



INTERIM REPORT:

Tree collapse and bank slump investigation on Yarra River adjacent to former Amcor site at Alphington

August 2019



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1 Introduction

The City of Yarra has engaged Alluvium Consulting Australia Pty Ltd (Alluvium) to investigate recent tree collapse and bank slumping events on the Yarra River adjacent to the former Amcor paper mill site in Alphington. The subject site adjoins the right bank of the Yarra River and is the subject of an urban renewal / development project by Glenvill.

The investigation is being undertaken through an expert panel process. The expert panel convened by Alluvium comprises specialists in the fields of hydrology and fluvial geomorphology (Ross Hardie, Alluvium), geotechnical bank stability (Tim Holt, A.S. James), groundwater processes (Jon Fawcett, C.D.M. Smith), surface water management (Jonathon McLean, Alluvium) and riparian ecology (David Carew, Alluvium).

The purpose of the investigation is to:

1. Identify the causes of the bank slump and tree collapse
2. Identify any short-term actions that should be undertaken
3. Identify long term remediation measures for the site

The investigation is being undertaken in two stages:

- Stage 1 interim report (this report): A qualitative assessment based on a field inspection and review of readily available existing information
- Stage 2: A detailed investigation based on additional data collection and analysis

This stage 1 interim report comprises a summary of the qualitative assessments undertaken by an expert panel convened by Alluvium on behalf of the City of Yarra. This stage 1 interim report includes the outcomes of the five assessments:

- Groundwater investigation
- Geotechnical assessment
- Surface water management
- Riparian ecology
- Stream stability

2 Background

The subject site is located on the right bank of the Yarra River upstream of Dights Falls, immediately upstream of the Chandler Highway and adjacent to the former Amcor paper mill. The riverbank at the subject site is located within freehold land. It is understood that a 30 metre-wide riparian corridor will be secured for public access and used as a component of the proposed redevelopment project.

The riverbank at the subject site comprises a lower terrace (including walking path) adjacent to the Yarra River's water edge and a steep embankment up to the former industrial and proposed residential lands. The steep embankment was established during the period of site occupation by Amcor, to the 1% AEP (approx.) flood elevation, to prevent flood inundation of the site.

The lower terrace and steep embankment have been revegetated with non-indigenous native trees. However, the edge of the riverbank comprises indigenous river red gums, likely to be from natural regeneration.

The riverbank on the lower terrace has been subject to recent slumping. Three large river red gum trees occur within and adjacent to a recent bank slump. One of these trees has fallen into the river and is currently lying across the Yarra River. Two other trees (T1 and T2) have been identified as at risk of collapse.

Members of the local community have raised many issues with the City of Yarra concerning the bank slump and tree collapse. These issues are set out in Appendix A to this report. Appendix A sets out the extent to which this report has addressed each of the issues raised by the community and the City of Yarra.

3 Investigation methodology

This stage 1 interim report has been based on a site visit, review of available reports and surveys, and an expert panel workshop to discuss the preliminary findings, identify an agreed most likely cause of the bank slump and tree collapse, and to agree on next steps in terms of both immediate risk mitigation measures and detailed investigations.

3.1 Site visit

The expert panel conducted a 2-hour site visit including locations of sediment pond, inceptor swale drains, retention dam connections, existing outfall drains, groundwater bores, and riverbank on the morning of 25 July 2019. The site inspection was undertaken to familiarise the expert panel with the site and review the bank morphology, existing slump areas, and condition of trees along the riverbank.



Figure 1. Location of trees assessed at bank slump zone

The issue of the tree collapse and management implications is confounded by the potential presence of asbestos on the lower bank in the vicinity of the subject trees. The expert panel were advised by Glenvill that the trees at risk of collapse may need to be removed as a component of the site remediation works. However, the panel was also advised that investigations into the presence of the asbestos or otherwise was nearing completion and the final program of asbestos remediation had not been finalised.

The two trees at risk of collapse are shown in Figure 2 and figure 3.



Figure 2. *Tree (T1) and bank slump site visit by Alluvium*



Figure 3. *Tree collapse (T2) at the edge of bank slump*

3.2 Data review

The expert panel has undertaken a review of available information and that information and the site inspection have formed the basis of this interim report.

Table 1. List of reports reviewed for interim report

Name of the report	Author	Year
Yarra River Northern Bank Slump / Erosion and Tree Toppling Instance	Douglas Partners	July 2019
Arboriculture assessment, Yarra Bend riverbank trees	Trees Department Pty. Ltd.	July 2019
Assessment of River Red Gums along the Yarra River, Alphington: Risk Assessment	Ryder Arboriculture and Environment	July 2019
Memo Yarra River bank subsidence – Amcor site	City of Yarra	June 2019
Arboriculture Report: APM Site - Heidelberg Road Alphington	Tree Radar Australia Pty Ltd	June 2019
Construction Management Plan	Glennville	October 2017
Integrated Quality, Health & Safety and Environmental Plan <ul style="list-style-type: none"> • Environmental Management Plan <ul style="list-style-type: none"> ○ Stormwater design drawings ○ Drain drawings 	CSC Civil Constructions	October 2017
Yarra River Flood Mapping Hydrological and Hydraulic Study	S P Goh and Associates	June 2016
HECRAS 1 Dimensional Hydraulic Model	Melbourne Water	Not dated
Geotechnical Investigation: Civil Works	Douglas Partners	June 2016
Groundwater Beneficial Use Impact Assessment	GHD	May 2016

3.3 Preliminary memo and Council meeting

Alluvium prepared and submitted a preliminary memo to City of Yarra (dated 29 July 2019), providing a preliminary site overview, site specific comments, and short-term management implications. The memo was based on the site inspection and review of risks of further tree collapse. The expert panel was of the opinion that:

- The bank collapse is most likely associated with an increase in groundwater levels and lubrication (of soils) at the site
- There are limited practical management interventions that can be applied, that will have an immediate impact on the groundwater that is causing the bank collapse (note that this wording has been refined by the Expert Panel to reflect the intent of that set out in the memo dated 29 July 2019)
- Ongoing bank collapse (instability) will continue to occur at the site until groundwater issues are addressed
- The bank instability threatens large trees on the riverbank. Two of these trees have been the subject of four recent arborist reports and were the main focus of that memo.

Two trees, referred to as T1 and T2 were identified at imminent risk of collapse. The outcome of the arborists reports on those two trees is set out in Table 2 below.

Table 2. Summary of Arborist report recommendations and updated Alluvium recommendation

Arborist report	Company	T1	T2
#1	Tree Department Pty Ltd (11 th July)	Removal recommended Unacceptable risk to cause harm and costs	Removal recommended Tolerable risk to cause harm – unacceptable risk due to costs post failure
#2	Ryder Arboriculture and Environment (12 th July)	Tree is likely to fail in short term (Weeks to months) Permit required for removal Assessed as Low risk to cause harm <i>Note: shown as T2 in report</i>	Tree is stable unless ground moves. Permit required for removal Assessed as Low risk to cause harm <i>Note: shown as T1 in report</i>
#3	Tree Radar Australia (2 nd June)	Removal recommended Safety risk and reduce further damage	Removal recommended Safety risk and reduce further damage
#4	City of Yarra (3 rd June)	Retain if possible. Monitor for movement. (Note: the arborist was not qualified to comment on the stability or otherwise of the tree)	Retain if possible. Monitor for movement. (Note: the arborist was not qualified to comment on the stability or otherwise of the tree)
	Alluvium summary	Remove tree Tree is on unstable ground within an active slump zone. This tree is likely to fall and cause further damage to the bank.	Retain tree and monitor ground stability. Tree is outside the active slump zone and is not imminently likely to fall unless further slumping occurs.

Following development of that memo, Ross Hardie (convenor of the Alluvium expert panel) attended a City of Yarra councillor briefing on 29 July and a City of Yarra Council meeting on the evening of 30 July 2019.

This memo was followed by a subsequent memo from Alluvium to City of Yarra dated 12 August 2019 that provided additional information and recommendations for the management of T1. This memo recommended urgent attention to fell T1. A copy of the memo is appended to this report. Tree T1 was felled on Friday 16 August 2019.

3.4 Expert panel workshop

On 1 August, Alluvium convened an expert panel workshop to discuss initial findings and strategies to finalise interim report. John Ghasperidis from City of Yarra also attended the workshop. During workshop, each expert presented their findings for 10 minutes followed by 5 minutes discussion. During the last session, the panel concentrated on following three key areas:

- Causes of the bank slump and tree collapse
- Short-term actions that should be undertaken
- Detailed investigations required to confirm the cause of the bank slump and to identify appropriate management measures

The findings of the expert panel members are set out in the appendices to this interim report have been summarised and discussed in section 4 of this interim report.

4 Discussion: Potential mechanism causing the bank slump

The expert panel considered a range of potential causes of the bank slump and tree collapse ranging from surface water, ground water, stream erosion, geotechnical issues, and riparian ecology.

4.1 River erosion

Discussions with Melbourne Water suggest that the bank slumping is concentrated at the subject site. A review of the existing hydraulic model for the Yarra River revealed the forces on the subject bank to be not dissimilar to other sections of riverbank and below the thresholds for scour of the bank material at the subject site, comprising clayey material with a matting of root material from the riparian vegetation .

Based on the information available for this assessment, we are of the opinion that the subject reach of stream in the vicinity of the proposed site is not likely to be undergoing accelerated rates of channel erosion that would have led to the bank collapse. However;

- The recently slumped bank material will be vulnerable to loss by erosion processes
- Further tree collapse will result in the loss of further bank material
- Further investigations will be required to confirm this assessment

The detailed analysis is presented in Appendix F to this report.

4.2 Tree collapse as a cause of bank failure

The site inspection revealed slumped material around the base of the existing tree collapsed across the Yarra River. Further T1 at risk of collapse is also in slumped material. T2 lies in intact material. There is no evidence tree collapse is driving the bank instability.

However, as set out above, it is likely that any further collapse of trees (arising as a result of other processes at work) will result in the further loss of bank material.

4.3 Increased soil moisture

Based on the site inspection and review of available information, the expert panel is of the opinion that the bank slumping and tree collapse are most likely the result of increased soil moisture in and on the lower terrace of the riverbank. The opinion is based on a number of factors including:

Presence of surface expression of soil moisture on the lower terrace

The site inspection revealed considerable surface expression of water in and on the lower terrace. Water was found in two soaks and was observed in recently slumped material adjacent to the water edge.

Vegetation on and adjacent to the lower terrace

The expert panel noted the poor condition (and death) of some of the introduced vegetation on the lower terrace and lower levels of the steep embankment. While a decline in vegetation condition could be the result of many factors, it is consistent with the elevated groundwater levels.

Further the panel noted the absence of wetland dependent vegetation in the areas of groundwater surface expression. The absence of wetland dependent vegetation suggests that the presence of water is unusual and out of character for the site.

Colour of soil

A preliminary review of the colour of the soil in the lower terrace suggest that the presence of water is a recent phenomenon and not consistent with long term presence of water in the soil material (refer Appendix B).

4.4 Cause of changes in groundwater

The site inspection and review of the available information suggests that the cause of changes to groundwater at the site is linked to the changed land and water management at the site. The panel has found no evidence that changes in groundwater and any subsequent bank slump and tree collapse were the result of any deliberate intent.

There is substantive evidence to suggest that the changes to groundwater levels in the lower terrace could be the result of increased surface water infiltration at the site. The evidence includes:

- **Sedimentation ponds**

The environmental management plan for the site provides for the diversion of runoff via swale drains and the containment of sediment laden runoff into sediment ponds. The environmental management plan provides for site surface runoff to be delivered to the sediment ponds to be stored and reused and any surplus water to be managed through evaporation and infiltration.

The expert panel noted the presence of water contained in the first two of a series of sediment ponds, following a rainfall event. However, the panel noted the absence of water in the third and final sedimentation pond located closest to the river. The absence of water in the sediment pond closest to the river suggests that water arriving at this pond is infiltrating into groundwater. The panel is aware that this series of sedimentation ponds are no longer in use and that stormwater is now diverted to an alternate sedimentation pond to the west of this series of ponds.

- **Health of trees in car park**

The expert panel also noted the presence of eucalypts within the existing gravel car park located at the top of the steep embankment on the east side of the subject site. Review of aerial photography reveals the subject carpark to be covered by a concrete hardstand up until 15 May 2014. This hardstand has been converted to a gravel area. These eucalypts were observed to be approximately 5 metres in height. We estimate that these trees have grown at a rate of approximately 1 metre per year. This rate of growth is consistent with loose, well drained soils.

- **Weathered / fractured basalt**

The proposed development is underlain by basalt. The Yarra River lies at the edge of the basalt. Geotechnical investigations (Attachment B: Geotechnical Investigation) have found this basalt to lie between 3-8 metres below the land surface. The geotechnical investigations for the site found the upper layers of the basalt to be weathered and fractured. Multiple paths will exist for any elevated groundwater under the site to move through the fractured basalt, toward the Yarra River and lower terrace.

Other factors that could have led to changes in the groundwater levels include, natural processes, changes to sewer mains and the installation of stormwater drainage systems.

- **Natural processes:** We have not found any compelling evidence to suggest that the rise in groundwater is associated with natural process such as an increase in regional groundwater levels associated with any increased rainfall. The information currently available to the expert panel suggests that the issues are isolated to the subject site and has occurred over the period of recent changes at the site. The last 4 years have not been unusually wet (refer Figure 4) and it would be highly unusual for such a localised groundwater issue to be linked to broader scale natural processes.

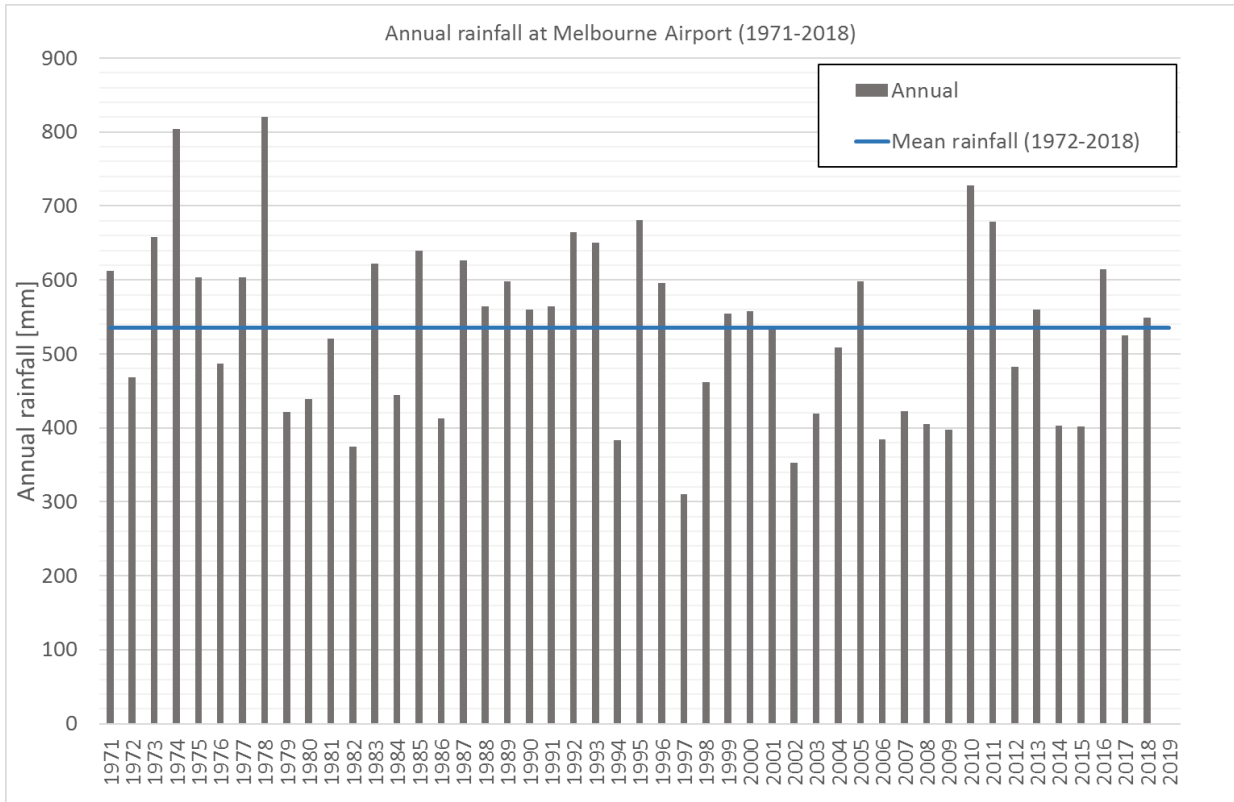


Figure 4 Rainfall records for Melbourne Airport 1971-2018

- Sewer main decommissioning:** We understand that a sewer main, close to the subject bank, has been recently decommissioned and infilled with grout. The location of the sewer main is shown in Figure 5.

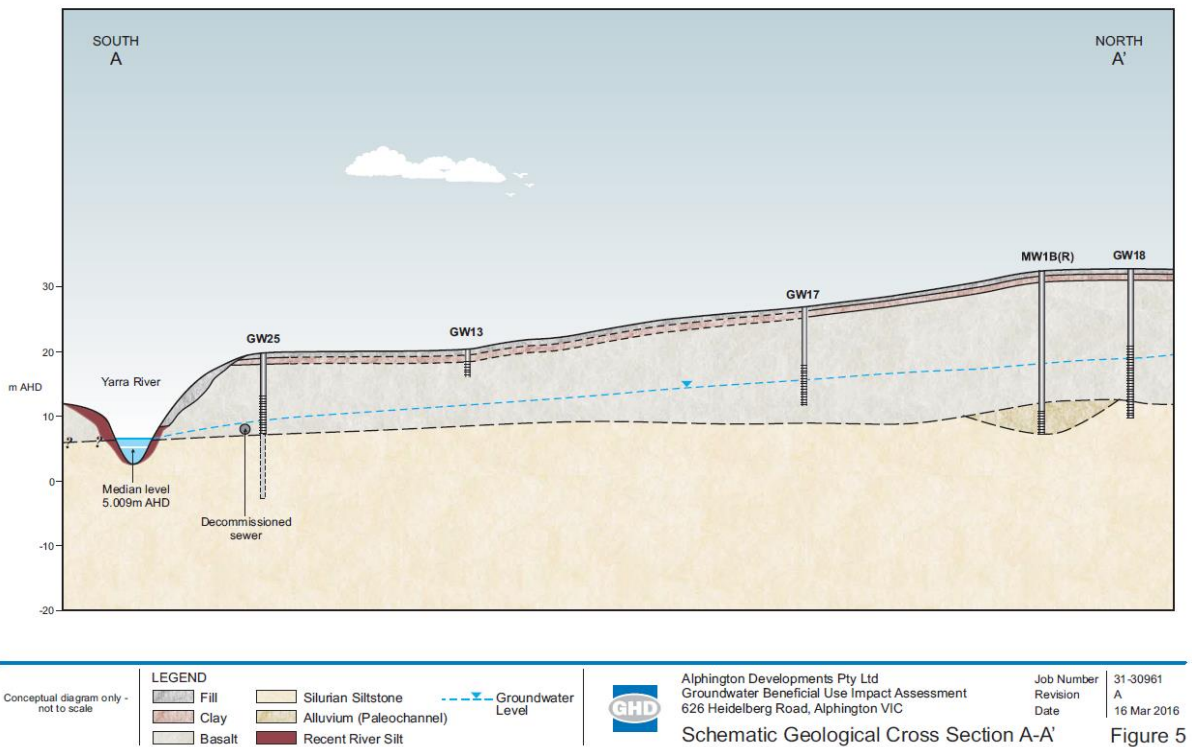


Figure 5 Cross section of the subject site including location of decommissioned sewer main (source GHD 2016)

Old sewer mains can be 'leaky' and can intercept and collect groundwater. It possible that;

- this sewer main, prior to its decommissioning, may have intercepted local groundwater and created a local drawdown in groundwater levels'
- the grouting of the sewer main have resulted in the loss of this drainage path and created a resultant rebound and increase in groundwater levels.

