

SEWAGE TREATMENT AND DISPOSAL OPTIONS FOR LINTON ARMY CAMP

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ABSTRACT

The N.Z. Army operates a military base at Linton, 5km south of Palmerston North. In 1986 an oxidation pond was constructed that discharged treated effluent into the Manawatu River. The Army has been under pressure to upgrade the quality of the discharge with particular emphasis on lowering the nutrient flux and pathogen load entering the River.

Over the last 8 or so years several options have been investigated including upgrading the existing treatment plant and disposing of the effluent to land.

One of the options investigated at an early stage was to pipe the sewage from Linton to the Palmerston North sewage treatment plant, but this option had been discounted because of the perceived technical difficulty and cost of piping the sewage across the Manawatu River which is about 100 metres bank to bank. Upon review of the options Pattle Delamore Partners Ltd was engaged by N.Z. Army to reinvestigate the piping option and this was then selected for detailed design.

This paper discusses the options that were investigated, the project risks associated with them and some of the areas where a project can get 'derailed' even with the best intentions. It discusses the option which has been selected for detailed design and construction and some of the relevant technical issues.

KEYWORDS

Sewage Treatment and Disposal, sewage pipeline, pipe bridge, sewage options

1 INTRODUCTION

The N.Z. Army operates a military camp at Linton, 5km south of Palmerston North which is the largest military camp in N.Z. and home to the recently purchased fleet of all-terrain Light Armoured Vehicles. Most of the Army's engineering training activities are undertaken at Linton. The camp covers an area of 257 hectares and was originally established during World War II as a major training area. Over the years it has been significantly re-developed and present infrastructure is valued at over \$146 million. Operation of the camp currently contributes over \$150 million annually to the local economy. The camp plus the adjacent village, is home to about 3,000 army and civilian personnel and a design allowance has been made for this to increase in the future to a maximum of 5,000 people. The camp has a reticulated sewage system which discharges to a single stage oxidation pond. The pond has a surface area of 2.25ha and was constructed in 1986 to provide sewage treatment for the camp and associated village. The discharge from the pond is by gravity flow into the Manawatu River. Over the years additional flow has been added to the pond with the construction of the nearby Manawatu prison.

The oxidation pond has over the years been upgraded with the installation of two floating aerators to reduce BOD, but overall, the quality is typical of a single stage oxidation pond. Average daily flow is approximately 900m³ but like many sewerage systems in N.Z. the reticulation experiences high flows during rainfall periods due to groundwater infiltration and direct inflow and peak flows of 1700m³/day have been designed for. The soils at Linton are generally stony silt loams and groundwater table is about 2 to 3 metres below the ground surface. The Manawatu River runs along the northern side of the base and the wide gravel bed and braided nature of the river provides a useful training area for Army drivers.

2 THE MANAWATU CATCHMENT WATER QUALITY PLAN

The Manawatu River in the vicinity of the discharge has a median flow of about 60m³/s. The lowest flow recorded in the River since 1928 was 8.4m³/s. The river is subject to high flood flows with an increase in water level of 6 to 7 metres not being uncommon. The River is well known for its dynamic nature and the bed is comprised of gravels and coarse gravels. The nature of the bed means it is used for gravel extraction and Higgins Quarries operates a large extraction and crushing plant on the opposite side of the River to the Linton camp. Adjacent to the Higgins Quarry is the Palmerston North City Council (PNCC) landfill and situated about 500 metres west of the landfill is the PNCC municipal sewage treatment plant. The proximity of the camp to these features is shown in Figure 1. The PNCC plant serves the city of Palmerston North and is currently being upgraded to produce a high quality effluent. This effluent is then discharged into the Manawatu River about 2600 metres upstream of the existing Linton discharge point. As the crow flies, the Linton oxidation pond is only about 1300 metres from the PNCC sewage treatment plant but the Manawatu River forms a considerable physical barrier in between. To travel by road between Linton and the PNCC treatment plant takes about 20 minutes and is about 14 kilometres although the closest municipal sewage connection to Linton, other than across the River, is at Massey University which is about 7km by road.

