PILES CREEK EMBANKMENT COLLAPSE – THE INVESTIGATIONS, THE EXPERT'S FINDINGS AND SUBSEQUENT IMPROVEMENTS IN ASSET MANAGEMENT OF CULVERT STRUCTURES ON MAJOR ROADS IN NSW

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ABSTRACT

This paper outlines the methods and techniques adopted to gather the field investigation data to further our understanding of the failure mechanisms for the Pacific Highway Culvert at Piles Creek. Details of the combined expert's opinions in to the mechanism and reasons for the failure will be presented.

Following the investigations and findings of the experts, the NSW Deputy State Coroner provided this recommendation in his Inquest report:

".....development and implementation of its (Gosford City Council) assets management and records management systems with particular reference to the need to implement an effective inspection regime for road assets, the identification of risks associated with such assets, the timely response to risks that are identified and the effective managerial oversight of such systems"

Since this incident a significant amount of work has also been commissioned by the Roads and Maritime Services of NSW (RMS) to improve culvert asset management along their network of roads. The details of the RMS culvert asset management system are available to local councils. The paper will conclude with brief details of the RMS cataloguing and culvert risk assessment developments.

1 INTRODUCTION

At approximately 15:30 hrs on Friday 8 June 2007, during a period of significant rainfall, a section of the Old Pacific Highway at Piles Creek, Somersby collapsed. A car subsequently drove into the void created by the collapse resulting in the death of all five occupants. See Figures 1 and 2.

Figure 1: Site location

Figure 2: Aerial photo of collapsed section

Aurecon was appointed to investigate the reasons for the collapse on behalf of the NSW State Coroner. Experts from Aurecon first inspected the site on 10 June 2007 at the request of the Department of Commerce. As part of this initial inspection Aurecon identified that the section of the Old Pacific Highway over Leask Creek, (adjacent catchment to the south), exhibited signs of failure similar to those suspected to have caused the collapse at Piles Creek. This section of the Old Pacific Highway was subsequently included in the investigation.

Following this initial site inspection a series of further site inspections, general and technical meetings were held between the interested parties and their appointed Technical Experts. The appointed technical experts agreed upon the scope and basic investigation methods to be employed as well as the key issues that the investigations and subsequent reporting should address.

Between July 2007 and February 2008 a series of detailed investigations were undertaken both at the site and in various laboratories with the aim of gathering as much data as possible to assist in understanding the reasons for, and the mechanism of, the road collapse. The field investigations were undertaken in a collegial manner by the appointed Technical Experts. Refer to Table 1.

Table 1: List of technical experts involved throughout the investigation at Piles Creek

Interested party	Discipline	Appointed technical experts
NSW State Coroner	Geotechnical	Aurecon Pty Ltd (Neutral Bay)
	Materials	Aurecon Pty Ltd (ATC Newcastle)
	Hydraulics	Aurecon Pty Ltd (Neutral Bay)
Roads and Marine Services (RMS)	Geotechnical	Pells Sullivan Meynink Pty Ltd (PSM)
	Materials	CTI Consultants Pty Ltd
	Hydraulics	Pells Sullivan Meynink Pty Ltd (PSM)
	Survey	RTA survey department
Gosford City Council (GCC)	Geotechnical	Jeffery and Katauskas (J&K)
	Materials	Bureau Veritas
	Civil Engineering and Hydraulics	Cardno (NSW) Pty Ltd
	Survey	CR Hutchinson and Co.

2 CORONER'S REQUIREMENTS

It was a key requirement of both the Coroner and Crown Counsel that the investigations be undertaken in a collegial manner so as to minimise the amount of time the technical experts would be required at the Coronial hearing. To achieve this aim the following was agreed to by all interested parties:

a A single set of factual data would be collected collegially by the technical experts representing each interested party

b A single factual data report would be compiled and agreed to by all parties as representative of the 'as found' conditions on site

c Technical experts from each interested party would compile their own interpretive report based on the information provided in the factual data report. Each report was to be based on an agreed common list of contents and schedule of key issues to be addressed

d A conference of technical experts would be held to identify areas of agreement and reasons for any areas of disagreement between the technical experts in their interpretation of the data and events leading up to the collapse. At the culmination of this conference a single report was to be compiled for the Coroner detailing the outcomes of the conference

3 THE INVESTIGATIONS

3.1 INVESTIGATIONS AT PILES CREEK

Prior to the commencement of fieldwork the technical experts agreed to the methods and approaches that would be used for the investigation. A progressive, controlled excavation of both sides of the collapsed zone was then undertaken to gather geotechnical information by inspection, mapping and testing of the embankment materials. Figures 3, 4 and 5 illustrate the investigation layout and notation used to distinguish between the different areas of the Piles Creek site.

