A new approach to measuring waterway physical habitat for biota

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Key Points

- Until recently, approaches to quantifying waterway physical habitat either lacked an explicit link to the needs of biota, or tended to include subjective or unrepeatable measures of geomorphic condition.
- Streamology and Melbourne Water developed an approach to quantifying physical habitat in waterways, founded on the habitat requirements of key biota, and applied this to a case study of platypus habitat in Diamond Creek, Victoria.
- If field measurements are designed with rigour and consistency to ensure repeatability, and if the indicators used to quantify physical habitat are explicitly linked to the role they play for specific biota, then results can highlight opportunities for enhancing habitat.
- This method enables repeat measurements of physical habitat in waterways to allow for condition to be tracked over time, allows for stronger relationships to be drawn with biotic data, and enables habitat enhancement to be specifically developed to improve the ecology and geomorphic condition of waterways.

Keywords

Physical form, geomorphic condition, habitat, biota, values, Healthy Waterways Strategy

Introduction

The values of a waterway depend, at the most fundamental level, on its physical form and condition. This includes environmental values like platypus, fish, and macroinvertebrates, along with social values like amenity, community connection, and recreation. However, physical form is currently not adequately monitored to inform its influence on these waterway values. For this reason, Streamology has developed a field procedure for monitoring physical form that explicitly links key environmental values to metrics of physical form change. While developed for Melbourne Water to inform progress towards meeting specific condition targets in the Healthy Waterways Strategy (HWS) in the Melbourne region, this new field procedure has broad applicability and the value-driven approach used to create it could be used in other Australian contexts.

Previous physical form monitoring for the Melbourne region has often not provided an explicit link to values and has relied on subjective assessment (observations of physical condition). The *Framework for Physical Form Asset Management* (the framework), developed for Melbourne Water by Streamology (Vietz et. al, 2019), sought to do so objectively at the desktop level. Using existing categorical datasets and new metrics of physical form (e.g. width-depth ratios, bank heights), the Framework categorised waterways according to their geomorphic condition, sensitivity, and catchment stress level.

In 2020 Streamology was engaged to create a new field-based procedure designed to assess those aspects of physical form that have the greatest influence on key environmental values, primarily via their impact on habitat presence, diversity and quality; and for monitoring condition change. This new field procedure complements and dovetails with the desktop-based framework to provide improved resolution for assessing geomorphic condition and monitoring change.

Achieving the project objective required answering and understanding the following questions for the Melbourne Water region:

- Which indicators of waterway physical form are critical to the health, abundance and diversity of the biota described by key HWS environmental values?
- What metrics are effective for detecting variability and change in critical physical form indicators at the field measurement scale?
- How can these metrics be applied in the field on an operational basis?

How we developed a field procedure for physical form monitoring

The development of the physical form field procedure involved three main stages (Figure 1). First, a refined conceptual model linking waterway environmental values with specific aspects of physical form. It is the specificity of 'habitat', and to how it is used by biota, that defines what physical form characteristics matter.

A set of field metrics were then selected from existing methods that could be used to measure change in the aspects of physical form highlighted by the models. Lastly, a field procedure that standardises the application of the key metrics was designed and tested, and a bespoke digital field tool developed for collecting data. The three stages are discussed in more detail below.

