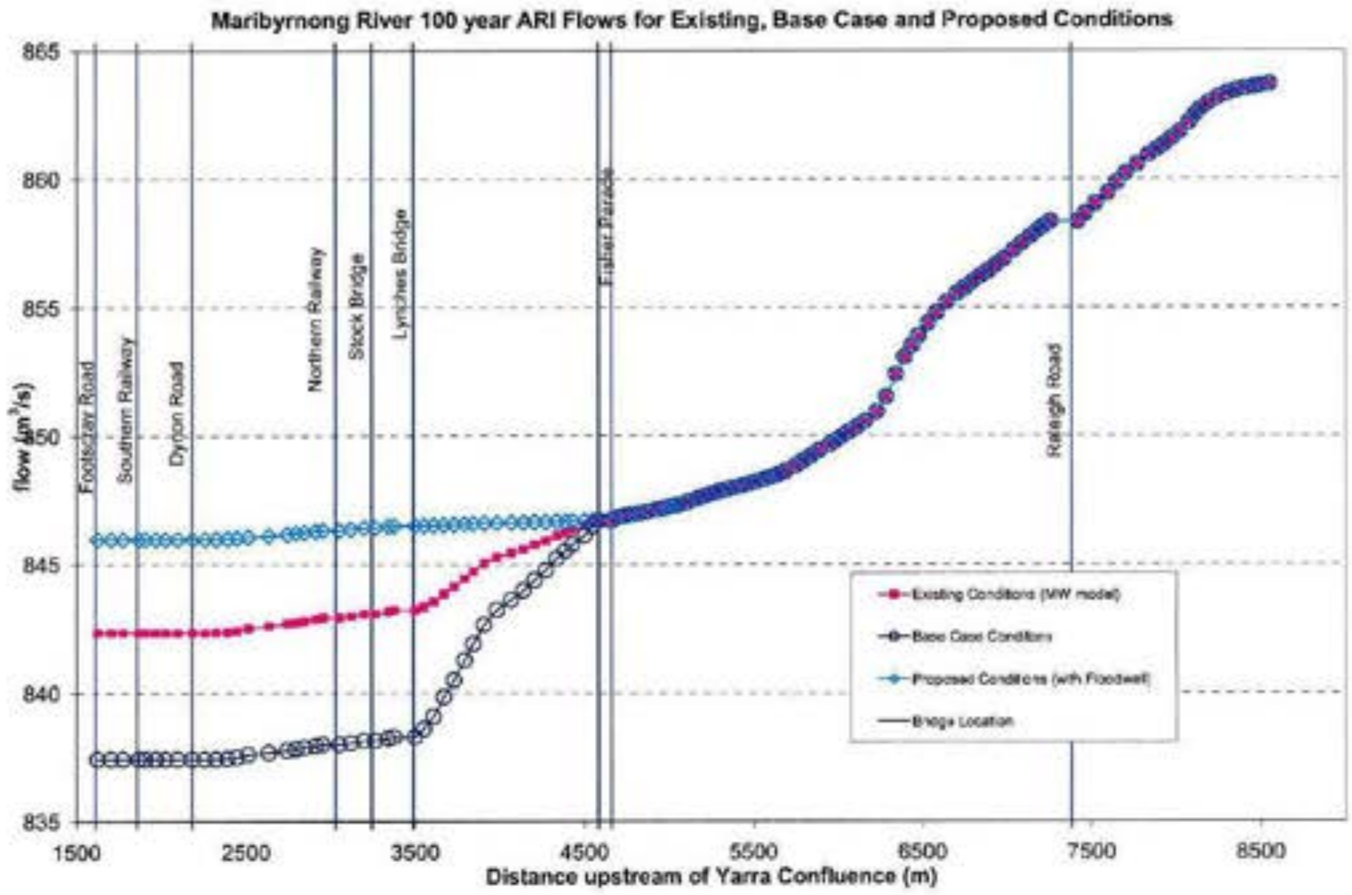
The change in attenuation due to the floodwall is 8.2 m^3/s, which is the difference between 8.4 m^3/s (RORB Base Case) and 0.2 m^3/s (RORB Proposed Conditions).

Table 3.1 100 year ARI Fows from Maribyrnong Village to Footscray Road

River Station (km)	Description	MW Existing Conditions (m^3/s)	Base Case (m^3/s)	Proposed Conditions (m^3/s)
8.614	upstream model boundary	863.7	863.7	863.7
7.481	just u/s Raleigh Road	858.3	858.3	858.3
5.899	Jack's Magazine	849.2	849.2	849.2
4.719	Fisher Parade (Upstream end of Site)	846.7	846.7	846.7
3.559	Lynchs Bridge (Downstream end of Site)	843.2	838.3	846.5
	Attenuation through Flemington Site	**3.5 ***	**8.4**	**0.2**
3.324	just u/s Stock Bridge	843.1	838.2	846.4
3.112	just u/s Northern Railway Bridge	842.9	838.0	846.3
2.319	just u/s Dynon Road	842.4	837.4	846.0
1.928	just u/s Southern Railway Bridge	842.4	837.4	846.0
1.685	just u/s Footscray Road	842.4	837.4	846.0

* It should be noted that 3.5 m^3/s forms a good approximation of the change in attenuation through the Flemington site as determined in the Melbourne Water unsteady state HEC-RAS model.

Figure 3.3 Flow Attenuation



4. Unmitigated Effect on Flood Levels

4.1 Introduction

The effect of the proposed floodwall on flood levels in the Maribyrnong River was determined using a steady state HEC-RAS model appropriately adjusted to incorporate the effects of the works as determined by more detailed local models.

The process involved establishing the base case model, and determining the downstream and upstream impacts of the proposed floodwall without mitigation works. It is essential to first quantify the unmitigated effects so that mitigation works can be located and designed to address the effects.

The following sections describe investigations aimed at determining the unmitigated effect of the proposed floodwall on flood levels in the Maribyrnong River, in particular the :

- Establishment of the base case model;
- Evaluation of downstream impacts due to loss of floodplain storage;
- Evaluation of upstream impacts due to loss of conveyance; and
- The overall impact of the floodwall without mitigation.

4.2 Base Case Hydraulic Model

4.2.1 Introduction

The base case HEC-RAS model incorporates the following changes to the existing conditions model provided by Melbourne Water:

- extension of model downstream to include Footscray Road
- review and update of select bridge modelling parameters (Northern Railway).
- Revised flows as detailed in the previous section

Details of these changes are outlined in the following sections.

4.2.2 Extension of model to include Footscray Road

The existing conditions model provided by Melbourne Water extends downstream to the upstream side of Footscray Road. The model was extended a further 95 m downstream to include a representation of Footscray Road based on design drawings and the cross section immediately upstream of Footscray Road with minor adjustments to better reflect conditions downstream. These adjustments comprised a 5m widening of the cross sections downstream of Footscray Road to reflect the widening on the left (east) bank and the addition of details including the Ports and Harbours wharf and the moored craft on the right (west) bank. The model parameters were chosen using engineering judgement to reflect our understanding of the reach and, with respect to the main channel roughness parameters, to be consistent with the existing conditions model.

The downstream boundary condition was adjusted so that the base case levels upstream of Footscray Road match the published Melbourne Water existing levels (ref 1) using both existing conditions flows and the revised (lower) flows. With the adopted downstream boundary conditions, levels are generally within 10 mm of the Melbourne Water existing conditions levels, refer Appendix B. A normal depth based on an energy slope of 0.00096 was used to achieve this fit and was adopted for all subsequent runs.

4.2.3 Bridge (and Culvert) Modelling Parameters

It was noted that the Melbourne Water existing conditions model was calibrated to the published MMBW 1986 flood profile. This process focussed on achieving realistic flood levels using reasonable bridge modelling parameters. It did not however seek to investigate each bridge in detail and while the overall bridge losses may be appropriate they were not necessarily achieved using a representative set of parameters.

A review of Manning's 'n' roughness values, contraction and expansion coefficients, and pier loss coefficients in the existing conditions model identified a high Manning's 'n' value within the Northern Railway Bridge of 0.055. Following a reassessment of the bridge it was decided to reduce the internal bridge roughness to a more realistic Manning's 'n' of 0.03 and to increase the pier width to account for the flow direction as it impacts on the bridge pier from the real width of 5m to the projected width of 8.9m. As the soffits of the Northern Railway culverts remain dry in the 100 year ARI event it was decided to model the 12 culverts as a second bridge opening with the same characteristics as the culverts. The net bridge loss in the base case remains virtually identical to that under existing conditions ref Table 4.1.

Table 4.1 Changes to the Northern Railway Bridge modelling approach

Model Parameter	MW Existing conditions model	Base Case
Manning's 'n'	0.055	0.03
Contraction Loss Coefficient	0.3	0.3
Expansion Loss Coefficient	0.5	0.5
Pier Drag Coefficient	2.0	2.0
Yarnell Pier Coefficient	1.25	1.25
Pier Width	5	8.9
Energy loss across bridge (m)	0.22	0.217

4.3 Downstream Impact Only (due to loss of floodplain storage only)

4.3.1 Introduction

The unmitigated model was formed by modifying the base case steady state HEC-RAS model to include the proposed floodwall and the proposed conditions attenuated peak flows as described in Section 3. The flood levels from base case and unmitigated models were compared downstream of Lynchs Bridge to provide an estimate of the increase in peak 100 year ARI flood levels (afflux), which would occur downstream in the event that the floodwall was constructed without mitigation works. The higher flood levels result from the loss of floodplain storage and the consequent increase in downstream flows and flood levels relative to the base case.

4.3.2 Results

The downstream afflux due to the loss of floodplain storage only (and consequent increase in flows) was determined to be approximately 30 to 35 mm, refer to Figure 4.1 and Figure 4.2.

Figure 4.1 Effect of loss of Floodplain Storage only
- Total Energy Levels without mitigation works

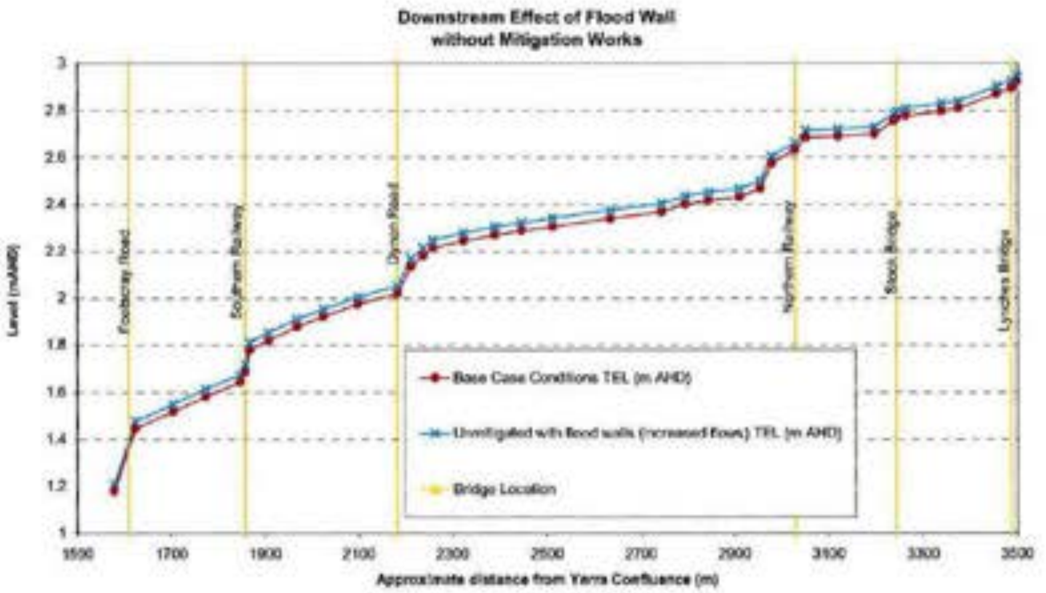
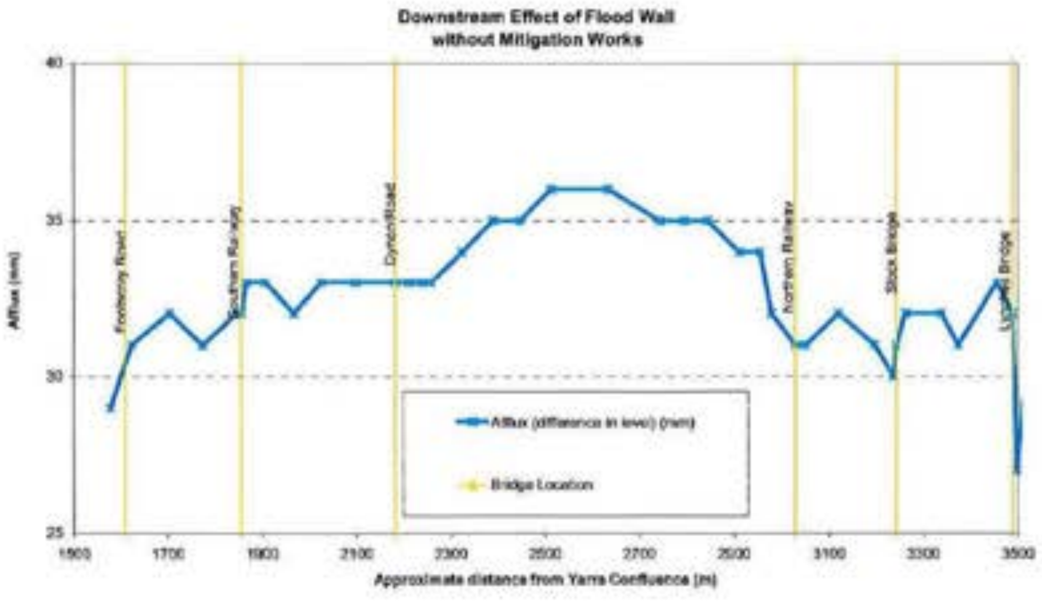


Figure 4.2 Effect of loss of Floodplain Storage only
- Total Energy Level Afflux without mitigation works



4.4 Upstream Impact (due to loss of conveyance)

4.4.1 Introduction

The previous analysis using HEC-RAS, (section 4.3),could have been used to provide an estimate of the upstream impact of the proposed floodwall due to both loss of conveyance and residual afflux from the increased downstream flows. However, this approach would be is subject to uncertainties. The uncertainties arise because the one dimensional HEC-RAS model is unable to suitably resolve the distribution of flow across the floodplain at Flemington. The flow distribution is critical to the assessment of upstream afflux since the larger the proportion of the total flow conveyed by the floodplain at Flemington, the larger the upstream impact and conversely.

The previously established two dimensional hydraulic model using FLS provides a detailed analysis of the flow distribution within the floodplain and is hence better able to quantify the local effects of the proposed floodwalls. As a result, the afflux due to the loss of conveyance was determined using FLS. The HEC-RAS model was adjusted as required to reproduce the same result and enable the effects to be assessed beyond the bounds of the local two dimensional model.

4.4.2 2D Hydraulic Modelling of Conveyance effects

Two Steady State (flow constant with time) FLS model runs were undertaken to quantify the upstream impact of the proposed floodwalls, ie. no floodwall and with floodwall. A tail water level of 2.60 m AHD was adopted as the downstream level at Lynchs Bridge and a constant inflow of 846.7 m^3/s was used for the upstream boundary condition. The existing and proposed geometry and roughness files were as adopted for the unsteady state flow attenuation analysis.

The actual water surface level at Lynchs Bridge in the proposed case may vary depending on the adopted mitigation works. For simplicity and consistency with HEC-RAS levels, a constant tail water level at Lynches Bridge was adopted. This approach enabled the loss of conveyance associated with the floodwall to be assessed in isolation.

