

Innovative Gullies
Remediation Project

Strathalbyn Station Gully Remediation Works Update

July 2019

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The Innovative Gullies Remediation Program initiative has been funded by the Queensland Government and Greening Australia to identify more innovative and cost-effective gully remediation techniques.



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Introduction

The Innovative Gully Remediation Project

The Innovative Gully Remediation Project is a collaborative project supported by the Queensland Government's Reef Innovation Fund and Greening Australia's Reef Aid Program.

The purpose of the collaboration is to develop cost-effective and scalable options for the reduction of sediment and particulate nutrient export to the Great Barrier Reef lagoon ecosystem from alluvial gullies in grazing landscapes. The program is specifically focussed on trialling methodologies that can be replicated in or transferred to other areas of the Burdekin and within other Great Barrier Reef catchments.

The project site is at Strathalbyn Station, 45km north-west of Collinsville and 60km due south of Ayr, located in the Burdekin-below-dam catchment on the eastern bank of the Burdekin River (*Figure 1*). The property is owned by the Hughes family, with Bristow Hughes managing all aspects of the property's grazing enterprise.

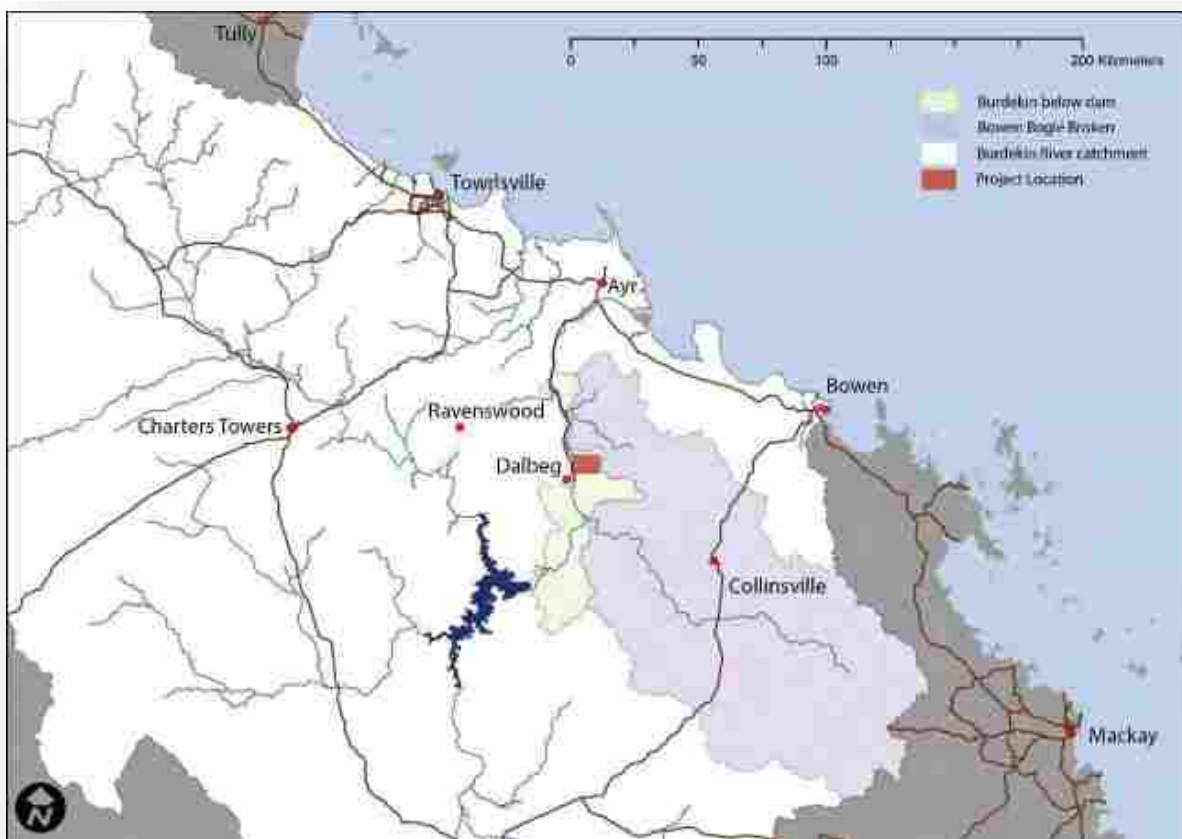


Figure 1 Strathalbyn Station, the site of gully stabilisation trials being implemented under the Innovative Gully Remediation Project.

The Innovative Gully Remediation Project has a number of objectives including to:

- 1. Trial different techniques for gully remediation on at least 5 treatment sites (across 150ha) to deliver more cost-effective solutions that can be applied across regions.**
2. Trial innovative monitoring techniques to determine reduction of sediment and particulate nutrient loads to the Great Barrier Reef and the costs of achieving those reductions based on different interventions.
3. Harness innovative ideas and facilitate cross boundary interaction and fresh thinking to tackle the challenge of gully erosion.
4. Engage innovative individuals and organisations with a history of success but not necessarily in the Reef catchments and industries to borrow learnings and successes from other fields.
5. Engage with scientists and remediation experts to ensure the project builds upon the latest scientific understanding.
6. Build upon and integrate with existing and new gully remediation projects being delivered by Queensland and Australian governments and other partner organisations.
- 7. Communicate the outcomes of the trials broadly, particularly in Reef catchments, to ensure broad uptake of best practice gully remediation techniques.**

This project works update addresses the Innovative Gully Remediation Project objectives 1 and 7.

This works update does not report on the effectiveness on any of the implemented trials or treatments, this will be evaluated at the end of the project when monitoring activities have been completed and the data assessed and evaluated. However, where appropriate general observations as to the response of the various treatments to rainfall events are provided. These observations represent the opinions of the author.

2017-2019 Program Works Overview

The Innovative Gully Remediation Project works program commenced in late 2017 after approximately 11 months of project planning and setup.

To date approximately 17.4 ha of direct gully remediation trials have been undertaken on the site, making the project the largest gully remediation trial undertaken in Queensland to date. Forty-four hectares (44 ha) of surrounding grazing area around the trials has been fenced and is currently being managed by the landholders in accordance with regenerative holistic grazing principles.

Table 1 provides a timeline of the works undertaken under the program. The distribution of the trial treatments over the Strathalbyn Northern Gully sites shown in Figure 2. Table 2 summarises the generalised suite of treatments undertaken over all sites implemented under the program.

