MID-TERM REVIEW

Geomorphic change and disturbance thresholds for the protection or recovery of stream form in urban catchments

Healthy Waterways Strategy 2018-2028
Port Phillip & Westernport, Victoria

Melbourne Water

Strategic alignment

Regional Performance Objectives (RPOs):

- RPO 17: Water quality in waterways and bays is improved by reducing inputs of sediment and other pollutants from urban construction and development.

Key Research Areas:

- Hydrology and environmental flows: Developing tools and frameworks to assist improved decision-making in the management of flows to meet environmental flow objectives
- Water Quality: Understanding the environmental impacts of pollutants, including contaminants of concern, to inform risk-based management of waterways across the region.

Summary

The project aims to improve understanding of the response of stream and floodplain physical form and functioning to past, current and planned urbanisation, including thresholds of change. Streams respond to changes in flow and sediment inputs with urbanisation, but the way we manage streams and corridors can modify these responses (e.g. rock protection, vegetation management), and wholesale changes to physical form can be imposed by waterway construction or piping. Once altered, our ability to return a more natural physical form is uncertain.

By exploring these responses, we sought to understand the nature and extent of catchment-scale intervention (i.e. stormwater runoff controls and harvesting) and riparian land required (i.e. corridor set-backs that allow floodplain connectivity), to achieve sustainable physical form and functioning of riverscapes for a range of contrasting geologies and stream types across the region. Our ability to understand physical form management priorities is severely restricted by availability of stream physical condition data for the region. Where high-quality LiDAR data and feature surveys exist, they are not yet processed in a way that allows geomorphic insight. We explored ways of capturing physical form data using remote sensing techniques (e.g. LiDAR) to complement on-ground physical form assessments currently being undertaken for Melbourne Water as part of the Healthy Waterways Strategy (HWS) Monitoring, Evaluation, Reporting and Improvement (MERI) Framework.

Sustainable physical form (i.e. self-adjusting, resilient channels, connected floodplains, diverse physical habitat) is a hallmark of healthy waterways, and identified in the HWS as an important component of stream condition that supports key environmental values and ecosystem function that are highly valued by human communities and contribute to Melbourne's liveability. Achieving it in the face of projected levels of future urban growth across Greater Melbourne in the next few decades will require improved stormwater management, greater stream corridor protection and reduced direct intervention – three facets of planning and management that will need to work together.

To inform these much-needed changes in practice, we need better information about:

- What is lost in business-as-usual urban development? E.g. loss of physical integrity, loss of geomorphic character (supporting habitat and amenity), loss of floodplain function.
- What could be protected? What are the pressure-response relationships? Are there thresholds of irreversible disturbance? Can imperfect action (e.g. partial hydrologic mitigation or corridor protection) provide benefits for physical form and functioning?
- What could be enhanced? Where legacy impacts (e.g. rural drainage, vegetation removal) mean pre-urban riverscapes are degraded, can good planning and management improve their physical form and functioning?

Recommendations

- Develop a decision support tool that could be used by urban development planners early in the planning process to determine the levels of flow management and floodplain setbacks to protect channel morphology across different parts of the region.
- Where action is required to adaptively address channel erosion, consider the channel evolution trajectory and work with channel evolution cycles to foster recovery (e.g. provide space for widening and stabilisation).
- Keep a database of processed channel morphology data (e.g. bankfull width and depth, bank slope) updated as our new data extraction tools are rolled out for current and future LiDAR surveys, to allow for future geomorphic modelling and insights to support the development of the next HWS including potential environmental predictors in Habitat Suitability Models for Key Environmental Values.
- Encourage use of new channel dimension tools within Melbourne Water and other stakeholders to assist with stream analysis and planning (e.g. identifying a reproducible

top of bank to set offsets for development).

What did we do?

