MATAMATA WTP UPGRADE – PRODUCING WATER FIT FOR HOBBITS

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ABSTRACT

In July 2007 Matamata Piako District Council (MPDC) received an E grading from the MoH for their 5ML/d Matamata WTP. This paper details the unique path that MPDC followed using a combination of innovative process design and in-house knowledge to turn an E grade plant into an A grade plant at the lowest possible cost to their rate-payers.

The catchment for the plant is in the Kaimai ranges. The water is usually of pristine quality (UVT>93%,<1.0NTU) however, the steep topography and heavy forestation results in extremely rapid deterioration in quality following rainfall. After heavy rain events the dissolved organic content of the water increases dramatically for 1-2 days (UVT<60%, 4NTU).

The existing plant was originally a manually operated and controlled direct filtration plant, followed by pH correction using lime and chlorination using chlorine gas. In order to comply with DWSNZ2005 (2008) and achieve an A grading the plant had to be modified to provide 3 Log of protozoal treatment.

The process selected for providing the 3 Log treatment was UV irradiation. However, in order for UV to be credited with 3 Log, certain pre-treatment conditions must be met. The most significant of these are for a turbidity of <1.0NTU for 95% of the time and a UVT of not less than 80%. The challenge therefore was to achieve sufficient dissolved organics removal following rainfall events to ensure that the UV pre-treatment criteria were always met. The upgrade design focused on the best way to achieve this objective utilising the existing assets.

Full-scale trials showed that direct filtration could achieve the required treatment aims during rainfall events provided the coagulant dose and flocculation pH were adjusted to respond to the changing source conditions. Once performance had been validated it was possible to optimise the design of the existing direct filtration plant.

The unique design innovation that allowed the process to work under all conditions whilst minimising the operational cost was the installation of an S::can on-line UV-Vis spectrophotometer configured with two custom algorithms. The first started the coagulant and poly dosing when the source water UVT dropped below 91% and stopped the dosing when it went back above 92%. The second, which operated once the coagulant dosing was started, automatically controlled the coagulant dose by using the predictive dose control package com::pass. Operating the plant in this manner meant that coagulant and poly are only dosed for approx 25% of the time, resulting in large chemical cost savings.

Other design innovations employed were converting an old leaf settling tank into a flocculation tank, replacing the old filter sand with single media filter coal beds thereby removing the need for replacing the filter floors and installing UV units on the outlets of each individual filter (3 No.). This had the advantage of providing inherent redundancy and enabled the plant to continue running throughout the UV installation.

The in-house knowledge was provided by Kaimai Valley Services (KVS) a business unit of MPDC who are responsible for operating the water treatment plants. KVS did all of the installation work and this gave the operators a real sense of ownership and pride in the upgraded plant.

KEYWORDS

Direct filtration; UV irradiation, predictive coagulation control.

1 INTRODUCTION

1.1 MATAMATA WTP

The Matamata WTP is owned and operated by Matamata Piako District Council (MPDC). The water supply has been used since 1883, the original leaf screen and settling tank was built in 1937 with the plant buildings and filtration added in 1965. It provides water to the people of Matamata (population 6,900). A schematic of the process is shown in Figure 1. The plant had three filters, pH correction and chlorine disinfection. The plant was manually operated as there was no PLC control and only very basic instrumentation.

In July 2007 the plant was graded and received an E grade. The executive team at MPDC decided that this result was unacceptable and wished to improve the quality of water that their consumers were receiving by upgrading the Matamata WTP. MPDC engaged $h_2$ope to provide process design services for the proposed upgrade.

