A method for assessing channel erosion risk at the regional scale

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Key Points

- A desktop assessment method has been developed to assess channel erosion risk at the regional (catchment) scale, focused on fine sediment loads.
- This includes a stream type approach, which considers microchannel systems.
- It is based on observed channel change in South East Queensland between 2009 and 2016, and the assessment of the volume of sediment in the channel erodible zone.
- The main limitation was a lack of available data, but this will change with ongoing data collection in the region (e.g. multi-temporal LiDAR data).
- The assessment will help managers identify areas to target further investigations, and inform planning, land use decisions, and high-level on-ground management responses.

Abstract

Fine sediment derived from channel erosion has been identified as having a major environmental and economic impact on South East Queensland. This includes reduced water storage and increased treatment costs, degradation of the Moreton Bay Ramsar site, and impacts on shipping operations in the Port of Brisbane. A rapid desktop method to assess channel erosion risk has been developed and applied to streams across South East Queensland. The method assesses both the likelihood of channel erosion and fine sediment availability at the reach scale. The approach can assist managers to identify stream reaches with high fine sediment generation potential, to help target additional investigations and inform planning.

Keywords

Channel erosion, fine sediment, stream type assessment, South East Queensland

Introduction

Erosional channel change has been a major management issue in South East Queensland (SEQ) since the devastating flood events of 2011 and 2013. It affects water supply, the health of Moreton Bay and riparian ecosystems, and the viability of agricultural areas. This paper presents a method for assessing channel erosion risk at the regional scale, which has recently been applied across SEQ. The method has been developed to help managers target areas for further investigations and to inform planning, land use decisions, and high-level on-ground management responses. The method is not intended to replace detailed geomorphic and hydraulic assessments, which are often required to assess and quantify erosional processes and channel trajectory at the reach scale.

Method

Overview

The approach developed is a broad-scale (whole of catchment) desktop assessment of channel erosion risk. The relative risk of fine sediment loads derived from channel erosion at the reach scale is dependent on two primary factors:

1. **Reach-scale erosion potential** – This is the potential for erosion in future flow events. It is related to the geomorphic form (i.e. the type of stream) and condition, along with a range hydrologic and hydrogeomorphic parameters (e.g. stream power, channel resistance, flow regime).

2. **Reach-scale fine sediment availability** – This is the volume of fine sediment available to be eroded by channel erosion processes. It is dependent on the fine sediment fraction in the channel and floodplain, and the volume of alluvial deposits that are within the channel erodible zone (e.g. floodplain, benches, islands).

These two factors are presented in Figure 1, along with the attributes used in this approach to assess each factor. These attributes are discussed in more detail below.

