INTEGRATED SEDIMENT ASSESSMENT:

Final Report - Draft

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1 Executive Summary

In recent years Seqwater and Healthy Land and Water (HLW) have invested separately in catchment modelling frameworks (primarily the eWater Source model) to identify areas of land within sub-catchments that produce/export high loads of sediments. This information is used by both organisations to inform natural resource management planning, as well as to quantify contributions to total suspended sediment (TSS) load in waterways and assess the effectiveness of works undertaken to control erosion and sedimentation.

An outcome of these previous modelling exercises using eWater Source was the recognition that the TSS input data requires updating in order to improve accuracy of model outputs. Specifically, the sources of sediment from catchment processes other than for hillslope erosion require improved identification and quantification. These other process includes channel erosion and gully erosion processes, as well as point sources of sediment pollution. Channel erosion is known to contribute more than 70% of the total sediment load downstream (Olley et al. 2013, 2014), however, the contribution of gully erosion and point sources remains largely unknown.

In order to address the knowledge gaps and update TSS input data relating to channel erosion, gully erosion and point sources of sediment pollution, Seqwater and HLW are collaborating on the Integrated Sediment Assessment project (ISA). The primary aim of the ISA project is to build on and improve existing data and modelling and provide a better understanding of sediment loads and sediment movement in SEQ waterways. The project will provide better information for prioritising investments in the drinking water catchments as well as regional planning initiatives, such as the Resilient Rivers Initiative, to which both HLW and Seqwater are signatories.

2 Introduction

The land use, geomorphic and hydrologic processes within South East Queensland (SEQ) catchments collectively pose substantial sediment-related risk to receiving environments, including water storage reservoirs, water treatment plants, waterways, estuaries and Moreton Bay.

Between November 2016 and June 2018, Alluvium Consulting Australia Pty Ltd (Alluvium), Seqwater and Healthy Land and Water (HLW) collaborated to undertake the Integrated Sediment Assessment (ISA) project across SEQ. One of the key objectives of the ISA project was to improve understanding of regional sediment erosion processes, through assessing the relative contributions of point, channel, gully and hillslope erosion to the receiving environments.

This report outlines the methods, data and results from the data collation, channel erosion, hillslope erosion and point source erosion components of the project, and a final integration chapter which outlines methods for evaluating all sources together.

3 Data collation

Sourcing and collation of relevant datasets for SEQ was initiated by HLW in January 2017 and continued throughout the project, with new data assessed and utilised (where possible) as it became available. This process involved numerous discussions with councils, utilities and the Queensland Government to identify available datasets and negotiate data agreements (where required).

Members of HLW's Monitoring and Evaluation Steering Committee (Attachment A) were also invited to contribute to the project and identify new data to inform the work through email correspondence and follow up phone calls (13/2/2017). Overall, members were supportive and assisted with data share arrangements.

As a result, four new data agreements were established (between HLW and Brisbane City Council, Sunshine Coast Council, Redland City Council and City of Gold Coast) and data was also accessed through existing data agreements between HLW and Ipswich City Council, Moreton Bay Regional Council, Logan City Council, Noosa Council and Scenic Rim Regional Council. The SEQ Council of Mayors provided data collated through the Resilient Rivers Program for western and rural catchments (including Lockyer Valley Regional Council, Somerset Regional Council and Scenic Rim Regional Council).

Seqwater provided all available LiDAR (Light Detection and Ranging) data that has been acquired for water supply catchments.

Data was also sourced from the online data portals including:

- Queensland Spatial Catalogue – Qspatial (http://qldspatial.information.qld.gov.au/catalogue/custom/index.page)
- Brisbane City Council (https://www.data.brisbane.qld.gov.au/)
- Sunshine Coast Council (https://data.sunshinecoast.qld.gov.au/)
- Moreton Bay Regional Council Data Portal (http://data.moretonbay.qld.gov.au/)
- Logan City Council (http://www.logan.qld.gov.au/about-logan/living-in-logan/open-data)
- City of Ipswich (http://www.ipswich.qld.gov.au/online_services/map_search)
- Redland City Council (https://www.redland.qld.gov.au/)
- City of Gold Coast (http://www.goldcoast.qld.gov.au/open-data-access-project-21818.html)

3.1 Datasets

The key datasets collated by HLW are summarised by category in the following sections:

3.1.1 LiDAR data
3.1.2 Imagery
3.1.3 Watercourse lines
3.1.4 National and Queensland spatial data

If the data was used in the ISA project, its use and limitations for erosion assessment is discussed.

3.1.1 LiDAR data

High resolution (i.e., 1m) LiDAR data was available for the majority of SEQ sub-catchments, i.e., the coastal catchments from Noosa to Currumbin and the Lockyer, Bremer, Logan and Albert catchments. High resolution LiDAR was not available for:

- the northern-most reaches of Upper Noosa and Teewah Creeks (outside the Noosa Council boundary); and
- some areas of Mid-Brisbane, Upper Brisbane and Stanley catchments.

A summary of the high resolution LiDAR coverage and datasets is provided in Table 1 and Figure 1.

LiDAR data was used in the channel, hillslope and gully erosion phases of this project; limitations in its use for each assessment phase are discussed below:

- channel erosion – the assessment method required a 1m digital elevation model (DEM) to determine channel confinement and to calculate channel width and height (used to assess the potential sediment availability of each reach), consequently only reaches with LiDAR data were able to be fully assessed.
- hillslope erosion – the Shuttle Radar Topography Mission (SRTM) 30m DEM dataset covers the entire SEQ region and also currently is used to inform the Queensland Government layer for the Length and Slope components of the Revised Universal Soil Loss Equation (RUSLE) hillslope method; consequently SRTM replaced LiDAR in this component.
- gully erosion – lower resolution datasets such as the Geoscience Australia 5m DEM and the SRTM were used respectively to infill gaps in the northern reaches of the Noosa catchment and the Mid- and Upper Brisbane and Stanley River catchments.

Table 1. Available LiDAR data and identified data gaps

Catchment	File name (rasters)	Data Source	Resolution	Year	% catchment	LiDAR data gaps
Noosa	Noosa_gympie_lidarDEM_2015	HLW*	1 m	2015	65	Teewah Creek, Upper Noosa
Maroochy	Esclidar14001	HLW/SCC*	1 m	2014	100	n/a
Baroon Dam	BaroonDEM	Seqwater	1 m	2013	100	n/a
Mooloolah	Esclidar14001	HLW/SCC*	1 m	2014	100	n/a
Pumicestone Passage	Esclidar14001/ moreton_bay_2014_dem	HLW/SCC/MBRC *	1 m	2014	100	n/a
Caboolture	moreton_bay_2014_dem	HLW/MBRC *	1 m	2014	100	n/a
Pine	moreton_bay_2014_dem	HLW/MBRC *	1 m	2014	100	n/a
Bramble Bay	Brisbane_2014_Lidar_float	HLW/BCC *	1m	2014	100	n/a
Brisbane River estuary	Brisbane_2014_Lidar_float	HLW/BCC *	1m	2014	100	n/a
Oxley Creek	Logan_DEM_2013 / Brisbane_2014_Lidar_float	HLW/BCC/LCC *	1 m	2013/ 2014	100	n/a
Woogaroo/Wolston	Ipswich_Lidar_DEM_Float_2014 / Brisbane_2014_Lidar_float	HLW/BCC/ICC *	1 m	2014	100	n/a
Sandy/Six Mile/Goodna	Ipswich_Lidar_DEM_Float_2014 / Brisbane_2014_Lidar_float	y HLW/BCC/ICC *	1 m	2014	100	n/a
Mid Brisbane	Ipswich_Lidar_DEM_Float_2014*/ Brisbane_2014_Lidar_float* / Mid_Brisbane_River_20111	HLW/BCC/ICC	1 m	2011/ 2014	60 (inc main channel)	Somerset regional council area (i.e., lower reaches of tributaries between Wivenhoe Dam and Sandy Creek including Blacksnake Creek, Splityard Creek, England Creek, Spring Creek and Branch Creek)
Upper Brisbane	UB_andTribs_2015_DEM	HLW/Seqwater *	1 m	2015	17	Majority of the catchment excluding the main Upper Brisbane River channel and major tributaries (Emu Ck, Maronghi Ck/ Cressbrook Ck) upstream of Wivenhoe Dam
Stanley	Moreton_bay_2014_dem	HLW/MBRC *	1 m	2014	60	50% of Eastern Stanley River, 100% of Western Stanley River, Southern Stanley River and Somerset Catchment
Lockyer	DEM_Full_Mosaic	LVRC	1 m	2013	100	
Bremer	Ipswich_Lidar_DEM_Float_2014/ Scenic_Rim_LiDAR_DEM_2011	HLW/ICC/SRRC *	1 m	2011/ 2014	100	

Catchment	File name (rasters)	Data Source	Resolution	Year	% catchment	LiDAR data gaps
Logan	Logan_DEM_2013 / Scenic_Rim_LiDAR_DEM_2011	HLW/LCC/SRRC	1 m	2011/ 2013	100	n/a
Albert	Logan_DEM_2013 / Scenic_Rim_LiDAR_DEM_2011 / Gold_Coast_2014	HLW/LCC/SRRC/CoGC	1 m	2011/ 2013/ 2014	100	n/a
Redlands	Redlands_lidarDEM_2014	HLW/RCC *	1 m	2014	100	n/a
Pimpama	Gold_Coast_2014	HLW/CoGC *	1 m	2014	100	n/a
Coomera	Gold_Coast_2014	HLW/CoGC *	1 m	2014	100	n/a
Nerang	Gold_Coast_2014	HLW/CoGC *	1 m	2014	100	n/a
Tallebudgera	Gold_Coast_2014	HLW/CoGC *	1 m	2014	100	n/a
Currumbin	Gold_Coast_2014	HLW/CoGC *	1 m	2014	100	n/a

* Data collated by Healthy Land and Water and provided in data transfer for ISA project

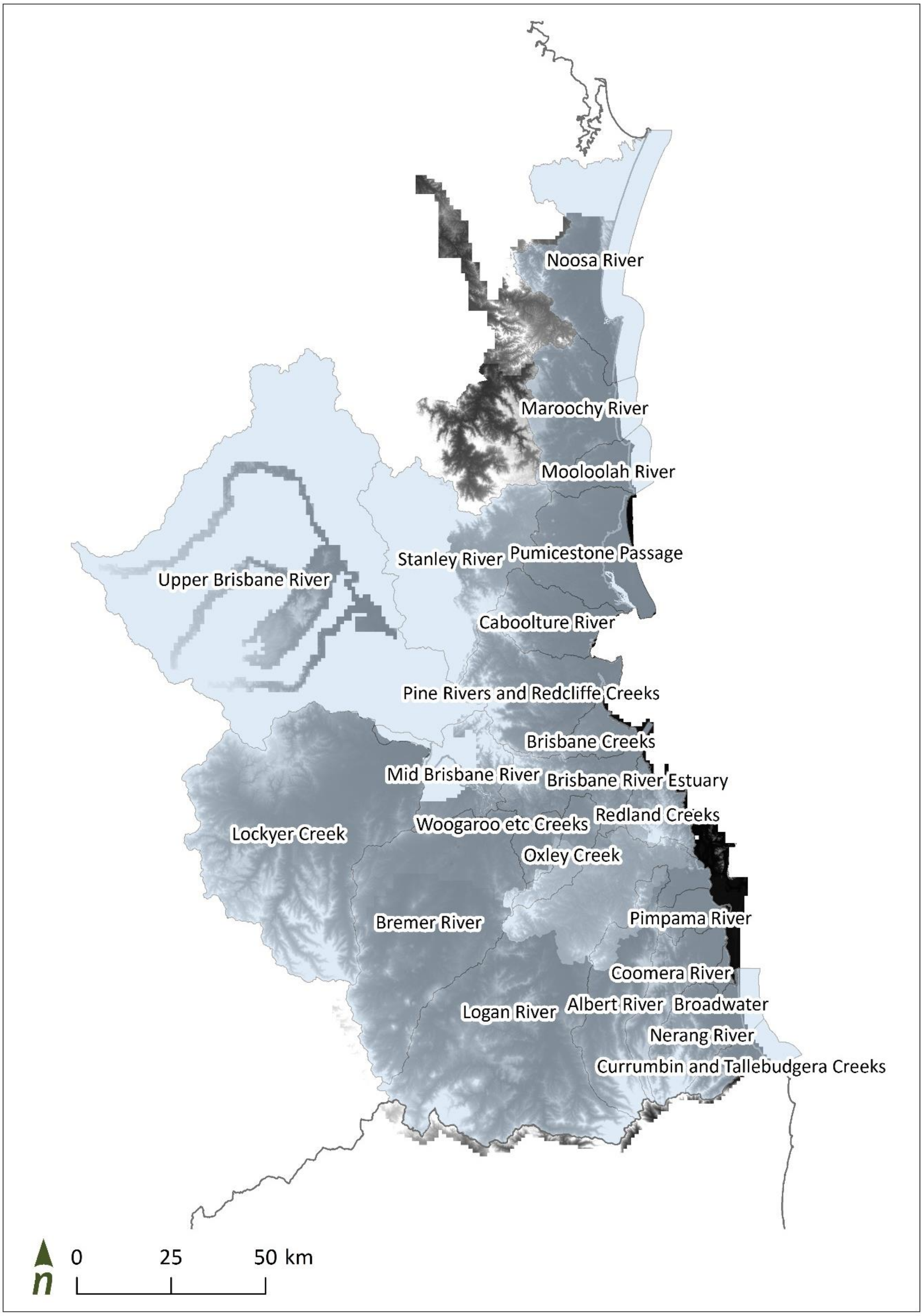


Figure 1. SEQ high resolution (1 m) LiDAR extent (shaded areas represent LiDAR data across the region). Major gaps identified in the Mid and Upper Brisbane, Stanley and Noosa catchments.

3.1.2 Imagery

High resolution imagery from 2016 covered all sub-catchments across SEQ, with 10cm resolution available within the coastal local government areas and 20cm resolution in the western local government areas. Imagery was also available for 2009 and 2013 (in some catchments) across the region and was used to assess the reach scale erosion potential (stability) assessment based on recent observed channel change. During this period all catchments across SEQ experienced moderate to major flooding. As a result, if reach scale unit stream power was likely to exceed channel resistance during floods, some channel erosion would be expected to be observed between 2009 and 2016 thus providing a useful indicator of overall channel erosion risk.

3.1.3 Watercourse lines

Multiple watercourse lines have previously been developed across SEQ and were available for this project. These included the state layer, council layers and the Healthy Waterways stream order mapping (developed using DEM resolution between 5 – 25m in 2012). The project team (HLW, Seqwater and Alluvium) undertook an assessment to compare individual layers and identify the advantages and disadvantages of all layers. Significant inconsistency in stream order and path were found between the layers.

The Healthy Waterways stream order mapping layer was found to not follow drainage lines well in the western catchments due to the lower resolution DEM (25m) used to create the layer, while the stream ordering and drainage lines of some council layers were not consistent with either the Department of Natural Resources, Mines and Energy (DNRME) layer or other council layers. Additionally, due to different methodologies used to develop mapping and council boundaries not following catchment boundaries, the quality of stream line mapping was inconsistent across individual catchments.

Based on the comparison assessment of the available stream layers, the DNRME layer (NRM_Watercourse_Lines_QBWSA_L2_Boundary.shp) was determined most appropriate for use in this project. A key reason for this decision was that the split between the proposed channel, gully and hillslope erosion assessment methods requires a clear definition of stream order and drainage lines which the DNRME layer provides.

3.1.4 National and Queensland spatial data

Multiple national and Queensland Government spatial datasets were used for the channel, gully and hillslope erosion assessments. Most of the layers covered the entire project area but some had varying resolution across the SEQ, e.g., geology/soil type.

The spatial datasets used for this study include:

- Australian Soil Resource Information System (ASRIS) clay content percentage 0-30 cm (varying resolution and quality across the study region) (Figure 2)
- ASRIS Australian soil classification (varying resolution across the study region)
- DNRME Detailed SEQ Geology (Figure 3)
- DNRME SEQ Soil Project Data (Figure 4)
- Queensland Land Use Mapping Project (QLUMP) 2012 and land use change layers
- Landcover 2012 (Figure 5)
- QLD Universal Soil Loss Equation (USLE) Factor layers, i.e., L, S, K and R.
- Scientific Information for Land Owners (SILO) gridded daily rainfall (5km grids)

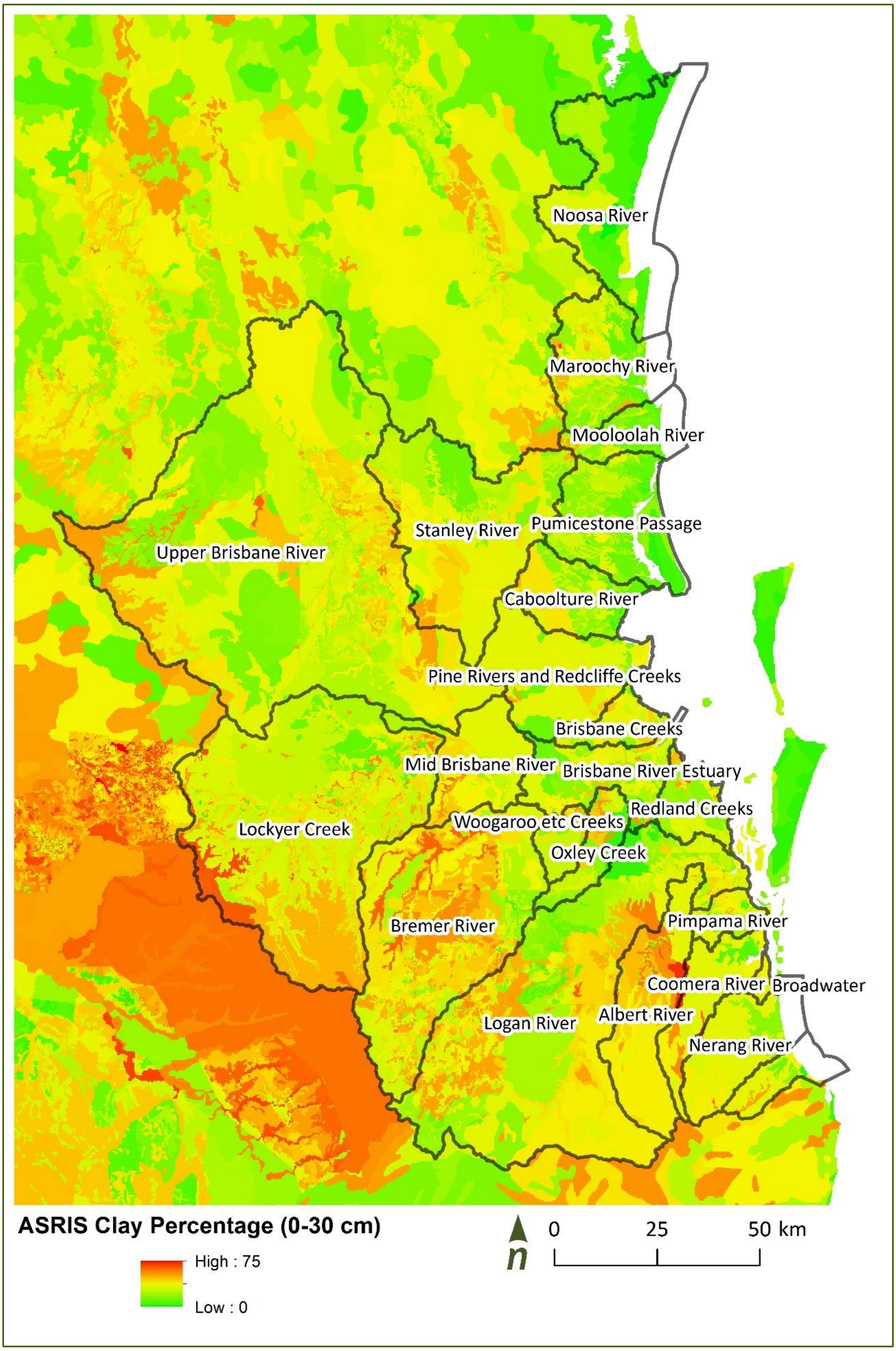


Figure 2. *ASRIS clay percentage (0-30cm) across the study region*

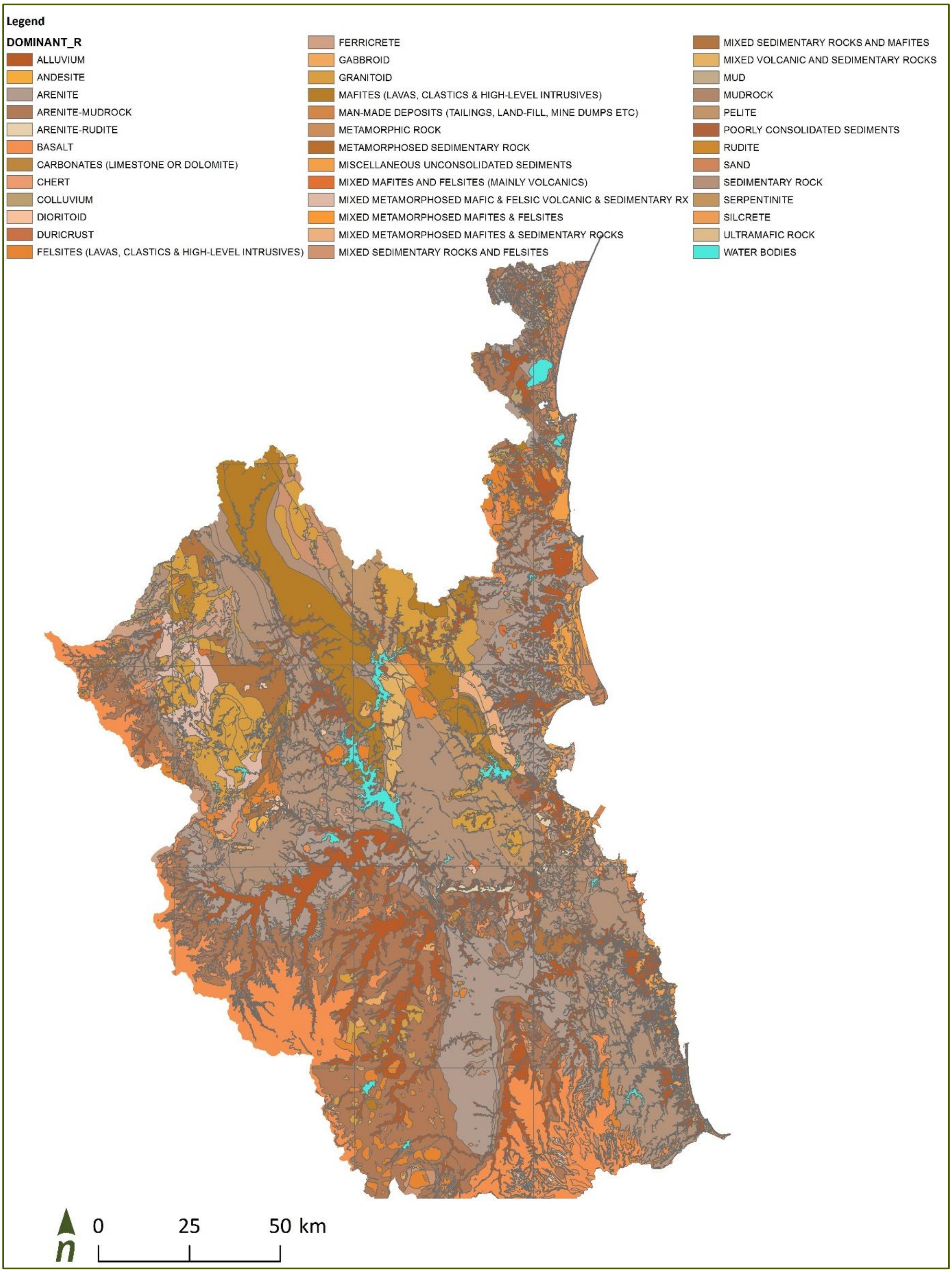


Figure 3. *DNRME Detailed SEQ Geology*

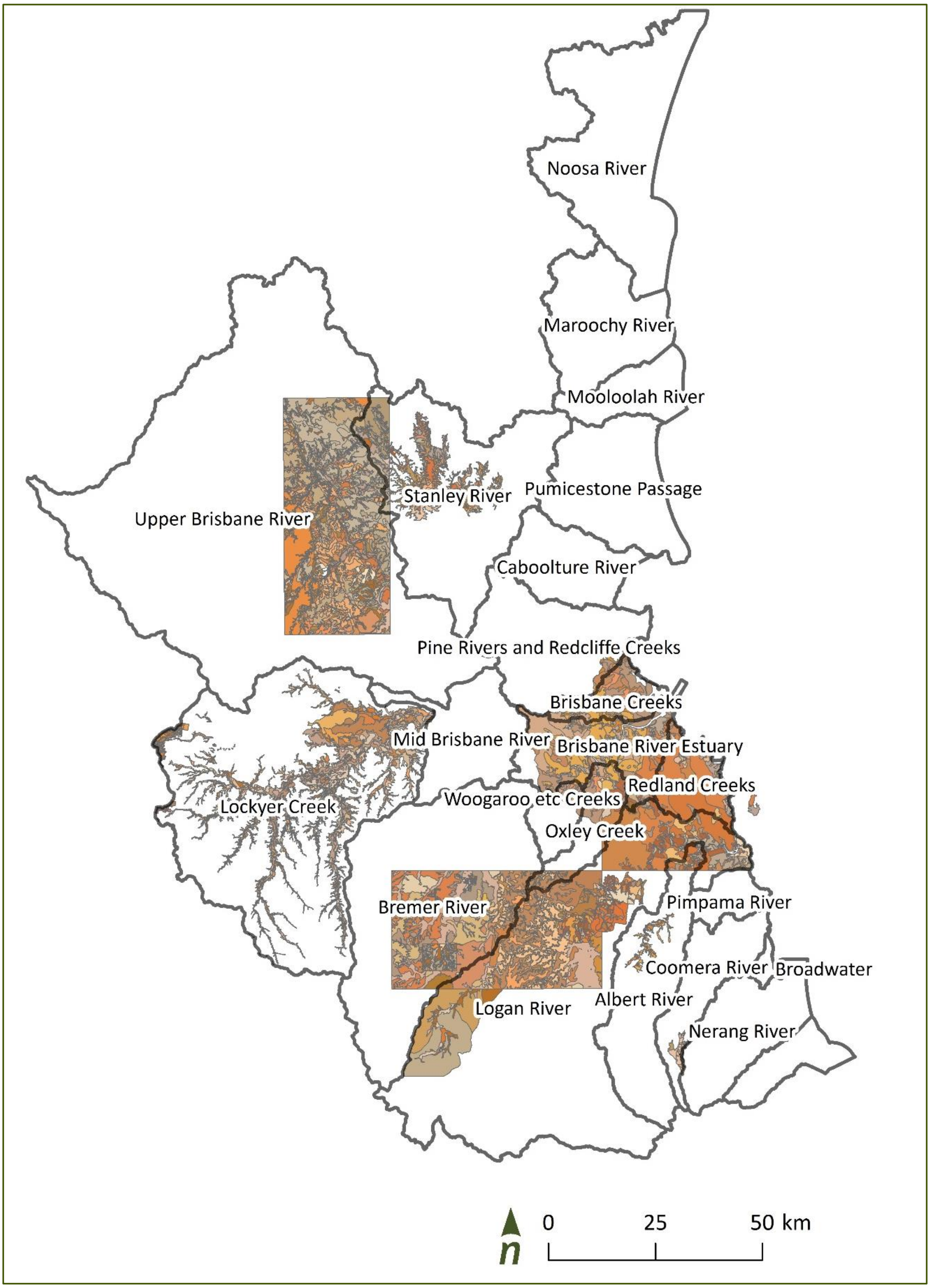


Figure 4. *Extent of soil project sites in South East Queensland*

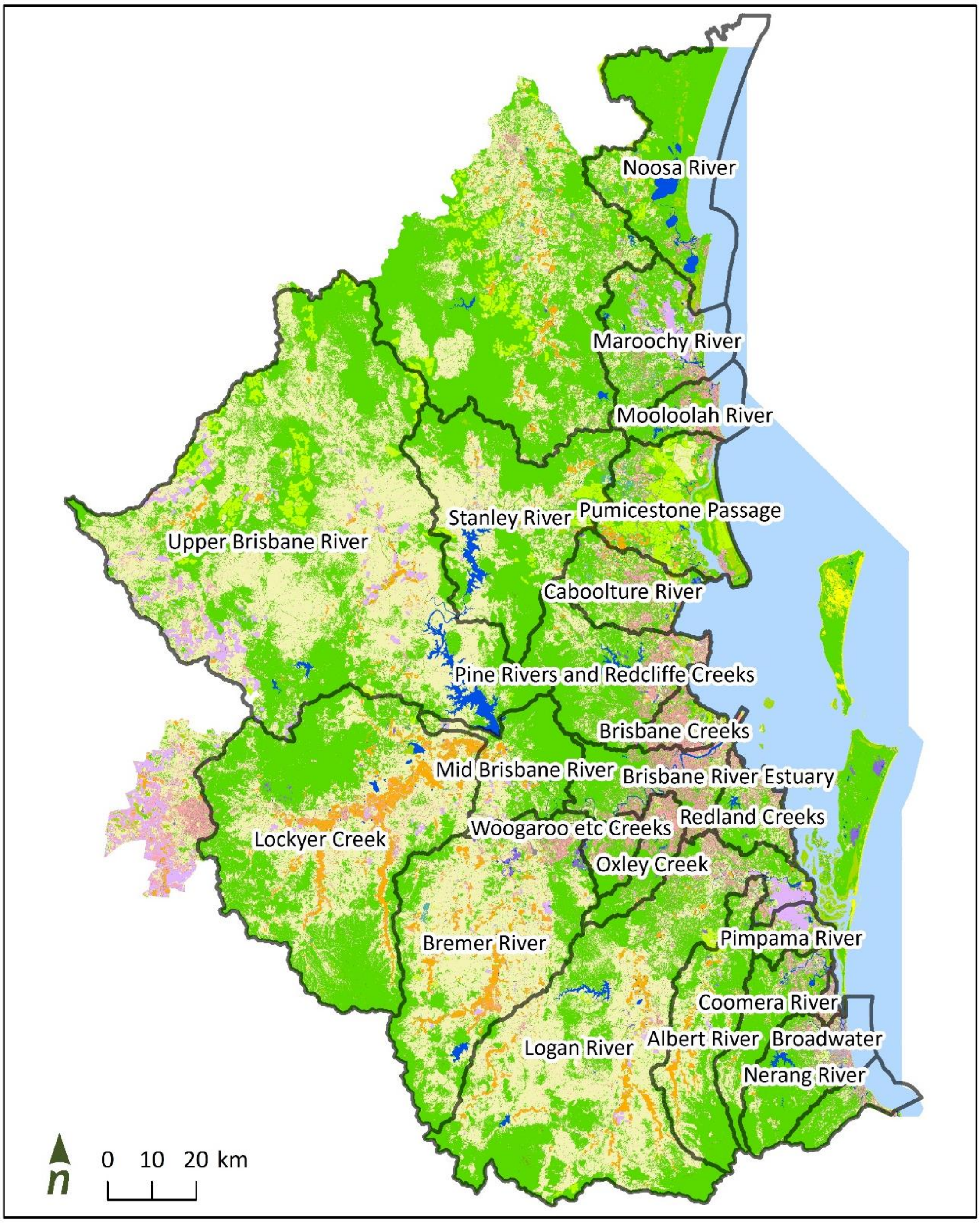


Figure 5. *Landcover 2012 extent across South East Queensland*

3.1.5 Summary of ISA datasets

A summary of key datasets and their application to the ISA project is provided in Table 2. To ensure the best available datasets were applied, throughout the project the project team consulted with data providers in relevant state departments and local councils.

Table 2. Summary of key data sets and proposed application to sediment erosion assessment

Dataset	Channel erosion	Gully erosion	Hillslope erosion
Digital Elevation Models			
1m LiDAR	✓	✓	✓
5m Geoscience Australia DEM		✓	✓
30m SRTM DEM			✓
High resolution aerial imagery			
2009 Imagery	✓	✓	
2013 Imagery	✓	✓	
2016 Imagery	✓	✓	✓
National and Queensland spatial data			
DNRME Watercourse lines	✓ (≥ stream order 3)	✓	✓
ASRIS clay content percentage	✓	✓	
ASRIS soil classification		✓	✓
DNRME SEQ Soil Project Data		✓	✓ *potentially update K factor in RUSLE
DNRME Detailed SEQ Geology		✓	
QLUMP 2012		✓	✓
QLUMP Land Use Change		✓	
Landcover 2012			✓
SILO daily rainfall			✓ * potentially update R factor in RUSLE
QLD USLE Factor Layers			✓ * potentially recalculate in regions where higher resolution data is available

4 Point source assessment

4.1 Background

Potential point sources of sediment pollution, such as activities requiring or causing discrete areas of bare earth to be exposed, are of interest to both Seqwater and HLW because:

1. their contribution to in-stream sediment loads may not be accurately represented in model development; and
2. their often highly conspicuous nature draws attention from the community as well stakeholders external and internal to both organisations.

