Full Paper

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Title: Building Stable and Resilient Foreshores using a Naturalised Approach

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Key Points

- Using innovative natural foreshore stabilisation design to address foreshore erosion protection can achieve ecological improvements
- Fluvial geomorphology assesses the cause of foreshore instability by understanding the hydrology, foreshore vegetation, the bank soil morphology and instream dynamics of the stream.
- Build it and mangroves will come!

Abstract

In 2015 parts of the Damian Leeding Memorial Park, adjacent to the upper estuary of the Coomera River, were undergoing significant bank scour and bed erosion resulting in a risk to infrastructure and public safety. There was also a long-term threat that the erosion could lead to the river channel capturing a nearby recreational lake within the park.

The naturalised stabilisation works that have been completed to address this issue helps to protect the park while allowing mangrove seedlings to re-establish and sediment to build up behind the logs delivering a more permanent solution to erosion issues at the site.

Using input from a geomorphic engineer, the City of Gold Coast undertook an erosion assessment and developed an innovative design using hardwood trees to help address the developing erosion. In 2018 the Damian Leeding Foreshore Stabilisation Project was completed and successfully stabilised 450 meters of foreshore. Hardwood instream structures were placed on the riverbed together with systematic revegetation of the bank. The logs were tethered to 106 marine hardwood piles. The structures are designed to reduce velocities on the foreshore by manipulating the hydraulic forces. The re vegetation works consisted of 7100 native riparian plants which helps to provide ongoing stability and habitat at the site.

The project is monitored for 5 years. Outcomes from 3 years monitoring todate include the bank adjusting to a more natural profile, sediment accreting behind the logs, mangrove seedlings establishment, and improvements to estuarine and terrestrial ecology.

The City of Gold Coast is sharing the stabilisation techniques with other stakeholders in an effort to promote this technique of foreshore stabilisation.

Keywords (*Up to 8 words)*

Stabilisation, foreshore, mangrove, habitat, erosion, estuary, ecology

Introduction

In 2014 local residents observed mature casuarina trees falling into the Coomera River at the Damian Leeding Memorial Park, Oxenford in South East Queensland. The erosion, leading to the loss of the mature trees, was triggered by a significant flood event in 2010 that changed the bathymetry of the river channel adjacent to the park. Continued bed erosion led to the bank becoming undermined, which caused the banks to collapse, resulting in severe erosion of the riverbank (Riparian Engineering, 2015). The City of Gold Coast's (CoGC) Catchment Management Unit (CMU), together with Riparian Engineering Pty Ltd, developed an innovative, sustainable solution to stabilise the riverbank and enhance the overall ecology of the site.

The Damian Leeding Memorial Park Foreshore Stabilisation Project (the Project) aimed to stabilise the bank, restore mangrove habitat, and improve riparian vegetation. Additional benefits expected through the delivery of

the project included improvements to water quality, fisheries habitat, and overall aquatic ecological values. The Project covers a 450m stretch of foreshore and protects the foreshore from hydrologic impacts and promotes sediment deposition behind the logs through natural tidal processes. The structures also encourage mangroves seedlings to establish.

Project expectations

With predicted increases in cyclones, and flood events due to a changing climate, the riparian vegetation and mangrove growth in this vegetated zone will become increasingly important to protect the Park foreshore. A healthy mangrove community also traps sediment and prevents nutrients and contaminants entering the waterway from runoff. A long-term beneficial outcome from the project is expected to be the improvement to water quality, improved recreational fish stocks and other aquatic species, as well as associated terrestrial flora and fauna. There are at least five mangrove species found on the Gold Coast, with two already establishing at the Project site, Grey mangrove (*Avicennia marina)* and River mangrove (*Aegiceras corniculatum).*

Instream works

The instream construction works consists of 96 hardwood tree logs with root balls that were placed on the riverbed together with systematic revegetation of the riparian bank. The works provide hydrological protection to the foreshore, restore bed erosion by sediment accretion, and encourage mangrove seedlings to establish each season behind the logs by natural river processes (figure 1).

Figure 1 Drone photo of Damian Leeding site showing piles and logs.

