DESIGN BUILD OPERATE – THE MANGAWHAI COMMUNITY WASTEWATER SCHEME – LESSONS LEARNT

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ABSTRACT

The Mangawhai Community Wastewater Scheme was a design, build, transfer, operate (DBO) project encompassing collection, treatment and disposal. This paper describes some of the more interesting facets of the project and draws on these to develop a number of lessons that may help other designers in the future. Pressure sewer systems were installed in the low lying areas of Mangawhai Village. Anaerobic activity in pressure sewers was greater than anticipated and the selection of materials for these conditions is discussed.

Measurement and control systems are considered by the authors to be critical to long term operational efficiency. PLC controls and SCADA were developed in conjunction with the electrical and controls contractor who was appointed early in the construction process. The early involvement of the contractor allowed the setting of site standards that were applied across the various equipment supply contracts. These systems have recently been updated a process we consider essential to ensure operational reliability.

Those charged with setting contractual and regulatory limits need to give more consideration to whether the limits are indeed within the ability of the parties to influence them. A limit in the DBO contract on maximum influent NH_3 was never met; more importantly it was not within the control of the council who were required to deliver effluent meeting this standard.

KEYWORDS (ARIAL, 11)

Design Build Operate, Pressure Sewers, Process Control, SCADA, Measurement

1 INTRODUCTION

The Mangawhai Community Wastewater Scheme (MCWS) was a design, build, transfer, operate (DBO) project encompassing collection, treatment and disposal. Previously Mangawhai was reliant on on-site disposal; septic tanks in the older areas and more advanced systems in newly developed areas most of which were required to connect to the central scheme when it became available.

The contract was based on a conceptual design the contractor had previously submitted to the council. It required the DBO contractor to finalise the design and construct the assets which were transferred to the client on completion of construction. The contractor was then required to operate the plant for 10 years (with a possible 5 year extension). The contract was a single maximum lump sum for a defined scope of work with any savings split between contractor and council. For a description of the formation of the contract refer the Auditor General’s report.

The MCWS has an operating staff of three based at the treatment plant and is responsible for operating and maintaining the scheme including reticulation treatment and disposal. The lead author joined the project shortly after the site office was established and was responsible for completing the treatment plant design, mechanical and electrical supply contracts while Terry joined at the start of commissioning later taking over as Operations Manager. Both are with the project today giving an unique opportunity to review what worked and what, with hindsight, could have been carried out differently.

Following award of the contract a site office was setup in Mangawhai under the project manager to carry out detailed design, purchasing, construction supervision and later commissioning with construction carried out under a series of subcontracts. This devolution of work to a site office worked well, a particular strength being the rapid response to contractor queries and the ability to obtain contractor input through the detail design process.

There have been two changes in the corporate entity contracted to the council following the award of the DBO contract to EarthTech. This has had minimal effect on the services provided under the contract with the successive DBO contractors being bound to the original contract terms. TRILITY, a major Australian DBO contractor took over the contract in 2015 retaining the operating staff.

Sections 2 to 5 discuss the principal features of the project followed by more detailed comment on particular aspects of the project that highlight the lessons learnt. Section 6 What Should I Measure discusses issues that can arise when setting limits in contracts and consents

2 RETICULATION

2.1 DESIGN CONCEPT

Figure 1: Mangawhai Showing sewage reticulation

Historically Mangawhai developed in two distinctly separate areas, the Heads, a hilly area fronting the estuary with a large proportion of holiday homes and the Village which in the days of costal shipping served the hinterland. The tender design was based on providing gravity sewers in Mangawhai Heads and pressure sewers in Mangawhai Village; while a limited number of pressure sewers were installed in the Heads to serve properties below the hydraulic grade line. Mangawhai Village is generally, low-laying with a high water table and a hard pan just below the surface a situation lending itself to pressure sewers. Because some developers in the Village had installed gravity systems within their developments prior to the letting of the DBO contract the scheme was modified and the Village is now served by a mix of gravity and pressure sewers.

Traditionally responsibility for providing and maintaining sewer systems stops at the property boundary. When pressure sewers are installed in mixed systems such as Mangawhai it was recognised that equity requires that the savings in reticulation are counterbalanced by the need to provide a tank and pump on each property. Only by including on property costs when carrying out studies can a true cost benefit analysis of the relative merits of gravity and pressure sewer systems be made. The council decided that where pressure sewers were provided the grinder pumps would be installed and maintained for the first 10 years of operation by the council and this requirement was included in the DBO contract.

