PRIORITISATION OF WASTEWATER PUMP STATION UPGRADES USING ASSET MANAGEMENT PRACTICE

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ABSTRACT

Christchurch City Council (CCC), has many pump stations (PStns) across the sewerage network.

The project objective was to use a Whole Life Cycle Assessment (WLCA) model as an investment decision tool to justify the replacement of the old long life pumps with more efficient modern technology pumps.

This paper describes how we worked with CCC's existing asset data, combined with expertise in PStn design and engineering, to devise a strategic prioritisation programme of PStn upgrades for input to the 2009-19 Long Term Council Community Plan (LTCCP).

The initial analysis was based on five PStns which CCC recognised required upgrade, due to high maintenance costs caused by asset dilapidation or insufficient capacity. We developed a series of standard concept upgrade designs and capital cost (CAPEX) estimates, adopting CCCs preferred pump technology and design standard that was then applied to each PStn.

The target payback period was between 5 and 7 years. Unfortunately, the predicted payback periods were significantly greater and generally as long as the residual life of each PStn, meaning WCLA alone could not be utilised to set priorities.

Therefore, in conjunction with CCC, we developed priorities based on PStn issues such as asset renewal date, high maintenance costs, high pump run hours and pump technology replacement. These were then extrapolated across all CCC PStns and the priorities set. We used the original standard upgrade options developed to assess the best upgrade option for each PStn and therefore the LTCCP cost.

KEYWORDS

Pump station, capital cost, cost model, pump technology, LTCCP

1 INTRODUCTION

1.1 OBJECTIVE

Christchurch City Council (CCC) intended to review their 47 existing long life wastewater pumps, which are generally installed in below-ground dry wells as part of Council's asset capacity review to cater for required future increases in capacity and improve operational efficiencies. There were also flooding concerns across these pump stations because generally the pump station switchboards were also below ground in the dry wells.

The project objective was to use a Whole Life Cycle Assessment (WLCA) model as an investment decision tool to justify the replacement of the old long life pumps with more efficient modern technology pumps. The payback method was used to create the WLCA model, with the target payback period set between 5 and 7 years.

The intention was to carry out a full WLCA on a limited number of pumping stations (5 No.) to obtain standard upgrades and their associated payback periods, for a limited number of types of upgrades then extrapolate these across the remaining pumping stations.

1.2 BACKGROUND

The existing CCC long life wastewater pumps are the old Christchurch Drainage Board split case axial impellor type. These pumps are installed in dry wells with pipe penetrations into wet wells and below-ground electric installations. These pumping stations are 30-80 years old. This pump installation was common before submersible pumps were widely used. The main issues identified by Council are:

- Flooding risk for below ground electrics at pump stations such as PS19, PS22, PS30 and PS61.
- Overhaul regime after 20,000 hours, averaging to a 9.2 year interval, costing between $1,500 and $10,000 was perceived as uneconomic.
- Excessive head losses in some of the wastewater pump stations due to the small diameter of the suction and discharge pipes when considering the future upgraded pump duty flows.

In order to build the WCLA model, data was extrapolated from CCC records including asset residual lives, maintenance costs, pump run hours, historical power consumption, pump overhaul costs, pumping station physical characteristics and rising main dimensions. Pump and/or pumping station replacement costs and new technology whole of life costs were also assessed.

2 WHOLE OF LIFE CYCLE ASSESSMENT (WLCA)

The WLCA is the industry best practice approach that can assist in CCC's intention to obtain optimal economic (and environmental) value by comparing the 'status quo' and improvement scenarios for its long life surface mounted wastewater pump stations. This method looks at the total 'lifetime' cost to purchase, install, operate, maintain, and dispose of the system.

2.1 LIFE OF AN ASSET

The life cycle of an asset is defined as the time interval between the initial planning for the creation of an asset and its final disposal.

