Constructed Wetlands for Greywater Treatment

Pre-Commissioning Procedures for Timbers Edge Residential Village

ENG470: Engineering Honours Thesis

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Declaration

This thesis is submitted to the School of Engineering and Information Technology, Murdoch University, as partial fulfilment of the requirements of ENG470 Engineering Honours Thesis and for the degree of Bachelor of Engineering Honours (BE(Hons)) in Environmental Engineering.

I, Melissa McLean Wong Gray, hereby declare that the work presented herein has been completed in accordance with Murdoch University policy on plagiarism, is my own work unless otherwise referenced.

Signed:

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Abstract

Australians are some of the highest water consumers per capita in the world. Australia's natural water resources are continuing to dry out and exceed sustainable extraction limits. As the population of Western Australia continues to grow so too does the pressure on current water resources and water demand. Seeking alternate water sources as a solution for fit-for-purpose end uses will help to reduce WA's reliance on mains water, reduce discharge of wastewater into sewers and obtain sustainability in the water industry.

This project focuses on the pre-commissioning stages for the Timbers Edge Greywater Treatment System which was built in 2004, but never commissioned due to bankruptcy of the land developer. The system treats and recycles the residential greywater to irrigate the 1.8ha of public open spaces at Timbers Edge via subsurface dripline irrigation. The treatment system has the design capacity to treat 48kL/day of greywater (excluding kitchen) from all residential homes in the Timbers Edge Residential Village. There are currently around 210 homes built, with a maximum of 260 lots. The collected water passes through a lint filter, four constructed wetlands (totalling a treatment area of 1,105m^2), two 10kL Envirophos tanks (which acts to absorb excess phosphorous), and a chlorine dosing system before being used for irrigation at a design application rate of 17ML per annum.

Ground-truthing was completed to verify the design documentation with the in-situ installation and a number of needed repairs and rectifications were identified. Subsequently, all repair and maintenance issues concerning the Timbers Edge Greywater Treatment System have been rectified and resolved in line with the WA Department of Health and AS1547 requirements. A chlorine dosing system has been installed to the irrigation tank's pump. The constructed wetlands will require planting of native species in autumn of 2017 to give the seedlings the best chance of survival after rehoming. The species selected to be replanted are *Schoenoplectus validus* and *Baumea articulata*. In order for this system to pass its commissioning stage, a Recycled Water Quality Management Plan is required to be submitted to and approved by the Department of Health and the preliminary documentation has been drafted.

There is still more research required into the field of greywater treatment through constructed wetlands and also the treatment role which native plants provide; future research recommendations are listed in this paper.

Table of Contents

Declaration ii
Abstract iii
Table of Figures vi
Table of Tables vi
Abbreviations vii
Acknowledgements vii
1. INTRODUCTION 8
1.1. Background 8
1.2. Research Project Context 8
1.3. Aim and Objectives 12
1.4. Limitations 12
1.5. Alterations to the Original Design 13
2. LITERATURE REVIEW 15
2.1. Water Crisis in Western Australia 15
2.2. Alternate Water Sources in Urban Areas 15
2.2.1. Rouse Hill Recycled Water Plant, New South Wales 17
2.2.2. Pimpama-Coomera Waters, Queensland 18
2.2.3. Cranbourne, Victoria 18
2.2.4. Mawson Lakes, South Australia 18
2.2.5. Bridgewater Lifestyle Village, Western Australia 19
2.3. Subsurface Horizontal Flow Constructed Wetlands 19
2.4. Possible Role of Vegetation in Constructed Wetlands 20
2.4.1. Selection of Species for Replanting 22
2.5. Review of Approval Processes 23
2.5.1. Water Quality Requirements 24
2.5.2. Chlorination 24
3. METHODS 26
4. RESULTS 28
4.1. System Component Analysis 28
4.2. Completed Pre-Commissioning Tasks 30

4.2.1. Recycled Water Quality Management Plan 34
4.3. Vegetation Sizing for the Constructed Wetlands 35
4.4. Timbers Edge Budget Sheet 36
5. DISCUSSION 37
5.1. Timbers Edge Greywater Treatment System 37
5.2. Vegetation Selection 37
5.3. Recycled Water Quality Management Plan 38
5.4. Commissioning Validation Monitoring 39
6. CONCLUSION 41
6.1. Findings 41
6.2. Recommendations 42
6.3. Future Work 43
7. BIBLIOGRAPHY 44
8. APPENDICES 49
8.1. Appendix A: Map of Timbers Edge Residential Village 49
8.2. Appendix B: Intended Timbers Edge Greywater Treatment System Design by Syrinx 49
8.3. Appendix C: List of Correspondents involved in the Pre-Commissioning of the Timbers Edge Greywater Treatment System 50
8.4. Appendix D: Plumbers Report on the Integrity of the System 53
8.5. Appendix E: Plumbers schematic of the layout of the Timbers Edge Greywater Treatment System 54
8.6. Appendix F: Draft Recycled Water Quality Management Plan (RWQMP) 55
8.7. Appendix G: Calculation of the amount of irrigation is required for the Timbers Edge Public Open Spaces 77
8.8. Appendix H: Image of clay from Envirophos Tank 77

Table of Figures

Figure 1. Intended schematic of the Timbers Edge Greywater Treatment System from 2004. Biofilters 5 and 6 were never built. 9
Figure 2. Biofilter typical cross sections, provided by Syrinx Environmental in 2004. 10
Figure 3. The design locations of all tanks in the Timbers Edge Greywater Treatment System, as provided by Syrinx Environmental in 2004 (not ot scale). 11
Figure 4. Image of one of the four biofilters at Timbers Edge, lacking in vegetation. Picture taken on the 26/04/16. 29
Figure 5. Picture looking into one of the Envirophos Tanks at Timbers Edge, taken on the 26/04/16 30
Figure 6. Map of Timbers Edge Residential Village and location of the greywater treatment apparatus. 49
Figure 7. Image of clay used in Envirophos tank at Timbers Edge. 77

Table of Tables

Table 1. A source comparison table outlining the roles vegetation can play in a constructed wetland treatment system, as seen in ‘Greywater Reuse’ by Gross *et al* [30]. 20
Table 2. A table summarizing the results of the initial Timbers Edge greywater treatment system analysis conducted on the 26/04/16. 28
Table 3. List of tasks concerning Timbers Edge’s greywater system which have been completed since the assignment of Melissa Gray to the project. 30
Table 4. Table summarizing the dimensions of the four constructed wetlands at Timbers Edge, as well as a few scenarios of the number of plants required for the total rounded area of biofilters. 35
Table 5. Timbers Edge commissioning budget sheet and the cost for yearly operation, all costs are in $AUD. 36

Abbreviations

IWSS – Integrated Water Supply Scheme

POS – Public Open Space

RWQMP – Recycled Water Quality Management Plan

CCPs – Critical Control Points

BOD – Biochemical Oxygen Demand

SS – Suspended Solids

DoH – Department of Health

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1. INTRODUCTION

1.1. Background

Across the globe, the water crisis has increasingly worsened due to growth in population, growth in the economy, as well as through the expansion of high water consuming industries. According to a UN estimate in 2007 [1], about one-fifth of the world's population is facing water shortage, and this number is expected to grow. The four main drivers which affect the expected growth of water shortage are: population growth, urbanization, increased personal consumption due to the rising standard of living, and climate change [1]. Australia is one of the highest per capita water consumers in the world [2], even though its climate continues to dry.

In south-west Australia the reduced rainfall has been accompanied by rising air temperatures which add to the impacts on surface water resources in particular [3]. The drier climate of the past 25 years has resulted in the need for water service providers to accelerate the development of new water sources [4]. New water sources can come in many forms; seawater desalination, reuse of greywater or blackwater, utilising bore fields, and stormwater to name a few. Through successful implementation of these alternate water sources it will be possible to reduce the dependence on historical water sources as they are becoming less predictable and also less available.

This report will focus on the implementation of a greywater reuse system in WA, set to reduce the demand for groundwater for irrigation purposes.

1.2. Research Project Context

The purpose of this project is to prepare the Timbers Edge Residential Village's Greywater Treatment System to the pre-commissioning stage so that it can become operational in 2017. In order to achieve this, the system will need to undergo repairs where necessary and a review of the Department of Health's commissioning procedures will be required. The Timbers Edge Residential Village is located south of Perth, in Dawesville alongside the environmentally sensitive Peel-Harvey estuary. In 2004 the greywater treatment system was built on the corner of Fernwood and Estuary roads in Timbers Edge, Dawesville. The system however was never commissioned and therefore has not been operational since 2006, due to bankruptcy of the land developer. The system was designed to provide the Timbers Edge's 1.8 hectares of Public Open Spaces (POS) with an alternate water source for subsurface irrigation. The POS were calculated to have a watering requirement of 70kL/day. Timbers Edge currently utilises scheme water for their irrigation needs. Bore water resources were intended to substitute this, however the groundwater became brackish [5]. The Timbers Edge

Greywater Treatment train involves a balance tank, a clarifier tank, four constructed wetlands (biofilters), and two 10kL Envirophos tanks; details of the original design from 2004 can be found in Appendix B: Intended Timbers Edge Greywater Treatment System Design by Syrinx. The Timbers Edge Greywater System utilises four constructed wetlands/biofilters to treat household greywater (excluding kitchen), while the clarifier tank acts to remove large suspended solids from the recycled

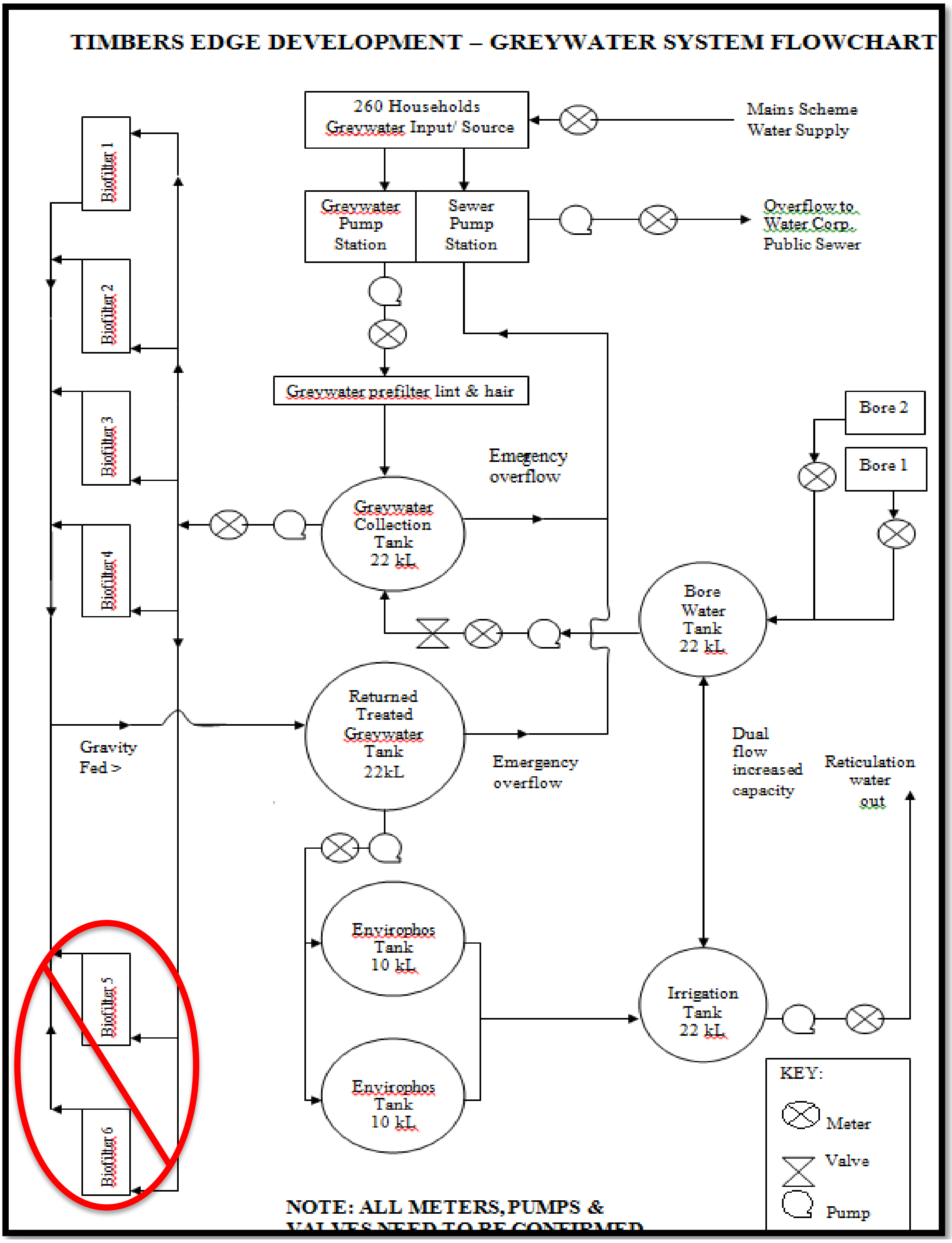

Figure 1. Intended schematic of the Timbers Edge Greywater Treatment System from 2004. Biofilters 5 and 6 were never built.

water before it enters the constructed wetlands.

The greywater is first gravity fed to the Balance Tank from each of the residences, located at the northern end of the southern bund (Appendix A). The closed tank reduces the velocity and turbulence of the pumped mixed water and provides storage, from which a constant feed can be drawn to the Clarifier. The Balance Tank has a sewer connection for discharge of settled material (as required) and for emergency overflows (bypass). The closed tank eliminates mosquito breeding opportunity. From the Balance Tank mixed water is pumped to the Clarifier through feed piping. From here the effluent discharges to a pump sump via gravity feed, where it is to be pulse fed to the Biofilters, with an emergency overflow discharging to the sewer. The Biofilter cells (Figure 2) are subsurface flow systems with a total area of approximately 1,100m^2 (at top water level), with depths varying from 0.5m to 0.6m and an average porosity of 43.5%, which provides an active treatment volume of approximately 260m^3. The species selected to fill the biofilters in 2004 was *Baumea* articulata and *Schoenoplectus* validus. From the Biofilters the recycled water is run through two Envirophos tanks, which remove any excess phosphorous in the recycled water through absorption onto a proprietary product ("Envirophos") in the tank. After this the recycled water is then dosed with chlorine, at a maximum injection rate of 2 parts per million (PPM), and sent out to irrigate the 1.8ha POS area through subsurface driplines (Netafim).

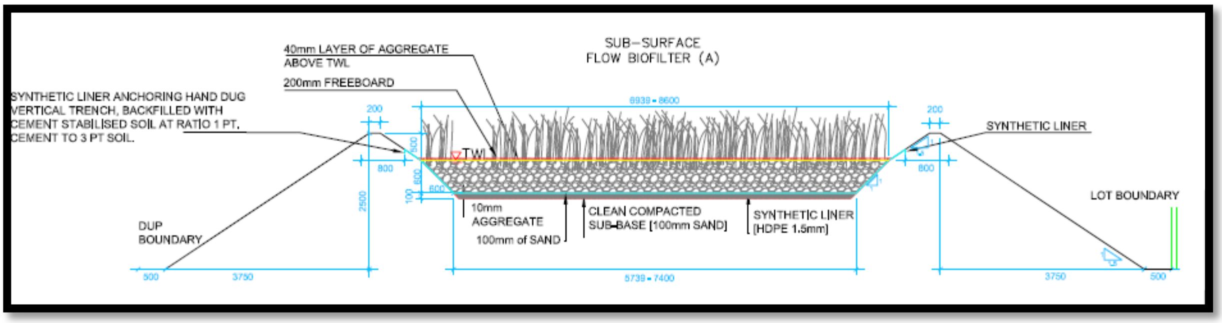

Figure 2. Biofilter typical cross sections, provided by Syrinx Environmental in 2004.

There are many steps and processes which need to be completed in order for the Timbers Edge Greywater System to become operational and commissioned. The progress of these steps and processes are detailed in Section 4.2, as well as their progress to completion. Due to the extensive period of abandonment of the Timbers Edge Greywater Treatment System, the documentation regarding irrigation drawings, greywater system schematics, tank details and other system specifics have been lost, misplaced or are inaccurate. This has called for a collaboration of related correspondents to help assist with the retrieval of these important pieces of information; a list of correspondents who helped throughout the pre-commissioning stages are listed in Appendix C.

KEY	TANK FUNCTION	SIZE	TANK DETAIL	TANK COVER LEVEL (AHD)
A	Balance Tank for Greywater Collection tank	14m3	Precast concrete tank, as per requirements of AS 4198-1994, suitable for burial .	15.35
B	Greywater Collection tank	27m3	Precast concrete tank, as per requirements of AS 4198-1994, suitable for burial .	15.35
C	Irrigation Collection tank	27m3	Precast concrete tank, as per requirements of AS 4198-1994, suitable for burial .Access to buried tank and pump from ground level, via a series of concrete well liners with a lockable steel lid at the surface.	0.30 AHD, below tanks E
D	Returned Treated Greywater balance tank	18m3	Precast concrete tank, as per requirements of AS 4198-1994, suitable for burial. Tank to be positioned at the level of returned greywater to allow gravity filling of tank. Submersible pump to be installed to lift water to top of tanks E. Access to buried tank and pump from ground level, via a series of concrete well liners with a lockable steel lid at the surface.	15.00
E	Post Flow Greywater Phosphorus Removal	10m3	2x 10000 litre fibreglass reinforced plastic, from Tanks west or similar.Not suitable for burial, Tanks to be filled with Virophos media from Virotech, to lower phosphorous levels, Media will require periodic removal and replacement from tanks hence positioning adjacent road, Media and solution is non-toxic. 10m3 Virophos media to be ordered from Virotec (07)5530 8014; allow five weeks for delivery.	tank base 0.20 above the level of existing conc footpath.
F	Pump tank enclosure with lockable steel lid	pump	precast concrete tank, as per requirements of AS 4198-1994, suitable for burial .	finished G.L.
Notes:	1. Detailed design and specification of tanks, pumps and associated electrical cabinets and control equipment by others. 2. Connection to the irrigation system and detailed design and specification by others.			

