METHOD OF ACCOUNTING FOR REDUCTION IN SEDIMENT RUN-OFF THROUGH GULLY REHABILITATION – VERSION 1.4

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CONSULTATION PROCESS

This method was developed in consultation with the Reef Credit Methodology Technical Working Group. Members of the working group include representatives from Industry, Qld Government, CSIRO, JCU, Griffith University, advocacy groups, NRM groups and subject matter experts. The method approach arose from discussion at two workshops, the first in September 2017 and the second in March 2018. This version of the Method incorporates feedback from the public consultation process and a peer review process, we thank Prof Ian Rutherfurd and Dr Tim Pearson for their detailed reviews.

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1 PROJECT DESCRIPTION

1.1 GOVERNING DOCUMENTS

Reef Credit Standard

Reef Credit Guide

1.2 REFERENCES

This methodology references the following policy documents and tools:

Reef 2050 Long Term Sustainability Plan

Reef 2050 Water Quality Improvement Plan 2017-2022

Paddock to Reef Integrated Monitoring, Modelling and Reporting Program 2018-22

Paddock to Reef Program Grazing Water Quality Risk Framework

Reef Trust Phase IV Gully and Streambank Toolbox

Agricultural ERA standard - Beef cattle grazing in the Great Barrier Reef catchment

Tool for the demonstration and assessment of additionality in VCS agriculture forestry and other land use project activities

Method of Accounting for Reduction in Sediment Run-off through Gully Rehabilitation Explanatory Statement

All other references are listed in section 7.

1.3 SUMMARY DESCRIPTION OF METHODOLOGY

This methodology (here onwards called the 'Method') describes the approach to achieve and quantify reductions in Fine Sediment (FS) from rural landscapes through gully rehabilitation, within the catchments of the Great Barrier Reef World Heritage Area (GBRWHA).

The core Method components are as follows:

1. Determine Eligibility: Sets the criteria for eligibility of projects under the methodology and the Reef Credit Standard.
2. Establish Project Boundaries and Scope: Provides guidelines for defining the geographical and temporal boundaries of the project, scope of activities and pollutant pools to be accounted for in the project.
3. Quantify Baseline FS Yields: Provides guidelines for determining FS yields for the baseline period.
4. Quantify Project FS Yield: Provides guidelines for determining project FS yield for the reporting period.
5. Quantify FS Yield Reduction: Details how to determine the reduction in FS resulting from project activities at end of catchment for the reporting period.

6. Quantify Reef Credit Units: Outlines the steps to determine the number of reef credits based on calculated pollutant reductions.
7. Project Monitoring: Provides guidelines for the implementation of a monitoring plan and identifies monitored parameters to assess the gully rehabilitation management strategy.
8. Project Reporting and Credit Issuance: Outlines requirements for reporting project abatement to the Reef Credit Secretariat and the application process for the issuance of Reef Credits.

1.4 PROJECT ACTIVITIES

The scope of this methodology includes the design and implementation of landscape rehabilitation measures to reduce the amount of sediment loss from gully erosion. Gully rehabilitation interventions may include:

1) Engineered rock-chute head control structures;
2) Engineered grade control structures;
3) Gully reshaping and capping with rock or mulch, or both;
4) Gully catchment drainage diversion structures (contour-banks and flow-spreaders);
5) Soil amelioration (i.e. with gypsum and other non-toxic chemical stabilisers);
6) Revegetation of treated gullies and gully catchments;
7) Grazing management in treated gullies and gully catchments
8) Other interventions undertaken to rehabilitate gullies which are fully described by the proponent in the ***Gully Rehabilitation and Management Plan.***

Project activity requirements and exclusions are outlined in section 2.3.

1.5 DEFINITIONS

Abatement – The reduction in fine sediment delivered to the GBRWHA as a result of interventions, calculated as the difference between projected yield and measured yield. Projected yield is determined by extrapolation of the trend observed in baseline sediment yield.

Additionality – as defined in the Reef Credit Standard Schedule 1.

Baseline period – a period of time immediately prior to project commencement that is either a) at least twenty (20) years where a linear growth trend is evident ; or b) the length of time since the gully commenced more recently than twenty (20) years, where it can be demonstrated that the gully is not a function of some land-use intensification or land-use practice implemented post 1 January 2017. Baseline period yield analysis (including provision for where full baseline period data is unavailable) is outlined in section 5.2.1.

Baseline sediment yield – The sediment yield determined over the baseline period. Baseline sediment yield must be reported as tonnes of fine sediment per annum (over water-year – 1 July – 30 June as defined by BOM) (t/a).

Crediting period – as defined in the Reef Credit Standard Schedule 1.

Crediting period length – 25 years

Fine sediment (FS) – particles < 20 µm, i.e. the clay and fine silt particle size fraction of the soil material judged to be the component most likely to impact the Reef. The proportion of fine sediment in a sample must be determined by particle size analysis undertaken by a certified laboratory.

Great Barrier Reef World Heritage Area (GBRWHA) – the marine and estuarine waters of the Great Barrier Reef from the low tide limit as defined by the Australian Government.

Gully – the defining characteristics of a gully (from Brooks et al. 2018) are:

a) A persistent erosional landscape feature > 0.3m deep (from the surrounding residual land surface) that has multiple modes of expansion, but always typically including headward retreat into an otherwise un-dissected landscape since land use intensification.

b) An active headscarp at the upslope limit, and sometimes the lateral margins of the gully. In some cases there may be a series of headscarps representing multiple incisional phases. A scalded area (i.e. an area stripped of its topsoil with degraded vegetative cover) may often fringe the upslope area of the headscarp.

c) The land upslope of, or beyond, the gully may be a swamp or drainage depression in keeping with the incisional caveats above.

d) Gullies are typically driven by ephemeral flows (i.e. associated with direct rainfall on the gully and in the gully catchment), although there are some alluvial gullies that can experience overbank flooding or backwatering from river channels to which they are connected (sensu Brooks et al., 2009; Shellberg et al., 2013a).

e) Sediment transported from a gully is primarily sourced from within the erosion feature itself (i.e. it is dominated by an 'autochthonous' source).

f) While gullies can have temporary depositional units within the gully floor, comprising materials predominantly eroded from within the feature (i.e. an 'autochthonous' source), they are not as spatially organised as the depositional features within a stream channel bed that will also have materials that can be identified as deriving from outside the feature location ('allochthonous' sources).

g) There is a wide diversity of gullies, differentiated into two fundamental types: alluvial and hillslope (i.e. in residual soil or colluvium) gullies (as well as their possible intergrade/ combination type). They are also found in a wide variety of soils, soil materials, and sediment types. The diversity of gullies is described in Brooks et al., 2018a.

