# Water Security for Regions: Belubula and Lachlan River Dam Investigation Report

Water NSW

December 2014

# Contents

## Tables



## Figures

# Executive Summary

This report documents the methodology, results and recommendations of the investigation of the potential of additional storage in the Lachlan Valley to provide improved water security for the central west region of NSW. The study identified and assessed the potential for additional storage for water security purposes considering economic, social and environmental outcomes and prudent management of risk.

The investigation concludes that there are four dam sites of potential, which, in order of preference are; Cranky Rock, Abercrombie, The Needles and raising the existing Wyangala Dam. It recommends next steps of investigation focussed in the vicinity of Cranky Rock.

**Background**

Storage options to improve water supply security in the Lachlan Valley have been considered many times over the last century. In the grip of the Millennium Drought, various studies were completed that identified the need for additional storage. However, most were focussed on single purpose solutions (e.g. town water supply) rather than a comprehensive review of all options providing the potential for multi-purpose solutions.

The NSW 2014-15 Budget announced the funding of scoping and feasibility studies, including environmental, geotechnical and preliminary design work, for the construction of a new dam on the Belubula River. Subsequently, the NSW Government commissioned Water NSW to undertake an investigation into potential storages in the Lachlan Valley, including the Belubula River.

This document is a report to the NSW Government on that investigation.

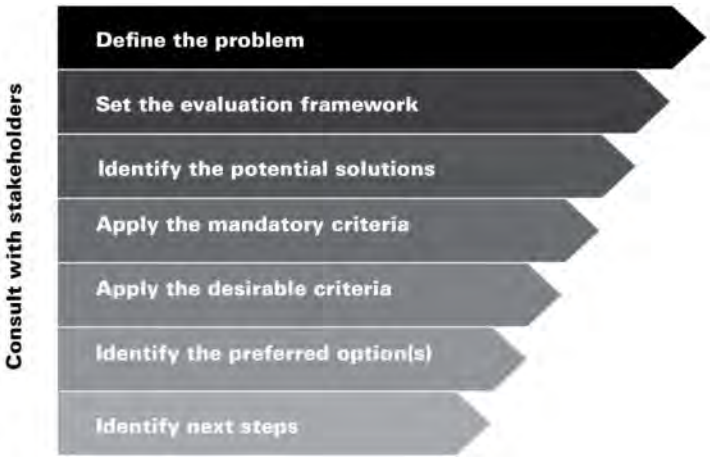
## Objectives

The objectives of this investigation were to undertake:

- A desktop assessment of identified storage options against technical, economic, social and environmental objectives.
- Consultation with key stakeholders to document views on the water security problem and the appropriateness of the various potential storage options.
- Reporting of the outcomes of the above including identifying a preferred option if conclusive, or other recommendations as appropriate.

## Process

This investigation was undertaken in a series of key steps:




1. Problem definition: what is the water security problem in the Lachlan Valley?
2. Evaluation framework: how will options be compared to identify a preferred option? What is a must have? What is a desirable outcome?
3. Potential solutions: what are all the possible storage locations (this is known as the 'long-list' of options)?
4. Apply the mandatory criteria: test the long-list against must have requirements to develop a short-list.
5. Apply the desirable criteria: investigate the economic, social and environmental implications of each site on the short-list to compare the options.
6. Identify the preferred option(s): rank the options and assess their implementation risks to identify the preferred option(s).
7. Identify the next steps: set out the actions required to progress the preferred option(s).

The investigation process was supported by consultation with key stakeholders.

## Consultation

The purpose of the consultation process was to seek key stakeholder feedback on the water security problem within the Lachlan Valley and the potential storage options to address this problem. The consultation outcomes have been considered in making the recommendations

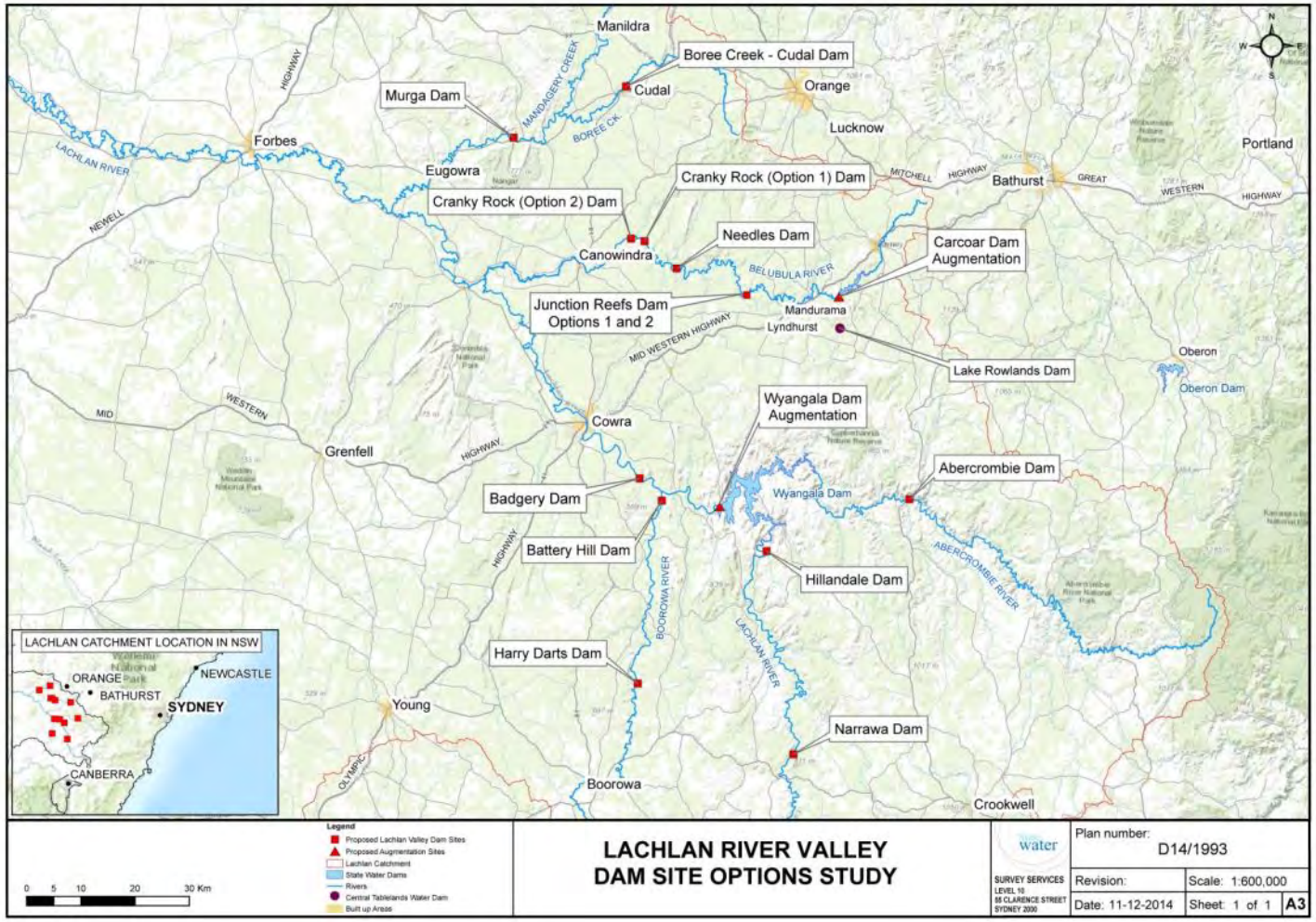
in this report and are documented to assist the NSW Government in understanding the various perspectives on the options. Key stakeholders included:

- Belubula Landholders Association
- Central NSW Councils
- Lachlan Riverine Working Group
- Lachlan Valley Water
- Lake Cargelligo community
- NSW and Federal government agencies
- Potentially impacted landholders near The Needles
- Speleological interests (Orange Speleological Society, Australian Speleological Federation)
- Water NSW Lachlan Customer Service Committee
- Wiradjuri land council region (Cowra)

**The Water Security Issue**

Lack of water security for both current and planned future consumptive users sourcing water from the Lachlan Valley is limiting economic growth. Market information and stakeholder feedback provide the following evidence of the issue:

- Severe restrictions have been in place on town water use during drought
- History of long periods of low or no general security agricultural water availability and high security water has been restricted
- Depression of agricultural economy of the region as evidenced in the trading of licences and lack of investment
- Limitations on the potential of mining industry in the region
- Consumptive extraction licences have been purchased to protect water for the environment, reducing the water available for consumptive water users.


Manildra
Boree Creek - Cudal Dam
Cudal
Orange
Murga Dam
Lucknow
Forbes
Eugowra
Portland
Cranky Rock (Option 1) Dam
Bathurst
Cranky Rock (Option 2) Dam
Needles Dam
Canowindra
Carcoar Dam Augmentation
Junction Reefs Dam Options 1 and 2
Mandurama
Lyndhurst
Lake Rowlands Dam
Oberon
Oberon Dam
Wyangala Dam Augmentation
Cowra
Grenfell
Abercrombie Dam
Badgery Dam
Wyangala Dam
Battery Hill Dam
Hillandale Dam
Harry Darts Dam
Young
Narrawa Dam
Boorowa
Crookwell
LACHLAN CATCHMENT LOCATION IN NSW
ORANGE
NEWCASTLE
BATHURST
SYDNEY
CANBERRA
Legend
Proposed Lachlan Valley Dam Sites
Proposed Augmentation Sites
Lachlan Catchment
State Water Dams
Rivers
Central Tablelands Water Dam
Built up Areas
0 5 10 20 30 Km
LACHLAN RIVER VALLEY
DAM SITE OPTIONS STUDY
water
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000
Plan number:
D14/1993
Revision:
Scale: 1:600,000
Date: 11-12-2014
Sheet: 1 of 1
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### Options

Fifteen options for storage locations were identified through a process of reviewing previous studies of the valley, examining the topography and consulting with stakeholders. These 15 storage options are referred to as the long-list of options for this investigation. Options included new dam sites as well as the potential raising (augmentation) of the existing Wyangala and Carcoar dams. Options were identified on watercourses including the Abercrombie River, the Belubula River, the Boorowa River, Boree Creek, Mandagery Creek and the Lachlan River itself.

