Supporting Nature: Rocky Outcrop Soil Stabilisation in Mt Vernon Park

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Executive summary

Deforestation of the Port Hills has caused ongoing erosion of discrete soil deposits on rocky volcanic outcrops through unconstrained surface water. This project investigates methods to reduce soil erosion and preserve these delicate soils required for endemic vegetation. Literature reviews analysed five subtopics: water dispersal methods, surface runoff, soil erosion processes, mitigation methods, and tools to measure soil erosion. These informed the design of in-situ testing of typical mitigation methods.

At the top of a rockface within Mt Vernon Park, coir matting, a bark-filled log, and silt fencing were installed and then tested for their effectiveness at reducing surface water flow and soil loss of placed soils on the outcrop in natural accumulation zones. In-situ testing indicated these methods were ineffective preventing soil loss, as surface runoff continued to concentrate in topographical lows and drainage zones on the outcrop, providing erosional force.

Due to the unsuccessful nature of mitigation at the top of the outcrop, controlled testing focused on mitigation strategies that looked to stabilise soils within their naturally occurring pockets on rock faces. A new design for soil pockets was developed and constructed from various materials: hessian, open-weave polypropylene shade cloth, polypropylene silt fence, and synthetic weed matting. Testing of soil pockets was conducted on campus, utilising a basaltic boulder, derived from the Port Hills, and with similar properties as encountered in in-situ testing. Direct slow release of water onto the outcrop was undertaken to replicate natural surface water flow channelisation on soils distributed within individual pockets. All products tested dramatically reduced soil loss, effectively holding the soil in place on the outcrop. Finer weave fabrics resulted in a build-up of water, causing a complete saturation of the soils, whereas coarser weave fabrics enabled rapid water transfer, but the potential loss of finer-grained sediments.

This study highlights that stabilisation of soils on outcrops and placement of new soils can be achieved. It is recommended that further field testing of hessian pockets be undertaken. Hessian, as a natural product, is preferred and should last up to 2-3 years. During which time, the root structures of native rocky outcrop species should support soil stabilisation on the outcrop, with complementary planting of indigenous species in the upslope region helping to slow surface runoff. This project can be continued in Mt Vernon Park with the implementation of hessian soil pockets to minimise soil loss during precipitation events and restoration towards the natural presence of native vegetation in Mt Vernon Park.

1 Introduction

Mt Vernon Park (MVP), located in the Port Hills of Christchurch, New Zealand, is a recreational area that was once covered in native forest (Port Hills Park Trust, 2016). The park has a volcanic origin, stretching from the valley floor to the ridgeline, forming part of the crater rim of the eroded Lyttelton volcanic complex (Port Hills Park Trust, 2016). MVP is covered in rocky outcrops, which are defined as geological features that protrude above the surface of the surrounding land (Fitzsimons & Michael, 2017). They suffer from soil erosion due to the instability of the soil caused by deforestation.

1.1 Context

Soils on rocky outcrops at MVP are volcanic; therefore are highly vulnerable to soil erosion (Martin, 2019). Concentrated leaks occur when water flow is concentrated through preexisting openings such as cracks or root holes (Martins, 2019). Contact erosion occurs when gravel or coarse soil encounters finer soil and causes the finer soil to erode (Martin, 2019). Aspects of soil erosion will increase with climate change modelling (Neverman et al. 2023). New Zealand has geomorphically dynamic landscapes, diverse rock characteristics, steep terrain and recent deforestation due to European settlers. Due to this diverse variation, regionally tailored mitigation efforts are required (Neverman et al. 2023).

Historically, fertiliser was applied in eroding areas in hopes of increasing fertility; however, due to the shallowness of hill country soils, topsoil becoming thinner, and poor drainage, these efforts failed. Erosion has led to large amounts of sediment entering rivers, increasing flood risk (Knight, 2009). Early aerial imagery indicated that indigenous forest patches limited erosion post-deforestation (Marden et al., 2014). Native bush has declined significantly, due to burning or milling for the conversion to pasture for farming (Knight, 2009). Reforestation in the Waipaoa catchment has seen a 64% decrease in soil erosion following exotic forest establishment (Marden et al., 2014).

Soil can be divided into three basic parts, topsoil, subsoil and parent material, with most soil erosion occurring in the topsoil as it is situated closest to where water flow would occur (Gregg, 2009). This study is somewhat unique as focusing not on soils on the slopes, but on discrete soil pockets that have accumulated over periods of time on rocky outcrop faces. Sheet erosion occurs when bare or uncovered soil loosens the fine particles, which are carried downhill, causing surface runoff (Gregg, 2009). Rill erosion occurs on slopes where water can gather in channels, causing soil erosion (Gregg, 2009). Sheet and rill erosion, dominant on slopes, further reinforces the need for targeted vegetation planting and potential micro barriers to slow water flow.

MVP was once densely covered in native forest before extensive deforestation and the introduction of pastoral farming, which drastically changed the landscape (Port Hills Park Trust, 2016). The removal of native vegetation has left the slopes exposed and highly susceptible to surface runoff, as the absence of deep-rooted plants reduces soil stability and infiltration capacity (Nedbal et al., 2024). Surface runoff is described as the overland flow of water, flowing down a landscape through a sheet or channelised flow (Buda, 2013).

Surface flow is generated when the soil's infiltration capacity is exceeded, either from precipitation or when the groundwater table reaches the surface (Buda, 2013). With much of the area now dominated by exotic grasses, rainfall is less effectively intercepted, resulting in a higher surface runoff coefficient and increased erosion on the steep volcanic slopes (Hampton 2025; Nedbal et al., 2024). Without the structural support of roots and the surface cover provided by plants, rainfall now more easily dislodges particles, leading to higher rates of surface runoff on rocky outcrops, meaning vegetation no longer has the correct attributes to establish and thrive (Jia et al., 2025). Vegetation also increases surface roughness, promotes infiltration, enhances soil organic matter and the evaporation process, all things that help reduce surface runoff because they reach the outcrop (Nedbal et al., 2024).

Rocky outcrops themselves are geological features that occur on a vast variety of physical environments, including cliffs, overhangs, escarpments, boulder-heaps and insular domes (Fitzsimons & Michael, 2017). They are formed when softer parts of the landscape, including soil and softer rock, erode over millions of years, leaving behind the hard outcrop (Fitzsimons & Michael, 2017). Rocky outcrops share the common aspects that they are normally steep, spatially isolated, and in many cases represent relatively undisturbed natural habitats (Fitzsimons & Michael, 2017). Over millions of years, water, sunlight, and wind interact to shape outcrops into unique and distinctive features (Fitzsimons & Michael, 2017). Rocky outcrops cover 5% of Banks Peninsula, and the weathered outcrops of volcanic rock are located all throughout MVP (Hampton, 2025).

The shape of the outcrop determines how the surface runoff flows (Figure 1). Rock surface flow causes water to either flow directly over the outcrop or infiltrate down to the rock-soil interface (Cen et al., 2024). The shape of the outcrop also alters the velocity and concentration of water. Concave sections of the outcrop concentrate surface runoff, which promotes soil erosion (Zeng et al., 2024). Rocky outcrops are natural indigenous ecosystems with soils that host important endemic flora and support habitats for fauna (Hampton, 2025). They have provided stable microclimates for thousands of years and support high levels of species diversity (Fitzsimons & Michael, 2017). Rocky outcrops influence vegetation patterns either directly or indirectly (Fitzsimons & Michael, 2017).

Climate change exacerbates these issues due to the increased frequency and intensity of rainfall events, placing additional stress on already fragile soils. These high-intensity storms accelerate water flow down slopes, stripping topsoil, inhibiting vegetation reestablishment (Oishy et al., 2025). Both deforestation and climate-driven precipitation extremes have created conditions of severe soil instability at MVP, making it a valuable site for studying mitigation methods to enhance soil retention on rocky outcrops.

This issue is widespread. Rocky outcrops across every continent are struggling with erosion and decreased biodiversity due to factors like surface runoff, livestock grazing or introduced species (Fitzsimons & Michael, 2017). This is not just a local issue for MVP, but one worldwide that is critically understudied.

