



RAPID GRASS

EROSION CONTROL

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Reduce maintenance costs, construction risks and environmental harm through effective erosion control treatment

Rapid-Grass processes will give your company the opportunity to secure a cost effective and sustainable method of erosion control to remain financially viable in an environmentally conscious future

SYNOPSIS

Embankments and cuttings are integral parts of rail and road networks that support the economy of every country including Australia. Water induced erosion from the steep slopes (batters) of these civil engineered structures costs tax-payers in terms of ongoing operation and maintenance of the land transport networks. Also the environment is degraded and sediments transported from sites have the potential to pollute the nearby water bodies downstream. This brochure provides an overview of RAPID-GRASS™ strategies to mitigate the erosion problems of land transport formation batters. Our research effort has been focused on strategies to aid quick establishment of grasses on the batters. The strategies include defining the topsoil quality of the batters, modification of batter topsoils to provide a conducive growth medium for the grasses, and seed treatment including pre-germination to accelerate the germination process. Provision of a cheap mulch to protect grass seeds/ seedlings and ameliorants from washout by high intensity and short duration rainfall events is another strategy. Development of a cost-effective drip irrigation system that sources water from either an existing pressurised water main or a temporary excavated pond/ dam (with solar pump) to supplement the unpredictable natural rainfall is a major strategy. It has been established that the target of 60% grass cover reduces erosion by over 90% compared with the bare scenario. The plot-scale verification work and experiences have already been successfully incorporated into large scale railway projects such as the 110 km Bauhinia Regional Railway Project spur line construction.

I. INTRODUCTION

Water erosion of the steep slope (batter) soils is caused by a two-part process. Raindrop impact and runoff cause soil particles to detach, and detached soil particles are transported by runoff. Erosion from batters may occur in different forms such as splash, sheet, rill, gully and tunnel (piping) erosion. The main objectives for preventing erosion and sediment production from batters are to quickly protect bare soil from rainfall impact, and to also manage water run-off. Sedimentation is managed by slowing flow and creating areas where sediment can be trapped or allowed to settle.

Upper layers of soils in much of the area of the Bowen Basin coal deposits in Central Queensland (CQ) are generally highly dispersive. The steep slopes required for earthworks within the narrow corridors of the export coal rail network are therefore particularly susceptible to water erosion, resulting in sediment transport and siltation of waterways. Some of the embankment and cutting batter erosion problems within Queensland Rail (QR) corridors are highlighted in Fig. 1. In Australia the erosion problems are not confined to CQ only, but they abound all over the country. Wherever soil is exposed there is erosion potential and the risk is aggravated by the steepness of embankment and cutting batters. Traditionally embankments have been designed and constructed without due regard to the hydrological processes and effects on the environment.



eroded sediments fouling ballast in a cutting



eroded sediments chocking culverts



eroded sediments chocking culverts



cracks on surface sealed batter



tunnel erosion inlet undermining mast foundation on an embankment



tunnel erosion outlet sediment fans

Fig. 1: Examples of erosion problems on embankment and cutting batters within QR corridors.

High maintenance costs, train delays due to speed restrictions and increasing environmental degradation persuaded QR to fund extensive research into cost effective and sustainable methods of erosion control in this ecologically sensitive area. This ten-year collaboration between QR and Central Queensland University (CQU), under the banner of HEFRAIL Project, has produced integrated systems to optimise the establishment of protective grass cover on steep slopes using fast growing non-invading plant species accepting of local conditions. These include seed treatment, amendment of sodic/saline/extreme pH soils, appropriate fertilization, innovative drip irrigation systems designed for site specific conditions with a view to being extremely economical with water use, and the management of fire risk to the protective grasses when it is necessary to burn off. This brochure provides an overview of the advances made on mitigation of erosion problems within QR corridors.

II. SEED GERMINATION ENHANCEMENT

The drought tolerant and quick regeneration after fire properties of Buffel Grass make it a preferred species for erosion control of railway batters in the semi-arid regions of Queensland. It has a larger and deeper root system capable of providing greater strength against erosion than other grasses. However, poor germination of Buffel seeds sown on railway batters due to inherent seed dormancy makes it difficult to achieve the rapid cover required for effective erosion control. This section presents experiments conducted at CQU on the use of sulphuric acid (H_2SO_4) to break Buffel seed dormancy for railway batter revegetation.

