Quantifying the Benefit of Vegetation in Reducing Sediment Delivery to Morton Bay

Michael Cheetham[1], Daniel Trnovsky[1], Andrew Brooks[2], Daryl Lam[1], Tim Peitsch[2]

1 Water Technology, Brisbane, QLD, 4101. Email: michael.cheetham@watertech.com.au

2 Griffith University, Brisbane, QLD, 4101.

Key Points

- Ongoing accumulation of fine sediments and associated nutrients in Moreton Bay poses a significant threat to the aquatic ecosystem health of Moreton Bay.
- A method was developed to estimate the potential for erosion reduction through defining a relationship between existing vegetation cover and the observed unit erosion rate.
- Sites were identified using the above relationship along with the use of multi-temporal LiDAR data, catchment wide sediment sampling and analysis, Rain on Grid hydraulic modelling, and vegetation density and coverage data.
- This study has developed and justified a reliable method to identify effective areas where riparian remediation will achieve the desired reduction in fine (<63µm) sediment export.

Abstract

Ongoing accumulation of fine sediments and associated nutrients in Moreton Bay poses a significant threat to the aquatic ecosystem health of Moreton Bay, a Ramsar wetland of international significance. Research over the last 25 years has identified that sediments are primarily derived from channel erosion in the Lockyer and Bremer River catchments. To address the threat, this investigation identifies the degraded channels in these catchments, where remediation would reduce sediment loads to the Bay by 50%.

The investigation focused on two large catchments; the Lockyer and Bremmer and required the development of a method to quantify the expected erosion in each river reach. This involved the use of multi-temporal LiDAR data, catchment wide sediment sampling and analysis, Rain on Grid hydraulic modelling, and vegetation density and coverage data.

Using a relationship between vegetation coverage and erosion, the analysis indicates that:

- For Lockyer Creek, revegetation of 130km of channel could achieve a 56% reduction in sediment generation from that catchment.
- For the Bremer River, revegetation of 89km of channel could achieve a 54.4% reduction in sediment generation from that catchment.

The investigation developed and justified a reliable method to identify effective areas where riparian remediation can achieve the desired reduction in fine sediment export. The method allows for a quantification of potential erosion associated with future high flow events and the achievable reduction in erosion sediment export if foliage projected cover, with a canopy height greater than 5m, was increased to 90%.

Keywords

Riparian Vegetation, Bank Erosion, Fine Sediment

Introduction

Ongoing accumulation of fine sediments and associated nutrients in Moreton Bay (a Ramsar wetland of international significance) is posing a significant threat to its ecosystem health. Research over the last 25 years has identified that bank erosion in the Lockyer and Bremer River catchments is the primary source of the fine sediments. A reduction in fine sediment and the associated nutrient load to Moreton Bay would result in a considerable improvement to water quality and ecosystem health in the Brisbane River and Moreton Bay.

To this end, Urban Utilities, the Department of Environment & Science and the SEQ Council of Mayors commissioned a research project to develop a science-based approach to identify reaches within the Lockyer and Bremer catchments where riparian restoration could achieve a minimum 50% reduction in fine (<63µm) sediment export to the Brisbane River and Moreton Bay.

The objective of this study was to identify and describe the reaches within the Lockyer and Bremer catchments where riparian remediation could achieve a minimum 50% reduction in fine (<63µm) sediment export to the Brisbane River and Moreton Bay. This was achieved using the best available data, empirical evidence and geomorphic expertise and will, in turn, support a science-based, systematic approach to riparian revegetation and remediation efforts in both catchments. This will contribute to improving and protecting aquatic ecosystems in these catchments.