1.2 Objective of Project

The objective of this project is to identify a strategy to mitigate soil erosion and provide soil stabilisation on rocky outcrops, hoping to give flora and fauna a chance to reestablish. The long-term goal for MVP is to restore the native forest and increase biodiversity. This land and its species hold significant cultural value for the local hapū within Ngāi Tahu; Ngāi Tūāhuriri Rūnanga and Te Hapū o Ngāti Wheke. Protecting these areas is essential to honouring Māori kaitiakitanga (guardianship) and maintaining the ecological and cultural integrity of the land. Developing an effective soil stabilisation strategy is crucial to prevent further degradation, as the loss of endemic species not only represents a cultural and ecological loss but will also have flow-on effects on the wider environment and local biodiversity.

1.3 Research Question

This research focuses on answering the question: "What are effective ways to mitigate soil erosion from water runoff on rocky outcrops?". The report is split into two parts. Part one discusses the in-situ testing at MVP, focusing on mitigation methods at the top of the outcrop. Part two discusses controlled testing conducted at the UC campus, with mitigation methods applied to the outcrop in discrete pockets of soil accumulation, to stabilise discrete soils on rocky outcrops that are susceptible to erosion due to surface water runoff.

2 In-situ Testing

Field testing consisted of testing on a rocky outcrop in MVP and a rock in UC's Geology Garden. Testing was divided across 3 days, which included one day at MVP to test mitigation products at the top of an outcrop and 2 afternoons at the UC campus to test mitigation products on a rock face.

2.1 In-situ Field Testing

During the in-situ field testing, it was hoped that mitigation products would slow water flow across the outcrop, therefore, reducing soil erosion. To select a suitable outcrop for testing, surface flow patterns and places of natural soil accumulation were considered (Figure 1C). A rocky outcrop in MVP with areas of soil erosion was selected (Figure 2).

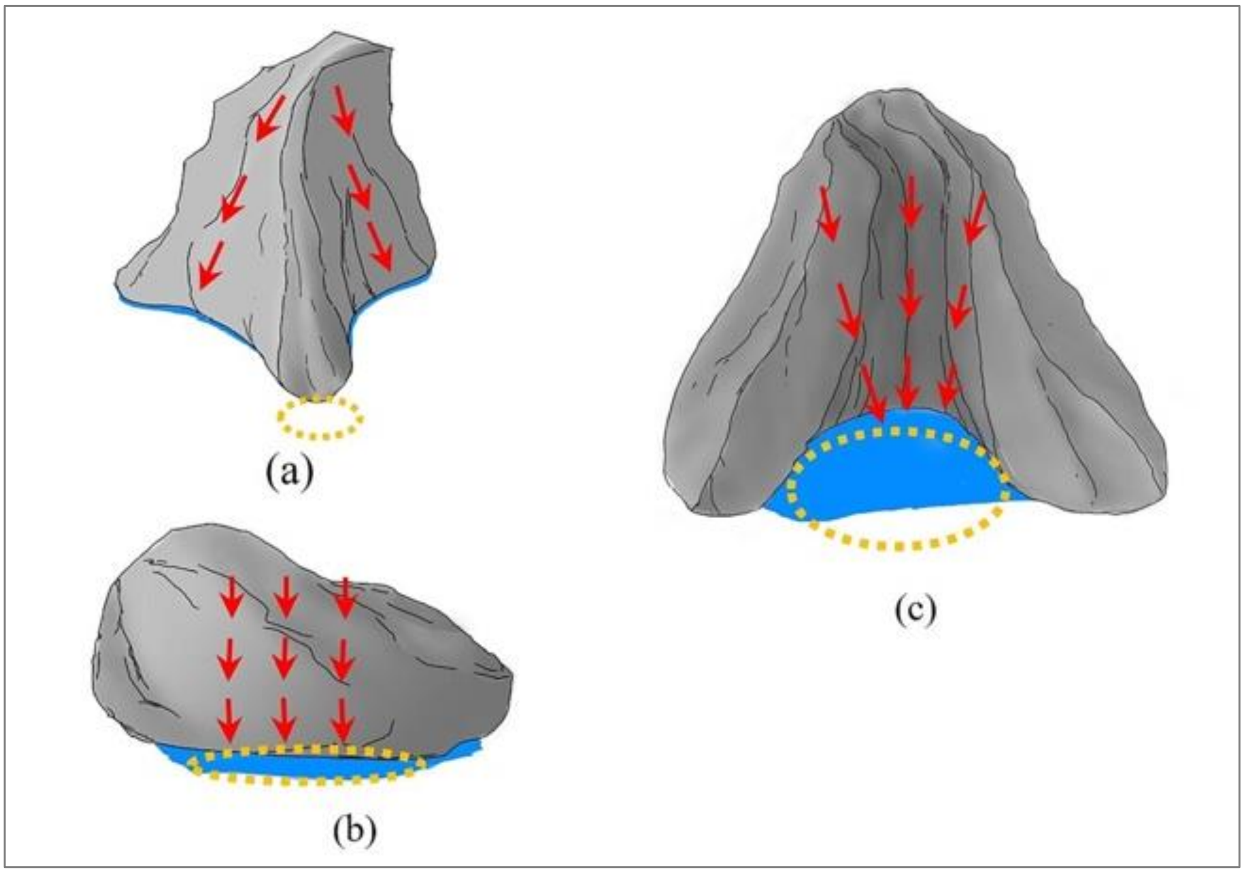

Figure 1: Diagram showing the influence of rock morphology on direction of water flow across an outcrop. Diagram C represents an outcrop shape where areas of natural soil accumulation are likely to experience erosion (Orlandini, 2012).

Figure 1: The selected rocky outcrop for in-situ testing in MVP (Ferguson, 2025).

2.1.1 Site Set-up

Site set-up included positioning cameras, adding markers on the outcrop, setting up the water dispersal method, and positioning the soil loss mitigation methods when required. Three cameras were positioned across the outcrop to record water dispersal and flow down the outcrop (Figure 3).

Figure 3: Annotated photo showing the position of 3 cameras on the chosen rocky outcrop during field testing (Bridgman, 2025).

A camera at the top of the outcrop recorded water dispersal (Figure 4), a second camera recorded a bird's eye view of a ledge where potting mix was added (Figure 5), and a third camera positioned at the bottom of the outcrop recorded soil and water movement (Figure 6).

Figure 2: Camera angle of the camera positioned on the top of the outcrop (Bridgman, 2025).

Figure 3: Camera angle of the camera positioned at the rock ledge where soil was applied, approximately 1m from the top of the outcrop (Bridgman, 2025).

Figure 4: Camera angle of the camera positioned at the bottom of the rocky outcrop (Bridgman, 2025).

Visual markers were added to the outcrop to act as consistent points where the timing of water flow after dispersal could be noted for each attempt. These marks consisted of five lines drawn in chalk, with their placement (Figure 7).