Horizons Regional Council is concerned about the ongoing deterioration of the Manawatu River which has a relatively high phosphorous and nitrogen concentration particularly during summer when flows are low. Army realized that tighter discharge standards would be imposed on any future Resource Consent which discharged to the River. Horizons has an operative Manawatu Catchment Water Quality Plan (Horizons, 1998) which is aimed at improving water quality effects within the Manawatu River catchment by 2009. The rules contained in the Plan include, inter alia, restrictions in the receiving water relating to colour and light penetration, slime and periphyton growth, concentration of organic matter, median concentration of enterococci of 33 N^o per 100ml and Dissolved Reactive Phosphorous (DRP) less than 0.015g/m³.

Compliance with these rules will be required when the Manawatu River is less than 50% of median flow and these standards are progressively being imposed on all existing Resource Consents.

Water quality data provided by Horizons as part of their compliance monitoring showed that in 2001 the background river water quality immediately upstream of the existing Linton oxidation pond outfall was as shown in Table 1.

Table 1: Background River Water Quality

Parameter ¹	MCWQP ²	Mean Background Concentration
Carbonaceous BOD ⁵ (g/m ³)	2	1.12
NH ₄ ⁻ Nitrogen (g/m ³)	0.8	0.66
DRP (g/m ³)	0.015	0.042
Suspended Solids (g/m ³)	5	7.32
Enterococci per 100mL	33	367
¹ Data from Good Earth Matters report (GEM, 2001)		
² Concentrations as reported in the Manawatu Catchment Water Quality Plan (Horizons, 1998)		

Table 1 shows that in 2001 the MCWQP concentration for DRP, suspended solids and enterococci was already exceeded and this was due to the influence of upstream agricultural practices and the discharge from the PNCC sewage treatment plant.

In 2001 PNCC was working through a new Resource Consent application to enable it to continue discharging effluent from the sewage treatment plant into the river. PNCC appreciated the need to upgrade its treatment plant and the new Consent took into account proposed process improvements. The conditions of the PNCC consent were aimed at moving the river quality closer to the water quality conditions outlined in the MCWQP. Preliminary calculations undertaken at that time (GEM, 2001) indicated that, based on likely effluent contaminant concentrations from the upgraded PNCC treatment plant, then the Linton plant would need to produce an effluent with 10g/m³ for suspended solids and BOD with NH₄⁻ Nitrogen and DRP concentrations of less than 1g/m³ each.

This would require the Linton plant to achieve high nitrogen and phosphorous removal efficiency which would be technically demanding and relatively expensive in terms of both CAPEX and operating costs.

2.1 THE LINTON SEWAGE TREATMENT OPTIONS

The Army held a Resource Consent to discharge up to 2700 m³/d of oxidation pond effluent (including stormwater) into the Manawatu River and this consent expired in May 2004. Army staff had realized the need to upgrade the quality of the Linton discharge for some years and investigation of options had been undertaken between 1997 and 2001. In all, some six studies and reports had been undertaken during this period but there was still no clear option which could be called 'the silver bullet'.

The most comprehensive options report was prepared in 2001 by Good Earth Matters (GEM, 2001) a Palmerston North based consulting company. This report looked at several treatment and disposal options including upgrading the existing oxidation pond system and continuing to discharge to the Manawatu River, disposing of effluent to land and treatment and disposal via the PNCC Sewage Treatment Plant.

The overall recommendation of the GEM report was that Army should treat the effluent by ultra filtration and discharge it to the Manawatu River. The estimated cost of this option was between \$2.0 million and \$2.9 million excl. GST.

In 2002, Army engaged Pattle Delamore Partners Limited (PDP) to review the GEM report. The overall recommendation of the PDP review was that prior to deciding on an option, Army should undertake additional investigation into discharging to the PNCC sewage treatment plant as this option had some distinct advantages for Army. The GEM report had also identified this option as having merit but had discounted it largely because of a greater level of risk and uncertainty in terms of both capital and future operating costs. As a result of the PDP review, Army engaged PDP to undertake further investigation of the PNCC pipeline option. The option would entail taking effluent from the Linton oxidation pond and pumping it to the PNCC treatment plant for further treatment prior to disposal to the Manawatu River.

