# Green Roofs - WSUD Case Studies

Two green roof case studies are presented in this fact sheet:
(1) the tussock-covered Mount Difficulty winery green roof primarily helps cool the wine barrel store and integrate the building into the adjacent natural landscape;
(2) the Remarkables Primary School green roofs also integrate the buildings, in a park bordering Lake Wakatipu, into the landscape but also provide a highly-valued and unique outdoor learning environment.

Despite these roofs being highly-successful, low to medium maintenance, and attracting much attention, there have been few imitators to date. In larger New Zealand cities green roofs are more commonly installed to mitigate stormwater by making impervious roofs 'pervious': even roofs with just 50-100 mm of media are highly effective at reducing peak flow and runoff volumes from the majority of storms (c. 2 to 20-30 mm events). They are therefore an 'alternative solution' where impervious area limits are exceeded.

## Mt Difficulty Living Roof

The Mt Difficulty Living Roof is a pre-grown, modular roof (LiveRoof) made from about 4800 modules filled with 150 mm deep, light-weight media. It was installed by Stormwater360 in March 2012. The tussock-dominated roof covers the barrel hall (wine store) at **Mt Difficulty Winery**, Bannockburn, Central Otago, New Zealand[1]. It was designed to provide evaporative cooling to maintain optimum temperatures for the wines beneath.

**Contractor:** Stormwater 360/ Naylor Love
**Specifier:** Wild Rooster design

**Roof specifications:**

- Approximately 900m$^2$ in size, 1:60 slope.
- Original plants: short and tall native tussocks (*Festuca coxii* and *Poa cita*), locally-sourced (wild) sedums and thyme (non-native)
- Growing medium: 150 mm deep, light-weight pumice, zeolite and compost conforming to internationally-used FLL green roof permeability standards.
- Drainage built into module design (no additional under-drainage required); 450 mm wide perimeter drain filled with local river-rounded gravels with separation from modules by stainless steel slot drain.
- EcoTuff TPO waterproof membrane on 90 mm concrete.
- Parapet or steel handrail in all places where fall from roof is more than 1 m height.
- The roof is irrigated with process water to provide evaporative summer-cooling for the wine store.

[1] http://www.stormwater360.co.nz/projects/study/Mt-Difficulty-Wine-Barrel-Store (accessed on 21 January 2019)

- Access: the barrel hall is built into the side of the hill, so the roof can be accessed by foot. The roof fully connects into adjacent landscape on two sides using modules over steep slopes

**Reason for installation:**
To reduce energy requirements needed to keep the barrel hall at optimum temperature all year round. The roof also has R4 insulation to optimize performance (and because no data was available to model the effectiveness of the green roof alone)[2]. The roof also complements adjacent restorative planting (1 ha in total) and has contributed tussocks to the restoration area.

**Construction:**
The green roof is a modularised "Living Roof" product supplied by Stormwater360. Modules were pre-grown in a local nursery and trucked to site[3]. The rigid plastic edges of modules interlock, so were also used to instantly cover and stabilise steep slopes between roof and adjacent road. Temporary edges around each module are removed during installation, allowing roots to grow from tray to tray, forming a resilient, integrated surface.

**Construction Cost:**
- $150,000 for the living roof components (approximately $167/m$^2$ – 2012 NZ$)
- $75,000 for the additional roof components (approximately $83/m$^2$ – 2012 NZ$)
- Total construction cost of approximately $250/m$^2$ (2012 NZ$)

**Maintenance:**
Maintenance mainly consists of weeding and ensuring irrigation is operating. Sedums die-back each winter but grow in summer, when they flower prolifically. Summer irrigation reduces drought stress and allows large pasture grasses (Yorkshire fog) and other visual weeds to establish and survive, increasing the amount of weeding. Safe access means no "heights" or harness training certifications are required by staff.
- The roof is weeded about 4 times a year over 1 to 2 days, with a total of about 4 to 5, 20 litre buckets being filled each time. Only visual weeds are removed (flat-weeds are retained as these are abundant in the adjacent areas)
- The roof was not fertilised for the first 5 years. Low nitrogen and moderate phosphate levels mean legumes are the most common weeds (e.g., clovers, lotus, lupins.).
- Thyme has died out, and not been replaced and blue tussocks are self-establishing
- Rabbits burrow into the roof and graze on the blue tussock (*Festuca coxii*).