Table 1 Completion dates of on-ground works activities under the Innovative Gully Remediation Program at Strathalbyn

| | 2017 | | | | 2018 | | | | | | | | 2019 | | |
|--|-----------|---------|----------|----------|------|------|------|--------|-----------|---------|----------|----------|------|------|------|
| | September | October | November | December | May | June | July | August | September | October | November | December | May | June | July |
| Quarry development | ■ | ■ | | | | | | | | | | | | | |
| Treatment 1 | | ■ | ■ | ■ | | | | | | | | | | | |
| Treatment 1 maintenance works | | | | | | | | ■ | | | | | | | ■ |
| Treatment 2 | | | | | | | ■ | ■ | | | | | | | |
| Treatment 3 | | | | | | ■ | ■ | | | | | | | | |
| Treatment 3 maintenance works | | | | | | | | | | | | | | | ■ |
| Treatment 4 | | | | | ■ | ■ | | | | | | | | | |
| Treatment 4 maintenance works | | | | | | | | | | | | | | | ■ |
| Treatment 3-4 Extension Area | | | | | | | ■ | | | | | | | | |
| Treatment 5 Diversion bund and rock chute | | | ■ | | | | | | | | | | | | |
| Treatment 6 | | | | | | | | | | | | | ■ | ■ | ■ |
| Treatment 6 Diversion bunds and rock chute | | | | | | | | | | | | | | ■ | ■ |
| Treatment 7 | | | | | | | | ■ | ■ | | | | | | |
| Treatment 8 | | | | | | | | | ■ | ■ | | | | | |
| Treatment 8 maintenance works | | | | | | | | | | ■ | | | | | ■ |
| Treatment 8b | | | | | | | | | | ■ | | | | | |
| Project site stock management fencing | | | | | | | | | | | | ■ | | | |

End 2017 Works

End 2018 Works

End 2019 Works

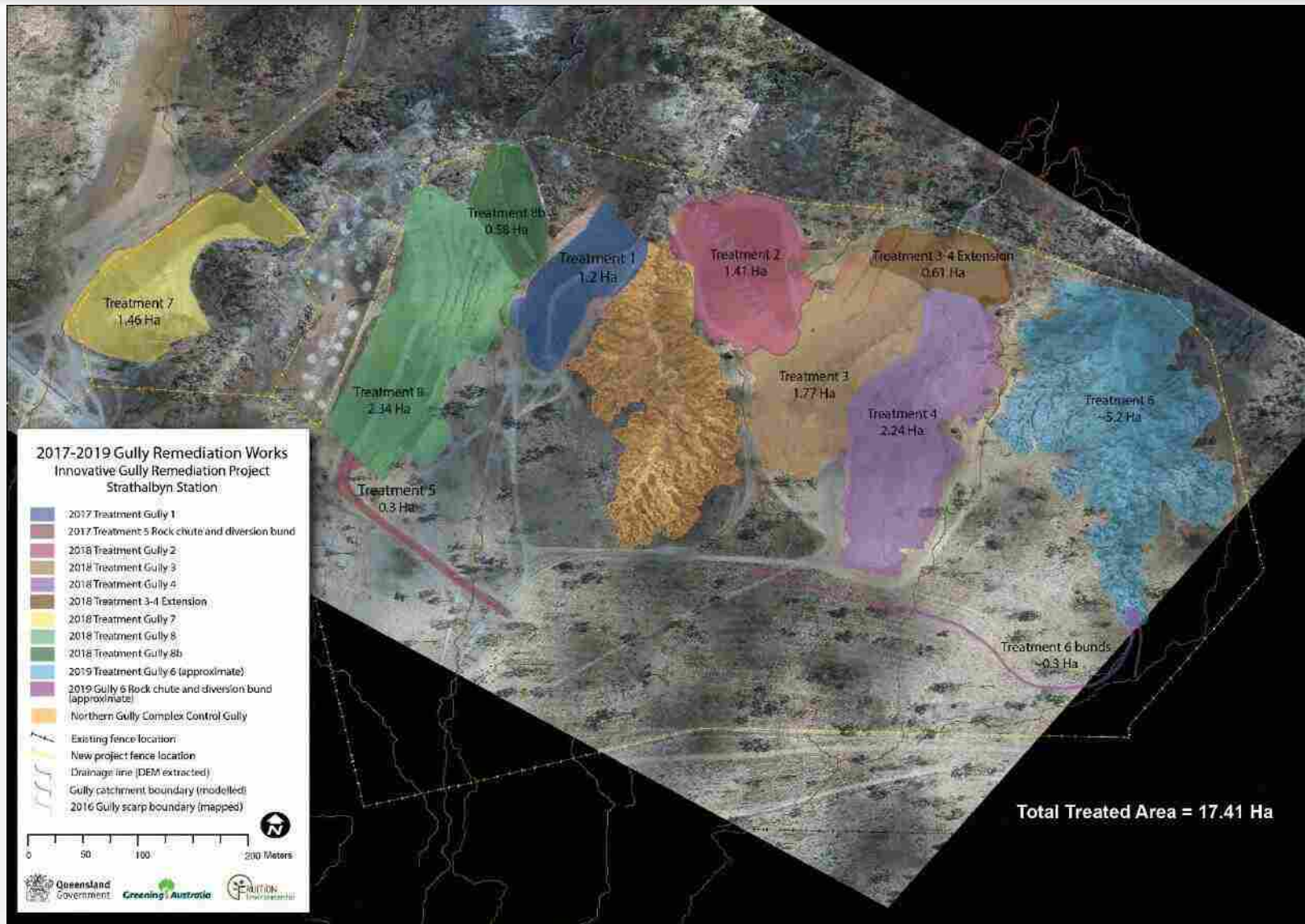


Figure 2 Strathalbyn Station Innovative Gully Remediation Project works overview 2017-2019.