2.2 SCOPE

The project scope included:

- Stage 1 work involving WLCA for PS19, PS22, PS30, PS56 and PS61. The work considered the 'status quo' and improvement scenarios. Consideration was given to:
    - Cost of new pumps or overhaul of existing ones every 20,000 hours.
    - Cost to convert the pump station to the submersible type taking into consideration maintenance, access and minimisation of network disruptions. In addition to this CCC required GHD to also assess the options involving dry mounted upgrades and wet retrofitting of submersibles into the existing wet wells where feasible.
    - Construction to upgrade suction/discharge pipes where existing pump configurations are retained and upgrade is necessary.
    - Cost to relocate electrical controls and cabinets above ground.
    - Electricity and maintenance cost.
    - Capacity upgrade limitations.
    - Payback period.

- Stage 2 work was to extrapolate the potential cost savings across the 42 remaining wastewater pump stations, with the priority of the pump station upgrades determined from this extrapolation.

2.3 WHOLE OF LIFE CYCLE ANALYSIS MODEL

The main elements of a WLCA model are summarised in Table 1.

Table 1 Summary of Pump Station Upgrade/Improvement Options

Element	Description	Relevance to this WLCA Study
Capital Cost	Investigation, design, purchase, installation and commissioning of the asset and its auxiliary services.	Capital costs developed
Energy	Energy costs of the asset over its life.	Costs developed
Operation	Labour costs for routine system supervision.	Excluded from this study – no baseline data for comparison.
Maintenance	Labour, plant and material costs to effect repairs and regular servicing.	Costs developed
Loss of Production	Cost incurred because asset is not working as intended.	Not relevant in this CCC study.
Environmental	Penalties for leaks/overflows.	Difficult to assess – not considered in this study.
Decommissioning Costs	Cost of disposal of the asset at the end of its useful life.	Not considered in this study.

3 STAGE 1 WLCA OF 5 PUMP STATIONS

3.1 EXISTING WASTEWATER PUMP STATION DETAILS

The data summary is based on information supplied by CCC including:

- Pump asset data.
- Pump maintenance costs.
- Pump run hours.
- Rising main and flow details.
- Pump test data.
- Pump dry well and wet well details.

This data has been used to assess the system capacity.

3.2 UPGRADE AND IMPROVEMENT OPTIONS

Five options for pump station upgrades were determined and costed and are summarised below. These options are not all applicable to all pump stations.

- Option 1 - maintain the 'status quo' by retaining the existing pumps, maintenance, and overhaul and asset renewal philosophy. This is applicable to PS30 and PS56, which are not yet due for capacity upgrades.

- Option 2 - install two new dry mounted pumps in the existing chamber including pipe discharge and suction upgrades where feasible. This option is applicable to all five pump stations. These pumps will either be vertical close coupled or horizontal type depending on the availability of space and the clearance between the suction pipe and wet well/dry well level. Construction work will involve dealing with existing flows by either over-pumping from the gravity sewer or using suction tankers during construction.
- Option 3 - install submersible pumps in the existing rectangular wet well, applicable to PS30 and PS61 which have rectangular wet wells. However, PS61 existing wet well dimensions cannot accommodate the two 37kW pumps earmarked for this site. Construction work will involve dealing with existing flows by either over-pumping from the gravity sewer or using suction tankers during construction.
- Option 4 - convert existing dry well into a wet well (all five pump stations). Structural assessment is required to assess this change of use. Construction work will involve dealing with existing flows by either over-pumping from the gravity sewer or using suction tankers during construction.
- Option 5 - install a new submersible pump station (all five pump stations). This can be constructed and commissioned without disrupting the existing pumping system. It is important to note that there is no land area available for PS19 and PS30.

CCC has specifically requested that assessment of the WLCA of a new submersible pump stations be included, due to the advantages a new pump station offers.

