SUMMARY:
As dams age and become structurally deficient, they can pose a threat to public safety and may no longer have any commercial value. Yet often they are considered by the local community as an integral part of their social, cultural, heritage and environmental landscape.

This paper focuses on two small dams. Both dams are more than a century old and do not satisfy current dam safety regulatory standards. The risks to the downstream residents were intolerable and the dam owner was required to remove these risks. The paper explores the challenges involved in the management of heritage dams by revisiting the outcomes of the two dam projects and describing the process used to arrive at the solutions.

The availability of funding for surveillance, maintenance and capital works plays a large role in determining the condition and ultimately the conservation of these early New South Wales dams.

It is imperative to resolve dam safety issues based on balanced decision making, with decisions taking into account the structural condition and the risks associated with dam, having due regard for the dam’s heritage and environmental value and role to the community.

GLOSSARY

Australian National Committee on Large Dams (ANCOLD):
ANCOLD is an incorporated voluntary association of organisations and individual professionals with an interest in dams in Australia. ANCOLD was formed in 1937 as the Australian national committee of the International Commission on Large Dams (ICOLD)

Dams Safety Committee (DSC):
The DSC is a NSW government statutory authority created under the Dams Safety Act 1978. Its role (among other things) is to “formulate measures to ensure the safety of dams” and to “maintain a surveillance of prescribed dams” (Dams Safety Act 1978). A “prescribed dam” is one listed in Schedule 1 of the Act. The Committee has a general responsibility to ensure the safety of all dams, and a special responsibility regarding prescribed dams.

Sunny Day Failure (SDF):
A "sunny day" dam failure is one that is not associated with a storm or flood wave. The failure mode may be due to a piping failure for earthen embankments, or a failure for concrete dams.

Operational Basis Earthquake (OBE):
The Operational Basis Earthquake is defined as the earthquake with a return period of 144 years.

Imminent Flood Failure (IFF):
As defined in the 1986 ANCOLD Guidelines on Design Floods for Dam, the flood event, which, when routed through the reservoir, with the existing spillway, just threatens failure of the dam.

Full Supply Level (FSL):
The maximum normal operating level of a reservoir, as distinct from flood surcharge.

Dam Safety Emergency Plan (DSEP):
A continually updated set of instructions and maps that deal with possible emergency situations or unusual occurrences at a related dam.

1. INTRODUCTION
The purpose of the paper is to outline the investigative, consultative and decision making processes in managing issues facing century old dams. These dams are generally medium size dams between 10 metres and 20 metres in height and were constructed at the turn of the 20th century, mainly to provide clean water for the growing populations and industry in New South Wales burgeoning rural towns. These dams were vital to the survival and development of rural New South Wales towns and other industries such as the railway, agriculture and mining of gold.

Whilst some of these structures continue to play their original role, the vast majority have since been superseded by larger dams and more efficient water supply schemes. Some have assumed a role as a recreational facility, attracting recreational fishers and picnickers, whilst others have long silted up and lay quietly surrounded by woodlands. The dams also play an environmental role as a habitat and food source for fish, birds and mammals.

Given their history and longevity, most of these dams are indeed integral to their community and its history. The majority of these dams have been assessed and found to have heritage significance ranging from local to State significance. Even where the dam may have no apparent benefit to the community, recreational use or water supply capacity, there can exist strong sentimental regard for the dam by individuals or groups in the community.

Yet the same longevity can often compromise the structural integrity of the dam. As the structure ages, its
structural and foundation materials deteriorate. Engineering design standards, materials and construction methods are also constantly evolving which may render such dams deficient vis-a-vis the current standards. Where public safety becomes a concern, the dam owner is required to address this concern.

Finding a solution to public safety and dam stability concerns often involves major rehabilitation or upgrade works. It could also mean that the dam has to be decommissioned and/or removed altogether. The success and acceptance of the final outcome relies greatly on the dam manager’s appreciation of the value of the structure to the community and environment. Similarly the community and other stakeholders need to understand the safety issues driving the project. This requires balanced decision making that takes into account the need for public safety and the conservation of the heritage, social and environmental values of the dam.

This paper draws on the writers’ experience in the management of two recent dam projects aimed at removing the risks posed by the dams to the downstream communities. Both Wellington Dam and Bethungra Dam did not meet current design standards and posed a real threat to the safety of downstream communities.

Wellington Dam was in such poor structural condition that it had to be demolished to remove the risks posed to downstream residents through a dam failure. Thorough environmental planning and works were implemented to minimise the environmental impacts pre, during and post dam removal. Heritage preservation and interpretation was a major consideration in the project.

Bethungra Dam is to be lowered by 2.9 metres to meet current dam safety criteria. This is considered the optimum and most practical solution from a wide range of dam upgrade and demolition options. The option minimises the impacts on the dam, its environment and heritage value. Heritage interpretation and environmental improvements works will be implemented to both preserve and enhance the dam’s social value.