The Project used recycled hardwood tree logs, which were obtained from a nearby development site. The hardwood tree logs were placed on the riverbed and secured to marine piles along the park foreshore (figure 3). Traditional methods for stabilising banks, particularly near infrastructure include the use of riprap, which are made from rocks or concrete of varying sizes placed from the top of the bank to the riverbed (Bariteau, et al., 2013). Riprap, however, has very little environmental benefits as it limits the ability for vegetation to grow on the substrate, as well as, restricting the availability of shelter for fish and other aquatic fauna along the foreshore (Massey, Biron, & Choné, 2017). By using this naturalized method, significant savings are achieved over the life of the project as there is no need for renewal of the natural asset while riprap requires maintenance at regular intervals.

The piles and logs were installed from the river using an excavator on a large industrial barge. This approach avoided possible impacts to the fragile foreshore bank at the site. Arborists coppiced several leaning casuarina trees to reduce the risk of wind generated bank slumping. Following the works, these trees survived and have

re-sprouted adding to the revegetated riparian zone. The coppiced material was recycled onsite and placed under the tree logs to add to roughness as well as estuarine macroinvertebrate habitat.

A conscious decision was made not to batter the bank. A battered bank is never the same as a natural riverbank profile. The instream works and riparian plantings allow the bank to adjust its slope overtime. Several mature casuarina trees would have been lost, and a batter would have increased the channel capacity at the site, increasing overall stream power within the channel.

To assist in maintaining the safety and environmental values at the site several measures were put in place to ensure no existing mangrove trees were damaged during construction works. Water quality sampling commenced prior to the works and continued weekly. Several sediment fences were set up from the bank along one third of the instream works to keep passing boat traffic away and sediment within the works zone. A mobile sediment fence was used from the barge to the bank at each pile installation area. The Gold Coast Waterways Authority (GCWA) deployed floating buoys "Underwater Obstructions" to warn passing boats.

Piling of 106 hardwood piles commenced early January 2018 and took four weeks to complete. First an auger drilled a pilot hole, then the pile was placed in the hole by sling (figure 2). The pile was vibrated to a depth of 5 meters for inside piles and 6 meters for outside piles and checked by the engineer. Material removed from the pile holes was removed from site as Potential Acid Sulphate Soils (PASS) were present.

After the piles were installed, the placement of 96 tree logs commenced. Prior to the placement of the logs, the fallen and coppiced casuarina trees were laid out on the beach area between the piles. The tree logs were brought in on the barge and placed on top of the casuarina brush to create roughness and maintain the fallen casuarinas in the river as habitat (figure 3). At the piles in deeper water two logs were placed with root balls facing upstream. Checks were made that each log didn't float and settled in place on the riverbed, the final tree log was placed on 26 February 2018. Dynema® rope (a high strength fiber rope used in the maritime industry for towing and mooring) was used to secure each log to its adjacent pile, the rope was certified by an RPEQ engineer for its strength and longevity. The piles were cut to size and required a block at the top of the pile to ensure logs can't float off the piles during a flood event. Finally, the tops of the piles were treated, and reflective tape adhered around the top of the outside piles, as requested by GCWA to allow boat users to see the structure at night.

Figure 2. Auger preps the hole for pile.

Figure 3. Placement of tree by excavator on barge.

Riparian vegetation works

The riparian vegetation phase commenced in late April 2018 following the completion of the instream works. Vegetation is an important component of the overall project outcome, by means of the instream structures working together with the riparian vegetation to stabilise the foreshore bank and bed.

A bioengineering method was used to stabilise the vertically denuded bank by using native Hibiscus plants (800) that were planted deep into the vertical eroded bank. Locally propagated *Hibiscus tiliaceus* were specifically grown in the nursery to be planted with extra-long stems of approximately 80cm, this allowed for their roots to establish deep inside the bank. Hibiscus were selected for their growth habit and their tolerance of salt exposure. The Hibiscus were planted in the mid bank zone just above the high tide mark, while two species of salt tolerant sedges were densely planted in the toe and mid bank as a ground cover as an aim to further protect the exposed bank from scour.

It is expected that the other riparian species that were planted on the top of the bank will connect with the Hibiscus in the vertical bank over time. Mangroves have and are expected to continue to establish behind the tree logs nearest the bank overtime, this is expected to create a dense forest along the foreshore in six to seven years, permanently protecting the bank from further erosion.