We understand that the grouting of the sewer main occurred over a wider extent than the subject site. While we cannot completely discount this pathway, the mechanism does not accord with the observed groundwater impacts being limited to the subject site. This potential mechanism should be investigated in the more detailed stage 2 investigations.

- **Stormwater drainage system:** A newly constructed stormwater drainage system has been installed on the east side of the development site. The underground pipe system would be typically installed within a trench with a sand or crushed rock base and partial or full backfill material. This bedding and partial backfill material would typically assist to drain and lower groundwater levels rather than contribute to an increase in groundwater levels. While a failure of a new stormwater drainage system, such as a breakage of the pipe network could lead to increased groundwater levels, this is unlikely to be the cause of the issues at hand.

In the absence of more detailed assessments, the expert panel has not been able to:

- confirm the extent of changes in groundwater levels and the source of such groundwater, or
- estimate the rate of groundwater movement through the site. The expert panel estimates that the movement of water from the surface (or any other source) through to exposure in the lower terrace could take weeks, months or years.

However, based on the information available, the expert panel is of the opinion, that the most likely source of the elevated groundwater is a change to the rate of surface water infiltration at the subject site. This process is illustrated in Figure 6.

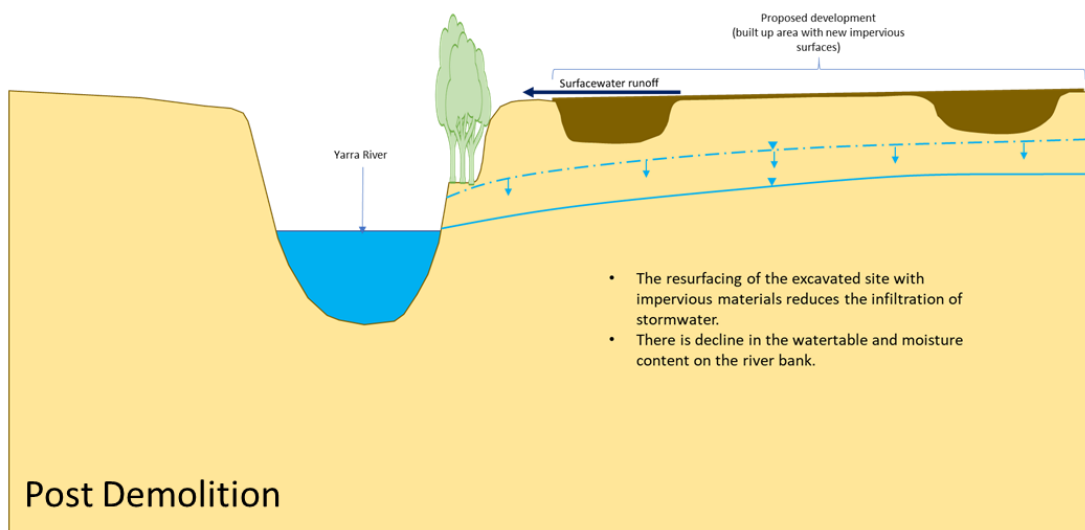
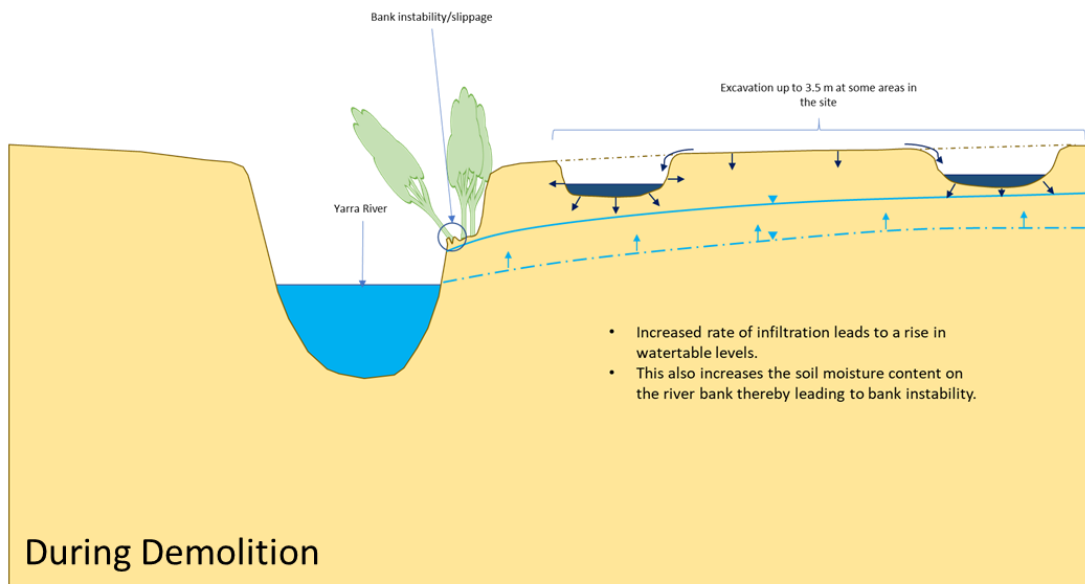
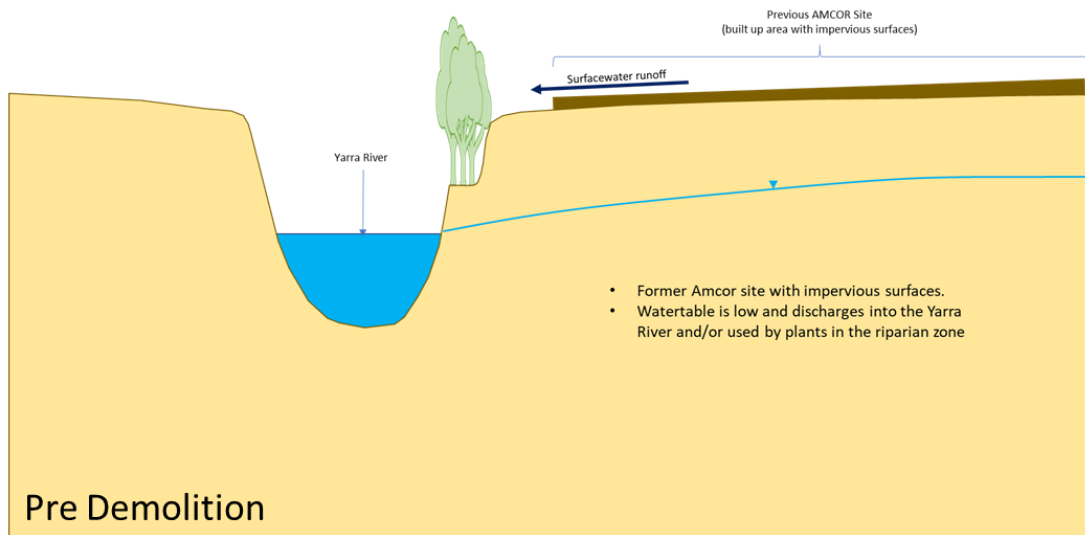


Figure 6 Conceptual model of possible changes to groundwater levels at the subject site (source CDM Smith refer appendix B)

5 Management implications

Based on the site inspection, advice from Glenvill, preliminary review of information, and expert panel assessment, the expert panel has developed a set of short term (interim) measures to manage the risks associated with bank slump and tree collapse. In addition, the expert panel has developed a set of further detailed investigations to confirm and or dismiss the opinions set out in this interim report and to form a basis for longer term management of the bank slump and tree collapse.

5.1 Short term risk mitigation

While the expert panel cannot be certain on the causes of the bank slump and tree collapse there are short term measures that can be undertaken that would not adversely impact on the bank stability and vegetation and may reduce the risks of these events.

High groundwater levels and bank slumping

Likelihood: As set out in this report there are limited mechanisms that can reduce the immediate risk of further groundwater induced bank slumping. None the less, and without pre-empting the outcomes of more detailed investigations, immediate efforts should be put in place to reduce surface water infiltration at the site. This should include

- sealing of existing abandoned and new sediment control ponds and
- reduction in groundwater infiltration from the existing gravel carpark adjacent to the steep embankment at the east of the subject site.

These works should be undertaken within the context of an interim site surface water management plan for the site. Issues that will need to be addressed include management of surplus site stormwater runoff including approvals for any off-site water disposal if and as required. The development and implementation of an interim surface water management plan for the site should be undertaken as a matter of priority.

In addition, and subject to work health and safety constraints, we propose the infilling of the slump tension cracks on the lower terrace with a suitable material to reduce direct water entry to cracks and slumped material.

Dewatering of groundwater may be an appropriate strategy for the site. However, the panel is of the opinion that such pumping will require more lengthy assessment, design approval and implementation and may not be achievable within the short-term scale of the interim site surface water management plan.

The development of an active groundwater pumping program will require investigations into:

- the quality of such groundwater and the mechanisms for disposal and
- the most appropriate locations for the installation of bores and pumps for the subsurface dewatering (refer detailed) investigations

The expert panel is of the opinion that the development and implementation of an interim surface water management plan should **not** be held in abeyance pending the outcome of investigations into and approval of a groundwater pumping program.

The panel has also considered alternate means to reduce the likelihood of bank collapse through structural reinforcement. We are concerned with the use of large equipment on the lower terrace to install bank protection works while the site is at risk of further slumping. The use of large machinery, with accompanying surcharge and vibration could increase the likelihood of collapse and may pose a work health and safety risk for operators. It may be possible to install bank protection works from the river by barge. However, such works including sheet piling and or rock beaching may not be successful and may have unintended longer-term

consequences. While we don't support the use of sheet piling at the site, there may be some benefit in the use of rock beaching to protect against the erosion of recently slumped material. Such rock beaching may also assist to prevent further bank slumping. The suitability of rock beaching at the site should be the subject of more detailed stage 2 investigations.

Consequence: The consequence of bank slumping includes the loss of further trees at the site and the further loss of the lower terrace and walking path. There are limited practical measures that can be put in place to reduce the short-term consequence of further bank collapse. However, the panel does recommend that the bank be photographed and surveyed as a record of condition, to enable repair and management into the future.

Tree collapse

Further tree collapse poses risks to public safety and to the existing walking track and streambank.

Likelihood: The likelihood of tree collapse can be reduced by reducing the groundwater levels and risks of bank slumping.

The likelihood of tree collapse can also be reduced by

- removal of trees at risk. Tree T1 has now been felled. We propose that Tree T2 be the subject of a regular (weekly minimum) monitoring program.
- Reducing access of air to the root zone of remaining trees. This can be achieved by infilling tension cracks.

Consequence: The expert panel supports the continued closure of riverbank pathway to public access as a means to reduce risks to the public. Additional warnings may also be required on the existing fencing and at the site of the existing bank slumps. In addition, the expert panel recommends the installation of safety signs to warn river users of dangers and the installation of buoys to guide boat traffic away from the subject bank and toward the opposite side of the river. The installation of such signs and buoys should be undertaken as a matter of priority. These warning and safety measures should be retained until such time as the bank slump and tree collapse issues are resolved.

Summary immediate and short-term management actions

Recommended immediate and short-term actions set out in the memo dated 29 July 2019 have been updated and are set out below:

- Public safety
 - Continue to restrict public access to the site including installation of additional signage.
 - the installation of safety signs to warn river users of dangers and the installation of buoys to guide boat traffic away from the subject bank and toward the opposite side of the river.
- Tree removal
 - T1: The fallen tree T1, be considered for installation as instream large wood habitat at the subject site
 - Tree T2: This tree has not received majority support by Arborists for removal. The tree appears to be outside the zone of the existing tension cracks. We suggest that the tree not be removed until;
 - such time as it is observed to lie within tension cracks, and or
 - results of contamination land assessment are complete, a remediation plan approved and the necessity for the removal of the tree as part of any such remediation plan is confirmed.
- Monitoring

- Photography:
 - Installation of photo monitoring sites
 - Photography of the existing trees at the site as a record of the current riparian vegetation for the site. This record can form a component of the dilapidation survey and can inform the future vision for the site and ultimate landscape plan.
- Dilapidation survey: We recommend that a dilapidation survey be undertaken immediately. The survey should include
 - Feature survey by a qualified surveyor to locate the extent of existing bank slumps, soaks and trees on the riverbank, lower terrace and steep embankment. This survey should be tied to the Australian Height Datum and GDA 2020. This survey could be combined with a wider topographic survey for the site (refer detailed investigations)
 - Site photography as set above and as required to assess changes to the extent and scale of bank slumping
 - Tree health and condition assessment. This should include all trees with a diameter at breast height greater than 200mm within 30 meters of the riverbanks.
 - Tree tilt monitoring.
- Installation of temporary benchmarks to monitor bank movement.
- Weekly monitoring (minimum) of the slump area and trees to determine if the conditions change and increase the likelihood of the trees collapse.
- Surface water management: The development, approval and implementation of an interim site surface water management plan for the former Amcor site that reduces surface water infiltration. Short term actions included in that plan should be focussed on reducing surface water infiltration including
 - the sealing of existing and proposed sedimentation ponds and
 - the management of surface water infiltration (and/ or interception of infiltrated water) from the gravel carpark adjacent to the steep river embankment at the eastern side of the site.

The plan should include consideration of alternate disposal mechanisms including water quality assessments and any necessary approvals.

- Infilling of tension cracks: Subject to work health and safety constrains, infill the tension cracks on the lower terrace with suitable material to prevent direct access of water to the cracks and air to the root zone.
- Groundwater pumping: Assess feasibility of groundwater extraction to reduce groundwater impacts on the lower terrace and riverbank. (refer detailed investigations below).

5.2 Detailed investigations into the causes and remediation of the site

The expert panel has proposed a set of detailed investigation to determine the cause of any elevated groundwater, the bank slump and tree collapse. The scope of investigations is concentrated on the issues of surface water ground water interactions and the geotechnical stability of the embankments at the site. The proposed investigations are set out in Table 3.

The investigations include some further bank stability assessment to confirm (or otherwise) the anecdotal evidence provided by Melbourne Water that the subject slumping is limited to and or concentrated at the subject site.

In addition, the investigations should include riparian ecology, surface water, and waterway management assessments to inform and assist development of an integrated long plan of management for the site.

Table 3: Proposed detailed investigations

Item	Proposed detailed investigations
Site survey	<ul style="list-style-type: none"> • Topographic survey of the subject site • Bathymetric survey of the Yarra River adjacent to the subject streambank
Groundwater management	<ul style="list-style-type: none"> • Identify source of water <ul style="list-style-type: none"> ○ Install up to 12 groundwater bores to assess soil material, water elevations, water quality and geochemistry, comprising <ul style="list-style-type: none"> ▪ 4 x lower terrace (may be possible to use 2 x existing bores) ▪ 4 x upper terrace adjacent to steep embankment (30m approx. from riverbank) ▪ 4 x sites 100 metres (approx.) from riverbank as close as possible and practicable to the location of previous bores ○ Assess age and origin of groundwater expression in lower terrace by geochemical testing of <ul style="list-style-type: none"> ▪ Surface water ▪ Groundwater through existing and proposed bores. ○ Develop preliminary groundwater model • Check feasibility of groundwater pumping. <ul style="list-style-type: none"> ○ Confirm sources and age of water ○ Design groundwater pumping if and as appropriate ○ Initiate EPA approval process if and as required.
Geotechnical stability assessment	<ul style="list-style-type: none"> • Undertake soil permeability testing • Undertaken slope stability analysis • Identify alternate management arrangements based on alternate groundwater and river management options
Stream stability assessment	<ul style="list-style-type: none"> • Reach scale bank stability assessment • Hydrologic assessment • Hydraulic assessment • Identify complementary river management options
Surface water management	<ul style="list-style-type: none"> • Identify mid to longer term surface water management strategy reflecting outcomes of groundwater and geotechnical assessments
Riparian vegetation assessment	<p>Undertake assessment of trees and vegetation in the proposed waterway reserve to gain baseline data on condition of the riparian vegetation.</p> <p>Tree assessment – all trees >200mm DBH to be mapped and assessed:</p> <ul style="list-style-type: none"> • <i>Botanical name</i> • <i>Estimate age, measure size (BDH and height)</i> • <i>Health - vigour</i> • <i>Structural assessment of trunk and branches</i>

- *Visible surface roots*
- *Ground stability observation (soil cracking and heaving)*
- *Location in reserve (e.g. river bank, terrace, embankment)*
- *Tree significance*
- *Origin of tree (planted, natural germination)*
- *Age class and estimated life expectancy*
- *Comments*

Vegetation assessment within proposed reserve.

- *Reference EVC comparison*
- *Number of trees and % cover*
- *Shrub layer % cover*
- *Native vs exotic cover*
- *Ground flora % cover*
- *Native vs exotic cover*
- *Areas impacted by waterlogging.*

Different vegetation groups to be mapped:

- *Indigenous trees (E.g. Eucalyptus camaldulensis - River Red Gum.*
- *Native non-indigenous trees (e.g. Casuarina cunninghamii, Eucalyptus sp, Grevillea robusta)*
- *Indigenous shrubs and ground covers – (e.g. Melicytus dentatus, Poa, Lomandra*
- *Exotic trees with amenity value – (e.g. Quercus sp - Oaks)*
- *Exotic trees*
- *Exotic ground cover*

Riparian management

- Identify mid to longer term riparian management options based on outcomes of vegetation, groundwater and geotechnical assessments

Integrated solutions

- Development of integrated mid to long term management options and arrangements for the site reflecting the outcomes of geotechnical, groundwater, surface water, riparian and waterway management assessments
-

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Appendix A: Issues raised by the community

Item.	Comments	Alluvium Response
1.	Investigate & address the water source seeping from the ground & running over the pathway	Interim report has addressed the most likely causes based on review of vegetation, surface water, groundwater, geotechnical, and stream stability.
2.	Test the water to confirm it is not contaminated	While the quality of groundwater is an important issue to address, this is not the primary issue to be resolved for the management of groundwater. None the less, issues of groundwater quality will need to be resolved to manage any groundwater discharges arising from interventions to manage the site. The proposed scope for the detailed Stage 2 investigations includes some water testing to determine the age of groundwater and hence likely sources of groundwater impacting on the lower terrace.
3.	Test for contamination the water in the storm water catchment ponds just above the area where the riverbank has collapsed	Quality of water to be assessed by others for the purpose of surface water disposal. However, the quality of groundwater is not the focus of the site stability assessment.
4.	Confirm the stormwater catchment pond design is sufficient for the application & not the cause of the problem.	Interim report recommends urgent development and implementation of an interim Surface Water Management Plan to manage surface water including the quality of stormwater discharges from the site.
5.	Confirm the stormwater runoff & pond design meets with the requirements of the Environmental Statement, given the site was full of asbestos material	Interim report recommends urgent development and implementation of an interim Surface Water Management Plan to manage surface water including the quality of stormwater discharges from the site.
6.	Investigate (independent) & report on what can be done to save the remaining trees from falling in the river	The issue of the existing trees has been covered in two separate memos dated 29 July and 12 August. Further works to protect the existing trees have been included in the recommendations of this report and in the outcomes of detailed investigations
7.	Report back on a timeline to action this plan	Proposed that this timeline be developed by City of Yarra following review of this report
8.	Provide timeline on how long the path will be closed to the public	The pathway will need to remain closed until such time as safe public access can be provided. This may not be possible until the groundwater levels are returned to pre-existing conditions and the health and safety of the trees confirmed by an arborist.
9.	Proved feedback on an alternative path bypassing this area but allow public access to the Chandler Highway & Coates Park	Alternative access to be explored by Council in conjunction with Glenwill. Interim access issues are not addressed by the investigation into the stability of the bank.