**Benefits (over and above temperature control):**
- aesthetic appeal – the roof is overlooked by the main winery restaurant, blends into the adjacent restoration (natural) areas and enlarges the effective restoration area;
- a 'free' source of tussock plants, which have been harvested from the roof and used in nearby landscaping, further integrating the roof into the adjacent area;
- reduces storm water peak flow and quantity volume. Although unquantified, the difference in runoff comparison is readily seen with a 'dribble' of runoff during a 20 mm storm coming off the green roof compared with a torrent from the adjacent traditional roof;

| What works well | Missed opportunities |
|---|---|
| Maintenance access | An excellent example of a roof design for low cost-maintenance. It would be useful to also design to exclude rabbits, as they graze and dig holes. However, the tray system prevents rabbits damaging the water-proofing. |
| Cooling through irrigation | Irrigation is needed to perform the cooling function but there may be potential to control watering to create drought stress that reduces weed establishment. |

[2] https://www.mtdifficulty.nz/pages/sustainability (accessed on 21 January 2019)
[3] http://www.livingroofs.org.nz/stormwater360-mt-difficulty-boutique-vineyard/ (accessed 21 January 2019)

| What works well | Missed opportunities |
|---|---|
| Stormwater mitigation | The drainage design and adjacent conventional roof is an rare opportunity to get runoff data for this region |
| Resilient plants that complement adjacent landscaping. This was achieved by selecting a variety of plant species that included local species, using the same plants in adjacent areas (e.g. as trays on adjacent slopes), and maintenance that removes same weeds as on adjacent restoration area. The original planting pattern has been allowed to soften and naturalise; the original design instead reinforced by retro-fitting the Mt Difficulty logo in stone | The media depth might now be varied by increasing it in localised places to allow some woody native plants to be established that are also on the adjacent slopes. Weights would be linked to engineers' revised weight loading estimates. |
| Regular maintenance supported by soil tests that compare areas with good plant performance and those with some plant dieback, to allow area-specific prescriptions | Include annual maintenance check to ensure gravelled edge drains remain clear of plants and the membrane remains fully covered with gravel or media. Have weed-free media/soil available to top up rabbit-excavations and areas where plants are salvaged, etc. |


**Mt Difficulty roof after about 12 months when thyme was still a dominant feature**

**Mt Difficulty roof at age 6.5 in early spring before sedums flower; the right photo shows the gravel drainage edge that runs along the concrete parapet with the restoration area that includes the hill slopes up to the restaurant (2018)**

# Remarkables Primary School Living Roof

The Remarkables Primary School Living roof was built in 2010. The School's Board of Trustees created a design competition for the new 460 pupil, 24 classroom school build to generate an innovative design featuring environmental sustainability principles and reflecting the rich cultural heritage of the area. The living roof covers parts of the main school buildings at the **Remarkables Primary School**, Queenstown, Central Otago, New Zealand.

**Contractor:** GreenRoofs Ltd/ Naylor Love **Consultant:** Babbage

**Roof specs:**

- Approximately 825m$^2$ integrated with adjacent decks.
- Plants: locally sourced (non-native) sedums and thyme.
- Medium: 60 mm deep, light-weight, pumice-based mix.
- A 50 cm to c. 2 m wide drainage band of local, rounded pebbles.
- Access: via locked gates from the decks. Metal railing and glass barriers prevent student access.

**Reason for installation[4]:**

- To showcase the school's environmental values (visitors enter the school through the roof).
- To provide a quiet outdoor "reflection" spaces for students, under supervision, increasing the usable area.
- To add value to a space that is accessible and enjoyed by the school community.
- To provide insulation for the school from the noise of aircraft flying overhead.

**Construction:**

The green roof was built in September 2010. Plugs of succulent sedums and thyme were supplied and planted into the 60mm planting media by GreenRoofs Ltd[5].

**Construction Cost:**

- $206,250 for the green roof (approximately $250/m$^2$ in 2010 NZ$ and excluding GST)
- Cost included irrigation and maintenance for the first year.

**Maintenance:**

The roof has a low level of maintenance. The sedums die-back during winter but start growing in late spring and flower prolifically in spring and summer. "Heights" and harness training certifications are required for anyone accessing the roof; maintenance requires clipping onto a steel cable along the deck (see photo).

- The roof is mown twice a year with a rotary push mower (after flowering in spring and at the end of summer)
- The roof has not been irrigated or planted (other than in the first year of establishment) or fertilized.
- The safety cable, gates and locks are inspected weekly. The decking is salted in winter (when icy).
- Most costly part of maintenance is an annual cable check ($1,500) and "harness" certification ($2,000).
- The maintenance hours are substantially lower than ground-level landscape maintenance.