Background

It is widely acknowledged in scientific literature that both in-channel and riparian woody vegetation play a crucial role in mitigating channel erosion caused by flooding (Simon and Collison, 2002; Brooks et al., 2003; Corenblit et al., 2007; Gurnell et al., 2012; McMahon et al., 2017; Sharpe et al., 2021, 2023). Various studies have highlighted that the extent of erosion in a channel, resulting from flood flows, is influenced by several factors (McMahon et al., 2017). However, the likelihood of erosion decreases significantly when the foliage projected cover (FPC) of in-channel woody riparian vegetation exceeds 30%, with a notable reduction when FPC surpasses 70% (Olley et al., in prep.). Consequently, in rivers where degradation or clearance of riparian vegetation has exacerbated channel erosion, restoration of riparian vegetation is commonly employed as an effective measure for managing erosion at a reasonable cost. This is emphasised by findings indicating that a substantial portion of channel erosion volume in several Queensland rivers is concentrated in a small percentage of the channel length (Brooks et al., 2014). Additionally, Sims and Rutherfurd (2021) demonstrate that targeted local interventions, coupled with broader catchment-scale remediation efforts, can result in significant improvements in remediation outcomes.

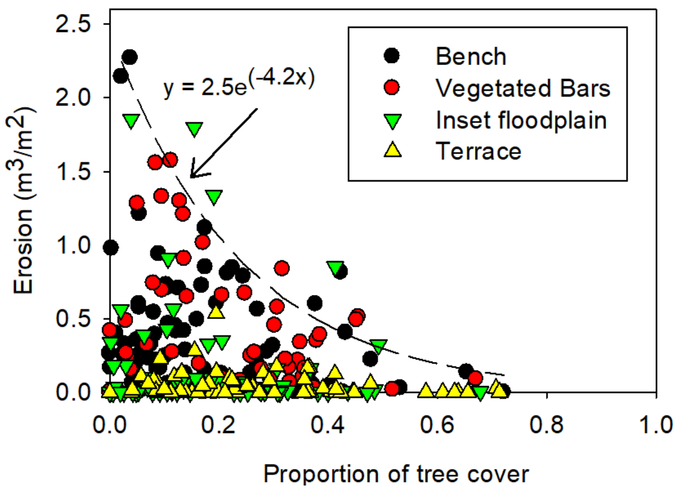

Figure 1. Relationship between erosion and proportional tree cover for different surfaces within the upper Brisbane River. From Olley et al. (in prep.)

In southeast Queensland there have been a number of studies over the last two decades that have used sediment tracing (Caitcheon et al., 2001; Douglas et al., 2003) and SedNet/Source Catchments sediment budget modelling (Wallbrink, 2004; Olley et al., 2006) to identify the dominant sub-catchments contributing fine suspended sediment to Moreton Bay. These tools serve as a form of prioritisation, directing remediation efforts toward key sub-catchments of the Brisbane River. The motivation for this study stems from these prioritisation efforts at the sub-catchment scale. However, given the significant spatial variability in erosion within these prioritised sub-catchments, a finer resolution prioritisation approach is necessary. This approach should facilitate targeting of remediation efforts to specific river reaches, and ideally, specific sites within those reaches. These tools have been relied upon for sub-catchment prioritisation but cannot be used for prioritising reach-scale remediation efforts (Brooks et al., 2014a, Prosser, 2018).

Source catchment models are commonly used for reach-scale bank erosion prioritisation with varying levels of success based on several issues. The limitations of the Source Catchment model as a tool for predicting channel erosion were identified in a 2014 Qld Smart Futures study (Brooks, et al., 2014a), and reiterated in reviews undertaken for the Queensland Water Modelling Network (QWMN) (Prosser 2018; Alluvium, 2020).

Instead, in this study the focus has been to keep the analysis as simple as possible and focused on the central premise that “maximising the extent of in-channel, bank face and bank top riparian woody vegetation is the primary management lever we have at our disposal”. Hence, the primary focus of this study has been to identify the reaches where channel erosion is currently higher than the average and vegetation cover is lower than average.