Whilst the end result is different for each dam, a similar process was used to determine the final solutions. This process involved engineering, environmental and heritage studies to determine the structural condition, impact on the environment and the value of the dam to the community. These studies were the basis for developing practical options to resolve the issues at each dam. The final solution was determined by several factors including availability of funding and, outcomes from community and stakeholder consultations.

2. EARLY DAMS IN NSW
The majority of early dams constructed before 1850 in NSW and Australia were simple earthen structures a few metres in height. These dams were built to store and supply water for settlements, small-scale irrigation or to divert floodwaters. Parramatta Dam was the first large dam built in NSW in 1856, at an original height of 15 metres. It was later upgraded to 18.3 metres.

Current international standards define a large dam as having a wall height of 15 metres or higher; dams over 10 metres high may be included if they are of unusual design, have a capacity at least equal to 1 million cubic metres, a crest length of 500 metres or more, or can deal with a maximum flood discharge not less than 2000 cubic metres per second.

The demand for clean water and better municipal infrastructure for the Sydney settlement led to the formation of the NSW Public Works Department (PWD) in 1856. The demand was echoed in other regional settlements whose populations were increasing rapidly. This demand for water became greater with the growth of industry and dams soon became vital to the development of Sydney and other regional settlements. One of the main objectives of the PWD was to provide country towns with a water supply that would alleviate their hardships through the provision of dams that were both economical to build and maintain (Coltheart and Fraser 1987:122).

In 1880, the Country Towns Water Supply and Sewage Act 1880 was enacted to enable town councils to raise loans or access low interest government funding for the provision of adequate water and sewage facilities. The Act was amended in the 1890s to allow repayments over a period of 100 years, making it cheaper for smaller rural towns to acquire these facilities. The PWD was responsible for the construction of the majority of the dams in the period between 1890 and 1920. PWD engineers like Cecil Darley, LAB Wade and EM de Burgh were recognised as leading experts in dam construction.

Figure 1. Concrete Gravity – West Gosford No.1 Dam
This expertise led to improvements in dam designs and made their construction more economical. Notably are the 13 thin cylindrical arch dams constructed by engineers Cecil Darley and LAB Wade between 1896 and 1908. These ranged from 9 metres to 27 metres in height and are renown for their thin, cost efficient sections. These dams were recognised internationally.
for their technical innovation, structural properties and economical use of material, and became one of the main type of dams constructed in this era.

![Figure 2. Cylindrical Arch - Medlow Bath Dam](image)

Other dam types of this era include the Concrete Gravity, Concrete Gravity-Arch, Buttress, Masonry and Earth Embankments.

![Figure 3. Historical Engineering Marker installed by IEAust 1994 most slender dam in the world at the time of its construction](image)

### 3. MANAGEMENT OF DAMS

The science of dam management is constantly evolving to reflect the developments in the design, construction, and maintenance of dams. These developments are due to technological advancements including the discovery or invention of superior construction materials and methodologies and increase in the understanding of hydrology and extreme events such as floods and earthquakes. The former is directly influenced by studies into dam construction and maintenance and the increase in expertise due to first hand experience. It is reported that one catastrophic dam failure occurs worldwide annually.

In September 2004, it was stated at the Association of State Dam Safety Officials annual meeting that 75 dams failures had occurred in the USA between the years 2001 and 2004. Whilst the majority of these failures have not been catastrophic, they resulted in considerable property and economic loss. Investigations into dam failures have yielded greater understanding of the design, construction and management of these structures.

Standards for dam design are also constantly changing due to the availability of better flood and earthquake data. These events are a major consideration in the design criteria for dams. This makes it necessary to review design estimates such as Design Floods and Design Earthquakes.

The Dams Safety Committee (DSC) is the NSW government statutory authority created under the *Dams Safety Act 1978*. Its main role is to “formulate measures to ensure the safety of dams” and to “maintain a surveillance of prescribed dams” ([www.damsafety.nsw.gov.au/general](http://www.damsafety.nsw.gov.au/general)).

A “prescribed dam” is one listed in Schedule 1 of the *Dam Safety Act 1978*. Generally any dam over 15m in height is considered a prescribed dam. Smaller dams may also be prescribed if their hazard category is high or significant.
The DSC requires dam owners to undertake the appropriate surveillance relative to the hazard rating of each dam. This hazard rating is determined based on the potential for loss of life from the Population at Risk (PAR), destruction of property and adverse effects on the community and environment in the hypothetical event of dam failure. It does not involve any assessment of the probability of failure for the dam. The Dams Safety Committee can give notice to the dam owner, under the Dams Safety Act 1978, to take action to ensure the safety of the population at risk from the dam.

