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CONVERSION OF A DECOMMISSIONED OXIDATION LAGOON INTO A FUNCTIONAL WETLAND

Jeram Mallis[1], Rhiannon Hamilton[2], Scott Rayburg[3] and Melissa Naeve[4]

[1]City West Water, Australia; [2]Phoenix Mecano, Australia, [3]Faculty of Science, Engineering and Technology, Swinburne University of Technology, Australia; [4]Centre for Urban Research, RMIT University, Australia

ABSTRACT: This study proposes an ecologically valuable reuse for a decommissioned oxidation lagoon at the Altona Treatment Plant in Victoria, Australia, which could be replicated elsewhere. Previous design attempts for this project had failed due to the potential risk they posed to both the surrounding environment and the Treatment Plant itself. Therefore one of the objectives was to undertake multiple assessments to mitigate these risks. The most important of these, and the focus of this paper, was the determination of the optimal source and quantity of water needed to sustain the wetland. Potential water sources included: water from a nearby estuarine swamp; treated class C or class A effluent from the treatment plant; and rainfall-fed runoff from the treatment plant site. Through an analysis of cost and quality of the available water sources, it was determined that locally captured rainfall-fed runoff with Class-A recycled water as a backup supply was the most feasible. In addition, hydrologic modelling revealed that this source could maintain flow in the wetland year round, even in drought years.

Keywords: Constructed Wetland, Recycled Water, Asset Recycling, Water Reuse

1. INTRODUCTION

Wetlands in Australia have immense ecological value and are known for both the diversity of their habitats and the biota they support. Moreover, the high biological productivity of wetlands and the strong selection pressures of an aquatic existence produce a rich biota associated only with wetlands [1]. This distinct and unique wetland biota includes communities of birds, reptiles, amphibians, fish, mammals and invertebrates which both live and breed in wetlands as a consequence of the shelter they provide from predators and the availability of abundant food sources. In addition to the ecological benefits, wetlands also serve a hydrological function by retaining flood waters, improving water quality and in the case of tidal wetlands, protecting coasts from erosion.

Despite their inherent importance, wetlands throughout the world have been extensively degraded and actively removed for various reasons, ranging from urbanisation to war. Wetland ecosystems in Europe, North America, Australia and China have faced, or are currently facing, substantial threats to their existence with the number of wetland ecosystems in these nations being halved in the 20th Century [2]. For example, in North America in the early 1900's, wetlands were drained by the federal government in the interests of urban and agricultural expansion, and for the eradication of mosquitoes [3]. Meanwhile, in Iraq in the late 20th century, the nation's leader at the time committed what was described by [4] as 'ecogenocide' by draining the marshlands of Iraq to destabilise the human inhabitants of an area which had revolted against the regime. In both examples, one deliberately (Iraq) and the other inadvertently (USA), the vital functions of wetlands and their associated benefits to humanity were lost, a pattern that has recurred all too frequently around the world. Throughout Australia, extensive wetland removal occurred over much of the 19th and 20th centuries.

It is only in the last 30-40 years that the ecological value of wetlands has been recognised at the global level [5]. This became formalised, for the first time in international law, in 1971 with the introduction of the Ramsar Convention. This convention was introduced as an instrument to encourage conservation of habitat with a focus on the conservation of wetlands from a legal perspective. The convention aims at protecting habitats rather than a particular species [6], which was a new concept at the time of its implementation. However, as many wetlands had already been lost by the time the Ramsar Convention was enacted (and continued to be), mitigation strategies for wetland replacement are still needed in many parts of the world. In an effort to redress some of the damage caused by wetland destruction, the use of artificial or constructed wetlands has become increasingly popular, especially in urban areas where nearly 100% of natural wetlands have been lost. In 1996 there was an estimated 1,000 constructed wetlands world-wide ranging in size from 500 m^2 to 4000 ha [7]. Since this time, the number of constructed

wetlands has vastly increased as awareness of the need for wetlands habitats has become more apparent.

Throughout Victoria and most of Australia, there is an ongoing and progressive tightening of the regulation for sewage treatment. The Victorian EPA expects the water industry to work towards a future way of operating that has little to no impact, or a net benefit to the environment [8]. These regulatory changes are placing pressure on the water industry to improve the quality of treated effluent discharges to local waterways, bays and oceans. The pressure on the industry is resulting in the gradual decommissioning of oxidation lagoons in favour of more technically advanced alternatives. This study proposes an ecologically valuable reuse for a decommissioned oxidation lagoon, which could be replicated elsewhere.