3.3 ASSESSMENTS

Some of the assessments used for establishing the upgrades were:

3.3.1 CAPACITY ASSESSMENT

Based on criteria and CCC previous studies, the improvements for the five pump stations in this WLCA are categorised as follows:

- Capacity upgrades for PS19, PS22 and PS61, therefore new larger pumps.
- Improvements to optimise energy and operational efficiency for PS30 and PS56.

3.3.2 PUMP TECHNOLOGY IMPROVEMENTS

Pump technology has improved significantly since the installation of the CCC long life wastewater pumps 30-80 years ago. Therefore, by upgrading the pumps, even where capacity upgrades are not required, may lead to operational and maintenance efficiencies.

Some of the features of the modern wastewater pumps are as follows:

- Pump systems with:
    - Easy to maintain submersible pumps with lifting guide rails and quick coupling mechanisms.
    - High-tech maintenance features such as smart trim (Grundfos SEV pumps), which allows low cost external adjustment of impellor diameters.
    - Easy to maintain features such as wear plate adjustment with pump bearing and shaft in-place.
    - Energy efficient pumps with open self-cleaning impellor (Flygt N Series pumps) and low risk of clogging.
    - Better pumping characteristics.
    - Readily available spare pump parts.
    - Energy saving high efficiency motors.
- Pump controls such as:

- Pump starters with variable speed drives. These require lower wet well operational volumes than standard fixed speed pumps.
- Pump alternators which can allow duty roles to be shared between the pumps hence existing available operational volume requirements can be reduced.
- Internally built condition monitoring systems.

The main element, with a direct correlation to maintenance costs, is the pump run hours. Energy costs are a function of pump run hours and motor size. As a result the extension of this study to the other 42 pump stations will involve pump run hours and motor sizes.

3.4 PROJECT OPTIONS AND CAPITAL COSTS

The pump station upgrade and improvement options and their associated initial capital costs are summarised in Table 2.

Table 2 Summary of Pump Station Upgrade/Improvement Options

	Improvement or Upgrade Description	PS19	PS22	PS30	PS56	PS61
Capacity Upgrade	Option 2 - New Dry Mount Pumps in the Existing Dry Well	$402,361	$311,464	-	-	$425,915
	Option 4 - Convert Existing Dry Well to a Wet Well	$573,597	$443,492	-	-	$587,341
	Option 5 - New Submersible Pump Station	-	$569,011	-	-	$812,298
Optimisation Improvements Only	Option 1 - Status Quo	-	-	$117,177	$124,598	-
	Option 2 - New Dry Mount Pumps in the Existing Dry Well	-	-	$235,726	$255,614	-
	Option 3 - New Submersible Pumps in the Existing Wet Well	-	-	$336,794	Not suitable.	-
	Option 4 - Convert Existing Dry Well to a Wet Well	-	-	$336,794	$403,405	-
	Option 5 - New Submersible Pump Station	-	-	-	$534,630	-

Capital costs for the above upgrade options were developed based on electrical costs supplied by CCC, pump supply costs from Flygt and Grundfos, and GHD cost estimates from pump stations constructed across New Zealand.

3.4.1 PSTN 19 AND 61 COSTS

A summary of the PStn 19 and 61 costs are outlined in Table 3 to Table 6.

The energy costs for the existing pumps were based on the pump run hours and annual power consumption. For the options involving new pumps, it has been assumed that variable speed drives will be installed on all new installations. The same daily pumped volume as the current pumps, with an assumed load profile, was used to model the energy savings gained from the new pumps.

Annual maintenance costs for the existing system, were extracted from CCC data. All the maintenance costs were converted to NPV costs using a discount rate of 7%.

The current pumps are overhauled every 20,000 hours. The overhaul frequency depends on the rate of growth and current pump run hours. We used the current annual pump run hours to predict the time between overhauls. The pump overhaul costs were also recalculated to present day values. For the new pumps, it has been assumed that the pumps and switchgear will be replaced as per CCC asset life guidelines. A 20 year asset life has been assumed.