Accordingly, during the development of the ISA project it was recognized that a robust and repeatable process is required to identify point sources of sediment pollution from spatial data (primarily GIS mapping) and then determine a risk score for each point source; this to be based on an estimated maximum potential sediment load generated from a site and the likelihood of sediment pollution reaching and impacting the aquatic environment. The following sections describe the methods used for identifying point sources of sediment pollution and determining their relative risk to in-stream water quality.

4.2 Method

4.2.1 Defining and identifying point sources of sediment pollution

For the purposes of the ISA project, point sources of sediment pollution have been defined as 'any singular, discrete and identifiable land use activity from which suspended sediments can be discharged from a specific point'. Accordingly, land use activities considered as point sources in the ISA project included: intensive agricultural industries (such as poultry farms, cattle feedlots, piggeries, dairies, and horse studs), construction sites, and industries/activities with large bare earth and impervious surface areas (including quarries, motocross tracks and forestry/dirt road crossings).

Given the geographic scale of south-east Queensland, identifying and assessing individual point sources as per the definition agreed on for the ISA project was problematical. Some sites or landuse activities within Seqwater's area of operation that are potential point source of sediment pollution are assessed for microbial and chemical pollution risk through bi-annual (every two years) Seqwater led Sanitary Surveys (see Baker et al. 2016 for details regarding Seqwater's catchment sanitary surveys). However, their contribution to sediment loads downstream is not able to be determined through the sanitary survey process and thus remain unclear. Other sources of information that could be used to identify point sources of sediment pollution across the region include databases held by state government bodies responsible for planning and environmental regulations for industrial and intensive animal and agricultural sites. For example, the Queensland Department of Environment and Heritage Protection holds information regarding what restrictions and management practices Environmentally Relevant Activities (ERA's) are subject to. However, these details are not easily accessed and any data available requires significant transformation for use in assessing risk to water quality. Additionally, while these records will detail what conditions these sites/activities are subject to, including allowable levels of pollutant discharge where applicable, the records will not indicate potential sediment loads generated from the activities.

Given the scarcity and dispersed nature of information useful to identifying and assessing point sources of sediment pollution as per the ISA definition, the project team concluded that the most effective approach to identifying potential point sources/sites/activities was to use high level location data available through State Government departments and within Seqwater and HLW, and manually examine (i.e., "by eye") key spatial/GIS data, mark point sources on a GIS layer, and where possible ground truth selected sites by staff within each organisation with knowledge of the sites selected. Data sources used for identifying potential point sources of sediment pollution are listed in Attachment F.

Following an initial examination of the data sources (Attachment G) the project team concluded that, due to the complexity of sediment generation from forestry roads and other unsealed roads, this point source of sediment pollution would be excluded from assessment under the ISA point source method and included in the overall catchment model in future. In addition, although areas of severe erosion (i.e., gully and channel bank erosion), and certain agricultural activities such as turf farms and other horticulture would be identified in the dataset, these would not be assessed in using the ISA point source risk assessment method. Rather, these potential sources of erosion and sediment generation will be addressed in the other aspects of the ISA project, for example the method to assess channel erosion risk across SEQ.

4.3 The risk assessment approach

A primary aim of the ISA project was to develop a process to determine the relative risk to water quality arising from a point source of sediment pollution, and incorporate this into a tool that can be used to assist in prioritising sites to target management. Undertaking a full quantitative assessment of sediment loads arising from each site would require a detailed and long term research project, which is beyond the scope of the ISA project. Therefore, a semi-quantitative risk assessment approach, broadly based on the system for estimating the level of risk is used in the Australian Drinking Water Guidelines Framework for Drinking Water Management (NHMRC, NRMMC 2011) and AS/NZS 4360:2004 (Risk Management) was developed. Thus, risk is the likelihood of identified hazards causing impact to the aquatic environment, including the severity of the consequences. In the context of the ISA point source project then, the *hazard* is sediment pollution, the *hazardous process* is the land use activity, the estimated maximum potential sediment load generated from a site determines the *consequence*, and the *likelihood* is determined by evaluating whether the sediment pollution generated will reaching and impact the downstream aquatic environment. The likelihood and consequence for each site is then applied to a qualitative risk analysis matrix to determine the level of *risk*.

4.3.1 Framework for determining point source likelihood and consequence

A review of available published and grey literature was undertaken in order to confirm the particular hazardous processes that contribute to sediment generation at sites (e.g., manure stock piles, bare earth, stormwater run-off), the potential quantity of sediment these hazardous processes can produce from specific studies, as well as acceptable management activities to limit the likelihood of sediment being generated or reaching the stream network. The literature used for this exercise is listed in Attachment G; the main findings pertinent to identifying point sources of sediment pollution and determining water quality risk scores include:

1. Cattle and feedlots including piggeries and abattoirs are likely to produce sediment generation from having increased bare earth areas, and soil disturbance such as compaction and pugging. These bare areas are more likely to be locations where the animals spend the most amount of time and therefore defecate, which is also a sediment source.

2. Poultry industries are usually restricted to sheds and not outdoors across SEQ, which means the main source of sediment generation from these industries are from manure stockpiles and accumulated dust from the fans drawing from inside the sheds. These stockpiles are supposed to be moved fortnightly but it is unknown if they are protected from weather conditions that could produce contaminated run-off.

3. Construction sites and industries such as quarries can directly produce sediment from their bare earth and impervious surfaces and also indirectly through undermining morphology to produce localised erosion, such as channel bank erosion.

4. Proximity to major waterways is a large factor affecting likelihood of sediment reaching the stream network and transported downstream, however a number of management practices can reduce this likelihood. This includes:

    - Vegetative buffers which can reduce up to 80% of sediment loads within overland flow systems within the first 10m of buffer;

- Settling basins and effluent ponds can reduce up to 60% of sediment loads although this is dependent on the settling time allowed and therefore efficacy increases with the number of basins/ponds present and/or volume;

- Laneway hardening and feedpad/calving pad hardening can lower the rate of sediment generation though this can also be dependent on manure removal;

- Installation of irrigation and infiltration systems from sheds and settling basins/ponds can reduce sediment loads by 80% if installed correctly and ground cover is sufficient for irrigation.

Given that this assessment could only be desktop based, not all factors contributing to sediment generation and likelihood of sediment being transported to the stream network could be included. However, a substantial effort was made to include any additional information that could be used in further analyses.

Following the review of the literature and discussion amongst the project team, it was determined that the most appropriate measure to determine *consequence* for the purposed of the point source component of the ISA project was the area of exposed bare earth detected in most recent 10-30cm aerial imagery. Five levels of consequence were determined by:

1. grouping the total number of sites identified in the point source dataset according to the total area of bare earth present at each site; and
2. assigning a maximum potential sediment generation of 31.2ha/yr (value assigned as per Weber et al. 2015; Attachment I).

NB. This means level of consequence is assigned to a particular site is its consequence relative to other sites (i.e., sites are rated against each other).

Table 3 illustrates the finalised consequence table developed for the point source component of the ISA project.

Table 3. Semi-qualitative measures of point source consequence (impact) in relation to bare earth

Consequence	Descriptor	Descriptors	Details
1	Insignificant	delivery of less than 33 tons of sediment per annum	<1 Ha bare earth
2	Minor	delivery of 33 to 330 tons of sediment per annum	1 - 10 Ha bare earth
3	Moderate	delivery of 330 to1 650 tons of sediment per annum	10 - 50 Ha bare earth
4	Major	delivery of 1 650 to 3 300 tons of sediment per annum	50 - 100 Ha bare earth
5	Catastrophic	delivery of more than 3 300 tons of sediment per annum	>100 Ha bare earth

In the context of the ISA point source assessment, likelihood is determined by evaluating whether sediment pollution generated will reach and impact the downstream aquatic environment. In a more typical water quality risk assessment process, a table is developed to facilitate categorization of the different levels of likelihood. Table 4 is an example of a typical likelihood table used in the risk assessment process.

Table 4. A typical likelihood table used in a risk assessment process (reproduced from NHMRC, NRMMC 2011).

Level	Descriptor	Example description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur or should occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

However, in the ISA project the likelihood (of sediment pollution generated from a point source connecting to and impacting the downstream aquatic environment) is attributed through assessing four main variables: distance to waterway (stream order ≥3), presence of 10m vegetative buffer, slope of site (10% slope equals steep), and the number of dams present. A decision tree was developed based on the five levels of likelihood (as per the standard risk assessment method), and incorporating decision rules regarding distance to stream order ≥3, presence of 10m vegetative buffer, slope of site (10% slope equals steep), and the number of dams present (Attachment H). Further technical details regarding data development and analysis of spatial data used to determine likelihood and consequence are outlined in Section 4.4.

Assigning a risk score

The objective of risk assessment is to distinguish between very high and low risks so that priorities for risk management can be established. As per the Australian Drinking Water Guidelines Framework for Drinking Water Management (NHMRC, NRMMC 2011) and AS/NZS 4360:2004 a level of risk is a function of likelihood and consequence. A risk level or score is determined by applying a qualitative risk analysis matrix. The risk matrix used for the ISA point source project is shown in. It is based on the Seqwater enterprise risk matrix, which is in turn a modified version of AS/NZS 4360:2004.

Table 5. The ISA point source project risk matrix.

Likelihood	Consequence				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Medium (6)	High (10)	High (15)	Extreme (20)	Extreme (25)
Likely	Medium (5)	Medium (8)	High (12)	High (16)	Extreme (20)
Possible	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
Unlikely	Low (2)	Low (4)	Medium (6)	Medium (8)	High (10)
Rare	Low (1)	Low (2)	Low (3)	Medium (5)	Medium (6)

A worked example

1. *Identification of a point source: A hypothetical sand and gravel extraction industry site has been identified via a HLW member organisation and confirmed through examining a state government list of ERA's. The site is located on a GIS program, and is determined to be a point source of sediment pollution because it is a singular, discrete and identifiable land use activity from which suspended sediments are being discharged from a specific point.*
2. *Determining consequence: Applying basic GIS tools establishes the site to have an area of bare earth of 45ha. Therefore the consequence (based on the estimated maximum potential sediment load generated from the site, see Table 3) is Moderate.*
3. *Determining likelihood: Further spatial analysis establishes that the site is <50m from a waterway of stream order 4, on a steep slope and there are two dams on the site. Therefore, the likelihood (of the estimated maximum sediment pollution load generated will reach and impact the downstream aquatic environment) is Likely (see Attachment I).*

4. *Assigning a risk score: Level of risk is a function of likelihood and consequence. Using the risk analysis matrix (Table 5), where consequence is Moderate and likelihood is Likely, the point source risk score assigned for the site is High.*

4.4 Data development and analysis

ARCGIS was used to measure the following attributes and criteria, which were compiled in a master spreadsheet and various shapefiles. Attributes measured to score Consequence and Likelihood include:

1. Point Source Area - PS_Area_ha (Relates to Total Area minus the Shed Area)
2. Shed Area - Shed_Area_ha
3. Bare earth area – Bare_Earth_Area (ha)
4. Presence of Sediment Dam/ Holding Dam - Dam_Pres (count)
5. Area of Sediment Dam/Holding Dam – Dm_Area_ha
6. Presence of Veg Buffer - Veg_Buf (metres)
7. Distance to nearest channelized flow path - WWay_Dist_Closest (metres)
8. Distance to Waterway (> 3rd Order stream) calculated as Wway_Dist_Closest plus channel length to stream order > 3 – Wway_dist_Major
9. Slope (high ≥ 10 % > low)

Other attributes (these were used to identify position in the landscape and site features, in order to improve system understanding, and did not form part of any calculations):

- Stock Number - Stock_No
- Shed Number - Shed_No
- Within flood lines / on alluvial flood plains - Flood_Pres (Yes/No)
- Waterway passing through site (but not directly passing through centroid of PS_Area)

Notes on additional information used for developing measurements:

- Centroid point is the best starting point for considering distance to stream, but will need a quick viewing for QA/QC when points fall on crest/ridge to ensure drainage path falls on correct side.
- The flow path direction is important, and should be noted when investigating the site. However, more sophisticated/suitable tools should be used in future if resources allow. These tools could potentially include Generic D8 flow direction and flow accumulation in ArcGIS, or the TauDEM toolset may offer more.
- The shed area calculation should not include feed shades as typically will be included in bare earth calculations.
- Additional objective definition of 'Stream' is being currently being developed – aiming for an intermittent and perennial channel description, which should generally equate back to 2-3rd stream order channel depending on the underlying method of stream network delineation.

5 Channel erosion risk assessment

5.1 Overview

The approach used to assess channel erosion risk was developed by Alluvium in consultation with Seqwater and HLW and with feedback from external specialist reviewers.

Key elements of the assessment approach included:

1. Development of a method to identify and assess existing channel erosion risk at the reach scale. This method was developed in conjunction with Seqwater and Healthy Land and Water catchment scientists and independently peer reviewed to ensure alignment with existing and developing research in this space.
2. Development of a spatial dataset identifying channel erosion risk at the reach scale.
3. Identifying knowledge / policy gaps outside the scope of this project where better monitoring / research of the variables contributing to channel erosion risk are needed.

This section documents the approach in undertaking this assessment and outlines the results from application across SEQ, using the Logan-Albert catchment as an illustration of the method and demonstration of the results. The full assessment resulted in channel erosion risk assessments for the majority of catchments in SEQ and parts of the Mary River catchment. These were provided as GIS data layers to HLW and Seqwater at the conclusion of the project. In this report, the results of the Logan-Albert catchments are presented for information, however all information has been derived from the component and final layers of channel erosion risk and could be calculated for any other region assessed. The full results for all regions are therefore not presented in the report to reduce repetition and report size.

The approach developed is a broad-scale (whole of catchment) desktop assessment of channel erosion risk. The outputs of the project are intended to identify where key areas at risk of erosion occur, rather than to identify where to specifically conduct channel works and should not replace more detailed geomorphic and hydraulic assessments where specific issues have been identified. However, the outputs can help managers identify areas at greater risk to target further investigations for:

- Detailed site-specific investigations
- Determining on ground management responses
- Informing planning and land use decisions

5.2 Method

The approach is outlined diagrammatically in Figure 6. The aim was to determine the relative risk of fine sediment loads derived from channel erosion that are associated with individual reaches throughout SEQ. This is dependent on two primary factors:

1. **Reach-scale erosion potential –** This is the potential for erosion in future flow events. This is related to the geomorphic form (i.e., the type of stream) and condition along with a range of different hydrogeomorphic parameters (i.e., stream power, hydrology, channel resistance etc.). For this assessment, the observed channel change assessment between 2009 and 2016 has been used as a surrogate for the reach scale erosion potential (discussed further in Section 5.2.2).
2. **Reach-scale fine sediment availability –** This is the volume of fine sediment available to be eroded by channel erosion processes. This is dependent on the fine sediment fraction in the channel and floodplain and the volume of alluvial deposits that are within the likely channel erodible zone (i.e., floodplain, benches, islands etc.). This project focussed on fine sediment due to downstream implications on water treatment and receiving environments (i.e., estuaries and Moreton Bay)

For this assessment, the following definitions were applied:

- A channel was defined as a non-estuarine watercourse line with a stream order ≥ 3 in the DNRME watercourse layer available from Queensland Government data portal. Estuarine reaches were not assessed due to other potential factors contributing to erosion within these reaches.
- a geomorphic reach was defined as a segment of channel with relatively homogenous geomorphic characteristics (i.e., stability and sediment availability).

To inform the assessment of both reach scale erosion potential and sediment availability a desktop stream type assessment was undertaken. The methodology and results of each phase of the assessment are discussed in the following sections:

- Section 5.2.2 – stream type assessment
- Section 5.2.3 – reach-scale erosion potential assessment
- Section 5.2.4 – reach-scale fine sediment availability

A decision tree was also developed to support end users understanding of the channel erosion risk method (Attachment A).

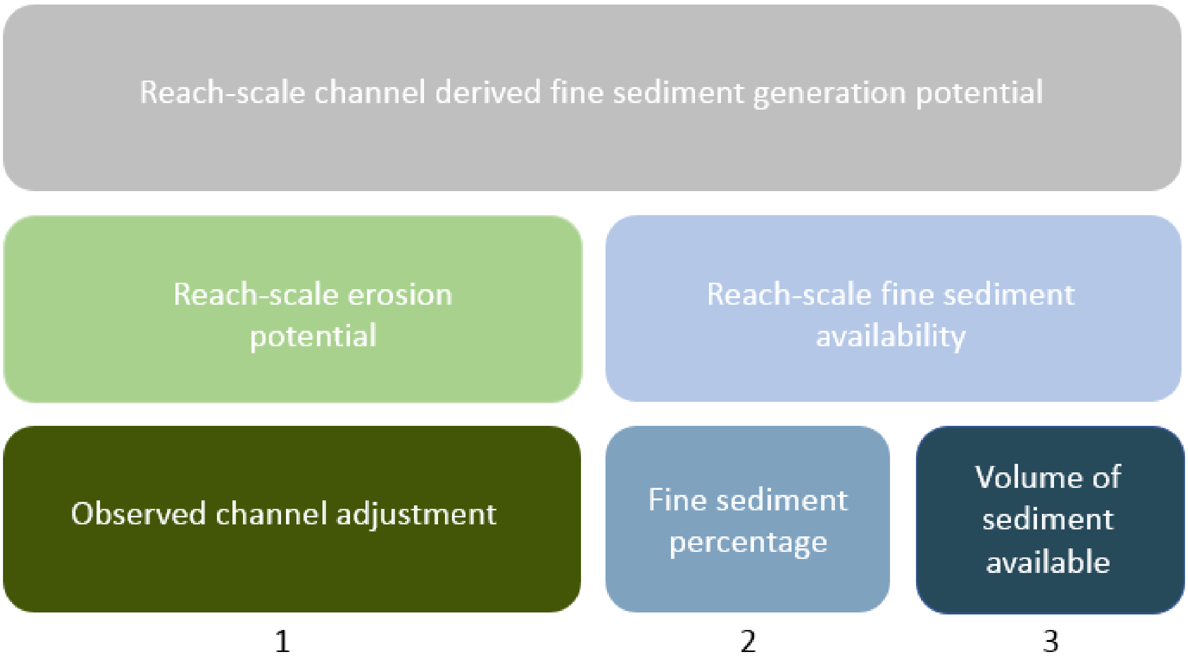


Figure 6. *Conceptual diagram highlighting the main factors which contribute to reach scale channel derived fine sediment generation potential. The three boxes along the bottom are the key pieces of information the methodology aims to determine/assess.*

5.2.1 Stream type assessment method

Overview

The 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 RiverStylesTM (Brierley and Fryirs, 2005), were considered, used and adapted in developing the method used in this project, to result in a method that addresses specific issues within the SEQ region's catchments.

The resulting classification recognises that many rivers in SEQ do not necessarily have 'classic' floodplain morphology and do not behave like true self-formed alluvial rivers. Many rivers in SEQ, including the Logan and Albert Rivers, have a macro channel morphology bounded by resistant old floodplain/terrace deposits (Croke et al. 2013; Fryirs et al. 2015; Brooks et al. 2014). Within the macro channel, 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).

For this rapid reach scale desktop assessment, hydraulic analyses and floodplain/terrace stratigraphy information were not available to assess whether a depositional unit was a contemporary floodplain (deposited within the Holocene period) or older terrace. The approach adopted is very sensitive to terrace identification as it will impact the volume of sediment available for erosion (discussed further in Section 5.2.3). To help reduce uncertainty the following criteria (all criteria met in order of importance) were used to determine if the channel is 'confined' by floodplain/terraces:

- macrochannel morphology present i.e., is bound by a high elevation depositional surface which is rarely inundated (determined from LiDAR data – see decision tree in Attachment A)
- Depositional inset units occur within the macrochannel (determined from LiDAR data – see decision tree in Attachment A)
- Dominant form of channel adjustment is from inset units (determined from aerial imagery – see decision tree in Attachment A)
- Minimal evidence of lateral adjustment of macrochannel in contemporary timeframes (determined from LiDAR/aerial imagery – see decision tree in Attachment A)

Two examples of typical SEQ macrochannel systems are shown in Figure 7 and Figure 8. Figure 7 shows a broader inset floodplain and is less confined by the floodplain/terraces than the macrochannel depicted in Figure 8. In Figure 7 there is more capacity for the low flow channel to adjust its boundary within the macrochannel.

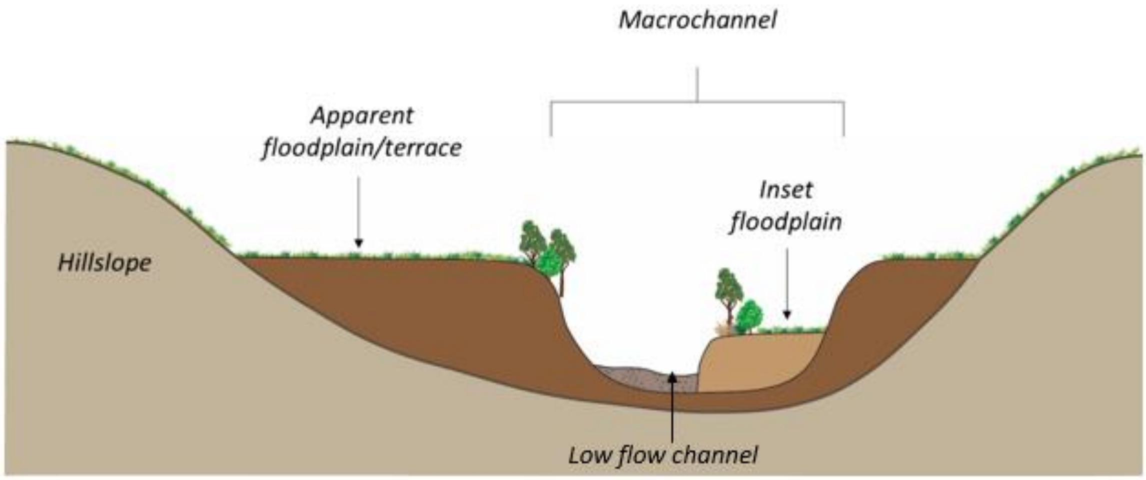


Figure 7. *Macrochannel with a broad inset floodplain*

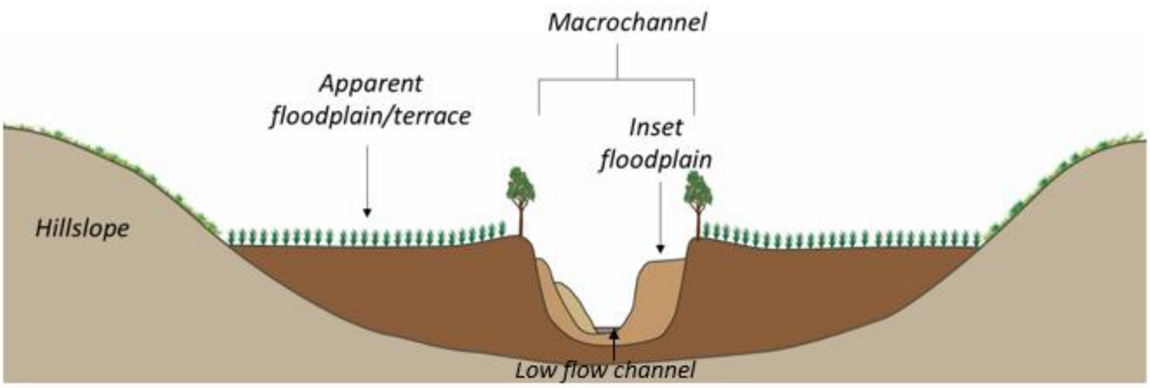


Figure 8. *Macrochannel with a narrow inset floodplain and a bench*

Method

The hierarchal stream type assessment method adopted for this project is presented in Figure 9. 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 bedrock hillslopes or floodplain/terraces. Four ranges of confinement are 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. Different examples of confinement are shown in Figure 10.
- **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 the planform for unconfined reaches. The planform in unconfined reaches can provide an initial indication of the mechanism and degree of alluvial channel adjustment (i.e., meander migration/ extension, cutoffs etc.). The planform was not be assessed in confined reaches as these were largely be defined by the confinement boundary.

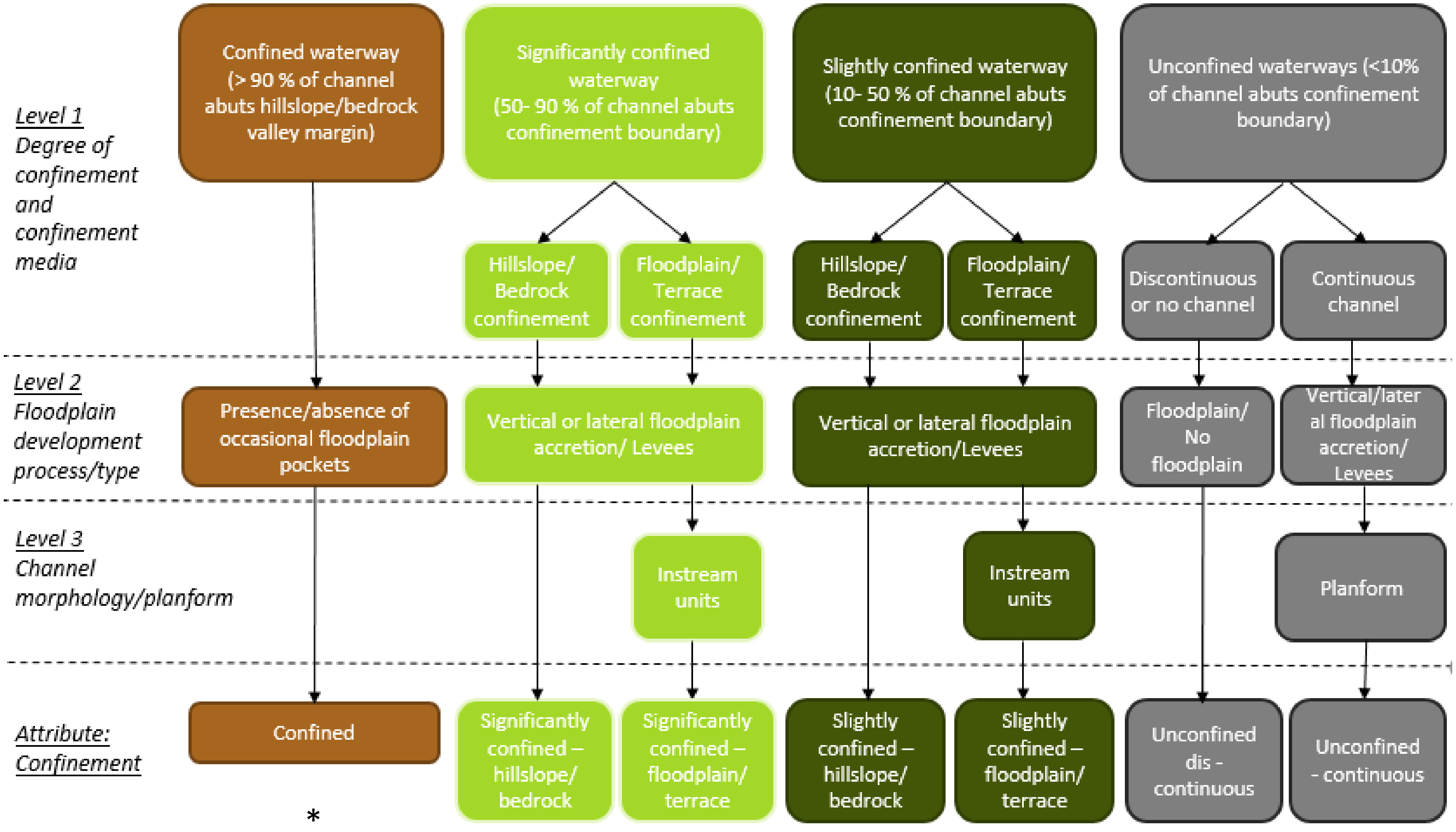
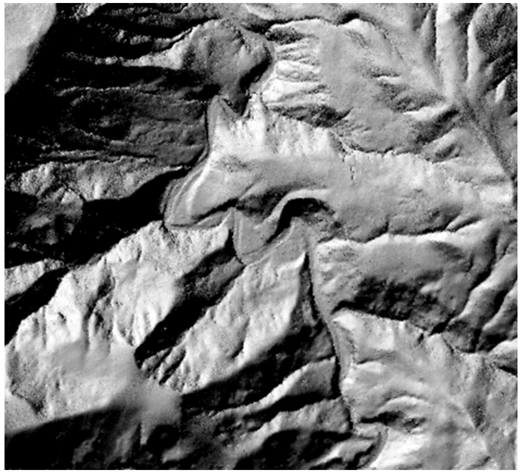


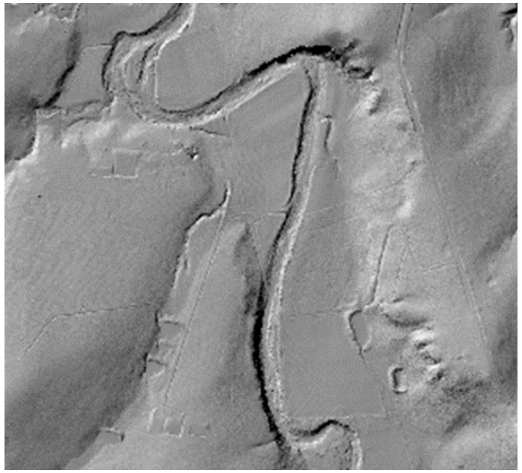
Figure 9. *Hierarchal stream type assessment* *

* From the above hierarchy, where a channel is attributed as confined, or unconfined discontinuous, no further assessment is completed as the channel erosion risk in these areas is considered as minimal. This does not mean that no erosion may occur, but in comparison to other areas in the catchment, the contribution to erosion risk would be negligible or in the case of discontinuous channels, will be considered in gully or hillslope calculations.



Upper Canungra Creek – Confined by hillslopes/bedrock

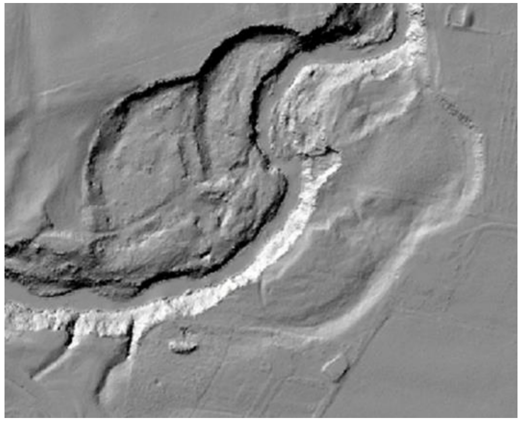
Canungra Creek – Significantly confined by hillslopes/bedrock



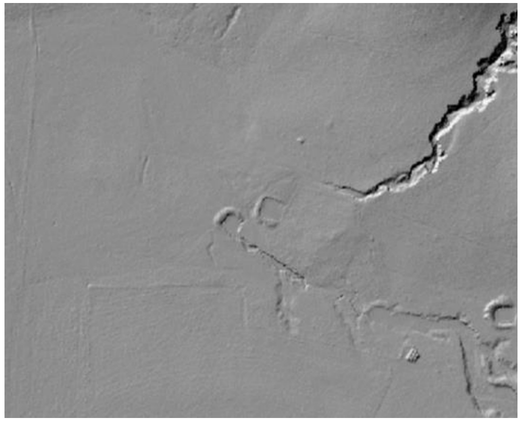
Cainbable Creek – Slightly confined by hillslopes/bedrock

Spring Creek – Unconfined continuous channel

Logan River – Significantly confined by floodplain/terrace



Logan River – Slightly confined by floodplain/terrace



Oakey Creek tributary – Unconfined discontinuous channel

Figure 10*. Examples of each confinement type in the Logan-Albert catchment used in channel erosion risk method - refer to decision tree in Attachment A for more detail*

Stream types in the Logan-Albert catchment

A map showing the results of the stream type assessment for the Logan-Albert catchment is presented in Figure 11. The majority of reaches were classified as significantly confined by floodplain/terrace (33%) or hillslope (19%) (Table 6). While these streams often flow through broad alluvial floodplains there is minimal lateral adjustment of the macrochannel boundary. Any channel erosion predominately occurs from the geomorphic units within the macrochannel. The unconfined reaches identified in the assessment are predominately at the base of hillslopes as the tributaries merge with the broader alluvial floodplains.