Methods

The method was developed to determine three key parameters across the Lockyer and Bremer Catchments, broken down into time periods based on LiDAR data capture date. Historic erosion (volume of fines), hydraulic conditions (cumulative stream power based on the flood history between LiDAR captures) and vegetation coverage (Foliage Projected Cover) were determined through a range of methods. This data was then added as attributes to a spatial layer for processing using GIS software to analyse the data and to determine relationships that could be used to estimate reductions in erosion through increasing vegetation coverage. The data was then processed to show which reaches in each catchment provide the most reduction in sediment through revegetation. It is of note that due to the large spatial scale of analysis required, the assessment was limited to Stream Order 3 channels and above.

The approach to this study involved:

- **Erosion Volume Estimation**
  - Bank sediments were sampled across all target waterways at representative locations and analysed for particle size distribution to define the <63µm fraction (fine silts and clays). Note the<63µm fraction was selected because this reflected the post-European sediments from cores collected within Moreton Bay (Coates-Marnane et al., 2018).
  - Lockyer:
    - DEM of Difference (DoD) development using available LiDAR data to determine erosion volumes for each available interval where multitemporal datasets overlapped spatially.
    - Eroded fine sediment volumes were mapped above a -0.5m threshold to exclude deposition and noise in the data.
  - Bremer:
    - Determining erosion volumes was not possible using the DoD method due to data limitations resulting from differing water levels confounding erosion mapping.
    - Erosion was assessed through cross-section comparison and field observations at various locations to ensure that bank erosion had occurred.
- **Hydrologic and Hydraulic Analysis**

  - Detailed, 2-dimensional, Rain-on-Grid TUFLOW models were built for both the Lockyer and Bremer catchments.
  - Recent events with annual exceedance probabilities less than 20%, measured at the most downstream gauge, were modelled for each catchment. The peak flow for the 2017 event in the Lockyer catchment was less than the 20% AEP flow but it was included as it was the only significant event between the 2015 and 2018 LiDAR data captures.
    - Lockyer 2011, 2013, 2017, 2021, 2022
    - Bremer 2011, 2013, 2017, 2022
  - The riparian zone was defined using various hydraulic parameters from a design storm event.
- **Vegetation Coverage Mapping**
  - LiDAR point clouds (LAS datasets) were classified to map woody vegetation with canopy heights greater than 5m.
  - Where point clouds were unavailable, vegetation mapping was based on previously available point cloud data.
  - Foliage density was based on the density of the woody vegetation relative to the respective reach polygons.
- **GIS Analysis:**
  - Top of bank (ToB) was mapped for each target waterway and polygons were developed to encompass 500 m lengths of channel reach.
  - The above datasets were then queried using the 500m polygons such that each polygon was assigned a value for Erosion Volume, Foliage Projected Cover and Cumulative Stream Power.
  - Limit lines, representing the maximum expected level of erosion for a given FPC, were established based on data for the Lockyer Catchment and compared to previous research to establish their applicability.
- **Reach identification:**
  - Plots for Unit Erosion vs FPC for each DoD timestep were prepared to demonstrate that the maximum unit erosion decreases with an increasing proportion of foliage cover.
  - Limit lines, representing the maximum expected level of erosion for a given FPC, were used to establish likely erosion for each polygon based on vegetation cover and likely changes (reductions) if vegetation cover were increased to 90%.
  - Sites were ranked iteratively based on stream power, vegetation coverage, and historic erosion (Lockyer Catchment only), with percent reduction in fine sediment production defined.

Prediction of Erosion Reduction

A method was developed to estimate the potential for erosion reduction through future treatment of identified sites. This involved attempting to define a relationship between existing vegetation cover and the observed unit erosion rate. This involved defining a limit line to identify the point at which a change in a variable became significant. Using a limit line approach allowed the observation of a trend, not by identifying the central trend in the data, but by finding the maximum values of erosion to occur for given states of vegetation (Carling, et al, 2022).