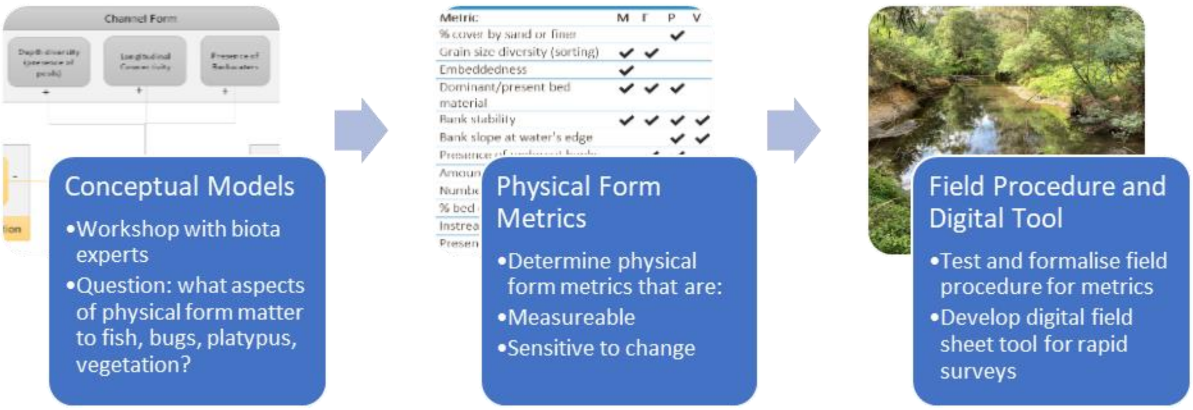

Figure 1. Process diagram depicting the stages of the project.

Linking physical form to biota: Development of refined conceptual models

Developing a set of physical form field measures that inform the waterway condition for environmental values requires an explicit understanding of what physical attributes are most important biota like platypus, fish, bugs and vegetation. This was the goal of the *Healthy Waterways Strategy Water Science Conceptual Models* (Alluvium, 2017). However, the metrics used in those original models were subjective and largely unmeasurable—for example, 'extent of suitable habitat' is the bed composition metric listed for platypus. The conceptual models, while useful for understanding the general threats to the key values, were not sufficient to inform monitoring programmes.

A workshop was held with biologists and ecologists with expertise in platypus, fish, macroinvertebrates and vegetation. The workshop focused on four key environmental values, and how to better incorporate measurable and objective physical form indicators. The existing physical form indicators and their associated metrics were unpicked, from an ecological perspective, to reveal what matters most to the respective value. As a result, some indicators were altered and some added, each with a metric that can be measured in the field. The output from the workshop was a set of refined conceptual model diagrams (Figure 2).

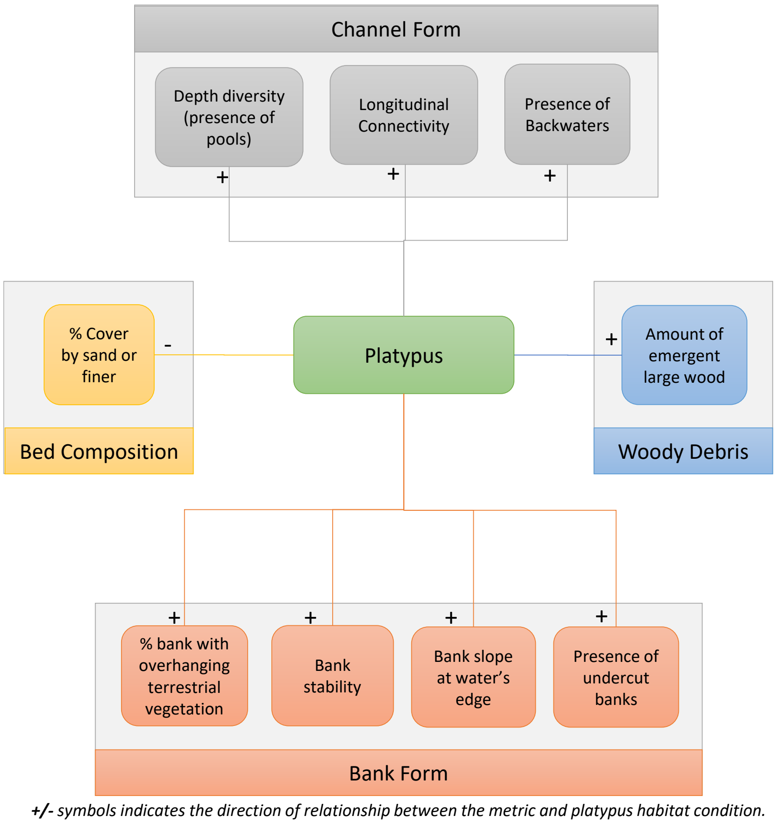

Figure 2. Example of one of Melbourne Water's refined physical form conceptual models, this one for platypus (Vietz et. al, 2020).

