

PROJECT SHOTOVER – WHAT DID WE LEARN? WHAT DID WE ACHIEVE?

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ABSTRACT (500 WORDS MAXIMUM)

The Wakatipu Basin is experiencing a rapidly growing resident population and rapidly growing tourist numbers in what is one of the most sought after destinations in New Zealand. Since the early 2000's, Queenstown Lakes District Council (QLDC) has been under pressure, from Otago Regional Council, to upgrade the facilities which discharge into the near pristine Shotover and Kawarau Rivers.

Project Shotover, serving the communities of Queenstown, Frankton, Lake Hayes, Lake Hayes Estate, Shotover Country and Arrowtown, is a three stage project to completely renew the wastewater treatment facilities.

This paper considers the Stage 1 project which was procured in 2014/15, built in 2015/16 and commissioned in 2017. At the time, it was the largest capital works project ever undertaken by QLDC. It followed Project Pure, the equivalent facility servicing Wanaka, which had encountered problems in its development and had left the Council nervous about the ability of the industry to deliver such projects to a high standard, within time and budget while meeting all of Council's needs.

Like Pure, Shotover was delivered using a Design, Build and Operate procurement method. However, for Shotover, the 'Operate' period was increased to 5 years (using the FIDIC Gold form of contract) emphasizing the importance of the operability/reliability of the plant to the contractor. While leaving the process selection completely up to proposers, Shotover also came with a very prescriptive set of 'Employer's Requirements' stipulating the minimum standards required and guarantees on performance and operating cost.

Shotover was completed prior to commencement of the new consents, it was completed within budget, with comparatively few and minor variations and the new MLE + UV process is producing a very high standard of effluent. This level of success demonstrated the Council team's ability to work through complex projects successfully and has given the Council the confidence to subsequently embark on its major infrastructure development programme, starting with the Eastern Access Road.

As with all major projects, Project Shotover also offers up learnings and lessons that are valuable to the wider water and wastewater industry. While D&B / DBO is still popular and is a very good delivery mechanism, it is not a silver bullet and nor is it appropriate in all situations. This style of delivery requires a substantial investment from the market to bid, adds to the level of risk carried by the contractor, and also requires substantial input on the client side to set up and manage. It does not do away with a consultant team and it is not necessarily a quicker means of delivery. The size and nature of contract selected for this delivery mechanism needs to be commensurate with the amount of risk that the contractor is required to take on.

Keywords

Design, Build, Operate, Procurement, Delivery, Risk

1 INTRODUCTION

1.1 BACKGROUND

The Wakatipu basin, situated toward the southern end of Queenstown Lakes District, is a mountainous location with a dry, almost continental climate with cold winters and hot dry summers. The basin communities, comprising communities of Queenstown, Frankton, Lake Hayes, Arrowtown, Arthurs Point, Jacks Point, Quail Rise and Hanley Downs are located around the 'knee' of Lake Wakatipu. It is an area of outstanding natural beauty and home to a vast array of year-round adventure tourism activities, making it 'a', if not 'the' premiere tourist destination in New Zealand.

The Shotover, Arrow, Kawerau and subsequently Clutha rivers drain the District down through Central Otago, into and through Clutha District and into the Pacific Ocean at Balclutha. These rivers are used extensively for adventure tourism but also for irrigation, fishing, recreational boating and hydro-power generation.

The normally resident population of the District is approximately 28,000 persons and for every local resident there are, annually, 34 international tourists visiting the District. As can be imagined, this level of visitation places an enormous burden on infrastructure and, consequently, the ratepayers who are funding the development and management of that infrastructure. Residents and visitors alike expect¹ of the District:

- Stunning scenery in an unspoilt environment
- World-class infrastructure and services
- A safe, secure environment in which to live and recreate
- Affordable facilities and accommodation
- Friendly, hospitable people
- A relaxing place in which to live or holiday
- A place for outdoor adventure, no matter what time of year

The aesthetic and biochemical quality of the 'waters of the District are therefore of paramount importance to the wellbeing and economy of the entire Otago Region.

1.2 PROJECT SHOTOVER ORIGINS

The Queenstown/Frankton area has been serviced, since the 1970s, by a three pond oxidation pond system, located on the delta of the Shotover River about 1.5km upstream of the confluence with the Kawerau River. Since the construction of the ponds, the serviced area has expanded to include the Arrowtown and Lakes Hayes communities, and more recently, the new developments at Lake Hayes Estate and Shotover Country have connected to the plant.

Project Shotover had its origins in 1998 when new consents were issued, whose conditions envisaged a move away from direct disposal to the Shotover River and to land based disposal. Investigation of various options commenced in 2002, following which, tenders were called for construction of a land disposal scheme on the Shotover Delta. At that time. All tenders were rejected and further investigations and options assessments followed.

In 2008 the Otago Regional Council (ORC) applied additional pressure on Council to improve the discharge. Further research was undertaken on disposal to ground and consent applications were made in late 2008. These were defended and 'orders' of the Environment Court were subsequently signed in October 2010. The main thrust of the new consents was nitrogen removal, disinfection and removal of the direct discharge to water. Minor

¹ Priority expectations taken from an actual survey of residents and visitors.

changes were made along the way with final sign off in 2015, just before award of the Project Shotover DBO contract.

An external team was appointed in early October 2010 to assist Council with implementation of Project Shotover. This included a legal team, technical advisors specializing in WW process engineering and Employer's Representative to manage the FIDIC 'Gold' Book DBO contract. This latter role being similar to the 'Engineer to the Contract' role under the NZS 3910 Book. Local authority elections were held toward the end of October, and with considerable pressure on to reduce debt and reprioritize infrastructure spending, Project Shot over was put on hold within days of the election.

The team was reconvened in May 2013 and from that point onward, Project Shotover Procurement commenced in earnest.

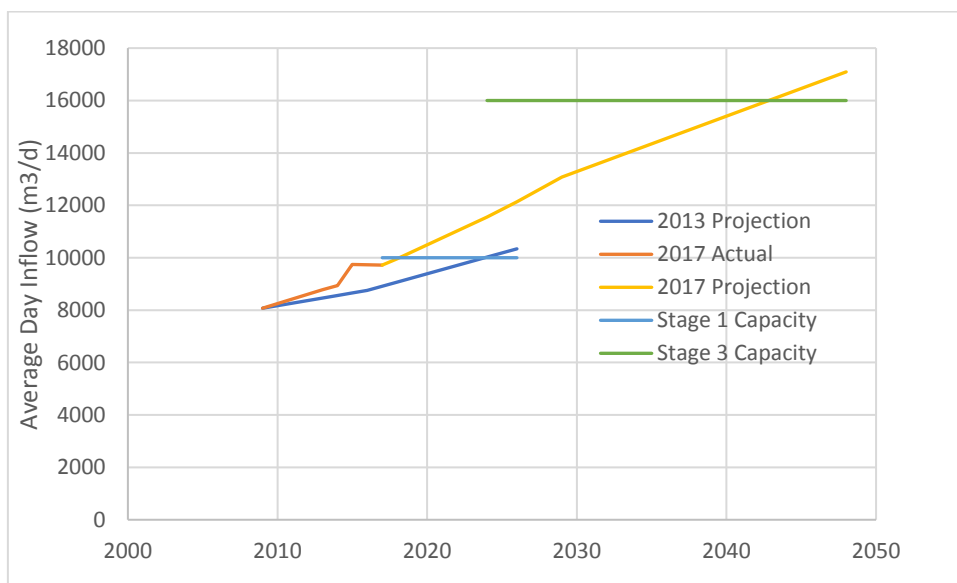
2 GROWTH IN THE WAKATIPU BASIN

Because the reputation of the District for its natural beauty, the adventure that it offers and the level of service provided to visitors is becoming widely renowned around the globe, the popularity of the District is growing rapidly, as are both its resident and visitor populations. With a current EP of approximately 42,400 (Residents PLUS Visitors), the Wakatipu ward is predicted to grow through to 2040 at a rate of approximately 2.6% compounding annually. Growth rates within that period however, will vary.