### Assessment

The 15 storage options were assessed against three mandatory criteria:

- **Technical feasibility:** primarily in relation to engineering constructability, but also preliminary consideration of cost-effectiveness
- **Level of security:** an assessment of the likely yield from each dam
- **Consistency with the Basin Plan:** all options must be consistent with the sustainable diversion limits set in this Federal water sharing plan

Application of the mandatory criteria to the long-list of options produced the shortlist set out in the table below.

| Site | Screen Against Mandatory Criteria | Shortlist |
|---|---|---|
| Abercrombie | Meets mandatory criteria. Up to 700 GL potential storage. | Yes |
| Battery Hill | Meets mandatory criteria. Up to 400 GL potential storage. | Yes |
| Cranky Rock Option 1 and 2 (also known as Pride of Oak) | Meets mandatory criteria. Up to 700 GL potential storage. | Yes |
| Narrawa | Meets mandatory criteria. Up to 1,000 GL potential storage. | Yes |
| Needles | Meets mandatory criteria. Up to 700 GL potential storage. | Yes |
| Wyangala Dam Raise | Meets mandatory criteria. Up to 780 GL additional storage. | Yes |
| Badgery | Impacts operation of Wyangala Dam | No |
| Carcoar Dam Raise | Small security improvement | No |
| Cudal Dam (Boree Creek) | Small security improvement | No |

| Site | Screen Against Mandatory Criteria | Shortlist |
|---|---|---|
| Harry Dart (also known as Roaring Rock) | Small security improvement | No |
| Hillandale | Significantly higher costs for the security improvement than other options | No |
| Junction Reefs Option 1 and 2 | Higher cost for smaller security improvement | No |
| Murga | Small security improvement | No |

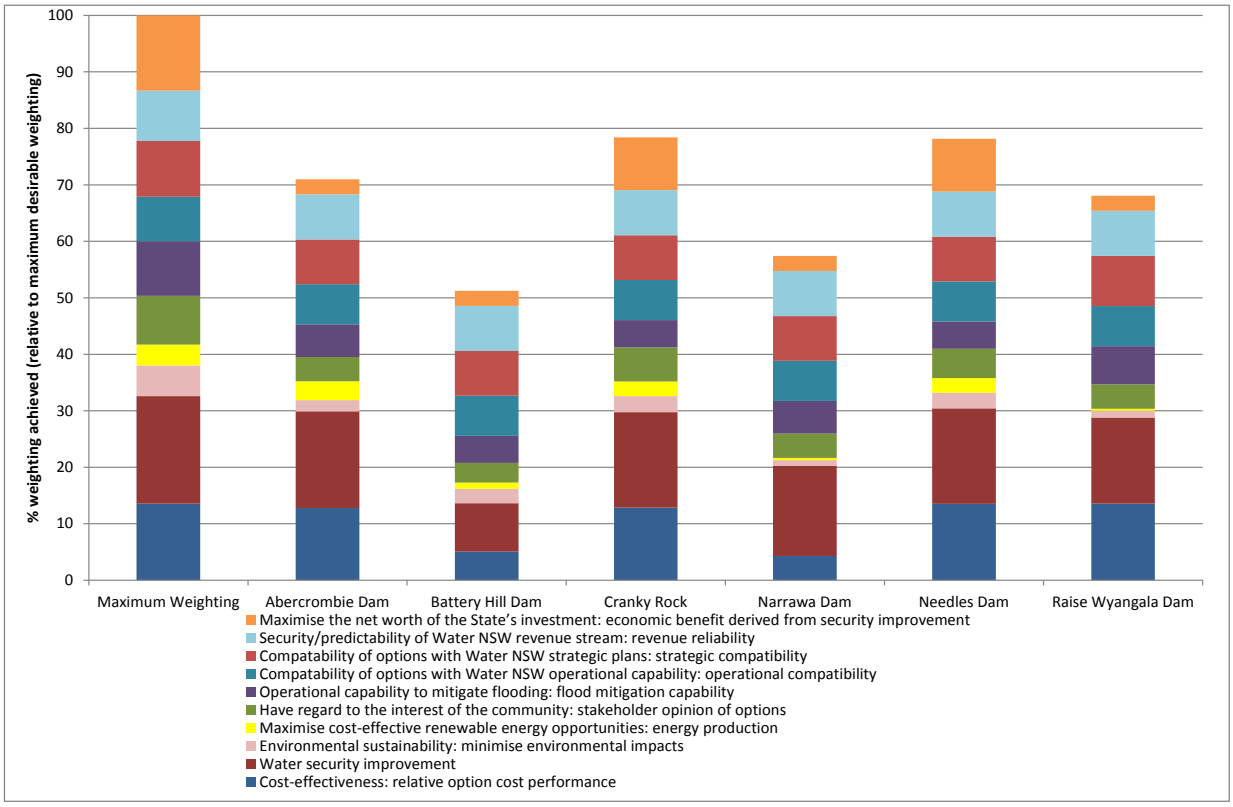
Further detailed assessment of the short-listed options was then undertaken in order to consider the relative social, economic and environmental impacts and benefits of the options. These desirable criteria were:

- **Environmental sustainability:** minimise environmental impacts. This was assessed by review of relevant environmental legislation, regulation and policy.
- **Maximise cost-effective renewable energy opportunities:** this was assessed by engineering review of the feasibility of hydro-electricity at each site.
- **Have regard to the interest of the community:** stakeholder opinion of options. This was assessed based on feedback from key stakeholders.
- **Operational capability to mitigate flooding:** this was assessed by considering the potential of storage to reduce the impact of flooding on towns and economic activity downstream of the storage sites.
- **Compatibility of options with Water NSW operational capability**.
- **Compatibility of options with Water NSW strategic plans**.
- **Security / predictability of Water NSW revenue stream**.
- **Maximise the net worth of the State's investment:** economic benefit derived from security improvement. This was assessed by desktop consideration of what various customers have historically paid for water security improvements. This was not a detailed a willingness to pay study or economic analysis.
- **Water security improvement:** This was assessed through hydrologic modelling of the options to determine the relative security improvement offered by each site.
- **Cost-effectiveness:** relative option cost performance. This was assessed through engineering cost estimation of the relative differences in the costs associated with

each storage option. The cost estimates are only of comparative costs, not total investment that would need to be made in order to provide storage in any location.

The criteria were weighted by the project team. Some stakeholder input was also provided on appropriate weightings. The criteria weightings were examined to see if different weightings produced different rankings of storage options (sensitivity tested), but the results were largely insensitive to different weightings.

Multi-criteria assessments such as this are only appropriate to help understand the relative performance of options and the trade-offs between criteria to assist decision-makers. The relative performance of shortlisted storage options is set out in the figure below.




The assessment highlights the following:

- Four of the storage options (Cranky Rock, Abercrombie, The Needles and Wyangala raise) perform similarly in relation to cost-effectiveness and potential water security improvement.
- If it is assumed that there is greater economic benefit from increased security to towns, then the options in the Belubula (Cranky Rock and The Needles) are preferable.

- As avoiding the potential impact on the known extent of Cliefden Caves is potentially achieved by the Cranky Rock option, but not The Needles, this option could be considered slightly better.
- The Belubula options, combined with the existing Carcoar dam, have the potential to allow for improved water security to the towns of the Central Tablelands.

**Conclusions**

- Battery Hill Dam and Narrawa Dam can be excluded from further consideration as there are better performing storage options.
- There is potential for storage to improve water security in the Belubula River. The Cranky Rock dam sites may be marginally preferred to The Needles site in that it has the potential to avoid the impact on the known extent of Cliefden Caves, but it is likely to be more expensive.
- There is potential for storage to improve water security in the Wyangala catchments. The Abercrombie dam site may be marginally preferred to raising Wyangala as this site is a more efficient dam location from an evaporation perspective.

**Risks**

An understanding of the risks of each option is also important in making recommendations. The risks associated with the four options vary considerably and cannot be quantified through desktop analysis of the sites. Key risks for consideration include:

- The potential foundation and storage integrity issues associated with the geology of the Belubula River options, in particular, The Needles. To better understand this risk, in-situ investigations would be required for the two Belubula River options.
- Certainty around the environmental, recreational and scientific values of the sites, in particular, the Cliefden Caves. To better understand this risk, environmental assessments would be required in conjunction with the in-situ investigations.

As a result of these risks, in ranking the options, it is prudent to continue to consider Abercrombie dam as this would be the next best performing option if the risks above materialise.

There are also potential benefits additional to water security associated with raising Wyangala dam as this dam is currently subject to dam safety upgrade requirements. It may be more economically efficient to align investments to solve multiple issues. To better understand this potential benefit, the raising of Wyangala dam should be considered as a comparison case in any subsequent cost-benefit analysis of the storage options.

As the analysis also highlights that the options perform similarly on many technical aspects, it is appropriate to consider broader public consultation as part of the next stages of the project to better understand community values and support.

Given the ability of options in the Belubula to improve water security for towns and other extractive water users, and the engineering risks and environmental concerns associated with The Needles, next stages of investigation should consider Cranky Rock as first priority.

**Recommendations**

The following recommendations are made in relation to next phases of planning:

- Progress with in-field investigations in the vicinity of Cranky Rock. Investigations should focus on establishing the potential foundation and storage integrity risks.
- Undertake a cost-benefit analysis to determine the economic value of the investment in water security improvement in the region.

# 1. Introduction

The NSW 2014-15 Budget announced the funding of scoping and feasibility studies, including environmental, geotechnical and preliminary design work, for the construction of a new dam on the Belubula River. Subsequently, the NSW Government commissioned Water NSW to undertake an investigation into potential storages in the Lachlan Valley, including the Belubula River. This document is a report to the NSW Government on that investigation.

This report documents the methodology, results and recommendations of the Water NSW investigation to identify and assess the potential, considering economic, social and environmental outcomes, of additional storage in the Lachlan Valley to provide improved water security for the central west region of NSW.

## 1.1 Objectives

The objectives of this investigation were to undertake:

- A desktop assessment of identified storage options against technical, economic, social and environmental objectives.
- Consultation with key stakeholders to document views on the water security problem and the appropriateness of the various potential storage options.
- Reporting of the outcomes of the above including identifying a preferred option if conclusive, or other recommendations as appropriate.

## 1.2 Background

Water security has historically been a significant issue in the Lachlan Valley (Figure 1). Drought, notably the Federation drought and the Second World War drought, has had major impacts on both the urban and rural communities of the region.

The Millennium Drought exposed the lack of water security in the whole Lachlan valley supplied from Wyangala Dam. Many of the region's cities and towns were forced to impose severe restrictions on domestic, commercial and industrial uses. Water dependent agricultural and mining businesses were also significantly impacted. Trends in the temporary trade in the water market suggest it is unlikely that this part of the regional

economy will recover without a significant improvement in water security for high value agricultural investments.

In response, increased storage in the region has been considered many times in the past, including most recently during the Millennium Drought.

The Central NSW Councils (Centroc) undertook a study in 2009 that identified a range of potential measures to improve urban water security, including the need to increase dam storage capacity. The study recommended an increase of at least 22GL at Lake Rowlands, a dam operated by Central Tablelands Water, that would in future, be used to serve the needs of a broader set of towns in the region than it presently serves. Lake Rowlands is on a tributary of the Belubula River.

*"We were pleased to hear Water NSW present the various options that are being considered in the study and to see the NSW Government's commitment to improving water security for the valley," Councillor Ken Keith, Chair of Centroc said.*

A subsequent study by Central Tablelands Water in 2013 concluded that construction of a larger dam on the Belubula, that might meet more water needs, would be a better option when compared to enlargement of Lake Rowlands. This study concluded that the proposed Needles Dam site provides a better location for constructing a dam for the expenditure involved.

In this context, determining the potential of additional water storage to improve security for water users in the Lachlan Valley, taking account of economic, social and environmental outcomes, is important to NSW Government.