Several factors had assisted Army to make the decision to re-investigate the feasibility of constructing the pipeline option. These included:

- NZ Army acknowledged that a continuing discharge of treated sewage effluent to the river would be offensive to Maori and at least contentious amongst the wider population.
- The PNCC sewage treatment plant had recently been granted new resource consents for discharge of treated effluent to the Manawatu River and was to be progressively upgraded.
- When the new PNCC consents were granted it had been anticipated that, at some time in the future, the effluent from Linton Camp would possibly be added to the flow through the plant and this was taken into account in all design calculations and in the resource consent decision.
- Initial investigation indicated that significant savings in capital expenditure could be available if sewage disposal by pipeline was feasible.

3 PIPELINE ROUTE OPTIONS

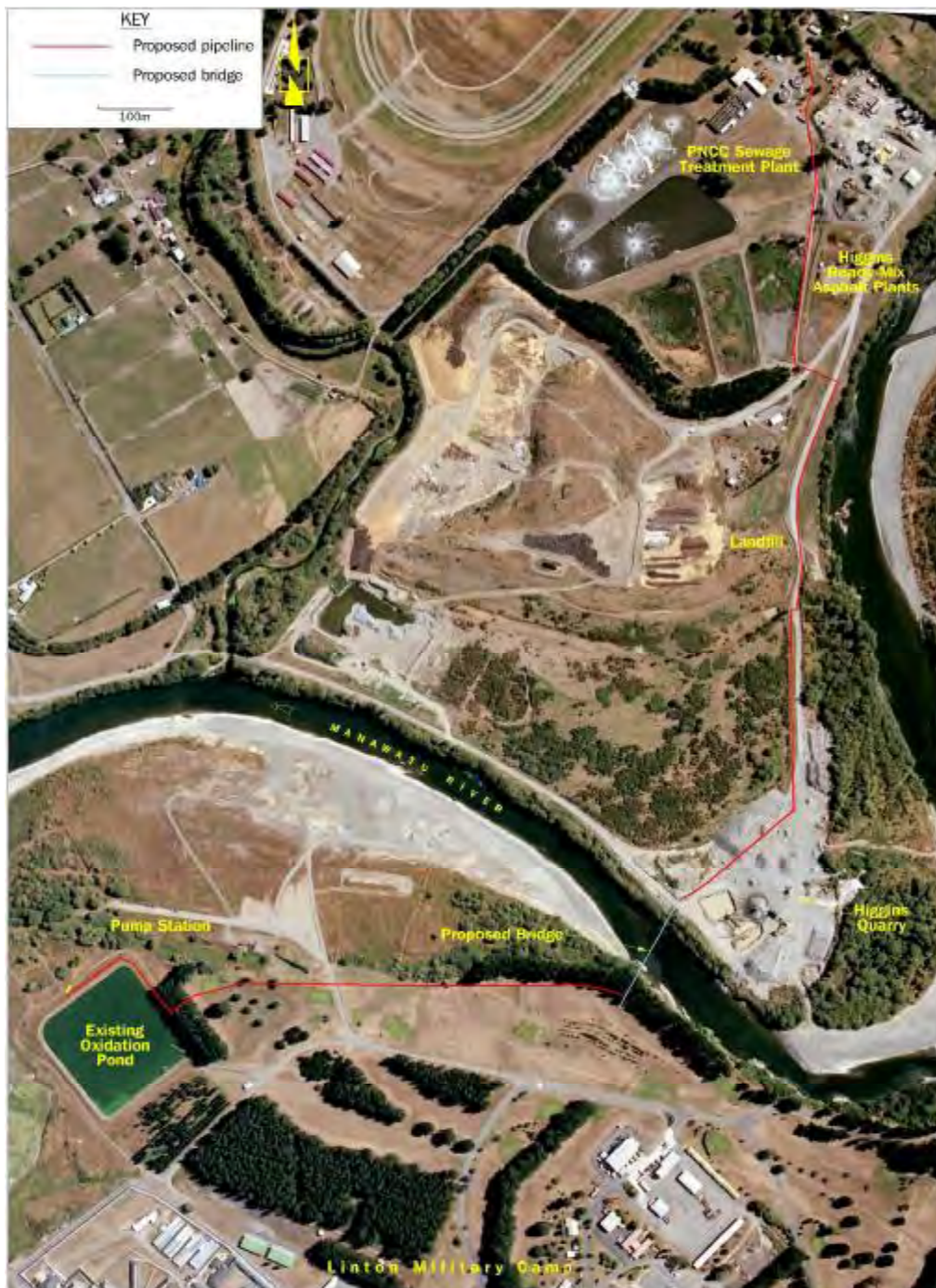
The PNCC option required constructing a pump station and laying a 200mm pressure pipeline from the Linton oxidation pond to the PNCC sewage treatment plant. Irrespective of the route this required crossing either over or under the Manawatu River with the pipeline. For all pipeline options it was considered that the existing oxidation pond would continue to be used to undertake some treatment and to provide flow balancing so that the treated effluent would be pumped to the PNCC treatment plant over a period of up to 18 hours per day.