This method has been applied by Olley et. al. (In prep.) to define such a relationship on the main stem of the Upper Brisbane River. The results of this analysis, including the limit line, are shown in Figure 1. The results from the Lockyer Catchment are shown in Figure 2. Comparing the two datasets, it is apparent that, for the Lockyer catchment, there are several points with relatively high FPC values (>0.4) that have unit erosion rates greater than that predicted by the limit line from the Upper Brisbane River data. As such, the outlying points were located and examined. It was found that they were almost all in lower order streams (SO<5). Of note, the Upper Brisbane River, the streams investigated by Olley et. al. (In prep.), were stream order 6 and 7. Filtering the Lockyer dataset to exclude all polygons within lower stream order creeks (SO<5) allowed for a more equitable comparison with the Upper Brisbane River data. Figure 2 shows that an improved fit is observed when looking at data from stream order 5 and above, and when looking only at stream order 6, the data from the Lockyer catchment fall almost entirely within the limit line for the Upper Brisbane River dataset.

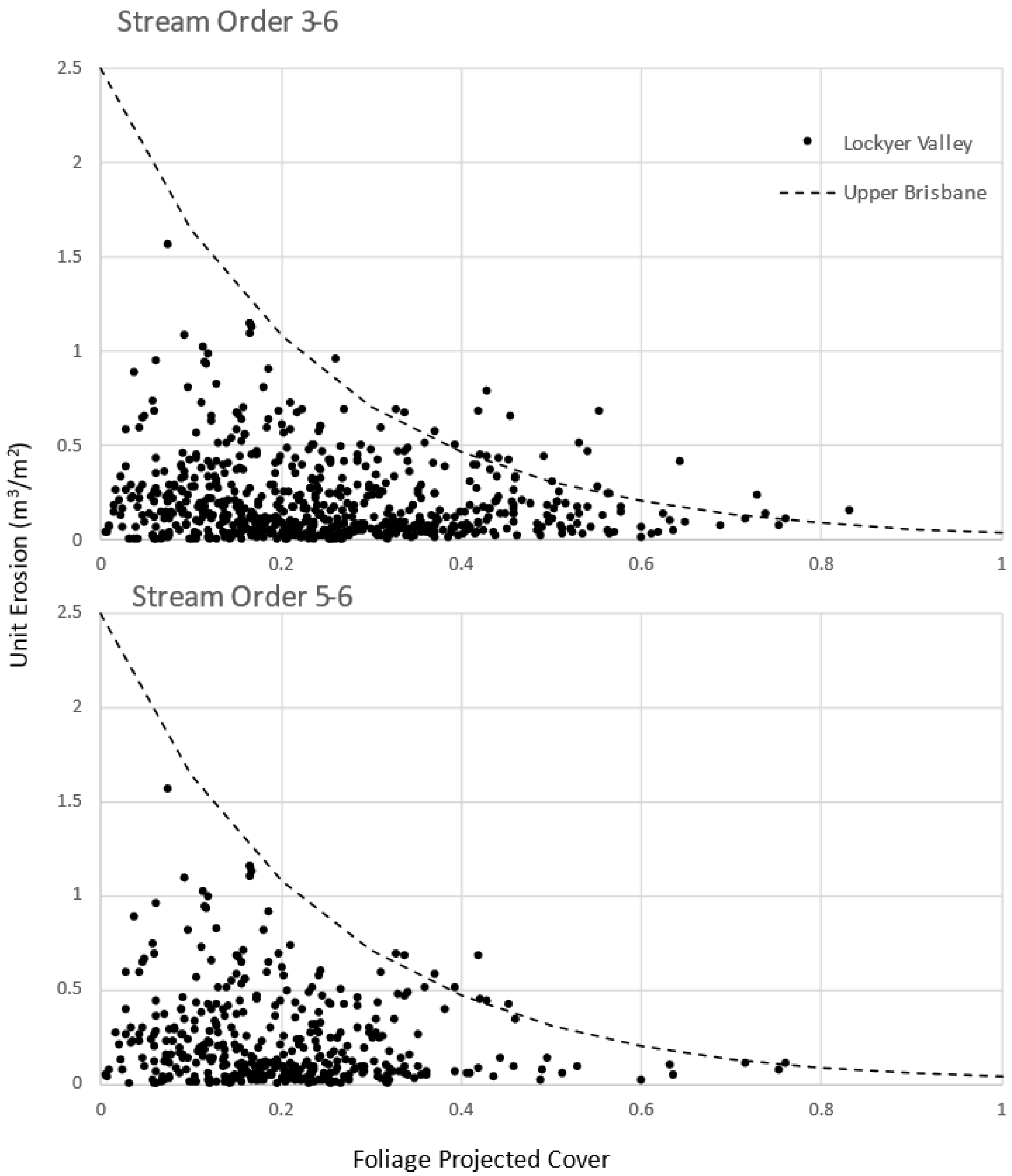

Figure 2. Lockyer Catchment Data – Erosion vs FPC

Sediment Sampling

Site selection for Particle Size Analysis (PSA) sampling was based on spatial distribution within the Study Area and guided by the Stream Order (SO) within each creek. The focus of this study was on the <63µm fraction. A weighted average was calculated for each site, with the weighting parameter being the proportion of the channel margin occupied by the unit from which each individual sample was collected. No clear spatial trend was identified for each sub catchment, as such an average percentage fine was selected for each of the creeks. These averages are shown in Table 1 and demonstrate the very high proportion of silts and clays in the bank material of both catchments.

Table 1. Selected percentage fines for each creek based on sampled site Particle Size Analysis results.

Lockyer Catchment		Bremer Catchment	
Sub catchment	**Selected Percentage (%) Fines**	**Sub catchment**	**Selected Percentage (%) Fines**
Laidley	70	Bremer	70
Lockyer	60	Warrill Up	48
Mama	60	Warrill Down	75
Murphy's	45	Purga	69
Sandy	70	Franklin Vale	69
Tenthill	60	Western	65
		Bundamba	58
		Deebing	55

Summary