Gully erosion – A persistent erosional landscape feature > 0.3m deep (from the surrounding residual land surface) that has multiple modes of expansion, but always including one or more instances of headward retreat into a landscape otherwise undissected by channels formed prior to land use intensification (from Brooks et al., 2018).

Gully Rehabilitation and Management Plan – Documented proposal for implementing project activities for the duration of the project period

Monitoring period – As defined in the Reef Credit Standard. For this method, the maximum monitoring period length is 5 years.

NRM Regions – The six Natural Resource Management Regions as defined by the Queensland Government that comprise the catchments that drain to the GBRWHA. In Cape York this is the eastern draining catchments only. See https://data.qld.gov.au/dataset/natural-resource-management-regional-boundaries-queensland.

Project application – As defined in the Reef Credit Standard.

Project application date – As defined in the Reef Credit Standard.

Project commencement – As defined in the Reef Credit Standard.

Project end date – 25 years after project commencement and must be defined at project application.

Reef Credit – Quantified mass of nutrient, pesticide or sediment reduction under the Reef Credit Standard.

Reef Credit Accounting Zone (RCAZ) - the catchment area (including the active gully) upslope of the most downstream point of the gully(ies) being monitored for Reef Credits. See Section 3.4.

Reef Plan Water Quality Risk Framework for Grazing: see – https://www.reefplan.qld.gov.au/__data/assets/pdf_file/0034/78865/grazing-water-quality-risk-framework-2017-22.pdf

Soil Material Analysis – Laboratory analysis for each main soil material layer identified including particle size analysis; major cations **(Ca, Mg, Na, K; and Al)** and cation exchange capacity (CEC); electrical conductivity (EC) and chlorides (Cl^-) for salinity; the R1/R2 dispersion ratio, and bulk density.

Sodic soils: Normally expressed as the Exchangeable Sodium Percentage (ESP). A farmed soil with an ESP > 6 is generally regarded as being a sodic soil in Australia. The equivalent SAR (sodium adsorption ratio) threshold is > 3 (assuming a 1:5 soil:water extract).

1.6 DOCUMENTATION REQUIREMENTS

This section outlines the documentation required for project application and for issuance of Reef Credits.

1.6.1 PROJECT APPLICATION

When applying for a project, the project documentation must include a **Project Summary**. The Project Summary report must include:

a. Names of project proponents and key partners with interest in the land parcel or enterprise.
b. Project location.
c. Summary description of gullies at the site, including:
    i. Gully area spatial files including active portion; partially active areas (e.g. scalded but not gullied) and gully catchment area;
    ii. Estimate of Baseline sediment yield and proportion of fine sediment (< 20 μm);
    iii. Estimate of abatement potential over the crediting period.

The project application must also include a **Project Eligibility Report** outlining how the project complies with the Reef Credit Standard and the methodology eligibility requirements, and a **Gully Rehabilitation and Management Plan**.

1.6.2 PROJECT CREDITING

When applying for issuance of Reef Credits, project documentation must include:

1. Project Summary
2. Project Eligibility Report
3. Project Spatial Report
4. Gully Rehabilitation and Management Plan
5. Project Abatement Report
6. Monitoring Report
7. Evidentiary Documents

In addition to the requirements outlined in this methodology, the project proponent must address how the project adheres to all Reef Credit rules when applying this methodology (e.g. documentary evidence of land ownership or rights to land management over the project area).

2 PROJECT ELIGIBILITY

This section outlines the project eligibility criteria to be eligible to implement this methodology under the Reef Credit Standard. For each of the eligibility criteria, credible evidence in the form of analysis, documentation and/or third-party expert reports is required as part of the project application.

2.1 LOCATION

Proposed project area must be located within the boundaries of one of the following Great Barrier Reef NRM Regions:

1. Cape York Peninsula (eastern seaboard draining catchments only)
2. Wet Tropics
3. Burdekin
4. Mackay-Whitsunday
5. Fitzroy
6. Burnett-Mary

Note that the sediment reductions are credited based on the volume delivered to the Great Barrier Reef, sediment delivery ratio for the specific site location/s is determined in Equation 7.

2.2 PROJECT LAND CHARACTERISTICS

The project area must include land that:

1) has demonstrated gully erosion contributing to the sediment load entering the GBR during the **baseline period**;
2) contains gullies for which the current rate of gully erosion cannot be attributed to land management practices implemented post 1 January 2017;

3) will continue to contribute sediment to the GBR through gully erosion without intervention; and
4) the project proponent has the legal right to manage through implementation of project activities.

2.3 PROJECT ACTIVITIES

Project activities must:

1) Include landscape rehabilitation measures with the intent to reduce the amount of sediment loss from gully erosion; and
2) Be consistent with those described in the latest version of the Gully Toolbox from the Reef Trust phase IV – https://www.environment.gov.au/system/files/pages/661595d3-749f-4aef-9c4a-6e4d245ecc59/files/reef-trust-phase-iv-toolbox.pdf or otherwise provide a justification as to why the strategies in the Toolbox are not appropriate; and
3) Address mitigative actions and monitoring approach to prevent additional erosion. For example, infrastructure, such as linear features (roads, tracks, fences, firebreaks, and water points) must be located and constructed to prevent new erosion; and
4) Be consistent with the regional NRM Plan, or otherwise provide a justification as to why the regional NRM Plan should be over-ridden.
5) Be compliant with all Federal, State and Local Government regulations.
6) Include ongoing site maintenance and management of weeds and pest animals.

2.3.1 EXCLUSIONS

The following treatments are not eligible:

1) Reshaping of gullies in sodic soil materials (be they dispersive and/or slaking) without the application on the reshaped surface of either:
    a. a stable topsoil; or
    b. organic mulch; or
    c. rock capping to an appropriate depth.

    Note: This applies regardless of whether the sodic soils are treated with gypsum, seeded and/or have fertiliser added.