10.	<p>The memo states that the bank slumping is due to higher groundwater levels but does not state the cause. I think it is important to investigate this further. Groundwater typically rises and falls with the seasons so you can sometimes get above average groundwater for short periods of time during heavy rainfall however it is quite obvious that the groundwater is now constantly at a higher elevation due to the storage ponds within the AMCOR site that have been constructed as part of the temporary works. This needs to be rectified irrespective of whether the tree is retained – otherwise more trees may be at risk. I don't understand why none of the reports are commenting on these storage ponds?</p> <p>They do mention under Section 6.1 that an investigation into soil moisture should be done – I think this should definitely be done and in the meantime I think there is sufficient evidence to make AMCOR empty those storage ponds.</p>	<p>These causes have been investigated in the Stage 1 Interim Report. Recommendations have been made regarding management of stormwater treatment facilities and other measures to limit surface water infiltration at the site</p>
11.	<p>Section 4.4. states that the root ball can still provide some stability to the bank even if the tree is removed. I am not sure about this because if the tree is removed, all the roots will die, creating 'gaps' where the dead roots use to be in the batter – this will create voids and loose material and is unlikely to provide additional support.</p>	<p>While it is acknowledged that the tree roots will die. They will continue to serve, albeit declining, benefit into the future</p>
12.	<p>Section 5.2 states that the bank is active and movement is continuing – why are they not making the developer empty the storage ponds! This would lower the groundwater and reduce the risk of further slumping!</p>	<p>This issue has been addressed in the Stage 1 Interim report,</p>
13.	<p>I think they should explore rock armouring further. They mention that rock slumping can still occur because the material can fall between the rocks but you can design against this. You can layer small rock adjacent to the bank and then progressively enlarge the rock to provide a well graded protection layer. You can also include layers of geofabrics, gabion baskets etc which can all be placed from the barge above and below water levels.</p>	<p>The use of rock beaching has been discounted as a short-term solution. This intervention will be explored as a component of the detailed Stage 2 investigations.</p> <p>Note: Rock beaching can impact on available instream near bank / undercut bank habitat. This issue can be mitigated to some extent with the provision of alternate near bank aquatic habitat. The issue will be considered in the development of options for the site within the detailed stage 2 investigations</p>
14.	<p>I think sheet piling is also a good option that they shouldn't discount without further investigation. They comment that it is not attractive but you could drill the sheet piles within the batter, providing structural support below the surface so it is not visible. Alternatively you could construct the sheet piling only along the lower portion of the bank (where the slip circle is located for the slumping) so that it is all below the water level (and would only be visible under very dry summer periods when the river level is extremely low). The other benefit of sheet piling is that it can be a very fast process, is often done via a barge so could be a quick solution for us.</p>	<p>The use of sheet piling has been discounted as a short-term solution. This intervention will be explored as a component of the detailed Stage 2 investigations</p> <p>Note: Sheet piling impacts on available instream near bank / undercut bank habitat including burrowing habitat for platypus. This issue will be considered in the development of options for the site within the detailed stage 2 investigations</p>
15.	<p>The three options they propose have the primary focus on the tree itself. All the appurtenant works surrounding this tree are a bit vague which is concerning because I think that they really need to start some rectification works to the batter ASAP</p>	<p>The interim report addresses the most likely cause of the issue and provides recommendations to reduce risks and for detailed investigations to confirm processes and identify preferred management responses.</p>

16.	Chemical analysis of water infiltration to determine source	Scope of work for stage 2 detailed investigation includes water testing to identify source of the groundwater.
17.	An assessment be conducted by Alluvium for an alternative solution that will enable preservation of the tree	A separate memo has been developed and submitted to council on 12 th August that addresses Tree T1.
18.	Weekly monitoring of the slump area and trees occurs to determine if conditions change and increase the likelihood of trees falling; (please clarify method - photographs and/or sensors?)	A recommended monitoring program has been recommended and submitted to Council. That monitoring program is described in the interim report.
19.	Remediation works that could be considered to prevent further deterioration of the riverbank and/or further loss of trees in this area	The interim report includes recommendations to prevent further bank slump and loss of trees.
20.	Have the swale drains and settlement ponds been built to standard <ul style="list-style-type: none"> • Are they located where they will not cause detriment in future once filled in? • Is the current permeability adequate/appropriate? • Consideration of consequences of infiltration to riverbank stability and possible migration of contaminants • Capacity to cater for annual anticipated rainfall • What is required of the developer in regard to constructing to standard, and what is Council's obligation to ensure that this is done. 	Interim report recommends urgent development and implementation of an interim 'Surface Water Management Plan' to manage surface water runoff, water quality treatment and infiltration at the site.
21.	Is Glenvill's environmental management plan adequate? What are the gaps.	Appendix D of the Interim report identifies shortcomings of the stormwater management arrangements developed under 'Environment management plan'.
22.	Are the newly constructed stormwater drains contributing to the problem	The interim report identifies the most likely sources of water than are contributing the groundwater issues on the lower terrace. While the new stormwater drains may be a factor, the broad extent of the slumping suggests that broader processes are at work
23.	Remediation measures for all of above.	Stage 1: Interim report provides recommendations for short term interventions to reduce site risks and the scope of work for detailed Stage 2 investigations to develop a more comprehensive management approach for the issues.
24.	What were/are the sampled AHD of GW24 and GW25 through 2018 and 2019.	Information is currently not available; we will seek further information from GHD if and as available
25.	Both audits were carried out in summer, what are the levels in winter or after rain? (The two trees fall events were preceded by heavy rains in the previous month)	Information is currently not available; we will seek further information from GHD if and as available
26.	Other groundwater wells to the north of Area 6A show reductions in levels between 2016 and 2017. Does this suggest there are bypass channels?	We don't recommend use of single borehole information without the context of a wider assessment of the processes at work. We currently only have information to 2016 and will seek to access more recent information for the purpose of the detailed Stage 2 investigations

27.	In the report Appendices GHD Figure 5 Schematic Geological Cross Section A-A. shows a clay layer above the Basalt layer through which the groundwater flows. With the remediation works clearing the site is there now greater seepage and subsequent salutation of the Basalt layer?	The removal of the clay cover over the fractured basalt is a potential pathway for increased surface water infiltration at the site. The extent to which this is the cause of the elevated groundwater levels in the lower terrace can only be resolved with the detailed stage 2 investigations as set out in the interim report
28.	Has having sedimentation ponds (uphill of groundwater flow direction) north of area 6A through which water seeps out contribute to the increase of the groundwater level in Area 6A?	The installation of infiltration ponds as part of the construction phase stormwater management is a likely pathway for increased surface water infiltration at the site. The extent to which this is the cause of the elevated groundwater levels in the lower terrace can only be resolved with the detailed stage 2 investigations as set out in the interim report
29.	Post development completion will the groundwater levels be at or below the pre-development levels? (On basalt aquifers elevated above the river back there should be no stormwater storage in porous basins relying on ground seepage to remove the stormwater.)	This can only be determined following the completion of the detailed stage 2 investigations. However, it is expected that the establishment of a stable lower terrace will rely on the return of groundwater levels to pre urban development levels.

Appendix B: Groundwater assessment

Subject	Groundwater
Distribution	Alluvium Consulting (Internal)
Date	15 August 2019
Author	CDM Smith. Dr Jon Fawcett
Project number	1000515
Project	Yarra River Riverbank Tree Collapse Review and Investigation, Alphington

Introduction

This memo provides an independent, initial assessment of the role groundwater may play in several riverbank collapses that are occurring along the Yarra river, directly adjacent the former Amcor Paper Mill. The former Amcor Paper Mill site is located on the corner of Heidelberg Road and Chandler Highway in Alphington. It covers about 16.5 hectares of land. The site was acquired by Alphington Developments Pty Ltd for redevelopment (referred to as Glenvill hereafter). As part of the redevelopment process, the facilities used by Amcor were demolished between 2014 and 2016. After the demolition and other earthworks, at least two subsidence and tree toppling events have occurred on the Yarra River bank between the Yarra River and the former Amcor site (now Glenvill site).

The outcomes of this memo will be used as expert advice for the Yarra City Council, in regard to describing the technical objectives/outcomes intended for future works. This memo provides additional context to better understand:

- 1) The role groundwater plays in the initiation and ongoing movement of the landslides, and
- 2) Groundwater aspects of potential future management actions.

The underlying assumption that is being tested in this memo is that works undertaken at the site have, to some degree, altered groundwater conditions and thus contributed to the cause of the landslides. In order to assess this assumption, this memo outlines a brief summary of the chain of events, based on different stakeholders' perspectives, a summary of available groundwater data, and an initial hypothesis of groundwater processes in relation to the landslides and additional works required to clarify and quantify these processes.

Site inspection and data review

An important first step in understanding the role of groundwater is to gain an appreciation of the timeline of events since the site re-development began. The following provides a summary of different stakeholder's interpretation of the sequence of events and cause of the riverbank collapse.

- 1) (based on Travers Nuttall email exchange with Yarra City Council - TN email to BP 190123.pdf in the City of Yarra Folder)**
 - Pre-1 January 2019: A tree toppled over into the Yarra River when there was "subsidence" on the riverbank.
 - 4 January 2019: Yarra City Council notifies Glenvill of seepages and cracks occurring on the riverbank.
Glenvill considered it is to be a result of natural water seepage due to the highly modified site conditions within the past two years.
 - 7 January 2019: Civil engineering firm (CSC Civil, engaged by Glenvill) visited the site. CSC Civil noted the following:

- The location where seepage is occurring is well away from where the bank collapsed. The bank failure is likely as a result of natural river process. The bank at this location had failed in May 2017, although there was no seepage.
 - The location where the tree had collapsed is about 3 – 5 m from where the seepage has occurred. The over-saturation of the soil during the previous wet months of November and December 2018 is believed to have caused high bank soil saturation and/or bank erosion.
 - The third location where there is evidence of “subsidence” on walk paths has no evidence of seepage. Natural bank erosion is believed to be the cause.
 - At the Glenvill site, up to 3.5 m of earth have been removed from some places (on the Lugton St side). As the Lugton St side of the property has been completely built up, run off are collected and channelled into a drainage system, south of the road, north of the river.
 - Cut-off drains are used to collect runoffs from “Area 6”. These runoffs and those generated from the larger area, west of Latrobe Avenue are directed into sediment ponds which are located at the southwestern boundary of the property.
- 11 January 2019: Yarra City Council not satisfied with CSC Civil’s email interpretation summary of the site issues.
 - 18 January 2019: GHD was contracted by Glenvill to undertake a review of historic groundwater data for the AMCOR site and the riverbanks.
 - 22 January 2019: After a field visit by both Melbourne Water and Glenvill staff, Glenvill noted that the conclusion after the site visit was that natural river processes were responsible for the tree’s toppling and that there is no connection to water seepage.
- During this field visit, another large crack in the soil was noticed. It had emerged about 50 m from where the first subsidence has occurred. This new crack was completely dry. There is a large gum tree at the edge of the river, away from the crack.
- 23 – 25 January 2019: Melbourne Water removed the toppled tree.

2) (based on Travers Nuttall email exchange with Melbourne Water - TN email to MW 190529.pdf in the City of Yarra Folder)

- 24 January 2019: Melbourne Water notified the Yarra City Council that the subsidence is not likely as a result of natural bank erosion process, as the location of the subsidence is away from the bend in the river that is in the path of high-energy flow.
- 20 – 29 May 2019: New subsidence has occurred after some rain event. Another tree topples into the river with the subsidence. The subsidence has affected other trees (at least two). This has led to the closure of the walking path.
- 29 May 2019: Melbourne Water conducted a visit to where the riverbank and tree had failed. It concluded that the likely cause for the bank slippage is from surface water originating from an unknown location on the Glenvill property. Visual evidence of water seeping through the subsided area was noted. Also, based on Melbourne Water’s site inspection in January 2019, there was evidence of water at the base of the large embankment.

‘Due to the presence of saturated soils around the base of the latest fallen tree across the Yarra River it has been determined to be a result of the saturated soils from the development site rather than from river erosion’.

Glenvill rejected the notion. Glenvill's investigation believes the "subsidence" is as a result of natural process. GHD findings based on historic data review showed that there is a natural perched water aquifer at the Glenvill site that discharges at or near the base of the embankment. As a result of the earth works, permeability has increased thereby resulting in an increase in the flow of this perched system (Glenvill considers this as a natural process and not a consequence of site redevelopment). Glenvill assumes that recent earth works by Melbourne Water (decommissioning of an old sewer line and the building of a replacement one) may have altered the localised flow of groundwater.

3) (see Memo - Amcor and Yarra River bank subsidence June 2019.pdf in the AMCOR folder)

3 June 2019: Water ponds can be seen on the walking paths. Where "subsidence" has occurred, topsoil is completely dry, however, about 30 cm below the topsoil, there is obvious water movement. The "subsidence" is away from the river, on the side towards the Glenvill property.

Yarra City Council Memo

(see Memo - Amcor and Yarra River bank subsidence June 2019.pdf in the AMCOR folder)

A Yarra City Council memo issued by Paul Whitten after a site visit on 3rd June 2019 detailed some findings.

The field visit was after a gum tree had collapsed due to recent ground subsidence. Two additional gum trees were also affected, although their footing is still well established. On close inspection, the top of the soil along with the upper soil layer around the subsidence were dry. However, about 300mm below the surface, water was forming freely within the soil.

The observations were that the recent soil movement and tree failures were not as a result of bank degradation by the river washing out of tree roots, but rather as a result of the increase in subsurface water content.

The memo summarised that:

1. The subsidence occurred on the path side of the trees and not close to the riverbank.
2. The subsidence occurred immediately south of major excavation works for the Glenvill main drain.
3. Around where the subsidence occurred, the topsoil is dry, however, there is observable water movement from about 0.3 m bgl.
4. Water ponds are forming on the footpaths.

Douglas Partners Report (2019)

(see: DP Report.pdf in the City of Yarra Folder)

Douglas Partners (DP) noted that development activities at the site involved the removal of former paved surfaces, removal and replacement of uncontrolled fill.

These earthworks activities would have resulted into temporary exposure of fractured basalts which could have resulted in a temporary increase in infiltration/localised recharge at some parts of the site. However, the backfilling with engineered clay filling soon after exposure over much of the site would have provided a low permeability surface seal.

Other earthworks identified by DP included the removal of decommissioned pipes and subsurface structures, and the eventual backfilling of the excavations with compacted clay. This would have resulted in a further reduction in near surface groundwater recharge pathways. Melbourne Water's decommissioned sewer is about 30 m away from the

recent slump. The brick-lined sewer was back grouted to prevent the leakage of groundwater into it – this, DP assumed, could lead to increase in groundwater level, as it prevents the likely discharge of groundwater into the sewer as before.

Also, during the site visit, two localised pools were observed to the east of the slump.

DP suggested some likely causes of ground movement in the area:

1. Pore-water pressures and soil moisture condition can play a significant role in the stability of the bank. A dry five-month period preceding the slump might have resulted in increased suction and strength within the clay profiles and the residual clay soils derived from the weathered basalt will be highly prone to significant shrink-swell behaviour. This can lead to increase infiltration rates and water pathways into the profile. This was considered important as the slump occurred around the time of a series of rainfall events at the end of the dry spell.
2. Fluctuation in river levels can also result in changes in soil's pore water pressure.
3. Upgradient changes in standing water level could influence the soil moisture conditions in the area of slump. For this to occur, there has to be a hydraulic connection between the fractured aquifer and the soil/rock materials in the terrace area near the slump. This requires further investigation.
4. River erosion of the riverbank.
5. Bank slumping and tree toppling is a common occurrence (evidence exist at the opposite side of the riverbank).
6. The interface between new fillings and the natural soil and/or rocks can form a plane of weakness along a slope.

Local resident's testimony

(see Seepage drivers dams on AMCOR siteJL2.pdf in the AMCOR folder)

A local track user (Spiro Georgakopoulos) presented a document that summarised the chain of events that he, along with other track users, considered to have been the cause of the slumping and tree collapse.

The view presented is that the earthworks at the Glenwill site was responsible for the land slumping, tree toppling and the emergence of "springs".

'New stormwater dams along with the stormwater trenches were built after the demolition of the AMCOR buildings. These facilities are located about 6 to 10 metres above and from the Yarra River. The dams are believed to be leaking, with the seepage resulting in localised groundwater recharge. The continuous seepage from these dams have contributed to an increase in soil saturation, thereby reducing the frictional shear strength of the soil and increasing the sliding forces within the terrace soil next to the Yarra River. It is also believed that the earthworks have created new groundwater flow paths that allows the seepage to flow towards the riverbanks'.

GHD's report (Groundwater Beneficial Use Impact Assessment, 2016¹)

(see BU Report Final.pdf the City of Yarra Folder)

GHD completed (most of) the groundwater monitoring programme at the site. A total of seven GMEs which were undertaken between 2008 and 2016, of which six were reported by GHD in their Groundwater Beneficial Use Impact Assessment report (GHD 2016).

Based on GHD's 2016 report, there were at least 31 groundwater monitoring wells at the site (Figure 6-1, Table 6-1). Over time, many of the wells were damaged and/or decommissioned. Groundwater level measurements from both

¹ GHD, 2016. Former Alphington Paper Mill, Alphington Groundwater Beneficial Use Impact Assessment, 2016

the Newer Volcanics and the siltstone indicated that the flow is south-eastwardly towards the Yarra River (Figure 6-4). The estimated gradient from one of the bores (GW25) to the Yarra River is 0.09.

Using Darcy's Law, GHD (2016) estimated the rate of groundwater discharge into the river from the site (using bore MW05's location and parameters) as 5.3 m³/day.

The report also identified that the water type of most of the bores screened in the basalts were predominantly Na-Mg-Cl, which is typical of basalts in Victoria (Figure 6-4). The wells screened in siltstone showed diverse water types – reflecting possible interactions with basalt groundwater and/or impact from site activities. The ionic ratios were also consistent across the 6 GMEs.

The latest round of groundwater level monitoring data was collected on 26th May 2019 by JBS&G. A total of 37 groundwater monitoring bores were gauged during this monitoring period. It is worth noting that some of the bore names were different from those in the historical data collected by GHD.

The data collected during all the GMEs cannot be used to determine seasonal variations as the GMEs were irregular and the bores monitored varied considerably across all the GMEs (see Figure 6-3).