For similar stream orders, the results from the Lockyer Catchment compare well with the envelope developed by Olley et. al. (in prep.), relating erosion to vegetation. Whereas the relationship could not be assessed in the Bremer Catchment due to the lack of consistent repeat LiDAR data, the confirmation rate established through cross-sectional analysis in the Bremer Catchment and the verification process in both catchments provides a high level of confidence that the identified reaches for remediation will achieve the target reduction in fine sediment. While there are limitations in available evidence, largely limited to the available LiDAR, there is a high level of confidence that the identified reaches for remediation will reduce fine sediment pollution from the catchments to the Bay by >50%.

The study used the best available data, which varied considerably between the Lockyer and Bremer Catchments. This required a varied approach for each catchment. However, validation efforts for both catchments provided a high level of confidence in the results.

Regardless of the identified limitations, field and desktop verification confirmed excellent agreement between site prioritised using 2015 and 2018 Vegetation Data and erosion during subsequent events (2021, 2022).

For the Lockyer Catchment, 45 polygons representing over 22.5km of stream length (approx. 10% of the 248km assessed) were used for verification. 20.5km (91% of validated polygons) showed excellent confirmation of the results. The remaining 2km were inconclusive due to weed coverage obscuring the banks and immediately adjacent floodplain; however, these were also qualitatively assessed as likely to have been eroded.

For the Bremer Catchment, 20 sites were assessed using recent aerial imagery and on-ground observations to verify model results. This consisted of 61 polygons and over 30km of stream length. Only 2 of the 60 sites were listed as inconclusive due to weed coverage hindering observations. This results in 97% of the assessed sites being verified successfully.

The outcomes of this assessment predict that:

- In the Lockyer Catchment, remediation of prioritised sites, representing 130km of channel, will achieve a 56% reduction in fine sediment from this catchment otherwise fated for Moreton Bay.
- In the Bremer Catchment, remediation of prioritised sites, representing 89km of channel, will achieve a 54% reduction in fine sediment from this catchment otherwise fated for Moreton Bay.

