alluvium

SUMMARY REPORT:

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

February 2021

CITY OF YaRRA

Document history

Revision:

Revision no.	01
Author/s	Ross Hardie Alex Sims Advait Madav Jon Fawcett (CDM Smith)
Checked	Alex Sims
Approved	Ross Hardie

Revision no.	02
Author/s	Ross Hardie Alex Sims Advait Madav Jon Fawcett (CDM Smith)
Checked	Alex Sims
Approved	Ross Hardie

Revision no.	03
Author/s	Ross Hardie Alex Sims Advait Madav Jon Fawcett (CDM Smith)
Checked	Alex Sims
Approved	Ross Hardie

Revision no.	04
Author/s	Ross Hardie Alex Sims Advait Madav Jon Fawcett (CDM Smith)
Checked	Alex Sims
Approved	Ross Hardie

Distribution:

Revision no.	04
Issue date	16 January 2021
Issued to	Ciaran Maher (City of Yarra)
Description:	Final summary report

Citation:

Alluvium (2021). Summary report: Tree collapse and bank slump investigation on Yarra River adjacent to former Amcor site at Alphington, Report by Alluvium Consulting Australia for City of Yarra

Ref:
R:\Work\2019\162_Yarra_River_tree_collapse_review\10_Project\1_Deliverables\Review of monitoring report and council summary report - Jan 2021\Council summary report\P119162.10_Tree_Collapse_Bank_Slump_Summary_R01V_4a.docx

Contents

1 Introduction

Yarra City Council (Council) has engaged Alluvium Consulting Australia Pty Ltd (Alluvium) to investigate tree collapse (2019) 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 Developments (Glenvill).

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 riverbank on the lower terrace has been subject to recent slumping. Members of the local community have raised concerns with the Yarra City Council regarding the bank slump and associated tree collapse including the coincident timing of the slumping with the redevelopment of the site.

Yarra City Council engaged Alluvium to investigate slumping at the site and to support Council in its review of documentation provided by Glenvill and its consultants. The investigation and the ongoing support have been provided 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 (Rob Dabal, Alluvium).

The intent of the work undertaken and or requested by Yarra City Council has been to develop an evidence-based approach to the management of the bank slump and tree collapse. The investigations were intended to:

1. Identify the causes of the recent 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 investigations and ongoing support provided by Alluvium have been undertaken in two stages:

- Stage 1 interim report (August 2019): A qualitative assessment to identify the most likely causes of the bank slump and trees collapse and to set out a program of investigations to provide an evidence-based approach to management of the issues. This qualitative assessment was undertaken in 2019 for Yarra City Council, by Alluvium, and was based on a field inspection and review of readily available existing information.
- Stage 2 (Ongoing since September 2019): Ongoing peer review of investigations and monitoring documentation undertaken by Glenvill and submitted to Yarra City Council. This work by Alluvium, to review the work presented to Yarra City Council, is the **subject of this report**

This purpose of this report is to provide a summary of the monitoring and assessments undertaken to date and to provide an independent peer review of this work. In addition, we have provided a background to the issue and a 'problem statement' to provide some context to the summary and peer review.

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 (Figure 1). The riverbank at the subject site is located within freehold land. It is understood that a 30-metre-wide riparian corridor will be established for public use as a component of the planning consent for the proposed redevelopment. This corridor includes the subject river bank.

The riverbank at the subject site comprises a lower terrace (including an informal walking path) adjacent to the Yarra River's water edge and a steep embankment up to the former industrial and proposed residential lands. The existing informal walking path is located on private land. It is understood that the steep embankment

leading from the lower river terrace up to the upper terrace was established though placement of fill material during the period of site occupation by Amcor. The fill has raised the land that now forms part of the upper terrace, to the 1% AEP (approx.) flood elevation, limiting flood inundation of the site.

Figure 1. *The bank slumping zone on the Yarra River, with the location of trees assessed at bank slump zone*

The lower terrace and steep embankment have been revegetated with non-indigenous native trees. However, the edge of the riverbank comprises mature indigenous river red gums, likely to have established from natural regeneration. The riverbank on the lower terrace has been subject to recent slumping (Figure 2Figure 3). The slumping of the riverbank has led to the collapse of several of these mature river red gums into the Yarra River.