**Benefits (over and above noise insulation):**

[4] http://www.scoop.co.nz/stories/ED1103/S00040/primary-school-becomes-first-in-nz-to-wear-a-green-roof.htm

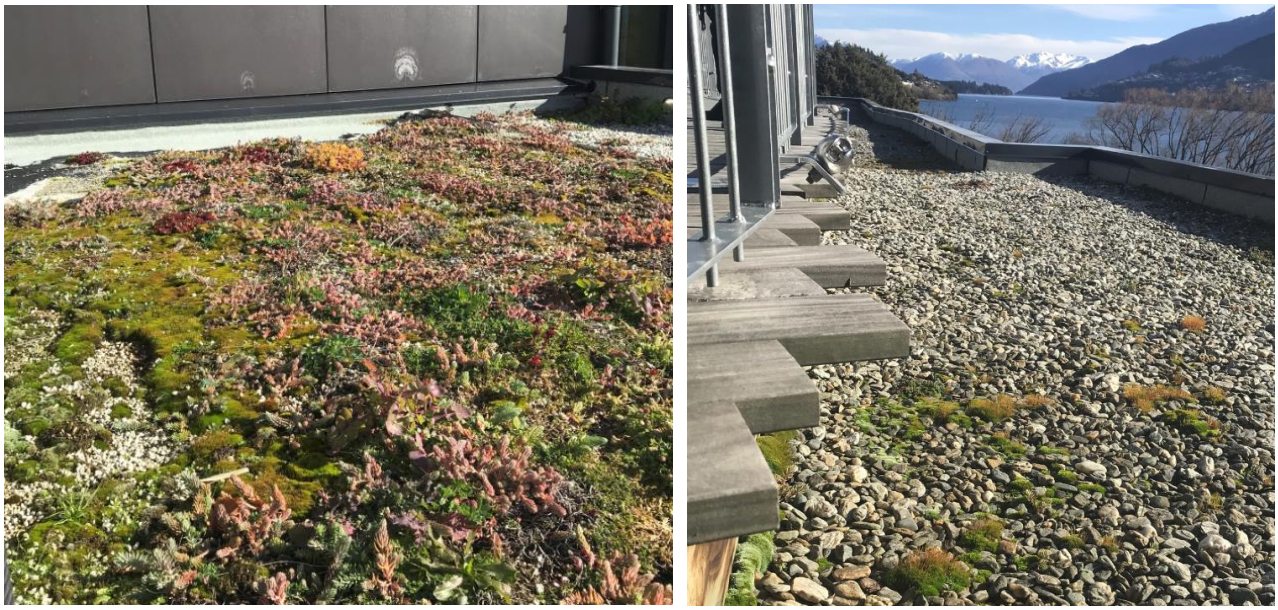
[5] https://greenroofs.co.nz/projects/remarkables-primary-school-queenstown-new-zealand/

- Helps blend the school into the adjacent lakeside environment; many houses have views over the school which adjoins an esplanade reserve
- aesthetic appeal – parents enjoy using the space during sporting activities
- educational opportunities – it is used as an outdoor classroom for the children; the roof is integrally woven into school life and is used as a reflection space for children
- water quantity volume reduction and peak flow reduction (no other WSUD features on site)
- roof encompasses fencing which mimics the cultural and physical attributes of the Remarkables environment, for example, paling heights are 'uneven' and links to the pa site and cultural history of the area. Glass barriers mimic the Remarkables and used in a short section (they're expensive).

