Site level vegetation and sediment processes observed over a decade of river rehabilitation

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Key Points

- A major river rehabilitation site in Southeast Queensland has reached 10 years since establishment
- LiDAR derived digital terrain models (DTMs) of difference (DoDs) and canopy height models provide detailed insight into site level sediment and vegetation processes.
- This information can inform future process informed river rehabilitation in the region.

Abstract

The interaction of vegetation and river processes and form are a foundational element of freshwater ecosystem health. Re-establishing vegetation and rebuilding freshwater ecosystem resilience are key challenges in mitigating channel erosion risk in high risk waterways with degraded riparian condition. Repeat LiDAR capture can provide insights into the functional role of recovering riparian vegetation in influencing sediment processes. LiDAR change analysis was used to investigate vegetation and sediment processes occurring within a large river rehabilitation site on the Logan River in Southeast Queensland, over a 10 year period of re-establishment of riparian vegetation. The analysis reveals the dynamics of erosion and deposition at the site, indicating there has been a net deposition of ~5000 tonnes of sediment from 2014 to 2023. This has occurred as vegetation has matured. Cover of dominant canopy species (*Eucalyptus tereticornis*) is currently at ~30% with an average tree height of > 5m. The transition from a net eroding site, with no woody native vegetation to a net accreting site with maturing native vegetation, illustrates the success of the rehabilitation site and provides insight into the role of vegetation on sediment processes at the site scale. River rehabilitation strategies informed by an understanding of river process are likely to result in improved outcomes across targeted ecosystem service values, such as water quality and freshwater biodiversity. Empirical evidence of the interaction between vegetation and river process can inform these strategies.

Keywords

River rehabilitation, stream bank erosion, monitoring and evaluation, geomorphic change detection, vegetation

Introduction

In Southeast Queensland, the recognition of many of the adverse effects of human impacts on aquatic ecosystems has resulted in an increasing level of investment in river rehabilitation. Although, the drivers and ecological objectives of specific strategies vary, key objectives include reducing fine sediment pollution originating from the highly rural upper catchments that drain into Moreton Bay, reducing the loss of high quality agricultural soils, improving water quality at bulk water supply intake points in water supply catchments, improving freshwater aquatic ecosystem biodiversity, and enhancing cultural and recreational values (Watkinson et al. 2012; Leigh et al., 2013). Despite the level of investment in rehabilitation across the region, information on the performance of rehabilitation effort against stated objectives is often limited.

Learning and adapting to insights gained from past attempts to rehabilitate these dynamic ecosystems can improve future practice.

Rehabilitation is an action to repair, enhance, or replace ecosystem processes and/or components, to improve intrinsic values or ecosystem services (DES, 2022). Ecosystem service and intrinsic values of waterway vegetation are diverse and widely acknowledged (Capon et al., 2013). In Southeast Queensland, riparian woody vegetation provides both water quality regulation and aquatic habitat provisioning services. For example, catchments with greater riparian vegetation cover have been found to export less suspended sediment and nutrients and have improved freshwater ecosystem health (Olley et al., 2014; Sheldon et al., 2012). For these reasons, the conservation and re-establishment of native vegetation along waterways has been a priority management action to both mitigate erosion risk and enhance multiple ecosystem services at scale.

On-ground actions aimed at restoring riparian vegetation in rural catchments have included, riparian vine weed management, grazing and stock access management, and revegetation works. The revegetation of channel networks in many catchments of South-East Queensland is challenging due to the highly unstable nature of riverbanks and highly variable rivers flows (Rustomji et al., 2008). In highly degraded river reaches revegetation works have been combined with bank reshaping in combination with 'soft' engineering works, such as pile fields, rock toes, and artificial log jams. This aims to support lateral bank stability while the riparian vegetation needed to provide long term resilience to channel erosion matures.