It was agreed that the embankment on both sides of the collapsed zone should be progressively excavated in 0.5m deep lifts (benches) to pipe obvert level as shown on Figures 4 and 5. The 0.5 m deep benching would allow a significant amount of ground exposure for inspection and logging, it would minimize the amount of information being lost by the excavation process. The benching also provided an easy means of dealing with and comparing field measurements and relating them back to surveyed measurements. Figures 6 and 7 below show excavated trenches which were used to capture and log the remaining embankment profile.

Geotechnical experts from each interested party were present throughout the deconstruction work to direct, log, map and sample all areas on interest.

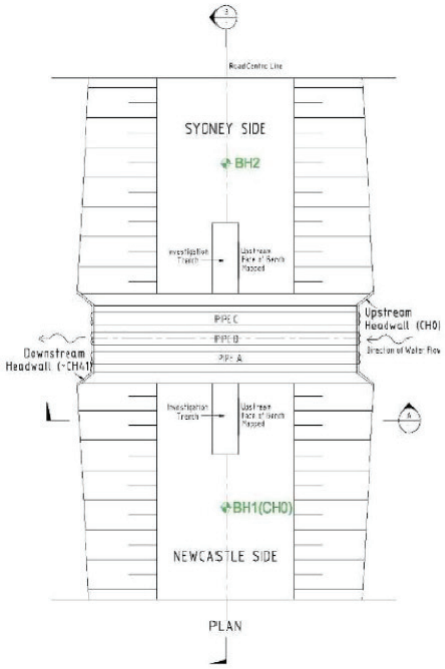


Figure 3: Schematic plan of the Piles Creek investigation area

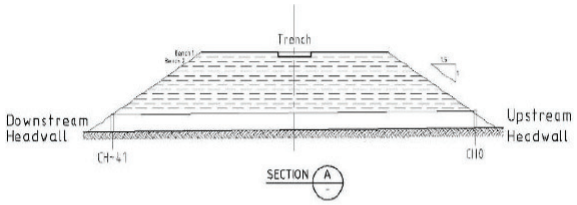


Figure 4: Schematic section A-A of the Piles Creek investigation area

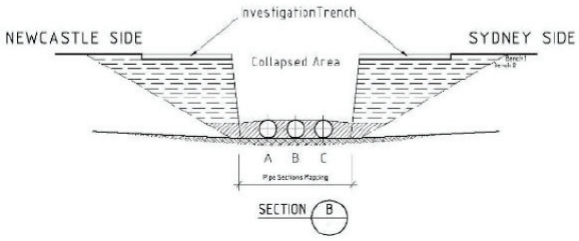


Figure 5: Schematic section B-B of the Piles Creek investigation area

Figure 6: Trench face exposing fill layering

Figure 7: Displacement feature seen in trench face

Below pipe obvert level, it was agreed by the technical experts that sections would be logged at 4.0 m intervals along the length of the pipes (see Figure 4). Figures 8, 9 and 10 illustrate one such section and Figure 11 shows the removal of the pipes in sections as the investigations progressed. As the entire investigation process was destructive, each stage of the work required complete agreement by the technical experts. A sufficient and relevant level of detail and accuracy had to be captured before progressing to the next phase of work

Figure 8: Typical section through the pipes

Figure 9: Typical section through the pipes

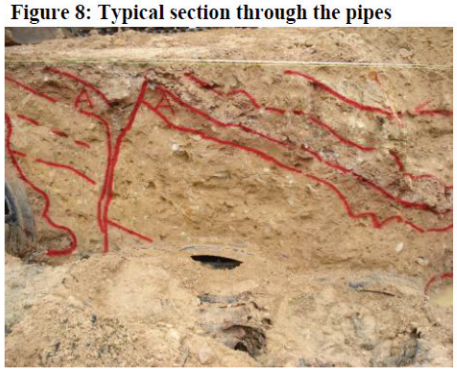


Figure 10: Section showing collapsed pipe

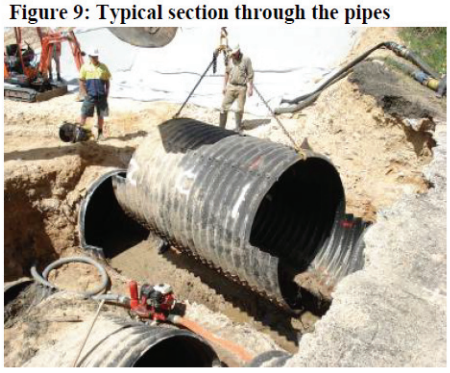


Figure 11: Pipe removal for a section of pipe

In addition to the visual assessment by the technical experts both *in situ* and laboratory testing was undertaken not only on soil, but also on water, the steel culvert sections, asphalt from the collapsed road pavement and concrete from both headwalls at Piles Creek. Table 2 below indicates the suite of testing undertaken.