At the time, New Zealand was emerging from the global financial crisis and Queenstown was not immune to the effects, with several large developments such as the Hilton complex in Kelvin Heights and the Henderson development at Five Mile stalling. Flow and growth projections provided to the team in mid-2013 suggested a comparatively modest growth rate of approximately 1.4% compounding annually (from 8,068 to 10,000 m³/d over 15 years – see blue line in Figure 1).

In practice growth actually continued to increase at an average of 2.6% compounding annually. Actual resident population statistics provide a guide to growth only and, given the very high proportion of visitors making up the total equivalent population at any one time, are of little use in a wastewater context.

Figure 1: Project Shotover - Projected Flows and Capacity



The exact cause of the sharp increase in AAF in 2015 is unclear but it may have coincided with much of the new 'Five Mile' commercial / industrial area coming on line.

Table 1 below shows actual (2001 – 2013) and projected (2020 – 2040) Resident Population the Wakatipu Ward of Queenstown Lakes District (Adapted from Statistics NZ, 2013 and from QLDC 2017 'Final QLDC Growth Projections').

Table 1: Actual and projected growth rates for Wakatipu Basin resident population 2001-2040

Year	2001-A	2006-A	2013-A	2020-P	2030-P	2040-P
Res. Pop' ⁿ	11,910	15,276	18,294	25,124	30,688	36,428
P.A Growth		5.1%	2.6%	4.6%	2.0%	1.7%

3 HISTORICAL PERFORMANCE

3.1 HISTORICAL LOADING

At the time that Project Shotover implementation commenced, loading to the facultative portion of the pond system was approximately 191kg.BOD₅/ha/d (221mg/L, 8,068m³/d, 9.35 ha), At the time the ponds were built, pond design was typically to a Ministry of Works and Development (MWD) guideline of 84kg.BOD₅/ha/day. While later researchers and practitioners such as Mara have proposed more permissive, temperature based loading rates, for the climatic conditions experienced in Otago, even these more modern guidelines give similar loading outcomes to the old MWD guidance.

The treatment plant was configured as a three pond system with 60% raw inflow to pond 1, 40% raw inflow to pond 2 with all pond 1 effluent also entering pond 2. As Queenstown grew and other communities such as Arrowtown were added, loading increased significantly above the guideline values and 33 kW of supplementary aeration was provided to Pond 1 and 21 kW to pond 2.

3.2 HISTORICAL PERFORMANCE

The historical performance of the 3 pond Shotover WWTP, for the period 2011 – 2013 was as shown in Table 2. In 2013 the average daily flow was 8,068 m³/d.

Table 2: Historical Performance of Shotover Three Pond System

Parameter	Pond 1	Pond 2	Pond 3		Consent
	Mean	Mean	Mean	95%ile	Mean
cBOD ₅ (mg/L)	68	53	36	56	50
TSS (mg/L)	130	106	65	101	65
NH ₃ -N (mg/L)	30	32	31	37	25
TN (mg/L)	42	40	39	48	35
TN (t/yr)	Based on 8,068m ³ /d ADF		115*		
TKN (mg/L)	44	43	38	47	
TP (mg/L)	6	6	6	7	7.5
e. coli (cfu/100ml)	377,322	582,269	44,099	231,500	3.5x10 ⁴

4 NEW CONSENTS

In July 2015, final versions discharge resource consents for the treatment plant were issued by the Otago Regional Council. Table 3 below summarises the key numerical conditions of those consents. Table 4 makes a comparison of historical, current and staged future consented effluent quality requirements.

Some key points to note:

The new, long term consents principally target total nitrogen and e.coli reduction. Even with projected growth increasing flows and loads by an additional 80% over 2013 values, the ultimate consent requires a 74% reduction in discharged nitrogen load when compared to the load discharged in 2013.

Table 3: Performance Improvements Required by New Consents

Parameter	Improvement Required	
	Over existing performance	Over Raw Waste
cBOD ₅	72% reduction	95% removal (221mg/l)
TSS	85% reduction	97% removal (287mg/l)
NH ₃ -N	NA. Driven by TN	N/A (32mg/l)
TN	74% reduction	78% removal (46mg/l)
TN Load	54% reduction	78% removal (243 t/yr)
TP	No Change	Nil (7)
e.coli	3.6 log ₁₀ reduction	5.9 log ₁₀ inactivation (8.7x10 ⁶)

As can be seen from Table 5 below, the first-year performance of the MLE plant is 'proof of concept' for achieving the requirements of Stage 3 and beyond.

Table 4: Staged Discharge Consent Requirements

Consent		Historical		13.215.02**		13.215.04		13.215.03		2008.238.V1	
		To Water		To Water		To Water		To Land		To Land	
Expiry		April 2016		Feb 2017		Dec 2022		Dec 2031		Mar 2044	
Q _{ave}	m ³ /day	8,068		8,680		9,285		11,238		14,500***	
Q _{max}	m ³ /day			26,049		26,672				45,000	
		Mean	95%ile	Mean	95%ile	Mean	95%ile	Mean	95%ile	Mean	90%ile
BOD ₅	mg/l	50	100	50	100	30	50	30	50	10	20
TSS	mg/l	65	130	65	130	30	50	30	50	10	20
Amm-N	mg/l	25	30	35	40	15	25				
TN	mg/l	35	40	45	55	23	35	23*	35	10	15
TN _{trigger}	T/yr					73.2		73.2			
TN _{max}	T/yr			142.6		75.5		75.5		53	
TP	mg/l	7.5	10	7.5	10	7.5	10			8	10
e.coli	cfu/100ml	3 x10 ⁴	1x10 ⁵	5x10 ⁴	3.5x10 ⁵	260	260	260	260	10	100 (95 th)

* Effectively 18mg/l

** Temporary consent reflecting existing performance

*** Projected Average Day Flow at Consent horizon

Table 5: Stage 1 First Year Performance vs Current & future Consents

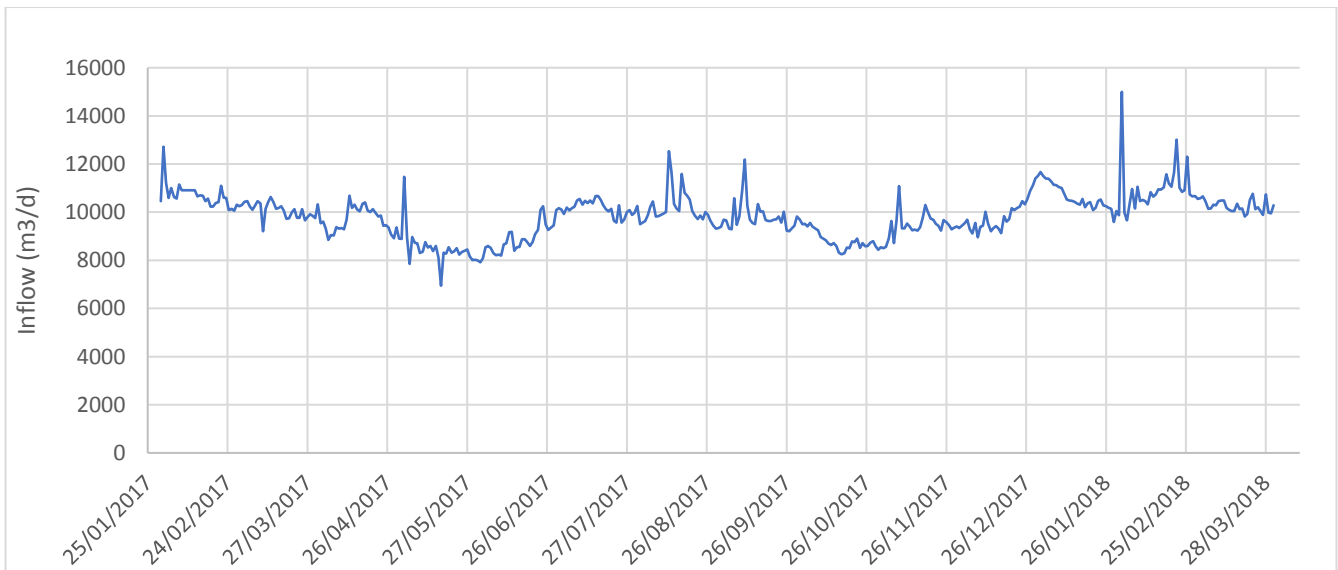
Consent		13.215.04		Stage1 Actual		Stage 1 MLE Actual		2008.238.V1	
		To Water		Blended effluent 75%:25% MLE:Pond				To Land	
		Dec 2022						Mar 2044	
Q _{ave}	m ³ /day	9,285		9,868		7,698		14,500	
Q _{max}	m ³ /day	26,672		14,998		8,900		45,000	
		Mean	95%ile	Mean	95%ile	Mean	95%ile	Mean	90%ile
BOD ₅	mg/l	30	50	6.0	11.8	Not sampled		10	20
TSS	mg/l	30	50	8.5	17.0	4.1	8.0	10	20
Amm-N	mg/l	15	25	10.1	16.4	0.1	0.3		
TN	mg/l	23	35	19.4	28.0	5.5	7.6	10	15
TN _{trigger}	T/yr	73.2		68					
TN _{max}	T/yr	75.5						53	
TP	mg/l	7.5	10	4.4	6.9	3.8	3.8	8	10
e.coli	cfu/100ml	260	260	20	81	Only blended effluent disinfected		10	100 (95 th)