The Beaudesert nutrient offset pilot project was among the first of its kind in the region to demonstrate the feasibility of large-scale river rehabilitation works in highly degraded river reaches. This study uses digital terrain models of difference (DoDs) and canopy height models (CHMs) to investigate sediment and vegetation process over the decade of site level rehabilitation. This informed an assessment of the performance of the site against stated rehabilitation objectives and offers insight into the interaction of vegetation and river processes and form.

Project location and divers

The Logan River system drains a large (4,133 km^2) catchment from the Lamington Ranges to Moreton Bay. The climate is subtropical, with high interannual variability in rainfall and river flow. Large tracts of remnant vegetation remain in the steep upper catchment areas, though much of the land area has been cleared for agricultural purposes including grazing and horticulture (Abal et al., 2005). Approximately 59 % of riparian areas within the catchment are covered by woody vegetation, yet only 27% of this is remnant, with the hydraulic properties needed to enhance bank stability (Healy et al., 2021). Extensive areas of the channel network are highly degraded with limited riparian vegetation and high rates of channel bank erosion (Figure 1). During major floods, high loads of channel-derived, fine sediment and nutrients are delivered to Southern Moreton Bay, threatening key coastal habitats including seagrass and sandy habitats (Grinham et al., 2024). Catchment and river rehabilitation have been identified as priority managed actions to reduce diffuse sources of pollution impacting sensitive marine environments and improve freshwater ecosystem health for many decades, including the Southeast Queensland Regional Water Quality Management Strategy (SEQRWQMS).

The Queensland Government *Point Source Water Quality Offsets Policy* (the Policy) and *Draft Point Source Water Quality Offsets Guideline* (2019) provides the framework for environmental authority (EA) holders, regulated under the *Environmental Protection Act* (1994), to meet their point source water emission discharge requirements through alternative investment options to achieve improved water quality in the receiving environment. The Beaudesert project provided the pilot study for development of the Policy; demonstrating the potential to optimise investments in whole catchment nutrient reduction, while delivering significant positive environmental externalities, including importantly, reducing fine sediment pollution to Moreton Bay (Clouston et al., 2014; Jackson et al., 2014). The project is located on the main Logan River channel several kilometers upstream of the Beaudesert sewage treatment plant outfall.

Figure 1. Site 1 prior to rehabilitation works showing extensive vertical eroding banks

Rehabilitation design

Rehabilitation design

The project has focused on restoring ~420 m of degraded riverbank along the Logan River through earthworks, engineered structures, and the establishment of riparian vegetation. Dominant erosion processes identified within the reach include fluvial scour and mass failure. Intervention design was informed by an understanding of these key erosion processes, through field assessments in combination with flood and bank erosion modelling (BSTEM version 5.4 as developed by the US Department of Agriculture). The stream bank at site 1 was predicted to be eroding at a rate of 14,400 tonnes per year (O'Mara et al., 2014). Two sites make up the combined site (Sites 1 & 2) about 400 m apart, and consists in total of 1.5 hectares transecting four private land holdings.

Site 1 stretches approximately 310 m of riverbank that in many places had sheer cliff faces upward of 10 m. Initial works included bank reprofiling and battering, emplacement of a rock toe, strategic use of infertile Vetiver and revegetation with a mix of native species, including; *Eucalyptus tereticornis*, *Casuarina cunninghamiana*, and *Melaleuca viminalis*. This process involved the removal of soil from the cliff to create a gentler slope that reduces the likelihood of erosion (or 'mass failure') when moderate to high flow events occur. At the downstream point of this 310 m stretch of river, a pile field has been established (Figure 2). The aim of the pile field was to slow the velocity of flood flows and in doing so, reduce the erosive potential of the water, which causes sediment to drop out of the water column, increasing beneficial sedimentation on the project site.

The intervention at site 2 aimed to stabilise a wet flow mass failure that initiated during the 2013 flood. The restoration of this site included the installation of a significant rock chute that controls water flows during flood and high rainfall events that result in overland flow. The rock chute aimed to minimise the potential for further erosion caused by overland flow. The area surrounding the chute was also reprofiled and revegetated with similar native species. In late 2023, the sites reached 10 years maturity.