The purpose of this project is to investigate the design of a constructed wetland to replace a decommissioned oxidation lagoon and to assist with the development of a project that meets pre-determined design criteria. Specific objectives associated with this project are to:

1) ensure that the wetland would complement the other wetland habitats in the area; and
2) select a preferred water source for the new wetland that ensures the wetland has good water quality and that the wetlands hydrology is consistent with surrounding natural wetlands.

2. SITE DESCRIPTION

The City West Water's Altona Treatment Plant is located 15 km southwest of Melbourne's city centre (Fig. 1). This plant was built in 1968 and is comprised of a series of trickling filters and a large oxidation lagoon. In 2005 the plant received a significant upgrade to a more modernized treatment facility, built around a central IDEA rector that currently treats up to 20 ML of sewage per day. Consequently, the existing treatment system, including the oxidation lagoon was decommissioned.

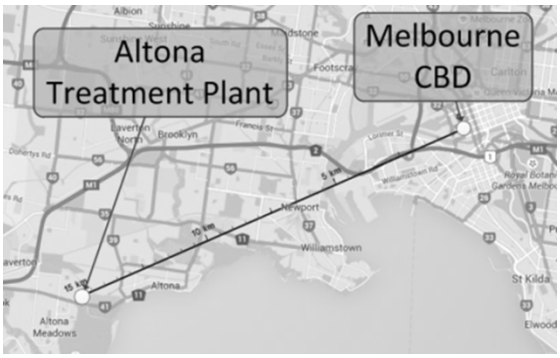

Fig. 1 Map, showing the Altona Treatment Plant relative to the Melbourne CBD.

On the eastern side of the treatment plant site is the 90,000 square meter decommissioned oxidation lagoon which is surrounded by a concrete covered retaining bank. The base of the lagoon in its current state is located at an elevation of approximately 1 m on the Australian Height Datum (AHD) while the surrounding natural surface sits at between 2.5 and 2.6 m (AHD). The lagoon has a thick clay liner to prevent groundwater contamination. This liner dates back to the treatment plant's construction in 1968, therefore its current condition is unknown. Beneath the liner are substantial quantities of volcanic basalt and dense clay. The water table in the area is at approximately 1 m AHD and is highly saline due to the close proximity of the site to Port Phillip Bay. Currently an estimated 10,000 cubic meters of biosolids is located within the lagoon and this has been moved into 'windrows' in anticipation of its removal at a later date. Historically (since 2005) the lagoon fills from rainfall-fed runoff in late winter and early spring (July-September) to a depth of 400-600 mm and evaporates in the summer months until dry. The lagoon also acts as an emergency overflow storage unit for the sewerage treatment facility. The location of the proposed wetland is show in Fig. 2.

Fig. 2 The Altona Treatment Plant site showing the large decommissioned oxidation lagoon which is the proposed site for the new constructed wetland.

3. METHODS

To begin the process of determining how best to convert a decommissioned oxidation lagoon into a fully functioning wetland, it was required to identify which type of wetland would be most suitable for the site and its surrounds. Specifically, this involved a series of site visits to both the decommissioned lagoon and nearby natural and artificial wetland ecosystems. At each site a visual survey was conducted to determine the species of flora and fauna present. An assessment was also carried out to classify the types of wetlands present in the local area and how the proposed wetland

might interact with these as part of a localised wetland matrix.

Another important consideration was the availably of a suitable water source for the proposed wetland and the associated quality of that water. There are four potential water sources in the vicinity of the proposed wetland, including: 1) Truganina swamp, a saline estuary that forms part of Laverton Creek and is located outside of the boundary to the east of the treatment plant; 2) treated effluent from the waste water treatment plant that can supply large volumes of class C water to the wetland; 3) rainfall-fed runoff from the large treatment plant site which is estimated to have 80,000 square meters of catchment area; and 4) a supply of class A recycled water from the Altona Recycled Water Plant. The approximate locations of these water sources are presented in Fig. 3.