All the electrical controls and cabinets located below ground level should be relocated to above ground level, above the 100 year flood level in accordance with CCC guidelines. Below ground electrical controls and cabinets pose a risk of malfunction in cases of flooding. CCC has an asset renewal programme for the pump station electrical assets. They are normally replaced after 30 years.

Table 3 Annual Energy Costs

Pump Station	PS19	PS61
Location	Beckford	O'Halloran Drive
Current Energy Costs per Year	$10,330	$7,785
Future Energy Costs per Year	$6,018	$6,252

Table 4 Annual Maintenance Costs

Pump Station	PS19	PS61
Location	Beckford	O'Halloran Drive
Current Maintenance Costs (Historical)	$3,537	$3,091
Predicted Maintenance Costs	$833	$833

Table 5 Pump Overhaul Costs

Pump Station	PS19	PS61
Location	Beckford	O'Halloran Drive
Last Overhaul Date	2006	2008
Pump Run Hours per Year	4,588	4,718
Estimated Next Overhaul Date	2010	2013
Pump Overhaul Costs (today's)	$6,545	$11,062

Table 6 Electrical Asset Renewal

Pump Station	PS19	PS61
Location	Beckford	O'Halloran Drive
Asset Renewal Date	2019	2025
Renewal Cost	$144,104	$153,151

3.5 ANALYSIS

CCC has nominated the payback method for this WLCA study.

Payback measures cash recoverability based on the amount of time during a project's life which it takes to recoup the investment.

Of all investment justification and decision making tools, payback method is the simplest because of the ease of calculation and suitability to evaluating several options at the same time.

However, the limitations of the payback method should be appreciated. These include:

- Inability to measure time value of money, financial costs and opportunity costs.
- Earnings beyond the payback period are ignored.
- Not related to profitability but cash recoverability only.

Based on the detailed analysis of the payback period, the results are summarised in Table 7, and Figures 1 and 2. The simplest description of the payback period is that if it costs $200,000 to renew an asset and the net cost saving per year of this renewal is $5,000 then it will take 40 years to repay the investment.

Table 7 Payback Period (Years) For Upgrade and Improvement Options

Improvement or Upgrade Description		Payback Period (Years)				
		PS19	PS22	PS30	PS56	PS61
Capacity Upgrade	Option 2 - New Dry Mount Pumps in the Existing Dry Well	20	20	N/A	N/A	-
	Option 4 - Convert Existing Dry Well to a Wet Well	20	20	N/A	N/A	-
	Option 5 - New Submersible Pump Station	20	20	N/A	N/A	-
Optimisation Improvements Only	Option 1 – Status Quo	-	-	-	-	-
	Option 2 - New Dry Mount Pumps in the Existing Dry Well	-	-	30	60	>60
	Option 3 - New Submersible Pumps in the Existing Wet Well	-	-	60	60	-
	Option 4 - Convert Existing Dry Well to a Wet Well	-	-	60	60	>60
	Option 5 - New Submersible Pump Station	-	-	-	60	>60