The only existing bridge across the Manawatu River which was closer to Linton than 5km was the North Island main trunk railway bridge which was about 2km in the opposite direction of the PNCC sewage treatment plant. Discussions with TranzRail indicated that the concept of attaching the pipeline to the Railway Bridge was feasible,

however, this overall route was some 6km in length and had issues associated with obtaining consent and easements from about 20 different landowners to cross their property. The estimated CAPEX of this option was about \$1.4million. Overall this option was considered too difficult to progress given the potential time delays and cost implications of obtaining consent from so many landowners.

A pipeline that used the existing Fitzherbert Road bridge between Massey University and Palmerston North was investigated but discounted as it required a new rising main of some 7km in length to be laid in the State Highway. In addition, the rising main would discharge into the municipal sewer about 7km from the PNCC treatment plant which could create capacity problems for the PNCC reticulation network.

Figure 1 – Linton Military Camp and Proposed Pipeline Route



3.1 CROSSING UNDER THE RIVER

The option of crossing under the River using either an open cut method or directional drilling was investigated. The internal diameter of the pipe was about 200mm which made the option practical and it had the obvious advantages of not requiring construction of a new bridge or long rising main. Crossing under the river would

utilise a much more direct route to the PNCC treatment plant than the railway bridge or road bridge options as the total pipeline length would only need to be about 2.5km.

An open cut method of construction was considered to be quite feasible but would require a large volume of river gravel to be excavated using large hydraulic excavators in order to achieve sufficient cover over the pipe to protect it in the event of river scour. Staff at Horizons Regional Council advised that no river crossings had been constructed in this vicinity in the last 20 years and that because of the very mobile bed, a pipe cover of about 4 metres would be required.

The general methodology proposed for the open cut river crossing was to excavate a trench across the river beach starting at the Linton side and extending as far as the running river channel. The pipeline would then be installed to that point. A river diversion channel would then be excavated across the beach (the inside of the bend), and most of the river diverted into this artificial channel. The remainder of the trench would then be excavated across the existing channel, and the rest of the pipeline installed.

The trench would be more than 4m below the existing river invert to allow for protection against riverbed scour and would need to continue at this depth for a sufficient distance beyond the banks to allow for future erosion and migration of the riverbed. The pipeline would need to be protected against damage from rocks and would be laid underwater in 'blind' conditions.

Whilst the CAPEX of this option appeared to be cheaper at about \$1.1million than the railway bridge option there were significant project risks including obtaining Resource Consent and risk during construction and during the life of the pipeline due to flooding and scour leading to loss of the pipeline. The large flood event of February 2004 in the Manawatu River reinforced the risk of this type of river crossing. That flood was unexpected and out-of-season and reached a flow of about 3500m³/s past Linton. An event of this magnitude (reported to be a 1 in 100 year event) would have had a major impact on any partially completed pipeline.