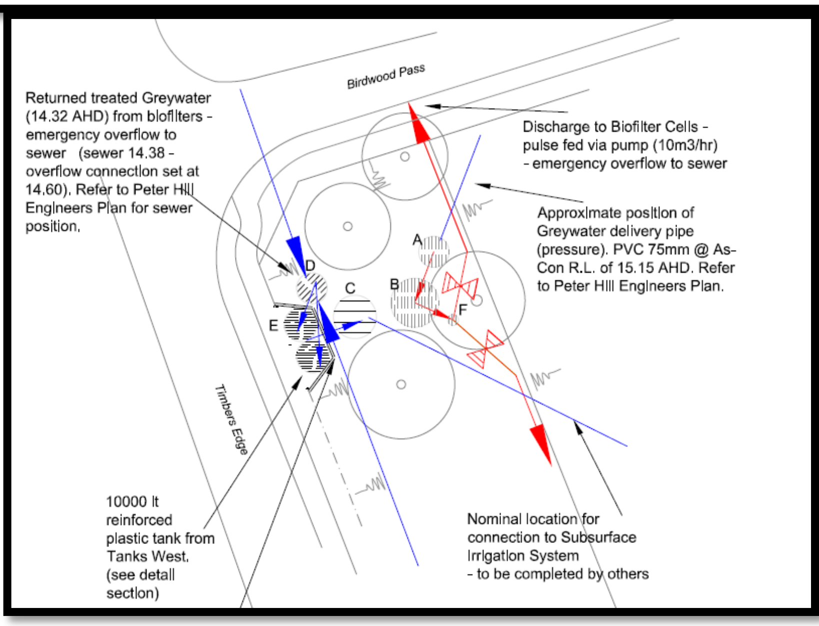

Figure 3. The design locations of all tanks in the Timbers Edge Greywater Treatment System, as provided by Syrinx Environmental in 2004 (not ot scale).

The location of the tanks in Figure 3, are inaccurate based on site visits, therefore ground-truthing is required to rectify this. The Timbers Edge community currently spends around $12,000 on scheme water a year to irrigate their POS area, so if the budget to re-establish the greywater treatment system can remain under or around $12,000 then approval for funds from the Strata body is not anticipated to be an issue.

1.3. Aim and Objectives

The main aim for this project is to develop the commissioning procedures for the Timbers Edge Greywater Treatment System.

The following objectives have been set out to be achieved by the completion of this project for the Timbers Edge Greywater Treatment System:

- Identify any maintenance or operational hazards and issues associated with the system.
- Resolve any maintenance or operational hazards and issues in the system.
- Research, select and quantify the native species to be replanted into the biofilters.
- Ground truthing: assess the system design (Appendix B) against what is actually installed on the ground.
- Determine if the reduced number of biofilters have the capacity to treat the residential village of Timbers Edge.
- Prepare a draft Recycled Water Quality Management Plan for the Department of Health.
- Determine the water quality of the end treated water.
- Prepare a budget for all maintenance and operational repairs so that the system can be commissioning ready.
- Devise recommendations on how to proceed to the commissioning stage.

1.4. Limitations

For the commissioning of the Timbers Edge Greywater Treatment System, there are many limitations which restrain the commissioning from being completed within the scope of this project, and hence this project outlines completed pre-commissioning stages. The limitations are listed in detail below:

- The Timbers Edge Strata Body have made it known that in order for the commissioning to be feasible, the cost for repairs and commissioning will need to remain around $12,000 and with yearly ongoing maintenance fees being well below that figure.
- In order for this system to be commissioned a Recycled Water Quality Management Plan (RWQMP) needs to be completed and submitted to the Department of Health for approval, this approval would then provide Timbers Edge with a permit to pump greywater through the greywater treatment system, and hence allow for water quality testing to be done. The length of the RWQMP has a template of 72 pages alone and since it is an official document requires a lengthy period to be completed to the appropriate standard. The potential to

outsource a professional to complete the RWQMP was not feasible due to budget restrictions maintained by the Timbers Edge Strata Committee.

- The native species in the biofilters require replanting, as the plants have not been looked after/have not received greywater (ie. Since the system was built they have dried out and therefore have died). It is ideal to replant these native species after summer, ie. April/May. This will give the plants the best chance to grow and mature without the stress of the heat and unpredictability of Australian summer weather.
- A ground-truth drawing is essential for the RWQMP submission, as many changes to the system design have not been documented so the location of system components are not accurate (Figure 3). This could not be completed in this project time-frame, as approval and installation of the chlorine dosing system had not been confirmed until the 18th of November.

Regarding the Envirophos tanks, the companies which produced them were never documented during the build and liaising with all contacts listed in Appendix C, none are familiar with the exact specifics of the material. There is no known documentation or manufacturer of this component which has been solidified through online research. However it is believed that the clay is made up of ferric chloride and polyelectrolytes, as these two substances are able to assist in the absorption of excess phosphorous.

The Timbers Edge Greywater Treatment System will not be commissioned by the completion of this project, due to the above mentioned limitations. Through the completion of these limitations, then the system will be operational and ready to be commissioned.

1.5. Alterations to the Original Design

The original Timbers Edge Greywater Treatment System design can be found in Appendix B, many alterations were made to its design when it was built, with most of the alterations not documented. These alterations to the original design are listed below, and are important to note as it may impact the treatment capacity of the greywater treatment system.

- The original design anticipated that six biofilters be built providing a total treatment area of approximately 1,600m^2; however only four biofilters were built totalling a treatment area of 1,105m^2. This reduction in treatment area also corresponds to a reduction in treatment capacity, from originally 70m^3/day to actually 48m^3/day. There are currently no plans for this to be altered. The Department of Health states that the average person uses 120L/person/day of greywater [6], which corresponds to a production of approximately 100L/person/day of greywater [7]. At the moment, Timbers Edge will produce on average

52kL of greywater per day (there are 210 built homes, with an average of 2.5 residents). So with the treatment capacity down to 48kL/day, this means that 4kL of greywater will need to be diverted to the sewer per day. The POS has a water demand of 77kL/day (Appendix G). So a draw of 25kL of scheme water will still be required for irrigation of the POS on watering days. If all 260 lots are built, then Timbers Edge will produce 65kL of greywater/day.

- The original design integrated a chemical dosing element into the Clarifier tank; please see Appendix B for the original plan. The original design was to facilitate chemical precipitation by the addition of either ferric chloride or lime combined with polyelectrolyte. “Ferric chloride was preferred to precipitate phosphorous and coagulate it for settling and removal as lime usage may pose problems due to a larger amount of bulk solids precipitation” (Appendix B). The chemical dosing was not installed during the installation of the greywater system, for reasons unknown. A liquid chlorine dosing system will be integrated into the final tank (irrigation tank) to assist with the operational maintenance of the system.
- A majority of the subsurface irrigation driplines were brought above ground since the greywater system was not operational or commissioned, for reasons unknown. These will have to be put back below ground, with a minimum of 10mm of mulch above.
- Two 10kL Envirophos tanks were added to the system during its build, and were not documented in the original plans (Appendix B). This step acts to remove excess phosphorus from the treated water, and is the final stage before the water is stored in the 22kL Irrigation Tank. The Envirophos tanks are comprised of a clay like mineral, please see Appendix H: Image of clay from Envirophos Tank.
- Upon site inspections, it was identified that a handful of homes may have their blackwater connected to the greywater treatment system. Document trails have led to no resolution. And later inspections have not shown anymore sign of blackwater connection to the treatment system. However it would be cautious to proceed to say that there is some blackwater contamination. The DoH’s regulations for the reuse of blackwater aligns with that of greywater, therefore there should be no issue in trying to get this system commissioned as long as the presence of blackwater is noted in the RWQMP and the regulations for greywater reuse are upheld.

2. LITERATURE REVIEW

2.1. Water Crisis in Western Australia

Over the years, the state of Western Australia (WA) has become drier and hotter; however it still remains one of the highest water using states in Australia [8]. WA's average rainfall use to deliver on average 189 billion litres of stream flow a year [9], however in 2015 WA received just 11.4 billion litres. Winter rainfall in WA has taken a significant hit, declining by up to 20% [3]. According to McFarlane *et al*. the surface water yields and the projected reduction in runoff for south-western Australia are both projected to decrease by 24% [10]. This has led to the implementation of permanent water saving measures. In Perth, the Water Corporation has set limitations to garden irrigation with mains water to two nominated days per week, and three times per week when irrigation is with water from a private bore [11]. "These water restrictions have resulted in increased consumer interest in water saving gardening practises, low water use plants and innovative technologies such as rainwater tanks, drip irrigation and greywater reuse systems" [12].

The Integrated Water Supply Scheme (IWSS), also known as "scheme water", is the main system which delivers water to over 2 million people in Perth, the Goldfields and Agricultural region and some parts of the South West each year. In 2015-16 water supplied to the IWSS was sourced from: 7% surface water, 46% groundwater and 47% desalinated seawater [9]. The energy requirement of desalinated water is currently around 4.1kWhr/kL [11], making Perth mains water the most energy intensive scheme of all capital cities in Australia [13]. Household irrigation continues to be one of the largest consumers of scheme water in the city of Perth, accounting for 39% of all residential water consumption [14]. Household irrigation is able to be substituted with water of a lower quality than that provided by scheme water, meaning that water with such high embodied energy can be replaced for an alternate source to irrigate gardens.

2.2. Alternate Water Sources in Urban Areas

The necessity for utilising alternate water sources in urban areas is slowly growing in acceptance and urgency globally; however if the growing water crisis is to be combatted, utilising alternate water sources for non-potable uses needs to become mandatory. As a result, many urban cities are emphasising a reliance on sourcing and utilising decentralised water systems in their future water strategies; these systems can include rainwater tanks, greywater systems and groundwater bores [9]. Decentralised water systems allow households to collect, treat and reuse localised water resources for applications where potable water quality is not required. These systems are able to provide water at a quality which is better suited to its use, also known as "fit-for-purpose", and reduce householders' reliance on mains water [15].

Historically in Australia, residential properties have two water-related utility connections: potable water inflow and sewage outflow. Advances in water treatment technology and the rising cost to produce potable-quality water have led to the installation of residential third pipe schemes as a solution for meeting consumer demand. Non-potable recycled water is an appropriate substitute for potable water for many uses around a residential property. Third pipe schemes work alongside traditional potable water connections, allowing delivery of fit-for-purpose (non-potable) recycled water to households [16]. “Residential third pipe recycled water infrastructure provides householders with access to recycled wastewater for non-potable uses within the home and in the garden” [16]. The wastewater is treated to a standard where it is declared fit-for-purpose, whilst also managing any risks to the environment or to human health. The cost for recycled water can often be higher than that of traditional supplies, even though it can have limited usage as well as lower quality [16].

Recycled water can in some ways be seen as superior to potable water supply, since it can have a higher reliability than potable supplies as it is climate independent and is usually exempt from water restrictions during droughts [16]. Recycled water is also deemed to have superior environmental performance than alternative water supply options such as desalination, this is because recycled water use reduces the amount of wastewater discharge, and is typically less energy intensive than desalinated water [16]. Treated wastewater typically has higher levels of biochemical oxygen demand, phosphorus, salt, nitrogen, micronutrients, and pathogenic organisms compared to other irrigation water supplies [17]. Therefore the land application of treated wastewater must be managed in order to minimise the risks of environmental damage and the risk to human health. If greywater reuse, for irrigation of lawns and gardens, occurred in every household in Perth there would be the potential for 35% less scheme water to be used or require treatment and disposal each year [18]. In house greywater usage has not yet been achieved in WA, and requires a lot more health regulations, monitoring and reporting.

In Western Australia, greywater re-use falls under the jurisdiction of both the WA Department of Health and the relevant Local Government. The DoH have an approved list of greywater re-use systems, which range from direct diversion systems, through to more sophisticated systems with temporary retention/storage capacity [19]. These units have varying costs, which can typically range from $400 for a simple direct diversion system, through to $8,000 for higher-end systems with temporary retention/storage capacity [12]. Rainwater in WA is unreliable and also reducing in its volume [14]. In WA it accounted for 12.1% of water used, however in Queensland where it is a more reliable source of alternate water, it made up 33.9% of water resources used [20].

Approximately a quarter of all Perth homes utilise residential bores exclusively for garden irrigation, estimated at a total of 141,000 residential bores in WA [21]. WA has a unique availability of local groundwater when compared to the rest of Australia's capital cities; Sydney has the next highest amount of residential bores (11,000), then followed by Melbourne (8,000) [21]. However according to the Department of Water, 50% of the Peel region's water ranges between brackish to saline in quality [5], this is within the locality of Timbers Edge, meaning that bores are an unsuitable alternate water source for this region. And their aquifer recharge has also seen a reduction of up to 50% [11], meaning that the concentration of salt in the bores are only getting stronger.

Despite WA having access to large amounts of an alternative water source for garden irrigation, mains water still accounts for over 70% of all other garden watering needs in Perth [21]. Greywater accounts for less than 3% of irrigation supply for households in Perth, with the national average across all capital cities sitting at 7.3% [20], Perth is not making the most of its alternate water potential.

Examples of successful alternate water systems from around Australia (New South Wales- Rouse Hill, Queensland- Pimpama-Coomera, Victoria- Cranbourne, South Australia- Mawson Lakes, and Western Australia- Bridgewater Lifestyle Village) are provided below.

2.2.1. Rouse Hill Recycled Water Plant, New South Wales

The Rouse Hill Recycled Water Plant (RHRWP) is one of the first and largest third pipe residential recycled water schemes in Australia, it has been supplying recycled water since 2001 and currently supplies to around 20,000 homes in Western Sydney [16]. The RHRWP serves an area of 13,000 hectares and approximately 40,000 people [16]. The RHRWP treats and purifies wastewater from surrounding suburbs to a high standard through a series of steps, both biological and non-biological processes [22]. The presence of the third-pipe infrastructure provides households with the flexibility to substitute between potable and non-potable water, allowing the maintenance of outdoor gardens to be at a standard otherwise not obtainable given budgetary and (potable) water conservation constraints. Customers in the Rouse Hill recycled water area, use on average, up to 40% less drinking water than other customers in greater Sydney [22]. Recycled water can save large amounts of drinking water, helping to support a sustainable water supply for the future. RHRWP helps to care for the environment and reduce impacts on waterways; it does this by reducing the amount of treated wastewater discharged into the Hawkesbury-Nepean River.

2.2.2. Pimpama-Coomera Waters, Queensland

The Coomera Waters development, in south-east Queensland, adopted the Pimpama-Coomera Waterfuture (PCWF) Master Plan in 2005. Since then, all new homes and businesses in the Pimpama-Coomera area have been built with two completely separate water supply networks. This is known as dual reticulation and comprises of the traditional scheme water network and a new Class A+ recycled water network [23]. “Class A+ recycled water is Queensland’s highest class of recycled water for non-drinking purposes and will replace precious drinking water for toilet flushing and outdoor use” [23]. Under the PCWF Master Plan, homes are also connected to rainwater tanks. This means they have access to three sources of water supply and can use each for its specified purpose – saving substantial amounts of valuable drinking water. This system will serve up to 45,000 homes, and has a predicted potable water savings of 35-45% [24].

Also in South East Queensland, “the Queensland Development Code MP 4.2 promotes the use of rainwater tanks at the domestic level to reduce direct reliance on mains water supply” [15]. The study was able to conclude that there was an acceptance of decentralised water systems in urbanised areas and that an expected 70kL of mains water can be saved per year.

2.2.3. Cranbourne, Victoria

Cranbourne is one of the mandated regions in Victoria which is supplied recycled water to their toilets and outdoor taps through distinctive purple pipes and a separate water meter. From the 1st of January 2015, Class A recycled water became available for use in residential laundry washing machines [25]. Alongside this, *Right Water* is a new household-focused initiative to help Victorian families make greater use of alternative water sources around their home and garden, helping to reduce the use of drinking water supplies for non-drinking purposes. The aim of the campaign is to help Victorians make greater use of rainwater. In 2013, a study concluded that a typical single-storey home in Cranbourne would have had approximately 172,000 litres of water fall on its roof, which would cost the equivalent drinking water a minimum of $385.40 [26]. These two alternate water sources provide the residents of Cranbourne with the ability to harness fit-for-purpose water and cut down on their reliance of potable scheme water.

2.2.4. Mawson Lakes, South Australia

Mawson Lakes in South Australia adopted dual water supply system in 2005, supplying drinking water and recycled water to homes. The recycled water is sourced from the Bolivar Sewage Treatment plant, approximately 8km away. The system also has stormwater from the Salisbury wetlands added to it, before it is treated to Class A standard recycled water [24]. The recycled water is for toilet flushing and outdoor use, as well as reserves. This system can serve up to 3,500 homes and is predicted to halve householder's potable water demand when compared to neighbouring suburbs' water usage [24].

2.2.5. Bridgewater Lifestyle Village, Western Australia

The Bridgewater Lifestyle Village (BWLV) is a 20ha site, located 40 kilometres south of Perth in Erskine. There are 389 homes with a central village clubhouse with recreation and social facilities. Each home has a lot scale greywater system, which is re-used to irrigate individual rear yards, with a total domestic irrigation area of 2ha [27]. Like the Timbers Edge Residential Village, BWLV is located alongside the environmentally sensitive Peel-Harvey estuary. BWLV utilises a greywater diversion device (GDD) individually installed at each home, which diverts greywater before entering the sewer. As greywater is produced, it is filtered and pumped immediately to the dripline irrigation system. The greywater from each home is used to irrigate the residences' rear garden which is planted with native vegetation, approximately 25m^2, sized according to the requirements of the Code of Practice set out by the DoH [6]. To ensure that the monitoring and maintenance could be carried out by the in-house management team, the selection criteria of the technology was simplistic [27]. However further requirements are necessary for homes located in areas of high water table, they need to have nutrient removal capabilities due to the high level of groundwater in certain areas of the development. At 88 of the 389 households, a lined constructed wetland or evapotranspiration trench was specifically designed and installed as the nutrient control solution to be coupled with the GDD [27].

