

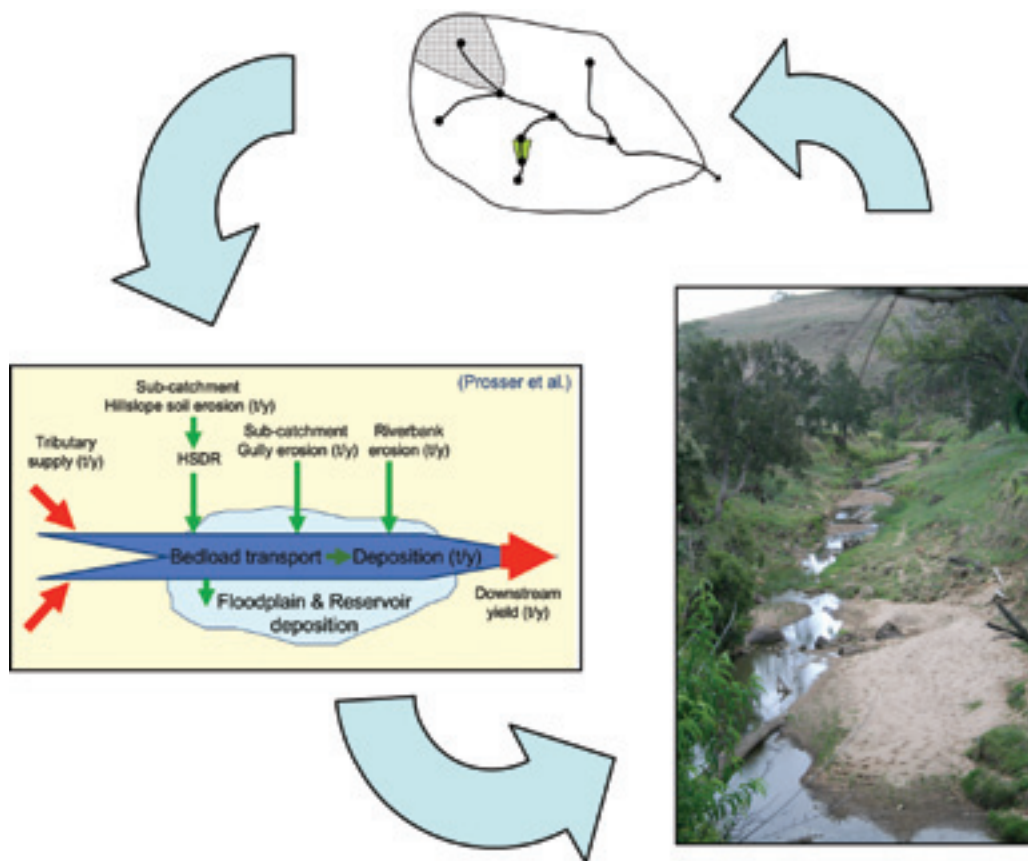
Healthy Country

managing the land for healthy waterways

Healthy Country Project Phase 1 Report: Monitoring and evaluation of restoration activities in three SEQ focal catchments

October 2009





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eWater Cooperative Research Centre in SE Queensland

This project is being undertaken as part of the eWater Cooperative Research Centre activities in SE Queensland. The eWater CRC was established in July 2005, the result of a merger between two former Cooperative Research Centres – the CRC for Catchment Hydrology and the CRC for Freshwater Ecology. Both CRCs had been operating since the early 1990s, notably with considerable research activity in SEQ, and provided the eWater CRC with a foundation of well-established science and a team of enthusiastic and experienced people. The eWater CRC retains strong partnerships established by its predecessor CRCs and incorporates a number of new participant organisations with new skill bases, end-user networks, intellectual property and specialist knowledge.

The eWater CRC has a directive to focus significant research resources into the SEQ region to support existing water quality and aquatic ecosystem health initiatives. This directive is a component of the eWater CRC research program to coordinate activities into four major research projects throughout Australia. Integration of the eWater CRC research program for SEQ with the Healthy Country project is an excellent opportunity to build on a significant State Government funded initiative, which addresses the erosion processes occurring in the upper catchments of SEQ that are responsible for the decline in both water quality and aquatic ecosystem health.

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1. Background

Southeast Queensland (SEQ) has one of the fastest growing populations in Australia, currently standing at 2.73 million people. By 2026 this is expected to increase to around 4 million people with much of this growth targeted to occur in the Logan-Albert catchments and along the Western Corridor passing through the Bremer and Lockyer catchments. This growth will bring further significant pressures to the health of the region's waterways, which is already a cause for concern. Non-urban diffuse source pollutant loads have been identified in the SEQ Healthy Waterways Strategy, 2007-2012 (SEQ HWS) to be a major contributor to poor water quality and aquatic ecosystem health in both fresh-water and estuarine/marine systems. The SEQ HWS includes an action plan to address non-urban diffuse sources in the catchments, which sets an overall target of "By 2026 non-urban diffuse source pollutant loads entering receiving waters will be reduced by 50 percent and in-stream ecosystem health will improve in targeted catchments." Modelling indicates that a 50 percent reduction in sediment export can be achieved through restoring about 20 percent of the total stream network at a cost of ~\$350M (McAlister and Weber 2004).

Interim management action targets (MATs) have been developed within the non-urban diffuse source pollutant loads action plan that are applicable across a 1-5yr timeframe. MATs contribute to progress toward longer term targets such as the action plan target, which has a 25yrs or more time frame.

The Healthy Country project aims to implement components of the following MATs in progress toward achieving the 50% reduction in diffuse source pollutant loads and improved in-stream ecosystem health in targeted catchments:

1. By 2012, efficient and cost-effective management programs to address major sources of sediment (including channel and hillslope erosion) of non-urban diffuse loads have been identified, developed and where possible, implemented.
2. By 2012 relevant and effective Best Management Practices (BMPs) for reducing non-urban diffuse source pollution have been developed.

The Healthy Country project is a Queensland Government funded 'proof of concept' initiative to demonstrate that bringing together the best science, planning and on ground implementation can significantly reduce non-urban diffuse source pollutants entering the waterways. It started in January 2008 with an \$8 million investment to address erosion in the south-east Queensland region by targeting and trialing restoration activities in three priority subcatchments within the Bremer and Logan Rivers and Lockyer Creek catchments. The three focal subcatchments are in the upper Lockyer Creek, in the upper Bremer River and Knapp Creek in the Logan-Albert River. Project partners include the SEQ Healthy Waterways Partnership (SEQ HWP), SEQ Catchments Ltd, Queensland Primary Industries and Fisheries (QPIF), Department of Employment, Economic Development and Innovation and the SEQ Traditional Owners Alliance (SEQTOA). As part of the project, three focal catchments (Figure 1) have been selected to develop appropriate rehabilitation tools and techniques for the region. Key outputs include: (i) the development of methods to determine the primary sediment and nutrient sources, (ii) the design of tools that can be used to specify what works should occur where, (iii) the trial of different rehabilitation methods and (iv) the development of methods to monitor, evaluate and adapt land and waterways management actions.

2. Purpose and Context of Monitoring and Evaluation Strategy

Purpose: This document provides guidelines for monitoring and assessment of the planned rehabilitation activities in the three focal catchments. The full extent and location of specific rehabilitation work is not confirmed at this time, hence specific recommendations, such as precisely where to locate sample sites, cannot be provided. However, some general principles, or rules of thumb are provided to aid in the selection of the most representative and environmentally appropriate sites.

Context:

There are two key areas associated with catchment-scale rehabilitation projects that have significant knowledge gaps. A regional-scale understanding of processes that lead to sediment and nutrient export from a catchment and a local-scale recognition of the effectiveness of management interventions at reducing sediment and nutrient load movement from a catchment. In order to further our understanding of these components within the timeframe of the Healthy Country project the monitoring and evaluation strategy has been developed to address these knowledge gaps through the use of monitoring methods that will generate applicable data within 1-3yrs. The context of each monitoring method is broadly represented in Table 1. Monitoring activities that address the regional process understanding component will be undertaken primarily by eWater CRC in conjunction with Griffith University. These data will be utilised in catchment models to determine priority areas for rehabilitation given the inherent risk of sediment export from each main erosion process, ie channel/bank or hillslope. Monitoring activities that address the question of local-scale management intervention effectiveness will be undertaken by a combination of resources as detailed in Table 1. These data will be used to develop understanding and experience in designing appropriate rehabilitation techniques for south east Queensland systems and for further parameterisation of the catchment models.

The current project funding for monitoring and evaluation activities is limited and so a prioritisation of monitoring is detailed in Table 1, along with an indication of where additional funding could be applied if resourced. It is anticipated that a steering group for monitoring and evaluation activities will be formed from project partners to ensure a coordinated approach to these activities.

Table 1: Summary of monitoring activities and associated application, available resources and costs

	DATA APPLICATION	CURRENT RESOURCES	POSSIBLE RESOURCES	PRIORITY	COSTING NOTES	DATA HOSTS
Aerial Photographs	Process understanding	eWater CRC/ Griffith University (funded)		Medium		Griffith University
Field Surveys-focal area scale	Process understanding/ modelling inputs	eWater CRC/ Griffith University (funded)		High		Griffith University
Sediment Tracing	Process understanding/ modelling inputs	eWater CRC/ Griffith University (funded)		High		Griffith University
Event Monitoring	Process understanding/ modelling inputs	DERM-Event Monitoring Team	Contractor (funded)	High	Additional funds sought	DERM
EHMP Monitoring	Process understanding/ modelling inputs	DERM-EHMP Technical Team (funded)		High		DERM
Soil Management Monitoring	Process understanding/ modelling inputs/ management intervention efficiency	eWater CRC/ Griffith University (partially funded) QDPIF	Contractor	Medium	Additional funds sought	Griffith University
Field Surveys-property scale	Management intervention efficiency		Griffith University/ eWater CRC Contractor (funded)	High	Additional funds sought	Griffith University
Erosion Pins	Management intervention efficiency/modelling input	eWater CRC/ Griffith University (funded)	Contractor (funded)	Medium		Griffith University
Riparian Condition Monitoring	Management intervention efficiency	SEQCatchments (funded)	Contractor	Medium	Additional funds sought for catchment scale assessment	SEQCatchments
Photo Points	Management intervention efficiency	SEQCatchments (funded)		Medium		SEQCatchments
Ambient Water Quality Monitoring	Management intervention efficiency	Community group in Bremer focal area (partially funded)		Low/Medium	Additional funds sought	SEQCatchments

Figure 1: Map showing the major sub-catchments in SE Queensland and the location of the three focal catchments.