Monitoring

The objectives of the monitoring program at the project site are to:

- measure the overall success of the project
- monitor the density and growth of mangroves that are expected to establish at the site
- measure the stability of the banks
- measure the accumulation of sediment on the foreshore; and
- record visual observations of associated fauna.

In addition to the above, the integrity of the logs and piles were checked every six months (over a period of two years) by City of Gold Coast and the contractor who provided a 2 year warranty to the use of dynema® rope. This is to ensure the structures are safe and able to maintain its function of erosion protection.

The monitoring program consist of 11 treatment sites within the restored area and 9 control sites, 4 upstream and 5 downstream (figure 4).

Figure 4. Monitoring sites: blue text-Treatment sites, yellow and black text-Control sites

Results measured in 2018, 2019 and 2020 show positive outcomes have been achieved. Each time there is a significant rainfall event the bank is slumping and adjusting with soils being captured behind the logs. The bank has not been modified as per the design and will alter overtime to a more stable slope.

Two species of mangrove are establishing naturally behind the logs with a substantial increase with the previous year. It is expected that in the longer term a mangrove forest will help to provide erosion protection. Fish, crustaceans, and wader birds are using the site.

Specific outcomes of the components of the project being monitored are outlined in the sections below.

Bank Profiles

Bank profiles were measured at 11 sites within the treatment area and 9 control locations. The aim is to measure change over time to show the bank profile gains a more natural gradient, rather than the vertical gradient prior to 2018. It is expected that sediment will build behind the logs, preventing loss of sediment to the river system. Figure 5 reveals the slope of the bank returning to a gradual slope over the 3 years of monitoring.