The adoption of a constant flow rate equal to the flow at Fisher Parade as per the Melbourne Water Existing Conditions HEC-RAS model is appropriately conservative for the steady state 2D model. The use of smaller or attenuated flows would lead to a slightly smaller estimate of upstream afflux.

Results of the FLS runs are summarised in Table 4.2. Given identical flows and downstream boundary conditions, the afflux at Lynches Bridge is zero by definition. Hence the difference in flood levels at the upstream end of the works, immediately downstream of Fisher Parade, is an estimate of the afflux due to the loss of conveyance resulting from the proposed floodwall. Being a two dimensional model, values at these locations vary slightly across the river, so mean values have been tabulated.

Table 4.2 Flood Level downstream of Fisher Parade

Condition	Water Surface Level (m AHD)	Total Energy Line (m AHD)
Existing	2.982	3.226
Proposed	3.002	3.242
Afflux (m)	0.020	0.016

4.4.3 Adjustment of HEC-RAS model to match FLS result

To enable direct comparison with the FLS analysis of afflux due to loss of conveyance only, the base case model was rerun with geometry modified to include the floodwall (no mitigation works). These results were compared with the results for the base case to determine the afflux due to the loss of conveyance. Initially the HEC-RAS afflux estimate was lower than that derived using FLS as discussed in section 4.4.2. The HEC-RAS estimate was adjusted to match the FLS result, by roughening the main channel alongside the floodwall, as shown in Table 4.3. The roughness in the main channel between Lynchs Bridge and Fisher Parade was increased from 0.015 to 0.0155. This adjustment was made to all HEC-RAS models that included the proposed floodwall.

Given that the model has Manning "n" values that are considered smoother than usual, the reasons for which are discussed in the Melbourne Water report (ref.1), the alternate approach of increasing conveyance in the base case model was considered unrealistic.

Table 4.3 Afflux due to loss of conveyance only, results from adjusted HEC-RAS model

	WSL Afflux (mm)	TEL Afflux (mm)
Maximum (at upstream end of works immediately downstream of Fisher Parade)	20	15
Afflux just upstream of Lynchs Bridge	0	0
Difference (estimate of afflux due to loss of conveyance)	20	15
FLS estimate of afflux due to loss of conveyance (for comparison from Table 4.2)	20	16
Comparison of HEC-RAS and FLS results (mm)	0	-1

4.5 Overall Results Without Mitigation

The unmitigated effect of the floodwall on flood levels in the Maribyrnong River including both downstream and upstream effects was determined by comparing flood levels from the with floodwall and base condition steady state HEC-RAS models. The with floodwall HEC-RAS model has the following features:

- Reduced attenuation due to loss of floodplain storage ie higher downstream flows as per "proposed conditions" determined in Section 3
- A geometric representation of the proposed floodwall with increased roughness to match FLS modelling as per section 4.4.3.
- No mitigation works to compensate for the effect of the floodwall.

The flood levels (based on Total Energy Levels) for the base case and the unmitigated with floodwall conditions are plotted against river distance in Figure 4.3. The difference between these two levels, or afflux, is plotted in Figure 4.4 at an enlarged scale for clarity.

Without mitigation the maximum increase in flood level due to the floodwall is 45 mm at Flemington and this tapers off to 15 mm at the upstream end of the Maribyrnong Village.

Figure 4.3 Flood Levels (TEL) for Base Case and Unmitigated with Floodwall Conditions

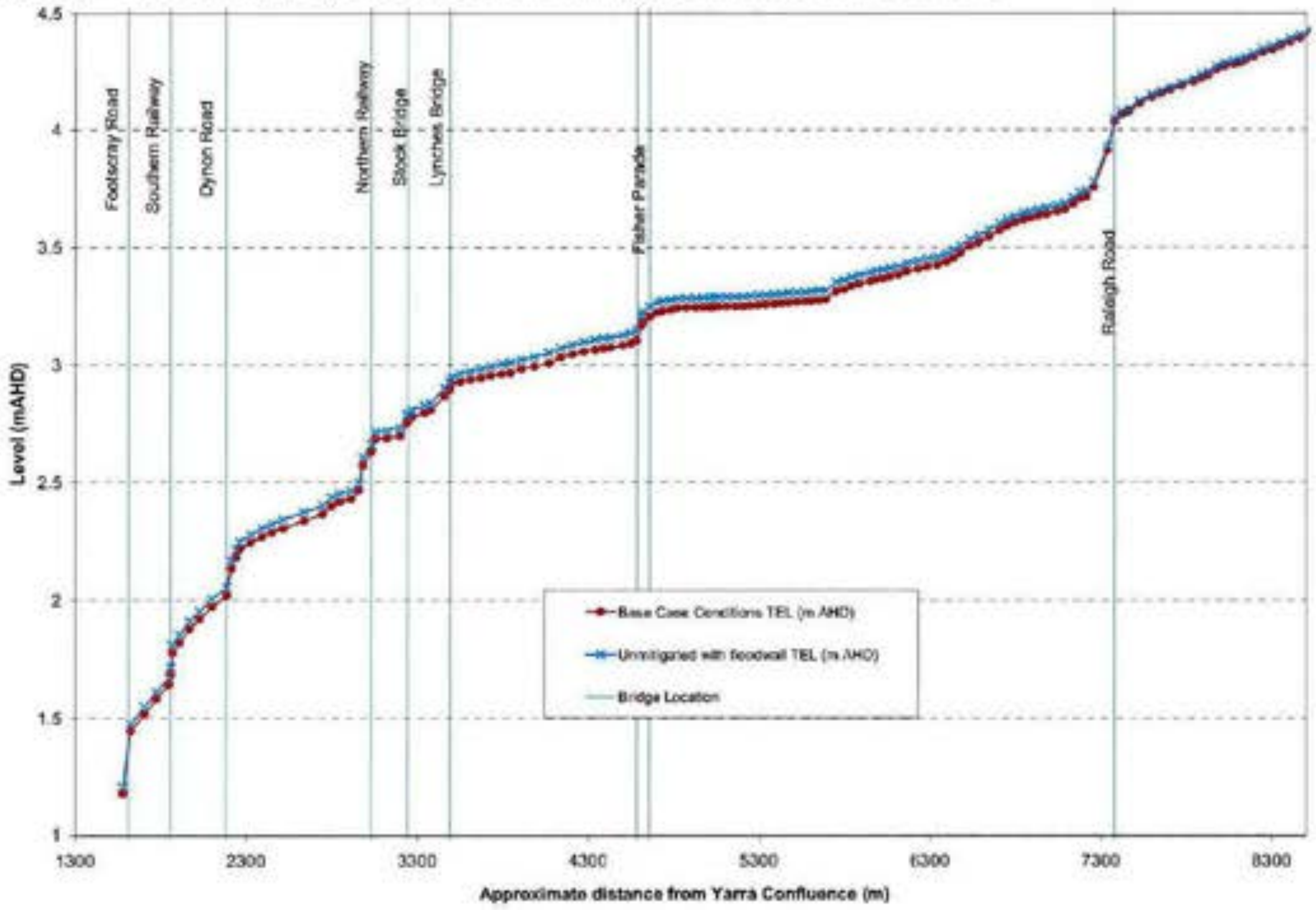
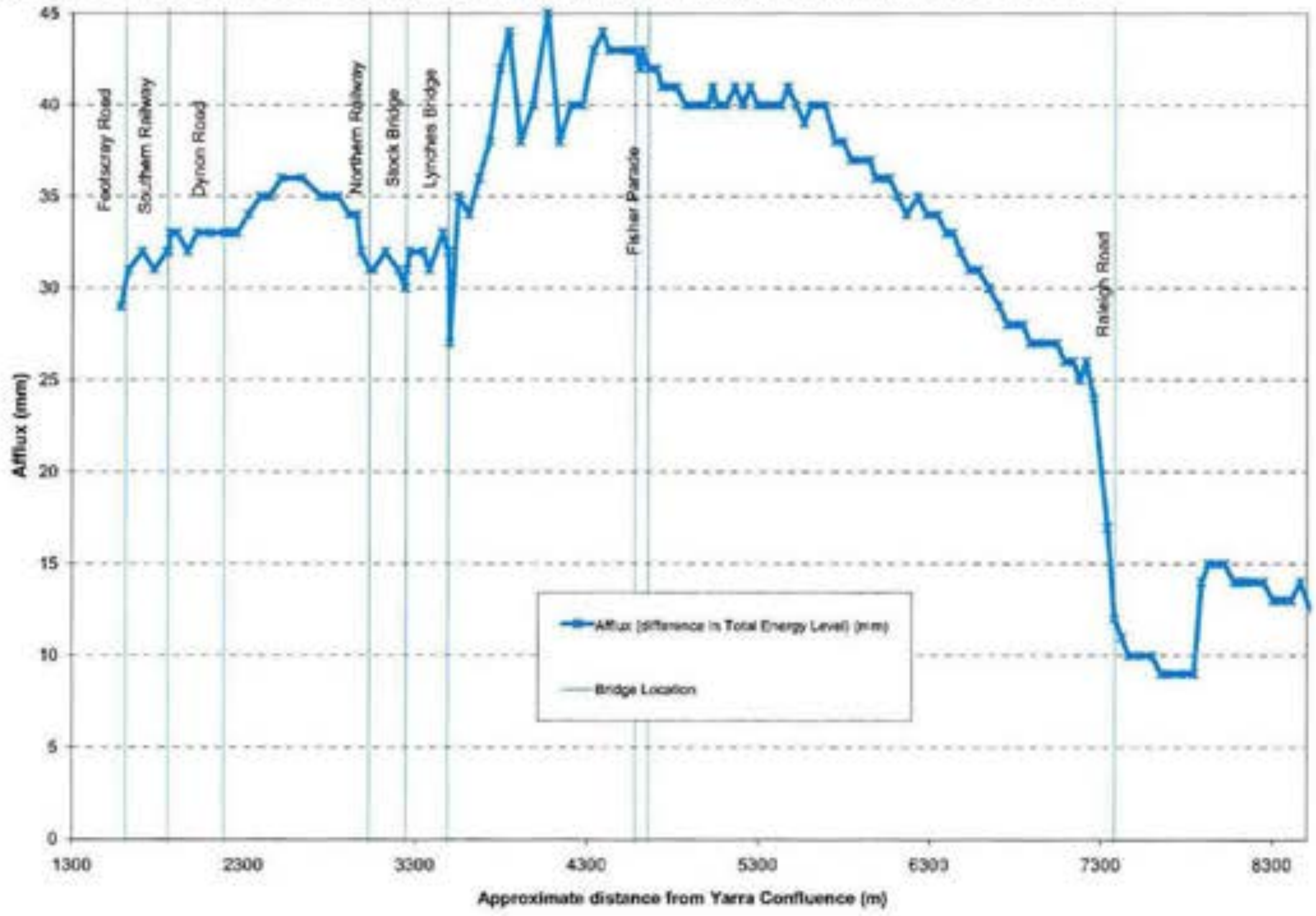


Figure 4.4 Increase in Flood Levels (TEL Afflux) Unmitigated with Floodwall relative to Base Case



5. Mitigation Works

5.1 Introduction

As discussed in the previous sections, the floodwall will reduce floodplain storage leading to an increase in downstream flows. Without appropriate mitigation works the larger flows will increase downstream flood levels and, when combined with the reduction in conveyance at the Flemington site, will increase flood levels through and upstream of the site. Without mitigation measures, these higher flood levels have the potential for increased flood damage.

Short of large scale retarding basin works similar in concept to the Arundel Retarding Bain identified by the MMBW in 1986 (ref 6) it is not practical to provide sufficient storage to compensate for the proposed removal of floodplain storage. As a result, mitigation works have been aimed at improving the capacity of the Maribyrnong River to cater for the increased flows. The mitigation works will provide some benefit for a range of events however their performance for floods greater or smaller than the 100 year ARI event has not been assessed.

5.2 Mitigation Works

There are opportunities to mitigate against the effects of the proposed floodwall. Following numerous site visits and analysis of flood profiles the following two feasible mitigation opportunities were identified:

- At Footscray Road Bridge left abutment :
  - Removal of the old abutment which will increase waterway area; and
  - Construction of flow training wall to reduce the expansion and contraction losses
- At Northern Railway Culvert :
  - Increase culvert capacity by removing downstream road embankment and hence increase flow through the culvert and accordingly reduce flow through the rail bridge;
  - This has the effect of lowering flood levels upstream of the Northern Railway embankment.

Interpretation and judgement is required to appropriately model the relatively small changes to bridge structures such as those proposed. We sought specialist advice from Dr Bob Keller of R J Keller and Associates with respect to design and modelling of these bridge improvement works. The conceptual design of the mitigation works and their modelling has been undertaken in conjunction with Dr Bob Keller to confirm that the modelled effects are a realistic assessment of the performance improvements, which are expected to be achieved by the mitigation works.

The mitigation works and the associated HEC-RAS parameter changes are as summarised in Table 5.1. Details of the works are documented in the following sections and in Appendix C.

Table 5.1 Modelling of Identified Mitigation Works

Description	MW Existing conditions model	Base Case	With Mitigation Works	Comment
Footscray Road Bridge				
Manning's 'n'		0.02	0.02	No change
Contraction Loss Coefficient		0.15	0.10	Construction of flow training walls on left bank with alignment based on Fargue Spiral
Expansion Loss Coefficient		0.35	0.15	
Pier Drag Coefficient		1.33	1.33	No change
Yarnell Pier Coefficient		0.9	0.9	
Other works				Removal of internal bluestone abutments on eastern bank
Energy loss across bridge (m)	Not modelled	0.266	0.211	Reduction of 55 mm
Northern Railway Crossing				
Manning's 'n'	0.055	0.03	0.03	Modelling refinement wider pier and smoother Manning's 'n' relative to MW existing conditions model.
Contraction Loss Coefficient	0.3	0.3	0.3	None
Expansion Loss Coefficient	0.5	0.5	0.5	
Pier Drag Coefficient	2.0	2.0	2.0	
Yarnell Pier Coefficient	1.25	1.25	1.25	
Other works				Remove road embankment on downstream side of railway culverts.
Energy loss across bridge (m)	0.22	0.217	0.200	Reduction of 17 mm

5.2.1 Proposed Hydraulic Improvements to Footscray Road

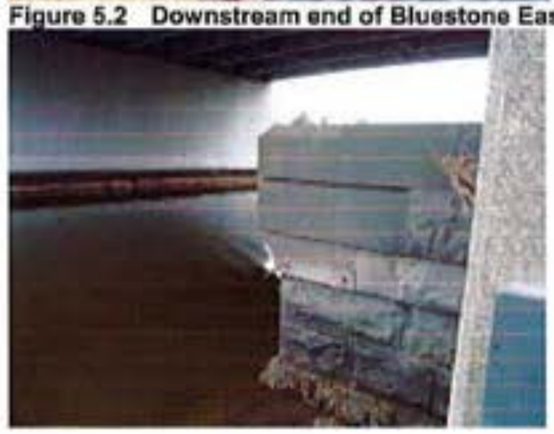
When the Footscray Road Bridge was redesigned in the 1950s, the existing bluestone abutments were partially retained. The original bluestone abutments are still evident projecting out into the river from within the new concrete abutments, refer Figure 5.1 and Figure 5.2. The proposed mitigation strategy is to remove the bluestone abutment from the left (eastern) bank and construct flow training walls upstream and downstream of this location, thus improving the flow through the bridge and thereby lowering the total energy loss across the bridge from 266 mm to 211 mm. No works are proposed for the right (Western) abutment since the effect of similar changes would be significantly less given the upstream jetty and downstream wharf structures.

The details of the flow training walls are important to achieving the desired improvements. A curvilinear vertical wall is proposed with a horizontal alignment smoothly transitioning between the bank and the abutment based on a Fargue spiral to minimise the contraction and expansion losses. The curves will be approximated by a series of straights such that the maximum deflection angle between adjacent straights is 6°. The height of the walls will be approximately 600 mm above the water surface level, which is approximately equal to the total energy level for the 100 year ARI flood. The expected order of cost for the Footscray Road east bank mitigation works is around $1.1M. Preliminary details and cost estimates are included in Appendix B.