Selection of field-based metrics for assessing value-linked physical form

Developing the field procedure incorporated both top-down (value driven) and bottom-up (measurement driven) approaches. The refined conceptual models provide insight into what physical form indicators are important to the four key values. To complement this, a broad list of existing field metrics was compiled from the literature with each ranked based on three factors:

- Measurability: How difficult is the metric to apply?
- Sensitivity: What is the likelihood the metric will capture change over appropriate timeframes?
- Relevance: Applicability to waterways and their values in the Melbourne Water region

The two approaches were combined in a workshop involving the whole project team, in which a set of field measures was selected (see Table 1 below).

Creation of a field procedure and mobile digital tool

The selected field measures were combined into a bespoke field procedure designed to be rapidly applied. Unlike existing field methods that require specialist knowledge, the new procedure is designed to be used by non-experts with limited training in geomorphology. The procedure included:

- Study site delineation
- Survey timing
- Transect-based measurements
- Whole-of-site measurements

Because of the number of field metrics in the procedure, and different classes of data they capture (numerical/categorical, measured/estimated, counts, photographs) a bespoke mobile digital field tool was developed to replace traditional field sheets. ArcGIS Survey123 allows for the creation of custom data collection forms that run on a smart phone or tablet with or without internet access. Fields can include numerical data or text entry, single or multiple-choice categorical lists, and photos—all of which is consolidated into a single geolocated record. An additional benefit of this tool is that, once uploaded, data is directly integrated within an organisation's existing spatial databases (Figure 3).

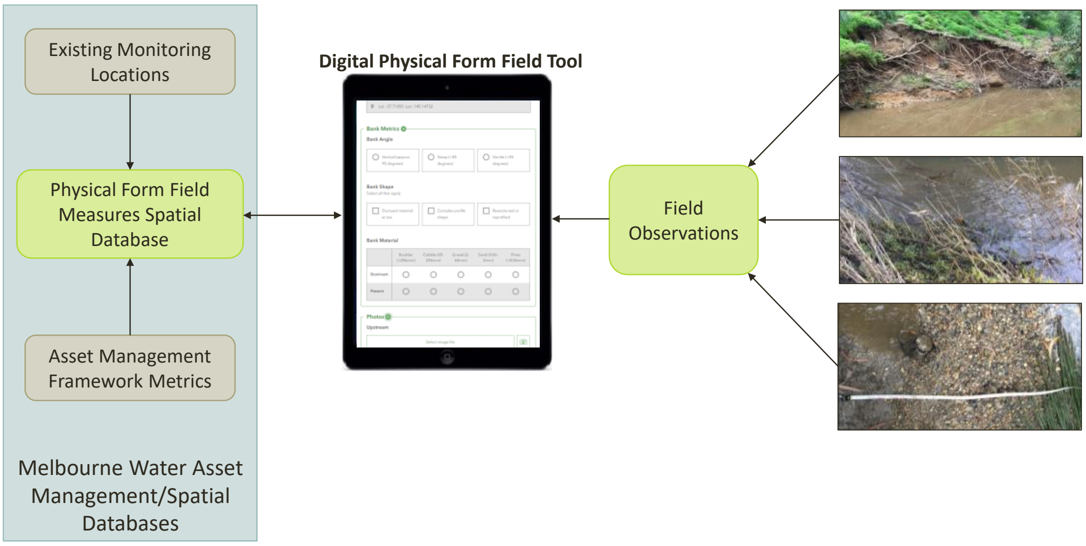

Figure 3. Digital field tool created using ArcGIS Survey123.

Findings

The key output of the field measures project was a set of metrics (Table 1) and a field procedure detailing how to apply them to waterways.

Table 1. Summary of physical form indicators, metrics used to assess them, and the actual measurement procedures to be used in the field. The key values that each metric applies to are denoted on the right.

