WHERE WE PLAY: USING WSD TO HIT CARBON EMISSIONS OUT OF THE GOLF COURSE

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ABSTRACT

The development and operation of golf courses results in a significant amount of CO_2 emissions. Roughly 33% of the CO_2 emissions results from the initial development of the course. The installation plus the materials for stormwater management and drainage on a golf course produces an average of 1,400 metric tonnes of CO_2 (Saito, O, 2010), just over 10% of the total CO_2 emissions from course development. Water sensitive design (WSD) can help offset and sequester CO_2.

WSD is a large part of the Te Arai Links golf course infrastructure design and overall development. The stormwater management and drainage on Te Arai Links golf courses resulted in the installation of 5.4 ha of swales, raingardens and bioretention basins. Around 50% of drainage related CO_2 emissions were reduced and offset through WSD.

A reduction of CO_2 emissions was achieved by reducing the amount of concrete pipe installed underground and keeping the drainage on the surface. One meter of 225 mm diameter concrete drainage pipe results in 17.17 kg CO_2 emissions for production and transport (Concrete Pipeline Systems Association, 2010). Using vegetated swales kept 15,000 lineal m of stormwater drainage above ground. The above ground drainage reduced the CO_2 emissions by 250 metric tonnes. Further CO_2 emissions reductions resulted from the vegetated swales requiring less hours of heavy earth moving equipment operation for installation. Unlike traditional drainage pipes, vegetated swales do not require trenches and deep excavations to be installed.

We know that vegetated swales, bioretention devices, and other green infrastructure remove metals and nutrients from stormwater runoff by mimicking natural systems. The same natural systems that remove contaminants are also efficient at sequestering carbon.

Grasses and reeds, common to vegetated swales and biotreatment systems continuously sequester carbon, offsetting CO_2 emissions resulting from construction. Bioretention basins and swales sequester an average of 3.1 metric tonnes/ha/year of carbon (Kavehei, E. et al., 2019). The sequestered carbon is permanently stored below ground within the roots and rhizomes where microorganisms help lock the carbon into the soils. Over a 30-year period, the 5.4 ha of bioretention devices, swales and raingardens will sequester 502 metric tonnes of CO_2.

As we were able to use the local sands overlain with coconut matting in the installation of the swales and biotreatment devices, the areas will not require excavation for maintenance or media replacement. As such, the CO_2 will remain permanently sequestered. The use of coconut matting had the added benefit of reducing greenhouse gas emissions resulting from the use of synthetic landscaping fabrics.

The WSD can successfully reduce and offset CO_2 emissions on a large project. The measurable reduction or offset was just over 1/3 of the CO_2 emissions associated with golf course drainage. The WSD also reduced costs as pipes and pipe installation are more

expensive than swales and biotreatment basins. As the green infrastructure has become part of the overall landscaping it adds to the amenity value of the overall project.

KEYWORDS

Water Sensitive Design, Carbon Sequestering, CO_2 Emission Reduction

PRESENTER PROFILE

After immigrating to New Zealand in 2006 Linda joined ACH Consulting. Achieving degrees in Chemistry, geology and an advanced degree in oceanography / marine geophysics, she has worked for NASA, Woods Hole Oceanographic Institution and the US Geological Survey. As scientist and engineer, she brings multidisciplinary experience to stormwater design.

1 INTRODUCTION

Golf is played in 209 countries and there are 38,864 golf courses around the world that cover a combined land area slightly larger than Kuwait (18,000 km^2). The carbon budget of golf course construction and operation has many contributing factors. Distance from urban centres, types of mowers, types of fertilisers and how electricity is generated, all impact the long-term carbon emissions resulting from the operations of a golf course.

The development of golf courses results in numerous CO_2 emissions sources. Deforestation, drainage infrastructure and stormwater management are amongst the highest emitters. Stormwater management is the 4^{th} highest contributor, generating over 700 metric tonnes of CO_2 for a typical 18 holes course (Saito, O, 2010). Drainage work releases another 725 metric tonnes of CO_2 (Saito, O, 2010). Where a golf course is sited determines not only its carbon emission but potential for carbon sequestering. Draining organic soils increases carbon emission while courses on mineral soils or sands have a higher potential for sequestering carbon (Roald, E. and Guðmundsson, J., 2021).