Table 6. Summary of Confinement across Logan-Albert catchment

Confinement	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Significantly confined - hillslope	176	375	19%
Slightly confined - hillslope	133	288	15%
Confined	195	319	16%
Unconfined - continuous	87	104	5%
Significantly confined - floodplain/terrace	302	652	33%
Slightly confined - floodplain/terrace	45	84	4%
Unconfined - discontinuous or no channel	53	73	4%
Dam	12	33	2%
Estuary	12	50	3%
Total	**1015**	**1978**	**100%**

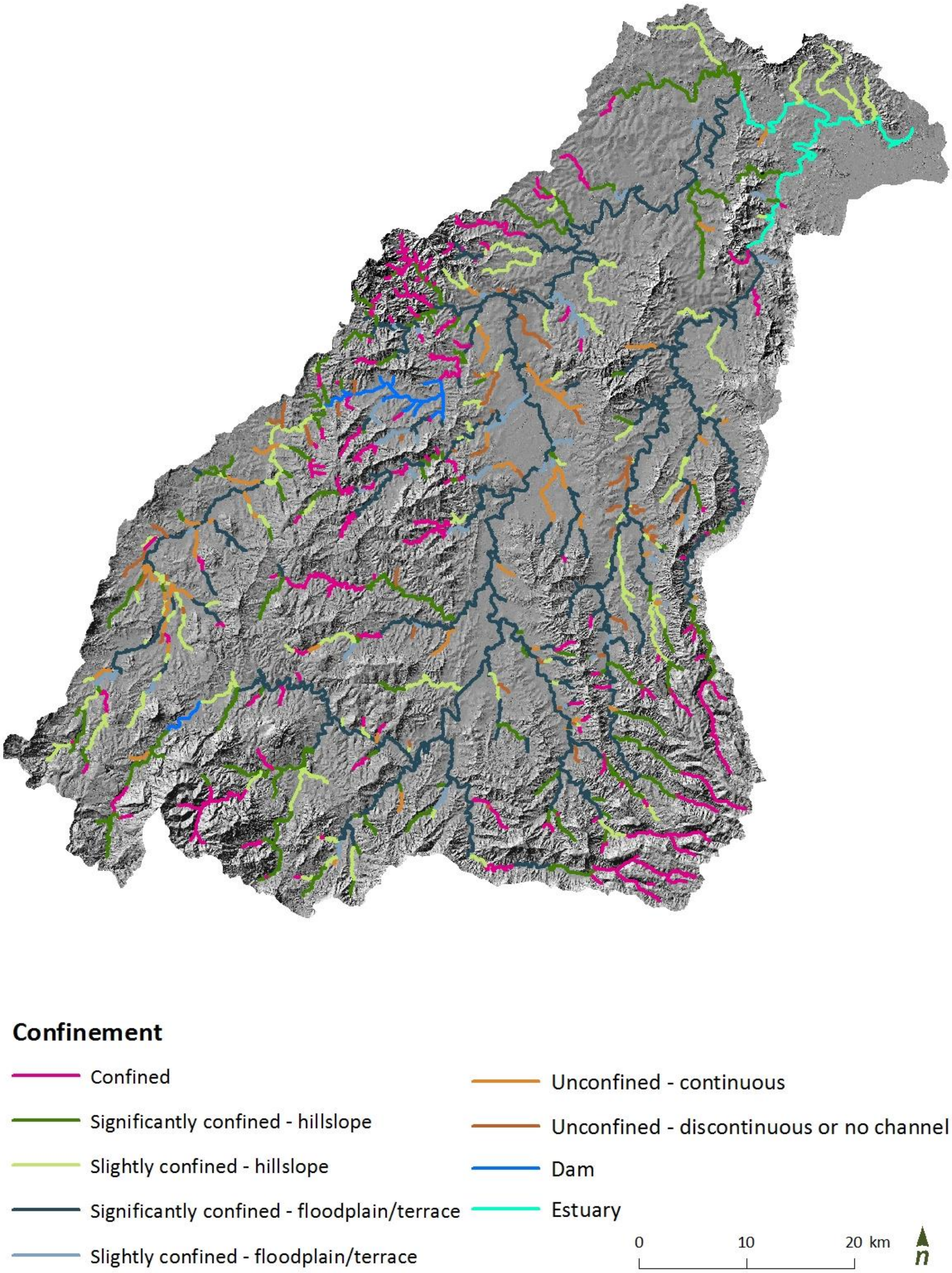


Figure 11. *Confinement of waterways (stream order ≥3) within the Logan-Albert catchment*

5.2.2 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 (i.e., bankfull discharge, 2 year ARI, 10 year ARI etc.) for which stream power will be based across all stream types
- Sediment supply, transport and storage processes within a reach will impact how stream power is dissipated within the reach which will impact channel change processes

Consequently, a surrogate measure was needed to determine erosion potential. The absence of other suitable regionally consistent data and the availability of 2009 and 2016 high resolution aerial imagery for the entire SEQ region, led to the determination to use observed channel change within this period 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, however generally well vegetated reaches would have minimal recent channel change. However, 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 degradation of inset units will be classified as having low "reach-scale sediment availability" (further description of approach in Section 5.2.3).

Method
Following the confinement assessment (outlined in Section 2.2), the lateral stability of each reach between 2009 and 2016 was assessed and assigned a stability and erosion potential category (Table 7). In addition, for reaches classified as floodplain/terrace confined, the stability of the inset units between 2009 and 2016 were assessed.

Table 7. Conversion between stability and erosion potential

Lateral Stability	Inset Stability	Overall Stability*	Erosion Potential **
Stable	n/a	Stable	Low
Minor instabilities	Minor instabilities	Minor	Moderate
Moderate instabilities	Moderate instabilities	Moderate	High
Major instabilities	Major instabilities	Major	Very High

* Overall stability is based on the higher rating of either lateral stability or inset unit stability
** Erosion potential is a predictive metric based on the assessment of stability between 2009 and 2016

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

Examples of each category within the Logan-Albert catchment are shown in Figure 12 to Figure 15.

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)

Examples of each category within the Logan-Albert catchment are shown in Figure 16 to Figure 19.

The reach scale erosion potential was then assigned for each reach using the below 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)

Figure 12. *A section of Burnett Creek in the Logan River catchment with no lateral adjustment between 2009 and 2016*

Figure 13. *A section of Sandy Creek in the Logan River catchment with minor lateral adjustment between 2009 and 2016*

Figure 14. *A section of Cyrus Creek in the Logan River catchment with moderate lateral adjustment between 2009 and 2016*

Figure 15. *A section of Swan Creek in the Logan River catchment with major lateral adjustment between 2009 and 2016*

Figure 16. *A section of Cannon Creek in the Logan River catchment with stable inset units between 2009 and 2016*

Figure 17. *A section of the Albert River which has minor adjustment of inset units between 2009 and 2016*

Figure 18. *A section of the Logan River with moderate adjustment of inset units between 2009 and 2016*

Figure 19. *A section of the Logan River with major adjustment of inset units between 2009 and 2016*

Logan-Albert catchment erosion potential

The results of the reach scale erosion potential assessment across the Logan-Albert catchment are provided in Figure 20. Reaches across the catchment have been predominately classified as having moderate erosion potential (Table 8). Erosion potential is highest in the mid to lower reaches of the Logan River, and along sections of Logan River tributaries (i.e., Cannon/Knapps Creek, Allan Creek, Christmas Creek and Teviot Brook) where there are reaches with either high and very high erosion potential. The Albert River sub-catchment generally has a lower erosion potential than the Logan River catchment. Within the Albert River there are some isolated sections (i.e., Canungra Creek) which have been classified as either high or very high erosion potential.

Table 8. Summary of channel erosion potential across Logan-Albert catchment

Erosion Potential	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Low	217	362	18%
Moderate	589	1242	63%
High	113	186	9%
Very High	21	32	2%
Discontinuous	51	73	4%
Dam	12	33	2%
Estuary	12	50	3%
Total	**1015**	**1978**	**100%**

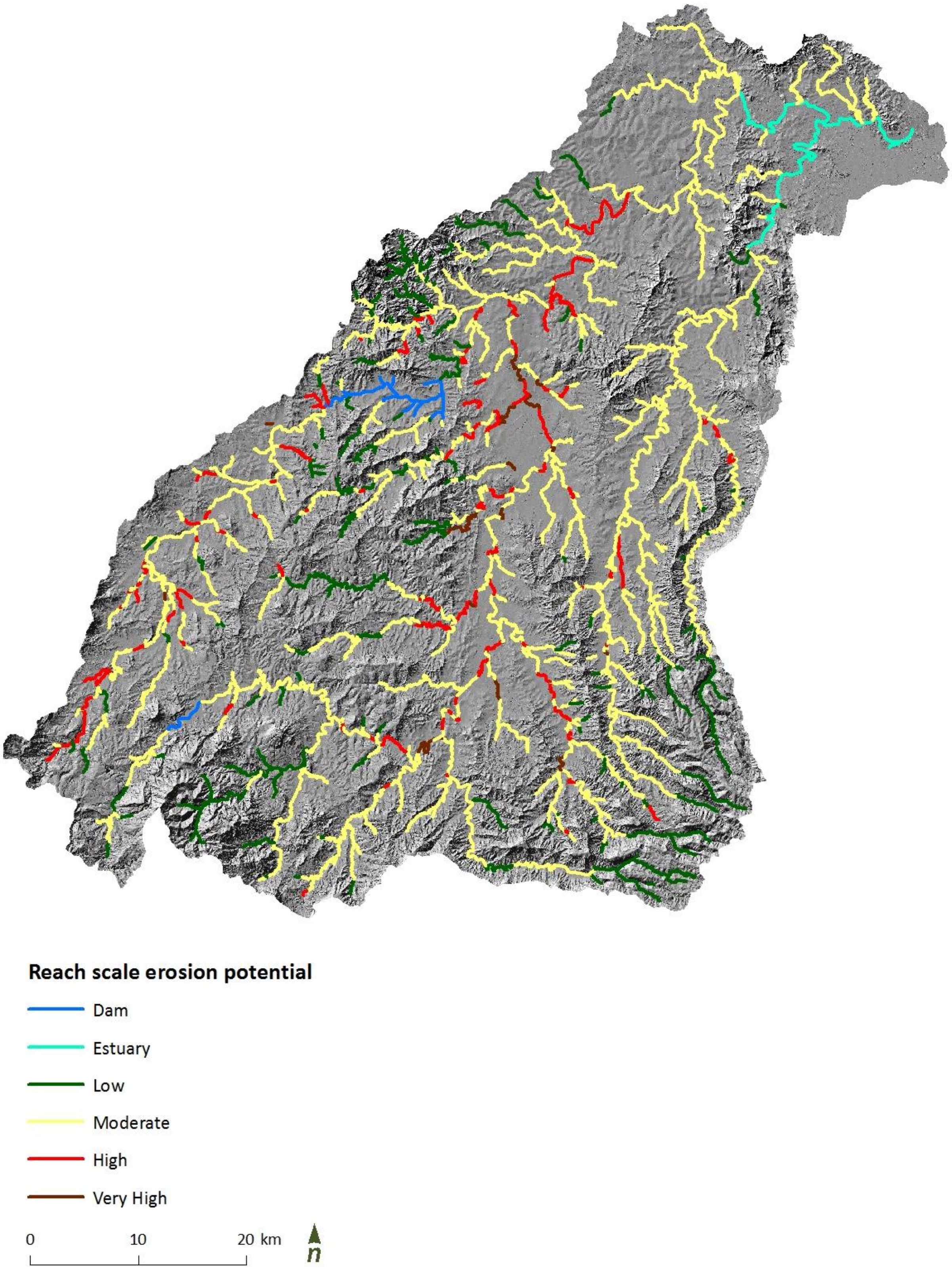


Figure 20. *Reach scale erosion potential across the Logan-Albert catchments (waterway SO ≥3)*

5.2.3 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 focussed 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 etc.)
- 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. It is proposed that 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.

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 of area of inset units –Erodible inset units in macro channel systems can contribute large volumes of sediment

Method

Elevation data (LiDAR) was used to assess the overall width and height of the primary geomorphic units within the erodible zone (Figure 21). The erodible zone is the area where the majority of channel derived sediment is sourced and will be assessed based on the stream type (confinement) assessment.

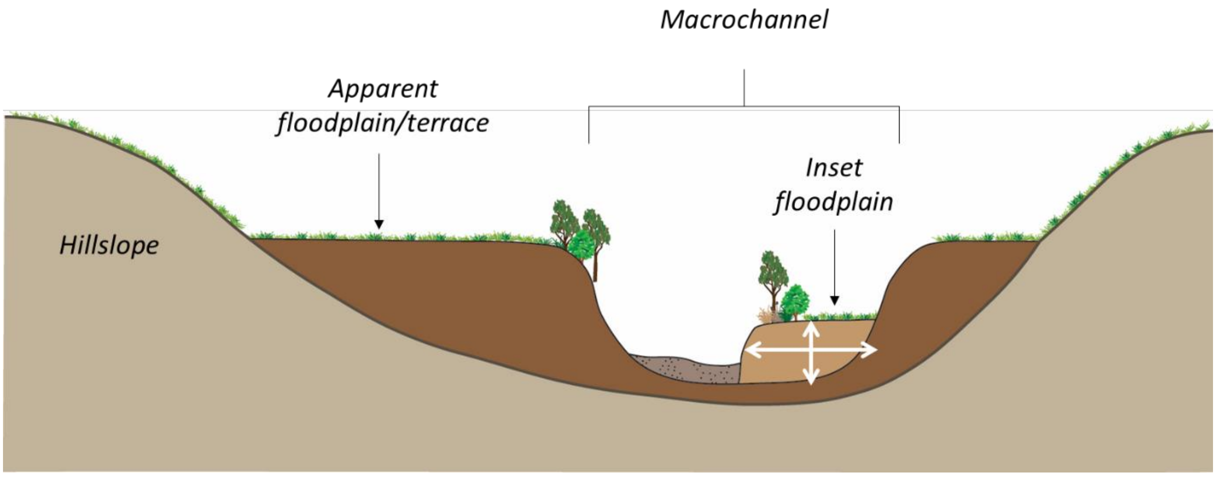


Figure 21. *Example of a macrochannel which is confined by floodplain/terraces* **where** *the erodible zone primarily consists of inset floodplains– the width and height dimensions are shown on one side of the channel*

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. The matrix used to define sediment availability is shown in Figure 22. Examples of the assessment for floodplain/terrace vs hillslope confinement types within the Logan River catchment is presented in Figure 23. The examples focus on floodplain/terrace confined systems as the assessment method for determining inset unit sediment availability was more complex than hillslope and unconfined systems.

Width	Height: 0 to 1 m	>1 to 3 m	>3 to 5 m	>5 m
0 to 10 m	Low	Low	Moderate	High
>10 to 25 m	Low	Moderate	Moderate	High
>25 to 50 m	Moderate	Moderate	High	Very high
>50 m	Moderate	High	Very high	Very high

Figure 22. *Sediment availability matrix*

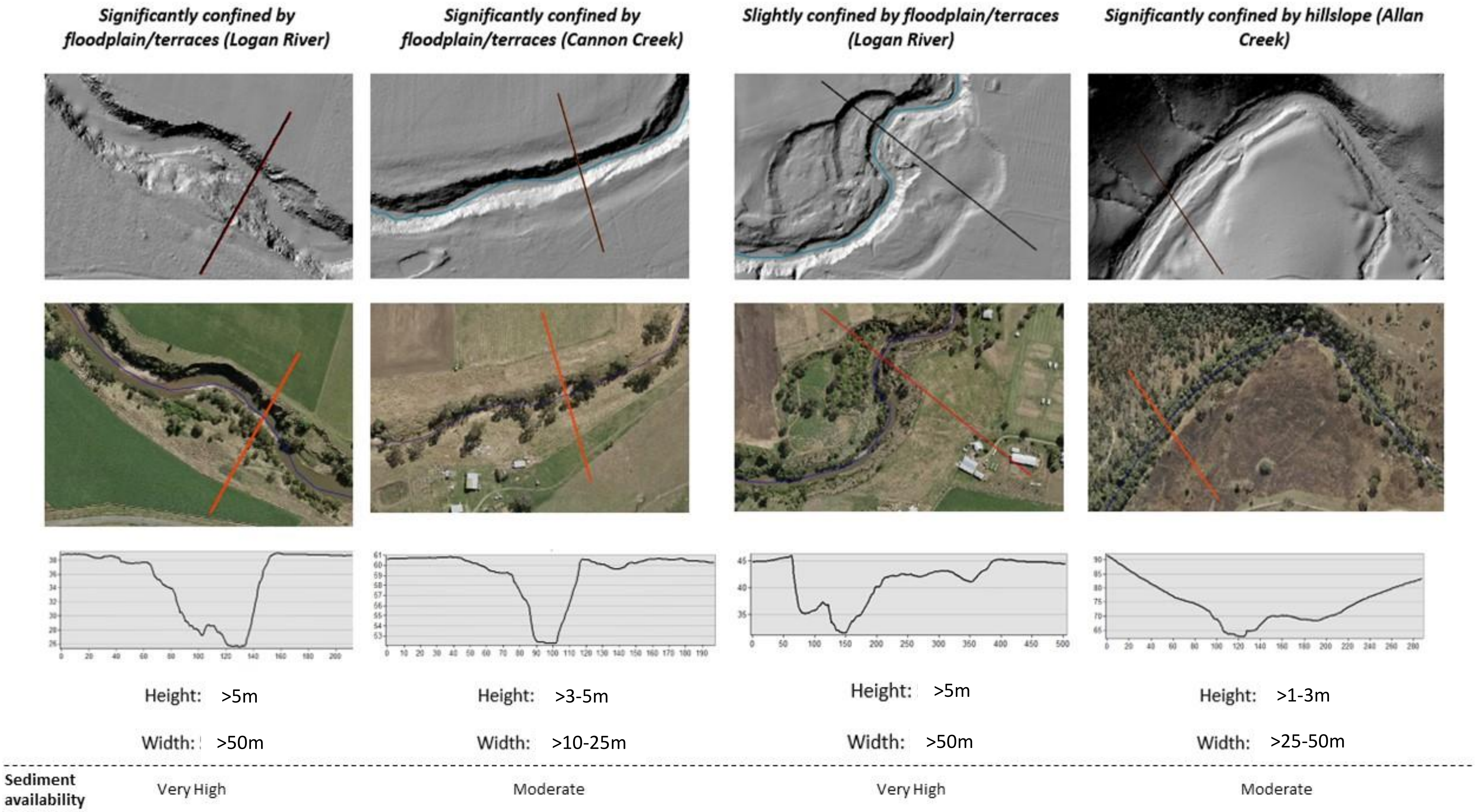


Figure 23. *The assessment of sediment availability in floodplain/terrace and hillslope confined watercourses within the Logan River catchment. Examples show how height and width were assessed between floodplain/terrace vs hillslope confinement stream types.*

Logan-Albert catchment sediment availability ratings

The assessment of sediment availability within the Logan-Albert catchment is presented in Figure 24 and Table 9. The highest sediment availability ratings are in the mid to lower sections of Logan River and Albert River where the inset units are more extensive. There is also significant sediment availability in the Burnett Creek and Teviot Brook sub-catchments in the upper Logan River catchment. For confined channels where there is minimal erosion risk, no sediment availability assessments are undertaken as channel erosion in these areas is highly unlikely.

Table 9. Summary of channel sediment availability across Logan-Albert catchment

Sediment availability	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Low	146	272	14%
Moderate	361	690	35%
High	168	362	18%
Very high	75	198	10%
Total	**750**	**1521**	**77%**

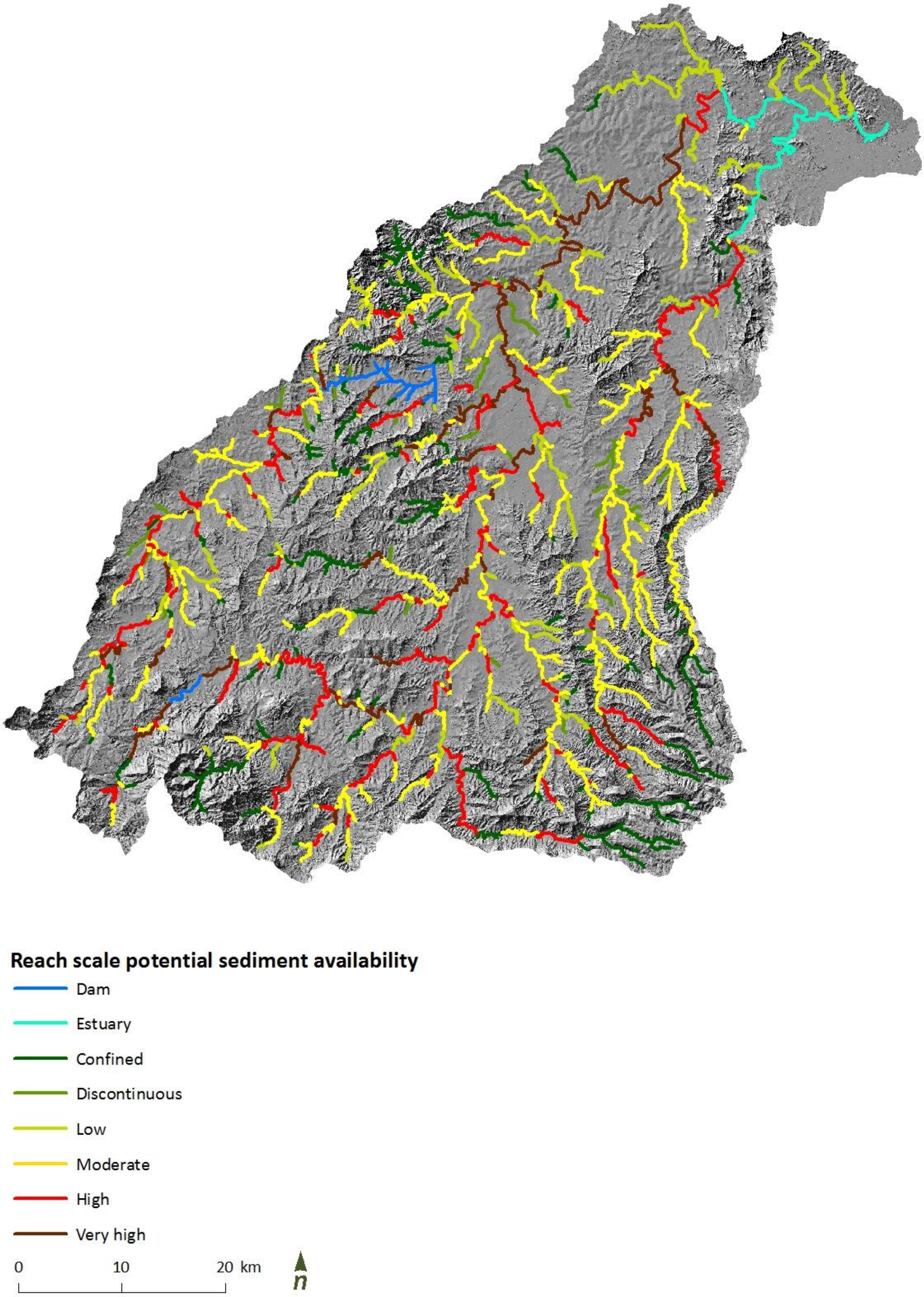


Figure 24. *Reach scale (SO ≥3) potential sediment availability (erodible units) ratings for the Logan-Albert catchment*

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 was considered to provide a reasonable approximation.

Logan-Albert catchment clay percentage

The ASRIS clay percentage associated with channels in the Logan-Albert catchment is presented in Figure 25 and Table 10. The mid and upper main reaches of Logan and Albert rivers and eastern tributaries (Running Creek, Christmas Creek and Canungra Creek) which drain large areas of basalts have the highest fine sediment fraction. Two methods are used by ASRIS to estimate clay content across the Logan and Albert catchments (refer Figure 26;

Table 11); estimates are either based on direct measurements from similar soils in the region (eastern reaches) or experience with similar soil types from other regions (western reaches). Zonal statistics were used to calculate the average clay percentage within each reach (watercourse line buffered 125m).

Table 10. Clay content across Logan-Albert catchment (excluding dam and estuary reaches)

Clay content	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Low (0-20%)	134	229	12%
Moderate (>20-35%)	254	523	26%
High (>35-50%)	575	1091	55%
Very high (>50%)	28	52	3%
Total	**991**	**1895**	**96%**

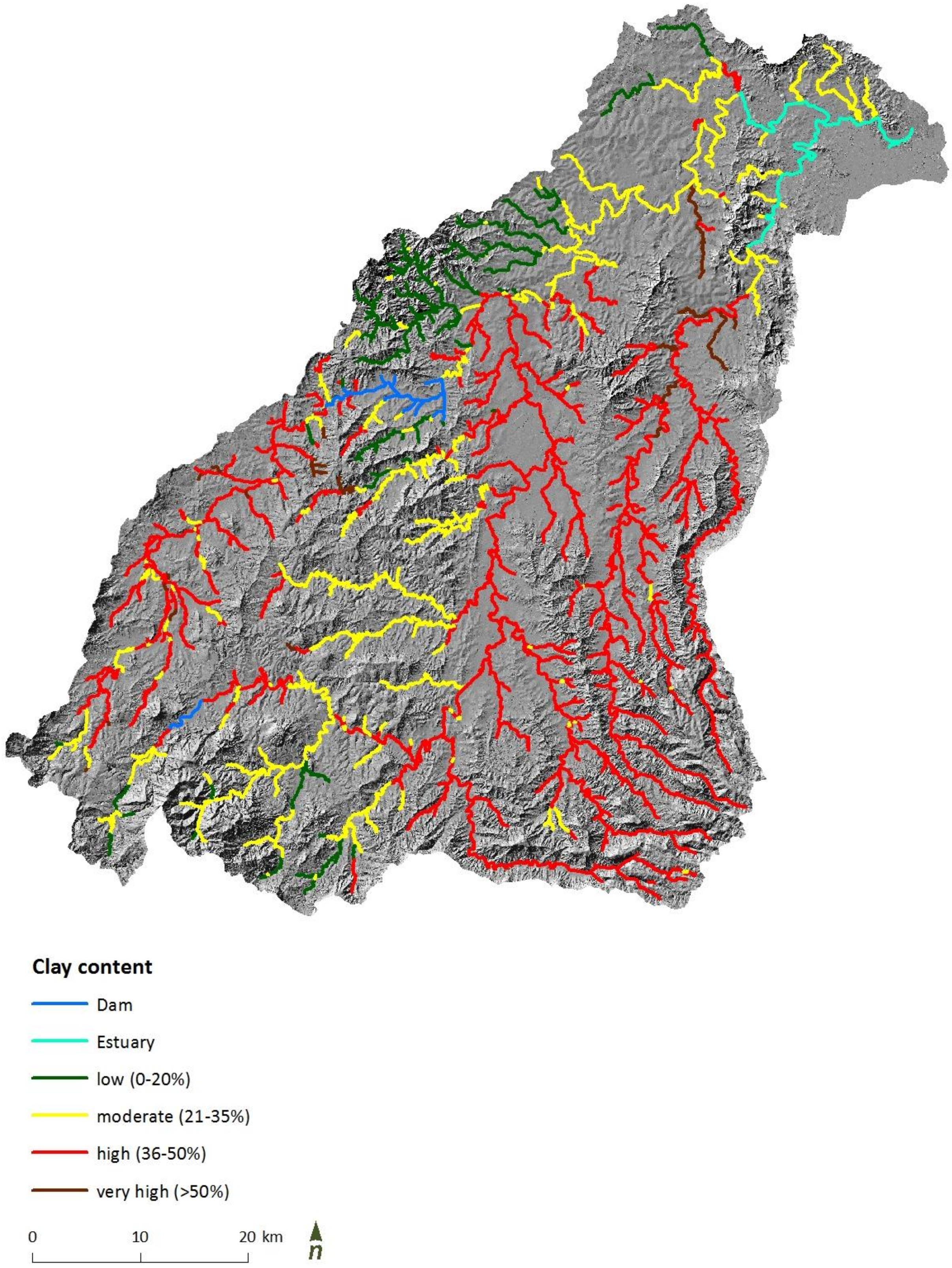


Figure 25. *Percentage clay content (0-300 mm) for streams (SO ≥3) in the Logan-Albert catchment. (Clay data layer from http://www.asris.csiro.au/themes/NationalGrids.html)*

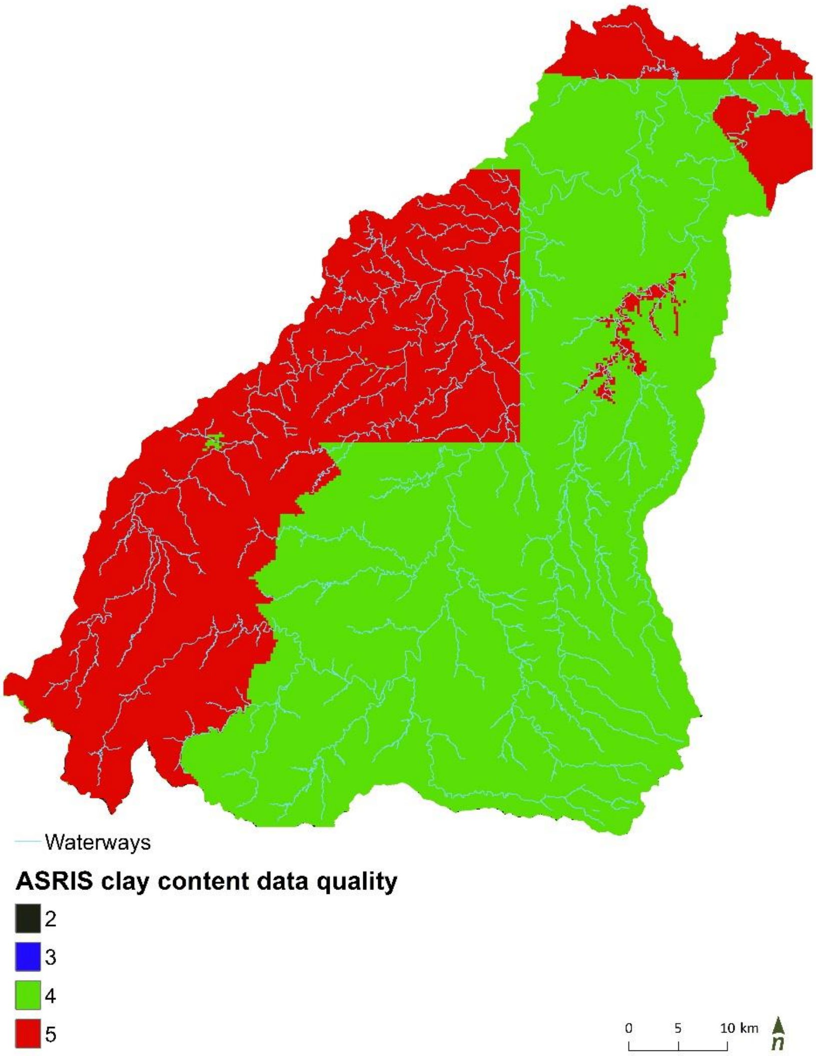


Figure 26. *ASRIS clay content (0-300mm) data estimation method*

Table 11. Estimation method for ASRIS clay content (McKenzie et al. 2005)

Estimation method	Description
1	Estimate based on replicated measurements of field texture in the land unit tract
2	Estimate based on an un-replicated measurement of field texture in the land unit tract
3	Estimate based on direct measurements of similar soils in the same land unit type (e.g., modal profiles)
4	Estimate based on direct measurements of similar soils in the region or project area
5	Estimate based on experience with similar soils (e.g., same taxa in the Australian Soil Classification but from other regions)

The fine sediment availability was determined using a matrix approach. The matrix was developed based on the combination of sediment availability (Figure 24) and the fine sediment fraction (ASRIS clay content) of the available sediment (Figure 25). The fine sediment availability matrix is provided in Figure 27.

	Clay content			
Sediment availability	0 - 20 %	20 - 35 %	35 - 50 %	> 50 %
Low	Low	Low	Moderate	Moderate
Moderate	Low	Moderate	Moderate	High
High	Moderate	Moderate	High	Very high
Very high	Moderate	High	Very high	Very high

Figure 27. *Fine sediment availability matrix (based on sediment availability and fine sediment fraction)*

Logan-Albert catchment fine sediment availabilty

The results of the fine sediment availability rating for the Logan-Albert catchment are presented in Figure 28 and Table 12. A significant difference between these results and the assessment of overall sediment availability (Figure 20), is apparent along the lower Logan River. As previously noted, confined channels are not included in this table of fine sediment availability given their minimal risk of channel erosion.

