CRITICAL INFRASTRUCTURE IN VULNERABLE LOCATIONS

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ABSTRACT

Hamilton City Council is responsible for the treatment, distribution and management of Hamilton's water supply. Raw water is drawn from the Waikato River into the water treatment plant, where it is treated to meet the Drinking Water Standards. This service benefits the community through provision of high quality water and sufficient pressure and flow to meet requirements for urban firefighting. The water supply network services more than 51,700 households and 5,500 commercial, industrial and rural premises through over one thousand kilometres of water mains and 7 storage reservoirs.

On the 2nd February 2017, through routine CCTV monitoring of the treatment plant inlet structure within the Waikato River, it was observed that a substantial section from the opposite riverbank had subsided, with approximately 500 cubic metres of material falling into the Waikato River. The slip occurred in close proximity to the eastern bulk water main, that services the eastern side of Hamilton.

The critical bulk water main was now exposed; water was seen flowing from the remains of the bank, initially believed to be from a stormwater outlet. An onsite inspection determined a failure within the bulk main valve chamber had occurred, triggering a water supply emergency to some 27,000 households.

What occurred over the following 6 weeks was of Coordinated Incident Management (CIMS), 16 hours of emergency shutdowns, extensive communication and collaboration with stakeholders, and extensive asset planning, operations and project management protocols.

The paper intends to provide an overview of emergency response techniques employed by Hamilton City Council, the methodology used to control immediate and future risk associated with the incident, issues encountered by personnel throughout the emergency response, repair, and business continuity phases, and also to share lessons learnt throughout each stage of the incident.

KEYWORDS

Asset Management, Operational Risk, Water leak, Water Supply Rehabilitation, Erosion

1.0 INTRODUCTION

The Waiora Treatment Plant located on the western side of the Waikato River was constructed in the early 1970's. The reticulation from the plant consisted of two sets of bulk mains for the Hamilton City's supply, namely the "eastern" and the "western".

The eastern bulk main was the first pipeline to cross the Waikato River in Hamilton City and allowed the eastern part of the city to be supplied with treated water. The installation was considered a major undertaking with the twin 24 inch diameter concrete lined spiral steel mains being welded above ground on the eastern banks of the Waikato River and lifted into a trench in the bed of the river.

From historical photos, it can be seen that the Waikato river was temporarily dammed to reduce the flows in order for the pipeline to be installed. Where the pipeline came out of the river and into the bank, fill material was placed around the pipeline and sheet piling was installed. The twin pipes are in connected on the eastern side through a series of valves and fittings located within a large concrete valve chamber.

Figure 1. Photograph of the eastern bulk mains installation on the eastern side of the Waikato River

Based on its location, required performance, and lack of an alternative supply, effectively made the eastern bulk mains, one of the most critical water supply assets within the water supply network.

The valve chamber and the bulk mains not only sit within close proximity to the Waikato River but also within the site of the City's key attraction the Hamilton Gardens.

In the 1980's in the immediate vicinity of the pipes, the water intake for the Hamilton Gardens irrigation supply was constructed.

Figure 2. Aerial location of the eastern bulk mains and valve chamber in proximity to Waikato River

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2.0 SPRUNG A WATER LEAK

Within the early hours of the morning of 2nd February 2017, it was noted during routine visual inspection that an unusual amount of water was observed coming from the embankment immediately adjacent to the valve chamber. It was unclear at the time, if the origin of the leak was from the Hamilton Gardens stormwater system, the nearby water intake structure, or from one (or both) of the bulk mains.

Not long after, a significant amount of the embankment slipped into the river surrounding the bulk mains. The sheet pile wall had failed resulting in the material behind it to slip into the river, revealing the twin mains and valve chamber. This was coupled with an alarm notification of pressure reduction within the eastern bulk main system and a visible gushing of water some ten metres into the air immediately above the valve chamber.

Figure 3. Aerial view of the erosion site shortly after erosion event occurred showing removed section of sheet piled structure

The initial incident was reported by the Treatment Plant operations team to the Reticulation operations team for first response.