5 WASTE CHARACTERIZATION

5.1 DAILY FLOW

Raw sewage feed to the treatment plant is through five separate pipelines from the various communities in the area of benefit. All are now individually flow metered. However, that was not always the case. In preparation for Project Shotover, there was reasonable dry weather flow data available. However, sewer network predictive modelling had been used to provide the team with peak flow information with which to go to tender. For the Stage 1 case, the predicted flows were: Average Day Flow (ADF) 9,960 m³/d, Peak Day Dry Weather Flow (PDWF) 14,609 m³/s and Peak wet weather flow (PWWF) 28,018 m³/d. So PWWF was predicted to be slightly less than three times ADF, which is not an unreasonable estimation for New Zealand Conditions. Figure 2 below depicts the actual net plant inflows over the first 14 months of operation. In practice, while the ADF has been 9,868 m³/d, Average dry Weather Flow² (ADWF) is 9,185m³/d, PDWF has been approximately 12,000m³/d and PWWF only 15,000 m³/d. This represents 1.6 x ADWF and 1.5 x ADF. While it cannot be considered that this represents actual PWWF, the rainfall events of that same period are significant enough that it can be said that the sewer system is comparatively tight and that PWWF is going to be significantly less than 3 x ADF. Typical rainfall events increase inflow by approximately 30%. For example, 22 May 2018, with 90mm of rainfall produced a daily inflow of 14,181 m³, or 1.5ADWF. This comparatively low wet weather peaking behavior is highly beneficial to smooth operation of the treatment plant

Figure 2: Net daily treatment plant inflows, first 14 months of operation



5.2 FLOW TRENDS

Figure 3 below shows the seasonal trends in plant inflow. These traces represent 30 rolling average net inflow to the treatment plant (net of plant recycles) there are two key points of interest from this information as follows:

² ADWF has been calculated as the 20th percentile of all net inflows

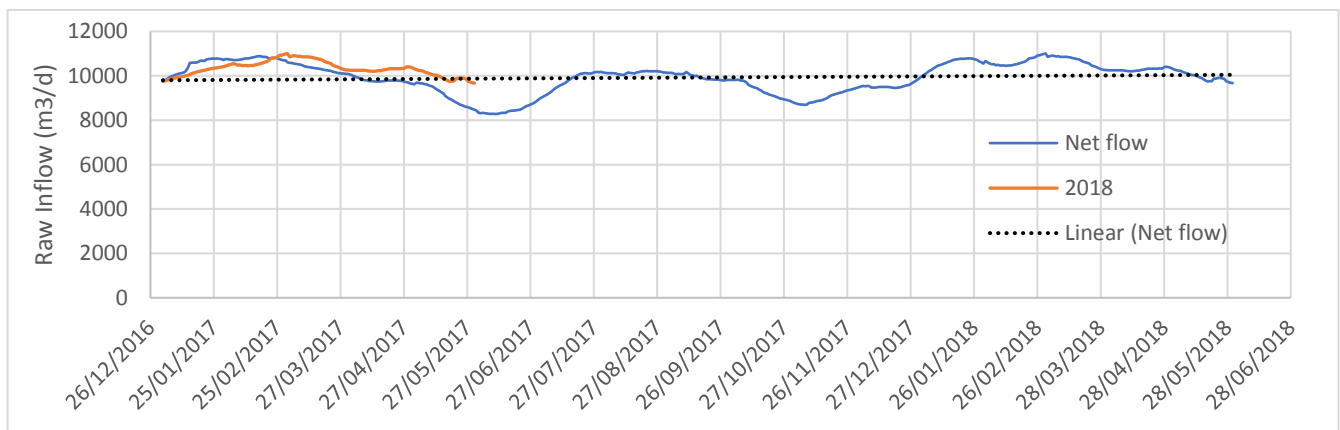
5.2.1 SEASONAL VARIATION

It would be expected of a resort destination that there would be pronounced seasonal variation in wastewater production, due to the influx of visitors taking advantage of the seasonal 'drawcards'. In the Wakatipu Basin, that might be expected to be snow sports from July onward and the Christmas new year break in mid-summer. However, such has become the popularity of this destination and such is the strain on accommodation, that the seasonal peaks and troughs have largely been flattened and there are only very short and not very pronounced shoulder periods. The measured variance from ADF was only 17% down to the troughs (June and November) and 17% up to the peaks (January & February). Again this small variance across the year is beneficial in terms of consistency of operation and minimizes the amount of plant process adjustment that must be made during the year.

5.2.2 GROWTH

Significant growth in flows to the treatment plant is being observed on a monthly and annual basis. Annual average flow (AAF) increases are shown in figure 2 above and discussed in section 2. These demonstrated a rate of growth significantly greater than projected in 2013. What is of note in Figure 3 is that the increasing trend appears to be continuing in 2018 and at a rate which is greater than the current planning projections of 2.5%p.a compounding. Since January 2018, the month on month comparisons with 2017 have been -1.9%, +3.7%, +1.8% and +14.0%. If these significant increases are restricted to 'off-peak' months, (i.e just maximizing use of accommodation across the entire year), the treatment plant capacity and that of Stage 3 are not greatly threatened, however the annual TN discharge load threshold is. This trend will be observed closely through the balance of 2018 and early 2019. While the already experienced growth between 2013 and 2017 means that Stage 3 of Project Shotover will be brought forward to around 2020, the current trend may dictate that an even closer look is taken at the ultimate capacity requirements for the plant and whether adjustments are required to the treatment train sizes allowed for in the current master plan.

Figure 3: Seasonal Variation -30 Day Rolling Average Inflow



5.3 WASTE COMPOSITION

In preparation for Project Shotover, QLDC invested in undertaking influent characterization analysis from 2009 to 2013. This resulted in the characterization shown in Table 6 below.