Refer to Table 1. DSC Hazard Ratings

By analysing surveillance data it is possible to assess dam behaviour and provide early and timely planning for investigations and implementation of remedial works, if required, as well as developing maintenance programs.

Some of the interim risk reduction measures for hazardous dams include the development and implementation of a Dam Safety Emergency Plan (DSEP) and an Early Warning System (EWS). This includes procedures for notification and coordination of emergency evacuations of the population at risk for flood events for which dam failure is highly likely. The plans are developed by the dam owner and are implemented by the local law enforcement or relevant emergency response agency, which in NSW is usually the State Emergency Services (SES). The community in the potential inundation area must be very familiar with this plan and the evacuation procedures.

Dam managers must also manage these facilities in accordance with various Government acts and guidelines including the Heritage Amendment Act 1998; Fisheries Management Act 1994; Occupational Health & Safety Act 2000; and the Environmental Planning & Assessment Act 1979. Satisfying requirements under one act may conflict with requirements under another act.

A good maintenance and works program must demonstrate compliance with all relevant regulations. Surveillance and other investigative reports will assist in rationalising and prioritising works and result in optimum use of scarce funding and other resources. The Burra Charter principle “do as much as necessary but as little as possible” applies well for heritage structures, such as some of these early dams.

With effective surveillance and maintenance, dams can perform satisfactorily over several centuries. However their safety needs to be constantly reviewed, taking into account the changing standards and knowledge since their design and construction and, the ageing of their materials and foundations. Another consideration is the developments both upstream and downstream of dams due to changes in population, commercial and recreational activities and the evolving environment.

4. BRIEF HISTORY OF WELLINGTON & BETHUNGRA DAMS

Wellington Dam

The town of Wellington went through a population explosion from 200 persons in 1861 to 1,500 in 1881. By 1901 the population was 3,000 leading to a demand for better municipal services. Some of the factors for this growth include the discovery of gold in this area in 1851 and the arrival of the railway in the district in 1877. Wellington Dam was constructed to provide a reliable water supply. Located on Bushranger’s Creek, the dam water gravitated some 2¼ miles to the town. It was the first municipal water supply scheme for Wellington and its construction was completed in 1898 by the PWD. It is one of the 13 thin cylindrical arch dams constructed between 1896 and 1908.

The dam was 15 metres high and 110 metres long, with a crest width of 0.9 metres.

Problems for the dam began early in its life. By 1908, the dam was completely silted, had failed to meet its purpose and a new water supply scheme was implemented. A new bore water supply, reservoir and pumping station were constructed to become the main town water supply. It is reported that cracks and leakage were evident in the dam as early as 1909.

Despite its failures and poor structural condition the dam was not removed. Although heavily silted the dam created an idyllic environment providing the local community with a facility for passive recreation.

In 1998, a geo-technical and structural investigation concluded that the dam was unstable for normal loading conditions. It was close to its stability limit when at Full Supply Level (FSL) or when subjected to the Operational Basis Earthquake when the reservoir was at

![Figure 6. View of Wellington Dam (Source: Report of NSW Public Works 1900)](image-url)
Full Supply Level. This was unacceptable for a high hazard dam such as Wellington Dam.

Seepage through the dam and its foundations was significant due to large cracks and faulty concrete cold joints. There was evidence of a significant loss of mortar on the upstream face. The downstream concrete was also in very poor condition.

Public safety was a major concern. The dam was situated in close proximity to downstream residents. The closest residence was only 1.5km downstream, with less than a 10-minute warning time in the event of dam failure. A further 12 properties along the creek valley were identified to be under risk in the event of a flood causing dam failure.

State Water developed a Dam Safety Emergency Plan which was presented to the State Emergency Services (SES) as an interim measure for warning and the evacuation of downstream residents in the case of a large flood and/or dam failure. For additional precaution, the dam was also completely de-watered. This however was only acceptable as an interim and short-term solution.

Although only 15 metres in height the dam was considered a high hazard dam and was added to the DSC Prescribed Dam List. In 1999, the dam was on the DSC’s top 20 most deficient dams list. The dam owner was required to address the intolerable risk to public safety, which included loss of lives due to dam failure.

Bethungra Dam

The advent of the railway link connecting Sydney with Melbourne played a large role in the growth of rural towns, including Junee. Availability of water was crucial for both the communities and for the steam locomotives. In 1866, Junee’s population was recorded as 12 people. This went up to 20 in 1876, with 200 living in the district. The railway line south reached Bethungra and Junee in August 1878. By 1887 the town population was 2,000 (JMJ 1936). This population explosion can be attributed to the digging of gold, which started in 1881, but more especially the work generated by the railways and the resulting commerce in agriculture and pastoral activities.

