Moreland City Council

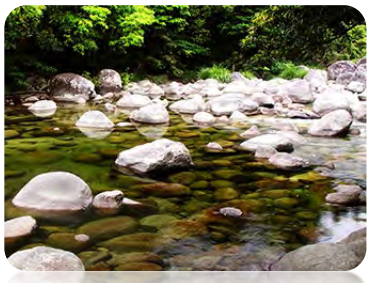
ENGENY
WATER MANAGEMENT

MORELAND CITY COUNCIL

10 % AEP Flood Mitigation – Drainage Improvement Plan

Stage 1



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V2023_006

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1. INTRODUCTION

The Moreland municipality covers an area of approximately 51 square kilometres and comprises of 12 suburbs in northern metropolitan Melbourne. The municipality is bounded by Moonee Ponds Creek to the west and the Merri Creek to the east. Moreland is highly urbanised and based on the 2016 census there are roughly 162,588 people living in Moreland, which is forecast to reach over 228,000 people by 2036. This increase in population will result in an increase in imperviousness of the catchment resulting in an increase in stormwater runoff. Engeny Water Management (Engeny) undertook flood modelling in 2017/18 of the Moreland municipality to help guide Council in the assessment of future developments and ensure the existing flooding 'hot spots' are not adversely impacted by future development.

Council engaged Engeny to prepare a Drainage Improvement Plan and assess 42 flood mitigation options as part of a municipality wide flood mitigation assessment to help prioritise these works and determine the infrastructure necessary to reduce flooding in the 10 % annual exceedance probability (AEP) storm event.

1.1 Moreland Drainage Catchments

To undertake detailed flood modelling the City of Moreland was split into 5 separate catchments (refer to Table 1.1 below). There was some overlap in catchments due to piped and overland flow in some areas draining in different directions.

Table 1.1 Moreland Catchment Summary

Catchment Name	Melbourne Water Drains within the Modelled Catchment	Approximate Catchment Area (km²)
Harding Street Drain (HAR)	Harding Street Main Drain	3.5
Melville Drain (MEL)	Albion Street Main Drain, Coonans Road Main Drain, Hope Street Main Drain, and Melville Main Drain	15.0
Chapman Avenue Drain (CHAP)	Chapman Avenue Main Drain	7.0
North East Catchments (NEC)	Acacia Street Drain, Campbellfield Creek, Merlynston Main Drain, Westbreen Creek and West Street Drain	25.0
South East Catchments (SEC)	Alexandra Parade East West Link, Elizabeth Street Main Drain (Coburg), Glenlyon Road Drain, Lygon Street Main Drain, Park Street DIV and The Avenue Main Drain	9.3

1.2 ARR2016 Adoption

The municipal wide Moreland flood study adopted Australian Rainfall and Runoff (ARR) 2016 methodologies. This involved using the ensemble approach to temporal patterns and running all ten temporal patterns through both the hydrologic and hydraulic model. Although ARR 2016 has now been superseded by ARR 2019; ARR 2016 was current when the modelling was undertaken.

For each duration storm (10-minute, 15-minute etc) there are 10 different temporal patterns collected from the ARR Data Hub online.

ARR 2016 Book 2 Section 5.9.2 discusses the ensemble considerations and recommends examining the entire catchment and determining an average pattern in terms of peak flow or volume to best represent the flooding shown within the catchment. After running all the temporal patterns through a flood model, we analysed the ensemble of temporal patterns for each duration and selected the individual temporal pattern from each duration which best represented the flood depths from the median temporal pattern.

The following temporal patterns for the 10 % AEP were chosen for all catchments within Moreland:

- 10 minute duration: temporal pattern 16
- 15 minute duration: temporal pattern 17
- 30 minute duration: temporal pattern 18
- 60 minute duration: temporal pattern 18
- 120 minute duration: temporal pattern 17
- 180 minute duration: temporal pattern 15

2. PROPOSED MITIGATION WORKS

2.1 Scope of Works

Engeny has employed the following scope of works to assess a range of mitigation options consistently across the municipality:

- Identify the location of existing drainage problems within each catchment based on detailed flood modelling undertaken as part of this project
- Undertake a hydraulic assessment to determine concept level upgrades required within each catchment
- Identify the number of properties that are impacted by the 10 % AEP flooding, whether it is an area of interest (such as a school or hospital) and what the hazard ratings are for properties impacted by the flooding
- Calculate the cost of the proposed upgrades using the Melbourne Water Drainage Scheme cost estimate spreadsheet and apply a 38.5 % increase in construction cost to account for uncertainties, administration and additional design work
- Undertake a comparison of each hot spot and order all sites in ascending order based on the cost estimates and the impact on properties.

2.2 Methodology

The aim of the mitigation assessment is to adopt a consistent approach across all flooding 'hot spot' areas. Engeny undertook a review of each site using the following steps to try and minimise the costs required to mitigate the flooding and avoid piping additional flows if it could be avoided:

1. Is there any land suitable to provide sufficient aboveground storage to mitigate the flooding?
2. Can the flow be diverted on the surface to reduce flooding, through implementation of speed humps, cloudburst roads ("V" shaped with the low point in the centre), raised footpaths?
3. Is there a potential site nearby, including under roads in which underground storage could be used to retard stormwater and release excess flows after the peak of the storms have passed?
4. Will the overland flows need to be fully piped to either a Melbourne Water drain or an open waterway?

No detailed hydraulic modelling for the proposed mitigation options has been undertaken as part of this assessment, concept level calculations and pipe sizing has been undertaken only. This approach of using the peak flow rates from the hydraulic model, Manning's calculations and some engineering judgement is acceptable to provide an indicative upgrade. It is important to note that without detailed modelling the downstream impact of the proposed works is not fully understood and, in some instances, further works may be required than those proposed in this report. This report has also focused on the Council system and some upgrades may not be possible without corresponding upgrades to the Melbourne Water drainage system to avoid increases in flooding over the Melbourne Water systems.

After the cost estimates were undertaken the properties that are impacted by flooding were determined based on if they were within the 10 % AEP flood extent and are attributed to the flooding hot spots. These properties were then analysed to determine the maximum flood hazard category from TUFLOW outputs. Each site has been prioritised based on the cost per property impacted and the cost per property with an ARR 2016 hazard rating greater than H1, which represents unsafe flows for some or all parts of the community. Refer to section 2.8 for details regarding the prioritisation breakdown.