Table 12. Summary of channel fine sediment availability across Logan-Albert catchment

Fine Sediment availability	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Low	107	219	11%
Moderate	453	864	44%
High	134	323	16%
Very high	56	116	6%
Total	**750**	**1521**	**77%**

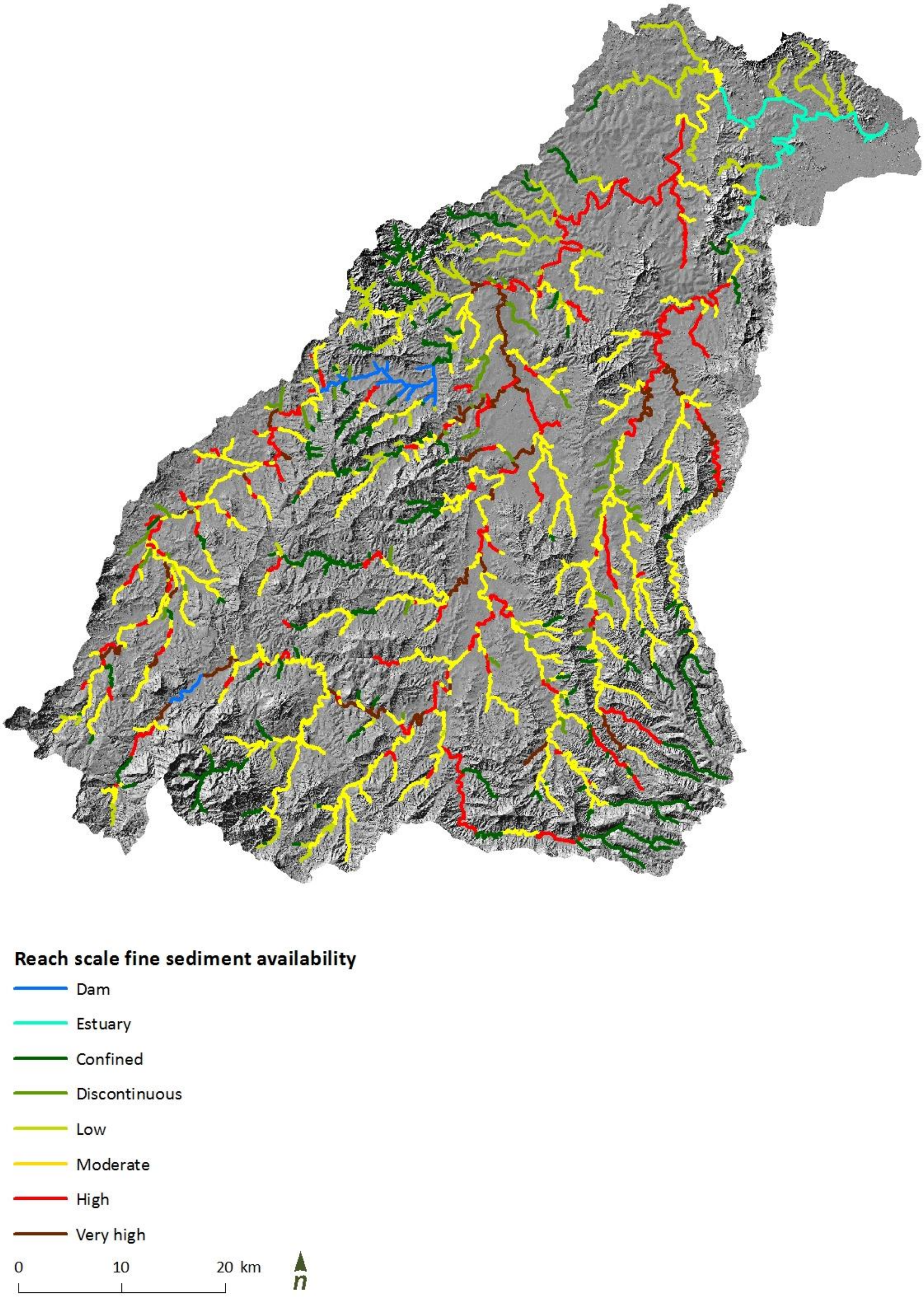


Figure 28. *The fine sediment availability ratings for the Logan-Albert catchments*

5.2.4 Channel erosion risk assessment

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 29.

	Reach-scale erosion potential			
Reach-scale fine sediment availability	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 29. *The matrix used to define reach scale fine sediment generation potential*

Logan-Albert catchment fine sediment generation potential

The assessment of reach scale fine sediment generation potential (i.e., overall channel erosion risk) for Logan-Albert catchment is presented in Figure 30. The assessment indicates the highest risk of fine sediment generation from channel erosion is from the lower to mid sections of the Logan River main channel where there are reaches with high and very high fine sediment generation potential. There are also sections of Allan Creek, Cannon/Knapps Creek, Christmas Creek, Canungra Creek and Teviot Brook which have been classified as high or very high. Fifty percent of the total stream length (SO ≥ 3) across Logan-Albert catchment was classified as having low fine sediment generation potential (Table 13).

Table 13. Summary of channel fine sediment generation potential (overall channel erosion risk) across Logan-Albert catchment

Fine sediment generation potential	Number of reaches	Length of reaches (km)	% of total stream length (SO ≥3)
Low	501	999	50%
Moderate	143	311	16%
High	77	159	8%
Very high	28	48	2%
Confined	191	306	15%
Discontinuous	51	73	4%
Dam	12	33	2%
Estuary	12	50	3%
Total	**1015**	**1978**	**100%**

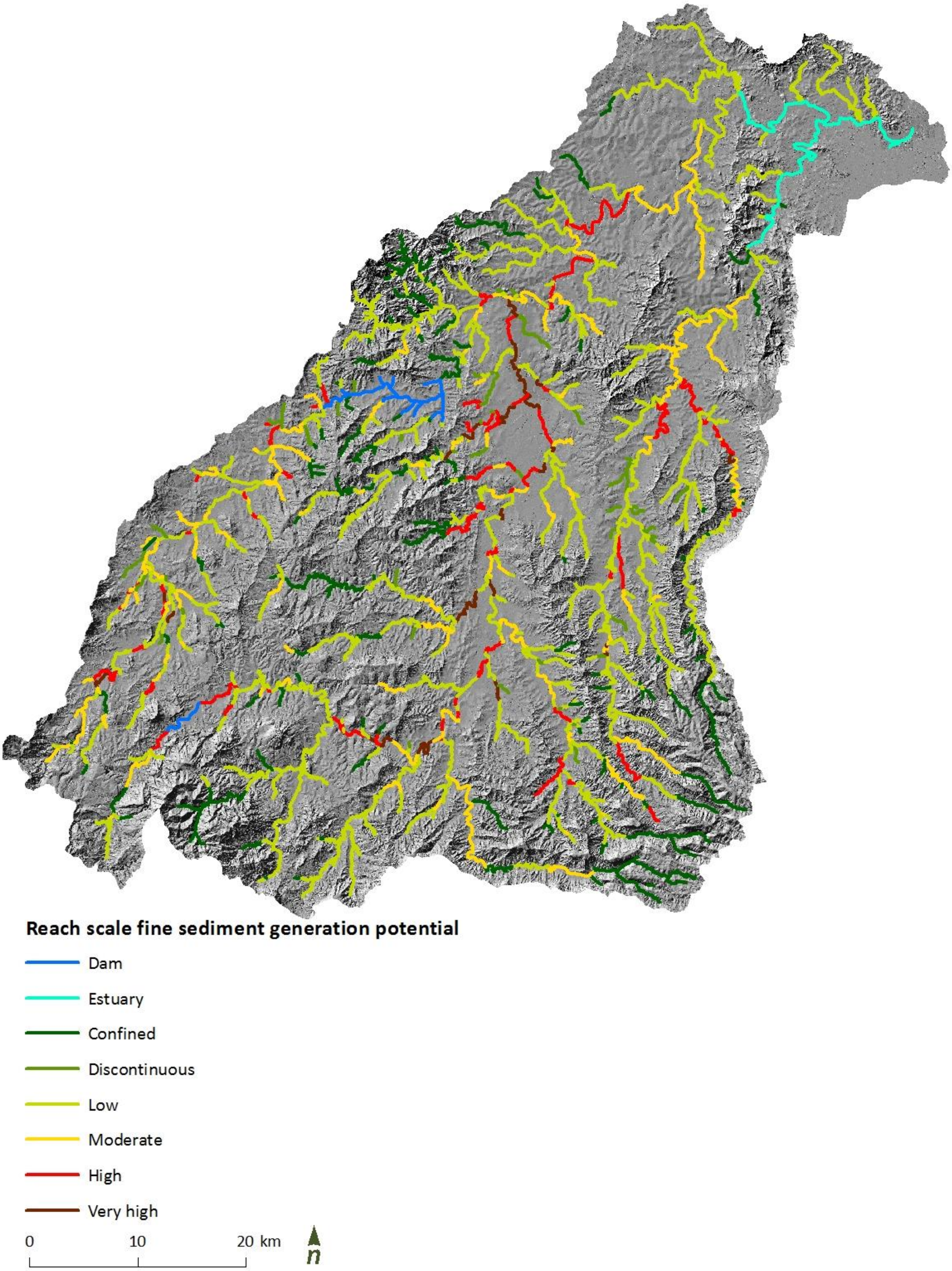


Figure 30. *Fine sediment generation potential (i.e., channel erosion risk) across the Logan-Albert catchments*

5.2.5 Field verification

To inform and verify the channel erosion risk method across the Logan-Albert catchment, field surveys were undertaken at 53 publicly accessible sites across the Teviot Brook, Logan River and Albert River sub-catchments (Figure 31). The sites were located on a variety of different stream confinement and stability categories that were accessible at public locations (i.e., bridges, parks) (Table 14). Due to access limitations, only a limited number of stable and major adjustment sites were able to be field verified.

The purpose of the field assessment was to verify the results from the desktop stream type (confinement) and channel stability (erosion potential) assessment. Generally, there was high correlation between the reach scale erosion potential desktop assessment and field observations, however this is not quantifiable as the desktop GIS stability assessment (adjustment between 2009 and 2016 using aerial imagery) is not directly comparable to the field observations (i.e., no direct measurements were undertaken). Nevertheless, all sites visited that were classified in the minor instability (moderate future erosion potential) did not show any evidence of extensive erosion that would have suggested that the reach had been incorrectly classified in the desktop assessment. Also, it is important to note that the field assessment was undertaken in December 2017, after a major flood in March/April 2017 caused by rainfall associated with ex Tropical Cyclone (TC) Debbie, while the desktop assessment looked at stability between 2009 and 2016 (prior to TC Debbie impacts).

A range of field examples are shown in Attachment B. The field verification gave high confidence that the multi-temporal comparison of aerial imagery approach used in this assessment provides a good indication of actual erosion potential and therefore channel erosion risk.

Table 14. Field verification site summary

Stability assessment	No. of reaches	No. of field sites	Access notes	Desktop assessment supported
Stable	229	1	Limited access	Yes
Minor	602	30	Point locations along reaches	Yes
Moderate	113	20	Point locations along reaches	Yes
Major	21	3	Limited access	Yes

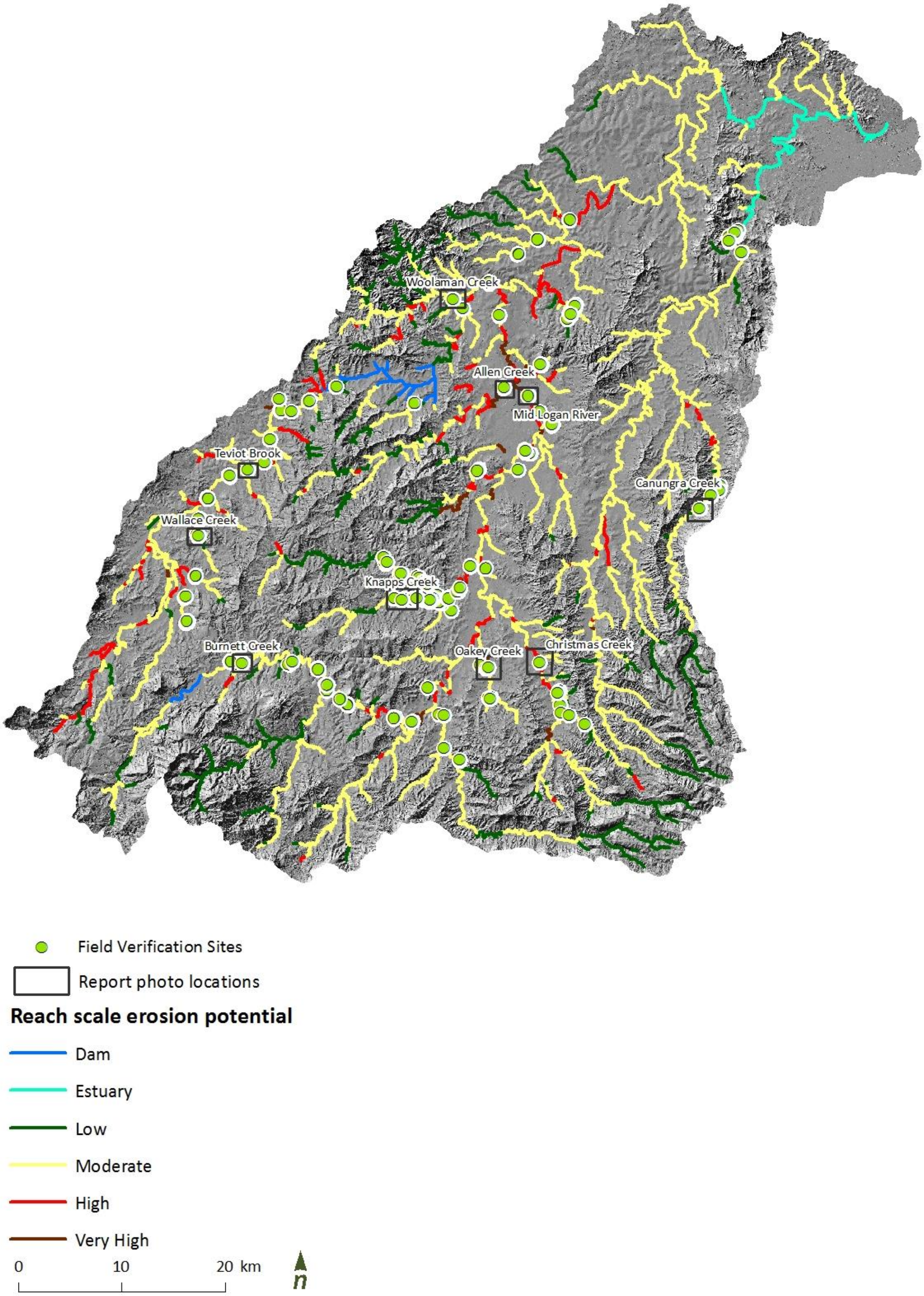


Figure 31. *Field verification sites across Logan-Albert catchment (to assess risk)*

5.3 Channel erosion 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, inform planning and land use decisions and inform 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 methodology 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 was 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.

The assessment of reach scale erosion potential has been based on observed channel change between 2009 and 2016 as an indicator of erosion potential. This assessment did not directly assess riparian vegetation, however generally well vegetated reaches would have minimal recent channel change. However, the opposite is not always true in reaches with low stream power streams can remain stable even with minimal riparian vegetation.

As discussed in Section 5.2.2, historical erosion is not always an indicator for 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 within the Logan-Albert catchment 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 the Logan-Albert catchment. 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 on 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. For confined or discontinuous channels, erosion risk is likely to remain minimal so these areas are not considered as an area for management interventions.

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 modelling of sediment transport capacity and on the extent, location and connectivity to downstream sediment sinks such as floodplains, in channel units and storages.

6 Hillslope sediment generation and delivery

Sediment generation, transport and delivery within a catchment are influenced by many factors including local climate, topography, soil type, vegetation cover and management interventions. By understanding the processes and their interactions both qualitative and quantitative methods can be used to estimate where sediment is being generated within a catchment and its potential for reaching catchment outlets.

The Queensland Government data portal provides spatial layers which can be used to estimate hillslope sediment generation across Queensland, at a spatial resolution of 100m grid size. Through a review of scientific literature and best practice applications across Australia, this project explored options for improving quantification of hillslope sediment generation across SEQ.

This study has shown that there is still considerable uncertainty in the calculation of different factors used to quantify sediment generation, and that the broad scale application of these methods has perhaps extended beyond the contexts for which they were designed.

As such, this study has focussed on developing a spatial distribution of risk of hillslope sediment generation and the likelihood of any mobilised sediment reaching waterways, and ultimately being discharged at catchment outlets. An estimate of sediment loads has been calculated, noting the limitations of current methods to estimate sediment generation and delivery.

6.1 Assessment of sediment generation

A commonly used method to assess catchment scale sediment generation processes is the Revised Universal Soil Loss Equation (RUSLE). Benefits of using RUSLE include the requirement of a modest amount of parameters that can be derived from commonly available datasets, it has been adapted to Australian conditions and the factor-based nature allows individual contributing factors to be easily analysed (Lu et al. 2011). The RUSLE determines mean annual soil loss (A, t/ha/yr) as a product of six factors as shown below:

$$A = RKLSCP$$

Where:

- A is the annual average soil loss per unit of area (tons per hectare per year),
- R is the rainfall erosivity factor,
- K is the soil erodibility factor,
- L is the slope length factor,
- S is the slope steepness factor,
- C is the cover management factor and
- P is the erosion control practice factor.

The equation helps determine where within a catchment that hillslope sediment generation is likely to occur.

Methods to calculate each of the RUSLE factors across South-East Queensland are shown in

Table 15 and discussed in detail below. There is some uncertainty in the RUSLE factors, particularly the site-specific nature of soil erodibility and erosion control practice. Therefore, without a rigorous field validation of these conditions the results should be used with some caution.

Table 15. RUSLE parameters used in the SEQ Integrated Sediment Assessment

Factor	Method
Rainfall erosivity (R)	State layer re-sampled to 5m
Soil erodibility (K)	State layer re-sampled to 5m
Slope length (L)	LS layer generated from 5m DEM
Slope steepness (S)	
Cover management (C)	C factors applied from land cover layer
Erosion control practice (P)	1 (assuming no erosion control)

Rainfall Erosivity (R)
The layers currently available on the Queensland Government data portal have been developed applying the method outlined in Yu (1998) to calculate rainfall erosivity (R) using daily SILO rainfall 'Data Drill' rasters (Jefferey et al. 2001) over the period 1915 - 2012 (inclusive).

Rainfall erosivity is defined as the mean annual sum of individual storm rainfall intensity (EI_{30}) values, where EI_{30} is the total storm energy (E) multiplied by the maximum 30 minute rainfall intensity (I_{30}). Continuous rainfall intensity data, such as pluviograph data, for at least 20 years (Wischmeier and Smith 1978) is required to compute EI_{30}. Given the limited spatial extent of pluviograph data over 20 year periods in SEQ, several studies have demonstrated the suitability of using daily rainfall to estimate storm erosivity.

$$\widehat{E}_j = \alpha[1 + \eta\cos(2\pi f j - \omega)]\sum_{k=1}^{N} R_k^{\beta} \quad when\ R_k > R_0$$

Where:

- $\widehat{E}_j$ is rainfall erosivity for the month j
- R_k is the daily rainfall amount
- R_0 is the threshold rainfall amount (12.7 mm)
- ω is the phase parameter which accounts for seasonal variability ($\pi/6$)
- f gives the fundamental frequency (1/12)
- N is the number of rain days
- j is the month (eg January = 1)
- α , η and β are calibration factors with a recommended set of parameter values:
- $\alpha = 0.395\left[1 + 0.0980\exp\left(3.26\frac{S}{P}\right)\right], \beta - 1.49, \eta = 0.29$ (where S is mean summer rainfall (November-April) and P is the mean annual rainfall)

Monthly rainfall erosivity values were summed to give an annual time series of rainfall erosivity and the average of these was taken to give the annual average rainfall erosivity, the R factor.

When considering possible methods for improving the calculation of rainfall erosivity as part of this study, the preferred option was to apply the above method to daily rainfall data over the period from 1980 to 2017 to more accurately reflect current climate conditions. A comparison of the R factor calculated using rainfall from 1915-2012 compared with from 1980-2017 was undertaken at five locations across South-East Queensland (see Figure 32). Surprisingly, a reduction in the R factor value was calculated for all sites (see Figure 33), which was contradictory to what was expected given current literature regarding increasing trends in rainfall intensity. It appeared that the reduction was largely driven by the exclusion of the period of high rainfall intensity during the 1970s (see Figure 34). Based on this analysis, it was concluded that there was not a strong case to justify the exclusion of the earlier data period, and hence the existing layer from the Queensland Government data portal was applied, re-sampled to a 5m grid resolution to be consistent with the spatial resolution of other layers.

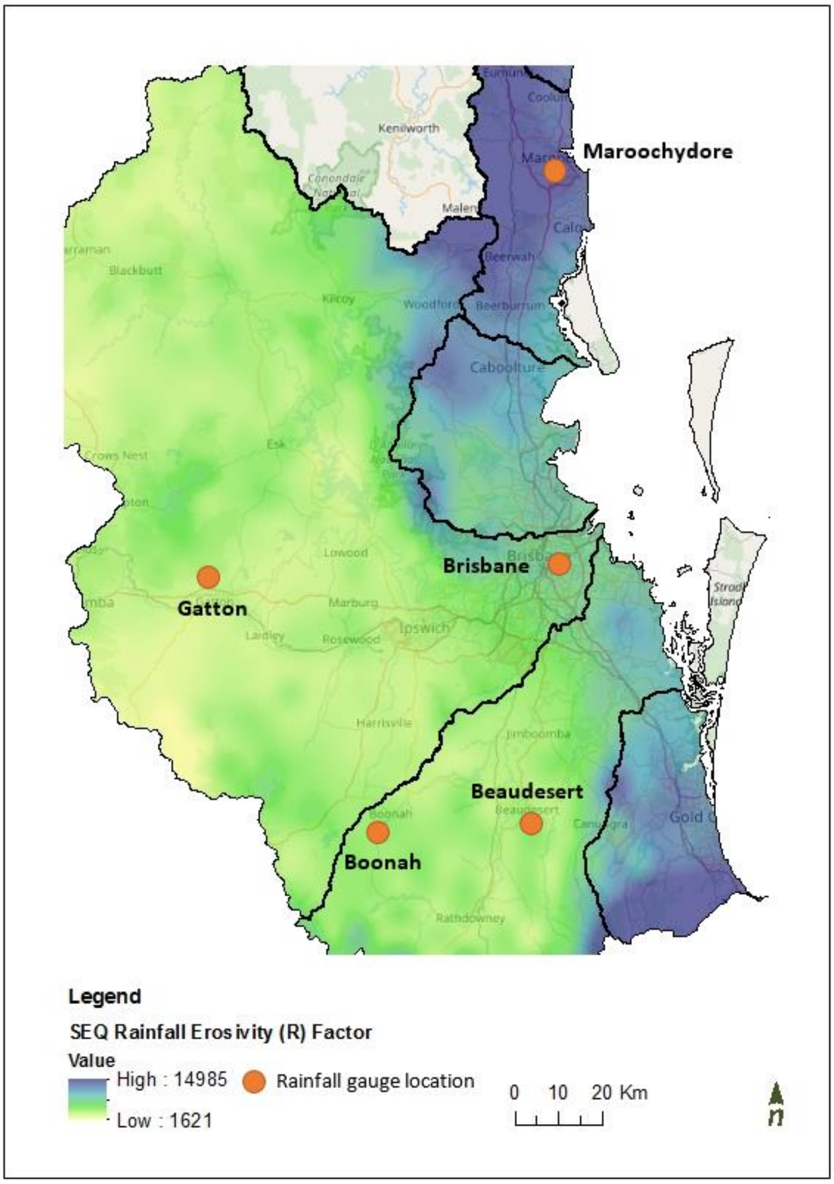


Figure 32. *Selected locations for R factor analysis*

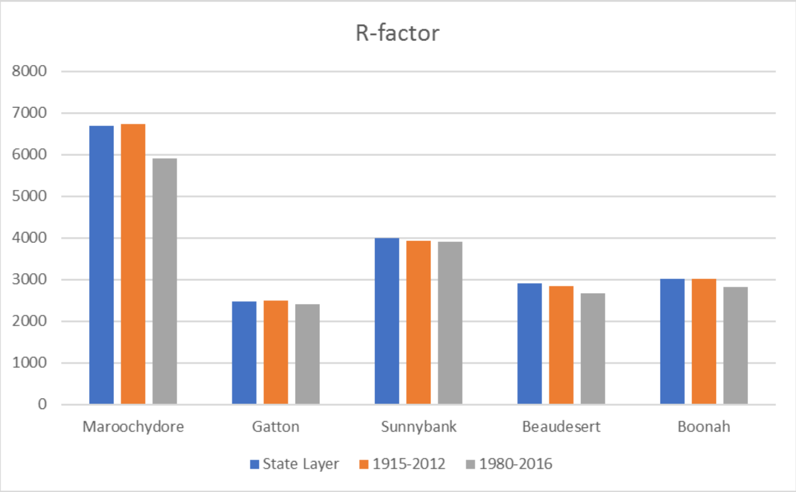


Figure 33. *Comparison of R calculation methods for selected locations*

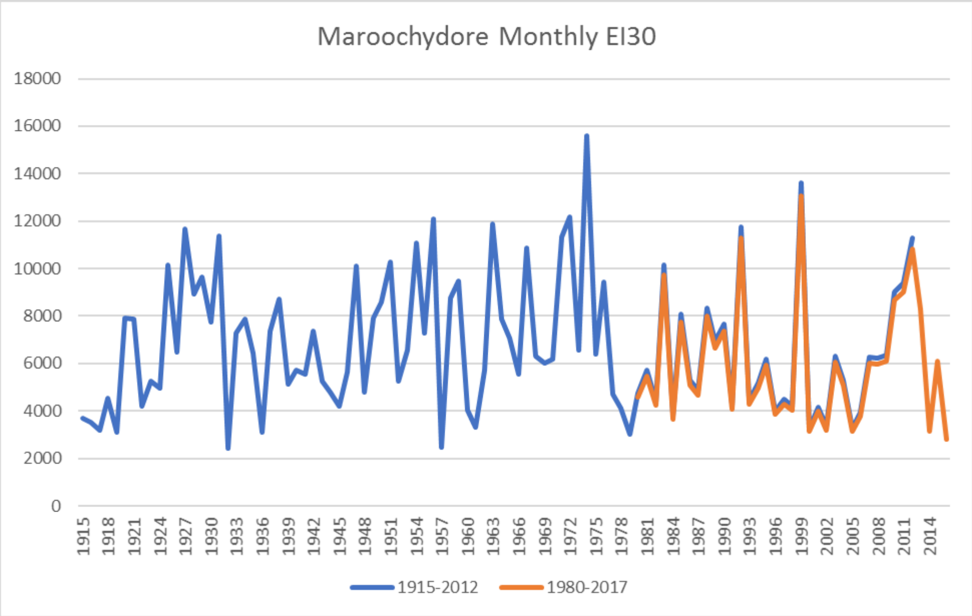


Figure 34. *Time series of month EI30 values from 1915 to 2014*

Figure 35 shows the rainfall erosivity factor values for SEQ at 5m resolution as applied in the RUSLE calculations.

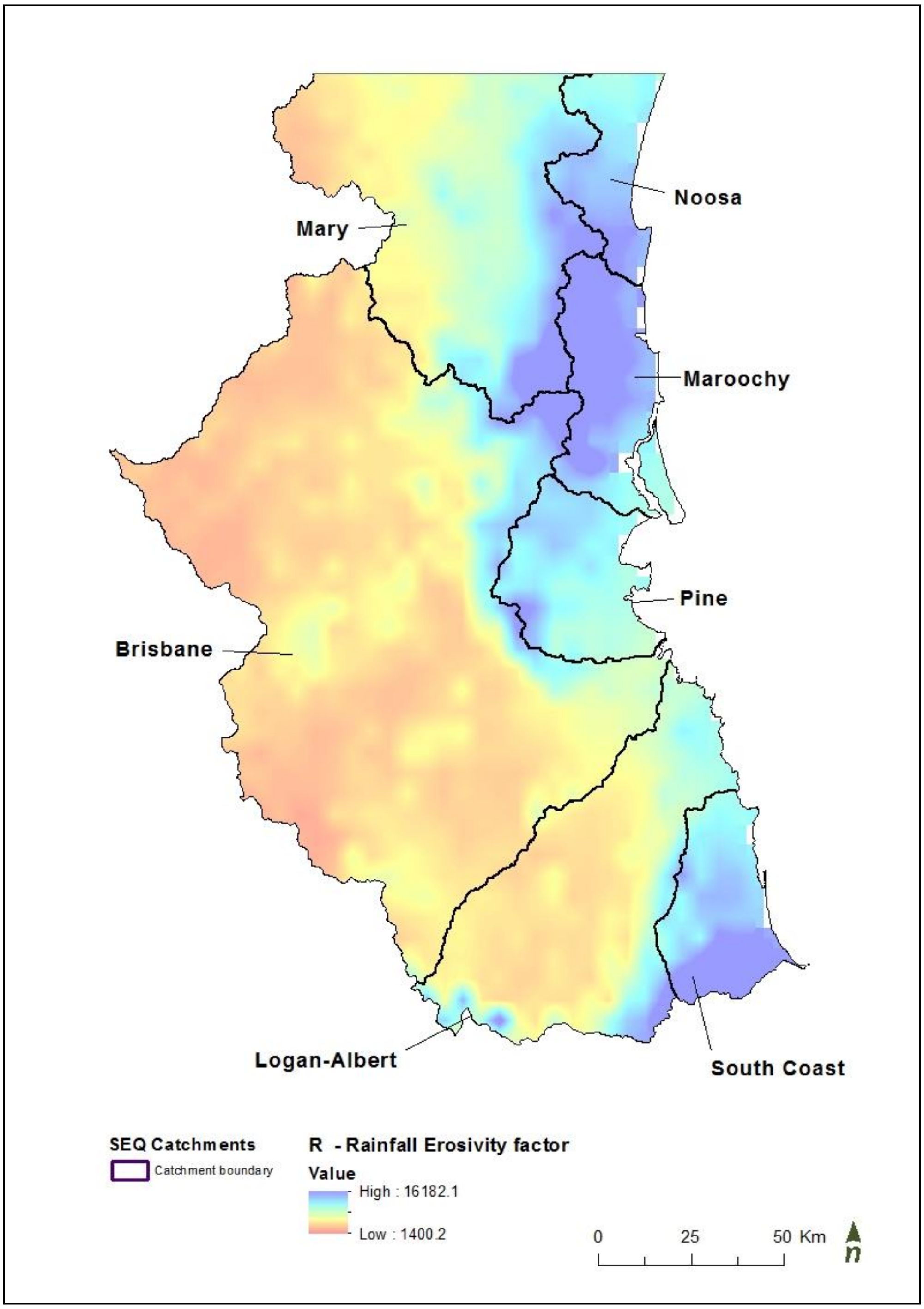


Figure 35. *SEQ Rainfall Erosivity (R) factor, 5m resolution*

Soil erodibility factor (K)
Data to calculate the K factor layer that was available on the Queensland Government data portal is taken from the Australian Soil Resource Information System (ASRIS) (McKenzie et al. 2012), which sources its data from the Queensland Government's Soil and Land Information (SALI) database. Consideration was given to improving this layer through patching of other datasets if these existed. Discussions with the Department of Environment and Science staff involved in soil mapping identified that several fine scale soil mapping projects were underway in SEQ, but none were at the stage where layers were available for use in this project. Therefore the existing K factor layer was adopted as outlined above. Attribute data in ASRIS varies in quality, with data sourced from a combination of field and laboratory measurements and pedotransfer functions. The land resource surveys comprising the Queensland ASRIS cover age vary in spatial scale from 1:2 million to 1:5,000.

Figure 36 shows the distribution of the soil erodibility (K) factor across SEQ as applied in the RUSLE calculations and Figure 37 shows a zoomed in layer at the mouth of the Brisbane River.