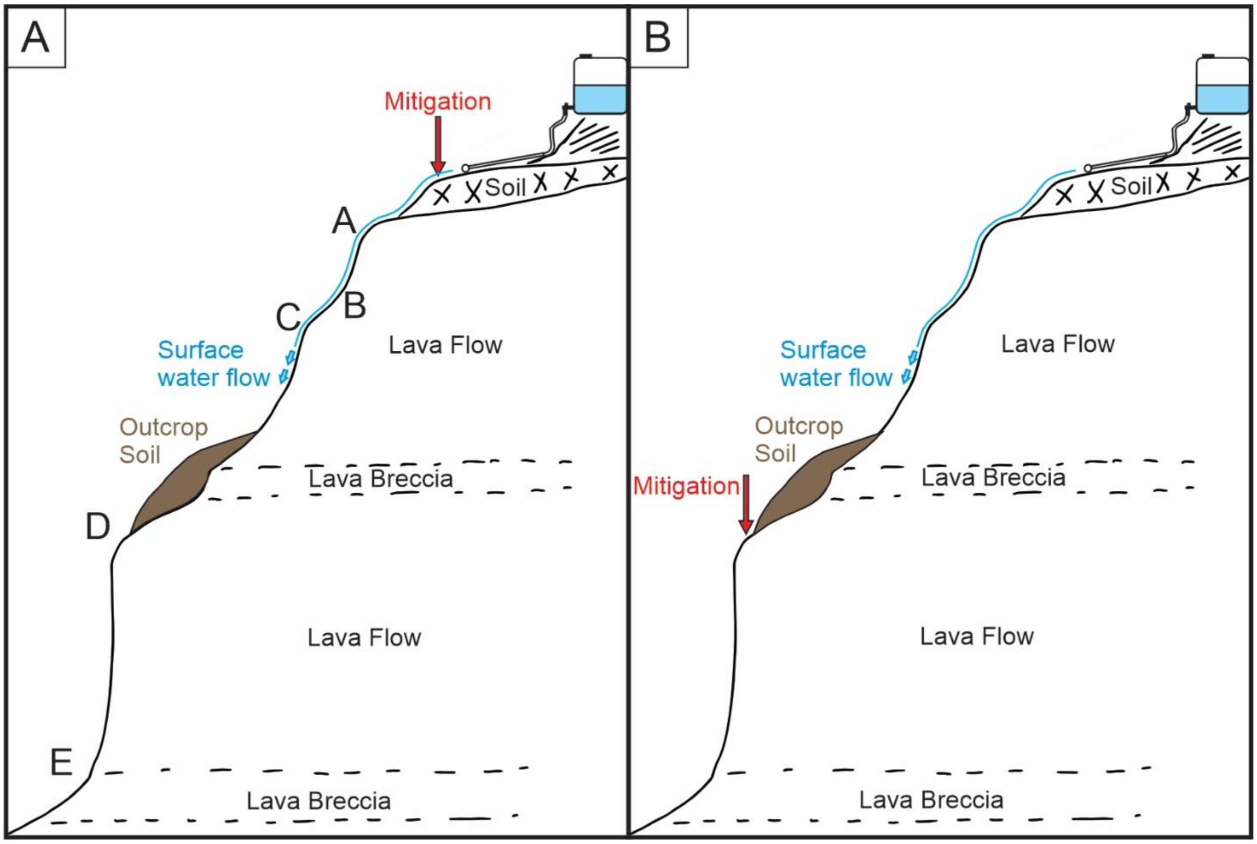

Figure 5: Diagram of the placement of visual markers A-E on the outcrop (Hampton, 2025).

The water dispersal method consisted of a T-shaped PVC pipe with holes to release water (Figure 8). This pipe was attached to a hose, which was connected to a raised 20L water tank. This set-up remained consistent across all tests. Research showed different in-situ water dispersal methods, including a water tank with a small tap (Orlandini et al., 2012), natural rainfall in set up plots (Li et al., 2023) and using portable rainfall stimulators with 1-8 nozzles (Neumann et al., 2022). Funding constraints exclude methods like Neumann et al. (2022) that require a water tanker and decent water pressure. Funding and lab constraints eliminated the possibility of set-up plots; therefore, natural rainfall did not allow for an accurate measurement of soil loss. The addition of a hose and a horizontal perforated pipe mimics natural runoff more closely than a tap and can be assembled at MVP. Before being used in MVP, it was tested on the UC campus to ensure it worked.

Figure 6: The water dispersal method. 1 = 20L water tank, 2 = hose connection, 3 = 4m spread tubing, 4= holes drilled 10cm apart spanning 1m (Bridgman, 2025).

2.1.2 Soil application

To test if the water flow would cause soil erosion, 1 cup of Tui potting mix was applied to a rock ledge approximately 1m from the top of the outcrop (Figure 5). To ensure consistency across tests, this was applied before every attempt, with the previous attempts' soil being scrubbed off.

2.1.3 Mitigation Products

The mitigation methods tested included a folded coir blanket (Figure 9), a fabric log filled with bark (Figure 10), and a silt fence (Figure 11), which were all placed below the water dispersal method at the top of the outcrop.

Figure 7: Folded Coir Blanket (Bridgman, 2025).

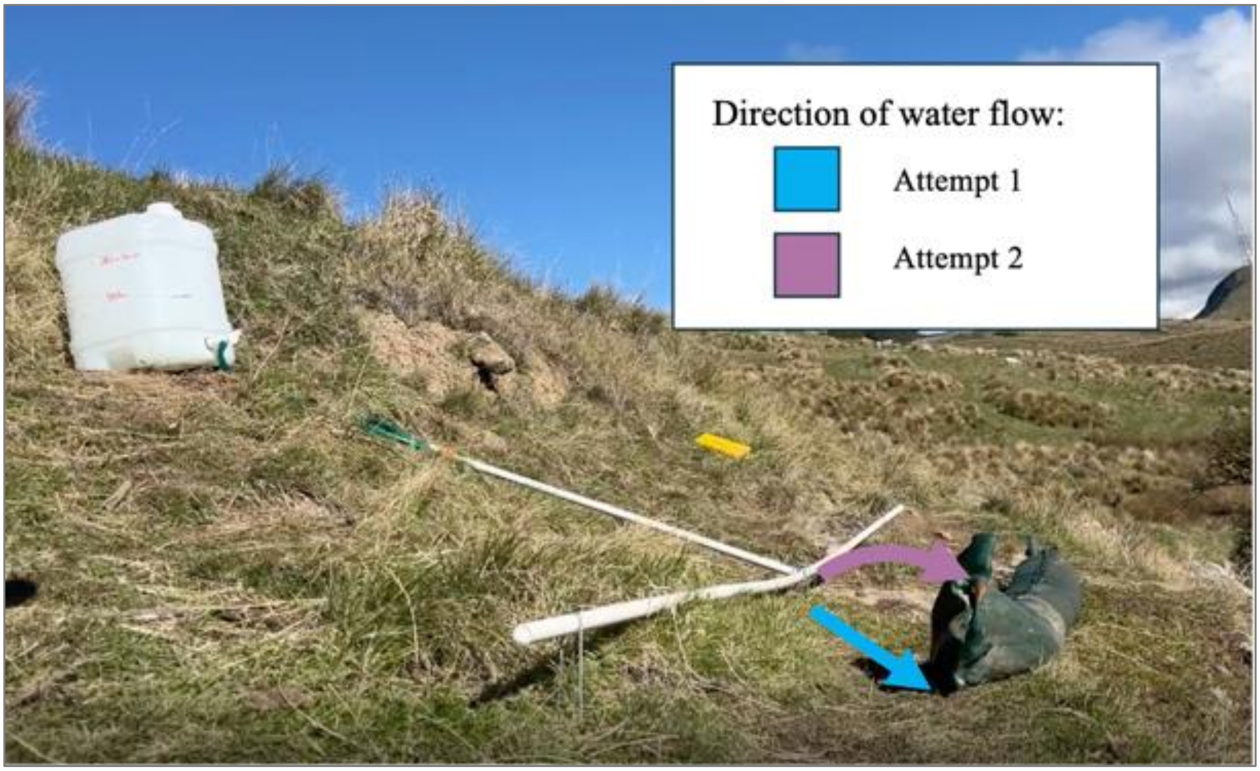

Figure 8: Bark-filled log that was pinned 35 cm below the hose. The angle of water direction was changed from along the ground in attempt 1, to landing on the log in attempt 2 (Bridgman, 2025).

Figure 9: Silt fence attached to the outcrop by 2 posts and inserted into a dug-out trench where possible (Bridgman, 2025).

Evidence shows that biodegradable geotextiles made from natural fibres, particularly jute, can reduce soil loss by up to 99% and significantly lower runoff rates (Kalivová et al., 2016). Sutherland and Ziegler (2007) found that coir-based rolled logs improved infiltration, delayed runoff initiation and reduced sediment yield, with random-fibre blankets outperforming open-weave designs. These results guided our decision to use a geotextile blanket made from coir matting, folded over itself, as one of our mitigation methods as an immediate erosion control measure.

To begin testing, the outcrop was covered in water to ensure consistency over the tests. Soil was added to the outcrop, cameras were turned on, and 20L of water was applied to the outcrop. A timer was started when water began flowing out of the hose, and times were noted when the water stream passed points A to E, and when it stopped travelling down the outcrop. This process was repeated with 3 methods placed at the top of the outcrop, each being tested twice.