At the time, water supply for Junee was insufficient and unreliable. Residents relied heavily on wells and the delivery of water from Wagga Wagga (JMJ- 1936). With the added demand for water for the railways, several solutions were explored.

Bethungra Dam was built primarily to provide a reliable town water supply for Junee and to provide the railways with water for steam locomotives. The dam was built in the Bethungra Hills 30km from Junee and 4km west of Bethungra township. Its location is 470 feet higher in elevation than Junee and provided a good location for a dam. From there water, could be piped to a reservoir near Junee. Construction of the dam was completed by PWD in 1895 and was funded under the Country Towns Water Supply and Sewage Act 1880.

The dam is a Concrete Gravity Dam, 13 metres in height with a crest length of 160 metres. Its storage capacity is 600 megalitres.

The dam suffered from a lack of reliable rainfall after its construction, causing the Junee water supply to fail. On a number of occasions water was brought in from Wagga Wagga. The dam was full only four times in the first decade of the twentieth century and the dam became labelled as a ‘white elephant’ in local press (Ferry 2001: 48). By 1908 a new scheme to pipe water from the Murrumbidgee River was approved by Parliament whereby water was pumped from the Murrumbidgee River at Tenandra. Bethungra Dam however continued to be used for town water supply for the smaller Bethungra town until 1985. Since then it has been used purely for passive recreation including fishing and as a picnic and camping area.

The dam is owned by the State of NSW through the Department of Lands, and is managed by State Water Corporation on their behalf. Bethungra is a prescribed dam and is required to comply with requirements set out by the NSW Dams Safety Committee and the Australia National Committee on Large Dams (ANCOLD) Guidelines. A safety audit conducted by State Water in 1998 concluded that Bethungra Dam does not meet current safety standards.
Inspection of the dam revealed significant cracking both along the crest and on the downstream side of the dam. The safety audit of the dam and other reports pointed out a number of deficiencies associated with this structure including:

- Dam does not meet the ANCOLD Guidelines for normal load case, reservoir at Full Supply Level (FSL), for either sliding or overturning.
- Dam is on the verge of failure for seismic events, which produces a horizontal acceleration of 0.1g. This is below the Maximum Design Earthquake (MDE) for this dam.
- The Population at Risk (PAR) was 72 persons, with the likelihood of loss of lives if the dam was to fail.

The risks were considered intolerable by the DSC and the dam owner has to ensure that the dam is either upgraded to satisfy the current standards or removed so that the intolerable risk to people downstream is eliminated.

In 2001, State Water developed a Dam Safety Emergency Plan and installed an Emergency Warning System at Bethungra Village to protect the population at risk. This is an interim measure until a long-term option is implemented and safety criteria met.

### 5. BALANCED DECISION MAKING

The planning and implementation of works for these heritage dams must take into consideration, not only the need to mitigate intolerable risks to people’s safety, but their history, heritage and environmental value, and the role they currently play in their communities. Given that the majority of these dams are not used for commercial purposes, a major constraint in their management and conservation is the availability of funding.

Aside from periodic surveillance, most of these dams have continued with minimum maintenance due to scarce funding. Public safety is often the main driver for any major works. With public safety being paramount, doing nothing is not an option for these deficient dams. The challenge then lies in exploring a range of options and arriving at a final solution, one that demonstrates due diligence to public safety as well as the value of the dam to the community and environment.

*Balanced Decision Making* was a major objective in arriving at a final solution to address the public safety risks posed by the two dams. The process undertaken for both projects was to ensure that all practical and feasible options were identified and explored and assessed against dam safety standards and heritage, social and environmental values. This involved extensive research and investigations, including engineering, heritage and environmental studies and community consultation.

By consulting with the general community and directly affected stakeholders throughout all steps in the decision making process the local community had a chance to be involved, understand and provide input into all the conflicting issues and gain acceptance of the final outcome, achieving overall procedural justice.

### Interim measures

The period between identifying the risk to the public and implementing a long-term solution can be as long as a few years. This was the case for both Wellington and Bethungra Dams. When the risk is intolerable, an interim solution was put in place to minimise the risks.

A Dam Safety Emergency Plan (DSEP) was prepared for both dams. This draws on the results from the hydrology and dam break studies to identify the members of the community likely to be affected by flood events or due to a Sunny Day Failure of the dam. The DSEP contains contact details of the residents and businesses likely to be affected, the appropriate emergency response agencies and a strategy to ensure they are alerted in the case of danger. The DSEP was coordinated by the State Emergency Service (SES) and workshops were conducted with the community to ensure familiarity with the evacuation procedures including safe area(s) to evacuate to.

Early Warning Systems were also installed at both dams, with a siren that alerts the community when the likelihood of dam failure is high.

Local communities and affected landholders were involved in the development and implementation of these interim measures.