The alternative option of directional drilling was considered in detail and a local contractor, Blackley Construction Ltd, was asked to prepare a ballpark CAPEX estimate. Thrust boring had been tried under the Manawatu River in about 1992 at a location 6km upstream but had been unsuccessful due to the presence of large boulders and buried logs. The theory promoted by the contractor was that improvement in drilling equipment and techniques now meant that it was feasible to drill a pipeline under the River even if these obstructions were encountered as percussion drill bits could now be used. The initial estimate provided by the Contractor plus the relatively short length of the thrust which was in the order of 200 metres made the option appear attractive. However, the risks to the project were quite significant. For example, a significant amount of geotechnical investigation would be required to 'prove' that solid rock would not be encountered and there was concern that if the equipment available in New Zealand proved to be inadequate to complete the task (e.g. if the drilling string got stuck) then the project would need to be abandoned or larger equipment would need to be hired from Australia. It was considered that whilst we all like a challenge and the excitement of using ground breaking technology this was not the project to use it on and so this option was discarded because of the relatively high risk.

3.2 BRIDGE OVER THE RIVER

Running in parallel with the investigation of options of laying a pipeline under the river was an assessment of building a purpose designed bridge across the river. Opus International Consultants Ltd were subcontracted to investigate the option of designing a clearspan bridge which could take pedestrians as well as the sewage pressure pipeline and future water supply pipelines. This option was developed because of interest expressed by PNCC to create a pedestrian walkway to Linton. The bridge concept which was developed by Opus comprised of a parallel chord truss steel bridge which was resting on piers at each end and was also supported by suspension cables attached to deadman anchors and hung from towers located on each side of the River. A photomontage of what this bridge would look like was developed by Opus and is shown in Figure 2.

Figure 2 – Photomontage of 'Heavy-bridge' option



The bridge was designed to not only resist vertical forces due to dead and live loads but also to resist lateral movement at right angles to the span due to wind forces. The clearspan of the bridge was 125 metres which was necessary so as to avoid having any piers in the River. The absence of piers would avoid construction and consent issues associated with building in the River and overcome problems associated with potential flood damage to the piers.

The purpose built bridge had several advantages, namely;

- Enabled additional water supply pipelines to be installed later if needed
- Could be used by pedestrians and cyclists and would enable the PNCC to develop its pedestrian and cycle link. This had the major advantage to both parties of sharing the construction cost between Army and PNCC. PNCC had previously considered constructing its own pedestrian bridge across the river to Linton as part of its walkway development along the Manawatu river bank.
- A bridge crossing avoids many of the uncertainties and risks inherent in a trenched crossing as once Resource Consents are obtained there is 100% certainty that the bridge project can be constructed and for a predetermined price.
- The bridge enables easy regular inspection of the pipeline for leaks or damage and it is relatively simple to undertake maintenance and replacement if necessary.
- The bridge could be constructed on land owned by Army and PNCC (the Higgins Quarry is on land leased from PNCC) thereby overcoming the uncertainties and risks associated with crossing private land or land owned by other utility operators.
- The bridge and pipeline would all be constructed on land that is already a highly modified environment and through land on which the existing uses are compatible with the pipeline and bridge.

A rough order CAPEX estimate was prepared based on the pipeline route shown in Figure 1 and the 'heavy-bridge' concept shown in Figure 2. This estimate was approximately \$1.3million excl. GST.

On the basis of the advantages outlined above and the CAPEX estimate (of which PNCC was paying a portion) Army made the decision to proceed with detailed design of this option. Army engaged PDP to undertake detailed design of the pipeline and bridge and PDP subcontracted the bridge design to Opus. Once design had been well advanced a revised estimate was prepared based on prices supplied by a structural fabrication company and a civil constructor. This put the CAPEX of this option at about \$1.7million largely due to the complexity of the bridge structure.

At this stage PNCC withdrew its support for the pedestrian capable 'heavy bridge' and a radical rethink was undertaken by Army and the design team to re-assess the purpose of the bridge. Because Army was now the only party funding the project it was decided that the bridge was only required to meet its core function of conveying sewage across the River. Accordingly, the bridge was stripped back to its basic function and the 'light bridge' concept was developed.

3.2.1 LIGHT BRIDGE DESIGN

The 'light bridge' comprised of a pipe suspended between two post tensioned cables. Such a large departure from the previous 'heavy bridge' concept meant that special consideration had to be given to behaviour of the structure and the pipe material given that it will move due to wind action. In addition, expansion and contraction of the pipe material must be allowed for. Because the light bridge has no superstructure on which personnel can get access to the pipe the issue of maintenance and construction access had to be addressed.