Subsequently the council has required homeowners to purchase and maintain the grinder pumps although following the set up of a community advisory panel this is now under review.

2.2 DESIGN AND OPERATION

2.2.1 GRAVITY SYSTEM

Design of the gravity systems followed conventional practice with gravity piping in PVC where trenched and PE for rising mains and drilled sections. Manholes, storage chambers and pump wet wells were sulphite resisting precast concrete.

Anaerobic conditions in pressure sewers; exacerbated by three out of four houses being only intermittently occupied thus leaving sewage sitting in pump chambers for long periods has seen accelerated concrete corrosion in the pump wet wells receiving inflow from pressure sewers. The largely gravity sections in the Heads have not experienced this problem.

A number of PE and fiberglass solutions are available for manholes, pump wet wells and storage chambers and in our view should be used where anaerobic conditions may occur. If concrete is required for structural or construction reasons there are a range of coatings available that can be applied to prevent corrosion. It is far easier to apply coatings to clean surfaces than after corrosion is noticed. While there is widespread application of plastics to pipelines there seems to be a reluctance to adopt plastics or fibreglass for other components.

2.2.2 PRESSURE SEWERS

Design of the pressure sewer system was based on the WSA 07-2007 Pressure Sewerage Code of Australia Version 1.1. PE piping was universally used for the pressure sewer network. The PE pipe collection system was installed by directional drilling; generally at a depth of 600 – 750. Fittings DN 75 and above were fusion welded with Plasson couplings being permitted in smaller sizes. Minimum pipe size for street mains was DN 50. Boundary kits (isolation valve, non-return valve and plugged tee) were installed at the street boundary.

Since the pumps were to be serviced by the DBO contractor the council decided that, where convenient a single grinder pump would be installed to serve two adjacent properties. These shared pumps were located on the boundary between properties. Power supply for shared units was direct from the street mains via a pole fuse; the council negotiated a fixed annual charge for supply thus negating the need for a meter. Single household pumps were connected to the house water pump circuit so that in the event of a circuit breaker trip the water supply would also cease.

While pump capacity is more than adequate to serve two properties problems arise when pumps are jammed with foreign objects as there is no possibility of placing blame on the household responsible. The pole fuse feed also means that to isolate the supply or replace a fuse the lines company service person needs to attend.

The selected grinder pump has proved to be less reliable than expected and the DBO contractor, in conjunction with the manufacturer has put in place an upgrade programme. There were no commercial consequences for the council as the DBO contractor was required to maintain the pumps for the contract period. There is no question that some of the problems are a result of stuff being put down the toilet that should not be there; also systems that stand idle for weeks (common in a holiday town) are more prone to fault. High use grinder pumps have proved more reliable than those on intermittently occupied holiday homes.

A well written long term DBO contract can place responsibility to maintain systems squarely on the contractor regardless of the nature of the problem.

3 TREATMENT

3.1 PROCESS

A twin tank Cyclic Activated Sludge System (CASS) was provided. This configuration allowed for single tank operation over approximately eleven months of the year with both tanks operating over the peak New Year period. The CASS process is essentially a sequencing batch reactor (SBR) but with a continuous feed. This is followed by media filters using a crushed glass media; the filters were installed to remove helminths since it was proposed to irrigate land used for grazing stock. The CASS process has proved to be extremely robust. The transition to two tank operation late December (when the flow trebles between 20th December and New Year's Day) is without problems with only a short spike in ammonia level in the effluent.

A basic four hour cycle is implemented in the PLC, two hours aeration, one hour settling, one hour decant. Under high flow conditions the overall cycle time reduces to three hours. A storm cycle of 30 minutes aeration, 30 minutes settling and 3 hours decant caters for high inflows due to flooding. (Property flooding to the extent that it inflows through household gully traps has proved to be a problem that was simply not expected.) The transition between cycles is based on water level in the CASS tank during the first part of the cycle and is fully automatic.