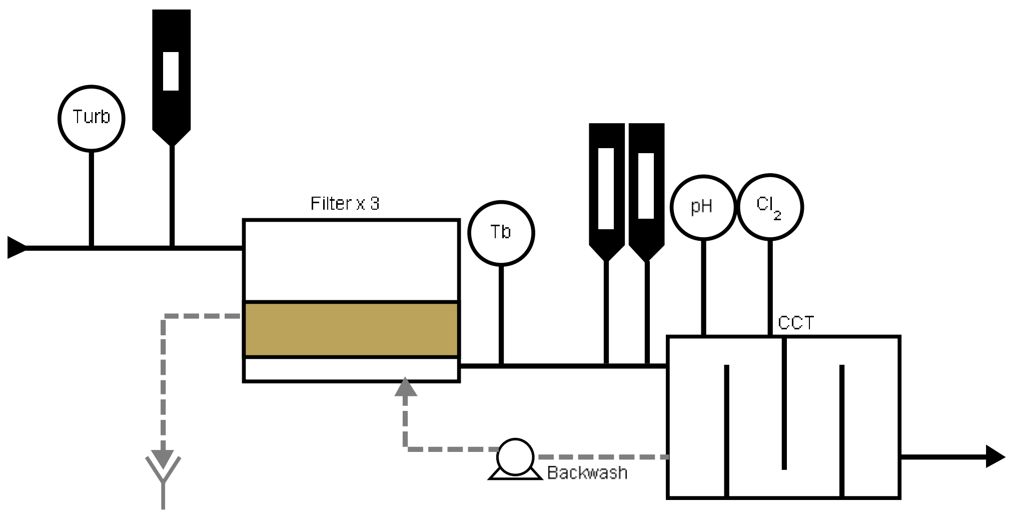


Figure 1: Process schematic of Matamata WTP – Before upgrade

1.2 UPGRADE OBJECTIVES

MPDC had four key objectives for the upgrade:

- To ensure that the plant would comply with DWSNZ 2005 (3 log protozoa treatment);
- To automate the plant;
- To achieve an A grading.
- To complete the works by the end of 2010

Furthermore MPDC wished to manage the project in-house and have their operations group – Kaimai Valley Services (KVS) – undertake as much of the project work as practicable.

2 PROCESS DESIGN

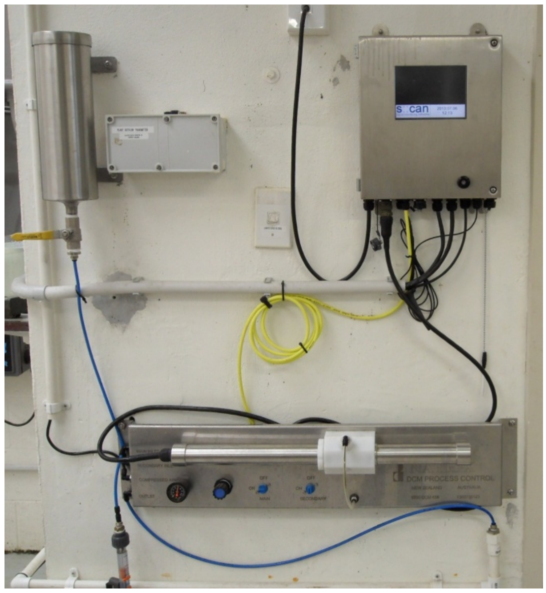
A number of process options were available to achieve the desired objectives. However, when selecting the best option for an upgrade it is first necessary to characterise the source water quality as fully as possible and to evaluate how the existing plant has performed. In the case of the Matamata WTP there was very little source water quality data available. The first task was therefore to collect a source water quality dataset. MPDC decided that the most effective way to do this would be to purchase and install an S::can UV-Vis spectro::lyser. The spectro::lyser was installed in September 2007.

2.1 SOURCE WATER CHARACTERISATION

The S::can UV-Vis spectro::lyser installation is shown in Photograph 1. Installing the spectro::lyser enabled the on-line collection of a large dataset on the dissolved organic content of the water in a relatively short time. This data was vital to be able to quantify the amount of organic matter occurring and to characterise the type and treatability of that organic matter.

An initial dataset collected between October 2007 and June 2008 was used for the original characterisation work. This data is summarised in Table 1. The data was augmented by daily testing of pH and alkalinity by the site operators.

The collected dataset showed that the water was usually of very high quality with both low turbidity and low dissolved organics. However the amount of soluble organics increased dramatically for up to 48 hours following rainfall events. An 8 month plot of the solids compensated UV254nm absorbance is shown in Figure 2.