Channel dimension data extraction

Existing channel dimension data from 2010 (Index of Stream Condition data) was not accurate enough to detect stream physical form responses to urbanisation. Therefore, we focused efforts on producing more accurate channel morphology data and investigating case studies of channel evolution which allow an evaluation of the role of legacy conditions and management responses in shaping urban channel morphology.

We developed channel dimension data extraction tools and tested them in pilot areas of Greater Melbourne. Using these data, we calculated relevant morphologic attributes (including stream channel width, depth, slope, bank slope) for each cross-section and reach (Figure 1). We have undertaken targeted field validation and compared the metrics extracted from LiDAR to those derived from field inspection. In addition to applying the bankfull channel dimension data extraction tool ourselves, we have also published the tool (https://github.com/k-russell/x_sections_tool) as a user-friendly GIS plugin alongside documentation and a quick practice note to allow MW staff (and other practitioners and researchers) to extract channel dimension information for any site of interest across Melbourne or indeed anywhere a high-resolution digital elevation model is available.

Case studies – Cardinia Creek channel evolution

This work examined the complexity of channel response to multiple drivers (such as legacy agricultural clearing and drainage, in-channel structures and contemporary urbanisation) that can't be understood from region-wide modelling at a snapshot in time. It has informed the next iteration of our region-wide study by fine-tuning our hypotheses of stream response and methods to detect them. The Cardinia Creek catchment has been subject to ongoing urbanisation over the last ~5 decades, and those land-use changes have occurred against a backdrop of legacy agricultural impacts including rural drainage, channelisation and channel incision. While we are most interested in understanding and improving current and future urban development practice, we look to past impacts to provide analogues. By understanding how Cardinia Creek has evolved, we can predict how current streams with similar legacies and pressures might respond to business-as-usual management and therefore what the value of improved management might be.

Case studies – floodplain function and physical form alteration in new developments

Further case studies have focussed our attention on recent and imminent urbanisation impacts on physical form and functioning of streams and floodplains. We investigated four components of floodplain function which can be impacted by urbanisation:

- Extent – can be reduced by fill, levees, or other built infrastructure
- Connectivity – can be reduced by channelisation or channel erosion
- Hydrology – can be increased by stormwater runoff