4. RESULTS AND DISCUSSION

The proposed wetland, as part of the Altona wetlands region, is expected to primarily interact with the two closest freshwater wetlands: 1) Truganina Wetland, which is a small storm water wetland 1 km south of the treatment plant; and 2) Cherry Lake, a large storm water retaining basin 3 km north of the treatment plant (Fig. 4). These two wetlands are inhabited by existing metapopulations and migrating flocks of birds that are expected to utilise the Altona Treatment Plant wetland to some extent. However, as part of a greater wetland mosaic, the proposed wetland is also expected to interact with both the freshwater and saline wetland environments within close proximity to the site, including the region's many saline wetlands, estuaries and beaches. Depending on the behavior of individual species, some birdlife may prefer to feed or nest in one particular wetland type over another; for example, the purple swamp-hen (*Porphyrio porphyrio*) has been shown to prefer wetlands that are densely planted with the Common Reed (*Phragmites australis*) and bulrush [9]. Although similar observations have been made for other wetland species in natural systems there is currently no information available to aid in the prediction of wetland mosaic alterations and metapopulation interactions in constructed wetland projects. Hence, although it is assumed that certain species will visit the proposed wetland at different times, it is impossible to know, *a priori*, which species these might be and what uses they will make of the wetland habitat.

Bird surveys in the existing oxidation lagoon however, have shown that as many as 16 different bird species regularly visit the existing wetland with several of these being threatened and/or endangered. In addition, other biota types in the Altona region that are of high importance might use this site. For example, [10] suggests that due to the halving of habitat area in Altona over the past 40 years, the threatened Altona skipper butterfly (*Hesperilla flavescens*) is facing extinction, because the specific sedgelands (*Gahnia filum*) that it inhabits have become isolated. This prevents metapopulations of the butterfly from developing due individual colonies of the species being unable to interact. One of the aims of the current project is to provide habitat for the Altona skipper butterfly by planting clusters of the Chaffy Saw-sedge (*Gahnia filum*). It is hoped that these new sedgelands would assist in closing the gaps between the existing sedgelands at the treatment plant site and nearby wetlands. This will allow for interactions between colonies of the butterfly, thereby creating a new metapopulation.

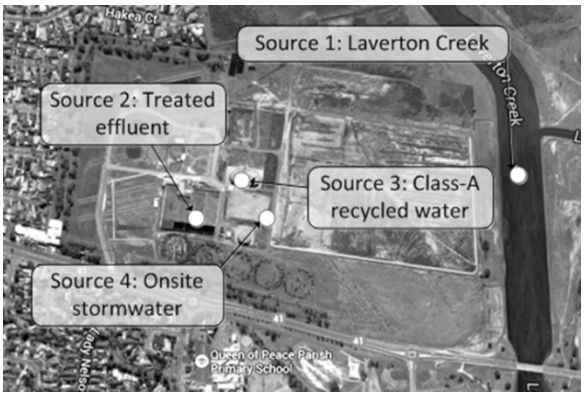

Fig. 3 Potential water sources for the new wetland.

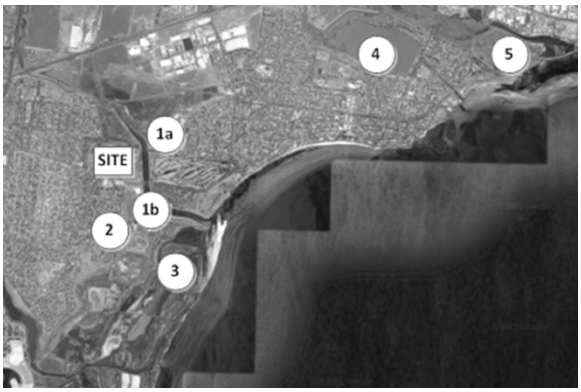

Fig. 4 Natural wetlands in the vicinity of the proposed constructed wetland: 1a) Westona Wetlands as part of Laverton Creek; 1b) Truganina Swamp as part of Laverton Creek; 2) Tuganina Swamp; 3) Cheetham Wetlands; 4) Cherry Lake; and 5) Altona Coastal Park.

This information was used to design vegetation plans for the proposed wetland that aim to meet three objectives: 1) to be consistent with the native species that occur in and around the site; 2) to include species that provide favourable habitat for

the 16 species that visit the current decommissioned oxidation lagoon; and, 3) to provide significant habitat for the Altona skipper butterfly.