2.3 Mitigation Sites

Engeny, with the help of Council have identified 42 key 'hot spots' across Moreland which were the focus for this mitigation assessment. Hot spots were chosen based on significant flood depths particularly within private properties, histories of flooding complaints, and associated flood hazards. These 42 locations were agreed upon with council prior to commencing this assessment. The mitigation sites chosen for this study are listed in section 2.4 below and displayed in Figure 2.1, refer to **Appendix A** for maps displaying the zoomed in locations of each site.

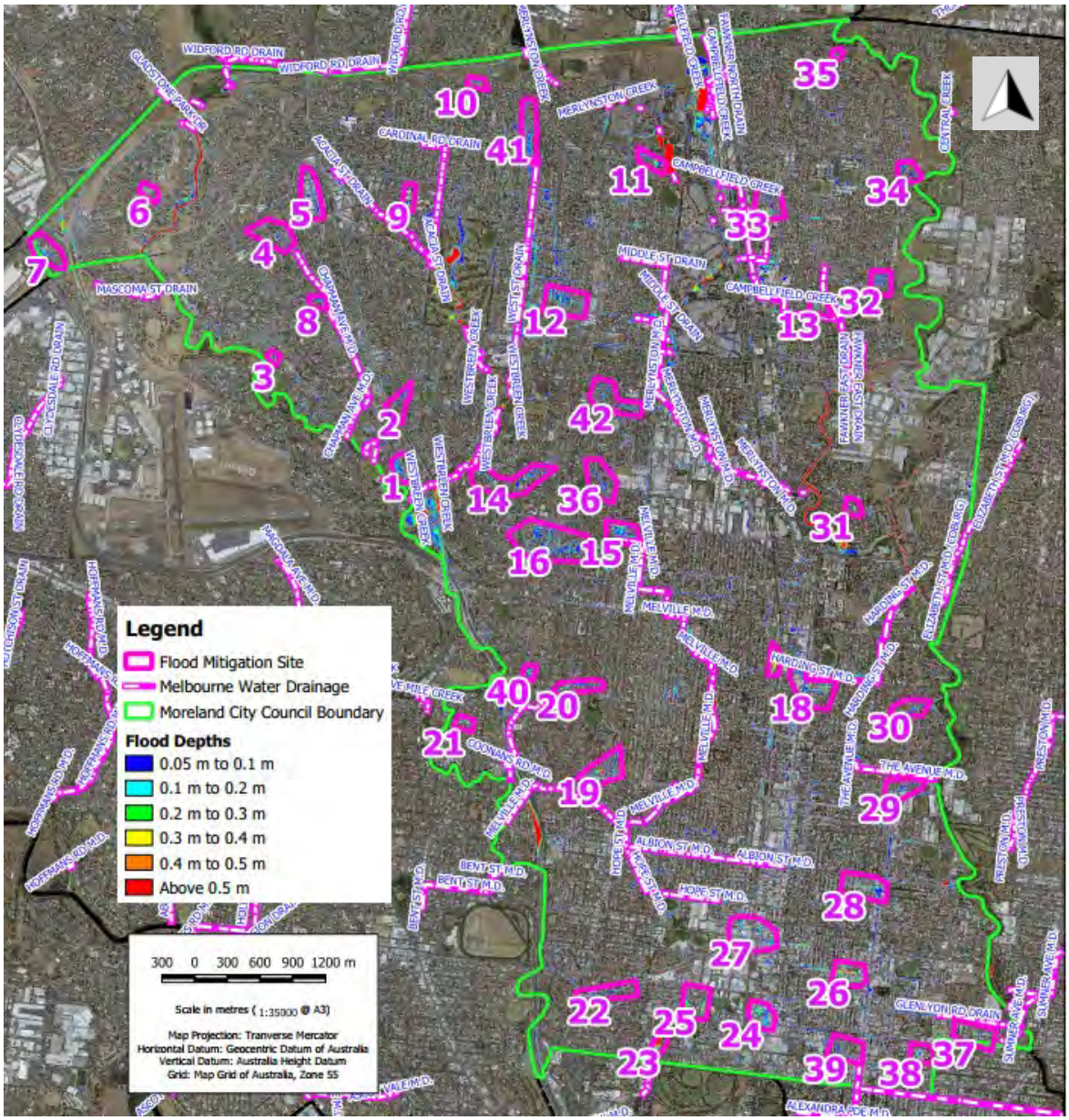

Figure 2.1 Chosen Flood Mitigation Locations

2.4 Chosen Mitigation Sites

1. Southern end of Park Street, Pascoe Vale
2. Edith Street and Devon Road, Pascoe Vale and Oak Park
3. Northern end of Winifred Street, Oak Park
4. Lytton Street, Gladstone Parade, Chapman Avenue, Glenroy
5. Post Office Place, Pascoe Vale Road, Glenroy

6. Gowanbrae Drive and Birk Court, Gowanbrae
7. Melrose Drive and Malvern Avenue, Tullamarine
8. Sim Crescent and Victoria Street, Oak Park
9. St. Agnes Court to Harold Street, Glenroy
10. Bindi Street and Justin Avenue, Glenroy
11. Morell Street and Liston Road, Glenroy
12. Everitt Street to West Street, Hadfield
13. Mutton Road, Fawkner
14. Norton Street, Pascoe Vale
15. Kirbister and Gaffney Street, Pascoe Vale
16. Bradley Street, Pascoe Vale
17. Victoria Street near Coburg Station to Sydney Road, Coburg
18. Sheffield Street to Harding Street, Coburg
19. Carrington Street, Pascoe Vale South
20. Grandview Avenue and Waverley Parade, Pascoe Vale South
21. Moama Crescent and Jhonson Street, Pascoe Vale South
22. Fitzgibbon Avenue to Moule Street, Brunswick West
23. Millward Street, Brunswick
24. Saxon and Michael Street, Brunswick
25. Barry and Fallon Street, Brunswick
26. Albert and Minnie Street, Brunswick
27. Percy and Henkel Street, Brunswick
28. Stanley and Lygon Street, Brunswick East
29. Beaumonde Street, Coburg
30. Carlisle Street near Glenora Avenue to Merri Creek, Coburg

31. Newlands Road and Shore Grove, Coburg North
32. Lynch Road, Fawkner to Merri Creek
33. Murray Street to Major Road, Fawkner
34. Jukes Road and McBryde Street, Fawkner
35. Alec Crescent, Fawkner to Merri Creek
36. Raeburn Street and Madoline Street, Pascoe Vale
37. Willowbank Road and White Street, Fitzroy North
38. Mary Moodie Way and Gear Street, Brunswick East
39. Weston Street, Brunswick
40. Gallipolli Parade, Pascoe Vale South
41. Lyons Street, Bouchier Street, Glenroy
42. Martin Street, Pascoe Vale

2.5 Proposed Works

For each of the flooding hot spot locations identified in section 2.4, the structural works have been investigated and sized to address flooding for storm events up to the 10 % AEP based on the methodology from section 2.2.