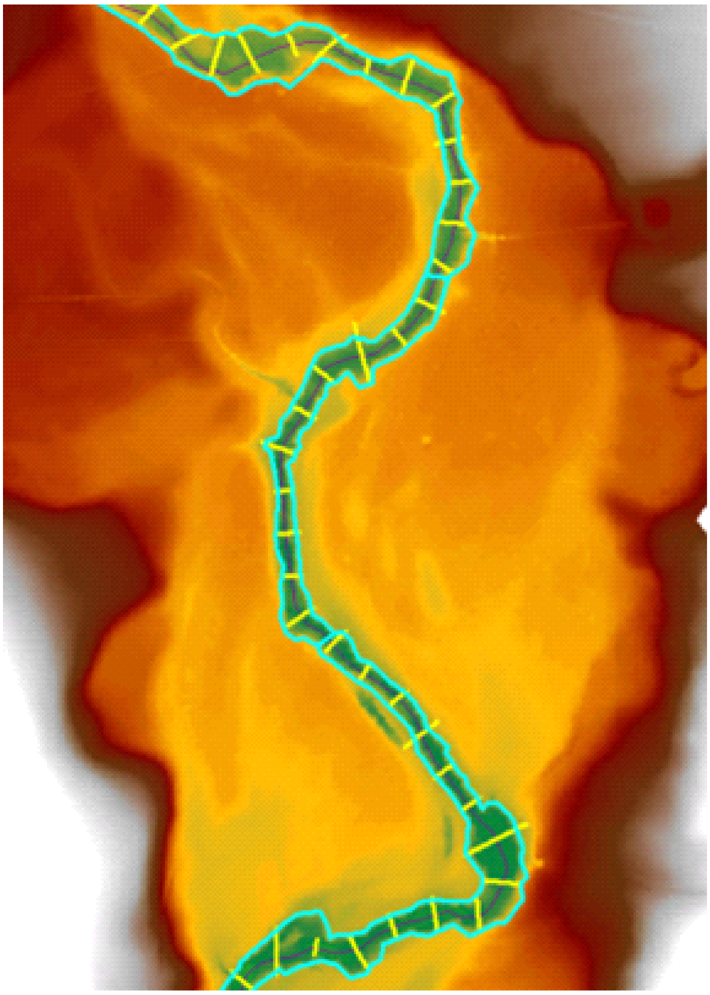

Figure 1: Outputs of channel dimension tool.

- Vegetation – can be altered by planting, removal, pruning, weeding, mowing

At each site, a pre/post-urbanisation assessment has been undertaken, either using repeat LiDAR and aerial imagery to assess change over time, design information provided by MW to predict future changes, or field/aerial inspection of upstream-downstream paired sites to compare a recently urbanised corridor segment with a pre-urbanised segment.

The case study sites included constructed waterway corridors as well as sites where existing stream channels will be retained within the Aitken Creek catchment in Craigieburn. Insights from these case studies are helping us to generalise how current urban development paradigms (i.e. waterway setbacks, constructed channels/wetlands, landscaping) alter physical form and functioning of stream channels and floodplains, and what opportunities might exist to preserve or restore those functions.

Statistical modelling

Initial statistical modelling set up hydraulic geometry models for the region. These models are used to assess relationships between channel dimensions and various catchment drivers (e.g. catchment area, water availability, urban land cover, riparian vegetation) across the region. The initial modelling resulted in:

i) testing of statistical methods (linear models, boosted regression trees);

ii) understanding of data quality;