2) Gully plug dams, i.e. non-porous dam walls constructed to occupy the entire gully cross section.
3) Treatments that will increase the risk of downstream pollution.
4) High intensity grazing (cattle stomping) on sodic dispersive/slaking alluvial soil materials.
5) Any activity on the negative list outlined in the Reef Credit Standard or Method.

2.4 ADDITIONALITY

For a project to qualify as additional it must initially fulfil three requirements:

1. The law must not require the proposed project activity/ies;

2. The project activity/ies must be on the ‘positive list’ outlined in the Reef Credit Standard or Method; and
3. The project activity/ies must not be on the negative list outlined in the Reef Credit Standard or Method.

Project proponents must then demonstrate additionality by applying the Reef Credit Additionality Tool or if not available or applicable, the Tool for the demonstration and assessment of additionality in VCS agriculture forestry and other land use project activities. When applying the tool project proponents shall consider any activity eligible under this method as an “eligible AFOLU activity”. Further project proponents should substitute “pollutant reductions” for “GHG emissions” and “Reef Credits” for “GHG Credits” and where appropriate “Reef Credit Standard” for “VCS”.

2.5 LEAKAGE

Leakage may be considered to occur if there is an increase in erosion due to a move to higher risk land management practices on areas outside the project RCAZ but under the management of the same land manager that is responsible for implementation of project activities.

Project proponents must complete steps under 2.5.1 at the time of project application and each monitoring period to determine if there is a risk of project leakage and if so the appropriate procedure to account for it.

2.5.1 DETERMINE IF THE PROJECT MAY BE AT RISK OF LEAKAGE

Step 1. Determine if the land owner and/or land manager is responsible for the management of other agricultural land outside the project RCAZ(s) within the Great Barrier Reef Catchments.

If the answer is no, then the risk of project leakage is considered to be zero and the project proponent should proceed to Section 3. If answer is yes, then proceed to Step 2.

Step 2. The project proponent must determine the area of **land subject to leakage** under the control of the land manager that is not a part of the project RCAZs. This would include, for example, areas of land that would be under the same kind of agricultural enterprise as the areas within the RCAZs. Project proponents should follow the same procedures for mapping land subject to leakage as described in Section 3. Project Mapping.

Step 3. Once the area of land has been identified, the project proponent must determine the ***credible risk*** of the **land subject to leakage** shifting to a management scenario as a result of the project where a higher risk level of management practice is undertaken as defined in the **Reef Plan Water Quality Risk Framework** or equivalent framework in place at time of **project application date.**

Credible risk should be qualified as either likely or unlikely. If the risk is considered to be likely the proponent must prepare a leakage management plan detailing the steps that will be taken to ensure that project leakage does not occur. The area must be monitored for compliance with the leakage management plan and reported on at the end of each monitoring period.

Step 4. At the end of each monitoring period the project proponent must provide evidence that the steps outlined in the leakage management plan were implemented to mitigate the risk of leakage. If the leakage management plan was not implemented, then the project will not be eligible to receive reef credits until the proponent can demonstrate that the risk of leakage has been mitigated by complying with the existing plan or implementing a revised plan.

3 PROJECT MAPPING

The project area boundaries must be delineated in accordance to the requirements of this section to include all RCAZ and exclusion areas within its extent.

For the purposes of stratification of the project area into Reef Credit Accounting Zones (RCAZ), the project proponent must use remotely-sensed and/or imagery products.

3.1 GEOSPATIAL CAPTURE

A project proponent may use any of the following sources of data to delineate the boundaries and/or features within the project area:

a) Aerial LiDAR
b) Terrestrial LiDAR
c) UAV (drone)-derived photogrammetry
d) Air-photo photogrammetry
e) Ortho-rectified aerial photographs
f) Ortho-rectified satellite imagery
g) Cadastral database

The application of each method must comply with the accepted current best-practice requirements at the time of reporting, commensurate with the technique's resolution and "limit of detection" and its application within the monitoring framework.

3.2 FITNESS FOR PURPOSE

Prior to using a dataset, project proponents should assess the appropriateness of the dataset for the intended use, or its fitness-for-purpose against criteria that include:

a) Age
b) Scale
c) Resolution
d) Accuracy
e) Signal-to-noise ratio – or "limit of detection"
f) Classification, aggregation, generalisation systems (e.g. smoothing)
g) Integrity of dataset

3.3 ACCURACY

For all projects under this method, the minimum requirement for spatial data is a horizontal accuracy of at least 0.5 m (95 % Confidence Interval (CI)) and for 3D data +/- 0.3 m vertical accuracy (95 % CI). Historical airphoto analyses should aim to achieve +/- 1.0m accuracy.

For post-treatment spatial monitoring data the required horizontal accuracy is +/- 0.1 m (95 % CI) and a vertical accuracy of +/- 0.1 m (95 % CI).

3.4 REEF CREDIT ACCOUNTING ZONES

For accounting purposes, it is necessary to place interventions within a Reef Credit Accounting Zone (RCAZ), with credits from each zone being claimed separately. As a guide, a RCAZ will ideally comprise and encompass a single gully and its catchment, including all the monitoring points either in or associated with it. Where interventions are undertaken in the gully catchment (e.g. fencing out livestock) then the catchment (or part thereof) will be included within the RCAZ. Where gullies are clustered together such that their catchments are adjoining, then the proponent may choose to treat the entire cluster as a single RCAZ, providing the output from the cumulative gully area can be monitored and has a baseline yield determined for the whole area.

4 GULLY REHABILITATION & MANAGEMENT PLAN

A Gully Rehabilitation and Management Plan ('The Plan') outlining the project design, implementation & monitoring must be submitted with the project application. Any updates to The Plan must be provided with the accompanying Monitoring Report.

4.1 GULLY REHABILIATION & MANAGEMENT PLAN CERTIFICATION

A Gully Rehabilitation and Management Plan must be developed in collaboration and signed off by a suitably qualified person with the following qualifications and/or experience:

1) Professional training in the field of geomorphology and/or soil conservation; and/or
2) Is certified by one of the following professional bodies:
    a) EIANZ CEnvP Specialist Geomorphologist (Professional Geomorphologist certification developed by the Australian and New Zealand Geomorphology Group and EIANZ).
    b) Certified Practicing Soil Scientist (CPSS, Australian Soil Science Society)
    c) Certified Practicing Erosion and Sediment Control (CPESC, International Erosion Control Association); and/or
3) A person approved as suitably trained by the Reef Credit Secretariat.

