# FLOATING TREATMENT WETLANDS – CULTURAL AND TREATMENT VALUES

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## ABSTRACT

Wetlands have been utilized in natural environment to treat waste, and this natural technology has been included in wastewater treatment plants as a polishing step in the forms of surface or more commonly subsurface flow wetlands. The success of the wetlands has been varied, with issues related to lack of maintenance and short circuiting.

Floating Treatment Wetlands system have been designed to utlised this natural process whilst incorporating greater flexibility of deeper pond systems to accommodate fluctuations in volume and depth, and ease of maintenance.

This paper presents a comparison of floating wetland systems, including an evaluation of their suitability of wastewater treatment and effluent polishing in the New Zealand context, where natural wastewater treatment process such as oxidation ponds, is more dominant.

## KEYWORDS

**New Approaches, Wetlands, Floating Treatment Wetlands, Bio Film Attachment Surfaces**

## 1 INTRODUCTION

Wetlands have been proven to be a robust, low cost treatment process which has been utilized in the natural environment for years. Wastewater treatment has also incorporated this natural technology as a nutrient removal and/or polishing step with varying degrees of success. The attractiveness of wetland over more mechanically-intensive processes such as activated sludge and trickling filters, due to the cultural benefits, low (almost zero) power requirement, zero chemical use and very low operating cost.

A number of natural reactions take place in wetland which breaks down the pollutants (organic and nutrients). In addition, wetlands can also be a habitat for wildlife animals and birds. As a result, wetlands are often viewed favourably by the community, local iwi and environmental groups as a natural means to treat wastewater or polish treated effluent, commonly in the forms of natural wetlands or constructed subsurface flow wetlands.

To be effective wetland systems, like any wastewater treatment process, require proper maintenance such as weeding, scrub removal and clearing of blockages. Moreover, they often require substantial amount of land area for breaking down the wastewater pollutant, thus potentially incurring significant capital expenditure and possibly land acquisition.

Recently, Floating Treatment Wetlands have been retrofitted in existing oxidations ponds to harness the benefits of wetland systems such as simplicity and low operational requirement as well as resolving some of the attributes that have restricted the use of wetlands in wastewater treatment to date.

The Floating Treatment Wetlands system consists of rooted emergent wetland plants growing in a non woven geotextile mat floating on the water surface of the pond. They have been designed to incorporate the nutrient attenuation capabilities of treatment wetlands and the flexibility of deeper pond systems to accommodate fluctuations in volume and depth.

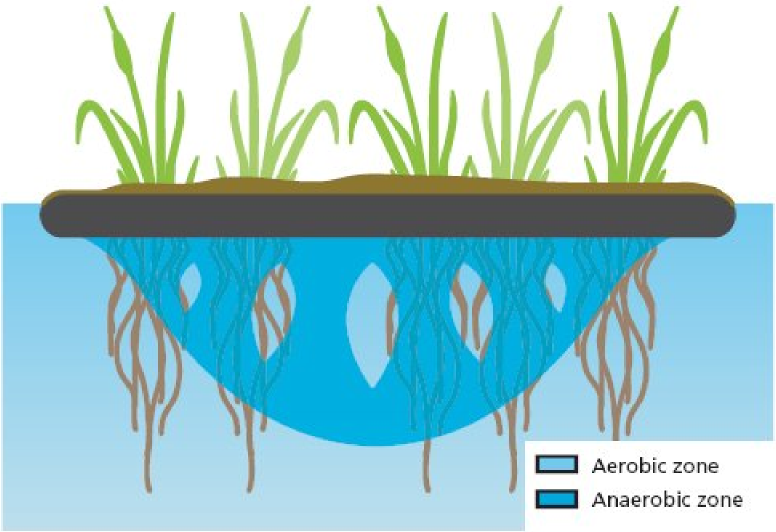



*Figure 1: Floating Treatment Wetland*

The hanging root mat that forms beneath the floating treatment wetland allows close interaction between the plant roots, attached biofilm and nutrients in the water column. Thus the plants have to meet there nutrient requirements from the water column and this encourages greater uptake of nutrient and other contaminants from the water as compared with conventional sediment rooted wetlands. In addition, the large root area provides a significant surface area for the development of biofilms which can contribute to phosphorous and nitrogen attenuation.