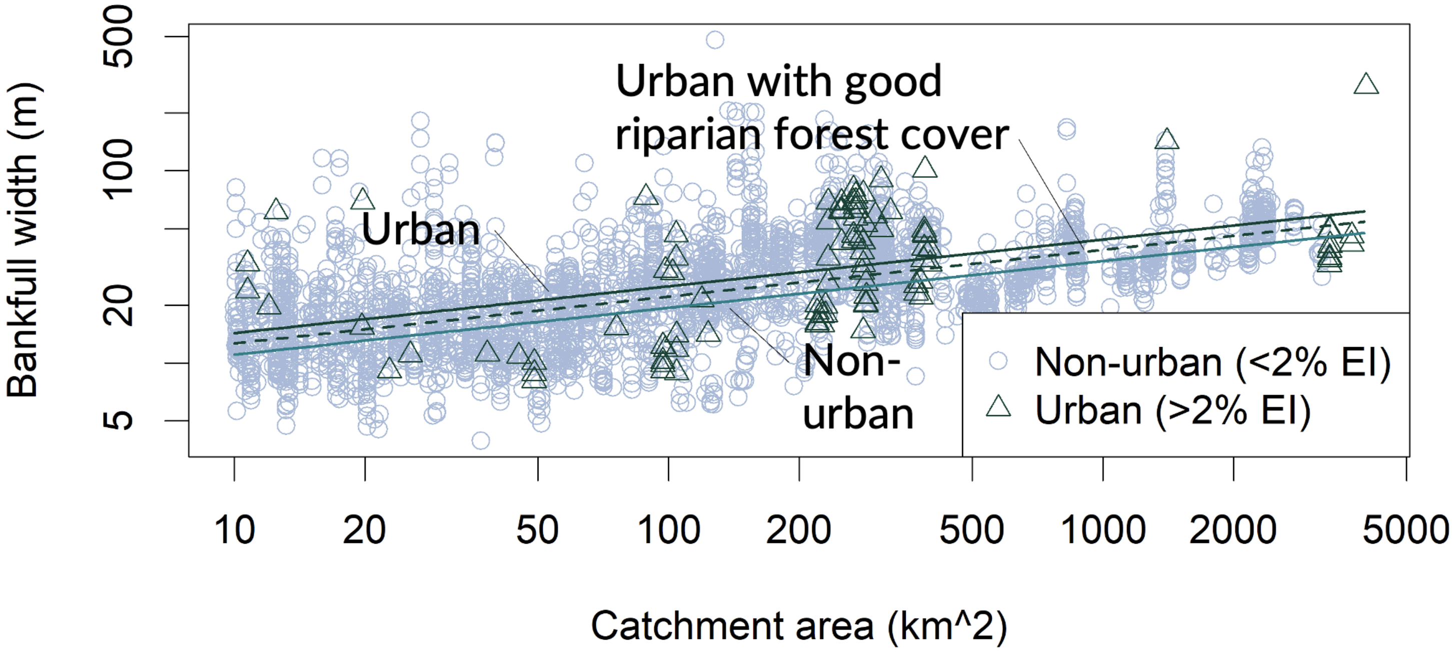

Figure 2: Results of initial data analysis, showing effect of urbanisation on urban versus non-urban stream width.

iii) Spatial structure, filtering, and methods to account for spatial autocorrelation across a stream network;

iv) Linkages with other datasets and models (e.g. stream network and associated environmental variables); and

v) data management systems.

What did we find?

Relationships between stream channel dimensions and urbanisation

Initial hydraulic geometry models indicated that responses of channel dimensions to catchment urbanisation were weak compared to responses to overall catchment area, however early results indicated channels with urban runoff tended to be larger than those without (Figure 2). Large-scale studies have found that catchment context (e.g. local geologic, topographic, and sediment supply attributes) can be equally or more important than hydrology in controlling morphology (Byrne et al., 2020; Faustini et al., 2009; Sengupta et al., 2018). Therefore, regional relationships for Melbourne and the tools they inform will need to account for catchment context and/or stream types.

Channel evolution models

Channel evolution is complex in channels which are responding to both legacy land-use impacts (e.g. land clearing, agriculture, rural drainage) and contemporary urbanisation. Many streams around Melbourne are susceptible to channel incision due to increased flows, which leads to a suite of other impacts (e.g. bank erosion, sediment release, removal of benthic habitat, destabilisation of structures). In areas with low risk of incision (e.g. bedrock channels), geomorphic impacts can be more subtle but can include erosion of instream features and benthic substrates, changes to hydraulic habitat conditions, bank erosion and channel widening. For incised streams, reversing incision is usually not feasible and recovery towards a new stable form is more appropriate goal, which can be assisted by grade control, vegetation establishment and allowing stream width and planform to adjust.

For example, Cardinia Creek is incised and widening through the urban reaches, whereas downstream of the urban area the channel has recovered from historical channel incision, assisted by a series of grade control structures. The incised urban reaches are larger and simpler than the non-urban reaches upstream, with temporary sediment stored in the bed indicating that waves of channel erosion are still moving through the system. This alluvial stream appears to follow the classic channel evolution sequence of deepening, then widening, then formation and stabilisation of inset floodplains. However, contemporary channel incision and widening due to urban development over the last ~25 years appears to be limited to the vicinity of the urban area, while reaches downstream which have recovered from legacy agricultural impacts appear to be resilient to renewed incision due to urban runoff.

Widespread observations of channel widening and lateral adjustment in Cardinia Creek, even in areas with minimal catchment urbanisation, indicate that providing adequate freedom space for alluvial rivers to adjust to urban runoff is important. Additionally, the assisted recovery of downstream reaches demonstrates the value of well-placed grade control structures.

Stream corridor treatment and floodplain functioning

Stream corridors which are protected from modification or floodplain disconnection retain important functions, including flood storage, sediment and organic matter retention and groundwater exchange. Retaining floodplain functioning in urban floodplains requires preservation of adequate floodplain space, near-natural hydrologic regimes, lateral and vertical connectivity, and vegetation.