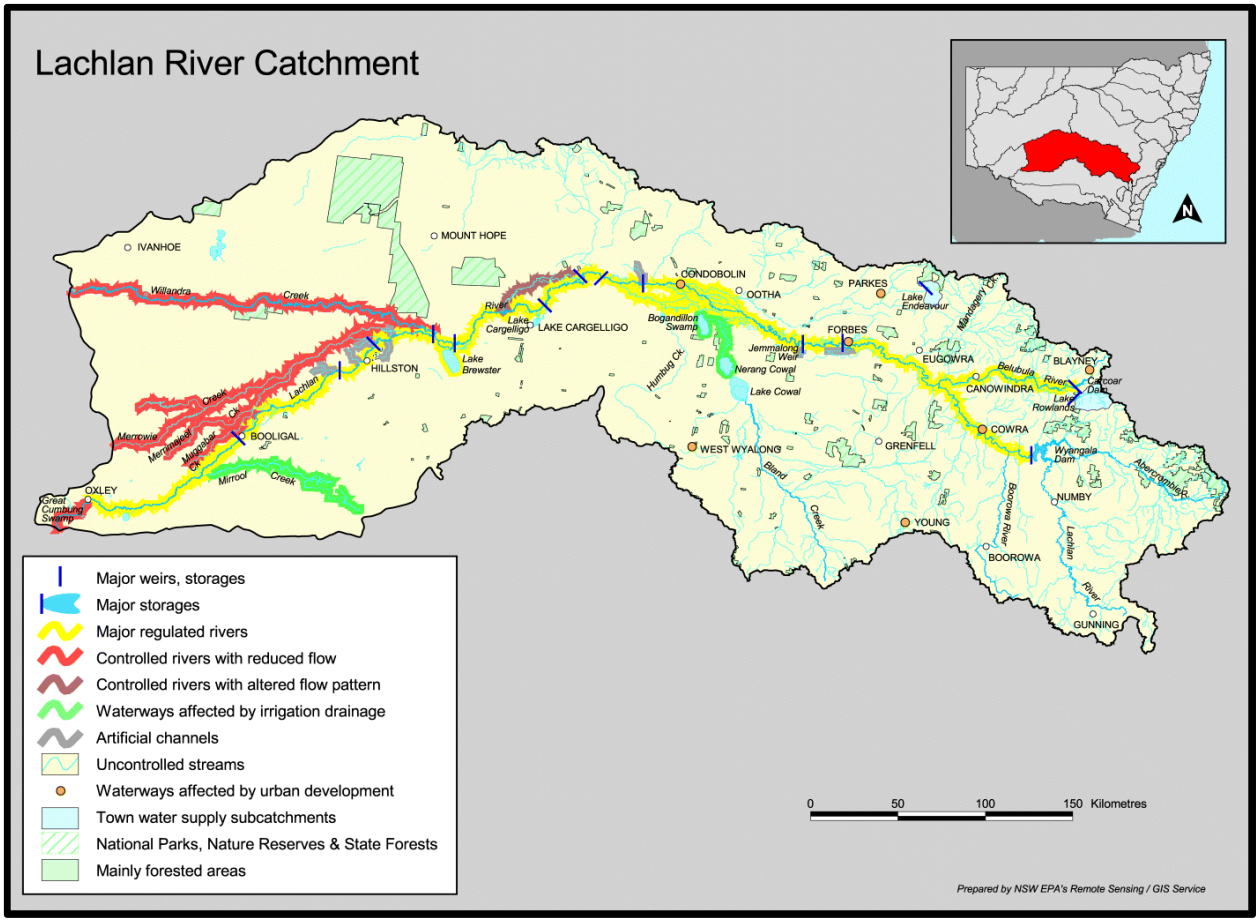



**Figure 1: Lachlan Valley (EPA, 2004)**

# 2. Study Process

This section of the report sets out the approach that was undertaken to formulate the recommendations of this scoping study.

## 2.1 Scope

The scope of this study was:

- Consultation with key stakeholders.
- Documentation of the scale and nature of the water security problem.
- A desktop review of previous Lachlan Valley storage studies and outcomes.
- Identification of potential storage options to potentially improve water security.
- Investigation of the potential storage options including hydrologic modelling, engineering, costing and environmental issues.
- Evaluation of those options against a framework of environmental, social and economic criteria.
- Development of recommendations based on the analysis and key stakeholder feedback.

## 2.2 Approach

The following principles shaped this study:

- Least cost, whole of life, assessment: consider capital, operating and maintenance costs associated with options over the life of their expected operation and provision of service (in this case, water security).
- Consider economic, environmental and social outcomes: define clear objectives in each of these areas and develop an assessment framework that encompasses these to ensure the various trade-offs associated with options are identified.
- Consult with key stakeholders: leverage stakeholder feedback as they have knowledge that can be applied to option identification and characterisation and have views that help to establish the economic, environmental and social outcomes.
- Relative option comparison: capture those aspects of options that make them different (i.e. relative level of security improvement provided for relative cost associated with the various storages) to understand the relative performance of

options is identified. Further planning work will need to be done at a later stage to establish absolute performance (i.e. cost estimates appropriate for budgeting).

- Identify alternatives to meet the objectives: whilst the scope of the study is to focus on potential storage options, there may be other options that could also assist in improving water supply security, which are outside of the present scope. This document identifies any such options that were noted during the investigation for future potential consideration.

**Box 1: Principles of Infrastructure Investment**

There are several key principles related to water infrastructure investment that have been considered, where appropriate, as part of this study. These principles will also shape future assessment requirements and outcomes.

Relevant principles include (but are not limited to):

- The National Water Initiative requires full cost-reflective pricing and user pays approaches to water service provision. Arrangements to achieve this requirement will need to be put in place around any infrastructure investment made.
- The State and Federal governments make investments in infrastructure that demonstrates a positive benefit-cost ratio as determined under a defined process for cost-benefit assessment. A cost-benefit assessment of the recommended options in this report will need to be undertaken.
- Water for the environment is important to protect and infrastructure investments must be consistent with the Murray-Darling Basin Plan and be subject to water-sharing arrangements managed by the State.
- Projects are prioritised by the NSW government in terms of their ability to maximise economic benefits, benefit the greatest number of people and maximise the use of existing investment and assets.

The scoping study process is set out in Figure 2.

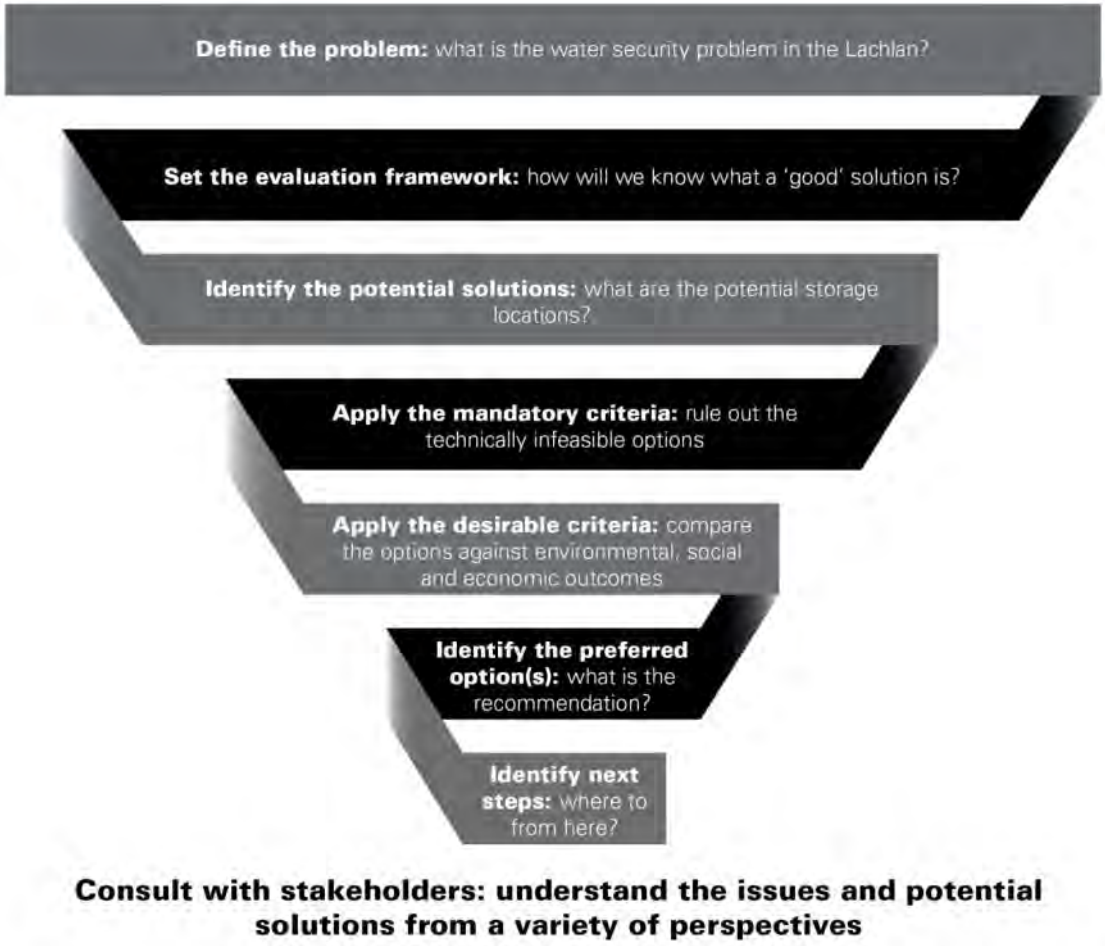



**Figure 2: The Scoping Study Process**

## 2.3 Stakeholder Consultation

The purpose of the consultation process undertaken as part of this study was to seek key stakeholder feedback on the water security problem within the Lachlan Valley and the potential storage options to address this problem. The consultation outcomes have been considered in making the recommendations in this report and are documented to assist the NSW Government in understanding the various perspectives on the options.

The consultation approach utilised in this study was consistent with the 'inform' and 'consult' levels of the International Association of Public Participation (IAP2) spectrum for engagement (see Appendix A)

The key stakeholders consulted are set out in Table 1. Full details of the consultation activities and outcomes are set out in Appendix A.

**Table 1: Key Stakeholders**

| Key Stakeholder | Consultation |
|---|---|
| Belubula Landholders Association | 29 October 2014: joint briefing meeting with the Belubula Landholders Association in Canowindra to introduce the project scope, options and evaluation criteria.<br><br>20 November 2014: presented preliminary findings to Lachlan Customer Service Committee which includes representatives of Belubula Landholders Association and Lachlan Valley Water.<br><br>25 November 2014: combined meeting with Centroc to discuss shared views on water security issues and potential solutions. |
| Lachlan Valley Water | |
| Central NSW Councils (Centroc) | 6 November 2014: briefing meeting with the elected representatives and staff of the member councils at Forbes to introduce the project scope, options and evaluation criteria.<br><br>24 November 2014: briefing meeting with and staff of the member councils at Forbes to present shortlisted options and consider Centroc views on the relative weightings of desirable criteria.<br><br>25 November 2014: combined meeting with Belubula Landholders Association and Lachlan Valley Water to discuss shared views on water security issues and potential solutions. |
| Government agencies:<br>• Bureau of Meteorology<br>• Central Tablelands Local Land Service<br>• Central West Local Land Service<br>• Commonwealth Environmental Water Holder<br>• Department of Planning<br>• Department of Primary Industries<br>• Department of Trade and Investment<br>• Murray Darling Basin Authority<br>• Office of Environment and Heritage<br>• Regional Development Authority Central West<br>• State Emergency Services | October 2014: letter advising of the scoping study and seeking agency advice on their involvement in subsequent planning efforts and matters for consideration. Subsequent emails and telephone conversations with agencies as required. |
| Lachlan Riverine Working Group | 2 December 2014: teleconference to brief members on the study scope, options, evaluation criteria and potential solutions. |
| Lake Cargelligo community | 20 November 2014: meeting with the elected representatives of Lake Cargelligo to introduce the project scope, options and evaluation criteria. |

| Key Stakeholder | Consultation |
|---|---|
| Potentially impacted landholders near The Needles | 29 October to 4 November: individual meetings on the various farms or other locations of their choice with potentially impacted landholders.<br><br>19 November: phone calls with other self-identified potentially impacted landholders associated with Cranky Rock and The Needles. |
| Speleological interests (Orange Speleological Society, Australian Speleological Federation) | 4 November 2014: meeting with representatives of the society and federation in Orange to introduce the project scope, options and evaluation criteria. |
| Water NSW Lachlan Customer Service Committee | 20 November 2014: briefing at standing meeting in Condobolin to introduce the project scope, options, evaluation criteria and preliminary findings. |
| Wiradjuri land council region (Cowra) | October 2014: letter advising of the scoping study and seeking advice on their involvement in downstream planning efforts and matters for consideration. |

**Figure 3: Centroc and Water NSW Representatives at Meeting on 6 November 2014**

## 2.4 Constraints

The study was undertaken within the following constraints:

- The study is geographically bound by the catchment of the Lachlan Valley.
- The study is focussed on surface water resources.
- The study is focussed on storage options to improve water security.
- Any new infrastructure must be consistent with the Basin Plan.

# 3. Defining the Water Security Problem

The first step in the investigation was to determine the problem or issue which is to be addressed. This section of the report defines the nature and scale of the water security problem in the Lachlan Valley.

## 3.1 Supply and Demand

The security of water supply is a function of the available water resources and the timing and volume of demand for water. Demand for water is also subject to an access regime, which sets priorities for various types of demand (i.e. environmental water, town water, high security and general purpose licences).

**Box 2: More Water or Water Security?**

The Murray-Darling Basin Plan requires that all catchments within the basin put in place water sharing arrangements that are within the Sustainable Diversion Limit (SDL) set for that catchment. The purpose of the SDL is to ensure that water for the environment is protected (MDBA, 2012).