Figure 2. *Tree (T1) and bank slump site visit by Alluvium (August 2019)*

Figure 3 *Tree collapse (T2) at the edge of bank slump (August 2019)*

The initial (stage 1) interim report of the expert panel (Alluvium 2019) was 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. While there are many elements that contribute to the slumping of riverbanks, the bank slumps at the site in early 2019 appear to have been triggered by recent increases in groundwater levels. The increase in groundwater levels was identified by the expert panel to have been most likely associated with the redevelopment of the site. However other factors, such as the grouting of a disused sewer main by Melbourne Water, were also identified as possible triggers.

The stage 1 report (Alluvium 2019) proposed a set of detailed investigation to determine the cause of any elevated groundwater, the bank slumps and tree collapse. The scope of the detailed investigations was concentrated on the issues of surface water / ground water interactions and the geotechnical stability of the embankments at the site. The recommended investigations set out in the stage 1 report also included further bank stability assessment to confirm (or otherwise) anecdotal evidence provided by Melbourne Water that the subject recent bank slumps were limited to and concentrated at the subject site.

This (stage 2) report focuses on the outcome of the subsequent detailed investigations set out in the Stage 1 report. These more detailed investigations have been undertaken by Glenvill and its consultants.

3 Problem statement

Elevated groundwater levels appear to have triggered the recent (2019) slumping on the left bank of the Yara River adjacent the former Amcor site. In the absence of options for remedial work on existing slumps, we expect some ongoing movement of the existing slumps, and that this movement will generate ongoing community concern. Slumping and tree collapse appears to have coincided with elevated groundwater levels within the lower terrace, expressed as surface water on the lower terrace.

The cause of elevated groundwater levels and the likely future changes in groundwater levels at the site require understanding to enable the development of an evidence-based management plan for the site. Numerous factors could lead to an increase in groundwater levels at the site. However, the timing of the slumping and the limited geographic location of the slumping led to the identification of two possible factors for increased groundwater levels at the site. The two factors are not mutually exclusive, and the ultimate cause of increased groundwater levels may be the result of a combination of the two triggers, or an alternative, as yet to be identified, factor. The two alternate potential factors for the increase in the groundwater levels and bank slumps are:

1. Factor No. 1: An increase in site infiltration associated with the removal of the drainage system servicing the former Amcor site and / or construction of infiltration based site construction site stormwater management: The activities had the potential to increase local (site) groundwater infiltration. This factor was identified by the expert panel as the most likely factor to have increased local groundwater levels.

2. Factor No. 2: Changes to groundwater levels associated with grouting of a disused sewer main. It is understood that Melbourne Water grouted a major sewer main associated with the decommissioning of that main. This work is understood to have occurred in 2015/2016. The old sewer main is understood to have been 'leaky'. However rather than sewerage leaking from the main, it is more typical for groundwater to leak into the sewer system. This leakage of groundwater into the system may have created a local draw down groundwater levels reducing the groundwater flux to the lower terrace. The grouting of the main had the potential to have halted such leakage of groundwater into the main and as a result, increased local groundwater levels. This was not the most likely factor identified by the expert panel. However, this factor could not be dismissed.

As previously discussed, factors other than the two outlined above may have caused the increased groundwater levels at the site. Further investigations and assessment were identified as being required to identify the most likely factors that led to an increase in increase in groundwater levels at the site. This information could then be used to develop a evidence based management plan for the site.

4 Key stakeholders and communication process

The Stage 1 investigations recommended a variety of monitoring data be collected at, and assessments undertaken for the study site, and that this data and the assessments be used to inform further an evidence-based management plan to address the bank slumping.

In practical terms, this monitoring data was;

- collected and analysed by consultants engaged by Glenvill Developments (Douglas Partners and others) and
- forwarded to Yarra City Council by Glenvill
- forwarded to the Alluvium team (engaged by the Yarra City Council) for review. In turn, Alluvium has engaged the services of Jon Fawcett of CDM Smith for groundwater expertise and other members of the expert panel if and as required.