Material	Testing	
	In-situ	**Laboratory**
In-situ Soil and Filling	• Compaction and density • Guelph Permeameter (permeability) • Double-ring Infiltrometer (permeability) • Standard Penetrometer Test (SPT) • Dynamic Cone Penetrometer* (DCP) • Corrosivity	• Soil Classification • Compaction • Remoulded Triaxial • Remoulded Shear box • California Bearing Ratio (CBR) • Permeability • Conductivity • Erosion / Dispersion • Chemical
Water	-	• Contamination • pH • Conductivity • Selected chemicals
Steel	• Dry film thickness (DFT) survey • Pipe invert corrosion survey	• Ultimate tensile strength • Dry film coatness thickness • X-ray diffraction (XRD) • X-ray fluorescence spectroscopy (XRF) • Steel Microstructure • Hardness • Slurry Abrasivity
Asphalt	-	• Visual examination
Concrete	-	• Compression • Density • Hardened concrete analysis

Table 2: Summary of in-situ and laboratory testing undertaken

* Undertaken at Leask Creek site only

The tests were either performed by the team of technical experts or by an agreed third party laboratory facility. One advantage of undertaking the investigation in a collegial manner is that we were able to allocate the most experienced and appropriate resources to each task from the team of experts. Duplicate *in situ* density testing, soil sampling and soil testing was undertaken for quality control purposes and to provide confidence in the parameters and results provided. Duplicate survey was also undertaken of the internal geometry of the pipe culverts.

The technical experts agreed that a detailed survey of the inside of the pipe culverts was needed in order to capture the final state of the pipes, the degree of deformation undergone by the pipes and the amount of perforation evident in the pipe inverts. Figures 12 and 13 outline the approach used to survey the pipe culverts. Figures 14 and 15 illustrate the degree of perforation and deformation of the pipe culverts.

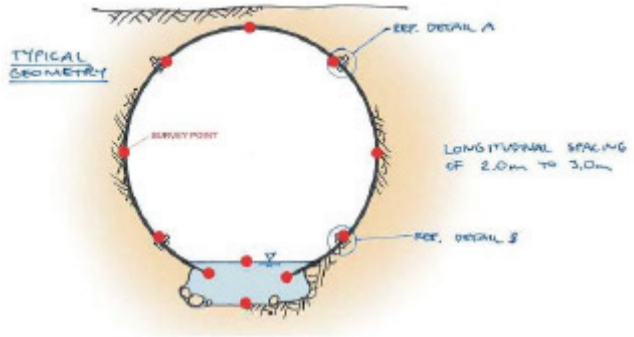


Figure 12: Survey points for typical pipe geometry

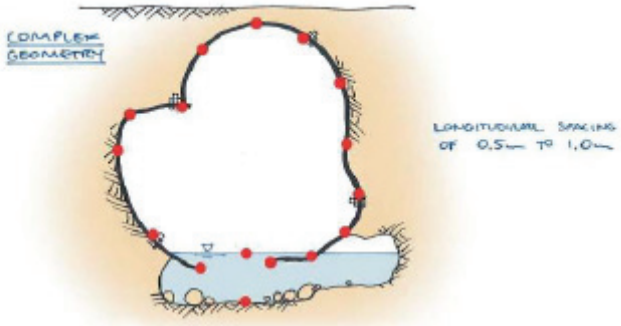


Figure 13: Survey points for complex pipe geometry

Figure 14: Deformation of pipe culverts

Figure 15: Perforation of pipe invert

3.2 FIELDWORK – LEASK CREEK

The technical experts agreed that due to the similarity in construction between the Leask and Piles Creek embankments, and the fact that the embankment at Leask Creek appeared to be exhibiting similar mechanisms of failure, that investigating the Leask Creek road embankment would provide more evidence to support our thoughts in regards to the mechanism of failure at Piles Creek. The investigative procedure undertaken was similar to that at Piles Creek with the exception of omitting sampling and laboratory testing of embankment materials. Figures 16, 17 and 18 illustrate the investigation layout and notation used to distinguish between the different areas of the Leask Creek site.