Figure 2. Site 1 in 2015 (left) and in 2023 (right)

Methods

LiDAR change analysis

The quantificaiton of erosion and deposition at sites 1 & 2 was achieved using digital terrain models of difference analayis (DoD) based on project specfic repeat LiDAR capture data (Croke et al., 2013). LiDAR data was captured post-intital works in 2014 and subsequently in 2015, 2016, 2017, 2018, 2021 and 2023. LiDAR point cloud data were intitally coverted to a DTM. Once a DTM was created for each year of interest, the raster calculator tool within ArcGIS Pro was used to determine the difference in elevation between years. Areas with elevation changes of between +0.3 m to -0.3 m were excluded from the analysis, as they are within the uncertainty range. For quality assurance purposes, a vertical acurracy assessment was completed using ground control points based on fixed infrastructure within the LiDAR coverage footprint. The area and height of each raster cell was then used to calculate changes in volume of sediment between years. A surface bulk density of 1.3g/cm^3 was used to convert volumes to tonnes.

Canopy height models and vegetation condition

To generate the CHMs, a surface model derived from the LiDAR returns (classified as the ground elevation points) was subtracted from points classified as the first LiDAR return (these represent the maximum height). A site vegetation volume was estimated, calculated as the total area below the canopy model surface (first returns) and surface terrain model. Tree survival has been regularly monitored during routine maintenance of the site since establishment. In 2023, a detailed riparian condition assessment was completed based on the Rapid Assessment of Riparian Condition assessment tool (Jansen et al., 2005).

Ground-truthing surveys

Areas of erosion and deposition indicated by the DoD analysis were confirmed by field surveys of the site in 2021 and 2023. For previous years, historical imagery (drone and aerial) of the rehabilitation site was used to interpret the DoD analysis.

Results and discussion

Sediment processes and vegetation condition

Since site establishment there has been an overall net accretion of sediment to rehabilitation sites 1 & 2 (Figure 3,4). Since initial works were established there has been a progressive increase in sediment deposition at the site. The greatest increase in sedimentation was observed between 2017 and 2018 (> 2000 tonnes), covering the period of the 2017 major flood caused by rainfall from ex-tropical cyclone Debbie (Figure 5). Between 2018 and 2021 a substantial export of sediment from the site occurred, covering the period of the January 2021 major flood event (Figure 2). Between 2021 and 2023 substantial deposition of sediment occurred at the site (> 5000 tonnes), covering a period of multiple floods including the 2022 major flood. The presence of recently deposited (<10 years) flood derived sediment (>0.3 m in depth) at locations across the rehabilitation site were confirmed in field survey in 2023 (Figure 4c).

Between 2014 and 2023, there was an overall increase in vegetation height across both sites 1 & 2 (Figure 6). The establishment of mature native woody vegetation has been successful overall, with a survival rate of >80%, average canopy height of > 5 m, and canopy cover at ~30%, based on field surveys. Understory vegetation remains dominated by non-native (naturalised) grasses and other weed species, and recruitment of native understory species remains very limited.

Sediment erosion and deposition at the rehabilitation site is event based, with major sediment stripping and deposition attributed to period of major flooding. The combination of change in bank-slope, pile-field emplacement and vegetation maturation vegetation is likely promoting sediment deposition at the site during the falling stages of major floods (Figure 7). Sediment is also being episodically stripped from the site during major flood events. The transition of the reach from an eroding highly degraded reach to a dynamic channel form with maturing riparian vegetation illustrate the successful outcomes of the rehabilitation works.