Floating Treatment Wetlands have the potential to provide cultural and process benefits for wastewater treatment systems. This paper outlines recent options where Floating Treatment Wetlands have been selected due to cultural and process benefits, and outlines the treatment pathways and presents results of existing systems.

# 2 EVALUATION OF FLOATING TREATMENT WETLANDS

Floating Treatment Wetlands have the potential to provide cultural and process benefits for wastewater treatment systems. This section outlines tow case studies where Floating Treatment Wetlands were selected for cultural and treatment reasons.

## 2.1 HELENSVILLE WASTEWATER TREATMENT PLANT

The wastewater treatment plant at Helensville is currently undergoing the resource consent process to re-consent the discharge of treated wastewater to the Kaipara River. The existing wastewater treatment at Helensville consists of two oxidation ponds in series. Ecological studies have indicated that the plant is not likely to be having an adverse effect on the environment, in part due to the poor water quality of the Kaipara River.

Upgrades are however required to increase the capacity of the treatment system and improve the effluent quality in terms of the biological oxygen demand, suspended solids and faecal coliforms. Upgrades for the plant were targeted at meeting these requirements at a cost that was affordable to the ratepayers. The proposed solution selected consisted of inlet screen, aerators to the ponds and an ultrafiltration system.

The District Council undertook discussions with the local community and Iwi to get their input into the proposed upgrades. The discharge of treated wastewater directly to the Kaipara River was a concern for the local Iwi whose strong preference was for land disposal of the treatment effluent. Land disposal was investigated during the options evaluation stage, but no suitable and/or affordable land was available for disposal.

Whilst the Iwi appreciated the improvements that would be made to the effluent quality, their strong preference was for treatment via natural or land based processes. To incorporate this natural based preference Harrison Grierson investigated options for wetland disposal and during this the use of Floating Treatment Wetlands instead of the traditional wetlands was discussed.

The Floating Treatment Wetlands were selected as a cultural solution. Trials of plant species were undertaken to ascertain the appropriate species for the system, and to allow Iwi to visually inspect the system. In a letter submitted to the consenting authority Iwi supported the wastewater consent application, particularly the incorporation of the Floating Treatment Wetlands.

## 2.2 COROMANDEL WASTEWATER TREATMENT PLANT

The Coromandel Wastewater Treatment Plant (WwTP) has been operational for approximately 30 years. The WwTP is located approximately 750m east of the Coromandel Township. Approximately 800m to the west of the site is McGregor Bay, and further to the west is the Firth of Thames.

Wastewater from the Coromandel Township enters the plant through a manual screen prior to the aeration pond. Aeration is supplied by four high speed vertical shaft and cage aerators. Following the aeration pond wastewater enters into three maturation ponds. The pond effluent is then pumped into the Works Filter System (WFS) with coagulant and polyelectrolyte dosing to assist coagulation and flocculation. The WFS consists of a floc tank followed by adsorption clarifiers and sand filters. The filtered effluent then flows by gravity into the Wedeco UV unit for disinfection prior to discharge. The final effluent is discharged into the Whangarahi Stream.

### 2.2.1 KEY DRIVERS FOR UPGRADE

The proposed treatment upgrades have been targeted to reduce the level of ammonia in the effluent has been identified in the ecological studies as being at levels that under low flow conditions could potentially have an effect on the downstream ecological system. In addition to ammonia the levels of suspended solids and faecal coliforms are also high at times and any potential upgrade will also need to address this.

Any upgrade must be affordable for the Thames Coromandel ratepayers and thereby maximize the use of the existing infrastructure and additionally provide benefits in terms of cultural amenity.

### 2.2.2 OPTIONS EVALUATION

Upgrades to the pond considered were targeted at treating the ammonia in the ponds whilst maximizing the use of the existing infrastructure. Four generic process upgrade options were considered, Tertiary Membrane Filtration; In pond attached growth systems; In-pond Activated Sludge Basin and Floating Treatment Wetlands.

The additional four process options evaluated represent different degrees of plant upgrade. The addition of a membrane filtration system to improve the pond effluent quality is a minor modification and retrofit that will improve solids, biological oxygen demand and pathogen removal. Attached growth upgrades will improve the biological treatment capacity in terms of nitrogen removal while utilizing the existing ponds. Construction of an activated sludge reactor basin in the existing pond is an extensive plant upgrade, but would provide high quality treated effluent. The Floating Treatment Wetland system was selected as the preferred option for the following reasons:

- Ability to easily retrofit to the existing ponds, thus maximizing the use of the existing infrastructure;
- Proven technology (supplier willing to provide process guarantees);
- Significantly more economical to the Coromandel ratepayers when compared with the other three options;
- Ability to achieve equivalent effluent quality and meet the required targets.
- Cultural Benefits.