The Commonwealth Government has purchased water licences in the Lachlan Valley over the past few years in order to provide water for the environment and to meet the SDL. This has resulted in a reduction in the total volume of water available for consumptive water use in the Lachlan Valley.

Investments in storages in the Lachlan Valley cannot be used to increase the overall water extractions from the valley. The total volumetric value of extraction licences must stay within the SDL on a long-term average basis.

The purpose of providing additional storage is to improve the security of the existing water entitlements. Dams can improve security by allowing water to be captured when it is available, and held for longer periods of time, so that the entitlements granted to consumptive water users through their licences can be delivered in more years (i.e. there are fewer years when announced allocations are zero).

The following sections examine the key types of water demand in the Lachlan Valley and indicators that their demand has not been met during the Millennium drought.

### 3.1.1 Town Water Supply Security

The water security needs of the cities and towns of Central NSW was documented by Centroc in their 2009 Water Security study (Figure 5). In consultation with Centroc during this investigation, the 2009 assessment was confirmed as still broadly representing the current situation. The councils also noted the proposed new government water security guidelines take a different approach to assessing town water supply security which may see the lack of water security of towns of the region further exacerbated.

*Central NSW Councils told us they support the idea of investigating new storages in concert with the inclusion of a proper assessment of the Lake Rowlands and Carcoar dam elements for urban water security in the Centroc region*

The conclusion of the Centroc Water Security Study was that the water security requirements of the towns could be improved through investment in additional town water supply storage for the region. It was proposed that the existing Lake Rowlands Dam, which is located in the Belubula River catchment, be augmented to meet these needs.

As there is no market for town water supplies, it is not a simple exercise to determine the economic value of improving water security to towns. However, investments in ensuring water security for towns that have been made in the region over the past 5 years have varied from $850/ML security improvement to $11,000/ML of security improvement (Molino Stewart, 2012). Costs are for capital and operation, discounted over time.

### 3.1.2 General Security Irrigation Security

The records of available water for the Lachlan Valley illustrate that the valley is less secure for irrigation activities than other valleys in NSW:

- As illustrated in Figure 4, general security licences in the Lachlan Valley are subject to periods of zero allocation both in terms of 'announced allocation' at the start of the water year (shown as the solid line) and in terms of 'actual allocation' by the end of the year (shown as the dotted line)
- In comparison, general security licences in neighbouring catchments, such as the Macquarie River, have very few, if any, years of zero allocation (Office of Water)

The market price of permanently traded water in the different NSW valleys also indicates that water in the Lachlan Valley is less secure. As illustrated in Table 2, although there is a similar tradeable volume of water in the Lachlan and the Macquarie, water in the Macquarie is more highly valued in the Macquarie as it is more secure. Although the table provides information for 2011, the market indicators below show this differential exists over a longer period. As the types of crops and agricultural activities, soils and other conditions are broadly similar between the two catchments, water is likely to be the limiting factor.

*The Belubula Landholders Association and Lachlan Valley water told us that improving water security for irrigation is about reducing the number of years the announced allocation for general security water is zero*

**Table 2: Value of Water Entitlements (NWC, 2011)**

| Valley | Licence | Tradeable Volume on Issue (ML) | Average Price for 2011 ($/ML) | Estimated Total Value of Entitlement ($ million) |
|---|---|---|---|---|
| Lachlan | General | 592,816 | 569 | 337 |
| Macquarie | General | 631,716 | 1,063 | 671 |

The volume weighted average price of water in the:

- Lachlan in 2013/14: $397/ML
- Murrumbidgee in 2013/14: $816/ML
- Lachlan in first half 2008/09: $668/ML
- Murrumbidgee in first half 2008/09: $1,208/ML

Lachlan Valley Water has also had an economic assessment of the value of irrigation water to the regional economy completed which highlights the importance of this sector in the region (WRI, 2011).

**Figure 4: Lachlan Regulated River – Frequency of General Security Water Availability**

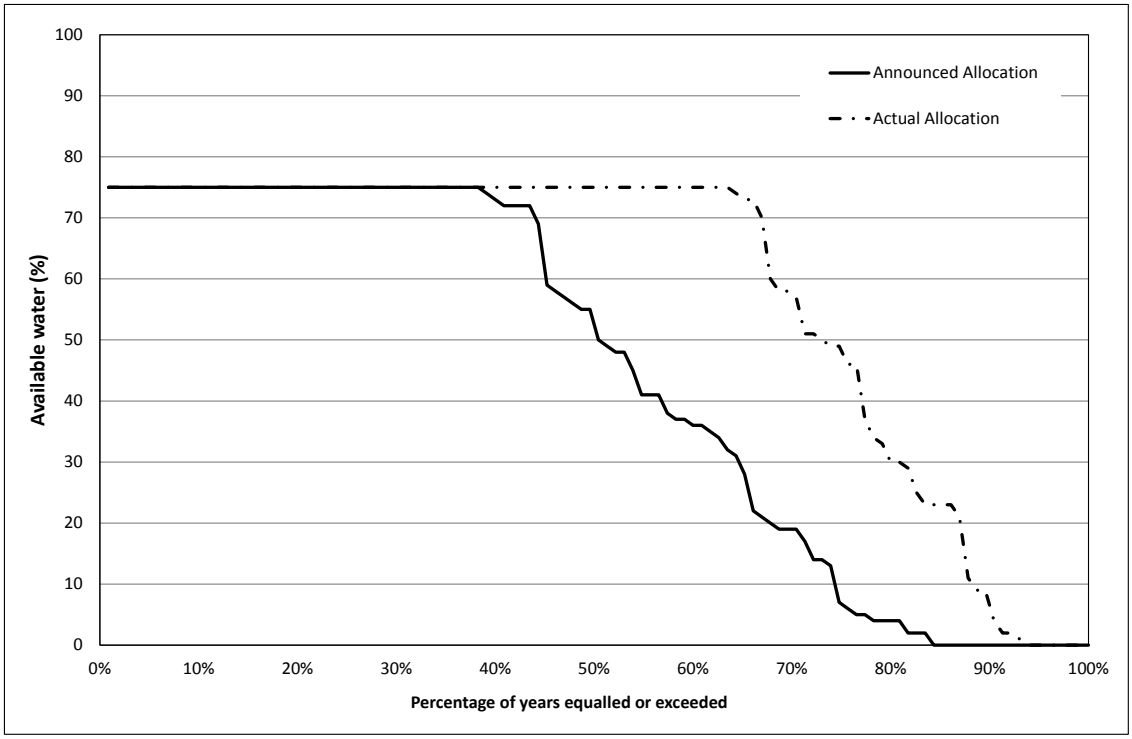
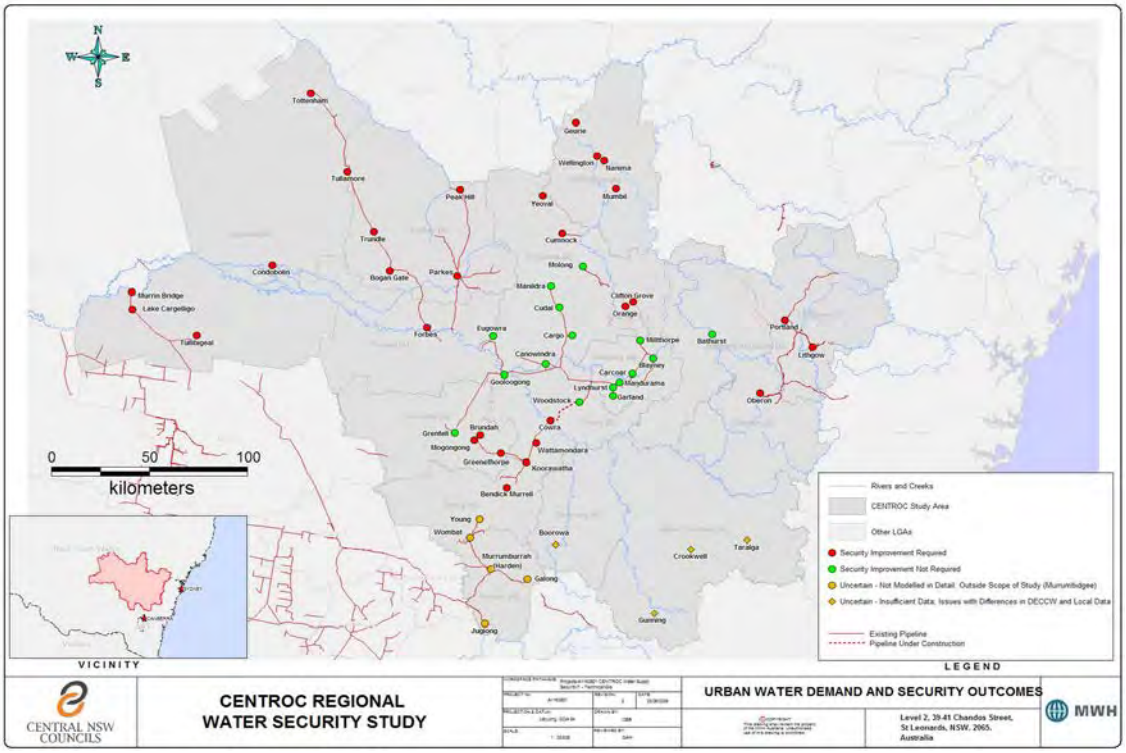



**Figure 5: Town Water Security in Central NSW**



### 3.1.3 Security for Other Economic Users of Water

The economy of Central NSW is driven by mining (18.5% of gross regional product), agriculture, forestry and fishing (6.1%) and manufacturing (8.3%), (RDA Central West, 2012). These sectors are also significant in terms of employment in the region (RDA Central West, 2012). These industries consume water as a factor of production, and in particular, the growth of mining and agricultural endeavours can be limited by the availability of water supply.

A detailed assessment of the economic benefits to be obtained from investing in water supply in the Lachlan Valley has not been undertaken as part of this study. However, consultation with stakeholders provided anecdotal evidence that the lack of water supply security in the region is limiting economic development. Examples cited included:

- Potential of a new gold mine in the Blayney area and discussion of a number of other potential mine interests
- Potential of a new abattoir in the Blayney area
- Possible food processing facilities

### 3.1.4 Water Security for the Environment

Water is required to protect the environment and the Lachlan Valley has a rich environment of nationally important wetlands and habitat for threatened species. Historically, the Lachlan Valley has been considered to be in very poor ecosystem health and subject to moderately high levels of water extraction for consumptive use (MDBA, 2011 and CSIRO, 2011).

Over the past five years, a total of 88 GL of entitlements in the Lachlan Valley has been bought by the Commonwealth Environmental Water Holder to provide water to protect environmental assets. Whilst necessary to protect the environment, this action has reduced the water available for consumptive use in the Lachlan Valley.

There is some discussion in the Murray-Darling Basin Plan that more water may be held for the environment in the Lachlan Valley than is required, but at this stage, there are no firm plans for changes to the SDL.

The stakeholders consulted expressed the views about water security in the Lachlan Valley set out in Table 3.

In general, irrigators, town water utilities, Water NSW customers and the potentially impacted landholders consulted agree that the lack of water security in the region is impacting on the economy and quality of life of the Central NSW region. These stakeholders also broadly agreed that investment in water storages is a key component of improving water security.

Environmental and recreational user groups have commented publicly since the initial announcement of this investigation that other options for improving security need to be considered including water efficiency options and recycling.