3. Components of the Monitoring and Assessment Program

Monitoring and assessment of restoration activities and their environmental responses are important elements of any river rehabilitation project, both in terms of providing feedback on the success of the rehabilitation, and in identifying areas that may require additional action. Restoration and rehabilitation projects require clear objectives (Kondolf, 2000) and the evaluation program needs to be tailored to the objectives of this particular program.

The stated goal of the SEQ Healthy Country program was developed by the regional committee members, who represent a majority of key stakeholder groups involved in the management of non-urban landscapes in SEQ:

The goal of a successful Healthy Country Program is to validate and refine the "proof of concept" for the catchment/community approach to waterways and landscape restoration and sustainable land-use.

In achieving this goal, the project aims to demonstrate that bringing together the best science, planning and on ground implementation can significantly reduce non-urban diffuse source pollutants entering the waterways. There are two key components to the monitoring and assessment program for the on ground works, which stem from the project goal, assessing changes in:

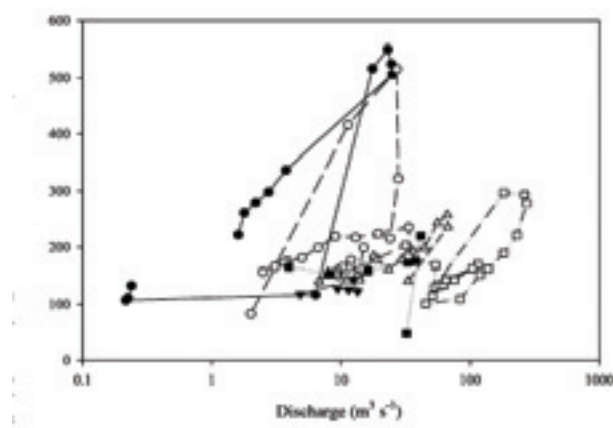
1. sediment loads
2. the health of the waterways.

3.1 Sediment Loads

One of the major challenges in any monitoring and assessment program is the selection of techniques which will provide a clear indication of success or failure of rehabilitation activities. In terms of evaluating the first objective, decreasing sediment loads in targeted catchments by 50%, this is particularly challenging for two reasons:

Firstly, the time-span of this project is relatively short (three years), and works such as riparian vegetation planting require many years to obtain a measurable effect, even at the local scale. Secondly, the hydrology of SE Queensland waterways is highly variable and the relationships between discharge and concentration of suspended solids is often complex. This is illustrated by the data presented in Figure 2. These data show that sediment concentrations, and hence sediment loads, can vary markedly between events and there is not a simple relationship between discharge and sediment load.

Figure 2: An illustration of the complex relationship between discharge and total suspended solids. Data are for event between four different flood events in 11- 2007 to 6-2008, the different symbols represent different flood events, in the Bremer River at Walloon (Data courtesy of the SEQ Event Based Monitoring Program).



These complex relationships mean that by monitoring suspended solid concentrations only at the outlet of each focal catchment, it is unlikely that a clear indication of the efficacy of rehabilitation work in decreasing the loads of sediment can be provided, unless the catchments were monitored for many decades. Consequently, the evaluation program will have to rely heavily on understanding and modelling sediment generation, transport and deposition processes within each focal catchment. The approach we are recommending is to use the concept of the sediment budget as a central organising framework. This will both guide the targeting of field data collection, as well as providing the tools for integrating the empirical data within a spatially distributed sediment budget and provide a means of assessing different rehabilitation options. The sediment budget concept has been a central organising principle within the discipline of geomorphology since at least the 1970s (Dietrich & Dunne, 1978; Dunne & Leopold, 1978), with the concept increasingly refined in subsequent decades. In more recent times, Prosser et al., (2001) developed a more structured approach to the use of sediment budgets as an organising framework with the development of the SedNet model. In essence this model provides a method of accounting for sediment inputs and outputs through the drainage network. Therefore, much of the monitoring program is designed to collect the data needed to parameterise this model at spatial and temporal scales appropriate for determining the efficacy of on-ground works in the focal catchments.

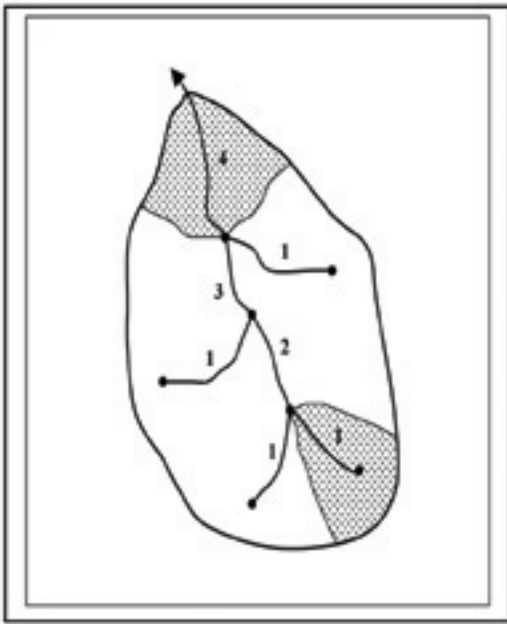


Figure 3: A river network showing links, nodes, Shreve magnitude of each link (Shreve, 1966) and internal catchment area of an order one and an order four link.

The SedNet model developed for the National Land and Water Resources Audit (NLWRA, Prosser et al., 2001) is a physically-based process model. It constructs sediment and nutrient budgets of a river network and identifies the major sources, stores and loads of material. In the model the river network is divided into a series of links which are the basic unit of calculation for the sediment and nutrient budgets. A link is the stretch of river between adjacent stream junctions or nodes (Figure 3). Each link has an internal sub-catchment, which is the catchment area added to the link between its upper and lower nodes and from which sediment is delivered to the stream network by hillslope, riverbank and gully erosion (see Figure 4). Sediment is processed sequentially through the river network beginning with first order links and terminating at the catchment outlet. The sediment load output from each link is calculated from the supply of sediment from tributary links and the local watershed, less losses through floodplain and reservoir deposition. The sediment yield at the terminating link constitutes the total yield of the river network. The model predicts sediment load and the relative contribution of hillslope and channel (gully and riverbank) erosion throughout the network.

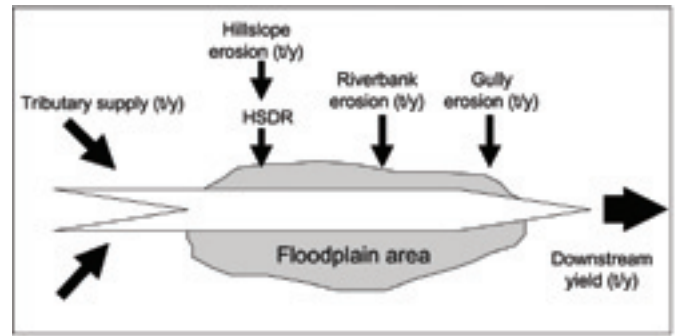


Figure 4: Conceptual diagram of the SedNet river sediment budget for one river link. HSDR is hillslope sediment delivery ratio.

3.1.1 Hillslope Erosion

The controls on hillslope erosion by surface wash and rilling are well understood and incorporated in several models. Consequently, we do not propose to monitor hillslope erosion in response to changes in land management in this study. Instead hillslope response will be predicted using the best known model - the Universal Soil Loss Equation (USLE) (Wischmeier, 1978).

$$\text{Soil Loss (t/ha/yr)} = R \times K \times L \times S \times C \times P$$

R = rainfall erosivity factor

K = soil erodibility factor

L = hill length factor

S = hillslope factor

C = vegetation cover factor

P = land use practice factor

All factors will be represented as spatially variable grids, allowing derivation of a spatially distributed hillslope erosion grid.

Not all soil eroded on land is delivered to streams. Much of it travels only a few metres. The reduction in soil erosion when moving from a plot-scale to small catchment scale is represented through a hillslope sediment delivery ratio (HSDR).

$$\text{Total sediment delivered to stream} = RKLSCP * HSDR$$

HSDR was approximated to a constant (0.05) for the Audit. The regional nature of the Audit study supported such an approximation. However at smaller scales such an approach would be unrepresentative (Kinsey-Henderson et al., 2003). Factors such as soil type and vegetation cover can significantly affect the HSDR. Therefore, we will need to develop a spatially distributed HSDR for each of the focal area catchments.

- Proposed component: A spatial distributed model of HSDR will be developed and calibrated using radionuclide measurements of the ratio of surface soil erosion to bank and gully erosion.

3.1.2 Riverbank Erosion

River bank erosion is the most uncertain of the sediment source terms in the development of a river budget model. Although it is known that degradation of riparian vegetation and other impacts on our rivers have resulted in greatly increased rates of riverbank erosion, there remains very little data on the rates of river bank erosion and the environmental factors controlling those rates. The NLWRA used an empirical rule for meander migration and bank erosion proposed by Rutherford (2000) following a review of global literature. It has since found that the rule does not accurately represent the observed pattern of historical river widening in Australia.

- Proposed component: Riverbank erosion rates will be measured using aerial photographs, erosion pins and field surveys.

3.1.3 Gully Erosion

A number of studies have demonstrated that erosion from gully and stream banks can generate up to 90% of the total sediment yield from catchments in SE Australia (Olley et al., 1993; Prosser and Winchester, 1996; Wallbrink et al., 1998; Wasson, et al., 1998; Olley and Wasson, 2003). There has been little quantification of the extent and mechanisms of gully erosion in tropical catchments, though there are indications that where gullies are present they are an important source of sediment in tropical catchments (Bartley et al., 2007).

- Proposed component: Gully erosion rates will be measured using aerial photographs, erosion pins and field surveys.