Preliminary discussions with Vic Roads and our structural engineers indicate that it will be feasible to undertake works to safely remove the projecting bluestone and maintain the structural integrity of the abutment. Vic Roads has informed GHD that the Footscray Road Bridge is not listed on either the heritage Victoria or National Trust Registers. Archaeological issues are yet to investigated.

Figure 5.1 Footscray Road Bridge (photograph from upstream on the eastern bank)

Figure 5.2 Downstream end of Bluestone Eastern Abutment to be removed



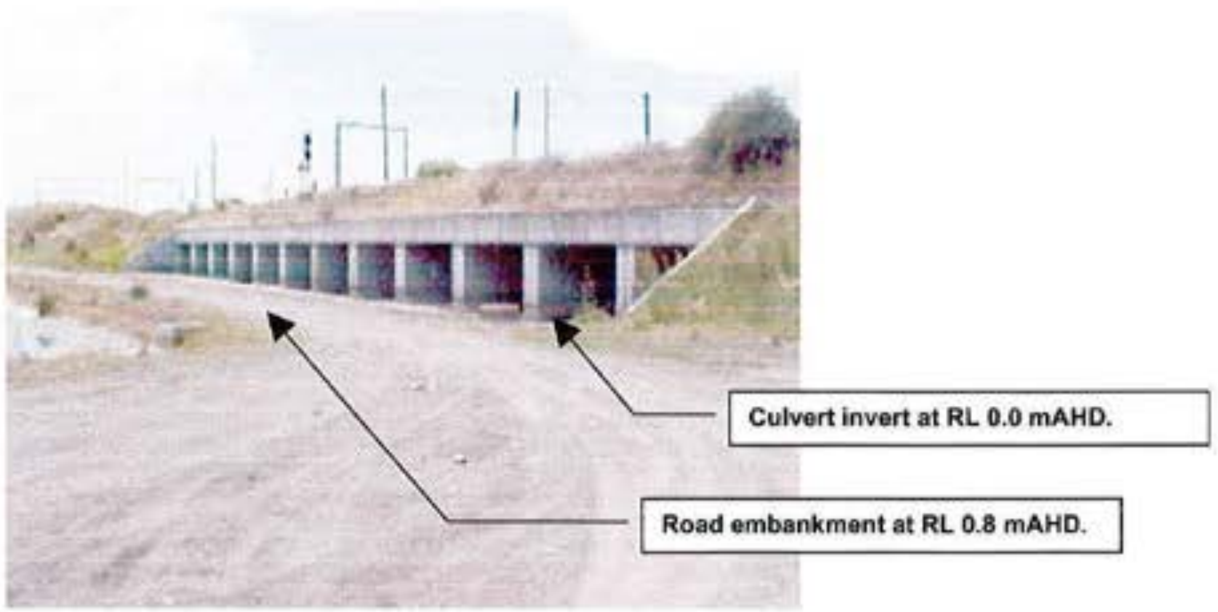
5.2.2 Possible Hydraulic Improvements to the Northern Railway Crossing

The railway tracks between South Kensington and Footscray Stations cross the Maribyrnong River and its floodplain on a substantial embankment. The following structures convey floodwater through this embankment:

1. A 60 m long single span bridge over the main channel dating back to the 1850s. This bridge is listed on the Victorian Heritage Register as the "Rail Bridge over the Maribyrnong between South Kensington, Footscray Stations Footscray", and as such is legally protected under the Heritage Act 1995. The registration relates to the extent of all the bridge structure including the abutments and wing walls as defined by the Heritage Council.
2. A second newer bridge located parallel and immediately upstream comprises two 40m spans with a central rectangular pier. The bridges are located on a reasonably sharp bend. This combined with their differing geometries produces significant hydraulic losses across the combined structures.
3. The "Railway Culverts" constructed as part of Lynchs Bridge Project in 1991 significantly reduced upstream flood levels. In a 100 year ARI design flood the 12 rectangular floodplain culverts each 5 m wide, with soffits above the flood level convey over 30% of the total flow.

The identified works are to lower a road embankment located immediately downstream of the railway culverts thus increasing the capacity of the railway culverts. Removing this obstruction increases the capacity of the culverts and the waterway immediately downstream, reducing the flow through the railway bridges and lowering upstream flood levels by 44 mm. The net bridge loss reported by HEC-RAS reduces from 217 mm to 200 mm, the other 27 mm reduction occurs as a result of the improved conveyance immediately downstream of the culverts (which is not reflected in the "bridge" head loss in HEC-RAS).

Figure 5.3 The road embankment downstream of the Northern Railway Culverts



Lowering the roadway is not expected to have any impact on the heritage listed bridge or any other railway structures. The roadway was constructed during the 1990s and is located on land owned by the Temple of Heavenly Queen Association, who at the time held a planning permit for the construction of a temple, with associated ponds, downstream of the railway embankment. It is understood that the planning permit has subsequently lapsed. The road embankment is understood to have two functions:

- As a means of access to the bridge abutment, culverts and power transmission tower. It is expected that constructing a downstream road to connect to the existing bike path could provide this function.
- As a separating weir between the upstream and downstream lake systems. At their current low levels the lakes are separated by the railway embankment although, there is currently no apparent need for the lakes to be separated. The Temple of the Heavenly Queen may have some future requirement for the lakes to be separated.

Subject to approvals, this option has hydraulic merit and is expected to cost in the order of $0.9M. Preliminary details and cost estimates have been produced and are included in Appendix C.

Given the uncertainties regarding approval to remove the road embankment it was considered appropriate to analyse the mitigation works with and without the works at the northern railway.

5.3 Net Effect of Mitigation Works

As the differences in flood levels due to the Flemington Racecourse Flood Protection works are relatively small it is difficult to see the difference on a plot of flood levels. Plotting the difference in flood levels (afflux) provides a much clearer indication of the changes. Afflux plots showing the effect of the Flemington Racecourse floodwall with and without the mitigation works are presented as Figure 5.4. In accordance with normal practise positive afflux represents an increase in flood level and negative afflux represents a reduction. The following sections briefly describe the two Proposed Condition Afflux curves.

5.3.1 Floodwall with Footscray Road Mitigation Works

The proposed works, which include the floodwall at Flemington Racecourse and the mitigation works at Footscray Road, lower flood levels between Footscray Road and the Northern Railway. The following points summarise the key changes in flood level (afflux) due to the proposed works:

- Immediately upstream of Footscray Road the flood levels are reduced by around 35 mm.
- The benefit of the mitigation works reduces with distance upstream.
- By the Northern railway bridge the flood levels are back to their original levels.
- Between the Northern Railway and Lynchs Bridge afflux increases from 0 to around 10 mm as a result of the reduced floodplain storage and consequently larger flows.
- The floodwall reduces conveyance resulting in increased flood levels (based on TEL). The maximum afflux occurs at the upstream end of the floodwall immediately downstream of Fisher Parade where flood levels (TEL) are increased by 26 mm. The **water surface level** alongside the floodwall is locally reduced by more than 50 mm due to an increased velocity head (the change in water surface level is not shown in Figure 5.4 which depicts changes in total energy level).

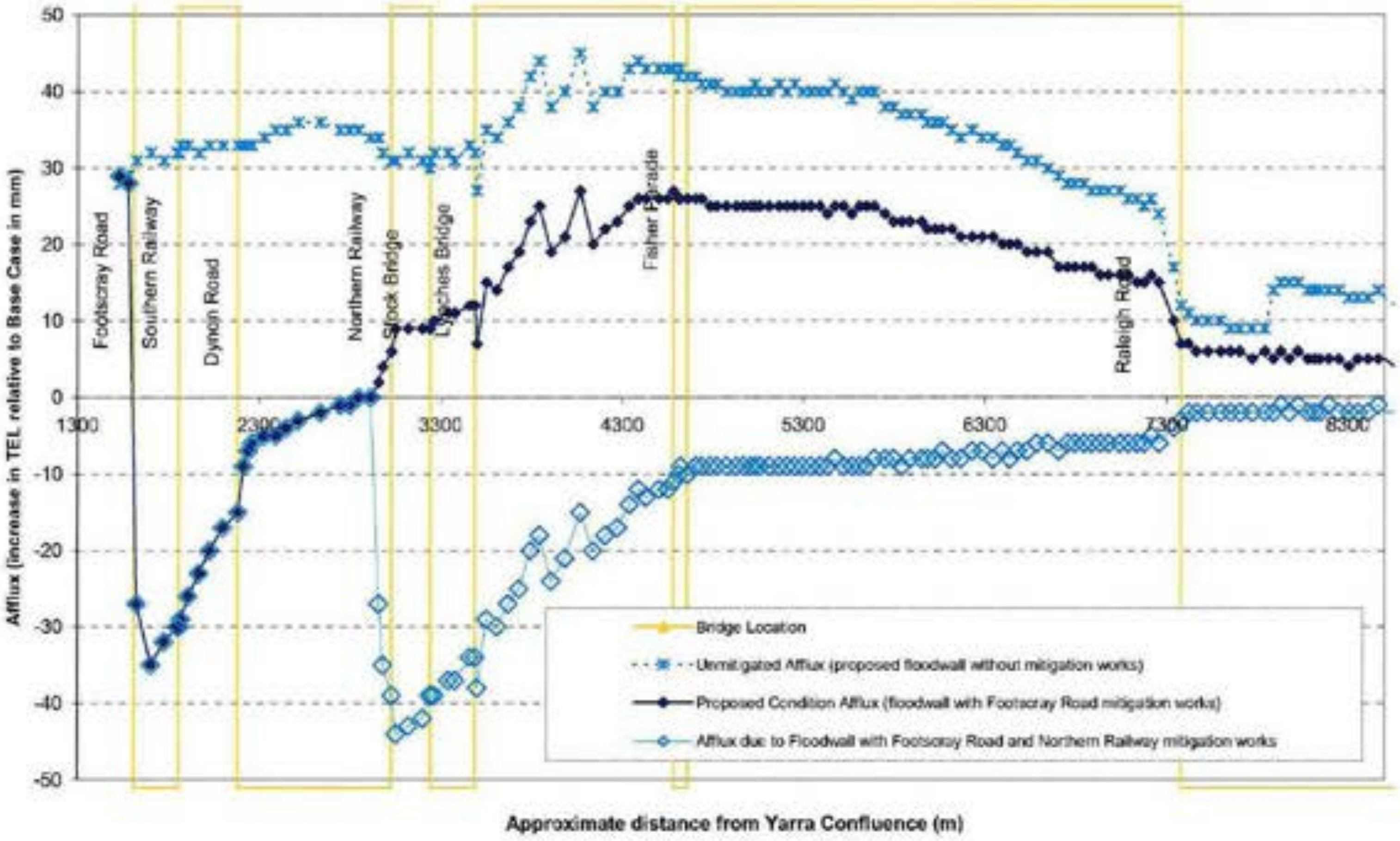
- From Fisher Parade the afflux diminishes with distance upstream. By Raleigh Road, afflux is less than 10 mm.
- The increase in flood level (afflux), due to the proposal, that occur upstream of the Northern Railway Bridge, are small in comparison with the reduction in flood level, which was achieved in this region in 1991 with the construction of the railway culverts.

5.3.2 Floodwall with Footscray Road and Northern Railway Mitigation Works

A second potential site for mitigation works was identified on private land immediately downstream of the Northern Railway Culverts as described in Section 5.2.2. Assuming the relevant approvals can be obtained and the works at the railway culvert are implemented in addition to the current proposal as per Section 5.3.1, a net lowering of flood levels could be achieved. Under this scenario flood levels would be lowered from Footscray Road through to Maribyrnong Village. The following points summarise the key changes in flood level due to the proposed works undertaken in conjunction with the mitigation works at the Northern Railway:

- Immediately upstream of Footscray Road the flood levels are reduced by around 35 mm.
- The benefit of the mitigation works reduces with distance upstream.
- By the Northern railway bridge the flood levels are back to their original levels (afflux is 0).
- Up to the Northern Railway bridge, conditions are as per the proposal described in Section 5.3.1.
- Removal of the road embankment downstream of the Northern Railway Culverts would lower flood levels by more than 40 mm.
- Reduced floodplain storage and larger flows reduce negative afflux from –45 to –30 mm between the Northern Railway and the proposed Flemington Floodwall.
- The floodwall reduces conveyance further reducing negative afflux (based on TEL) from –30 to –10 mm bringing the flood level back closer to the existing conditions levels. The **water surface level** alongside the floodwall is locally reduced by more than 100 mm due to an increased velocity head (the change in water surface level is not shown in Figure 5.4 which depicts changes in total energy level).
- Lower flood levels continue upstream of Fisher Parade tapering gradually from a 10 mm benefit at Fisher Parade to a couple of millimetres at Maribyrnong Village.

Figure 5.4 Effect of Proposed Flood Protection Works



6. Conclusions

It is concluded that :

- The change in attenuation (increase in 100 year ARI flood flow) due to the floodwall at Flemington is 8.2 m^3/s;
- Without mitigation the increase in flood level associated with the increased flood flow peaks at 36 mm downstream of the Flemington floodwall;
- The loss of flood conveyance through Flemington due to the floodwall would lead to an increase in flood level at Fisher Parade of approximately 15 mm (20 mm in WSL);
- The total effect of the floodwall (increased flood flow and loss of conveyance), assuming no mitigation, would be higher flood levels (afflux) from Footscray Road (30 to 35 mm) to Maribyrnong Village (10-15 mm) and a maximum TEL afflux value of 45 mm at Fisher Parade;
- Mitigation works have been identified at two locations, i.e. at Footscray Road Bridge and the Northern Railway Culverts;
- The effect of implementing the mitigation works at Footscray Road Bridge east abutment would be to achieve zero or negative afflux (lower flood levels) from Footscray Road to the Northern Railway bridge. Upstream of the northern railway afflux peaks at 27 mm just downstream of Fisher Parade and reducing to less than 10 mm by Raleigh Road at Maribyrnong Village;
- If both the Footscray Road Bridge and Northern Rail Bridge mitigation works are implemented, zero or negative afflux would be achieved along the entire reach of the Maribyrnong River under consideration;
- Indications are favourable that the mitigation works at Footscray Road Bridge would be acceptable to VicRoads and other authorities;
- The mitigation works at the Northern Railway Culverts are located on private property and negotiations with the owners need to be managed carefully to avoid the potential for protracted negotiations;
- The estimated order of cost for undertaking the mitigation works at Footscray Road is \$1.1M. This estimate excludes any compensation that may be required and will be refined during the detailed design stage.
- The estimated cost of undertaking the mitigation works at the Northern Rail Bridge is \$0.9M. This estimate excludes any compensation that may be required and will be reviewed as approval conditions are better understood and detailed design is undertaken.

7. Recommendations

This report has been prepared to inform and facilitate further discussions between the VRC, its consultants, Melbourne Water and other stakeholders.

Following a review by the VRC, it is recommended that this report be presented to Melbourne Water for their comment. It is expected that presentation of this report will:

- Enable Melbourne Water to assess the VRC's proposal with respect to the Maribyrnong River;
- Facilitate further comment with respect to requirements for mitigation works; and
- Assist with obtaining approval in principle for the proposed floodwall and associated mitigation works.