Different concentrations of H_2SO_4 were applied to Buffel Grass seeds for various soaking (dipping) durations in order to improve the germination process. Fig. 2 shows the final germination percentage after 15 days. The final germination of Buffel Grass seed increased with increasing concentrations of H_2SO_4 . The 100% concentration of H_2SO_4 treatment recorded 94% germination compared to 20-25% without acid treatment. However, an interaction effect between H_2SO_4 concentration and duration of soaking treatment was significant, revealing that at 100% H_2SO_4 , the seed final germination level peaked at 4 minutes, and declined with longer seed soaking duration to almost nil germination after 10 minutes of soaking. Seed treatment with H_2SO_4 is promising but there are safety issues that call for cautious handling, and mechanized treatment for large applications is recommended.

An alternative simpler and large-scale practical approach for improving the Buffel seed germination was by soaking the seeds in water and pre-germinating in potting mix or soil media maintained at a constant soil moisture close to field capacity. Plastic covers on seeded batters in winter were found to speed up the germination process. It helped build up heat and prevented evaporation, maintaining the moisture content at field capacity. However it was found that if the plastic cover is left longer than required, the built up heat could kill the seedlings.

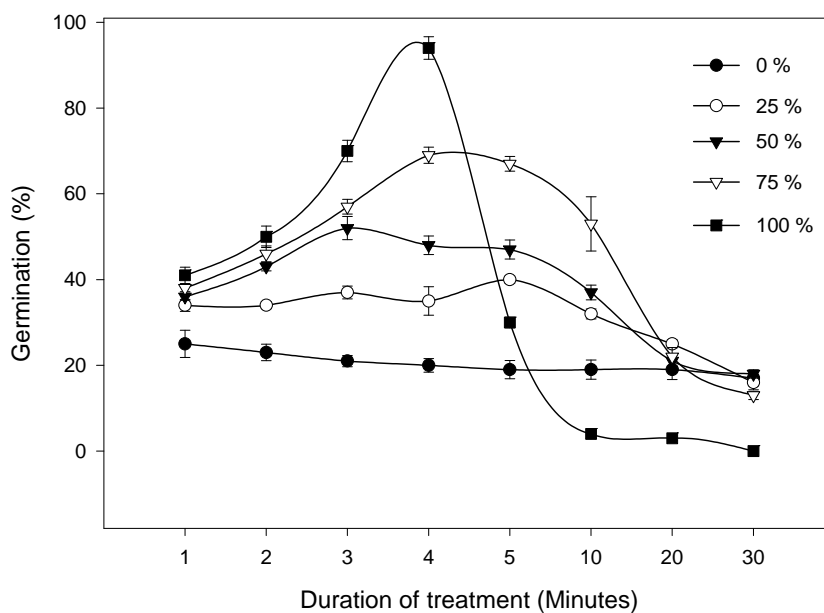


Fig. 2. Final germination percentage of Buffel seeds at 15 days.

III. SOIL MODIFICATION

The soil profile in many parts of Central Queensland is duplex. The top 0.5 m may consist of good quality topsoil but beneath this layer the soil properties are significantly different and of poor nutritional quality to support vegetation growth. This explains why, for some cutting batters, vegetation growth is confined to the top sections and there is a lack of vegetation cover on the subsoil used to construct the embankments. Therefore, the high salinity (indicated by chloride and electrical conductivity levels) and sodicity (reflected by exchangeable sodium percentage levels), and extreme acidity (pH levels) of the soils need to be improved for the soils to provide a conducive environment for sustained grass growth. A cheap source of calcium is used to counteract the negative effects of high sodium content, thus decreasing the exchangeable sodium percentage value. For a sodic soil with pH level below 7 (the neutral value), lime is applied to the soil before seeding. Apart from supplying calcium, lime also raises the pH level. Gypsum being neutral is applied to sodic soils if a change of pH is not required. Application of calcium to sodic soils also increases soil porosity, increases structural stability, reduces soil swelling and shrinkage, increases soil infiltration and hydraulic conductivity, reduces surface crusting and improves root penetration and seedling emergence rates. Suitable fertilisers need to be added to the soil to provide nutrients required for the growth of the grasses. Rates of application of the ameliorants and fertilisers depend on the soil chemical properties. Where the soil properties are found to be very poor, the batters are topsoiled in lieu of chemical modification.