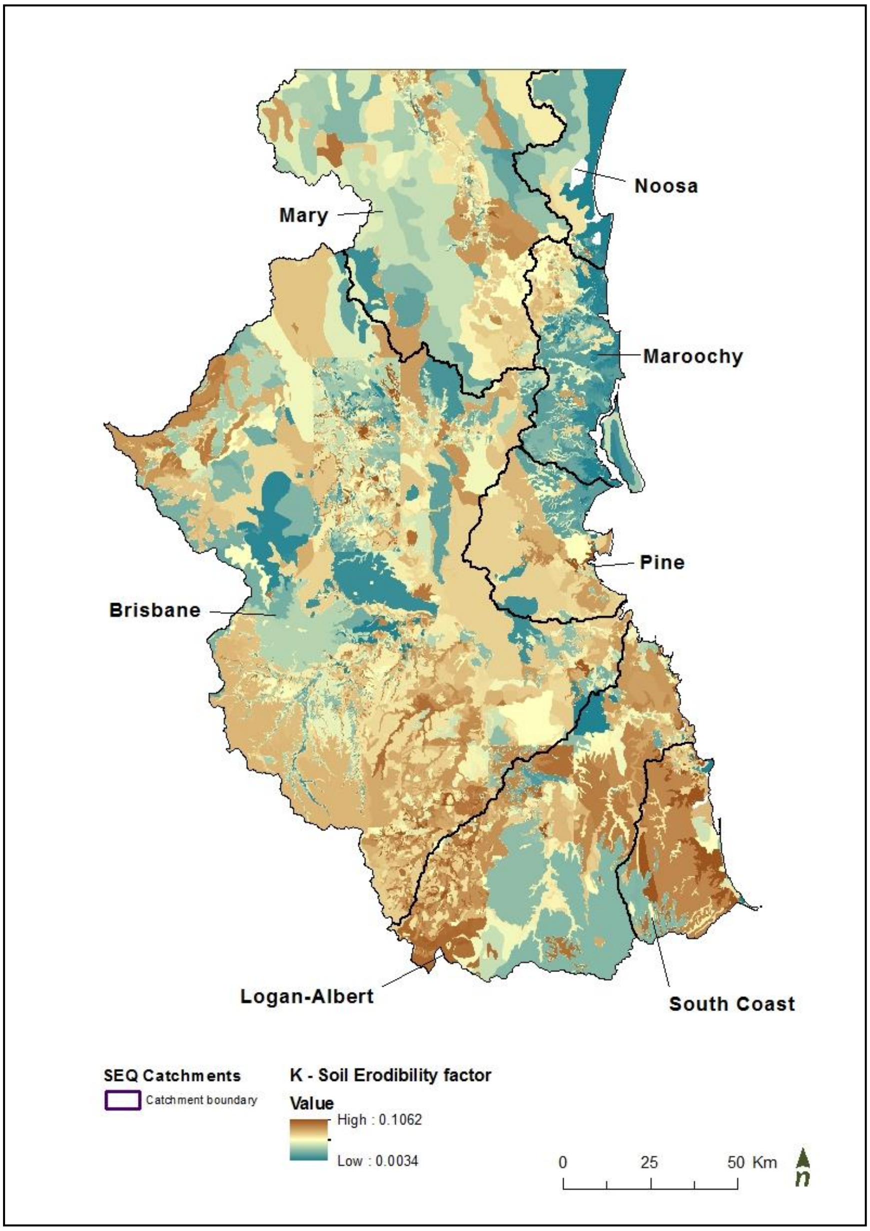


Figure 36. *SEQ Soil erodibility (K) factor, 5m resolution*

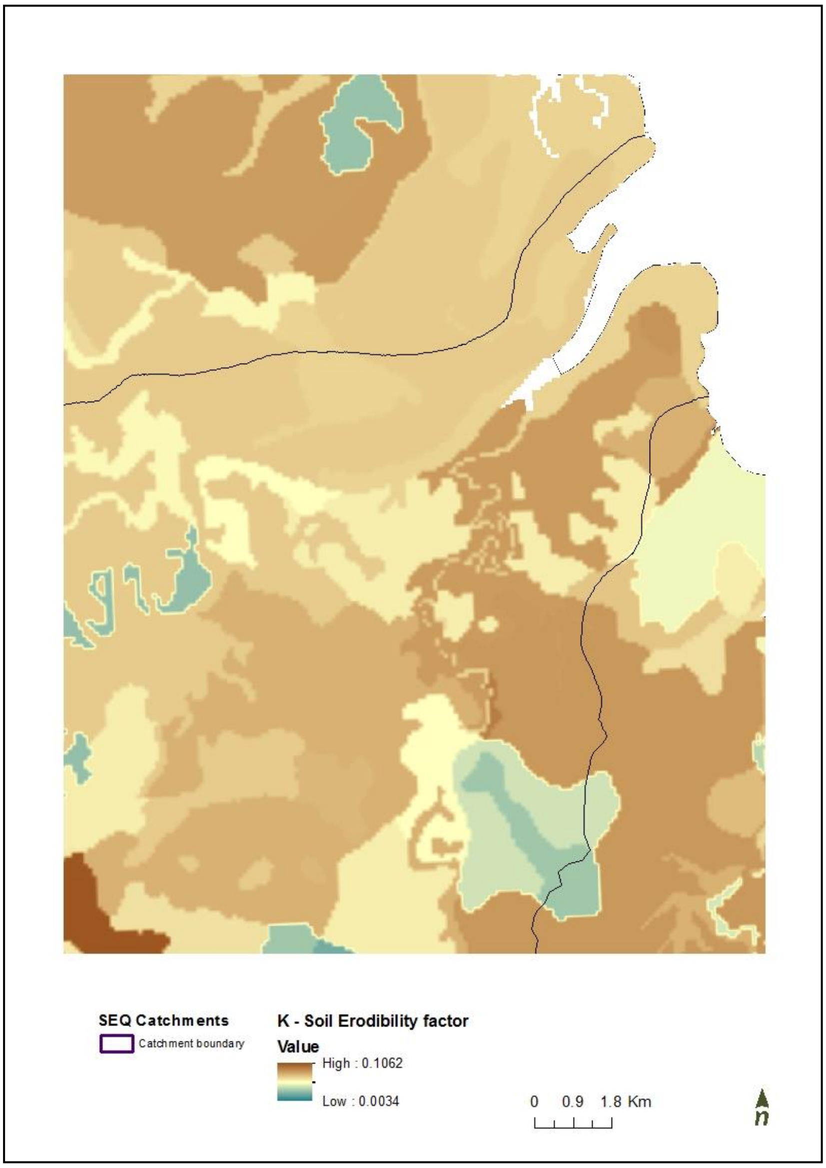


Figure 37. *SEQ Soil erodibility (K) factor, 5m resolution*

Slope length factor and slope steepness factor (LS)
The L factor (slope length) and S factor (steepness) are often combined as LS, representing the effect of the topography on hillslope erosion rates (Zhang et al. 2017).

The L factor and S factor layers currently available on the Queensland Government data portal use smoothed 3 second (~90m) Shuttle Radar Topography Mission (SRTM) Derived DEM to separately calculate the L factor and S factor, which can be multiplied together to give the LS factor (Zhang et al. 2017).

Various GIS based algorithms have been developed for calculating a combined LS factor using high resolution DEMs. The combined LS factor in RUSLE represents the ratio of soil loss on a given slope length and steepness to the soil loss from a unit slope that has a length of 22.13m and a steepness of 9%, where all other conditions are the same (Yang 2015).

Elevation data of 5m resolution is available for most of SEQ. This was used where available and combined with the 25m DEM. The LS factor was calculated using the SAGA (System for Automated Geoscientific Analyses) GIS LS factor tool, which requires a layer of contributing area for each point in the grid, and a layer of slope. These layers were developed using TauDEM (Terrain Analysis Using Digital Elevation Models), a set of tools developed by Utah State University for the analysis of terrain using digital elevation models. The tools can be used as a plug-in to most mapping software.

The following steps were undertaken to develop the LS factor layer:

1. TauDEM: Pit removal of the 5m DEM to ensure hydraulic connectivity within the watershed
2. TauDEM: Computation of flow directions and slopes using the D8 method which selects which adjacent grid cell water will flow to for each cell in the grid
3. TauDEM: Contributing area using the D8 flow direction method
4. SAGA: LS factor tool in Terrain>Hydrology to convert slope and contributing area layers to the LS factor layer

Figure 38 and Figure 39 show the distribution of LS values for the whole of SEQ and a sample area.

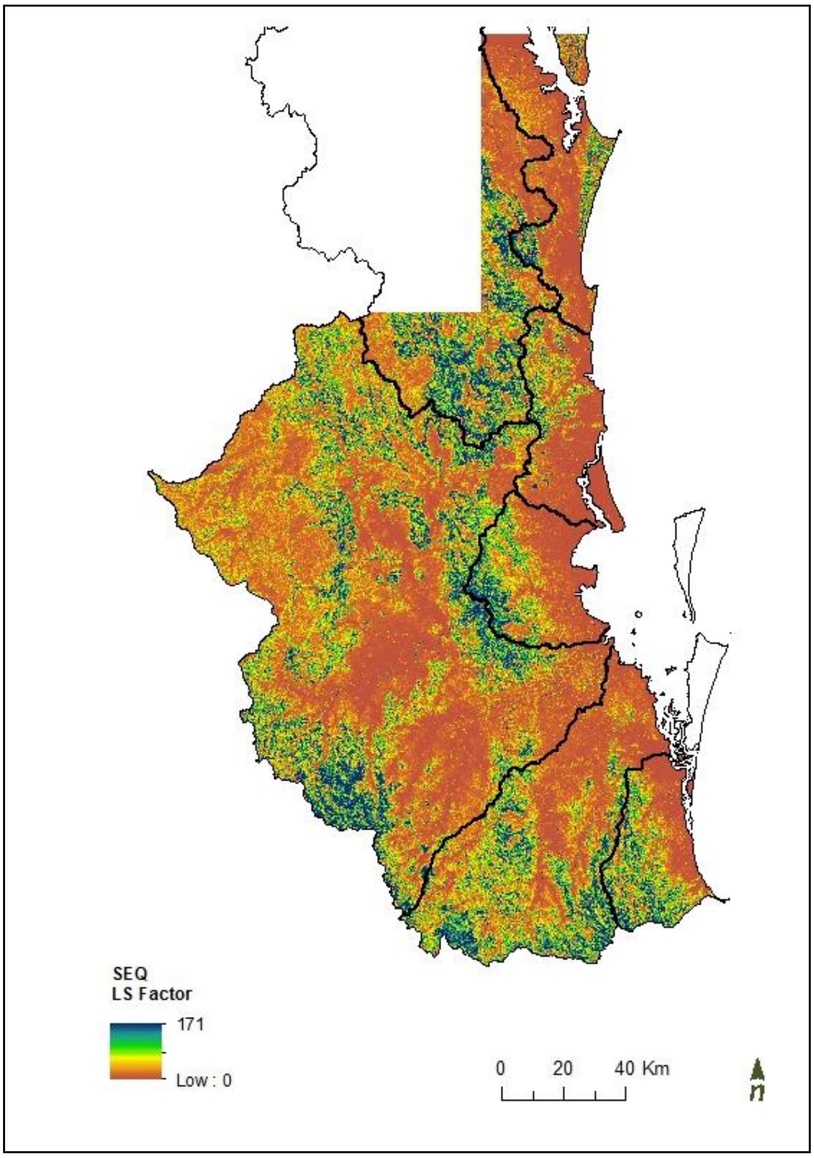


Figure 38. *SEQ Slope length (LS) factor, 5m resolution*

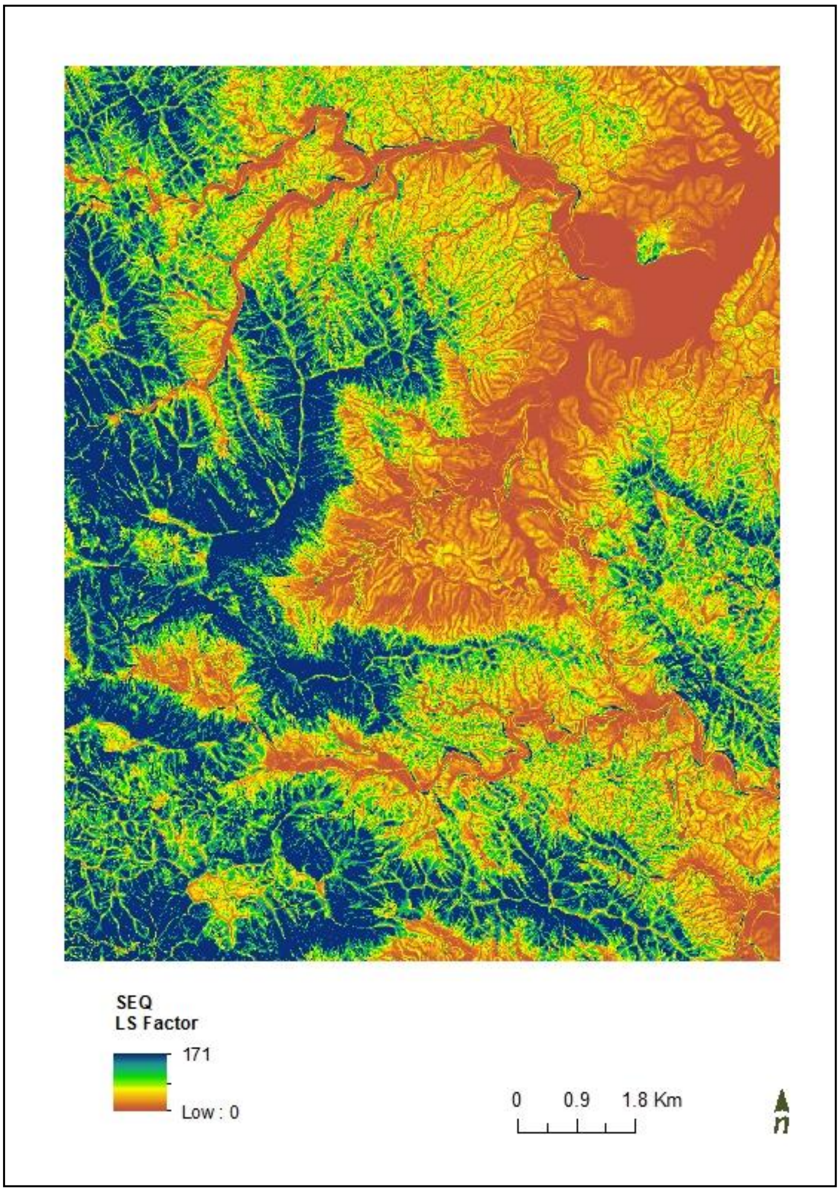


Figure 39. *SEQ Slope length (LS) factor, 5m resolution – sample area*

Cover management factor (C)
There are several methods currently used to estimate the C factor based on ground cover estimates or land use layers.

Previous studies have determined C factor values to be applied to various land use types (Pal and Samanta 2012). For this project, these values were applied to the SEQ land cover spatial layer (which uses 2012 SPOT imagery and updated GIS datasets) and has a finer level of detail than available land use data. Table 16 shows the C factor applied to each land cover code based on similar land use types and Figure 40 shows its application across east Brisbane and the Brisbane River estuary.

Table 16. C factor applied to each landcover type

Code	*Primary*	*Secondary*	*Tertiary*	*Landcover*	*Land use (matched)*	*C factor*
1	B Non-vegetated areas	B1 Terrestrial non-vegetated	B15 Built-up and associated area	Impervious Road Surface	Barren land (construction)	0.5
2	NA	NA	NA	Cloud	NA	0.2
3	B Non-vegetated areas	B2 Aquatic non-vegetated	B28 Inland or marine water	Ocean	Water	0
5	B Non-vegetated areas	B1 Terrestrial non-vegetated	B15 Built-up and associated area	Mine | Quarry | Industrial	Barren land (construction)	0.5
6	B Non-vegetated areas	B2 Aquatic non-vegetated	B28 Inland or marine water	Waterbody	Water	0
8	B Non-vegetated areas	B2 Aquatic non-vegetated	B27 Artificial water bodies	Canal	Water	0
9	A Vegetated	A1 Vegetated terrestrial	A12 Natural and semi vegetation	Native Forest	Forest (vegetated)	0.004
10	A Vegetated	A1 Vegetated terrestrial	A11 Cultivated terrestrial	Plantation	Forest (vegetated)	0.004
11	A Vegetated	A1 Vegetated terrestrial	A12 Natural and semi vegetation	Non-forest Native Vegetation	Forest (vegetated)	0.004
13	B Non-vegetated areas	B1 Terrestrial non-vegetated	B18 Bare areas	Sand | Mud Bank	Barren land (construction)	0.5
14	A Vegetated	A1 Vegetated terrestrial	A11 Cultivated terrestrial	Grass	Dry land pasture/shrub land (agriculture)	0.05
15	A Vegetated	A1 Vegetated terrestrial	A11 Cultivated terrestrial	Tree Crop	Forest (vegetated)	0.004
16	A Vegetated	A1 Vegetated terrestrial	A11 Cultivated	Irrigated Crop and	Irrigated Pasture	0.125

Code	Primary	Secondary	Tertiary	Landcover	Land use (matched)	C factor
			terrestrial	Pasture		
17	A Vegetated	A1 Vegetated terrestrial	A11 Cultivated terrestrial	Dryland Crop	Dry land pasture/shrub land (agriculture)	0.05
18	B Non-vegetated areas	B1 Terrestrial non-vegetated	B18 Bare areas	Natural Rock | Cliff	Barren land (construction)	0.5
19	B Non-vegetated areas	B1 Terrestrial non-vegetated	B15 Built-up and associated area	Non-vegetated	Settlement (urban)	0.002

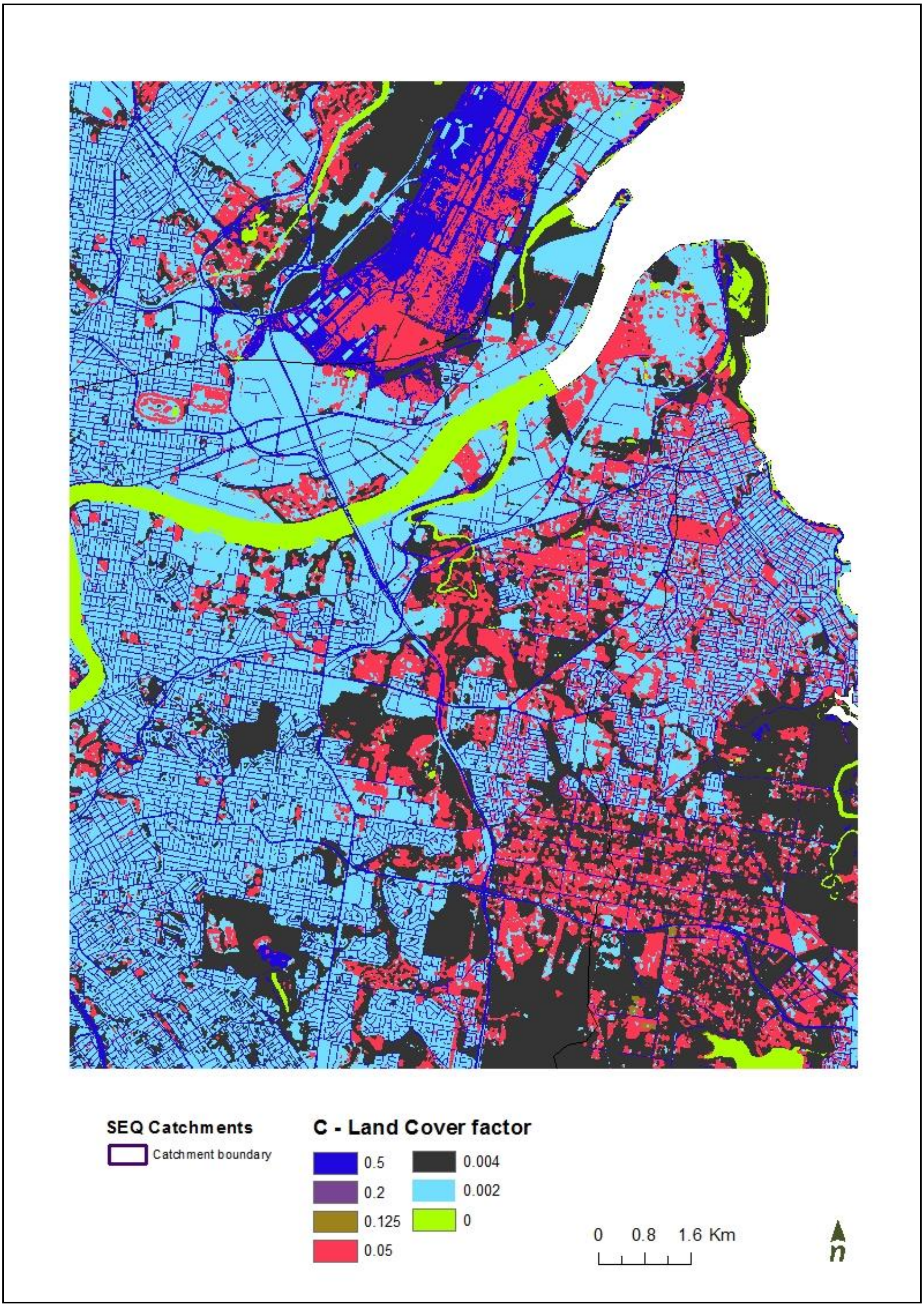


Figure 40. *SEQ Land cover (C) factor, 5m resolution – Brisbane River estuary*

As part of Paddock to Reef program (established to measure and report on progress towards the Great Barrier Reef Water Quality Protection Plan), several improvements were made to the calculation of the C-factor used as an input to RUSLE. This included: the way that remotely sensed ground cover data was adjusted to account for tree cover; accounting for seasonal changes in ground cover; and converting satellite to visual cover data prior to the calculation of the C-factor.

$$C = e^{(-0.799 - (4.74\times10^{-2}\times\text{GC}) + (4.49\times10^{-4}\times\text{GC}^2) - (5.2\times10^{-6}\times\text{GC}^3)))}$$

where GC is total ground cover (visual) as a percentage and GC (Visual) % = 0.00925*(Satellite % ^2))

This method was not able to be applied a there was no available spatial layer of ground cover for SEQ but could be considered in future should this become available.

Erosion control practice factor (P)
No adjustment has been applied to account for erosion control practices.

6.2 Assessment of sediment delivery ratio

Not all sediment generated from hillslope erosion processes will enter waterways, or discharge at catchment outlets.

In Fu et al. (2010) an assessment of the delivery of sediments from unsealed roads in forested catchments showed that the distance the source of sediment to the stream was a critical measure of delivery ratio. Based on this research and similar studies, it was assumed that for sediment generated within 10m, 30m and greater than 30m of a waterway, 100%, 35% and 10%, respectively, of generated sediment would enter the waterway.

6.3 Estimation of sediment loads from hillslope erosion

The analysis described above shows that there are various assumptions and multiple levels of uncertainty involved in the estimation of hillslope erosion generation and delivery rates. The following table provides an estimation of sediment loads from hillslope erosion for each of the SEQ catchments. These estimates provide an indication of the relative loads (see Table 17), and can be used in combination with the spatial layers which allow the identification of sites with potentially high risk of hillslope erosion.

Table 17. Summary of RUSLE derived sediment yield for SEQ

Catchment	Catchment area (ha)	% area SEQ	Mean sediment generation (t/ha/yr)	Mean sediment delivery (t/ha/yr)	Catchment yield (t/yr)	Delivered to waterway (t/yr)	Proportion of SEQ sediment delivered
Noosa	194,685	8%	2.4	0.3	471,000	59,000	3%
Maroochy	153,757	6%	6.1	0.8	942,000	127,000	6%
Brisbane	1,354,235	57%	4.9	0.7	6,636,000	907,000	46%
Pine	148,266	6%	8.2	1.0	1,220,000	153,000	8%
Logan-Albert	414,920	17%	8.6	1.2	3,568,000	500,000	25%
South Coast	130,302	5%	13.2	1.9	1,714,000	243,000	12%
TOTAL	2,396,166	100%	6.1	0.8	14,551,000	1,989,000	100%

7 Integration of assessments

7.1 Integration methods

The individual assessments of erosion and sediment generation risk need to be integrated so that a total estimation of risk can be made. The challenge with this is the risk is dependent on both the end use of the water (e.g., drinking water, recreation, ecosystem health) and also the point of assessment (e.g., individual stream reaches, storages, drinking water offtakes, estuaries or Moreton Bay). Developing a single integrated assessment therefore that covers all of these elements cannot easily be provided. An additional complication is that the methods used for assessment of risk do not necessarily quantify the amount of sediment generated, only the likelihood and consequence of sediment generation. In the assessments documented, only the hillslope assessment results in a numeric value of sediment generation that relates directly to risk.

Point source integration

For point source erosion, the quantum of export is associated with consequence only, with a likelihood then based on a decision tree to derive the final sediment generation risk. It would be relatively straight forward to convert the likelihood to a ratio based on expected performance of each of the likelihood modifiers (e.g., presence of vegetation, farm dams etc), but this has not been completed in this study.

Hillslope integration

For hillslope erosion, values are provided for each cell in the hillslope sediment generation raster, which has a factor of delivery based on distance to stream. The challenge with integration of these values with other assessments is relating the cell to a delivery point in the stream. It is possible to evaluate this by identifying, through a contributing catchment assessment, which stream each cell contributes to, or alternatively, applying a hydrologic boundary of subcatchments or planning units and summing up the values of each of the cells within each hydrologic boundary. Seqwater have prepared planning units for all of their catchments of interest which cover the majority of SEQ (Figure 41), but there are some sections of the region that would need to be infilled from other sources such as existing catchment models.

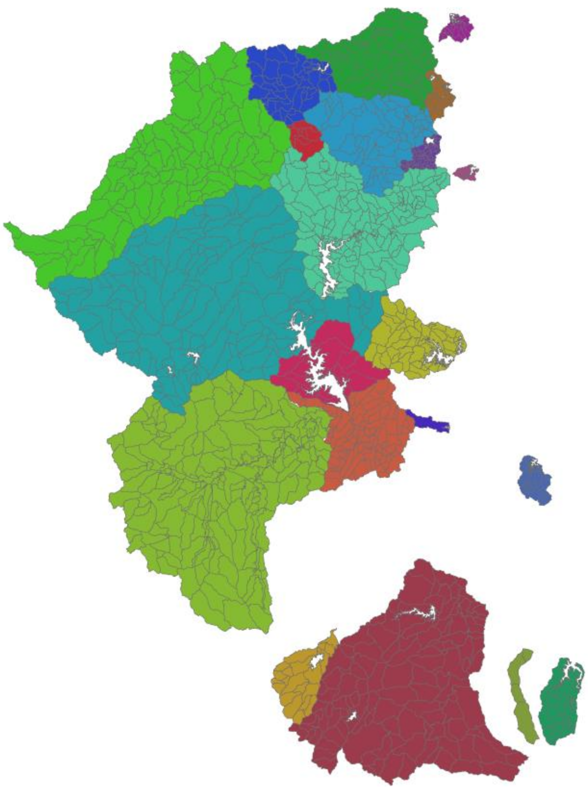


Figure 41. *Seqwater planning unit coverage*

Channel erosion integration

For channel erosion, the sediment generation risk is related to a range of factors, including the quantum of sediment available for transport. To convert these into numerical values, a method was developed that converted the volumes of sediment available into a mass based on bulk density, but then this value was modified by categorising retreat rates and bank heights into separate minimums and maximums based on their risk category. This is documented below.

To quantify volumes attributed to stream bank erosion, the following steps were undertaken:

1. For each overall instability class a minimum and maximum multiplier was applied based on the length of reach affected by erosion and observed retreat rates. This value was derived from Table 18.

Table 18. Retreat rate for instability class

Instability class	% of reach length potentially affected by erosion	Retreat (m/yr)	Assumptions
Minor - min	1%	0.014	min retreat of 0.1m over 7yrs
Minor - max	15%	0.714	max retreat of 5m over 7yrs
Moderate - min	16%	0.014	min retreat of 0.1m over 7yrs
Moderate - max	100%	0.714	max retreat of 5m over 7yrs
Major - min	16%	0.714	min retreat of 5m over 7yrs
Major - max	100%	2.857	max retreat of 20m over 7yrs

2. For each group of bank heights related to different risk classes, a mid-range value was used to determine the total volume of sediment available. This was then multiplied by an assumed bulk density to derive a minimum or maximum tonnage of sediment likely to be discharged.

   sediment (t) = reach length(m) * retreat (m/yr)*ave bank height (m)*1.6 (assumed bulk density)

The bank heights used for this evaluation are shown in Table 19.

Table 19. Average bank heights assumed

Bank height available for erosion	Average bank height (m)
0 to 1 m	0.5
1.1 to 3 m	2
3.1 to 5 m	4
Greater than 5 m	7

3. Derivation of minimum or maximum channel erosion rate based on mass of sediment per reach divided by reach length.

The results from this gave a minimum and maximum unit sediment generation rate (t/km/yr) that could be used for comparison across the SEQ region, as shown in the Figure 42 and Figure 43.

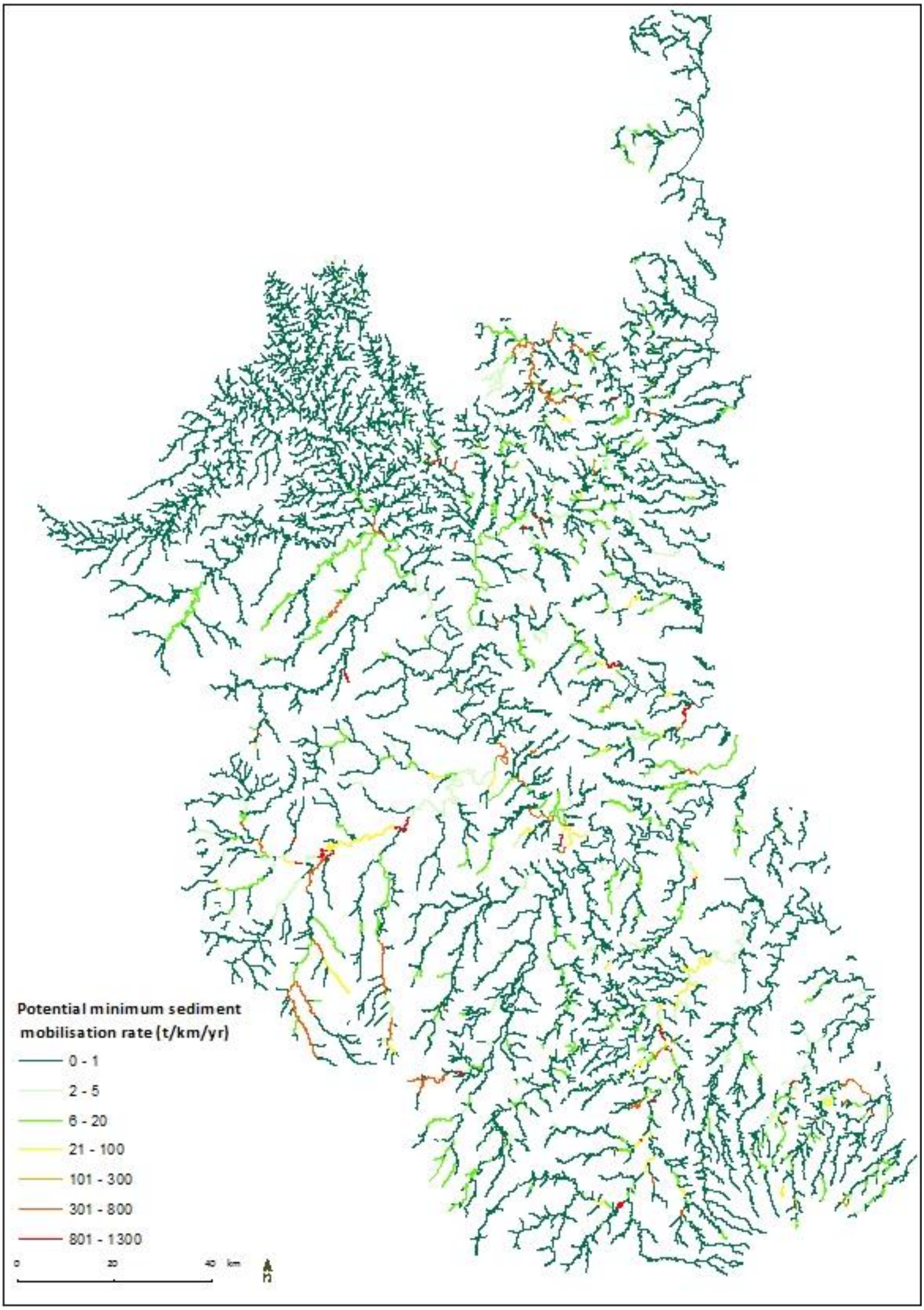


Figure 42. *Minimum sediment generation rate from channel erosion*

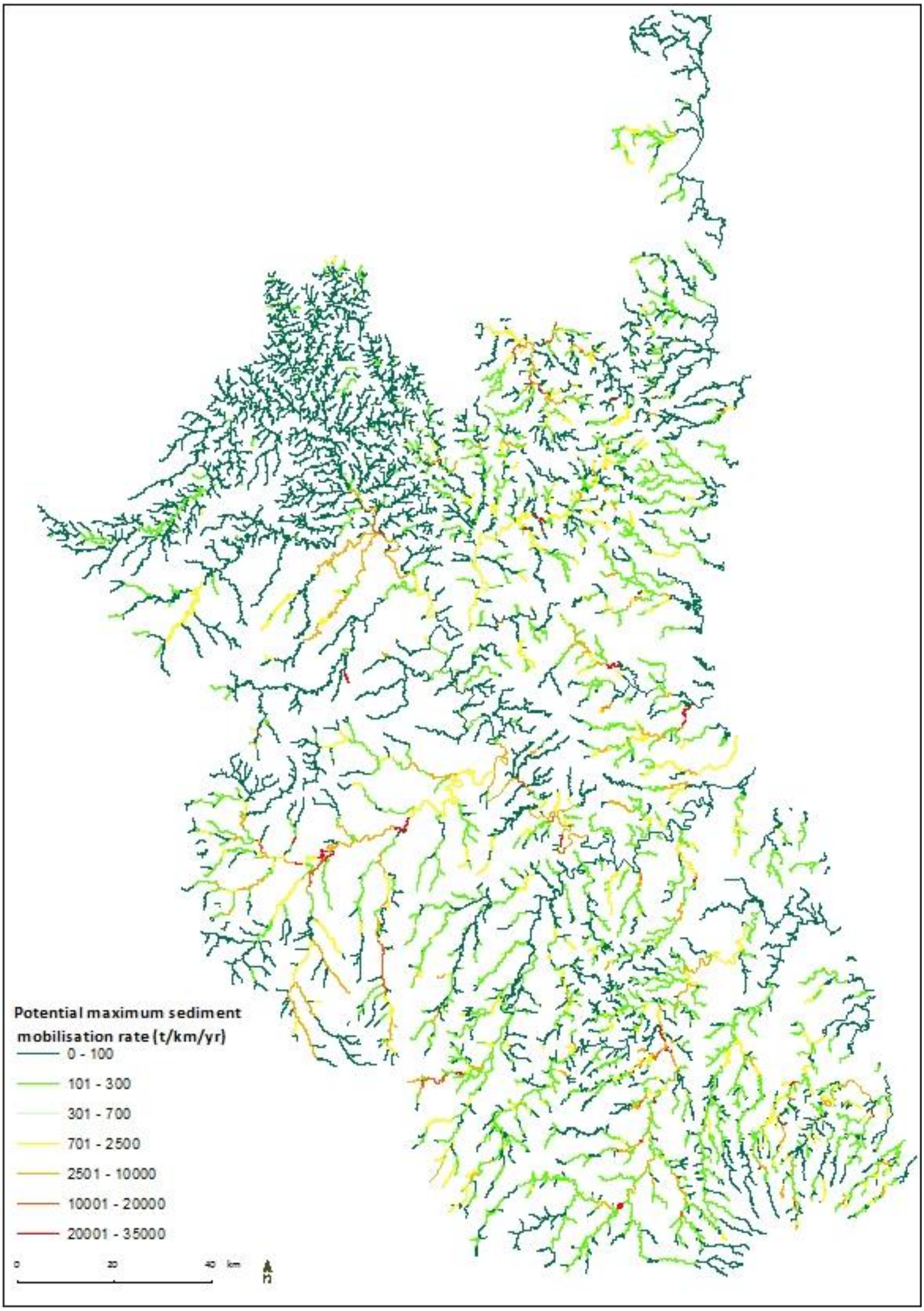


Figure 43. *Maximum sediment generation rate from channel erosion*

These sediment generation values could be considered as the likely channel sediment generation from minor events (minimum generation rate), or from extreme events (maximum generation rate), but obviously, this is highly dependent on the characteristics of the events themselves. For example, the 2011 and 2013 flood events resulted in high sediment generation in the Lockyer and Mid Brisbane catchments, and the Logan catchment, but the Cyclone Debbie event (i.e., heavy rainfall post Cyclone Debbie) focussed largely on the Logan-Albert catchments.