The first response team assembled onsite to make an assessment of what had occurred and to determine what steps were required to mitigate the immediate safety risks and to ensure continuity of water supply to the customers on the eastern side of the Waikato River.

It was eventually found that a gibault fitting had failed allowing water to shoot into the air at a rate of about 50 litres per second.

Figure 4. Photograph showing exact location of gibault failure once isolated

Maintaining a minimum level of service to the City was at risk hence the decision was made to declare the situation as an emergency, triggering an incident management team being established under the *Coordinated Incident Management System* (CIMS) framework. CIMS is a proactive incident management frameworks used primarily by emergency management agencies "*to coordinate, command, and control incident response of any scale"* (*Coordinated Incident Management System (CIMS), 2nd Edition, NZ Government, April 2014*).

From here the response to the incident became essentially three parallel streams of work; accessing and undertaking the repair of the leak without compromising supply to more than 27,000 properties, assessing the stability of the bank to ensure the valve chamber was not going to move, the planning and design of immediate and long term solutions that would not only provide bank stability, but also mitigate further risk to the infrastructure.

2.1 MISSION #1 REPAIRING A LEAK

Isolation of the water supply to determine the origin of the leak was challenging due to the difficulties in locating valves that were operable. As the team found through trial and error, valves in the network were either not where the GIS records indicated or were not adequately sealing. Inaccurate GIS records is a common issue amongst water authorities primarily due to the lack of accurate records for older assets and misinterpretation of location details through the digitisation process.The staff on site had to venture nearly a kilometre away from the break in search of a valve which would isolate the network and to the frustration of the team, water continued to flow back through the break. Later it was found that modifications to the network had been made and an interlink installed. As builts had not been provided hence the Council records were inaccurate.

While it was important to maintain service to the properties fed from the bulk mains on the eastern side of the river, the time had come to commence the shutdown sequence from the water treatment plant side of the river. A process that would take up to 5 hours.

The majority of the water supply for Hamilton City and surrounds is either stored or transported via infrastructure located on the western side of the river, without the eastern bulk mains in service, it was inevitable that either a complete loss or reduction in water would occur in parts of the network. A resilience risk that is currently being addressed through the construction of new reservoirs over the next 4 years on the eastern side of the river.

As the bulk mains are a ring system which are connected in the north of the City via a bridge crossing, water was able to be supplied through to the east side of the river. This required increasing the pumping capability of the distribution pumps located at the treatment plant. While this solution did ensure that no properties were without water, operating pumps at their maximum range was not sustainable and increased the risk of failure of the older pipework in the network. Fortunately, there were no known reported issues of water outages from the customers supplied by the Hamilton City Council. Only a few calls received relating to reduced water pressures.

In parallel to the team out on the ground, staff were searching reports and running different scenarios using the water hydraulic model throughout the outage period. This ensured that properties affected as a result of isolating the bulk mains were identified prior to isolating. This allowed targeted communication and allowance for alternative water supplies to be arranged.

Almost a day after discovering the initial incident, the valve chamber was able to be emptied of the water revealing a fracture through the centre sleeve of the gibault coupling on one of the eastern bulk mains. The origin of the leak had been located meaning it was time to canvass suppliers for a replacement gibault. Due to the age of the pipe, finding a fitting designed in metric units to fit a pipe designed in imperial units was going to be a challenge. Initial enquiries into replacement fittings been made earlier that day meaning up to 5 replacement gibaults of differing sizes had all been delivered on from Auckland and were all lined up adjacent the valve chamber ready to go.

By late evening on Friday 3rd February, 25 hours after the initial leak, the repair had been completed. The water supply ‘re-livening’ sequence could begin, however not before further confined space entries to re-open network valves, and implementation of disinfection protocols being completed. The crisis had been averted, for a short time anyway.

With the leak repaired, service levels restored and no immediate risk to water supply, it was considered that the risk had been effectively mitigated and now attention could turn to the stabilisation of the valve chamber and the rehabilitation of the river bank.

2.2 BANK STABILISATION

Determining the status of bank stability was key and technical assistance was going to be required from specialist engineers. Through the Council’s consultancy panel, a call was put out for assistance and BECA consultants responded immediately.