IV. MULCHING

The risks of washout of seeds/ seedlings and ameliorants by high intensity and short duration rainfall events that characterise the semi-arid environment need to be minimised. Limited use of waste ballast and erosion control blankets as mulch has been quantitatively investigated. The mulch will help reduce raindrop impact and runoff velocities. The inter-ballast voids will increase water storage and retention time, thereby increasing hydraulic gradient and hence increasing infiltration. The grass will anchor the ballast from washout or gravity sliding/ rolling. Should fire occur after establishment of the grasses, the ballast would be in place to minimise erosion on the batters, before a revegetation program becomes effective. This is to say, the ballast provides a degree of permanent protection against erosion. The blankets can be costly where laid on all batter sections. Therefore, attention has been focused on laying the blankets on critical sections of the batter in order to reduce costs. For an embankment the most critical section is the topmost batter section where the blanket is expected to spread runoff thereby reducing the risk of rill erosion before the grasses are established.

V. IRRIGATION SYSTEM

A. Water Sources

Water can be sourced from existing dams, existing creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor. Two example water sources are shown in Fig. 3. The overriding factor is the cost of the water which can range between AU\$1/kL and AU\$10/kL.

B. Advantages of Drip Irrigation

Drip Irrigation is the most efficient and manageable system by which water is supplied directly near the root zone of the plants as per the demands of the plants through drippers or emitters, used interchangeably. The emitter is enclosed and inseparably welded to the inside wall of the tubing as it is extruded in the manufacturing process. Fig. 4 shows some elements of the drip line (lateral) network.



tapping existing pressurised water mains (at scour valve)



solar pump pumping from a temporary pond

Fig. 3. Examples of water sources.

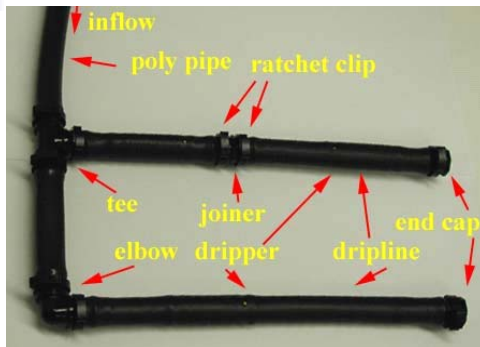


Fig.4. Elements of drip lines.

The specific benefits of drip irrigation as related to railway batter applications are:

- enormous water savings as little water is lost to evaporation;
- grasses undergo less stress from variations in soil moisture, enhancing appearance;
- slow application rate prevents excess surface water build-up;
- the low application rate and the use of automatic timers result in precise water control, allowing variation of water demand to fit grass growth stages;
- system's low flow rate allows irrigation of larger areas from a small water source, and economical to use in dry weather conditions;
- less labour requirement for monitoring and maintenance once the system is established and in operation;
- low labour and installation costs since there is no hole punching, emitters are factory spaced at equal intervals, and low risk of handling damage;
- water is kept off top of embankment, ballast and track section, access roads, thus preventing weed growth in these areas;
- the multi-outlet emitters/drippers provide highly uniform discharge rate and precise irrigation pattern;
- the jointless design guarantees longer lateral lengths, and makes it ideal for railway batters;
- being rugged, lightweight and very flexible, installation is very easy, and drip lines can be recovered mechanically regardless of grass cover levels;
- easy roll-up and storage make it easy for re-use from site to site, cutting down cost considerably;
- if irrigation water is mixed with fertilizer, it offers a more effective way of applying fertiliser and chemicals into the root zone.

C. Design and Layout

Fig. 5 shows an example design and layout of a network of drip lines with the actual site shown in Fig. 6 displaying the emitter wetting front. A 40 mm poly pipe is used to deliver water at the desired pressure to the irrigation controllers. A rain sensor attached to the controllers increases the efficiency of the automated drip irrigation system and avoids wastage of water. The submains taking water from the controllers to the bays are 25 mm poly pipe. A 20 mm dripline with an emitter maximum discharge of 2.5 L/h and 0.3 m spacing has been found to be adequate. The total area to be irrigated is divided into bays, making sure the maximum bay water demand does not exceed the supply rate.