It is important to understand both the historic rates of gully and channel erosion to provide a context for the contemporary sediment yields and determine whether rates are increasing or decreasing over time.

3.1.4 Floodplain Deposition

The suspended sediment loads of Australian rivers, and rivers in general, are supply limited (Olive and Walker, 1982; Williams, 1989). That is, rivers have a very high capacity to transport suspended sediment, so sediment yields are limited by the amount of sediment delivered to the stream. Consequently, if sediment delivery increases, sediment yield increases proportionally. Deposition of suspended sediment only becomes significant when flows spread onto floodplains because flow velocity is greatly reduced in these environments. The amount of deposition on a floodplain depends upon the residence time of water on the floodplain and the sediment concentration of flood flows. Some rivers have narrow floodplains with deep, fast overbank flows providing short residence times of water and little opportunity for deposition. Others have broad open floodplains on which water can sit for several weeks, providing ample opportunity for deposition. In developing a predictive model for sediment transport in each of the focal catchments, it is important that both the extent and trap efficiency of floodplain sediment sinks are understood. To develop this understanding, the following information is required:

- Maps of the distribution and characteristic of floodplains in each of the focal catchments.
- The extent and duration of flood inundation.
- Trap efficiency determined from rates of sedimentation and previous sediment yields.

3.1.5 Total Sediment Loads

Finally, testing of the model will require measurement of the total sediment load leaving the catchment.

- Proposed component: Total sediment load estimated using the existing Event Water Quality Monitoring Program

3.2 Aquatic Ecosystem Health

As well as achieving a 50% reduction in sediment loads from targeted catchments, the Healthy Country Program aims, through the catchment and channel restoration, to improve the ecological health of the waterways in each of the focal area catchments.

3.2.1 Aquatic Ecosystem Health

The SE Queensland Ecosystem Health Monitoring Program (EHMP) is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia. It delivers a regional assessment of the ambient ecosystem health for each of South East Queensland's major sub-catchments, estuaries, and Moreton Bay. The program measures waterway health using a broad range of biological, physical and chemical indicators. Currently, 135 freshwater sites are monitored twice a year (in spring and autumn). The results provide an assessment of the responses of aquatic ecosystems to human activities, such as catchment alterations and point source discharges (e.g. wastewater treatment plants), and also take into account natural processes such as rainfall.

For each of the 135 sites sampled as part of the EHMP program the relationship between each of the 16 indicators of ecosystem health and three spatial scales of land-use (upstream catchment land-use, upstream riparian cover and site based riparian condition) have been generated. These relationships provide a predictive modeling tool for forecasting the expected change in ecosystem health indicator values with different degrees of change in catchment and/or riparian cover. In generating these predictive relationships the unknown factor is the 'lag-time' between catchment or riparian restoration and a measured ecosystem health response. Small scale trials of riparian restoration in the Maroochy River Catchment (Sheldon et al., 2005) have suggested that water quality indicators such as and the diel temperature range and diel dissolved oxygen range respond rapidly (within years) to riparian restoration. However, assemblage indicators such as the percentage of native fish present take either a much longer time to respond after riparian restoration, or require restoration at much larger scales.

This program is ideal for assessing the aquatic ecosystem outcomes of the on-ground work being conducted in each of the focal catchments and essentially testing the predictive models generated for ecosystem health response.

- Proposed action: Given the small size of the focal catchments it is proposed that EHMP monitoring sites be established only at the outlets of each of the catchments.

3.2.2 Riparian Vegetation Condition

The restoration activities being undertaken in each focal area catchment include riparian tree-planting, riparian grazing management and the reduction of stock access to riparian areas. It is therefore important to monitor riparian condition throughout each focal area catchment at a number of fixed points to determine which restoration activity is having the greatest influence on improving riparian condition.

- Proposed action: Riparian Condition Monitoring

Controlling stock access to the riparian zone and improving riparian vegetation are also likely to improve ambient water quality throughout the catchments, especially during low or no flow periods. In this context, it is also proposed that ambient water quality be monitored in the focal area catchments particular upstream and downstream of areas which have had heavy stock access (eg stock crossing or watering points).

- Proposed action: Ambient Water Quality Monitoring

3.3 Integration of Regional and Local Scale Monitoring

The monitoring program for the Healthy Country will predominantly assess sediment loads and waterway health on a sub-catchment scale. It will monitor the progression towards project targets through the assessment of sediment movement across the focal areas and sediment loads at the end of catchment and improvements in condition of riparian zones and associated aquatic ecosystem health. At the end of the project timeframe (2011), the monitoring and evaluation activities aim to inform further investment in catchment scale rehabilitation by achieving the following outcomes:

1. Improve the parameterisation inputs of SEQ sub-catchment models;
2. Minimise uncertainty levels associated with predictive modelling for sediment and nutrient load reductions through catchment scale rehabilitation;
3. Minimise financial costing uncertainty levels associated with catchment scale rehabilitation;
4. Determine the most cost-effective rehabilitation techniques for SEQ systems; and
5. Inform predictive modelling for aquatic ecosystem health improvement through catchment-scale rehabilitation

Specific monitoring activities will also be conducted at a local scale to gather data relevant to process understanding and will be used to inform further prioritisation of on ground works. These activities could include assessment of gully erosion rates with or without rehabilitation, efficiencies of riparian revegetation techniques or land management practices such as reduced traffic or rotational grazing.

Property scale monitoring will be undertaken in conjunction with on ground works to look at the effectiveness of rehabilitation techniques with baseline monitoring activities such as establishing photo-points or riparian condition assessment. These activities are associated with each individual on ground project site and will be integrated into the sub-catchment monitoring and evaluation program to inform future prioritisation of rehabilitation investments.

The proposed monitoring methods are applicable for both regional and local scale assessments of sediment movement and aquatic ecosystem health. Monitoring for process understanding maybe refined to answer specific questions and as such could include further monitoring methods.

At the regional scale we have models that can relate changes in instream ecosystem health with changes in catchment landuse and riparian cover (Peterson et al. submitted). Using the understanding of catchment condition and instream health gained at the subcatchment scale along with the broader regional models, we should be able to predict the instream health changes associated with different levels of catchment restoration.

4. Sediment Monitoring – Methods

This section describes the monitoring and measurement program that will address the key knowledge gaps identified in section 3.1.

4.1 Spatial Distributed Model of HSDR

Factors such as soil type and vegetation cover can affect the HSDR (Kinsey-Henderson et al., 2003). At the scale of the focal area catchments, variability in soil type, vegetation cover and topography means that the efficiency of delivery of sediment from the hillslope to the stream lines is likely to be highly spatially variable and the HSDR will vary along the streamlines. Fallout radionuclide data can be used to assess the variations in HSDR along the stream line (Hancock et al., 2007). The sediment model described above predicts the relative contribution of hillslope to channel erosion along the stream line. The fallout radionuclide tracing method uses differences in activity concentrations and ratios between Caesium-137 (^{137}Cs), which is anthropogenic, and naturally-occurring and excess fallout Lead-210 ($^{210}\text{Pb}_{\text{ex}}$) to determine the relative contribution of hillslope or channel erosion. This can be used to calibrate the HSDR.

4.1.1 Fallout Radionuclides

Fallout ^{210}Pb (half life 22 years) is part of the ^{238}U decay series and is present in all soils and rocks. In surface soils ^{210}Pb has two source components: the first is formed from decay of ^{226}Ra through a number of short lived gases, the longest of which is ^{222}Rn , to form in-situ or 'supported' ^{210}Pb in the soil. The second component is formed when some of the ^{222}Rn escapes into the atmosphere where it also decays to ^{210}Pb and subsequently returns to the earth's surface in association with rainfall and dust particles. On reaching the earth's surface it becomes rapidly attached to soil and organic particles. It is this second fallout component that comprises the excess or unsupported ^{210}Pb activity seen in soils and sediments. In undisturbed soils most of the excess ^{210}Pb ($^{210}\text{Pb}_{\text{ex}}$) is held in the upper 3 cm of the soil profile.

Caesium-137 (half life 30 years) is a product of atmospheric nuclear weapons testing that occurred during the 1950-70s. Initially the distribution of this nuclide in the soil decreased exponentially with depth, with the maximum concentration at the surface. However, due to processes of diffusion the maximum concentration is now generally found below the surface in undisturbed soils (Peart and Walling, 1986; Loughran et al., 1987; Walling and Woodward, 1992; Wallbrink and Murray, 1993; Basher et al., 1995). The bulk of the activity of this nuclide is retained within the top 100 mm of the soil profile in Australian soils.

The different penetration depths of the fallout radionuclides can be used to determine the original depth location of sediment particles, and thus infer the erosion process responsible for producing it. For example, high values of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ in transported sediments indicates material derived from sheet or minor rill erosion

of hillslopes. Very low or undetectable levels of ^{137}Cs and $^{210}\text{Pb}_{\text{ex}}$ suggest a subsoil source that has not been exposed to fallout of either nuclide, such as an eroding gully wall.

4.1.2 Sampling Method and Sites

The focus will be on fine-grained sediment rather than coarse sediment (sand) for three reasons:

- Fine sediment is the size fraction preferentially delivered to the Bay.
- Fine-sediment is known to carry much higher concentrations of nutrients and other contaminants.
- Measuring tracer properties in a narrow particle-size range enables a better comparison of the properties of river sediment and soil sources because it reduces concentration variations associated with variable particle surface area and mineralogy.

Soil samples: To characterize material coming off the hillslopes, topsoil samples will be collected from each of the major land units (common soil-type and landuse). The hillslope samples will be collected from areas where obvious soil mobilisation and transport is occurring, such as drainage lines separating hillslopes, or animal tracks. In order to provide the best representation of the sources, many (up to 30) small soil samples will be collected at each site and combined. Samples from a single land unit in each of the focal area catchments can be combined. Between 4 and 10 samples will be used to characterise each land unit.

Channel bank samples will be collected from the full vertical exposure of the eroding face of the bank. As for hillslope soils, bank samples can be combined for analysis.

Gully and subsoil samples will be collected from the debris trails of sediment down-slope from the erosion source. Between 4 and 10 samples will be used to characterise the sediments coming from the channel banks and gullies.