4.2 GULLY REHABILITATION & MANAGEMENT PLAN PROJECT DESIGN

The Plan must include the following project design documentation:

1) The gully rehabilitation project plan which is appropriate to the gully type. The Plan will identify which portions of the site require a design that requires an engineering design signed off by a RPEQ. If it is considered that a design does *not* require sign off by an Engineer, justification as to why not will need to be provided. Activities requiring an engineering design include:
    a) Rock chutes
    b) Fully or partially reshaped gullies with major cut-and-fill and rock armouring
    c) Major rock grade control structures
2) A project area map with description and location of each gully and gully sub-unit to be rehabilitated. These will typically be synonymous with the RCAZ.
3) The contributing catchments for each gully/gully complex (as per Brooks et al., 2018a).
4) Site stock management plan(s).

5) A site access plan (roads, tracks etc and a strategy for minimising any impact during construction, and a plan for post-construction rehabilitation).
6) A maintenance plan (proactive and reactive). Proactive maintenance must include: fence maintenance, plans for weed and feral animal management within the gully exclusion area; fire management. Reactive management must include a strategy to deal with repairs to structures in a timely fashion.
7) A whole-of-property land management plan that includes:
    a) identification of enterprise and project area map indicating agricultural management zones;
    b) identification of all existing and new fence lines relevant to the rehabilitation site(s) to ensure appropriate stock management into the future;
    c) a summary report on the grazing management strategy that will be employed on the remainder of the property, specifically addressing leakage.
8) A Workplace Health and Safety Plan for the construction phase, and the ongoing monitoring phase must be in place prior to the commencement of works.
9) Locations of any new or existing quarries that will be developed/accessed for the project. If these require permits, evidence of approval to be supplied.
10) Evidence for permit approval for working in designated streams and/or for any unavoidable tree clearing.
11) A heritage/cultural assessment and associated site clearance report.

4.3 GULLY REHABILITATION & MANAGEMENT PLAN SOIL ANALYSIS

The Plan must include a section outlining soil material analysis for the purposes of calculating baseline and projected fine sediment yields, as well as to enable incorporation of geotechnical considerations into engineering designs, in accordance with the following criteria:

1) Gully soil material analysis comprising a minimum of three (3) soil material exposure profile descriptions and associated soil material analyses at the major soil material units within each gully. A minimum of three (3) samples must be collected and analysed for each soil material exposure profile, and more where there is more complex stratigraphy and/or vertical soil material differentiation, ensuring all soil material variants are adequately sampled. The boundaries of the major soil material units must be mapped so that the relative volume of the different soil units can be estimated, and their relative contribution to the historical and projected sediment yields assessed. Soil material analyses must include:
    a) Particle size analysis (using Mastersizer method, or similar, with mechanical dispersion only; or hydrometer method – see Appendix 1: Soil Sampling and Laboratory Analysis)
    b) Standard soil physicochemical analysis (major cations; CEC, pH, ESP, and bulk density) as described in Appendix 1.
    c) If topsoil is being used from the site and applied as a surface growth medium it must comply with the requirements for suitable topsoil material used in mine land rehabilitation (see Appendix 1: Soil Sampling and Laboratory Analysis).
2) Soil material amelioration treatments, including justification for the chemical application rates as a function of the soil material analyses outlined above in (1).
3) Soil cores must be obtained within the land into which the gully is projected to grow during the crediting period (based on the project gully growth rate as per 5.2.1) to demonstrate that the soil materials are similar to those found in the gully walls. A minimum of six (6) cores must be collected within three (3) transects, with one sample per transect at the furthest extremity of the maximum projected growth distance, and one at half the distance, to a depth of the

projected gully floor. Sample selection and analysis will follow the same approach as in 4.3.1. In some situations fewer cores may be required (e.g. for a large linear gully), however, pre-approval to collect less samples is required from the Secretariat under this scenario.

4.4 GULLY REHABILITATION & MANAGEMENT PLAN MONITORING

The Plan must include a project monitoring proposal. This must include a combination of some form of topographic monitoring, coupled with water quality and quantity monitoring that will enable sediment loads to be determined for the post intervention period. The monitoring plan must include:

1) the location of all monitoring points;
2) topographic monitoring that includes surveys using one of the following techniques:
   a) Repeat high-resolution aerial LiDAR survey (minimum 50 points/m^2)
   b) Repeat terrestrial LiDAR survey (minimum 500 points/m^2) over at least 10 % of the treated gully area, encompassing representative sections of all residual, erosional, and depositional surfaces within the gully system (see Brooks et al 2018a for full description), if they have been retained, or reshaped areas that were formerly occupied by said features if wholesale reshaping has been conducted. Active zones to be delineated using the methods detailed in Brooks et al., 2020b.
   c) Hand-held LiDAR surveys (e.g. Zeb-Revo) (minimum 500 points/m^2) over at least 10 % of the treated gully area, encompassing representative sections of all residual, erosional, and depositional surfaces within the gully system (see Brooks et al., 2018a for full description) if they have been retained, or reshaped areas that were formerly occupied by said features if wholesale reshaping has been conducted.
   d) Other high intensity survey methods that enables creation of a digital elevation model of equivalent precision and accuracy to that achievable using methods described in a-c above.
3) Water quality/quantity monitoring (minimum requirements are outlined below, and are based on the need for redundancy in the difficult conditions prevailing in many gullies as per Brooks et al., 2020a):
   a) Tipping bucket rain gauge within a 500 m radius of any monitored gully (closer if possible).
   b) At each gully outlet a monitoring station including:
      i) Rising-stage samplers (three (3) minimum assuming relatively narrow gully outlet (< 2m); 2 sets of 3 for wider outlet channels); and
      ii) Stage recorder (pressure-transducer type with a 5-minute minimum sampling interval); and
      iii) A velocity meter (doppler type) or in the absence of a velocity meter – manually measured flow velocity data such that a flow rating curve can be derived (according to best practice methods) across the typical flow stage likely to be encountered in 80 % of the flows experienced within the gully; alternatively discharge may be determined by means of an installed hydraulic structure (flume or weir). In most situations this is likely to be the most practicable means of measuring discharge.
      iv) A PASS sampler (time-weighted continuous sampler, after Doriean et al., 2019) or similar; and
      v) A time-lapse camera; or
      vi) Other instrument array that can be shown to provide data equivalent to, or better than, that obtainable with the instrumentation described in i-v above.
      vii) Other instrument array(s) which will be subject to the discounts described below.

c) For gullies with a treated area > 1 ha an autosampler must be added to the array of equipment outlined above in (3)b).