Once Melbourne Water conveys its approval of the concepts and its requirements, the concepts should be progressed through a detailed design process prior to construction. The following issues will need to addressed prior to and or during detailed design phase :

- Establish the land ownership issues associated with the identified mitigation works at the Northern Railway crossing
- Detailed discussions with relevant authorities and asset owners and managers should be undertaken with a view to obtaining required approvals for the works;
- Additional survey to enable accurate computation of quantities and set out;
- Detailed Design of proposed mitigation works;
- Refine cost estimates; and
- Establish an agreed program for all of the above;

8. References

1. Melbourne Water Corporation: "Maribyrnong River Hydraulic Model, Final Report, February 2003", by GHD
2. Manual Delft-FLS 2.55 July 2001 WL | Delft Hydraulics
3. E.M. Laurenson and R.G. Mein Monash University Department of Civil Engineering, "RORB – Version 4 Runoff Routing Program, User Manual" May 1988.
4. US Army Corp of Engineers, Hydrologic Engineering Centre: "HEC-RAS, River Analysis System. Hydraulic Reference Manual Version 3.1 November 2002.
5. Les Hamill, "Bridge Hydraulics" University of Plymouth 1999
6. Melbourne Metropolitan Board of Works: "Maribyrnong River Flood Mitigation Study, March 1986, MMBW-D-0040".

Appendix A

2D Hydraulic Modelling

A. 2D Hydraulic Modelling

A.1 Overview

Unlike one dimensional hydraulic models which use a cross section based flow representation which assumes flow is travelling in one direction, two dimensional hydraulic models work on a grid structure enabling far more accurate representation of geometry and more realistic flow behaviour. Their structure allows the modelling of real life flow characteristics such as lateral flows, eddying etc. They provide far greater resolution of flood flow behaviour and are less subject to modelling judgement and interpretation. The downside of two dimensional models is their intensive data, computational and calibration requirements.

A two dimensional model extending from upstream of Fisher Parade to downstream of Lynchs Bridge was developed to model the effects of the proposed flood wall. The model uses a rotated rectilinear grid of 103,875 cells (277 rows by 375 columns), each cell measuring 5 m by 5 m square. The model was created and run using Delft FLS version 2.47.

Delft FLS (Delft Flooding System) is a 2D Hydrodynamic simulation package developed at Delft Hydraulics in the Netherlands. It is suitable for the simulation of dynamic behaviour over initially dry land and is based on the full 2D shallow water equations. The model requires good topographic data, roughness parameters and upstream and downstream boundary conditions. Direct outputs from the model include water surface levels, depths, velocities (magnitude and direction), and flows at specified time intervals and locations.

A.1.1 Terrain Data

Topographic data for the Flemington model is consistent with that adopted for the Melbourne Water existing conditions HEC-RAS model (ref 1), and includes a combination of detailed photogrammetry over the Eastern floodplain, river bathymetry from depth soundings and lower reliability information from the MW 1 m contours primarily for the western flood plain. The effect of this lower quality data from the 1m contours is expected to be insignificant given that the proposed works do not alter the western flood plain.

The "proposed" model, incorporating the effect of the proposed floodwall, was established by raising the terrain levels to above the 100 year ARI flood level for the area to be protected by the floodwall.

A.1.2 Calibration of Two Dimensional Hydraulic Model

The existing conditions 2D model was calibrated to the January 2003, 100 year ARI profile from the Melbourne Water existing conditions HEC-RAS model using a constant flow rate of 845 m^3/s. This is the average of the 100 year ARI flow from Fisher Parade to Lynchs Bridge as determined for the Melbourne Water Report (ref Table 4.2 of Ref 1). A downstream level of 2.60 mAHD was adopted. This level is the downstream water surface level published in the Appendix of the Melbourne Water Report (ref 1). The adopted Manning's n values are displayed in Figure A.3

It is noted that these values are smoother than normally expected however this is consistent with the Melbourne Water existing conditions model. Just as important is the relative roughness of the main channel and flood plain, which is considered to have an appropriate balance.

A.2 Unsteady State Modelling

The FLS model was run with time varying boundary conditions for both existing and proposed conditions with a view to determining attenuation estimates between Fisher Parade and Lynchs Bridge. These unsteady state runs are time consuming (approx 12 hours). FLS automatically adjusts its time step to minimise run time within the maximum time step which was set to 10 seconds. The modelling of the 100 year hydrograph was started at $45m^3/s$ (t=0) and peaked at around t=26hrs. Computations were continued until sufficient results were obtained up to a maximum of 62 simulation hours.

A.2.1 Boundary Conditions

The 100 year ARI hydrograph at Fisher Parade was used as the upstream boundary condition for all unsteady state runs. This hydrograph was extracted from the Existing Conditions unsteady state HEC-RAS model provided by Melbourne Water.

The downstream boundary condition for existing condition unsteady state runs was a rating table (flow versus elevation) for Lynchs Bridge. This relationship was obtained using the existing conditions steady state HEC-RAS model provided by Melbourne Water. The HEC-RAS model was run for a range of flows using the downstream rating table from Melbourne Waters' unsteady state HEC-RAS model (ref 1). Flows and levels at Lynchs Bridge from each of these runs were tabulated and used as the downstream boundary condition for FLS.

A.3 Model Reliability and Limitations

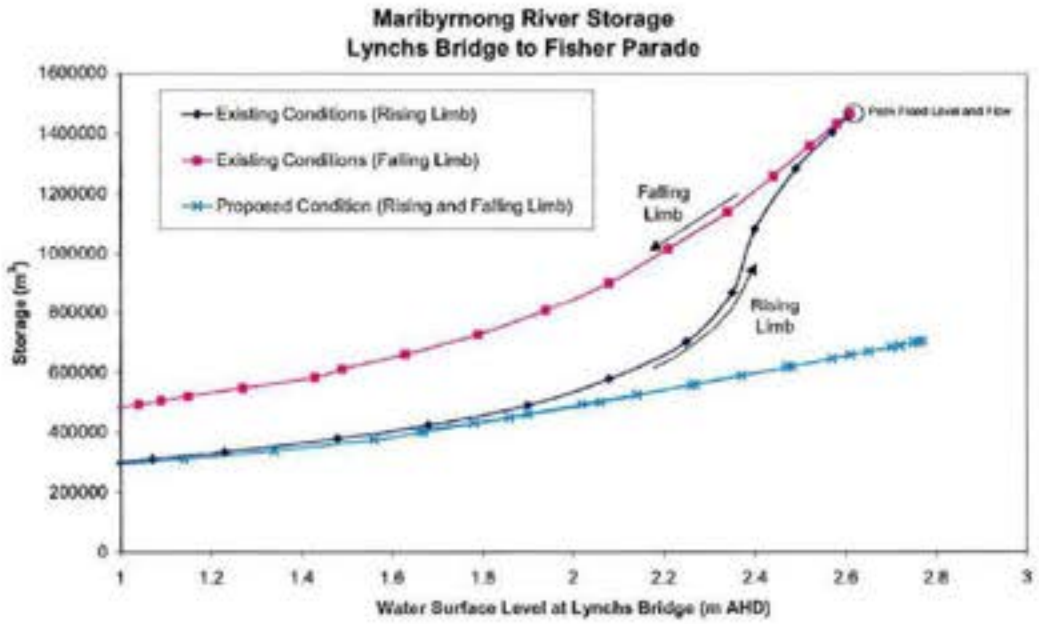
The model is generally considered reliable for modelling of flood levels and velocities between Lynchs Bridge and Fisher Parade. In unsteady state runs the model is capable of determining attenuation however as with all modelling some interpretation and understanding of the underlying simplifications is required. With respect to attenuation estimates from the unsteady state FLS model two limitations (or effects) have been identified and are discussed in the following sections.

A.3.1 The 'Levee' Effect

The floodplain storage, for the 100 year ARI flood, between Lynchs Bridge and Fisher Parade (1,440,000 m^3) is small compared to the volume of the 100 year ARI hydrograph (89,700,000 m^3) ie 1.6%. In such situations, attenuation of the peak flow is dominated by the storage available near the peak of the flood. Storage volume filled well before the peak flow does little to reduce the flood peak. If a region is levied off so that it overtops near the peak of a particular flood event, the storage behind this levee is effectively reserved to store flood water from the peak of the hydrograph, thus maximizing the attenuation benefit provided by this region for that particular event. This 'levee' effect can occur as a result of natural or man made banks in a flood plain. Leakage into the storage area reduces storage available when the bank is overtopped. Ignoring the effect of leakage will lead to an overestimate of attenuation. At Flemington, numerous drains, culverts and ditches enable the storage to fill progressively. These features are too small to be modelled in the FLS model with its 5m grid, as a result the model tends to overestimate the attenuation.

This levee effect is significant for the analysis of the 100 year ARI flood and is best understood by looking at the storage relationship derived from the FLS unsteady state results refer to Figure A.1. The base case results clearly show a difference in storage available at a given level between the rising and falling limbs, this difference is due to the 'levee' effect.

Figure A.1 The Stage Storage relationship extracted from FLS model results



A.3.2 Boundary Condition Effects

The FLS model extends a short distance upstream of Fisher Parade and downstream of Lynchs Bridge to enable establishment of a realistic flow distribution, refer Figure A.2. The boundary conditions are applied at these upstream and downstream limits of the model. This means that the upstream input hydrograph is slightly attenuated by the time it reaches Fisher Parade and that the Lynchs Bridge levels are slightly above the downstream boundary levels. With good modelling practice these differences are minimised and will have little effect on results. The following paragraphs describe the upstream and downstream boundary condition effects.

Upstream Boundary Condition Effect:

Some attenuation occurs between the upstream model boundary where flow enters the model and Fisher Parade (846.7 to 845.4m3/s). This section of the model is primarily designed to establish the correct distribution of flow upstream of Fisher Parade. The levels and attenuation modelled within this reach are based on an incomplete geometric representation of the actual topography with an establishing flow distribution; hence attenuation upstream of Fisher Parade should not be relied upon. While estimates of the attenuation through the site were made by comparing peak flows at the two bridges, the comparison is slightly affected by the hydrograph at Fisher Parade being slightly attenuated rather than being identical to the hydrograph in the HEC-RAS model supplied by Melbourne Water (ref 1).

Downstream Boundary Conditions Effect

Downstream of Lynchs Bridge the model is not expected to produce accurate levels and attenuation. The Downstream rating curve obtained from HEC-RAS results inside Lynchs bridge was applied downstream of Lynchs Bridge and an overly smooth connecting channel used to connect the boundary to Lynchs Bridge. The smooth connecting channel was kept at the same dimensions as the bridge cross section to avoid expansion losses and the smoothness reduces friction losses to a small amount. This small amount is nevertheless a source of error, leading to slightly higher levels through the site.

The effect of the boundary conditions on the FLS analysis of attenuation through the site is significantly smaller than the levee effect. Nevertheless the effect of these limitations was removed by using RORB with a stage storage relationship derived from FLS as described in the main body of the report.

A.4 FLS Model Figures

Figure A.2 Terrain Model without Floodwall

Figure A.3 Adopted Manning's 'n' values for FLS Model

Figure A.4 Steady State 100 year ARI Water Surface Level Contours Without Floodwall

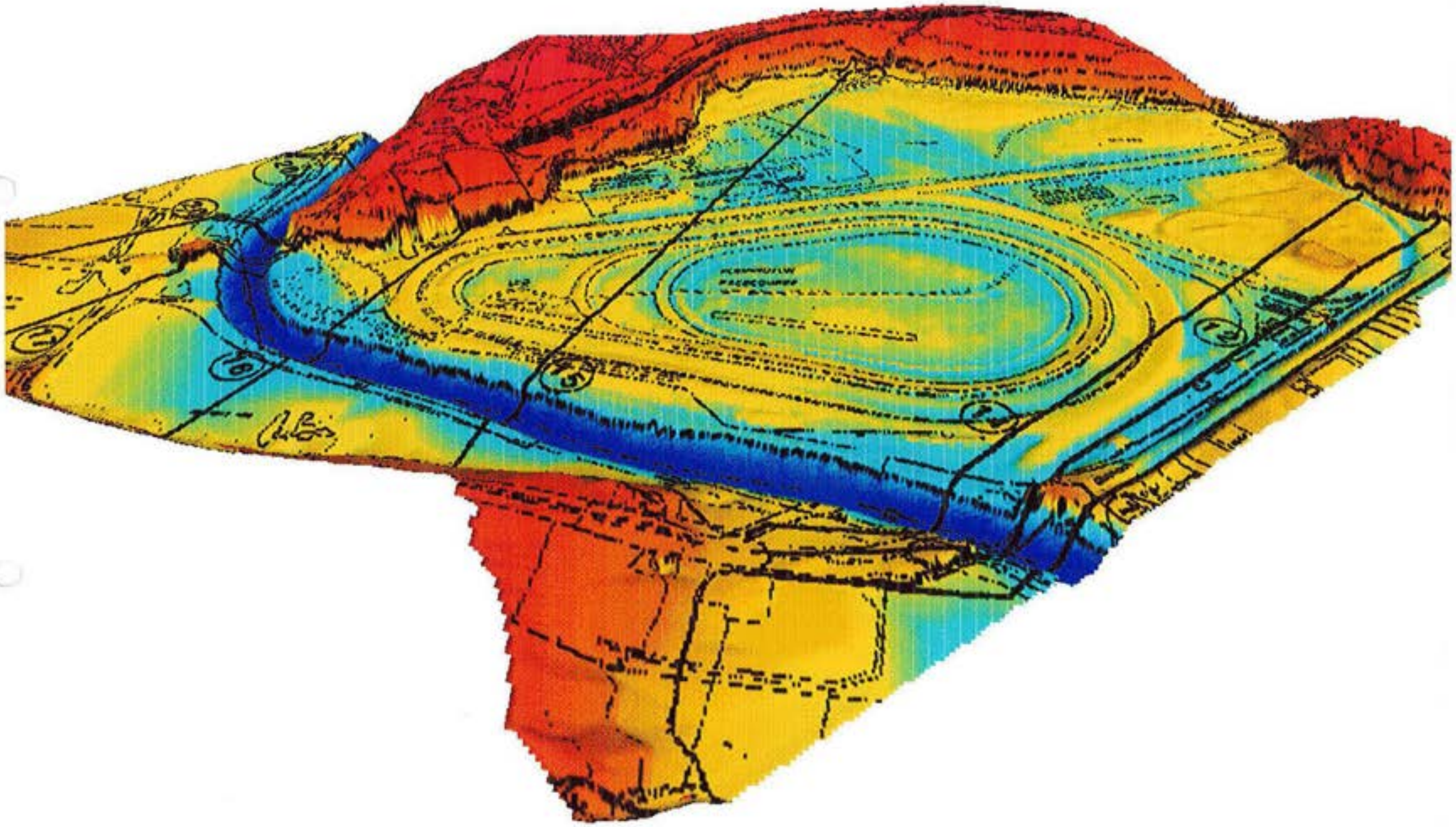
Figure A.5 Steady State 100 year ARI Water Surface Level Contours With Floodwall

Figure A.6 Steady State 100 year ARI Velocity Vectors Without Floodwall

Figure A.7 Steady State 100 year ARI Velocity Vectors With Floodwall

Figure A.8 Steady State 100 year ARI Afflux (WSL with – WSL without Floodwall)

Figure A.9 Non-Steady State 100 year ARI Innundation Extent Progression Without Floodwall



VICTORIA RACING CLUB

FLEMINGTON RACE COURSE FLOOD PROTECTION

Surface Elevation (m AHD)