Table 6-1 Groundwater bore details

Bore ID	Count	Date Installed	Well Depth (mbgl)	Screened Unit	Status (2016)
MW04	6	30-04-08	10	Unknown	Good
MW05	6	30-04-08	12	Siltstone	Gatic lid removed but serviceable
MW03	5	30-04-08	16	Basalt/Siltstone	Good
GW8	5	15-11-10	9.6	Basalt	Damage to headworks but serviceable
GW10	5	25-11-10	22	Basalt	Good
GW16	5	09-12-10	22	Basalt/Siltstone	Good
GW18	5	14-01-11	23.4	Basalt/Siltstone	Good
MW02	4	29-04-08	23	Basalt	Decommissioned (removal of tank)
GW17	4	10-12-10	15	Basalt	Good
GW6	3	12-11-10	13	Basalt	Good
GW7	3	12-11-10	14.3	Basalt	Destroyed
GW11	3	17-11-10	12.2	Basalt	Destroyed
GW12	3	17-11-10	27.5	Basalt	Decommissioned
GW14	3	25-11-10	22	Siltstone	Destroyed
MW01	2	28-04-08	17	Basalt/Siltstone	Decommissioned and replaced with nested wells MW01A and MW01B
MW01B(R)	2	28-05-15	25	Alluvium	Good
GW13	2	26-11-10	4	Clay/Basalt	Destroyed
GW15	2	29-11-10	15	Basalt/Clay	Destroyed
GW20	2	20-04-15	15.8	Basalt	Good
GW21	2	20-04-15	16	Basalt	Some damage to well head but serviceable

Bore ID	Count	Date Installed	Well Depth (mbgl)	Screened Unit	Status (2016)
GW22	2	20-04-15	17.1	Basalt	Good
GW23	2	20-04-15	15.5	Basalt	Good
GW24	2	28-05-15	17.6	Basalt	Good
GW25	2	28-05-15	12	Basalt	Good
MW01A	1	06-03-14	18	Basalt	Destroyed
MW01B	1	06-03-14	25	Alluvium	Destroyed
GW9	1	12-11-10	2.8	Fill	Decommissioned (Dry as perched water removed)
GW19	1	27-03-14	17	Basalt	Destroyed
GW19R	1	17-02-16	18	Basalt	Good – replacement for GW19
GW26	1	17-02-16	21	Basalt	Good
GW27	1	23-02-16	22.7	Basalt	Good

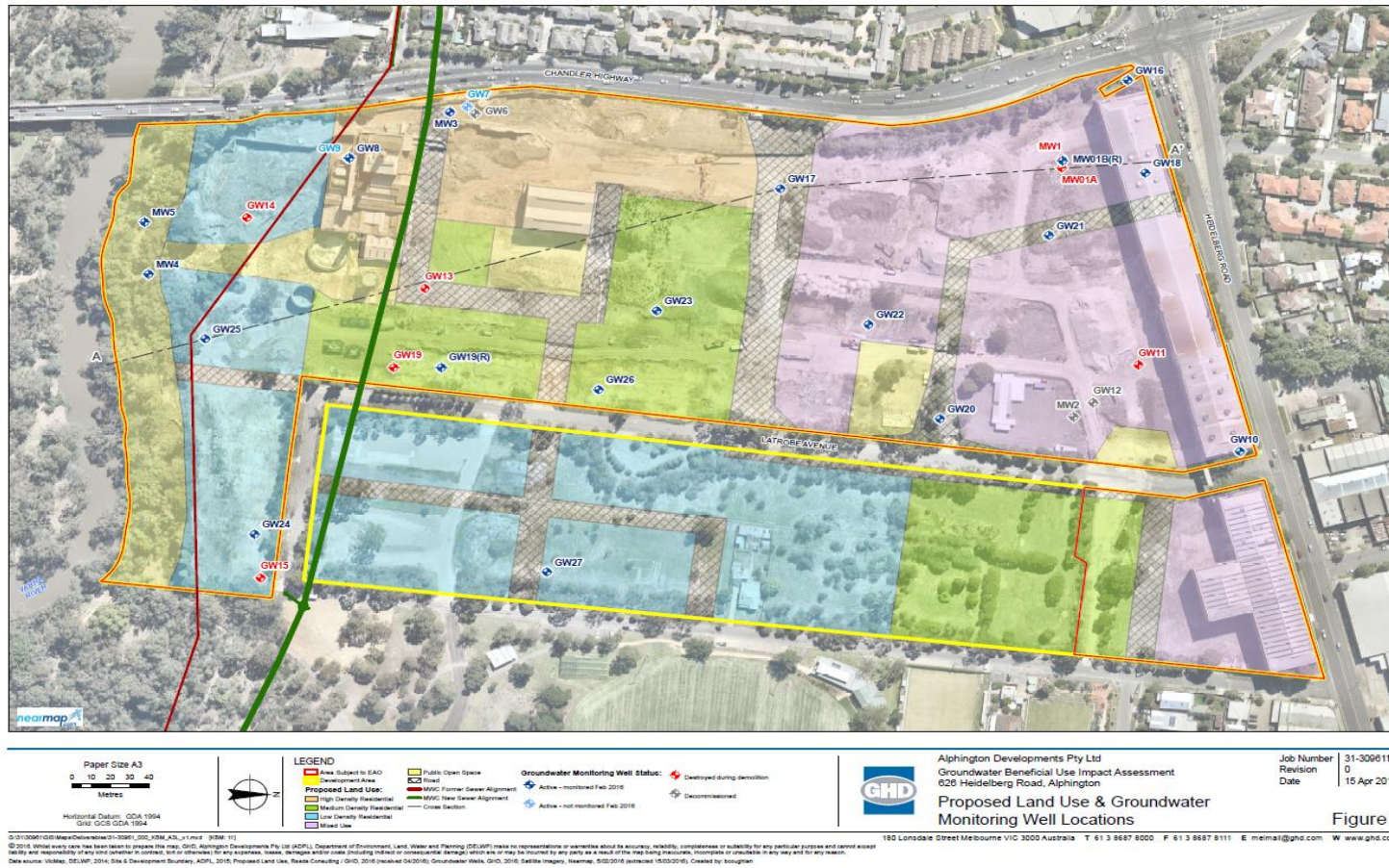


Figure 6-1 Bore locations (GHD 2016)²

² Most of the bores have been destroyed or decommissioned as part of the site development.

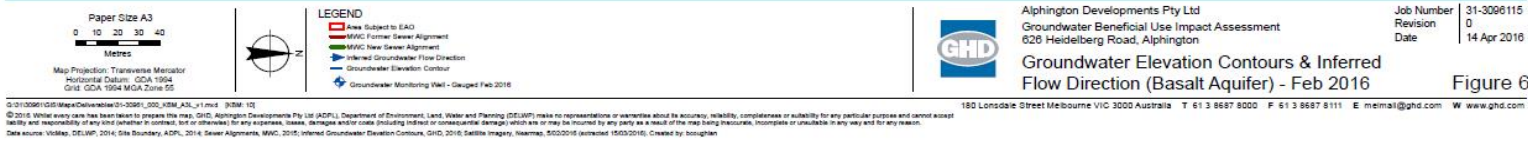


Figure 6-2 Groundwater flow direction based on GME 6 in 2016 (GHD 2016).

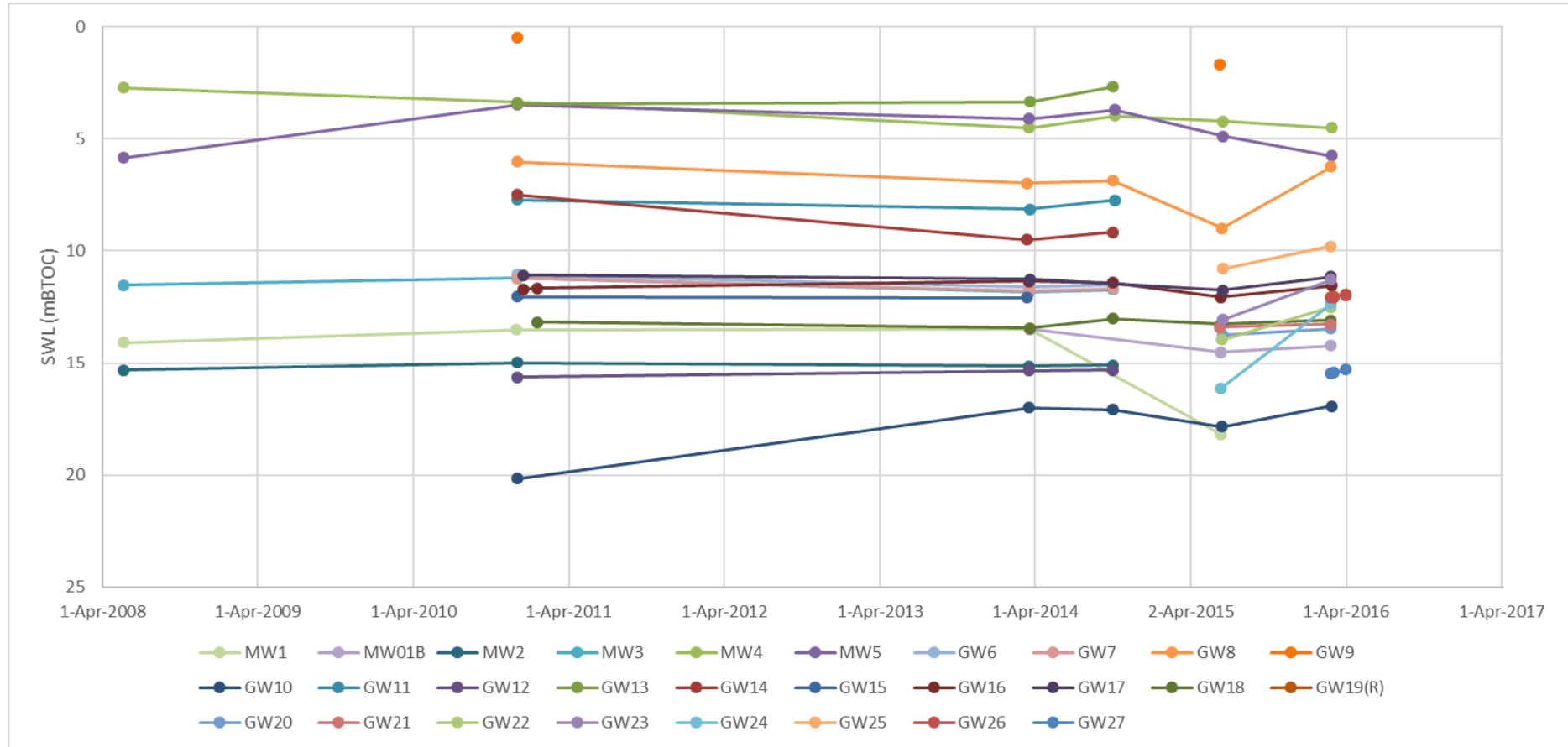


Figure 6-3 Standing Water Level data extracted from GHD 2016

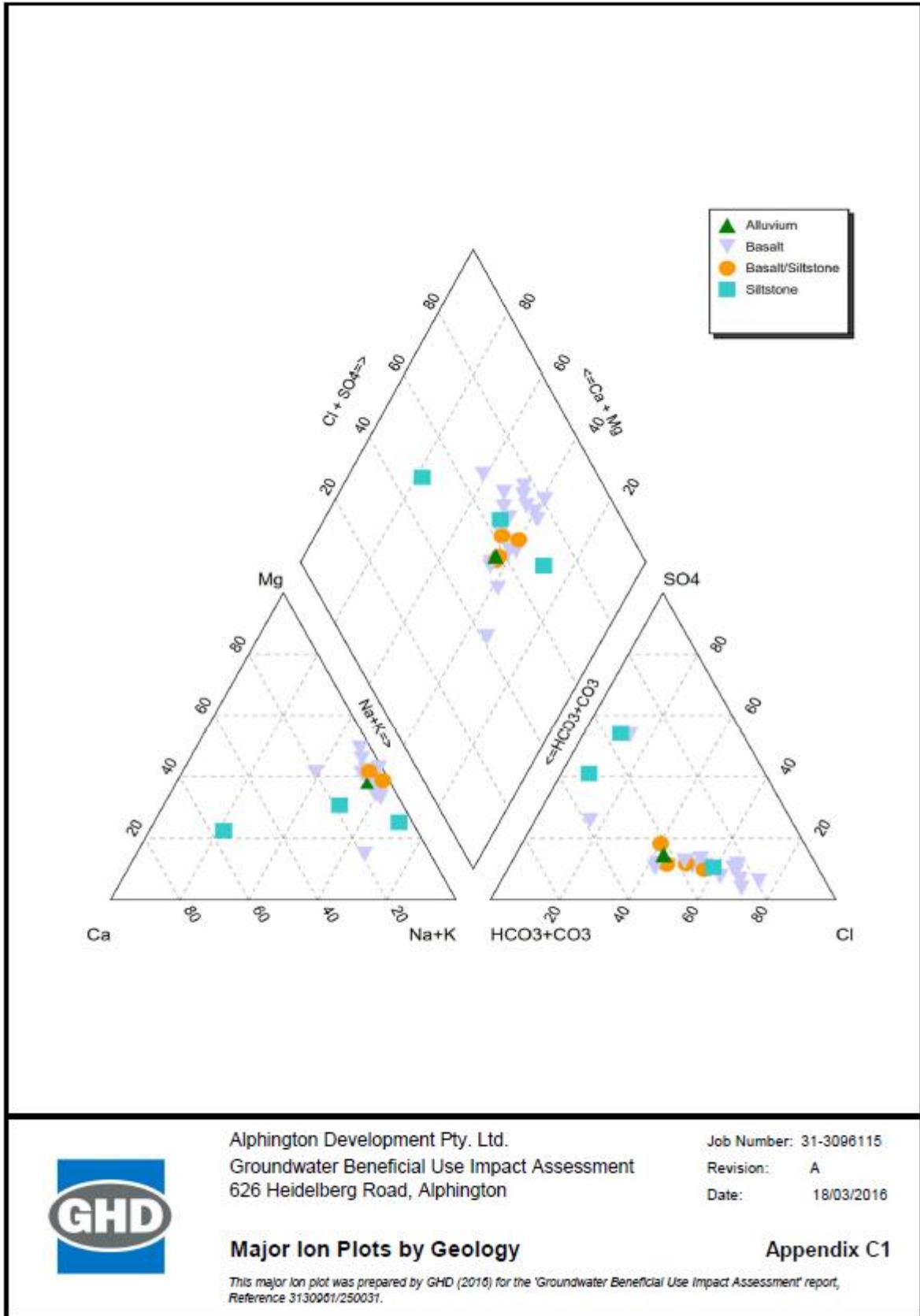


Figure 6-4 Major ions from GME 6 (GHD 2016)

GHD (2016) identified the fractured unconfined Newer Volcanics basalt and the Silurian siltstone as the main hydrostratigraphic units (HSUs) at the site. As the river is likely at the end of a groundwater flow path, there is high potential for interaction between the river and the site's groundwater. Plant uptake around the riparian zone will also be another means of groundwater discharge.

Standing water level (SWL) collected from these wells between 2008 and 2016 indicated that the SWL varied between 0.5 and 20 mBTC (as reported by GHD 2016). SWL were not reported as metres below ground level (mbgl) or metres Australia Height Datum (mAHD) (see Figure 6-3), thereby preventing the comparison between the river stages and the watertable.

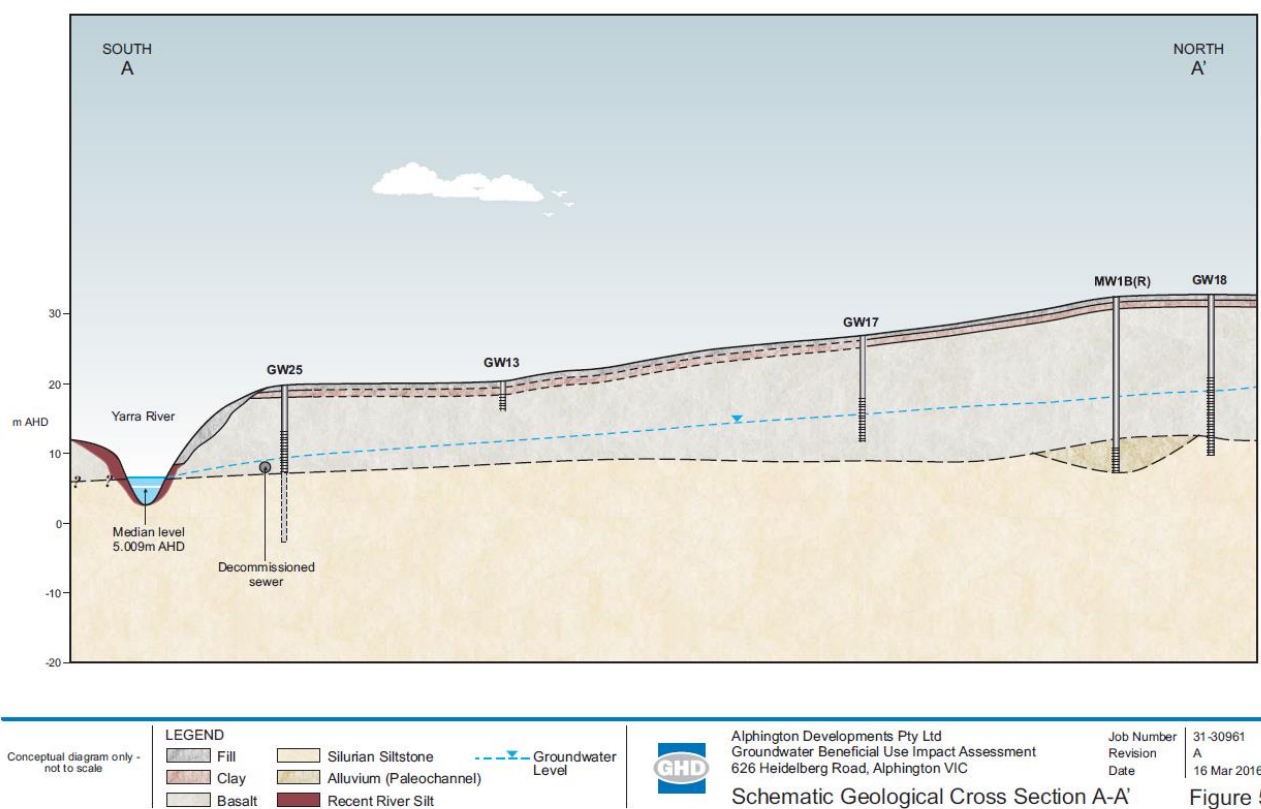


Figure 6-5 Geological Cross section of the site (GHD 2016)

Site Visit

Key observations made during a site visit on the 25th of July related to groundwater processes are:

- 1) Site modification have removed sealed surfaces, exposing the underlying regolith.
- 2) Site modification such as surface water ponds have concentrated surface ponding and may have increased infiltration.
- 3) Groundwater discharge adjacent to the riverbank appears relatively recent (less than 3 years) – this is based upon;
 - a. No pronounced drainage line from the discharge zone, if it was permanent discharge it would be expected to see a distinct drainage line.
 - b. Lack of vegetation that has evolved to permanent saturation, for example Swamp Melaleuca.
 - c. The presence of vegetation (Tree Violet, Blackwood) that has recently died within the discharge zone, however, are healthy away from the discharge zone.
 - d. Soil colour within the discharge zones appears very similar to soil within the adjacent dry soil. If discharge was permanent would expect to see gleyed colouring or iron staining due to redoximorphic processes.
 - e. The lack of discharge in lower areas – such as the steps to the adjacent baths, if it was a broader process based on recent rainfall then would expect to see discharge in lowest landscape position.

Potential mechanisms influencing bank collapse

A simplistic conceptual site model provides an initial assessment of the likely role groundwater may have played in initiating the river bank collapse and how development activities have contributed to changing GW processes. The assessment area has been divided into 3 stages (Figure 6-6), pre-demolition and major earthworks (pre-2014), during development 2016 onwards, and a hypothetical post development:

1) Pre-demolition and major earthworks

Due to the built nature of the former AMCOR site (now Glenvill site), the amount of infiltration into the soil was negligible, as the vast majority of rain onto the site would be redistributed by stormwater flows off as runoff. It is likely the watertable at the site discharges into the Yarra River.

2) During and post-demolition and massive earthworks

During demolition and other earthworks, excavations were up to 3.5 m at some locations at the Glenvill site (based on CSC Civil email communication to Glenvill). This resulted in the removal of the impervious surfaces across the site, thereby exposing the underlying geology. This would have enabled the increase in stormwater infiltration, thereby leading to increased recharge to the underlying aquifers. In addition, stormwater runoff from the undeveloped parts of the site are directed and stored in sediment ponds, which could potentially act as point recharge zones. Subsurface moisture will increase and potentially cause very localised mounding of the water table immediately below the site.

Subsequently, the increased elevation of the water table causes groundwater to discharge higher than the river level, saturating the riverbank and contributing to bank instability.

3) Post development

The resurfacing of the Glenvill site with impermeable materials and the design of a proper stormwater collection system will lead to a reduction of percolating water into the underlying soil/HSUs. This will result in the continual lowering of the groundwater back to pre-demolition works, thereby lowering the accumulation of moisture within the bank. A proper stormwater collection system will also ensure that point recharge zones are eliminated.

The decline in the groundwater level and moisture content in the bank will reduce bank instability.