4) estimates of uncertainty associated with each load measurement (i.e. the measurement based on topographic monitoring and the measurement based on water quality/quantity monitoring);
5) the anticipated timing of monitoring activities. Note that it is anticipated that the timing of monitoring activities will be variable through the post-intervention period, such that water quantity/quality monitoring will be more frequent in the early years, for example every year for the first 3 years, declining in frequency thereafter; topographic monitoring will need to occur immediately after intervention and then at intervals of between 5 to 10 years thereafter. Where significant repair/maintenance works are undertaken additional topographic surveys should be done prior to repair. An example monitoring schedule is provided, noting that this should be adapted for each individual circumstance:

Timing	Water Quality Monitoring	Topographic Survey
Year 1	✓	✓
Year 2	✓	
Year 3	✓	
Year 5	✓	✓
After damaging storm		✓
Year 10	✓	
Year 15	✓	✓
Year 20		
Year 25	✓	✓

5 PROJECT ACCOUNTING

This section outlines the steps which must be followed to determine project FS reductions as a result of project activities.

5.1 RELEVANT SEDIMENT POOLS

For this section, the relevant sediment fraction is the fine silt and clay fraction (< 20 µm) delivered to the GBRWHA (see definition of ‘fine sediment’).

5.2 BASELINE SCENARIO

This section outlines the procedure to determine the sediment yield for the baseline period.

5.2.1 BASELINE FINE SEDIMENT YIELD ANALYSIS

Project proponents must complete a baseline sediment yield analysis for each gully being rehabilitated.

Baseline sediment yield analysis must include historical air-photo reconstruction of the gully expansion and may also include direct monitoring, or LiDAR change-detection, over more recent years. Photo (and LiDAR if available) time series should include at least 4 data points, and proponents should make all reasonable efforts to obtain the entire photo record held by QLD Government.

A longer historical air-photo time series (> 40 years), having at least 5 time periods, must be used where gully volume is observed to have increased in a non-linear fashion. Furthermore, a non-linear yield can only be used where the fitted model used for extrapolation has a coefficient of determination (R^2) value greater than 0.6. Finally, regardless of the actual determined non-linear growth rates, a ceiling is set at twice the yield at the beginning of the project, such that the yield used for any period within the 25 year abatement period can never be more than twice that projected for year 1. The extrapolation from a non-linear trend to determine projected erosion rates requires this increased data and extra constraint given the greater potential for non-linear trends to amplify small discrepancies between model and actuality.

Shorter term baselines (of at least 5 years) derived from monitored data are acceptable if longer term rates cannot be determined from historical aerial photography, particularly for smaller gullies obscured by vegetation.

Project proponents must specify how the two-dimensional (2D) change data has been transformed into three-dimensional (3D) volumetric change data, including detailed survey data of the remnant surfaces that have been used to reconstruct the prior gully volume. The 2D to 3D data transformation must be fit for purpose and done in accordance with industry standard and/or best practice. Baseline sediment yield should be reported as tonnes of fine sediment per annum.

An example of the method can be found in Stout et. al. (2019).

5.2.2 CALCULATION OF BASELINE FINE SEDIMENT YIELD

Project proponents must apply the following equation to calculate baseline fine sediment yield for each gully/gully system for which credits are being claimed:

$$FSL_b = \sum \frac{\Delta V_{b,i} * BD_i * FS\%_i}{t_b}$$

EQUATION 1

where:

FSL_b = fine sediment yield in baseline period, b, in tonnes $year^{-1}$;

$\Delta V_{b,i}$ = change in gully volume in RCAZ, *i*, during the baseline period, *b*;

- If a non-linear trend in volume increase during the baseline period is being claimed, a full report justifying the non-linear trend must be included in project application;
- Gully volume is to be determined by comparing the present day surface with a constructed pre-erosion surface, built via three dimensional interpolation amongst residual surfaces (see Stout et al., 2019);
- Detailed field verification of the residual surface levels used to reconstruct the former 3D land surface prior to gullying must be provided and audited in the field.

BD_i = sediment field bulk density of RCAZ, *i*, (using standard field sampling and laboratory methods as described in Appendix 1); the proponent may use standard values of 1.6 g/cm^3 for all other material as an alternative to taking field measurements.

$FS\ \%_i$ = proportion of gully source sediment in RCAZ, *i*, that is < 20 μm. (This requires particle size analysis as outlined in Section 4.3;

t_b = baseline period in years.

5.2.3 DETERMINE MEAN ANNUAL RAINFALL DURING BASELINE PERIOD

To determine the Mean Annual rainfall for the site for the baseline period based on the relevant grid cell in the BOM 0.05 degree (~5km) grid data apply:

$$Rf_{avSb} = \frac{Rf_{TSb}}{t_b}$$

EQUATION 2

where:

Rf_{avSb} = mean annual rainfall, in mm year^{-1}, for site, *S*, during baseline period, *b*;

Rf_{TSb} = total rainfall, in mm, for site, *S*, for baseline period, *b*;

t_b = baseline period in years

Note for the purposes of calculating total rainfall, the Baseline Period begins on the 1st of July in the first year of the Baseline Period and ends on the 30th of June in the last year of the Baseline Period.

5.3 PROJECT MONITORING PERIOD CALCULATIONS

The methodology estimates fine sediment yield (in accordance with Shellberg et al. 2013a) based on empirical measurements of rainfall and water runoff, sediment production at gully head scarp modelled from retreat rates and change in gully area over time, and sediment transport loads using a combination of empirical data and modelling (i.e. empirical modelling). This section outlines the procedure to determine the sediment yield during the current project monitoring period.

5.3.1 PROJECT SEDIMENT YIELD MEASUREMENT

Project proponents must measure the fine sediment yield (***FS***) from each RCAZ, *i*, in tonnes.

The proponent must use a multiple lines of evidence approach whereby a best estimate of the sediment yield over the monitoring period is arrived at by consideration in parallel of both topographic measurement and the water quality/quantity monitoring. The proponent must describe how the results from each independent approach are consistent with each other, or provide detailed description of, and analysis of the reasons for, any discrepancies.