Table 6: Shotover WWTP Influent characterization

Parameter	Min	Max	Mean	95%ile
cBOD ₅ (mg/L)	88	360	221	290
Dissolved cBOD ₅ (mg/L)	2	130	63	98

Parameter	Min	Max	Mean	95%ile
Total COD (mg/L)	268	1980	601	829
Dissolved COD (mg/L)	40	349	143	203
Flocculated & Filtered COD (mg/L)	30	230	100	152
Ammoniacal Nitrogen (mg/L)	23	43	32	37
TKN (mg/l)	19	106	46	60
Dissolved TKN (mg/L)	23	44	34	41
DRP (mg/L)	2	6	4	5
TP (mg/L)	5	15	7	10
TN (mg/L)	24	120	46	54
Oil and Grease (mg/L)	5	384	100	216
pH	6.7	7.6	7.2	7.4
Total Alkalinity (mg/L)	101	361	189	220
TSS (mg/L)	130	2564	287	400
F.Coli (cfu/100ml)	2.9×10^5	33×10^6	8.7×10^6	24×10^6

This characterization and the extensive raw data set that lay behind it highlight that the Queenstown wastewater presents with an unusually high particulate slowly or unbiodegradable COD and consequently a lower than would be expected fraction of readily biodegradable COD. This was perhaps the most contentious and difficult of any issue that had to be dealt with during the Proposal preparation, evaluation and due diligence phases.

6 PROCUREMENT

6.1 SELECTION OF CLIENT'S ADVISORS

QLDC, in October 2010, appointed a professional advisory team in three parts. These being legal, technical and contractual to try to ensure that the best of historical experience and available skills was brought to the project. The technical team was from consulting engineer's CPG which brought the consents team, civil, process and structural engineering skill sets. The contractual team was selected from Opus International Consultants which brought significant previous experience in managing design and build contracts for wastewater treatment plants.

Immediately following the local authority election in late October 2010, the project was once again put on hold as the new Council reassessed the project. The team was reconvened in May 2013. At this time CPG had divided into a number of smaller private companies including LEI, ADI and Fluent Solutions. However, the individuals originally nominated as forming the advisory team all remained. A key success of this project was that from that point onward, the individuals involved, although from separate and competing companies, formed a close nit team that remained intact for the duration of the project. Another key feature of this team was that, internally, a 'best for project' approach was taken with people taking on responsibilities that they had not been engaged for, without getting 'precious' about protecting fees and margins. A key quality of the QLDC management of this team was that it was given the flexibility and the resourcing to ensure that a good outcome was achieved.

6.2 PROCUREMENT MODEL

Prior to the advisory team being appointed in 2010, Council had determined that the works would be procured under a design, build and operate model, using the comparatively new (2008) FIDIC 'Gold' Book for Design, Build and Operate. This decision was partly helped through demonstration of successful 'Design and Build' wastewater outcomes at Thames Coromandel and Western Bay of Plenty Districts using very similar FIDIC based models.

During the 'On-Hold' period the existing inlet works became almost completely dilapidated and at very high risk of complete failure. Opus was engaged to provide a concept and detailed design for and to manage construction of a new inlet works that would be capable of serving the existing and ultimate treatment plants. This and other ancillary services and replacement of associated trunk sewers cost approximately \$3M.

A prequalification process was used in late 2013 and, from that, three consortia were chosen to bid for the project.

The Design and Build procurement process encourages bidders to economise because they are not given a specific design to price and are trying to find all avenues possible by which to gain a cost advantage over their competitors. This has led to problems in some previous DB / DBO contracts where the Employer has found it very difficult to achieve exactly the quality they want for the price they have agreed i.e. there is significant price / quality ambiguity remaining when the contract is signed. The Council team therefore assembled a comprehensive set of 'Employer's Requirements' that set out the minimum requirements for undertaking the work on site, process expectations and the minimum technical standards to which the various work types had to be designed and constructed, commissioned then operated. The prescriptive nature of these specifications was a key learning from the Project Pure (Wanaka WWTP) experience, to help ensure the desired outcomes were achieved.

Significant focus was also placed on ensuring the project risks were apportioned to the party most appropriately placed to manage the risks over the life of the project. The specifics of the risk allocation are discussed in Section 9.2.

6.3 PROPOSAL DEVELOPMENT

A relatively conventional Design and Build proposal development process was used which included a common briefing followed by a series of confidential one on one meetings where Proposers were encouraged to come with their teams to discuss, with the Employer's team, the development of their Proposal and any issues they were experienced. A probity auditor was appointed to oversee all 'in confidence' interactions between the Employer's Team and each Proposer. This is a common practice to minimise the risk that any party is given important information that is not available or provided to others or that confidential information is not transferred from one party to another. In many of the interactions there is a hold point to determine whether the issue for discussion is actually confidential or needs to be shared with other Proposers.

The key issue that arose during this period was that two of the design teams did not accept the wastewater characterization as presented, despite the length of the data record. The COD fractionation did not sit within the default or limits normally accepted in the two most commonly used commercial biokinetic models (BioWin and GPS-X) for the activated sludge biological process. A review of the laboratory testing methods indicated that the unusual characterization was not likely to be because of a laboratory protocol error. This issue was not resolved until late in the evaluation process. The implications and resolution method are discussed further in section 6.4 below.

Two parties submitted full proposals. One withdrew without making a submission. One party, Downer submitted two proposals. One a well known, 'safe' Modified Ludzack-Ettinger (MLE) based technology and the other an innovative, technology (Organica) using an aeration system and hydroponically grown plants. The commercial part of the Proposal was 'closed' 1 week after the technical offer to allow proposers time to concentrate on adequately finalizing the price after all technical work was completed and to allow a 'head start' to be made on the technical evaluation.

6.4 PROPOSAL EVALUATION

The proposal evaluation and associated due diligence was a protracted process which was frustrating and expensive for all parties. All up, this took a year to progress through to Contract award. A significant portion of this time was due to two enforced stops made by Council during the process to review the procurement process, and to change legal teams. Neither of these stoppages resulted in any material changes to the approach being taken.

The process commenced with an evaluation for 'completeness'. Requests were then made for the information required to complete technical evaluation. Technical evaluation followed to a) ascertain the suitability and robustness of the technical solution offered and to identify both explicit and implicit 'tags' contained in the offer. It is critical for these, intended or otherwise (many appear simply as a result of ambiguity of lack of explicit detail in the Proposal) to be dealt with and closed out prior to contract award. Any ambiguity carried over into the contract is likely to result in additional cost later. All three Proposals contained numerous issues that needed to be dealt with in this manner. This took considerable time.

The Downer Organica proposal was very innovative and appeared promising. Given its nature, it would also have had significant political support. Considerable effort was put in into evaluation of the proposal, however, in the end, the proponents were not able to demonstrate a site where it had delivered the nutrient removal capabilities required at Shotover, and there was no ready way of using first principals or commercial modelling to test the likely efficacy and as such it was eventually discarded.

The two remaining proposals involved MLE and intermittently decanted extended aeration (IDEA) process configurations. Both are robust and both were known to be capable of delivering the level of treatment envisaged by the Stage 3 consent conditions. The Downer MLE proposal included a 63:37% split between the new plant and ponds with 10 years capital deferral until the balance of plant was built. The IDEA proposal was to build all required Stage 3 capacity at Stage 1, in a single large reactor. This proposal provided no means of achieving capital deferral.

The key technical issue for resolution (and the one which took most time) was how the measured COD fractionation would be adequately accounted for in the accepted Proposal. The implications of the high F_{up} and low $rbCOD$ included higher than normal sludge production and potentially the need for a supplementary readily biodegradable carbon source to achieve the required levels of denitrification. It is beyond the scope of this paper to go into all the detail of how this was worked through. However, in the end, the Employer negotiated an additional sum into the contract value to provide an additional 15% capacity into the treatment plant to ensure that the sludge management and denitrification facilities were sufficient to comfortably provide the required performance without supplementary $rbCOD$ addition.

Following completion of the technical evaluation and marking, the commercial proposals were opened and evaluated. By contrast with the technical queries, the commercial conditions were largely as would be expected with a Contract of this nature and were comparatively easily dealt with and settled.

7 DESIGN AND CONSTRUCT PHASE

7.1 OVERVIEW OF UPGRADE

The accepted proposal put forward by the Downer/Jacobs team consisted of a new activated sludge reactor, clarifier, ultraviolet disinfection plant (UV), septage reception facility, sludge dewatering facility and associated equipment.