**Table 3: Stakeholders Views on Water Security**

| Topic | What we Heard |
|---|---|
| Evidence of a lack of water security | • Water security is a major concern facing many regional communities<br>• There is a lack of water security for consumptive users<br>• Sourcing water from the Lachlan valley is limiting economic growth.<br>• Both town water security and irrigation security need to be addressed<br>• The water security problem for towns is as it was documented Centroc Water Security study<br>• The new NOW modelling and guidelines, which have not been formally released, seem to show supplies are less secure than thought. Could be as much as 20% less secure.<br>• Continuous accounting in the Belubula River is not working as illustrated by the current lack of water in Carcoar when accounts have water in them.<br>• There is concern that the general security water in the Lachlan Valley in 2015/16 may not be deliverable<br>• Our business was impacted by the Millennium drought. High security was cut back by 50% in 2009<br>• Carcoar is only 30% full and will shortly be only stock and domestic. There is a need for water in the area<br>• Water security in Canowindra and down the Lachlan is an issue<br>• We do need more water storage on this side of the divide. Many of the people against the dam are from the other side of the divide (Sydney)<br>• Kings Plain mine cannot go ahead because they do not have water security<br>• Water is required for the environment, but has too much been reserved under the current water sharing plan?<br>• Without water security, there is no food bowl - and this is our livelihood. Our shire provides 38% of the oat crops of the state. Hillston is one of the largest producers of citrus in NSW and is dependent on water being deliverable to the lower parts of the Lachlan Valley.<br>• There was not enough water in the lower river to meet the needs of Condobolin during the Millennium drought. Wyangala dam, and State Water operations, failed. |
| Potential of water security problem to worsen | • New approaches to understanding the security of town water supplies are being developed by the NSW Government. These approaches include different modelling approaches to those used historically to determine town water supply security. There is a general understanding by Local Water Utilities that when assessed under these new approaches, their supplies may be less secure than previously thought<br>• Changes in catchment practices appear to be resulting in less runoff even though the rainfall is the same |

| Topic | What we Heard |
|---|---|
| Impacts caused by the lack of water security | • Loss of income<br>• Loss of regional economic development opportunities<br>• Loss of town amenity and recreational assets<br>• Impacts on mental well-being of the community |
| Better use of existing water supplies | • There is a need to be more efficient with existing water supplies<br>• Consider the use of alternatives such as demand management and recycling<br>• Consider options such as piping water to reduce transmission losses<br>• Operational improvements (alter water allocation rules to keep more water in storage so that water security during dry years is improved). |

## 3.2 The Water Security Problem

For the purposes of this investigation, the water security problem in the Lachlan Valley is described in Table 4.

**Table 4: The Water Security Problem**

| Aspect | Evidence Points |
|---|---|
| Lack of security for current consumptive users sourcing water from the Lachlan Valley is limiting economic growth | Severe restrictions on town water use during drought (Centroc, 2009).<br>History of long periods (10 years) of no general security agricultural water availability and high security water being restricted.<br>Depression of agricultural economy of the region as evidenced in the trading of licences and lack of investment.<br>Consumptive extractions have been reduced to protect water for the environment (MDBA, 2012). |
| Lack of future security for towns and other development that would rely on water from the Lachlan Valley | The Centroc Water Security Study 2009 forecasts the demands of the cities and towns of the region for the next 50 years and compares them to the available supplies. The study concluded additional storage was required to meet future needs (Centroc, 2009).<br>Limitations on potential of mining industry in the region. |

**Box 3: Cost-Benefit Analysis**

Investments in infrastructure in NSW are subject to cost-benefit analysis and must demonstrate that benefits exceed costs before they will be funded. This detailed assessment quantifies the economic benefits that can be expected to arise from the costs associated with building, operating and maintaining the infrastructure under consideration.

It will also consider a 'do nothing' option. Such studies use concepts such as direct economic impact and indirect measures such 'willingness to pay' and 'existence value' to capture the full economic benefit to be compared against the costs associated with the infrastructure.

Economic assessment of the value of water supply security has not been undertaken in this investigation. This study has focussed on identifying the preferred location for any new dam in the Lachlan Valley. Whilst preliminary consideration of the economic outcomes of increased security has been considered in the assessment, the recommendations of this investigation will be subject to detailed cost-benefit analysis as part of the ongoing feasibility and planning steps that will follow this report.

# 4. Evaluation Framework

It is important to clearly define the approach to evaluating storage options to ensure consistency of the assessment and ranking of the options. This section sets out the evaluation framework for comparing storage options for the purposes of this scoping study.

## 4.1 Evaluation Approach

The evaluation approach for this study is two-pronged:

- Mandatory objectives: these represent minimum conditions of satisfaction or threshold positions that all potential options to solve the water security must meet. These were used to filter the long-list of potential options (all of the options identified) to a shorter list for detailed investigation;
- Desirable objectives: these represent goals that will be strived for in selecting options, but will be achieved to different levels by each of the options considered. Hence, these criteria are often ultimately weighted to understand their relative importance as trade-offs between options on the short-list are investigated.

These two sets of objectives were applied progressively through the study as illustrated in Figure 6.

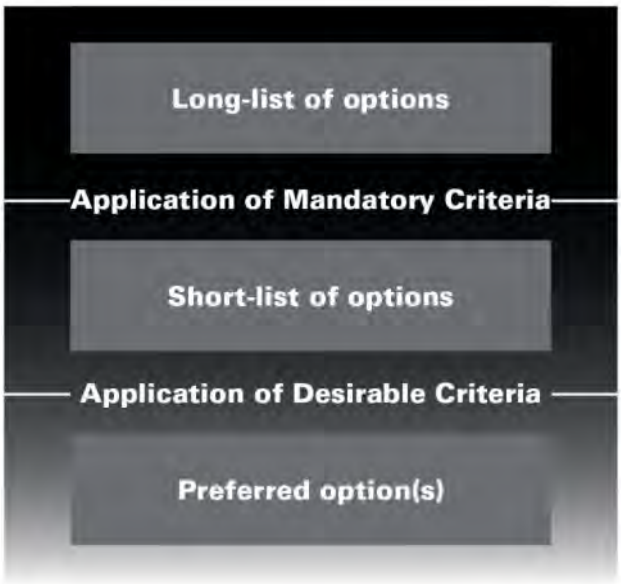



**Figure 6: The Evaluation Approach**

## 4.2 Evaluation Criteria

A series of mandatory and desirable objectives, and criteria against which to measure how any given option performs, have been defined for the purposes of evaluating storage options (Table 5).

**Table 5: Objectives, Measures and Criteria**

| Objective | Measures | Criteria |
|---|---|---|
| **Mandatory** | | |
| Technically potentially feasible solution | Hydrologic and engineering considerations | Rapid quantitative assessment including hydrologic modelling or equivalent yield and preliminary consideration of relative cost-effectiveness. |
| Consistent with the Basin Plan | Health riverine environment | Ensuring the environmental objectives required under the plan are met. |
| Regulatory compliance | A regulatory barrier that causes option to fail | Qualitative assessment |
| **Desirable** | | |
| Maximise the net worth of the State's investment | Economic benefit from the security improvement | Qualitative assessment of likely benefits associated with improvement in security to different types of water users |
| Cost-effectiveness | Relative cost efficiency of options | Comparative whole of life direct costs/GL equivalent yield |
| Water security improvement | Maximise long term water availability to customers | Equivalent yield and hydrologically modelled supporting considerations of security improvement |
| Have regard to the interest of the community | Stakeholder opinion of options | Qualitative assessment |
| Maximise cost-effective renewable energy opportunities | Energy production | Semi-quantitative assessment |
| Environmental sustainability | Minimise environmental impact | Semi-quantitative assessment |

| Objective | Measures | Criteria |
|---|---|---|
| Security/predictability of Water NSW revenue stream | Revenue reliability | Qualitative assessment |
| Compatibility of options with Water NSW strategic plans | Strategic compatibility | Qualitative assessment |
| Compatibility of options with Water NSW operational capability | Operational compatibility | Qualitative assessment |
| Operational capability to mitigate flooding | Flood mitigation capability | Qualitative assessment |

# 5. Potential Solutions

This section documents the range of potential solutions considered in this scoping study and documents the application of the mandatory criteria to identify a short-list of options for more detailed consideration.

## 5.1 Previous Studies

A list of the available data for this project is set out in Section 9 and Appendix B.

The following key reports and documents were reviewed as part of this study. Other reports considered are detailed in the various appendices.

*It has been over 30 years since a dam has been built in NSW, but some things cross the generations. In reviewing the data for this project, we came across reports completed by the Water Resources Commission that were authored by John Duchatel. The environmental assessment supporting this report was prepared all this time later by his daughter, Kathryn Duchatel.*

- Lachlan Valley Dam Sites Preliminary Estimates of Streamflow and System Yields, September 1980
- URS Cranky Rocks and Needles Reports
    - 19 June 2014 – Preliminary Concept Estimate for New Belubula River Dam
    - 19 June 2014 – Needles Dam – Geology
    - 19 June 2014 – Needles Dam Site A – Cost Estimates
- Stage, storage, surface area curves extracted from Water NSW GIS information
- Geological and geotechnical date including 1:100,000 maps from the NSW Government Resource and Energy website and geological information held in the Water NSW GIS.

Storage sites identified as a result of the previous studies are set out in Table 6.

**Table 6: Potential Storage Sites**

| Site | Description |
|---|---|
| Abercrombie Dam | A new dam on the Abercrombie River near Tuena and upstream of the Goulburn Road crossing of the Abercrombie River. |
| Badgery Dam | A new dam on the Lachlan River, approximately 18 km downstream of Wyangala Dam, below Darby Falls. |

| Site | Description |
|---|---|
| Battery Hill Dam | A new dam on the Boorowa River, upstream of its confluence with the Lachlan River and upstream of Cowra. |
| Boree Creek Dam | A new dam on the Boree Creek upstream of Cudal. |
| Carcoar Dam Raise | Raising the exiting parabolic arch Carcoar Dam on the Belubula River. |
| Cranky Rock Dam site 1 | A new dam on the Belubula River, above Moorbel approximately15km east of Canowindra. |
| Cranky Rock Dam site 2 | A new dam on the Belubula River, approximately 2km downstream of Cranky Rock Dam site 1 and approximately 13km east of Canowindra. |
| Harry Darts Dam | A new dam on Boorowa River below Mount Collins and upstream of the Battery Hill Dam site. |
| Hillandale Dam | A new dam on Lachlan River, upstream and south of Wyangala Dam at Hillandale. |
| Murga Dam | A new dam on the Mandagery Creek approximately 2.5 km northwest of Murga. |
| Narrawa Dam | A new dam on the upstream of Lachlan River and south of Hillandale Dam site. |
| Needles Dam | A new dam on the Belubula River approximately 10 km upstream of Cranky Rock Dam site. |
| Wyangala Dam | Raising the exiting embankment dam on the Lachlan River by 20m. |

## 5.2 Stakeholder Views

Consultation with stakeholders identified potential options as set out in Table 7.

**Table 7: Stakeholder Identified Potential Storage Sites**

| Category | Options | Response |
|---|---|---|
| Known storage sites | See the list in Table 6. | Carried into long-list in Section 5.3. |
| Other storage sites | Roaring Rock Dam | The project team determined this dam is either the same site as Harry Darts Dam, or very nearby, and hence, only Harry Darts Dam has been assessed. |
| | Pride of Oak | The project team determined this dam is Cranky Rock Dam site 1. |

| Category | Options | Response |
|---|---|---|
| | Junction Reefs | A new dam on the Belubula River at Mandurama, downstream of the existing heritage listed dam structure. Carried into long-list in Section 5.3. |

Stakeholders also identified that additional storage is one aspect of improving water security and noted there are also other potential solutions that should be considered. These are set out in Table 8. Although the scope of this study is limited to consideration of storage options to improve water security, the assessment of these alternative options could be progressed in parallel with any recommended actions related to the development of additional storage in the Lachlan Valley. An opportunity would exist at a later point in the overall planning process to optimise the investment in storage and other solutions.