Table 2 Comparison of works undertaken at each trial site under the Innovative Gully Remediation Project at Strathalbyn Station

| Site | Works implemented | | | | | | | | | | | | | | | | | | |
|------------------------------|---------------------------------|---|---|-------------------------------|---|---|-------------------------------|----------------------|------------------------|--------------------------------------|--------------------------------|------------------------|---------------------------|----------------------------|---|--------------------------|-----------------------------|---------------------------------|---|
| | Catchment treatments | | | Gully Scarp treatments | | | | Gully bed treatments | | | Regraded batter treatments | | | | | | | | |
| | Fenced for managed stock access | Diversion bund to intercept catchment flows | Rock chute to control diverted flows to gully bed | Earthworks to reshape/regrade | Gypsum application and incorporation to 0.15m | Capping with gravel materials nominal 100mm | Capping with borrowed topsoil | Graded rock bed | Porous Rock check dams | Gypsum application and incorporation | Coir mesh applied over batters | Blanket mulching - Hay | Patchily spread hay mulch | Blanket mulching - Bagasse | Bagasse applied with a spreader or blower | Hay bunds on the contour | Debris bunds on the contour | Direct seeding – exotic grasses | Direct seeding with sub-surface incorporation |
| Treatment 1 | x | x | | x | x | C | | x | | x | | x | | | | | | x | |
| Treatment 2 | x | | | x | x | | x | | | x | x | | | | | | | x | |
| Treatment 3 | x | x | | x | x | x | | | x | x | | x | | | | | | x | |
| Treatment 4 | x | x | | x | x | x | | x | | x | | x | | | | E | | x | |
| Treatment 3-4 Extension Area | x | x | | x | x | x | | | x | x | | x | | | | | F | x | |
| Treatment 5 | x | x | x | x | x | | | | | x | | | | | | | | | |
| Treatment 6 | x | x | x | x | B | | | | x | | | | | | x | x | | G | |
| Treatment 7 | x | A | | x | x | x | | | x | x | | | x | | | | | | x |
| Treatment 8 | x | x | x | x | x | x | | D | x | x | | | | H | I | J | | x | |
| Treatment 8b | x | x | | x | x | x | | | x | x | | | x | | | | | x | |

A – diversion bund implemented under an adjacent Greening Australia – Australian Government funded Reef Trust 4 program: B – incorporated to 0.2m depth: C – nominal 200mm thick: D – upstream half of Treatment 8 bed has been treated with graded rock: E – on north east batter only: F – on north west batter only: G – to be undertaken in September 2019: H – bagasse spread with a semitrailer mounted blower on parts of the eastern and all of the western batter: I – hay bales spread on the contour on the north eastern batter only: J – Debris spread on the contour in the inter-rows of the hay contours on the north eastern batter.



2017 Works Program

The initial program of works had proceeded on the basis that on-ground works would commence in September 2017 however early wet season rains late in the month prevented mobilisation to the site. Ultimately the first works on-ground were commenced in October, shortly after processing of quarry materials at the project's on-farm quarry site some 3.5km from the works location. A reduced program of works was implemented to avoid working into the wet season with the aim of reducing complications and risks associated with undertaking earthworks in the dry tropics at that time of year.

Figure 3 shows the extent of on-ground works undertaken in 2017.

A summary of the works undertaken at each site is provided below along with observations of how the treatments have performed since being implemented up until the time this update report has been compiled (July 2019).

Treatment 1

Treatment 1 involved the use of earthworks machinery to reshape and regrade a 1.2ha alluvial gully site and then follow up treatments to stabilise the new landform (*Plate 1*). Follow-up treatments at this site included:

- the application and incorporation of gypsum at 18t/ha;
- spreading of a 200mm thick layer of 50mm minus quarry materials (essentially blasted and screen gravels and fines) over the batters and upslope areas;
- blanket mulching of the batters and disturbed upslope areas using rain-spoiled 450kg Rhodes grass hay bales
- hand seeding of the site at approximately 20kg per hectare using exotic perennial grass species including Tolga Rhodes and Sabi grass



Plate 1 Before and after remediation works at the Treatment 1 site

The site has been substantially stable since completion, having been through two wet seasons to date. Of note there have been a number of maintenance activities undertaken at this site after each wet which provide useful information about post-remediation processes that may influence remediation success at similar sites. As a summary:

1. There has been an area of repeat rilling of the batter face in the south east corner of the remediated gully (see *Plate 2*), caused by overland flow during intense rain events. This area was repaired in July 2018 using the 50mm minus quarry materials, with two whoaboys installed on the remediation access track to dissipate flows to the area. Despite these actions the rilling reappeared again during the 2018-2019 wet season. The area was subsequently repaired in July 2019 using porous cobble checks down the batter face and bagasse bunding to reduce flow velocities above the batter. **Avoiding creating access tracks to the heads of gullies is an important lesson from this experience.**
2. This was the first gully treated at the site and at this stage the techniques for dealing with tunnel erosion at this site were not well developed. In areas where tunnel erosion was not completely removed subsidence later occurred creating depressions which risked reinitiating tunnel erosion. **The importance of the careful removal of all tunnelled areas and effective compaction at optimal moisture content was the lesson from this experience.**
3. The site has been seeded four times since the earthworks were completed. It was first seeded in January 2018 when the ground had been wet by a rain event and very good germination occurred. However, follow-up rainfall did not occur and actual grass establishment was poor. The site was reseeded in late February and again germination was good however most grasses did not reach maturity and seed before the dry season took hold. The site was again seeded in October 2018 and December 2018 and germination was fair with most plants growing to maturity and producing seed. **The lesson here was to ensure seed is sown early in the wet season and preferably multiple times at a lower rate to increase the chance of having early germination and having the plants reach maturity.**



Plate 2
Treatment 1 site in May 2018, at the end of the 2017-2018 wet season

4. Early observations of the site's progress in terms of revegetation success suggests that grass cover on the 200mm capping material is patchy. Of interest, this site has significant regrowth of poplar gum tree seedlings. It is not known whether the growth of tree seedlings on the batters is a positive outcome in terms of maintaining the batter capping consistency and preventing moisture seepage into the underlying dispersive soils. This issue will be monitored over the project's life and reported on in future project updates. In any case the capping thickness seems to be major factor in the stability of the site since the remediation works were completed.

Treatment 5

Treatment 5 involved the construction of a diversion bund and drain to intercept catchment flow during rain events and safely deliver that runoff to the level of the future Treatment 8 gully bed through an engineered rock chute (*Plate 3*). The rock chute is designed to take a much larger flow than is currently diverted as the diversion drain is to be extended to intercept part of the catchment flows of the control gully in the last stage of the project.

The chute was constructed using rock from the on-farm quarry established for the project. Geofabric has been placed in the crest and apron cut-off walls only with a granular filter made of 50mm minus aggregate being used as method for retaining fines and reducing dispersion in the chute base as is common practice for rock chute construction in sodic dispersible soils.

The diversion drain and chute have been stable over the two subsequent wet seasons since installation.



Plate 3 Treatment 5 rock chute installed in November 2017 prior to the Treatment 8 remediation in 2018 (left image), and same site in February 2019 post Treatment 8 and mid 2018-2019 wet season.