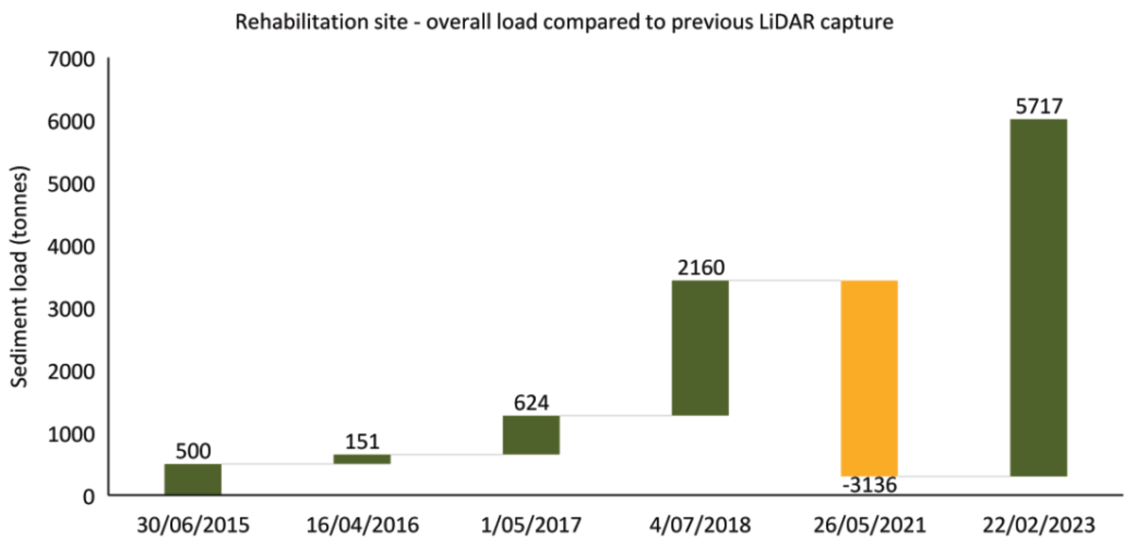

Figure 3. Rehabilitation site overall sediment load compared to previous LiDAR capture