As designed disinfection was by UV with provision to use chlorine (as sodium hypochlorite) if required. The UV transmissivity of the effluent was lower than anticipated and coupled with fouling on the quartz tubes did not produce the required kill. The UV units were specified as an in-pipe design; although the selected units allowed additional tubes to be installed upgrading costs were such that it was decided to rely on chlorination using sodium hypochlorite for disinfection. The DBO contractor installed a new chlorine dosing system designed with full standby capacity and the plant now relies on sodium hypochlorite for disinfection. (The resource consent did not define the type of disinfection system to be employed.) Because the DBO contractor provides all consumables the change had no effect on council costs.

In retrospect an open channel UV system would have given increased flexibility at lower cost than the inline system specified.

Waste activated sludge is dosed with polymer and dewatered using a belt press. The dewatered sludge is transferred to landfill by skip. The system has proved simple to operate and while solids are not as high as with a centrifuge or filter press. Much larger annual volumes would be needed to justify any change. (disposal costs are met by the DBO contractor.)

4 EFFLUENT DISPOSAL

Treated effluent is pumped to a council owned farm for irrigation to land. Effluent is stored in a lined dam with a capacity of 170Ml with irrigation limited to the drier months of the year (nominally October to April). The scheme was designed to irrigate an initial 25 ha to be extended when required by population growth. While the decision to dispose of effluent to land had been made prior to signing of the DBO contract details of how and where the water would be applied were not. The consequences of this are discussed in the Auditors General report.

The irrigation system was tendered as a design and build package; while there were no restrictions placed on design only two tenders were received both based on post mounted sprinklers. The initial area was divided into some 18 zones and a PLC based control system allowed application rates to be individually set for each zone. The volume applied to each zone was recorded and provides the basis for reporting to the regional council

Originally intended to be operated by the farmer it was found that the farmer's priorities differed from those of the BDO contractor and Council. (The farmer, not unreasonably gave priority to farm operation.) This resulted in application rates being lower than expected. When the farm lease came up for renewal responsibility for operation of the irrigation was transferred to TRILITY and the grazing contract amended to make it clear that getting water on was the priority. This changes resulted in increased application rates and consequent improved utilisation of the available irrigation area.

The change in operator increased the importance of providing remote setup, monitoring and data retrieval over the internet. A web browser duplicates the field LCD touch panel giving full remote functionality and application data is retrieved using a file transfer protocol initiated from the treatment plant.

5 CONSTRUCTION

5.1 RETICULATION

The reticulation contract was let as a single package to a major national contractor. The contractor set up a site office and yard in Mangawhai and carried out the work via a number of smaller subcontractors. The DBO contractor managed the reticulation contract via a construction supervisor and two site based engineers. A council appointed engineer, who worked from the contractor's office, provided the link to property owners and council. The Australian based reticulation designer made regular site visits over the course of the contract.

With most construction activity taking place in established residential areas street corner meetings with residents were held weekly, attended by the DBO contractor and council engineer. This worked well with residents also able to call in to the DBO contractor's office to discuss any issues they had.

Wet well pumps and controls were purchased under the treatment plant contract. Submersible pumps were selected on price, we requested pricing from suppliers we were happy with and inspection of specifications showed very little difference in pump efficiency between offers. Orders were placed with a single supplier for across both the reticulation and treatment plant to get the advantage of volume discounts offered and consistent interfaces.

A feature we did not appreciate sufficiently at the time was the plug in power connections provided on smaller pumps up to 11 kW. The ability to swap out a pump without the need for an electrician has proved to be a real advantage in terms of both convenience and cost.

5.2 TREATMENT PLANT

A New Zealand consultant was engaged to carry out all geotechnical investigations and provide documentation for the civil works. Full designs were prepared for the main concrete structures using in situ concrete construction. A Whangarei precast concrete company was awarded the work based on a precast design. While this change increased design costs the overall savings in both cost and reduction of on-site activities were significant. With the increasing use of precast concrete the practice of providing a full conventional design that warrants review. One possibility is to provide the design calculations leaving it to the contractor to produce working drawings which would then be reviewed by the original designer.

5.2.1 EQUIPMENT AND MECHANICAL INSTALLATION

Individual equipment packages were tendered using AS/NZS4910 or 4911.Most packages were tendered without installation however where supplier installation was considered desirable packages included installation. In total three supply and install and 15 supply contracts were awarded. A single mechanical contract was let covering site above ground piping and equipment installation. This was let to a local Mangawhai firm who set aside a partitioned off section of his workshop as a stainless steel pipe fabrication shop. (Above ground piping was specified as stainless steel dairy tube.) Underground piping was PVC and was installed under a separate contract. A strong site team allowed the use of local resources and this produced substantial savings.