The water consumption at BWLV was measured across a six month period and compared to the water consumption volumes from the Perth Domestic Water Use Study. Compared to the Perth average, a BWLV household had a water use saving of 36% [27]. The water consumption for the exterior of the house at BWLV was 14L/person/day compared to the Perth average of 126L/person/day [27]. This demonstrates that utilising greywater for external purposes can significantly reduce a household's scheme water usage as well as not be difficult to operate.

2.3. Subsurface Horizontal Flow Constructed Wetlands

Theoretically, wastewater treatment within a constructed wetland occurs as it passes through the wetland medium and the plant rhizosphere. A thin film around each root hair is aerobic due to the leakage of oxygen from the rhizomes, roots, and rootlets [28]. In subsurface horizontal flow constructed wetlands, the effluent moves horizontally by gravity, parallel to the surface, with no surface water, thus avoiding mosquito breeding [29]. Aerobic and anaerobic micro-organisms facilitate decomposition of the organic matter in the recycled wastewater [28]. Microbial nitrification and subsequent denitrification releases nitrogen gas to the atmosphere. Phosphorous is coprecipitated with iron, aluminum, and calcium compounds located in the root-bed medium. Suspended solids are physically filtered out by the medium within subsurface flow wetlands [28]. And harmful bacteria and viruses are reduced by filtration and adsorption by biofilms on the gravel or sand media in the subsurface flow system [28].

2.4. Possible Role of Vegetation in Constructed Wetlands

The role of vegetation in constructed wetlands is still a grey area in terms of their treatment capacity, more in depth studies need to be conducted. It has been found that they do not provide a negative treatment effect, however they are costly to implant and so a choice to utilise vegetation in a constructed wetland treatment body needs to be backed by evidence that they provide more than just an aesthetic benefit. Table 1 outlines a range of benefits, backed by sources, which macrophytes can provide to a constructed wetland treatment environment, as well as a list of sources which claim that macrophytes play a passive role in water treatment.

Table 1. A source comparison table outlining the roles vegetation can play in a constructed wetland treatment system, as seen in 'Greywater Reuse' by Gross *et al* [30].

Possible Role of Vegetation in Constructed Wetlands			
Positive	**Source**	**Neutral**	**Source**
Roots' structure- physical influences			
Filtration	[31], [32]	Macrophytes do not contribute to hydraulic conductivity and even cause clogging	[33], [32]
Preventing clogging in the substrate	[34]	No influence on removal of suspended solids	[31]
Improving hydraulic conductivity	[33]		
Roots as substrate for microorganisms			
Surface supply for clinging of microorganisms	[33], [31]		
Gas and secretion release by roots			
Oxygen release- creating another	[28], [35], [36], [31]	Oxygen fluctuations have a limited effect in	[31]

aerobic niche		horizontal constructed wetlands	
Oxygen release- increased aerobic decomposition	[37], [38]		
Oxygen release- support of the deposition of heavy metals	[31]		
Oxygen release- increased nitrification	[33], [39], [40]		
Oxygen release- increased denitrification	[41], [42]		
The roots' secretions encourage chelation of metals that reduces their toxicity	[31]		
Absorption			
Nutrient Storage	[43], [44], [31]	Nutrient absorption by plants is marginal	[34], [45], [46], [47], [48], [29], [31]
Microclimate conditions			
Reducing the light that limits the growth	[33]		
Insulation from cold weather in the winter	[49], [33]		
Insulation from radiation in spring	[50], [34]		
Reducing the speed of wind	[31]		
Stabilizing the sediment surface	[31]		
Other roles			
Pathogen removal	[51]		

Insect and odour control	[52]		
Creating decorative gardens	[53], [54]		
Increasing the variety of wildlife	[33]		
Aesthetic appearance	[34], [52]		
Bioindicators	[55]		
Plant Production			
Producing fibers for construction material	[31]		
Crops for bioenergy	[31]		
Animal feed	No reference		

From Table 1, it can be seen that the role of vegetation in constructed wetlands for treatment of greywater has more sources confirming that they play a beneficial role, than a neutral role. As Section 2.3 indicates, majority of the water treatment occurs on the wetland medium and in the plant rhizosphere. Therefore the presence of plants in constructed wetlands is preffered.

However there are enough sources (Table 1) which confirm that the roles of plants in constructed wetlands is quite minimal, specifically in important processes which are believed to be only achieved through the implementation of vegetation. Brix and Stottmeister have said that macrophytes do not contribute to hydraulic conductivity and can even cause clogging in the system [33] [32]. Vymazal has proved that macrophytes provide no influence on the removal of suspended solids, as well as that the nutrient absorption by the plants is marginal [31]. This means that commissioning the Timbers Edge greywater treatment system without replanting the macrophytes should not pose a significant variation in the treatment level of the greywater; especially since a chlorine dosing system is to be installed.

2.4.1. Selection of Species for Replanting

A study was completed by Tanner [44], which compared the allocation of above and below-ground growth and nutrient uptake, and pollutant removal by *Schoenoplectus validus* and *Baumea articulata*. The plants were grown in triplicate 0.238 m^2 x 0.6m deep gravel-bed wetland mesocosms fed with dairy farm wastewaters pre-treated in an aerobic lagoon. Mean removals of 76-88% of suspended solids, 77-91% of biochemical oxygen demand, and 79-93% of total phosphorus were recorded for the established mesocosms irrespective of plant species [44]. Mean removal of total nitrogen ranged from 65 to 92%, showing significant positive linear correlation with plant biomass [44]. These are excellent results by the macrophytes demonstrating that these species are capable of treating wastewater in a constructed wetland environment, and are able to remove important water quality parameters set out by the DoH.

Baumea articulata and *Schoenoplectus validus* are two of the most commo n species of macrophytes found in native nurseries in Perth, Western Australia. They are also the same two species which were selected to be planted in the constructed wetlands back in 2004 (Section 1.2), during the original construction. Therefore these two species will remain the macrophyte species of choice for Timbers Edge, as they are able to cope with the weather and climate in Dawesville.

2.5. Review of Approval Processes

As the greywater system was already built and installed in 2004 at Timbers Edge but not commissioned, it can be said that the system falls within the Department of Health's "Approved Greywater Systems" criteria [19], and has passed the Department of Health's application process for "approval of recycling water scheme"

The Timbers Edge Greywater Treatment System needs to follow the Department of Health's "Guidelines for the non-potable uses of recycled water in WA, 2011". In this document [56] the approvals process requires:

- Commissioning validation monitoring (over a minimum of 7 weeks), to produce at least 6 samples from the inflow and the relevant CCPs in the process and 1 week margin for error.
  - The Department of Health prepare a commissioning validation sampling program based on the proposed treatment train and identified CCPs.
- A 'Recycled Water Supply Agreement' must be made between the supplier and the user of the recycled water to ensure both parties know their responsibilities.
  - The Department of Health requires the submission of the agreement before the approval to use the recycled water.
- Annual reports shall be submitted to Department of Health by 30th September each year. The report corresponds to the immediately preceding financial year and contains the detailed information outlined in Appendix K.
- Internal audits should occur at least every 3 years.
- External audits should occur every 5 years.
- Non-drinking water approvals process (already completed):
  - Option evaluation and concept design study

    - Preliminary design study
    - Detailed design study and obtain approval
    - Implementation
        - Ongoing monitoring and reporting
- During the commissioning phase, the applicant must upgrade the RWQMP and complete the commissioning validation and verification report to demonstrate the treatment plant is producing the water quality objectives in a reliable manner.
- A permit to use the recycled water will be issued after the submission of an upgraded RWQMP that includes the commissioning validation and verification report.
    - As part of the approval, annual reports are to be submitted to DOH as per Appendix K of the RWQMP.
    - "Permit to use" approval is issued from the local government.

2.5.1. Water Quality Requirements

Following the Department of Health's 'Guidelines for the non-potable uses of recycled water in WA', the Timbers Edge Greywater Treatment System ranks as 'Low' in its exposure risk level. This is because its potential end-uses are: 'communal sub-surface irrigation' and 'urban irrigation with enhanced restricted access and application' [56]. The validation and verification monitoring has the following requirements for the effluent compliance values [56]:

- E. *coli*: <1000 MPN or c*f*u /100mL
- BOD: <20mg/L
- SS: < 30mg/L
- pH: 6.5 – 8.5
- Disinfection: Cl: 0.2 – 2.0mg/L

2.5.2. Chlorination

Chlorination is the most common method of wastewater disinfection used worldwide for the disinfection of pathogens [57]. Chlorine is known to be effective in removing a variety of bacteria, viruses and protozoa, which also includes Salmonella, Shingella and Vibrio cholera. Chlorination can also play a key role in the wastewater treatment process by not only removing pathogens, but also other physical and chemical impurities [57]. These physical and chemical benefits can include: aiding scum and grease removal, controlling foaming and filter flies, destroying cyanides and phenols, and ammonia removal [57].

A chlorine dosing system will allow the Timbers Edge Treatment System to disinfect the treated greywater, which could be essential if the system were to have a malfunction during operation or were to be commissioned without any plants in the constructed wetlands. The DoH have stated that commissioning approvals can be granted even if revegetation has not occurred in the biofilters, however there must be an intention for replanting to still occur later on. Also the chlorine will act to break down any bio-solids or biofilms which may have been missed during the treatment process/may have built up in the driplines [57].

3. METHODS

In order to take on this project and have it completed to the pre-commissioning stage, the following method was followed:

1. **Literature review:**

   A literature review to understand the growing water crisis in WA, greywater, constructed wetlands, implementation of alternate water sources, treated water quality standards and regulatory requirements (Section 2).

2. **Semi structured interviews:**

   Interviews were conducted with parties who had previously been involved during the design and construction process of this project. The purpose of the interviews was to primarily collect technical data relating to the Timbers Edge Greywater Treatment System in an effort to fill in blanks not documented when the system was abandoned in 2004. These parties include: Stewart Dallas, Martin Anda, Sam Milani, Clemencia Rodriguez, and Wayne Finigan (Appendix C: List of Correspondents involved in the Pre-Commissioning of the Timbers Edge Greywater Treatment System).

3. **Ground truthing and review of original design drawings:**

   It is important to identify and locate all system components as the documentation left from its build is inaccurate and does not list all system components or components which were in the end not installed. The original design can be found in Appendix B.

4. **Review of Department of Health requirements:**

   A review of all regulatory requirements set out by the Department of Health concerning greywater recycling schemes.

5. **Document analysis:**

   A review of all relevant documents related to the Timbers Edge Greywater Treatment System. These include the intended Timbers Edge Greywater Treatment System design (Appendix B), other documents left by Syrinx Environmental during the system's construction, the Department of Health's Guidelines for the Non-potable Uses of Recycled Water in WA 2011, and a few others which are referenced throughout this dissertation.

6. **Identification of missing/faulty system components:**

   This requires site visits to Timbers Edge and individual trial runs of the greywater system to ensure that the integrity of the treatment system is still intact and that all elements are still operational.

7. **Preparation of a budget:**

The budget is to include the cost of replanting the biofilter's vegetation, cost of the thesis student's petrol to do site visits, cost of obtaining and installing a chlorine dosing system, cost for maintenance and monitoring of the treatment sysem, cost for water quality tests, and costs for conducting the appropriate commissioning tests.

8. **Procurement:**

   All identified maintenance requirements and quotes are to be amended by the appropriate party, a chlorine dosing system is to be quoted and installed, also by the appropriate party.

9. **Identification of future actions:**

   A set of actions required in order for the Timbers Edge Greywater Treatment System to be ready for commissioning. These are listed in Section 7.

4. RESULTS

The results of the pre-commissioning stage are listed below. Table 2 outlines what tasks were completed during the duration of this project (Section 4.2) and the results of a system component analysis (Section 4.1). Calculations for estimating the appropriate number of plants to order for revegetation can be found in Section 4.3. The final budget sheet which was presented to the Timbers Edge Strata body Committee is in Section 4.4.

4.1. System Component Analysis

During the handover process of this project, one of the first important tasks was to go through and identify each system component of the Timbers Edge Greywater treatment system and also to ensure that each of these components was operational. A series of basic tests were conducted to determine the operational conditions of these system components. For the tanks and biofilters each component was individually turned on to test if the component's hydraulic inflow and outflow abilities were still intact from construction in 2004. This process also involved inspections of all accessible piping related to the system to see if any breaks could be identified. For non-accessible pipes, a plumber was called, and their report on the integrity of the system can be found in Appendix D. For non-operational components, arrangements would need to be made for the appropriate trade to come in to rectify the problem.

These results are presented in Table 2. A table summarizing the results of the initial Timbers Edge greywater treatment system analysis conducted on the 26/04/16. and have comments regarding the analysis, and photos from site can also be found in this section.

Table 2. A table summarizing the results of the initial Timbers Edge greywater treatment system analysis conducted on the 26/04/16.

System Component	Operational?	Comments	Identification
Greywater Pump Station	Yes		Confirmed
Untreated Balance Tank	Yes	Blackwater identified	Confirmed
Untreated Greywater prefilter lint & hair	Yes		Confirmed
Untreated Greywater Collection Tank	Yes		Confirmed
Biofilter 1	Yes	Very little vegetation	Confirmed
Biofilter 2	Yes	Very little vegetation	Confirmed
Biofilter 3	No	Very little vegetation, broken outlet pipe.	Confirmed

Biofilter 4	Yes	Very little vegetation	Confirmed
Biofilter 5	[redacted]		Not constructed
Biofilter 6			Not constructed
Returned Treated Greywater Tank	Yes	Float pump	Confirmed
Envirophos Tanks	Yes	Random pipe parts left inside, however clay is still in good form. Flow was able to be evaluated.	Confirmed
Polished water- Irrigation Tank	No	Overflows when greywater system is active, therefore its outgoing pump maybe broken.	Confirmed

The identification that some blackwater is connected to the system was noted in the Balance Tank, this however does not pose an issue as the DoH's regulations for the reuse of blackwater align with that of greywater. Also since this is a low risk exposure case, as long as the driplines remain 20mm subsurface and that blackwater is noted to be present in the RWQMP, approval for this system should still be granted by the DoH.

Figure 4. Image of one of the four biofilters at Timbers Edge, lacking in vegetation. Picture taken on the 26/04/16.

Figure 5. Picture looking into one of the Envirophos Tanks at Timbers Edge, taken on the 26/04/16

4.2. Completed Pre-Commissioning Tasks

A list of all tasks completed to/for the Timbers Edge Greywater treatment system, including the allocation of the task, its status of completion to date by the end of this project (January 2017) and any related comments.

Table 3. List of tasks concerning Timbers Edge's greywater system which have been completed since the assignment of Melissa Gray to the project.

	Task	Task Allocation	Completion status	Comments
1	Initial site visit to Timber Edge to identify all maintenance issues associated with the greywater system.	Melissa	Completed on the 16/03/16	A broken pipe was identified near the 3rd biofilter. Evidence of black water connection from a handful of homes was identified at the balance tank.
2	Identify quantity and location of homes at Timbers Edge having their black water connected rather than just greywater.	Wayne, Paul and Russel	Incomplete	Document trail does not specify the "as is constructed".
3	Establish location of each tank and pump component in the greywater system; and	Melissa, Wayne, Paul, Russel	Completed on the 26/04/16	All components of the greywater system were identified and photographed. The system has

	determine if the system is operational.			now been deemed operational.
4	Research and select suitable native macrophyte species to revegetate the biofilters with and establish what quantity is required.	Melissa	Completed	*Schoenoplectus validus* and *Baumea articulata* are to be used to revegetate the biofilters.
5	Obtain a quote for selected revegetation species selected.	Melissa & Weeding Women Mandurah	Completed on the 25/08/16	Quote by Men of the Trees: $1.60 per forestry tube delivered to Timbers Edge. Replanting will happen between April- May 2017. Comprehensive analysis has been done to compare the possible role of vegetation in constructed wetlands (Section 2.3).
6	Prepare a budget spreadsheet for the Timbers Edge Annual General Meeting in August to seek approval from the Strata body for the commissioning of the project.	Melissa	Completed on the 30/06/16	Please see Section 4.4
7	Establish a ground truth drawing of the greywater system.	Syrinx	Incomplete	Unable to have been completed during the duration of this project as the approval and installation of the chemical dosing system occurred too late. However a schematic has been drawn by Ballantyne Plumbers (Appendix E: Plumbers schematic of the layout of the Timbers Edge Greywater Treatment System).
8	Meet with Clemencia Rodriguez, senior project	Melissa	Met on the 30/08/16 at	A chemical dosing component is required for the system to

	officer, from the Department of Health (DoH) to provide a run-through of the Timbers Edge project and establish the next stages required to work towards the commissioning of the system.		2pm	receive approval from the DoH, especially if approval is sought before revegetation occurs. An up-to-date Recycled Water Quality Management Plan is required to receive a permit from the DoH to use the recycled water. A plumbers report is required to confirm the integrity of the pipelines. Identification of incorrectly installed homes is required for the RWQMP.
9	A Recycled Water Quality Management Plan required by the DoH before approval of permits can be put forward.	Melissa	Incomplete.	Not within scope for Melissa's honours thesis. However a draft was started and is attached in Appendix F: Draft Recycled Water Quality Management Plan (RWQMP).
10	Meet with Sam Milani from Advanced Waste Water Systems to discuss suitable chemical dosing systems which can be added to the final irrigation tank.	Melissa	Met with Sam on the 8/09/16	Sam has suggested an ozonation system, and so required the specifications of the irrigation pump in order to quote a system.
11	Site visit to Timbers Edge with Clemencia from DoH.	Melissa, Paul & Russel	9/09/16	Clemencia confirmed that the chemical dosing system is not for disinfection purposes, rather for operational maintenance purposes to prevent blockages in the drip lines. Therefore ozonation is unsuitable.