Once the vegetation plans were developed, the next step in the design process was to determine the best water source(s) for the proposed wetland. The potential water sources included: water from a nearby estuarine swamp (Laverton Creek); treated class C or class A effluent from the treatment plant; and rainfall-fed runoff from the treatment plant site. To determine which one of these would be the best water supply source, locally available water quality samples (from Laverton Creek and the recycled water supplies) were laboratory tested and these were then assessed to determine if they were suitable for the proposed wetland.

The results of these analyses showed that the water quality of Laverton Creek was poor for multiple parameters when compared to ANZECC trigger values, Melbourne Water mean values and other known water standards. In particular, 1) the mean measured turbidity was 460% higher than the given ANZECC trigger value; 2) the peak measured salinity was of a similar salinity to sea water; 3) the mean metal content including Aluminium, Boron, Chromium and Zinc where significantly higher than the ANZECC trigger values; and 4) the mean measured E.coli was 1137 organisms/100 ml which is more than seven times the mean value as measured by Melbourne Water for E.coli across Melbourne's waterways. In addition, the nutrient levels were very high, although this observation is based on anecdotal evidence as there are no existing trigger values or averages for nutrient levels that are applicable. Hence, although Laverton Creek is able to supply the volume of water required to meet the wetland's demands, this water source is not of a sufficient quality and is therefore excluded as a potential source.

The second considered water source was treated effluent from the Altona Treatment Plant (either class C or class A). The effluent quality was available from regular sampling and testing programs that already occur at the treatment plant (Table 1).

There was limited data available to compare the treated effluent quality with, because the ANZECC trigger values are not applicable to treated effluent. Consequently, the quality of the effluent was assessed against a consultancy report by [11], commissioned by City West Water to investigate the potential for using this water in artificial wetlands. A risk assessment within this report concluded that the water quality of the treated effluent was poor due to elevated salinity, nutrients, dissolved solids and sulphates. The risks were identified as moderate and high and included; 1) odour, which posed a risk to the treatment plant's EPA licence agreement; and 2) eutrophication, which could potentially be harmful to the treatment facility if treated effluent containing toxic algae was returned to the plant for re-treatment. It was therefore concluded that although the treated effluent was of a higher water quality than the water from Laverton Creek and could provide a sufficient quantity of water to meet the proposed wetland's needs, it was unsuitable as a water source and was therefore excluded as a potential source for the wetland.

Table 1 Altona Treatment Plant effluent discharge quality.

Parameter	Average value
TN	6 mg/L
TP	3 mg/L
TDS	4600 mg/L
EC	7500µS/cm
SS	5 mg/L
BOD	3 mg/L
Sulphate	430 mg/L

This left rainfall-fed runoff as the only remaining potentially viable water source for the proposed wetland. To determine if this source would be able to meet the wetland's requirements, a flow balance model was created to determine the frequency and duration of wetting that could be achieved by capturing this water and routing it to the wetland. As the water source in this case would be rainfall runoff, it was assumed that the runoff would be of sufficient quality.

The inputs into the flow-balance model included rainfall and evaporation rates that were sourced from Bureau of Meteorology records (1976-1999), rainfall catchment area, estimated runoff coefficients, wetland volume and wetland surface area. The model simulated a 24 year period (the period for which input data existed) in 24 hour iterations to identify the seasonal variation in wetland volume and retention times. This long term dataset is of sufficient duration that it included both wet and dry periods that are representative of local rainfall variability and as such should be a valid surrogate for future conditions.

The modelling scenario involved the supply of rainfall-fed runoff from a catchment area of 85,000 square m (the area available on the grounds of the Altona Treatment Plant from which water could easily be routed to the proposed wetland) into the wetland as the only water source. The model assessed the viability of rainfall-fed runoff as the only water source and allowed for the following conclusions to be drawn: 1) the optimum volume

of the wetland for the utilisation of rainfall-fed runoff was found to be 6600 kL with a surface area of 13,700 sq m, these were the largest dimensions possible without extending the longest dry period beyond 90 days; 2) the wetland displayed characteristics similar to that of an ephemeral wetland, with the water body being full for the majority of the year and having healthy retention times but drawing down below 50% capacity during an average summer period; 3) in a hot, dry summer the wetland had the potential to completely dry off; and 4) during periods of prolonged drought the wetland would remain empty or near empty (<1 ML) for extended periods of up to 90 days, completely removing the wetland as an aquatic ecosystem and aesthetic amenity for this period as well as increasing the risk of odour through the exposure of the wetland's base to the atmosphere. The results of the simulation are presented in Fig. 5.