Evidence shows reinforced and properly trenched silt fences perform significantly better at reducing sediment loss and preventing water underflow compared to standard installations (Bugg et al., 2017). Based on this, a silt fence was installed using a trenching method to enhance stability and prevent underflow during high-intensity precipitation events. This could not be achieved in areas of exposed volcanic rock, as no surface was available to trench.

2.2 In-situ Testing Results

2.2.1 Surface Water Flow

The initial in-situ testing results show the duration of time taken for the simulated rainfall surface water flow to cover the entire front face of the rocky outcrop (Figure 12).

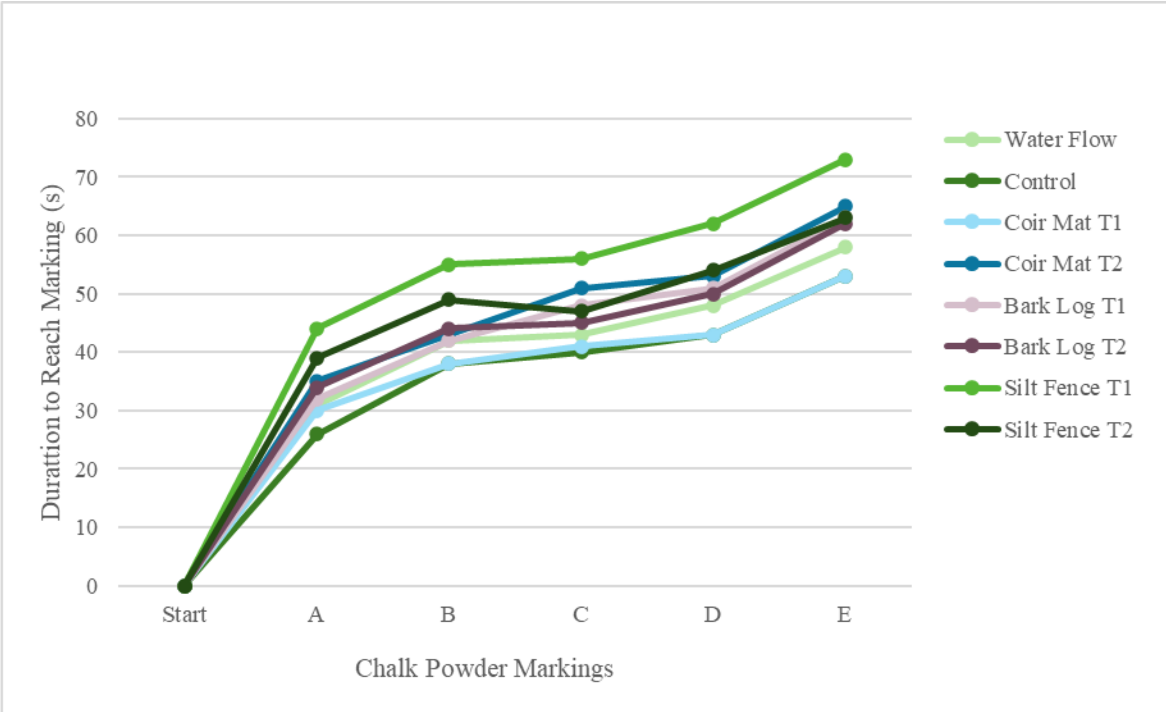

Figure 10: Graph of surface water flow on the rocky outcrop front face measured by duration (seconds) to reach locations (chalk powder marking) across the face (Greaves, 2025).

The timings show the mitigation method had no statistically significant effect on slowing the surface water flow across the testing area. The water flow test was the median line for reaching each point. Furthermore, the control line had non-significant second-based differences from each mitigation method (Table 1). This delay in time was also observed to be due to the duration it took to saturate the soil. Because dry soil was added to the rockface with every test, the delay between point A and B was the time needed for this soil to reach peak saturation and allow water runoff through. Shutoff represents the time duration it took for the 20L of water to be dispersed across the rocky outcrop front face (Figure 13). Furthermore, 'End' is the time it took for the water flow to stop and not be observed past point E.

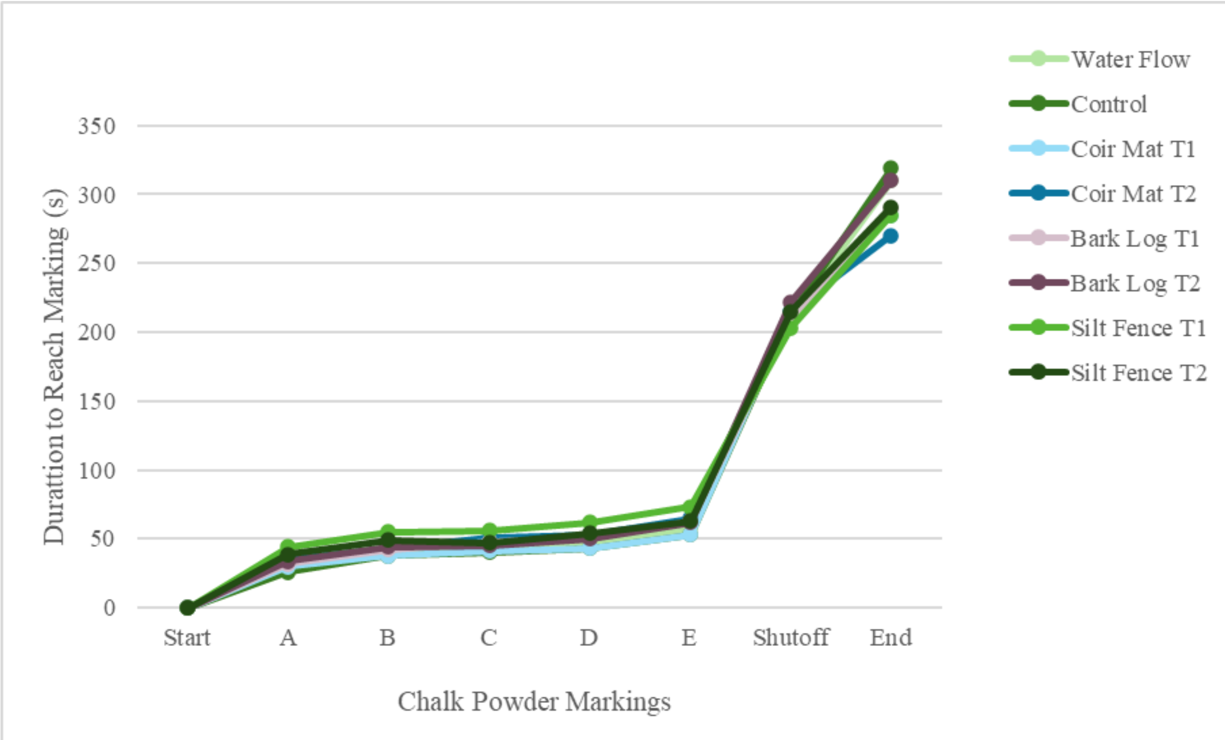

Figure 11: Surface water flow on rocky outcrop front face measured by duration (seconds) to reach locations (chalk powder marking) using 20L water dispersed (simulated rainfall).Figure 12: Surface water flow on rocky outcrop front face measured by duration (seconds) to reach locations (chalk powder marking) using 20L water dispersed (simulated rainfall), (Greaves, 2025).

All mitigation methods reduced the time for water to flow to point A, and either reduced or did not alter the time for water to reach point B (Table 1). The duration of time for water to stop travelling down the outcrop was reduced with the implementation of all mitigation methods (Table 1).

Table 1: Time taken (seconds) to reach the designated surface water flow points across the rocky outcrop surface, and full 20L flow capacity of simulated rainfall (Bridgman, 2025).