The degree to which these characteristics need to be preserved depends on the character and sensitivity of the channel and floodplain. For example, in Aitken Creek (Craigieburn), floodplain areas that are protected from alteration (e.g. areas reserved for endangered species habitat) are providing functions similar to their pre-development condition. Some of their functioning is able to be retained despite large increases in runoff because they have bedrock controls which prevent channel erosion. By contrast, alluvial floodplains are expected to need preservation of both floodplain space and near-natural hydrology (i.e. mitigating urban runoff) to prevent channel incision and disconnection of floodplains. This variability highlights the importance of place-based objectives for floodplain management requirements as opposed to generic region-wide setback requirements.

Tributaries of Aitken Creek where wholesale floodplain alteration has occurred (e.g. construction of online wetlands and constructed waterways) provide new ecosystem services such as water treatment, but some of the functions and services provided by the original floodplain and headwater streams, which may have been more suited to the local context, have been lost in the process. Corridor treatments that are more sensitive to protecting existing functions (e.g. lateral connectivity, sediment storage, groundwater-surface water exchange, habitat) may provide greater benefit for local and downstream hydrology, water quality, geomorphology and ecology.

Future direction and Knowledge gaps

As our channel morphology data extraction tools are applied more broadly across the region, they will provide updated and higher quality data for input to our analysis and modelling efforts. Using these data, we will extend the morphologic data beyond bankfull channel dimensions to channel shape (i.e. width-depth ratio, bank slope), and diversity metrics (cross-sectional variability, longitudinal variability).

New morphology data and new insights from the case studies will help bridge the gap between what we observe at site scales (e.g. case studies, field measures) and patterns across the whole region, including thresholds of geomorphic change that can inform stormwater management.

Building on the findings of the case studies of recent channel change and long-term channel evolution, this work will reassess how to incorporate the time dimension (i.e. time since urbanisation) and the effects of legacy impacts and management interventions (e.g. constructed waterways, rock protection).

We expect to evaluate the importance of local context versus regional drivers in shaping stream responses, in order to inform to what extent waterway planning and management guidance can be regionalised.

Where novel stormwater management and floodplain protection is being undertaken, and particularly where attempts are made to preserve natural stream morphology without bank protection, we see an opportunity to undertake geomorphic monitoring to confirm whether physical form and functioning can be protected under these conditions.

The importance of hydrologic mitigation and floodplain protection on resistant (e.g. bedrock) streams is not well understood. Even if channel morphology change does not occur, physical process such as sediment transport, flooding regimes and disturbance regimes are still likely to be affected, and therefore management objectives in resistant streams may need to consider stream power or similar metrics.

How are we sharing

Partnership reports

- Mike Sammonds & Kathryn Russell. Report (2022) No. 22.6 Field validation of dSedNET gully mapping for the esternport catchment.

Publications

- Garber, J., Thompson, K., Burns, M. J., Kunapo, J., Zhang, G. Z., & Russell, K. (2024). Artificial Intelligence and Objective-Function Methods Can Identify Bankfull River Channel Extents. Water Resources Research, 60(1), e2023WR035269.

References

- Byrne C.F., Pasternack G.B., Guillon H., Lane B.A., Sandoval-Solis S., 2020. Reach-scale bankfull channel types can exist independently of catchment hydrology. Earth Surface Processes and Landforms 45: 2179-2200. https://doi.org/10.1002/esp.4874
- Faustini J.M., Kaufmann P.R., Herlihy A.T., 2009. Downstream variation in bankfull width of wadeable streams across the conterminous United States. Geomorphology 108: 292-311. 10.1016/j.geomorph.2009.02.005
- Sengupta, Sengupta A., Hawley R., Stein E.D., 2018. Predicting Hydromodification in Streams Using Nonlinear Memory-Based Algorithms in Southern California Streams. Journal of Water Resources Planning and Management 144: 04017079

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