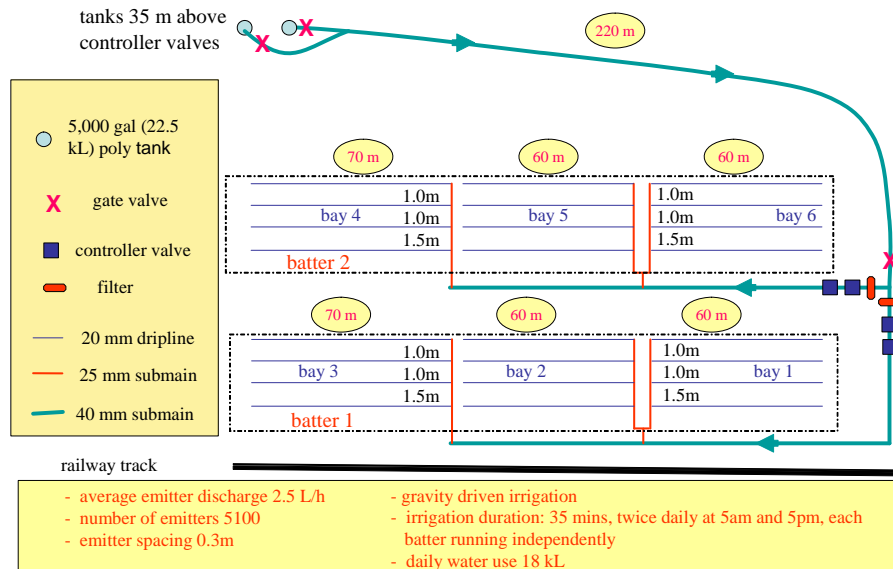


Fig. 5. Line diagram of drip lines for the lowest two batters of Holmes Cutting.



Fig. 6. Holmes cutting site – lowest two batters showing emitter wetting fronts (left) and the irrigation control valves (right).

VI. RESULTS TO DATE

Strategies for erosion control on railway embankment batters have been quantitatively evaluated using world class equipment consisting of dataloggers, pluviometers, runoff tipping buckets, and sediment filter troughs at the Gregory experimental site. Rainfall and runoff were monitored at one-minute intervals on 10-m wide embankment batter plots. Total bedload and suspended sediment eroded from the plots were also measured but only for a group of storm events within sampling intervals. It has been established that 60% grass cover on a railway batter reduces erosion by over 90% compared with the bare scenario (Fig. 7).

The integrated systems developed to combat the steep slopes erosion problems have been tested on a large scale at several locations in Queensland (Fig. 8) with excellent results. With the developed

strategies, the threshold grass cover of 60% is achievable between 8 and 14 weeks after seeding depending on the establishment season, maintenance, water source reliability and soil quality. The photographs shown in Figs. 9 through 14 best demonstrate the success stories of the advancements made in controlling erosion on railway formation batters. No maintenance has been carried out at any of these sites, briefly discussed below, after treatment. Given the environmental risks associated with erosion, and the estimated cost of about AU\$11.73/m² every 10 years in maintenance if the railway batters are not treated, the estimated total cost of between AU\$3/m² and AU\$7/m² of batter area treated with irrigation is justified.

A. Boundary Hill Site

As shown in Fig. 1, this cutting site (650 m long, 1.3 km batter length) had serious erosion problems; excessive scouring of rill and tunnel erosion on the batters, tunnel erosion on the access road and adjacent property, ballast fouled by eroded sediment, shallow seated slope failures, batter surface crusting (hard setting) and off-site sedimentation problems. The erosion problems were largely due to the soil being acidic (pH = 4.4), strongly alkaline and sodic. A catchment-based approach was adopted in the mitigation of the erosion problems, viewing the cutting as an integral part of a drainage system that extends beyond the railway easement. Several earth banks and catch drains were constructed to divert runoff away from the railway cutting crest. A series of rock check dams were put in the catch drains to help control flow velocity, stop erosion, and trap sediment. All erosion pipe inlets and outlets were excavated and filled with basalt spoil material obtained from the nearby mine. The site was well graded to prevent ponding of runoff water on the disturbed areas before treatments were imposed in February and March 1999. Pressurised water was tapped at the hydrant of the nearby mine 600 m away.