**Table 8: Other Potential Solutions Identified by Stakeholders**

| Category | Options | Response |
|---|---|---|
| Market options | Reconsideration of the environmental water provisions as defined in the Murray Darling Basin Plan and the Lachlan Regulated River Water Sharing Plan. There is a view that the needs of the environment in the Lachlan Valley have been over-estimated and should be reconsidered.<br>Inter-basin transfers from the Macquarie Valley.<br>Establish a medium security licence type. | Further exploration of these opportunities is warranted as part of the overall planning process in parallel with the implementation of the recommendations of this report. It is likely that the responsibilities for undertaking these assessments and implementing these actions sit with a variety of organisations including the Office of Water and local government. |
| Demand management measures | Efficiency options including:<br>• Piping of the effluent channels of the Lachlan River to reduce transmission losses<br>• Piping of the needs of town water supplies along the Lachlan River to reduce transmission losses<br>• On-farm water efficiency measures<br>• Town water supply demand management. | |
| Recycling | Alternative water source for towns and industry. Recycling of water from mines such as those near Lithgow. Treated sewage effluent recycling. | |
| Groundwater | Review of the sustainable utilisation of groundwater within the Lachlan Valley. | |

| Category | Options | Response |
|---|---|---|
| Re-regulation options and operational options | Consideration of mid-Lachlan storage options for efficient re-regulation of flows.<br>Change the water allocation rules and keep more water in storage so that water security during dry years is improved. | Optimisation of the operation of the water storage assets of the Lachlan Valley will need to be undertaken prior to the construction of any new storage. This is a consideration for next steps beyond this study. |

**Box 4: Sharing Water**

Many of the stakeholders consulted as part of this study raised concerns about the sharing of water in the Lachlan Valley. Stakeholders noted concerns about the equitable distribution of water along the full length of the river, the history of competition between extractive users such as irrigators, miners and towns, and between extractive users and the environment. There were also concerns about providing water from the Lachlan to cities and towns outside of the valley. Stakeholders often acknowledged the difficulty that has historically been faced in striking an appropriate balance across these competing needs.

This study has assumed that all storage options will be compliant with the existing Murray Darling Basin Plan, and that storage would be provided for the purposes of security improvement, not increased extraction (see Box 2). However, should a new storage asset be created, it would be necessary to reconsider the operational regime for water delivery and the water sharing arrangements across the valley. In addition, it would be necessary to consider how the additional security provided would be shared across the valley. Similarly, other processes, such as the Sustainable Diversion Limit (SDL) adjustment processes in the Murray-Darling Basin Plan, provide the opportunity to balance the benefit of certainty that comes from having a plan, with the need to continue to adjust and refine the plan as markets change and understanding of environmental assets improves.

Whilst sharing water is a significant issue, it is outside the scope of this study. Instead it forms part of the next steps for implementation of the recommendations.

## 5.3 Characterising the Long-List of Options

The long-list of options is set out in Table 9. The options are illustrated on the map of the region set out in Figure 7.

**Table 9: Long-list of Options**

| Options | Catchment | Engineering Storage Potential | Considerations |
|---|---|---|---|
| Abercrombie Dam | Abercrombie River | There is a storage potential of approximately 1,480 GL. | - |
| Badgery Dam | Lachlan River | There is a storage potential of approximately 45 GL. | It will be necessary to determine if a dam site at this location will drown the outlet at Wyangala Dam. |
| Battery Hill Dam | Boorowa River | There is a storage potential of approximately 1,100 GL. | - |
| Boree Creek Dam, also known as Cudal Dam | Boree Creek | There is a storage potential of approximately 500 GL. | - |
| Carcoar Dam Raise | Belubula River | A capacity increase from 36 GL to approximately 220 GL. | Raising this existing storage would be expected to trigger dam safety related changes to the existing structure. |
| Cranky Rock Dam site 1, also known as D site or Pride of Oak | Belubula River | There is a storage potential of approximately 1,000 GL. | There are a number of slightly different locations that have been identified historically. Two have been chosen as representative for the purposes of this desktop assessment. |
| Cranky Rock Dam site 2, also known as site E | Belubula River | There is a storage potential of approximately 1,000 GL. | |
| Harry Darts Dam, also known as Roaring Rock Dam | Boorowa River | There is a storage potential of approximately 380 GL. | - |
| Hillandale Dam | Lachlan River | There is a storage potential of approximately 1,480 GL. | - |
| Junction Reefs site 1 | Belubula River | There is a storage potential of approximately 90 GL. | There is an existing heritage listed dam structure in the vicinity of the potential site. |
| Junction Reefs site 2 | Belubula River | There is a storage potential of approximately 240 GL. | |
| Murga Dam | Mandagery/ Boree Creek | There is a storage potential of approximately 1,200 GL | - |
| Narrawa Dam | Lachlan River | There is a storage potential of approximately 1,000 GL. | - |
| Needles Dam | Belubula | There is a storage potential of | Presence of calcareous materials in |

| Options | Catchment | Engineering Storage Potential | Considerations |
|---|---|---|---|
| | River | approximately 810 GL. | the reservoir and their reaction (solubility) to inundation needs to be considered. |
| Wyangala Dam raise | Lachlan River | A capacity increase by 780 GL to approximately 1,200 GL. | Raising this existing storage would be expected to trigger dam safety related changes to the existing structure. |

**Box 5: Shared Views Amongst Some Stakeholders and a Desire to Work Together**

Representatives of the Belubula Landholders Association, Central NSW Councils and Lachlan Valley Water met with Water NSW on 25 November in Parkes. In relation to the lack of water security in the region, the three organisations agree:

- The prosperity of our region is closely tied to both healthy towns and a successful agricultural sector.
- Water security is limiting economic development in the towns, industry, mining and agricultural sectors of the Lachlan Valley.
- Investment in additional water storage to provide water security improvements is supported by all three organisations.
- Options that offer substantive improvements for both urban water security and agricultural water security should be supported.
- Failure of urban water supplies is socially unacceptable.
- We look forward to being part of evaluations and informing the decision-making process related to storage investments in the region going forward.

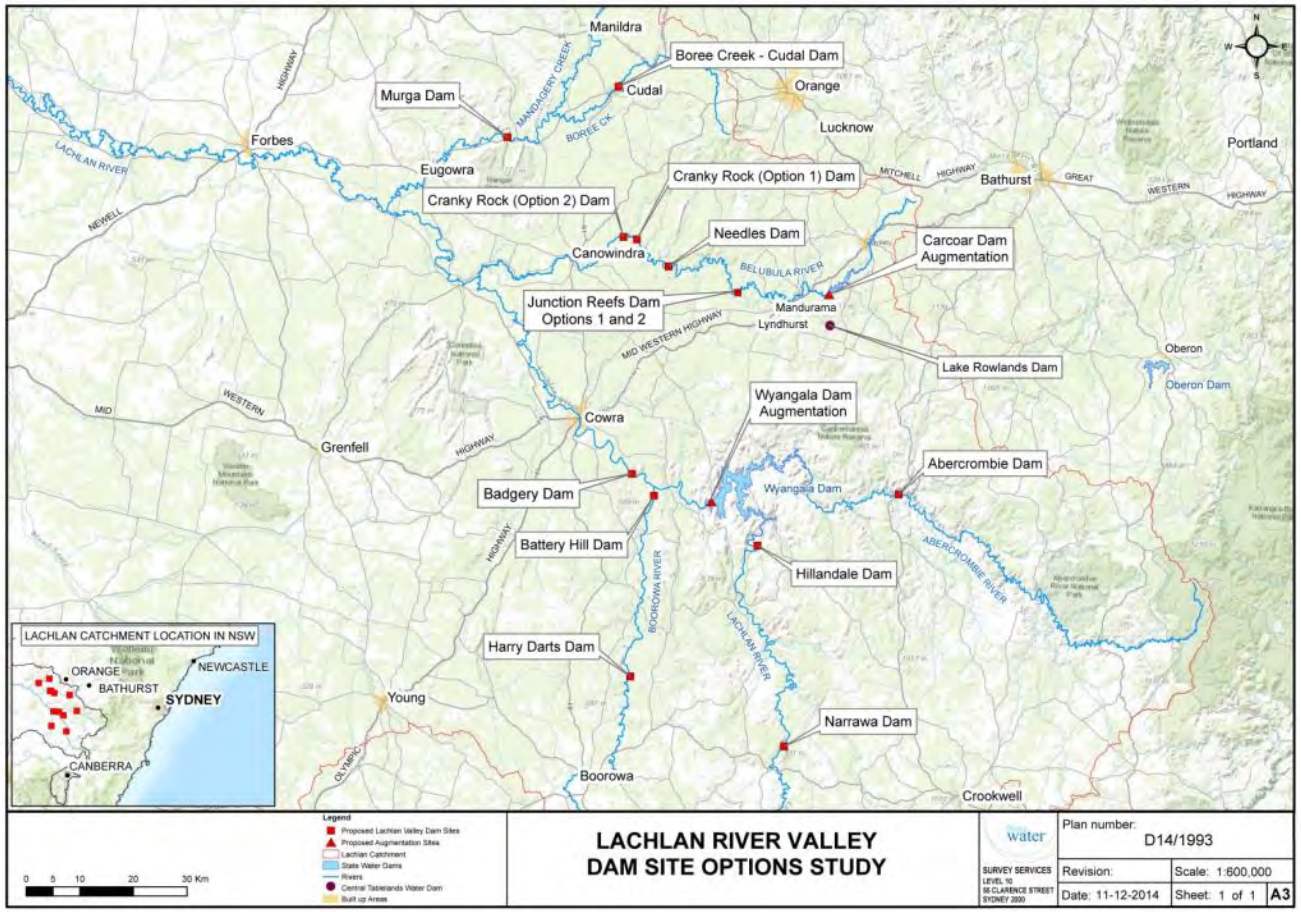



**Figure 7: Map of Long-List of Options**

## 5.4 Applying the Mandatory Objectives

To develop a short-list of options, the mandatory criteria defined in Section 4.2 have been applied to the long-list of options. The details of this assessment are set out in Appendix C and F. The results of this assessment are summarised in Table 10.

**Table 10: Results of Application of Mandatory Objectives**

| Site | Screen Against Mandatory Criteria | Shortlist |
|---|---|---|
| Abercrombie | Meets mandatory criteria | Yes |
| Battery Hill | Meets mandatory criteria | Yes |
| Cranky Rock Option 1 and 2 (also known as Pride of Oak) | Meets mandatory criteria | Yes |
| Narrawa | Meets mandatory criteria | Yes |
| Needles | Meets mandatory criteria | Yes |
| Wyangala Dam Raise | Meets mandatory criteria | Yes |
| Badgery | Impacts operation of Wyangala Dam | No |
| Carcoar Dam Raise | Small security improvement | No |
| Cudal (Boree Creek) | Small security improvement | No |
| Harry Dart (also known as Roaring Rock) | Small security improvement | No |
| Hillandale | Significantly higher costs for the security improvement than other options | No |
| Junction Reefs Option 1 and 2 | Higher cost for smaller security improvement | No |
| Murga | Small security improvement | No |

## 5.5 Short-List of Options

The short-list of options for more detailed consideration is set out in Table 11.

**Table 11: Short-List of Options**

| Option | Catchment | Description | Storage Potential |
|---|---|---|---|
| Abercrombie Dam | Abercrombie River | A new dam on the Abercrombie River near Tuena and upstream of the Goulburn Road crossing of the Abercrombie River. | Up to 700 GL |
| Battery Hill Dam | Boorowa River | A new dam on the Boorowa River, upstream of its confluence with the Lachlan River and downstream of Cowra. | Up to 400 GL |
| Cranky Rock Dam | Belubula River | A new dam on the Belubula River, above Moorbel and approximately 15km east of Canowindra or about 2km downstream of Cranky Rock Dam site 1 and about 13km east of Canowindra. The two sites are very difficult to distinguish for the purposes of desktop assessment and hence have been considered as a single location. | Up to 700 GL |
| Narrawa Dam | Lachlan River | A new dam on the Lachlan River upstream and south of Hillandale Dam site. | Up to 1,000 GL |
| Needles Dam | Belubula River | A new dam on the Belubula River about 10 km upstream of Cranky Rock Dam site. | Up to 700 GL |
| Raise Wyangala Dam | Lachlan River | Raising the exiting embankment dam on the Lachlan River by 20m. | Up to an additional 780 GL |

**Box 6: Linking Carcoar Dam and Lake Rowlands**

Towns use approximately 2-3% of the allocation of the Lachlan valley. However, as documented in the Centroc Water Security Study (MWH, 2009) the towns have a significant need for water security improvement.