Change Metrics					
Indicator	**Metric**	**Bugs**	**Fish**	**Platypus**	**Vegetation**
Bed composition	% cover by sand or finer			✓	
	Grain size diversity (sorting)	✓	✓		
	Embeddedness	✓			
	Dominant/present bed material	✓	✓	✓	
Bank form	Bank stability	✓	✓	✓	✓
	Bank slope at water's edge			✓	✓
	Presence of undercut banks		✓	✓	
Wood and organic matter	Amount of large wood	✓	✓	✓	
	Number of debris jams	✓	✓	✓	
	% bed covered by CPOM	✓			
	Instream vegetation cover	✓	✓		
Channel form	Presence of bars and/or benches				✓
Character Metrics					
Indicator	**Metric**	**Bugs**	**Fish**	**Platypus**	**Vegetation**
Channel form	Depth diversity		✓	✓	
	Presence of backwaters	✓	✓	✓	
	Longitudinal connectivity		✓		
Metrics considered but not included in the field procedure					
	Lateral connectivity		✓		

The procedure is now being implemented by Streamology at 30 sites (Figure 4) across Melbourne to further refine the techniques and to gather baseline data that can be used in future to assess physical form change. Baseline monitoring sites were selected based on:

- Proximity to existing platypus, bug, or vegetation monitoring sites
- Geomorphic sensitivity of the waterway (from the *Framework for Physical Form Asset Management,* Vietz et. al, 2019)
- Location in a Melbourne Water priority catchment for physical form
- Geographic spread, variety of physical form, geomorphic condition, and degree of urbanisation

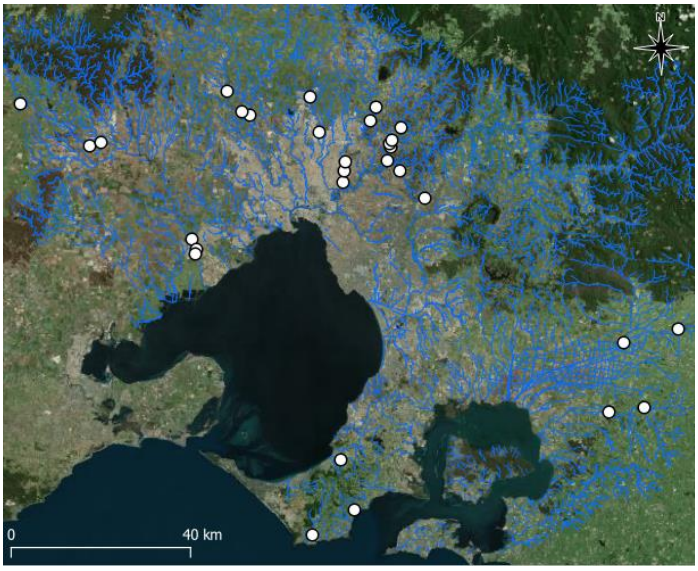

Figure 2. Baseline monitoring sites.

Field observations from the baseline monitoring have allowed for further refinements to the procedure as a greater variety of waterway forms are accounted for. For example, macrophyte cover was originally measured as the percentage of the wetted channel occupied by in-stream vegetation along a transect. During the baseline monitoring at some sites macrophytes were observed growing outside the wetted channel and up the banks, so the metric was changed to measure linear meters of cover along the transect, which can then be compared to the bankfull width (also measured) to provide a percentage cover.

The baseline monitoring will be built upon with repeat surveys to capture change in those aspects of waterway physical form that are most important to the environmental values. Examples of how the data may be presented over time to illustrate change are provided below. Figure 5 depicts a theoretical steepening of banks (a common sign of urbanisation-driven stream incision), and a potential negative change to bed substrate (reduction in coarse particulate organic matter (CPOM) and bed material size diversity).