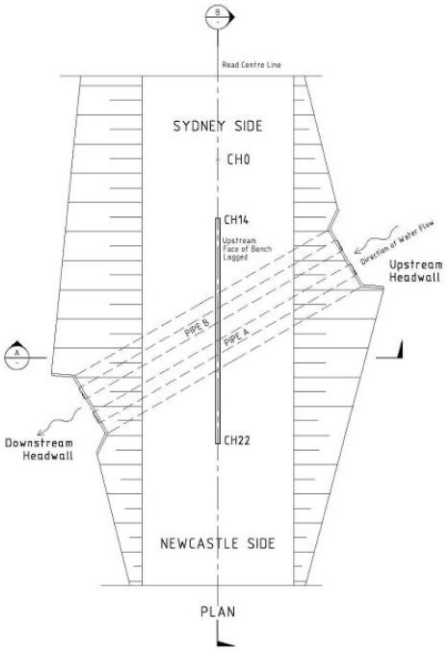


Figure 16: Schematic plan of the Leask Creek investigation area

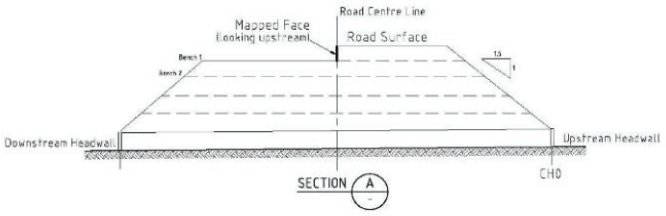


Figure 17: Schematic section A-A of the Leask Creek investigation area

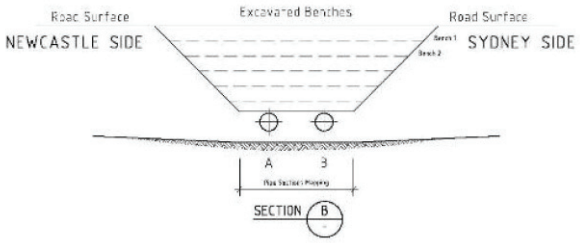


Figure 18: Schematic section B-B of the Leask Creek investigation area

It was agreed that 1.5m deep benches would be excavated, located at the centre of the road directly above the pipes. The fieldwork at Leask Creek comprised of the following:

- Mapping the upstream and downstream embankments
- Logging the *in situ* embankment materials
- Installing extensometers to measure the movement of the headwalls during heavy rainfalls
- DCP testing within the lower benches to identify any softer areas or voids within the embankment and around the pipes.

Figures 19-22 below illustrate some of the interesting features found whilst deconstructing the site at Leask Creek which assisted in determining the manner and cause of the collapse embankment section at Piles Creek.

Figure 19: Voids in the embankment fill beneath the road Pavement

Figure 20: Dip evident in embankment fill layering

Figure 21: Further dipping of embankment layering and voids present above pipes

Figure 22: Perforation of pipe inverts at Leask Creek

3.3 INVESTIGATION OUTCOMES

The following key collegial outcomes were achieved by the technical experts:

- A single set of data was produced and accepted by all parties
- Significant agreement was reached in our interpretation of the failure
- The report resulting from the conference of technical experts was provided to Counsel from all interested parties and to the Coroner
- There was no requirement for any of the technical experts to appear before the court

The outcomes are a significant improvement on previous hearings of a similar nature where a great deal of court time was required to cross examine technical experts on discrepancies/differences in the factual data collected.

4 THE FINDINGS

The experts were in agreement as to the mechanism that resulted in the failure of the road. They described the process as follows:

- *'The mechanism of collapse commenced with the abrasion/corrosion of the inverts of the corrugated steel pipes,*
- *Once the invert had been substantially perforated, the water flowing through the pipes began to wash soil out from around and beneath the pipes, causing voids around and eventually over the pipes,*
- *The ongoing loss of embankment fill material, as it was washed away by the flowing water through the culvert, progressively reduced the stability and integrity of the embankment,*
- *The progressive loss of embankment fill material and creation of voids caused subsidence to occur on the road surface above the pipes,*
- *The rain event on 8 June 2007 combined with the pre-existing instability and loss of integrity caused by the formation of the voids above and around the pipes resulted in the collapse of the embankment above the culvert and subsequent complete washout of the embankment fill material.'*

The experts were also in agreement as to the cause of the collapse of the embankment. They said:

- *'The cause of the collapse of the embankment above the culvert was the failure to adequately maintain the culvert.'*