New Zealand has the second highest number of golf courses per capita of any country in the world, just behind Scotland. There are approximately 400 golf courses in New Zealand. World class golf courses like Te Arai Links, Tara Iti, and Millbrook derive about 50% of their income from international golfers. According to Pacific Golfer, international golfers typically stay longer in New Zealand and spend more money. As such, golf is important to the tourism market and the development of new world class courses will only increase over time. It is important to examine how we can develop new courses with an eye on both reducing CO_2 emissions as well as long term carbon sequestering.

The Te Arai Links development consists of two 18-hole golf courses, two club houses, three restaurants/bars, 48 short term visitor accommodations, staff accommodations, a wellness centre, a maintenance area, and 15.5 km of access roads. The development also includes luxury residential lots, but the residential lots sit outside the scope of the overall site development.

Photograph 1: Te Arai Links Golf Course development nearing completion.

The courses are designed as premier golf courses catering to the international golf market. The site is located south of Te Arai Point in the southern section of the Mangawhai Forest, adjacent to Te Arai beach. Te Arai Links is sited on sandy soils and prior to development the site contained a 457 ha area of radiata pine plantation forest. Stormwater drainage and disposal for the development took advantage of the sandy terrain employing WSD.

The additional benefit of the WSD was the reduction of CO_2 emissions from construction and long-term carbon sequestering. WSD also resulted in savings in both construction and maintenance. This paper assesses CO_2 emissions resulting from the construction of stormwater assets at Te Arai Links and CO_2 offsets achieved by WSD.

1.1 THE CLIENT BRIEF

The guidance from the golf course designers was to make the finished development appear as if it had always been there. The preference was to keep as much of the stormwater drainage as possible above ground to reduce maintenance requirements and avoid difficult and costly pipe burials in the sandy environment. Due to the desired market demographic of Te Arai Links all nuisance flooding was to be avoided.

Keeping the drainage on the surface and reducing buried pipes required a WSD approach to all the drainage assets. The soakage rates of the underlying sands are greater than 25 mm/min. As such, the drainage needed was to convey water away from buildings, roads and other infrastructure and create temporary storage to allow time for infiltration. The drainage and infiltration areas had to blend with the surrounding landscape treatments.

2 WORKING WITH THE SOILS

Te Arai is characterised by rolling sand dunes located above an unconfined aquifer. The Holocene dune sands are between 16 – 22 m deep. The sands have high rates of permeability and allow stormwater runoff to infiltrate into the ground. Permeability testing was conducted at eight locations within the Te Arai development. Permeability ranged between 39 mm/hr to 262 mm/hr with an average permeability of 180 mm/hr. The sands are poor in organic material and almost homogenous in their makeup.

Photograph 2: Typical sandy soils during golf course construction, November 2020.

The underlying sands provided an opportunity to allow stormwater to infiltrate to ground with reduced pipe work and fewer manholes and catchpits. As such vegetated swales have been constructed to both act as small infiltration areas, and to convey water to designated infiltration raingardens or bioretention basins where rainfall exceeded the infiltration capacity of the swales. The swales vary in width from 1.6 m – 2.5 m.

Photograph 3: Fully planted vegetated swale.

Photograph 4: Recently planted infiltration basing serving the overflow clubhouse parking, April 2023.

3 CARBON EMISSIONS OF STORMWATER MANAGEMENT ON A GOLF COURSE

The stormwater management on the golf courses, using traditional infrastructure would have produced 1,400 metric tonnes of CO_2 emissions (Saito, O, 2010). The carbon embodied in construction materials represents a large part of the carbon footprint for stormwater infrastructure in any environment. The manufacturing and transporting of reinforced concrete pipes results in 17.17 kg CO_2 emissions for every meter of 225 mm diameter pipe. Installation in sandy soils can be machinery intensive, with higher CO_2 emissions. Every 1 m deep manhole generates 177 kg of CO_2 emissions in production and transport according to Stanton Precast. Based on size and thickness, the standard stormwater catchpit creates 75 kg of CO_2 emissions.

At Te Arai stormwater pipes and manholes were kept to a minimum. The stormwater infrastructure for the development over the 457 ha site included:

- 20 concrete stormwater manholes = 3,540 kg of CO_2 emissions
- 71 concrete stormwater catchpits = 5,325 kg of CO_2 emissions
- 2,850 m of pipe* = 48,934 kg of CO_2 emissions

The stormwater infrastructure hardware resulted in 58 tonnes of CO_2 emissions. However, 15,600 m of drainage swales along access roads saved the following:

- 150 concrete stormwater manholes = 26,550 kg of CO_2 emissions
- 300 concrete stormwater catchpits = 22,500 kg of CO_2 emissions
- 15,600 m of pipe* = 267,852 kg of CO_2 emissions

Employing WSD reduced the CO_2 emissions embodied in construction materials by 317 tonnes or approximately 85%.