	-5.0
	-0.0
	0.5
	1.0
	1.5
	2.0
	3.0
	4.0
	5.0
	10.0
	15.0
	24.0

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

NOTE: EXAGGERATED VERTICAL SCALE

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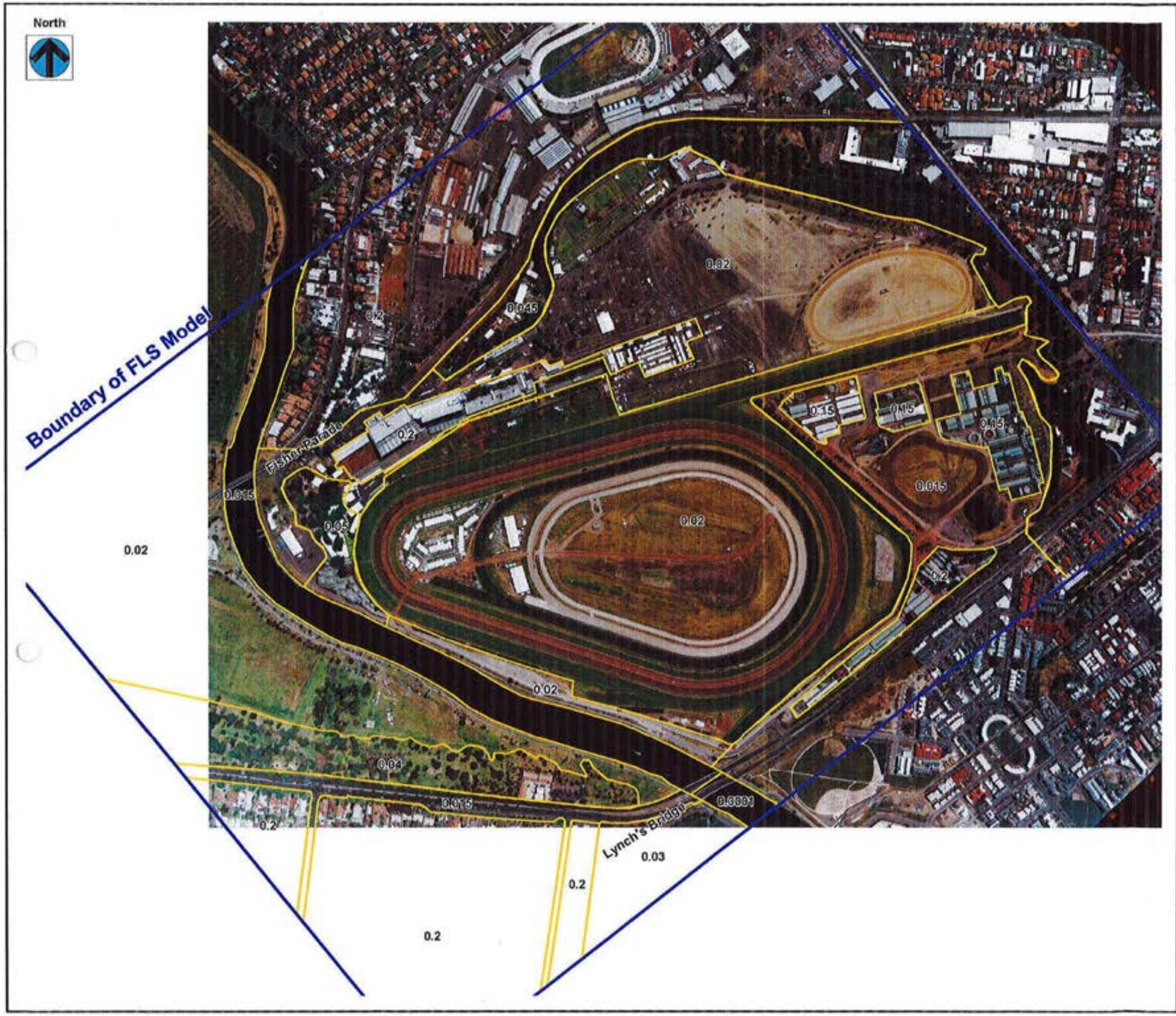
FIGURE A.2
Terrain Model Without Floodwall



VICTORIA RACING CLUB

FLEMINGTON RACE COURSE
FLOOD PROTECTION

SCALE 1 : 7,000 at A3

70 0 70 140 210 280 350 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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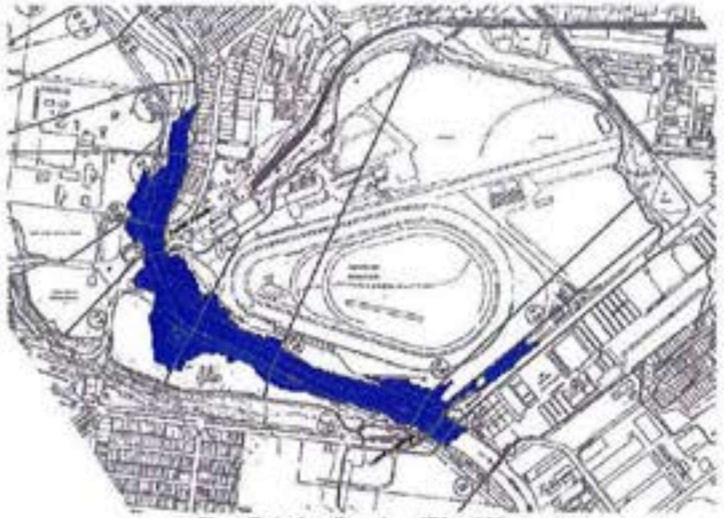
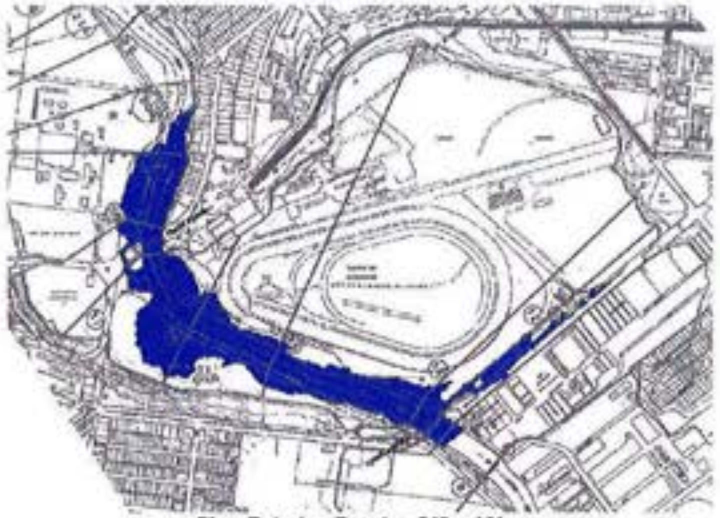
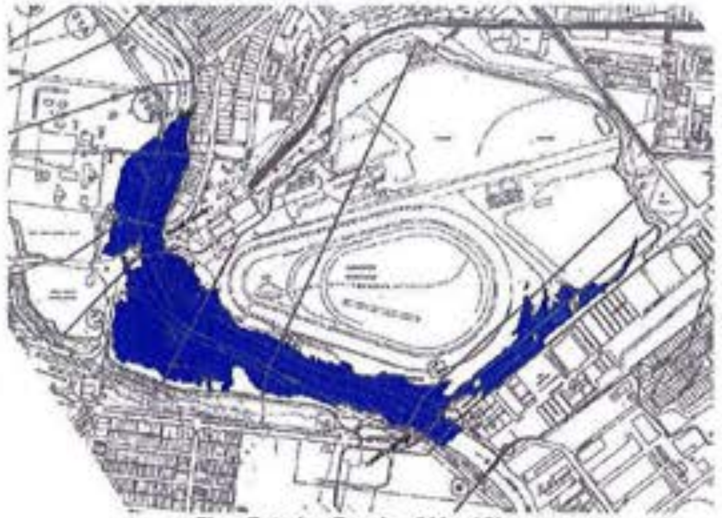
FIGURE A.3
Adopted Mannings 'n' Values for FLS Model



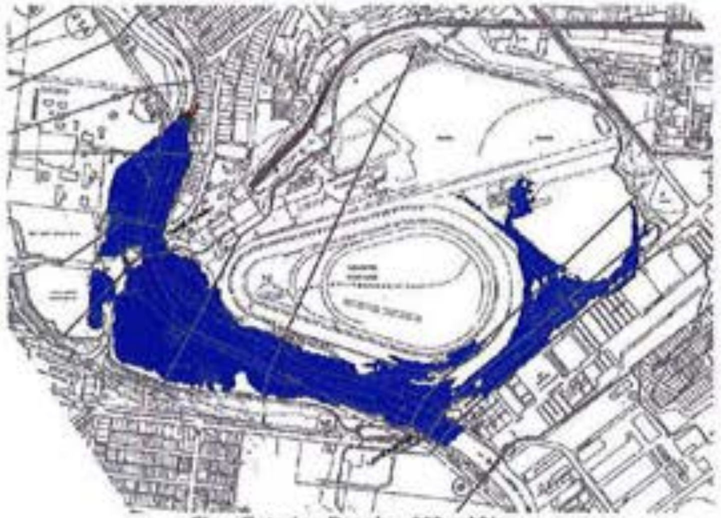
Flow Entering Reach = 472 m^3/s
Relative Time Step = 16 hrs



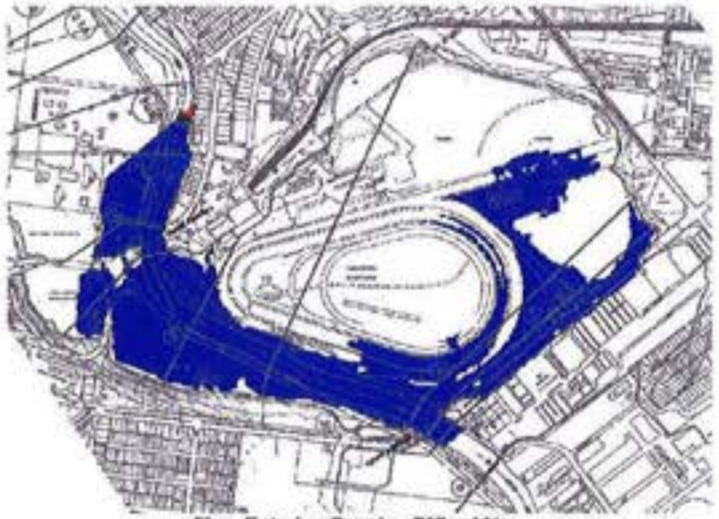
Flow Entering Reach = 546 m^3/s
Relative Time Step = 17 hrs



Flow Entering Reach = 611 m^3/s
Relative Time Step = 18 hrs

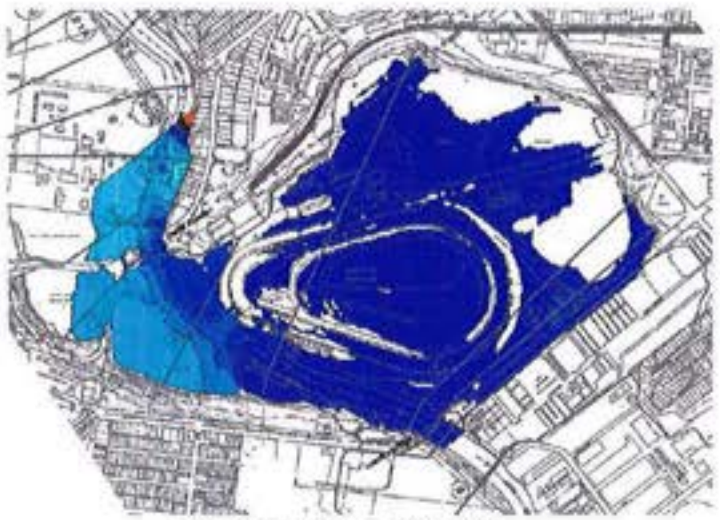


Flow Entering Reach = 669 m^3/s
Relative Time Step = 19 hrs



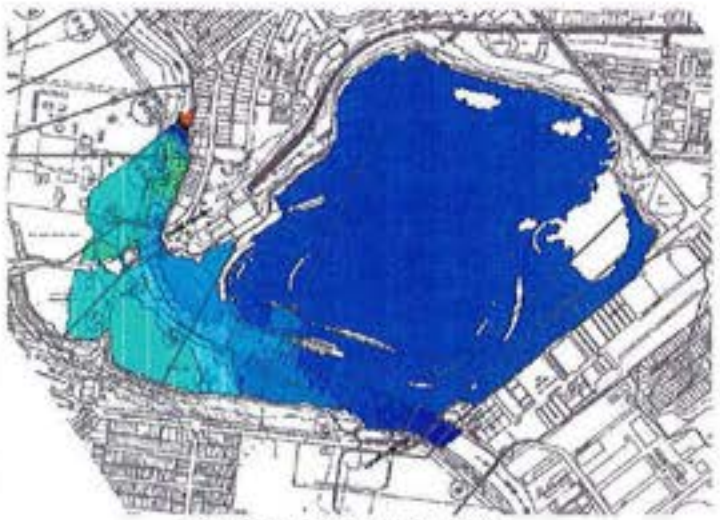
Flow Entering Reach = 727 m^3/s
Relative Time Step = 20 hrs

Flow Entering Reach = 782 m^3/s
Relative Time Step = 21 hrs



Flow Entering Reach = 817 m^3/s
Relative Time Step = 22 hrs

Flow Entering Reach = 839 m^3/s
Relative Time Step = 23 hrs



Flow Entering Reach = 847 m^3/s
Relative Time Step = 24 hrs

VICTORIA RACING CLUB

FLEMINGTON RACE COURSE FLOOD PROTECTION

Water Surface Level Contours at 0.05m Intervals (m AHD)

- < 2.55
- 2.55 to 2.60
- 2.60 to 2.65
- 2.65 to 2.70
- 2.70 to 2.75
- 2.75 to 2.80
- 2.80 to 2.85
- 2.85 to 2.90
- 2.90 to 2.95
- 2.95 to 3.00
- 3.00 to 3.05
- 3.05 to 3.10
- 3.10 to 3.15
- 3.15 to 3.20
- 3.20 to 3.25
- 3.25 to 3.30
- 3.30 to 3.35
- 3.35 to 3.40
- > 3.40

North

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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FIGURE A.9
Non-Steady State 100 Year ARI Inundation Extent Progression Without Floodwall

Appendix B

Base Case Establishment

B. Base Case Establishment

B.1 Introduction

The base case HEC-RAS model incorporates the following changes to the existing conditions model provided by Melbourne Water:

- extension of model downstream to include Footscray Road
- review and update of select bridge modelling parameters (Northern Railway).
- Revised flows as detailed in the previous section

Details of these changes are outlined in the following sections.

B.2 Extension of model to include Footscray Road

The existing conditions model provided by Melbourne Water extends downstream to the upstream side of Footscray Road. The model was extended a further 95 m downstream to include a representation of Footscray Road based on design drawings and the cross section immediately upstream of Footscray Road with minor adjustments to better reflect conditions downstream. These adjustments comprised a 5m widening of the cross sections downstream of Footscray Road to reflect the widening on the left (east) bank and the addition of details including the Ports and Harbours wharf and the moored craft on the right (west) bank. The model parameters were chosen using engineering judgement to reflect our understanding of the reach and, with respect to the main channel roughness parameters, to be consistent with the existing conditions model.

The downstream boundary condition was adjusted so that the base case levels upstream of Footscray Road match the published Melbourne Water existing levels (ref 1) using both existing conditions flows and the revised (lower) flows. With the adopted downstream boundary conditions, levels are generally within 10 mm of the Melbourne Water existing conditions levels, refer Table B.2. A normal depth based on an energy slope of 0.00096 was used to achieve this fit and was adopted for all subsequent runs.

B.3 Bridge (and Culvert) Modelling Parameters

It was noted that the Melbourne Water existing conditions model was calibrated to the published MMBW 1986 flood profile. This process focussed on achieving realistic flood levels using reasonable bridge modelling parameters. It did not however seek to investigate each bridge in detail and while the overall bridge losses may be appropriate they were not necessarily achieved using a representative set of parameters.