The outcomes of reviews undertaken by Alluvium were forwarded to Yarra City Council for distribution to Glenvill and its consultants.

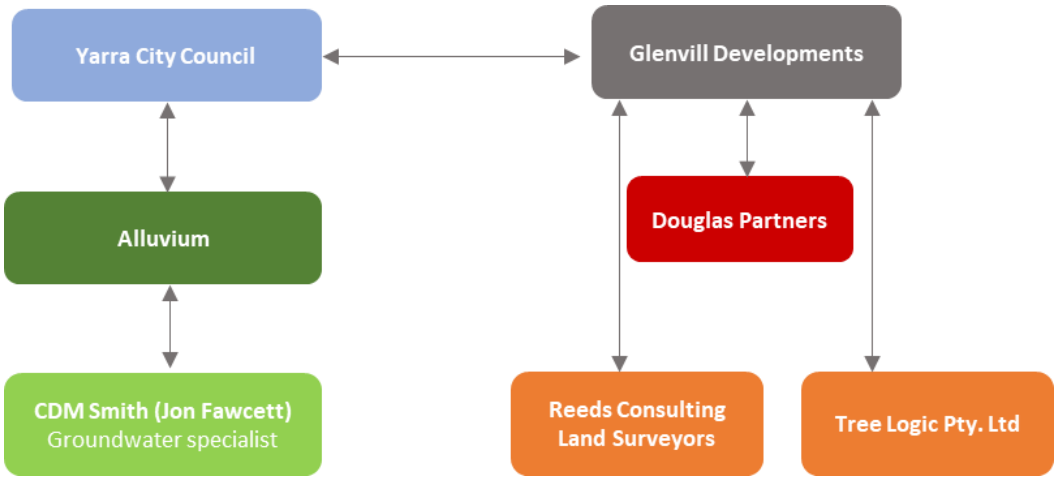

Figure 4. *Key stakeholders and data exchange for monitoring at the Yarra Bend bank slump site*

The intent of this process was that Glenvill Developments (with assistance from their consultants) compile monitoring data, undertake additional investigations and then build an evidence-based management plan to address bank slumping at the site.

Several iterations of this process have been completed over the past 18 months. Subsequent sections of this report summarise the data requested, the data provided, and the monitoring data and management plans available as of February 2021.

4.1 Data and information requests

Data and information requests have included:

- Reach scale context of slumps -This data provides context for the site by assessing the stability (evidence for ongoing bank slumping or historic bank collapse) in the study reach. This assessment was sought to identify whether recent instability at the study site is isolated to the site, or part of a wider pattern of instability in this section of the Yarra River.
- Slump movement monitoring – This data includes surveying the rate of slump movement to identify slump dynamics. Slumping rates can then be related to possible causal factors.
- Site topography and bathymetry surveys – this data was sought to be used as an input to hydraulic modelling, bank stability assessments, development of conceptual models of the processes at work and groundwater modelling.
- Erosion of bank toe – This assessment included hydrologic (analysis of variations in discharge in the Yarra River over the monitoring period) and hydraulic analysis (calculation of the forces exerted by flows on the toe of the left bank) used to determine whether natural processes are scouring the toe of the bank, triggering bank slumping.
- Groundwater assessment – the groundwater assessment was proposed to identify the role of groundwater in driving bank slumping. The assessment sought had three components:
    - Characterise soil properties (permeability, stability and chemical composition). This data was sought to contribute to an understanding of site stability and as inputs to groundwater modelling.
    - Monitor and model groundwater levels at representative locations across the site – groundwater level data can be used directly to indicate the elevation of the water table across the site. High groundwater levels in riverbanks can increase pore pressure and cause bank instability. The data is also used to calibrate groundwater modelling, which can be used to calculate the total flux of fluid through the bank.
    - Characterise groundwater chemistry – identify the source of groundwater moving through the bank. Because the chemical composition of rainwater that has recently infiltrated the ground differs from the composition of groundwater that has been stored underground for prolonged periods differ, comparing their chemical composition allows water sources and subsurface flow paths to be identified.
- Assess tree health – tree health is used to identify rapid tree die-off, which may be a precursor to tree collapse and accelerated slumping of the bank. Tree health can also be used as secondary evidence for elevated groundwater, as water-logging kills root systems
- Conceptual model and management plan – use the insights gained from monitoring and other assessments to develop a conceptual model of the underlying cause of bank slumping at the site, and from this develop a management plan to address the underlying causes.