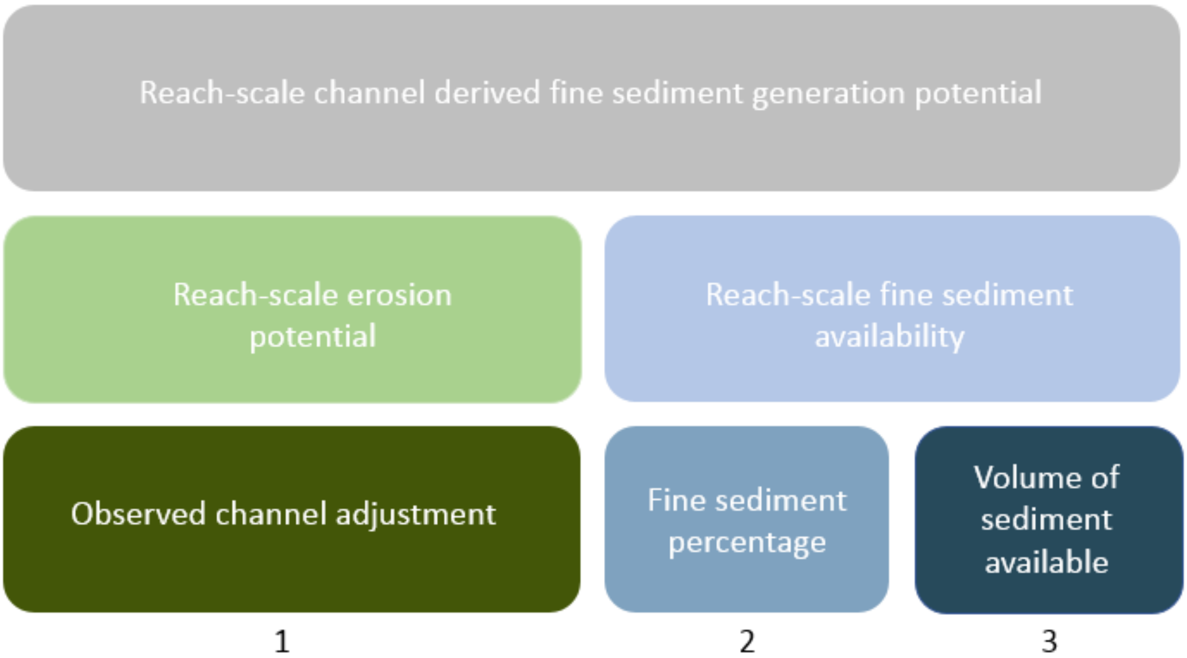

Figure 1. Conceptual diagram highlighting the main factors which contribute to reach scale channel derived fine sediment generation potential. The three boxes along the bottom are the key pieces of information the methodology assesses.

Stream type assessment

To help determine the main factors which impact reach-scale, channel-derived fine sediment generation potential, a stream type assessment was undertaken by desktop geospatial analysis of available aerial imagery, LiDAR data and other spatial data (i.e. geology, soils etc.) and verified through a targeted field work program. Many aspects of other stream type assessments, such as RiverStyles^{TM} (Brierley & Fryirs, 2005), were used and adapted in developing the method used in this project, to produce a method that addresses specific issues within the SEQ region's catchments.

The resulting classification recognizes that many rivers in SEQ do not have 'classic' floodplain morphology, and do not behave like true self-formed alluvial rivers. Many rivers in SEQ have a macrochannel morphology bounded by resistant old floodplain/terrace deposits (Croke et al. 2013; Fryirs et al. 2015; Brooks et al, 2014). Within the macrochannel, an inset channel and a range of geomorphic units (e.g. bars, benches, islands, inset floodplains) can be found. Research indicates the majority of channel erosion in SEQ occurs from these inset units in macrochannel systems (Brooks et al, 2014; Croke et al., 2013). Within macrochannel systems, there is minimal lateral planform adjustment of the main channel as the main channel is 'confined' by the floodplain/terrace (Fryirs et al., 2015).

The hierarchal stream type assessment method adopted is presented in Figure 2. Each key level is discussed below:

- **Level 1 – Degree of confinement and confinement media:** The degree to which the channel is confined and, as a result, its ability to laterally adjust within contemporary timeframes. The channel can be confined by either hillslopes or the floodplain/terraces. Four ranges of confinement were used, based on the percentage of channel which abuts the confinement boundary. This assessment helps determine the likelihood of lateral adjustment and the channel erodible zone.
- **Level 2 – Floodplain development process/type:** Whether floodplains are present and the dominant floodplain development process (i.e. vertical or lateral accretion). This provides an indication of channel migration processes and avulsion risk.
- **Level 3 – Channel morphology and planform:** Whether there are inset units in confined reaches, and assessment of the planform for unconfined reaches. The planform in unconfined reaches can provide an initial indication of the mechanism and degree of alluvial channel adjustment (e.g. meander migration/ extension, cutoffs). The planform was not assessed in confined reaches as these are largely defined by the confinement boundary.