12	Discuss with Sam Milani an appropriate liquid chlorine dosing system to integrate to the irrigation tank at Timbers Edge.	Melissa & Sam (AWWS)	Quote sent on 15/10/16	In order for Sam to size a suitable system, he required the flow rate of the pump and the pipe size leaving the irrigation tank. The flow rate was 0.034kL/min, the circumference of the irrigation pipe is 90mm.
13	Selection of chlorine dosing system to be installed.	Timbers Edge Strata Body Committee to decide; quote from AWWS	Funds approved on the 18/11/16	The Strata body have decided to select the ¾" New Tefen proportional injector, costing $350 plus GST.
14	Have a plumber fix the Irrigation Tank's pump which was identified as broken on 05/10/16.	Ballantyne Plumbers	Repaired on 17/10/16	Once the repair was completed then the flow rate from the irrigation tank could be determined, listed in the comments of item number 12 in this table.
15	Have a plumber inspect the integrity of the pipeline system at Timbers Edge, and produce a report which can be included in the RWQMP.	Wayne, Paul, Russel	Report completed on 24/10/16	Please see Appendix D: Plumbers Report on the Integrity of the System for the plumbers report.
16	Determine the irrigation demand by the POS area at Timbers Edge, and conduct a water balance to establish if the reduced number of biofilters is able to accommodate this.	Melissa	Completed	The water demand by the 1.8 ha POS is around 540kL/week, 28 ML/year. Please see Appendix G: Calculation of the amount of irrigation is required for the Timbers Edge Public Open Spaces for the calculations. The reduced number of biofilters is able to treat 48kL/day of greywater, 92%

				of greywater produced at Timbers Edge, meaning that based on the design figure, 4kL/day of greywater will need to be sent to the sewer.
17	Ensure all greywater drip line (purple piping) irrigation is 100mm below mulch/soil top.	Melissa, Wayne, Paul, Russel	Incomplete	This step is not a priority to complete until the completion of the RWQMP.
18	Paint all external pipes linked to the greywater system purple.	Wayne, Paul & Russel	Incomplete	This step is not a priority to complete until the completion of the RWQMP.
19	DoH Commissioning Validation Monitoring requiring a minimum of six samples.	Sub-contractor	Incomplete	This task requires the completion of the RWQMP so that greywater can be pumped through the system.
20	Installation of the chlorine dosing system onto the irrigation tank's pump (¾" New Tefen proportional injector).	Wayne, Russel, Paul	December 2016	Successful installation.
21	Test, using scheme water, to see if the hydraulic inflow and outflow of all system components are intact and operational, post completion of repairs and maintenance.	Melissa, Wayne, Paul, Russel	Completed on 25/10/16	All system components were able to fulfil their role in the hydraulic movement.

Please see Section 6.2 for a list of recommendations to be completed in order for the Timbers Edge Greywater System to reach commissioning.

4.2.1. Recycled Water Quality Management Plan

The RWQMP is a documented, risk-based system for managing the production and supply of recycled water. Its purpose is to protect public health, and to ensure that critical recycled water schemes continue to operate [58]. A draft RWQMP was prepared for the Timbers Edge Greywater Treatment System, and is attached as Appendix F: Draft Recycled Water Quality Management Plan (RWQMP).

Due to time constraints the RWQMP was not completed during the completion of this project. The following sections of the RWQMP have been completed:

- 1. Introduction
  - 1.1. Site description
  - 1.2. Existing environment
  - 1.3. Scheme overview
- 2. Recycled Water Quality Policy
  - 2.3. Stakeholder engagement
- 3. Roles and Responsibilities
  - 3.1. Supplier
  - 3.2. Scheme manager
  - 3.4. Duty of care
  - 3.5. List of contact details
- 4. Assessment of the recycled water scheme
  - 4.1. Source water
  - 4.2. Water quality objectives
- 5. Treatment train
  - 5.1. Treatment description

4.3. Vegetation Sizing for the Constructed Wetlands

The four constructed wetlands at Timbers Edge vary in size (Table 4), however they make up a total treatment area of 1,105m^2. As seen in Table 2 and Figure 4, all four constructed wetlands have very little vegetation therefore they require replanting since plants play a contributing role to the treatment of wastewater through constructed wetlands. Tall sedges will be selected to be replanted as they are most suitable, and therefore can grow with 2-3 plants per square meter. Table 4 summarizes the dimensions of the 4 biofilters and also the number of plants required to replant them.

Table 4. Table summarizing the dimensions of the four constructed wetlands at Timbers Edge, as well as a few scenarios of the number of plants required for the total rounded area of biofilters.

Biofilter	Length (m)	Width (m)	Area (m^2)	Rounded Area (m^2)
1	30.672	8.6	263.7792	264
2	32.175	7.801	250.9971	251
3	32.558	7.556	246.0082	246

4	40.835	8.340	340.5639	341
			Total	**1105**
		Spacing Scenario	**Number of plants required**	
		3 plants per m^2	3315	
		2 plants per m^2	2210	
		Spacing Scenario	**Number of plants required + 10%**	
		3 plants per m^2	3647	
		2 plants per m^2	2431	

4.4. Timbers Edge Budget Sheet

In order to gain financial approval to proceed with the steps required to commission the Timbers Edge Greywater Treatment System a budget had to be prepared and presented to the Timbers Edge Strata Body Committee. Table 5 is the budget sheet which was presented to the Timbers Edge Strata Body Committee on August 1st 2016, where approval was granted for the funding. The total estimated cost to commission the system and its allocated yearly maintenance and operational cost is approximately $10,500, which is ideal as it is less than Timbers Edge's annual cost of scheme water allocated to irrigation.

Table 5. Timbers Edge commissioning budget sheet and the cost for yearly operation, all costs are in $AUD.

Item	Occurance	Quantity	Cost per unit	Total Yearly Cost
Replanting vegetation	Once	3647	$ 1.6	**$ 5,835**
Maintenance and Monitoring	Quaterly	4	$ 250	**$ 1,000**
Water Quality Tests (WQT)	Monthly	12	$ 122	**$ 1,464**
Total Nitrogen	Monthly	12	$ 22	
Total Phosphorous	Monthly	12	$ 22	
E.coli	Monthly	12	$ 22	
BOD	Monthly	12	$ 22	
TSS	Monthly	12	$ 13	
pH	Monthly	12	$ 7	
Chloride	Monthly	12	$ 14	
Liquid Chlorine Dosing System	Once	1	$ 385	**$ 385**
Commissioning Tests	Once	7	$ 122	**$ 854**
DOH bi-annual/annual nutrient monitoring	Quaterly	4	$ 100	**$ 400**
Travel costs for thesis student	Fortnightly	10	$ 50	**$ 500**
Total				**$ 10,438**

For the replanting of the vegetation into the bunds, a 'Busy Bee' will be held, which will rely on local volunteers to assist with the planting of the seedlings. The location and pattern of the planting will be set out prior to the commencement of the Busy Bee so that a structure is still followed. And external source, to be determined at a later date, will be subcontracted to complete the RWQMP at a cost which will be covered by the Timbers Edge Strata Body. All ongoing maintenance and operational costs will be paid for by the Timbers Edge Strata Body Committee.

5. DISCUSSION

5.1. Timbers Edge Greywater Treatment System

Based on the results of Section 4, the state of the Timbers Edge Greywater Treatment System can be deemed operational, as all system components were able to pass a hydraulic test. The quality of the treated water cannot be determined until the system is granted permission to pump greywater through it by the DoH, so that water quality samples can be taken. Based on the results, the Timbers Edge Greywater Treatment System is suitable to treat 92% of the quantity of greywater produced, and should be able to meet the water quality standard outlined by the DoH. According to design figures, there will be an excess of 4kL of greywater produced per day which will be diverted to the sewer, however the true amount will not be known until the system is commissioned and running. The below lying aquifers will also be able to receive plenty of recharge, since winter water restrictions will not apply to this water recycling system.

A chlorine dosing system was selected by Sam Milani from Advanced Waste Water Systems and installed at Timbers Edge in the month of December, 2016. The chlorine dosing system has been connected to the irrigation pumping system so that it is the final element of the treatment train. The purpose of the chlorine dosing system is to aid with maintenance issues concerning the dripline irrigation used, it will prevent build-up of solids around the dripline holes, as the chlorine will act to break down biological solids and inhibit biofilm formation.

The Water Corporation charges the Timbers Edge Village for its discharge to the sewer, so since this system reduces the volume of water sent to the sewer. The associated savings should favourably affect the economics of the system. These savings from the Water Corporation will be determined once flow rates of the system are able to be calculated demonstrating the amount of wastewater diverted from entering the sewer.

5.2. Vegetation Selection

Each of the four constructed wetlands at Timbers Edge are unique in treatment capacity and size, their dimensions and total area are listed in Table 4. And depending on which species of vegetation is selected, the number of plants per square metre will vary; these results can also be seen in Table 4. Based on the results from Section 2.3, the plants which will be used for replanting into the biofilters will be an even mixture of *Schoenoplectus validus* and *Baumea articulata*. These two species are classed as tall sedges, as they range from 2m or more in height, and therefore have a space restriction of 2 to 3 plants per square metre. When estimating the number of plants required for replanting, it is important to cater for a 10% mortality rate (Table 4). In order to optimise the treatment performance of the biofilters, 3 plants per square metre will be ideal, therefore a total of 3,647 plants are needed.

Supplementary planting is essential in most cases within the first 12 months after construction. Plant mortality can vary from 10-20% of the total number of tube stock planted. Plant losses are to be replaced at the beginning of the second active growing season. Supplementary planting is of high importance to reduce the risk of weed infestation in areas with low plant survival, to ensure nutrient removal rates remain acceptable within the biofilter and to retain the aesthetics of the landscape design (Appendix B). Plant survival should be monitored monthly and the species and number of replacement tube stock required should be determined to allow for ordering from nurseries 3 to 6 months prior to the next planting period.

5.3. Recycled Water Quality Management Plan

The RWQMP needs to be completed and submitted to the DoH before any greywater is able to be pumped through the system. Based on Appendix F the following sections of the RWQMP need to be completed before it can be submitted to the DoH:

- 2. Recycled Water Quality Policy
    - 2.1. Policy document
    - 2.2. Regulatory and formal requirements
- 4. Assessment of the Recycled Water Scheme
    - 4.3. Health risk assessment
    - 4.4. Recycled water storage
    - 4.4. Reticulation network and application
    - 4.5. Systems operation
    - 4.6. Prevention of cross connection with potable supplied
- 5. Treatment Train
    - 5.2. The hazard analysis and critical control points (HACCP)
    - 5.3. Operational monitoring and maintenance
    - 5.4. System operators competency
    - 5.5. Alarms, critical control points and critical limits
    - 5.6. Water supply arrangements
- 6. Monitoring Plan
    - 6.1. Validation monitoring
    - 6.2. Operational monitoring
    - 6.3. Verification monitoring

- 7. Employee Training and Public Education
    - 7.1. Employee awareness and involvement
    - 7.2. Employee training
    - 7.3. Training records
    - 7.4. Occupational health and safety procedures
    - 7.5. Public safety
- 8. Incident and emergency response
    - 8.1. Communication
    - 8.2. Incident and emergency response protocols
- 9. Community Involvement and Consultation
    - 9.1. Community consultation
    - 9.2. Communication
- 10. Documentation and reporting
    - 10.1. Management of documentation and records
    - 10.2. Reporting
    - 10.3. Annual report
- 11. Evaluation and audit
    - 11.1. Long-term evaluation of results
    - 11.2. Audit

5.4. Commissioning Validation Monitoring

"Commissioning validation monitoring is required to take place over a minimum of six weeks to gain a minimum of 6 samples from the inflow and the relevant CCPs in the process. This is essential to ensure that the system works to the established operational limits and can be safely operated before recycled water can be reused on-site" [56].

"DoH will prepare a Commissioning Validation Sampling Program based on the proposed treatment train and the identified CCPs. The operational parameters of each critical control point and their corresponding operational targets will be monitored during commissioning validation. The CCPs will vary depending on the type of system in use and processes and will adjust during commissioning validation to correct any failure or inefficiency of the system to achieve the operational targets. No approval to use will be granted until the system is producing the water quality expected for the intended end-use(s)" [56]. Depending on the outcome of the test results, the system can then be fine-tuned to ensure that the water quality objectives can be achieved.

The Timbers Edge Greywater Treatment System, falls within the 'Low' exposure risk level, and so will need to meet the following water quality parameters in order to get approval [56]:

- E. *coli*: <1000 MPN or c*f*u /100mL
- BOD: <20mg/L
- SS: < 30mg/L
- pH: 6.5 – 8.5
- Disinfection: Cl: 0.2 – 2.0mg/L

6. CONCLUSION

The Timbers Edge Greywater Treatment System will be able to treat the greywater to the Department of Health's standards as the greywater treatment process will provide adequate treatment to yield water quality parameters which meet the DoH's low exposure risk category. The treatment system coupled with the chlorine dosing system will be able to provide adequate treatment to the recycled water. Timbers Edge Residential Village will be able to divert, on average 48kL per day, around 17ML per year of greywater from entering the sewer. Also during the winter months excess treated greywater will be able to recharge the underlying aquifers through excess watering in an effort to combat the brackishness. This not only results in a saving in scheme water usage, but will also reap benefits from the Water Corporation for a reduction in wastewater volume sent to the sewers. This will not impact sewer hydraulic flows as blackwater and the design figure of 4kL of greywater are still being discharged into the sewers.

The RWQMP needs to be improved and completed as soon as possible so that it can be approved by the DoH, a sub-contractor maybe hired to complete the documentation, however this will depend on approval for funds from the Timbers Edge Strata Body Committee. The system is now left in pre-commissioning stage, and deemed operational, now just awaits the completion and approval of the RWQMP and results of water quality tests in order for commissioning to go ahead.

6.1. Findings

The aim for this project "to develop the commissioning procedures for the Timbers Edge Greywater Treatment System" has been achieved. All procedures required for the Timbers Edge Greywater Treatment System have been explored and listed for this project to reach commissioning. This is a positive achievement in the right direction, since the project has been abandoned since 2004, meaning that the Timbers Edge Village will be able to make use of their existing greywater treatment infrastructure in the near future.

Below is the list of objectives which have also been achieved throughout the duration of this project:

- All maintenance and operational hazards associated with the system were identified and resolved.
- *Schoenoplectus validus* and *Baumea articulata* are to be used to revegetate the biofilters, a total quantity of 3,647 is to be purchased for the replanting to occur in April-May 2017.
- Ground truthing has been completed; however the ground truth drawing is needed to be completed for the RWQMP.

- The reduced number of biofilters has the capability to treat around 92% of greywater generated at Timbers Edge if the Department of Health's greywater generation standard of 100L/person/day runs true at Timbers Edge.
- The draft RWQMP was unable to be completed in the time frame, however a partial draft has been attached in Appendix F: Draft Recycled Water Quality Management Plan (RWQMP).
- The water quality of the end treated water was unable to be determined during the timeframe of this project. Based on literature reviews, it can be said that the treatment train will provide suitable treatment to the recycled water so that it can be used for subsurface irrigation. A chlorine system has been installed as to ensure that the water quality of the treated water aligns with the requirements set out by the DoH, also to provide operational sustainability.
- A budget was prepared and approved by the Timbers Edge Strata Body Committee (Section 4.4).
- A list of recommendations for proceeding towards the commissioning of this system can be found in the following section.

6.2. Recommendations

The final commissioning works on this system to meet the Department of Health's requirements are not onerous and not expensive, and we therefore recommend proceeding to bring this system online. In order for this to occur the following will need to be completed:

- A completed RWQMP submitted to and approved by the Department of Health.
- Commissioning validation monitoring (over a minimum of 7 weeks) for the Department of Health.
- Regular monitoring of the balance tank, to identify if blackwater is connected to the system, or if the occurrence built up sometime during its abandonment and the commencement of this project.

Warning signs about the non-potable water scheme will need to be put up around Timbers Edge in order to reduce the risk of exposure, including serious accidents, the signs will need to follow the following Australian Standards:

- "AS 1319 – 1994 Safety signs for the occupational environment
- AS 2416 – 2002 Design and application of water safety signs
- AS 1744 – 1975 Forms of letters and numeral for road signs
- AS 2700S – 1996 (R13) colour standards for general purposes – red

- ISO 20712 – 1:2008 Water safety signs and beach safety flags – Part 1: Specifications for water safety signs used in workplaces and public areas." [59]

Please refer to the Department of Health website (www.health.gov.au/) for the complete set of rules and mandatory requirements regarding signage of non-potable water schemes.

6.3. Future Work

In the field of greywater treatment through constructed wetlands, there still lies room for research and future work to increase the knowledge and information about this field. Listed below are some suggestions for future work regarding greywater treatment through constructed wetlands:

- A treatment performance study should be completed on the Timbers Edge Greywater Treatment System and documented so it can be used as a case study for other residential villages considering the switch to recycled water.
- Research and testing into the treatment levels affected by *Schoenoplectus validus* and *Baumea articulate,* as they are the most commonly available plants from nurseries in WA.
- More research should be conducted on the water quality produced from other constructed wetland treatment systems on greywater.
- An improved understanding of the effects of greywater reuse on the environment is required:
    - If any nutrient benefit is provided by using greywater instead of scheme.
    - And how does greywater compare to scheme water for irrigation for the health of the plants it is irrigated with.
- New urban, industrial and agricultural approaches to planning and design, integrated with water and wastewater services should be encouraged.
- Encouragement to increasingly incorporate advancing "fit-for-purpose" recycled water technologies as appropriate and economically viable.
- Policy collaborations for the implementation of alternate water sources between levels of government should be reinforced.

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8. APPENDICES

8.1. Appendix A: Map of Timbers Edge Residential Village

Figure 6. Map of Timbers Edge Residential Village and location of the greywater treatment apparatus.