* = Polypropylene pipe was used on the site. Greenhouse gas emission of polypropylene pipe is variable but is at least as high as concrete pipe over its entire life cycle.

3.1 NON-QUANTIFIED CO_2 EMISSIONS SAVINGS

The CO_2 emissions related to the installation of stormwater infrastructure are dependent on a range of factors including the type of earthmoving equipment, soil type, depth of burial, duration of construction and distance contractors must travel to site. Burying stormwater pipes, which requires gravity fall, in sand can be time consuming and requires trench shields for any pipe being installed over 1 m in depth. The installation of swales and associated bioretention basins at low spots along road is less labour intensive, reducing construction time and the use of heavy machinery. As such, CO_2 emissions from construction are further reduced.

3.2 MATERIAL SAVINGS

The landscape designers for the course required dunes to hide or shield buildings and parking from view from the golf course. The presence of dunes adjacent to the swales required the dunes be stabilised and planting be completed through the stabilisation fabric. Due to the environmental impact of geotextile cloth, coconut matting was chosen as the material for landscape stabilising purposes. Geotextile cloth generates 2.0 kg of CO_2 emissions per 1 kg of material. Coconut mating generates 367 g of CO_2 emissions per 1 kg of material (Grasselly, D.., et al., 2009). The volume of matting used has not been quantified and landscaping works area still ongoing. However, the selection of coconut matting has reduced emission by 80% where the material is used.

Photograph 5: Coconut matting used to stabilise dunes, March 2022.

4 THE SEQUESTERING OF CARBON

Carbon sequestering goes beyond the net volume, as there are significant differences in where and how different plants sequester carbon. All tree species use C3 photosynthesis which produces a three carbon atom compound stored as a starch within the xylem of the tree. Grasses and rushes grasses employ either C3 or C4 photosynthesis (producing a four carbon atom). Similarly, carbon fixed through photosynthesis in grasses and rushes is stored as a starch (Xiong, S. and Katterer, T., 2010), in the parenchyma cells. It is where the storage occurs that makes the difference.

4.1 THE FATE OF THE CARBON IN THE HARVESTED TREES

As part of the development 226 ha of the 457 ha plantation radiata pine forest was harvested for wood export and wood product production. The remaining trees left standing continue to sequester carbon for the duration of their life cycle.

To understand the long-term carbon budget of the golf course it is important to understand how and where carbon is stored in the trees. In trees carbon is sequestered in the trunk bark and woody material, predominantly above ground.

Photograph 6: Plantation Radiata pine forest prior to harvesting, June 2018.

On average 1 ha of pine trees will have sequestered 630 tonnes of CO_2 by the time it is harvested (27 years) (Wakelin, S.J. et al., 2020). Wood products continue to sequester carbon throughout their life cycles. For New Zealand wood product lifecycles vary between 1(paper and fuel) -110 years (timber framing for houses) (Wakelin, S.J. et al., 2020). So though 287,910 tonnes of tree embodied carbon were removed from the site, much of it remains sequestered as part of the short-term carbon cycle. However, most of the carbon sequestered by plantation forests does not get sequestered permanently.

4.2 PLANTED GRASSES SEQUESTERED CARBON

Unlike trees grasses stores most of its carbon starch in rhizomes, roots and below ground shoot bases (Xiong, S. and Katterer, T., 2010). Due to the location of carbon storage grasses can permanently store carbon below ground where soil microbes process it into soil organic carbon. Soil organic carbon accumulates in the soil, and grasses can continue to sequester carbon at significant rates for up to 45 years on sandy soils (Wang, R., et al., 2022).

Photograph 7: "Secret life of Roots" exhibit at the US Botanic Gardens.

According to a study of north American native grasses (Indigenous Landscapes, 2019) about 1/3rd of the roots breakdown annually a portion of which binds to soil particles becoming soil organic carbon (SOC). Until the SOC levels out, which can take decades an average of 226 tonnes/ha of SOC is accumulated and sequestered below ground.