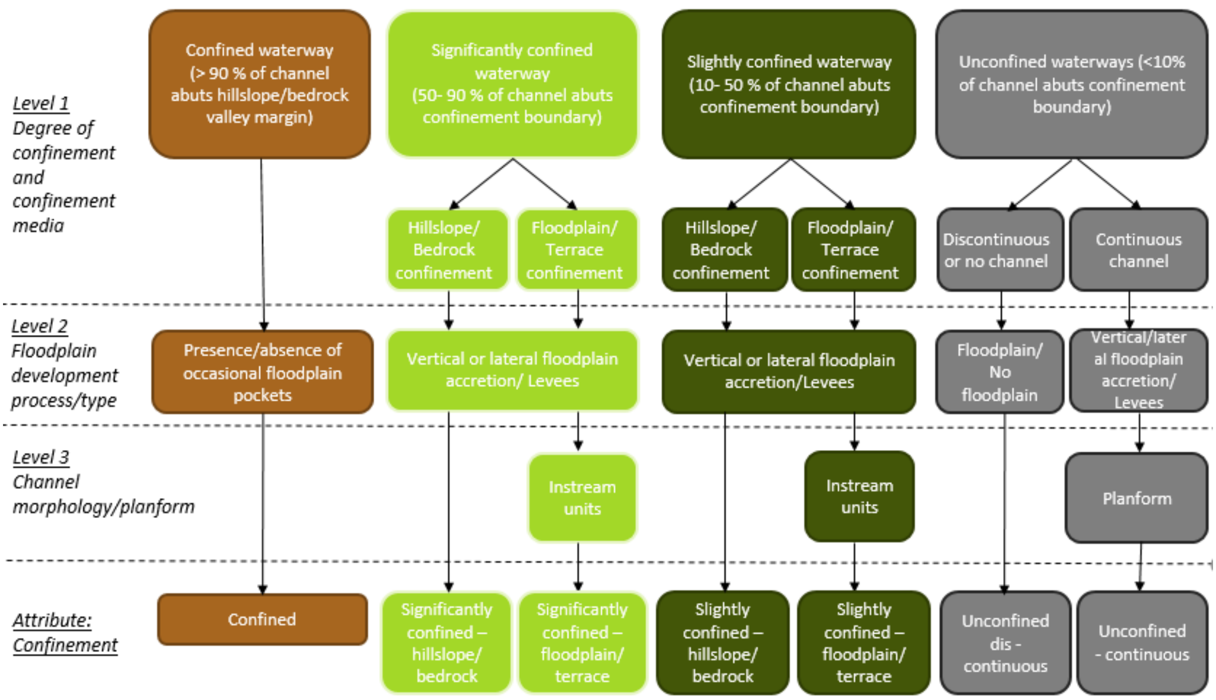

Figure 2. Hierarchal stream type assessment.

Reach-scale erosion potential

Overview

Reach-scale erosion potential will be dependent on the geomorphic form, processes and condition of the reach. Factors that are likely to influence the reach-scale erosion potential will include:

- Reach-scale unit stream power
- The resistance of bed and bank material to the applied stream power (bed load sediment supply, channel substrate composition and riparian condition)
- Bank height and slope – Steep, high banks have greater potential for bank mass failure, which can be unrelated to stream power

Both qualitative and quantitative methods for determining and using reach-scale unit stream power were explored during the development of this desktop assessment approach. However, both methods had several issues and were disregarded. The main reasons were:

- High degree of uncertainty when stream power surrogates (i.e. bed sediment size, bed grade, width - depth ratio etc.) are used to infer unit stream power
- Accurately extracting stream parameters (i.e. channel slope, width) across large spatial scales is difficult and time consuming
- Difficulty in determining a representative discharge (e.g. bankfull discharge, 2 year ARI, 10 year ARI), on which stream power will be based across all stream types
- Sediment supply, transport and storage processes within a reach will affect how stream power is dissipated within the reach, which will affect channel change processes

Consequently, a surrogate measure was needed to determine erosion potential. Due to the absence of other suitable regionally consistent data, and the availability of 2009 and 2016 high resolution aerial imagery for the entire SEQ region, observed channel change within this period was used as an indicator of erosion potential. During this period all catchments across SEQ experienced moderate to major flooding. As a result, if reach-scale unit stream power is likely to exceed channel resistance during floods or the banks are excessively steep, some channel erosion would be expected to be observed between 2009 and 2016. This assessment did not directly assess riparian vegetation. Well-vegetated reaches would generally have minimal recent channel change, but the opposite is not always true – in reaches with low stream power, streams can remain stable even with minimal riparian vegetation.

In some cases, historical erosion is not always an indicator for future erosion potential. Inset units can be significantly eroded, which initiates a new phase of deposition and channel recovery (Erskine et al., 2009; Baggs Sargood et al., 2015; Thompson et al., 2016). Additional research is required to expand on the findings of Thompson et al. (2016) and assess channel evolution processes in different stream types across SEQ. However, under the adopted approach, reaches which have had significant erosion of inset units will be classified as having low 'reach-scale sediment availability' (discussed below).