4.2 On-site actions

Other on-site actions sought by Yarra City Council have included:

- Provision of public safety arrangements including:
    - controls on public access
    - management of at-risk trees
- Planning, design and implementation of modification to construction phase surface water management arrangements on the upper terrace including:
    - Works to prevent ponding of surface runoff.
    - Sealing of stormwater treatment ponds.
- Installation of temporary sub surface 'ag' drainage to lower the groundwater levels and hence limit the surface expression of groundwater within the lower terrace. This work was sought pending development of long-term management arrangements for the site.

A program of additional monitoring was requested to monitor the performance of these works including the monitoring of discharge from the temporary sub surface drain. This discharge rate could be used to inform the understanding of groundwater flow rates (flux).

5 Chronology of information requested and provided to date

This section summarises the timeline of data requests and if and when that data was provided to Yarra City Council and Alluvium for review.

Table 1. Summary of monitoring data requested from Glenvill Developments by City of Yarra. The table relates the reason specific data was requested, whether the monitoring data was provided.

Investigation component	Data requested	Date of request	Provided as of January 2021	Reviewed and response provided	Outcome or further requests
Reach scale context - This data provides context for the site by assessing the stability (evidence for ongoing bank slumping or historic bank collapse) in the study reach. This assessment determines whether instability at the study site is an isolated event, or part of a wider pattern of instability in this section of the Yarra River	Reach scale bank stability assessment	20 August 2019	Not provided	N/A	Data still required as of February 2021
Slump movement monitoring – surveying the rate of slump movement to identify slump dynamics. Slumping rates can then be related to possible causal factors.	Slump monitoring survey	20 August 2019	Yes Currently 12 monitoring points across the site assessed over an eleven month period between December 2019 and December 2020	Yes	Supporting data and integration with additional monitoring data still required
Site topography and bathymetry surveys – this data is used as an input to hydraulic modelling, bank stability assessments and groundwater modelling.	Topographic survey of the subject site	20 August 2019	Yes Provided in combination with other surveying data in monitoring reports	Yes	The survey is of appropriate scale and quality
	Bathymetric survey of the Yarra River adjacent to the subject site streambank	20 August 2019	Not provided	N/A	Data still required as of February 2021

Investigation component	Data requested	Date of request	Provided as of January 2021	Reviewed and response provided	Outcome or further requests
Erosion of bank toe – hydrologic (analysis of variations in discharge in the Yarra River over the monitoring period) and hydraulic analysis (calculation of the forces exerted by flows on the toe of the right bank) are used to determine whether natural processes are scouring the toe of the bank, triggering bank slumping.	Hydraulic assessment	20 August 2019	Not provided	N/A	Data still required as of February 2021
	Hydrologic assessment	20 August 2019	Not provided	N/A	Data still required as of February 2021
Groundwater assessment – the groundwater assessment is used to determine the role of groundwater in driving bank slumping. The assessment has three components: **Characterise soil properties** (permeability, stability and chemical composition). This data is used to assess overall stability and as inputs to groundwater modelling. **Monitor and model groundwater levels** at representative locations across the site – groundwater level data can be used directly to indicate the elevation of the water table across the site. High groundwater levels in riverbanks can increase pore pressure and cause bank instability. The data is also used to calibrate groundwater modelling, which can be used to calculate the total flux of fluid through the bank **Characterise groundwater chemistry** – identify the source of groundwater moving	Soil stability analysis	20 August 2019	In part	Yes	Borehole logs provided in December 2019 were used to characterise soil conditions at the site, but a more robust analysis which identified soil strength, possible failure planes and a probability of failure analysis was not undertaken
	Soil permeability testing data	20 August 2019	Yes	Yes	Soil permeability testing was undertaken via falling head tests and the data are fit for purpose
	Groundwater data from 12 groundwater bores (4x Lower terrace, 4x upper terrace, and 4x 100m from riverbank)	20 August 2019 Note: Alluvium requested that an additional bore be installed in the northern section in March 2020	Partially provided A total of 9 groundwater monitoring bore were installed across the site	Yes	There is now a substantial body of groundwater data available for the subject site. (see . Table 2) However, integration of the groundwater process understanding with the wider monitoring data and assessments for the site has not been completed.