The sandy soil at Te Arai had additional factors that made it predisposed to efficient carbon sequestering. The factors are:

- Low organic content allowing greater microbial activity transforming carbon stored in the roots and rhizomes of plants to SOC.
- The soils consist of clay components which act as sticky surfaces for carbon molecules (Roald, E. and Guðmundsson, J., 2021).

The above factors allow a larger portion of the SOC to become part of the long term carbon cycle.

4.3 QUANTIFYING THE WSD CARBON BUDGET

As part of the Te Arai Links development 3,135 m^2 of bio-infiltration basins (infiltration raingardens) were installed as well as 51,000 m^2 of vegetated swales. The vegetated swales are planted in various grasses and rushes. Little research has been done on New Zealand native grasses to be able to precisely quantify the volume of carbon sequestered by these species. Further complexity in estimating is a result of the fact that many of the New Zealand native grasses used for vegetation in WSD such as Oioi are part of the Restionaceae family.

The Restionaceae family is an older grass type species that is believed to have evolved during the Late Cretaceous period (Christenhusz, M. J. M. and Byng, J. W., 2016). At one time it was a major global family in grassland and wetland environments; however, due to climatic shifts about 60 million years ago the Restionaceae family was largely supplanted by modern grasses. Currently the Restionaceae family only exists in the southern hemisphere and as such has no northern hemisphere analogues (Cowling, R. M., et al., 2009). Additionally, the Restionaceae family employs C3 photosynthesis and not C4. With no analogue and no species specific research estimating the carbon sequestering ability is at best an estimation. The Restionaceae plant family of rushes are likely responsible for the peat deposits around New Zealand (Meduna, V., 2021). As such the lowest values of carbon sequestering ability of grasses that have been studies were used to estimate the carbon budget of the WSD at Te Arai Links.

Conservatively, the planted bio-infiltration areas and basins have the ability to sequester 3.1 metric tonnes/ha/year of carbon. Considering the total planted area of the swales and infiltration raingardens the WSD infrastructure is sequestering 16.78 tonnes of carbon a year. Over a 30 year period this will equate to more than 500 tonnes of carbon.

4.4 OVERALL CARBON BUDGET

In the building of two 18-hole golf courses as well as the ancillary service the typical CO_2 emissions resulting from the construction of stormwater infrastructure would have been approximately 1,400 metric tonnes of CO_2 emissions (Saito, O, 2010). Through WSD we were able to reduce the hard infrastructure at Te Arai Links reducing the CO_2 emissions by 317 tonnes. The WSD assets will, over a 30-year period, remove at least 500 tonnes of carbon from the short-term carbon cycle. Employing WSD across the Te Arai Links Development has reduced the CO_2 emissions related to stormwater infrastructure by at least half.

5 COST SAVINGS FROM WSD

The cost savings around WSD verses traditional grey infrastructure are significant. Savings around manholes and catchpits are around 3 million dollars. Savings around pipe are about the same. Labour savings due to the less labour intensive WSD installation were significant as installation man hours were halved. Further to this, the maintaining of the WSD assets is part of the overall landscaping teams ongoing work at Te Arai with fewer requirements for specialist equipment to flush lines and vacuum cesspits.

6 CONCLUSIONS

Golf course and particularly high-end golf courses are an emerging and important part of New Zealand's tourism industry. The development of golf courses can generate significant CO_2 emissions. As the construction and tourism industry seeks to do their part in New Zealand's net zero goals WSD should be added to the toolbox. The potential of WSD to offset CO^2 emissions by reducing use of concrete and other grey infrastructure, reduces the CO^2 emissions embodied in construction materials.

Moving towards New Zealand's 2050 net-zero goals also requires new and better ways to permanently sequester carbon. Though the contribution of WSD towards sequestering carbon appears small in terms of land use it is still a significant contribution as WSD remove carbon from the short-term carbon cycle.

In terms of stormwater treatment, WSD on the Te Arai Links development provides:

- Reduced CO_2 emissions embodied in construction materials;
- Reduced CO_2 emissions resulting from construction;
- Reduced CO_2 emissions resulting from maintenance;
- Sequestering of atmospheric carbon into SOC;
- Removal of carbon from the short-term carbon cycle to the long-term carbon cycle;
- Cost savings on construction materials, installation, and maintenance, as well as
- Amenity value

While the accuracy of quantifying the ability of WSD design can be improved through research into New Zealand native plant species, it is a start to understand that WSD can help offset CO_2 emissions resulting from stormwater infrastructure.

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