Figure 1: PStn 19 Payback Period

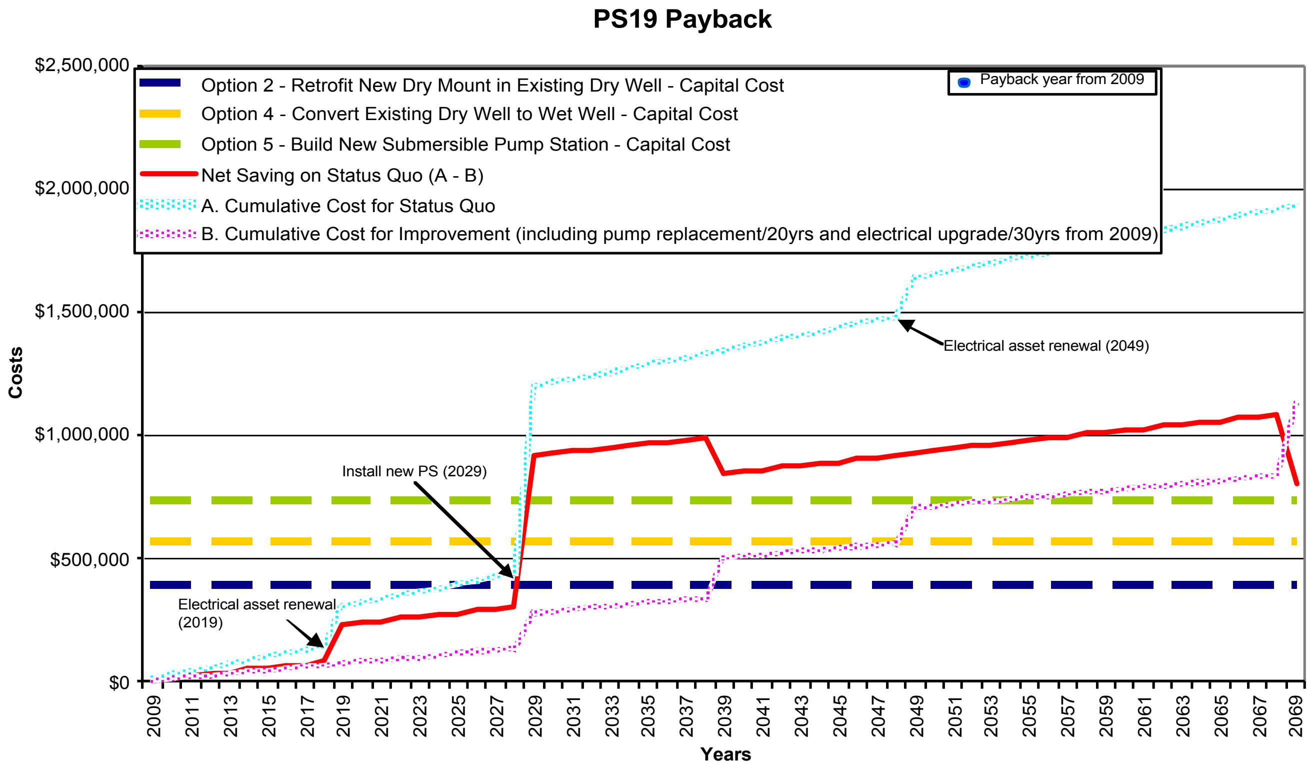
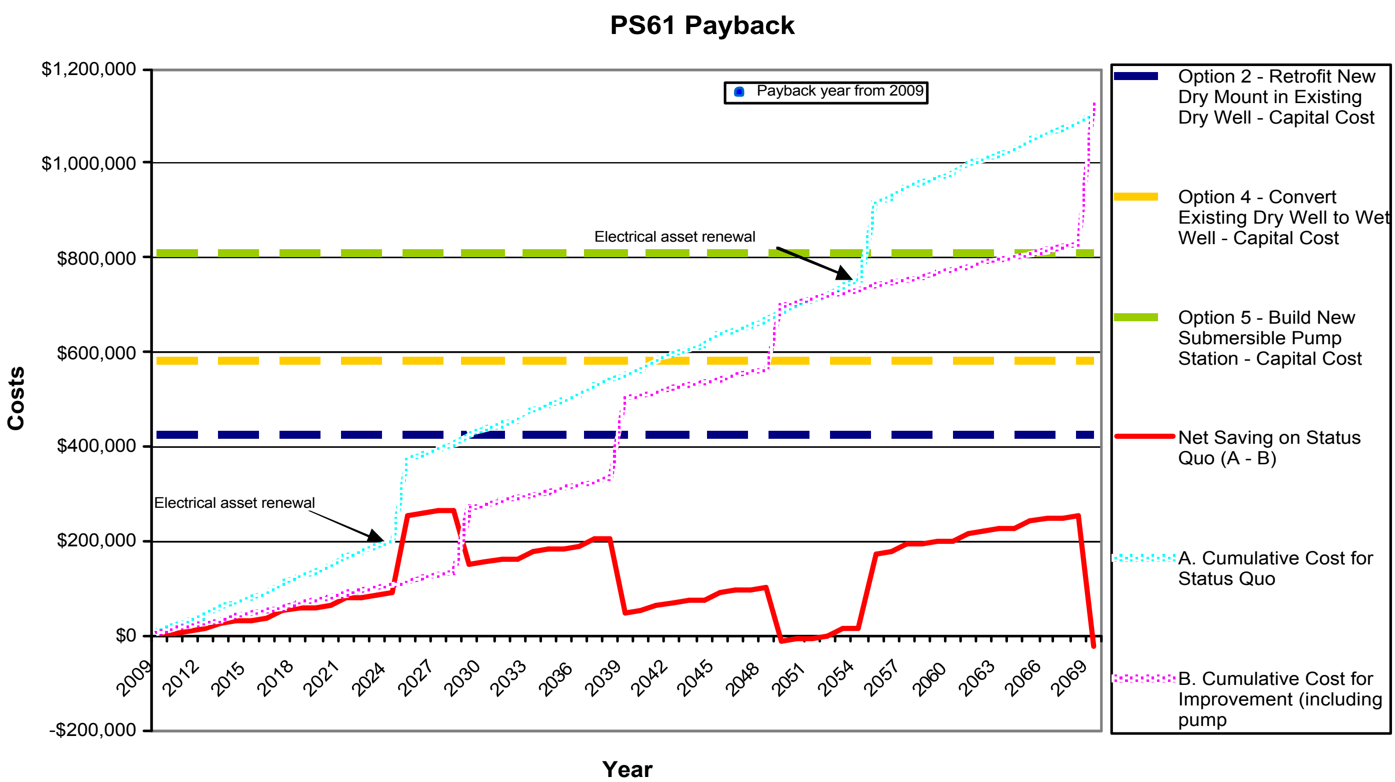