	Water Flow	Control	Coir Mat T1	Coir Mat T2	Bark Log T1	Bark Log T2	Silt Fence T1	Silt Fence T2
Start	0	0	0	0	0	0	0	0
A	31	26	30	35	32	34	44	39
B	42	38	38	43	42	44	55	49
C	43	40	41	51	48	45	56	47
D	48	43	43	53	51	50	62	54
E	58	53	53	65	63	62	73	63
Shutoff	210	213	215	215	210	222	203	215
End	310	319	285	270	290	310	285	291

The non-statistically significant slowing of surface water flow (Figure 13), where the water reservoir was distributed across the rocky outcrop testing face showing that the overall duration for water flow to continue across the rocky outcrop is not affected by any of the mitigation methods. This reinforces that under normal precipitation, the mitigation methods would have limited to no impact on slowing or impeding surface water flow. Therefore, in-situ results gathered and interpreted showed that the mitigation methods being implemented were predominantly ineffective in delaying surface water flow.

2.2.2 Soil Erosion

Measures of soil loss within each mitigation method were high and relatively ineffective at reducing soil erosion. Measured soil erosion under a control, and each mitigation method was recorded (Figure 14). The control (no mitigation) had 62.5% of the soil eroded after testing. From this, each mitigation method had between 37.5% – 87.5% of the soil eroded (Figure 14).

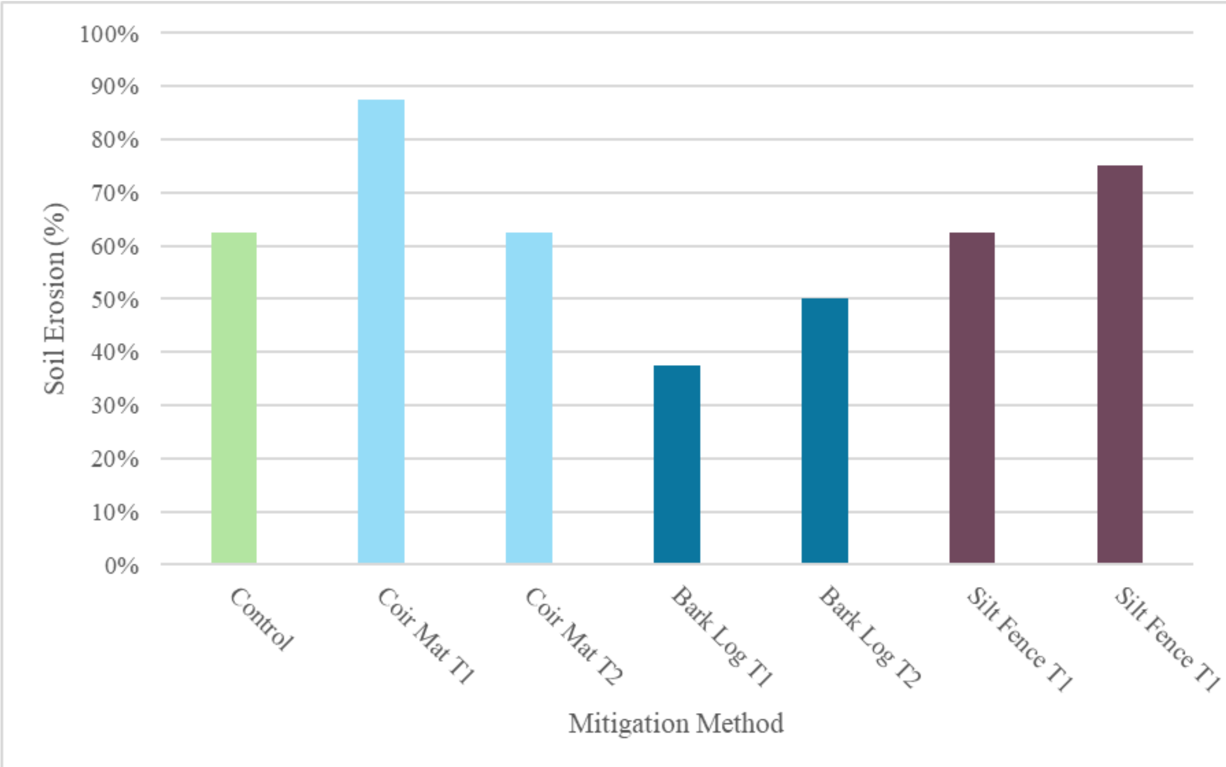

Figure 13: Graph showing the amount of soil loss (%) on the rocky outcrop ledge during simulated rainfall testing (Greaves, 2025).

The tested mitigation methods had no significant impact on preventing soil erosion (Figure 14), and confirms the three mitigation methods were ineffective (Figure 15). Bark log produced less average soil erosion than standard test conditions. However, bark log was observed to cause water displacement, with the water being dispersed outside of the testing zone. This re-routing of surface water flow reduced water being directed down the outcrop channel, leaving less potential for surface erosion in these tests. Therefore, this mitigation method also had no consistent effect in reducing soil erosion from rocky outcrop ledges.

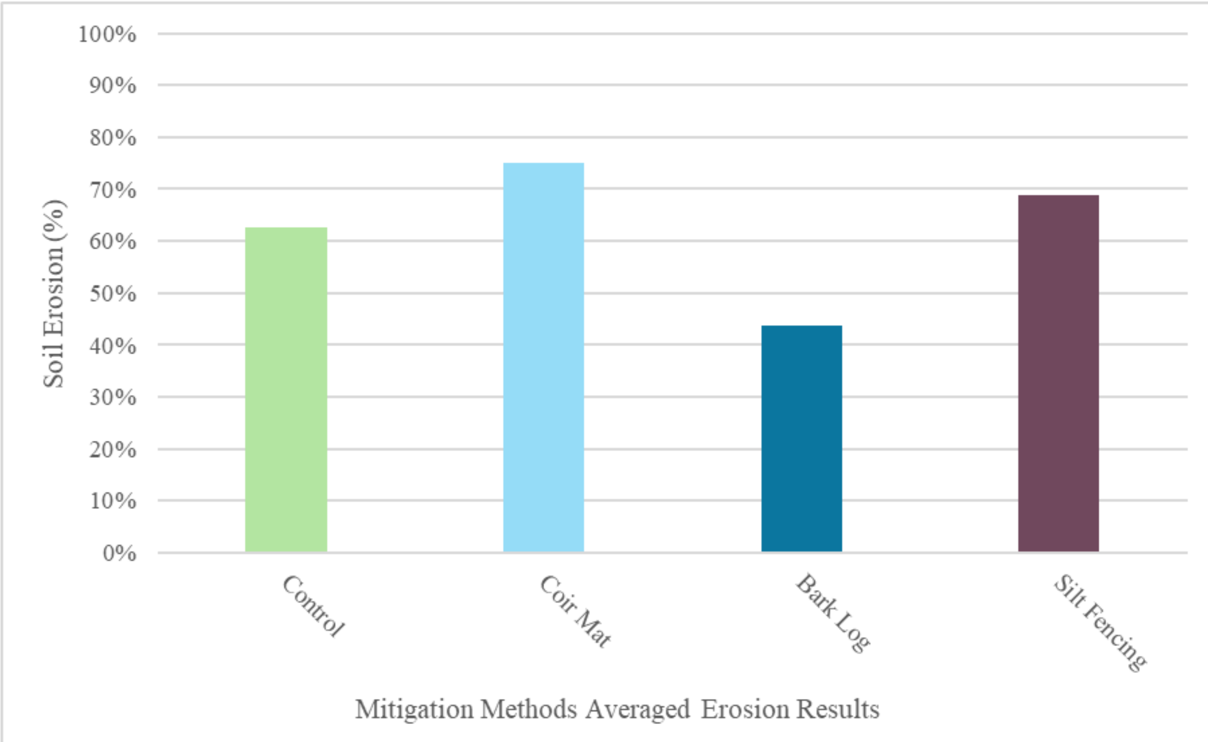

Figure 14: Graph showing the average amount of soil loss (%) on the rocky outcrop ledge during simulated rainfall when implementing the three mitigation methods (Greaves, 2025).