### 2.2.3 TRIALS

Floating Treatment Wetlands are based on the treatment processes that happen in natural wetlands, and the purpose of the trial is to quantify the treatment levels in terms of the specific removal rates of ammonia and total nitrogen that they can achieve at the Coromandel Wastewater Treatment Plant.

The trials have been designed to reflect as closely as possible the real conditions of the wastewater treatment plant, in particular in respect to the location where a full-size system would be installed as well as in respect to the hydraulic and loading conditions under which it would operate. Operating conditions during the trial will be adjustable in order to allow optimizing the test regime in respect to flow and load conditions.

The aim of the trial is to explore the efficiency of the floating wetland technology for treating highly loaded wastewater and/or lower strength wastewater. The trial is expected to last over a period of about two to three months, including the time required for the growth and the possibly a requirement for an adaptation of the plants to the site specific wastewater.

The trial system would consist of an approximately 1.0m by 0.75m by 4.0m (HxWxL) channel times two. The two channels would be operated in series in order to create a sufficiently long flow path and hydraulic residence time within the system.

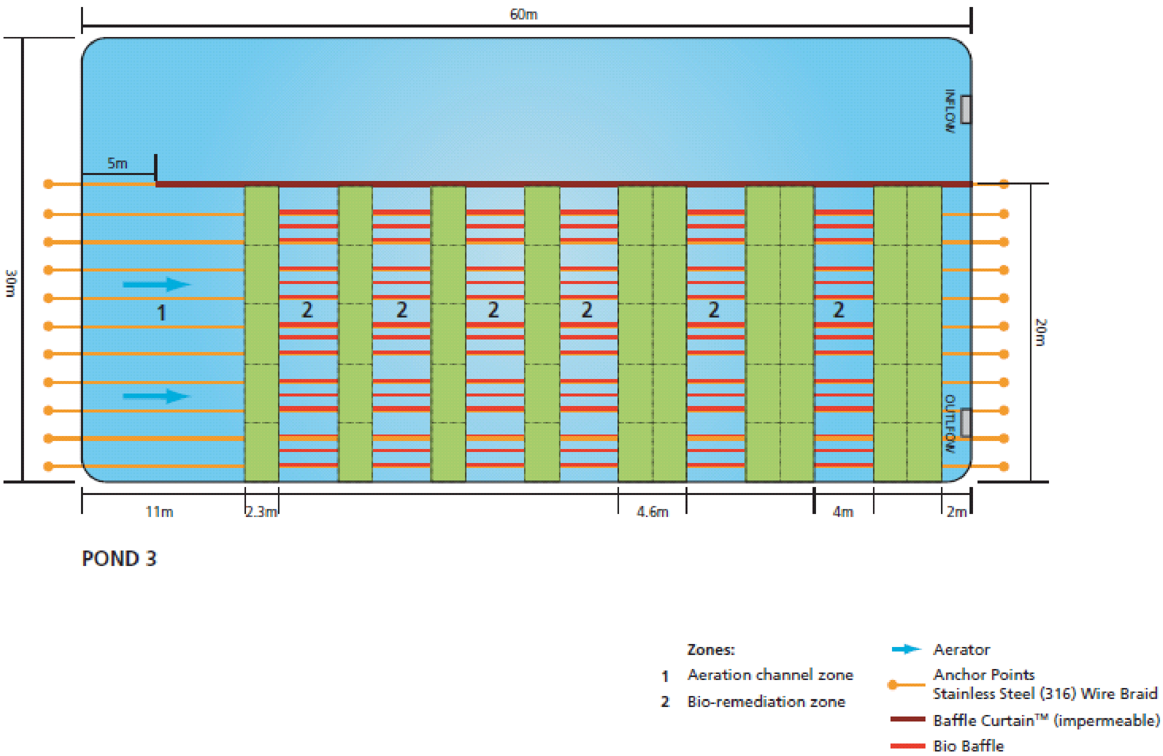



*Figure 2: Proposed Trial Layout*

The main parameters analyzed during the trial will be total suspended solids, biological oxygen demand, ammonical nitrogen, total nitrogen, dissolved reactive phosphorus and faecal coliforms:

The trials are set to start over the 2010/2011 summer period. Should, however at the end of the trial it be found that the floating treatment wetland system is incapable of treating the ammonia to the required standard (consented values) then additional aeration will be added to the treatment system to meet the ammonia levels.