The overarching philosophy was to utilize the pond based system, to streamline the capital expenditure so as to align with the staged resource consent that had been negotiated with Otago Regional Council (ORC). In this arrangement the incoming flow is split, following preliminary treatment, between the new activated sludge process and the pond system, with the effluent streams from each process being blended prior to ultraviolet (UV) disinfection.

The plant was designed to treat wastewater to the quality as described in Table 4. The new MLE process working in conjunction with the existing ponds was designed to accommodate the wastewater flows as set out in Table 7 below.

Table 7: Summary of Design Flows

	Stage 1	Stage 3
Peak day dry weather flow (l/s)	311	438
Peak instantaneous wet weather flow (l/s)	522	609
Full flow to treatment through MLE process (l/s)	215	430
Average day flow, ADF (m ³ /day)	9,960	14,391
Peak day dry weather flow, PDWF (m ³ /day)	14,609	21,137
Peak wet weather flow , PWWF (m ³ /day)	28,018	32,979

7.1.1 GRIT REMOVAL AND FLOW SPLITTING

The upgrade to the treatment plant completed in 2013 did not include a facility for grit capture. The pond based treatment process was not sensitive to grit, however, moving to a mechanical treatment process meant this was a necessary inclusion to protect the downstream equipment.

The screened wastewater leaving the screens enters a vortex grit removal system to remove sand, grit and other fine inorganic materials. The chamber is designed to induce vortices in the flow of wastewater which encourages the inorganic material to settle to the bottom of the chamber.

The collected grit is then pumped through to a grit classifier where the grit is dewatered prior to being conveyed into the shared screenings bin. The water separated from the grit is conveyed by gravity through to the inlet works wastewater pump station from where it is returned to the head of the works.

7.1.2 REACTOR TANK

The Activated Sludge treatment stream utilises the MLE process. The main reactor consists of several zones: three pre-anoxic zones, an anoxic zone, swing zone, and aeration zone.

MLE 1 receives screened sewage into Pre-Anoxic Zone 1 and RAS from Clarifier 1, the two streams are perpendicular to promote mixing. The exit from each Pre-Anoxic zone has 900 x 900mm undershot port which transmits approximately 80% of the flow, with the remaining portion passing over a 2m wide drowned overflow. The A-Recycle discharges in front of the undershot port from pre-anoxic

Figure 4: View across MLE reactor (Anoxic Zone 4 in foreground)



zone 3, again to promote mixing of the two streams. Approximately 83% of the flow from the Anoxic Zone discharges through a 1.7 x 1.7m undershot port in the diametrically opposed corner, and the remaining portion passes over a 6m wide drowned overflow above. There is a similar undershot and overflow arrangement between the Swing Zone and the Aeration Zone.

Mixed liquor flows over the outlet weir and is transferred to the clarifier via a DN900 pipeline.

7.1.3 CLARIFIER

The Clarifier is 34m in diameter, 5m side wall depth, and equipped with a syphon lift RAS withdrawal system. Scum on the clarifier surface is carried to the scum box by the scum skimmer. The scum box opens when the bridge and skimmer passes and the Scum Pump delivers scum to the WAS Holding Tank. Scum may be diverted back to the MLE reactor if not of a filamentous nature, reducing the water content of the WAS to centrifuge.

Return Activated Sludge (RAS) is recycled from the Clarifier syphon withdrawal system back to Pre-Anoxic Zone 1 of the Bioreactor, via two dedicated dry mounted pumps. WAS is split from the RAS line and directed to the WAS Holding Tank

Figure 5: Clarifier tank (RAS pumps in foreground)



7.1.4 UV DISINFECTION

Clarifier effluent and pond effluent from the Pond Discharge Pump Station combine in the blending chamber, then gravitate through the channel UV disinfection system. The concrete channel has been designed to accommodate two rows of seven banks of UV lamps (Banks A to G). The second series of banks is planned to be installed at a future time in a section of the channel that is isolated by removable concrete inserts in Stage 1. A motorised downward opening penstock controls the level in the channel so that it is in the required range for disinfection and is essential for disinfection performance.

The output of the Pond Discharge Pump Station is controlled to minimise fluctuations in flow and UV transmittance that would require banks to be switched on and off. The target flow is a percentage of total UV flow that is determined from a table of blend percentage set points vs. UV transmittance. During periods of flow lower than the feasible output of the pump station, the pumps operate periodically so that the required flow is achieved without an excessively high proportion of pond effluent. The pumping 'periods' are sufficiently long that UV flow changes infrequently.

The UV system is designed for a peak instantaneous flow to disinfection of 275 l/s. The design water quality of the effluent entering the system is E.Coli of 1×10^7 cfu/100ml, maximum TSS of 25mg/l, and a mean UVT of 40%.

7.1.5 SOLIDS PROCESSING

Part of the RAS flow is split as Waste Activated Sludge (WAS) and directed to the WAS Holding Tank. The WAS flow rate and volume is controlled by a WAS line actuated valve and a RAS line actuated valve, with measurement by the WAS Flowmeter and RAS flowmeters. The system wastes each day to achieve a daily volume set by the operators

via the PLC. When the system is asked to waste the WAS actuated valve opens and the RAS control valve restricts to a set position to encourage flow to the WAS tank.

The WAS tank is a glass coated steel tank with a top water depth of 5.3 m, giving a working volume of 100 m³. The tank is intended as a holding tank to keep a store of WAS to allow for continuous WAS processing. The tank is continuously aerated to prevent odour generation.

Two progressive cavity pumps feed WAS from the holding tank to the dewatering centrifuges. The pumps are operated via VSD and have a maximum flow rate of 20 L/s. Sludge is pumped from the WAS feed pump station into either of the two centrifuge units. As the sludge pipework enters the dewatering building, polymer is dosed into either of two locations along the pipework, one located just inside the building, and secondly just prior to the WAS entering the centrifuge feed chamber (normal dosing point).

Figure 6: Sludge bins and loading conveyors



The sludge enters the centrifuge feed chamber through a central pipe. The denser solids settle against the bowl wall under the influence of the centrifugal force implied on it by the rotating bowls of the centrifuge. The lighter liquid is clarified from the bowl by flowing to the liquid discharge port via an adjustable weir, which determines the clarifier pool depth. Solids deposited on the bowl wall are transported towards the conical end of the bowl by the internal conveyor scroll to the discharge ports. A series of three shaftless screw conveyors, conveys the dewatered sludge from the dewatering building into one of two self levelling bins. The centrate produced by the process is drained under gravity to the site waste pump station, from where it is conveyed back to the head of the works. The centrifuges are designed to process at a rate of up to 550 kg/hr, with a feed solid of 0.8%.

7.1.6 POND PROCESS STREAM

The facultative ponds are silt-lined ponds with concrete wave bands, which are approximately 1.35m in depth. Pond 1 has an area of 5.5Ha and Pond 2 has an area of 3.9Ha. All three ponds were de-sludged in November 2012.

Both of the facultative ponds have mechanical aerators to add additional oxygen to the ponds to assist in the breakdown of the organic matter. Pond 1 has seven Tornado 3kW horizontal mixing aerators with subsurface propellers which are mounted on floating platforms and four fixed position 3kW paddle wheels aerators. Pond 2 has four Tornado 3kW horizontal mixing aerators with subsurface propellers which are mounted on floating platforms and three fixed position 3kW paddle wheels aerators.

Following the facultative ponds the effluent is polished in a single 6.5Ha maturation pond which has a depth of 1.5m. The pond contains a rock groyne which is used to direct the flow, increasing the retention time in the pond. The maturation pond is used to reduce faecal coliform levels via treatment from the sun light and the retention time allows algae passed over from the facultative ponds to settle out.

The Pond Pump Station is designed to lift effluent from the maturation pond (Pond 3) to the blend chamber at the head of the UV channel.

The inlet to the pond pump station comprises of a concrete headwall and two DN450 stainless steel pipes, each inlet pipe is open to the atmosphere, while the downward facing intakes are located approximately 550mm above the floor of the pond to limit the amount

of sludge or solids drawn into the pump station. The vertical pipes to atmosphere serve as baffles to prevent the top 500mm of algae rich water being drawn into the pump station. An isolation valve has been placed on both DN450 pipe lines entering the pump station.