Investigation component	Data requested	Date of request	Provided as of January 2021	Reviewed and response provided	Outcome or further requests
through the bank. Because the chemical composition of rainwater that has recently infiltrated the ground differs from the composition of groundwater that has been stored underground for prolonged periods differ, comparing their chemical composition allows water sources and subsurface flow paths to be identified.	Groundwater chemistry assessment	20 August 2019	Partial Some borehole locations and surface water sampling data are absent from assessment.	Yes	The groundwater sampling methods were undertaken to a high standard and are fit for purpose. Complete analysis of data still required as of February 2021
	Groundwater modelling	20 August 2019	Not provided	N/A	Requested for modelling data and report Modelling still required as of February 2021
Assess tree health – tree health is used to identify rapid tree die-off, which may be a precursor to tree collapse and accelerated slumping of the bank. Tree health can also be used as secondary evidence for elevated groundwater, as water-logging kills root systems	Tree assessment – all trees >200mm Diameter at Breast Height	20 August 2019	Provided A tree health survey was undertaken in monitoring period 3 (March 2020-December 2020)	Yes	This vegetation assessment has been undertaken to a high standard and appears fit for purpose. Additional tree survey data provided 11 February 2012 but has not yet been reviewed
Conceptual model and management plan – use the insights gained from monitoring to develop a conceptual model of the underlying cause of bank slumping at the site, and then develop a management plan to address the underlying causes	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	20 August 2019	In part	Yes	Conceptual model and management plan provided, but analysis is of insufficient detail to support the proposed management actions. Comprehensive conceptual model that brings all data together and clearly links data to a long term management plan still missing.

6 Summary of works completed to date and site monitoring data collected

6.1 On site actions completed to date

Several of the actions sought by Yarra City Council have been undertaken by Glenvill:

- Risk assessment and ongoing monitoring of trees identified at the slump site as being at-risk
- Revision of the construction management plan to prevent ponding of surface runoff
- Modification of stormwater treatment ponds to eliminate this potential groundwater recharge pathway
- Efforts to limit public access to the slumping site
- Commencement of an additional monitoring program for the site, as outlined in Tables Table 1 Table 2 including the installation of motoring bores, a groundwater sampling program and soil permeability testing
- Installation of temporary sub surface 'ag' drainage to lower the groundwater levels and hence limit the surface expression of groundwater within the lower terrace.
- Design of additional modifications to the temporary 'ag' drain installed at the site

6.2 Monitoring data provided

This section summarises the three data monitoring periods for the site and sets out the data that has been collected. Monitoring data should form part of the evidence base for a conceptual model of processes driving bank slumping and the management plan that addresses the slumping.

Table 2. Summary of monitoring data available at the study site as of February 2021.

Monitoring report	Monitoring data requested	Monitoring data supplied to Council/Alluvium	Monitoring data reviewed
Round 1 November 2019 - June 2020	Groundwater level	Yes	Yes
	Slump movement	Yes	Yes
Round 2 November 2019 - June 2020 Northern section of slump	Groundwater level	Yes	Yes
	Slump movement	Yes	Yes
	Groundwater chemistry data	Yes	Yes
Round 3 March 2020 - December 2020	Groundwater level	Yes	Yes
	Tree health	Yes	Yes
	Slump movement	Yes	Yes

7 Summary of investigation outcomes to date

This section summarises the insights obtained from monitoring data collected to date, whether that information is fit for purpose, and whether the insights from the monitoring period have been used to inform management of the site.