# 3 FLOATING TREATMENT WETLANDS PROCESS METHODOLOGY

The Floating Treatment Wetlands are comprised of 100% recycled PET non woven matrix of 200mm thickness and is injected with PU foam which provides buoyancy and bonds the matrix layers (4) together. Planting holes at a density of 8/m$^2$ and 150mm in depth are located evenly across the Module. Each module is typically 4m x 2.3m in size and is interwoven with nylon webbing between aluminum joiner plates. The typical reserve buoyancy is 40kg – 50kg per m$^2$.

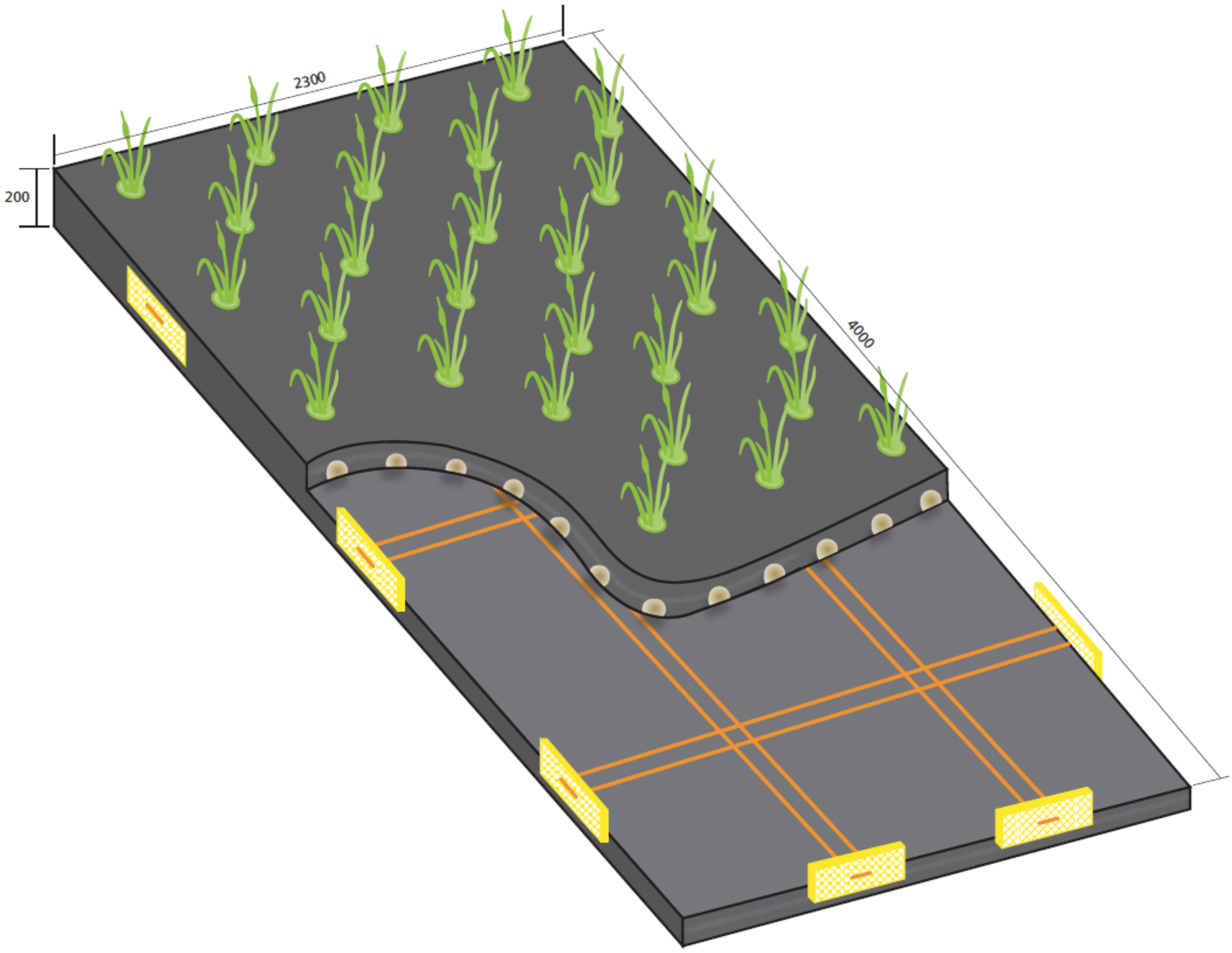



*Figure 3: Typical Module layout showing cutaway section of PU foam and Nylon webbing connecting between Aluminum Joiner Plates*

Surface area for Bio Film Attachment is the principal of the treatment processes. This surface area is quantified as the Bio Mediation Quotient BMQ. One square metre of the non woven matrix has a BMQ of 200m$^2$ and one square metre of plant roots equates to 300m$^2$ giving a BMQ of 500m$^2$ per 1m$^2$ of Floating Treatment Wetland. The aforesaid BMQ provides a high rate growth media as Bio Film Attachment Surface. The bio mass accumulation within the root zone cannot "plug up" rather it sloughs the decaying bio mass to the benthic layer beneath providing a constantly living system. In contrast to this is Subsurface Flow Wetlands with gravel substrates. The voids in the substrate quickly "plug up" and the wetland begins to "track" through the path of least resistance leaving the wetland deteriorating in treatment efficacy.