5.2.2 SUPPLY PACKAGE INTEGRATION

Where supply packages came as standard with their own control package it was decided that if they did not require close integration with the overall control system (e.g. sludge processing and inlet works) they would not be required to comply with site standards. This kept prices down and in practice has not proved to be a problem; alarm and run indication but not control is provided on the SCADA.

The media filter contract required full adherence to site standards but allowed the supplier to provide either a local PLC and control panel or simply provide an IO rack with the program loaded into the plant PLC and control from the SCADA. (In comparing offers tenderers were advised there would be no price adjustment for the omission of a local PLC and display.) The successful tenderer elected to provide a local PLC and display screen with an Ethernet connection to the SCADA to provide interfacing. He considered the advantage of being able to fully shop test the filter unit outweighed the additional equipment costs This proposal was accepted and the main SCADA page was configured to display, but not adjust filter parameters . During commissioning both supplier and DBO contractor came to the conclusion that full integration using the plant PLC and SCADA would have been the better option and is supported by operating experience.

5.2.3 ELECTRICAL

The equipment packages were complemented by a single electrical and controls package including supply installation and commissioning of power and control systems across both the treatment plant and reticulation pump stations. This package (E&C) was tendered at an early stage as a single lump sum contract based on a motor and control list developed from the plant P&ID's. The early letting of this contract allowed key suppliers to be identified early which in turn allowed these selections to be incorporated in process equipment tenders.

This means that we have a single point of contact for all control and power system maintenance and development. Subsequently the same control systems are being rolled out across all Kaipara water and wastewater assets giving a common platform that will produce long-term operational benefits. Given the importance the authors place on measurement and control further detail is provided in the following section.

5.2.4 TELEMETRY

Pump stations are in many ways the public face of the system. It is therefore vital that a robust control and communication system is provided. The E&C contract was let at a time when rapid advances in telemetry were occurring, The contract did not specify the technology to be used rather it was left to be decided during the detail design phase. The use of Ethernet radio appealed as having low operating costs however despite supplier claims regarding range, site tests by several equipment suppliers showed that the terrain made a successful implementation unlikely. This left either a fixed “phone” line or the recently introduced 3G mobile data system. SMS solutions were ruled out as not providing real-time information.

Despite the lack of operating history a 3G solution was selected as representing the future. Early adoption showed up the lack of experience of both the system developer and Telecom (as it was then) staff. Initial problems included high data volumes (a programming issue) and transmission delays (due to voice priority). Despite the early problems the 3G network has subsequently provided a sound platform for control and monitoring of pump stations. This highlights an advantage of the BOM model; the ability of operations staff to play a part both in finding solutions and manually monitoring systems while problems are resolved.

5.2.5 SERIAL ETHERNET

The serial (daisy chain) Ethernet connection (see Figure x) VSD’s merits separate discussion. The serial scheme was adopted as reducing cabling requirements. The daisy chain was fed from both ends thus allowing a single VSD circuit breaker to be isolated either manually or by a circuit breaker trip. (The daisy chain requires power to be available at the VSD.) This dual feed design never worked. (The supplier eventually conceded this was the case.). The end result of changing to a single feed meant that a single circuit breaker trip or isolation will disrupt communications along the chain. In practice this has not caused problems as field faults have been handled by the VSD – I don’t think we have had a circuit breaker trip in the seven years of operation. Isolation of a single VSD does however require the operator to rearrange the break in the daisy chain prior to isolation. For this reason we would not recommend it for future installations. (The alternative is a switch with Ethernet cables run to each drive.)

5.2.6 SCADA

The original installation was based on the windows XP platform. With the discontinuance of support for windows XP we considered the risk of staying on an older platform for the duration of the operating contract outweighed the upgrade cost. We therefore made the decision to upgrade to Windows 7 and Citec 7.4. To make the changeover as seamless as possible both the SCADA and Historian PC’s were replaced with new units allowing a full setup and shop test before changeover day.

We had previously identified that a Snapgear router that formed the link between the pump station and the SCADA had gone out of manufacture soon after it was installed. A search on eBay failed to find a replacement unit hence with the time required to program an alternative it was decided to install a replacement router at the time of the SCADA upgrade and also to keep a pre-programmed unit on the shelf.