8.2. Appendix B: Intended Timbers Edge Greywater Treatment System Design by Syrinx

8.3. Appendix C: List of Correspondents involved in the Pre-Commissioning of the Timbers Edge Greywater Treatment System

Below is the list of correspondents associated with the pre-commissioning stages for the Timbers Edge greywater system. Their company, position, contact number, email address and address are all listed below so that if the project is to be taken over at any stages then there would be no issues in understanding who is responsible for what. Tasks involving these contacts are detailed in Section 5.1.

Name	Company	Position	Contact number	Email Address	Address
Melissa Gray	Murdoch University	Honours Thesis Student	0411371671	melissamwgray@gmail.com	24 Pickering Way, Booragoon, WA
Martin Anda	Murdoch University	Academic Chair- Environmental Engineering	0433707196	m.anda@murdoch .edu.au	Science and Computing 3.017, Murdoch University, WA
Stewart Dallas	Josh Byrne & Associates	Manager- Urban Water	0430576200	stewart@joshbyrne.com.au	Suite 10, 16 Phillimore Street, Fremantle, WA
Sam Milani	Advanced Waste Water Systems (AWWS) PTY LTD	Greywater specialist	0405459533	sammilani@awws.com.au	Unit 6, 18 Buckingham Drive, Wangara, WA
Clemencia Rodriguez	Department of Health	Senior Project Officer	(08) 93884910	clemencia.rodriguez@health.wa.gov.au	Grace Vaughan House, 227 Stubbs Tce, Shenton Park, WA

Peter Hill	Origin Projects	Managing Director	0410640457	peter@edgeengineers.com.au	Suite 4, 39 Cedric Street Stirling, WA
Ross Mars	Water Installations Pty Ltd	Wastewater specialist	0439971213	rossmars@waterinstallations.com	Unit 1/18 Wandeara Crescent, Mundaring, WA
Julie Swindlehurst	Weeding Women Mandurah	Franchisees	0488399300	mandurah@weedingwomen.com.au	Support Office: 105/396 Scarborough Beach Rd, Osbourne Park, WA
Tony Freeman	Apace WA: Revegetation specialists	Co-ordinator	(08) 93361262	apace@apacewa.org.au	1 Johannah Street, North Fremantle, WA
Wayne Finigan	Timbers Edge Strata Committee	Sub-committee member	0417462069	wfin4899@bigpond.net.au	49 Wildwood Hill, Dawesville, WA
Russell Garbutt	Timbers Edge Strata Committee	Sub-committee member	0428869228	rgarbutt2@bigpond.com	50 Wildwood Hill, Dawesville, WA
Paul Keeley	Timbers Edge Strata Committee	Sub-committee member	0419196045	no email	51 Wildwood Hill, Dawesville, WA
Doug Cross	Timbers Edge Strata	Chairperson	0413439004	cdtc1942@gmail.com	52 Wildwood

	Committee				Hill, Dawesville, WA
Terry Waldron	Timbers Edge Strata Committee	Assistant Treasurer	0488742957	twaldron54@gmail.com	53 Wildwood Hill, Dawesville, WA
Michael Manson	Timbers Edge Strata Committee	Council Member	0408481911	michaelsuzanne6@bigpond.com	54 Wildwood Hill, Dawesville, WA
Liana Smith	Timbers Edge Strata Committee	Administration Manager	(08) 95821421	timbersedge@bigpond.com	55 Wildwood Hill, Dawesville, WA
Ballantyne Plumbers	Ballantyne Plumbers	Preferred plumber at Timbers Edge	(08) 95354365	works@ballantyneplumbing.com.au	33 Gibla Street, Mandurah, WA

8.4. Appendix D: Plumbers Report on the Integrity of the System

BALLANTYNE PLUMBING, GAS & ELECTRICAL
PEEL SEPTICS

Tel. 08 9535 4365
PO Box 599
Mandurah WA 6210
ABN 36 584 134 397

works@ballantyneplumbing.com.au
ballantyneplumbing.com.au
Licence # PL842 EC7809 T752

CUSTOMER JOB NO. 104042

Site: Timbers Edge
Site Contact: Wayne
Site Phone:

Owners Of Timbers Edge
55 Wildwood Hill
Lot 9000 Fernwood Road
Dawesville WA 6210

Attend site and carry out investigation of operation of GWTS to determine whether system is capable of transfer from grey water collection station through to reticulation holding tank prior to irrigation.

24-10-16 Mario

Meeting with Wayne Finigan (Timbers Edge Representative) to run system operation as follows:

Grey water tank auto operation OK – located at grey water pump station:

- Set grey water to auto – pumped water to lint filters located top of hill – gravity feed into holding tank 2.
- Float in tank 2 pumps into Bio Filter mound which gravity feeds into holding tank 4.
- Float controls in tank 4 activate pump to charge clay filtration mound / bund.
- This gravity feeds into holding tank 6 ready for re-circulation.
- The system although requiring further work transfers as designed.
- Please refer to attached schematic for tank numbering.

Please note:

- Tank number 2 & number 4 will need floats upgraded with connections to be housed above ground.
- As there are no drawings for control circuits cannot assure of any fail safe methods to pause grey water tank pumps when pit 2 is full.
- And fail safe to prevent bore pumps from filling tank 6.
- Also low level pump in tank 6 to stop reticulation pump from starting.
- Please also note. freshwater make up in tank 6 from mains water no Reduced Pressure Zone Device fitted (RPZD) however this has a registered air gap.
- We will have to have this registered with Water Corporation or RPZD fitted prior to commissioning.

End of report.

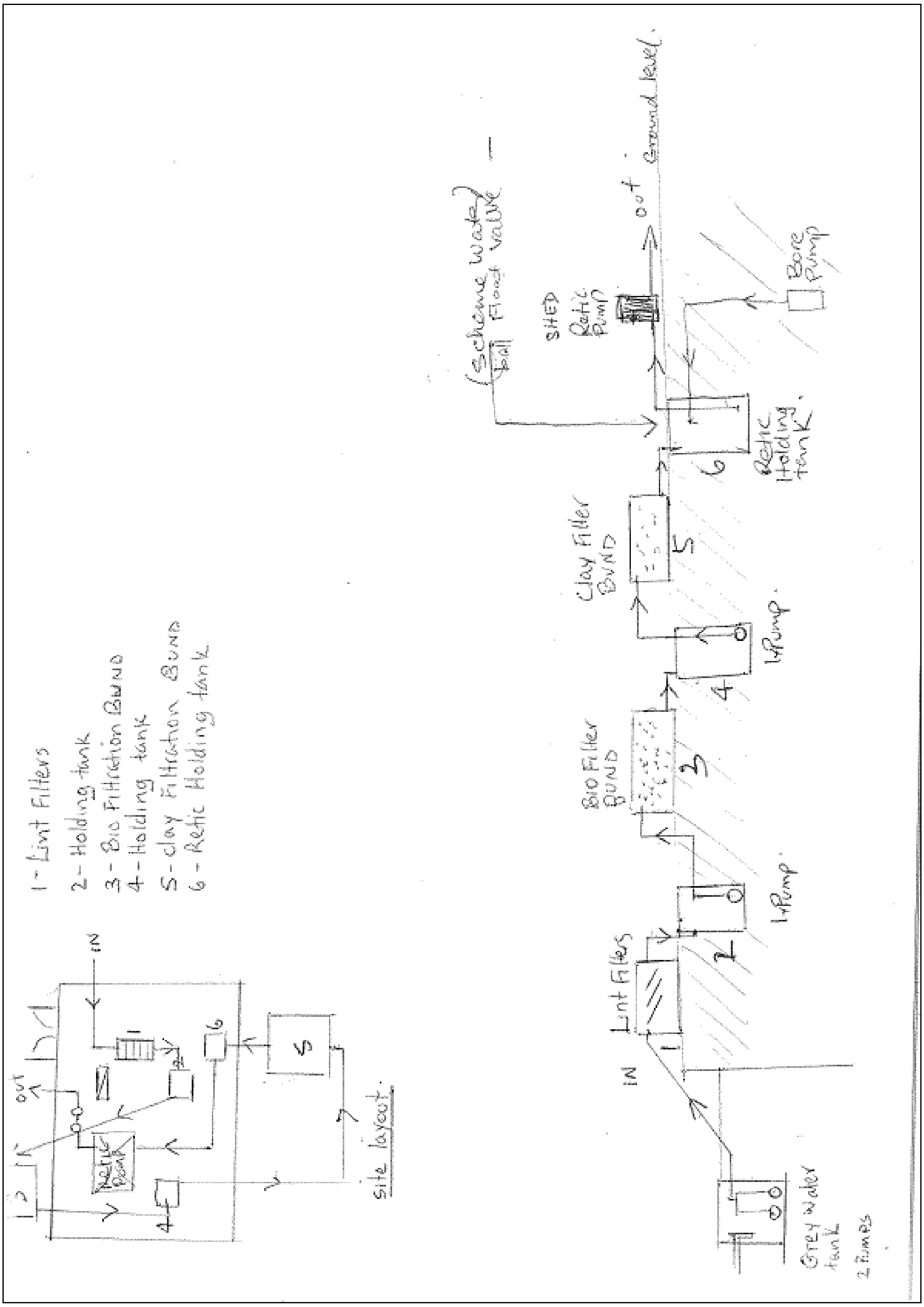
PP - PITS & PUMPS - REPAIR & INSTALL

Sub-Total ex GST	$0.00
GST	$0.00
Total inc GST	$0.00

Sub-Total ex GST	$0.00
GST	$0.00
Total inc GST	$0.00

Page 1/1

8.5. Appendix E: Plumbers schematic of the layout of the Timbers Edge Greywater Treatment System



8.6. Appendix F: Draft Recycled Water Quality Management Plan (RWQMP)

INSERT LOGO IF AVAILABLE

Recycled Water Quality Management Plan (RWQMP)
Timbers Edge Recycling Scheme

Version No: 1

Date: 01/09/2016

This document has been prepared by Melissa Gray. The information contained in this publication is intended for general use of personnel involved in the Timbers Edge Recycling Scheme to assist in the implementation and management of the recycling scheme.

The styles in the template may be altered to suit your organisation's style. While every effort has been made to include all relevant aspects of a RWQMP in this template, recycling schemes may consider adding other relevant information. Other documents the organisation/scheme have that support the RWQMP can be referred, linked or included as an Appendix to this template.

The template has been prepared by The Department of Health, Western Auswtralia (DOHWA) based on the Australian Guidelines for Water Recycling Managing Health and Environmental Risk Phase 1 (2006), the Guidelines for the Use of Recycled Water in Western Australia (2010) and other supporting documentation. Users of the template should review the DOHWA web site for any updates http://www.public.health.wa.gov.au/2/643/2/recycled_water.pm

Development and implementation of RWQMP is regarded as an essential component of assuring recycled water safety and quality. This RWQMP template is designed to be flexible and suitable for application to all recycled water schemes irrespective of size and complexity. The level of detail in the plan needs to reflect the nature of the risk with those of lower risk being simpler and much shorter than those with higher risk.

All recycling schemes need to complete Appendices A to L. Appendices M to Z may need to be included if relevant for your recycling scheme. For example, if the scheme received the recycled water from another recycled water supplier, Appendix O (Operational and Maintenance Manual of the WWTP) is not required while Appendix M (Recycled Water Supply Agreement) is required.

Document History

Issue No (version)	**Original prepared by**	**Issued to (description /section revised)**	**Date**	**Reviewed by**	**Revision Date**	**Approved by**	**Approval Date**
V1	Melissa Gray	incomplete					

This table need to reflect annual reviews and revisions

Foreword

Include:

- **Purpose of the RWQMP**

The Timbers Edge recycled water quality management plan (RWQMP) is a stand-alone document to be used by all parties in the day to day operation and management of the scheme. The purpose of this RWQMP is …

- **Scope of the RWQMP**

This RWQMP provides an overview of how the 12 elements of the risk management framework of the Australian Guidelines for Water Recycling Managing Health and Environmental Risk has been addressed in the **Timbers Edge recycling scheme.**

This management plan is a live document in a process of continual development and review.

- **Structure of the document**

Chapters 1 to 11 of this RWQMP provides the basic information of **Timbers Edge** recycling scheme and the risk management requirements. Additional information is provided in the Appendices

Contents

Foreword 3

Contents 4

1. Introduction 12

1.1 Site description 12

1.2 Existing environment 12

1.3 Scheme overview 12

2. Recycled Water Quality Policy 14

2.1 Policy document 14

2.2 Regulatory and formal requirements 14

2.3 Stakeholder engagement 14

3. Roles and Responsibilities 16

3.1. Supplier 16

3.2 Scheme manager 16

3.3 Users 16

3.4 Duty of care holder 16

3.5 List of contact details 17

4. Assessment of the Recycled Water Scheme 18

4.1 Source water (influent) 18

4.2 Water quality objectives 18

4.3 Health risk assessment 19

4.4 Recycled water storage 19

4.4. Reticulation network (distribution system) and application (receiving environment(s) 20

4.5 Systems operation 20

4.6 Prevention of cross connection with potable supplies 20

5. Treatment Train 21

5.1 Treatment description 21

5.2 The HACCP 22

5.3 Operational monitoring and maintenance 22

5.4 System operators competency 22

5.5 Alarms, critical control points and critical limits 23

5.6 Water supply arrangements 23

6. Monitoring Plan 25
6.1 Validation monitoring 25
6.2 Operational monitoring 25
6.3 Verification monitoring 26
7. Employee Training & Public Education 27
7.1 Employee awareness and involvement 27
7.2 Employee training 27
7.3 Training records 27
7.4 Occupational health and safety procedures 27
7.4.1 Recycled water inductions and hand-over procedures 27
7.4.2 Management measures 27
7.5 Public safety 27
7.5.1 Educational material 28
7.5.2 Management measures 28
8 Incident and Emergency Response 29
8.1 Communication 29
8.2 Incident and emergency response protocols. 29
9 Community Involvement and Consultation 30
9.1 Community consultation 30
9.2 Communication 30
10 Documentation and Reporting 31
10.1 Management of documentation and records 31
10.2 Reporting 31
10.2.1 Internal 31
10.2.2 External 31
10.3 Annual report 31
11 Evaluation and Audit 32
11.1 Long-term evaluation of results 32
11.2 Audit 32
11.2.1 External audit 32
11.2.2 Internal audit 32
References 33
Glossary 35

Appendices 39
Appendix A: Scheme Location 40
Appendix B: Drawing of the Recycled Water Scheme from Source to End-use(s) 41
Appendix C: Water Balance 42
Appendix D: Treatment Plant Process Flow Diagrams 43
Appendix E: Health Risk Assessment 44
1. Hazard identification 44
1.1 Microbial hazards 44
1.2 Chemical hazards 44
1.3 Hazardous events and other hazards 44
2. Dose response 44
3. Exposure assessment 44
3.1 Routes of exposure 44
4. Risk characterisation 44
5. Risk mitigation 47
Appendix F: Validation and Verification Report 48
1. Introduction........ 48
2. Sampling methodology 48
3. Results 48
4. Operational/online data 49
5. Influent flow 49
6. Discussion 49
7. Conclusions 49
8. Copy of original results 49
Appendix G: OHS Procedures and Material Safety Data Sheets 50
Appendix H: Sampling Plan 51
1. Safety procedures 51
2. General rules of sampling 51
3. Sample bottle labelling 51
4. Microbiological collection technique 51
5. Chemical collection technique 51
6. Chlorine residual measurement 51
7. Sample preservation and transportation 51

8. Documentation/records 51
9. Site code number(s) and their map location........ 51
10. List of laboratories 51
Appendix I: Warning Signs 53
Appendix J: Training/ Education 54
1. Operator training manual........ 54
2. Induction program and hand-over procedures 54
3. Training of sub-contractors........ 54
4. Training forms 54
5. Educational material........ 54
Appendix K: Annual Report 55
1. Introduction........ 55
2. Quality of recycled water 56
2.1 Recycled water quality sampling 56
2.2 Analysis of results 56
3. Emergency and Incident Management........ 56
4. Complaints 57
5. Audit 57
Appendix L: Incident Management Plan 59
1. Incident classification 59
2. Notification process 59
3. Emergency communications contact list 59
4. Containment and remediation procedures 60
5. Incident cause and investigation procedures 60
Appendix M: Recycled Water Supply Agreement 61
Appendix N: Operational Monitoring and Critical Control Points 62
Appendix O: Operational and Maintenance Manual of the WWTP 64
1. Overview of treatment process........ 64
2. System Drawings 64
3. Plant Sart-up 64
4. Alarm systems........ 64
5. Sludge Management 64
6. Equipment 64

7. Materials and chemicals 64
8. Troubleshooting Guide 64
9. Plant safety and personal hygiene 65
10. Plant monitoring 65
11. Sample collection 65
12. Maintenance 65
13 Communications protocol for emergency and contingency situations 65
Appendix P: Operational and Maintenance Manual of the Irrigation System 66
1. Map of the pipeline route from WWTP to irrigation sites 66
2. Irrigation map 66
3. Areas of responsibility 66
4. Maintenance of storage tank, reticulation system 66
5. Irrigation compliance 66
6. Warning Protocol 66
7. Contingency/emergency plan 66
Appendix Q: Validation Report of Individual Treatment Components 67
1. System description 67
2. Validation ranges 67
3. Results 67
Appendix R: Mosquito Management Plan 68
1. Introduction 68
2. Mosquito breeding habitats and human risk 68
3. Risk management measures 68
4. Roles and responsibilities 68
Appendix S: Algae Management Plan 69
1. Introduction 69
2. Risk management measures to prevent algae blooms 69
3. Risk management practices in algae blooms 69
4. Incident Response 69
Appendix T: Land Capability Assessment 70
1. Site Characteristics 70
2. Irrigation assessment requirements 70
3. Irrigation areas 70

4. Soils 70
5. Irrigation application rates (L/m^2) 70
Appendix U: Environmental Risk Assessment 71
1. Routes of Exposure and environmental end-points 71
Include: 71
Exposure pathways 71
Receiving environment 71
Environmental end-points (soil, surface water, biota..) 71
2. Environmental risk assessment 71
3. Risk mitigation 71
Appendix V: Environmental Management Plan 72
1. Soils description 72
2. Water resources 72
3. Land management 72
4. Nutrient and irrigation management plan 72
5. Proposed irrigation scheme 72
6. Nutrient application 72
7. Drainage management 72
8. Vegetation in the irrigated area 72
9. Pesticide storage and use 72
10. Sample locations (soil, groundwater, surface water) 72

Appendix W: Odour Management Plan 73
1. Odour assessment 73
2. Odour control measures 73
3. Odour monitoring 73
4. Standard operational procedures 73
5. Contingency plans 73
Appendix X: Noise Management Plan 74
1. Noise assessment 74
2. Noise management 74
3. Noise monitoring 74
4. Standard operational procedures 74

5. Contingency plans 74
Appendix Y: Catchment Characterisation 75
Appendix Z: Audit Report 76
1. Introduction 76
2. Audit Methodology 76
3. Findings 76
4. Discussion 76
5. Recommendations 76

List of Tables

Apply the ‘Table’ style to the table headings in your document and then generate the list (similar to the TOC generation)

Table 1 Summary of the Name-F11 recycling scheme 13
Table 2 Expected/measure water quality parameters of the source water (influent) 18
Table 3 Water quality objectives of the recycled water 19
Table 4 Alarms message, effect on plant and corrective actions 23

List of Figures

Apply the ‘Figure’ style to the figure headings in your document and then generate the list (similar to the TOC generation)

1. Introduction

The proposed treatment system is designed to treat grey water (and some black water) from 210 residential homes at Timbers Edge through biofilter treatment, to provide an irrigation supply for approximately 1.8ha of Public Open Space (POS). This area has a peak irrigation demand of 70kL/day, in accordance with the Water Corporation's "10mm standard drink" (Water Corporation, 2016). Surplus treated grey water will irrigate road reserves within the development, recharging the underlying aquifers, and discharge to the sewer during peak flow events and maintenance periods. During peak flow events, maintenance and shutdown periods, discharge will divert to the sewer. The expected treatment capacity is 48kL/day through all four constructed wetlands/biofilters.