Figure 2: PStn 61 Payback Period



3.6 OVERALL CONCLUSIONS OF STAGE 1

This study has shown that there are multiple options for potential upgrades in order to reduce operational costs and provide efficiencies. However, the payback period is considerable and whilst the reduced operational and maintenance costs that can be achieved by installing new pumps may initially appear attractive, the pump station must be considered as a complete entity (structure, pumps, pipework and electrical system). Any additional works required to facilitate the installation of new pumps will affect the payback period; for example in the case of PS19, the recommendation is to upgrade the dry mounted pumps, run them to the end of their useful life and then renew the entire pump station (to the preferred wet well configuration) in 20 years time. Details for two of the pump stations are discussed below.

3.6.1 PUMP STATION 19

The existing pumps will not meet future capacity. It is CCC's intention to upgrade the existing 35l/s PS19 to provide additional capacity to cope with future flows (83l/s). These upgrades could be achieved by either:

- Option 2 - retrofitting new dry mounted pumps in the existing dry well chamber including discharge and suction pipe upgrades and the relocation of electrical cabinets from the dry well to the surface.
- Option 4 - converting the existing dry well to a wet well system with new submersible pumps.
- Option 5 is not feasible at PS19 because of lack of space.

The WLCA of the existing PS19 was based on the existing asset life of 80 years, pump overhaul period after 20,000 hours, maintenance costs and energy costs based on power consumption. A complete pump station overhaul was assumed within a 20 year horizon. For the upgrade options, the replacement pumps and switchgear was assumed to have an asset life of 20 years.

The payback period for both upgrade options is 20 years. This 20 year payback period is too long in comparison to the ideal target of less than 10 years.