For stream sediments, samples of suspended sediment will be collected from along the main channel during flow events. Rising stage or grab samples should be of sufficient size to provide a minimum of 10 grams of suspended sediments for analysis. Alternatively, in-stream samplers will be built and deployed to capture fine sediment samples during flow events.

Site selection: For this purpose we are recommending the installation of rising stage samplers at five locations along the main channel of the Logan and Bremer focal area catchments and three in the Lockyer focal area catchment.

4.1.3 Sample Preparation

All soil and sediment sample analyses will be performed on the <10 µm size fraction. The particle size fractionation procedure involves standard wet sieving and settling procedures. When dry the <10 µm sample will be ground in a ring mill and analysed by gamma spectrometry (Murray et al., 1987). The nuclides measured will include 238U, 226Ra, 210Pb, 228Ra, 228Th and 137Cs.

A sub-sample of the dried ground sample will also be analysed by X-ray fluorescence (XRF). The major and trace elements measured can be used to determine the characteristic of the spatial sources and determine which rock/soil types the river sediments were derived from.

4.1.4 Data Analysis

Using a modification of the mixing model developed by Wallbrink et al. (1998), the relative contribution from each land unit can be determined. The modification to this model will depend on the number of distinguishable land units. If more than three are represented then the major element data will have to be incorporated into the model. In its simplest form Cu, Cc, Cb and Pu, Pc, Pb represent the 137Cs and 210Pb concentrations from uncultivated, cultivated, and channel/gully bank sources and Cs and Ps represent the respective total concentrations of 137Cs and 210Pb on suspended sediments, then:

$$A.Cu + B.Cc + C.Cb = Cs$$

$$A.Pu + B.Pc + C.Pb = Ps$$

$$A + B + C = 1$$

where A, B, and C represent the relative contributions from uncultivated lands, cultivated lands and channel/gully banks, respectively. This data can then be used to calibrate the HSDR in the sediment budget model.

4.2 Gully and Channel Erosion

4.2.1 Historic Erosion Rates

Analyses of sequences of aerial photographs provides a means of assessing the extent and rates of gully and channel erosion over the last 40 or 50 years (Beavis et al., 1999). The steps in this assessment are:

- For each focal area catchment, acquire the historic sequence of aerial photographs over the past 50 years in digital format.
- Geo-reference each image and correct for any distortion using photogrammetry software such as *Leica Photogrammetric Suite*.
- Map the drainage network for each year for which aerial photographic images are available by tracing the channel/gully extent.

- Transfer the mapped drainage network to Geographic Information Systems (GIS) and determine for each year for which aerial photography of the catchment is available
 - Total extent of gullies in each catchment.
 - Changes in channel form
 - Extent of channel erosion

4.2.2 Contemporary Erosion and Deposition Rates

Two methods which can be used to assess the contemporary rates of channel and gully erosion are the use of erosion pins and channel cross-sectional surveys.

Erosion Pins: These provide a simple, cheap and sensitive means of estimating channel and gully bank erosion/deposition rates. The method involves inserting rods into the bank material so that a known portion remains visible, as bank erosion proceeds more of the rod is exposed, if deposition occur less rod is exposed. Measurements are made from the end of the pin to the bank surface to detect erosion or deposition. Extensive information about use and limitations for erosion pins is given in Lawler 1993, pp. 798-807. In this study it is recommended that erosion pins be used to estimate bank erosion on both gullies and channel sites with and without vegetation.

Channel erosion sites: In the Logan and Bremer focal area catchments it is recommended that 10 distributed sites along the main-channel be installed with erosion pins (5 vegetated, and 5 without vegetation), and in the Lockyer focal area catchment, 6 sites (3 with and 3 without vegetation). These sites should correspond with those selected for channel cross-sectional surveys (see below).

Gully erosion sites: For gully erosion it is recommended that the site selection be stratified to capture the different rates of erosion and changes in erosional process along the gullies. The following stratification was used by Kinsey-Henderson et al., (2003):

- Gully heads – top 20% of the gully – these are the most active parts of the gullies, where the most slumping occurs, and where all of the gully head advance takes place, walls are vertical or nearly vertical
- Gully middles – middle 40% of the gully – these still have a significant amount of slumping, although the walls tend to slope at a lower angle.
- Gully valleys – bottom 40% of the gully – these behave more like a stream, and in general have less slumping than either of the categories above

It is recommended that approximately 12 gully monitoring sites, four gullies each with three sites stratified as per Kinsey-Henderson et al., (2003), be established in each focal area catchment. Half as positive control sites where re-vegetation is occurring and the others without.

Method: At each site on both the left and right bank, ten 50 cm erosion pins with a diameter of 5 mm need to be inserted horizontally into the bank face spaced 1 m apart (following Bartley et al., 2007). The erosion pins should be installed perpendicular to the bank below the bankfull stage with ~5cm of the pin left exposed. The exposed section of the erosion pin needs to be measured and recorded after installation and then bi-annually before and after the wet season.

Cross sectional surveys: Permanent cross-section survey sites will be established either immediately upstream or downstream of the erosion pin sites. These will be surveyed biannually, at the same time that the erosion pins are measured, to determine any changes in cross-sectional channel form through time and to provide channel cross-sectional areas for the flow modelling. To ensure exact reproducibility of measurement, the ends of the survey lines need to be marked by stakes set back approximately 1 channel width from the bank top to allow for future stream migration.

4.3 Floodplain Deposition

In developing a predictive model for sediment transport in each of the focal area catchments, it is important that both the extent and trap efficiency of floodplain sediment sinks are understood. To do that the following information is required:

- o Maps of the distribution and characteristic of floodplains in each of the focal area catchments will be developed. Floodplain extent- this can be estimated using a modification of the Multi-Resolution Valley Bottom Flatness (MRVBF) terrain analysis technique (Gallant and Dowling, 2003), field survey and aerial photographic interpretation.
- o The extent and duration of flood inundation. To determine this parameter, channel cross-sectional areas, slopes and bankfull discharge will be estimated for each floodplain stream-link. Flow duration curves will be determined/estimated for each catchment outlet and scaled for each stream link by upstream catchment area.
- o Trap efficiency determined from rates of sedimentation and previous sediment yields. To determine sedimentation rates, sediment cores will be collected from key depositional zones from floodplains throughout the catchments. Dating and tracing techniques can be applied to determine the rates of sedimentation and the source of the sediment. The dating techniques will include ²¹⁰Pb and ¹³⁷Cs profiles (Leslie and Hancock 2007), and optical dating (Olley et al., 2004). Corresponding measurements of carbon, nitrogen and phosphorus will also be examined to assess changes through time in nutrient levels of the sediment.

4.4 Event Water Quality Monitoring (including nutrients)

Currently, the Event Monitoring Program is a specific task under the EHMP. The event program provides information on the potential pollutant loads and impacts associated with sediment and nutrients sourced from non-urban catchment areas during “wet” periods (i.e. during/following significant rainfall events). At the regional scale, data from this program is used to provide information on catchment land use change and performance benchmarks for the assessment of catchment remediation measures such as riparian rehabilitation works.

Within this restoration project implementation of an Event Monitoring network is extremely important to assess conditions under “wet” periods. An Event Monitoring approach will enable the project to:

- o quantify sediment and nutrient loads at the end of each focal area catchment
- o compare event mean concentrations (EMCs) between the upstream (before intervention) and downstream (after intervention) sections of each focal area catchment
- o assess sediment processes and nutrient transformations in the focal area catchment

4.4.1 Site Selection

Since the emphasis of this project is to reduce sediment export from the sub-catchments, event monitoring stations will be located at the end of each focal area catchment. Stations at these locations will pick up cumulative effects of restoration activities, which will provide valuable information relating to how restoration works can begin to achieve the stated goals of the restoration project. The exact position of the proposed Event Monitoring stations will be determined in consultation with the Event Monitoring team (SEQ Healthy Waterways Partnership, SEQ Catchments Ltd and the Dept of Environment and Resource Management [DERM]). The positioning of these sites will not interfere with the proposed EHMP sites at the terminus of each focal area catchment.

4.4.2 Methods

Stream Flow: To calculate the event loads of nutrients and sediments, stream flow data are required. Stream flow rates will be calculated from continuously logged stream water level height data (stage height) using specific rating curves for each site. Hydrographical measurements, including stream height and the physical measurement of stream width, depth and velocity will be undertaken according to the DERM procedures. Continuous stream heights will be recorded using an in-stream pressure transducer or gas bubbler system connected to a data logger. Accurate rating curves for each site will be generated and are needed for the production of reliable stream flow.

Water Quality Monitoring: Water quality monitoring under the Event Monitoring Program is conducted throughout major flow events. Sampling can be undertaken using automated sampling devices (refrigerated or non-refrigerated auto-samplers and rising stage samplers). More details can be found at http://www.ehmp.org/FileLibrary/p1819_event_monitoring_methods.pdf

Water quality samples will be analysed for a range of parameters, including:

- o Suspended sediment
- o Total nitrogen (TN)
- o Total phosphorous (TP)

4.5 Testing and Analysis of 'Best Practice' Soil Management in Horticulture

The assessment of improved land management practices in the focal areas is a key component for sediment and nutrient export analysis. Results will be used to inform sediment budget modelling and as an extension tool to inform the production community of the soil health benefits of best practice soil management and the cost-benefit of reducing losses from the production system. The focal areas differ in their percentages of land use for horticulture and grazing but the following methods will be applicable to most trial sites, where different levels of land management practice change are occurring. The main aim of monitoring off production lands will be the assessment of soil and production system input loss.

4.5.1 Methods

Horticulture Land Monitoring : 2 x treatment sites which measure the effect of change in production system practice. It is anticipated that treatments will consist of (or a combination of) organic materials, ground covers, equipment modifications (controlled traffic farming).

1 x bare plot – measures the inherent erodibility of the soil.

2 x Gerlach runoff collection troughs (10m each) which have a 300m² soil capture capacity with a manifold system with tipping bucket and logger-counters.

300m pluviometer with 0.1mm tipping mechanism and electronic logger delivering 1 minute data to measure rainfall and rainfall intensity to calculate rainfall erosivity.