The proposed drainage infrastructure has been sized for the 10 % AEP with the aim of addressing what would be considered relatively frequent flooding issues, rather than rarer issues identified in a 1 % AEP storm. The proposed works are required to safely convey the flows through or around existing private properties and mitigate the impacts from the flood depths and velocities.

As outlined in the Victorian Floodplain Management Strategy (2016), 'Local Government Authorities are accountable for managing urban stormwater flood risk' arising from their council drains. As such section 2.7 of the report outlines the recommended mitigation works required to address this flood risk.

These works have been sized utilising the results from the existing conditions flood modelling and Melbourne Water's Development Services Scheme (DSS) costing spreadsheet (updated as of December 2017).

For proposed works which have included upgrades to existing Council drains, the proposed works have aimed to:

- Consider alternative alignments where the existing drains are not located within easements and terrain levels permit a diversion along a road reserve.

- Give preference to the replacement and upgrade of Council drainage assets within existing easements, as opposed to creating new easements.

Appendix B provides a layout plan of the proposed works for each of the identified 'hot spot' locations, and refer to section 2.7 for further discussion regarding the proposed works of each location.

2.6 Cost Assessment

Cost assessments have been carried out using Melbourne Water's drainage scheme cost estimate spreadsheet (updated as of December 2017). The spreadsheet includes all costs for drainage related works including pipes, culverts, earthworks, and WSUD features. The nature of the works has not been completely detailed therefore some uncertainties will remain, particularly for:

- The extent and costs of modifications required for conflicting services

- Detailed cost of constructing within easements through private property. The Melbourne Water Drainage Scheme cost estimate spreadsheet allows for a greater cost to construct underground drainage through private property as a result of working in a confined area, however any existing structures or trees within the easement may increase this cost further.

It is critical that an allowance is made for these items as they could potentially increase the cost of the project or stage considerably. Melbourne Water's cost estimate spreadsheet allows for costs associated with site establishment, environmental and traffic management, engineering and administration fees as well as other contingencies, therefore a 38.5 % increase in construction cost has been included to account for these uncertainties and further design work.

The cost of traffic management for major and minor Council roads and roads managed by VicRoads has been taken into account based on $3000/10 metres of pipe length. This is based on Engeny's previous experience which suggests that roughly 10 metres of underground drainage can be constructed per day and the traffic management with two people costs up to $3000 per day.

The costings for the proposed mitigation works have considered the following details and assumptions:

- Pipe grade based on average terrain levels

- Rubber Ring Jointed (RRJ) Pipe type

- 100 % Fine Crushed Rock (FCR) backfill material for all pipes that would be built along Major Roads, Minor Roads, VicRoads and under Railways
- 20 % Fine Crushed Rock (FCR) backfill material for all pipes through private properties and reserves
- Specific rates associated to the pipe crossing type i.e. reserve, private property, minor council road etc
- $15,000 for a standard 6.5 metre wide speed hump, $30,000 for a 13 metre wide speed hump. This is based on costs previously quoted to Engeny
- Underground storage cost of $450 per cubic metre of storage, based on previous quotes for large underground storages provided to Engeny
- Retarding Basin costed based on estimate excavation and allowance for inlet and outlet structures and embankments where applicable
- Raw construction cost increase of 38.5 % as discussed above.

Refer to Table 2.1 for the capital costs summary of all the proposed mitigation works, **Appendix C** contains the full breakdown costs of each mitigation location.

2.7 Site Scenario Discussion

Since a number of mitigation sites are within the same catchment and ultimately impact one another, a few sites have been combined to better evaluate the costs and benefits overall.

2.7.1 Site 1 and 2

A valley is present from Albert Street to Devon Road in Site 2 resulting in properties being flooded. Due to the difference in ground level between the low point in the streets and the ground levels on the adjacent cross roads (~5 m fall in both directions to the east and west to the nearest cross road), an upgraded pipe through the easements is required from Albert Street to the railway line south of Devon Road.

Flooding occurs on the eastern side of the railway line which should also be mitigated, a crossing at the railway line is required to alleviate the flooding upstream of the railway which is impacting on nearby properties.

The proposed pipe would bring flows onto Park Street just south of Devon Street. This is upstream of flooding occurring further along Park Street at Site 1. By connecting the proposed mitigation pipes for Site 2 with those required for Site 1, additional properties can benefit on the western side of Park Street and all flows can be discharged into Moonee Ponds Creek near Stewart Street. Works in Site 1 must be completed prior to any works associated with Site 2 so the downstream pipes have sufficient capacity to ensure no increases in flooding in the area around Site 2.

Site 1 Estimated Cost: $1,374,000

Site 2 Estimated Cost: $2,622,000

Total Estimated Cost: $3,996,000

2.7.2 Site 3

Flooding at Site 3 occurs at a localised low point on Winifred Street. The existing pipe through private properties which flows to Moonee Ponds Creek does not have sufficient capacity to convey all of the runoff reaching this location. Increasing the pit inlet capacity and upgrading pipes through the properties and reserve will have the capacity to take approximately 40 % more flow than the current flow rate.

To construct the upgraded pipe through the Oak Park Tennis Court, one of the tennis courts would need to be cut open and then reinstated. No special allowance for reinstating the tennis court has been made in the cost estimate.

Estimated Cost: $510,000

2.7.3 Sites 4 and 5

At Site 4, water overtops the kerb at a low point in Lytton Street and a low point in Gladstone Parade between William Street and Chapman Avenue. New pipes are proposed at the low points of Lytton Street and at Gladstone Parade which lead to proposed upgraded pipes along Chapman Avenue. The proposed upgraded pipes at Chapman Avenue will end at Chapman Avenue at the Grandview Street intersection, where the additional flow will surcharge as it is believed that flow could be conveyed overland along Chapman Avenue without negatively impacting on other private properties. Flood modelling would be required to ensure that flooding is not worsened within downstream properties.