The day following the incident, BECA consultants were on site assessing the infrastructure and surrounding ground conditions. Inspection of the site from the ground above the pipework was challenging and it was decided to get a better understanding of the site, a visual inspection from the water was needed, fortunately the Waikato Regional Council’ s harbourmaster was able to provide the assistance in the form of a boat.

From the initial inspection the key observations and comments identified were as follows:

- Material holding the bank had failed, along with the sheet piling anchors evidenced from the sheet piles bent over under the water line. Along with exposure of the twin pipes and the water intake, material had been lost from beneath the concrete chamber.

- A pipeline joint located within the concrete chamber had failed , water had built up within the chamber eventually surfacing from the top (through the lid).

- The remaining material in the immediate vicinity of the pipe and the chamber was classified as weakly cemented alluvial soils, hence presenting a risk of further erosion.

- Water seepage from the bank was observed following the isolation of the water supply.

Figure 5. Photograph showing failure of sheet pile wall and erosion extent

It was clear, that although we had managed to address the damage to the pipeline, the infrastructure was still at risk and subject to failure if we did not act immediately. Worst case scenario for Council at this stage was further subsidence resulting in the chamber being undermined and potentially falling into the river and taking the twin pipes with it.

BECA consultants was instructed to commence developing a temporary solution to stabilise the bank, in the meantime Council focused on what could be done to mitigate the risk of further erosion.

The fluctuating levels of the Waikato River was the greatest concern. The Waikato River is part of the Mercury's (previously Mighty River Power) power generation scheme, the river levels are subject to the release of the dams upstream, Council worked with Mercury to limit the fluctuations of the river levels until Council could stabilise the site.

2.3 THE INITIAL CONCEPT

The initial concept that BECA developed included immediately stabilising the weaker materials through the use of shotcrete applied to the exposed bank slopes, removal of material around the valve chamber to alleviate any pressure on a chamber considering it's base had been compromised. Then progressing to a temporary solution of rock fill placed around the infrastructure and reno mattresses placed on the river bed.

Further investigations including geotechnical testing was required to confirm the design.

With the initial concept in hand, stakeholder communications could be initiated, contractors engaged and cost estimated developed.

2.3.1 CONTRACTOR ENGAGEMENT

Getting a contractor on board promptly was critical with the risks to the water supply still present, using the Council's emergency procurement provisions, Brian Perry Civil (BPC) were approached to provide a proposal to assist along with two other contractors. BPC had recently completed the construction of the Council's low river contingency intake structure and they were well versed in working with Council and working in the Waikato River, they were the logical choice to tackle the current challenge.

2.3.2 STAKEHOLDER ENGAGEMENT

Waikato Regional Council (WRC) was one of the stakeholders that had been engaged with early on, they had been notified on the day of the incident. To ensure that we could commence construction promptly the Regional Council was invited to discuss the works to date and the implementation of the concept.

WRC were supportive and acknowledged the urgency of addressing the risks. We worked collaboratively and were able to get an understanding of what was permissible under emergency provisions and what would require consents.

Immediate stabilisation using shotcrete application to the bank was able to proceed, but a rethink of the temporary solution was needed as the regional council had concerns about the extent of the works into the river bed.

To ensure we captured all the required stakeholders and adhering to all rules, a planning needs assessment was undertaken. Iwi was identified and again Council had already commenced the communications earlier. The assessment identified that the site was part of a historical Pa, which was a complete surprise to the team. Any progression of physical works was halted immediately until Council could get an archaeological assessment undertaken. It was fortunate for Council that the original watermain construction photos were kept, along with a site inspection completed by a qualified archaeologist, this provided sufficient evidence to present to the Heritage New Zealand to confirm an archaeological authority was not required.

2.4 'STICKY PLASTERING' THE BANK

While the design consultant worked on the temporary solution, the contractor commenced the stabilisation of the area immediately around the pipes and valve chamber.

As the contractor began to remove the material above the slip and around the chamber, the investigation into the water seeping from the bank was conducted in parallel, what was found was plethora of underground services, none of which were documented – stormwater infrastructure, irrigation pipes and potable water pipes. Testing and confirming what the pipes were and if they were "live" slowed the process to stabilise the bank.