1.1 Site description

The development site is located on the corner of Fernwood and Estuary roads in Dawesville and is in close proximity to the Peel-Harvey estuary system, in the City of Mandurah. The residential development consists of 260 lots, with only 210 built, and infrastructure covering a total area of approximately 18ha. Each home has occupancy of around 2 people per dwelling, meaning a total population of 220 for Timbers Edge.

1.2 Existing environment

Timbers Edge is located less than 1km from Collins Pool, and less than 4km from the Indian Ocean. The area of Dawesville averages a temperature range of 12.4˚C to 23˚C, and a mean annual rainfall of 866.6mm (BOM, 2016). The land use at Timbers Edge is majority residential housing, with less than 10% allocated for public open spaces. The topography of Dawesville ranges from 26m above sea level down to 2m (Topographic-map, 2016). According to the Western Australian Planning Commission Dawesville will not be impacted by a 1 in 100 year flooding event (Commission, 2002).

1.3 Scheme overview

Grey water and some black water (mixed water) from 210 households at Timbers Edge is collected by gravity at the north-eastern corner of the site, as it is the lowest area, where it is then pumped to the treatment system. The treatment system is located along Timbers Edge Road, and comprises of a balance tank, four subsurface flow constructed wetlands, a clarifier tank, a liquid chlorine dosing unit, subsurface irrigation system and a winter excess recharge zone. There are four 22kL tanks which are below ground along with the clarifier tank on the southern corner of Spring Boulevard and Timbers Edge Road, labelled as the irrigation shed. The irrigation shed is within 5m of the water main.

The recycled water is to be used to irrigate the 1.8ha of POS at Timbers Edge, which is made up of 30% lawn area, 60% garden beds, 5% flower beds and 5% trees. Please see Appendix # for the reticulation dripline location.

Table 6 Summary of the Timbers Edge recycling scheme

Scheme Characteristic:	**Description:**
Location	Corner of Fernwood and Estuary roads in Dawesville, Mandurah, WA
Source of recycled water	Household wastewater, with some toilet and kitchen wastewater
Volumes of recycled water to be produced	125kL/day (design figure)
Proposed end uses of the recycled water	Subsurface irrigation of the 1.8ha POS
Percentage of recycled water used in each one of the proposed end uses	100% to be used for subsurface irrigation of POS
Type of treatment system	*Constructed wetland treatment system*
Location of the WWTP	Please see #
Expected flows per day	Minimum: 15kL Average: 48kL Maximum: 70kL
Peak inflow of the plant	48kL/day
Estimated number of people that will benefit/use the recycled water scheme	220
Irrigation area (m^2)	17,000
Risk exposure level	Low risk

2. Recycled Water Quality Policy

2.1 Policy document

Develop a recycled water policy statement, endorsed by senior managers and implemented by the scheme including participant stakeholders. The policy needs to address the commitments of the organisation/scheme manager with the recycling scheme including commitment to high levels of management and monitoring through the life of the scheme as well as allocation of financial and human resources.

2.2 Regulatory and formal requirements

Identify and document all regulatory requirements of the scheme and list of relevant agencies.

This management plan will be submitted to DOHWA for review, as part of the conditions of approval for the **Timbers Edge** recycling scheme.

2.3 Stakeholder engagement

Stakeholder	Position	Responsibilities
Melissa Gray	Murdoch University Environmental Engineering Honours Student	Assisting in the pre-commissioning stages and tests
Martin Anda	Murdoch University Academic Chair-Environmental Engineering	Advisory role in the pre-commissioning stages
Stewart Dallas	Josh Byrne & Associates Manager-Urban Water	Advisory role in the pre-commissioning stages
Sam Milani	Advanced Waste Water Systems PTY Greywater specialist	Advisory role, quote and installation of liquid chlorine dosing system
Clemencia Rodriguez	Department of Health Senior Project Officer	Advisory role in the pre-commissioning stages
Peter Hill	Origin Projects Managing Director	Advisory role in the pre-commissioning stages
Ross Mars	Water Installations Pty Wastewater specialist	Advisory role in the pre-commissioning stages
Julie Swindlehurst	Weeding Women Mandurah Franchisees	Advisory role, assisting in maintenance of the dripline irrigation
Tony Freeman	Apace WA Co-ordinator	Advisory role in the pre-commissioning stages
Doug Cross	Timbers Edge Strata Committee Chairperson	Scheme manager, ensure that the system continues to be maintained and operational
Wayne Finigan	Timbers Edge Strata Committee Sub-committee member	Assisting in the pre-commissioning stages and tests

Russell Garbutt	Timbers Edge Strata Committee Sub-committee member	Assisting in the pre-commissioning stages and tests
Paul Keeley	Timbers Edge Strata Committee Sub-committee member	Assisting in the pre-commissioning stages and tests
Terry Waldron	Timbers Edge Strata Committee Assistant Treasurer	Approval of funds and budgeting of the recycled water scheme
Future Committee members	Future Timbers Edge Strata Committee Council Members	To be accepting of the scheme and also to play a necessary role in selection of washing detergents etc
Liana Smith	Timbers Edge Strata Committee Administration Manager	Administrative role
Ballantyne Plumbers	Preffered plumber at Timbers Edge	Maintenance and upkeep of the plumbing of the system

3. Roles and Responsibilities

Provide details of the responsibilities of each stakeholder involved in the scheme

3.1. Supplier

The supplier of the scheme water is the Water Corporation, and the supplier of the recycled water is the residents of Timbers Edge. The Timbers Edge Strata body will be in charge of ensuring that the production of recycled water is fit for purpose. This can be achieved by educational posters in the strata communal facilities, as well as community meetings to educate the residents prior to the commissioning of the scheme. Since the recycled water is mostly coming from showers, sinks and washing machines the water is already fit for purpose. There is a small portion of black water in the recycled water scheme, due to incorrect installation during the construction of a handful of residential homes in the village.

Refer to Appendix M: Recycled Water Supply Agreement or the MoU between the supplier and the scheme if applicable.

3.2 Scheme manager

Timbers Edge Strata Body.

It will be up to the management body to maintain, monitor and operate the Timbers Edge Water Recycling System by employing either a village maintenance manager or by subcontracting the operating and maintenance to a licensed wastewater service provider.

3.3 Users

The user is the person, organisation or community group that uses the recycled water

Include the planning and implementation of activities conducted by the scheme manager to ensure end users are informed, educated and trained of the "conditions of use" to use the recycled water in a safe manner.

3.4 Duty of care holder

The Duty of Care Holder for the Recycled Water Scheme is: Timbers Edge Strata Body Committee
Name of Company/organisation: Timbers Edge
Address: 55 Wildwood Hill, Dawesville, WA

The contact person for the **Timbers Edge** Recycled Water Scheme is

Name of person: Doug Cross
Position: Timbers Edge Strata Body Chairperson

Phone number on (08): 9582 1421

3.5 List of contact details

Name	Position	Phone
Melissa Gray	Murdoch University Environmental Engineering Honours Student- thesis project	0411371671
Martin Anda	Murdoch University Academic Chair- Environmental Engineering	0433707196
Stewart Dallas	Josh Byrne & Associates Manager- Urban Water	0430576200
Sam Milani	Advanced Waste Water Systems PTY Greywater specialist	0405459533
Clemencia Rodriguez	Department of Health Senior Project Officer	(08) 93884910
Peter Hill	Origin Projects Managing Director	0410640457
Ross Mars	Water Installations Pty Wastewater specialist	0439971213
Julie Swindlehurst	Weeding Women Mandurah Franchisees	0488399300
Tony Freeman	Apace WA Co-ordinator	(08) 93361262
Wayne Finigan	Timbers Edge Strata Committee Sub-committee member	0417462069
Russell Garbutt	Timbers Edge Strata Committee Sub-committee member	0428869228
Paul Keeley	Timbers Edge Strata Committee Sub-committee member	0419196045
Doug Cross	Timbers Edge Strata Committee Chairperson	0413439004
Terry Waldron	Timbers Edge Strata Committee Assistant Treasurer	0488742957
Michael Manson	Timbers Edge Strata Committee Council Member	0408481911
Liana Smith	Timbers Edge Strata Committee Administration Manager	(08) 95821421
Ballantyne Plumbers	Preffered plumber at Timbers Edge	95354365

Refer to Appendix L: Incident Management Plan

4. Assessment of the Recycled Water Scheme

4.1 Source water (influent)

- Water source is from residential and shared facilities at Timbers Edge, which includes majority washing machine water, shower water and sink (excluding kitchen) water. There are a few homes with their black water connected to the system, which means the overall quality of the recycled water will be a mixture of grey and black water.
- The population at Timbers Edge is on average roughly 420 people. If we follow t he Department of Health's estimate of grey water production per person, 120L/person/day, then a total of 50.4kL of grey water is produced per day on average. The treatment capacity of the constructed wetlands is 48kL/day, which means when the treatment system is commissioned on average 2.4kL of greywater will be sent to the sewer per day.
- Unable to provide discharge patterns into the sewers.
- Expected water quality can be seen in Table 2, the results are based off of the literature by Fraser-Williams *et al.* (2008), and has only accounted for grey water.

Table 7 Expected water quality parameters of the source water (influent). Data for high strength grey water has been used, since the grey water at Timbers Edge contains some blackwater (Frazer-Williams, et al., 2008).

Parameter	Units	Value
E Coli	cfu/100 mL	2.8 log_{10}
Coliphage	pfu/100 mL	
Clostridia	cfu/100 mL	3.1 log_{10}
BOD	mg/L	164
SS	mg/L	93
pH	pH units	6-8
Turbidity	NTU	67.4
TN	mg/L	12.3
TP	mg/L	8

4.2 Water quality objectives

Chemicals are not generally considered to be a human health risk where wastewater is derived predominantly from domestic catchments, and recycled water is used for non-drinking purposes.

Industrial recycling schemes or other schemes in which chemical inputs from the catchments are considered to be significant, require the identification of specific chemical water quality objectives through risk assessment.

Describe the expected recycled water quality after the treatment.

Include indicative log reductions from treatment

Table 8 Water quality objectives of the recycled water (Gross, Maimon, Alfiya, & Friedler, Comparing Technologies, 2015)

Parameter	Units	Value
E Coli	cfu/100 mL	<1000*
Coliphage	pfu/100 mL	
Clostridia	cfu/100 mL	
BOD	mg/L	53
SS	mg/L	30*
pH	pH units	6.5-8.5*
Turbidity	NTU	58
TP	mg/L	1.6
TN	mg/L	5.6

*= Guidelines followed from the Department of Health (Department of Health, 2011)

4.3 Health risk assessment

Health risk assessment is used to identify the most serious threats of recycled water based on likelihood of occurrence and severity of consequences. Health risk assessment evaluates the hazards and events that can compromise recycled water quality and safety.

Include a summary of

- *Hazards*
- *Risks identified (including risks associated with unintended uses e.g. cross connections)*
- *Management priority (High, Medium, Low)*
- *Existing preventative measures*
- *Additional controls required to minimise risk*

Detailed HRA is presented in Appendix E: Health Risk Assessment.

4.4 Recycled water storage

Include:

- *Details and capacity of storage tank*
- *Security (accessibility to public)*
- *Turnover time*
- *Properly sealed? (accessibility to animals/insects)*

- *Maintenance*
- *Structure soundness (Australian Standards compliance)*

Refer to Appendix B: Drawings of the Recycled Water Scheme from Source to End-uses; Appendix D: Treatment Plant Process Flow Diagram, and/or Appendix N: Operational Monitoring and Critical Control Points

4.4. Reticulation network (distribution system) and application (receiving environment(s)

Map out the zones of the recycled water system.

Refer to Appendix D: Treatment Plant Process Flow Diagram, and/or Appendix; Appendix V Environmental Management Plan and/or Appendix P: Operational and Maintenance Manual of the Irrigation System.

4.5 Systems operation

Describe briefly the systems operation from source to distribution.

4.6 Prevention of cross connection with potable supplies

Describe measures in place to minimise risk of cross-connection of the recycling scheme with potable water

Refer to Appendix E: Health Risk Assessment, Appendix L: Incident Management Plan and/or Appendix N: Operational Monitoring and Critical Control Points

5. Treatment Train

5.1 Treatment description

The mixed water is first pumped to the Balance Tank, located at the northern end of the southern bund. The closed tank reduces the velocity and turbulence of the pumped mixed water and provides storage, from which a constant feed can be drawn to the Reactivator Clarifier. The Balance Tank has a sewer connection for discharge of settled material (as required) and for emergency overflows (bypass). The closed tank eliminates mosquito breeding opportunity. From the Balance Tank mixed water is pumped to the Reactivator Clarifier through feed piping. Clarifier sludge is to be discharged to the sewer to maintain a closed system. If sewer discharge is not permitted, sludge filtration may be required to reduce water content. The sludge waste may then be used as compost or disposed as solid waste. There are no issues envisaged with using the dried sludge as compost.

Pre-Treatment Clarifier effluent discharges to a pump sump via gravity feed, where it is to be pulse fed to the Biofilters via a $10m^3$/hr pump with an emergency overflow discharging to the sewer.

The Biofilters receive effluent water from the Pre-Treatment Clarifier system in $10m^3$/hr pulses (divided between the six cells over a 24 hour period). Unpublished data collected by Syrinx Environmental indicates that Biofilters provide improved removal if they are pulse fed in such a wat, as the system has more time to remove contaminants than if it were continuously loaded.

Biofilter Cells are subsurface flow systems with a total area of approximately $1,100m^2$ (at top water level), with depths varying from 0.5m to 0.6m (a mean depth of 0.55m) and an average porosity of 43.5%, which provides an active treatment volume of

- *Provide details of the treatment steps that will be used to treat the source water.*
- *Discuss the validation of treatment efficacy to remove contaminants from source water.*
- *Include details of alternative treatment systems that will be used in an event of treatment system failure.*

As detailed in Appendix D, Greywater is collected in the north-eastern corner of the site (lowest area of the site) and pumped to the treatment system. The Greywater treatment system consists of a two-stage process, which utilizes the following components:

Stage 1 Pre-treatment

- Balance Tank;
- Reactivator Clarifier; and
- Pump and sump, to discharge Clarifier effluent to the Biofilters.

Stage 2 Biofilter and Irrigation Collection Tank

- Subsurface Biofilter Cells;
- Chlorine dosing; and
- Irrigation Collection Tank

Once Greywater has been treated to the required concentrations (see Table X) it is utilized to irrigate POS areas on site throughout the year with excess flow irrigated to road reserves or discharge to the sewer.

Refer to Appendix D: Treatment Plant Process Flow Diagrams

5.2 The HACCP

A preventive risk management system such as Hazard Analysis and Critical Control Point (HACCP) shall be used for assessing risks and managing risk. The purpose of the HACCP is to identify all hazards in the treatment process that could cause the final product to be out of specification, such that it could cause illness or injury.

Refer to Appendix N: Operational Monitoring and Critical Control Points

5.3 Operational monitoring and maintenance

Include details on the operational monitoring and maintenance of all the major apparatus within the recycled water system including:

- *Availability of operational monitoring and maintenance manual / procedures / checklists;*
- *Personnel in-charge of operational monitoring and maintenance; and*
- *Operational monitoring and maintenance frequencies.*

Refer to Appendix N: Operational Monitoring and Critical Control Points

5.4 System operators competency

Provide details on the competency of personnel that will operate the system

5.5 Alarms, critical control points and critical limits

Include a summary of:

Identified critical control points (CCPs)
Critical limits and corrective actions
Describe the modes of plant operation

- *Automatic*
- *Manual*
- *Star up and shut down procedures*

The operation of shutdown systems must be fully tested at commissioning and the outcome of these tests recorded.