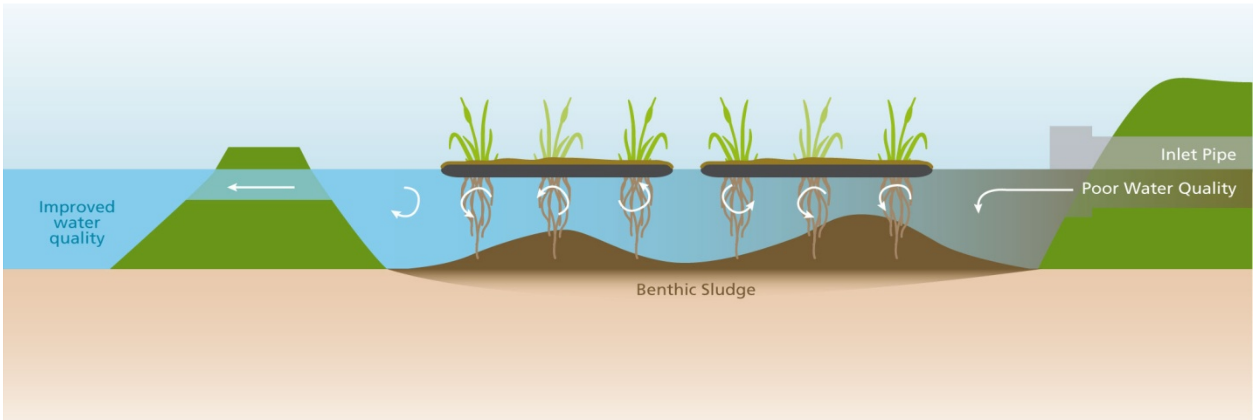



*Figure 4: Stormwater Fore Bay application*

Bio Film and the associated microbial activity provide the treatment methodology of the Floating Treatment wetland approach. Studies (*see "Attenuation of Nutrients in Eutrophic Lake Water using Floating Treatment Wetlands – Mesocosm Trials"- 2008).* have revealed that density of microbial presence is far greater on the plant roots than on inert substrates such as plastics or rock/sand; the reason being a symbiotic relationship between the plants and the support life forms within the root bio mass. There is an exchange of nutrients and sugars constantly occurring. The ability of the Bio Films to occupy anaerobic and aerobic zones all within the one combined area is beneficial as hydraulic and nutrient loads change through daily and annual wastewater patterns.

Floating Treatment Wetlands can be retrofitted to existing assets and are generally laid out opposing flows to maximize contact time of the flow within the suspended Bio Film Attachment Surfaces (root mass). Additionally Bio Baffles as an impermeable curtain are often incorporated into designs to assist in control and directing flows evenly throughout the root mass. This encapsulates the suspended solids and ensures that the hydraulic retention time is maximized. Suspended solids and associated nutrients/heavy metals are caught by the sticky bio films and are either used by the organic bio mass as food or precipitated (sloughs) to the sludge layer beneath the Floating Treatment Wetlands.