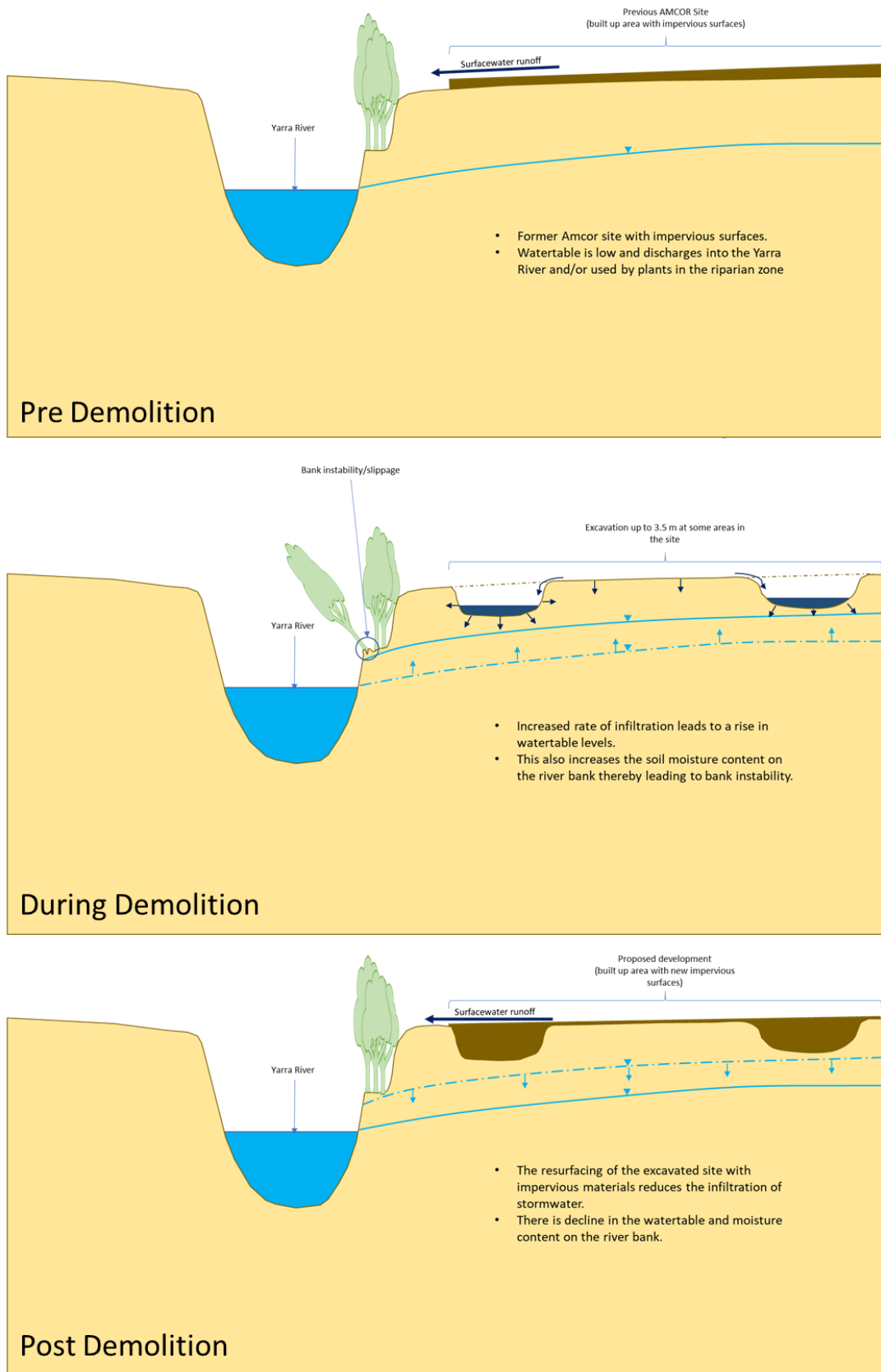


Figure 6-6 Conceptual site model

Short term management implications

Based upon the initial review of literature and field-based observations it appears that the most likely cause of the groundwater discharge is associated with localised recharge at the site. It also appears that the discharge started around a year after site redevelopment began. It is likely that groundwater discharge will not cease in the coming weeks to months, as more infiltration is expected during winter and spring rainfall events.

Therefore, the role groundwater plays with the river back collapse is not likely to cease in the coming weeks or months.

Scope of work for Part 2: Detailed investigations

The hypothesis provided is not based upon a technical investigation designed at determining the role groundwater has with the landslides, but rather a preliminary assessment of existing data.

To better clarify the role development at the site has had on altering groundwater processes, the following are recommended:

1) Conduct a detailed topographic survey and develop a digital elevation model

A well-designed drone topographic survey will help in developing the site's detailed digital elevation model (DEM). It will also be useful in identifying current site features like surface water holding ponds and their depths, stormwater drains, site of land subsidence and locations of toppled trees (subject to visibility due to tree cover).

The DEM will be important when comparing the elevations of groundwater levels, surface water holding dams and the river heights, thereby informing the relative water levels across the site.

2) Determine source of groundwater discharging at the riverbanks. This will involve:

- a. An initial site visit and sampling of existing wells and discharge zone to compare against GHD data to begin investigations.
- b. The installation and monitoring of groundwater level and quality monitoring bores across the site. This will help determine whether (and to what extent) the current groundwater flow patterns have been altered post-demolition works.
 - i. Estimated 6 new bores of up to maximum of 20 metres
 - ii. 2 rounds of chemical sampling and analyses
 - iii. Hire and installation of data loggers
- c. The collection of water samples from the groundwater monitoring bores and the Yarra River for major ions, stable water isotopes and radionuclides (radon) analyses. This task will aid in determining the age and source if the groundwater.
- d. Preparation of a technical memorandum describing the likely source of discharge water and any existing data gaps and recommendations.

3) Determine lag time and length of discharge based upon groundwater model:

- a. Using a modelling approach (yet to be determined) to assess how long increased recharge and water table mounding may take to dissipate, and the influence future development may have on groundwater discharge.

Appendix C: Geotechnical assessment

TJH:sk

2 August 2019

ALLUVIUM

Level 1, 105-115 Dover Street,

CREMORNE VIC 3121

Attention: Ross Hardie

Ref: 119927/A

Dear Sirs,

RE: Yarra Bank Slump Investigation, Fairfield

Further to our previous correspondence in connection with the tree removal, attached as Appendix I, we confirm having reviewed most of the information provided in relation to the trees present, and our views have not changed.

Following the recent workshop we have discussed the overall issues with Mr Andrew Murphy at Douglas Partners and formed some view from the workshop from a geotechnical perspective, and these are summarised as follows.

Most Likely Mechanism Pathway for the Bank Collapse

There are two possible mechanisms in place, in my view, firstly the normal river processes creating localised instability in the embankment. To examine this in detail it will be required to gain an appreciation of the river profile, and Douglas Partners agree with this, but from a visual perspective the river processes are, in our view, likely to be the least significant factor in the overall embankment instability to date.

The second likely influence is seepage water within the embankment, although the source of this not completely identified, however appears likely associated with two issues, firstly the siltation ponds and build up behind the immediate embankment, and the second, probably associated with the original drainage of the site (La Trobe Street), and the old creek or water course that is shown on the plans discovered by Douglas Partners. The profile and recent topography is also considered a relevant issue and we have marked up the profile by GHD with our suspected localised flow mechanism, but this needs verification. This is attached as Figure 1.

Douglas Partners advised they are currently preparing a proposal for Glenvill Homes to address the water model on the site and will invite input from ourselves into this model with a view to providing an overall satisfactory response to the issues of the embankment.

Our initial comments are that the geology is somewhat complex where the basalt meets the Silurian sequence and there may be seepage paths in the less weathered basalt or above a clay that is allowing easy access of the seepage from the Glenvill site into the embankment, and the following through the embankment and into the Yarra.

We saw some evidence of this possibility in our walkover.

Short Term (No Regret) Actions to Address the Risks

The establishment of a water model and some understanding of the water pathways from the Glenvill site to the river is seen as critical. Both Glenvill and our group were conscious of this and it will take some time to collate the existing water bore data and the proposal that will be forthcoming from Douglas Partners. Douglas Partners are acutely aware of the issues and do not dismiss that either moving forward or at present the influence from the site of the housing development will be a significant factor.

Having said this, the engineering issues, in my view, should be relatively easily overcome, either by appropriate drainage (groin drains or similar), the selection of a relatively low permeability backfill in some of the Glenvill backfill or a combination of these, or may simply dissipate quickly with improvements to the Civil Construction Management Plan, which clearly needs addressing.

It is also possible that the embankment will be denuded in any event, largely due to the contamination issues and a new embankment constructed, suitably engineered.

Thus, in answer to the above, very little short term actions to address the risk will be possible over the next month or two at least, and the priority should be to establish a course of action for summer works.

It is also apparent that the residences close to the property boundary may have basements, which will also influence seepage flows and possibly lower these in the longer term.

The following may be of benefit.

- Line or replace the siltation ponds.
- Alter and implement a revised Construction Management Plan.

Scope for More Detailed Stage 2 Quantitative Investigation

It is apparent talking to Douglas Partners that a collaborative approach would be best to ensure there is no duplication in what I will call the base data. Douglas Partners obviously propose a hydraulic model and, whilst views may differ on this, most of the input information need only be gathered by one investigative process.

As mentioned at the site meeting, the key information, moving forward for us, is the ground water bore data, the profile at the river edge (below the water line), knowledge of the proposed development by Glenvill and profiles along the embankment.

At this point, geotechnically until these aspects are firm, there is no point in doing stability analyses or similar for them, either existing embankment or long term embankment.

- 1 Mobilisation
- 2 Auger drilling -4 bores at river level to 4.0m and 4 bores top of embankment to 8.0m, total 48.0m
- 3 Field testing
- 4 Laboratory testing
- 5 Install piezometer (no caps)
- 6 In-situ permeability testing (4 bores)
- 7 Stability analysis
- 8 Preparation of report

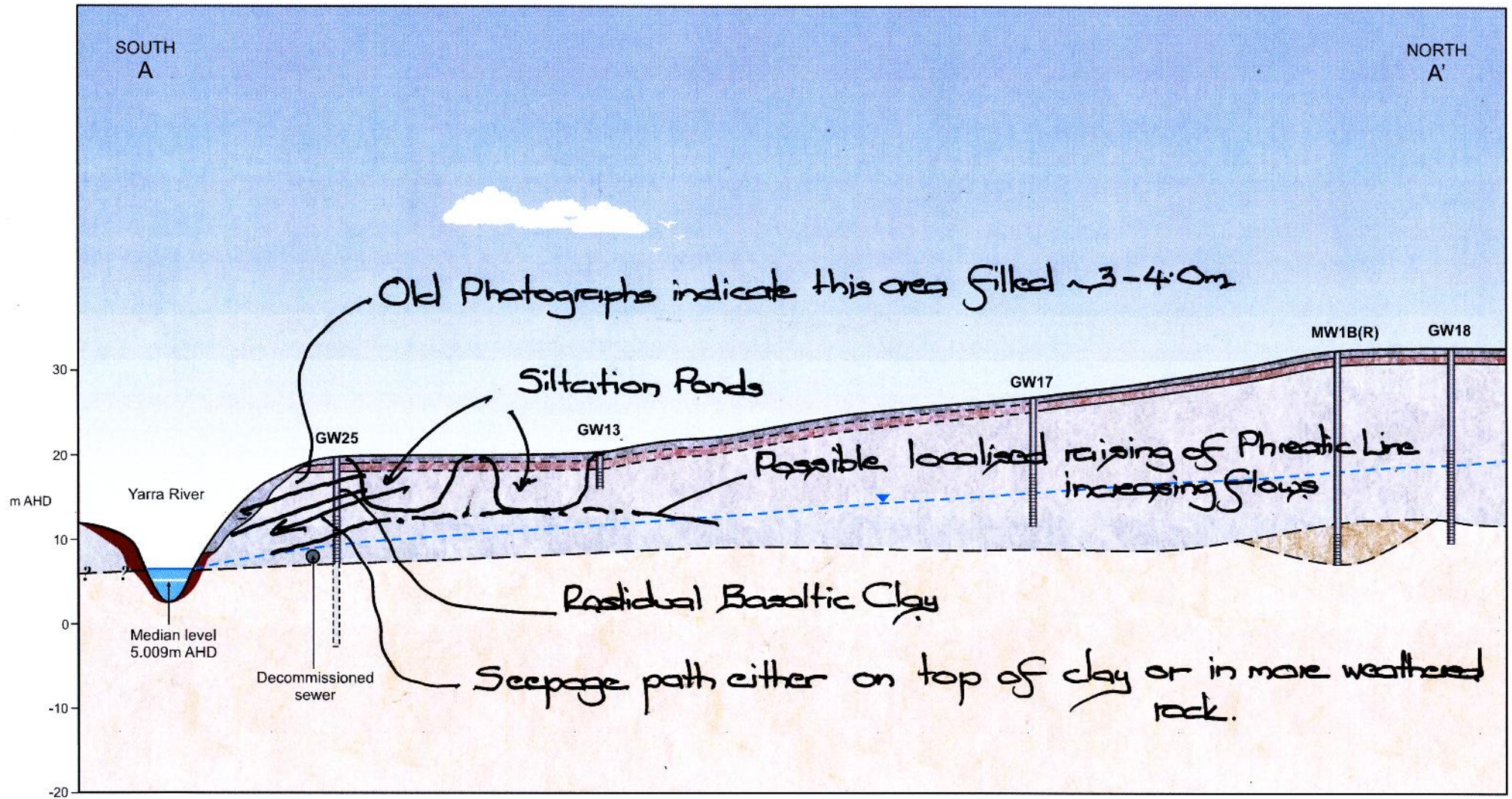
We trust the above comments are of some assistance and should any point remain in doubt please do not hesitate to contact us.

Yours faithfully,



T.J. HOLT MIEAust CPEng EC-1022
A.S. JAMES PTY LTD

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Conceptual diagram only - not to scale

LEGEND

	Fill		Silurian Siltstone		Groundwater Level
	Clay		Alluvium (Paleochannel)		
	Basalt		Recent River Silt		



Alphington Developments Pty Ltd
Groundwater Beneficial Use Impact Assessment
626 Heidelberg Road, Alphington VIC

Job Number	31-30961
Revision	A
Date	16 Mar 2016

Schematic Geological Cross Section A-A'

Figure 5 1

APPENDIX I

Preliminary Tree Report Reference 119927

TJH:sk

26 July 2019

ALLUVIUM

Level 1, 105-115 Dover Street,

CREMORNE VIC 3121

Attention: Ross Hardie

Ref: 119927

Dear Sirs,

RE: Tree Collapse, Yarra River Embankment Old APM Site, Fairfield

Further to our mutual inspection along the embankment of the Yarra River on 25 July 2019, we would confirm our verbal advice at this early stage in connection with the more pressing issue of two existing trees that are within, or close to, a slumped zone on the riverbank that may fall into the river in the relatively short term.

One tree (designated T1) is within a completely slumped zone or a zone that is likely to fail within the near term, ie between one and six months. The other (designated T2) is adjacent to this zone and has a significant lean, but may just be a slow progression with time.

It is likely that the river processes or localised instability will result in the collapse of one of these trees (T1) without notice, and as such it will present as a danger to either river users at that location or downstream.

This is perhaps not so in the short term for the tree outside the slumped zone (T2).

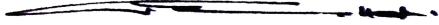
As much as this company would like to preserve this vegetation actually within the slumped zone (T1), this appears impractical or not possible. It may be it can be "lightened", but the same risk appears to exist.

Other trees were inspected that were not within slumped zones to the North that had a significant lean, but because the river processes or localised instability had not put these in danger, these obviously need not be removed.

The cause of the localised instability or river processes at this point will be the subject of the further analysis. We note, however, that this company was requested by the City of Yarra in 2017 to inspect similar deterioration in the riverbank at this location and so the river processes or cause of these instabilities would appear to have been ongoing for some time.

Should any point remain in doubt please do not hesitate to contact us.

Yours faithfully,



T.J. HOLT MIEAust CPEng EC-1022
A.S. JAMES PTY LTD

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Appendix D: Surface water assessment

Memo

Subject Surface water
Distribution Alluvium Consulting (Internal)
Date 15 August 2019
Author Jonathon McLean
Project Tree collapse review and investigation

Introduction

Alluvium Consulting was engaged by the City of Yarra to consider the potential influence of surface water and drainage on tree collapse and bank slump on the Yarra riverbank at Fairfield. The purpose of this document is to identify any potential surface water issues that may contribute to mechanisms influencing bank collapse by reviewing existing reports, surveys, construction documentation and plans. The investigation will also identify for the City of Yarra any short-term management implications and potential scope of work for detailed investigation.



Figure 1 – Bank collapse

Site inspection and data review

Jonathon McLean was Alluvium’s lead expert on surface water and drainage. He attended an expert panel site visit including locations of sediment ponds, inceptor swale drains, retention dam connections, existing outfall drains, groundwater bores, and the Yarra River bank on the morning of 25 July 2019. The site inspection was undertaken to familiarise the expert panel with the site and gain an appreciation of the failed ground and bank conditions impacting trees along the riverbank.

The following information and documents have formed the basis for the review:

- Nearnmap aerial images
- Douglas Partners report dated 3/7/19
- CSC Civil Constructions “Construction Management Plan” dated 24/11/17
- GHD report “Groundwater Beneficial Use Impact Assessment” dated May 2016
- “Main Drain Stage 1” drawings by Reeds dated 23/6/17
- Road and drainage plans (HLR1- HLR24) by Reeds dates 20/3/17
- Stormwater quality plans (SWQ1 – SWQ6) by Reeds dates 20/3/17

Potential surface water drainage influence on bank collapse

The Amcor site covers an area of approximately 16 hectares, with the development divided into two distinct precincts, referred to hereon as the “west precinct” and the “east precinct”. There is a fall of about 14 metres from north to south, with an addition “steeper” drop of over 10 metres from the top of the fill escarpment to the Yarra River bank. It is our understanding that the “fill escarpment” was artificially created many years ago by Amcor to lift the site above the Yarra River 1% AEP flood level.

The Amcor production site on the “west precinct” was predominately covered by buildings and hard stand areas, whilst the “east precinct” was predominately vegetated with grass and trees. Demolition and clearing of the site appears to have commenced sometime in 2015 (based on aerial images) with the entire site progressively being stripped and remediated. As of July 2019 the redevelopment of the “east precinct” to residential dwellings has predominately been completed whilst the “west precinct” remains bare earth.

The overwhelming opinion from the expert panel is that the failure or slumping of the riverbank is due to change in moisture conditions. From a drainage perspective the key question is “has upstream surface water conditions contributed to the change in bank moisture levels?”.

As shown in Figure 1, there has been a significant change in land use on the catchment over the past few years. Land use and hydrology are intrinsically related. Therefore, a change in land use is likely to lead to a change in hydrology. During the Amcor Paper Mill operations (i.e. pre 2015) the western portion of the site was predominately impervious (i.e. roof, hardstand areas etc) and it is assumed that the vast majority of stormwater runoff from these surfaces were collected and conveyed by a drainage system of gutters, pits and pipes that connected to the existing underground 1050mm pipe network through the site. The outfall from this 1050mm pipe was directly to the Yarra River. We estimate that very little of the rainfall that landed on the “western precinct” would have had the opportunity to infiltrate into the existing groundwater. On the “eastern precinct” the majority of the site was vegetated with grass and trees. A “bluestone open channel” conveyed any surface flows to the east of the Amcor site and into the Yarra River.

As shown in Figure 1, the stripping and demolition of the site removed all of the original underground drainage systems. Rainfall that falls on the site under these circumstances lands on exposed earth, where it runs along the surface to a swale drain or pools on the surface. During bulk earthworks, it is standard practice (and a permit requirement) to manage stormwater runoff to mitigate potential erosion and sediment laden water from entering the downstream receiving environment (i.e. the Yarra River). Therefore, as you would expect a “Construction Management Plan” was prepared by CSC Civil Constructions. One element of this plan included information on the protection measures to control stormwater runoff, which involved the use of swale drains or cut-off drains and a sediment pond (refer to Figure 2).