Overall, much of the data requested to date has either not been provided to Alluvium, has been provided in part only, or has been provided without supporting/contextual information (Table 1). Without supporting documents, such as a suitable conceptual model that integrates the monitoring data and describes the processes causing bank slumping, we are unable to properly evaluate the information that has been provided.

We outline the status of each set of monitoring data below.

7.1 Slump survey and tree monitoring data

The slump monitoring and tree health data is fit for purpose and of appropriate resolution. However, the slump survey and tree data has not been integrated with other monitoring data collected (for example groundwater levels). The lack of additional monitoring data that was requested (see table 1) also makes evaluating this data difficult.

Importantly, the monitoring data reveals recent movement of slumps and trees. The survey data indicates that:

1. At some sites, approximately 50% of total observed slump movement occurred in the 3-month period between September 2020 and December 2020.
2. Most of the tree movement that has been monitored at the site has also occurred between September2020 and December 2020
3. This December 2020 phase of slump movement has occurred despite the provision of the temporary 'ag' drain that was intended to reduce water levels on the lower terrace and reduce such movement.

The movement was recorded on 8 December 2020 and was provided to Yarra City Council on 11 December 2020. On receipt of the slump monitoring data Yarra City council noted their concern and requested that Glenvill undertake:

1. Assessment and reporting of the significance of the movement;
2. A risk assessment on the trees that have been subject to movement to identify the risk of tree or limb collapse;
3. Evaluation of the recent slump and tree movement and related data setting out;
    a. the conditions that have accompanied the movement (e.g. groundwater, river levels, rainfall),
    b. a conceptual understanding of the cause of the movement and
    c. any proposed remedial measures

The 8 December 2020 slump movement is referenced in the Douglas Partners management advice report (January 2021). That documentation states: "*While these movements represent an increase compared to the previous period of negligible movement, the movement magnitudes follow an inundation event and are insignificant in comparison to the initial slump height. It is recommended that quarterly monitoring continue*" (p. 10). Further comment regarding movement on the existing slumps states: "*the existing slumps have not significantly moved, as demonstrated by the survey data collected since the drainage was installed*" (P. 12).

However, a formal risk assessment was not undertaken as part of the management advice report. We remain concerned at the movement and note that the Douglas Partners management advice report does not contain sufficient analysis to alleviate these concerns. We believe the December slumping warrants urgent attention as previously requested.

7.2 Groundwater chemistry data

We are confident that the water chemistry analysis by ALS is of an acceptable standard. However, data provided does not adequately address the original data request. The report describes the data collection method as well as an interpretation of the groundwater chemistry results. The source of much of the groundwater samples has been identified as the basalt aquifer beneath the study site, on the landward side of the slumping bank with the chemical signature of discharge water consistent with that consistent with that of the regional basalt aquifer (Douglas Partners, Yarra River Northern Bank Slump Monitoring Report – 3, December 2020).

Although the accompanying report does identify the source of sampled water (the basalt aquifer), the report does not explore the link between the source of the water emanating at the surface of the terrace and the factors that may be driving elevated groundwater levels, driving groundwater to the surface of the lower terrace.

7.3 Groundwater level data

Although groundwater level data has been collected for all three monitoring periods, a more detailed assessment is required to understand groundwater flow dynamics, including:

1. Calculation of groundwater flux to the riverbank slumps in order to assess how long groundwater discharge may persist for.

2. Groundwater recharge and mounding calculation to determine the relative influence of the decommissioned sewer and site sourced recharge to the development of the elevated groundwater levels.

3. Modelling of how effective draining of the subsurface will be in reducing soil moisture and drawing down the groundwater mound.

We also note that it is unlikely that ongoing monitoring of groundwater bores alone will be able to provide adequate information to assess the effectiveness of the mitigation plan and/or to determine the cause of the elevated groundwater levels and how long they may persist, creating ongoing risk of riverbank collapse.

7.4 Vegetation survey

A vegetation survey was conducted at the site by Tree Logic Pty Ltd in June 2020. A total of 137 trees were assessed for health and their risk of collapse. The report recommended 12 leaning trees be monitored and for a total of 3 leaning or dead trees to be removed.