The final light bridge design comprises a 225mm diameter high density polyethylene pipe pressure rated to 8 Bar supported between twin 40mm diameter wire rope cables. The pipe is supported at 2 metre centres by brackets which are clamped to the pipe. Each bracket has an 'eye' on each end which fits loosely around the wire rope thus permitting the bracket to move longitudinally on the cables. During construction, once the cables are suspended in position the pipe will be assembled in one long prewelded string, the brackets will be attached and then the pipe will be pulled out from one side similar to a curtain on a curtain rail. The cables are tensioned and fixed to a low tower on each side of the River. The towers are tied back to deadman anchors. The pipe bridge has been designed to have a minimum clearance of 3.5 metres above the 100 year River flood level. This will provide a clearance of about 11 metres above typical River level.

Because there is no significant lateral restraint to the 'light bridge' Professor Flay from the Department of Mechanical Engineering at the University of Auckland was commissioned to analyse the potential effects of wind load and movement on the structure. Whilst movement is expected Professor Flay concluded that excessive dynamic motion due to wind excitation is not expected. It is also considered that the inherent damping effects of the polyethylene pipe material will be beneficial in reducing movement. To accommodate this lateral movement and also allow for longitudinal movement due to thermal expansion of the pipeline special reinforced rubber pipe couplings will be installed at each end of the pipe bridge.

To enable inspections and maintenance to be undertaken on the pipe bridge an additional 40mm diameter cable supporting a trolley cage has been provided for. The cage is capable of carrying two people plus equipment and has an electric winch system to enable accurate positioning anywhere along the pipe. Minor maintenance including welding of the polyethylene pipe and replacement of pipe lengths up to 6 metres will be able to be performed. Major maintenance of the pipeline or replacement of the pipe will be undertaken by pulling the entire length of pipe back to the Linton side of the river.

With adequate planning complete replacement of the pipe could be undertaken in 2 or 3 days and there is sufficient storage capacity within the oxidation pond to allow for an outage of this duration.

3.2.2 PUMPSTATION AND PIPELINE DESIGN

The design allows for growth in population at Linton Military Camp with a peak projected daily flow of 1,700m³/day being pumped to the PNCC sewage treatment plant. This flow rate has been calculated based on historical flow data.

The oxidation pond will remain in service once the pipeline is operational for the following reasons:

- a) To enable partial treatment of the sewage, thereby reducing the load on the PNCC sewage treatment plant.
- b) To enable flow balancing of effluent to the PNCC sewage treatment plant by pumping effluent at times outside of peak flow. This is advantageous as it produces a more even load on the PNCC plant.
- c) To provide storage capacity in the event that the pipeline is temporarily taken out of service for maintenance.
- d) To provide flow attenuation during wet weather flows. The operation of the pond will allow for the 1 in 100 year, 72 hour rainfall event to be stored for a period of 2 days whilst still providing a free board of 170mm.

The pumping system has been designed with two submersible pumps in an underground pumpstation. The first pump will be the duty pump, and the second is a 100% standby pump that will operate in the event that the first pump fails. These are conventional sewage pumps as used in PNCC's sewage pumpstations.

Effluent will be pumped to the PNCC plant at a rate of 30L/s. Based on the existing winter average daily flow at Linton of about 1,100m³, this will mean that the pump will run for 10 hrs/day.

The pump operation will be controlled by level switches within the oxidation pond. In the event that the pumps are not activated or the pumps fail to switch off, telemetry automatically sends an alarm to the PNCC treatment plant operations room.

A flow meter is installed at the pumpstation which will supply continuous flow data, and if the flow rate is outside a preset flow range of approximately between 25L/s and 35L/s for a period in excess of 15 minutes, the pump will switch off and the PNCC treatment plant operations room will automatically alerted by telemetry. The purpose of this is twofold. It stops pumping and alerts the operator should a pump be blocked and, most importantly, it shuts the pump off in the unlikely even that there is an accidental break in the pipeline.