Real-time monitoring linked to an appropriate alarm monitoring system and automatic shut-down is required for all critical control points and must be available at all times. List all measures in place to minimise the risk of cross-connection with drinking water

Table 9 Alarms message, effect on plant and corrective actions

Alarm message	Affected components	Effect on plant	Corrective actions
Low Effluent Chlorine*	Sampling pump, pH/Cl analyser, NaOCl dosing	Effluent is out of specification, reuse will be suspended until cause is identified, rectified and alarm is reset	Check NaOCl tank level, verify dosing pump is running, confirm analyser is reading correctly
CCP1			
CCP2			

Low Effluent Chlorine* provided as an example only

Refer to Appendix N: Operational Monitoring and Critical Control Points and Appendix O: Operational and Maintenance Manual of the WWTP

5.6 Water supply arrangements

If a recycled water provider supplies recycled water to another recycled water provider, the description of infrastructure/delivery scheme can cease at the point where the water enters the other provider's infrastructure.

- Details about the quality of water being provided, or to be provided.
- Details on the volume of recycled water being supplied for each of the uses per year.

Include contract/agreement in Appendix M: Recycled Water Supply Agreement if applicable

6. Monitoring Plan

Monitoring will be undertaken as a two phase approach based on the AGWR as follows:

6.1 Validation monitoring

Validation is a critical component of treatment process management because it ensures that the required water quality objectives will be achieved.

Refer to section 6.5 Table 6.1 "Verification and Validation Monitoring Requirements" of the Guidelines for the Use of Recycled Water in WA (2010) for the validation monitoring requirements based on risk exposure level.

Include pathogen removal validation data from the manufacturer for individual processes, within the treatment train in Appendix Q: Validation Report of Individual Treatment Components

Validation monitoring will be undertaken during commissioning of the treatment plant in accordance with the Guidelines for the Use of Recycled Water in WA (2010). Before the scheme is approved, a validation and verification report of the treatment system needs to be reviewed by DOHWA.

Refer to Appendix F: Validation and Verification Report.

6.2 Operational monitoring

Operational monitoring refers to the parameters monitored at each CCP to demonstrate the treatment plant is operating correctly. Each operational parameter has critical limits and alert limits that are established during the validation monitoring. Corrective actions that need to be taken if a critical limit is breached need to be included.

The procedures for operational monitoring shall include:

- *What is being monitored*
- *How the monitoring is done*
- *When the monitoring is done*
- *Where the monitoring is done*
- *Who is responsible for ensuring it is completed*
- *The critical limits, alert levels an corrective actions*

Detail information is included in Appendix N: Operational Monitoring and Critical Control Points

6.3 Verification monitoring

Verification monitoring assesses the overall performance of the system and compliance with the overall water quality objectives. It is independent of the routine operational monitoring of the system and it is used to confirm product water quality objectives.

Testing need to be conducted by a laboratory that is National Association of Testing Authorities (NATA) accredited laboratory.

Refer to section 6.5 Table 6.2 "Operational Monitoring Requirements" of the Guidelines for the Use of Recycled Water in WA (2010) for the operational monitoring requirements based on risk exposure level.

For details refer to Appendix F: Validation and Verification Report and Appendix H: Sampling Plan.

7. Employee Training & Public Education

7.1 Employee awareness and involvement

Employees including plant operators and contractors shall have a sound knowledge base from which to make effective operational decisions. This requires training in the methods and skills required to perform their tasks efficiently and competently. Employees need to be aware of the potential consequences of system failures, and of how their decisions can affect the safety of the scheme.

Provide details on the suitability of the operators' and contractors' qualifications, training and experience.

7.2 Employee training

Detail employee training needs, programs and frequency.

7.3 Training records

Training records need to include the following information:

- *Names of attendees*
- *Signature of attendees*
- *Signature of trainer*

Refer to Appendix J: Training and Education

7.4 Occupational health and safety procedures

Include:

7.4.1 Recycled water inductions and hand-over procedures

7.4.2 Management measures

- Chemical storage and handling
- Hygiene practices in the workplace
- PPE

Refer to Appendix G: OHS Procedures

7.5 Public safety

Provide copies of the information to be given to recycled water users to promote awareness of recycled water quality issues, allowable uses, responsibilities and the impacts of unauthorised uses.

7.5.1 Educational material

Refer to Appendix I: Warning Signs

7.5.2 Management measures

8 Incident and Emergency Response

The recycling scheme shall include all possible incidences that will affect the water quality or any aspect of the recycled scheme. Include details of:

- *Incident giving rise to hazard;*
- *Possible causes;*
- *Consequences;*
- *Risk (Likelihood and consequence);*
- *Response action and Personnel in-charge;*
- *Reporting protocols; and*
- *Preventative measures.*
- *Who is responsible for reporting incidents to DOHWA*

Incidents and accidents provides a useful occasion to monitor and review risk and treatments and to gain insight on how the risk management process can be improved. Questions to be answered include:

- Did we previously identify and analyse the risk involved?
- Did we identify the actual causes in risk identification?
- Did we rate and assess risks and controls correctly?
- Did the control operate as intended?
- Were the treatment plans effective? If not, where could improvements be made?
- How our risk management in general be improved?
- Who needs to know about this leanings and how should be disseminate?
- What do we need to do to ensure that failure events are not repeated but that successes are?

8.1 Communication

8.2 Incident and emergency response protocols.

Detail incident and emergency protocols specific to the production and supply of recycled water including response actions, roles and responsibilities and communication arrangements.

Detail the arrangements and procedures for notification of incidents

The following must be immediately notified to DOHWA, Water Unit (Telephone 9388 4999)

- A system failure that may potentially impact on the users of the recycled water.
- An emergency or incident that potentially places public health at risk.
- Any changes to the RWQMP or operation of the treatment process that may potentially impact achieving the required water quality objectives

Refer to Appendix L: Incident Management Plan

9 Community Involvement and Consultation

9.1 Community consultation

Describe any community consultation process conducted

9.2 Communication

Describe how responsibilities will be understood and communicated to all stakeholders

10 Documentation and Reporting

10.1 Management of documentation and records

Document control procedure shall be implemented to ensure that all copies of documents referenced in the RWQMP are current and controlled. Include who is responsible for keeping the records and preparing the annual report.

Detail how documents will be managed

Records shall be kept for:

- Treatment plant monitoring results and analyses
- Breaches of critical limits and corrective actions taken
- Verification monitoring
- Incidents and emergencies and corrective actions taken
- Inspection and maintenance activities relevant to water quality
- Training activities
- Compliance records

10.2 Reporting

10.2.1 Internal

10.2.1.1 Incident report

All employees and contractors shall record the initial incident information including:

- Date, time, location and nature of the incident.
- Persons injured, equipment damaged or environment impacted.
- Nature of injury or damage and estimate of severity.
- Immediate corrective action being taken.
- Assistance required.
- Activity in progress at the time.

10.2.2 External

10.3 Annual report

The scheme needs to submit the annual report by 30 September each year to DOHWA. The report corresponds to the immediately preceding financial year and contains the detailed information in Appendix K: Annual Report. The report should be publicly available on the web site and available free of charge to the scheme users.

11 Evaluation and Audit

- Detail the process for reviewing and updating the RWQMP
- Describe the audit process, scope and frequency specifically relating to auditing for compliance of the system with the RWQMP, DOHWA conditions of approval and the AGWR.
- Describe the method of report

11.1 Long-term evaluation of results

11.2 Audit

Audit results shall be made available to DOHWA on request.

11.2.1 External audit

11.2.2 Internal audit

References

Australian and New Zealand Standard AS/NZS 3500:2003, Plumbing and Drainage

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Glossary

Term/Abbreviation	Definition/Description
Activated Sludge	An activated mass of micro-organisms capable of stabilising waste aerobically – a “biomass”.
AGWR (2006)	Australian Guidelines for Water Recycling: Managing Health and Environmental Risk (Phase 1)
Alert limit	Is the early warning that process is becoming unstable. May indicate the possibility of exceeding a regulatory requirement or a critical limit for a CCP
AS/NZS	Australian Standards/New Zealand Standards
BOD	Biological oxygen demand
CCP	Critical control point. CCPs are activities, procedures or processes where a control can be applied and that is essential for preventing, eliminating or managing a hazard to an acceptable level.
cfu	Coliform forming units
COD	Chemical oxygen demand
Commissioning verification	A validation monitoring conducted to the treated water to prove that the expected water quality is being constantly produced by the commissioned treatment plant
Critical limit	A prescribed tolerance that must be met to ensure that a critical control point effectively controls a potential health hazard; a criterion that separated acceptability from unacceptability.
Ct	The production of disinfectant concentration (C in mg/L) and contact time (t in minutes), used in disinfection
DO	Dissolved oxygen
E Coli	Escherichia coli. The most common thermotolerant coliform present in faeces and used as indicator of faecal contamination
Exceedance	Water quality that goes outside identified limits. This limits may include alert levels, critical limits or water quality objectives
g	gram
GL	gigalitre
HACCP	Hazard analysis and critical control points
Hazard	A biological, chemical, physical or radiological agent that has the potential to cause harm
Hazardous event	An incident or situation that can lead to the presence of a hazard, or often directly contains a hazard
kL	Kilolitre
L	Litre
Log reduction	Used in reference to the physical-chemical treatment of water to remove, kill or inactivate microorganisms such as bacteria, protozoa and viruses (1-log removal = 90% reduction in density of the target organism, 2-log removal = 99% reduction, 3-log removal = 99.9% reduction, etc).
MBR	Membrane bioreactor
mg/L	Milligrams per litre
ML	Megalitre
MoU	Memorandum of understanding
NATA	National Association of Testing Authorities

NTU	Nephelometric turbidity unit
Operational monitoring	The routine monitoring of control parameters that confirm the treatment process are under control and operating within the operating criteria
PCT	Process control table
PLC	Programmable logic controller
Point of supply	The physical point of transfer to the user
PPE	Personal protective equipment
Public open space	Any open space, such as parks, sporting fields, racecourses, school ovals, municipal parks and gardens, golf courses, footpaths, car parks, road verges, where either members of the public, staff or employees may be exposed to recycled water. It does not include gardens in domestic residences nor agricultural farmland
QA/QC	Quality assurance/quality control
Recycled water provider	An entity that owns infrastructure for the production and supply of recycled water
Residual risk	The risk remaining after consideration of existing preventive measures
Risk	The likelihood of a hazard causing harm in exposed populations in a specified time frame, including the magnitude of that harm.
RWQMP	Recycled water quality management plan
SBR	Sequential batch reactor
SCADA	Supervisory control and data acquisition
Scheme	Refers to a recycled water scheme
Sewage	Household and commercial wastewater that contains or may contain faecal, urinary or any other human waste
Sewerage	A sewer, access chamber, vent, engine, pump, structure, machinery, outfall or other work used to receive, store, transport or treat sewage
Sludge	The constituents removed from wastewater treatment plants include screenings, grit, scum and sludge. Sludge is usually in the form of a liquid or semisolid liquid that typically contains from 0.25 to 12% solids by weight.
SS	Suspended solids
Target limit	Refers to the normal operational value(or value range) for a process which indicates that the process is stable
TN	Total nitrogen
TP	Total phosphorous
Treatment Validation	A documented program about how the plant or equipment used for the treatment of recycled water are to be tested to demonstrate the quality f the recycled water consistency meets the water quality objectives for the intended end use. Treatment validation includes the operational criteria to ensure capability to effectively control hazards
TSS	Total suspended solids
UV	Ultraviolet
Violation limit	Critical limit is the operational value or performance criteria (that has been violated) which separates acceptable from unacceptable in terms of hazard control and recycled water safety. Corrective actions need to be implemented immediately to regain process control

WWTP	wastewater treatment plant

Appendices

Required for all Projects

Appendix A: Scheme Location
Appendix B: Drawing of the Recycled Water Scheme from Source to End-use(s)
Appendix C: Water Balance
Appendix D: Treatment Plant Process Flow Diagrams
Appendix E: Health Risk Assessment
Appendix F: Validation and Verification Report
Appendix G: OHS Procedures and Material Safety Data Sheets
Appendix H: Sampling Program
Appendix I: Warning Signs
Appendix J: Training and Education
Appendix K: Annual Report

Required on a case by case basis

Appendix P: Recycled Water Supply Agreement
Appendix Q: Operational Monitoring and Critical Control Points
Appendix R: Operational and Maintenance Manual of the WWTP
Appendix S: Operational and Maintenance Manual of the Irrigation System
Appendix T: Validation Report of Individual Treatment Train
Appendix U: Incident Management Plan
Appendix V: Mosquito Management Procedure
Appendix W: Land Capability Assessment
Appendix X: Environmental Assessment
Appendix Y: Environmental Management Plan
Appendix Z: Catchment Characterisation

Appendix A: Scheme Location

Include

- Location map
- Site photographs

Appendix B: Drawing of the Recycled Water Scheme from Source to End-use(s)

Include a schematic overview of the recycling scheme with:

- Location of source water
- Location of treatment plat
- Storages pipeline route(s) and
- End uses

Appendix C: Water Balance

Include:

- Assumed scheme occupancy patter
- Volumes of wastewater produced by person and in total per day
- Recycled water demand (e.g. irrigation demands, maximum design irrigation rate)
- Climate data
- Stormwater

Table Scheme water balance in (ML)

	Jan	Feb	Mar	Apr	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Scheme Inputs												
Rainfall												
Potable water supply												
Groundwater abstraction												
Other												
Total inputs												
Scheme Outputs												
End-use 1												
End use 2												
Stormwater system												
Sewer System												
Other												
Total outputs												

Appendix D: Treatment Plant Process Flow Diagrams

Include:

- A site plan showing the general arrangement of the treatment facility
- A process flow diagram, and
- A process instrumentation diagram.
- Location of critical control points
- Capacity of tanks

Appendix E: Health Risk Assessment

1. Hazard identification

Sources of potential hazards shall be identified

1.1 Microbial hazards

1.2 Chemical hazards

1.3 Hazardous events and other hazards

Potential hazardous events shall be identified and listed at each step in the process flow.

Include the unauthorised or incorrect use of the recycled water and the onsite controls that need to be implemented to minimise the risk.

2. Dose response

3. Exposure assessment

3.1 Routes of exposure

3.1.1 Dermal

3.1.2 Direct ingestion

3.1.3 Inhalation

4. Risk characterisation

Risk characterisation integrates the information gathered in the hazard identification, dose response and exposure assessment.

When assessing the risk consider:

- The number of people exposed
- How often they are exposed
- How long they are exposed for
- Any combination of hazards
- The seriousness or severity of any consequence

Table 1 Qualitative measures of health consequences

Category	Acute health consequences (per hazard or outbreak)	Chronic health effect requiring:

Catastrophic 1	Health: Major impact for a large population >1 fatality or Major impact for a large population OR >5 permanent disabilities OR Non-permanent injuries requiring hospitalisation for 5-10% of population at risk OR Acute health effect requiring hospitalisation for >5-10% of population at risk Environment: Potentially lethal to regional ecosystem or threatened species; widespread on-site and off-site impacts	Medical treatment for 10-15% of population at-risk*
Major 2	Health: Major impact for a small population No fatality AND (1 permanent disability OR Non-permanent injuries requiring hospitalisation for >1-5% of population at risk OR Acute health effect requiring hospitalisation for >1-5% of population at risk OR Evacuation is necessary Environment: Potentially lethal to local ecosystem; predominantly local, but potential for off-site impacts.	Medical treatment for 2-10% of population at-risk*
Moderate 3	Health: Minor impact for large population No fatality AND No permanent disability AND (Non-permanent injuries requiring hospitalisation for 1-2% of population at risk OR Acute health effect requiring hospitalisation for 1-2% of population at risk AND No evacuation Environment: Potentially harmful to regional ecosystem with local impacts primary contained to on-site.	Medical treatment for 1-2% of population at-risk*
Minor 4	Health: Minor impact for small population No fatality AND No permanent disability AND (Non-permanent injuries requiring hospitalisation for 1-5 persons OR no acute health effect requiring hospitalisation) AND No evacuation Environment: Potentially harmful to local ecosystem with local impacts contained to on-site.	Medical treatment for about 0-1% of population at-risk*
Insignificant 5	Insignificant impact or not detectable	No chronic health effect

*Estimated average size of population at-risk across project lifecycle

Table 2 Qualitative measures of likelihood

Level	Likelihood descriptor	Frequency of incident or outbreak with non-chronic health effect	% Chance of chronic health effect during life of project
1	**Rare/remote**	Once in more than 100 years May happen only in exceptional circumstances	Up to 5%
2	**Unlikely**	Could occur within 20 years May happen in unusual circumstances	6 - 30%
3	**Possible/ occasionally**	Once in 5 – 10 years May happen	31% - 60%
4	**Likely**	Once in 1 to 5 years May easily happen	61% - 90%
5	**Almost certain**	More than once a year Expected to happen many times within a year	Over 90%

Table 3 Qualitative risk estimation

Likelihood	Consequences				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain	Low	Moderate	High	Very High	Very High
Likely	Low	Moderate	High	Very High	Very High
Possible	Low	Moderate	High	Very High	Very High
Unlikely	Low	Low	Moderate	High	Very High
Rare/remote	Low	Low	Low	High	High

5. Risk mitigation

The final output from Appendix E (Health Risk Assessment) will produce a ranked table with all hazards and hazardous events. Risk mitigation table include the control measures that need to be implemented to minimise risk to an acceptable level.

Complete the table based on the health risk assessment

Include actions related to wastewater catchment management

Table 4 Risk characterisation and mitigation

Hazard	Likelihood	Consequence	Qualitative risk	Mitigation (existing/proposed controls)
** Mosquito breeding in storage tanks (e.g.)*	*Unlikely*	*Major*	*High*	• *Ensure sealed lids* • *Chemical treatment of active mosquito populations* • *Education on Mosquito Borne diseases* • *Mosquito management manual*

*Mosquito breeding given as an example

Appendix F: Validation and Verification Report

1. Introduction

This report documents the testing of the microbiological removal and the effluent water quality of the Name-F11 recycling scheme.