Timing: Plot instrumented throughout winter 2009 and ready to collect data prior to spring rainfall period 2010. Plot to be established for at least one cropping cycle (this will depend on

rainfall, ongoing producer support, data quality).

Sample collection and analysis: Samples of sediment (bedload) and suspended fraction (suspended load) collected will be analysed for the following:

Table: Summary of parameters measured for 'Best Practice' soil management in horticulture.

PARAMETER	RATIONALE	ANALYSIS METHOD
Particle size distribution	Determine the quantity of sediment type lost from each treatment	Sieve & weigh
Bed load & suspended sediment	<ul style="list-style-type: none"> • Quantify the amount of material lost from each treatment • Identify farming input loss through sediment analysis(e.g. macronutrients, agro-chemicals) 	Weigh Analysis of sediment as per M&E 4.1.2
Water quality	As above	As per EHMP procedures.

5. Ecosystem Health Monitoring – Methods

This section describes the monitoring and measurement program need to address the issues identified in section 3.2.

5.1 Ecosystem Health Monitoring Program

The Ecosystem Health Monitoring Program (EHMP) is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia. It delivers a regional assessment of the ambient ecosystem health for each of SE Queensland's major sub-catchments, estuaries, and Moreton Bay. The program measures waterway health using a broad range of biological, physical and chemical indicators (see Table 3). Currently, 135 freshwater sites are monitored twice a year (in spring and autumn). The results provide an assessment of the responses of aquatic ecosystems to human activities, such as catchment alterations and point source discharges (e.g. wastewater treatment plants), and also take into account natural processes such as rainfall.

Table 3: Summary of indicators measured as part of the freshwater EHMP program.

INDICATOR	INDICES
Physical and Chemical	<ul style="list-style-type: none"> pH Electrical Conductivity Ambient water temperature (Diel maximum and range) Ambient dissolved oxygen (DO) concentration (Diel minimum and range)
Nutrient Cycling	<ul style="list-style-type: none"> Nitrogen Stable Isotopes Ambient nutrients
Ecosystem Processes	<ul style="list-style-type: none"> Algal growth (Chl a) Carbon stable isotopes
Macroinvertebrate	<ul style="list-style-type: none"> Benthic metabolism (R24 and GPP) Number of taxa PET Richness SIGNAL Score
Fish	<ul style="list-style-type: none"> PONSE O/E50 Proportion Alien

We recommend that the EHMP indicators as currently assessed (see EHMP Technical Report 2007) as part of the EHMP program be measured at a minimum of one site per focal area catchment. The recommended number of sites for each focal area catchment is outlined below and the Standard Operating Procedures (SOP's) for each indicator are included in Appendix 1.

5.1.1 Site Selection

In the original design for the Ecological Health Monitoring Program (EHMP), sites were allocated to each 3rd order stream and to the catchments of all larger 2nd order streams until adequate spatial coverage was achieved. This coverage saw an initial 120 sites placed strategically across the study area so that all major subcatchments were assessed in the initial EHMP sampling of 2001. The average size of these subcatchments was approximately 160 km². Since 2001, more sites have been added to the ambient EHMP program, such that in 2006 there were 127 sites (See Figure 5). This spatial coverage means that some EHMP sites are located within the focal area catchments, utilising these existing sites means only two (2) extra sites will be added for adequate baseline coverage of the restoration activities. It also means that data collected at these sites over the past 5 or 6 years of EHMP activities will be available to provide context to changes in indicator values over the course of the restoration works.

For each focal area catchment, we recommend at least one (1) EHMP style sampling site and this site should be located at the end of the focal area catchment. We also recommend that the extra EHMP monitoring sites needed in the focal area catchments be sampled by the current EHMP technical team (from the QLD Dept of Natural Resources and Water) to both maintain methodological and sampling consistency between sites and allow comparisons with other EHMP sites within the region.

Figure 5: Spatial coverage of the EHMP Monitoring sites in South-East Queensland (2006).



5.1.2 Site Locations

- o The Bremer River focal area catchment currently has an EHMP monitoring site at the end of the focal catchment area; this is site 143-0046, Bremer River upstream at Adam's Bridge on top end of weir pool. We therefore recommend that this site be used as the EHMP monitoring site for this focal area catchment, no extra sites are needed.
- o The Lockyer Creek focal area catchment currently has no EHMP monitoring sites within the focal area, however there is a reference EHMP site upstream of the restoration area; this is site 143-0037, Blackfellow Creek at entry to Glen Rock Regional Park. We therefore recommend that an EHMP monitoring site be established for this focal area catchment, the site should be located at the terminus of the focal catchment area.
- o The Logan River focal area catchment currently has no EHMP monitoring sites within the focal area. We therefore recommend that an EHMP monitoring site be established at the terminus of this focal area catchment.

The exact position of the two new proposed EHMP sites should be determined in consultation with the EHMP Technical Advisory Team. The sites should be representative of the surrounding region and at least 100m away from any major physical structure (eg. bridge, road, weir). If no adequate sites for EHMP sampling can be established at the end of the Logan and Lockyer focal catchment areas, options for establishing sites within the focal areas should be explored. This would need to be done with the spatial arrangement of restoration activities in mind.

5.2 Riparian Condition Monitoring

The restoration activities being undertaken in each focal area catchment are tree-planting, grazing management and the reduction of stock access to riparian zones. It is therefore important to monitor riparian condition throughout each focal area catchment at a number of fixed points to determine which restoration activity is having the greatest influence on improving riparian condition.

5.2.1 Site Selection

EHMP Sites: At each EHMP site a rapid assessment of riparian condition should be undertaken using the methods outlined below.

Other Sites (Ambient): A minimum of 5 fixed sites throughout each focal area catchment will be assessed for ambient riparian condition. These sites will be located to cover the complete spatial extent of each catchment, including tributaries. As the assessment of riparian condition is "rapid" it is expected that more sites than the recommended minimum would be assessed. Riparian condition at each fixed site only needs measuring every 3-5 years – allowing a rotating assessment of perhaps 30 sites per focal area catchment over 3 years (10 per year).

Other Sites (Restoration): Where riparian restoration activities are being undertaken, we recommend the riparian condition be assessed using the BACI.

5.2.2 Methods

At each site, the rapid riparian condition assessment will be undertaken over a 100m reach with data collection along the reach for continuity and 0, 25, 50, 75, and 100m box plots for a range of other variables listed below. The assessment will begin at a point designated the 0m point (for the EHMP sites the 0m point will be where EHMP teams place the benthic metabolism domes) and from this point use a 100m tape measure to delineate the experimental segment following the contours of the stream. The measurements outlined in Table 3 will be completed.

NOTE: SEQ Catchments are currently developing and modifying these Rapid Riparian Condition Assessments – so the modified methods should be used when available.

Table 4: Rapid Riparian Assessment Methods Summary

INDICATOR	ACTUAL DATA COLLECTED	SAMPLING LOCATION
GPS Coordinates	Document the latitude and longitude coordinates to import the location into GIS and also so the site assessment could be repeated in the future.	Taken at 0m on the right or left bank and recorded noting the bank.
Riparian Width	Measure actual riparian width using a tape measure. Measure the width of the riparian zone from the channel edge to the edge of the riparian zone, or to a maximum of 30m whichever comes first. The edge of the riparian zone was identified either by a change in vegetation type or a lack of canopy vegetation. On some instances this was estimated (if absolutely necessary).	Taken on both banks at 0, 50 and 100m points upstream of the EHMP site.
Channel Width	Measure the width of the channel from the toe of the left bank to the toe of the right bank. Measure with a tape measure or estimate on some occasions (if absolutely necessary). This was not necessarily the current wetted width.	Taken on both banks at 0, 50 and 100m points upstream of the EHMP site.
Linear Continuity	Measure the canopy continuity on the bank edge between points 0m (downstream) to 100m (upstream). The canopy was classified into 3 categories, 0-5%, 6-50% and 51-100% cover. A percentage for each category will be compiled back at the office.	Walk one parallel transect along the stream from 0 m to 100m and document the linear continuity of the canopy within the classified categories on both the left and right bank.
Canopy Density or Periscope Average and Variance	Using a periscope, record five canopy density readings (%). The five readings for each plot were then averaged and variance calculated and based on Walker and Hopkins canopy cover documentation.	The periscope recordings are taken in a 5m box plot on each bank edge at 0, 25, 50, 75 and 100m starting from each point and going upstream 5m and into the riparian zone to form a square with one recording in the middle of the box plot.
Werren and Arthington Score	A rating of the Werren and Arthington protocol was documented along with the periscope reading. The rating is 1 – 5 categories of canopy vigour, health and structural intactness: 5 – Canopy appears intact, no/few standing dead spars; 4 – Canopy slightly irregular, some gaps, no/few dead spars; 3 – Canopy +/- sparse or lacking vigour, dead spars evident, minor crown dieback; 2 – Canopy sparse, individuals exhibit dieback, dead spars evident; and 1 – Canopy very sparse/non-existent, shrubs and/or grasses prevalent, spars may occur.	The Werren and Arthington scores are recorded for the 5m box plot on each bank edge at 0, 25, 50, 75, 100m described above.
Ground Cover Percentages	A visual estimation of percent cover were recorded for: - Groundcover organic matter; - Ground cover live growth; - Shrubs; and - Bare ground and rocks.	Observed on both banks at 0, 50 and 100m points upstream of the EHMP site.