Topographic surveys must be undertaken prior to and immediately after any ongoing maintenance undertaken during the monitoring period.

Over the first ~5 years, sediment yields will be determined from water quality/quantity monitoring alone, as the estimate based on topographic monitoring will not be available until after the first repeat topographic survey is conducted in year 5 (see Table in Section 4.4.5). As such, these calculations may need to be adjusted once they can be reconciled against the topographic survey based estimates of sediment yield.

5.3.2 CALCULATION OF FINE SEDIMENT YIELD FOR PROJECT MONITORING PERIOD

Determine the total Fine Sediment Export for the current project monitoring period using the following equation:

$$FSE_r = \sum FS_i$$

EQUATION 3

where:

FSE_r = Total fine sediment export for the current project monitoring period, *r*;

FS_i = Measured fine sediment yield from RCAZ, *i*, in tonnes as determined in section 5.3.1

5.3.3 DETERMINE MEAN ANNUAL RAINFALL FOR MONITORING PERIOD

Determine the mean annual rainfall for the site for the current project monitoring period based on on-site tipping bucket rain gauge data. Use:

$$Rf_{avSr} = \frac{Rf_{TSr}}{t_r}$$

EQUATION 4

where:

Rf_{avSr}= mean annual rainfall, in mm $year^{-1}$, for site, *S*, during the project monitoring period, *r*;

Rf_{TSr} = total rainfall, in mm, for site, S, for current project monitoring period, r;

t_r = monitoring period in years.

Note, as for Section 5.2.3, the Crediting Period should align with the Water Year (1st July – 30th June)

5.3.4 PROJECT RAINFALL ADJUSTMENT FACTOR

Determine the Rainfall Adjustment factor (A_{Rf}). Use:

$$A_{Rf} = \frac{Rf_{avSr}}{Rf_{avSb}}$$

EQUATION 5

where:

A_{Rf} = rainfall adjustment factor;

Rf_{avSr}= mean annual rainfall, in mm year^{-1}, for site, *S*, during the project monitoring period, *r*, as determined in Equation 4;

Rf_{avSb} = mean annual rainfall, in mm year^{-1}, for site, *S*, during baseline period, *b*, as determined in Equation 2.

5.4 CALCULATE CHANGE IN FINE SEDIMENT YIELD

The following equation is used to determine the change in fine sediment yield resulting from project activities (i.e. the abatement):

$$\Delta FS_r = \left(FSL_b \times t_r \times A_{Rf}\right) - FSE_r$$

EQUATION 6

where:

ΔFS_r = the change in fine sediment yield, in tonnes, for the project monitoring period, *r*;

FSL_b = baseline fine sediment load in tonnes year^{-1} as determined using Equation 2;

t_r = monitoring period in years;

A_{Rf} = rainfall adjustment factor as determined in Equation 5;

FSE_r = Fine sediment export, in tonnes, for the current project monitoring period, *r*, as determined by Equation 3.

5.5 CHANGE IN FINE SEDIMENT ENTERING THE GREAT BARRIER REEF

The reduction achieved during the monitoring period in fine sediment exports transported to the end of catchment, must be calculated by applying the following equation:

$$FSA_r = \Delta FS_r * SDR$$

EQUATION 7

where:

FSA_r = fine sediment abatement, in tonnes, exported to the Great Barrier Reef for monitoring period, *r*.

ΔFS_r = the change in fine sediment yield, in tonnes, or the project monitoring period, r, calculated in accordance with Equation 6;

SDR = the sediment delivery ratio or contribution to export, which reflects the proportion of FS that is transported to the GBR based on project location[1].

In order to be eligible for Reef Credits, FSA_r must be greater than zero.

[1] Contribution to export is a dataset generated by the Queensland Government. Please refer to the Reef Credit website for information on accessing the data.

5.6 CALCULATION OF MONITORING PERIOD REEF CREDITS

To determine the quantity of Reef Credits generated by project activities during the Crediting Period, apply the following equation:

$$RC_r = \left(FSA_r \times C_f\right) + RC_{r-1}$$

EQUATION 8

where:

RC_r = Reef Credits generated in monitoring period, *r*;

FSA_r = fine sediment abatement, in tonnes, exported to the Great Barrier Reef for monitoring period, *r*.

C_f = the correction factor to convert a fine sediment reduction to an equivalent Reef Credit as stated in the Reef Credit Standard.

RC_{r-1} = negative balance of Reef Credits brought forward from previous monitoring period (if applicable).

If RC_r is zero or less than zero, then no credits are issued for the monitoring period.

5.6.1 WATER QUALITY MONITORING REQUIREMENTS FOR CALCULATION OF REEF CREDITS

For Reef Credits to be claimed in any one monitoring period at least three (3) separate flow events must be sampled for each water-year, including a minimum of three (3) samples per event at a range of discharges in accordance with the requirements of Section 4.4 of this methodology.

Sediment yields across a water-year will need to be determined either through the construction of a one-dimensional (1D) flow model (HEC-RAS V 5.0.6 or equivalent), calibrated with the monitored fine sediment concentration data, or through the construction of a calibrated 'at-a-station' discharge rating curve (see Shellberg et al., 2013a).

If claiming credits in the **first year** post-treatment, at least five (5) separate events must be sampled with a minimum of three (3) samples per event across a range of discharges. In the event that insufficient events occur, or insufficient samples are successfully collected in a single water-year, the data from one year can be accrued to the next year/monitoring period.

For the purposes of monitoring, an event is defined by reference to the rainfall record, where an event is defined as a peak on the rainfall time series separated from other peaks by 24 hours or more of rain <5mm/day and where the total event rainfall exceeds 50 mm.

A pressure transducer stage recorder must be installed at each water quality sampling station to both keep a record of the gully discharge hydrograph so that the sample points can be identified on the hydrograph, as well as determining whether the samples have been impacted by backwatering from downstream. No samples can be used that are influenced by backwatering (see Brooks et al., 2020b).