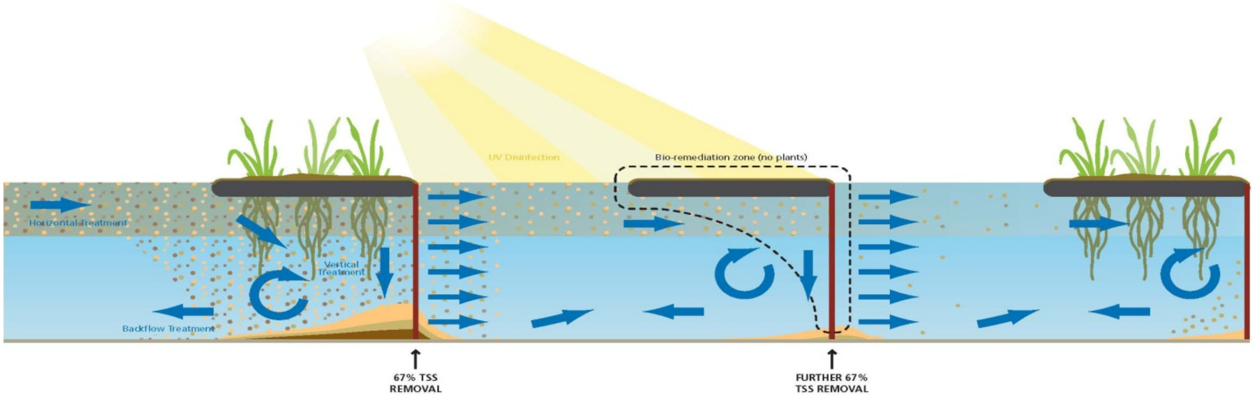



*Figure 5: Wastewater Layout showing Baffle curtains and flow paths.*

Aerobic Bio Films and conditions allow for the nitrification process to occur and the organic and the availability of carbon in anaerobic zones provides the denitrification processes. These combined principals can be retrofitted to existing pond systems and high rate Total Nitrogen reduction rates can be achieved.

The Nutrient Removal Pathways are:

- Nitrification through aerobic Bio Films - Aerobic combinations of oxygen and biological processes nitrify NH4-N to nitrates. Numbers provided by research range between 600mg/m$^2$/day (*see "Attenuation of Nutrients in Eutrophic Lake Water using Floating Treatment Wetlands – Mesocosm Trials"- 2008.*) and 4,970mg/m$^2$/day *(Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes – results of laboratory scale tests - 2008).* The variation is dependant upon additional sources of $O_2$ giving higher nitrification

- Denitrification through anaerobic Bio Films and plant uptake - Anaerobic combinations and biological processes denitrify nitrates and are released as nitrous gases or utilized as food for plant growth.. Numbers provided by research range between 975mg/m$^2$/day (*see "Attenuation of Nutrients in Eutrophic Lake Water using Floating Treatment Wetlands – Mesocosm Trials"- 2008.*) and 100,600mg/m$^2$/day *(Floating islands as an alternative to constructed wetlands for treatment of excess nutrients from agricultural and municipal wastes – results of laboratory scale tests - 2008).* The variation is dependant upon additional sources of carbon giving higher denitrification.

- Phosphorus uptake into the plants – The colloidal removal pathway has 75mg/m2/day. (*see "Attenuation of Nutrients in Eutrophic Lake Water using Floating Treatment Wetlands – Mesocosm Trials"- 2008.*)

- Phosphorus attenuation within the organic accretion – Ongoing data compiled from installations are showing the increase of Phosphorus beyond the phosphorus uptake into plants suggesting the increase of accretion of organics increases the Phosphorus removal pathway. Phosphorus is an important element in cell structure. All living cells need Phosphorus therefore the accretion of organics that contain single cell life forms through to larger living organisms will have an increasing demand for Phosphorus.

- Sedimentation and precipitation of Phosphorus. Phosphorus that is attached to the Suspended Solids will in theory be removal with the TSS and will become immobilized in the benthic sludge beneath the Floating Treatment Wetlands.