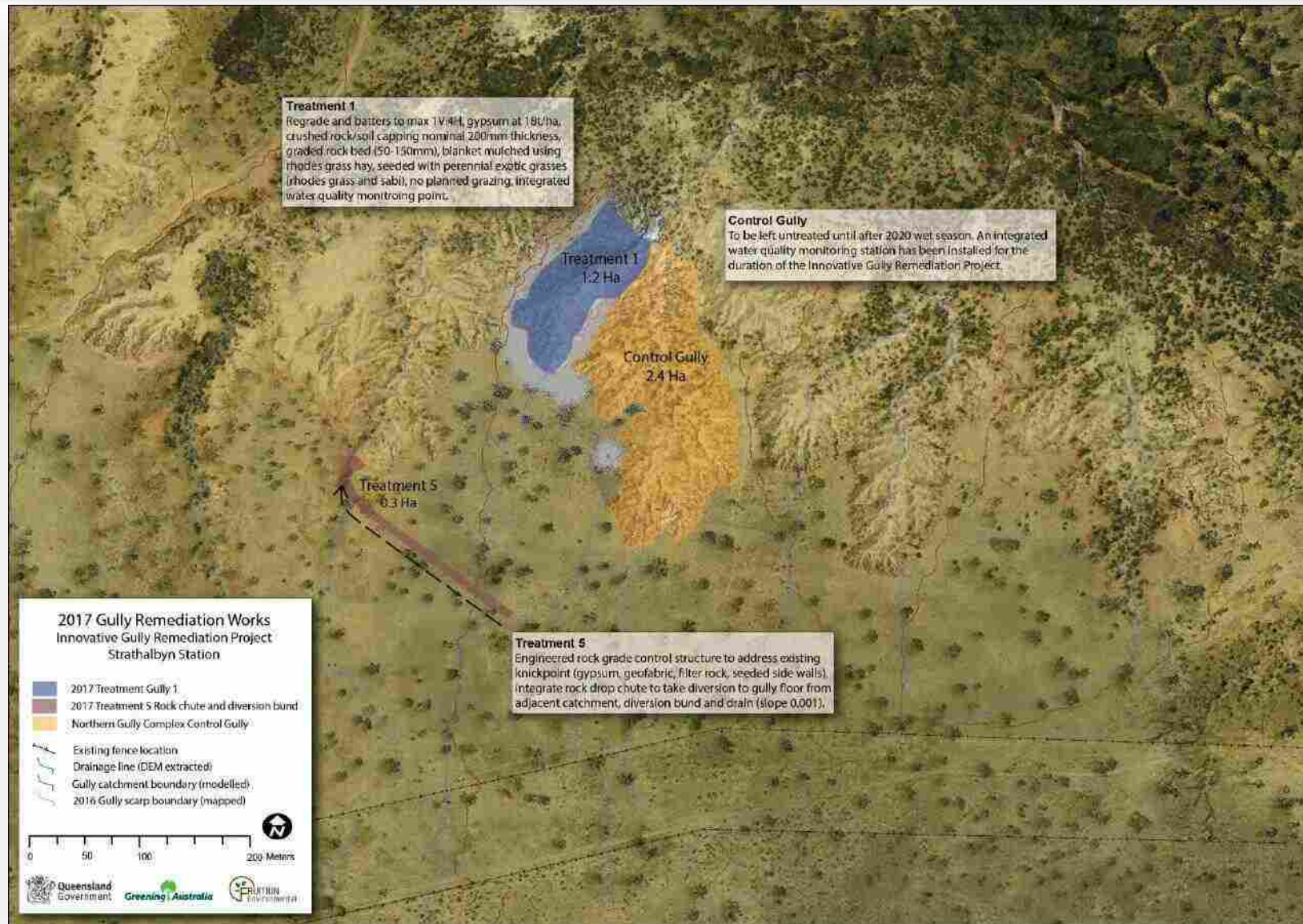


Figure 3 2017 Strathalbyn Station Innovative Gully Remediation Project works program.

2018 Works Program

The second year of works under the program commenced in May 2018 and ran through to October 2018.

Treatments 2,3,4, 7 and 8 were all completed with a number of variations and extensions added due to practical considerations or design issues. Treatment 6 was not completed due to concerns as to the suitability of the proposed earthworks design for that area.

By October, 10.4 hectares of eroding gully area had been remediated (*Figure 4*). Fencing around the project site to manage grazing within the remediation area was completed in December 2018.

A summary of the works undertaken at each 2018 remediation trial site is provided below along with early observations as to treatment performance. The effectiveness of the treatments over coming wet seasons will be further evaluated as part of the program's on-going monitoring and evaluation program.

Treatment 2

Treatment 2 involved the use of earthworks machinery to reshape and regrade a 1.41ha alluvial gully site and then follow up treatments to stabilise the new landform (*Plate 4*). In the 2018 earthworks program, particular attention was paid to careful foundation preparation to remove tunnel erosion. As Treatment 2 was not planned to be capped with quarry materials, batters were kept at a low slope which in some parts of the treated gully increased slope length.



Plate 4 Treatment 2 in December 2018 post-completion (left) and in February 2019 mid 2018-2019 wet season, note the heavily incised control gully in the photo backgrounds.

Follow-up treatments at this site after the bulk earthworks included:

- the application and incorporation to 0.15m depth of gypsum at 18t/ha over the batters, bed and disturbed upslope areas;

- spreading of topsoil stripped from the adjacent treatment 3 and treatment 4 site over the batters at a nominal thickness of 50-100mm;
- spreading of 50mm minus quarry material over all disturbed upslope areas
- the laying and pinning of coir mesh over all batter slopes (predominantly 4mm weave with a small area of heavier duty 7mm weave mesh used in the most upstream end of the gully);
- the construction of 14 porous rock check dams at a nominal height of 200mm using 50-150mm graded quarry rock;
- the construction of a rock sill of 1m length, 1.4m depth and 16m width at the downstream extent of the treated gully, at the confluence of the treated gully with the untreated main channel of the gully complex
- hand seeding of the site at two sperate intervals at approximately 20kg per hectare using exotic perennial grass species including Tolga Rhodes and Sabi grass (40kg per hectare total application).