INDICATOR	ACTUAL DATA COLLECTED	SAMPLING LOCATION
Dominant Species	List the 5 most dominant canopy, shrub, and groundcover species in no particular order.	Listed on both banks at 0, 50 and 100m points upstream of the EHMP site.
Extent of Indigenous Regeneration	Note the extent of indigenous regeneration was recorded based on a ranking of 1 – 5: 5 – Various stem size classes represented and/or canopy seedlings abundant; 4 – Variation in stem classes evident, canopy seedlings frequent; 3 – Little variation in stem size classes, canopy seedlings occasional; 2 – Stem size class distribution uniform, canopy seedlings rare/not present; and 1 – Few canopy stems present, or when so relatively uniform, canopy seedlings absent.	Noted on both banks at 0, 50 and 100m points upstream of the EHMP site.
Bank slope	Measure using a slope in each of the plots in the riparian zone that is representative of the landscape by measuring the vertical drop from a 1 metre ruler held level from the bank slope. The slope will be calculated using right angle triangle trigonometry.	Noted on both banks at 0, 50 and 100m points upstream of the EHMP site.
Bank Condition	Bank conditions is visually observed according 5 categories: 1: Extreme instability; 2: Extensive erosion; 3: Moderate erosion; 4: Limited erosion, and 5: Stable.	Noted on both banks at 0, 50 and 100m points upstream of the EHMP site.
Channel stability	Categorize channel stability as either: Very Stable; Stable; Active Eroding; or Active Depositing.	Noted on both banks at 0, 50 and 100m points upstream of the EHMP site.
Adjacent land use	Categorize the land use both within the riparian zone and on the edge of the riparian as: -Road; -Track (dirt road or track); -Bridge; -Pasture; -Cleared; -Crop / Horticultural; -Woody Vegetation; -Rural Residential; -Urban -Urban Park or Reserve; or -Weedy non Natural.	Noted on both banks at 0, 50 and 100m points upstream of the EHMP site.

5.3 Ambient Water Quality Monitoring

The restoration activities being undertaken in the focal area catchments focus strongly on reducing non-urban diffuse sediment and nutrient loads and concentrations to the streams. It is therefore important to monitor both sediment and nutrients within the streams of each focal area catchment in order to determine if restoration activities are making a difference to sediment and nutrient loads, and if so at what point in each focal area catchment and after what duration (and extent) of restoration.

5.3.1 Site Selection

Given the size of the focal area catchments, ambient water quality samples will be taken from a minimum of five sites within each area. Sites will be distributed along the mainstream of each catchment and be as spatially separate as practicable. Where possible, extra sites will be included on tributaries, or on the mainstem downstream of where tributaries join the focal stream, and in areas with remnant vegetation or catchment cover to act as reference sites. Water quality monitoring is dependant on the existence of water, and the value of measured parameters will be strongly related to the flow status of the waterbody. We therefore recommend the use of a standard Water Quality Assessment Sheet that includes an assessment of flow status for each site.

5.3.2 Methods

Monthly ambient water quality samples will be collected to reflect baseflow conditions throughout each focal area catchment. Coupled with event sampling, this level of sampling effort will generate valuable data in terms of setting and revising nutrient goals for each sub-catchment. The suggested ambient measurements to be taken monthly at each site include in situ measures of pH, dissolved oxygen, conductivity and water temperature. These measurements will be taken using a handheld multi-probe (ref community water quality monitoring techniques). Water samples should also be collected for the determination of total nitrogen, total phosphorous and suspended sediment.

Water quality samples will be analysed for a range of parameters, including:

- o Suspended sediment
- o Total nitrogen (TN)
- o Total phosphorous (TP)

Details methods for ambient water quality monitoring can be found at:

http://www.epa.qld.gov.au/environmental_management/water/water_quality_monitoring/assessing_water_quality/water_quality_indicators/

<http://www.epa.qld.gov.au/publications?id=330>

6. Monitoring site locations and methods to be applied at each sites

This section summarizes the information provided in sections 3 and 4 and identify monitoring and measurement site locations in each of the focal catchments. Final location of the sites will depend on access, local conditions and sampling practicalities.

Table 5: Monitoring and measurement to be carried out at each site shown on the maps of the focal catchments. Final location of the sites will depend on access, local conditions and sampling practicalities.

MONITORING/ SAMPLING METHOD	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE G	ADDITIONAL SITES
EHMP	x								
Event based monitoring	x								
Riparian condition assessments	x	x	x	x	x	x			
Ambient Water Quality	x	x	x	x	x	x			
HSDR sediment samples	x	x	x	x	x	x		x	Plus tributary sites – shown in yellow
Cross-section surveys	x	x	x	x	x	x		x	
Erosion pins	x	x	x	x	x	x		x	
Aerial photograph mapping									Whole catchment
Sediment cores									Locations to be decided once the floodplain extent has been mapped
Spatial sediment source samples	x	x	x	x	x	x		x	Additional site locations shown as blue dots on the map –sites are located at changes in geological units