3.6.2 PUMP STATION 61

Similar to PS19, the 23l/s capacity PS61 was identified by CCC for capacity upgrades, to cope with future flows (60l/s). Total system capacity assessments completed as part of this study confirmed the need for the proposed capacity upgrades. These upgrades could be achieved by:

- Option 2 - retrofitting new dry mounted pumps in the existing dry well chamber. Work would include discharge and suction pipe upgrades, and the relocation of electrical cabinets from the dry well to the surface.
- Option 4 - converting the existing dry well into a wet well. Work would involve new discharge pipes, benching, guide rails, and valve chamber.
- Option 5 - constructing a new submersible pump station complete with new electrical cabinets, valve chambers and satellite manholes on the incoming gravity sewer.

The three options have similar payback periods over 60 years. This WLCA is affected by the comparison of these options against the 'status quo' scenario which has smaller pumping capacity than the alternatives. The consequence is an understating of the savings.

4 STAGE 2 – EXTRAPOLATION TO OTHER PUMP STATIONS

A WLCA of PS19, 22, 30, 56 and 61 was undertaken by GHD as discussed in the preceding sections, which determined that the payback period is similar to the residual life. Therefore, a further 3 Pump Stations were analysed to check the results of the first 5 pump stations.

Detailed WLCA, similar to Stage 1, was undertaken for these three pump stations, which all had very high maintenance costs. All three pump stations also had payback periods similar to the pump station residual lives.

Therefore, we looked for other ways to prioritise the pump stations, out with WLCA costs and ultimately to utilise the information to aid prioritisation of the upgrade of 47 surface mounted pump stations.

In this prioritisation exercise, the findings on the 5 Stage 1 pump stations were extrapolated into Stage 2 by grouping the pumps according to the following issues:

- Insufficient capacity issues for those pumping stations where future catchment flows were higher than existing capacities as typified by high pump run hours.
- Asset life issues where the renewal date has either been exceeded or is imminent.
- High maintenance and/or pump run hours.
- Asset renewal dates.

4.1 EXTRAPOLATION

Based on the further analysis of the 47 pump stations, using their residual life, maintenance costs and pump run hours, each pump station was assigned a priority as shown in

Table 8, categorised as below. Priority 1 is the most critical.

- Priority 1 – Pump station renewal date exceeded or imminent.
- Priority 2 – High maintenance costs and pump run hours (>2500hrs/year).
- Priority 3 – High maintenance cost.
- Priority 4 – High pump run hours (>2500hrs/year).
- Priority 5 – High daily pump run hours (>8hrs/day) based on measured hours from December 2008 to January 2009.
- Priority 6 – Pumps are due for replacement in less than or approximately equal to 20 years.
- Priority 7 – All other pump stations that have not been categorised.

Starting at Priority 1, each pump was put into the first category where it met the criteria.

Table 8 47 Long Life Pump Stations Priorities

Priority	Issue	CCC Work Required	Pump Station(s)	
			Number	Name
1	Pump station renewal date exceeded / imminent.	Durability study. Renew or refurbish pump station.	2	PS2 and PS4
2	High annual maintenance cost (>$7,500) and annual pump run hours (>2500hrs).	Upgrade pumps.	1	PS41
3	High maintenance cost.	Upgrade pumps, if necessary	2	PS44 and PS60
4	High pump run hours.	Include in LTCCP. Upgrade pumps when due.	19	PS7, PS9, PS10, PS12, PS19, PS21, PS22, PS23, PS26, PS28, PS30, PS33, PS34, PS35, PS37, PS43, PS45, PS53 and PS61
5	High daily pump run hours (>8hrs).	Monitor pump station.	7	PS6, PS13, PS31, PS38, PS39, PS55 and PS57
6	Pump replacement due.	Incorporate in next LTCCP.	3	PS8, PS25 and PS27
7	-	Nil.	14	PS18, PS40, PS42, PS46, PS47, PS50, PS51, PS52, PS54, PS56, PS58, PS59, PS65 and PS85

4.2 OVERALL RECOMMENDATIONS

The visibility afforded by the information used within the WLCA allows the CCC Asset Manager to confidently plan for renewals and upgrades, hence this study was expanded to include all the 47 long life wastewater pumping stations, so that any potential upgrade benefits are identified across the network, and put into context with regard to their payback period.