The other challenge for the contractor was application of the shotcrete to the lower levels of the bank. The Waikato Region experienced a mild, wet summer, the La Nina weather pattern that was experienced resulted in a number of cyclone events. During these weather events, Mercury was unable to sustain the low river levels we required and along with the flow from the contributing tributaries meant the river levels rose well above the norm for the time of the year.

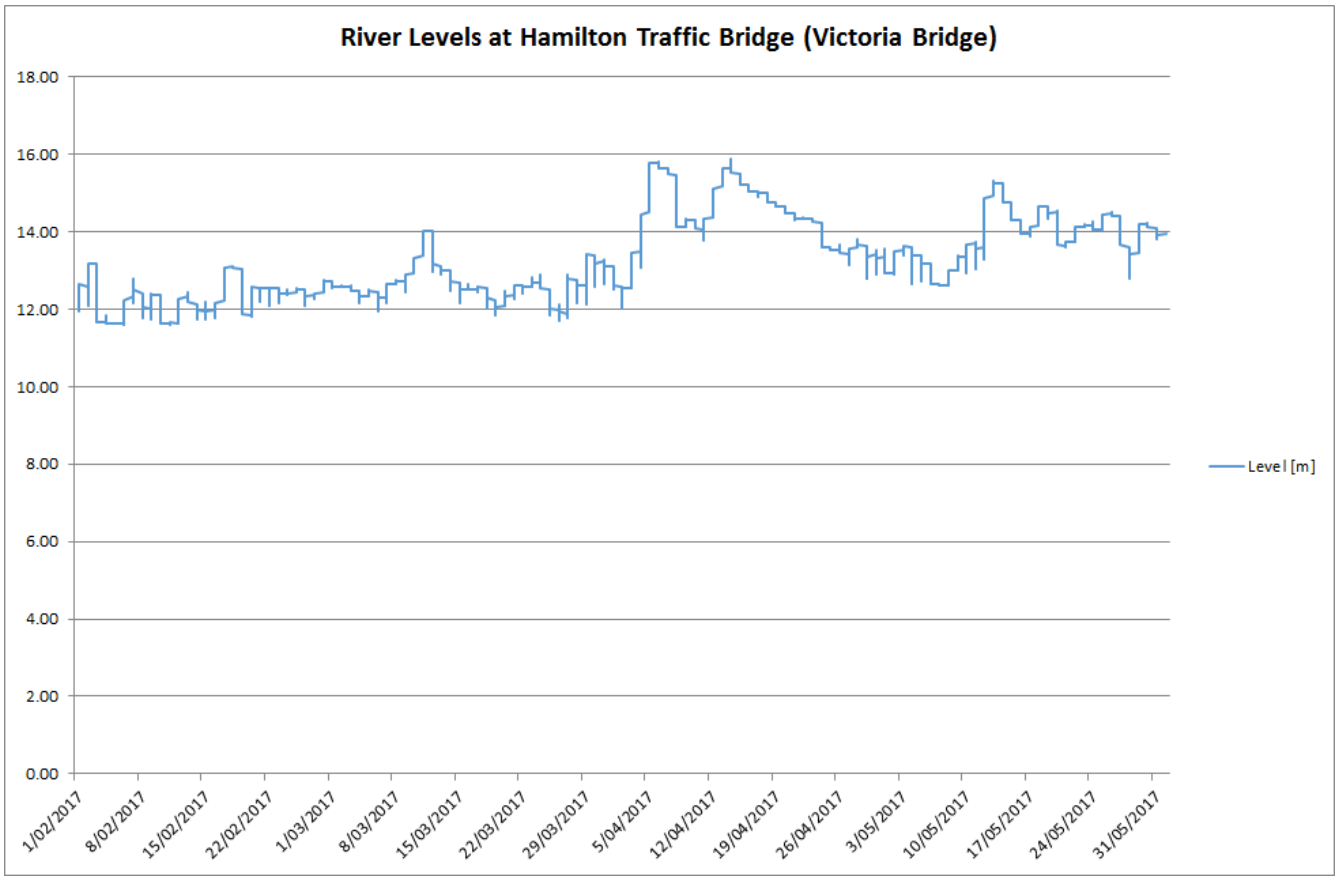

Figure 6. Waikato River Levels (Source: WRC website) Note: Levels taken from Victoria Bridge Hamilton approximately 200mm lower than recorded levels at slip site.