- Food webs – Food webs are another removal pathway that is hard to quantify and is of a lesser scale to other pathways. This does have cultural proof that the cleansing of the wastewater is to a standard that aqua life forms can survive within these systems therefore nutrients are being removed from the system through the food chain.

- Volatilization – The same processes apply here as any oxidation pond and cannot be attributed to Floating Treatment wetlands but do surround the technology.

# 4 CASE STUDIES

A number of Floating Treatment Wetlands have been commissioning and are providing a low cost efficient treatment. The maintenance and running costs of these systems post the 12 month commissioning period, is very low compared to power driven mechanical options. Five installments of floating wetlands are discussed in the subsections following.

## 4.1 HELENSVILLE WASTEWATER TREATMENT PLANT

As discussed previously Floating Treatment Wetlands were installed at Helensville with the aim of ascertaining the most appropriate plant species for this wastewater application. The trialed plant species were Juncus, Schoenoplectus tabernaemontani and Carex species.

*Photograph 1: Different Plant Species Trialed at the Helensville Wastewater Treatment Plant*

There was clear evidence of some species e.g. .Juncus, that are not suitable and have failed. This species also has a very low surface area of root mass.

Schoenoplectus tabernaemontani grew as expected and proved to be a species that should not be planted at the edge of the mats; due to the pressure through wind loading on the floating mat edge and causing sinking belo w the surface.

A previously known, the Carex species perform well and provide quick cover and very high quantities of Bio Film Attachment Surfaces in the roots. Water fowl were attracted to the floating platforms until the plants grew together. The water fowl appeared to avoid the platforms, and it is the same worldwide, with the assumption and belief that the dense growth is good cover for predators.

## 4.2 TIP ROAD (LANDFILL LEACHATE)

Tip road is a landfill leachate treatment system located in the New Zealand. The name and location of the project has not been included to protect customer sensitivity. Floating Treatment Wetlands have been installed here as a retrofit to a series existing gravel subsurface flow wetlands. The existing wetland cells were excavated and the vegetation removed, with Floating Treatment Wetlands installed in their place.

Budget constraints dictated the sizing of the system and therefore less than half of the recommended system was installed. The effluent quality parameters targeted for reduction were total nitrogen, total suspended solids and biological oxygen demand.

*Table 1: TIP Road Influent and Effluent Performance*

| **Results**<br><br>(Averages since September 2009) | | |
|---|---|---|
| **Parameters** | **Floating Treatment Wetland Removal Rate (mg/day/m2)** | **Improvement Compared to Pre Floating Treatment Wetlands** |
| Total Nitrogen | 21,560 | 40% |
| TSS | 1,740 | 89% |
| BOD | 7,380 | 46% |

As presented in Table1 above, after the first summer plant growth and root development, the removal rates exceeded expectations in total suspended solids but are undersized for Total Nitrogen and BOD as expected.

## 4.3 MARTON WASTEWATER TREATMENT PLANT

The Marton wastewater treatment plant receives high organic load due to the industrial components in the area. The wastewater treatment plant itself consists of anaerobic pond, aerobic pond and due to continuing non-compliance in odour, Rangitikei DC approached Kauri Park with the reasoning of providing a complete cover with Floating Treatment Wetlands to mitigate odour in the Marton anaerobic pond.

2,700m$^2$ cover of planted Floating Treatment Wetlands was installed in the anaerobic pond and has successfully mitigated the odour. Six aerators have been removed from the pond that was acting as an oxygen blanket. An ancillary benefit of the system has been the reduction in BOD but due to a short circuiting issue being rectified, this data is variable over the whole pond with the overall reduction being 70 – 100mg/L.

*Photograph 2: Installed Cover*

The plant species selection is critical in a situation such as anaerobic cover. Two issues that arise are anaerobic growing conditions and high ammonium causing toxicity to the roots. Certain plant species can translocate oxygen to their roots and survive if there is an area of freeboard in the Floating Treatment Wetlands of aerobic conditions. The toxicity in raw wastewater will burn the root tips and root systems may take time to establish. The success of the planting at Marton ponds is good and the picture shows the freeboard aerobic zone proving to be an average to ideal condition for Carex virgata.