Photograph 1: S::can UV-Vis spectro::lyser

Table 1: Source water quality data (Oct 2007 to June 2008)

Parameter	Units	5%ile	Avg	95%ile	99%ile	Std dev
pH	-	6.2	6.8	7.3	7.5	0.3
Alkalinity	mgL^{-1} as $CaCO_3$	5.0	7.8	13.0	18.0	2.7
SAC UV254 Absorbance[1]	m^{-1}	1.1	2.9	8.4	18.3	3.1
UV Transmitivity[2]	%	77.2	93.5	96.1	96.4	7.5
Turbidity	NTU	0.3	0.7	1.8	4.0	0.8

Notes: (1) SAC UV254 is solids compensated i.e. filtered.
(2) UVT is non solids compensated.

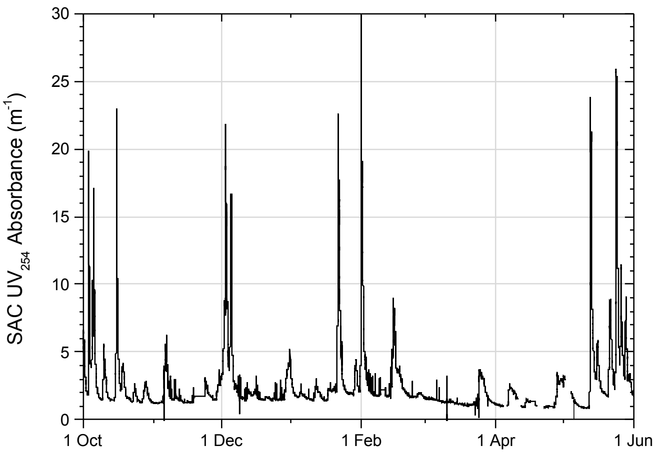
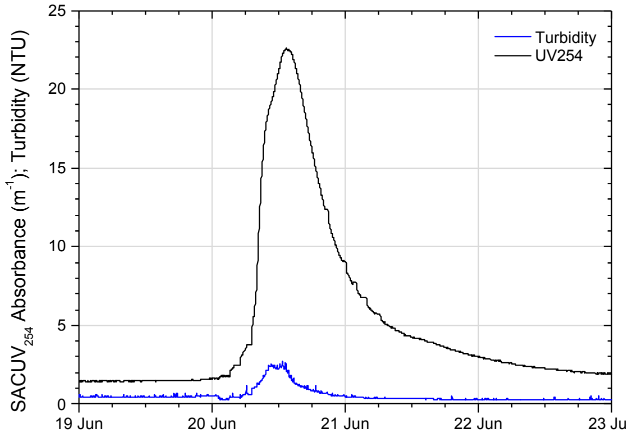


Figure 2: Source water dissolved organics.

A single event is shown in Figure 3. This figure also includes the turbidity data. In this example the peak of the event occurs after only 12 hours. After a further 12 hours the event has almost passed. The UV transmitivity (UVT) for the same event is shown in Figure 4. This shows that the UVT drops down to almost 50% during the event.

The type of organic matter present can be characterised using information from the UV-Vis spectrum or "fingerprint" (Figure 5). One such organic matter characterisation parameter is the specific UV absorbance or SUVA (UV_{254}/DOC). This is a widely used parameter that provides an indication about the molecular weight of the dissolved organics present and their propensity to be removed by coagulation and subsequent solids separation (Edzwald and Tobiason, 1999). The SUVA for the same event plotted in Figure 3 is shown in Figure 6. A low SUVA value is symptomatic of low molecular weight organic molecules, such as polysaccharides. This organic material is poorly removed by coagulation and subsequent solids separation. A high SUVA value is symptomatic of high molecular weight organic molecules, such as fulvic and humic acids. These molecules are highly amenable to removal by coagulation and subsequent solids separation. In Figure 6 it can be seen that the background SUVA value before the event is very low. The SUVA then increases dramatically as the event takes place. This suggests that fulvic and humic acids are being washed out of the heavily forested catchment following the rainfall. The steep topography of the catchment explains the short duration of these events.