The pump station comprises of two 22kW pumps operating in a duty/assist configuration. The pump station is capable of conveying up to 240L/s to the UV channel. Each pump discharges into a DN300 stainless steel line with a non-return valve and manual isolation valve. These lines are then coupled into a DN400 line and pass through a single flow meter prior to entering the UV blend chamber.

7.1.7 ODOUR TREATMENT

The plant includes an odour removal system for treatment of foul air extracted from the following areas:

- Sludge thickening / dewatering centrifuges
- Sludge out loading conveyor / bins
- Site Wastewater Pump Station
- Septage Facility Septage Holding Tank

The unit includes a biological scrubber followed by a carbon bed for polishing. The lower section of the scrubber contains media that supports a film of biomass. Sprays distribute recycled effluent across the media which trickles down in the opposite direction to foul air and exits via a drain to the site waste pump station. Above the sprays is a layer of carbon media, which adsorbs any remaining odorous compounds. The top of the unit is formed into a vent, where treated air exits to the atmosphere.

Figure 7: Odour treatment system



The system is designed to treat up to 1,280m³/hr.

7.1.8 SEPTAGE RECEPTION

The new septage reception system is designed to provide a controlled collection and metering of the septage loads to the plant. The storage tank allows the septage to be fed into the process in a controlled manner so as to avoid shock loading.

The septage trucks connect to the system at a male camlock fitting on the inlet to the rock trap. The rock trap is designed to capture heavy debris. The collected material is dumped manually by actuating the valve beneath the rock trap, into a basket. The incoming septic waste is macerated prior to being pumped into the holding tank.

Figure 8: Septage reception system (mixing and transfer pumping system visible)



Access to the system is via a swipe card system. Upon swiping a legitimate card the actuated valve will open, the macerator will start and the inlet pump will also start. At this point the flow meter will commence logging such that a disposal record can be created against the card ID.

The septage discharge pump transfers septage to the site waste pump station, allowing the fluids to get mixed with site wastes prior to transferring to upstream of the inlet

screens. The Septage return pump is a positive displacement pump to assist with keeping a constant flow rate of 2 L/s being pumped from the septage tank.

7.2 DESIGN PROCESS

7.2.1 GEOTECHNICAL CONSIDERATIONS

A key aspect of the design that was not recognized by the Downer/Jacobs team during the tender stage was the liquefaction potential of the site. Further analysis and testing post award identified that the site posed a higher risk than initially thought, and that additional treatment was necessary to mitigate the associated risks of developing in the selected location.

Learnings from the Canterbury earthquake also played a part in how the information available at the time of tender was interpreted both pre and post tender. A significant component of the geotechnical information made available to the proposers pre-dated the earthquakes and some of the risk assessments made in these reports was inconsistent with the thinking of the geotechnical community following the Canterbury events.

The primary geotechnical considerations for the design and construction of the upgrades were; the relatively loose near surface sands and gravels and, the relatively high ground water level. Ground improvement in the form of densification of the near-surface soils was deemed necessary to provide uniform support of the structures comprising the new plant.

Densification of the upper layer of loose silty sand and gravel, and the placement of a geogrid under the structures was provided to produce post liquefaction differential settlements of 1/750 or less across the structures.

A Broom's roller was used to densify the upper 2 to 3 meters of ground in the area of the large structures (MLE and clarifier). Due to existing services and features this treatment could not be applied universally across the site for all structures, and where improvements by densification were not possible, a 3m deep gravel raft was constructed to reduce the effects of liquefaction.

The Settled Effluent Chamber was unique due to its location, and was constructed on a series of steel 'H' piles. The piled design consists of eight piles driven to approximately 6m deep.

The late realization of this key design consideration placed significant challenges on the project programme and required the construction team to reassess the proposed methodology of the MLE reactor to minimize delays through the project critical path.

7.2.2 PEER REVIEWS & CLIENT REVIEWS

An element of the design phase, which had a material impact on the design process, was the involvement of peer reviewers, the requirements for which were set out in the Employer's Requirements. The Contract required the Contractor to undertake peer reviews for critical elements of the work, including:

- Geotechnical design
- Process design
- Structural design

In addition to these reviews, all design information was required to be submitted for review by the Employer's advisory panel. A key challenge developed through the design stage regarding the timeframes associated with these reviews, coupled with inconsistencies in feedback received between the client review and peer review.

These review processes are essential for ensuring the project outcomes are consistent with requirements and wider expectations. They provide an opportunity for assumptions to be challenged, and also for additional investment to be considered by the client to add value.

On reflection, the contracting organization could have improved the efficiency of this process by including these steps in the design phase programme developed as part of the tender. This exercise would have demonstrated how critical these functions were in regard to overall project timing, as well as the overall programme sensitivity to any review processes requiring multiple iterations. This information would have helped all parties better understand risks to the critical path associated with the significant number of reviews required, and may have motivated a more collaborative approach to streamlining this process.

7.2.3 DESIGN WORKSHOPS

Throughout the design phase a number of workshops were held, bringing together the various stakeholders to try and streamline the design process, and bring all parties along on the journey. In total three workshops were held, as described below:

- ***Design 'Kick off' Workshop (1 day)***

This review was largely focused at a Process and Instrumentation Diagram (P&ID) and general layout level. Having an early workshop allowed the design team an opportunity to present changes and improvements they were considering from the tender design. One such change was the relocation of the dewatering room to be adjacent to the reactor tank with a shared wall with the tank (the tender showed this as a shared building with the operators).

- ***HAZOP 1 Workshop (2 days)***

This workshop formed the first formal workshop as required under the contract. This was conducted as a hazard and operability (HAZOP) study facilitated by an independent specialist. During this session each aspect of the design was assessed in detail, through pre-determined nodes, against a set of keywords representing possible modes of failure, or unusual operation. The response of the system was assessed in each condition and deficiencies noted for action by the design team.

A challenge at the time of this workshop was that the design team were waiting on some suppliers to deliver detailed design information in order for them to complete aspects of the design. This precluded these aspects of the plant from being reviewed to the same level as the other features.

- ***HAZOP 2/Safety in Design Workshop (3 days)***

The final workshop was held in November 2015, when the design work was largely complete, and detailed layouts of each process area were available. A key outcome from the workshop was that a review of the location of the septage facility was triggered to allow for better traffic movement, and allow for the system to be more easily serviced by the odour removal system. The change saw the septage system relocated to the same side of the access track as the odour system and site waste pump station. This removed a pipe bridge spanning across the road for the odour ducting, with the advantage of deleting the operational task of condensate drainage, and eliminating the risk of over height vehicles damaging the pipe bridge.

7.2.4 VENDOR DELIVERABLES TO INFORM DESIGN

A challenge across the design phase of the project was achieving the required level of vendor design input in the constrained design timeframe. The typical issues in this regard were complicated through changes made during the contract negotiations. These changes, along with the significant time that had elapsed since the tender selection were made,

meant that a number of the equipment selections at tender time needed to be revisited for the revised requirements. The process of amending specifications, tendering, evaluating and awarding consumed a significant amount of time, and prevented aspects of the detailed design from being progressed within the intended programme.

Compounding these challenges was the intention for a small number of the supplier packages to be completed as 'design and build', most notably the aeration system. The introduction of these supplier led design packages caused some interfacing difficulties, requiring the parties to work together to resolve.

7.2.5 'JUST IN TIME' DESIGN DELIVERY

Given the relatively short planned design phase of 6 months, combined with the complex nature of the facility, the incremental delays associated with review process, the geotechnical issues, and delays around vendor design information became a significant concern to the project team.

To offset the consequences of these factors, approval was sought on certain elements in isolation to feed work through to the construction team such that work on critical path items could progress prior to the design as a whole being accepted.