Figure 1 – Aerial photo of the site. March 2014 (top image), August 2018 (bottom image)

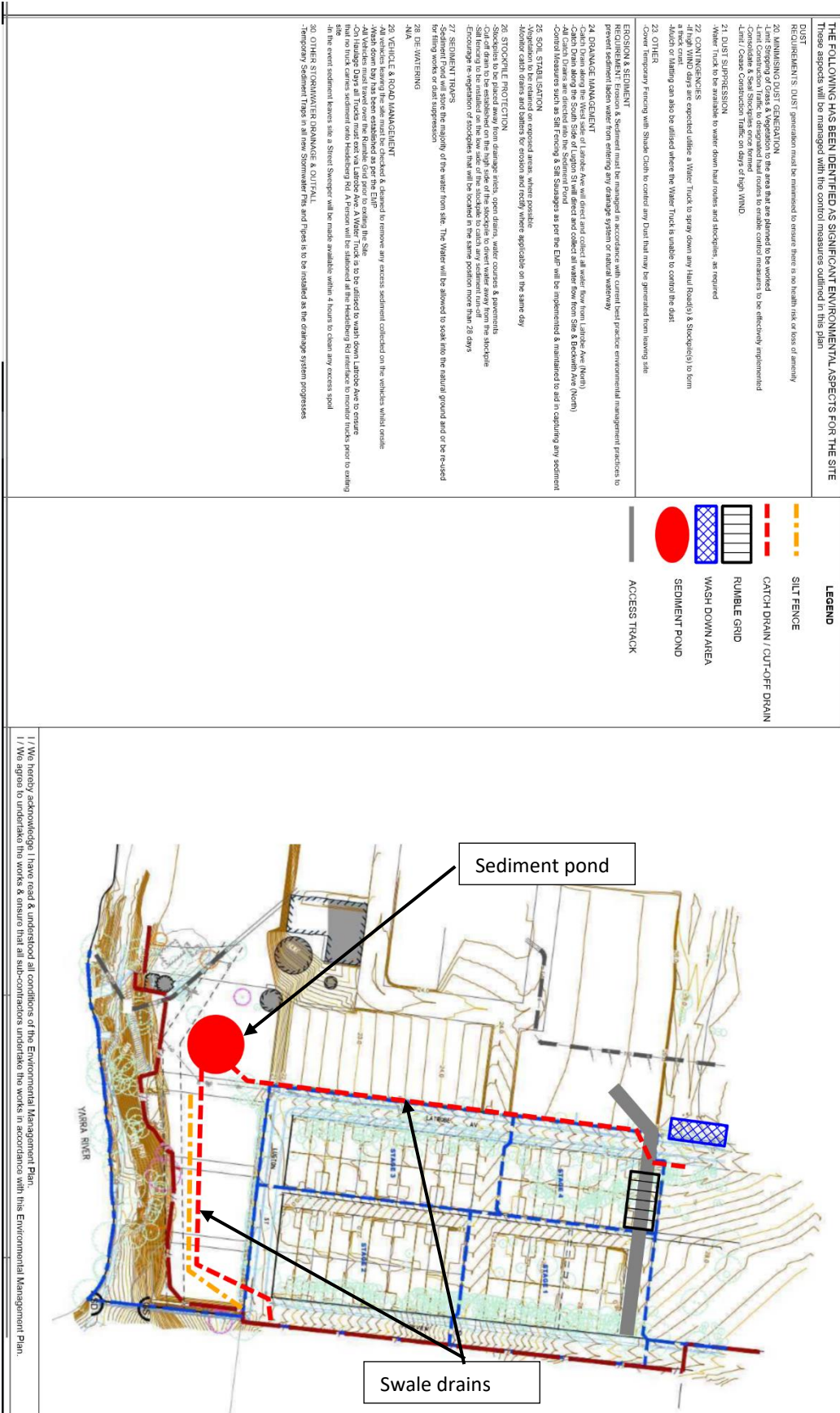
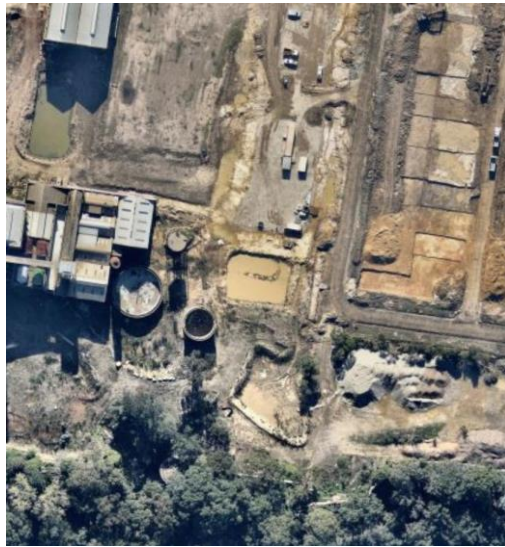


Figure 2 – extract from CSC Civil Construction “Construction Management Plan”

From an examination of aerial images, it is clear that the location of the surface water management sedimentation ponds has moved over time (see Figure 3).



4 May 2017



17 Sep 2017



16 Jan 18



23 Aug 18



7 Apr 2019

Figure 3 – Images showing the change in sediment pond location over time

From the available documentation it appears that there were no design plans or calculations undertaken to determine the size and material specification for the sediment basins. From the site visit there does not seem to be a formal drainage outlet for the sediment ponds, which is unusual in the Melbourne context. Therefore, it appears that the sediment pond system is relying upon reuse, evaporation and infiltration to draw down the water levels. This assumption is supported by the “Construction Management Plan” which encourages the concept of infiltration loss as evidenced by item 27 as follows:

27. SEDIMENT TRAPS

-Sediment Pond will store the majority of the water from site. The Water will be allowed to soak into the natural ground and or be re-used for filling works or dust suppression

A very high-level water balance assessment was undertaken to gather a broad understanding of the possible “order of magnitude” volumes associated with the hydrological cycle on the site. Note that the specific numbers are not important, it is the “order of magnitude” that is informative.

Over the 2017-2018 period the average annual rainfall was approximately 540mm (refer to Figure 4).

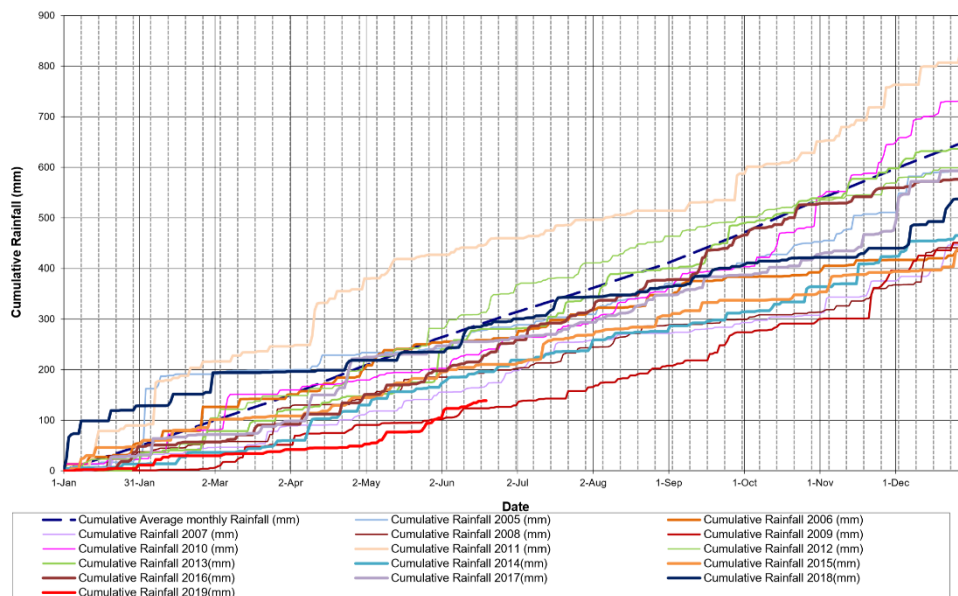


Figure 4 – Rainfall (source Douglas Partners report 3/7/19)

“Ball Park Water Balance”:

- Site area of 16ha
- Assume 30% of rainfall becomes runoff (i.e. 26,000 m³ per annum)
- Sediment ponds/ basin surface area of 2,500m²
- Evaporation of 1200mm per year from the sedimentation ponds gives an evaporation volume of 3000m³ per annum
- Surplus water = 23,000m³

So, if the sediment ponds are collecting all the runoff then what happens to the excess of 23000m³ in a year?

- Does it keep accumulating like a bathtub before it spills?
- If so we, would expect the sediment ponds to look like a permanently full dam – but the aerial photos don’t suggest this?

- Therefore, a significant portion of the surplus 23,000m³ of water (the proportion that is not being reused on site) will be infiltrating into the ground as per the EMP

Based upon the site visit, an examination of the “Construction Management Plan” and the “ball park” water balance assessment it is my opinion that it is highly possible that the surface water management system on the site is contributing increased volume to the groundwater/subsurface system.

Short term management implications

The developer should develop an updated site management plan, which includes a short-term stormwater strategy that:

- Confirms the location of the proposed sediment pond
- Provides a liner to the sediment ponds to prevent infiltration
- Considers subsoil drains in the old concrete hard stand area to prevent infiltration
- Include a review of alternate discharge/treatment mechanisms of stormwater that complies with any necessary EPA requirements and guidelines.

Scope of work for Part 2: Detailed investigations

- Review and comment on the proposed short-term stormwater strategy

Appendix E: Riparian ecology assessment

Memo

Subject	Ecology / Vegetation
Distribution	Alluvium Consulting (Internal)
Date	15 August 2019
Author	David Carew
Project	Tree collapse review and investigation – Yarra River Alphington

Introduction

City of Yarra has engaged Alluvium to investigate recent tree collapse and bank slumping events occurring on the Yarra River adjacent to the historical paper mill site in Fairfield. An expert panel convened by Alluvium Pty Ltd (Alluvium) conducted a site visit on 25 July along with John Ghasperidis (City of Yarra) and Travers Nutall (Glennvill). The expert panel reviewed the information from the site visit and other reports on Thursday 1 August 2019.

The purpose of this memo is to summarise the key vegetation issues arising from the site inspection especially the potential for imminent tree collapse and additional follow up work require.

Background

David Carew was Alluvium’s lead expert on ecology and vegetation management. He attended the site visit on 25th July 2019 to gain an appreciation of the site and to review the vegetation along the waterway corridor adjacent to the Glennvill development. Two trees in and adjacent to a bank slump have been identified to be at risk of failing with another tree already having fallen into the river.

The following information and documents have formed the basis for this review:

- Nearmap aerial images
- Arboricultural assessment, Yarra Bend riverbank trees 11/06/2019 Tree Department Pty Ltd
- Assessment of River Red Gums along the Yarra River, Alphington. 15/07/2019 – C&R Ryder Consulting
- ARBORICULTURAL REPORT APM Site Heidelberg Road Alphington 05/06/2019 – Tree Radar Australia Pty Ltd
- Memo Yarra River bank subsidence – Amcor site 03/06/2019 City of Yarra
- AS 4970-2099 Protection of trees on development sites. 31/07/2009
- Victorian Planning Provisions Clause 52.17 (Native Vegetation) 31/07/2017
- Yarra Planning scheme – Significant Landscape Overlay 31/07/2018
- Yarra Planning scheme (SCHEDULE 1 TO THE SIGNIFICANT LANDSCAPE OVERLAY) 24/02/2017
- Exemptions from requiring a planning permit to remove, destroy or lop native vegetation. Dec 2017 – DELWP
- NatureKit (2019) DELWP

Waterway vegetation

Vegetation of this section of the Yarra River has been mapped as Floodplain Riparian Woodland (EVC 56) by EDWLP as shown in the NatureKit biodiversity tool. This is described as:

An open eucalypt woodland to 20 m tall over a medium to tall shrub layer with a ground layer consisting of amphibious and aquatic herbs and sedges. Occurs along the banks and floodplains of the larger meandering rivers and major creeks, often in conjunction with one or more floodplain wetland communities. Elevation and rainfall are relatively low and soils are fertile alluviums subject to periodic flooding and inundation. DSE, 2004

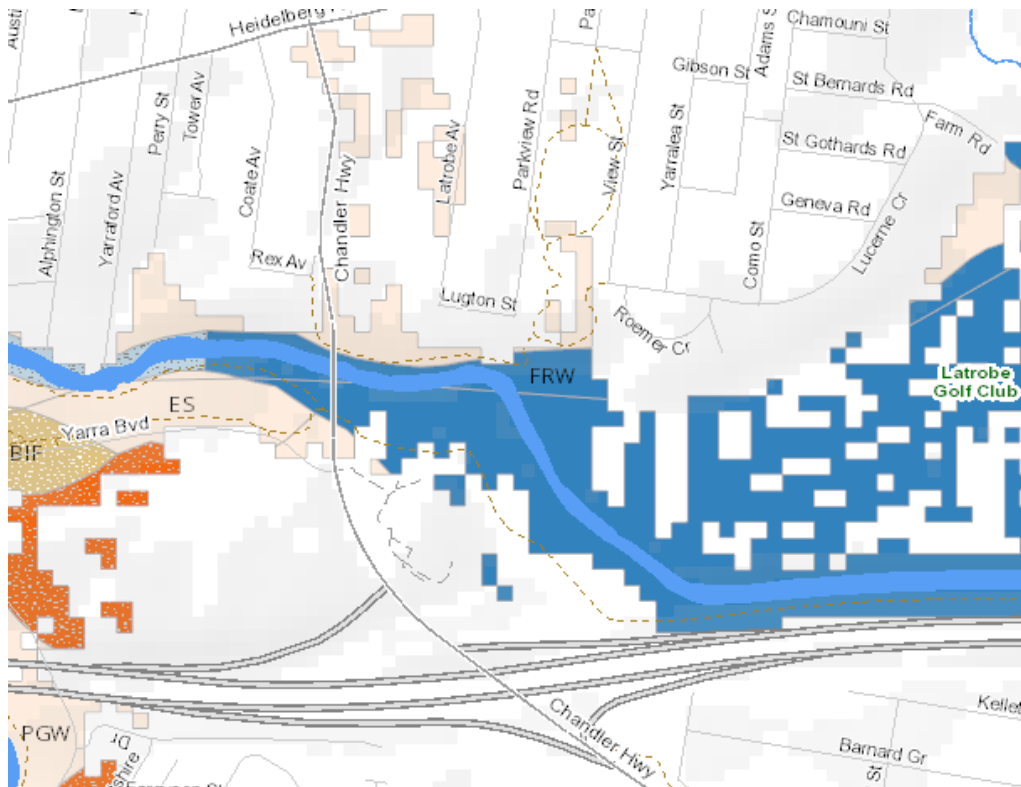


Figure 7: EVC mapping for the Yarra River at Alhington

Eucalyptus camaldulensis (River Red Gum) is a canopy character species of this vegetation community. This species occurs along the riverbank and some of the individuals are large enough to classify as large trees for this EVC (>80cm DBH). Most of the River Red Gum would be 30 to 80 years old and growing as a result of natural regeneration from earlier clearing. These trees should be retained whenever possible.

The waterway corridor is predominately planted with non-indigenous native species such as *Eucalyptus cladocalyx* (Sugar Gum), *Eucalyptus botryoides* (Swamp Mahogany), *Grevillea robusta* (Silky Oak), *Casuarina cunninghamii* (River She-oak). Newer plantings are local indigenous plants such as *Acacia melanoxylon* (Blackwood). A few significant exotic species also are present (*Quercus* sp – Oaks) and these will be of ongoing value provided they are not invasive species.

There is a low diversity native mid storey E.g. *Acacia melanoxylon* (Blackwood), *Meliccytus dentatus* (Tree Violet) and exotic dominated ground layer.

Overall while the canopy is only partially comprised of indigenous plants it does provide appropriate structure for the site context and landscape value to users of the waterway corridor.



Figure 8: Riparian planting west of slump area -River Red Gums occur along the riverbank. The waterway corridor is predominately planted with non-indigenous natives. Newer plantings are local indigenous plants.



Figure 9: Planted trees on embankment - Trees on the embankment are 20+ year old non-indigenous natives. The trees on the embankment are growing at different angles to each other. Investigate for slumping or ground heaving to determine stability of the trees.

Site condition and vegetation observations

The site was walked from the site stormwater discharge point in an easterly (upstream) direction to the eastern boundary of the development. The bank slump and trees highlighted to be at risk were visited during the inspection. The location of the trees is shown in Figure 10



Figure 10. Location of trees assessed at bank slump zone

Three trees occur within and adjacent to the recent bank slump. One of these has fallen into the river and is not a major focus of this memo. The two trees identified as at risk of failure during previous visits by others are shown in Figure 11 and

Figure 3.



Figure 11: Tree (T1) and bank slump site visit by Alluvium



Figure 12. *Tree collapse (T2) at the edge of bank slump*

The tree which has fallen into the river (see Figure 13) is firmly held into the riverbank and has not swung around with the river current. This suggests that the tree had a healthy root system prior to falling.



Figure 13: *Tree in slump which has fallen into river*

Areas of the lower terrace adjacent to the riverbank were observed to be waterlogged with the vegetation in those areas showing stress or death consistent with waterlogging.



Figure 14: *Dead native plants in waterlogged area*

Figure 14 shows an area where some planted native plants (<5 years old revegetation) which were growing well but are now dead. They are in a waterlogged area. The same species growing nearby in non-waterlogged soils are growing healthily. This indicates that the ground conditions have changed affecting the plants – estimated to be within 5 years.

Some mature Oak trees are growing within and adjacent to a waterlogged area. These are significant local trees and would be a priority to be retained in a future landscape. One of these (see Figure 15) appears to also be suffering from the waterlogged ground. These trees need to be assessed in spring to check the seasonal regrowth and their health.



Figure 15: *Oak in waterlogged area*

A Eucalyptus species (see Figure 16) has grown in the construction carpark with was a concrete covered hardstand (see Figure 23). This tree has grown >4.5m since 2016. This indicates that the ground in this area is not highly compacted and has moisture to enable rapid growth. This rapid tree growth suggests that the carpark area has well-watered but free draining soils, consistent with a site that has high levels of surface water infiltration.



Figure 16: Juvenile tree in carpark - old logistics hardstand



Figure 23: Juvenile Eucalyptus growing in carpark

Vegetation risk assessment

Four arborists have assessed the trees associated with the slump before the Alluvium site visit.

These reports are summarised in

Table 2 below. Alluvium broadly agree with the observations in the report and consider that the T1 will fail and needs to be removed and T2 can be retained with ongoing monitoring.

Table 2. Summary of Arborist report recommendations

Arborist report	Company	T1	T2
#1	Tree Department Pty Ltd (11 th July)	Removal recommended Unacceptable risk to cause harm and costs	Removal recommended Tolerable risk to cause harm – unacceptable risk due to costs post failure
#2	Ryder Arboriculture and Environment (12 th July)	Tree is likely to fail in short term (Weeks to months) Permit required for removal Assessed as Low risk to cause harm <i>Note: shown as T2 in report</i>	Tree is stable unless ground moves. Permit required for removal Assessed as Low risk to cause harm <i>Note: shown as T1 in report</i>
#3	Tree Radar Australia (2 nd June)	Removal recommended Safety risk and reduce further damage	Removal recommended Safety risk and reduce further damage
#4	City of Yarra (3 rd June)	Retain if possible. Monitor for movement.	Retain if possible. Monitor for movement.
	Alluvium summary	Remove tree – permit will be required Tree is on unstable ground within an active slump zone. This tree is likely to fall and cause further damage to the bank.	Retain tree and monitor ground stability. Tree is outside the active slump zone and is not imminently likely to fall unless further slumping occurs.

Note: Ryder Arboriculture have nominated T1 and T2 oppositely to the other reports.

Vegetation status and recommendations

The status of the subject trees has been the subject of previous memos from Alluvium to Yarra City Council. Based on the site inspection, advice from Glenvill and review of information we are of the opinion that

- The existing trees at the site be photographed as a record of the current riparian vegetation for the site. This record can inform the future vision for the site and ultimate landscape plan.
- **Tree T1:** We consider T1 will fall in the short to medium term (this could be at any time within a few days to months) and should be removed to reduce the future risk to public safety and bank damage.

The tree has suffered damage to the surface root plate within 1 to 3m of the trunk for more than 60% of the circumference of the tree. This is within the Structural Root Zone (SRZ) of the tree and is significant damage of the tree's roots. A tree suffering this level of root damage will most likely die

within 1 year. NOTE: The SRZ of the tree is calculated to be 3.2m with the Tree Protection Zone being 10.44m (as per AS 4970-2099 *Protection of trees on development sites*).

This tree is within a bank slump which has damaged the informal earthen pedestrian path along the riverbank. This is now an unsafe pathway and has been fenced off preventing pedestrian access.

The subject tree lies within land that was subject to significant additional slumping over a period of wet and windy days (Friday 9 August to Sunday 11 August). The slumping will have further threatened the stability of the tree. The tree also contributes to the surcharge on the unstable bank. Further slumping not only threatens the lower terrace but also the adjoining steep embankment.

Based on this recent movement we have advised the City of Yarra (refer Appendix B) that the tree is at immediate risk of collapse and that such collapse would impact on property. The active movement of the bank and the extent of damage to both property and the Yarra River, constitute 'an immediate risk to property' and enables activation of clause 42.03-3 of the state planning provisions, creating an exemption for emergency works.

A copy of this advised is appended to this report.