5.7 UNCERTAINTY

Estimates of monitoring period sediment savings at the gully calculated in accordance with this methodology are based on direct site measurements/surveys using a multiple lines of evidence approach. The relative uncertainty associated with interim sediment yield estimates made in years when only one line of evidence is available (e.g. in the first five years or so before repeat topographic data is available) will be higher than those associated with estimates based on the multiple lines of evidence approach. However, the interim sediment yield estimates will need to be adjusted (along with any reef credits claimed) if/when the totality of data available after repeat topographic survey suggests that the estimates were inaccurate.

If the approach outlined in this method is followed then no additional confidence deduction is required to account for uncertainty.

6 MONITORING AND RECORD-KEEPING REQUIREMENTS

This section sets out monitoring and record-keeping requirements for a sediment reduction through gully remediation project that is a registered Reef Credit project.

A Monitoring Report must be submitted as a requirement for each monitoring period. The project proponent must monitor the RCAZs of the project for compliance with the Gully Rehabilitation and Management Plan (section 4.4) and document land management activities and any unplanned disturbances to project area.

The Monitoring Report must also include all spatial data, a change detection analysis and a detailed report on the documentary evidence of water quality monitoring during the reporting period including, but not limited to:

- a detailed description of the monitoring setup;
- all laboratory results;
- photographs of equipment setup;
- all field monitoring data and analysis, showing the time of sampling on the flow hydrographs;
- any digital elevation model (DEM) of difference data for the monitoring period, including the ground control data and the spatial tolerances;
- time-lapse camera imagery of the monitoring site.

Records must be kept in relation to each of the requirements for remotely-sensed imagery set out in Section 3, including but not limited to:

i. The defined gully being treated;
ii. Historical airphoto rectification points;
iii. Shapefile polygons of the gully areas defined for each historical time slice;
iv. The location of monitoring points;
v. The location of soil sampling points and associated soil mapping indicating the representative nature of the soil materials sampled under the Method;
vi. The field evidence used for the 3D reconstruction of the prior gully form (from which historical sediment yields have been calculated), i.e. the identification of the remnant surfaces used in the field for reconstructing the 3D land surface prior to gullying.

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8 APPENDICES

8.1 APPENDIX 1: SOIL SAMPLING AND LABORATORY ANALYSIS

8.1.1 FIELD ASSESSMENT

8.1.1.1 DEVELOP A SIMPLE SAMPLING PLAN

A simple sampling plan should aim to sample all the distinct soil material layers that have been identified. It should also include a check on the spatial variation of these layers if the gully site being investigated is large or complex, or both.

The most appropriate observation and sampling plan depends on:

- the type of gully (or gully system);
- the size of gully (or gully system);
- the perceived spatial complexity and number of the soil material layers;
- the time available for field assessment.

The number of samples to be taken for laboratory analysis will depend upon:

- the spatial complexity and number of soil materials layers;
- the scale of rehabilitation works being considered;
- the budget available.

8.1.1.2 SELECT SOIL MATERIAL OBSERVATION POINTS (OPs)

The number of observations of the soil materials to be recorded will depend on the size of the Gully or Gully (Sub-)System being investigated. See '*Sampling Intensity*' below.

- Observation Points should be selected where:
  - a full sequence of layers can be clearly seen and accessed, especially in the active erosion zones;
  - there is evidence of most active erosion of heads and walls;
  - there is the greatest depth of exposure through the soil materials.

8.1.1.3 SAMPLING INTENSITY

At least three (3) OPs will be required to characterise the soil materials in any gully or gully system. It is recommended that at least three (3) OPs usually be used to sample the soil material layers for any gully site investigation for rehabilitation management.

At least three (3) OPs for observing, recording and sampling for laboratory analysis will be required, depending on the size of the gully or gully system being investigated. Further soil material OPs will be required to describe the layer variation and to map the soil material pattern over the whole gully area.

For small, isolated, gullies, up to 0.75 ha, **two OPs** for observing, recording and sampling soil material layers for laboratory analysis may be sufficient. Further soil material OPs (as 'Check Sites') may be required to describe the layer variation and to map the soil material pattern.

A rule of thumb should be **no less than three (3) OPs per hectare** for recording soil materials, with **four (4) OPs per hectare** for more complex sites. All these specified OPs are 'Sample Sites' and should be used for sampling for laboratory analysis. Further soil material OPs (as Check Sites) may be required to describe the layer variation and to map the soil material pattern.

Multiple soil material systems and Stratified systems may need further OPs. Choose further Sample Sites and Check Sites if soil material complexity demands it.

8.1.1.4 SITE DESCRIPTIONS

Soil site descriptions should be undertaken with the provided field data recording protocols which are in accordance with the *Australian Soil Survey and Land Survey Field Handbook 3rd edition* (NCST, 2009), where relevant. Soil material site descriptions include a soil material exposure profile description and site observations of erosion features and processes at each location.

Soil material profile descriptions include (where applicable) the following details (see Table: Soil Sampling Methods for sampling procedures):

- Layer depth and thickness, and designation;
- Dominant colour;
- Presence and colour of mottles;
- Fabric (texture/structure);
- Segregations (nodules or soft precipitations, e.g. calcium carbonate);
- Gravel/rock inclusions (isolated or as beds/lines);
- Field tests (pH, $CaCO_3$, aggregate stability).

8.1.1.5 SOIL MATERIAL SAMPLING

- Gully exposures should be cut back by 0.2 m wherever possible by spade or pick.
- Samples should be taken from every main layer identified, starting at the top where sample material should be taken from the surface to 0.1m below the surface. It is preferable to sample the top layers (up to 0.1 m) by soil auger about 1 m back from the gully edge.
- At least three (3) samples down the exposure profile will be required to characterise the soil materials at any specific site, even if there are fewer than three layers.
- Bulk density samples also need to be taken from each sample site (see table below).