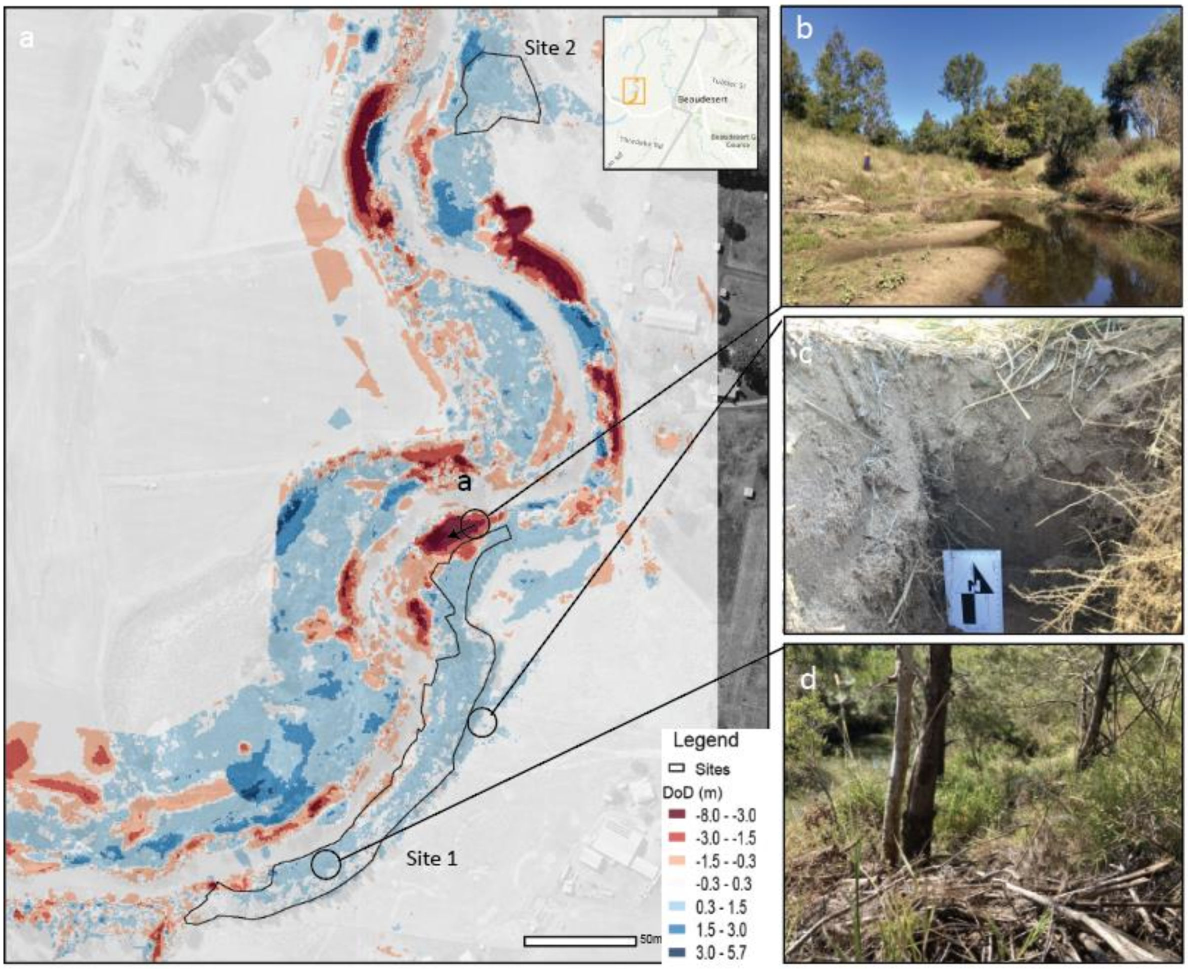

Figure 4. A) Digital terrain models of difference (DoD) for 2023 – 2014, indicating area of erosion and deposition within the rehabilitation sites. B) fluvial scour and mass bank failure associated with a flood cut off chute at the downstream end of site 1. C) Un-consolidated fine sands on the natural levee indicating flood deposition. D) Woody debris observed at the upstream end of site 1 in 2023.

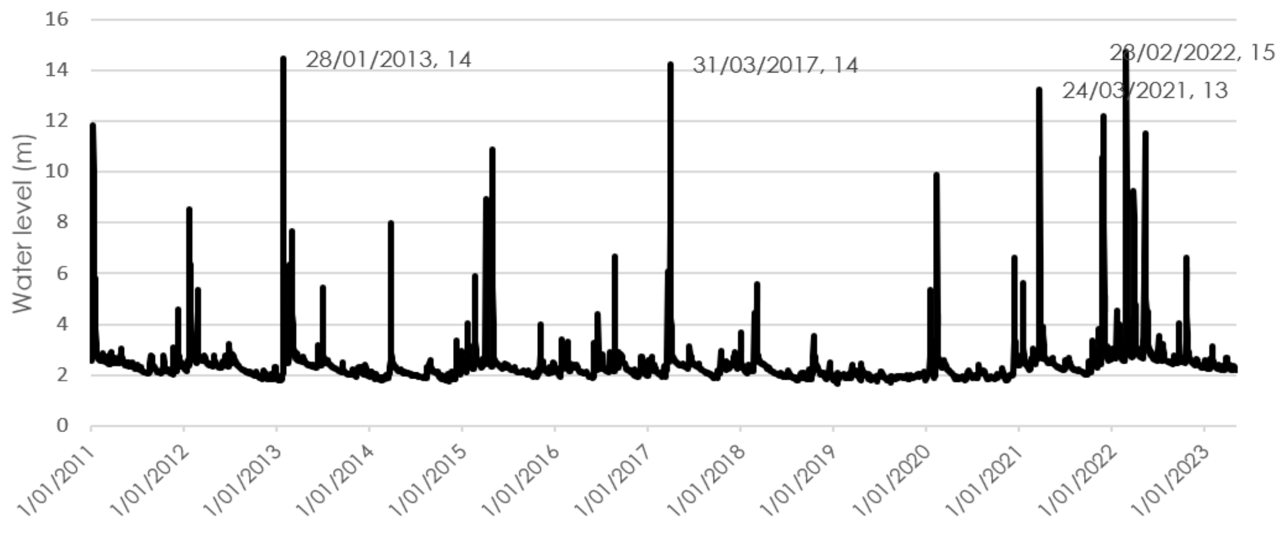

Figure 5) Water level measured at Round Mountain (145008A) from 2011 to 2023.