- **Tree T2:** We are less certain of the imminent fate of T2. This tree has not received majority support by Arborists for removal. The tree appears to be outside the zone of the existing tension cracks. We suggest that the tree not be removed until:
 - Such time as it is observed to lie within tension cracks, and or
 - Results of contamination land assessment is complete, a remediation plan approved and the necessity for the removal of the tree as part of any such remediation plan is confirmed.
- Monitoring of the slump area and trees is undertaken weekly to determine if the conditions change and increase the likelihood of the trees falling. Installation of photo monitoring posts and tree tilt sensors should be considered.
- Continue to restrict access to the site maintain public safety.
Consider signage along the riverbank warning people on the river of the tree hazard.
- If tree removal is undertaken, the stump and root plates must be retained to reduce damage to the bank and to provide ongoing soil stability.

Short- and long-term recommendations

Short term

- T1 – should be removed as a matter of urgency. Until this occurs the exclusion fencing must be kept in place.
- T2 – weekly monitoring of this tree should be put in place.
- Assessment of trees and vegetation in the waterway corridor.

Undertake assessment of trees and vegetation in the waterway corridor to gain baseline data on condition of the riparian vegetation. This assessment similar to a dilapidation report which identifies the current condition of the trees and vegetation of the waterway corridor. Assessment to be compliant with data required under AS 4270-2009 *Protection of trees on development sites*.

Tree assessment – all trees >200mm DBH to be mapped and assessed:

- *Botanical name*
- *Estimate age, measure size (BDH and height)*
- *Health - vigour*
- *Structural assessment of trunk and branches*

- *Visible surface roots*
- *Ground stability observation (soil cracking and heaving)*
- *Location in corridor (e.g. riverbank, terrace, embankment)*
- *Tree significance*
- *Origin of tree (planted, natural germination)*
- *Age class and estimated life expectancy*
- *Comments*

Vegetation assessment of corridor.

- *Reference EVC comparison*
- *Number of trees and % cover*
- *Shrub layer % cover*
 - *Native vs exotic cover*
- *Ground flora % cover*
 - *Native vs exotic cover*
- *Areas impacted by waterlogging.*

Different vegetation groups to be mapped.:

- Indigenous trees (E.g. *Eucalyptus camaldulensis* - River Red Gum.
- Native non-indigenous trees (e.g. *Casuarina cunninghamii*, *Eucalyptus* sp, *Grevillea robusta*)
- Indigenous shrubs and ground covers – (e.g. *Melicytus dentatus*, *Poa*, *Lomandra*)
- Exotic trees with amenity value – (e.g. *Quercus* sp - Oaks)
- Exotic trees
- Exotic ground cover

Long Term

- Develop a waterway corridor landscape plan with community consultation.

David Carew and Advait Madav

Excerpts from the Victorian Planning Provisions

https://www.planning.vic.gov.au/data/assets/pdf_file/0023/104792/FTGLS-FT98-3.3.-Significant-Landscape-Overlay-Clause-42_03.PDF

42.03 SIGNIFICANT LANDSCAPE OVERLAY

42.03-3 Table of exemptions

02/04/2015
VC124

No permit is required to remove, destroy or lop vegetation to the minimum extent necessary if any of the following apply:

- Emergency works**
- The vegetation presents an immediate risk of personal injury or damage to property and only that part of vegetation which presents the immediate risk is removed, destroyed or lopped.
 - The vegetation is to be removed, destroyed or lopped by a public authority or municipal council to create an emergency access or to enable emergency works.

http://planningschemes.dpcd.vic.gov.au/schemes/vpps/52_17.pdf

52.17 NATIVE VEGETATION

31/07/2018
VC148

52.17-7 Table of exemptions

31/07/2018
VC148

- Emergency works** Native vegetation that is to be removed, destroyed, or lopped:
- in an emergency by, or on behalf of, a public authority or municipal council to create an emergency access associated with emergency works; or
 - where it presents an immediate risk of personal injury or damage to property. Only that part of the vegetation that presents the immediate risk may be removed, destroyed or lopped under this exemption.

Guidance on the use of the exemptions from requiring a planning permit to remove, destroy or lop native vegetation is provided by DELWP.

https://www.environment.vic.gov.au/data/assets/pdf_file/0018/91251/Exemptions-from-requiring-a-planning-permit-to-remove,-destroy-or-lop-native-vegetation-Guidance.pdf

This guidance document includes the following statement in Section 2.4 - *Emergency works*.

The second part of the exemption enables the removal any native vegetation that presents an immediate risk of personal injury or damage to property (e.g. a building) without a permit. For the risk to be considered immediate, the only option to manage the risk is by removing native vegetation within a shorter timeframe than it would take to apply for and be issued with a permit for its removal.

This exemption does not apply to native vegetation that has the potential to cause personal injury or property damage in the longer term. If future injury or damage from native vegetation is a concern, a planning permit can be sought to remove it.

Options analysis

Subject	Options analysis for Tree T1, AMCOR paper mill, Alphington
Distribution	City of Yarra
Date	12 August 2019
Project	P119162.10_Tree_Collapse_Bank_Slump_Investigation

Introduction

The City of Yarra has engaged Alluvium Consulting Australia Pty Ltd (Alluvium) to investigate recent tree collapse and bank slumping events on the Yarra River adjacent to the former Amcor paper mill site in Fairfield. The subject site adjoins the right bank of the Yarra River and is the subject of an urban renewal / development project by Glenwill.

Alluvium has convened an expert panel to review the issues associated with the bank slump and tree collapse. Alluvium submitted an initial memo to identify any immediate issues arising from a site inspection including potential for imminent tree collapse and additional information requirements.

The purpose of this memo is to identify management options for tree T1 covered in our previous memo on this topic.

The memo covers following:

4. A description of the processes leading to tree collapse
5. Development of a set of objectives for tree T1
6. Identification of constraints to the attainment of those objectives
7. Options to manage the subject tree

Background

The subject site is located on the right bank of the Yarra River upstream of Dights Falls, immediately upstream of the Chandler Highway and adjacent to the former Amcor paper mill. The riverbank at the subject site is located within freehold land. It is understood that a 30metre wide riparian corridor will be secured for public access and use as a component of the proposed redevelopment project.

The riverbank at the subject site comprises a lower terrace (including walking path) adjacent to the Yarra River water edge and a steep embankment up to the former industrial and proposed residential lands. A portion of the lower terrace comprises fill at site of a prior confluence of the Yarra River and a small creek. The steep embankment was established during the period of site occupation by Amcor, to the 1% AEP (approx.) flood elevation, to prevent flood inundation of the site. The steep embankment contains uncontrolled historic fill material.

The lower terrace and steep embankment have been revegetated with non-indigenous native trees. However, the edge of the riverbank comprises indigenous river red gums (*Eucalyptus camaldulensis*), likely to be from natural regeneration.

The riverbank on the lower terrace has been subject to recent slumping. There are three large (but not mature hollow bearing trees) River Red Gum trees within and adjacent to a recent bank slump. One of these trees has fallen into the river and is currently lying across the Yarra River. Two other trees (T1 and T2) have been identified as at risk of collapse.

A further River Red Gum fell into the river in January 2019. This tree has been removed leaving the root ball in the bank. Other bank slumps are present and other trees along the waterway corridor may be at risk.

The mechanisms for the cause of the bank slumping is to be the subject of detailed investigations into the extent and cause of the problem and the identification of mitigation measures.

It is understood that City of Yarra and members of community wish to explore options to retain Tree T1. This memo sets out those options.

Potential process leading to tree collapse

The expert panel, convened by Alluvium to assesses the issues, has identified the potential processes leading to the collapse of trees at the site and has identified the following factors that could contribute to the collapse of T1.

Bank slump

The primary driver of T1 collapse will most likely be further ground movement destabilising the tree. Tree T1 has tilted due to bank slump and unless this issue is addressed, there is an imminent (weeks to months) risk of Tree T1 falling. Further slumping will lead to further tilting of the tree and the ultimate collapse of the tree

The expert panel has identified a rise in groundwater in lower the terrace of the Yarra River at the subject site as the likely cause of the bank slumping. The expert panel noted the poor condition (and death) of some of the introduced vegetation on the lower terrace and lower levels of the steep embankment. While a decline in vegetation condition could be the result of many factors, it is consistent with the elevated groundwater levels, indicating water logging of roots.

In addition to the tilting, the root system of T1 has most likely been damaged as a result of the bank slumping. The damaged root system reduces the ability of the tree to:

- collect and transport water to the foliage.
- Support the tree at a tilt and from falling in wind events

Initial baseline investigations suggest that riverbank erosion at site is unlikely to be the cause of the slumping. However, stream erosion has the potential to remove recently slumped material leading to further slumping and tree movement.

Wind load

The impact of wind load on trees depends on wind velocity, diameter and volume of stem, height of tree, crown area, steam breakage strength, root system (depth, weight, and diameter of roots), and strength of roots and soils. If the tree has a root system inconsistent with the size of the crown, there is a significant risk of tree collapse due to uprooting. Due to recent slumping, the root system of Tree T1 has been compromised. Heavy wind load under current root conditions can destabilise the tree, leading to collapse.

However, T1 is in a relatively well protected location and has other trees around it offering wind protection. Therefore, the tree is not highly exposed to wind, and while contributing to the threats, the wind load may not be the immediate primary driver of collapse.

Drought stress

The root system of T1 has been disturbed by the bank slump. This will have an impact on the tree's ability to transport water to the crown. The effect of this will be seen when the water demand of the tree increases in summer and the tree experiences seasonal drought stress. The tree will be expected to lose much of the foliage and may begin to shed branches. If the root system is not able to supply adequate water to the tree it will most likely die within two summers. Ongoing shedding of limbs will create an ongoing risk to access. An ongoing decline in the condition of the tree will also increase the WHS risks to arborist and others tasked with the ongoing management of the tree.

Objectives

Council meeting (30th July) and ongoing discussion with council officers have assisted the expert panel identify objectives for the management of Tree T1. The objectives can be listed as:

Ecological value

Tree T1 (River red gum) is an indigenous native tree that has provided a healthy arboreal habitat. The tree is a character species of the endangered EVC56 Floodplain Riparian Woodland, the natural vegetation community for this section of the Yarra River. The tree has not matured into a hollow bearing tree and so is not providing valuable nesting habitat.

The tree can provide ecological value as a standing dead "stag". Standing dead trees provide rooting and nesting sites especially if they have hollows in them.

Trees falling into rivers introduces large wood structures to the river and can form primary instream habitat features. The Yarra River has a low density of large wood. The tree could provide significant ecological value as instream large wood.

Aesthetic value of tree

The Tree T1 together with other trees along this reach of the river provides significant aesthetic value to riverbank and walking path. As an indigenous species to the area, the tree contributes to the character of the river and riparian zone.

Public access

The public access to riverbank has been restricted since past few months as a result of the bank collapse and risk of tree fall. The current bank slump and condition of Tree T1 prevents access to the site. Return of public access is sought for the site.

Protection of riverbank

An uncontrolled collapse of Tree T1 will compromise the existing lower terrace of the riverbank. The tree also contributes to the surcharge / load on the riverbank.

The collapse of tree will result in further loss of bank material and damage to the path. The uncontrolled loss of the lower terrace will also compromise the stability of the steep upper bank. The loss of the lower bank and steep upper bank would result in significant loss of property, with potential release of the uncontrolled historic fill material into the Yarra River.

However, the root ball of the existing tree can offer stability to the bank and could be kept if the tree is removed.

Protection of other trees

If T1 falls in an uncontrolled manner it may fall onto adjacent trees and shrubs damaging them. The size of this tree means other trees could be lost on the site following an uncontrolled failure of the tree. Protection of other trees will be important for the site.

Constraints on options

Constraints that impact on the feasibility of options include:

Work health safety

The use of large machinery, on the lower terrace with accompanying surcharge and vibration could increase the likelihood of collapse and may pose a work health and safety risk for operators.

Similarly, any tree work that requires an arborist to climb the tree can pose some work health and health safety risks. Retention of the tree, that results in an ongoing decline in its health, will increase the WHS risk to staff tasked with the management of the tree

Environmental regulations

A planning permit is required for native vegetation removal. However, clause 42.03-3 of the state planning provisions provides for an exemption to the requirements for a planning permit for vegetation removal to enable emergency works.

A review of the risk assessment (likelihood and consequence framework) used by Ryder Arboriculture has not changed the low risk assessment to the public safety. With pedestrian controls in place, this situation (while not ideal) may not constitute an emergency.

However, the subject tree in its current form threatens the bank stability. Council officers, have advised that the subject riverbank has undergone significant further movement over the weekend (10 and 11 August 2019), refer figure below. The subject bank is active. Further bank slumping can be expected over the forthcoming days and weeks.

The loss of the lower terrace and steep upper bank would result in significant loss of property including the walking path, with accompanying adverse outcomes for the Yarra River including release of uncontrolled historic fill material. Removal of the tree T1, to reduce the mass of the tree, and the uncontrolled collapse of the tree would meet the requirements of emergency works to protect the riverbank.



Tree T1 on and related bank slump 12 August 2019

Timeliness of action

Timeliness of actions are essential in the identification of the best available option for management of Tree T1. Based on the recent bank movement over the last few days, actions to address the risks should be undertaken with a level of urgency over a period of days rather than months.

Option assessment

Possible interventions

A set of possible interventions for management of T1 are set out below. All the following interventions will require the input from specialist contractors and a work safe assessment to ensure a safe method is applied. These interventions have been combined into three alternate management options in section 7 of this report.

Restrict site access

Ongoing signage and fencing of the path to prevent the public access along the waterway corridor. This is required while the tree is in an unstable state. Signs in the river to inform people on the water are also required. This must be in place in the short term until the site can be made safe.

This is an unlikely to be a long-term intervention option as the public will require access along the river to make use of their public spaces.

Fall tree

Tree to be cut down in a controlled manner ensuring adjacent vegetation is not impacted. The trunk and main branches to be kept intact as much as practical to enable the tree to be used for instream habitat. The root ball to be retained intact to assist the protection of the bank

Install main trunk and large branches in river as a habitat snag

The tree can be used as large woody debris (snag) in the river. This will provide desirable instream habitat which is at low levels in this section of the Yarra River.

Approval from Melbourne Water will be required for this intervention. The installation of large wood is consistent with Melbourne Water's management and priorities for waterways improvement and subject to appropriate placement, approval will most likely be given for this action.

Brace tree

Install cables and land anchors to stabilise the tree. This will provide support to the tree against wind loads until significant ground movement occurs. If further ground movement occurs the bracing will most likely fail.

This intervention may require machinery to install the land anchors.

Infill slumping cracks

Infilling the slumping cracks with a sandy-loam soil will assist in stabilising the site and help protect the roots from exposure to air. This will also provide a substrate for roots to regrow into assisting in future growth of the tree. Infilling the slump cracks will also reduce water access to the slumped soil.

Reduce crown of tree

Lop tree to remove branches over public access paths and to even the weight distribution in the crown. This will also reduce the water demand of the tree and potential drought stress it will experience in summer.

After lopping, the tree it will produce epicormic shoots to replace the reduced crown. These can be prone to dropping and pose an ongoing safety hazard. Regrowth on the tree will need to be managed over time to maintain public safety.

- It will involve arborists climbing the tree.
- A permit is required to lop the tree.

Kill tree, reduce crown and retain upright as habitat tree

This aims to retain the tree as a stag for future habitat. The tree will have most of the branches removed and be treated with herbicide to prevent regrowth and hazards from epicormic growth. Holes can be bored into the tree structure to initiate hollows for nesting.

This will not reduce weight on the bank and the stag will most likely fall if there is further ground movement.

Rock armour the bank

Rock rip rap can be used to prevent the loss of slumped bank material via river erosion processes.

To limit the safety risks, this work would need to be undertaken from the river via a barge. Placement of rock in this manner is not generally used to prevent slumping from banks as the saturated bank material can still pass through the rock. As a consequence, the approach may limit the erosion of slumped material but may not prevent further bank slumping.

Melbourne Water approval will be required to undertake rock armouring.

Sheet pile the bank

Sheet piling could be used to 'prop up' the riverbank. Stabilising the bank using sheet piling will have less intrusion into the river channel than rock and may be more successful in preventing further slumping than rock beaching. The sheet piling would also need to be installed from a barge on the river

However, sheet piling introduces a highly unnatural engineered feature into the river which is both visually and ecologically unacceptable in this location. The sheet piling may also further damage (cut) the root material of existing vegetation

Melbourne Water approval will be required for sheet piling. It is unlikely that sheet piling would be approved for installation at the site. Although this has not been tested with Melbourne Water.

Reduce slumping potent by managing soil moisture

Further soil movement and slumping will be activated by increased ground water flowing to the location. If the ground water is intercepted the risk of slumping may be mitigated.

This option requires further detailed investigation of the ground water and geotechnical conditions to ensure this is the driver for soil movement.

Option package

The development of the option for the removal or retention of T1 has considered the site context.

Tree T1 raises a problem at this location due to the level of public access. In addition, the location has been modified in the past with vegetation clearing, replanting, land filling and land use changing over time. The current and planned use of the waterway corridor is for public use, amenity and waterway health. The waterway is expected to be in a naturalistic state but not a fully intact ecological condition. The trees along the river provide support to the waterway aquatic environment, habitat to birds and arboreal animals and visual amenity for the corridor users.

Three alternate options have been developed for T1 (the tree within the recent bank slump).

Option 1: Fall the tree and install as instream habitat

Interventions

- Fall the tree
- Place the tree in river as aquatic habitat
- Infilling of slump cracks
- Retain the root ball for bank protection
- Manage soil moisture

Advantages	Limitations:
Short term <ul style="list-style-type: none"> • Opens potential for access of river frontage to community • Increases instream habitat • Reduces damage to bank due to tree falling in uncontrolled manner • Reduces risks to other trees from an uncontrolled fall • Removes safety hazard to river users • Predictable outcome. 	<ul style="list-style-type: none"> • Tree is not standing/ loss of existing aesthetic and ecological values
Long term (>10 years) <ul style="list-style-type: none"> • Access to site is unrestricted • Future planning can provide outcomes for the community • Habitat improvement in waterway. 	

Discussion

This option addresses the current safety issue presented by T1 and provides an opportunity to reopen the existing walking path to the community (refer discussion below). It provides a certain outcome including the potential addition of large wood habitat in the river. The option is not confounded by other issues related to the ground stability and success is not dependent on other issues being resolved. This option is consistent with recommendations of arborists that have visited the site.

The requirement to obtain a permit for native vegetation removal does not apply to emergency works to reduce immediate risk to property. The active movement of the bank and the extent of damage to both property and the Yarra River, constitute 'an immediate risk to property' and enables activation of clause 42-03.3 of the state planning provisions, creating an exemption for emergency works.

Reopening of the walking path: While this option provides the opportunity for reopening of the walking path, significant further work will be required to provide safe public access. The extent of such work should be explored in subsequent investigations and reporting.

Option 2: Retain the living tree with possible engineering interventions

Interventions

- Rock beaching to protect slumped material from river erosion
- Bracing of the tree to enable safe river access, limit direction of tree fall and enable access to tree for crown lopping
- Infill slump cracks
- Reduce the crown (lopping)
- Ongoing monitoring of tree
- Ongoing maintenance of crown (if possible) if the tree suffers dieback
- Manage soil moisture
- Intermittent site access subject to tree condition and access for maintenance

Advantages	Limitations:
Short term <ul style="list-style-type: none"> • Tree could be alive, but is increasingly unlikely given recent ground movement 	<ul style="list-style-type: none"> • Tree will be changed from current visual condition. • Uncertain outcome with ongoing likely collapse. • Limited public access • Ongoing safety hazard • No guarantee of tree survival, tree loss is imminent
Long term (2-5 years) <ul style="list-style-type: none"> • Tree may be retained on the site 	<ul style="list-style-type: none"> • Ongoing survival of tree is not certain • Tree will fall or die and investment in retaining it will be lost • Ongoing site access constraint. • Ongoing safety hazard from tree of branches falling • Ongoing maintenance requirement • Tree is likely to fall

Discussion

This option partially addresses the current safety issue presented by T1. This option provides a short-term benefit with the outcome of delivering a living tree that may persist for some years.