Because there are several high points in the pipeline air valves have been installed to bleed off any accumulated air and gas and at some locations vacuum breaker valves have been installed to prevent siphon situations developing. A variable speed drive has been installed on each pumpset to provide a ramped startup which will allow time for any entrained air to be expelled via the air valves.

In the unlikely event that the pipeline were damaged or broken when the pump is not operating, for example, if it were accidentally broken by an excavator operating at the Higgin's quarry, then there would be a release of effluent. However, the volume of effluent which would be released would be no more than 26 cubic metres because the vacuum valves will prevent effluent being siphoned out of the entire length of the line.

In the event that maintenance work is required to be carried out on the pipeline or bridge than the pipeline can be taken out of use for several days and the Linton Military Camp oxidation pond used to temporarily store the effluent. The storage volume available is such that during present average dry weather daily flow, there is approximately 7 days of capacity and 4 days of capacity during predicted future average flow.

3.3 CONSULTATION

During the design process the need for a Resource Consent to construct the pipeline and bridge was identified and consultation with potentially affected parties was begun. There were 12 parties whom the City and Regional Councils' had identified as being potentially interested and this included five iwi groups.

Over a period of several months support was received from all interested parties except one iwi group. This group, Tanenuiarangi Manawatu Incorporated (TMI), was based in Palmerston North and expressed concerns about the project's impact on its cultural values. TMI staff suggested that they should be engaged to undertake a cultural impact evaluation, however, Army resisted engaging TMI as its staff would not provide a clear specification of what its study would cover.

After a number of discussions, exchanges of correspondence and meetings it was determined that the main concerns of TMI related to (a) development of a suitable protocol to cover any historic artifacts found during construction of the pipeline and (b) that the overhead passage of the oxidation pond effluent (via the bridge) was offensive. TMI suggested that a pipeline under the River would be acceptable to them. This was acknowledged by Army and the reasons that the submarine option was not favoured were then explained to TMI.

After a period of several months, during which time further dialogue and a pre-hearing 'meeting' was held, no resolution of the impasse had been reached and a date for a joint Council Hearing was set.

The outcome of the Hearing was the granting of the necessary consents with conditions attached relating to the aforementioned excavation protocol. The overall effect on the project of proceeding to the formal hearing process was a delay in commencing construction of about 10 months.

4 CONSTRUCTION

The light bridge project was sent out for construction tender to four pre registered tenderers. Only two tenders were received which reflected the very busy nature of the construction industry within the Manawatu region in 2005. Construction began in May and is expected to be completed by October 2005. The final construction cost is expected to be about \$1.2 million excl. GST.

There was an extension of time of 3 weeks granted early in the project to allow for the delay in obtaining PVC pipe for the underground sections of the pipeline. This is an unusual situation but came about because there was no pipe available in N.Z. due to the high level of activity within the construction industry and the pipe had to be manufactured to order.

5 CONCLUSIONS

This project has had a very long gestation period and did not really start to take shape until 2001 when the imminent expiry of the discharge consent for the Linton pond forced a degree of urgency to be applied to the project. Prior to 2001 progress was hampered by Army attempting to make decisions based on an inadequate amount of sound engineering investigation and evaluation.

Once the decision to build the bridge option had been made there were two further steps during the design process which proved costly in terms of achieving timely project delivery. The first of these was the assumption that PNCC would remain strongly committed to jointly funding the bridge even if the cost increased. The revised estimate of \$1.7 million was still within the +/-30% upper bound of the original estimate which had been advised early in the project. However, the political fortitude appeared to falter and this was the downfall of the 'heavy-bridge' option.

The second step was due to the delay of about 10 months working through the Resource Consent process. This effectively pushed tendering and construction into a very busy time within the local (and national) construction industry which affected the number of tenders received and likely influenced the competitiveness of the prices which were received.

Overall, whilst infrastructure projects often do take five or more years to get to fruition, particularly when there are multiple players involved, every project still needs to have a champion who will drive it and all decisions of an engineering nature must be made based on sound technical advice and a full understanding of the issues and risks involved.

ACKNOWLEDGEMENTS

We would like to acknowledge the work of Steven Charles (ex Opus) and Will Parker of Opus International Consultants Ltd, Palmerston North, who undertook the detailed design of the bridge structures.

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