pluviometer



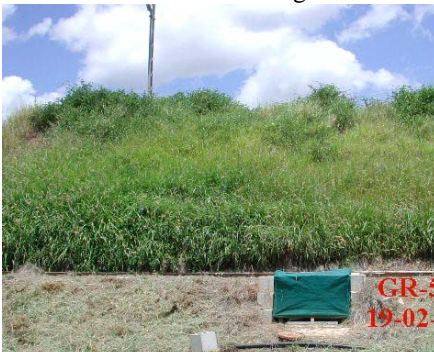
sediment filter basket



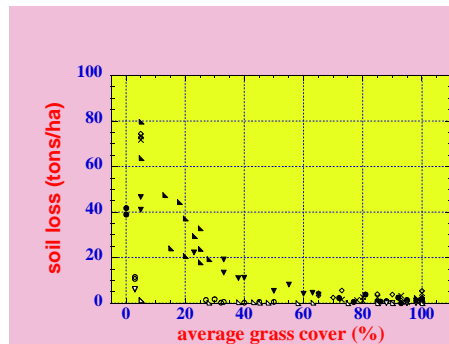
control plot – rill, inter-rill & tunnel erosion occurring



runoff tipping bucket



treated plot – 100% cover and no erosion



effect of grass cover on soil loss

Fig. 7. Equipment for plot scale field trials and results



Fig. 8. QR network showing the field trial sites.

B. Laleham Site

The soil at this embankment site (300 m batter length) is characterised as strongly alkaline, moderately saline, and strongly sodic, and was exhibiting severe rill and tunnel (piping) erosion on the batters and access road before HEFRAIL treatment (Fig. 1). Previous attempts made by QR workers to improve the access road by filling the pipes with soil and ballast did not work. Owing to the severe and extensive nature of rill and piping erosion, the embankment shoulder had to be reconstructed before treatments were imposed. Water was tapped at an air valve of a high pressure main 1.3 km away.



Fig. 9 Boundary Hill Site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m



Fig. 10. Laleham site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m

C. Riverside Mine Site

This embankment site consisted of four batter sections of a combined batter length of 1.2 km. There were numerous erosion pipe inlets on the top of the embankment, and erosion pipe inlets and outlets on the batters as a result of the acid soils prohibiting vegetation colonisation. The erosion pipe inlets under some overhead traction mast foundations could topple the masts with devastating consequences. The diameter of the pipe inlets ranged between 0.3 m and 2 m, with depths varying between 1 m and 3 m. Rill erosion, as a result of concentrated surface flow, and inter-rill (sheet) erosion were also occurring on the embankment batters. The embankment sections were widened to repair the erosion damage and also

to improve the access roads. Two sections were first treated in February 2001, and after grass establishment the irrigation materials and equipment were used to treat the other two sections in December 2001. This is an example of progressive treatments to save costs. Water was tapped at a scour valve of a high pressure main 700 m away.

D. Black Mountain Derailment Site

This site demonstrated an advanced technology cost-effective drip irrigation system design and setup on the environmentally sensitive elevated batters of a coal train derailment site. The final profile of the coal burial site consisted of six batters and associated berms with a drop in elevation of about 35 m, and a total batter length of 542 m. A small dam constructed downstream of the confluence of the two main drainage channels at the site supplied water for irrigation, and also served as a sediment trap. Water was periodically pumped from the small dam to three storage tanks using a petrol pump. Three solar pumps drew water from the storage tanks and dam to irrigate the top four batters. Contactors, pressure switches and irrigation control valves in turn shared a single solar power source between the solar pumps. Level balls (floating switches) placed in the storage tanks cut the solar power supply to the pumps when the storage tanks were nearly empty. The automated system cut labour costs considerably. Treatments were imposed in December 2001.



Fig. 11 Riverside Mine site. Drip lines were laid on all batter sections at row spacing between 1 m and 2 m.



Fig. 12. Black Mountain Derailment Site. Drip lines were laid on all batter sections at row spacing from 1m to 2 m.

E. Bauhinia Regional Railway Project

The Bauhinia Regional Rail Project is the first commercial application of HEFRAIL erosion control processes developed so far. It was a 110 km new spur line including several embankments that needed to be protected against erosion. The progressive treatments were integrated with the earthworks construction. In order to reduce the treatment costs, the embankment batters were categorised with different levels of treatment. The top 3 m of batters of all embankment sections exceeding 4 m in height and embankment batters on the downstream side of the two major flood plains (37 sites with a total embankment length of 15.1 km, treating both sides) received the full HEFRAIL erosion control treatment. The remaining embankment batters were treated but without irrigation. Water from existing dams and creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor were used to supply the irrigation water. To increase the germination rate and accelerate the germination process the seeds were soaked for 5 minutes in water and pre-germinated in potting mix before spreading on the batter surface. The project spanned between October 2004 and June 2006.