### Community consultation

Community consultation commenced early, prior to the development of remedial options. Many rural towns are faced with dwindling populations as members of the community leave for larger urban centres in search of jobs. Consequently some towns are faced with the closure of many services such as banks and grocery stores. Any project that could lead to a loss of an
amendly is likely to meet community opposition and adverse publicity. Early consultation works favourably for the project when the community gains an understanding of the issues early and is involved in the development and gain ownership of the final solution.

The strategy adopted for the Bethungra Dam project was one of inclusiveness. The small population of Bethungra township was ideal for one-on-one interaction between the dam owner’s consultation manager and the members of the community. This was not only effective in getting the communities concerns and comments to the project team, but also importantly the community gained a good understanding of the dam safety issues and other drivers for the project.

State Water worked closely with relevant local Councils on the Projects. Several consultation workshops were held for the general public, whilst individual consultation was undertaken with the downstream residents at risk. Several local community interest groups were also invited for their input in shaping the project outcomes.

Structural and geological investigations
A starting point was to ascertain the structural condition of the structures. This included determination of the structural integrity of the dam and foundation. Core samples from various locations in the dam and foundations were taken for analysis. The samples retrieved were taken along the entire dam profile, from the crest to the foundations. Drilling at various locations along the dam’s length draws a more accurate picture of the dam’s construction method and materials used, as well as identifying any defects or anomalies in parts of the structure. By analysing these samples, the dam’s structural condition can be interpreted. Its material properties are determined and utilised for the structural analysis of the structure. Results of this analysis were then compared with modern dam design standards and it was confirmed that both dams did not meet these standards.

Review of hydrology
A review of the dam’s hydrology is necessary in recognition of the accumulation of better rainfall and precipitation statistical data, over the years, by agencies such as the Bureau of Meteorology. Whilst this data may not be readily available for the smaller dam catchment areas, it is possible to estimate values for regional flood events using estimation tools such as the Runoff Routing (RORB) program. Estimation techniques should be in accordance with acceptable methodologies as given in the Institution of Engineers, Australia’s “Australian Rainfall and Runoff, A Guide to Flood Estimation” (ARR).

By routing flood estimate inflow hydrographs through the dam storage and spillway, it was possible to determine if the spillway was adequate and the level or extent by which the dam would overtop for various flood events. The Annual Exceedance Probability (AEP) of various flood events was determined.

Dam Break Study
The dam break study involves estimation of the outflow hydrographs due to dam breach. These outflow hydrographs were considered for both Sunny Day Failure (SDF) and failure due to flood events. These hydrographs were routed through the downstream valley to determine the water levels and velocities at different locations downstream.

Of great importance also were the estimates of the flood wave travel time, for flood events passing through the dam to reach downstream residents, properties, towns and other important community infrastructure. Flood inundation maps were also developed.

The dam break study was useful for estimating the population at risk due to dam breach, as well as the impact on the environment, land use and businesses downstream.

Heritage assessments
The heritage value of the structures was determined through a heritage assessment, undertaken by an experienced specialist in this area, in accordance with the NSW Heritage Office assessment guidelines. This included researching the dam’s history, its fabric and functions. The assessment criteria included:

- **Historic:** Is the item important in the course, or pattern, of NSW’s cultural or natural history;
  
  Does the item have a strong or special association with a particular community or cultural group in NSW for social, cultural or spiritual reasons;

- **Social:** Does the item have a strong or special association with the life or works of a person, or group of persons, of importance in NSW’s cultural or natural history;

- **Technical/Aesthetic/Creative:** Is the item important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW;

- **Scientific/Technical:** Does the item have the potential to yield information that will contribute to an understanding of NSW’s cultural and natural history;

- **Rarity:** Does the item possess uncommon, rare or endangered aspects of NSW’s cultural or natural history;

- **Representative:** Is the item important in demonstrating the principal characteristics of a class of NSW’s cultural or natural places; or cultural or natural environments.

Both dams were found to have local heritage significance. A comparative heritage study was also undertaken for Wellington Dam in comparison with seven other similar dams, all from the 13 thin cylindrical arch dams constructed by PWD engineers Cecil Darley and LAB Wade between 1896 and 1908.
Existing environmental value
An environmental assessment for each dam site was undertaken by experienced specialists. This included a search of the relevant databases to identify plant and animal species, in particular, the existence of any endangered or threatened species. The studies also identified land use adjacent to the dams.

A site inspection was undertaken covering the lake, and the surrounding upstream and downstream environment likely to be impacted. An analysis of the silt in the dam and the surrounding soil types likely to be disturbed was conducted to identify any risk of land contamination and degradation.