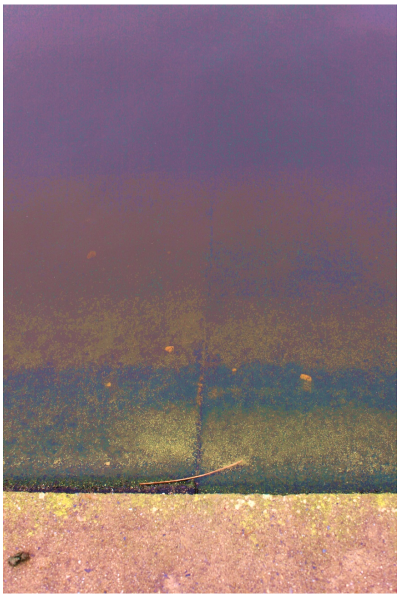
Photograph 3: Carex Virgata

## 4.4 SHANNON WASTEWATER TREATMENT PLANT

Floating Treatment Wetlands were proposed as an alternative to a constructed wetland design for the Shannon wastewater treatment plant. Floating treatment wetlands were selected as the preferred option due to the ability to retrofit this into the existing oxidation pond and thus leaving the adjacent land (wetland site) available for the future.

The system is designed to meet discharge consent levels for biological oxygen demand, total suspended solids, total nitrogen, total phosphorus and E Coli.

*Photograph 4: Prior to Entering the Floating Treatment Wetlands.(Clarity visually to approx 100mm – 200mm)*



*Photograph 5: Adjusted photograph to show the full waveband and water clarity to a depth of 900mm.*

The system is in it's infancy but has visually clarified the discharge effluent to a visibility of 800mm-900mm.

In addition to the treatment value and site saving retrofit, the system can be considered to have sustainable values. This installation alone has reused 334,000 600ml PET bottles in the manufacturing of the non woven matrix. This equates to approximately $1,000,000.00 worth of soft drink sales.

## 4.5 REHBERG RANCH (RESIDENTIAL SUBDIVISON WASTEAWATER TREATMENT PLANT)

This system has a different approach in layout and hydraulic flows due to the absence of plants during the Montana USA winters. This has been included to show the principal of Surface Area and it gives a challenging circumstance. This system relies on mechanically drawing the wastewater from beneath the system and letting it flow back down through the matrix and Bio Film Attachment Surfaces.

The Rehberg Ranch Residential Subdivision was built in 2005 on the outskirts of Billings, Montana USA, serving a city of 120,000 people. Rehberg Subdivision is located in an area beyond the reach of the City of Billings' municipal sewer system.

The stand-alone wastewater treatment system for the subdivision consists of an aerated lagoon wastewater treatment system designed to meet USEPA secondary standards for biological oxygen demand and total suspended solids which are 30mg/l and 30mg/l respectively.

Treated wastewater, rather than being discharged to surface water or groundwater, is land-applied to native prairie grasses that require relatively low nutrient loads. Floating islands (Floating Treatment Wetlands) are being used to remove contaminants so treated water can be applied to less acreage at a higher rate, which will reduce costs.

*Photograph 6: Rehberg Ranch Subdivision floating island, May 2010*

*Photograph 7: Floating island after installation, November 2009*

*Table 2: Rehberg Ranch Results*

| Rehberg Ranch Results (Averages since April 2010) | | |
|---|---|---|
| **Parameters** | **Floating Treatment Wetland Removal Rate (mg/day/ft2)** | **Improvement Compared to Control Lagoon** |

| | | |
|---|---|---|
| Ammonia | 480 | 38% |
| Total phosphorus | 54 | 27% |
| Total Suspended Solids | 200 | 9% |
| Biological Oxygen Demand | 630 | 9% |

# 5 CONCLUSIONS

Floating Treatment Wetlands are based on the treatment processes that happen in natural wetlands. The advantages of this system over other similar technologies such a surface or subsurface wetlands are:

- Ease and ability to retrofit this technology into existing oxidation ponds (which are a common treatment technology for New Zealand);
- Cultural benefits as Iwi and environmental groups perceive the Floating Treatment Wetland system as a land based treatment as it provides treatment with the natural environment and supports aquatic life;
- Process benefits as based on installed systems with future trials are proposed of this system in existing wastewater treatment plants and the results from this trial will confirm the treatment removal.
- Sustainable advantage as the technology has a very low whole of life cost and requires relatively minimal maintenance inputs. The sustainable aspect of the non-woven matrix being manufactured from 100% recycled PET plastic


## ACKNOWLEDGEMENTS

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