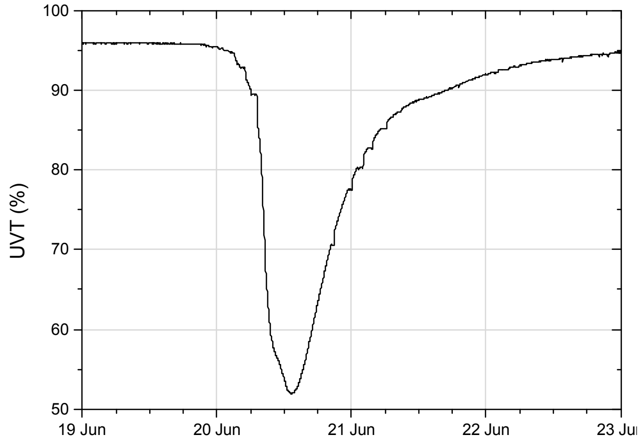


Figure 3: Water quality following a rainfall event.

Figure 4: UVT following a rainfall event

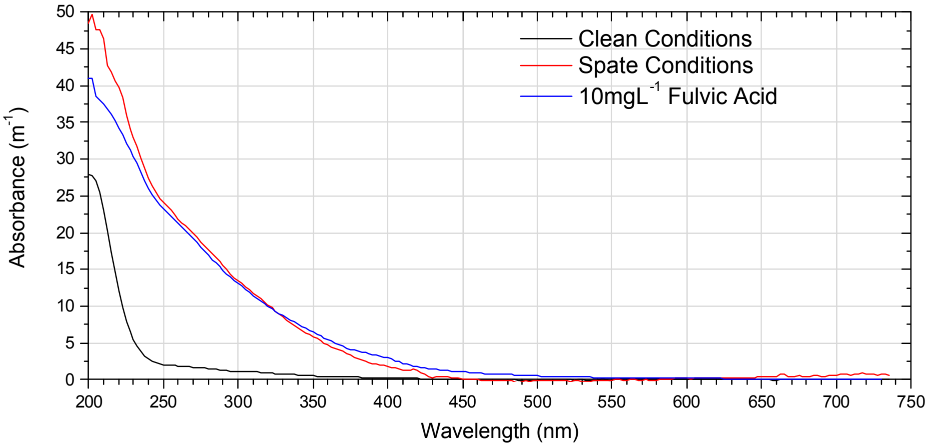
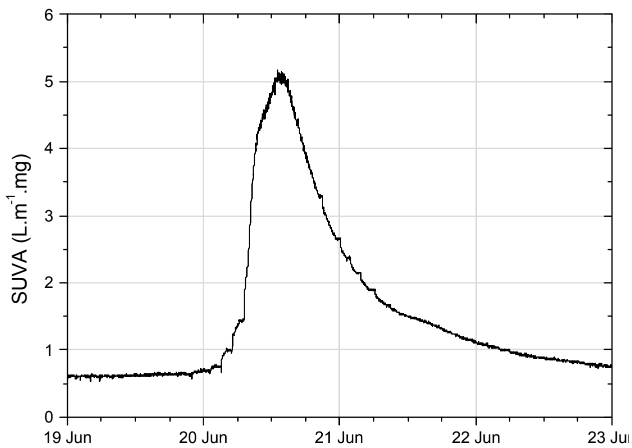


Figure 5: UV-Vis spectral data under clean water and spate conditions.
A fulvic acid preparation is also included for comparison (Courtesy Luke Zappia, Watercorp)



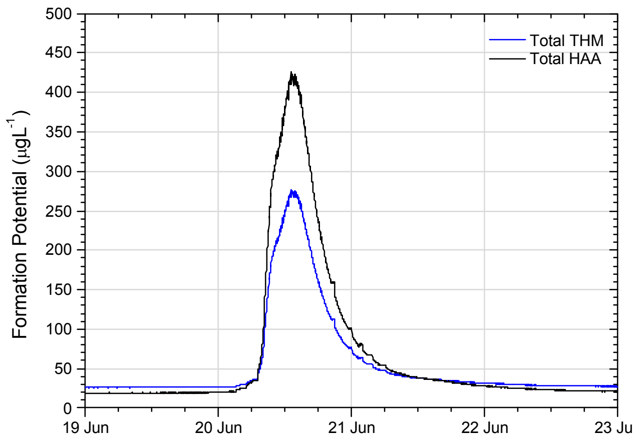


Figure 6: Organic matter characterisation. *Figure 7: TTHM and THAA formation potential*

It is also possible to use the UV-Vis spectral data to estimate the formation potential of total trihalomethanes (THMs) and halo acetic acids (HAAs). The formation potential is the amount of these compounds that would form if the water was chlorinated without further treatment i.e. the worst case (Figure 7). By analysing the formation potential of source waters it is possible to identify the risk of forming THMs and HAAs and to determine what how much organics removal is required to ensure that treated water limits are not exceeded.