Risk Assessment
A Portfolio Risk Assessment (PRA) was undertaken for both dams, as part of a larger portfolio of 14 small dams. This was a very useful tool in ranking the risk associated with each dam and the urgency of any risk mitigation action, thus determining the allocation of scarce resources, including funds, across the assets in the portfolio. In this case, all the 14 dams did not meet current design standards. The PRA took into consideration the condition of the various dams, the probability of dam failure, and the consequences of dam failure such as loss of lives, economic losses, and the environmental and heritage impacts. Wellington Dam and Bethungra Dam were ranked No.1 and No.2 respectively for their intolerable risks due to their high probability of failure and the catastrophic nature of the consequences including loss of lives.

Development of options
Options explored for the dams included both engineering and non-engineering options. More than 15 preliminary options were considered for each dam. These options can be summarised by the following categories
1. Do nothing
2. Downstream buttressing
3. Upstream buttressing
4. Post-tensioning
5. Provision of a adequate spillway capacity
6. Buy up/or secure downstream properties subject to downstream flooding
7. Partial demolition
8. Full demolition

Preliminary environmental and heritage impact assessments were also undertaken for each option. The options were then assessed for their effectiveness in reducing the risks to public safety, their practicality, costs and impacts. The objective was to arrive at a smaller but broad final range of options. For example, it was agreed that to ‘do nothing’ was not an option where the risk to public safety was unacceptable.

The final range of options was developed in more detail, including environmental and heritage considerations. The total cost for each option was also refined. The final option was determined by the availability of funds and its effectiveness in removing or reducing the risks to the downstream residents to an acceptable level. The communities’ concerns and measures to mitigate the impacts on the community, heritage value and environment were incorporated throughout the development of options.

Project funding
The costs for both projects were well beyond what the local communities and councils, as the beneficiaries of these facilities, could manage. It therefore was a matter for the State Government, as the owner and carrier of any liability, to bear the costs for removing the risks associated with the dams. The NSW Treasury provided funding for both projects.

Final option
On determining the final long-term solution, detailed studies were undertaken to determine the specific impacts on the environment and the dam’s heritage significance. The findings of the Environmental Impact Study (EIS) and Statement of Heritage Impact (SoHI) were incorporated in the final scope of works. Any opportunities to benefit the local communities were also explored and implemented where possible.

6. PROJECT OUTCOMES
The final outcome(s) for each dam are vastly different. The structural condition of each dam is a major influence in the final option as it dictated the extent of works required to make the structures safe. This translates into costs for the various options. Both structures have not been in commercial operation for decades and only serve a recreational purpose for their relatively small communities. Never the less, the community and stakeholder concerns and the environmental and heritage values of each structure, were a strong influence in the final outcome for both projects.

Wellington Dam project outcomes

Dam demolition
In 2002, Wellington Dam was totally removed due to its very poor structural condition and the high risks of dam failure, which included the possibility of loss of lives. The process followed to arrive at this solution is outlined in the Balanced Decision Making section above.

The upgrade costs to rehabilitate the dam and to satisfy current design standards for a high hazard dam were estimated at approximately $4 million. The costs to remove the dam and rehabilitate the site were just under $1 million. To ensure public safety, one downstream residence, which was likely to be subject to nuisance flooding as a result of the dam’s removal, was demolished and the owners relocated to a new dwelling and compensated for any inconvenience. Access to the
property was also improved to ensure access even during large flood events.

**Figure 10. Removing the Wellington Dam wall**

The dam was removed using a demolition technique called Permeating Cone Fracture (PCF). This allowed for careful and gradual demolition of the concrete, breaking the dam into manageable pieces for carting away.

**Heritage preservation and interpretation**

The dam was in such poor structural condition that any upgrade option would involve buttressing across the entire structure, at a very prohibitive cost. The intolerable risks associated with the dam demanded immediate action. The dam’s heritage could not be allowed to compromise public safety and thus the dam was removed.

However, the dam’s presence was not lost. The final option incorporated measures to ensure heritage interpretation of the site. This included retaining some physical evidence of the dam. A footprint of the dam comprising a section of the wall, approximately 1 metre in height, was retained across the full length of the dam, except for a 20 metre central portion that had to be completely removed to avoid any retention of water behind the remnant wall.

Remains of the original water supply pipes and their concrete bases were protected from damage during the demolition works and remain in-situ. The valves, trunnion and any loose pipes found on the site were cleaned and stored at the Works Depot of Wellington Council.

**Figure 11. Profile of the dam wall has been left for heritage interpretation**

An interpretive display was also installed on site giving a brief history and physical description of the original dam. The dam was also properly recorded prior and after demolition in accordance with the Heritage Office’s ‘Guidelines for Photographic Recording of Heritage Items’.