Lateral stability was assessed using aerial imagery between 2009 and 2016 and classified as:

- **Laterally stable** (no observed lateral adjustment)
- **Minor lateral adjustments** (longitudinally isolated adjustment of channel boundary of less than or equal to 5 m or 10 % of channel width between 2009 and 2016)

- **Moderate lateral adjustments** (longitudinally widespread adjustment of channel boundary of less than or equal to 5 m or 10 % of channel width, or isolated adjustment of major instabilities, between 2009 and 2016)
- **Major lateral adjustments** (longitudinally widespread adjustment of channel boundary of greater than 5 m or 10 % of channel width between 2009 and 2016)

The stability of inset units (floodplain/terrace confined reaches) was assessed using aerial imagery between 2009 and 2016 and classified as:

- **Stable** (no observed adjustment of units between 2009 and 2016)
- **Minor adjustments** (isolated adjustment inset units between 2009 and 2016– less than 20 % of unit area)
- **Moderate adjustments** (widespread adjustment inset units between 2009 and 2016 – less than 20 % of unit area or isolated major adjustments of inset units)
- **Major adjustments** (widespread adjustment inset units between 2009 and 2016 – greater than 20 % of unit area)

For this assessment adjustment includes both lateral adjustment of unit and vertical stripping. If vegetation is stripped from the unit it is also assumed there is some degree of vertical stripping.

The reach scale erosion potential was then assigned for each reach using this four-tier assessment:

- **Low** (laterally stable or stable inset units (if present) between 2009 and 2016)
- **Moderate** (minor lateral adjustments or minor adjustments of inset units (if present) between 2009 and 2016)
- **High** (moderate lateral adjustments or moderate adjustments of inset units (if present) between 2009 and 2016)
- **Very high** (major lateral adjustments or major adjustments of inset units (if present) between 2009 and 2016)

Reach-scale fine sediment availability

Overview

Channel erosion results in the release of coarse and fine sediment to the stream system and receiving environment. This project focused on fine sediment due to downstream implications on water treatment and receiving environments (i.e. estuaries and Moreton Bay). The volume of fine sediment available for release as a result of channel erosion is dependent on:

- The volume of sediment in the erodible channel zone (e.g. within floodplain, benches, islands)
- The percentage fraction of fine sediment in the erodible material

The transport and fate of fine sediment released into the stream system does not form a part of the project approach. The approach adopted considers the potential for fine sediment to enter the system. The extent to which such fine sediment, released through bank erosion, is transported through the system to downstream points of interest (e.g. Moreton Bay) will be the subject of subsequent assessments.

Volume of sediment available

The volume of erodible sediment within each reach is dependent on the stream type. Key factors include:

- Degree of confinement – long-term sediment loss will be less from reaches with high degrees of lateral confinement
- Height of erodible unit – high banks abutting erodible geomorphic units will contribute larger volumes of sediment
- Surface area of inset units – erodible inset units in macro channel systems can contribute large volumes of sediment

Elevation data (LiDAR) was used to assess the overall width and height of the primary geomorphic units within the erodible zone. The erodible zone is the area where the majority of channel-derived sediment is sourced and was assessed based on the stream type (confinement) assessment. The width and bank/unit height were classified into four ranges based on a relative distribution of channel widths, and a matrix approach was then used to define the overall sediment availability (Figure 3).

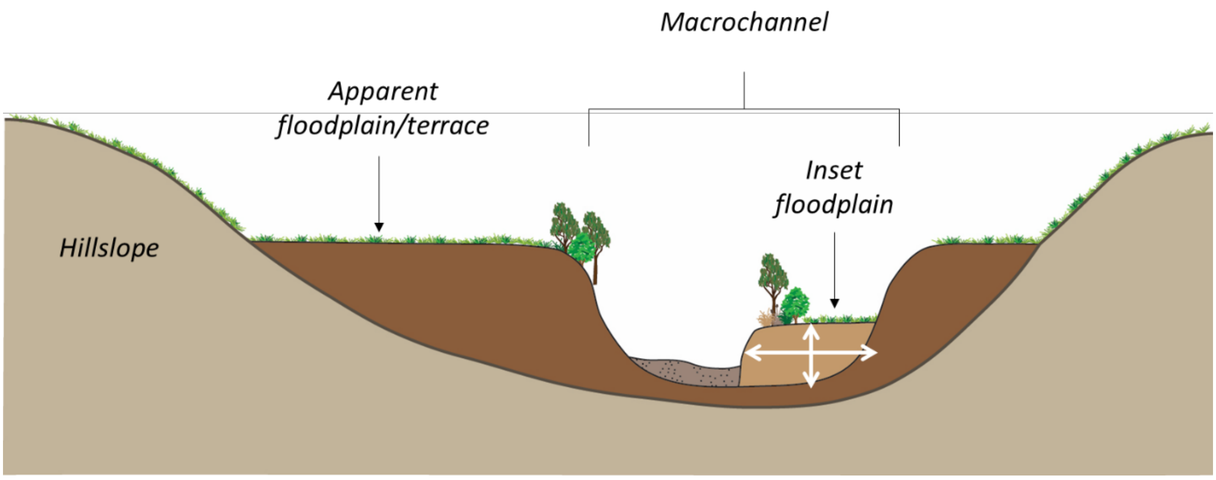

Figure 3. Example of a macrochannel which is confined by floodplain/terraces where the erodible zone primarily consists of inset floodplains – the width and height dimensions are shown on one side of the channel.