5.3 POWER SYSTEMS

VSD’s were adopted as standard for motor drives requiring speed control and or reduced current starting. Pump stations use pump control cards installed into the drives making programming of station parameters available to the operators via the HMI interface and eliminating the need for a pump station PLC. At the treatment Plant VSD’s were installed in a central switch-room except for those in the sludge building where distance dictated local installation. VSD’s were wall mounted with the HMI panel at eye level. (Figure 2 below) Connections to the VSD(besides power) were limited to emergency stops plus the Ethernet control cable linking the drive to the PLC. This gave a standardized interface and minimized cabling. Operators have found the HMI on the VSD easy to use. In the few cases where a field control station was required this was wired through the PLC and not direct to the VSD.

Photograph 1: Wall Mounted VSD's - note the break in the daisy chain

5.4 BRIEF COMMENTS

- Looks count – a good clean design encourages operators to maintain a high standard of housekeeping.

- 4-20 mA loop powered instruments are not dead yet. Simple interfacing and ease of service make them a good choice particularly for plants without readily available specialist service staff.

- IP 56 rating does not mean that instruments and controls can be exposed outdoors. The effects of UV light on plastics including display screens can be disastrous. Despite fitting simple weather shields we have had to replace a dissolved oxygen transmitter due to UV damage.

- Mount instrument displays at eye level particularly where reference is required for adjustment and calibration. Hand rail mounting of DO transmitters was convenient but eye level mounting would have been so much better.

- Floor trenches make for a clean and tidy switchroom.

- Fully paint out Switch rooms before letting the electricians in. We did not paint the floor trenches (time pressures) before installing cabling – this was a mistake - even in these enclosed areas concrete generates dust. Vinyl flooring encourages good housekeeping.

- Size flow meters based on pressure drop and allowable velocities; in the vast majority of cases you can drop one line size and a pair of reducers is cheaper than the next size up magflow meter; as a side benefit measuring accuracy is improved

- Pressure sensors with 4-20mA output were used for tank and wet-well level measurement – Hart compatibility allowed the selection of a single model for all level applications. With over 20 installed we have not had a failure.in seven years.

- Problems were experienced with VSD's tripping when sized close to but above pump running current. In the worst case going up one size of VSD fixed the problem. Consider requiring a safety margin (10%?) when specifying.

- Installing a heat pump in electrical switch rooms removes the need for ventilation and consequently reduces dust ingress. A constant temperature also benefits the electronics.

- With our expanding dairy industry stainless steel dairy tube and fittings are readily available. For above ground piping it gives a great looking long life installation.

6 WHAT SHOULD I MEASURE

The DBO contract set a range of measures that the contractor and council were required to meet. In addition the resource consent set limits on discharge both at the plant and on the farm. The DBO contract set a maximum limit on the influent ammonia concentration that the council was required to guarantee. The intent was probably to control high strength trade wastes (of which there were none at the time). From day one this limit was exceeded; NH_3 content of incoming sewage averaging 90 mg/l compared with a contract "limit" of 50 mg/l In hindsight with virtually all properties reliant on tank water the contract writer should have expected flows to be lower and concentrations higher than elsewhere. The ammonia content of the influent was clearly outside the control of the council and should not have been included as a contract limit.

Similarly the resource consent set a limit on Total Dissolved Solids in the effluent. This limit is exceeded from time to time, again almost certainly due to the higher strength sewage. Again there is nothing the DBO contractor can do about this. To date none of the parties have sought to take any action based on these limits.

In short if you have no control over a variable don't set controls based on that variable. This is not to say that you should not measure - it may provide valuable information for future design - simply don't include them as contract limits.

7 RELATIONSHIPS

We placed considerable emphasis on maintaining good relationships with stakeholders including the clientl, suppliers, contractors and local residents. The site team had considerable autonomy and was able to quickly make decisions on issues that arose during construction. – Contractors and suppliers valued prompt decision making highly even if it was not the answer they would have liked.

8 CONCLUSIONS

The DBO model allowed the contractor flexibility in pursuing an efficient design. The requirement to operate and maintain the facility for a period of 10 years placed emphasis on ease of operation and the development of a multi skilled operating staff. It also allowed the engineer to introduce innovative ideas knowing that if they did not live up to expectations these issues could be resolved during the operation period. This is exemplified by the work done to solve issues relating to pressure sewer pumps.

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