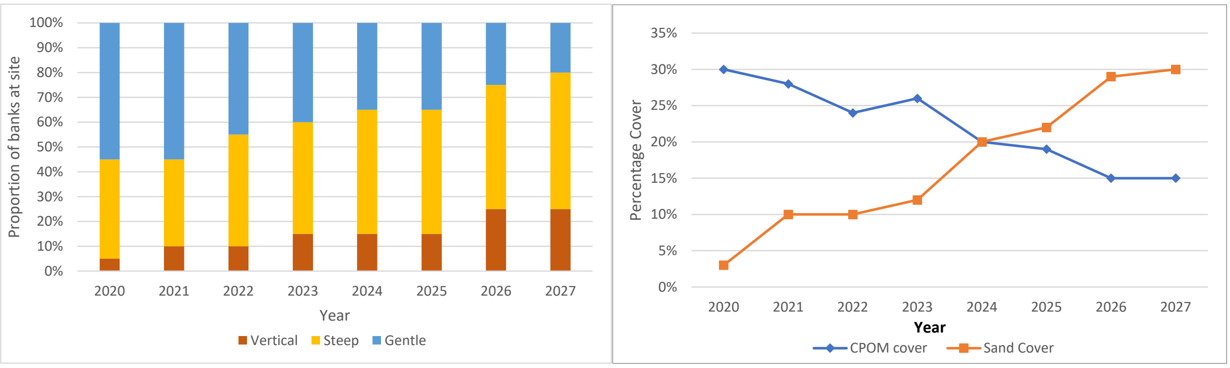

Figure 3. Example plots showing how observations from the field procedure can be used to visualise change over time. Left: Increase in bank steepness. Right: Decline in the percentage cover of the bed by CPOM and increase in sand cover (Vietz et. al, 2020).

Application for assessing and improving habitat in Diamond Creek

Diamond Creek has been assessed in detail using the field procedure with the aim of identifying opportunities to improved instream habitat—primarily for platypus. Platypus are considered vulnerable due to low flows and sub-standard habitat and, as such, the Healthy Waterways Strategy (HWS) performance objectives within the catchment include:

- Investigations into how threats to the physical habitat can be mitigated.
- Identification of methods to maintain or improve flows.

The physical form conceptual models (e.g. Figure) developed by Streamology and Melbourne Water provided a useful starting point for designing targeted habitat improvements in Diamond Creek. From these models, multiple aspects of Diamond Creek physical habitat were identified for enhancement or protection through habitat improvement works. Field surveys conducted during Diamond Creek project and its precursor (see Ecology Australia, 2020) indicate that Diamond Creek contains less wood than studies indicate is optimal for good platypus habitat. Large wood is beneficial for platypus, but also supports fish, algae and macroinvertebrates. Large wood also helps establish instream vegetation, which can take advantage of lower flow velocities and sediment deposition resulting from the altered hydraulics that the wood produces.

Combining the results from the field procedure with desktop analysis of LiDAR and imagery, we identified and prioritised five pools along the creek that could benefit from the reintroduction of large wood for improving habitat and managing bank erosion. Concept plans were produced to guide future detailed design of large wood habitat structures for these pools (e.g. Figure 7).