At a high level some of the early/individual works approvals were:

- Long lead time equipment
- Ground improvement works
- MLE reactor tank
- Clarifier structure
- Blower Building
- Dewatering building
- Operations building

This approach ensured the consequence of design slippage on the project critical path could be managed. In a conventional procurement model this approach would not be possible, and project delays would have been unavoidable.

7.3 CONSTRUCTION

7.3.1 CRITICAL PATH

The project critical path primarily ran through the MLE tank structure, mechanical fit out, electrical works and commissioning. The MLE tank had shared walls with both the blower building and the dewatering building, and as such the downstream consequences of delays associated with this structure would be significant. This was the critical path identified at project inception and this was representative of the actual critical path.

Hydrostatic testing of the MLE tank had substantial programme implications due to the volume of water required for the test, restrictions on rate of fill and the risk of failure. Ultimately the tanks required re-test as a result of the appearance of fine longitudinal cracking, observed when under test with unacceptable levels of seepage. These cracks were treated with a surface applied crystalline treatment which reacts with the water and un-hydrated cement to form crystals which fill pores and micro-cracks.

Given the treatment process is a biological system, the length of time to culture the biomass to provide the desired level of treatment was a distinct programme risk.

7.3.2 MLE REACTOR CONSTRUCTION

The MLE tank was built as a fully poured in-situ concrete tank. Upon commencement of the reactor construction the project was tracking behind the baseline programme. To offset

the early delays the construction approach was reviewed to enable some of this time to be recovered. The final methodology allowed for larger concrete pours than originally planned, this reduced the number of construction joints to be catered for and allowed larger crews to work on the structure at one time. To facilitate this change in methodology the quantity of formwork available at one time needed to be increased.

The floor slab was constructed in two pours, each of approximately 400m³. At the time these were the largest concrete pours ever completed in Queenstown and required detailed planning to ensure continuity of supply. The pours were completed at night for two key reasons; the cooler temperatures and the lower volumes of traffic.

The exterior walls were also poured in two sections, each of around 120 linear meters with a height of 6.2m. Special Doka formwork was brought in from overseas suitable for the concrete loading at this height. The reinforcing steel was pre-tied in panels (on-site) that could be lifted into place against one side of the formwork. This allowed the steel tying activities to be advanced whilst the inner formwork was erected. The steel fixers then attached the splicing steel with the carpenters placing the formwork immediately behind them. Panel vibrators were used during the pour to help ensure the concrete was effectively vibrated across the full height and width of the pour.

7.3.3 CLARIFIER CONSTRUCTION

The clarifier tank consisted of a poured in-situ concrete base, and precast, post tensioned walls. The pre-cast panels were precast locally in Cromwell. The clarifier mechanism rotates about a central column on the top of the clarifier walls, due to this precision placement of the cast-in centre column and precast panels was essential to ensure correct operation.

7.3.4 GRP DISCHARGE PIPE

Another significant element of the construction was the 1-kilometer section of DN1000 GRP discharge pipework between the clarifier and the UV chamber located at the outlet of the ponds. The pipe route was adjacent to the existing ponds and a busy track, which provides access to two of the local quarries as well as forming part of the Queenstown cycle trail.

The length of trench open at any one time was minimised to reduce the risk of pond embankment breach, which would have had significant adverse environmental consequences.

7.3.5 CLOSE OUT

The project had a substantial requirement around handover documentation at completion, including the O&M manual, as built drawings, asset register, producer statements etc. The volume of documentation involved meant that the collation, submission and subsequent review of the information was a lengthy process. A learning from the experience on this project was that starting this process earlier, and addressing elements of this handover package as the project progressed would have streamlined the process, and managed the associated workload for all parties.

8 COMMISSIONING AND OPERATIONS

8.1 PLANT SEEDING

The plant was brought into commission without the use of an imported seed sludge. This decision was made to avoid carrying over issues from other plants (such as filamentous bacteria) and allowing the new process to have a 'clean slate'. The plant commenced receiving wastewater in November 2016, slightly later than planned, but more favorable from the perspective of establishing the biomass due to the warmer temperatures.

The location of the plant, adjacent to SH6 and in full public view meant that all parties were very conscious that common commissioning issues such as foaming or odour could have significant reputational damages for QLDC, especially coming in to what was peak tourism season. To manage the risks in this regard sewage was introduced very slowly, at a fixed volume per day, and the levels kept low. This allowed any foaming to be kept within the tank, without risk of being picked up by the wind. The sewage was well aerated at all times which prevented odours.

Over time the level within the tank was steadily increased until all the facilities could be brought into action i.e. mixers and A-recycle pump. At around day 30, sludge wasting was commenced through the centrifuge. Discharge from the clarifier was closely monitored and initially returned to the pond process prior to disposal. As the volumes increased return of the effluent to the pond was no longer possible and the effluent was passed, following UV treatment, to disposal. The MLE effluent at this time was equivalent, or better in quality to the pond effluent. Initially the pond effluent was maintained through the existing outlet, without UV treatment, this continued until the MLE effluent was within the desired quality range. At this time the pond pump station was commissioned and the blend control configured.

The blend proportion was gradually increased until the desired flow split (63% MLE to 37% pond effluent) was achieved. During this time the key parameters were monitored to ensure the required disinfection requirements were complied with.

An identified risk leading into this aspect of the plant commissioning was the potential ultraviolet transmittance (UVT) of the blended stream. The design had been based around an average of 40% and on site trials during the construction phase indicated this may be difficult to achieve. To date this has not been a problem.

8.2 PERFORMANCE TO DATE

Table 5 in Section 4 summarised the plant's performance over the first year of operation. From this information it is evident that the new plant is performing well, with the effluent quality within the required consent limits, and that a 2 train MLE will be able to meet Stage 3 effluent quality requirements.

However, a challenge that has arisen relates to the performance of the original pond system. The design assumed an improvement in the performance of the pond process with regard to Total Nitrogen (TN) removal as a result of the reduced loading (approximately a two third reduction). In reality, whilst the pond performance has improved due to the reduction in load (as measured by BOD₅ and TSS in the effluent), the pond system is not achieving a notable reduction in TN. To offset the poorer than anticipated pond performance in regard to TN it has been necessary to treat more of the incoming sewage through the MLE plant than was the design intention.

At the completion of the first year of operation the influent flow split was sitting at approximately 70%, as compared with the design of 63% (a 10% increase in flow to MLE).

This issue combined with rapid growth in the Wakatipu basin is putting pressure on the mass load of TN into the river. The trigger point for the subsequent upgrade is exceeding a discharge of 200kg/day. At the end of the first year of operation the plant was discharging an average of 192kg/day.

9 LESSONS LEARNED

9.1 LEARNING FROM PROJECT PURE

Project Pure (P.Pure), a new wastewater treatment serving Wanaka, was the predecessor to Project Shotover. There were a number of failings with the project which lead to a difficult outcome for Council. There was therefore considerable nervousness within Council over a similar but larger undertaking at Shotover. Nervousness at both the project size and procurement method. Nevertheless, based on observations of other successful DB / DBO projects around the country, QLDC did decide to proceed with Shotover as a single design and build contract.

Key learnings from P.Pure, which were carried forward to development of the P.Shotover procurement process were as follows:

- The Employer's requirements needing to be more prescriptive, while allowing for the generalised nature of the approach to process selection. For example, "If you wish to use this equipment, these are the minimum acceptable requirements for such equipment". Another example is having the contractual effluent quality requirements slightly more stringent than the discharge consent conditions in case there are misinterpretations of the statistical compliance meanings.
- Invest in good quality influent characterisation data. By all means provide a summary of that data but require that Proposers interrogate the full data sets for issues such as seasonality and legitimate 'outliers'
- Use of purpose written Design and Build Conditions of Contract rather than relying on a rewrite of NZS3910.

These learnings were necessary to reduce the risk to Council of an overall project failure while also providing the opportunity to more equitably apportion key individual risks as described in section 9.2 below.

9.2 TREATMENT OF KEY RISKS

A comprehensive risk register was developed at the start of the Project Shotover procurement process and maintained and update all the way through the project.