At Site 5, sections of new and upgraded pipes are proposed along the southern side of Post Office Place and eastern side of Pascoe Vale Road between Post Office Place and Glenroy Road, to alleviate flooding on these roads. It is then proposed to divert the pipe along Gladstone Parade, and then connect to the pipe proposed to be upgraded on Chapman Avenue (at the Chapman Avenue/Gladstone Parade intersection) as part of Stage 4 works.

Site 4 Estimated Cost: $784,000

Site 5 Estimated Cost: $1,370,000

Total Estimated Cost: $2,154,000

2.7.4 Site 6

Water overtops the kerb in a low point at Gowanbrae Drive and causes flooding of downstream properties. New pits and pipes at the low points of Gowanbrae Drive are proposed which leads onto sections of upgraded pipes through Gowanbrae Community Garden reserve (a duplicate pipe could also be installed in this area instead of an upgraded pipe but may require an increase in easement size). Flows will surcharge once the upgraded or duplicated pipe connects to an existing council junction pit at the reserve. Increasing the surface levels of the footpath at Gowanbrae Drive can also be implemented to prevent/reduce water overtopping the kerb. Flood modelling would be required to ensure that downstream properties are not impacted by the proposed pipe upgrade.

Estimated Cost: $71,000

2.7.5 Site 7

Runoff from Melrose Drive overtops the kerb and flows through properties located at 56A-62 Melrose Drive, also resulting in flooding up to 300 mm deep in Malvern Avenue Reserve on the corner of Malvern Avenue and Melrose Drive. There is a significant powerline easement north of the area also experiencing flooding which may be a suitable site for a retarding basin to hold back the overland flows and prevent flooding through this area. Consultation with the relevant power authority would be required to confirm that this option could be pursued further, however there is precedent of stormwater assets such as wetlands being located within powerline easements.

Estimated Cost: $94,000

2.7.6 Site 8

There is a low point in Sim Crescent just north of the intersection with Victoria Street. A shallow valley then continues through private properties north of Victoria Street towards Pascoe Vale Road, causing up to 300 mm flooding in properties in this area. New pipes are proposed at the low point of Sim Crescent, which will lead into new pipes at Victoria Street running at the northern end of the road which will alleviate flooding at the low point of Victoria Street that is up to 650 mm deep. The new pipe will connect to the Melbourne Water Drain at Pascoe Vale Road. Flood modelling would need to be undertaken to ensure that flooding within downstream properties is not worsened.

Estimated Cost: $314,000

2.7.7 Site 9

Water overtops St. Agnes Court and causes overland flow to run through Glenroy College and also through a number of private properties on Glenroy Road and Harold Street. Upgrading the existing pit on St. Agnes Court and the pipes through the properties are proposed. This will lead to a duplicated pipe along Logan Street, and then an upgrade of the existing pipes from Glenroy Road until the connection to the Melbourne Water drain

between Harold Street and Acacia Street. Raising footpath levels at St Agnes Court should also be considered to reduce/prevent water overtopping the kerb and allow for additional ponding depth to improve the capture efficiency of the pits in St Agnes Court.

Estimated Cost: $1,100,000

2.7.8 Site 10

Properties within Bindi Street get flooded to depths up to 200 mm from overland flow entering from the reserve to the north. A swale is proposed from the low point at the reserve north of the lots at Bindi Street and will come into the existing local pipe system that is proposed to be upgraded until the Bindi Street/Justin Avenue intersection where it will surcharge and continue as overland flow.

Estimated Cost: $53,000

2.7.9 Site 11

Runoff becoming trapped in a low point along Evell Street creates an overland flow path through properties to the corner of Morell Street and Liston Road. Insufficient conveyance is provided in the existing pipe network to the Melbourne Water retarding basin to the east. A proposed mitigation pipe aligned along Evell Street, Liston Road and a new pipe through the easement from Liston Road to the retarding basin would minimise the number of upgraded pipes through the rear of private properties. Additionally, speed humps could be introduced at the intersection of Evell Street and Ogden Street, as well as Morell Street and Ogden Street to redirect flows along Hilton Street.

Estimated Cost: $562,000

2.7.10 Site 12

An overland flow path from west to east goes through properties between Walter Street and South Street, linking low points in Halsbury Street, Everitt Street and Francis Street. New grated pits and pipes are proposed at the low points of Halsbury Street and Everitt Street to mitigate flooding that is up to 500 mm deep. Those pipes will connect to a duplicate drain along South Street that will directly connect to the Melbourne Water drain in West Street. A speed hump is also recommended at the entry to Peachey Court at the intersection of South Street, to pond water in South Street and allow it to be captured by the upgraded pits and pipes and conveyed to West Street in the new drain which will minimise flooding on Peachey Court.

Estimated Cost: $949,000

2.7.11 Site 13

Water overtops the kerb at a low point in Mutton Road and causes flooding of the downstream properties to the east. New grated pits and pipe is proposed at the low point of

Mutton Road, which will lead to upgrading the existing pipe which run through number 12, Mutton Road, which will then be connected to the Melbourne Water pipe under the oval in Charles Mutton Reserve. Flood modelling would be required to ensure that downstream properties are not adversely impacted by the pipe upgrade.

Estimated Cost: $327,000

2.7.12 Site 14

Overland flow in excess of the pipe capacity at Site 14 flows through a number of private properties as the valley floor in this area passes through private property and has not been protected with roads or reserves.

The mitigation works for Site 14 include diversion pipes from a low point in Hazel Grove and a diversion pipe from a low point in Cumberland Road, which includes replacing and regrading some pipes to the intersection of Prospect Street and Cumberland Road. Additionally, at the low point at Norton and Campton Streets there is proposed to be new mitigation pipes directing water to the proposed diversion drain along Prospect Street. From the intersection of Prospect Street and Northumberland Road it is proposed for the drain to be directed northwards and connect to the existing Melbourne Water drain at Northumberland Road. Flood modelling would be required to ensure that flooding within downstream properties is not worsened.

Estimated Cost: $2,105,000

2.7.13 Sites 15 and 16

The proposed mitigation works for of Site 15 requires additional pipe conveyance from the low point in Gaffney Street to O'hea Street. A speed hump at the intersection of Gaffney Street and Sussex Street, along with a speed hump at Gaffney and Derby Street will reduce the amount of overland flows ending up in the low point in Gaffney Street. Additionally, a speed hump along Derby Street at the end of Shedden Street may also help to redirect flows to Waratah Street.