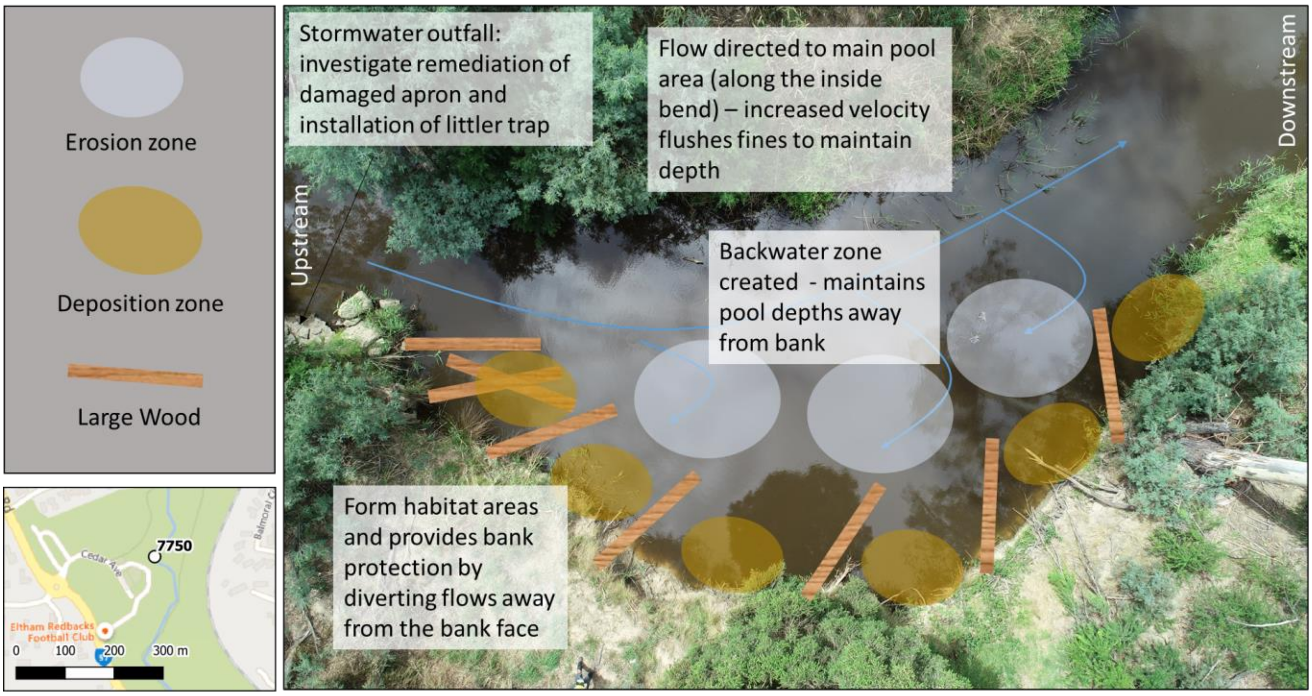

Figure 4. Concept design for large wood habitat improvement in a pool on Diamond Creek (Streamology, 2021).

Discussion

The development of this new physical form field procedure for waterways presents both opportunities and challenges.

Opportunities

- This approach, linking values to physical form metrics, could be used more broadly. For example, in other geographic areas, for different biota, or to incorporate social or cultural values.
- The conceptual model refinement process, where knowledge from experts in different aquatic biota is combined with understanding geomorphic processes, provides a template for linking values to physical form to better inform strategic management of waterways more broadly than the Melbourne Water region.
- Melbourne Water now has a bespoke physical form monitoring procedure that can be rolled out to track change in physical habitat without the need for expertise in geomorphology, meaning more waterways can be monitored with existing resources.
- Because of the linkages to values, habitat in particular, the procedure can be deployed to design targeted habitat improvements, such as through increasing large woody debris for the benefit of platypus.
- Increasing the adoption of digital field sheets using software like ArcGIS Survey123 for monitoring means all waterway data is spatially situated and can be directly integrated into existing spatial and asset management databases.
- Possibility in the future to create custom web-based dashboards to display monitoring data for managers in an accessible way, allowing condition and change to be tracked more easily.

Challenges

- Any monitoring protocol must balance the need for simplicity and ease of use with the ability to capture a wide variety of physical features in geomorphically, hydrologically, and hydraulically diverse waterways. This field procedure has been designed to be applied relatively rapidly by users with limited geomorphic knowledge. There will, therefore, be sites where the nature of the waterway does not lend itself to assessment with this method (e.g. multiple channels). Identifying anomalies and variations to the field-procedure are an important part of the method refinement process.

- Assessing bed sediment is a universally challenging task in waterway monitoring. This procedure is no exception and requires the bed to be able to be safely accessed, which will not be possible in many situations.
- With the procedure only now being rolled out for baseline monitoring, it remains to be seen how sensitive each metric is to changes in the relevant aspect of physical form. For example, in the case of large woody debris or bank slope, how large will the changes need to be for the procedure to detect them from one year to the next? Or conversely, how many years will it take until the changes will be noticeable?
- Ensuring the procedure captures all the relevant characteristics of waterway physical form that make for overall ‘good’ geomorphic condition, will take time and repeated application.
- Broadening waterway physical form to consider social elements is an important next step, starting with the conceptual models of social values for waterways.

Conclusion and Recommendations

Physical form of waterways has, until recently, not been considered to the extent that it should in monitoring and subsequent management decision making. This is partly because monitoring change to physical form is a challenging task. Where physical form monitoring has taken place, it has often lacked a strategic connection to the values that we are trying to maintain or enhance. This field monitoring procedure explicitly links the metrics being assessed to the aspects of physical form that matter most to fish, bugs, platypus and vegetation. While designed for Melbourne Water to support the HWS, the field procedure, and the method used to develop it, could be applied broadly, which will ensure the continued refinement and advancement of the method.

Recommendations to advance this work include:

- Application to more than the initial 30 sites, providing a stronger dataset and more outliers for considering the applicability of the method.
- Expanding the use of physical form conceptual models to include not just biota but other values, for example social and cultural values.
- Further testing of the conceptual models and the procedure, and refinement of both.

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