The Waikato Region experienced three tropical storm events following the February 2nd incident which impacted on the ability to carry out visual assessments of the slip site and continuance of the remediation works.

In between the storm events and when the river dropped, it was observed that the bank continued to lose material. It was the continual change in levels that did the most damage, as the river would drop, the weakly cemented materials that were exposed would drop with the river. It was estimated that over 700 m3 of soil had been lost from around the immediate area.

To put it into perspective, the peak river level experienced during the days after the initial event (16.1metres) which equates to approximately 550 cumecs of flow at the slip site. The only other level that was greater since recorded levels began was on July 15th, 1998 (16.92).

Loss of material immediately below the chamber was the biggest concern, as the contractor battled the environment to get the shotcrete applied, Council staff went into emergency mode, 24/7 monitoring during rain events was necessary in case the infrastructure failed and the water supply needed to be isolated.

With alarm notification set points on a level switch, and with the installation of a high resolution camera that would allow remote monitoring of the site, the onsite presence was able to be reduced.

The bulk mains were isolated as a precautionary action on one further occasion. This was due to the river level almost exceeding the top height of the remaining sheet pile, any large debris coming down the river could strike the exposed bulk mains, causing damage beyond repair and potential longer term water supply issues.

Figure 7. Extreme river levels at bulk main site

3.0 THE FINAL HURDLE - IMPLEMENTATION OF THE SOLUTION

As the contractor and Council staff battled with the elements to implement the immediate fix, the consultant continued with the solution to stabilise the bank. Along with the results of the geotechnical investigations, the feedback from WRC and the observations made following the rain events a solution was formulated that was different in method and scale from the initial concept.

The design evolved from being a temporary solution to being permanent bank stabilisation. The design was for a soil nail-reinforced shotcrete structure to stabilise the slope above the river level, reno mattresses placed in the river bed at the base of the shotcrete structure to prevent further degradation and re-contouring of the site and diversion of all overland flow paths.

The decision was made not to re-case the pipes in material, just to focus on stabilising the bank and the valve chamber, this meant the a protection structure for the pipes would need to be constructed. Council made the call that this could be done later and include the new intake structure for the Hamilton Gardens.

The works are continuing through the 2017 year with expected completion date of the reinforced embankment and new protection structure to be completed in 2018.

4.0 DESCRIPTION OF FAILURE

At the time of publishing this report, the investigations into the root cause of the failure is continuing.

However, an initial key learning from the investigation noted that *"regular inspections of the wall may not have identified the risk of failure...however, monitoring of the wall age and condition through asset management and inspection may have prompted more investigations or replacement of the asset"* (Eastern Bulk Watermain Failure Investigation Report, AECOM, July 2017).

Council is yet to document all the learnings and potential improvements for managing the water supply. Some of the key elements from the incident identified were:

- Identifying critical assets is important, but also capturing any supporting infrastructure is just as important, like retaining walls and sheet piles
- Understanding the operational network and the impacts of key assets on the customer.
- Ensure that Business Continuity Plans are developed and distributed to the teams managing and operating the system
- Ensuring emergency response plans are in place and protocols for managing the emergency are understood by the team.

This emphasises the need for robust asset management for existing and new infrastructure to ensure risks are accounted for and understood. This leads on to having in place preventative maintenance programmes to ensure critical infrastructure are regularly assessed and monitored to mitigate the risk of failure.

ACKNOWLEDGMENTS

Mercury Energy, Waikato Regional Council, MWH Stantec NZ, Brian Perry Civil, West Construction, Hynds NZ, Mott MacDonald NZ, BECA NZ, Tiro 360/RPA consulting, AECOM, OPUS International Consultants

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