For Site 16 it is recommended that speed humps are introduced at the northern end of Dale Avenue, Kinross Street and Irvine Street to redirect flows down Gaffney Street and Ray Street. Along with additional pipes capturing flow from the low points in Cumberland Road, Dale Avenue, Kinross Street and Irvine Street down to the Melbourne Water pipeline.

Site 15 works would need to be constructed prior to commencing works for Site 16.

Site 15 Estimated Cost: $2,143,000

Site 16 Estimated Cost: $4,882,000

Total Estimated Cost: $7,025,000

2.7.14 Site 17

Upgraded pits and pipes are proposed at the rear of Hudson Street within the Coburg Station Reserve, where flood depths are up to 800 mm deep. These pipes would connect to upgraded existing pipes along Munro Street, which will then connect to the Melbourne Water Drain at Harding Street near the intersection with Sydney Road. Flood modelling would need to be undertaken to ensure that flooding is not worsened within downstream properties.

Estimated Cost: $1,278,000

2.7.15 Site 18

An upgrade of the pipes along Sheffield Street between Sydney Road and Chambers Street is proposed due to flood depths in this area being up to 450 mm deep. The upgraded pipes will connect to the existing Melbourne Water drain at Harding Street. Flood modelling would need to be undertaken to ensure that flooding is not worsened within downstream properties.

Estimated Cost: $720,000

2.7.16 Site 19

There are low points at the southern end of Carrington Street and Melville Road near the intersection with Moreland Road where flooding occurs. Additional conveyance needs to be provided to convey stormwater away from this area and out to the Melbourne Water Drain located South of Moreland Road. Flood modelling would need to be undertaken to ensure downstream properties are not affected due to Melbourne Water having flooding issues downstream.

Estimated Cost: $2,357,000

2.7.17 Site 20

The location of an existing valley through residential properties beginning in Melville Road and going through to Reynard Street results in flooding of those properties when the drainage network capacity is exceeded. The existing pipe network through the back of properties has insufficient capacity to convey all the overland flows. The proposed mitigation works includes diverting a proportion of flows from the north to Balmoral Avenue through the implementation of speed humps along Springhall Parade, Grandview Avenue and Waverley Parade a their intersections with Princes Terrace and by pipe upgrades through the property easements to Waverley Parade, followed by a diversion pipe out to Reynard Street and then down Winifred Street to the Melbourne Water Drain.

Consideration would need to be given to potential adverse impacts on the Melbourne Water system as a result of the proposed drainage upgrade.

Estimated Cost: $1,810,000

2.7.18 Site 21

New grated pits and pipes are proposed at the low points of Moama Crescent to alleviate flooding of up to 450 mm in depth in the 10 % AEP and reduce or prevent overland flow through properties. The new pipes will lead to Johnson Street, north of Moama Crescent and connect to the existing council drain going through the reserve at Brentwood Avenue being upgraded to the outlet at Moonee Ponds Creek. This alignment minimises pipe upgrades through private properties and maintains the existing outfall to Moonee Ponds Creek.

Estimated Cost: $328,000

2.7.19 Site 22

The existing overland flow path is along the laneways between Foden Street and Collier Crescent. It is proposed for existing pipes to be upgraded from the laneway between Foden Street and Fitzgibbon Avenue, through Collier Crescent, South Daly Street and the pipes within the Brunswick South West Primary School where they would connect back into the existing drainage network. Excess flows at the connection between the upgraded and existing pipe will surcharge and flow along Wattle Valley Road to Moonee Ponds Creek. Flood modelling would be needed to be undertaken to ensure that flooding is not worsened within downstream properties.

Estimated Cost: $878,000

2.7.20 Sites 23 and 25

Hot spots 23 and 25 are located in Brunswick. Mitigation Site 25 refers to the flooding occurring between Fallon Street and Hennessey Street, and Site 23 refers to the flooding on Millward Street and Brunswick Road. These sites are on the southern edge of the Moreland Municipality. At site 23, the proposed upgraded pipe joins to the existing 1500 mm diameter local pipe between Brunswick Road and Park Street. Site 25 works would need to be built first to avoid downstream impacts.

Site 23 Estimated Cost: $645,000

Site 25 Estimated Cost: $787,000

Total Estimated Cost: $1,432,000

2.7.21 Site 24

Site 24 is located at the intersection of Saxon Street and Michael Street. Site 24 is the site relating to the article published in The Age on the 15th of November 2018 where a disabled resident was allegedly trapped in his apartment due to flash flooding causing the lifts to fail, along with another elderly man falling into a drain due to a pit cover coming loose, see Figure 2.2 below.

Figure 2.2 Flooding along Michael Street 6th November 2018, (The Age, 2018)

The flooding occurs at this location as it is a localised low point when compared with the surrounding area. This means that overland flow can enter the area but must be conveyed out of the area by pipes, so when the pipe capacity is exceeded water can flow onto the road and then into the buildings. Due to this site being such a high-profile location and affecting many residents Council is currently in the process of constructing a mitigation solution. This includes:

- Large storage pipes under Michael Street to temporarily store water before reconnecting to the existing pipe system along Sydney Road.
- Re-grading the existing footpath and road cross-fall, and lowering the kerb and channel along the south side of Michael Street and north-east corner of Saxon Street to prevent water entering the private properties.
- New drainage system to collect the flow along Manallack Street and connect into existing 900 mm diameter drainage pipe along Union Street.
- Join the two existing 900 mm diameter drainage pipes on either side of Union Street to split the flow among these pipes.

2.7.22 Site 26

Water ponds up and overtops the kerbs at the low points of Albert Street and Evans Street. Proposed pipes at the low points of Albert Street and Evans Street can divert the water further south to Glenlyon Road where is could surcharge and flow overland to Merri Creek. Flood modelling would need to be undertaken to ensure downstream properties are not affected.

Total Estimated Cost: $2,150,000

2.7.23 Site 27

There is insufficient capacity in the existing drainage pipes along Percy Street, Talbot Street, Lyle Street, Cliff Street, and Hope Street down to the Melbourne Water drain. Larger pipes and greater inlet capacity will help reduce the flooding collecting in low points in the topography. Consideration would need to be given to potential adverse impacts on the Melbourne Water system as a result of the proposed drainage upgrade.