The source water characterisation work highlighted the following facts:

- The dissolved organic content and the turbidity were very low during dry weather conditions;
- The organic content of the source water increased very rapidly to moderately high levels following rainfall;
- The increases in organic content only lasted up to 48 hours and were often less than 24 hours;
- The organic matter present following rainfall events was likely to be fulvic and humic acids;
- The organic matter present following rainfall events was likely to form THMs and HAAs;
- The organic matter present following rainfall events would be removable by using metal based coagulants and a solid separation process.

2.2 PROCESS SELECTION

The principal process performance requirement was to be able to achieve 3 log protozoa treatment under all source water conditions. The source water characterisation exercise had shown that the organic matter that occurred following rainfall events was highly likely to be removed by coagulation and solids separation. The key decision therefore was to select the solids removal process. Four main options were considered:

- MF/UF membrane treatment;
- Clarification and filtration;
- Direct filtration;
- Direct filtration and UV.

Direct filtration and UV treatment was provisionally selected as the best option for the site. The process schematic for this option is shown in Figure 8. This option comprised an upgraded plant front-end with polyaluminium chloride (PACl) coagulant, pre-lime and polyelectrolyte dosing; a full filter refurbishment with dual media sand/anthracite filters and new filter floors; a new backwash handling process; and the addition of UV irradiation. The upgrade works were planned out in stages such that the final process would only be confirmed after full-scale trial work.

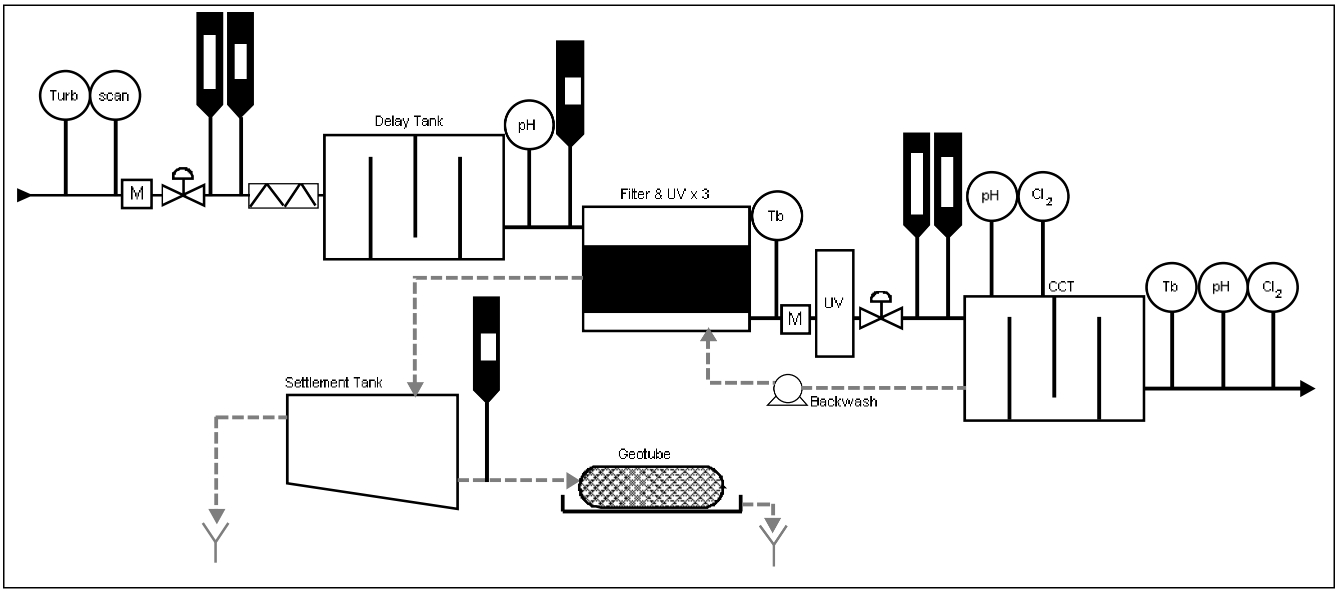


Figure 8: Process schematic of Matamata WTP – Direct filtration & UV

2.3 PROCESS DESIGN DEVELOPMENT

The plant upgrade was progressed in discrete stages (Table 2) in order to validate the process design and therefore minimise the process risk. The key steps in the process design development were as follows:

- To determine if enough organic material could be removed to meet the pre-treatment requirements for UV protozoa compliance (DWSNZ2005 – Section 5.16);
- To determine if the coagulant dose could be effectively controlled to respond to such rapid source water changes;
- To determine the solids holding capacity of the existing filter media and to decide if a filter refurbishment was actually required;
- To determine the long term efficacy of the backwash process;
- To determine the specification for the UV plant.

Table 2: Upgrade work stages

ID	Key Activities	Start Date	End Date	Process Validation Work
1	• New inlet flow control • New static mixer and chemical dosing points • Modifying strainer house to provide contact time • New PACl storage and dosing • New com::pass coagulant dose controller • New poly storage and dosing • New pre-lime dosing • New PLC • New backwash pipework • New backwash settling tank • New Geotube • New compliance instruments • New 100KVA generator	March 2008	March 2009	• Test amount of organics removal to see if UV pre-treatment requirement could be met. • Test coagulation control to see if dosing could match source water changes. • Determine solids holding capacity of existing filter media
2	• Filter refurbishment • New air scour blower and pipework • Replacement backwash pump	April 2009	Sept 2009	• Determine solids holding capacity of new filter media. • Test backwash effectiveness.

				• Prepare specification for UV Plant
3	• New UV plant • Automation of plant flow control • Automation of filters & UV	March 2010	August 2010	• Final performance testing

2.3.1 STAGE 1 PROCESS VALIDATION

The modified plant front-end was commissioned in February 2009. The new chemical dosing regime was run for two weeks with the existing filter media (0.42-0.85mm sand) to determine the amount of organics removal, the filter solids holding capacity and therefore the filter run times that could be expected under all conditions. The period of testing included a rainfall event.

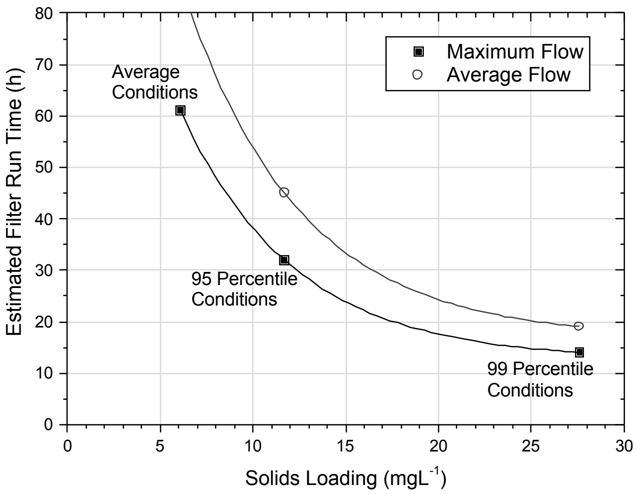
The PACl coagulant dose was controlled using the dose prediction software com::pass. This software is embedded in the s::can spectro::lyser control computer . The response to changing conditions was instant and the dose predicted achieved a turbidity less than 0.1NTU and a UVT>90% under all conditions.

The solids holding capacity of the fine sand filter beds was low at $950gm^{-2}$. Filter runtimes were 29 hours with good quality source water but dropped to below 15 hours when the source water quality deteriorated. A runtime of only 6 hours was predicted at 95 percentile source water conditions, which was unacceptable.

Outcomes: *Direct filtration could achieve UV pre-treatment requirements.*
Filter refurbishment would be required to achieve manageable filter run times.

2.3.2 STAGE 2 PROCESS VALIDATION

The planned dual media filter design required a new filter floor system to accommodate increased wash water velocities. Since the cost of a new filter floor system was significant at approx $240k it was decided to initially refurbish a single filter with anthracite only rather than dual media. Since anthracite has a lower density than sand it would be possible to use lower wash water velocities and still achieve an effective wash (with an increased air scour velocity). Thus if the anthracite only media configuration could achieve the filtered water quality targets there would no longer be a need to modify the filter floors.