Fine sediment fraction

The fine sediment fraction from erodible units is likely to have the greatest consequence on downstream receiving waters. Unfortunately, the alluvial material of the channel banks and inset units cannot be easily identified from currently available soil mapping.

The best available information across SEQ for the fine sediment fraction layer is the Australian Soil Resource Information System (ASRIS) clay percentage layer. This information is only available for the upper 300 mm of the soil profile. While the clay percentage from this layer is unlikely to be representative of all channel banks and inset units it is the best information available across SEQ. Improved mapping of alluvial deposits in the future will improve this assessment.

The fine sediment availability was determined using a matrix approach. The matrix was developed based on the combination of sediment availability (discussed above) and the fine sediment fraction (ASRIS clay content) of the available sediment.

The reach-scale channel-derived fine sediment generation potential (i.e. channel erosion risk) is derived based on the combination of the reach-scale erosion potential and the fine sediment availability. A matrix approach has been adopted as shown in Figure 4.

Reach-scale fine sediment availability	**Reach-scale erosion potential** Low	Moderate	High	Very High
Low	Low	Low	Low	Moderate
Moderate	Low	Low	Moderate	High
High	Low	Moderate	High	Very high
Very high	Moderate	High	Very high	Very high

Figure 4. The matrix used to define reach scale fine sediment generation potential

Conclusions

The rapid desktop assessment method developed for this project provides a good indication of the reach-scale, channel-derived fine sediment generation potential across SEQ. The assessment will help managers identify areas at greater risk to target further investigations, and inform planning, land use decisions, and high-level on-ground management responses. Detailed on-ground management efforts in priority reaches need to be further informed by more detailed geomorphic and hydraulic assessments, to help determine and quantify the erosional processes and channel trajectory.

The assessment has been based on observed channel change between 2009 and 2016. The method that was developed was limited by current data availability, and will be significantly improved by ongoing data collection across SEQ. Most importantly, multi-temporal LiDAR data for all of SEQ will help determine channel erosion processes and quantify channel adjustments. Currently, multi-temporal LiDAR data is only available in a limited number of sub-catchments so it has not been used in this method. Where available (i.e. parts of Lockyer and Logan), multi-temporal LiDAR data were used to validate aspects of the desktop assessment. A better understanding of the fine sediment fraction within inset units and streambanks will also help improve the approach.

Furthermore, this assessment did not directly assess riparian vegetation, which will affect channel stability and change, and historical erosion is not always an indicator of future erosion potential. In reaches with high fine sediment availability, additional research/studies should be undertaken to assess channel evolution processes. Channel evolution models, similar to those developed by Thompson et al. (2016) for the Lockyer Creek, can help managers target works for sediment reduction.

The majority of streams across SEQ catchments were classified as having low to moderate fine sediment generation potential. However, despite the low rates of channel adjustments and/or sediment availability, collectively these reaches still represent a major fine sediment source in SEQ. As a result, improved riparian management (protection or restoration of riparian vegetation, exclusion fencing, weed/pest management, stock management etc.) in these reaches remains a critical part of ongoing sediment reduction programs. Restricting ground management responses to the reaches with either high to very high fine sediment generation potential is unlikely to achieve the desired level of catchment reductions in sediment loads. The approach can provide on ground managers with confidence that riparian works in low to moderate fine sediment generation potential reaches will have a high likelihood of success. In reaches with high to very high fine sediment generation potential on-ground management efforts need to be further informed by more detailed geomorphic and hydraulic assessments to increase the likelihood of success.

The approach adopted considers the potential for fine sediment to enter the system. The transport and fate of fine sediment released into the stream system does not form a part of the channel erosion risk method. Future work should assess the extent to which such fine sediment, released through channel erosion, is transported through the system to downstream points of interest (e.g. Water Treatment Plants, Moreton Bay). The assessment of sediment transport and fate should be based on field observations and the extent, location, roughness and connectivity of downstream sediment sinks such as floodplains, in-channel units and storages.

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