Alluvium has reviewed the summary report, provided with the vegetation assessment. The report is fit-for-purpose and the methods and recommendations clearly articulated. While the tree assessment was appropriate and useful, it has yet to be integrated with other monitoring data collected at the site.

7.5 Conceptual model and proposed remediation measures

Conceptual model and management advice

Investigations have been undertaken by Douglas Partners and other consultants on behalf of Glenvill. Investigations included collection of monitoring data and its analyses. The management advice report (Douglas Partners January 2021) received by Yarra City Council was expected to:

1. Collate and integrate all monitoring data collected and assessment undertaken between December 2019 and December 2020.

2. Provide a conceptual model of the processes at work including those that triggered the bank collapse.

3. Provide and assess options for management of the site.

4. Provide recommendations for a preferred option.

The management advice report by Douglas Partners (2021) did not include a clearly framed set of conclusions arising from the investigations. However, Douglas Partners (2021) included various findings and conclusions through their report. We have extracted these findings and conclusions and set these out in Table 3. Our response to these conclusions is also included in Table 3.

Table 3 Conclusions from Douglas Partners (2021)

Conclusions drawn by Douglas Partners 2021 (Douglas Partners, *Report on Yarra River Northern Bank Slump Management Advice*, January 2021)	**Alluvium response to conclusions**
Groundwater conditions in the alluvial terrace were identified as a critical factor contributing to the slump issue. Groundwater conditions in the terrace alluvium are influenced by upgradient conditions as well as fluctuating river water levels. *The significance of river level fluctuation on bank stability is unclear. It is likely that that critical instability conditions occur due to a combination of upgradient groundwater condition effects and falls in river level following elevated levels*	We concur that groundwater conditions in the lower terrace are critical factor in the slumping. We concur that groundwater levels in the lower terrace are influenced by upgradient conditions as well as fluctuating river water levels. However, the conclusions fail to tell a complete story. The conclusions have not reflected data that indicate the issues have recently emerged and are confined to the site. This evidence suggests that the issues are likely to have been triggered by local hydrologic and hydrogeologic changes rather than regional processes that influence river levels.
The main upgradient feature affecting groundwater conditions in the terrace alluvium is the basalt rock aquifer. Planned development related site alteration will result in increased sealed surfaces and likely reduced recharge	The conclusion explicitly states that development of the site will reduce infiltration at the site and thereby reduce groundwater levels. From this conclusion it could be implied that the redevelopment of the site and the removal of the previous buildings, hard surfaces and associated drainage system is likely to have resulted in increased infiltration and increased groundwater levels. We concur that the explicit and implied conclusions are likely, however evidence to support the conclusions has not been provided.
There is no current evidence indicating the need for measures in the western area other than continuing the periodic monitoring	Suitable evidence has not been presented to suggest that measures will not be required in the western area. We concur that ongoing monitoring will be required. However, monitoring alone is unlikely to provide the evidence required. This monitoring should be supported by the development of an agreed conceptual model and additional investigations aided by such monitoring data.
Installation of suitable interim and long-term sub-surface drainage measures are considered to be the most practical approach to manage the riverbank slump issue subject to continuing periodic survey monitoring	While temporary sub surface drainage may have been effective at lowering groundwater levels and hence reduced the rate of slumping, the investigations to date have not demonstrated that such drainage is adequate for management of the existing slumps. The investigations to date have not demonstrated that sub soil drainage will prevent ongoing movement of the existing slumps and prevent the loss of residual riparian vegetation.

The report (Douglas Partners 2021) does not address the information gaps, has not integrated all the data and assessments completed to date, has not provided suitable conceptual models of the processes at work and has not provided or assessed the options for management. The report does not integrate available monitoring data into a single, well-reasoned conceptual model or models for the site. The conclusions drawn are either

not supported by the evidence or do not tell a complete story that is supported by available evidence. As a result, the management recommendations that follow, namely the installation of limited subsurface drainage between the terrace at the river's edge and the adjacent basalt aquifer, is not well justified. Further discussion on this option is provided in the discussion on the proposed drainage solution set out below.