7.2 Full integration – potential approaches

Given the methods shown above, there are several approaches that could be used to integrate all of the assessments. These will be highly dependent on both the issues requiring the risk assessment and the locations where the assessments are to be quantified.

Three possible methods have been considered:

1. **Reach-scale:** summing the mass loads of sediment being delivered to each reach used in the channel erosion risk assessment. This would allow an understanding of the components of erosion that are likely to be the dominant source in each reach.

2. **Planning unit:** summing the mass loads for each sediment generation process to a planning unit or subcatchment. This would allow an understanding of the components or erosion that are likely to be the sources of sediment for regional spatial comparison.

3. **Risk-based:** representing all sediment generation processes as the risk only, coloured in a uniform fashion. This would allow a spatial understanding of where the highest forms of sediment generation are likely to be in any area across SEQ.

As an initial quantification method, the one most likely to provide a broad assessment would be where the Seqwater planning units are combined with the subcatchment layers used in current catchment modelling of SEQ, and then the quantities of each erosion risk is added up within the individual planning unit/subcatchment to allow a total mass load to be calculated. Steps in this process would be:

1. Prepare planning unit/subcatchment layer
2. Compile hillslope sediment delivery per planning unit
3. Derive factors to associate with point source likelihood
4. Multiply likelihood factors with point source consequence mass loads
5. Compile point source sediment delivery per planning unit
6. Calculate lengths of channel reaches in each planning unit
7. Multiply reach lengths by unit channel erosion rate per reach
8. Compile mass load of channel sediment delivery per planning unit

This would provide an indication of the sources of sediment for each planning unit/subcatchment across SEQ.

8 Conclusions and recommendations

This project has demonstrated that it is possible to derive sediment generation risks for hillslope, gullies, point sources and channels for all regions in SEQ. The combination of commonly accepted methods (e.g., RUSLE for hillslope) and newly derived methods have provided new insights into the spatial distribution and quantum of sediment potentially available for generation.

This work has generated a number of useful products, including the sediment generation risks, but also a compilation of the useful data sets and agreement on the appropriateness of these data sets for future sediment assessment works.

The project has also shown the benefits of a collaborative research style approach to this work that was flexible enough so that each partner was able to focus on elements that they were best able to deliver, but that we also learned from each partner in completing this work.

A number of recommendations were identified as part of the project. These included:

a) A commonly agreed dataset describing streams in SEQ was needed. Through analysis of all the data, the NRME stream layer provided the most suitable coverage for stream orders of 3 or greater, but there is still considerable uncertainty for stream orders 1 and 2.
b) High quality LiDAR data coverage is needed for all streams in SEQ. Currently reaches in the Upper Brisbane and Stanley Rivers are missing.
c) Regular LiDAR data collection is extremely useful for comparison of stream movement in the region and this should be continued as a priority.
d) Assessment of the fate of sediment once it is delivered to the stream is required in order to understand the roles of sediment fluxes during small and large events, including the impacts of different particle sizes and interaction of floodplains.
e) The results of these assessments can be included within updated models of streams and catchments across SEQ, though there may need to be further work to understand the uncertainties around the quantification of sediment loads derived in the integration steps.

Overall, the project was a valuable opportunity to build on the previous high quality research into sediment generation and delivery that has been undertaken in SEQ and it is hoped that this project demonstrated the practical application of that research and datasets that are currently available in the region.

9 Acronyms and Abbreviations

DNRME	Department of Natural Resources, Mines and Energy
ESC	Erosion and Sediment Control
ERA	Environmentally Relevant Activity
HLW	Healthy Land and Water
ISA	Integrated Sediment Assessment
LiDAR	Light Detection and Ranging
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
RUSLE	Revised Universal Soil Loss Equation
SEQ	South East Queensland
TSS	total suspended sediment
USLE	Universal Soil Loss Equation

t	tonnes
ha	hectares
m	metres

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[NHMRC, NRMMC] National Health and Medical Research Council, National Resource Management Ministerial Council (2011). Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

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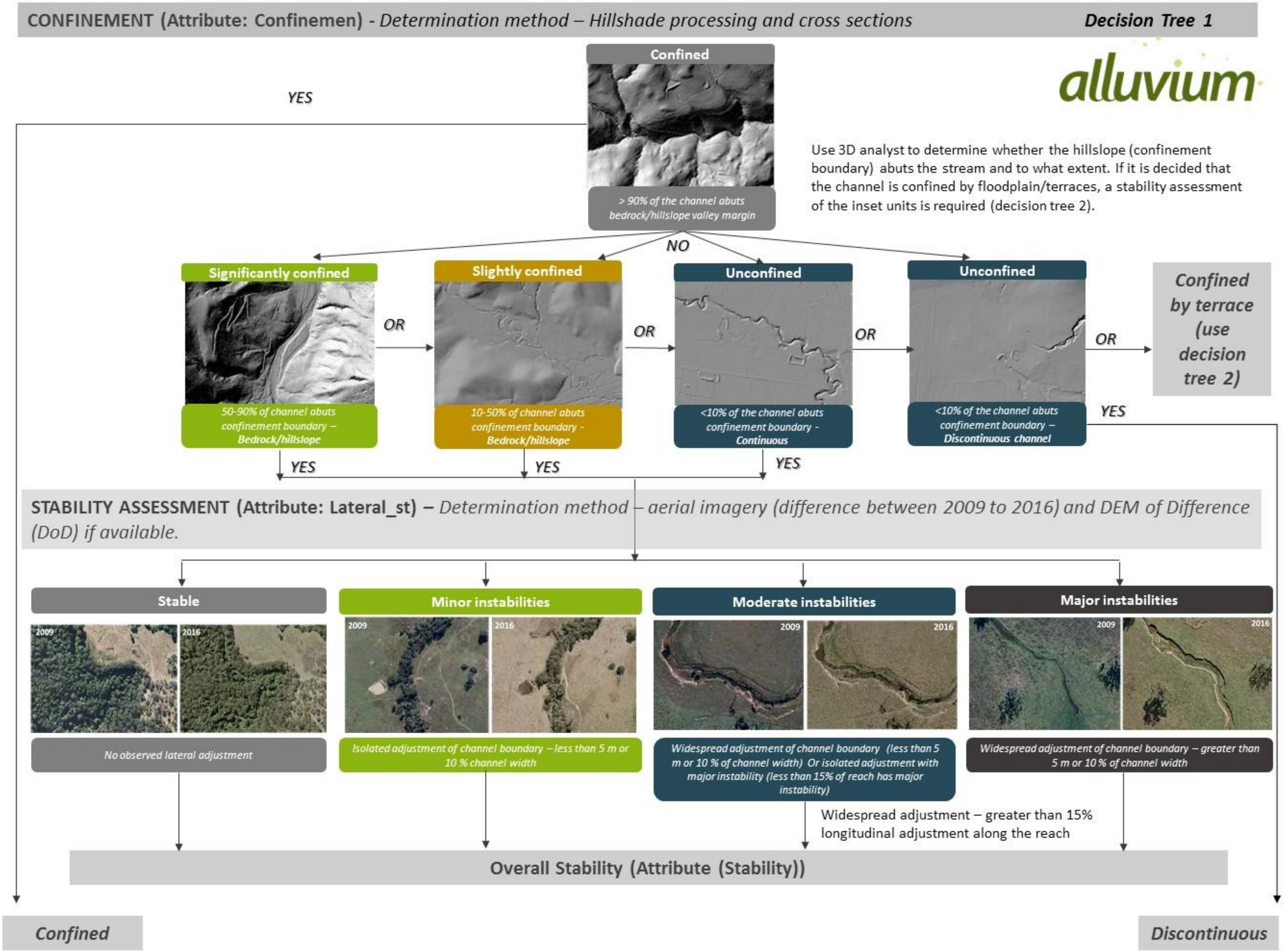
Attachment A
HLW Monitoring and Evaluation Steering Committee Members

Members of HLW Monitoring and Evaluation Steering Committee (as at January 2017)

First Name	Last Name	Organisation
Joshua	Baker	Scenic Rim Regional Council
Natalie	Baker	Brisbane City Council
Michael	Bartkow	Seqwater
Kaye	Cavanagh	Ipswich City Council
Jamie	Charlish	Brisbane City Council
Kylie	Crouch	Unitywater
Diana	Dawson	Council of Mayors
Jim (James)	Fewing	Department of Environment and Heritage Protection
Matthew	Griffiths	Department of Environment and Heritage Protection
Dominic	Groth	Gold Coast City Council
Anna	Hollingsworth	Gold Coast City Council
Mike	Holmes	Department of Science, Information Technology and Innovation
Cameron	Jackson	Qld Urban Utilities
Helena	Malawkin	Redland City Council
Paul	Maxwell	Healthy Land and Water
Andrew	McLaughlin	Scenic Rim Regional Council
Karen	McNeale	Redland City Council
Darren	McPherson	Somerset Regional Council
David	Moffat	Department of Science, Information Technology and Innovation
Michael	Newham	Department of Environment and Heritage
Cherie	O'Sullivan	Noosa Council
Barnaby	Resch	Logan City Council
John	Robertson	Department of Agriculture, Fisheries and Forestry
Mike	Ronan	Department of Environment and Heritage Protection
Leanne	Sommer	Moreton Bay Regional Council
Alan	Teague	Moreton Bay Regional Council
Cameron	Veal	Seqwater
Dale	Watson	Redland City Council
Graham	Webb	Sunshine Coast Regional Council
Patrina	Webb	Redland City Council
Belinda	Whelband	Lockyer Valley Regional Council

Attachment B
Channel erosion method decision tree

Attachment A



CONFINEMENT cont. (Floodplain/Terrace) - *Determination method – Hillshade processing and cross sections* ***Decision tree 2***

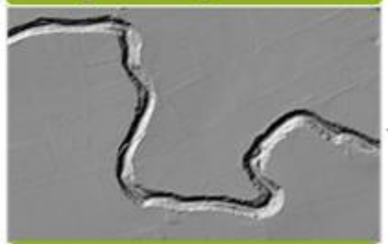
alluvium

Is it a "Floodplain/Terrace confined"?

- ✓ Has a macrochannel morphology i.e. bound by a high elevation depositional surface which is rarely inundated
- ✓ Depositional inset units within the macrochannel
- ✓ Dominant form of channel adjustment is from inset units
- ✓ Minimal evidence of lateral adjustment of macrochannel in contemporary timeframes

Confined by floodplain/terrace (from decision tree 1)

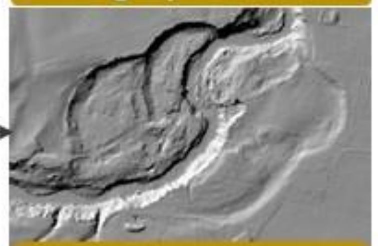
Significantly confined



50-90% of channel abuts confinement boundary

OR

Slightly confined



10 -50% of channel abuts confinement boundary

STABILITY ASSESSMENT (Attribute: Inset_st) – *Determination method – aerial imagery (2009 to 2016) and DoD if available. Focusing on the inset unit movement.*

Minor instabilities

Isolated adjustment of inset unit – less than 20 % of unit area

Moderate instabilities

Widespread adjustment of inset unit– less than 20 % of the unit area) Or isolated adjustment with major instability (less than 15% of reach has major instability)

Major instabilities

Widespread adjustment of the inset unit – greater than 20 % of the unit area

Widespread adjustment – greater than 15% longitudinal adjustment along the reach

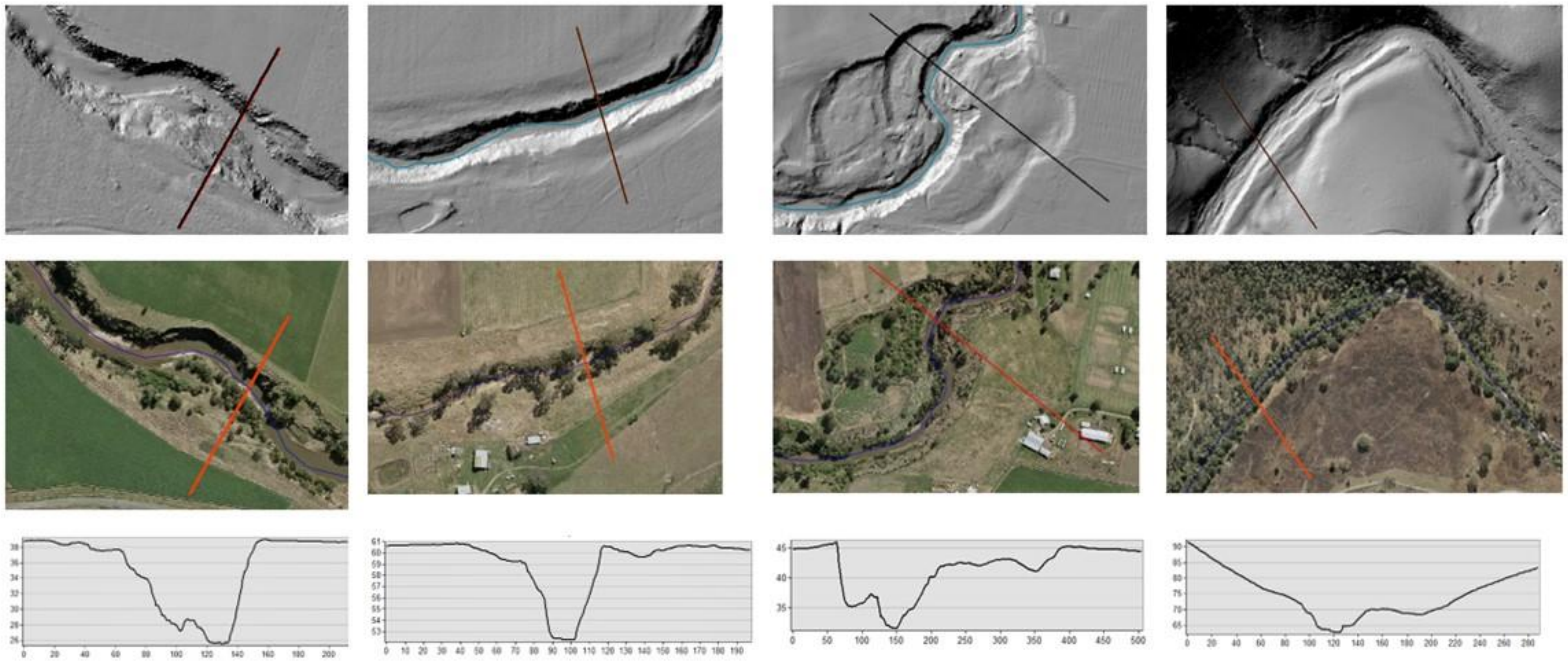
Overall Stability (Attribute (Stability)

SEDIMENT AVAILABILITY (Attribute: Erosion_w; Erosion_h)

Determination method – *Use 3D analyst to assess the bank unit height and width representative of the approximate volume (area under the curve) of* ***sediment available along each reach****. At least 5 cross sections along each reach were used to determine the representative height and width. Process results in EXCEL.*

3D Analyst

Significantly confined by floodplain/terraces (Logan River)	*Significantly confined by floodplain/terraces (Cannon Creek)*	*Slightly confined by floodplain/terraces (Logan River)*	*Significantly confined by hillslope (Allan Creek)*



Height: >5m	Height: >3-5m	Height: >5m	Height: >1-3m
Width: >50m	Width: >10-25m	Width: >50m	Width: >25-50m

EXCEL

	Bank unit height			
Bank unit width	0 to 1 m	>1 to 3 m	>3 to 5 m	>5 m
0 to 10 m	Low	Low	Moderate	High
>10 to 25 m	Low	Moderate	Moderate	High
>25 to 50 m	Moderate	Moderate	High	Very high
>50 m	Moderate	High	Very high	Very high

→ **Sediment Availability (Attribute: Sed_avail)**

CHANNEL EROSION MATRIX

Determination method – *Once confinement, stability and sediment availability are determined for each reach – process results through Channel Erosion Matrix. These results do not consider likely particle size unless Sediment Availability column is replaced by results from Fine Sediment Availability Matrix (see below).* ***EXCEL***

Overall Stability (Attribute (Stability)

Sediment Availability (Attribute: Sed_avail)

Reach scale sediment availability	Reach scale erosion potential: Stable	Minor	Moderate	Major
Low	Minor	Minor	Minor	Moderate
Moderate	Minor	Minor	Moderate	High
High	Minor	Moderate	High	Very high
Very high	Moderate	High	Very high	Very high

EROSION POTENTIAL

Lateral Stability	Inset Stability	Overall Stability	Erosion Potential *
Stable	n/a	Stable	Low
Minor instabilities	Minor instabilities	Minor	Moderate
Moderate instabilities	Moderate instabilities	Moderate	High
Major instabilities	Major instabilities	Major	Very High

* erosion potential is a predictive metric based on the assessment of stability between 2009 and 2016

FINE SEDIMENT AVAILABILITY

Determination method – *Buffer streams (125m) and use the ASRIS clay percentage layer to determine average clay percentage of each reach (note: clay layer resolution is poor across most of SEQ). Results from matrix can be reapplied to the Channel Erosion Matrix (above) to determine fine sediment channel erosion risk.*

EXCEL

Fsed Availability (Attribute: FSed_avail)

Sediment availability	Clay content: 0 - 20 %	20 - 35 %	35 - 50 %	> 50 %
Low	Low	Low	Moderate	Moderate
Moderate	Low	Moderate	Moderate	High
High	Moderate	Moderate	High	Very high
Very high	Moderate	High	Very high	Very high

Clay content	Category
0-20%	Low
21-35%	Moderate
36-50%	High
>50%	Very High

Attachment C
Field Verification Photos

Attachment B

Figure 44. *Mid Logan River – classified as significantly confined by floodplain/terrace with moderate instabilities in the inset units between 2009-2016 and no lateral movement in microchannel. Classification supported by field observations which indicated degraded inset units.*

Figure 45. *Knapps Creek – classified as significantly confined by floodplain/terrace with moderate instabilities of inset units between 2009-2016. Field verification indicated bank instabilities along the lower bank which comprised of inset benches and no lateral adjustment of macrochannel bank observed.*

Figure 46. *Knapps Creek – classified as significantly confined by floodplain/terrace with moderate instabilities of inset units and a isolated bank instabilities. Field verification identified degraded inset units and isolated bank instability at one site along the reach (~1m retreat between 2009 and 2016 based on aerial imagery – refer to* Figure 47*)*

Figure 47. *Knapps Creek – isolated bank instability along reach shown* in Figure 46 *– field observations verified minimal evidence of lateral adjustment of the channel apart from this isolated example*

Figure 48. *Christmas Creek – classified as significantly confined by floodplain/terrace with moderate instabilities of inset units. Field verification indicated bank instabilities along the lower bank which comprised of inset benches and no evidence of lateral adjustment of macrochannel bank.*

Figure 49. *Oakey Creek – classified as slightly confined by hillslope with major lateral instabilities. Classification supported by field observations which shows degraded banks on both side of the channel.*

Figure 50. *Allan Creek – classified as slightly confined – floodplain/terrace with moderate instabilities of inset units. Field verification indicated bank instabilities along the lower bank which comprised of inset benches and no observed lateral adjustment of macrochannel bank.*

Figure 51. *Burnett Creek – classified as significantly confined by floodplain/terrace with minor instabilities of inset units. Classification supported by field observations with only minor erosion of inset units observed.*

Figure 52. *Wallace Creek – classified as hillslope confined. High suspended solids potentially from gravel/dirt roads and moderate to high clay content in region based on ASRIS mapping. Reach classification supported by field observations.*

Figure 53. *Teviot Brook – classified as significantly confined by floodplain/terrace with minor instabilities of inset units. Reach classification supported by field observations.*

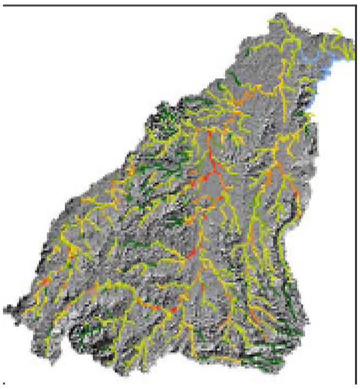
Figure 54. *Woolaman Creek – classified as significantly confined by floodplain/terrace with minor instabilities of inset units. Reach classification supported by field observations.*

Figure 55. *Canungra Creek – classified as significantly confined by hillslope with minor lateral instabilities. Reach classification supported by field observations.*

Attachment D
Channel erosion metadata

Attachment C

Logan/Albert Channel Erosion Assessment



Tags

There are no tags for this item.

Summary

Alluvium Consulting Australia was engaged by Seqwater and Healthy Land and Water to develop a method to assess channel erosion risk across South East Queensland as part of the Integrated Sediment Assessment project. The method has been applied at a reach scale for the Logan and Albert catchments. The approach develop is a higher level rapid desktop assessment with targeted field verification and includes reach scale erosion potential (stability) and potential sediment availability (width/height). The outputs are intended to help managers identify area at greater risk to target further investigation to inform on-ground managment responses. The outputs are not intended to directly inform on-ground managment effors, nor should they replace detailed site geomorphic and hydraulic assessments.

Description

Aim of the project was to determine reach scale fine sediment loads derived from channel erosion. **(RESULTS LAYER - Attribute: FineErosio - Reach scale fine sediment channel erosion risk assessment)**. This was dependent on two primary factors: 1) reach scale erosion potential and 2) reach scale sediment availability. The DNRM stream layer was used as the base layerr - Channel erosion assessment was undertaken on stream order >=3

1) Reach scale erosion potential:

The potential for erosion in future high flow events. This will be dependent on the geomorphic form (i.e. the type of stream) and condition along with a range of different hydrogeomorphic parameters (i.e. stream power, hydrology, channel resistance etc.). For this assessment, the observed channel change assessment between 2009 and 2016 (using high resolution aerial imagery) has been used as a surrogate for the reach scale erosion potential . Refer to project reports and decision tree for more details.

2) Potential Sediment Availability

The volume of fine sediment available to be eroded by channel erosion processes. This will be dependent on the fine sediment fraction (ASRIS clay percentage layer) in the channel and floodplain and the volume of alluvial deposits that are within the likely channel erodible zone (i.e. floodplain, benches, islands etc.) - erosion width and height determined from 1m LiDAR. Refer to project reports and decision tree for more details.

Refer to Decision Tree and Project Reports for more detailed methodology.

ATTRIBUTE DESCRIPTION:

lengthKM- length of reach (units - km)

Name - Creek name if available in DNRM layer

Confinemen- Reach scale confinement (refer to decision tree for more details)

Lateral_st - Lateral stability (hillslope/unconfined - refer to decision tree for more details)

Inset_st - Inset stability (floodplain/terrace confinement - refer to decision tree for more details)

Erosion_w - Representative reach erosion width potenital - refer to decision tree for more details)

Erosion_h- Representative reach erosion height potenital - refer to decision tree for more details)

Stability- Reach scale erosion potential based on aerial imagergy between 2009 - 2016 (wet period - refer to decison tree for more details)

Sed_avail - Reach scale sediment availability - refer to decision tree for more details

ErosionRis- Channel erosion risk assessment (all sediment - not considering clay content) - refer to decision tree for more details

Clay_con - Reach scale clay content - calculated using ASRIS clay percentage layer

FSed_avail- Fine Sediment Availability - calculated using ASRIS clay percentage layer and Sed_avail column - refer to decision tree for more details

FineErosio - Reach scale fine sediment channel erosion risk assessment

EroPoten - Erosion potential. Determined through stability assessment.

Credits
Alluvium Consulting Australia, Seqwater, Healthy Land and Water

Access and use limitations
There are no access and use limitations for this item.

Attachment E
Hillslope maps

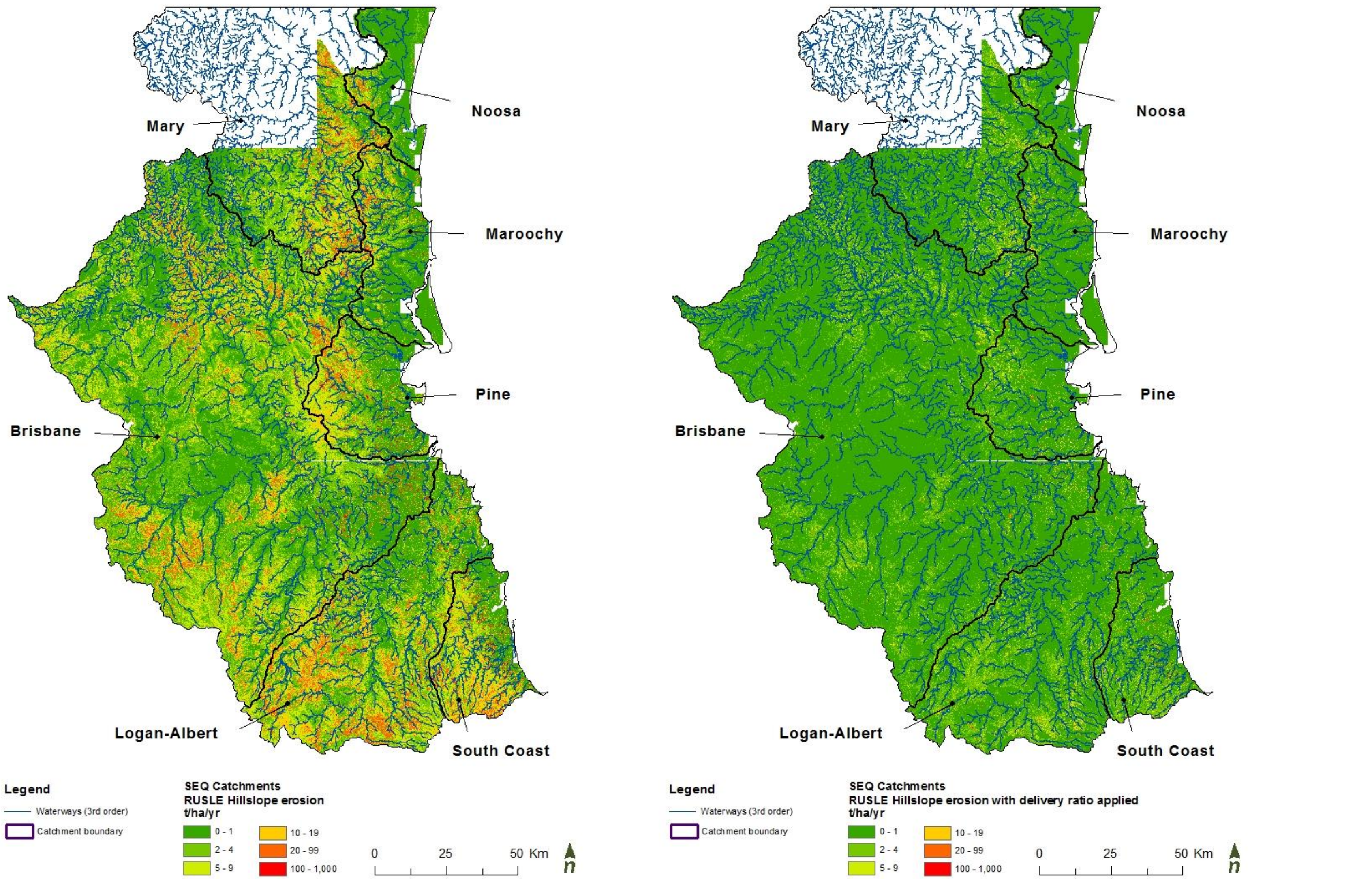
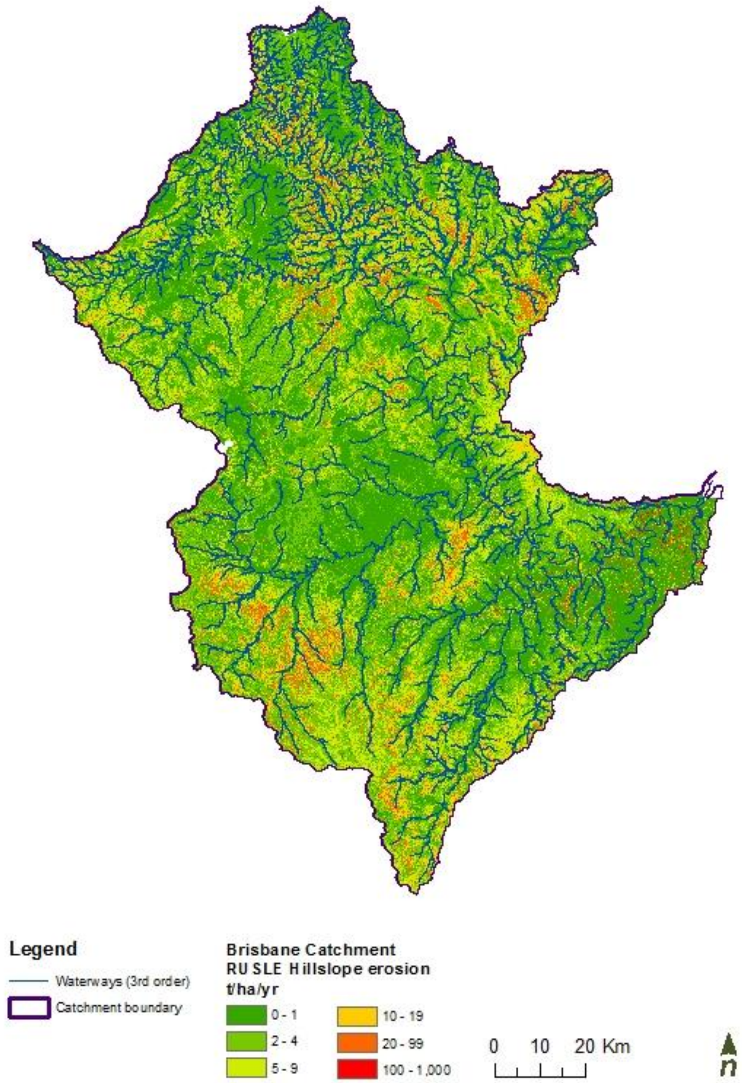