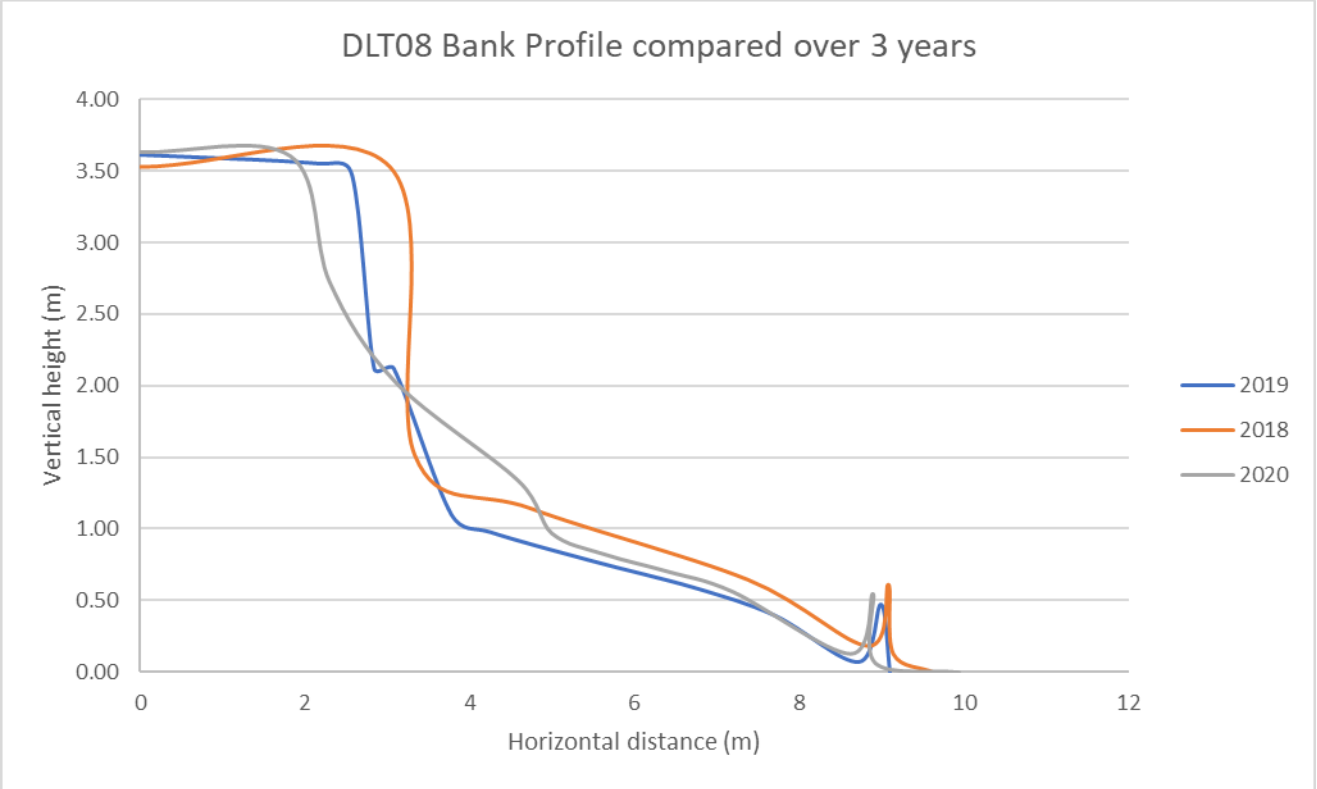

Figure 5. Bank profile data shows adjustments of the bank over the last 3 years.

Mangroves

Mangroves seedlings are establishing and growing at a fast rate behind the logs and in between the organic debris on the foreshore. Results suggest the logs with fallen trees underneath, have created a protected zone from wave action and fast flows allowing for establishment of the mangroves.

Two species of mangrove are establishing naturally behind the logs, *Avicennia marina* and *Aegiceras corniculatum.* From 2018 to 2019 an overall increase of mangrove seedlings of almost 800% was measured at our monitoring sites, and a substantial increase again in 2020 (figure 6). The instream structures have provided protection from excessive hydrology (up to 3m/s) allowing mangrove seeds that deposit in the foreshore to start to grow. While in the control sites without the protection of the logs, the mangroves have not been able to establish as successfully (figure 6, 7).

It is expected that in the longer term a mangrove forest will help to provide erosion protection. Fish, stingrays, crustaceans, and birds have been observed using the site.

In February 2020 and March 2021 flooding conditions from significant rainfall events tested the stabilisation works and resulted in mangroves surviving the impacts and structures remaining in place. Further bank adjustments were experienced as a result of these weather events.