The report fails to address the broader management of the existing slumps (e.g. riparian vegetation management) and the range of options to prevent slumping in areas not protected by the proposed drainage solution.

Proposed drainage solution
Glenvill has installed an interim (temporary) 'ag' drain within the lower terrace to reduce groundwater levels. This temporary drain has assisted in reducing the presence of surface water on the lower terrace. We assume that it has contributed to a reduction in bank movement, although we remain concerned over recent bank movement recorded in the most recent slump surveys.

On site discussions were held with Glenvill (12 October 2020) regarding modification and extension of that temporary drain to further reduce the surface expression of groundwater at the site. The modifications to the temporary arrangements, discussed on site, included the use of the existing temporary sub surface drain outlet to the Yarra River. We support the modification to the current temporary arrangements as discussed on site.

Glenvill has subsequently provided Council (5 February 2021) with a design drawing for a proposed modification to the temporary ag drain. This proposed arrangement was under review at the time of preparation of this report.

While installation of additional sub surface drainage is likely to reduce groundwater levels, the absence of any quantitative analysis, in support of a conceptual model, that identifies the extent, dimension, orientation and number of drains required to be installed in the bank, we are unable to evaluate whether the design arrangements are appropriate as a longer-term resolution to the issues at the site. Further monitoring, evaluation, investigations, design, and reporting will be required to confirm whether the proposed drainage solution is an appropriate long-term solution to issues at the site.

8 Summary

Bank slumping and tree collapse occurred on the lower terrace of the Yarra River in 2019. The slumping and tree collapse coincided with the timing of recent works associated with the redevelopment of the former Amcor site. The slumping and tree collapse also coincided with community observed increase in the presence of surface water on the lower terrace. The increased presence of surface water on the lower terrace is indicative of elevated groundwater levels. While bank slumping can be caused by many factors, the increased occurrence of bank slumps at the subject site appears to have been triggered by a localised increase in groundwater levels.

In response to the bank slumps and tree collapse, Yarra City Council sought investigations by Glenvill to enable the development of an evidence-based solution to bank slumping at the subject site. Yarra City Council requested that Glenvill collect and analyse various monitoring data for the site and undertaken additional investigations necessary to develop a conceptual model that would contribute to that evidence-based solution.

As of February 2021, the information sought by Yarra City Council is incomplete. Given the limited available monitoring data, the incomplete analyses of that data and the lack of a conceptual model for the processes at the site, it is not possible to definitively attribute the cause of bank slumping or support the majority of the substantive findings and conclusions drawn by Douglas Partners (2021). We are not in a position to support the long-term management recommendations provided by Glenvill nor are we able to provide an evidence-based strategy for managing existing, and preventing future, bank slumps at the site.

A temporary sub surface drain was installed at the site in March 2020. Glenvill recently proposed (February 2021) modification to the current sub surface drain for the site. While there are details that are yet to be resolved (construction technique and design suitability), the modifications to the existing sub surface drain will provide a low-risk interim measure that will improve the outcomes at the site. The long- term adequacy of these interim measures has not been determined.

9 References

Alluvium, 2019. Tree collapse and bank slump investigation on Yarra River adjacent to former Amcor site at Alphington, Report by Alluvium Consulting Australia for City of Yarra

Douglas Partners, 2020. Report on Geotechnical Investigation and Groundwater Study

Douglas Partners, 2020. Yarra River Northern Bank Slump Monitoring Report 2, Yarrabend, Alphington

Douglas Partners, 2021. Report on Yarra River Northern Bank Slump Management Advice, prepared for Alphington Developments Pty Ltd

Douglas Partners, 2021. Yarra River Northern Bank Slump Monitoring Report – 3, Yarrabend, Alphington

Douglas Partners, 2021. Drawing no 22185G_SEMP_Agi outfall 14.01.2021

Reeds Consulting, 2020. Monitoring Yarra Bank Visit 19

Reeds Consulting, 2021. Yarrabend River Corridor Tree Monitoring No. 75