**Figure 12. Pipe for town water supply**

**Figure 13. Interpretive display sign**

**Restoration of the environment**

The silt in the dam was removed prior to demolition of the dam wall. Prior to its removal, the silt was analysed to ensure it did not contain heavy metals, toxic materials or seeds of weeds. The exposed soils were then levelled and any erosion gullies repaired.

The expansive area left exposed by the draining of the reservoir was revegetated to restore it to its original state of more than 100 years ago. A total of 2,340 plants, from 20 indigenous species, of higher stratum and understorey plants were planted in 2003. This was followed by a maintenance program in 2004 and 2005 including watering and plant replacement and management of noxious weeds to improve the well being and chances of the plants surviving to maturity.

**Figure 14. Wellington Dam site - Exposed area before revegetation**

**Figure 15. Wellington Dam site after revegetation (young plants)**
With the removal of the dam wall and the silt, a major barrier was removed from the river system. The removal will allow the restoration of the natural flow pattern of the riverine ecosystem, improving water quality and fish passage.

**Other benefits to the community**

- 2,000 tonnes of concrete was placed on the Bell Riverbank, downstream to protect the historic Wellington Polo Club grounds, which were prone to erosion during floods. The club is a popular sporting and recreational facility for Wellington town. The Club and Council had tried in vain to fund this work.

- The storm water infrastructure downstream of the dam was upgraded to mitigate any effects due to removal of the dam. This included installation of culverts and batter protection in parts of the causeway.

**Bethungra Dam project outcomes**

**Engineering works**

The proposed works involve a permanent reduction of the dam wall by 2.9 metres. This is considered to be the minimum reduction in height and storage volume required for the dam to meet acceptable safety standards. The estimated forward project cost for the option is approximately $1.5M and includes restoration of the lake foreshore, water quality improvements and heritage interpretation of the site. However, the storage volume behind the dam will decrease from 600ML to 275ML resulting in a substantial reduction of the lake surface.

The upgrade options to strengthen the dam were estimated between $3 million and $4 million dollars. The cost for removing the dam is under one million dollars.

The selected option would lead to a reduction of the loads against the dam wall in accordance with modern dam design criteria. The dam will have an acceptable factor of safety for both the normal and extreme case loadings. The reduction in storage will also remove the risks to the downstream residents in the event of a Sunny Day Failure.

**Heritage Interpretation**

Interpretive displays will be installed on site giving a brief history and physical description of the original dam. Information displays will also be erected at various locations around the dam area including at the dam wall, the Bethungra Falls and at proposed viewing platforms.

Viewing platforms are to be erected at the Bethungra Spiral and at the dam to link the dam to its history with the railways.

**Figure 16. Culverts and roadworks**

**Figure 17. Other improvements for storm water drainage**

- The silt removed from behind the dam wall was utilised by Council for various projects including the Wellington-Dubbo road works and as landfill at the Council rubbish pit.

- All effort was undertaken to ensure that the majority of work associated with the dam’s removal was undertaken by local firms or Wellington Council. This included the removal of silt and the demolition works.

**Restoration of the environment**

Environmental work will focus on lake foreshore rehabilitation and water quality improvements. The exposed foreshore will be stabilised by planting indigenous pastures and shrubs.

Sediment fences comprising Cumbungi, Spike Rushes and Phragmites will also be planted at the lake's edge.
and upstream reaches to restrict stream bank and foreshore erosion. A stock fence will be installed to keep cattle and sheep from accessing the lake. An alternative water supply such as a farm dam will be installed for stock. The objective of these works is to reduce the high nutrient and sediment loads entering the dam.

Other environmental works will include stabilising existing active erosion sites. This includes gully erosion in the creek upstream of the dam and erosion along the access track.

The final solution will also ensure the continued role of the Bethungra Wetland, which is listed on the Directory of Important Wetlands in Australia. Although very small, the wetland is recognised for its role as a source of food and water for various bird species during periods of drought.

Fire fighting
The final solution also addresses the dam’s role as a water supply for bush-fire fighting. The storage will have a capacity of about 280 megalitres, which can still be safely drawn from the dam by fire fighting helicopters.

7. SUMMARY/DISCUSSION
The reality is that the greater majority of the early dams are deficient in many ways due to the changes in design standards and deterioration with age. For example, a Safety Audit in 1998 of 14 of the then Department of Land and Water Conservation small dams concluded that none of the dams met current design standards and many were recommended for decommissioning. Their longevity has lead to their inevitable deterioration over time. Most of these small rural dams are heavily silted and their outlet valves are inoperable. Many have developed cracks, concrete spalls and leakages. It can be expected that some of these dams will require major works in the near future.