*Plate 5
Treatment 2 site in
February 2019, midway
through the 2018-2019 wet
season.*



*Plate 6
Treatment 2 site in July
2019.*

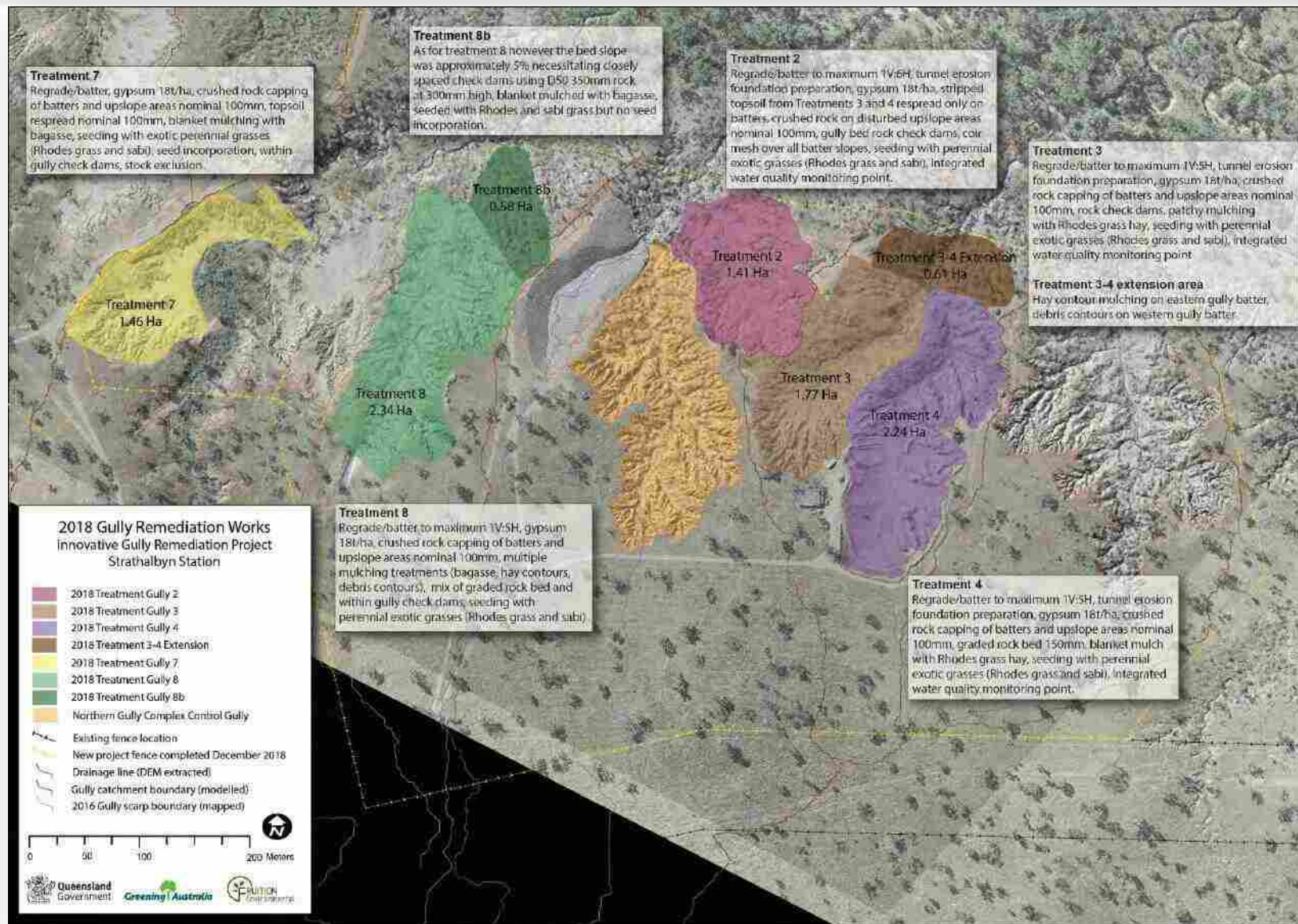


Figure 4 2018 Strathalbyn Station Innovative Gully Remediation Project works program.

Observations of the response of Treatment 2 to the 2018-2019 wet season include:

1. Germination of direct seeded grasses was initially poor. This is thought to be due to the seed not being able to be effectively incorporated into the soil surface after placement of the coir mesh. The site was reseeded and was subsequently relatively successful. There is a clear contrast evident in grass cover above the gully however this is predominantly due to these areas not been seeded.
2. Rilling and some erosion at the interface of the gravel capped upslope areas and the topsoiled and coir netted batters was evident wherever the slope concentrated flows towards the batter. This is despite this area being graded flat upon completion of the coir placement. **It would seem judicious to attempt to try to slow flows at this interface using porous materials such as hay or debris or bagasse placed on the contour.**

Treatments 3 and 4

Treatments 3 and 4 involved the regrading of an entire gully complex which historically had exported in excess of 2000 tonnes of fine sediment to the GBR lagoon per year over a 70 year period. The earthworks involved significant foundation preparation of heavily tunnel eroded areas (see *Plate 7*) which caused a number of practical issues in terms of site management, earthworks process and project/contract management. Foundation preparation on this scale requires substantial double handling of excavated materials as the tunnelled area are boxed out, the material conditioned using water trucks and then compacted back into the reformed shape in 300mm layers using a dozer, excavator and padfoot roller. The area of the treated gully was expanded to include some additional areas below the design footprint which were also eroded allowing the entire area of alluvial gullying to be treated. The final area of treated gully was approximately 4.62 hectares (*Figure 4*).

Post earthworks the two sites had slight variations to the batter treatments and bed treatments as detailed below:

- both sites were treated with gypsum at 18t/ha over all disturbed areas, incorporated to a depth of 0.15m using a grader;
- both sites had 100mm of 50mm minus quarry material spread over the batters and all disturbed upslope areas
- Treatment 3 had ?? porous rock check dams constructed along the length of the gully bed, Treatment 4 had a graded rock bed including 50-150mm quarry materials for the upper two thirds of the bed and larger ~ 250mm materials used in the lower third (see *Plate 8*);
- a rock sill of 1m length, 1.4m depth and 8m width was constructed at the downstream extent of the gully complex , below the confluence of the two treatments;
- Treatment 3 was mulched by hand using Rhodes grass hay with the intention of leaving some of the gravel capped surface exposed as a seed bed, Treatment 4 was blanket mulched (partly using manual spreading and partly using a positrack with mulcher attachment which proved unsuccessful, see below for more details).
- Both treatment areas were hand seeding at two sperate intervals at approximately 20kg per hectare using exotic perennial grass species including Tolga Rhodes and Sabi grass (40kg per hectare total application). Seed germination and establishment appeared more successful on Treatment 3 when compared to Treatment 4 (see *Plate 9*)



Plate 7
The pre-remediation state of treatment areas 3 (left) and 4 (right) in February 2018. The hay stack contains 415 450kg Rhodes grass hay bales used in the 2018 remediation program.