A review of Manning's 'n' roughness values, contraction and expansion coefficients, and pier loss coefficients in the existing conditions model identified a high Manning's 'n' value within the Northern Railway Bridge of 0.055. Following a reassessment of the bridge it was decided to reduce the internal bridge roughness to a more realistic Manning's 'n' of 0.03 and to increase the pier width to account for the flow direction as it impacts on the bridge pier from the real width of 5m to the projected width of 8.9m. As the soffits of the Northern Railway culverts remain dry in the 100 year ARI event it was decided to model the 12 culverts as a second bridge opening with the same characteristics as the culverts. The net bridge loss in the base case remains approximately the same as under existing conditions ref Table B.1.

Table B.1 Changes to the Northern Railway Bridge modelling approach

Model Parameter	MW Existing conditions model	Base Case
Manning's 'n'	0.055	0.03
Contraction Loss Coefficient	0.3	0.3
Expansion Loss Coefficient	0.5	0.5
Pier Drag Coefficient	2.0	2.0
Yarnell Pier Coefficient	1.25	1.25
Pier Width	5	8.9
Energy loss across bridge (m)	0.22	0.217

B.4 Summary of Level Changes

A summary of the minor flood level changes associated with the establishment of the base case geometry and flows is presented in Table B.2. The subsequent assessment of proposed works and mitigation measures are all undertaken with respect to the base case model as described in the preceding sections.

Table B.2 Flood Level Changes due to establishment of Base Case - relative to the Existing Conditions provided by Melbourne Water

	Revised geometry, flows as per MW existing conditions model (ref 1)	Base Case revised geometry and flows.
Average change* (mm)	7	-5
Change at Fisher Parade (mm)	5	-8
Change at Lynchs Bridge (mm)	7	-9
Change upstream of Footscray Road (mm)	15	-3

* Average change is the arithmetic mean of differences to MW existing conditions model.

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Appendix C

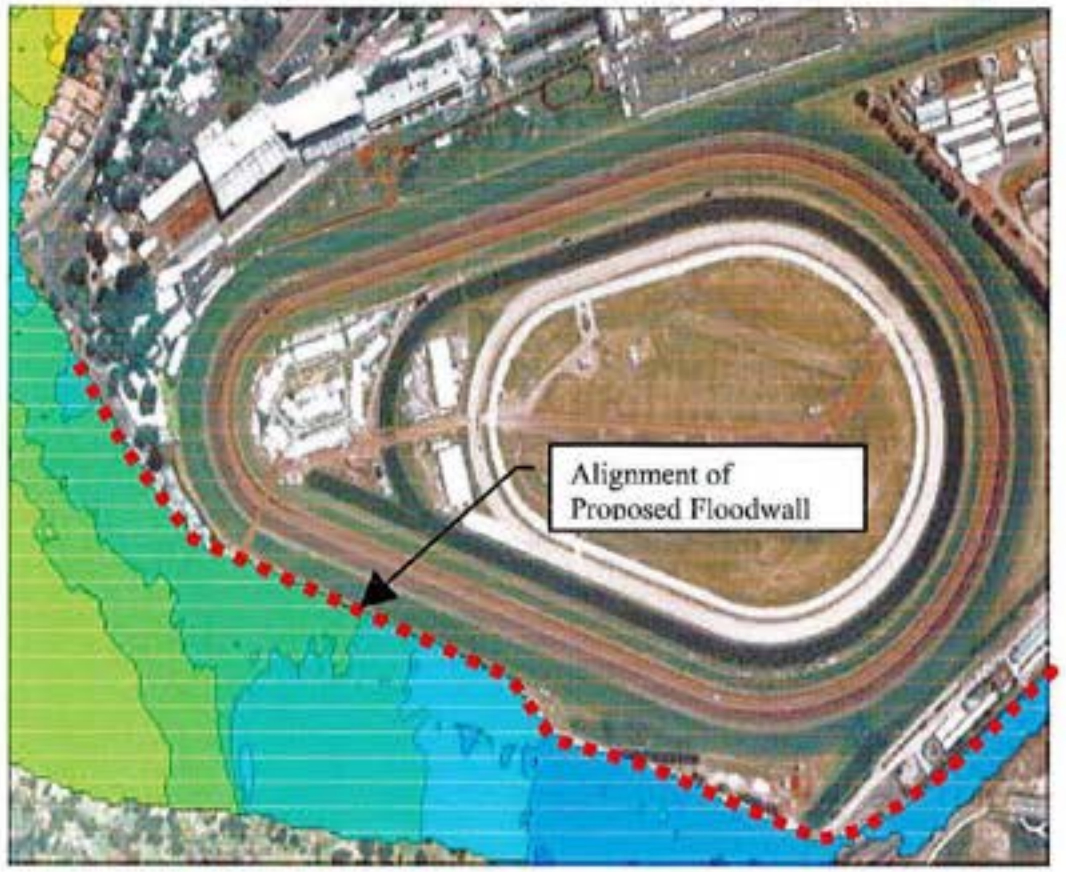
Proposed Works

C. Proposed Works

C.1 Proposed Floodwall Alignment

A vertical floodwall is proposed to separate the Maribyrnong River and the racecourse. The proposed wall will extend from high ground near Fisher Parade to high ground along Smithfield Road. The proposed floodwall alignment is shown in Figure C.1. It follows the northern boundary between the proposed flood extent and the aerial photo.

Figure C.1



C.2 Proposed Mitigation Works at Footscray Road

The Footscray Road mitigation concept involves removal of the bluestone abutment and flow training walls for the left (east) abutment only. No works are proposed on the right abutment.

C.2.1 Removal of Bluestone Abutment

Preliminary assessment of this task has identified the need for:

- a temporary cofferdam during the construction phase;
- cutting equipment and a monorail gantry to remove the bluestone slabs;
- temporary propping prior to permanent stabilisation works; and

- the flow training walls.

A detailed structural analysis is yet to be undertaken.

C.2.2 Flow Training Walls

The conceptual horizontal alignments of the flow training walls are displayed in Figure C.2. Please note the distorted scale with flow from left to right. Detailed survey will be undertaken as part of the detailed design process at which time the alignment will be revised as required to blend into the river bank.

Figure C.2 Conceptual Flow Training Walls

Plan of Proposed Abutment Works - Concept Sketch **NOT FOR CONSTRUCTION**

Footscray Road Left (East) Abutment

Set out points for new vertical flow training walls

Upstream wing wall (minimum crest height 1.8m AHD)

river distance (m)	offset (m)
-12.04	3.21
-11.50	2.71
-10.88	2.24
-10.18	1.79
-9.37	1.37
-8.44	0.98
-7.35	0.64
-6.02	0.35
-4.27	0.12
0.00	0.00

Downstream wing wall (minimum crest height 1.3m AHD)

river distance (m)	offset (m)
60.14	6.23
51.72	5.99
48.29	5.54
45.64	4.96
43.48	4.29
41.65	3.53
40.05	2.70
38.22	1.94
36.06	1.27
33.44	0.69
29.98	0.24
21.56	0.00

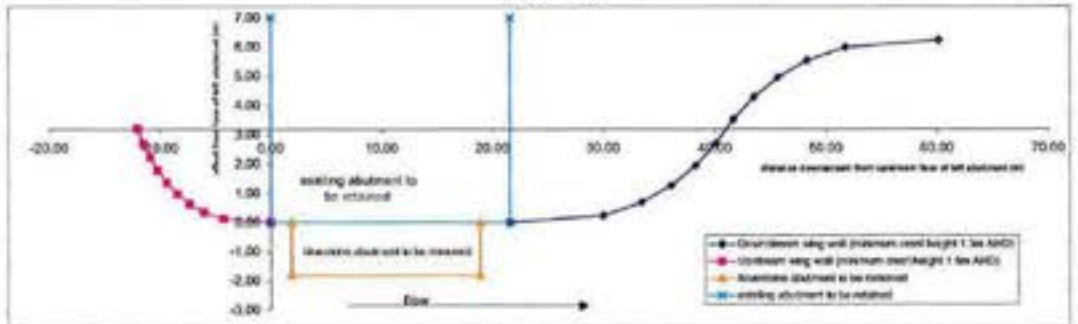
Notes

Curves can be constructed as straights between nominated points

Bank to be reinstated to match walls

walls to be tappered into existing banks

coordinates subject to revision following detailed survey



C.2.3 Cost Estimate

A preliminary "order of cost" estimate has been prepared for the Footscray Road mitigation concept and is presented in Table C.1. No allowance has been made for any compensation, which may be required.

Table C.1 Footscray Road left abutment Improvements – Indicative Schedule of Costs

Item	Description	Order of Cost ($1,000)
1.	Site Establishment / Environmental	100
2	Survey, Detailed Structural Assessment, Design and Approvals	150
3a	Remove Bluestone Abutment (cofferdam, labour and mechanical)	200
3b	Construction of wingwalls and support to facia	300
4	Site reinstatement	50
5	Service Relocations (provisional)	100
	Contingency (22%)	200
	TOTAL	**1,100**

C.3 Northern Railway Culverts

The Northern Railway mitigation concept involves removal of the road embankment located immediately downstream of the railway culverts. Approximately 70 m of earth roadway embankment is to be removed, lowering levels from approximately 0.8 mAHD to 0 mAHD to match the invert level of the culverts. The cost estimate allows for the earth embankment to be disposed of as contaminated fill. There is potential for approval difficulties with this mitigation concept.

C.3.1 Cost Estimate

A preliminary "order of cost" estimate has been prepared for the Northern Railway mitigation concept and is presented in Table C.2. No allowance has been made for any compensation, which may be required.

Table C.2 Northern Railway Culvert Improvements - Indicative Schedule of Costs

Item	Description	Order of Cost ($1,000)
1.	Site Establishment / Environmental	100
2	Survey, Design and Approvals	100
3a	Lowering Road Works	50
3b	Disposal to Contaminated Fill	75
3c	Construction of Alternate Access 500m x $600	300
4	Site reinstatement	75
5	Service Relocations (provisional)	20
	Contingency (25%)	180
	TOTAL	**900**

Appendix D

Expert Review

D. Expert Review

D.1 Changes to Draft Report

Some editorial changes have been made to the draft report provided to and reviewed by Dr Robert Keller. Since no changes have been made to the calculations or supporting analysis, Dr Keller's review comments remain valid for this report.

D.2 Review of Modelling and Draft Report

The following 6 page review of this investigation was undertaken by [redacted] of R. J . Keller and Associates.

FLEMINGTON RACECOURSE FLOOD PROTECTION – INVESTIGATION OF MARIBYRNONG RIVER FLOOD PROTECTION – DRAFT REPORT

Review undertaken for GHD Pty. Ltd.

PREAMBLE

This review has been undertaken at the request of GHD. Pty. Ltd. The draft report was passed to me on 8th April 2003 and is Document Number 31/12638/1939. In addition, electronic copies of the HEC-RAS data sets associated with the project were passed to me.

Throughout the hydraulic studies presented in this report, I was consulted on a number of occasions by [redacted] and [redacted] of GHD Pty. Ltd. In addition, I visited the site on 12th March 2003.

In undertaking this review, I have read the report thoroughly and checked, run and examined the results of each of the data sets. The review covered a range of issues including:

- The appropriateness of the changes to the attenuation estimates under existing conditions.
- The change in modelling parameters for the Northern Railway Bridge
- The determination of the unmitigated effect on flood levels associated with the protection works
- The proposed mitigation works at the Footscray Road Bridge and the Northern Railway Bridge
- The determination of the afflux associated with the protection works with a mitigation strategy based on works at the Footscray Road Bridge alone.
- The determination of the afflux associated with the protection works with a mitigation strategy based on works at the Footscray Road Bridge and the Northern Railway Bridge together

Each of these issues is examined separately in the following. A brief summary completes this review.

The flood levels presented in the report are based on the results of steady-state runs, utilising peak flows at each cross-section which, in turn, are based on local, detailed hydraulic modelling of unsteady flows. There is an evident inconsistency here, in that a steady-state analysis of a river in which the flow reduces with distance downstream implies, physically, that there are associated progressive outflows from the river. This is clearly not the case in the present study, for which the calculated attenuation in peak flow with distance downstream is the result of temporary flood plain storage.

Nevertheless, the approach adopted is consistent with the aims of this study, which centre on the effects of changes in attenuation on flood levels. It is important to note that a steady state run, utilising the peak flow of a hydrograph, will always result in a higher prediction of flood level (all other things being equal) than will an unsteady run, utilising the full hydrograph. The estimates presented are, thus, appropriately conservative.

CHANGES TO THE ATTENUATION ESTIMATES UNDER EXISTING CONDITIONS

The base case model prepared in an earlier study for Melbourne Water included an estimate of peak flow attenuation due to storage within the Flemington Racecourse for the purpose of calculating flood levels resulting from the 100year ARI event.

If the attenuation is underestimated (ie downstream flows are estimated to be larger than actual), higher consequent flood levels will be predicted. Clearly conservatism in this direction is appropriate for the purpose of determining flood levels for planning purposes.

On the other hand, the results of the present study are predicated on the change in attenuation (reduction) resulting from the construction of the flood protection wall at Flemington Racecourse. A conservative approach then requires uncertainties in the determination of the base case attenuation to be in the direction of an overestimate to permit a conservative prediction of the attenuation change associated with the flood protection wall.

This approach has been recognised and acted on in the current study. A thorough analysis and explanation have been provided and I concur with the results of the analysis.

It is worth noting, from the results presented in Table 3.1, that the predicted change in attenuation between the proposed conditions and the base case is $8.2m^3/sec$ for the modified base case, but would only have been predicted to be $3.3m^3/sec$ if the original base case had been adopted. The larger attenuation change will lead to larger afflux predictions, and is, accordingly, conservative.

CHANGE IN MODELLING PARAMETERS FOR THE NORTHERN RAILWAY BRIDGE

The Northern Railway Bridge was originally modelled with an internal Manning's n value of 0.055 and a pier width of 5m. It was recognised that the Manning's n value was inappropriately large relative to values used at other structures. The value used was based on the original calibration of the model against the 1986 Melbourne Water published flood levels.

Reassessment of the flow patterns through the bridge indicated that the flow direction is strongly skewed, relative to the pier, due to the location of the bridge on a bend in the river. As a result, the projected width of the pier, presented to the flow, is substantially greater than its physical width. The replacement in the bridge model of the actual pier width by the projected pier width lead to a much more realistic value of internal Manning's n of 0.03 with virtually no change in the computed energy loss across the bridge.

The importance of modelling the bridge using realistic values lies in the correct modelling of the re-distribution of flows between the bridge and the culvert bank at the same site, associated with mitigation works.

I fully agree with the amended model of this bridge.

DETERMINATION OF THE UNMITIGATED EFFECT ON FLOOD LEVELS ASSOCIATED WITH THE PROTECTION WORKS

The effect of the flood protection works on flood levels results from different factors upstream and downstream of the location of the works. Downstream of this location, the peak flow rates increase above those obtained in the absence of the flood protection works because of the loss of flood plain storage. The increased flood levels are associated with the increased flows.

Upstream, on the other hand, flows are not affected. Increased flood levels in this region are associated with the upstream propagation of the downstream influence, coupled with the effect of the decreased conveyance at the site of the works.

The effect downstream was assessed by comparison of the predicted flood levels associated with the different flow attenuations without and with the flood protection works. As indicated above, the difference in attenuation is conservatively estimated.

The results are presented as respective graphs of flow profiles and afflux. The latter is especially useful in indicating the change in flood level associated with the flood protection works.

The results indicate a variable afflux throughout the downstream reach between Flemington racecourse (Lynches Bridge) and Footscray Road of between about 29mm and 36mm. I have checked the HEC-RAS model runs that produced these results and confirm that the results are correct.

The upstream impact of the flood protection works on flood levels will be a maximum immediately upstream of the works location. This impact was assessed using the two-dimensional model FLS because it is much more appropriate for determining the distribution of flow across the flood plain. An accurate estimation of this distribution is important because of the substantially higher roughness of the flood plain compared with that of the channel. An under-estimate of the proportion of total flow carried by the flood plain will, as a consequence, result in an under-estimate of the upstream impact.