Although the majority of these dams are owned or managed by local councils and Government agencies, funding is not always readily available to undertake remedial works and upgrades, which can be expensive, in some cases several million dollars. The lack of economic activity for many such dams means they do not generate any income. The availability of funds is increasingly diminishing as Government departments and corporations are expected to become financially efficient, and in some cases, self-sufficient. This is the case for State Water Corporation, the former dam manager as part of the former Department of Land and Water Conservation and the Department of Lands, the current owner. Yet the Dam Safety Act 1978 and guidelines require that where dams pose a significant or intolerable risk to public safety the risk must be removed or reduced to an acceptable level. Dam removal becomes more likely where the risk is intolerable and funding limited. Alternative sources of funding for such work need to be explored by the dam owner, the communities and local councils and by the Government, if it is required to preserve these structures for reasons such as their heritage significance or as recreational facilities.

Regardless of the final outcome, conservation of the history and heritage value of an item should be given due consideration when seeking a solution to public safety for heritage dams. These dams have contributed to the growth and are part of the history of rural NSW towns. Whilst it is not always possible to preserve heritage items in-situ, any opportunity for interpretation and documentation must be seized for the benefit of present and future generations.

Some of the agencies with the custodianship of these early dams may not have the expertise to manage these structures. Situations may occur at the dam that require remedial works, yet may go undetected. At a minimum, such agencies should consider arrangements for regular surveillance and inspections of their dams. For example, the Department of Lands has continued to engage State Water Corporation to undertake the surveillance and management of 12 dams. Utilising experts for dam surveillance ensures that the integrity and the behaviour of the dams are effectively monitored for the safety of the downstream residents. It also ensures that the dams are managed and maintained appropriately, thus conserving their heritage and environmental value and their role in the community.

It is highly prudent to begin community and stakeholder consultations early so as to involve the community and improve their awareness throughout the development of the project. Inadequate communication can quickly create apprehension, mistrust and anxiety in the local communities and can also lead to delays in approvals from the relevant agencies.

Consultation on these projects highlighted the different perceptions of dam risks by dam engineers and community groups. Engineering terms for estimates of flood frequencies, probability of dam failure and the downstream consequences can sometimes be misunderstood and trivialised or sensationalised. Utilising consultation experts can greatly improve the communities understanding of the dam’s issues, and thus the success of the consultation process.

Evidence of a balanced decision making process is very critical during consultations with various stakeholders. It gives the community and the relevant agencies more confidence that procedural justice is being performed and ultimately more acceptance and ownership of the project outcomes. Effort should be made to ensure that decisions are based on recent and broad investigations and research, taking into consideration various aspects including engineering/structural condition, environmental and heritage value and social/economical aspects. It should be recognised that any decision resulting in permanent changes will impact on the dam structure and the community for generations.
8. ACKNOWLEDGMENTS
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- Abel Immaraj, Chief Executive Officer
- Paul Percival, Corporate Counsel & Manager Risk Management

Many thanks to the management at the Department of Lands, who inherited many of the small dams from the former Department of Land and Water Conservation and who have been very kind in allowing us to ‘scratch the surface’ of some of the issues facing these heritage dams, in particular,

- Graeme Ford, Manager Business Operations (Crown Lands NSW)
- Leanne Taylor, Manager South (Crown Lands NSW)

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### Table 1. DSC Hazard Rating Table

<table>
<thead>
<tr>
<th>Population at Risk (PAR) (Note 7)</th>
<th>Severity of Damage Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negligible</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>1 to 10</strong></td>
<td>Low (Notes 1,4 &amp; 5)</td>
</tr>
<tr>
<td><strong>10 to 100</strong></td>
<td>(Note 1)</td>
</tr>
<tr>
<td><strong>100 to 1000</strong></td>
<td>(Note 2)</td>
</tr>
<tr>
<td><strong>&gt;1000</strong></td>
<td>(Note 3)</td>
</tr>
</tbody>
</table>

Note 1: With a PAR of 5 or more people, it is likely that the severity of damage and loss will be “Negligible”.

Note 2: “Minor” damage and loss is unlikely when the PAR exceeds 10.

Note 3: “Medium” damage and loss is unlikely when the PAR exceeds 1000.

Note 4: Change to “Significant” where the loss of itinerant lives is reasonably likely, given dam failure.

Note 5: Change to at least “High C” where the loss of non-itinerant lives is reasonably likely, given dam failure.

Note 6: Refer to Section 2.7 and 1.6 of the ANCOLD Guidelines on Assessment of the Consequences of Dam Failure for explanation of the range of High Consequence Categories.

Note 7: The contribution of PAR of non-itinerant (ie. regular occupant of dwellings, schools, hospitals, nursing homes, commercial and industrial premises and other permanent places of occupation) shall be the largest population that is exposed at the one time on a regular basis. To allow for the variable exposure of itinerants, the contribution of PAR of such populations shall be computed on the basis of exposure factors. Where low exposure factors are applies to few itinerants, it is possible to have a notional PAR, which is less than 1.0.