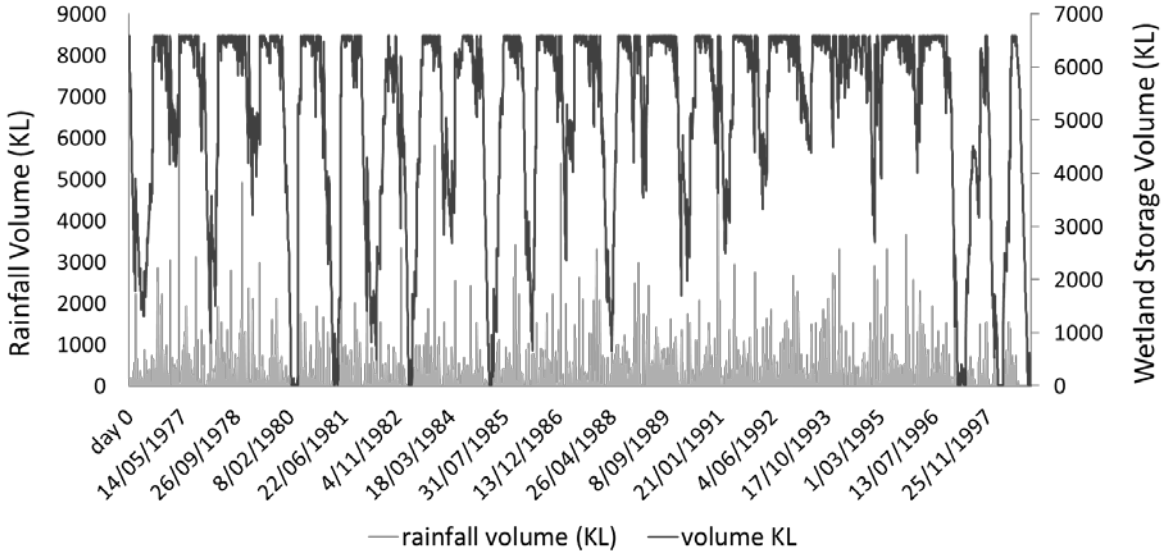

Fig. 5 Simulation of wetland storage levels over time using the rainfall-runoff water supply option.

To minimise the potential for the wetland to dry completely, a Class A recycled water supply was introduced to the model to supplement the rainfall-fed runoff. In the model, recycled water was made available when the wetland water level dropped below two-thirds capacity and was then delivered in 100 kL allocations for each day the wetland remained below this capacity.

All other parameters for the model remained the same as in the first scenario. From the model outputs, the following conclusions can be drawn: 1) the wetland displayed characteristics of a permanent wetland amenity, where the water body remained at greater than 60% capacity for the full duration of the simulation; 2) the average volume of recycled water required per year for the wetland was 3.9 ML which is estimated to cost approximately $10,000 pa to supply; 3) the full wetland permanently retains its ecosystem benefits and aesthetic amenity; and 4) the retention time was estimated to be 18 days on average over the 24 year period. The results of the simulation are presented in Fig. 6. Given the potential risks associated with the wetland drying out and the ecological benefits of a permanent wetland amenity, it was determined that the recycled water supplementation scenario was most viable.

Once both the vegetation plan and the most favourable water source were identified, the next step was to complete a risk assessment to determine how well the proposed wetland would perform across a broad spectrum of potential threats to itself and to the surrounding local community. The results of this assessment are provided in Table 2. Table 2 also summarises proposed control measures to help minimize potential risks associated with the wetland. These control measures include: using rainwater as the primary source of inflows to the wetland; maintaining perennial flow in the wetland using recycled water top-ups as needed; optimizing wetland layout to minimize stagnant areas; using mechanical aeration to further prevent stagnant water; and optimizing plant selection to suit the needs of locally important animal species and to limit other threats. It is anticipated that these control measures will reduce all potential threats to be of moderate consequence or better, an unlikely occurrence or better and a medium risk or better.