However, the longevity of the tree would remain uncertain. The retained tree will have a compromised health and a changed visual appearance. The tree will also pose an ongoing safety hazard. The compromised tree is likely to continue to shed limbs. This may restrict access in the future and will require ongoing monitoring and maintenance commitments.

The success of this options is uncertain as is dependent upon the underlying ground stability issue being resolved. If the slump progresses the tree will fail regardless of the interventions applied.

Option 3: Retain the dead standing tree with possible engineering operations

Interventions

- Rock beaching
- Bracing
- Infill slump cracks
- Reduce the crown
- Restrict access
- Manage soil moisture
- Kill tree with herbicide

Advantages	Limitations:
Short term <ul style="list-style-type: none"> • Tree is retained vertically • Habitat is retained riparian zone • Local character is maintained to some extent 	<ul style="list-style-type: none"> • Uncertain outcome • Restricted public access • Possibility of collapse with future ground movement • Limits options for future corridor plans
Long term (5-10 years) <ul style="list-style-type: none"> • Habitat is provided in riparian zone • Local character is maintained to some extent 	<ul style="list-style-type: none"> • Ongoing persistence of standing stag is not certain • Tree may fall and investment in retaining it will be lost • Further damage to the bank.

Discussion

This option partially addresses the current safety issue presented by T1. The outcome of a standing stag on the site is uncertain. If this achieved it is likely to provide a 5-10-year ecological benefit to the riparian zone. Uncontrolled failure of the tree with further damage to the bank and adjacent vegetation is possible.

However, the tree will pose an ongoing hazard. This may restrict access in the future and will require ongoing monitoring and maintenance commitments.

The success of this option is uncertain as it is dependent upon the underlying ground stability issue being resolved. If the slump progresses, the stag is more threatened and may fail.

Recommendation

The success of Options 2 and 3 are uncertain. These options retain the tree at the current location in an altered state. However, they also retain a safety hazard on the site and will require ongoing maintenance input. Option 3 should be immediately dismissed as an unacceptable outcome as it provides limited benefits over Option 2

Option 2 seeks to retain the current aesthetic and ecological attributes of the existing T1. However, the crown of the tree would need to be modified and would pose an ongoing public risk as the condition of the tree declines and sheds timber. The option does not provide a practical and feasible solution to the risks at the site and is not recommended.

Option 1 (Remove the tree and retain trunk for habitat and root ball for bank protection) provides a predictable outcome for the site and enables most short- and long-term objectives to be achieved. While the loss of the tree will have some impact on the character of the site, this is the only option that provides for the practical and feasible resolution to the risks posed by the severely compromised tree T1. Option 1 is the only feasible option that addresses the immediate risk of damage to property (riverbank).

Option 1 is recommended for implementation as a matter of urgency. The active movement of the bank and the extent of damage to both property and the Yarra River, constitute 'an immediate risk to property' and enables activation of clause 42.03-3 of the state planning provisions, creating an exemption for emergency works.

While not essential for public safety, the option would also help to reduce risks to public safety. Until this option is enacted, site access control (walking and boating) must be in place to manage the site safety risks.

Appendix F: Stream stability assessment

Memo

Subject	Stream stability assessment
Distribution	Alluvium Consulting Australia (Internal)
Date	15 August 2019
Author	Ross Hardie & Advait Madav
Project	Bank slumping and tree collapse review and investigation

Introduction

Alluvium Consulting Australia (Alluvium) has been engaged by City of Yarra to investigate bank slumping and related tree collapse on the Yarra River at the subject site, the former Amcor site at Fairfield. The subject site adjoins the right bank of the Yarra River and is the subject of an urban renewal / development project by Glenwill. The purpose of the investigation is to:

8. Identify the causes of the bank slump and tree collapse
9. Identify any short-term actions that should be undertaken
10. Identify long term remediation measures for the site

Three trees occur within and adjacent to a recent bank slump (Figure 18). One of these has fallen into the river and is not covered in this memo. Two other trees (T1 and T2) have been identified as at risk of failure during previous visits by others. Further discussion on the stability of the trees is provided in the riparian assessment that has been undertaken in parallel to this stream stability assessment.

This memo forms part of a first stage (interim) assessment of the issues and has been based on a site inspection and review of available information. A more detailed second stage assessment is proposed based on the outcomes of the stage 1 assessment.

This memo comprises one of five, first stage assessments, undertaken by an expert panel convened by Alluvium on behalf of the City of Yarra. The other stage 1 interim assessments comprise:

- Riparian ecology
- Geotechnical study
- Groundwater management
- Surface water management

The purpose of this investigation, covered by this memo has been to identify the extent to which the subject bank slump and tree collapse could be attributed to fluvial geomorphic processes. The memo has sought to identify:

- whether the slumping is the result of stream bank erosion
- any stream management actions that could be undertaken to reduce site risks
- the scope of work for any detailed stage 2 investigation.

Site inspection and data review

The expert panel conducted a 2-hour site visit on the morning of 25 July 2019. The site visit included locations of sediment pond, inceptor swale drains, retention dam connections, existing outfall drains, groundwater

bores, and riverbank at the subject site. The site inspection was undertaken to familiarise the expert panel with the site and review the bank morphology, existing slump areas, and condition of trees along the riverbank.



Figure 18. *Tree collapse site*

Alluvium has reviewed following reports, surveys and information provided by City of Yarra and Melbourne Water for the stage 1 interim stream stability assessment.

- Geotechnical investigation report (Douglas Partners Pty. Ltd.)
- 1-D HECRAS model and cross section survey (Melbourne Water)
- Arborist report (Ryder Arboriculture and Environment)
- Yarra River Flood Modelling report (S P Goh & Associates)

Discussion: Potential mechanisms influencing bank collapse

Bank material

The riverbank comprises a lower terrace (including walking path) adjacent to the Yarra River water edge and a steep embankment up to the former industrial and proposed residential lands. The steep embankment was filled, during the period of site occupation by Amcor, to the 1% AEP (approx.) flood elevation to prevent flood inundation of the site.

The fill material at the site includes clay and bricks and to also include asbestos. Evidence of the clay and brick fill material was observed on site.

The lower terrace and steep embankment have been revegetated with non-indigenous native trees. However, the edge of the riverbank comprises indigenous river red gums, likely to be from natural regeneration. The root material from the river red gums provide a matting within the clays and fine silts making up the riverbank material.



Figure 19. Root material along bank of Yarra River at subject site

Historic creek on riverbank

As set out above there is evidence of fill material on the lower terrace. Figure 20 illustrates provides an extract of a MMBW Historic Survey Plans (1910-1911) (refer Douglas Partners 2019) of a creek on entering the Yarra River through the now lower terrace of riverbank. Figure 21 sets out an indicative location of the creek in the current landscape. We are aware of a stormwater pipe located in the area of the old creek, however there is limited surface evidence of this creek in the current landscape, suggesting that the creek and its confluence with the Yarra River have been infilled.

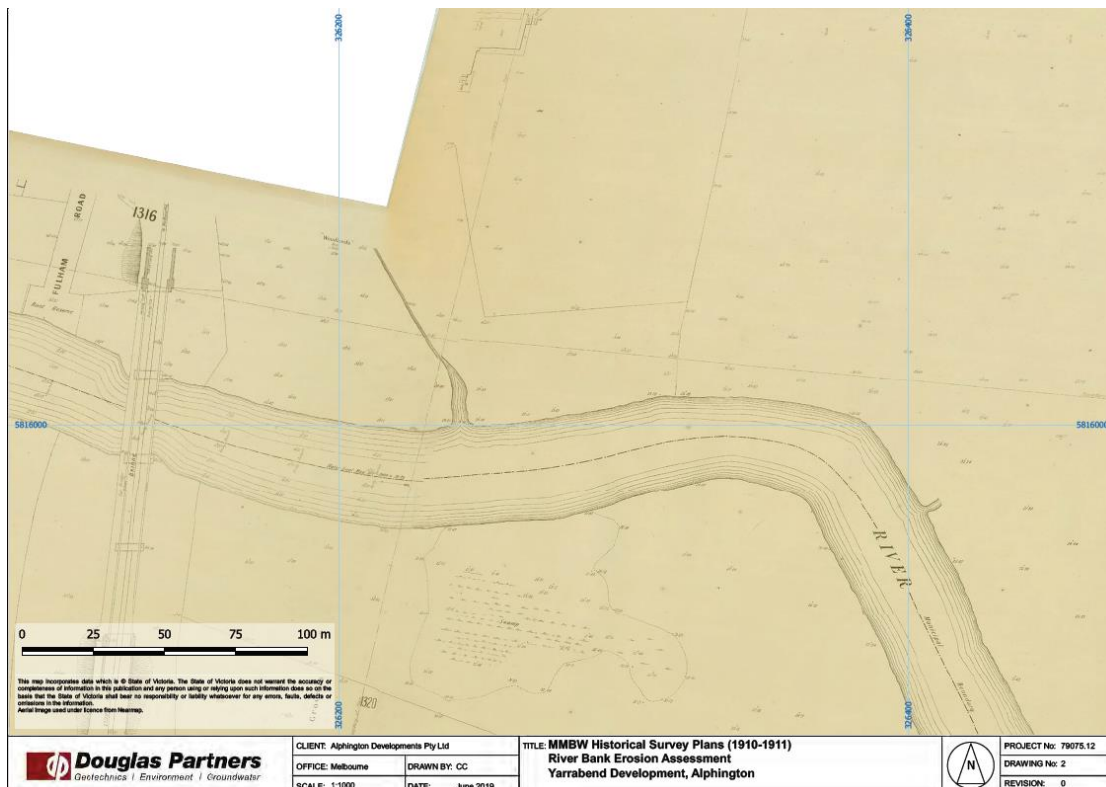


Figure 20. Old Creek location from historic survey

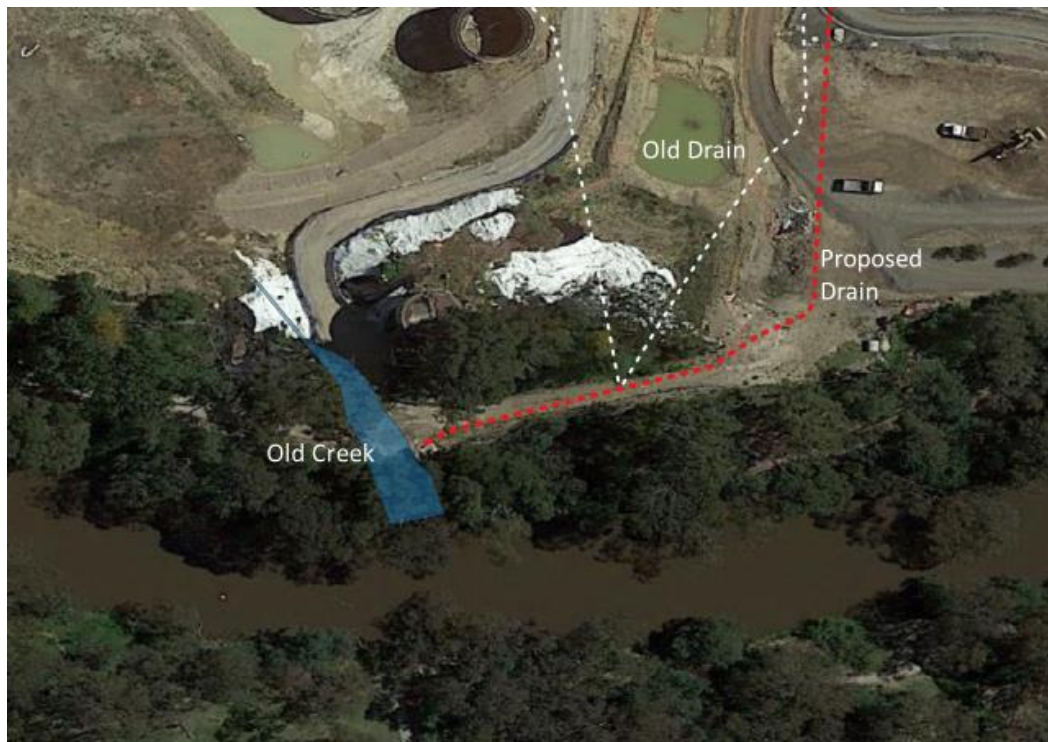


Figure 21. Indicative location of creek in current landscape

Review of Melbourne Water hydraulic model

Shear Stress

Melbourne Water provided a 1-D HECRAS hydraulic model of the Yarra River based on bathymetric and topographic information and the 1% ,2%, 5%, 10%, 20%, and 50% AEP flow events.



Figure 22. Cross section survey and aerial view of site

Figure 22 demonstrates the riverbank site lies between CH 31752 and CH 31470 of HECRAS model. The bank slumps and tree collapse site are located between these two cross sections. The shear stress for the subject site has been assessed at both these cross sections. The results are set out in Table 3.

Adjustment of shear stress for outside bends

The hydraulic modelling results provide shear stress based on the depth of water and hydraulic grade. However, shear stress is higher on the outside of a meander bend than in the centre of a straight reach. The shear stress results for each cross section 31752 have been increased to reflect the influence of the meander bend. The method of adjustment is set out in below.

The method of adjustment was based on that set out in *Technical Guidelines for Waterway Management* (DSE, 2007), refer Figure 23. whereby the shear stress is scaled by a factor based on the radius of curvature (Rc) divided by the base width (W) of the channel (Rc/W). The resultant factor was used to factor up the cross-sectional shear stress value for the design events giving larger shear stress values on the outside of the bend.

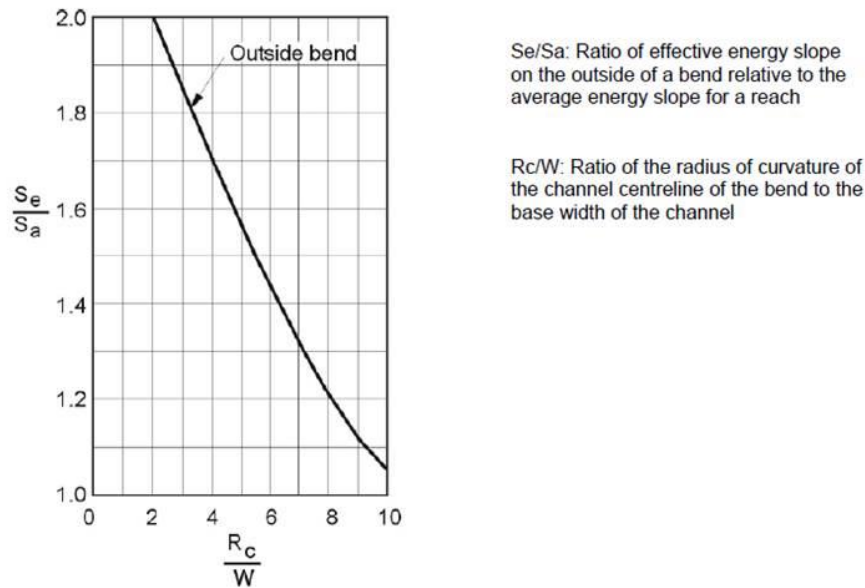


Figure 23. Effect of channel bend on effective energy slope (DSE 2007)

The shear stress results are set out in Table 3 below.

Table 3. Shear stress at riverbank (High Flow)

AEP Flow	Shear stress (N/m ²)		
	Cross section 31470	Cross section 31752	
	Channel	Channel	Channel adjusted for meander
1%	51.69	13.74	24.73
2%	47.7	12.88	23.18
5%	43.63	12.23	22.01
10%	40.74	12.1	21.78
20%	38.99	11.84	21.31
50%	35.15	11.86	21.35
100%	29	12.53	22.55

Shear stress resistance

The shear resistance of different stream bank material is set out in Table 4.

Table 4: Shear stress thresholds (Fishenich 2001)

Boundary category	Boundary type	Permissible shear stress (N/m ²)
Soils	Fine colloidal sand	1.44
	Sandy loam (noncolloidal)	1.92
	Alluvial silt (noncolloidal)	2.39
	Silty loam (noncolloidal)	2.39
	Firm loam	3.59
	Fine gravels	3.59
	Stiff clay	12.45
	Alluvial silt (colloidal)	12.45
	Graded loam to cobbles	18.19
	Graded silts to cobbles	20.59
	Shales and hardpan	32.08
Vegetation	Class A turf	177.16
	Class B turf	100.55
	Class C turf	47.88
	Long native grasses	81.40
	Short native and bunch grass	4.55
	Reed plantings	28.73
	Hardwood tree plantings	119.70

The banks of the Yarra River comprise a silty clay material reinforced by vegetative root matt. The shear stress applied by stream flow in the Yarra River exceeds that for clay material but is well below the shear stress resistance of hardwood tree plantings, found by Alluvium to approximate the shear stress resistance of streambanks with structurally diverse native vegetation. We do not expect streambank erosion to be a primary cause of bank slump at the subject site

Discussion with Melbourne Water

Alluvium engaged in technical discussions with Melbourne Water to discuss potential slump mechanism and to understand if there have any similar incidents of bank collapse in the reach of river upstream of Dights Falls. Melbourne Water (A Mellor. Pers comm.) have advised that while isolated bank failure and tree collapse can occur in this reach of the Yarra River, the subject site has incurred slumping and tree collapse at significantly higher rates (2 trees lost in 2019 and 2 to 3 locations of bank slump) than other similar reaches of the Yarra River.

Short term management implications

Based on the information available for this assessment, we are of the opinion that the subject reach of stream in the vicinity of the proposed site is not likely to be undergoing accelerated rates of stream flow related channel erosion that would have led to the bank collapse. However

- The recently slumped bank material will be vulnerable to loss by erosion processes. The slumped material is loose and relatively susceptible to fluvial scour
- Trees that are at risk of collapse will further risk the loss of existing bank material. An uncontrolled fall of the trees at risk of collapse will result in further destabilisation of the riverbank and further expose material for erosion by fluvial processes

- Further investigations will be required to confirm this assessment

In short term we recommend

- Removal of T1 at imminent risk of collapse (refer riparian ecology report). Subject to approval of Melbourne Water the subject tree could serve as important instream habitat
- management of boat traffic including installation of buoys and other warning signs to ensure river users do not venture close to the subject riverbanks
- continued fencing of the site to prevent pedestrian access pending resolution of the bank slumping and tree collapse issues.

We have considered the practicalities of additional works to protect the subject banks and trees from further collapse. Such works could include placement of rock beaching or sheet piling in the river to support the slumped bank material. Use of such material to protect the bank would require further investigations including geotechnical assessment for effectiveness. The subject site is at risk of further movement and for safety reasons may not be suitable for heavy earthmoving equipment. As an alternative, such work could be placed from the Yarra River by barge. Suitable equipment for barge-based rock and sheet piling placement is available in Victoria. However, these options will require significant further investigation, may not meet short term stability outcomes and may not meet desired long- term outcomes for the river.

Scope of work for Part 2: Detailed investigations

The following investigations will be required to confirm the findings of this interim assessment

Reach scale bank stability assessment

A reach scale bank stability assessment will be required to confirm (or otherwise) the anecdotal evidence provided by Melbourne Water that the subject slumping is limited to and or concentrated at the subject site. The assessment would comprise:

- Review of Melbourne Water records of staff and stakeholder reports on bank stability through the subject reach
- Walk and/ or boat-based review of left and right bank stability over a 1km reach of river (approx.) upstream and downstream of the site.

Hydrologic assessment

Review of flood history of the subject site over the period prior to and during the current site construction. The purpose would be to identify the extent to which recent hydrologic conditions (river heights) are consistent with or divergent from historic stream flow conditions

Hydraulic modelling

Development of a detailed 2-dimensional hydraulic model of the subject site to assess shear stress against the left bank of the river and compare these values with:

- Other similar reaches of river not subject to bank failure
- Shear stress thresholds for the subject bank material.

Topographic and bathymetric survey

The hydraulic investigations will require topographic and bathymetric survey of the river in the vicinity of the subject bank.

References

DSE (2007). *Technical Guidelines for Waterway Management*. Department of Sustainability and Environment, Victorian Government, Melbourne.

Fischenich, C. (2001). Impacts of stabilization measures. U.S. Corps of Army Engineers, Engineer Research and Development Center. Vicksburg.