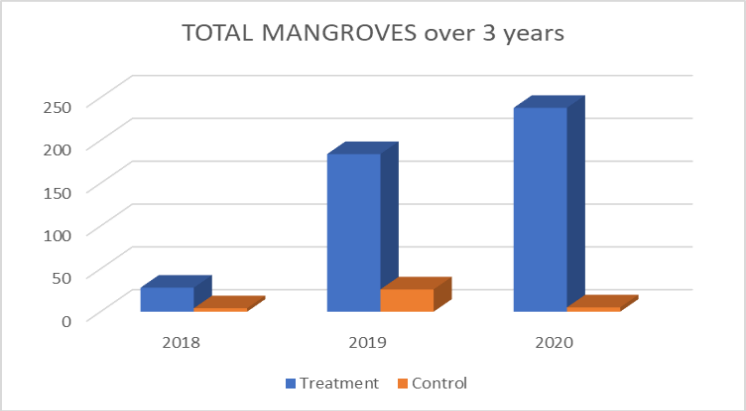

Figure 6. Mangrove count over 3 years

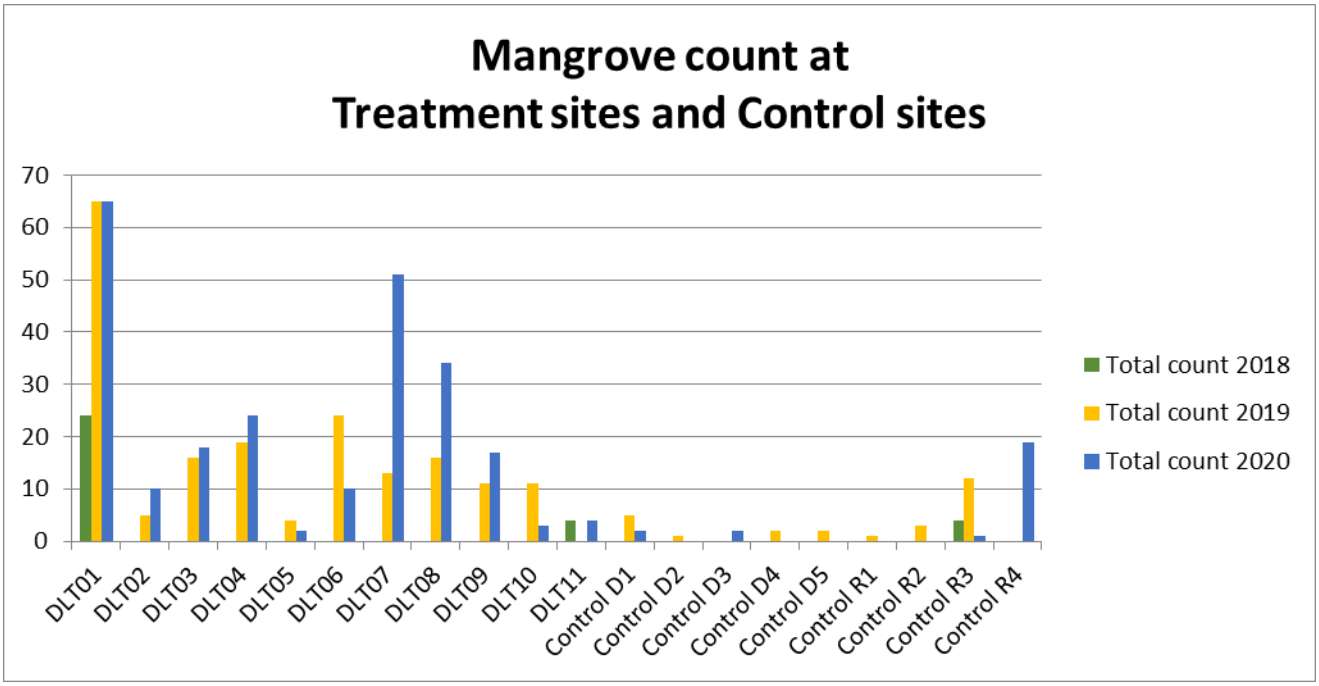

Figure 7. Mangrove count for each site over 3 years

Figure 8. Left photo August 2018, right photo September 2019 mangrove seedlings behind logs

Riparian zone

The planted and existing vegetation in the riparian zone took some time to establish and recover due to dry weather but started thriving after approximately one year. Sections of the riparian buffer have been planted with lower type vegetation to maintain views of the river while walking in the park (figure 9).

The Hibiscus plants are growing slowly with only a small number of plants lost. None of the sedges at the toe of the bank have survived.

Figure 9. Drone shot of riparian zone September 2020

Conclusions

The Damian Leeding Memorial Park Foreshore Stabilisation Project was successfully constructed and planted. Good planning has been instrumental and geotechnical investigation of the riverbed showed minimal rock up to 5 meters depth. The piling contained the risk of hitting rock below 5 meters, but only one pile perceived rock. The initial design used steel chain to secure the hardwood logs to the piles. Rope (Dynema®) was suggested by the marine civil contractor as a better alternative.

Three years monitoring to date show that the Project has achieved positive outcomes. It will take a minimum of five years to conclude the works a final success. The bank has not been modified and, as per the design, will alter overtime to a more stable and natural slope from tidal river processes. Each time there is a significant rainfall event the bank is adjusting with soils being captured behind the logs. The riparian vegetation took a year to establish due to dry weather following the planting and is now on general maintenance. The life cycle of the instream structure is expected to incur negligible cost because nature is helping to settle the logs and sediment is building around the deeper logs. Once these logs are completely covered, they will act as a stronghold on the riverbed providing resilience and long-term stability. Each season mangrove seeds float into the foreshore and establish behind the logs, while crustaceans, fish and other wildlife are observed using the structures as habitat.

The City of Gold Coast is planning to roll out more naturalized riverbank stabilisation techniques in 2022, using for example, earth ankers to tie tree logs into the foreshore eliminating the use for piles. Keeping in mind that each site is different and not all methods work everywhere. A skilled fluvial geomorphologist coastal engineer is required for final assessment and design.

Acknowledgments

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