2.2.3 Critical Observations

Table 2 highlights the visual observations from this initial in-situ testing. The observations showed no significant reduction of soil erosion from mitigation methods (Table 2). There was a lack of cohesion between the ground and the method itself (Figure 16). This displacement of water had significant effects on the amount of surface water flow through the erosion channel, affecting the amount of soil that eroded when using each mitigation method.Table 2 highlights the visual observations from this initial in-situ testing. These observations also point to no significant reduction of soil erosion from our mitigation methods.

Table 2: Table showing the visual observations of each mitigation test from the initial in-situ testing at MVP.

Table 2		
Test	**Soil Observations**	**Flow Observations**
1. Control	Medium soil erosion	Consistent streamlined flow down a pre-prescribed channel of rocky outcrop
2. Coir Matting	High soil erosion 20cm movement is classified as erosion Soil was concentrated, and erosion was worse than without the mitigation	Water flows straight through the mitigation method Matting not thick enough/not bunched enough to conform to outcrop contours
3. Coir Matting	Medium soil erosion Less soil erosion than in test 2 Slope has not dried any further throughout the day and between tests	The addition of metal pins is still not enough to stop the water flow underneath the mitigation method
4. Bark Log	Low soil eorison Less soil erosion than previous mitigation methods	Water is being slowed and diverted around the edges of the testing parameters

	Mitigation method was slightly useful, but still saw significant particle movement	The simulated rainfall is falling on the upper edge of the bark log rather than directly on top
5. Bark Log	Medium soil erosion Greater soil erosion than in the previous test Significant soil movement down the outcrop channel ~ same amount as other mitigation methods and more than the control	Water seems to be diverting further around the left + right sides of testing parameters once the mitigation log is saturated Still reduced flow through the testing channel location
6. Silt Fencing	Medium soil erosion Consistent levels of soil erosion are still observed Mitigation method not impacting the soil erosion down the outcrop face	Fencing could not be applied on rock, as a trench cannot be dug Ground surface was disturbed, which put more sediment into the top outcrop system It could also cause a catastrophic failure if sediment caught the fencing and pushed through the trench

7. Silt Fencing	High soil eroison More soil erosion than in the control test Further soil erosion from the previous test, once the mitigation method is saturated	Water seems more concentrated in one stream coming through the fencing fabric Fencing isn't working as water is still infiltrating the fabric Water diversion occurring on the right, similar to the bark log

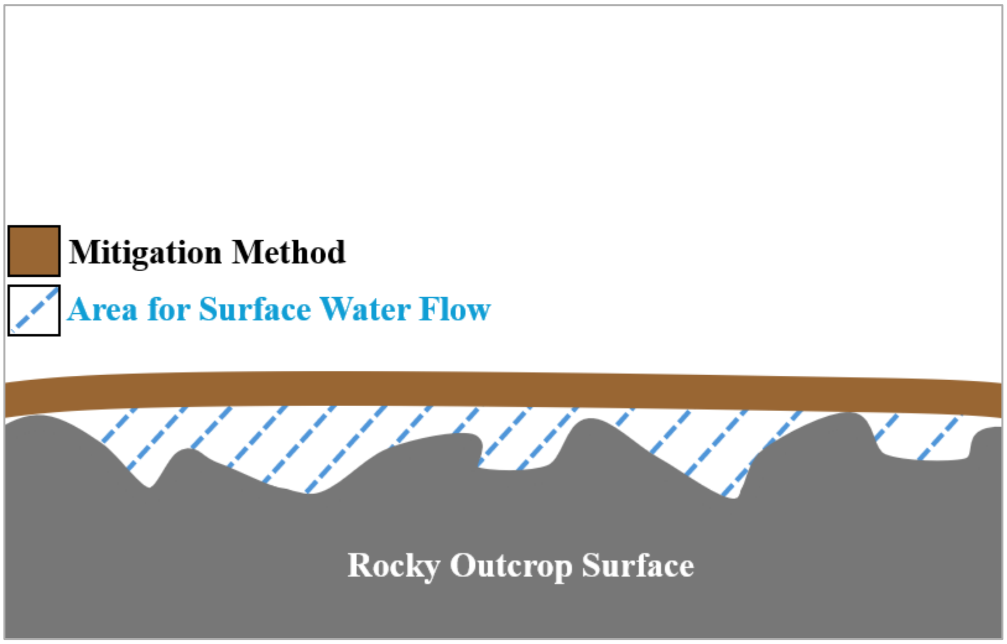

Figure 15. diagram visualising the lack of cohesion between the mitigation method and rocky outcrop surfaces, leaving room for exposure and surface flow underneath the method (Greaves, 2025).

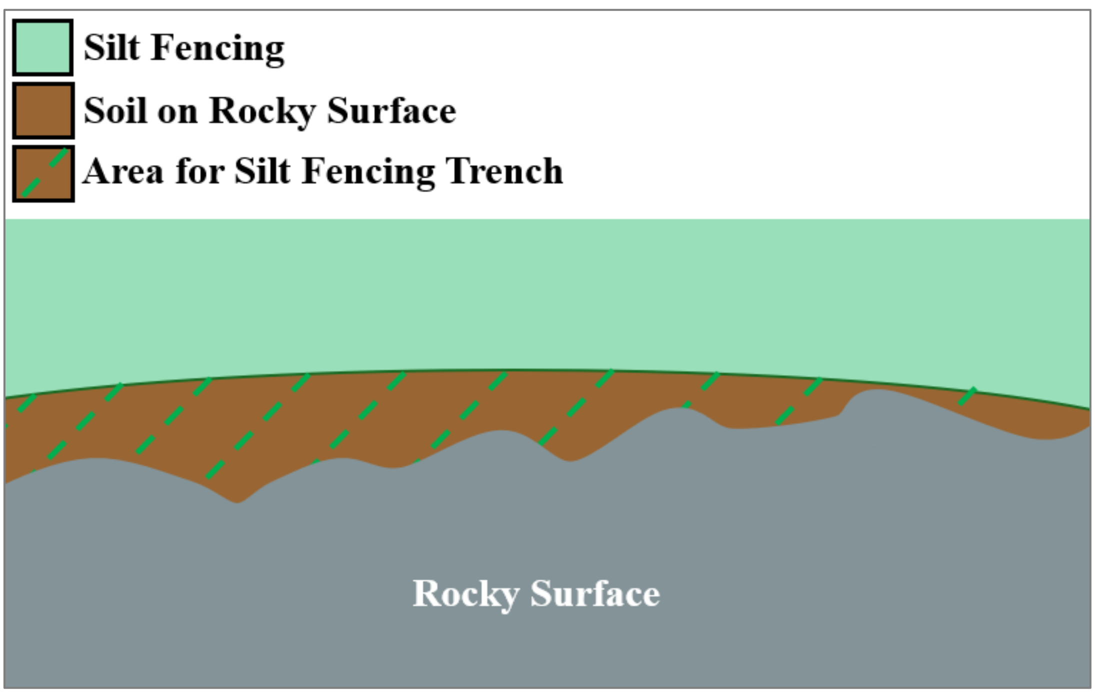

Figure 16. Diagram showing silt fence trench capabilities on a rocky surface at the top of a rocky outcrop ledge (Greaves, 2025).

Soil coverage impacted the usability of the silt fencing on the rocky surface above the outcrop (Figure 17). The areas that had minimal or no soil coverage on the rocky surface meant the silt fencing may not have been installed correctly, therefore inhibiting its ability to influence surface water flow and soil erosion. Overall, when assessing the surface water flow, soil erosion, and visual observations from the in-situ testing at MVP, it has been deemed that the mitigation methods being implemented were not effective.

3 Controlled Testing

3.1 Controlled Testing 1

As a result of the failure of the first three mitigation methods at the top of the outcrop, a concept of on-rock support to hold soil in place was developed. These were tested on a rock at the University of Canterbury's (UC) campus to test proof of concept, develop and refine the design.

3.1.1 Rock Selection

Figure 17. The rock in UC's Geology Garden that was deemed successful for testing (Ferguson, 2025).

Rock in UC's Geology Garden had suitable characteristics, including a ledge where potting mix could be applied (Figure 18). The rock had a morphology where water flow would be directed to the middle of the rock (Figure 18; see Figure 1C) and of volcanic origin from the Port Hills, so it is directly comparable to in-situ outcrop testing.