Estimated Cost: $769,000

2.7.24 Site 28

The existing valley located within residential properties results in an overland flow path beginning from Barrow Street and continuing to Lygon Street / Eddy Street. Additional pipe conveyance is proposed from the low points in Barrow Street, Victoria Grove, Ashmore Street and Stanley Street down to Hickford Street where the pipes would surcharge. It is believed that Hickford Street has additional capacity to convey overland flows. To try and minimise the impact of downstream flooding the pipes on the eastern side of Lygon Street are proposed to be replaced with a new 1350 mm diameter pipe and surcharge pit to convey some flow along Hickford Street. Flood modelling would need to be undertaken to ensure downstream properties are not affected, in particular the properties in Bellvue Street.

Estimated Cost: $2,589,000

2.7.25 Site 29

To mitigate flooding in the low point in Nicholson Street, it is proposed to capture and conveyed stormwater via pipes to the Merri Creek. Drainage pipes on the corner of East Street and Moore Street have insufficient capacity to convey the flows down Moore Street. By upgrading the pipes from the low point in East Street and connecting to the other mitigation pipes proposed along Nicholson Street additional properties can benefit. This should mitigate the existing overland flows from Nicholson Street, through properties to Beaumonde Street and to Kirkby Street.

Estimated Cost: $1,032,000

2.7.26 Site 30

The existing pipe system between Glenora Avenue and Merri Creek is at capacity, resulting in properties located within the overland flow path being flooded. It is proposed for the existing pipes to be upgraded at Carlisle Street between Glenora Avenue and Nicholson Street. From the upgraded pipes, there will be a new duplicate pipe extending north to Grant Street, to eliminate upgrades within properties. A section of the existing pipes at Grant Street will be upgraded and a new outfall may be required to Merri Creek. The alignment through the reserve has been chosen to minimise impact on vegetation. It may be possible to surcharge high flows at or near the eastern end of Grant Street and utilise the existing outfall for low flows.

Estimated Cost: $1,166,000

2.7.27 Site 31

An overland flow path begins at Shore Grove and extends to Newlands Road. The proposed pipes will to capture additional flows along Shore Grove and at the low point in Newlands Road and can provide an additional outlet to the Merri Creek from Nola Street. The existing pipes discharging to the existing wetland can function to take low flows (e.g. 3 month flows) to the wetland.

Estimated Cost: $681,000

2.7.28 Site 32

The direction of flow in this area is from north to south. Flooding occurs in properties between Lynch Road and Vervale Avenue. New pipes are proposed along Lynch Road to minimise properties being flooded. This pipe will connect upgraded pipes along McBryde Street towards an upgraded outfall to Merri Creek. Pipes will not be required to be upgraded along the whole length to the outfall. The upgraded pipe will connect to the existing 675 mm diameter pipe in the reserve and there will be water surcharging at the reserve.

Estimated Cost: $792,000

2.7.29 Site 33

The pipes in Murray Street does not have enough capacity to convey all of the runoff that enters the road and runoff overtops the kerb causing an overland flow path to occur between Murray Street to Lynch Street. Upgraded pipes along Murray Street with a direct entry into the Melbourne Water drain on the western side of Sydney Road and additional pipes along Major Road connecting directly into the Melbourne Water drain (on the eastern side of Sydney Road) should mitigate these overland flow paths. Flood modelling would be required to ensure that downstream properties are not affected by the proposed upgrade.

Estimated Cost: $769,000

2.7.30 Site 34

There is a single side entry pit along Jukes Road to the east of McBryde Street. The lack of flow capture capacity creates an overland flow path through the back of properties to Merri Creek. There are also no pits along the eastern side of McBryde Street which results in the kerb being overtopped near the intersection of McBryde Street and Elsa Street. Additional pits along Jukes Road and McBryde Street along with a pipe upgrade along the eastern side of McBryde Street to Merri Creek is proposed to mitigate these overland flow paths.

Estimated Cost: $337,000

2.7.31 Site 35

An upgrade of the existing side-entry pit at Alec Crescent to provide additional capture capacity and an upgrade of the existing pipes through the properties and the reserve to the outlet at Merri Creek is proposed. This will increase the pipe system capacity and help to alleviate flooding that is up to 420 mm deep at Alec Crescent. The upgraded pipe will connect to the existing pipe at the reserve and there will be surcharge pit at that location.

Estimated Cost: $458,000

2.7.32 Site 36

The flooding north of Raeburn Street could potentially be conveyed to and retarded in an underground storage at Raeburn Reserve. This would involve diverting the flows from Keogh Court and regrading and replacing pipes along Raeburn Street through the reserve. An outlet pipe would need to be built from the storage and reconnect into an existing pipe along Derby Street, a weir pit is recommended at the underground storage upon entry to the downstream pipe to protect properties on the south site of Oakbank Grove if the storage was to reach capacity during a storm event.

Estimated Cost: $1,195,000

2.7.33 Site 37

A new duplicate pipe is proposed at King Street which will lead to duplicate pipes along the Willowbank Road connecting through to Merri Creek. Due to the embankment at the eastern end of Willowbank Road, depths pond to approximately 700 mm. Therefore, it is recommended that the Melbourne Water drain is also upgraded. The cost to upgrade the Melbourne Water pipes is approximately $58,000.

In addition, at White Street, where depths are up to 800 mm deep, additional pits and upgrade of pipes are proposed, which will connect to the Melbourne Water drain at Glenlyon Road. Flood modelling would be required to ensure that downstream properties are not affected by the proposed upgrade.

Estimated Cost: $636,000

2.7.34 Site 38

Additional grated pits and an upgrade of the existing pipes along Edwina Way and Gear Street are proposed to alleviate flooding in this area that is up to 300 mm deep in the 10 % AEP. The upgraded pipes will lead to a new duplicate pipe along Mary Moodie Way and Glew Street. The pipe is proposed to be extended to the intersection of Barkly Street/Nicholson Street where flows will join to the existing pipe system and excess water will surcharge and flow south on Nicholson Street.

It is noted that this is a new development area and there may be issues in the LiDAR which may mean that the flooding is showing up in the modelling is not representative of the current on ground conditions. Further investigation of the current ground levels in the development and how they relate to the ground levels recorded in the LiDAR are recommended before any mitigation works are undertaken in this area.