Figure 6: A map of the Bremer focal catchment monitoring site locations

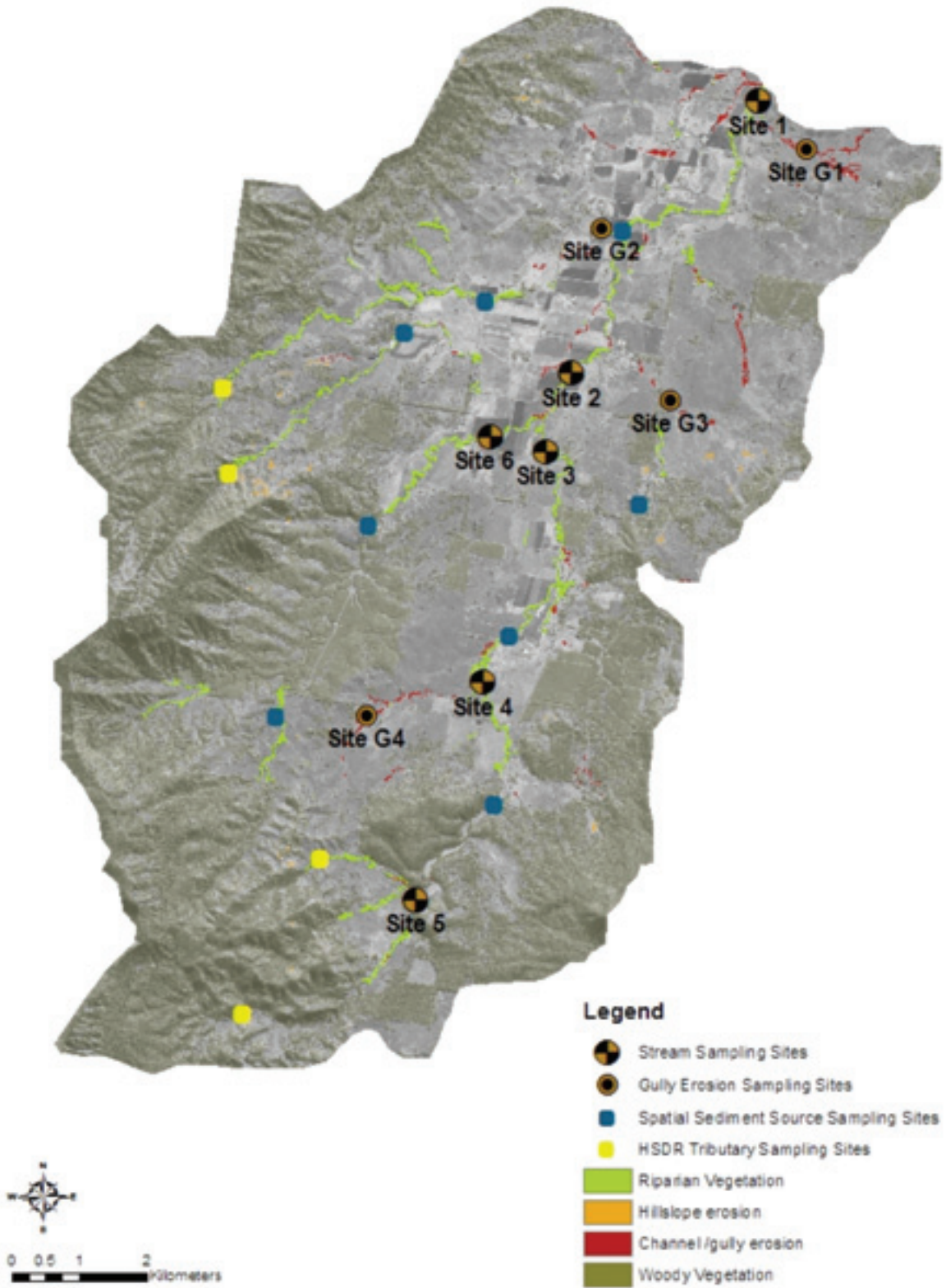


Figure 7: A map of the Logan / Albert focal catchment monitoring site locations

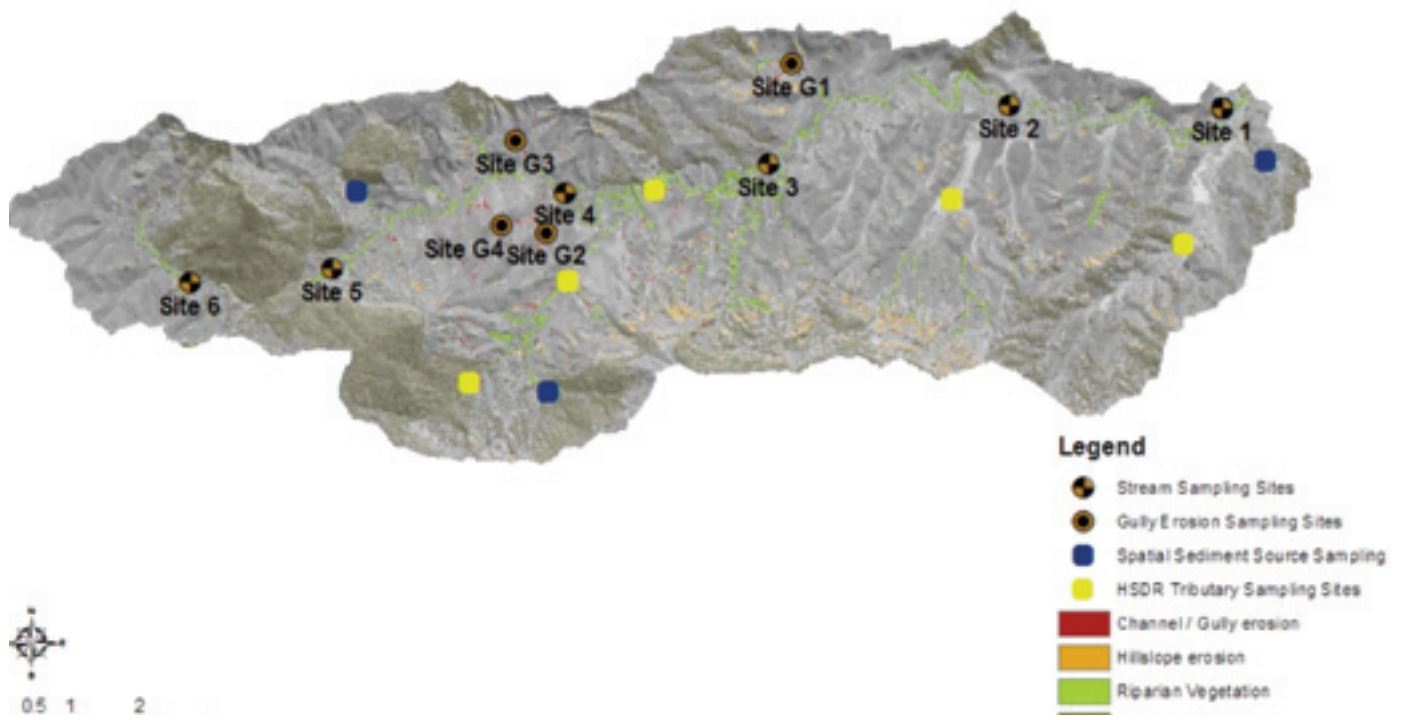
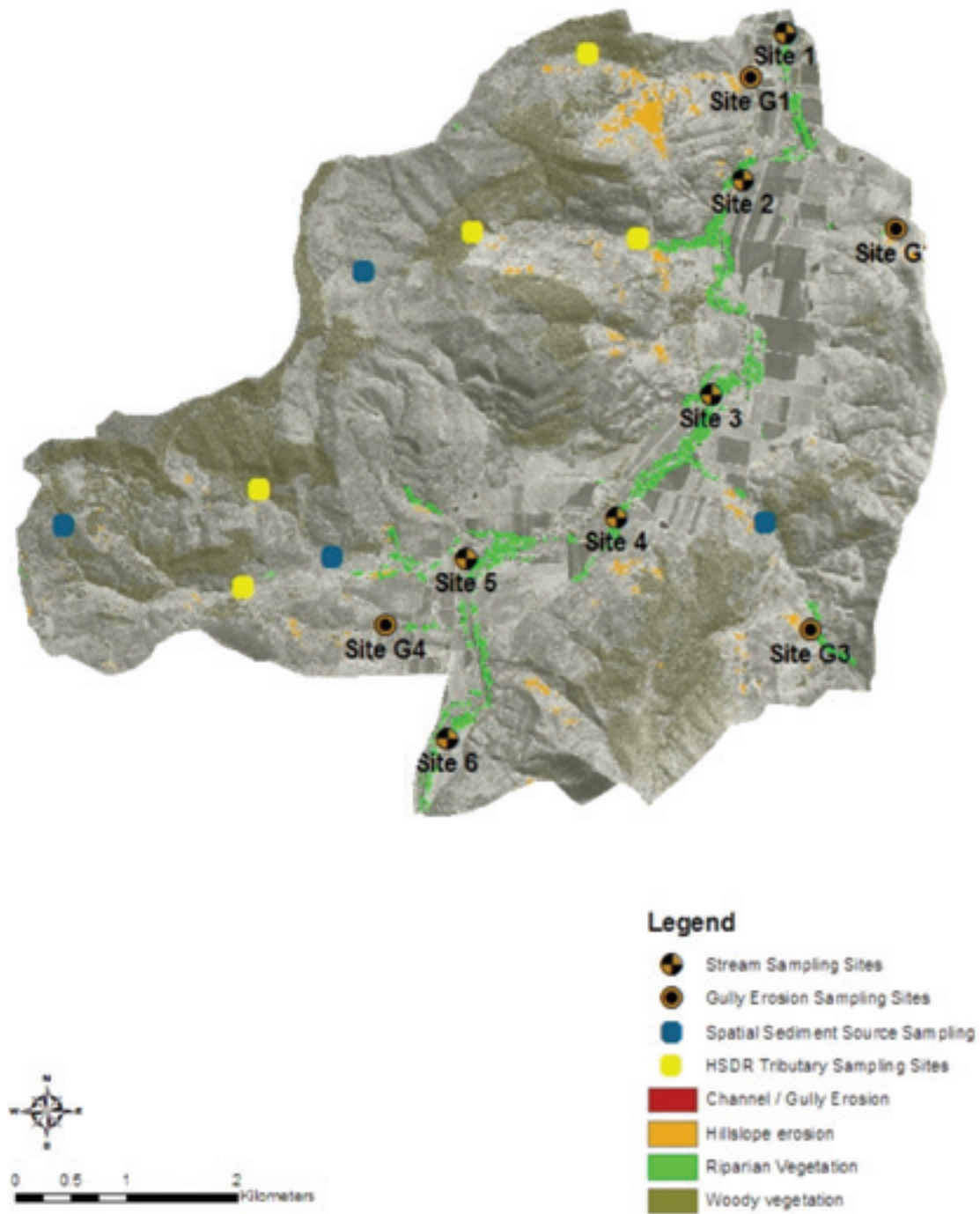


Figure 8: A map of the Lockyer focal catchment monitoring site locations



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Appendix 1: EHMP methods

The Standard Operating Procedures (SOP's) for the collection of the EHMP indicators should be used. The current SOP's are currently being updated by the Queensland Department of Natural Resources and Water. The following methods summaries have been taken directly from the 2002-2003 EHMP Technical Report.*

Fish Sampling Methods (EHMP Technical Report, 2002-2003).

The freshwater fish sampling method uses a combination of electrofishing and, where possible, seine netting, and has been designed to capture as many different species and individuals as possible.

Where available, an entire meander wavelength (i.e. riffle-pool-run sequence of approximately 100m) of stream is sampled to incorporate as much hydraulic and environmental variability as possible. A site is divided into individual hydraulic units (riffles, pools, runs) and each unit is sampled separately. Weighted seine nets (9mm stretched mesh) are placed both upstream and downstream of the hydraulic unit to prevent fish from moving into or out of the area. The area is then electrofished using a Smith-Root model 12B Backpack Electroshocker.

A current is passed through the water between submerged electrodes and if a fish is located between the two electrodes it forms part of a closed circuit and some current flows through its body. Pulses of high-voltage, low-amperage current are sent through the water from an anode ring which is attached to a fibreglass pole with an ON/OFF switch. Fish that form part of the closed circuit are involuntarily drawn towards the anode through the process of galvanotaxis. As they approach the anode they are scooped up in a 1 cm mesh net that is tied to the anode ring. Each pulse stuns the fish temporarily (for between 0.5 and 5 seconds); however, they recover quickly once the current stops.

Two staff work together to electrofish a site: an operator shocks and captures the fish while an assistant records the species name and number of individuals captured. Both wear rubber waders and gloves to avoid being shocked. They commence electrofishing at the downstream end of the hydraulic unit and progress upstream in a zigzag pattern, attempting to electrofish a variety of habitats, until they reach the top end of the study area (this represents a single 'pass'). The procedure is then repeated back downstream with three to four passes usually required for estimates of species richness and abundance to stabilise.

To catch fish the operator quietly approaches likely fish habitat (snag, undercut bank, macrophyte bed) then thrusts the anode probe towards it while pressing the ON switch. Pulses of current are passed through the water for between 5 and 10 seconds during which time the operator sweeps the net on the anode ring from side to side to collect any stunned fish. The assistant helps by using a dip net to collect fish that are out of the operator's reach.

All fish are identified by the operator and recorded and enumerated on the data sheet by the assistant. The fish are then placed in a large, rectangular plastic tub filled with water, which sits inside an inflated tube and is towed by the assistant. Eels and other large fish are usually released downstream of the seine net to avoid fouling (i.e. sliming) in the tub.

When no additional species or further individuals are collected electrofishing ceases, and the elapsed time (i.e. time spent electrofishing) is recorded. It usually takes between 30 and 60 minutes to effectively fish a single hydraulic unit. Where possible, supplementary seine netting is performed to capture openwater, schooling species that are difficult to stun with the electrofisher.

Seine netting is performed by pulling the net from the upstream end of the unit to the downstream end, ensuring that the bottom of the net is in contact with the substrate at all times. When this is complete, the downstream block seine is removed and additional numbers and/or species are added to the data sheet. This procedure is then repeated on each remaining hydraulic unit until the entire site has been sampled. Once all hydraulic units have been electrofished and seine netted, and all fish have been identified and enumerated, the native species are released, unharmed, back into the water. Alien species (those introduced from other countries) are euthanased. On return to the laboratory, the data for all hydraulic units within a site are combined and entered into a database.

Three indices are then calculated as outlined below.

1. **Native Species Richness:** The number of native fish species observed (i.e. collected) at a site is compared with the number of native species predicted by the computer model. The ratio is then converted to a percentage. A score close to 100% means that the number of native species is close to that of a similar, minimally disturbed site and is deemed "healthy". Lower scores reflect some form of disturbance: the lower the score, the greater the disturbance.
2. **Native fish assemblage O/E:** The fish assemblage (i.e. list of native species) observed when sampling is compared with the fish assemblage predicted by a computer model. The ratio of Observed to Expected (O/E) is used as a measure of ecological condition. A ratio close to 1 is deemed "healthy" while lower scores reflect some form of disturbance: the lower the score, the greater the disturbance.

* EHMP (2004). *Ecosystem Health Monitoring Program 2002-2003 Annual Technical Report*. Moreton Bay Waterways and Catchments Partnership, Brisbane.

3. **% Alien Individuals:** The number of alien individuals recorded at a site is calculated as a percentage of all fish recorded from the site. A percentage close to 0 is considered “healthy” while higher percentages reflect disturbance due to the introduction of alien species: the higher the percentage, the greater the disturbance.

Macroinvertebrate Sampling Methods (EHMP Technical Report, 2002-2003).

Field Collection: The aquatic invertebrate sampling method used for the EHMP is the same as that used for the Queensland AusRivAS (Australian River Assessment System) program. This rapid bioassessment technique has been designed to collect as many different aquatic invertebrate taxa as possible from a specified habitat. All EHMP samples are collected from the edge habitat to maintain consistency between sites and sampling events.