Figure 56. *SEQ catchments RUSLE hillslope erosion (left) with delivery ratio applied (right).*


Legend
Waterways (3rd order)
Catchment boundary
Brisbane Catchment
RUSLE Hillslope erosion
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0 10 20 Km

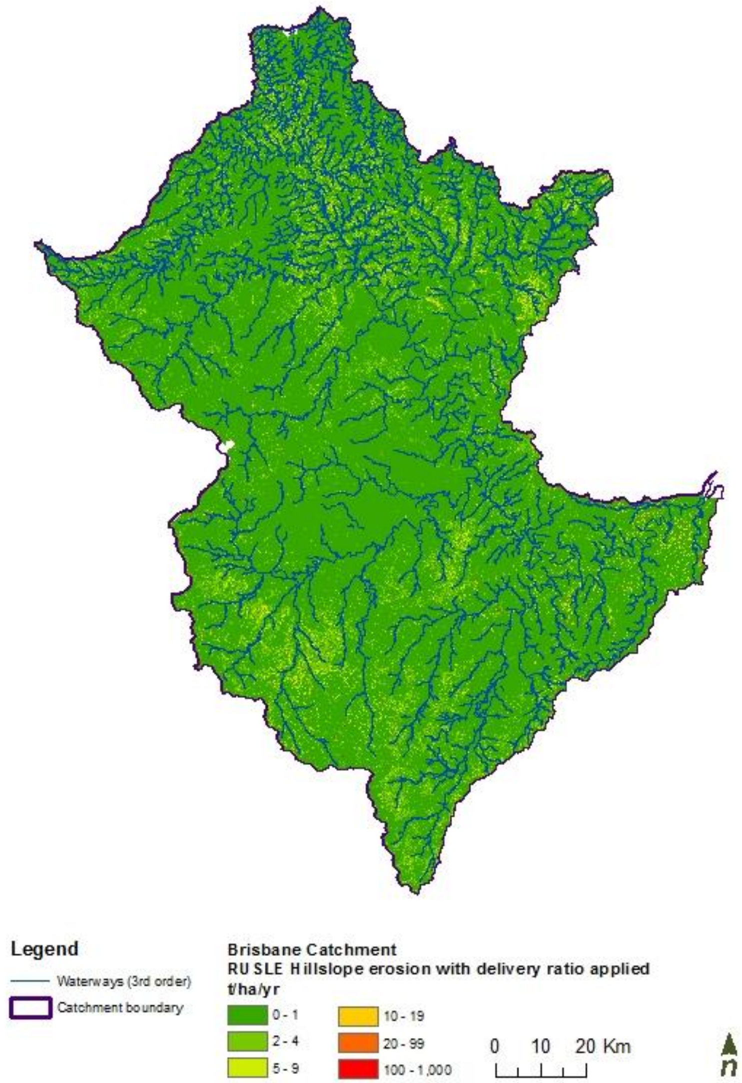
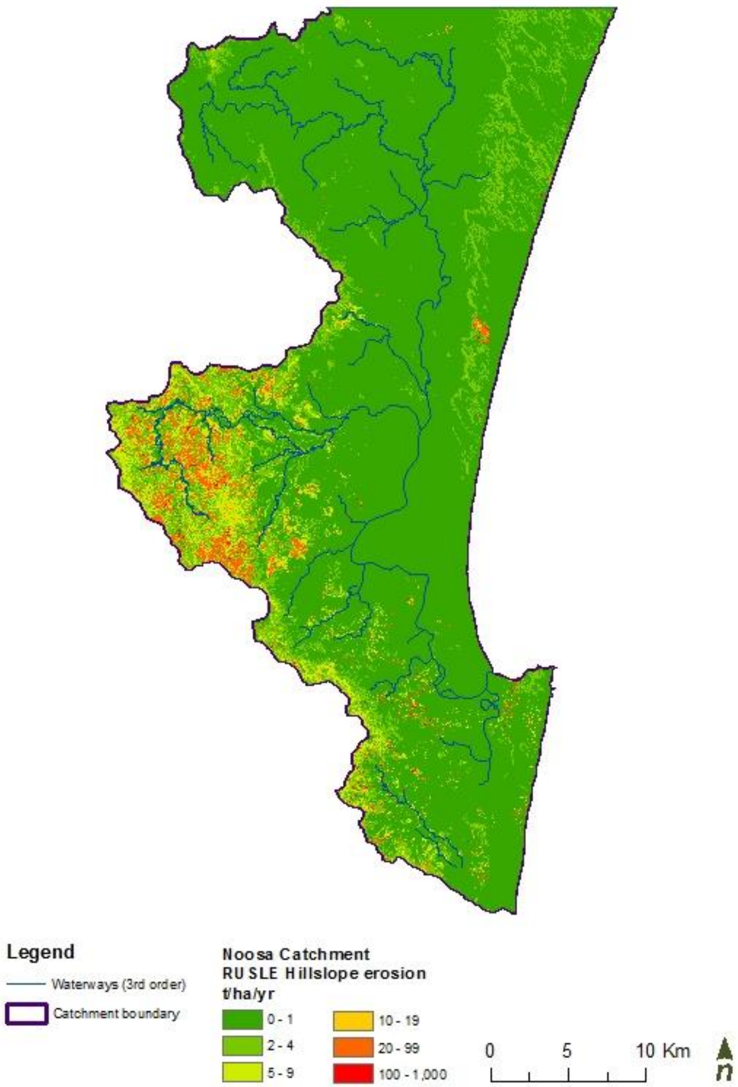

Legend
Waterways (3rd order)
Catchment boundary
Brisbane Catchment
RUSLE Hillslope erosion with delivery ratio applied
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0 10 20 Km

Figure 57. *Brisbane catchment RUSLE hillslope erosion (left) with delivery ratio applied (right)*


Legend
Waterways (3rd order)
Catchment boundary
Noosa Catchment
RUSLE Hillslope erosion
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0
5
10 Km

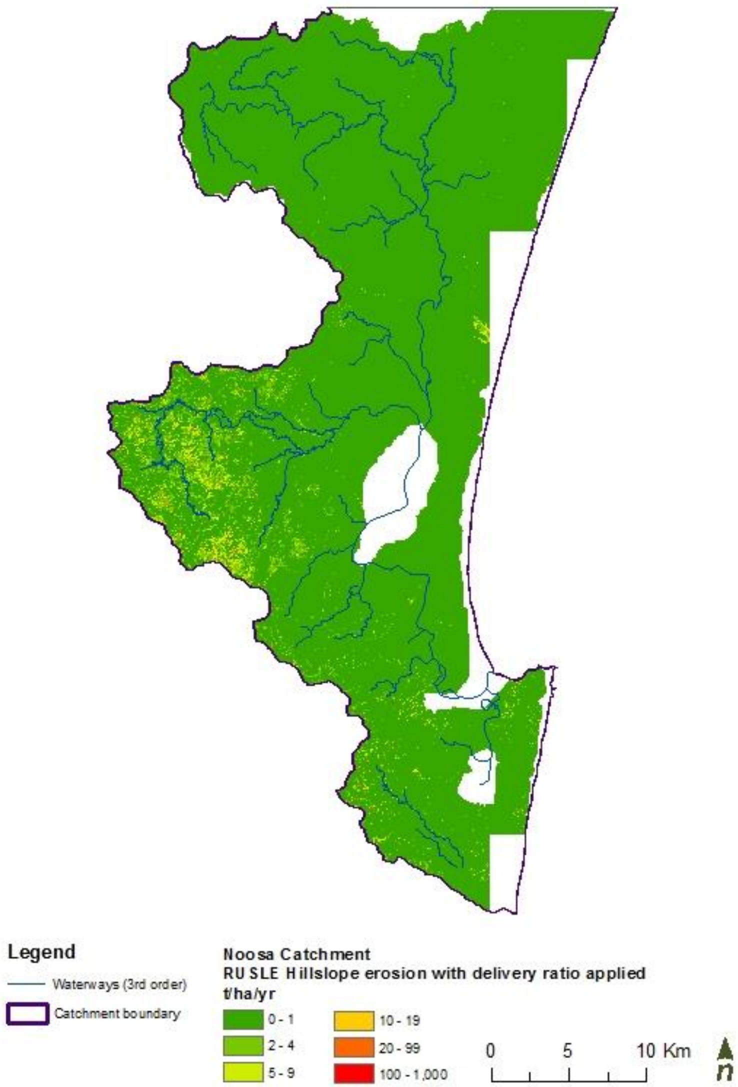

Legend
Waterways (3rd order)
Catchment boundary
Noosa Catchment
RUSLE Hillslope erosion with delivery ratio applied
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0
5
10 Km

Figure 58. *Noosa catchment RUSLE hillslope erosion (left) with delivery ratio applied (right)*

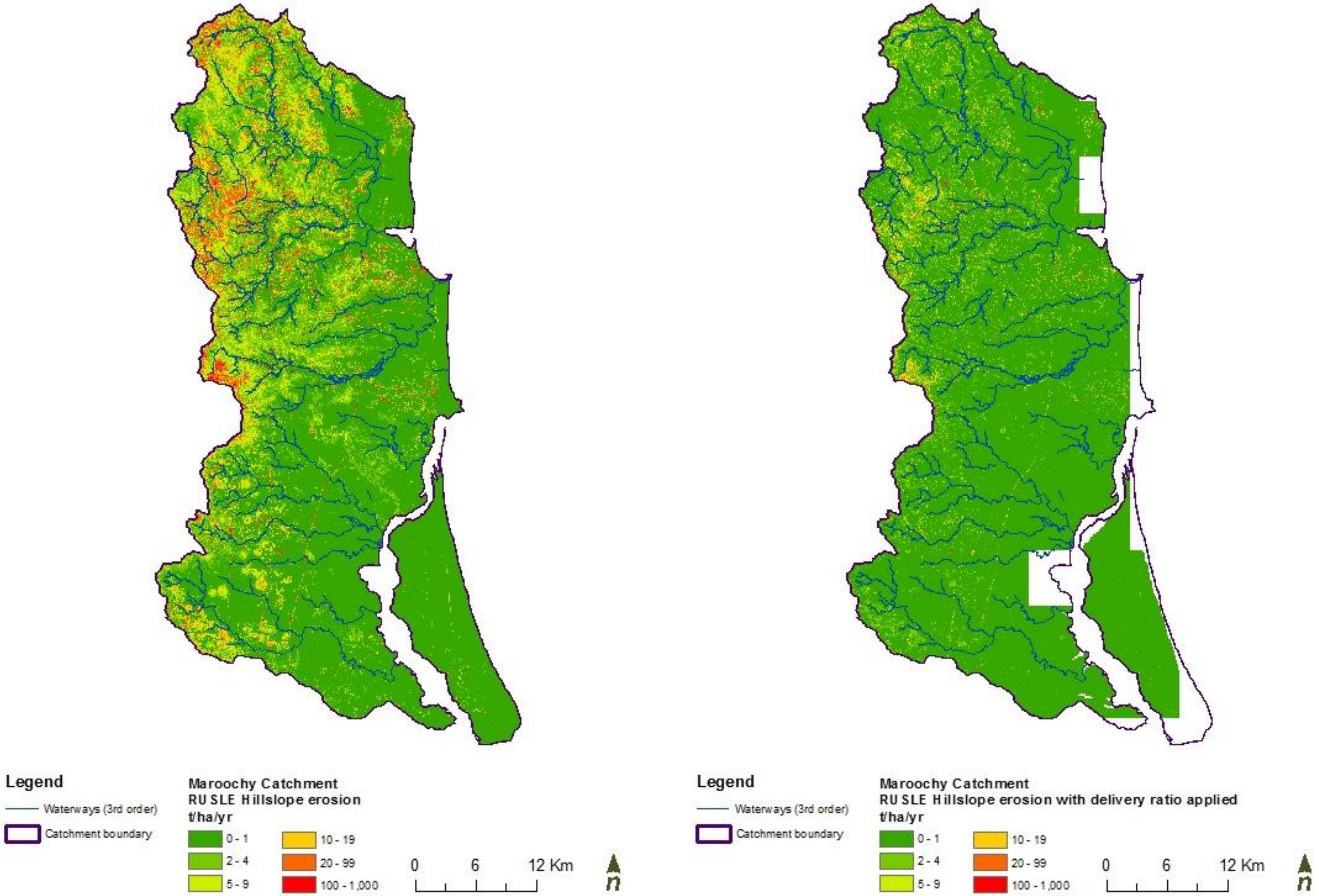
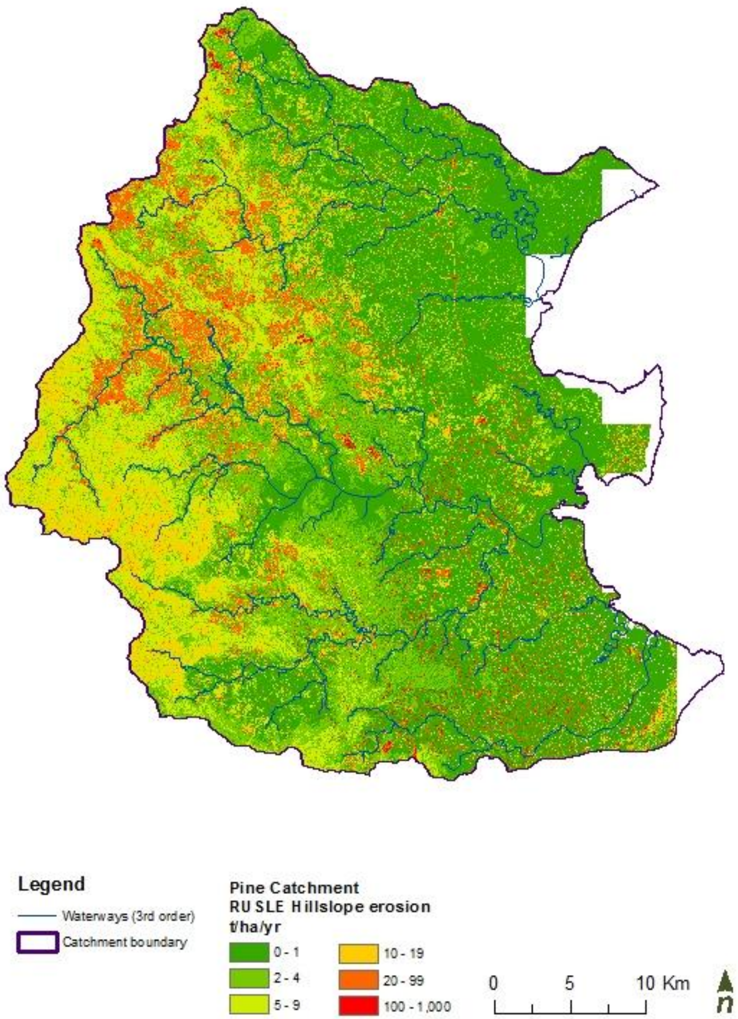


Figure 59. *Maroochy catchment RUSLE hillslope erosion (left) with delivery ratio applied (right).*


Legend
Waterways (3rd order)
Catchment boundary
Pine Catchment
RUSLE Hillslope erosion
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0
5
10 Km
n


Legend
Waterways (3rd order)
Catchment boundary
Pine Catchment
RUSLE Hillslope erosion with delivery ratio applied
t/ha/yr
0 - 1
2 - 4
5 - 9
10 - 19
20 - 99
100 - 1,000
0
5
10 Km
n

Figure 60. *Pine catchment RUSLE hillslope erosion (left) with delivery ratio applied (right).*

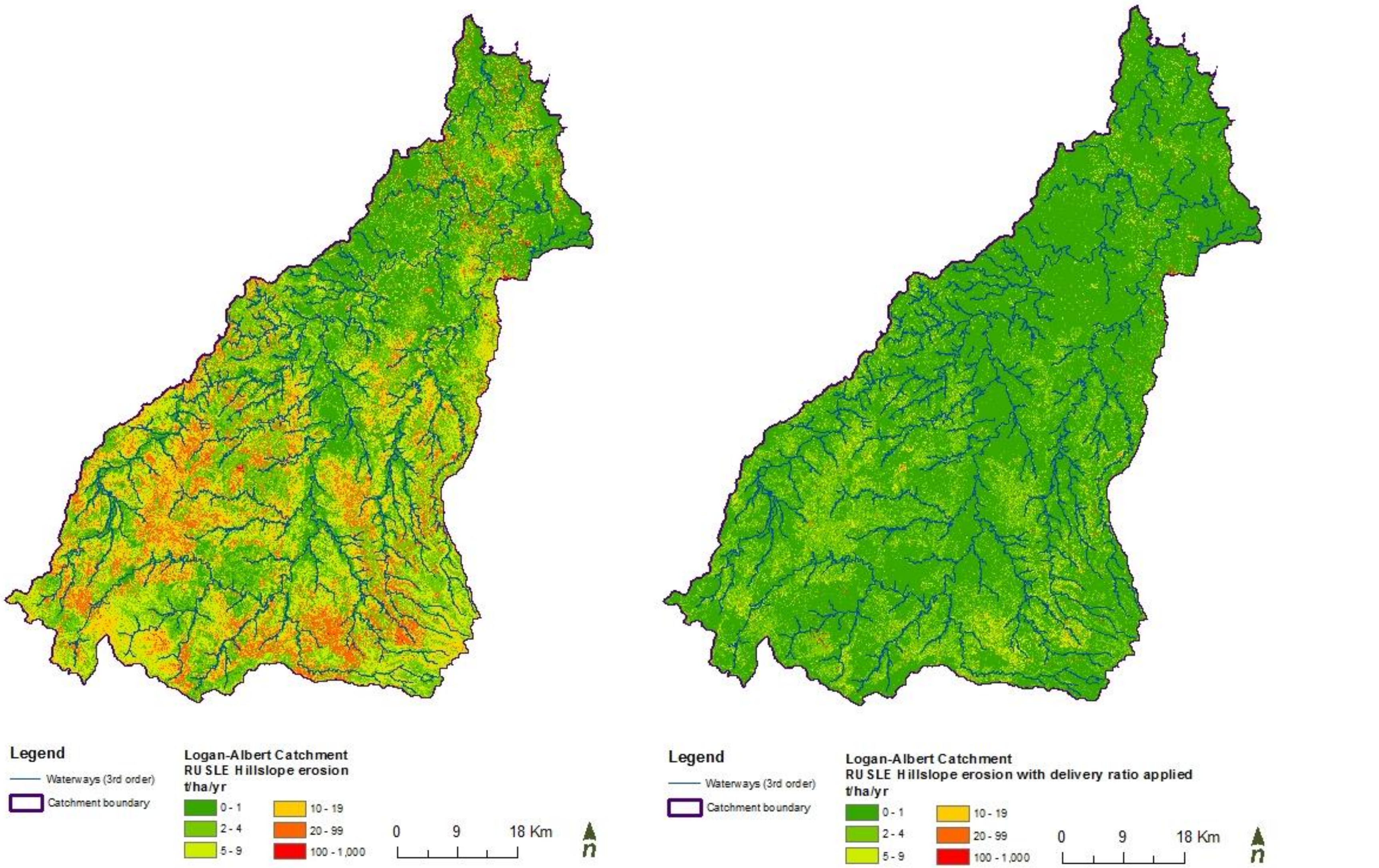


Figure 61 *Logan-Albert catchment RUSLE hillslope erosion (left) with delivery ratio applied (right)*

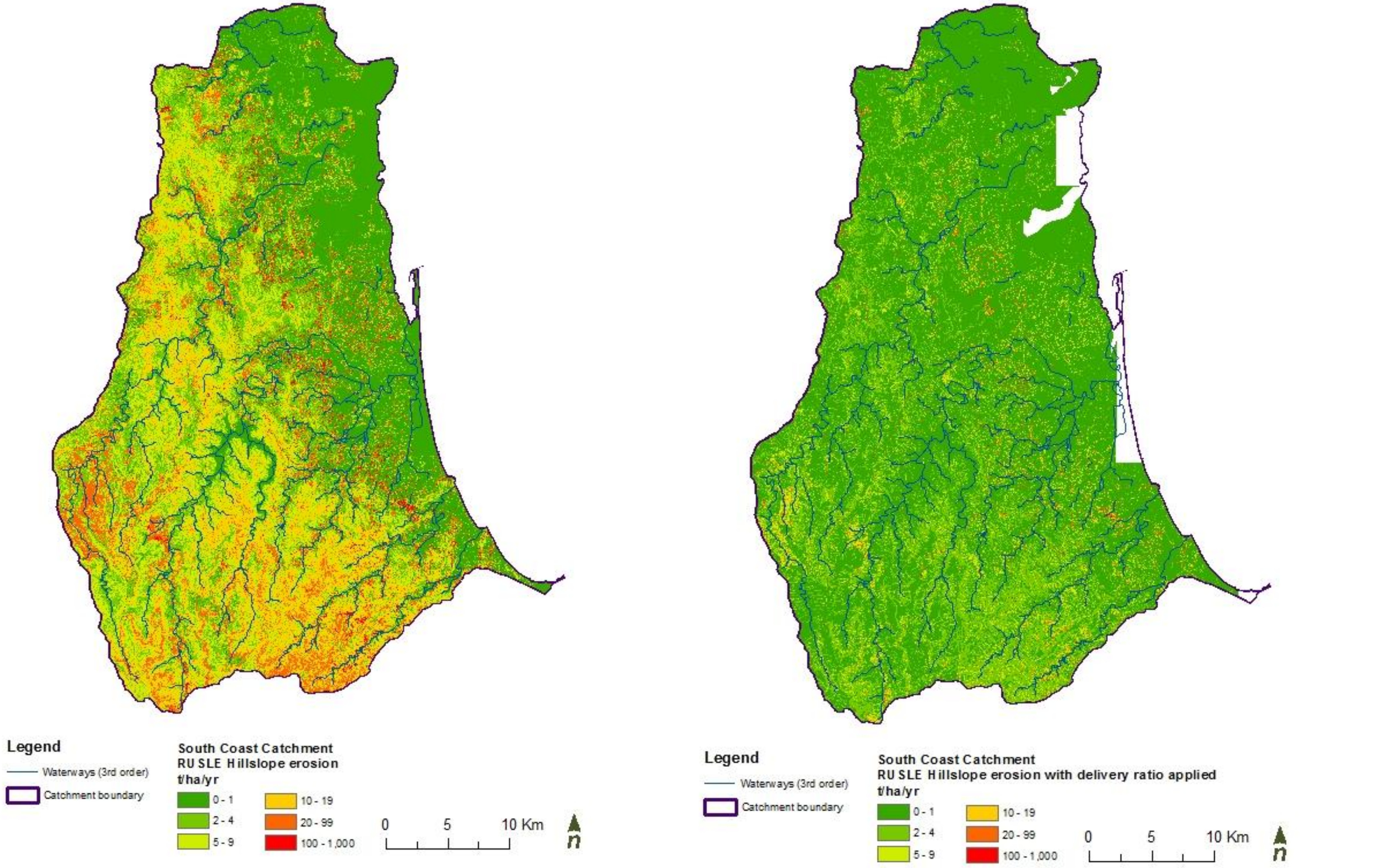


Figure 62. *South Coast catchment RUSLE hillslope erosion (left) with delivery ratio applied (right*

Attachment F
Datasets included in HLW data transfer

The following section include screenshots of datasets provided by Healthy Land Water in the data transfer (headings correspond with folder names)

Council data

BCC_QPP_BRISBANE_RIVER_CORRIDOR.CPG	Raster Dataset
BCC_QPP_BRISBANE_RIVER_CORRIDOR.shp	Shapefile
BCC_QPP_EROSION_STORM_TIDE.shp	Shapefile
BCC_QPP_FLOOD_PLAN_OVERLAND_FLOW.CPG	Raster Dataset
BCC_QPP_FLOOD_PLAN_OVERLAND_FLOW.shp	Shapefile
BCC_QPP_FLOOD_PLAN_RIVER.CPG	Raster Dataset
BCC_QPP_FLOOD_PLAN_RIVER.shp	Shapefile
BCC_QPP_LANDSLIDE.CPG	Raster Dataset
BCC_QPP_LANDSLIDE.shp	Shapefile
BCC_QPP_WATER_RESOURCE_CATCHMENT.shp	Shapefile
BCC_QPP_WATERWAY_CENTRELINE.CPG	Raster Dataset
BCC_QPP_WATERWAY_CENTRELINE.shp	Shapefile
BCC_QPP_WATERWAY_CORRIDORS.CPG	Raster Dataset
BCC_QPP_WATERWAY_CORRIDORS.shp	Shapefile
GCC_Watercourses_2016.shp	Shapefile
GCC_Waterwaysline.shp	Shapefile
ICC_Flood_Line_1_in_100_region.shp	Shapefile
ICC_Stream_Order_Catchments.shp	Shapefile
ICC_Stream_Order_Line.shp	Shapefile
ICC_Stream_Order_Polygon.shp	Shapefile
ICC_Urban_Stormwater_Flow_Path_region.shp	Shapefile
LCC_Env_Waterways_Centrelines_2015.shp	Shapefile
LCC_Env_Waterways_Topbank2015.shp	Shapefile
LCC_Flooding_Inundation_Areas.shp	Shapefile
LCC_Plan_LPS2015_Landslide_Slope_15percent_Plus.shp	Shapefile
LVRC_2013 Events Floodline Line.shp	Shapefile
LVRC_Creeks Polygon.shp	Shapefile
MBRC_DCWP_minorcatchments.shp	Shapefile
MBRC_Draft Ecological Stream Health Caboolture.lyr	Layer
MBRC_Draft Ecological Stream Health Caboolture.shp	Shapefile
MBRC_Planning_Scheme_Flood_Hazard_Overlay_June_...	Raster Dataset
MBRC_Planning_Scheme_Flood_Hazard_Overlay_June_...	Shapefile
MBRC_Planning_Scheme_Landslide_Hazard_Overlay.C...	Raster Dataset
MBRC_Planning_Scheme_Landslide_Hazard_Overlay.shp	Shapefile
MBRC_Planning_Scheme_Riparian_Wetland_Setbacks_...	Raster Dataset
MBRC_Planning_Scheme_Riparian_Wetland_Setbacks_...	Shapefile
MBRC_Planning_Scheme_Riparian_Wetland_Setbacks_...	Raster Dataset
MBRC_Planning_Scheme_Riparian_Wetland_Setbacks_...	Shapefile
MBRC_ripVeg_sept2010.shp	Shapefile
MBRC_Rivers_Creeks.CPG	Raster Dataset
MBRC_Rivers_Creeks.shp	Shapefile
MBRC_StreamOrders.shp	Shapefile
MBRC_waterbodies.shp	Shapefile
NC_DrainageLines_polyline.shp	Shapefile
NC_RiparianBufferAreas_region.shp	Shapefile
NC_SlideHazard_AllCombined_region.shp	Shapefile
NC_RiparianBufferAreas_region.shp	Shapefile
NC_SlideHazard_AllCombined_region.shp	Shapefile
NC_StreamsRivers_polyline.shp	Shapefile
RCC_CUL_URB_PLN_DRAINAGEBUF_P.shp	Shapefile
RCC_CUL_URB_PLN_FLOODPRONE_P.shp	Shapefile
RCC_Flood_Prone.shp	Shapefile
RCC_HYD_LND_WCS_REACHES_P.CPG	Raster Dataset
RCC_HYD_LND_WCS_REACHES_P.shp	Shapefile
RCC_HYD_LND_WCS_WATERWAYS_P.shp	Shapefile
RCC_Landslide.shp	Shapefile
SCC_PlanPSvec_OVJi_LandslideArea.shp	Shapefile
SCC_PlanPSvec_Waterbodies.shp	Shapefile
SCC_pub_PlanvecLanduseRural_2009.shp	Shapefile
SCC_Riparian_Buffers.shp	Shapefile
SCC_WatrvecWatercourses.shp	Shapefile

HLW data

SEQ_2009_Imagery	Folder
SEQ_Streams	Folder
SEQ_Waterways_2017	Folder
Channel Erosion Hazard.lyr	Layer
eroding_gullies_Merge_buf25m.shp	Shapefile
Erosion_Risk_Revised_rc2_hdsr2.img	Raster Dataset
Gully Erosion.lyr	Layer
Hillslope Hazard.lyr	Layer
Landcover (SPOT 2012).lyr	Layer
Landcover_2012.img	Raster Dataset
landcover_2012_impervious_rc2_Urban.img	Raster Dataset
Point_Sources_Greenfield_Development_Revised.img	Raster Dataset
point_sources_road_crossings.shp	Shapefile
Road Waterway Crossings.lyr	Layer
Roads_SDRN_2011_1_5_buffered_rc2_Urban.img	Raster Dataset
SEQ Growth Areas.lyr	Layer
streams_on_alluvium.shp	Shapefile
Urban Impervious.lyr	Layer
Urban Roads.lyr	Layer

SEQ 2009 imagery sub folder

Compression.JPG	Raster Dataset
Gold_Coast_15cm_mosaic_mga56_2.tab	Text File
Gold_Coast_15cm_mosaic_mga56_2009.ecw	Raster Dataset
Gold_Coast_15cm_mosaic_mga56_2009.ers	Raster Dataset
Gold_Coast_15cm_mosaic_mga56_2009.tab	Text File
Whole_SEQ_Project_Mosaic_MGA56.tab	Text File
Whole_SEQ_Project_Mosaic_MGA56_2009.ecw	Raster Dataset
Whole_SEQ_Project_Mosaic_MGA56_2009.ers	Raster Dataset

SEQ_streams sub folder – layers not used in assessment

SEQ_CAT_L2_V2_050607.tab	Text File
SEQ_CAT_L2_V2_050607_region.shp	Shapefile
SEQ_CAT_L3_V2_050607.tab	Text File
SEQ_CAT_L3_V2_050607_region.shp	Shapefile
SEQ_STR_L1_V2_050607.tab	Text File
SEQ_STR_L1_V2_050607_point.shp	Shapefile
SEQ_STR_L1_V2_050607_polyline.shp	Shapefile

SEQ_Waterways_2017 sub folder

BCC waterways example 1.jpg	Raster Dataset
BCC waterways example 2.jpg	Raster Dataset
BCC waterways example 3.jpg	Raster Dataset
BCC waterways example 4.jpg	Raster Dataset
BCC_QPP_WATERWAY_CENTRELINE.CPG	Raster Dataset
BCC_QPP_WATERWAY_CENTRELINE.shp	Shapefile
CoGC_Waterwaysline.shp	Shapefile
ICC waterways example 1.jpg	Raster Dataset
ICC waterways example 2.jpg	Raster Dataset
ICC waterways example 3.jpg	Raster Dataset
ICC waterways example 4.jpg	Raster Dataset
ICC waterways example 5.jpg	Raster Dataset
ICC waterways example 6.jpg	Raster Dataset
ICC_Stream_Order_Line.shp	Shapefile
LCC waterways example 1.jpg	Raster Dataset
LCC waterways example 2.jpg	Raster Dataset
LCC waterways example 3.jpg	Raster Dataset
LCC_Env_Waterways_Centrelines_2015.shp	Shapefile
MBRC waterways example 1.jpg	Raster Dataset
MBRC waterways example 2.jpg	Raster Dataset
MBRC waterways example 3.jpg	Raster Dataset
MBRC_StreamOrders.shp	Shapefile
RCC waterways example 1.jpg	Raster Dataset
RCC waterways example 2.jpg	Raster Dataset
RCC waterways example 3.jpg	Raster Dataset
RCC_HYD_LND_WCS_WATERWAYS_P.shp	Shapefile
SCC waterways example 1.jpg	Raster Dataset
SCC waterways example 2.jpg	Raster Dataset
SCC waterways example 3.jpg	Raster Dataset
SCC_WatrvecWatercourses.shp	Shapefile
waterway mapping.mxd	Map Document

Imagery folder

2016_aerial	Folder
Brisbane_2016_10cm_Mosaic_a.ecw	Raster Dataset
Brisbane_2016_10cm_Mosaic_a.ers	Raster Dataset
Brisbane_2016_10cm_Mosaic_a.tab	Text File
Gold_Coast_2016_10cm_Mosaic_a.ecw	Raster Dataset
Ipswich_2016_10cm_Mosaic_a.ecw	Raster Dataset
Ipswich_2016_10cm_Mosaic_a.ers	Raster Dataset
Ipswich_2016_10cm_Mosaic_a.tab	Text File
Logan_2016_10cm_Mosaic_a.ecw	Raster Dataset
Logan_2016_10cm_Mosaic_a.ers	Raster Dataset
Logan_2016_10cm_Mosaic_a.tab	Text File
Moreton_Bay_2016_10cm_Mosaic_a.ecw	Raster Dataset
Moreton_Bay_2016_10cm_Mosaic_a.ers	Raster Dataset
Moreton_Bay_2016_10cm_Mosaic_a.tab	Text File
Noosa_2016_10cm_Mosaic_a.ecw	Raster Dataset
Noosa_2016_10cm_Mosaic_a.tab	Text File
Redland_2016_10cm_Mosaic_a.ecw	Raster Dataset
Redland_2016_10cm_Mosaic_a.ers	Raster Dataset
Redland_2016_10cm_Mosaic_a.tab	Text File
Sunshine_Coast_2016_10cm_Mosaic_a.ecw	Raster Dataset
Sunshine_Coast_2016_10cm_Mosaic_a.ers	Raster Dataset
Sunshine_Coast_2016_10cm_Mosaic_a.tab	Text File

SEQ_Regional_2016_Centre_East_20cm_Mosaic_a.ecw	Raster Dataset
SEQ_Regional_2016_Centre_East_20cm_Mosaic_a.tab	Text File

LiDAR folder

Logan	Folder
UpperBris_andTribs_DEM_Mosaic	Folder
Brisbane_2014_Lidar_float.img	Raster Dataset
DNRM_Lidar_Project_Status_2016.xlsx	Excel File
esclidar14001	Raster Dataset
Gold_Coast_2014.img	Raster Dataset
Ipswich_Lidar_DEM_Float_2014.img	Raster Dataset
Lidar percent cover by catchment.csv	Text File
LidarExtentSEQ.shp	Shapefile
moreton_bay_2014_dem.img	Raster Dataset
noosa_gympie_lidarDEM_2015.img	Raster Dataset
redlands_lidarDEM_2014.img	Raster Dataset
Scenic_Rim_LiDAR_DEM_2011.img	Raster Dataset
SEQlidar_percent_extent.cpg	Raster Dataset
SEQlidar_percent_extent.shp	Shapefile
sr_dem_2011hs	Raster Dataset

SEQWater folder

Dam_Full_Supply_Level.shp	Shapefile
QBWSA_catchments_L2.shp	Shapefile
Water Storages.lyr	Layer
Water_Treatment_Plants.shp	Shapefile

State folder

Landuse (2009-2013).lyr	Layer
Landuse_2009to2013.shp	Shapefile
NRM_Detailed_SEQGeology.shp	Shapefile
NRM_SEQ_SoilProject_Data.shp	Shapefile
NRM_Watercourse_Lines_QBWSA_L2_Boundary.shp	Shapefile

Council Data

The data sets sourced from the SEQ councils and their intended use in the ISA erosion assessment are outlined below in Table 20.