The anthracite only filter was tested for two weeks and was found to be capable of achieving the filtered water targets of <0.1NTU and UVT >90% under all conditions. The solids holding capacity of the filters was increased to 2000gm^{-2} which meant a predicted filter run time of 32 hours under 95 percentile conditions and 14 hours under 99 percentile conditions (Figure 9).

The decision was made to refurbish the remaining two filters with anthracite only.

During this test work it was realised that it was unnecessary to dose coagulant continuously since the UV pre-treatment conditions could be met under most source water conditions without any coagulant and poly dosing.

Figure 10 shows a cumulative frequency graph of source water UVT taken from a year of on-line data as measured by the spectro::lyser. This shows that for 80% of the time the UV pre-treatment criteria (>90%UVT) could be met without dosing.

Figure 9: Predicted filter runtimes.

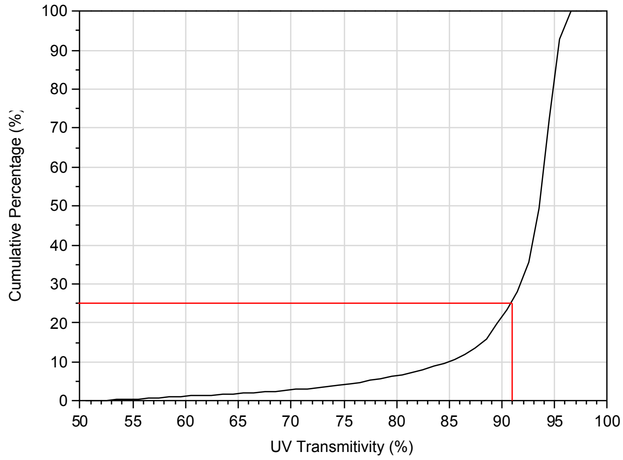


Figure 10: Source water UVT.

As a conservative approach the plant was set up to start coagulant and poly dosing when UVT dropped below 91% and to stop when it went back above 92%. Therefore coagulant dosing occurred 25% of the time. When dosing did start the coagulant was automatically controlled by the com::pass software.

The backwash effectiveness was assessed by measuring the accumulated solids content of the media and by analysing the clean bed headloss over a six month period. Neither the dirt content nor the clean bed headloss showed any signs of deterioration and it was therefore concluded that the backwash regime was effective.

A specification was prepared for the UV plant based on a duty point of 90% UVT.

Outcomes: *Filters refurbished with anthracite only.*
No filter floor modifications required, resulting in significant cost saving.
Coagulant only dosed 25% of the time when UVT <91%.

2.4 FINAL PROCESS DESIGN DETAILS

The process design evolved during the project as a result of the step-wise approach and full-scale validation works. This resulted in a final process design that achieved all of the water quality objectives with the least capital outlay and a reduction in operating costs. The final process design is summarised in Table 3.

Table 3: Final process design parameters

Parameter	Units	Value
Plant flow – (Maximum/Average)	m^3h^{-1}	204/144
Delay time between coagulant and poly at max flow	min	4.8
Average PACl Dose (when dosing)	mgL^{-1} Al^{3+}	1.8
Average LT22 poly dose (when dosing)	mgL^{-1}	0.05
Anthracite media effective size	mm	1.15
Media depth	mm	1000
L/de		870
Filtration rate – (Maximum/Average)	mh^{-1}	5.3/3.8
UV Dose	$mJcm^{-1}$	40

Number of UV reactors		3
Number of lamps per reactor		8
Filtered Water UVT (Average/Minimum)	%	>90/>80

2.4.1 MAXIMISING THE USE OF EXISTING ASSETS

One of the features of this upgrade project has been the philosophy to get the most out of existing assets wherever possible. This is most aptly demonstrated in the conversion the old leaf settling tank into a combination chamber (for the static mixer, flowmeter and flow control valve) and baffled contact tank to provide delay time between coagulant and poly addition (Photographs 3 and 4).