At each site aquatic invertebrates are collected using a D-framed pond net (350 mm x 250 mm with 250 µm mesh). The net is swept through the water several times at right angles to the bank. The first sweeps dislodge the bottom-dwelling animals while subsequent sweeps collect them from the water column. At each site a 10 m² sweep sample is taken from various sections of edge habitat along a 100 m length of stream. Following collection, the sample is rinsed and the contents of the net are poured carefully through a 2 cm sieve into a bucket to allow the coarse debris (leaf litter) and large invertebrates to be removed.

Live picking: The contents of the bucket is then mixed and carefully poured into white plastic trays where animals are “live-picked” using forceps and/or a pipette. Two operators pick the sample for 30 minutes with the objective of collecting as many different taxa as possible. Ten representatives from each taxon are collected with the exception of the family Chironomidae where 30 individuals are collected. The most common taxa are picked for the first five minutes after which time operators look for less conspicuous animals. All macroinvertebrates picked are placed in a labelled vial containing 70% alcohol.

Laboratory processing: On return to the laboratory, animals are sorted into taxonomic Orders and then identified under a dissecting microscope using taxonomic keys. Most animals are identified to Family level with the exception of the Chironomidae (non-biting midges) which are sorted to Sub-family. Acarina (mites), Oligochaeta (segmented worms) and Nematoda (unsegmented worms) are only sorted to Order. Families from each site are then stored in separate, labelled vials so that quality control checks can be performed.

All data are entered into a dedicated database and checked prior to analysis.

Three indices of ecological condition are derived from each sample:

1. **Invertebrate Richness:** Invertebrate family richness is measured by counting the number of invertebrate families found at a site. This number is then compared with the ecosystem health guideline for the type of stream on which the site is located and a ratio is derived. A ratio close to 1 indicates that a site is “healthy” or equivalent to reference condition, while lower scores reflect some form of disturbance: the lower the score, the greater the disturbance..
2. **PET Richness:** The number of families belonging to the PET Orders are summed and compared with the appropriate ecosystem health guideline with results being expressed as a ratio. A ratio close to 1 indicates that a site is “healthy” or equivalent to reference condition, while lower scores reflect some form of disturbance: the lower the score, the greater the disturbance.
3. **Average SIGNAL Score:** The SIGNAL scores for all invertebrate families collected at a site are summed and then divided by the number of families collected to obtain an average SIGNAL score. The score is then compared against the appropriate ecosystem health guideline and presented as a ratio. Again, a ratio close to 1 indicates that a site is “healthy” or equivalent to reference condition, while lower scores reflect some form of disturbance: the lower the score, the greater the disturbance.

Ecosystem Process Methods (EHMP Technical Report, 2002-2003).

Gross Primary Production (GPP) and Respiration (R24)

Both GPP and R24 are determined by measuring the net change in Dissolved Oxygen (DO) concentration within transparent, perspex domes (diameter = 29.5 cm, height = 15 cm in sediment) over a 24-hour period. Where the stream bed consists predominantly of large cobbles, one or several cobbles are placed inside the dome with a plastic base to provide a watertight seal. In streams with a substrate of sediment (sand or mud), the domes are pushed into the sediment to a measured depth.

Once the domes are in position, an oxygen sensor (YSI 5739, USA) is inserted into an opening in the top to seal the dome and a pump is used to recirculate water through the chamber to ensure flow saturation across the membrane of the oxygen probe. A data logger (TPS 601) is attached to the DO meter and DO concentration (ppm) is recorded at 10 minute intervals over 24 hours.

Changes in DO concentrations over time (g O₂ L⁻¹ hr⁻¹) are multiplied by dome volume and divided by substrate surface area to obtain oxygen production rates in units of g O₂ m⁻² hr⁻¹. These rates are then converted to units of carbon (C) assuming that 1 mole of C is fixed for every mole of O₂ produced (i.e. 1 g O₂ = 0.375 g C).

R24 is calculated by converting the rate of consumption of DO during the night to C (g C m⁻² day⁻¹) in the same way. Finally, GPP (g C m⁻² day⁻¹) is calculated by adding the amount of C produced during the day to the amount consumed (respired) during the night. This addition is necessary because the rate of production measured during the day is over and above the rate of R24 which continually removes C from the system. R24 is assumed to be constant during the 24-hour period.

Carbon isotope signature of aquatic plants (¹³C)

Where available, samples of filamentous algae or biofilms are collected, placed in labelled, zip-lock bags and frozen. On return to the laboratory, samples are cleaned with distilled water then oven dried at 60°C for 24 hours before being ground with a mortar and pestle. Ground samples are oxidised at high temperature and analysed with a continuous-flow ratio mass spectrometer (IsoPrime, Micromass, UK). Ratios of ¹³C/¹²C are expressed in delta (δ) notation as the relative per mil (‰) difference between the sample and conventional standard (Australian National University sucrose standard): $\delta^{13}\text{C} = \left[\left(\frac{R_{\text{sample}}}{R_{\text{standard}}} \right) - 1 \right] \times 1000$ where R = ¹³C/¹²C.

Nutrient Cycling (EHMP Technical Report, 2002-2003).

Nitrogen isotope signature of aquatic plants (¹⁵N)

Where available, samples of filamentous algae and biofilms are collected, placed in labelled zip-lock bags and frozen. On return to the laboratory, samples are cleaned with distilled water, then oven dried at 60°C for 24 hours, before being ground with a mortar and pestle. Ground samples are oxidised at high temperature and analysed with a continuous-flow ratio mass spectrometer (IsoPrime, Micromass, UK). Ratios of ¹⁵N/¹⁴N are expressed in delta (δ) notation as the relative per mil (‰) difference between the sample and conventional standard (N₂ ambient air standard): $\delta^{15}\text{N} = \left[\left(\frac{R_{\text{sample}}}{R_{\text{standard}}} \right) - 1 \right] \times 1000$ where R = ¹⁵N/¹⁴N.

Ambient Nutrients

Water samples should be collected from a location that is part of the main body of the stream (i.e. not in an isolated stagnant pool or backwater), at least 20 cm deep, away from the bank, and upstream of any other activity that you have conducted in the stream.

For the assessment of total nitrogen (TN) and total phosphorus (TP) one unfiltered water sample is collected, in a 250 ml bottle.

For the assessment of dissolved nutrients (dissolved organic carbon (DOC), ammonia (NH₄), nitrogen oxides (NO_x), and dissolved phosphorous (FRP)) two filtered water samples of 40 ml are collected, in 100 ml bottles, using a syringe (60 ml (latex free) plastic Luer lock-tip syringe (Terumo 3SS-60L), a glass fibre pre-filter (glass-fibre Luer lock outlet pre-filter (Sartorius Minisart GF 17824 K)),

and a 45 µm filter (0.45 µm Luer slip outlet filter (Sartorius Minisart high-flow 16533 K)), for the analysis of. Water samples are collected using a) with

Equipment should be rinsed with water prior to collecting the sample for analysis. Samples are frozen with dry ice on site and maintained in this state until delivery for analysis.

For the calculation of ambient nutrient indicators the value for DOC and the ratios of nutrients FRP:TP and TP:TN should be calculated.

Water Chemistry (EHMP Technical Report, 2002-2003).

Water temperature

Temperature is measured using a TPS WP-81 water chemistry meter with an inbuilt thermistor. The temperature probe for the meter is placed in the stream (at a depth of approximately 20 cm) and the meter is connected to a TPS Y-82 data-logger which logs the temperature every 10 minutes. The equipment is deployed for 24 hours after which data are downloaded to a computer. Maximum and minimum values are identified and diel (i.e. 24-hour) range is calculated.


pH

pH is measured with a TPS WP-81 water chemistry meter and pH probe. The probe is lowered into the water to a depth of approximately 20 cm and a pH measurement is recorded once the reading has stabilised. The probe is a combination of two electrodes: the first is a proton selective glass reservoir filled with buffer at approximately pH 7 and the second an electrode that uses a gelled electrolyte. The concentration of protons (i.e. H⁺ ions) on both sides of the glass set up a potential gradient across the glass membrane. The meter then converts this potential difference into a pH reading.

Calibration procedures The pH sensor is calibrated weekly using a two-point calibration procedure with pH 4.0 and 6.88 standards. All calibrations are performed at room temperature (25°C).

Dissolved Oxygen

DO concentration is measured using a TPS WP-81 water chemistry meter and an oxygen probe. The probe is covered with a Teflon membrane and DO concentration is calculated according to the change in electrical current associated with the reduction of oxygen as it diffuses across the membrane, the current being proportional to the partial pressure of oxygen in the water. The probe is placed in the stream (at a depth of approximately 20 cm) and the meter is connected to a TPS Y-82 data-logger which logs DO concentration every 10 minutes. The equipment is deployed for 24 hours after which data are downloaded to a computer. DO is initially measured as a concentration in mg L⁻¹ but is later recalculated using temperature and altitude to return percentage saturation (%). Maximum and minimum values are identified and diel range is calculated.



Calibration procedures: Prior to fieldwork, DO probes are calibrated using a two-point procedure: the first in air (100%) and the second in oxygen free-water (0%). Each probe is then checked again in the field prior to being deployed.

Conductivity

Conductivity is measured with a TPS WP-81 water chemistry meter and conductivity probe. The conductivity probe is lowered into the water to a depth of approximately 20 cm and a conductivity measurement is recorded once the reading has stabilised. The sensor within the probe is comprised of four nickel electrodes which measure conductance of the water. Two of the electrodes are current driven, and two are used to measure the change in current. The measured change is then converted into a conductance value in micro-Siemens per cm ($\mu\text{S cm}^{-1}$). As a rule of thumb, a measure of $1800 \mu\text{S cm}^{-1}$, at 25 °C, is approximately equivalent to a salinity of 1 mg L^{-1} .

Calibration procedures The conductivity probe is calibrated weekly using a one-point calibration procedure. A $1413 \mu\text{S cm}^{-1}$ standard at 25 °C is used as this is most appropriate for the majority of freshwater sites in SEQ.