As part of this study, the potential to meet the security needs of towns from Carcoar Dam, assuming another source was being used for other extractive purposes, was tested. It was assumed that to be a viable potential solution, Carcoar Dam would need to be able to meet the additional demands to be placed on an augmented Lake Rowlands, as per the findings of the original security study.

Based on the hydrologic modelling set out in Appendix D, it was determined that Carcoar Dam could meet the additional security requirement of the towns. This would mean that there is some potential to connect Carcoar Dam with Lake Rowlands to meet town demands, if another source on the Belubula River is the preferred site for a new storage. Further hydrologic assessment would be required to optimise the operation of the system and to examine if there is additional benefit to be had through the combined operation of Lake Rowlands and Carcoar Dam.

There are a number of other issues associated with this potential option that have been raised by Centroc, which will need to be considered in subsequent phases of planning:

- How would the water in Carcoar Dam be licenced?
- If there are other demands on the storage for other water users, how can we be certain the town water will be preserved?
- Who would own the assets?
- Who would operate the assets?

# 6. Option Investigation and Assessment

This section documents the detailed investigation and assessment of the short-listed options.

## 6.1 Option Characterisation

Detailed characterisation of the short-listed options is set out in Appendix C, D and E.

A summary of the short-listed options is set out in Table 12.

**Table 12: Characterisation of Short-Listed Options**

| Option | Hydrology | Engineering | Environmental |
|---|---|---|---|
| Abercrombie Dam | This site provides the potential for an improved yield of 23.1 GL/year.<br>The site and hydrology provides for a storage potential of up to 700 GL. | Construct a new concrete-faced rockfill dam of 101m in height and 613m in length.<br>There is significant potential for hydro-power at this site.<br>The comparative cost of this dam is 34 cost units per GL of equivalent yield improvement. | Results in the inundation of 2,000 ha of land<br>Impacts on 63 ha of national park and 518 ha of vegetation.<br>There are some protected flora and fauna at this site. |
| Battery Hill Dam | This site provides the potential for an improved yield of 12.6 GL/year.<br>The site and hydrology provides for a storage potential of up to 400 GL. | Construct a new zoned earthfill dam of 55m in height and 908m in length.<br>There is some potential for hydro-power at this site.<br>The comparative cost of this dam is 85 cost units per GL of equivalent yield improvement. | Results in the inundation of 3,000 ha of land.<br>Impacts on 286 ha of vegetation.<br>There are a number of Indigenous heritage sites in this inundation area.<br>There are some protected fauna at this site. |
| Cranky Rock Dam | This site provides the potential for an improved yield of 22.9 GL/year.<br>The site and hydrology provides for a storage potential of up to 700 GL.<br>This location allows most Belubula irrigation demands to be met from the new storage and for Carcoar Dam to be applied in some part to meet other potential water security needs including town water in the Central Tablelands area. | Construct a new concrete-faced rockfill dam of 87m in height and 657m in length.<br>There is significant potential for hydro-power at this site.<br>The comparative cost of this dam is 34 cost units per GL of equivalent yield improvement. | Results in the inundation of 2,800 ha of land.<br>Impacts on 164 ha of vegetation.<br>There are numerous Non-Indigenous heritage sites in this inundation area.<br>There are some protected fauna at this site. |

| Option | Hydrology | Engineering | Environmental |
|---|---|---|---|
| Narrawa Dam | This site provides the potential for an improved yield of 21.8 GL/year.<br><br>The site and hydrology provides for a storage potential of up to 1,000 GL. | Construct a new zoned earth fill dam of 80m in height and 897m in length.<br><br>There is limited potential for hydro-power at this site.<br><br>The comparative cost of this dam is 91 cost units per GL of equivalent yield improvement. | Results in the inundation of 6,000 ha of land.<br><br>Impacts on 1,122 ha of vegetation.<br><br>There are a number of Indigenous heritage sites in this inundation area. There are numerous Non-Indigenous heritage sites in this inundation area.<br><br>There are some protected flora and fauna at this site. |
| Needles Dam | This site provides the potential for an improved yield of 22.9 GL/year.<br><br>The site and hydrology provides for a storage potential of up to 700 GL.<br><br>This location allows most Belubula irrigation demands to be met from the new storage and for Carcoar Dam to be applied in some part to meet other potential water security needs including town water in the Central Tablelands area. | Construct a new concrete-faced rockfill dam of 102m in height and 480m in length.<br><br>Presence of calcareous materials in the reservoir and their reaction (solubility) to inundation needs to be considered.<br><br>There is significant potential for hydro-power at this site.<br><br>The comparative cost of this dam is 29 cost units per GL of equivalent yield improvement. | Results in the inundation of 2,800 ha of land.<br><br>Impacts on 146 ha of vegetation.<br><br>There are numerous Non-Indigenous heritage sites in this inundation area.<br><br>There are some protected fauna at this site.<br><br>Whilst acknowledged as valuable in the Local Environment Plan, as with a number of other sites, the Cliefden Caves are not protected under a State or Federal register or legislation.<br><br>Similarly, Fossil Hill, potentially home to Late Ordovician fossil records, is not protected. |

| Option | Hydrology | Engineering | Environmental |
|---|---|---|---|
| Raise Wyangala Dam | This site provides the potential for an improved yield of 22.9 GL/year.<br><br>The site and hydrology provides for a storage potential of up to an additional 780 GL bringing the total storage of Wyangala Dam to 2,000 GL. | Raise the existing dam by 20m taking the dam to a height of 105m and 1,600m in length. The raise would be achieved by putting in place a downstream buttress.<br><br>Raising this existing storage would be expected to trigger dam safety related changes to the existing structure.<br><br>There is limited potential for hydro-power. The comparative cost of this dam is 29 cost units per GL of equivalent yield improvement. | Results in the inundation of an additional 2,800 ha of land.<br><br>Impacts on 35 ha of national parks and 600 ha of vegetation.<br><br>There are numerous Indigenous heritage sites in this inundation area.<br><br>There are some protected flora and fauna at this site. |

## 6.2 Stakeholder Views

During the consultation process, preliminary views on the short-listed options were shared with key stakeholder groups including Centroc and the Lachlan Customer Services Committee. Consultation with these stakeholders provided the following views on the short-listed options (Table 13).

> *"Conservation groups are appalled by the Needles Gap Dam proposal because of the damage it will do to the beautiful Belubula River, the Cliefden Caves and prime farmland," Nature Conservation Council campaign manager Daisy Barham, Central Western Daily, 21 November 2014*

**Table 13: Stakeholder Views on Short-List**

| Option | What we Heard |
|---|---|
| All options | In general, key stakeholders considered the shortlisted options to be broadly reasonable and there is support for investing in dams for improving water security for all types of economic development in the region. Stakeholders tended to note that the identified list predominantly contained sites that had been subject to investigation in the past.<br><br>Key stakeholders also tended to note that no single option provides a resolution to all potential needs for water supply security in the valley. In particular, it was noted that there are towns, such as Boorowa, that is currently facing severe water supply shortage that would not benefit from any of these potential sites.<br><br>Whilst acknowledging a view that, in general, there is broad, qualified, support for more storage in the Lachlan Valley, the Centroc representatives found it difficult to take a view on how differently the short-listed options would be received by the public. In the absence of specific public discussion of the shortlisted options, it was difficult for representatives to determine if any one site was more acceptable to the community than another.<br><br>Some environmental groups and recreational users of the cave system support a 'no new dams' policy position. They are concerned dams degrade the river system and the Lachlan catchment already has a large number of water storages and will lose more productive land.<br><br>Elected representatives of Lake Cargelligo are not opposed to new storages but wish to see the environmental water needs of Lake Cargelligo reconsidered in water sharing processes and advocate for water security equity along the full length of the Lachlan River. |
| Wyangala catchment options | Some stakeholders expressed concerns about the hydrologic performance of the Wyangala catchment, suggesting that modifications in land use practices over time have resulted in less run-off from this catchment now when compared to the past. Other stakeholders noted this catchment is greater than the Belubula which was seen as an advantage. |

| Option | What we Heard |
|---|---|
| Belubula River options | Stakeholders noted that the Belubula River options have the potentially additional benefit of providing water for extractive needs within the Belubula and allowing Carcoar dam to be utilised for other security improvement needs which may include towns, industry and mining.<br><br>Some stakeholders noted these options would provide flood mitigation potential for the Belubula valley downstream of the dam including Canowindra.<br><br>Some stakeholders were concerned that new dams on the Belubula would impact on the recovering Murray cod populations in the river and prevent fish passage and breeding. Some stakeholders were also concerned about the environmental impact of the changed hydrology of the river once it is regulated and the potential for contamination of the source from mining. |
| Cranky Rock | Some stakeholders prefer this site as it offers storage on the Belubula River without impacting on the Cliefden Caves. This site also has a greater catchment than The Needles and some stakeholders view this as preferable. |
| The Needles Dam | Environmental groups such as those represented by the Central West Environment Group and the Nature Conservation Council and recreational users of the Cliefden Caves, such as the Orange Speleological Society, oppose the The Needles dam site option. They are concerned about the loss of the caves, fossils, a thermal spring, cave and riverine habitat and Aboriginal and Non-Indigenous heritage associate with the site. There is also concern that the storage will leak as a result of the geology and be ineffective as a result.<br><br>There is general interest in the key stakeholder groups in being able to avoid the loss of the caves if a better alternative exists.<br><br>Some stakeholders noted the existence of minerals and mining exploration licences in the region and questioned how these would interact with a dam at this site. |

## 6.3 Applying the Desirable Criteria

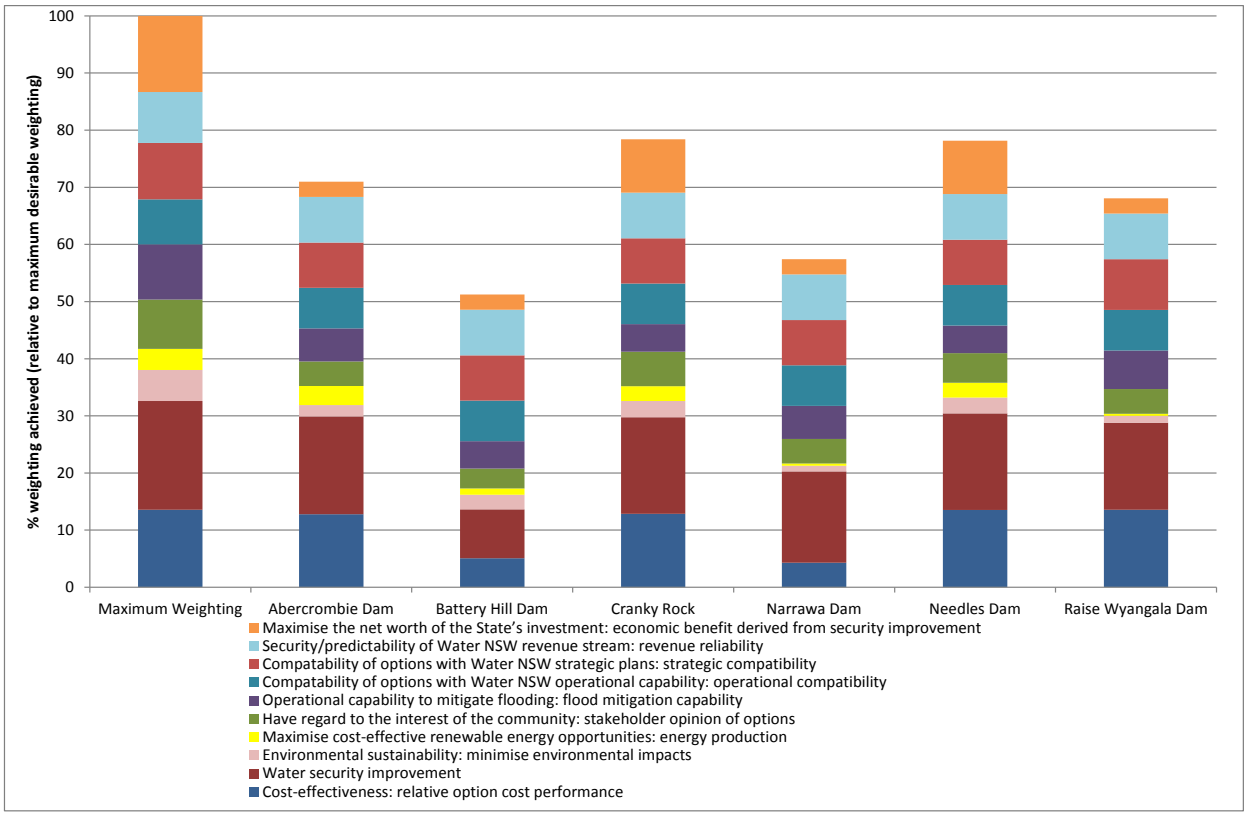
To assess the short-list of options, the desirable criteria defined in Section 4.2 have been applied to the short-list of options. The details of this assessment are set out in Appendix C and F.