Estimated Cost: $536,000

2.7.35 Site 39

Water overtops the kerb in Weston Street between Sterling Street and Ewing Street. Proposed pipes including a diversion drain in Ewing Street connecting into an upgraded pipe section along Weston Street and a diversion down Sterling Street and Barkly Street to the Melbourne Water Drain at Lygon Street.

Since this mitigation option convey extra flows to the Melbourne Water Drain, consideration would need to be given to potential adverse impacts on the Melbourne Water system as a result of the proposed drainage upgrade.

Estimated Cost: $906,000

2.7.36 Site 40

The existing pipe system along Gallipoli Parade does not have enough sufficient capacity to convey all of the runoff in a 10 % AEP event, causing flooding within properties in this area. Water overtops the kerb at Le Cateau Street. An upgrade of the existing pipes at Gallipolli Parade and Le Cateau Street is proposed as well as additional grated pits within Gallipolli Parade and Le Cateau Street. The pipe will connect to the existing pit further south (downstream) on Gallipoli Parade where excess flows will surcharge. Modelling would be required to ensure that downstream properties are not impacted by mitigation works.

Estimated Cost: $339,000

2.7.37 Site 41

There is a shallow valley in between Morley Street/Valencia Street and West Street resulting in properties in this area being flooded. Proposed pipes include upgraded pipes along Everard Street leading to a diversion pipe down West Street, as well as, new pipes at the low points of Lyons Street and Bourchier Street connecting to the diversion pipe at West Street. The diversion pipe at West Street leads to the Melbourne Water Drain at the intersection of Hilton Street and West Street. Since this mitigation option will increase flows in the Melbourne Water Drain, modelling would be required to ensure that downstream properties are not affected by the mitigation works.

Estimated Cost: $709,000

2.7.38 Site 42

An overland flow path at the intersection of Martin Street and Derby Street flows through a valley at the back of a number of properties towards Heather Avenue.

Engeny proposes additional pit capacity at the intersection of Derby Street and Martin Street which would then be conveyed by diversion pipes along Derby Street, Dorset Road, Sussex Street and Shorts Road to the Melbourne Water drain.

Flood modelling would need to be undertaken to ensure downstream properties are not affected due to Melbourne Water having flooding issues downstream.

Estimated Cost: $1,021,000

2.8 Cost summary of proposed mitigation works

Table 2.1 shows the summary of the construction costs for each of the proposed mitigation works.

Table 2.1 Summary of capital costs for the proposed mitigation works

Location	Total Cost (incl. 38.5 % increase in construction cost)	Location	Total Cost (incl. 38.5 % increase in construction cost)
Sites 1 and 2	$3,996,000	Sites 23 and 25	$1,432,000
Site 3	$510,000	Site 24	$400,000
Sites 4 and 5	$2,154,000	Site 26	$2,150,000
Site 6	$71,000	Site 27	$769,000
Site 7	$94,000	Site 28	$2,589,000

Location	Total Cost (incl. 38.5 % increase in construction cost)	Location	Total Cost (incl. 38.5 % increase in construction cost)
Site 8	$314,000	Site 29	$1,032,000
Site 9	$1,100,000	Site 30	$1,166,000
Site 10	$53,000	Site 31	$681,000
Site 11	$562,000	Site 32	$792,000
Site 12	$949,000	Site 33	$769,000
Site 13	$327,000	Site 34	$337,000
Site 14	$2,105,000	Site 35	$458,000
Sites 15 and 16	$7,025,000	Site 36	$1,195,000
Site 17	$1,278,000	Site 37	$636,000
Site 18	$720,000	Site 38	$536,000
Site 19	$2,357,000	Site 39	$906,000
Site 20	$1,810,000	Site 40	$339,000
Site 21	$328,000	Site 41	$709,000
Site 22	$878,000	Site 42	$1,021,000

2.9 Prioritisation

Prioritisation of these works are undertaken based on two criteria, one being the cost per property the works will benefit, and the other being cost per property with a hazard H2 rating or above as described in ARR 2016. The H2 rating corresponds with flooding which is unsafe for some vehicles and is also near the threshold of safety for certain groups of people such as children and the elderly).

The hazard rating curves/descriptions according to ARR 2016 are displayed in Figure 2.3 below.