Table 20. Datasets provided by SEQ councils

Data Custodian	Data Layer	ISA erosion assessment
Brisbane City Council	2014FINAL_2009FINAL1_Min_LoD_0.20.tif	Reviewed but not required in assessment
	BCC_impervious_surfaces.tif	Inform hillslope assessment
	PRP_WASTE_SITE_LL.shp	Inform Point Source assessment
	QPP_EROSION_SEA_LEVEL_RISE	Reviewed but not required in assessment
	QPP_EROSION_STORM_TIDE	Reviewed but not required in assessment
	QPP_ROAD_HIERARCHY	Inform hillslope assessment
	QPP_WATER_RESOURCE_CATCHMENT	Reviewed but not required in assessment
	QPP_WETLANDS	Inform hillslope assessment
	QPP_ZONING	Reviewed but not required in assessment
	QPP_FLOOD_PLAN_OVERLAND_FLOW.shp	Potentially inform connectivity
	QPP_FLOOD_PLAN_RIVER.shp	Reviewed but not required in assessment
	QPP_LANDSLIDE.shp	Reviewed but not required in assessment
	QPP_WATERWAY_CENTRELINE.shp	Used to inform combined SEQ stream layer
	QPP_WATERWAY_CORRIDORS.shp	Used to inform combined SEQ stream layer
City of Gold Coast	Flood_assessment_required.shp	Reviewed but not required in assessment
	Constructed_drainage.shp	Inform connectivity in urban areas
	Watercourses2016.shp	Used to inform combined SEQ stream layer
	Waterwaysline.shp	Used to inform combined SEQ stream layer
Ipswich City Council	Stream_Order_Catchments.shp	Used to inform combined SEQ stream layer
	Stream_Order_Line.shp	Used to inform combined SEQ stream layer
	Stream_Order_Polygon.shp	Used to inform combined SEQ stream layer
Logan City Council	Env_State_ERA_Lics_Reg	Inform Point source assessment

Data Custodian	Data Layer	ISA erosion assessment
	Env_Waterways_Centrelines2015	Used to inform combined SEQ stream layer
	Env_Waterways_Topbank2015	Used to inform combined SEQ stream layer
	Plan_LPS2015_Waterways_Erosion_Prone_Area.tab	Reviewed for consistency
	Waterway_Corridor.tab	Used to inform combined SEQ stream layer
	Plan_LPS2015_Landslide_Slope_15percent_Plus.shp	Reviewed for consistency
Moreton Bay Regional Council	MBRC_Planning_Scheme_Landslide_Hazard_Overlay.shp	Reviewed for consistency
	MBRC_Rivers_Creeks.shp	Used to inform combined SEQ stream layer
	MBRC_ripVeg_sept2010.shp	Used to inform the vegetation assessment part of channel erosion
	MBRC_Streams_Reaches.shp	Used to inform combined SEQ stream layer
	StreamHealth2010_UPDATED_WW_ID.shp	Reviewed but not required in assessment
	MBRC_StreamOrders.shp	Used to inform combined SEQ stream layer
Noosa City Council	DrainageLines_polyline.shp	Used to inform combined SEQ stream layer
	StreamsRivers_polyline.shp	Used to inform combined SEQ stream layer
Redlands City Council	HYD_LND_CAT_SUBCATCHMENTS_P	Used to inform combined SEQ stream layer
	HYD_LND_WCS_REACHES_P	Used to inform combined SEQ stream layer
	RCC_HYD_LND_WCS_WATERWAYS_P.shp	Used to inform combined SEQ stream layer
Sunshine Coast Council	PlanPSvec_OVJi_LandslideArea.shp	Reviewed for consistency
	PlanPSvec_SCRC_Waterways_Poly.shp	Used to inform combined SEQ stream layer
	Riparian_Buffers.shp	Reviewed for consistency
	WatrvecWatercourses.shp	Reviewed for consistency
Lockyer Valley Regional Council	LVRC_2013 Events Floodline Line	Reviewed but not required in assessment

Attachment G
Data for identifying potential point sources

Table 21. Data assessed for point sources

Point Source	Type	Land Characteristics	Dataset	Files
Aquatic Risk	Diffuse	QA dataset	Aquatic Conservation Assessment (QG ACA)	
Bare Slopes over 7° / Hillslope Erosion	Diffuse	Rural	Hillslope Risk / LiDAR Slope Hazard / Landslip Risk	BLHAS_Landslide_Hazard_ply.shp (Caboolture)
Cereals, sugar and cropping, Hay and silage	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Cleared areas 2010 to 2015	Diffuse	Rural	SLATS Clearing Polygons	
Geology - Highly erodible soil types	Diffuse	Rural	Detailed Geology (1:100,000) / Soil Data (SALI and Lithographic Summaries)	Detailed_SEQGeology_GDA94.shp; SOIL_STABILITY_SSC_POLYGON.shp (Caloundra)
Grazing modified pastures	Diffuse	Rural	Land Use Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Intensive horticulture	Diffuse	Rural	Land Use	LU_2011_2013_X_Merge.shp
Irrigated crops and fodder	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Irrigated fruits, nuts, vegetables and herbs, flowers and bulbs	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Irrigated modified pastures	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Irrigated plantation forestry	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Irrigated seasonal horticulture	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Irrigated turf farming	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Livestock grazing	Diffuse	Rural	Land Use	LU_2011_2013_X_Merge.shp
Non-vegetated/Urban, Urban	Diffuse	Urban	Landcover	lc2012_2014_05_02_cloudrevised_1.shp

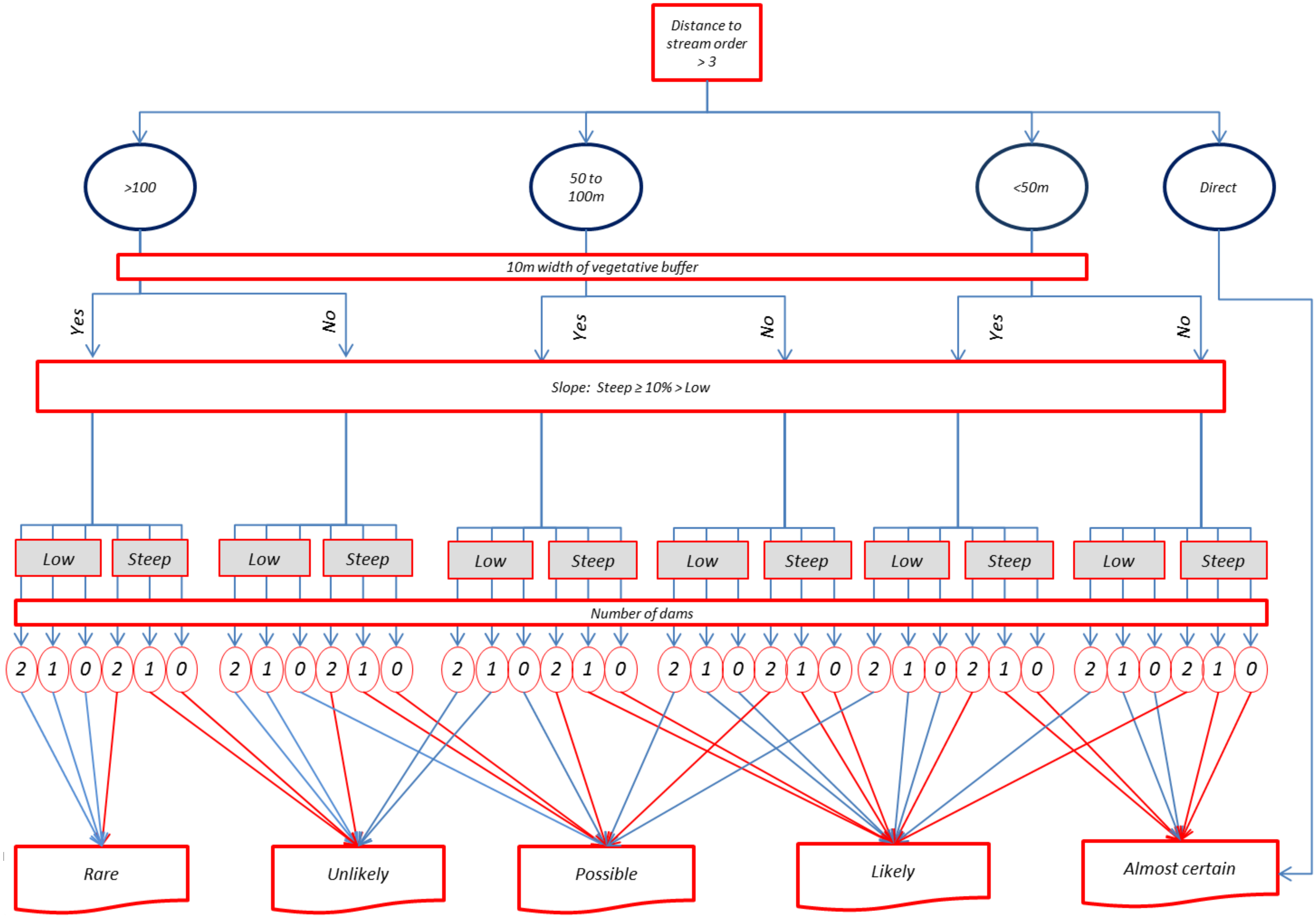
Point Source	Type	Land Characteristics	Dataset	Files
Footprint			Low Level of Protection Draft Land Use Categories	LOP_sml_Merge_Dissolve_SEQ.shp? Check version Proposed_Draft_SEQ_Regional_Land_Use_Category_changes_2016.shp
Perennial horticulture, fruits, nuts, vegetables and herbs, flowers and bulbs	Diffuse	Rural	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Water Quality Hotspots	Diffuse	QA dataset	Waters database	
Bare Ground	Diffuse	Rural	Bare Ground Index and Persistent Green	
Horse studs	Point	Rural	Land Use	LU_2011_2013_X_Merge.shp
Intensive animal production and husbandry, Poultry farms, Piggeries, Cattle feedlots	Point	Rural	Land Use / Agricultural Land Audit	LU_2011_2013_X_Merge.shp N:\Data\Agriculture\Agricultural_Land_Audit
Land in transition New residential areas (incl Construction Sites, Growth Areas, UDAs, SDAs)	Point	Urban	Land Use / Land Cover	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Abbatoirs (incl Stockyards/saleyards)	Point	Industry	Land Use	LU_2011_2013_X_Merge.shp
Dairy sheds and yards	Point	Rural	Land Use	LU_2011_2013_X_Merge.shp
Fire Hotspots and Burnt Areas (wildfires and unplanned)	Point	Rural	Fire Scars (DSITIA) / Sentinel Data (HWC Fire Density and Fire Hotspots)	
Gravel/unsealed roads	Point	Rural	State layer (SDRN intersect with Stream on high slopes)	
Industry and Impervious Surfaces	Point	Industry	Landcover / Landuse	
Landfill and Waste Transfer Stations (incl Waste treatment and disposal)	Point	Industry	Land Use	LU_2011_2013_X_Merge.shp
Mines and Mining, Quarries, KRA, KRA X	Point	Industry	Land Use / Land Cover / Key Resource Areas	LU_2011_2013_X_Merge.shp lc2012_2014_05_02_cloudrevised_1.shp
Poultry Farms (incl local and state data - see item 9)	Point	Industry	State and Local Government Mapping / State Land Audit	PoultryFarmLocations.shp

Attachment H
Literature used to determine point source likelihood and consequence

Table 22. Literature used to determine point source likelihood and consequence

Industry Type	Reference
All	Woerner and Lorimor. (2006). Alternative Treatments to Minimize Water Pollution From Open Animal Feedlots. *Iowa State University Extension*
	Yuan et al. (2009). A Review of Effectiveness of vegetative buffers on sediment trapping in agricultural areas. *Ecohydrology* 2, 321-336
Beef Feedlots / Dairies	Aarons and Gourley. (2012). The role of riparian buffer management in reducing off-site impacts from grazed dairy systems. *Renewable Agri. And Food Systems*, 28, 1-16
	Koelsch et al. (2006). Vegetative Treatment Systems for Management of Open Lot Runoff: Review of Literature. *App. Eng. In Agric.,* 22, 141-153
	Larney et al. (2014). Soluble salts, copper, zinc, and solids constituents in surface runoff from cattle manure compost windrows. *Can. J. Soil Sci.,* 94, 515-527
	McDowell et al. (2005). Restricting the grazing time of Cattle to decrease phosphorus, sediment and E. coli losses in overland flow from cropland. *Aus. J. Soil Res.,* 43, 61-66
	National Guidelines for Beef Cattle Feedlots in Australia, 3rd Edition. (2012).*Meat and Livestock Australia Limited.*
	Rahman et al. (2013). Performance Evaluation of Three Vegetative Filter Strip Designs for Controlling Feedlot Runoff Pollution. *J. Civil Environ. Eng.,* 3, 124-133
	Birchall et al. (2008). Effluent and Manure Management Database for the Australian Dairy Industry. *Dairy Australia*
Poultry	Gerber et al. (2008). Poultry production and the environment – a review. *Proceedings of the International Conference Poultry in the Twenty-First Century: Avian Influenza and Beyond.*
	McGahan et al. (2014). National Environmental Management System for the Meat Chicken Industry, Version 2. *Rural Industries Research and Development Corporation,* RIRDC Publication No 14/100, RIRDC Project No PRJ-005765
	Skunca et al. (2015). Environmental Performance of the Poultry Meat Chain – LCA Approach. *Procedia Food Sci.* 5, 258-261
Equine	Bott et al. (2013). Production and Environmental Implications of Equine Grazing. *J. Equine Vet. Sci.,* 33, 1031-1043
	Nicholson and Murphy. (2005). Assessment of Best Management Practices For Equestrian Facilities in the Tomales Bay Watershed*. Marin County Stormwater Pollution Prevention Program.*

Attachment I
Likelihood framework decision tree



Distance to stream order > 3
>100
50 to 100m
<50m
Direct
10m width of vegetative buffer
Yes
No
Yes
No
Yes
No
Slope: Steep ≥ 10% > Low
Low
Steep
Low
Steep
Low
Steep
Low
Steep
Low
Steep
Low
Steep
Number of dams
2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0 2 1 0
Rare
Unlikely
Possible
Likely
Almost certain

Attachment J
Literature review – extract from erosion and sediment control business case

Literature Review

1.1 Background

The availability of literature with regards to sediment export and treatment measure efficacy in construction site sediment management is relatively sparse, however several papers contain information regarding typical construction site loads during runoff events. In some cases, these also focus on the application of management techniques and studies of their efficacy.

For this review, eleven papers were identified with a range of applicability to this study. These varied from rainfall simulation on different construction soils (Pudisaini et al. 2004), through to analysis of the reduction in sediment loads from application of composts to bare soil (Faucette et al. 2005). Six papers were directly related to sediment generated from construction sites and potential efficacy of management actions.

The key objective in reviewing these papers was to identify estimates of sediment export rates from land and infrastructure development, including resolving differences between total sediment and suspended sediment export, temporal variability in sediment generation (as construction progresses) and any relationships related to the scale of development.

Note that where sediment is referred to in the text, it is as total sediment load unless otherwise specifically noted.

1.2 Sediment Generation Rates

It would appear that the sediment export rates from construction sites are highly variable as would be expected. Pudisaini et al. (2004) stated a range of sediment export of 50-500t/ha/yr from background literature assessment with individual plot exports of 0.9-10.8t/ha per individual runoff event.

In an assessment of experimental plots on actual construction sites across China, Wang et al. (2012) measured an average sediment export rate of 441.4t/ha/yr, which was 7,456 times higher than that measured from native vegetation (0.06t/ha/yr). Major variables in export were related to:

- Vegetation cover;
- Engineering methods in construction;
- Rainfall erodibility index of the soil;
- Slope;
- Organic matter content of the soil;
- Original land use; and
- Soil lithology.

A study of two small scale construction sites in Wisconsin, as reported in USGS (2000), measured an average of 0.948 t/ha of per individual runoff event for Total Solids, which was approximately equal to 22.8t/ha/yr, assuming the data represented in the paper included all measured runoff events over a 12 month period.

In a similar study, Faucette et al. (2005) noted that soil loss from construction sites was 10-20 times greater than that of agricultural lands and approximately 200 times greater than forested land use. Export rates stated in a review of literature in that paper noted soil loss rates of 0.36t/ha/yr for forest, 5.5t/ha/yr for agricultural lands and 73.3t/ha/yr for construction sites. Measured data from an assessment of the performance of using compost to reduce erosion showed that bare soil export rates of 54.6 t/ha per event after three months were being obtained. This suggests that source exhaustion of sediment load was not occurring, and once exposed, soil loss rates are likely to be

Gardner (2010) measured sediment exported into a branch of Whalley Creek near Nambour in SEQ from Heritage Heights, a 9ha urban subdivision in steeper land at Burnside. Using surveyed cross-sections of the creek, an estimated 1600m^3 of sediment was deposited in the branch of the creek. Using a bulk density of 1.6t/m^3, this was equivalent to 2,560t of sediment, or 285t/ha from the development over an 18-24 month period. This represents one of the few documented measurements of total sediment, however it is not known what proportion of total sediment exported from the development this represented (i.e., what proportion was not deposited but flowed downstream into Whalley Creek).

Brisbane City Council (1999, 2005) completed a surface water runoff monitoring program over a residential development site at Cannon Hill. As far as was determined by site visits, no apparent erosion and sediment control (ESC) was in place during the development. From the raw data presented, the measured export rates ranged from 0.036-44.4t/ha per event, with a total of 101.5t/ha over a 12 month monitoring period. Further data collection summarised in the 2005 report provided log-normal distributions of event concentrations. We used this data in a MUSIC (Model for Urban Stormwater Improvement Conceptualisation) model for a five year rainfall period in Brisbane to approximate an annual export rate. The results of this simple modelling approach yielded an export rate of 31.17t/ha/yr. This is based on TSS export only, not total sediment.

A summary of the available information is presented in Table 23. Note that these rates are for unmitigated constructions sites in all cases (no ESC in place).

Table 23. Unmitigated Construction Site Sediment Export Rate Summary

Reference	Landuse	Scale	Average Total Sediment Export Rate (t/ha)	Time Period
Pudisaini et al. 2004	not specified	400m^2	3.82	per event
Faucette et al. 2005	Urban	4.8m^2	54.6	per event
Faucette et al. 2005	not specified	not specified	73.3	per year
Wang et al. 2013	Infrastructure	30-300m^2	441.4	per year
USGS 2000	Commercial	6960m^2	0.948	per event
USGS 2000	Residential	1375m^2	0.067	per event
USGS 2000	Commercial	6960m^2	22.8	per year (assumes all events captured)
Gardner 2010	Residential	9ha (steep)	285	18-24 months
BCC SW Monit 99/00	Residential	17ha	4.73	per event *NB based on TSS measurements*
BCC SW Monit 99/00	Residential	17ha	101	over 1 year (assumes all events captured) *NB based on TSS measurements*

Reference	Landuse	Scale	Average Total Sediment Export Rate (t/ha)	Time Period
BCC SW Monit 2005/6 +MUSIC modelling	Residential	17ha	31.2	per year *NB based on TSS measurements*

As can be seen from the above, there is little correlation between scale or land use vs sediment export, however it does show that the variability is high as expected. The ranges presented in Chapter 4 based on using the Revised Universal Soil Loss Equation (RUSLE) would indicate sediment generation rates in the order of 48-248 t/ha/yr. Note that this does not account for losses in delivery of sediment to a waterway. Typically in models, sediment delivery ratios of 10% are used, that is, 10% of the sediment generated is actually exported from a site. This would suggest that a value of 31.2 t/ha/yr as derived from the BCC program would be the most suitable figure in SEQ, though this is based on TSS measurements only. Higher values would be typical where higher rainfall intensities were expected, as illustrated by Gardner (2010) which was collected from a high rainfall region. For tropical climates then, estimated sediment export rates of 100 t/ha/yr are likely to be more typical (based on the 1 year BCC (2000) value, an assumed export rate of 143 t/ha/yr from Gardner 2010 and consistent with the order of magnitude of the remaining values. Again, site specific studies may provide better estimates.

The literature also indicates the magnitude of increase of sediment export from undisturbed sites to construction runoff is between 200 – 7500 times. This would indicate that the influence of construction runoff in terms of sediment delivery is always likely to be significant and therefore significant downstream waterway impact would be expected to occur whenever construction is occurring in a catchment if ESC measures are not present. With ESC in place, the magnitude of loads are such that very high efficiency measures are likely to be required in order to reduce the loads to an acceptable level.

1.3 Event Runoff Concentrations

Several of the publications noted above also contain information of storm event runoff concentrations measured during construction works or as part of other literature reviews. For example, in USGS (2000), a range of values were presented for both the commercial and residential construction sites. During the active construction phase of the commercial construction site, an average Total Suspended Solids (TSS) runoff concentration of 14,702 mg/L was measured, with 2,388 mg/L coming from the active residential construction phase. It was also noted that there was no direct correlation with first flush runoff in terms of the elevated concentrations noted. Both total solids and TSS were measured, with an average of 97% of the total solids being suspended solids.

Faucette et al. (2005) noted that TSS concentrations of 355 mg/L were recorded immediately downstream of a construction site. While not explicitly stated, given that the study was focussed on mitigating bare soil sediment export, it was assumed that no ESC measures were in place on the construction site measured.

In measuring the performance of grassed filter strips treating synthetic construction site runoff in Malaysia, Fulazzaky et al. (2013) prepared runoff with concentrations of 1180 mg/L, however whether this is directly relevant to real construction site runoff is not known as no measurements of actual construction site runoff in Malaysia were presented.

Ridley (2012) presented information on the performance of a range of sediment basins in New Zealand obtained TSS concentrations in inflows to the basins ranging from 810 – 47,000 mg/L with an average of 11,500 mg/L on an urban construction site. Again, no specific information was presented on whether ESC measures were in place other than the sediment basins, however imagery from the site appeared to show no other treatments were implemented.

In another study examining the impacts of construction and operation of a highway, Barrett et al. (1995) noted that TSS in untreated runoff may exceed 3,000 mg/L and noted that downstream of highway construction with extensive erosion and sediment control measures (mostly rock berms and silt fences), TSS concentrations still increased 5 fold from 34.8 to 179 mg/L. Observed data also indicated that silt and clay particles comprised 92% of the total suspended solids load.

One of the more comprehensive datasets was from another study measuring the performance of high efficiency sediment basins in New Zealand as reported in Auckland Regional Council (2004) measured concentrations in the inflow to sediment basins of TSS ranging from 128 – 28,800 mg/L with an average of 7,600 mg/L. No other ESC measures were in place from observations of imagery of the sites

Similarly, Brisbane City Council (2005) measured concentrations from 890 – 12,800 mg/L of TSS during a period assumed to be the most active construction phase of a residential development site, with a flow weighted event mean concentration of 5,341 mg/L for the period being monitored. As far as was determined by site visits, no apparent ESC was in place during the development.

In measurements of event runoff in the Townsville – Thuringowa Region in North Queensland undertaken by Liessman et al. (2009) from the Australian Centre for Tropical Freshwater Research, median values downstream of two developing urban sites sites were 278 and 351 mg/L, however opportunistic sampling from additional developing urban sites yielded a peak TSS concentration in excess of 30,000 mg/L which was stated as being the highest ever recorded in any study in the Great Barrier Reef Region.

The values obtained from the literature are summarised in Table 24.

Table 24. Unmitigated Construction Site Event Runoff TSS Concentrations

Reference	Landuse	Scale	Mean TSS (mg/L)	Notes
USGS 2000	Commercial	6960 m^2	14,702	monitored
USGS 2000	Residential	1375 m^2	2,388	monitored
Faucette et al. 2005	not specified	not specified	355	referenced
Fulazzaky et al. 2013	not specified	not specified	1,180	synthesised
Ridley 2012	Urban	not specified	11,500	monitored
Barrett 1995	Highway	not specified	3,000	monitored
Auckland Regional Council 2004	Urban	not specified	7,600	monitored
Liessman et al. 2009	Urban	not specified	278 (median)	monitored
Liessman et al. 2009	Urban	not specified	351 (median)	monitored
Brisbane City Council 2005	Urban	17 ha	5,341	monitored (flow weighted mean)

Again, as for the sediment export rates, it is obvious that there is considerable variability in the values available in the literature. However, given the range of factors that can affect event runoff, this is to be expected. Overall though, there is generally good agreement between those sites which have reported monitored values, suggesting that event mean concentrations in the range of 2,500 – 15,000 mg/L would be expected in most construction site runoff. Within Queensland, the Brisbane City Council (2005) data appears to be the most relevant such that for unmitigated construction site runoff, a value of 5,300 mg/L of TSS is appropriate as this is consistent with the magnitude of TSS concentrations reported in the literature and is based on locally relevant monitoring data. As for sediment export, locally derived TSS concentrations may provide additional certainty, though given the variability present in the data, any monitoring is also likely to be subject to the same variability.

Several of the papers reviewed were primarily focussed on quantifying the performance of treatment measures for erosion and sediment control management. Perhaps the most comprehensive review of the performance of a range of measures was presented in Barrett et al. (1995). This found that rock berms and silt fences were the most common measures being used for highway construction erosion and sediment control, though sediment ponds were determined as being the inexpensive control on a cost per area basis, with erosion control blankets being the most expensive. Field evaluation of silt fences showed a median total sediment removal of 0% through filtration alone (particle settling behind the silt fence was not measured), such that upstream and downstream of the silt fence the concentrations did not vary, however the settling of coarse particles by slowing down of the flow can be one of the key ways of reducing total sediment load. They also found that the median TSS concentration downstream of a silt fence was 500mg/L with the majority of the efficiency of sediment removal dependent on the detention time of the runoff upstream of the control. Monitoring of a rock berm also showed negligible TSS removal. Poor maintenance, including holes in the silt fences and "under runs" where the fence was bypassed by flow underneath the fence due to poor installation, plus openings for high flows often actually promoted erosion downstream. This was as a corollary to flume studies which demonstrated removals from 68-90% in terms of total sediment for silt fences. This is consistent with silt fences removing coarser particles though not being effective for silts and clays (fine particles). The term silt fence is therefore misleading perhaps and their use as a sediment fence is probably more aligned with their actual function.

Fulazzaky et al. (2013) also reported the performance of grass filter strips treating synthetic construction site runoff with an average reduction of 63.4% for TSS. For differing slopes and flow rates, the performance of filter strips designed for a five minute resident time and 10cm of grass depth averaged reductions of between 62.5-88.2%. This compared well with a review of performance from other literature sources within that paper, which documented that catch basin inserts had a TSS removal of 10-42%, silt fences 69.6%, wet ponds 93% and skimmer basins 99.6%.

In reviewing the performance of different compost/mulch mixtures on erosion, Faucette et al. (2005) showed that a compost/mulch cover had sediment export rates 99.7% lower than bare soil after a three month period, with a hydroseeded area flowing through a mulch berm showing 98.5% lower export and 96% when the hydroseeded area flowed through a silt fence.

Ridley (2012) measured the effectiveness of optimised sediment basins with chemical dosing, bed load forebays and in-pond baffles for a residential construction site in NZ. The performance of the basins showed removal rates for TSS averaging 98.8% with outflow concentrations from the basin ranging from 16-38 mg/L. Ridley (2012) noted that non-structural controls and active management of contract staff were perhaps as critical as the structural controls in maintaining effective treatment of the construction site.

A very similar study was conducted by Auckland Regional Council (2004) on the use of high efficiency sediment basins using Poly Aluminium Chloride (PAC) as a coagulant as part of sediment controls on a large motorway project. This showed TSS removal rates of between 92-99.9% with TSS outflow concentrations from the basins ranging from 3-996 mg/L.

A summary of the performance characteristics noted in the literature is shown in

Table 25.

Table 25 Erosion and Sediment Controls Performance

Treatment Measure	Reference	% removal	TSS or Sediment	Notes
Silt fence	Barrett et al. 1995	0	Sediment	Field measurement (compromised implementation)
Silt fence	Barrett et al. 1995	68 - 90	Sediment	Flume studies
Silt fence	Fuzalakky et al. 2013	69.6	TSS	Referenced in paper
Rock berm	Barrett et al. 1995	Negligible	Sediment	Field measurement
Grass filter strip	Fuzalakky et al. 2013	62.5 – 88.2	TSS	Field experiments
Catch basin insert	Fuzalakky et al. 2013	10 – 42	TSS	Referenced in paper
Wet pond	Fuzalakky et al. 2013	93%	TSS	Referenced in paper
Skimmer basin	Fuzalakky et al. 2013	99.6	TSS	Referenced in paper
Compost/mulch cover	Faucette et al. 2005	99.7	Sediment	Field measurement
Hydroseed / mulch berm	Faucette et al. 2005	98.5	Sediment	Field measurement
Hydroseed / silt fence	Faucette et al. 2005	96	Sediment	Field measurement
Optimised sediment basin with chemical dosing	Ridley 2012	98.8	TSS	Field measurement
High efficiency sediment basin with chemical dosing	Auckland Regional Council	92 – 99.9	TSS	Field measurement

Overall, it is quite apparent that enhanced sediment basins with chemical control demonstrate the highest potential reduction of TSS in construction site runoff, and lead to a significant reduction in total suspended solids. Other measures as noted above, especially erosion controls such as the compost/mulch cover are also especially effective at reducing sediment loads from construction sites. There is still some evidence to suggest that some measures do not perform well if not properly installed (e.g., silt fences) so a focus on implementation measures and capacity building in the industry would appear warranted. In some cases it was noted that high concentrations of turbidity were still observed downstream and this indicates that the purpose of ESC measures is to minimise environmental harm though unless care is taken, it may not completely prevent it. In cases where very sensitive receiving environments exist, it may be that other controls (such as staging of works in dry weather, immediate ground cover reinstatement etc) may also be required to ensure sufficient protection and further studies and research on the practicalities and effectiveness of this are required, as there was no formal literature studies on this that were able to be found.

From this literature review it is also obvious that there are limited studies on the overall implementation of ESC measures with some studies indicating significant differences between field and experimental studies and the importance of non-structural controls in addition to structural measures. This would show that some research focus on the application and degree of implementation compliance with “good practice” would be warranted and justifies further studies on auditing ESC measures.