3.1.2 Site set up

Figure 18: Onsite Testing Water Dispersal Method (Ferguson, 2025).

Site set-up included setting up two cameras, with one showing the whole rock and one aimed at the soil placed within a sling. The 20L water tank used during the in-situ testing was held at the top of the rock, with the hose and pipes removed (Figure 19).

Figure 19: The three materials used in the first onsite field testing, including hessian (left), weed matting (middle), and shade sail (right) (Ferguson, 2025).

A set of three slings, made of hessian, weed matting and shade sail fabrics, was designed (Figure 20). These were attached to the outcrop using four command hooks, while the bottom edge was reinforced and adhered to the rock with duct tape.

3.1.3 Testing

Testing began with dispersing water onto the outcrop and scrubbing it to remove debris. Water was run for 3 minutes, and two cups of soil were applied onto the rock in each test to ensure consistency. In the initial hessian sling test, tape was used to secure the bottom of the sling to the rock; however, the side walls were not in full contact with the rockface (Figure 21). This gap allowed soil and water to erode from the barrier. In the second test, the sling was repositioned to sit flush against the rockface. As the rock surface was wet, tape could not be applied, and the soil itself acted as the stabilising force holding the sling in place for the weed mat and shade sail tests (Figure 21).

Figure 20: The hessian sling (left), weed matting sling (middle) and shade sail sling (right) during controlled testing (Ferguson, 2025).

3.1.4 Controlled Testing 1 Observations

Sling testing provided consistently successful results of mitigating soil erosion from rocky outcrop ledges (Table 3). Hessian incorporated both permeable material pore sizes, with soil stability, to produce a successful mechanism.

Table 3: Table showing the visual observations of each mitigation test from the first controlled on-site testing at the University of Canterbury

Table 3		
Mitigation Methods	**Soil Observations**	**Flow Observations**
1. Control	Significant soil erosion from rocky outcrop ledges Soil particles carried across rocky outcrops and consolidated at the bottom of the rockface	Consistent, streamlined flow that followed the pre-prescribed channel of the rocky outcrop Water flow down the front channel and landing on the main ledge
2. Hessian Sling	Positive results Limited soil erosion from the rocky outcrop ledge Some slight erosion occurring on sides of hessian sling, and miniscule seepages occurring through the hessian fabric.	Flow is being halted at the hessian sling Water runoff is being directed out of the sides of the sling area, underneath the sling material, and permeating through the hessian Slight water flow buildup behind the hessian sling mechanism
3. Shade Sail	Further positive results Still limited soil erosion from the sides of the sling. No soil erosion through the pores of the fabric, as too tightly wound	The flow was being fully stopped by the sail sling Water being diverted round the outside of the channelised ledge

		Water seepage underneath the sling as adhesive not fully adhering to the damp rockface Pores of the material too fine to allow water flow to permeate leading to water buildup and possibility for overtopping of material from sling
4. Weed Matting	Consistent soil erosion mitigation Limited soil erosion through the larger pores of this fabric Some seepage from sides of sling design, and underneath of sling as not adhered to the rock	Material was the most effective at allowing water flow Larger pore size allowed water to permeate through and avoided buildup Significant diversion round testing area through sides of sling design, and underneath the sling design

3.2 Controlled Testing 2

3.2.1 Site Setup

The site set up remained consistent with the first controlled testing; however, a fourth material of a shade sail with smaller pores was added (Figure 22). Liquid Nails were used to adhere the slings to the rock, but did not dry in time for testing, so clamps were used to hold the sling in place (a limitation due to time constraints of this project). Water was run for 3 minutes as per the first controlled testing.

Figure 21: The materials used in the second controlled testing, including weed matting (left), hessian (middle left), finer shade sail (middle right), and shade sale with larger pores (right). A ruler shows their approximate pore sizes).A ruler shows their approximate pore sizes (Ferugson, 2025).

3.2.2 Controlled Testing 2 Observations

Controlled testing day 2 provided the most successful and consistent results of all three testing days. The four mitigation methods used showed consistent abilities to prevent soil erosion on a rocky outcrop in simulated rainfall. Furthermore, the product development of the sling allowed minimal soil loss from underneath and around the sides of the sling mechanism. Table 4 shows the visual observations from this controlled testing day and represents how the hessian sling was observed to be the most effective sling material to allow water to permeate whilst holding soil on the rockface.

Table 3: Table showing the visual observations of each mitigation test from the second controlled on site testing at the University of Canterbury.

Table 4		
Mitigation Methods	**Soil Observations**	**Flow Observations**
1. Control	Significant soil erosion from rocky outcrop ledges. Soil particles carried across rocky outcrop and consolidated at bottom of rockface.	Consistent streamlined flow that followed the pre-prescribed channel of the rocky outcrop. Water flow down the front channel and landing on the main ledge.
2. Hessian Sling	Positive results Limited soil erosion from rocky outcrop ledge Side wings prevented soil erosion from sides of sling mechanism and bottom seepage has been mitigated through design	Flow being slowed at the hessian sling Water able to permeate through fabric, and seep away from rocky outcrop ledge without carrying soil Water runoff clear, containing no soil particles
3. Shade Sail	Further positive results No soil erosion through the pores of the fabric as too tightly wound	The flow was being fully stopped by the sail sling Pores of the material too fine to allow water flow to permeate leading to

	Soil mitigation from the sides and base of the sling mitigated with design adjustments	water buildup and possibility for overtopping of material from sling Now no water being diverted round the outside of the channelised ledge, leading to further overtopping probability
4. Weed Matting Large Pore	Consistent soil erosion mitigation Limited soil erosion through the larger pores of this fabric Some seepage through this fabric as the pores are too large to hold small soil particles	Material was the most effective at allowing water flow Larger pore size allowed water to permeate through and avoided buildup, however carried soil Significant diversion round testing area through sides of sling design, and underneath the sling design
5. Weed Matting Small Pore	Further consistent soil erosion mitigation Smaller pore size allowed less soil erosion through weed matting material Some seepage still occurred, even with revised wing designs	Material still effective at allowing water flow, however smaller pore size held more water Didn’t allow water to permeate as well as other materials tested Pores small enough to consider possibility of overtopping

4 Discussion

4.1 Top of Outcrop Mitigation

The simulated precipitation tests showed no statistically significant delay in water movement across the outcrop, with only minor time differences between the control and mitigation methods. Soil erosion remained high across all tests, indicating that none of the mitigation methods provided significant stabilization. Visual observations showed that poor cohesion between the rock and the mitigation methods allowed water to flow both underneath and around the methods, reducing their effectiveness. In particular, the coir matting failed to conform to the surface roughness (Figure 22), the bark log diverted flow and the silt fencing was unable to be properly installed due to the inability to dig into rock. Overall, the top of the outcrop mitigation methods were unsuccessful at reducing soil loss.

4.1.1 Materials as Surface Water Flow Suppression

The mitigation methods tested at the top of the outcrop were ultimately ineffective because they were not designed for this specific context or surface type. The project aimed to manage surface water runoff, whereas the design was adapted from mitigation strategies that were developed for different conditions and therefore didn’t function as expected in this context. The selected materials were designed to pool sediment behind them and allow water to pass through, not intercept and slow runoff before it reaches the sediment (Kalibová et al., 2016; Robichaud et al., 2019; Sutherland & Ziegler, 2007). The materials were also designed for soil-covered conditions. The context of a rockface meant that challenges of surface cohesion were present. For example, the silt fence should have been properly trenched to prevent water from flowing underneath. However, areas of bare rock meant patches of the silt fence couldn’t be covered and therefore, allowed for underflow (Figure 22). The overall design of selected mitigations is for capturing sediment entrained in flow, and not the suppression or slowing of surface water flows, making them ineffective in their use in this instance.