Plate 8
Treatment areas 3 and 4 post remediation in December 2018.



Plate 9
Treatment areas 3 and 4 midway through the 2018-2019 wet season, February 2019.



Plate 10
The pre-remediation state of treatment areas 3 (left) and 4 (right) in February 2018. The hay stack contains 415 450kg Rhodes grass hay bales used in the 2018 remediation program.



Plate 11
Treatment 2 site in February 2019, midway through the 2018-2019 wet season.

The treatment sites were subjected to significant rainfall (including rain intensities of up to 75mm per hour) during the 2018-2019 wet season. Both treatment areas remained substantially stable throughout the wet, although a number of maintenance issues were identified after the wet season. As a summary:

1. Of note, rill erosion in the corners of the upstream “cul-de-sac” area of the post remediation gully form, similar to that which occurred in Treatment 1, was evident on both gullies and particularly on the east side batter slope of Treatment 3. It is clear that, during periods of

heavy rainfall, overland flow over the upslope areas and down the batters still creates an erosion risk. Once rilling erodes through the batter capping and then through the gypsum treated top of the sub-surface, the reinitiation of erosion of the underlying dispersible soils is likely. **The use of porous check structures in the corners of the gullies at locations where surface flow is likely to be concentrated is recommended as a preventative measure (see Plate 12).**



*Plate 12
Cobble (50-150mm quarry rock) and bagasse checks installed at the location of rilling on the batter face caused by concentration of overland flow during intense rainfall events.*

2. At the downstream end of Treatment 3, a slight depression in the upslope (above batter) area has created a drainage basin which has concentrated flow down the adjacent batter. The depression eventuated from an error in the design quantities that left too little fill to create an even free draining area at this location. The issue was identified in November 2018 and debris was placed along the contour to reduce the potential for concentrated overland flows. In December 2018 diversion bunds were installed to spread flows however these efforts were undermined by an intense rainfall event which dumped 65mm of rain on the site over the site in a 50 minute period, 10 minutes after construction was completed. The result was that the bunds failed and a large incision was initiated down the batter face (see Plate 13). The erosion liberated approximately 80 tonnes of sediment into the bed. Repairs were undertaken in June 2019 including regrading the eroded area, constructing a rock lined batter chute, reorientating the diversions to direct flow down the chute, and reinstating the debris bunds to slow flows (Plate 14). **The main lessons learnt from this experience are to ensure that designs and any subsequent earthworks do not leave drainage depressions that concentrate event flows down the batters as the capping materials are not sufficient to prevent significant erosion via these processes.**



*Plate 13
Erosion on the batter face
caused by failure of
diversion bunds intended to
disperse concentrated flow
caused by a small drainage
depression after
earthworks.*



*Plate 14
Repairs of the above site
underway involving the
regarding of the eroded
area and construction of a
batter chute to take flows
(diversion bunds to the
throat of the batter chute
not yet installed at the time
of photo).*

3. The porous rock check dams installed in Treatment 3 have proved effective at trapping sediment within the bed of the gully (including fine silts and clays; see *Plates 15 and 16*). Some reorganisation of bed sediments between the check dams can be expected. The design used which is to have a low but wide rock check (approximately 200mm high but 2.4m long and full channel width) appears to reduce scour at the downstream extent of the check provided the appropriate spacing is used to allow back-flooding of upstream checks during higher flow events.

4. Germination and establishment of the direct seeded perennial exotic grasses was, based on observations, clearly more prolific in the areas where mulch was spread coarsely (Treatment 3) when compared to areas which were carefully blanket mulched (Treatment 4). Coarse spreading of mulch materials assists seed germination if seed incorporation into the soil surface is not undertaken.



*Plate 15
Porous check dams
installed in the bed of
Treatment 3.*



*Plate 16
Approximately 200mm
depth of sediment
deposition behind porous
check dams in Treatment 3,
flow from photo left to
right*

Treatment 7

Treatment 7 represents the most intensive remediation effort undertaken under the Innovative Gully Remediation program. Colloquially it represents the “optimal” treatment approach utilising all available resources to produce the best possible outcome.

Ultimately, the optimal treatment at any site will be dictated by what is reasonable in terms of costs and what is possible in terms of remediation materials, both generally dictated by logistics and site remoteness. The initial treatment plan for this site involved the use of compost and hay mulch but at the time of construction neither of these materials were available. Aged and semi-composted bagasse was used as an available alternative.

Plate 17 and 18 show the before and post-treatment gully form and condition.



Plate 17
Treatment are 7 prior to
remediation works in early
2018



Plate 18
Treatment 7 post
treatment in February
2019.

The treatments at this site included:

- Careful removal of all tunnel eroded areas, compaction at optimal moisture content, and regrading to a batter slope not exceeding 1V:5H;
- the application and incorporation to 0.15m depth of gypsum at 18t/ha over the batters, bed and disturbed upslope areas;
- spreading of 50mm minus quarry material over all batters and disturbed upslope areas at a nominal thickness of 100mm;
- spreading of topsoil stripped from the adjacent treatment 8 site over all batters at a nominal thickness of 100mm;
- spreading of semi-composted bagasse over all batters and disturbed upslope areas at a nominal thickness of 50-100mm;
- hand seeding of the site at approximately 40kg per hectare (double rate) using exotic perennial grass species (Tolga Rhodes and Sabi grass), and incorporation to 20mm into the final surface using a coir nett biscuit dragged over the seeded surface;
- the construction of 5 porous rock check dams at a nominal height of 200mm using 50-150mm graded quarry rock;
- hand weeding of the remediation site to remove exotic shrub (belly-ache bush) from the batters, imported with the stripped topsoil from Treatment 8

This treatment has performed extremely well over the observation and monitoring period. No issues were recorded at the site and no maintenance activities were required post the 2018-2019 wet season. Clearly the use of a stable capping material amended with the use of topsoil and semi-composted bagasse with effective seed incorporation with seeding at a very high rate has produced good results. Of note:

1. The seed germination and establishment rate far exceeded any of the other treatments used to date (see *Plate 19* and *20* overleaf).
2. No rill erosion from overland flow occurred on this site predominantly because overland flows were diverted to an adjacent catchment under an adjoining Australian Government funded Reef Trust program (remediation of an adjacent photo is visible in the top right corner of *Plate 18*)



Plate 19
Early establishment of sown exotic grasses at Treatment 7.