This allowed GHD to develop a prioritised programme that will develop both a short and long term programme for renewals and undertake the appropriate financial planning to cover these costs. Some of the prioritisations will require further analysis from CCC. Again details for two of the pump stations are discussed below.

4.2.1 PUMP STATION 19

The two upgrade options (Option 2 and 4) were compared to the ‘status quo’ scenario involving the retention of the existing pumping systems. The comparison of the ‘status quo’ to the upgrade options does not compare like to like. However, the comparison is useful to compare between the upgrade options. Stage 2 work categorised PS19 in Priority 4 (capacity upgrades).

Notwithstanding the limitations of the payback periods, it is recommended that CCC proceed with the design of PS19 upgrades and adopts the least cost capital cost option (Option 2) involving dry mounted pump installations and operating the pumps for the next 20 years. At the end of the 20 year period, the pump replacement will coincide with the pump station renewal at which time the Council preferred submersible pump option could be adopted. At design stage, Multi-Criteria Analysis can be used to confirm the optimum option.

It is also recommended that a detailed durability assessment be undertaken for the PS19 structure. This may allow for the use of the asset beyond its asset life, if the structural integrity has not been compromised by corrosion. At this stage, Council should also provide for the replacement of the existing rising main and gravity inlet main. The rising main scope may be reduced at design stage to the AC section only if further investigations show that the uPVC pipe is adequately designed for future flows. In addition, the electrical controls and cabinets located below ground level should be relocated to above ground level, above the 100 year flood level in accordance with CCC guidelines.

4.2.2 PUMP STATION 61

Stage 2 work categorised PS61 into Priority 4 (capacity upgrades). The very long payback periods and the sound structural condition of the existing structure with a residual 60 year life seems to point towards the need to optimise the existing structures, instead of installing a new submersible pump station.

It is recommended that CCC proceeds with the design of PS61 upgrades and considers either the installation of higher capacity dry mounted pumps or the conversion of the dry well to a wet well as options for the pump station upgrades, in addition to the CCC preferred option involving a new submersible pump station. The installation of higher capacity dry mounted submersible pumps is the least cost option.

It is further recommended that at design stage, CCC use Multi-Criteria Analysis to confirm the optimum option and considers both the rising main and gravity inlet main in conjunction with the pump station upgrade in future design. Also, the electrical controls and cabinets should be relocated to above ground level, above the 100 year flood level in accordance with CCC guidelines.

5 CONCLUSIONS

After determining the standard upgrades and costings for the 5 pump stations in Stage 1, the payback period was in excess of that considered reasonable and generally was in line with the residual life of each of the pump stations. GHD analysed a further 3 pump stations to check the conclusions and they all gave similar results

Therefore, WCLA alone could not be used to prioritise the pump station upgrades and GHD had to look at other issues in Stage 2 to extrapolate the priorities for the 47 pumps stations. These were such as Residual Life of the Asset, High Maintenance Costs and High Pump Run Hours. These items had already been calculated for all pump stations to aid the calculation of the WLCA and therefore were available to the project team.

Subsequently, pump station 19 and pump station 61 have been designed for Council using the findings of the WLCA to inform the detailed design process. Both have been designed using Option 4 converting the existing dry well to a wet well. Pump station 19 was converted to a full wet well, whereas pump station 61 has installed submersible pumps into the dry well and will allow the dry well to flood in certain circumstances.

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REFERENCES

Gandashanga, E (2009), “Wastewater Surface Pumping Station – Whole of Life Cycle Assessment”, GHD

Hickling, B (2009), “Long Life Pump Station Brief”, Christchurch City Council