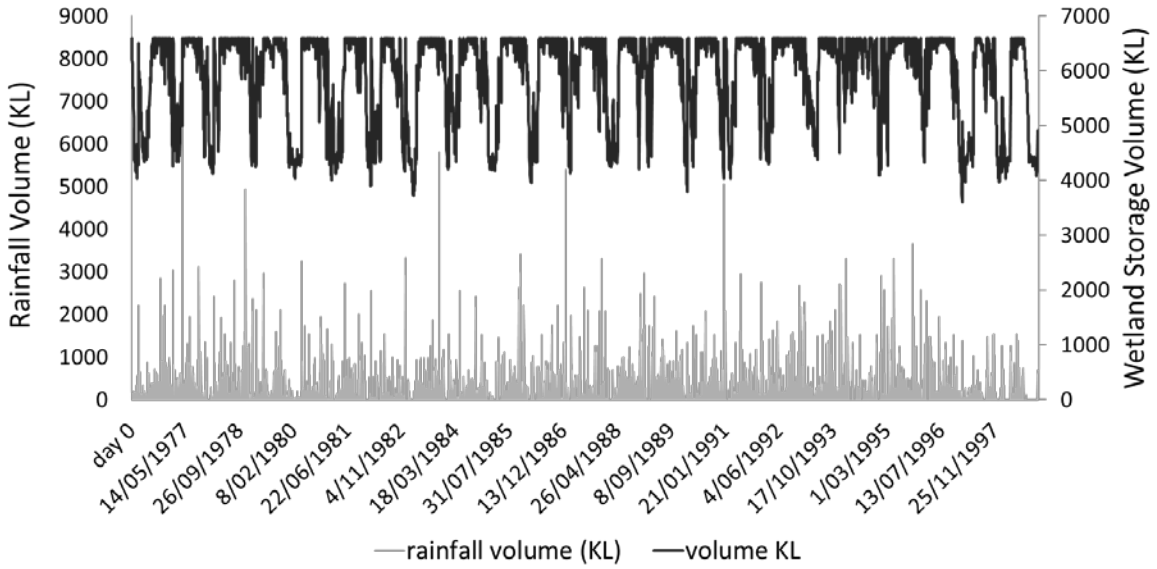

Fig. 6 Simulation of wetland storage levels over time using the rainfall-runoff water supply option with a recycled water top-up.

Table 2 Risk assessment for the proposed wetland [11].

Risk category	Impact on	What can happen & how can it happen	Control measures	Cons.	Like.	Risk
Water source	Wetland health	Drought causes the wetland to dry harming the ecosystem	Top up rainfall with recycled water	MO	UN	M
Odour	Local resident amenity	Development of odour in the wetland.	1. Wetland layout; 2. Plant selection; 3. Mechanical aeration	MI	UN	L
Algae	Wetland health	Toxic algal blooms harm the ecosystem	1. Wetland layout; 2. Plant selection; 3. Mechanical aeration; 4. Action plan	MI	UN	L
Mosquitos	Local resident amenity	Increased mosquito population	1. Wetland layout; 2. Plant selection; 3. Mechanical aeration	I	LI	L
Weed management	Wetland health and aesthetic amenity	Weed proliferation harms the ecosystem	Weed management plan	MO	UN	M
Dust	Local resident amenity	Dust production from a dry wetland disrupts the local community	Top up rainfall with recycled water	MI	R	L
Heavy metals	Wetland health	Bioaccumulation of metals and other compounds harms the ecosystem	Use rainfall as primary water source; limit top-ups with recycled water to times of need	I	R	L

Note: Cons. = consequence: I = insignificant; MI = minor; MO = moderate. Like. = likelihood: UN = unlikely; L = likely; R = rare. Risk: L = low; M = medium.

5. CONCLUSION

A design is proposed to replace a decommissioned oxidation lagoon with a constructed wetland at the Altona Treatment Plant in Altona, Victoria. The design accomplished all of its key objectives. Thus, the proposed wetland will provide meaningful habitat for locally relevant species, including rare and endangered populations of birds and other wildlife; the wetland will contain high quality water (supplied by local rainfall-fed runoff) and will stay wet perennially with needs-based recycled water top-ups; and a risk assessment identified potential threats and elucidated a series of control measures that minimised potential risks to the wetland habitat itself and the surrounding community. This proposal demonstrates how artificial wetlands can help to reverse the worldwide decline in wetland habitats and that decommissioned oxidation lagoons present opportunities for redevelopment into artificial wetlands.

6. ACKNOWLEDGEMENTS

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Corresponding Author: Scott Rayburg