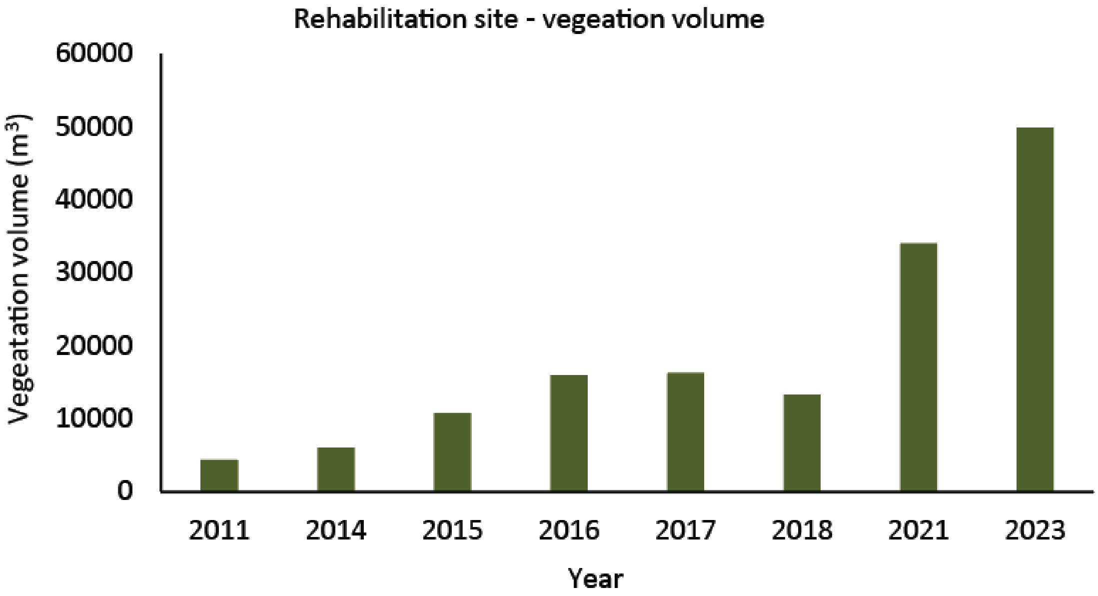

Figure 6. Rehabailiation site vegaetion volume illsturating the progressing increase in vegeation height and coverage within the site from 2014 to 2023.

Figure 7. The rehabiliation site on the river following a major flood caused by rainfall from ex-tropical cyclone Debbie – March 2017.

Conclusions

A major rehabilitation site on the Logan River has reached 10 years maturity. The relatively minor level of erosion observed at the site, the relatively successful re-establishment of native riparian vegetation, and the evidence of net sedimentation over the decade, which has two major floods and multiple smaller flows, illustrate the successful performance of the rehabilitation site. BSTEM modelling results in planning stages indicate that the estimated erosion load avoided since site establishment over a period of 10 years is >140,000 tonnes. Key factors that have influenced the success of the site included;

- detailed rehabilitation planning based on hydraulic and geomorphic assessment of the site, including an understanding of dominant erosion processes.
- ongoing and frequent site maintenance (weeding and replanting).
- hybrid rehabilitation techniques that incorporate ‘soft ’engineering in high degraded and actively eroding channels.

Episodic deposition of sediment and woody debris within the site also indicates the site has transition from a net eroding site to a net depositional site. Although, it is challenging to isolate the direct contribution of the maturing native vegetation to sediment deposition at the site, the detailed quantification of sediment export and import to the rehabilitated site reported here provides proof of concept that best practice riparian rehabilitation will mitigate channel erosion risk and potentially, moderate downstream transport of upstream-derived sediments. Empirical evidence of these processes with river rehabilitation project sites can inform process-based river rehabilitation strategies.

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