I have reviewed the results of the FLS modelling and confirm that they have been accurately determined. The calculated total energy line afflux immediately upstream of the works due to loss of conveyance alone is 16mm.

The attenuation of this afflux with distance upstream was then determined using the HEC-RAS model. This required a minor adjustment to the roughness of the main channel adjacent to the flood wall in order to match the predicted water surface elevations from the FLS model and the HEC-RAS model at the upstream end of the proposed works. The noted discrepancy was anticipated due to the differing abilities of HEC-RAS and FLS to model the flow distribution between the channel and the flood plain.

With the HEC-RAS model adjusted to incorporate the results of the FLS modelling at the site of the works, the unmitigated effect of the flood wall on flood levels throughout the full study reach could then be determined. This showed a maximum afflux, consequent to the works, of 45mm at the site of the works, reducing to 15mm at the upstream end of the study reach.

I have reviewed the data sets for the HEC-RAS runs and confirm the appropriateness of the modelling techniques, as outlined above, and the accuracy of the consequently determined values of afflux.

PROPOSED MITIGATION WORKS AT FOOTSCRAY ROAD BRIDGE AND NORTHERN RAILWAY BRIDGE

Footscray Road Bridge

The proposed mitigation works at this site comprise the removal of the remnant bluestone abutment on the left (eastern) bank coupled with the construction of flow training walls through the bridge site on this bank. I concur with the observation that similar works on the western bank are not feasible, due to the presence of a jetty upstream and wharf with moored boats immediately downstream.

The design of the training walls is a critical issue to ensure the minimisation of energy losses through the bridge site. The use of smooth transitions, based on the Fargue spiral is proposed.

I am in full agreement with this proposal. The Fargue spiral has been identified as the shape which most closely follows the natural plan shape of meandering rivers. It has been established that rivers, that are free to meander, adjust their shape to minimise the expenditure of energy. I have also used the same principle in designing Minimum Energy Loss transitions for bridge waterways and culverts, resulting in substantial and verifiable reductions in structure head loss.

Within the HEC-RAS model, these features have been modelled by increasing the waterway width slightly – to account for the removal of the remnant abutment – and by reducing expansion and contraction loss coefficients from 0.35 to 0.15 and from 0.15 to 0.10. In my judgement, these changes are appropriate. Even greater reductions would be possible if the same treatment could be applied to the western bank.

Northern Railway Crossing

The identified hydraulic improvement at this site comprises the removal of a low road embankment at the outlet of the 12-cell box culverts on the right (western) flood plain. It was clear from observations during the site visit that removal of this embankment would alter the flow distribution between the culverts and the bridge and lead to a reduction in the overall structure head loss.

The improvement is modelled in HEC-RAS by altering the appropriate cross-section, immediately downstream of the culverts. I confirm that this is appropriate and will lead to an accurate assessment of the effect of this improvement on the structure loss.

DETERMINATION OF AFFLUX ASSOCIATED WITH THE PROTECTION WORKS WITH A MITIGATION STRATEGY BASED ON WORKS AT FOOTSCRAY ROAD BRIDGE ALONE

I have checked the HEC-RAS data set established for this assessment and confirm that it has been correctly set up. I have run the program myself and have checked the results. I confirm that the results presented in the draft report are correct and represent an accurate determination of the reduced afflux associated with these works.

DETERMINATION OF AFFLUX ASSOCIATED WITH THE PROTECTION WORKS WITH A MITIGATION STRATEGY BASED ON WORKS AT FOOTSCRAY ROAD BRIDGE AND NORTHERN RAILWAY BRIDGE

The additional change to the HEC-RAS data set at the cross-section downstream of the culverts has been checked and determined to be correct. I have run the program myself and have checked the results. I confirm that the results presented in the draft report are correct and represent an accurate determination of the reduced afflux associated with these works.

RESULTS OF MITIGATION STRATEGY

The effects of the two proposed mitigation strategies are presented in Figure 5.4 of the draft report. From my own checking of the computer models, I confirm the correctness of the results.

It is indeed striking to note the greatly improved hydraulic performance of the system when the additional mitigation works at the Northern Railway Bridge are included.

SUMMARY COMMENTS

I have carefully and thoroughly checked the draft report and the associated numerical model studies. In my judgement, the input parameters for the models are appropriate and the resultant determinations of afflux and afflux mitigation are correctly determined and are accurate. I have commented extensively on the important aspects of the study within this review and the consequences of some of the key assumptions on the results.

In my view, the study has been professionally and competently carried out. The results accurately reflect the impact of the flood protection works on the 100year flow profile and the effect of the mitigation options. The proposed mitigation works represent the most appropriate options for the study reach.

I recommend that the results be accepted as the hydraulic basis for final determination of the most appropriate mitigation strategy and for the subsequent design of the mitigation works.

[redacted]

30th April 2003

GHD Pty Ltd ABN 39 008 488 373

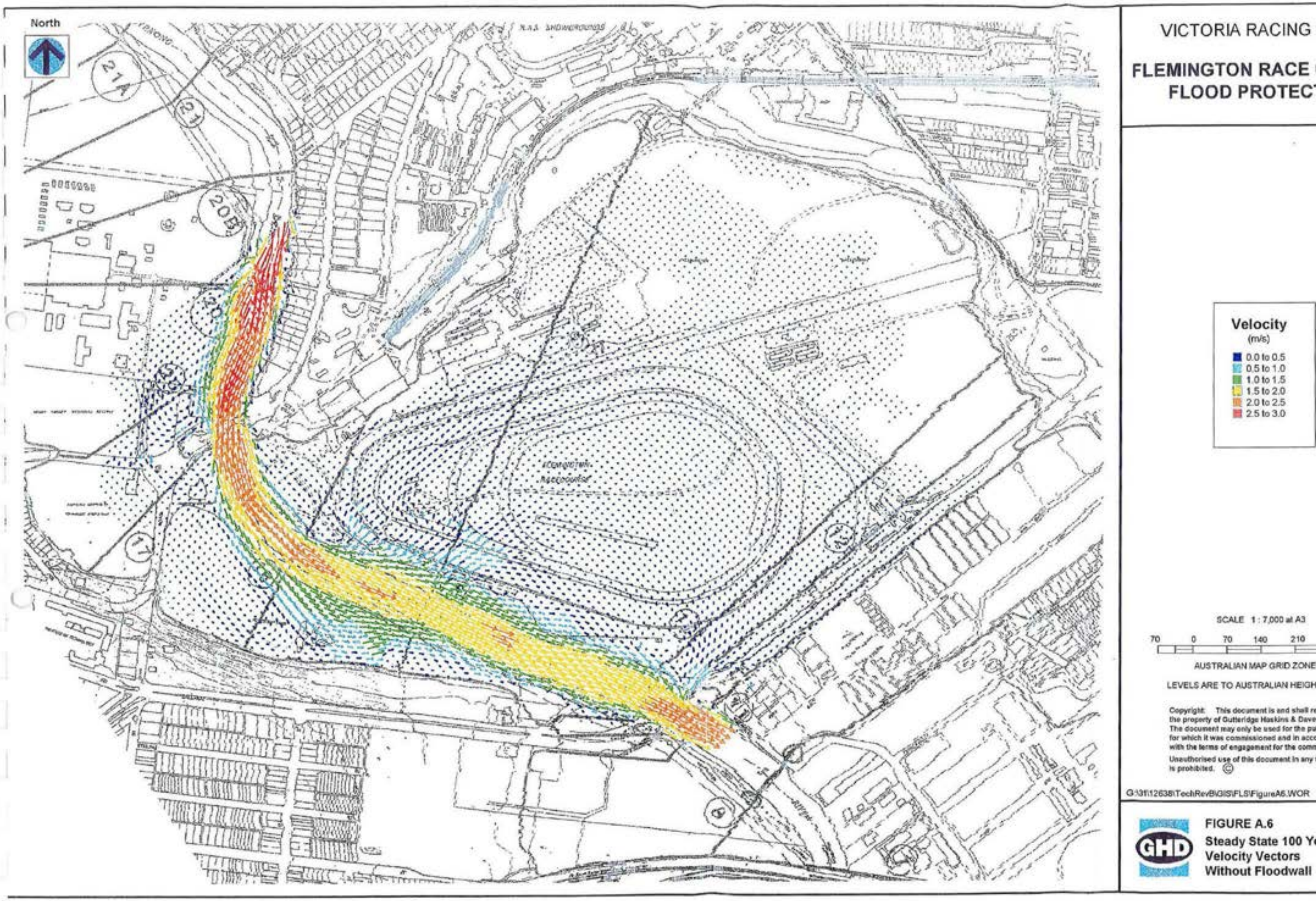
[redacted]

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	[redacted]		*********	[redacted]	**********	27/5/03

VICTORIA RACING CLUB

FLEMINGTON RACE COURSE FLOOD PROTECTION



SCALE 1 : 7,000 at A3

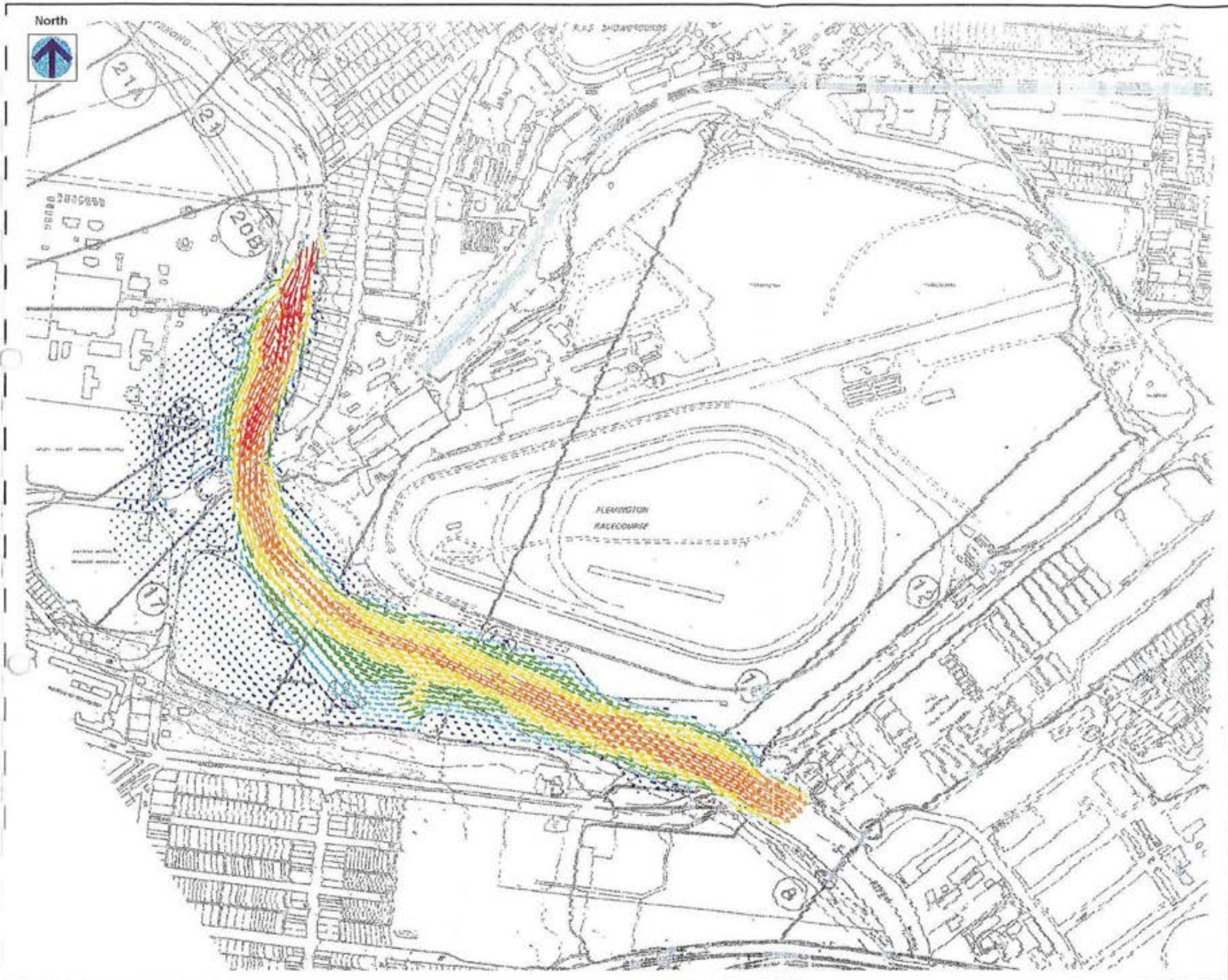
70 0 70 140 210 280 350 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

G:\31\12638\TechRevB\GIS\FLS\FigureA6.WOR 27 March 2003

FIGURE A.6
Steady State 100 Year ARI Velocity Vectors Without Floodwall



VICTORIA RACING CLUB

FLEMINGTON RACE COURSE FLOOD PROTECTION

Velocity
(m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0

SCALE 1 : 7,000 at A3

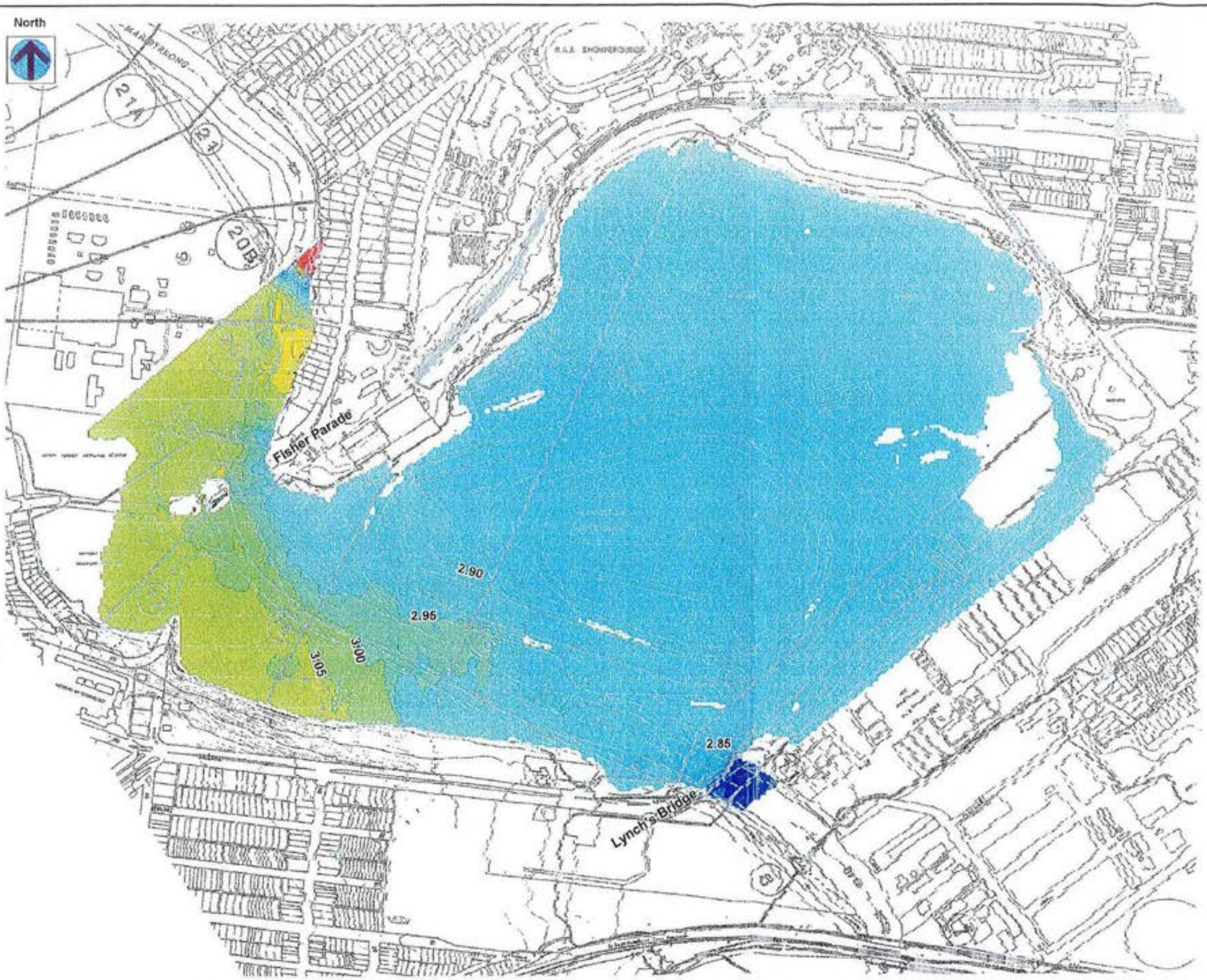
70 0 70 140 210 280 350 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