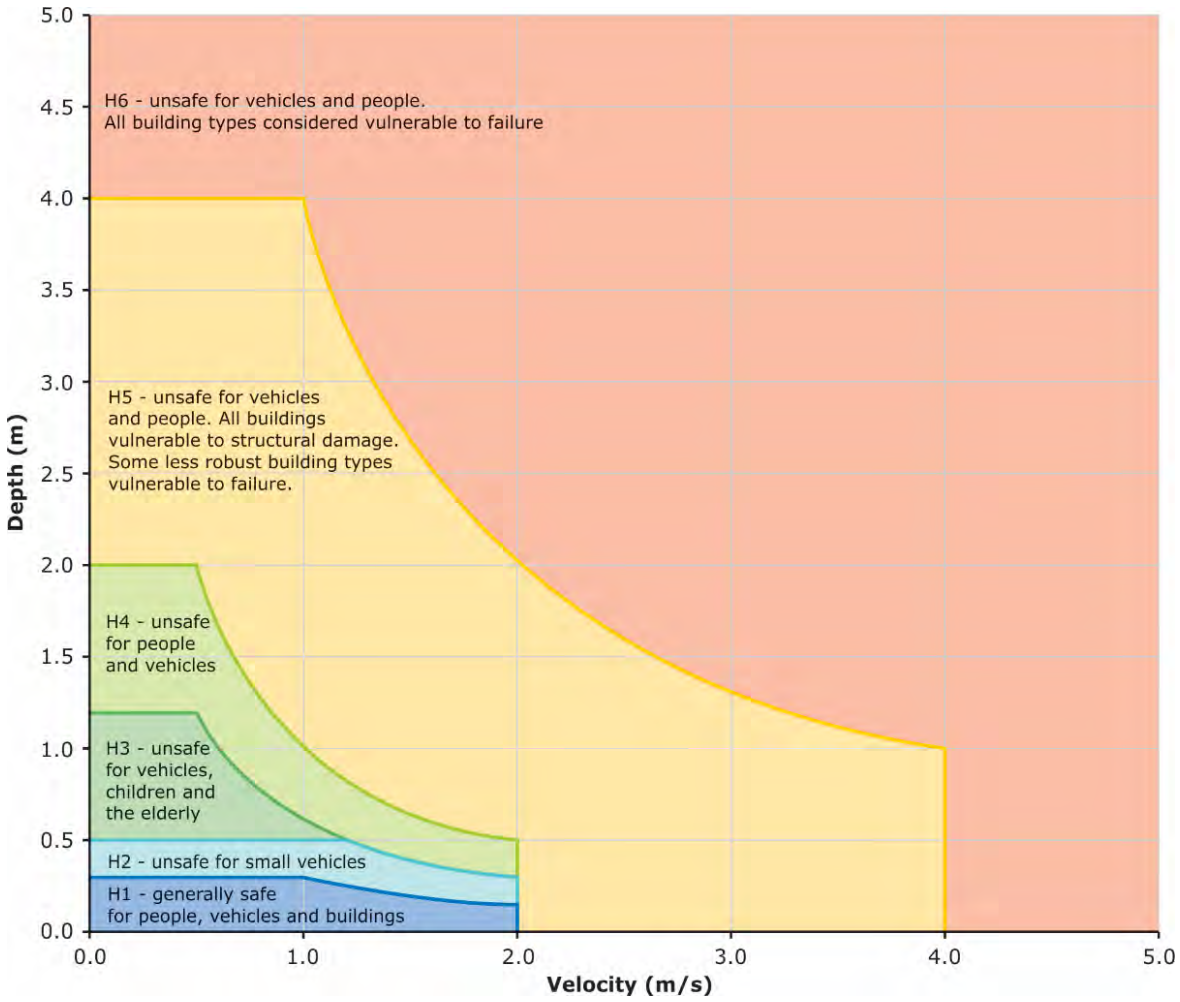

Figure 2.3 General Flood Hazard Curves, (Smith et al, 2014)

Table 2.2 below represents a summary of the benefits according to the two criteria and the ranking against the other sites.

Table 2.2 Prioritisation of mitigation works

Location	No. Properties Benefited	No. Properties >H1 hazard rating	Total Cost per property ($/property)	Total Cost per property ($/properties >H1)	Priority Rank Based on $/property	Priority Based on $/properties >H1
Sites 1 and 2	118	23	$33,900	$173,700	25	22
Site 3	5	3	$102,000	$170,000	38	20
Sites 4 and 5	63	0	$34,200	-	26	-

Location	No. Properties Benefited	No. Properties >H1 hazard rating	Total Cost per property ($/property)	Total Cost per property ($/properties >H1)	Priority Rank Based on $/property	Priority Based on $/properties >H1
Site 6	14	11	$5,100	$6,500	1	1
Site 7	10	5	$9,400	$18,800	4	2
Site 8	11	8	$28,500	$39,300	19	5
Site 9	28	2	$39,300	$550,000	28	28
Site 10	10	0	$5,300	-	2	-
Site 11	26	4	$21,600	$140,500	15	19
Site 12	100	20	$9,500	$47,500	5	7
Site 13	26	0	$12,600	$327,000	7	26
Site 14	79	21	$26,600	$100,200	18	16
Site 15 and 16	222	10	$31,600	$702,500	21	29
Site 17	91	18	$14,000	$71,000	9	11
Site 18	48	20	$15,000	$36,000	10	4
Site 19	60	27	$39,300	$87,300	28	13
Site 20	34	17	$53,200	$106,500	33	17
Site 21	10	7	$32,800	$46,900	24	6
Site 22	30	14	$29,300	$62,700	20	9
Site 23 and 25	90	28	$15,900	$51,100	11	8
Site 24	38	2	$10,500	$200,000	6	23
Site 26	156	87	$13,800	$24,700	9	3
Site 27	39	1	$19,700	$769,000	14	30
Site 28	81	26	$32,000	$99,600	23	15

Location	No. Properties Benefited	No. Properties >H1 hazard rating	Total Cost per property ($/property)	Total Cost per property ($/properties >H1)	Priority Rank Based on $/property	Priority Based on $/properties >H1
Site 29	65	9	$15,900	$114,700	11	18
Site 30	24	5	$48,600	$233,200	32	25
Site 31	12	4	$56,800	$170,300	35	21
Site 32	14	0	$56,600	-	34	-
Site 33	48	1	$16,000	$769,000	13	30
Site 34	8	1	$42,100	$337,000	31	27
Site 35	6	0	$76,300	-	37	-
Site 36	34	1	$35,100	$1,195,000	27	32
Site 37	20	6	$31,800	-	22	-
Site 38	13	7	$41,200	$76,600	30	12
Site 39	38	0	$23,800	-	16	-
Site 40	5	5	$67,800	$67,800	36	10
Site 41	79	8	$9,000	$88,600	3	14
Site 42	40	5	$25,500	$204,200	17	24

3. CONCLUSIONS AND RECOMMENDATIONS

Engeny undertook a mitigation assessment on 42 key 'hotspot' locations identified from Engeny's Moreland municipality wide flood mapping from 2017/18. These sites were selected based on the depth of flooding and were discussed with council prior to beginning the assessment.

The recommended works have been assessed and prioritised based on the cost per number of properties mitigated and the cost per number of properties mitigated with a hazard rating of H2 or higher.

Engeny recommends the following works be undertaken for those sites identified as a priority within this report that will inform Council's Drainage Improvement Plan:

- Undertake detailed hydraulic modelling of concept options to confirm the size and extent of mitigation works and assess the effectiveness.

- Discuss flood modelling results and mitigation options with Melbourne Water particularly for areas where Melbourne Water assets are downstream of proposed mitigation works. It is likely in these instances that a corresponding upgrade of Melbourne Water assets will also be required to cater for the greater piped flows from the proposed Council mitigation works, which is predominantly in the form of pipe duplication/upgrades.

Additionally, we understand Council is likely to implement a Special Building Overlay (SBO) or other building or planning controls to prevent new dwellings from being constructed with floor levels below known flood levels. This is an effective non-structural mitigation measure that will help to significantly reduce the costs and risks associated with overland flooding at all flood prone locations within the municipality.

4. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e. This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this report.

f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g. This report does not provide legal advice.

5. REFERENCES

Melbourne Water, 2016, Flood Mapping Projects Guidelines and Technical Specifications.

The State of Victoria Department of Environment, Land, Water and Planning, 2016, Victorian Floodplain Management Strategy, Chapter 14; Managing stormwater and urban flooding.