Whereas revegetation is seen as the primary goal, remediation will also involve supporting soft engineering works where necessary. The outcomes of this report reinforce the need for remediation to be guided by good science and be undertaken within a governance framework that provides a medium-term focus and requires smart monitoring/auditing.

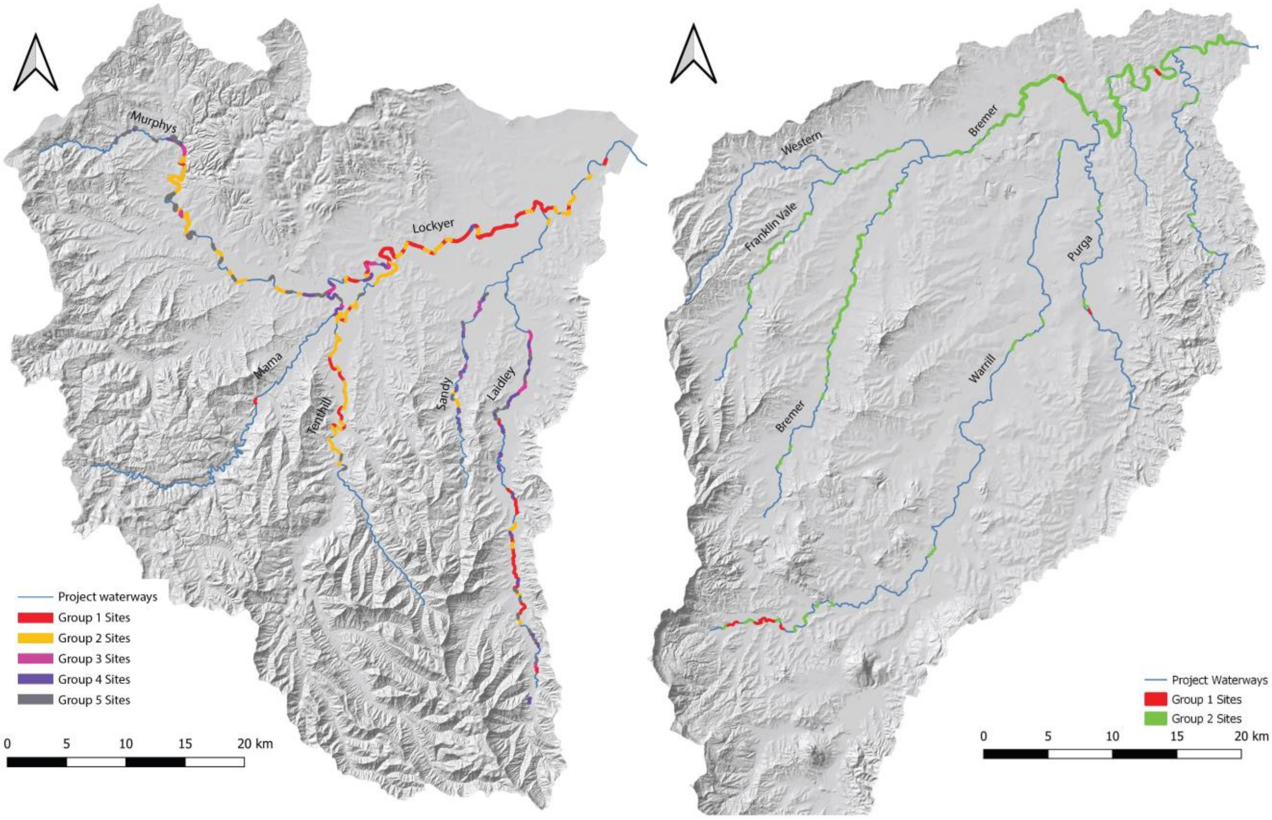

Figure 2. Prioritised sites in the Lockyer Catchment (left) and Bremer Catchment (Right).

Conclusions

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