G:\31\12638\TechRevB\GIS\FLS\FigureA7.WOR 27 March 2003

FIGURE A.7
Steady State 100 Year ARI Velocity Vectors With Floodwall



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FLEMINGTON RACE COURSE FLOOD PROTECTION

Water Surface Level Contours at 0.05m Intervals (m AHD)

2.50 to 2.55
2.55 to 2.60
2.60 to 2.65
2.65 to 2.70
2.70 to 2.75
2.75 to 2.80
2.80 to 2.85
2.85 to 2.90
2.90 to 2.95
2.95 to 3.00
3.00 to 3.05
3.05 to 3.10
3.10 to 3.15
3.15 to 3.20
3.20 to 3.25
3.25 to 3.30
3.30 to 3.35
3.35 to 3.40
> 3.40

SCALE 1 : 7,000 at A3

70 0 70 140 210 280 350 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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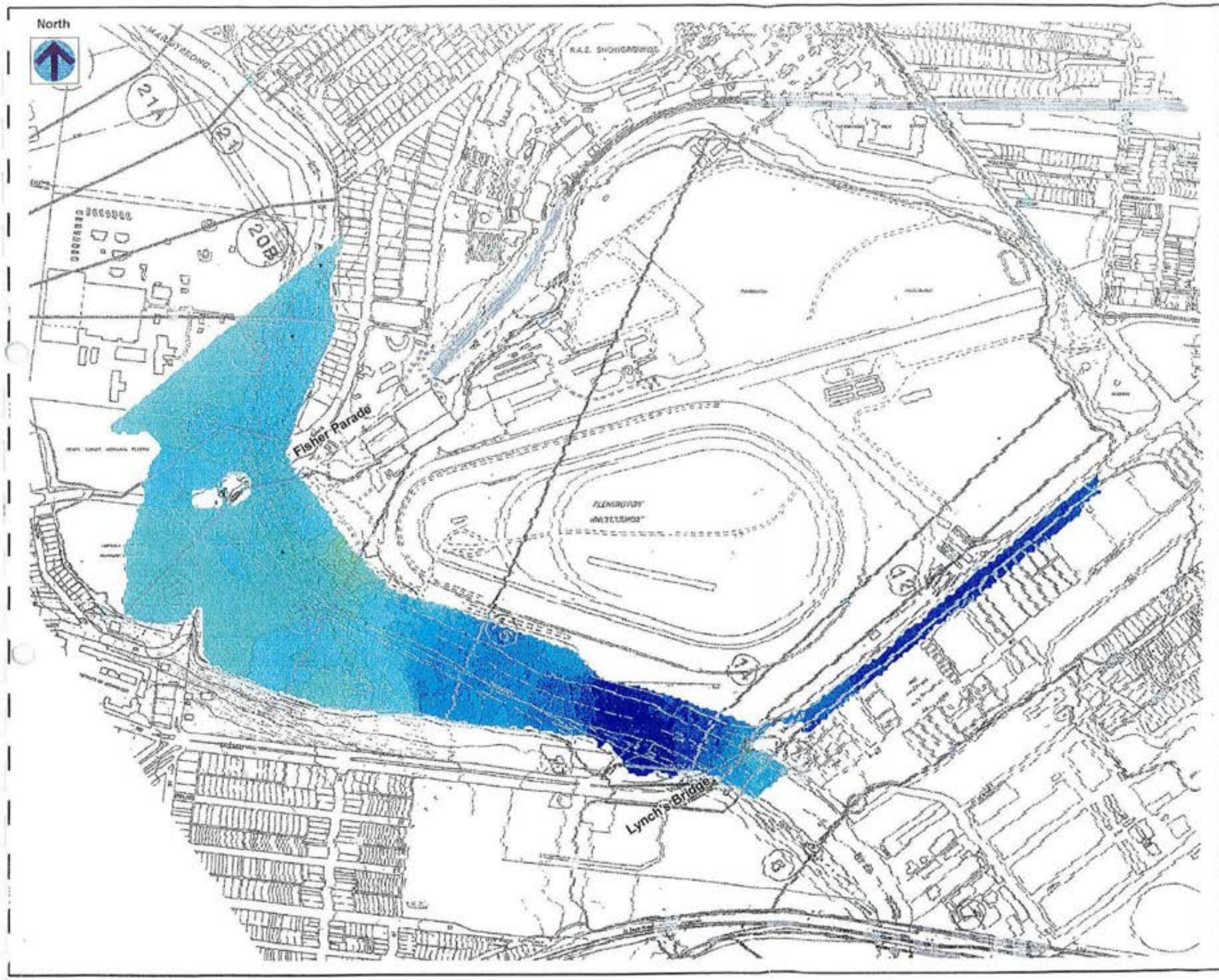
FIGURE A.4
Steady State 100 Year ARI Water Surface Level Contours Without Floodwall



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FLEMINGTON RACE COURSE FLOOD PROTECTION

Afflux
Based on Water Surface Levels
(m)

-0.10 to -0.09
-0.09 to -0.08
-0.08 to -0.07
-0.07 to -0.06
-0.06 to -0.05
-0.05 to -0.04
-0.04 to -0.03
-0.03 to -0.02
-0.02 to -0.01
-0.01 to 0.00
0.00 to 0.01
0.01 to 0.02
0.02 to 0.03
0.03 to 0.04
0.04 to 0.05
0.05 to 0.06
0.06 to 0.07
0.07 to 0.08
0.08 to 0.09
0.09 to 0.10

SCALE 1 : 7,000 at A3

70 0 70 140 210 280 350 m

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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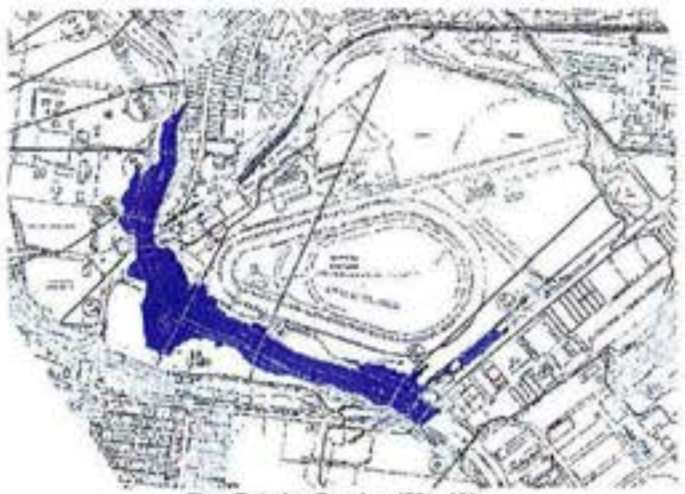
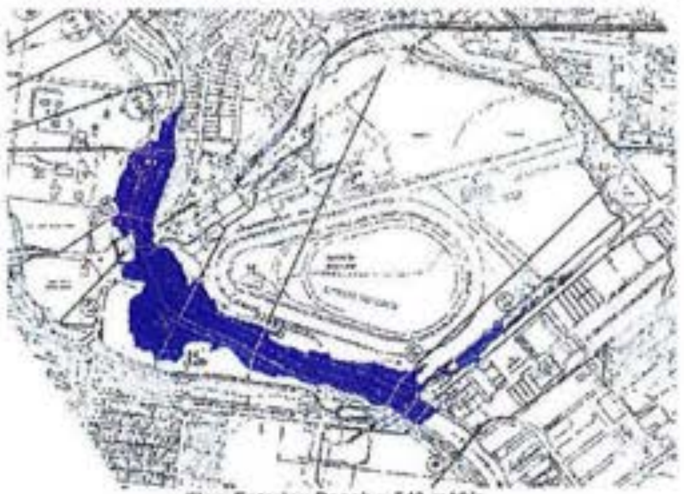
FIGURE A.8
Steady State 100 Year ARI Afflux
(WSL with - WSL without Floodwall)

VICTORIA RACING CLUB

FLEMINGTON RACE COURSE FLOOD PROTECTION

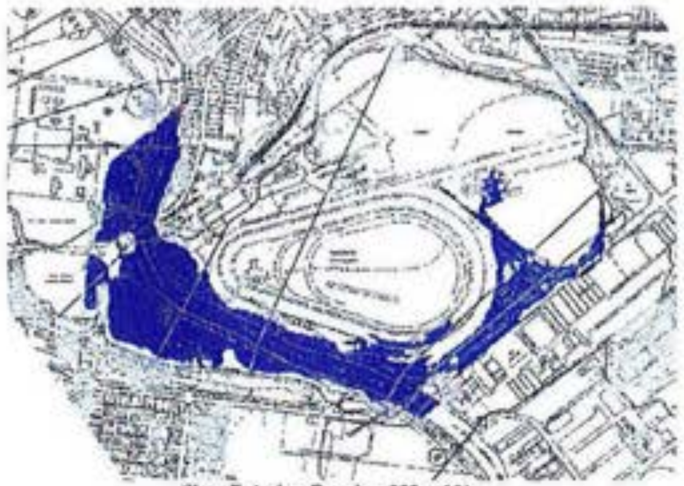


Flow Entering Reach = 472 m^3/s
Relative Time Step = 16 hrs



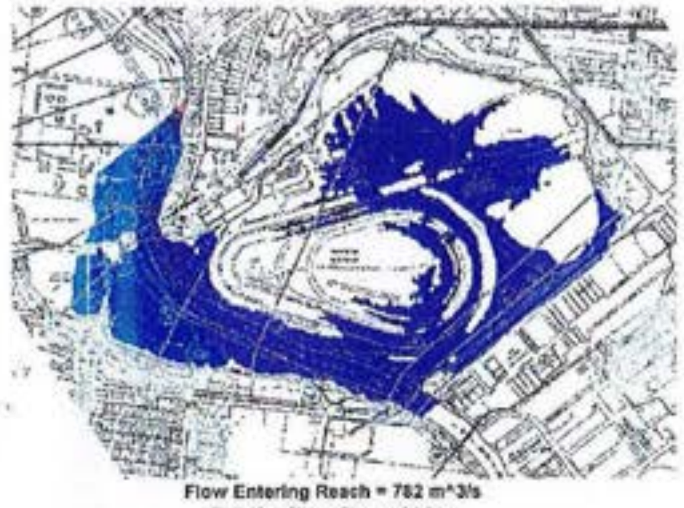
Flow Entering Reach = 546 m^3/s
Relative Time Step = 17 hrs

Flow Entering Reach = 611 m^3/s
Relative Time Step = 18 hrs

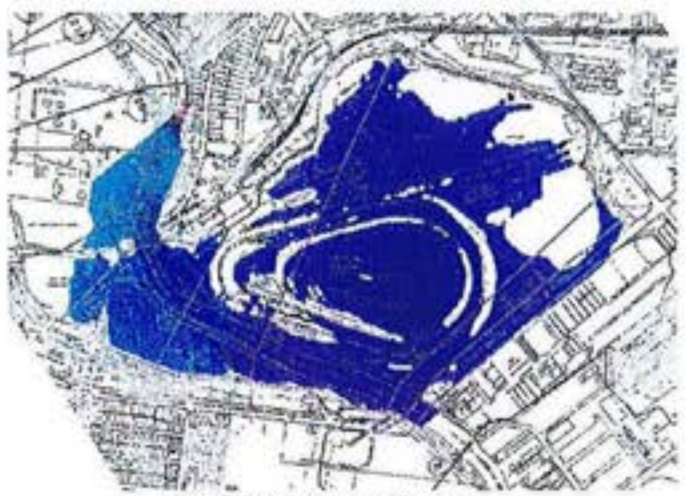


Flow Entering Reach = 669 m^3/s
Relative Time Step = 19 hrs

Flow Entering Reach = 727 m^3/s
Relative Time Step = 20 hrs

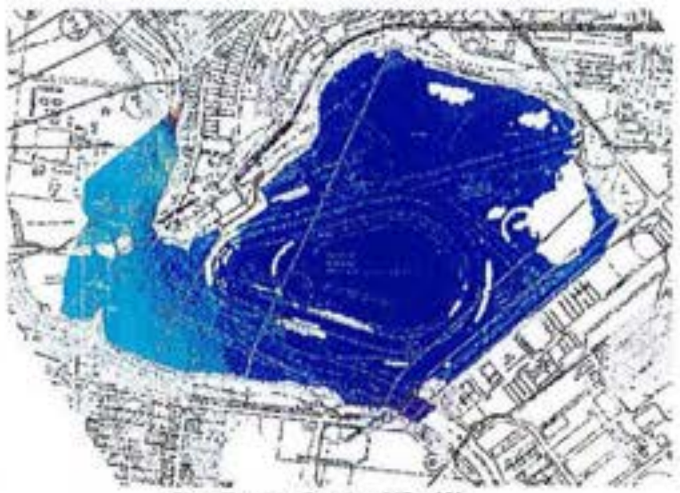


Flow Entering Reach = 782 m^3/s
Relative Time Step = 21 hrs



Flow Entering Reach = 817 m^3/s
Relative Time Step = 22 hrs

Flow Entering Reach = 839 m^3/s
Relative Time Step = 23 hrs



Flow Entering Reach = 847 m^3/s
Relative Time Step = 24 hrs

Water Surface Level Contours
at 0.05m Intervals
(m AHD)

< 2.55
2.55 to 2.60
2.60 to 2.65
2.65 to 2.70
2.70 to 2.75
2.75 to 2.80
2.80 to 2.85
2.85 to 2.90
2.90 to 2.95
2.95 to 3.00
3.00 to 3.05
3.05 to 3.10
3.10 to 3.15
3.15 to 3.20
3.20 to 3.25
3.25 to 3.30
3.30 to 3.35
3.35 to 3.40
> 3.40

North

AUSTRALIAN MAP GRID ZONE 55

LEVELS ARE TO AUSTRALIAN HEIGHT DATUM

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FIGURE A.9
Non-Steady State 100 Year ARI Inundation Extent Progression Without Floodwall

Department of Planning and Community Development

[redacted]

Ref: STA/2003/000086

PROJECT PLANNING AND
20 MAR 2008
MANAGEMENT PTY. LTD.

17 MAR 2008

[redacted]
SOUTH MELBOURNE VIC 3205

[redacted]

PLANNING PERMIT NO. 2003/86
RACECOURSE TRACK UPGRADE AND FLOOD PROTECTION WORKS

I refer to your submission of plans and information submitted to the Department of Planning and Community Development in response to the outstanding conditions of Planning Permit No. 2003/0086.

I am please to advise that the Department's records indicate that the conditions of planning permit 2003/86 have either been discharged or are ongoing. Those conditions that are on going are 2, 3, 6, 7, 9, 30, & 33.

If you have any queries do not hesitate to contact [redacted] on telephone [redacted]

Yours sincerely

[redacted]

Encl.

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