The following table provides a very brief description of how key implementation risks were addressed in Project Shotover. The team attempted to assign these mitigation strategies and risk assignments on the basis of the party best able to manage the risk. All too often it seems contractors are required to cover the risk of circumstances over which they have no control or ability to mitigate (through investigation or other means). The result is that the owner pays a significantly higher (than necessary) price for the works. The risk assignments are presented here in the context of a design and Build procurement model.

Risk	Risk Allocation & Comments
Influent beyond limits in Employer's Requirements	Employer: This is an issue over which the Contractor has no control. Part of the mitigation is to 'require' that contractor builds in additional capacity. Part of it is for the Employer to maintain an appropriate contingency fund and for a master plan that provides for expansion.
Effluent Quality	Contractor: While the influent flows and loads remain within prescribed limits, it is the D&C contractor who has control over this. Facility needs to be provided so that if the influent flows and loads venture outside the required limits, there is a mechanism for calculating fair reparations, rather than this being a one sided, carte blanche process.

Obtain Discharge Consents	Employer: This is an issue over which the Contractor normally has no control. It is not recommended that responsibility for obtaining discharge consents be placed upon the Contractor. He/she should only be responsible for obtaining temporary, construction related consents.
Geotechnical	Shared: In order for the designer to take responsibility for their design, they need to be given the geotechnical information that they want. In this case, all D&C bidders were requested to specify what geotechnical information that they wanted. An investigations contractor was primed and ready to start work so that the investigations could be done early in the bid phase in order to inform the proposal designs and pricing.
Contaminated Ground	Shared: The contractor cannot be expected to ascertain the presence or extent of ground contamination during a tender or proposal preparation period. In this case, the Employer had a HAIL investigation undertaken and had identified at least one measure for management of contaminated soil that was expected to be encountered. From that point, it was the responsibility of the Contractor to handle and manage the contaminated soils appropriately.
Forecasts of future flows and loads	Employer: Only the Employer can take responsibility for this. Even though they may not have much more influence than the Contractor, the Employer does maintain control over the Planning function of their organization and so has a better understanding of likely growth than the Contractor ever can.
Noise and Odour	Contractor: While the Employer can greatly assist by providing appropriate buffers to sensitive areas such as residences, these are known constraints during the tender / proposal preparation period (i.e they are not an unforeseen circumstance). The Contractor can therefore take account of them in their design and the Employer will pay accordingly as a component of the tendered price.
Funding	Employer: The Employer must take the risk for funding the project. After all, it is they who will reap the benefits of the work. That does not mean that the Contractor is not meant to be the source of the funding. That <u>can</u> be a requirement of the contract. The Employer will then pay accordingly for the costs of sourcing the funds and paying the interest and capital at the nominated times.
Cost Escalations	Shared: In this case, because the design and build phase of the contract was a relatively short period, 18 months, and within a relatively low inflation environment, Council required the Contractor to manage escalations. Because the Proposal Evaluation process was protracted, and that in turn led to an unfavourable starting season, an escalation cost <u>was</u> actually agreed upon prior to contract award.
Foreign Exchange Rate	Contractor: Advice would typically be for the owner / employer to manage the exchange rate risk: <ul style="list-style-type: none"> • Most large organisations have some form of facility to manage FOREX. So some of the cost of cover is already committed anyway. • If you do not have hedge contracts, there is just as much likelihood of making on the deal as loosing. • If you make the Contractor manage – you will pay. If you choose to manage it yourself, you might pay. <p>In this case, probably again because of the relatively short duration, QLDC asked the Contractor to manage.</p>

Consumables during operation	Shared: The Contract includes a 5 year operate period in order for the Contractor to demonstrate OPEX, effluent quality, plant capacity and build quality. Certain guarantees must be met including the use of consumables such as power, chemicals, labour and sludge production. The total use is the Employer's care as they control how much wastewater comes into the plant.
Insurance	Shared: Because it was an already operational site, QLDC covered insurance of the new and existing works. This is readily covered as part of a very large insurance portfolio across the district, probably more economically than could be provided by a Contractors Insurer.
Operation of existing site	Shared: Because of potential interfacing issues in the operational site, the Contractor was made responsible for operation of the existing WWTP, from the time of possession of site, but within the bounds of compliance pre-existing before they took over.
Plant performance	Contractor: As they were responsible for design and construction and commissioning, the Contractor was made responsible for the performance of the treatment plant on condition that loading remained within a small margin of the prescribed design limits. Initial proving was required to be over a very intensively monitored 60-day period post commissioning. This would allow a commissioning certificate to be awarded and the 5-year operational proving period to commence.
Plant construction quality	Contractor: Again, as designer and builder, the Contractor was made responsible for the quality of the build. This also is required to be demonstrated over the 5 year operations period.

9.3 IMPLICATIONS, CHALLENGES AND ADVANTAGES OF DESIGN BUILD

Design-Build (DB) and Design-Build-Operate (DBO) contracts are recognised as an effective and important procurement option for water sector infrastructure projects. However, in the view of the authors, all of whom have significant experience in delivery of such projects, their use should be adopted with care and after carefully considering the benefits and pitfalls of the alternatives. There are popular misconceptions that adopting a DB style procurement will lead to the project being delivered more quickly and cheaply, eliminating, for example, an entire level of professional services input. This is not necessarily the case, particularly in New Zealand where we do not have the benefit of the availability of large resident 'Process Lead' contractors who deliver proprietary processes and equipment with only site civil/structural work being bespoke.

- With DB/DBO delivery, as we know it in NZ, the contracting consortia is typically led by a large civil engineering contractor who must engage most of the required design disciplines and mechanical and electrical sub-contractors.
- In parallel, the Employer / Principal needs to engage their own technically and contractually expert advisors to assist with the procurement process and due diligence pre and post contract award.
- The development of the procurement documents in itself is a significant undertaking
- The Proposal / Tender preparation period is significantly longer than for a conventionally delivered project because each consortia must go through a process selection process, then prepare a Preliminary level design before the Proposal price and commercial offer can be developed.

- The evaluation period is prolonged because the evaluation team, rather than evaluating a tender for a design that was a previously known quantity must go through an exhaustive process of determining if they consider the offer will perform adequately, then addressing all of the technical and commercial issues raised by the offer.
- An issue arising early in the design – for example, the need to preload foundation materials - with a conventional delivery model, can be addressed as soon as the site general arrangement drawings are developed at concept design stage. With a DB approach, they cannot be addressed until after the DB Contract is awarded.

In our opinion, DB/DBO procurement models may be more appropriate in New Zealand where / when:

- The project is sufficiently large (>>\$20M) that the potential profit is commensurate with the costs and risks that the Contractor must take on.
- The project is sufficiently small and of such limited scope that it can easily be managed by suppliers of proprietary equipment that requires minimal additional or external professional support.
- Significant equipment / process supply packages that feed into a larger project that is being delivered by a more conventional 'designed' project.

Project Shotover is a comparatively simple treatment concept in that it seeks to remove large amounts of nitrogen and bacterial contamination. While there are many potential solutions to this, there are two very robust, commonly used, cost effective configurations that easily deliver what is required in terms of effluent quality. Ability to innovate cost effectively is therefore limited.

While very successful in terms of what has been delivered, Project Shotover, in our opinion, would probably have been more simply and efficiently delivered by a conventional model of a full design, followed by a main construction contract, likely to be supplemented by a number of supply and commission contracts for key equipment systems such as dewatering, UV and aeration.

10 CONCLUSIONS

Overall, Project Shotover has been a significant success for QLDC. The new treatment facility has proved itself robust and capable of producing an excellent effluent quality. Of equal importance, the delivery of this complex project provided QLDC with confidence in both the ability of itself, and the market, to execute largescale capital works.

The experience at Project Shotover has also provided an education around the appropriateness and potential shortcomings of the Design-Build procurement model. The level of input and investment to set up, evaluate and manage this style of contract (measured in both time and dollars) can be significant, and this needs to be carefully considered when selecting the most suitable procurement model for any project.

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