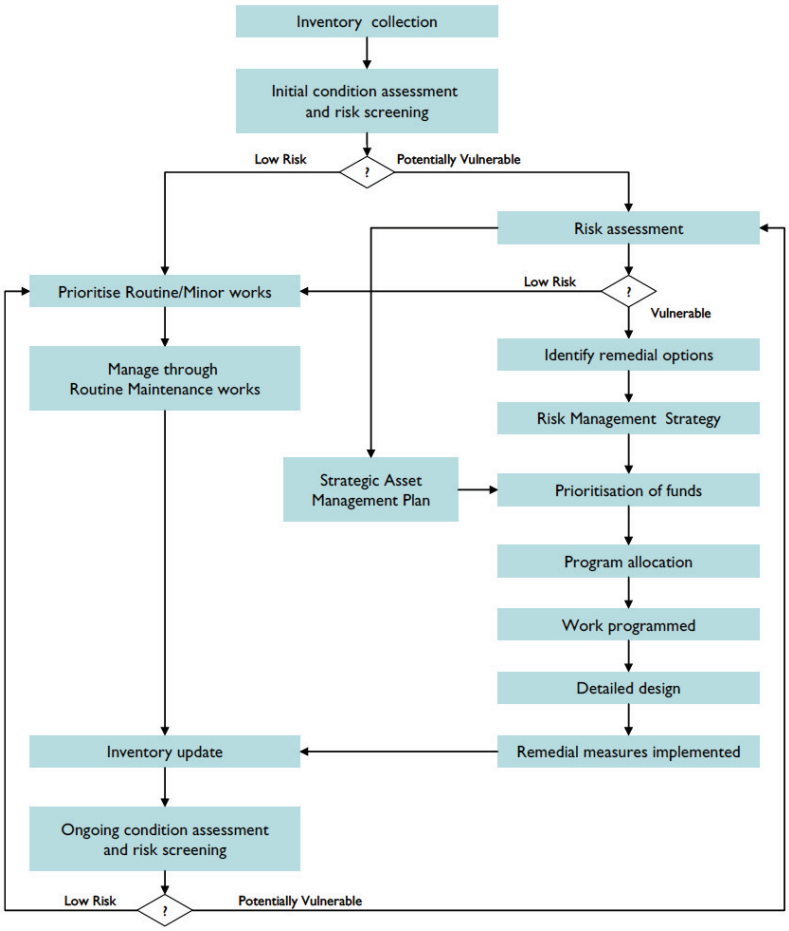
The engineers appointed by the GCC agreed with the above proposition but added a rider to the effect that had the initial design of the culvert included a concrete lined invert then that would have prevented the problem of abrasion and corrosion from arising within the approximate 50 year design life of the culvert.

The coroner concluded that:

- *'I accept the joint evidence of the expert engineers retained and find that the cause of the collapse of the Old Pacific Highway above the culvert at Piles Creek on 8 June 2007 was the failure to adequately maintain the culvert.'*

5 ADVANCEMENTS IN CULVERT ASSET MANAGEMENT IN NSW

Over the past 6 years the Roads and Maritime Services of NSW has developed a robust framework for the long-term management of its culverts assets across its network of roads in NSW. The flowchart below details the frame work process



Taken from RMS Culvert Risk Assessment Guideline Version 3.02 December 2010

The first stage of the culvert asset management programme, *Culvert Inventory Collection* was developed to establish an inventory of all the RMS culvert assets. The process included recording of the number, location, type and condition of each culvert in the RMS road network. This process is now believed to be complete and is understood to have identified a total of 70,000 culverts.

The second stage, *Culvert Risk Assessment*, comprises a formal risk assessment of culverts identified during the first stage as warranting further assessment. The Culvert Risk Assessment guideline was developed along similar lines to the now well-established Slope Risk Assessment Guidelines. The Culvert Risk Assessment Guideline establishes a robust mechanism to establish potential failure mechanisms for individual culverts, to then asses the likelihood of that failure mechanism developing, the likely consequence relating to the specific failure event and thereby establish a specific Assessed Risk Level (ARL) for that culvert. This provides RMS with both an early warning mechanism alerting them to culverts that are or could become at risk of failure and a tool to appropriately allocate maintenance budgets.

6 REFERENCES

Aurecon report, *Investigation of the Piles Creek Embankment Collapse*: *Factual Report,* dated 11 April 2008 ref 29579 Rev 1

Aurecon report, *Investigation of the Piles Creek Embankment Collapse*: *Interpretive Report,* dated 28 April 2008 ref 29579 Rev 1

Roads and Maritime Services, *Culvert Inventory Collection Guideline,* October 2008.

Roads and Maritime Services, *Culvert Risk Assessment Guideline*, Version 3.02 December 2010.

NSW State Coroners' Court, Inquest touching the death of: - Adam Holt, Roslyn Bragg, Travis Bragg, Madison Holt and Jasmine Holt. Glebe Files: 989, 988, 992, 990 and 991of 2007