The treatment plant comprises the following processes:

List

- 1
- 2
- 3
- 4

2. Sampling methodology

Include:

- The parameters tested
- The frequency of testing
- The sampling location(s)
- Quality assurance/Quality control (QA/QC)

3. Results

Include:

- A summary of test results for the commissioning verification
- A summary of any water quality exceedances (if they occur), the circumstances that led to them occurring and any corrective/preventive actions taken or put in place
- A statistical analysis of the data collected to determine the confidence level for meeting the water quality objectives on a continuous basis.

Table 1 Summary of test results

Date	Report No	Lab	Parameter	Units	Effluent Compliance value	Sampling Point	Result	Comments

4. Operational/online data

Table 2 Summary of operational data results

Date	Parameter	Units	Sampling Point	Result (Daily average)

5. Influent flow

6. Discussion

7. Conclusions

8. Copy of original results

Appendix G: OHS Procedures and Material Safety Data Sheets

Include material safety data sheets of all chemicals used in the treatment plant and the end uses (e.g. irrigation system)

Appendix H: Sampling Plan

1. Safety procedures

2. General rules of sampling

3. Sample bottle labelling

4. Microbiological collection technique

- Equipment required
- Preparation
- Procedure

5. Chemical collection technique

- Equipment required
- Preparation
- Procedure

6. Chlorine residual measurement

- Equipment required
- Preparation
- Procedure

7. Sample preservation and transportation

8. Documentation/records

9. Site code number(s) and their map location

10. List of laboratories

Laboratory Name	
Contact Person:	
Position:	
Business Address:	
Phone:	
Fax:	
E-Mail:	
Laboratory Name	
Contact Person:	
Position:	
Business Address:	
Phone:	
Fax:	
E-Mail:	

Include the Sampling Technique Factsheet from DOHWA.

Appendix I: Warning Signs

Include photos of the scheme showing the location of the scheme warning signs

Include the Warning Signs Factsheet from DOHWA

Appendix J: Training/ Education

1. Operator training manual

Include training manual for WWTP operators

2. Induction program and hand-over procedures

3. Training of sub-contractors

4. Training forms

e.g. Training declaration form, list of training attendance form

5. Educational material

Appendix K: Annual Report

Define the financial year of the report (e.g. 2010 – 2011). Include more than one of each one of the tables below if more than one WWTP or different end-uses apply for the recycling scheme.

1. Introduction

Include an overview of the project and complete the table below

Table 1 Summary of the Name-F11 recycling scheme

Name of Scheme	
Approval Number	
Date of Approval	
Local Government	
Address of Scheme Owner	
Scheme Information	
Location	
Source of recycled water	
Volumes of recycled water produced per year	
End uses of the recycled water	
% of recycled water used in each one of the proposed end uses	
Type of treatment system	
Location of the WWTP	
Minimum, average and maximum flows per day	
Peak inflow of the plant	
Number of people using the recycled water	
Irrigation area in m^2	
Risk exposure level	

2. Quality of recycled water

2.1 Recycled water quality sampling

Include:

- Locations and dates of recycled water quality sampling
- A tabulated presentation of laboratory recycled water quality test results.
- An assessment of recycled water quality compliance with the Guidelines for the use of Recycled Water in WA values

Table 2 Summary of laboratory recycled water quality results

Location (site code)	Parameter	Units	Frequency of sampling (e.g weekly, monthly)	Total No of samples	Min	Max	Mean	Median	Complying (Yes/No)

2.2 Analysis of results

Include:

- Performance comparison against guidelines
- Comparison against previous years data

3. Emergency and Incident Management

A summary of events and issues that affected recycled water quality and/or caused a non-compliance with the guideline values. Include details of corrective actions/response procedures.

Include:

- Power failure
- Mechanical failure
- Excess wastewater produced (sewerage overflow)
- Effluent quality failure

- Chemical spills
- Major infrastructure failure or disruption
- Failure in the recycling pipework or end uses of the recycled water

Major Infrastructure Works Carried Out

Include days of the year the WWTP was no operational and the reasons for that

4. Complaints

Include a summary of public/staff complaints regarding recycled water quality.

All complaints records shall be registered immediately with the following details:

- Name, contact, location and general nature of complaint;
- Proposed steps to investigate complainants requests made;
- Method of notification by complainant;
- Regulatory authority notified (if applicable);

Table 3 Summary of complaints relating to recycled water Quality

Type/nature of the complaint	Location	Actions to investigate/correct	Notification to DoH (if applicable)
(e.g. odour/suspected illness/ ponding)			

5. Audit

Include details of proposed improvements to the recycling scheme based on internal/external audit that will strengthen the scheme's ability to supply safe recycled water for the intended end-use(s)

Table F.4 Response to audit report

Auditor/ reviewer comment (System deficiency and non-compliances)	Scheme response	Corrective actions to prevent reoccurrence	Timetable for corrective/preventive action	Person(s) responsible	Completion Date
(e.g. odour/suspected illness/ ponding)					

The report must be signed by the chief executive officer or general manager of the water authority.

Appendix L: Incident Management Plan

Notification procedures and adequate contingency provisions to address unforeseen events which may lead to health or environmental harm or nuisance, including

Wastewater/ recycled water overflow

Failure or breakdown of wastewater pumps, pipes or equipment

- Power failure or interruption
- Natural events such as floods and fires, cyclones or heavy storms
- Discharge of hazardous substances to the wastewater stream
- Malicious actions and vandalism

The purpose of this document is to overview the incident management process for the Name-F11 recycling scheme. The document outlines the process of managing incidents as part of compliance management.

1. Incident classification

Minor incident/ significant incident/ major incident

2. Notification process

Include how notification of incidents will be made

This procedure is most effectively presented using a flow diagram and should include:

- The scheme's internal protocol for reporting an incident to responsible staff (including main and back-up staff names, titles and phone numbers)
- the protocol (including phone numbers) for reporting to relevant emergency authorities, eg Department of Environment and Conservation, Swan River Trust, Fire and Emergency Service (FESA), Department of Health (DH), local government, etc.

3. Emergency communications contact list

Environmental incidents must be reported using the Emergency Pollution Response line 1300 784 782 or to EPA: 1800 100 833.

Incident reporting sheets need to include the following details:

- location of the incident
- time and date of the incident
- nature of the release (estimated quantity, quantity and receiving environment)
- licensee's name if applicable

- name and telephone number of contact person.

Name:	
Position:	
Business Address:	
Phone:	
Mobile Phone:	
Fax:	
E-Mail:	
Name:	
Position:	
Business Address:	
Phone:	
Mobile Phone:	
Fax:	
E-Mail:	
Name:	
Position:	
Business Address:	
Phone:	
Mobile Phone:	
Fax:	
E-Mail:	

4. Containment and remediation procedures

5. Incident cause and investigation procedures

Appendix M: Recycled Water Supply Agreement

Include the agreement, contract or MoU between the Recycled Water Supplier and the Water Recycling Scheme Manager

The document shall include:

- Details about the quality of water being provided, or to be provided.
- Details on the volume of recycled water being supplied for each of the uses per year.
- The commitment for continuous supply for essential services and contingencies for supply

Appendix N: Operational Monitoring and Critical Control Points

Operational monitoring is the routine, often continuous (on-line), monitoring of Critical Control Points and Process Control Points in the WWTP to ensure compliance within the defined operational criteria. It is used to determine if each preventative measure is effectively controlling hazards, and provides an advance warning if treatment barriers are moving away from a stable operational state.

CCP require operational parameters that can be measured and for which critical limits can be set to define the operational effectiveness of the activity. The operational parameters need to be monitored sufficiently frequently to reveal any failures in a timely manner. CCP also have process for corrective actions that can be implemented in response to deviations from critical limits and alert levels. Alert levels are more conservative than critical limits and represent an early warning so that corrective actions can be implemented before a critical limit is exceeded.

- *Identify operational procedures required for all key processes and activities applying to the recycled water system.*
- *Describe how operational performance of the recycled water system will be ensured.*
- *Provide specific reference to CCPs and their mechanisms for operational control.*
- *Include statements on the capability and reliability of this equipment*
- *Provide copies of preliminary operating procedures relating to all key processes and activities (including all CCPs) in a preliminary operations manual. These must include the critical limits, corrective actions and detail when the system can be brought back online after a shut-down.*
- *Describe use of alarm systems where applicable.*
- *Provide links to monitoring protocols, including sampling, testing, auditing and equipment calibration.*
- *Provide a table listing corrective actions for non-compliance of all key operational parameters (specifically CCPs), e.g. disposal of non-compliant water if key processes fail.*

Table P.1 Operational Monitoring Parameters

Critical Control Point	Hazard removed by CCP	Parameter monitored	Rationale	Monitoring Type/ Frequency	Target range	Target Limit	Critical Limit (Violation)	Corrective Actions
*Membrane filtration**	*Particulates, pathogens*	*Turbidity*	*Monitoring the MF filtrate turbidity confirms that the membrane barrier has not had a significant breach detectable by a turbidity increase that would be due to solids 'breaking through'*	*Continual on-line monitoring*	*< 0.15 NTU*	*< 0.15 NTU*	*< 0.3 NTU*	*Alert: initiate backwash* *Violation: Take unit out of service*

*Membrane filtration given as an example

Appendix O: Operational and Maintenance Manual of the WWTP

1. Overview of treatment process

2. System Drawings

- Process schematic
- Site plans
- Electrical drawings

3. Plant Sart-up

- Pre start-up checks
- Initial Start up

4. Alarm systems

5. Sludge Management

6. Equipment

- Quality certification
- Plant and equipment technical information
- Electrical and PLC equipment technical information
- Equipment Failure
- Equipment suppliers schedule (Include list of recommended spare parts that should be held on-site to enable timely rectification of any faults)

7. Materials and chemicals

8. Troubleshooting Guide

Table 1 Operational troubleshooting

Problem	Possible Cause	Possible Solution

9. Plant safety and personal hygiene

10. Plant monitoring

- Routine inspection, monitoring and maintenance

11. Sample collection

12. Maintenance

- General plant maintenance
- Overall maintenance schedule timetable
- Include daily/weekly/monthly/three monthly inspection reports

13 Communications protocol for emergency and contingency situations

Table 2 Contact details for contingency situations

Contact Person	Company	Position	Mobile phone

Appendix P: Operational and Maintenance Manual of the Irrigation System

1. Map of the pipeline route from WWTP to irrigation sites

2. Irrigation map

3. Areas of responsibility

Include responsibilities/tasks for all staff involved in the operations and maintenance of the irrigation system (e.g. watering, application of fertilisers)

4. Maintenance of storage tank, reticulation system

- General plant maintenance
- Overall maintenance schedule timetable
- Include daily/weekly/monthly/three monthly inspection reports
- Include specific forms used (e.g. Pump station audit sheet, distribution system audit sheet)

5. Irrigation compliance

Location	**Day (start)**	**Time on**	**Time off**	**Comment**

6. Warning Protocol

Colour pipe and warning signs

7. Contingency/emergency plan

Incident	**Responsible person/s**	**Action to be taken**

Appendix Q: Validation Report of Individual Treatment Components

Pre-commissioning validation is undertaken as part of the feasibility study, to determine what treatment process will be required to meet the water quality objectives.

Manufacturers specifications can be used to support the validation process but any removal rates provided by the manufacturer should be confirmed by monitoring during commissioning of the plant.

Include the following information for each one of the treatment components (e.g. ultrafiltration)

1. System description

2. Validation ranges

Include methodologies and conditions under which experiments were performed

3. Results

Include log reductions achieved by the treatment component

Appendix R: Mosquito Management Plan

1. Introduction

Include purpose and definitions

Identify sources and extent of mosquito impacts based on:

- Previous mosquito surveys or reports if they exist
- Public complaints (most local governments keep a complaints register)
- Geographical survey:
- location of man-made water infrastructure (e.g. sewage lagoons, constructed wetlands, rainwater and effluent re-use tanks, roadside drains and culverts)
- maps, aerial photographs
- local knowledge
- Land ownership & responsibilities (council planners, Dep't of Land Administration)
- Applicable environmental legislation (council planners; environmental agencies)

2. Mosquito breeding habitats and human risk

Include potential mosquito breeding locations and periods of the year with increased risk (e.g. cyclone season)

If there is no prior information about mosquito breeding sites, seasonal productivity and the most prevalent
species, then the following baseline surveys will be essential.

- Larval surveys: survey all potential mosquito breeding habitats, natural and man-made
- Adult surveys: undertake adult mosquito trapping in a range of natural and domestic locations
- Timing of surveys: surveys should follow breeding triggers [e.g. rainfall, irrigation, dam releases, effluent re-use)] to maximise the effectiveness of the survey to locate breeding sites
- Prioritise surveys in areas closest to residential and recreational areas and work out from there

3. Risk management measures

List procedures/measures in place to minimise risk of exposure

The analysis of existing information and baseline mosquito surveys (above) will allow you decide whether, when, where and how mosquito management should be undertaken.

4. Roles and responsibilities

The end-users of the recycled water have a key role and responsibility in any integrated program to manage mosquitoes. It is important to that users are kept informed and become stakeholders in achieving a successful mosquito management procedure.

Appendix S: Algae Management Plan

High concentration of nutrient in recycled water can lead to algae blooms in water storages exposed to the sun. Similarly long periods of dry stable warm weather provide favourable conditions for algae blooms. Recycled water storages (reservoirs, dams and tanks) could also suffer from excessive algal growth and eutrophication. In addition to producing toxins, algae in recycled waters may clog irrigation systems.

1. Introduction

Identify sources and extent of algae bloom impacts based on:

- Local knowledge
- Previous data or reports if they exist
- Location of man-made water infrastructure (e.g. sewage lagoons, constructed wetlands, rainwater and effluent re-use tanks, roadside drains and culverts)
- Maps, aerial photographs

2. Risk management measures to prevent algae blooms

List procedures/measures in place to minimise risk algae bloom formation including:

- *Source control or catchment management practices to reduce nutrient inputs*
- *Treatment barriers used to reduce nutrient concentrations in the plant effluent*
- *Restriction of light entering storage systems*
- *Measures to control storage times and stagnation prevention*
- *Visual daily monitoring during high risk periods*
- *Turbidity management*

3. Risk management practices in algae blooms

Algae blooms should be treated as toxic until species have been identified and are considered safe.

List procedures/measures in place to manage algae bloom events including:

- *Monitoring of algae levels*
- *Limitation of light entering storage systems*
- *Chemical treatment*
- *Physical controls*

4. Incident Response

Include contact details of people responsible.

Appendix T: Land Capability Assessment

1. Site Characteristics

2. Irrigation assessment requirements

3. Irrigation areas

4. Soils

5. Irrigation application rates (L/m^2)

Include geotechnical report if available

Appendix U: Environmental Risk Assessment

1. Routes of Exposure and environmental end-points

Include:

Exposure pathways

Receiving environment

Environmental end-points (soil, surface water, biota..)

2. Environmental risk assessment

3. Risk mitigation

Appendix V: Environmental Management Plan

1. Soils description

Include:

- Soil type
- Phosphorus retention index
- Acid sulphate soils
- Imported soils

The key physical properties that should be identified in initial soil investigations include:

- Texture/structure
- Topsoil depth
- Depth to drainage or root impeding layers
- Infiltration rates
- Soil−water holding capacities

2. Water resources

Include:

- Groundwater table
- Distance to surface waters

3. Land management

4. Nutrient and irrigation management plan

5. Proposed irrigation scheme

6. Nutrient application

7. Drainage management

8. Vegetation in the irrigated area

9. Pesticide storage and use

10. Sample locations (soil, groundwater, surface water)

Appendix W: Odour Management Plan

1. Odour assessment

Include Guidelines, software, modelling or data used

2. Odour control measures

Include control measures to be implemented to limit odour releases for primary, secondary treatment and sludge handling. Include measures such as covers, odour treatment units, stacks and buffer distances.

3. Odour monitoring

Inlclude periodic monitoring during operations

- Complaint registration and response
- Odour surveys

4. Standard operational procedures

Include operational activities such as checks of flows and loading or replacement of scrubber media.

5. Contingency plans

Inlclude contingency plans and complaint procedures for

- Upsets or maintenance
- In the event of exceedances

Appendix X: Noise Management Plan

1. Noise assessment

Include background noise levels, noise modelling and noise prediction

2. Noise management

Include control measures to be implemented to limit noise

3. Noise monitoring

Inlclude periodic monitoring during operations and complaint registration and response

4. Standard operational procedures

Include operational activities to minimise/control noise.

5. Contingency plans

Inlclude contingency plans and complaint procedures for

- Upsets or maintenance
- In the event of exceedances

Appendix Y: Catchment Characterisation

Include:

- Commercial inputs
- Industrial inputs
- Residential inputs
- Land uses

Appendix Z: Audit Report

1. Introduction

2. Audit Methodology

3. Findings

4. Discussion

5. Recommendations

8.7. Appendix G: Calculation of the amount of irrigation is required for the Timbers Edge Public Open Spaces

The Water Corporation's 'Standard Drink'= 10mm or 10L/m^2

Allowance:

- Scheme: 20mm of irrigation, 2 times per week.
- Bore/alternate source: 30mm of irrigation, 3 times per week.

Netafim dripline: 3L/hour @100kpa; with a spacing of 0.3m, row spacing of 0.35m

POS area= 1.8ha= 18,000m^2

18,000m^2 x 10L/m^2 x 3 times per week= 540,000L/week= 540kL/week x 52weeks per year=

28,100kL/year

77kL/day

This accounts for watering 3 times per week throughout the year, including during winter. This is ok since the excess treated water can be used to recharge the local aquifers.

8.8. Appendix H: Image of clay from Envirophos Tank

Figure 7. Image of clay used in Envirophos tank at Timbers Edge.