8.1.1.6 SOIL MATERIAL SAMPLING METHODS

TABLE 1. THIS TABLE OUTLINES THE SOIL MATERIAL SAMPLING METHODS

Activity	Details
Soil Material OP locations	Sampling locations are recorded with a handheld Global Positioning System (GPS) unit with an accuracy of generally +/-4 m.
Soil Material observation	Appropriate gully exposure cut back by 0.20 m where possible by spade or pick to access fresh, unexposed material. Soil hand-auger can be used to gain fresh material from the top 1.0 m, 1 m back from the gully wall.
Abandonment	Any soil hand-auger holes on the land surface must be backfilled to the existing natural ground level using soil material retrieved during soil coring and surrounding material.
Soil description	Soil material characteristics are described on provided field data sheets. These aid the description of the land surface condition in the vicinity, and the characteristics of each soil material layer in the gully exposure at each OP.
Field tests	Field tests are also conducted on each layer at each OP. Field pH

Activity	Details
	Soil material aggregate stability test for slaking and dispersion. Status recorded a) at immersion and b) after 10 mins: 0-nil; 1-some; 2-obvious; 3-total. 1 M HCl drops on nodules to test for calcium carbonate ($CaCO_3$). Rate of reaction No audible or visible effervescence: non-calcareous Audible and slightly visible effervescence: moderately calcareous Moderate to strong visible effervescence: highly calcareous
Soil material sampling	Soil material samples, approximately 500 g in weight, should be obtained directly from the exposure or the auger from each evident layer between clear boundaries. If only two layers or one layer can be discerned then at least three samples must be taken down the profile: at 0.20 m from the surface, 0.20 m from the bottom, and one from the approximate middle. Topsoil / top layer samples (5-10) should be gained from at least three different locations within the vicinity of the OP and bulked together (composite sample). Discrete soil material samples must be collected and placed into resealable plastic bags and appropriately labelled for dispatch to the laboratory.
Labelling	Sample bags should be labelled with the site name or code and site OP number; the layer ID; the sampling depth; the date of collection; and the unique ID for the sample. This data should also be recorded on a separate label and inserted in the sample bag with the soil material sample. For instance, a sample collected at OP 'DEL S01' at a depth of 0.10 m below the surface in layer 'DEL_01' is labelled as follows: DEL S01; DEL_01; 0.10 m; dd/mm/yy, 09886 (unique ID number)
Dispatch	Samples should be stored out of direct sunlight and transported for analysis. Topsoils requiring nitrogen and organic carbon analysis should be kept cool and dispatched to the laboratory as soon as possible.
Bulk density sampling	Samples for bulk density (BD) should be taken using a BD ring or square tin, open both ends, of known volume. The ring or tin should be pushed/eased into a fresh exposure (at least 0.2 m from the exposed face) and sunk into place by digging around the ring/tin so that the coherent, undisturbed soil material fills the ring/tin and extends beyond it for at least 5 mm. The back end of the ring/tin should then be dug out with the soil material still extending well beyond the margins of the tin. Once extracted, the excess soil material should be carefully shaved off both ends until flush, flat with the ring/tin edges. The enclosed soil material can then be fully emptied into a zip-lock sandwich bag, with any soil material adhering still to the inside of the ring/tin also included in the bag. The bag can then be suitably labelled as above and despatched for lab analysis.

8.1.2 LABORATORY ANALYSIS

All soil materials samples should be analysed in an ASPAC/NATA accredited laboratory.

Any soil material management recommendations and amelioration rates are derived from this data.

Laboratory certificates for all sample sites analysed should be provided in the reporting as an appendix.

For consistency purposes it is recommended that the laboratory use the methods described in Rayment and Lyons (2010) which are a common standard Australia-wide. The Rayment and Lyons analytical code is provided after each analyte presented below.

- C = carbon
- Ca/Mg = Calcium: Magnesium ratio
- EAT = Emerson's Aggregate Test

- EC = electrical conductivity
- ESP = exchangeable sodium percentage
- N = nitrogen
- OM = organic matter
- PSD = particle size distribution
- P = phosphorus
- Topsoil / top layer
  (sample depth 0.0 – 0.2 m and bulked/composite from at least three locations in the vicinity)
  - pH (1:5 water) [4A1]
  - EC (1:5 water) [3A1]
  - Cl (1:5 water) [5A2b]
  - Exchangeable cations (Ca, Mg, Na, K,) (aqueous NH_4Cl [15A1] or if soil pH > 7.3[alcoholic NH_4Cl 15C1])
  - Exchangeable Al (15G1)
  - Total C (6B3) and OM (6G1)
  - PSD: < 2 µm (clay), 2 – 20 µm (silt), 20 – 50 µm (fine-medium sand), 0.05 – 2 mm (coarse sand) [Mastersizer or Hydrometer method for fines];
  - Colwell P (for alkaline soils) [9B2]
  - Total N [7A1, 7A5]
  - Total CEC [15J1]
  - ESP [15N1]
  - Ca/Mg [15M1]
  - Bulk density [oven-dry (105°) wt. / BD ring volume]
  - Mechanical dispersion:
  - EAT [Emerson, 1967; Australian Standard, 1980]
  - Dispersion ratio (R_1, R_2) [Baker & Eldershaw, 1993]

- Subsoil / lower layers
  (at nominated depths within the layers)
  - pH (1:5 water) [4A1]
  - EC (1:5 water) [3A1]
  - Cl (1:5 water) [5A2b]
  - Exchangeable cations (Ca, Mg, Na, K,) (NH_4Cl [15C1] or ammonium acetate [15D3] depending on pH and EC of sample)
  - Exchangeable Al (15G1)
  - PSD: < 2 µm (clay), 2 – 20 µm (silt), 20 – 50 µm (fine-medium sand), 0.05 – 2 mm (coarse sand)) [Mastersizer or Hydrometer method for fines];
  - Total CEC [15J1]
  - ESP [15N1]
  - Ca/Mg [15M1]
  - Bulk density [oven-dry (105°) wt. / BD ring volume]
  - Mechanical dispersion:
    - EAT [Emerson, 1967; Australian Standard, 1980]
    - Dispersion ratio (R_1, R_2) [Baker & Eldershaw, 1993]

8.1.3 TOPSOIL

Determination of suitable soil to conserve for later use in gully rehabilitation can been conducted in accordance with modification of that proposed by Elliot and Veness (1981) with respect to mined land materials. The approach involves the assessment of soil materials based on their physical and chemical parameters. The key parameters are presented in Table 2. Topsoil / top dressing suitability criteria.

TABLE 2. TOPSOIL / TOP DRESSING SUITABILITY CRITERIA

Criterion	Desirable state or range
Structure Grade	Some structure evident (i.e. aggregates, peds)
Coherence	Coherent when wet and dry
Mottling	Absent
Texture	Finer than sandy loam
Gravel and Sand Content	< 50%
pH	5 to 8
Salinity (EC)	< 1.5 dS/m
Sodic Limit (ESP)	6 %

8.1.4 REFERENCES

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