F. Holmes cutting

At this site QR eased the track curves, that is increased the curvature radii, at this section of the Toowoomba range. This activity resulted in fresh cuttings (Fig. 6) and spoil placed in embankment berms above the cuttings. The batters of the cuttings and embankments were progressively treated between August 2006 and October 2007. Four rows of drip lines were laid at the top sections only. The two poly tanks located about 40 m above track level (Fig. 5) were periodically filled by a water truck. This site is an example of gravity driven irrigation system.



Fig. 13. Bauhinia Site. Grasses established before track was laid. Three rows (1 m spacing) of drip lines were laid at the top batter section only.



Fig. 14. Holmes cutting – four rows (1 m spacing) of drip lines were laid at the top section only.

VII. SUMMARY

Research on erosion control of railway formation steep slopes (batters) has been carried out by QR and CQU for the last 11 years. This paper provides advances made in this research effort which has been focused on strategies for quick establishment of grasses. The strategic erosion control plan is customized to suit the local conditions. In general, the erosion control strategies involve some or all of the following:

- topsoiling or amelioration of the surface soil with lime or gypsum where it is established that the surface soil is dispersive, sodic, saline and/or has an extreme pH;
- fertilisers spread to provide a medium conducive to rapid growth of grasses;
- cheap mulch (waste ballast) or erosion control blankets are spread or laid to protect grass seeds/seedlings and ameliorants from washout by high intensity and short duration rainfall;
- grass seeding with non-invading species that are fast growing and accepting of local conditions;
- a cost effective drip irrigation system to aid grass establishment is an integral part of the erosion control process options; the choice of water source depends on availability and cost;
- in order to reduce the treatment costs, the embankment and cutting batters may be categorised for different levels of treatment.

The key benefits of erosion control are:

- minimisation of maintenance costs;
- minimisation of interruptions to normal train operations;
- minimisation of the risks of moisture and erosion induced formation failures and associated outages or derailments;
- minimisation of failures of railway signalling systems due to fouling of ballast by sediment;
- aesthetically pleasing batters and surrounds enhance your corporate image;
- minimisation of the risk of lawsuits resulting from sediment delivery from your easements to nearby water courses (e.g. creeks, stock ponds);
- compliance with environmental legislative requirements.

The RAPID-GRASS™ trademark has been established by QR and CQU to advance the HEFRAIL Project into a commercialisation phase, extending our expertise beyond QR corridors.

PROJECT OUTCOME PUBLICATIONS

- [1] S.P. Bhattarai, J. Fox, and Y. Gyasi-Agyei, “Enhancing Buffel Grass seed germination by acid treatment for rapid vegetation establishment on railway batters,” *Journal of Arid Environments*, 72, 255–262, 2008.
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- [3] Y. Gyasi-Agyei, “Erosion risk assessment of controlled burning of grasses established on steep slopes,” *J. Hydrol.*, vol. 317, pp. 276-290, 2006.
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- [6] Y. Gyasi-Agyei, “Cost-effective temporary micro-irrigation system for grass establishment on environmentally sensitive steep slopes,” *J. Irrig. Drain. Eng.*, vol. 130(3), pp. 218-226, 2004.
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- [8] Y. Gyasi-Agyei, “Pond water source for irrigation on steep slopes,” *J. Irrig. Drain. Eng.*, vol. 129(3), pp. 184-193, 2003.
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- [12] Y. Gyasi-Agyei, J. Sibley, and N. Ashwath, “Quantitative evaluation of strategies for erosion control on a railway embankment batter,” *Hydrol. Process.*, vol. 15, pp. 3249-3268, 2001.
- [13] Y. Gyasi-Agyei, J. Sibley, P. Truong, and D. Nissen, “A catchment-based approach to the mitigation of erosion problems in a railway cutting,” in proceedings, *Conference on Railway Engineering CORE2000*, Adelaide, Australia, 22-23 May 2000, pp. 22.1-22.13.



before



after

Rehabilitation of cutting batters at Boundary Hill



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