Photograph 3: Old leaf settling tank

Photograph 4: Converted settling tank

2.4.2 PROCESS INNOVATIONS

Another feature of the project has been the number of process design innovations employed. The key innovations are listed below:

- Part-time (25%) dosing of coagulant, with coagulant dosing initiated and controlled by the s::can spectro::lyser and com::pass software;
- Use of monomedia anthracite filters;
- Installation of UV on the outlets of individual filters. This arrangement provides inherent redundancy, avoids the need for any re-lift pumping and enabled installation without any plant shuts.

3 IMPLEMENTATION WORKS

The project was managed by Kaimai Valley Services (KVS) a business unit of MPDC who are responsible for operating the MPDC water treatment plants. KVS operations staff were closely involved in all aspects of the upgrade. They were integral in making all key design decisions and in construction planning.

All installation work was managed and performed by KVS staff with the help of local specialised contractors and on one occasion the local rugby club!

All operations staff were rotated through the plant during the trials and upgrading works. This approach got the maximum value from the operator's tacit knowledge of the plant and the source.

Feedback from the operators showed that their involvement throughout the upgrade gave them a real sense of ownership of the upgraded plant.

Photograph 5: Filter media installation.

Their presence during the trial works also gave them a thorough understanding of the treatment process and provided excellent on the job training.

The fact that all the KVS staff had a "day-job" to do in addition to the upgrade works meant that the upgrade was completed over a reasonably long period of time. However, the benefits accrued from using KVS more than compensated for the extended project timeframe.

Photograph 6: Old filter gallery

Photograph 7: Upgraded filter gallery

4 PROJECT COSTS

4.1 CAPITAL COST

The actual capital cost for each work stage is compared to the budgeted capital cost in Table 4 and in Figure 11. It can be seen that the work was completed under budget. The actual cost of the work was 75% of the original budget. By removing the need for the filter floor modifications in Stage 2 a saving of $240k was realised. If the filter floor modifications had been included the actual cost would have been 95% of the budgeted cost.

Table 4: Project capital cost

Work Stage	Budget Cost ($1000)	Actual Cost ($1000)	Difference (%)
Stage 1	496.5	480.2	3.3
Stage 2	552	267.6	51.5
Stage 3	154	151.5	1.7
Total	1202.5	899.2	25.2

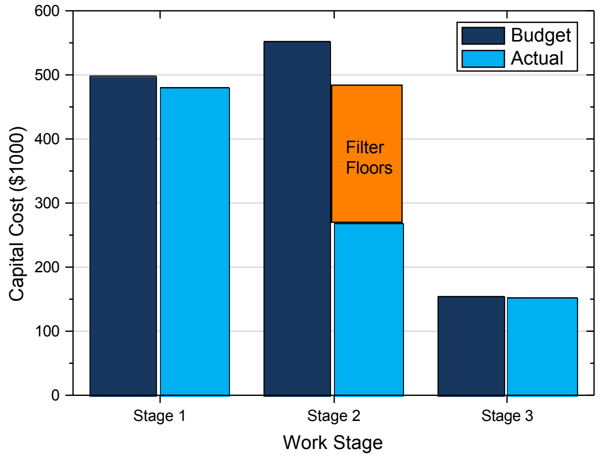


Figure 11: Project capital cost

4.2 OPERATING COST

The part time dosing of coagulant and poly has had a significant effect on the operating cost of the plant. The costs for full-time dosing and part-time dosing are shown in Table 5. It can be seen that the switch to part time dosing has resulted in a saving of $18k per annum. This saving covers the cost of running the UV plant (power and lamp replacement) at $12.2k per annum.

Table 5: Operating cost

Parameter	Units	Full Time Dosing	Part Time Dosing (25%)
Average Chemical Cost	$\$ML^{-1}$	28.33	13.9
UV Cost	$\$ML^{-1}$	9.69	9.69
Total	$\$ML^{-1}$	38.02	23.59
Annual Cost	$	47,960	29,757
Annual Saving	$	18,203	

5 CONCLUSIONS

MPDC took a unique path when deciding to upgrade the Matamata WTP. The approach adopted employed a combination of innovative process design and in-house knowledge. The upgrade transformed an E grade plant into an A grade plant at the lowest possible cost to their rate-payers.

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