Plate 20
Grass establishment on the Treatment 7 batters midway through the 2018-2019 wet season in late February 2019.

Treatment 8

Treatment 8 targeted a large complex gully system downstream of the Treatment 5 rock chute. The gully complex had multiple fans expanding from a central drainage line. The initial design created three remediated gully basins however problems with design quantities forced an on-site redesign. The final “as-constructed” design created a large basin with a significant batter slope at the downstream eastern extent (approximately 90m; see *Plate 21* and *22* below) with a small but steep secondary remediated gully to the north east (known as Treatment 8b, see upper middle of *Plate 22*).



Plate 21
Complex multiple gully fans were a feature of the Treatment 8 site.



Plate 22
A long low slope batter on the downstream eastern extent of Treatment 8 as a result of a plan redesign necessitated some innovative approaches to slope stabilisation.

As with other sites completed under this trial, significant effort was expended undertaking the careful removal of all tunnel eroded areas, compaction at optimal moisture content, and regrading the gully to a batter slope not exceeding 1V:5H and the lowest slope bed profile given the design constraints. Once the final gully regrading was completed the gypsum was applied over the entire site at a rate of 18 tonnes/hectare and ripped in with a dozer and grader to incorporate to a depth of

0.15m. A 100mm layer of 50mm minus quarry material (gravels and fines) was then spread over all batters and disturbed upslope areas.

Although the basic approach was similar to other gullies treated in terms of the bulk earthworks, amelioration and capping, the plan redesign created significant practical remediation issues with regard to stabilising the constructed batters and bed forms. These included the creation of a long batter slope on the downstream eastern side of the Treatment 8 gully and a small but very steep gully bed profile at Treatment 8b. The following treatment notes detail the various approaches used to addressing these issues in each treatment, several of which equate to trials within the treatment 8 trial itself:

1. At the downstream eastern extent of Treatment 8, the long batter slope was stabilised using a mix of wide and widely spaced Rhodes Grass mulch bunds on the contour interspersed with debris bunds (salvaged from the pre-earthworks grubbing of the gully). This area was then heavily seeded with exotic perennial grass seed (*Plate 23*)



Plate 23
Hay and debris bunds inter-sown with exotic grass seed on the downstream eastern batter of Treatment 8 proved very effective for stabilising long low slope batters.

2. Across the majority of the remaining Treatment 8 batters, bagasse was spread at a depth of 50-100mm to provide a cover mulch over the gravel capping with the intent of holding sufficient moisture to improve revegetation success. Bagasse was spread using two methods, firstly using a semi-trailer mounted mulch blower which proved slow and expensive but also shredded the bagasse into fine particles which appeared to be less resistant to flow (appearing to wash down the batters during intense rainfall). The second approach was to spread the bagasse using a small side-tipper and grader which was quicker and produced a better effect in terms of material thickness and resilience to rain and run-off. *Plate 24* provides some indication of the areas treated with bagasse using the blower (area indicated by the yellow rectangle) as opposed to the side-tipper and grader (red rectangle).



Plate 24
Areas of bagasse spreading on the Treatment 8 and 8b batters, yellow rectangle indicates areas where a mulch blower was utilised, red rectangle is where a side-tipper and grader were used.

3. Porous rock checks were used in the bed of both Treatment 8 and Treatment 8b, although Treatment 8 also utilised a graded rock bed in the upstream half of the treatment area. The bed slope in Treatment 8b was extremely steep and so the rock checks utilised a rock size with a D^{50} of 350mm and were spaced approximately 2m apart. Observations made after the 2018-2019 wet season showed significant undermining and subsequent resettlement of the rock checks in Treatment 8b (see *Plate 24* centre to bottom right of red rectangle). **It is possible that rock checks could work in steep bed slope situations however they are high risk and most likely require placement on a non-dispersive base such as crushed gravel. A safer approach would be to design the gully form and bed profiles to reduce steep bed slopes, instead opting for steeper shorter batters where flow and erosive forces can be more effectively controlled through other more cost-effective means.**
4. Similarly to Treatment 3, a slight depression in the upslope area above the eastern batter on Treatment 8 has created a drainage basin which has concentrated flow down the batter. Again, repairs were undertaken in June 2019 including regrading the eroded area, constructing a rock lined batter chute, reorientating the diversions to direct flow down the chute. **The repeat occurrence of significant erosion down the batter face below hardly perceptible depressions in upslope (above batter) area reinforced the need for very careful design and construction to ensure drainage depressions do not concentrate event flows down batters.**

Fencing and grazing management

A total of 3.4km of permanent fencing was installed around the entire remediation site in December 2018. The sites grazing management is to be managed by the landholder in accordance with regenerative grazing practices in line with the property's holistic grazing management strategy. The location of the project fencing is shown in *Figure 4*.

2019 Works Program

The third year of works under the program commenced in May 2019 and ran through to July 2019.

Treatment 6 targeted an entire gully complex of approximately 5.2 hectares and was the only area remediated in 2019. The design implemented was a redesigned approach after the initial design was reviewed to incorporate learnings from previous years and a diversion bund and associated drain and rock chute added into the site plan. The rock chute has been designed to complement the other rock chute and diversion drain at Treatment 5 and will eventually be extended to assist in diverting catchment flows currently entering the control gully mid site (*Figure 5*).

No observations as to treatment performance are yet available however the effectiveness of this treatment approach will be evaluated over future wet seasons as part of the program's on-going monitoring and evaluation program.