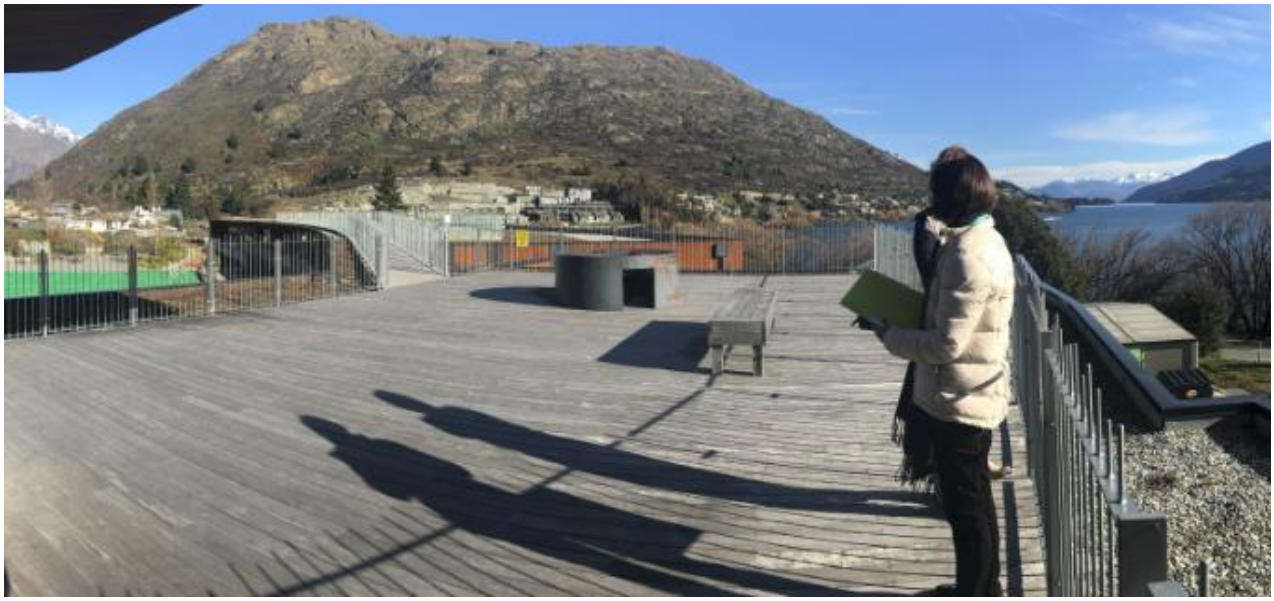

**Remarkables School decking with safety cable, sedum carpet and adjacent pebbled drainage strip which also minimises maintenance near the edge. Warning signs, locked gate and camera surveillance are used to discourage roof access.**

| What works well | Missed opportunities |
|---|---|
| The accessible decking and adjacent living roof is a great asset for the school; children love the space, and it provides a superb viewing area, for example, for parents on sports-days and special events (e.g., a wedding). | The living roof is incomplete. Parts of the roof are bare membrane due to lack of funding. However, the structure can support a green roof and plans have been approved.<br>Solar panels are being considered. Green roofs and solar power are complementary as plants moderate the roof temperature so it is within peak operating zone for longer (not too hot), and the solar panels cast shade and redistribute water to help plants. |
| The decking area and green roof forms an outdoor classroom and quiet, reflective spaces that are especially valuable because the school has half the 'standard' footprint. | Children can't touch, feel or directly interact with the roof. Providing these opportunities would increase the value of the green roof. Options include increasing green roof height near parts of the rails (using alternative drainage board or other low-weight options), creating a green roof 'bridge' across a corner, or adding butterfly/bee water-dishes that can be filled using a water-can from the decking without accessing the planted part of the roof. |
| Plants are hardy and reflect seasonal changes with mass flowering in summer. Honeybees are attracted by the flowers. | Nearly all the plants are all non-native; thyme has died out but mosses (some bright green and very tactile) and lichens have established. A wider range of plants, including natives, could be grown if there are places (or new roofs) where media depth can be increased to 100-125 mm and/or water stress is reduced; a variety of media depths would also expand the learning opportunities, but may complicate maintenance unless new features are able to be mowed with the rest of the roof. |
| Maintenance. The roof is very low maintenance and was designed to allow efficient, safe access. In particular, the safety cable is secured to the | There is no Ministry of Education funding for specific maintenance.<br>Best practice would be to have a 2 to 3 year establishment contract that includes overlap and training of local (school) ground landscaper. |

| What works well | Missed opportunities |
|---|---|
| decking (avoiding membrane penetrations) and wide gravel edges clearly identify the danger edge zone and minimise maintenance there. The thin media is supporting the sedums, while being stressful enough to minimise weed growth. | There is no specific post-establishment assessment. Such assessments help identify reactive maintenance needs specific to living roofs, and how to rectify common issues. For example, treatment of wind-scoured areas and exposed areas of membranes, and removal of sedums from specific areas of drainage. |
| The fencing and glass panels are shaped to link with cultural and landscape history. | The local ecological history could be enhanced in places where roof weight loading allowed by strategic placement of larger local rocks and growing media in ways that create insect hiding places and places where small tussocks or other tough native plants can survive. Some rock lichens and mosses support specific native insects that feed on them. |



**Left: The pale strip at the base of the wall is the waterproof membrane that has been exposed by wind-scour of the thin media. Salting of the roof may also have had an effect. Right: Bright-green mosses have established in some places and are very tactile.**



**The large deck area has a partial roof cover. This is a favourite reflective space for students.**

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