4.2 On the Outcrop Mitigation

4.2.1 Design Development

Following the unsuccessful results of the in-situ testing, new mitigation methods were developed. After group discussions with the academic supervisor, Sam Hampton, it was concluded that the next phase of testing would involve mitigation methods placed on the outcrop, rather than at the top. The method developed was a sling product that would be adhered to the rock (Figure 23). This concept looked to stabilise soils within their naturally occurring pockets on rock faces. A design that came to be in response to the discrete nature of soils located on rocky outcrops. Second controlled testing confirmed proof of concept but indicated necessary design improvements. Increasing the size of the bottom and side flaps was discussed to enhance stability and overall functionality of the sling (Figure 23).

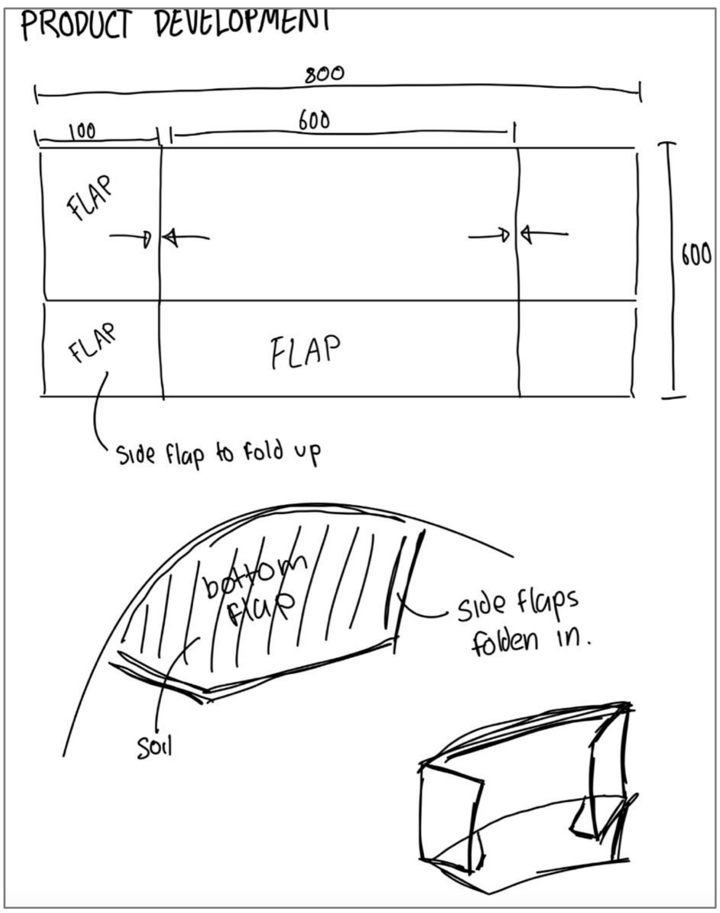

Figure 23: Product development diagrams

4.2.2 Controlled Testing 1

The second stage of testing produced positive results, as all materials tested were successful in mitigating soil erosion to some degree. The hessian sling performed most effectively due to its optimal pore size, which allowed water to pass through while retaining soil. In contrast, the weed matting sling had the smallest pore size; therefore, it successfully contained soil but restricted drainage, resulting in pooling of water within the sling. The shade sail sling exhibited the largest pores, promoting water flow but allowing soil to escape.

4.2.4 Controlled Testing 2

The results from the third stage of testing were consistent with the previous test. The hessian sling performed exceptionally well, as the water flowing through it remained clear with no visible soil loss. The weed matting sling produced similar outcomes to the earlier stage; although it successfully retained the soil, pooling within the sling continued to present a potential failure risk. In a real-world context, such pooling could compromise performance during heavy rainfall events. The two shade sail slings again proved ineffective in fully mitigating soil erosion, allowing some soil displacement. A larger weave could lead to loss of finer soil over time.

4.2.5 Refinement of Design Recommendation

Overall, the third and final testing stage confirmed that the modified hessian sling was the most effective erosion mitigation method. The increased flap size enhanced surface contact and overall structural stability, as the additional soil weight on the enlarged flaps helped secure the sling firmly in place against the rock surface.

Our recommended mitigation method is the modified hessian sling. The optimal pore size and enlarged bottom and side flaps provided a balanced level of drainage and soil retention within the sling. The biodegradable composition, made from vegetable fibre, aligns with Ngāi Tahu's requests for environmentally sustainable geotextiles.

4.2.6 Application of Sling in Disturbed Rocky Outcrops

The proposed hessian product has not yet been tested on an outcrop at MVP. Currently, the prototype has only been tested on-site at the UC campus. To evaluate its effectiveness in real-world conditions, an in-situ testing day should be carried out at MVP. The slings should be monitored a few days after installation to assess stability and again after a heavy rainfall event to ensure no soil loss has occurred. Each sling has the potential to support an individual plant. An example of a plant that could be implemented is *Veronica Lavaudiana*, which is both at risk and endemic to MVP. Other suitable species for sling planting include *Coprosma Crassifolia, Sophora Prostrata, Pseudopanax Crassifolius, Myoporum Laetum, Kunzea Ericoides,* and *Corokia Cotoneaster* (Payne et al., 2024).

4.2.7 Constraints and Considerations

This method is a relatively low-cost solution that can be implemented across MVP; however, it is labour-intensive and tailored for discrete locations. Each sling must be individually installed on the outcrop, following an assessment to ensure the surface is suitable for application and soil accumulation. Depending on the outcrops' size and shape, multiple slings will be required.

4.2.8 Broader Scale Potential

Following successful tests at MVP, the sling product could be extended to other erosion-prone rocky outcrops across Banks Peninsula and throughout New Zealand, particularly in regions where native forests have been cleared. Sites that experience soil loss, whether it's from natural processes or human-induced disturbance, may have suitable conditions for the application of this product

Rocky outcrops require site-specific restoration approaches due to their unique geomorphological and ecological characteristics. The sling product offers a targeted solution for these specific environments. In deforested landscapes with isolated rocky outcrops experiencing extreme surface runoff, this method can be effectively applied to stabilise soil. By providing the structural support for soil retention, the sling provides an environment for the reestablishment of species and habitats (Figure 24).

Figure 24: Equation of factors required for plant growth and habitat establishment (Hampton, 2025).

4.2.9 Aspects Yet to be Considered or Included

Table 5: Table showing the aspects yet to be considered or included within the controlled testing.

Table 5
Aspects Yet to be Considered or Included
Durability of materials
Life span of products
Detailed costing and manufacturing
Permanent quick-fix attachments on rock faces
Detail design aspects and plant suitability

5 Conclusion

The project investigated effective ways to mitigate soil erosion from water runoff on rocky outcrops at Mt Vernon Park, located on the Port Hills, Christchurch. Using three stages of in-situ and controlled testing, we demonstrated the challenges of achieving soil stabilisation on rocky outcrops and identified a recommended mitigation method designed for the long-term goal of reforesting Mt Vernon Park.

The first stage of in-situ testing showed the coir matting, bark log, and silt fencing were unsuccessful. The lack of cohesion between the mitigation materials and the surface of the ground allowed water to flow beneath the barriers, resulting in observed soil loss, highlighting the importance of conformity and effective sealing when designing mitigation barriers for soil erosion.

The controlled stages of testing produced significant results. The hessian sling emerged as the most effective material, balancing drainage and soil retention due to optimal pore size. The enlarged bottom and side flaps increased the ability and functionality of the sling and allowed the weight of the soil to act as an anchor to the rock. In contrast, the weed matting sling retained soil but caused water to pool due to its small pore size; while the shade sail slings drained effectively but failed to prevent soil loss. Together, these results confirmed material permeability and structural stability are critical for mitigating soil erosion on rocky outcrops.

Testing showed that the modified hessian sling was the most effective mitigation strategy. Its biodegradable composition, being made from vegetable fibre, aligns with Ngāi Tahu’s request for natural geotextiles and supports the long-term goal of reforesting the park. Future steps include testing the modified hessian sling on a rocky outcrop in Mt Vernon Park to better understand the effectiveness and durability of this design. Although this project was done on a small scale, the findings offer a strong foundation for practical, culturally aligned, and ecologically sustainable soil stabilisation strategies. Following successful results at Mt Vernon Park, the sling product could be implemented on other erosion-prone outcrops across Banks Peninsula and wider New Zealand, particularly in areas where native forest has been lost.

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