Treatment 6

Treatment 6 involved the use of earthworks machinery to reshape and regrade approximately 5.2ha of alluvial gully with follow up treatments to stabilise the new landform (*Plate 25*). This treatment trial was significantly different in that no imported capping material was to be used over the batters, only topsoils stripped from within the gully remediation footprint. Careful removal of all tunnel eroded areas followed by compaction at optimal moisture content and regrading to a batter slope not exceeding 1V:6H defined the main earthworks approach. The following notes detail the main treatment options used after the bulk earthworks were completed:

- Soil amelioration was intensified with the target gypsum application rate increased to between 18 and 44 tonnes/hectare depending upon soil analyses. Gypsum was ripped into the prepared landform to an incorporation depth of 0.2m.
- A diversion bund and drain and engineered rock chute were constructed to safely bring any overland catchment flows to the regraded gully bed;
- 20 porous rock check dams at a nominal height of 250-300mm at spacings between 6 and 21m (depending on design bed slope) were installed;
- A rock sill installed to a depth of 1.4m, 9 metres wide and 1m long was installed at the downstream extremity of the site to prevent the bed lower from secondary incision should that process occur;
- Stockpiled topsoil that was won during the bulk earthworks phase from within the gully footprint was respread over the batters and immediately above the batters on upslope areas (where possible) at a thickness of approximately 50mm;
- Imported bagasse and hay materials were utilised to assist in controlling overland flows that were predicted to accumulate on the batters or upslope areas.
- Mulch hay and salvaged debris bunds which were laid on the contour and then track rolled by excavator were also placed on any long slopes to mimic the previous successful of these techniques as used on Treatment 8
- Repeat hand seeding of the site at approximately 20kg per hectare using exotic perennial grass species (Rhodes and Sabi grass) and incorporation into the final surface using a coir nett biscuit dragged over the seeded surface is to be undertaken in September, October and November;



Plate 25

Phases in the remediation of the Treatment 6 gully (clockwise from upper left): the gully prior to remediation works in early 2019; bulk earthworks commenced including foundation preparation to remove tunnel erosion and topsoil stripping; bulk earthworks nearing completion with batter grades established; rock chute being installed with associated diversion bunds.

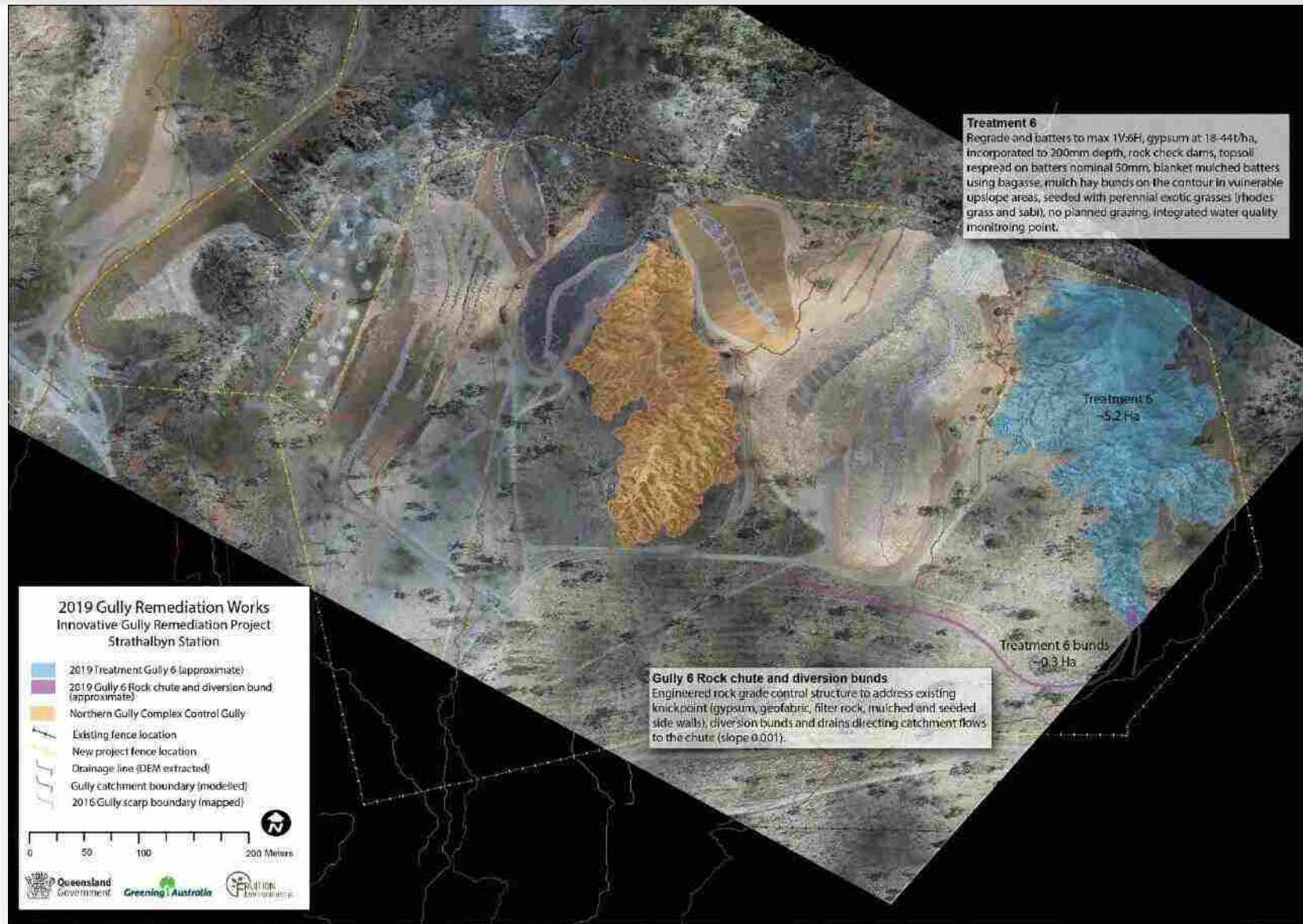


Figure 5 2019 Strathalbyn Station Innovative Gully Remediation Project works program.

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A large number of locally based businesses have also supported the on-ground implementation of the Strathalbyn Station remediation works. These include (in no particular order):



- Rugendyke Bashforth Contracting Pty Ltd (photo bottom)
- Markwells (photo top)
- GJCM Surveys Pty Ltd
- Vision Construction Pty Ltd (photo middle)
- Coalfield Services, Collinsville
- Zammit Earthmoving
- Neilly Group Engineering
- Bulk Fuels Australia, Townsville
- Cornett's IGA Home Hill
- Harvey Norman Ayr
- Enzed Ayr
- Alluvium
- Hastings Deering Townsville
- Tutt Bryant Townsville
- Drillmasters Townsville
- Inkerman Lime and Gypsum
- Geofabric Australia
- Ward's Tilt Trays
- Ayr Irrigation
- Ausco
- NDL Transport
- Fruition Environmental Pty Ltd
- Prime Rentals - Bowen
- Orica Townsville
- RE & KJ Whalan Fencing
- ABC Towing, Townsville
- Brookes Hire, Brisbane
- Kubota, Brandon