The criteria were weighted by the project team. Some stakeholder input was also provided on appropriate weightings. The criteria weightings were examined to see if different weightings produced different rankings of storage options (sensitivity tested), but the results were largely insensitive to different weightings.

Multi-criteria assessments such as this are only appropriate to help understand the relative performance of options and the trade-offs between criteria to assist decision-makers.

The relative performance of shortlisted storage options is set out in Figure 8.

**Figure 8: Assessment of the Short-listed Options against the Desirable Criteria**




The assessment highlights the following:

- Four of the storage options (Cranky Rock, Abercrombie, The Needles and Wyangala raise) perform similarly in relation to cost-effectiveness and potential water security improvement.
- If it is assumed that there is greater economic benefit from increased security to towns, then the options in the Belubula (Cranky Rock and The Needles) are preferable.
- As avoiding the potential impact on the known extent of Cliefden Caves is potentially achieved by the Cranky Rock option, but not The Needles, this option could be considered slightly better.
- The Belubula options, combined with the existing Carcoar dam, have the potential to allow for improved water security to the towns of the Central Tablelands.

Conclusions include:

- Battery Hill Dam and Narrawa Dam can be excluded from further consideration as there are better performing storage options.
- There is potential for storage to improve water security in the Belubula River. The Cranky Rock dam sites may be marginally preferred to The Needles site in that it has the potential to avoid the impact on the known extent of Cliefden Caves, but it is likely to be more expensive.
- There is potential for storage to improve water security in the Wyangala catchments. The Abercrombie dam site may be marginally preferred to raising Wyangala as this site is a more efficient dam location from an evaporation perspective.

# 7. Preferred Options

This section documents the preferred storage options for consideration in relation to any further feasibility investigations post this scoping study.

## 7.1 Preferred Options

Based on the assessment in Section 6, the preferred options identified through this scoping study are, in order:

- Cranky Rock dam site;
- Abercrombie dam site;
- The Needles dam site; and
- Raising of Wyangala Dam

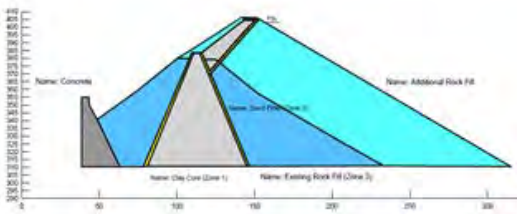
Additional feasibility investigation work is required to progress planning. This effort is detailed further in Section 7.3.

## 7.2 Option Descriptions

A description of the preferred options is set out in Table 14.

**Table 14: Description of the Preferred Options**

| Option | Description | |
|---|---|---|
| Cranky Rock Dam |  |  |
| | A new concrete-faced rockfill dam of potentially 87m in height and 657m in length and up to 700 GL in storage potential. | |

| Option | Description | |
|---|---|---|
| Abercrombie Dam |  |  |
| | A new concrete-faced rockfill dam of potentially 101m in height and 613m in length and up to 700 GL in storage potential. | |
| The Needles Dam |  |  |
| | A new concrete-faced rockfill dam of potentially 102m in height and 480m in length and 700 GL in storage potential. | |
| Raise Wyangala Dam |  |  |
| | Raise the existing dam by 12m taking the dam to a potential height of 105m and 1,600m in length and an additional 780 GL in storage potential. | |

## 7.3 Implementation Considerations

Implementation considerations for the preferred options are considered in Table 15. These have been considered in the development of the outline project plan in Section 7.4.

**Table 15: Implementation Considerations**

| Issue | Description | Potential Mitigation |
|---|---|---|
| Engineering | The Needles, and to a lesser extent, Cranky Rock dam sites, are located in karst landscape which includes limestone caves. There are also shales in the geology of the area. These features mean the desktop assessment of foundation efforts and costs are highly uncertain.<br><br>Raising the existing Wyangala Dam by buttressing of the existing embankment could overstress the existing concrete arch dam, therefore detailed structural analysis is required to investigate if the raising is feasible.<br><br>The presence of faulting near the Abercrombie dam site introduces the potential for seismic ground displacement, strong shaking or leakage. Abercrombie Cave is located North of the site and extent of calcareous (solubility) material would need to be mapped. | Preliminary in-situ investigations are required to understand the potential risks associated with the engineering issues. |
| Storage integrity | The Needles, and to a lesser extent, Cranky Rock dam sites, are located in karst landscape which includes limestone caves. Whilst often achievable, these types of landforms represent a risk of having a storage that loses water from the impoundment into the surrounding area. | |
| Environmental, recreational and scientific value | Whilst acknowledged as valuable in the Local Environment Plan, the Cliefden Caves are not protected under State or Federal registers or legislation. However, there is some uncertainty around the environmental, recreational and scientific value of the Cliefden Caves as their existence has not been well known and their features and habitats may not have been completely documented. This is also true of the value of Fossil Hill. | Preliminary fauna studies may be required to document the habitat significance of the caves, particularly in relation to bats.<br><br>Preliminary karst feature assessment may be required to document the significance of this landform.<br><br>Preliminary assessments of the value of fossil finds at Fossil Hill may be required to document the significance of these relics. |
| Public support | Whilst key stakeholders have been engaged, public consultation has not been undertaken as part of this scoping study. Whilst most of the key stakeholders are clear water security is an issue limiting the economic development of the region, it is difficult to ascertain the width of public support for investment in new storage infrastructure. | A program of opportunities for public participation during the remaining planning processes is required. |

| Issue | Description | Potential Mitigation |
|---|---|---|
| | The sites identified also potentially impact on Aboriginal heritage. Stakeholders noted the need for engagement with these stakeholders to determine the impacts and mitigation strategies. Similarly, engagement with these stakeholders is important for establishing any opportunities for this disadvantaged sector of the community to directly benefit from any dam construction and or operation activities. | |
| Economic benefit | Whilst preliminary consideration of economic benefit was undertaken in this scoping study, it is not a detailed and complete cost-benefit analysis. Stakeholders, especially those likely to be customers bearing the costs of the investment, such as general security irrigators, are keen to ensure any proposed dam investment is subject to a transparent cost-benefit assessment, including differences associated with different sized storages, as there is a concern small storages will make a limited economic contribution for a large cost.<br><br>There are also potential benefits additional to water security associated with raising Wyangala dam as this dam is currently subject to dam safety upgrade requirements. It may be more economically efficient to align investments to solve multiple issues. To better understand this potential benefit, the raising of Wyangala dam should be considered as a comparison case in any subsequent cost-benefit analysis. | A cost-benefit assessment is required. |
| Potentially impacted landholder consultation | Potentially impacted landholders will want to be kept informed of the progress of detailed investigations. Consultations are most likely best to be one-to-one and concerns will include understanding project timelines and when a certain decision will be made, understanding resumption and compensation processes and understanding operational regimes between any dam operator and the on-going economic use of these properties. | Individual consultations to inform potentially impacted landholders of the planning process, timelines and opportunities for engagement is required. |

As Table 15 identified, the risks associated with each of these four preferred options vary considerably and cannot all be quantified through desktop analysis of the sites. Key risks for consideration include:

- The potential foundation and storage integrity issues associated with the geology of the Belubula River options, in particular, The Needles. To better understand this risk, in-situ investigations would be required for the two Belubula River options.

- Certainty around the environmental, recreational and scientific values of the sites, in particular, the Cliefden Caves. To better understand this risk, environmental assessments would be required, in conjunction with the in-situ investigations.

As a result of these risks, it is prudent to continue to consider Abercrombie dam as this would be the next best performing option if the risks above materialise.

As the analysis of the short-listed options also highlights that the four preferred options perform similarly on many technical aspects, it is appropriate to consider broader public consultation as part of the next stages of the project to better understand community values and support.

## 7.4 Outline Project Delivery Plan

Table 16 sets out a high level plan for the subsequent stages of project development required in order to progress planning, taking account of the implementation considerations identified in Table 15. The timelines set out in the outline plan are indicative only and will depend on the selected option/s and any associated complexities. In addition, timeframes are dependent on procurement strategies, delivery and ownership vehicles, all of which are yet to be determined. The timeframes will be refined at each phase to provide more confidence around subsequent phases.

**Table 16: Outline Project Delivery Plan**

| Phase | Description | Outcome | Indicative Timeline |
|---|---|---|---|
| Phase 1 – Service delivery options | Desktop scoping study identifying preferred sites based on economic, social and environmental benefits and impacts. | Identification of four sites and recommendations for detailed investigation. | Completed December 2014 |

| Phase | Description | Outcome | Indicative Timeline |
|---|---|---|---|
| Phase 2 – Justification of proposed option | Parallel investigations including:<br>• In-situ investigations and feasibility study in the vicinity of Cranky Rock<br>• Finalising the siting and alignment of the dam<br>• Hydrologic modelling and planning optimisation of operations<br>• Finalising optimum size of storage on the basis of further hydrological and economic analysis<br>• Preliminary design concepts for the purposes of a high level budget (preliminary estimate)<br>• Engineering assessments to investigate feasibility of raising Wyangala Dam with consideration of the existing original arch dam<br>• Cost benefit assessment including willingness and capability to pay considerations<br>• Parallel consideration of demand-side options in addition to storage<br>• Initial public consultation on the broad investment proposal<br>• On-going landholder consultations<br>• Customer engagement, funding sources and delivery model preliminaries | Assessment of feasibility, including a preliminary budget estimate for investment, assuming a cost-benefit ratio greater than 1 | January 2015 to March 2016 |
| Phase 3 – Project definition | Project definition business case:<br>• Appoint governance team and establish roles, scope, brief and risk analysis<br>• Concept design<br>• Funding sources identified | Project team, project delivery plan governance established.<br>Concept design completed. | March 2016 to August 2017 |
| Phase 4 – Procurement strategy and detailed business case | Project planning activities including:<br>• Initiation of planning and statutory approvals<br>• Land resumption matters<br>• Procurement strategy for delivery which may include design and delivery models or design may be separate<br>• Business case for detailed design and construction<br>• Treasury Gateway Review (Gate 2) for detailed business case | Procurement strategy in place. Pre-tender estimate and an approved budget for 'design then construction' or 'design and construction'.<br>At this point, a capital project for asset creation exists | August 2017 to June 2018 |

| Phase | Description | Outcome | Indicative Timeline |
|---|---|---|---|
| Phase 5 – Detailed design | Parallel project development activities including:<br>• Specification and contract documentation for detailed design<br>• Detailed design<br>• Environmental impact assessment<br>• Planning and statutory approvals<br>• Specification and contract documentation for construction<br>• Early Tenderer Involvement<br>• Treasury Gateway Review (Gate 3) for Pre-construction tender Operational planning matters including dam safety emergency planning documentation<br>• Long term pricing structuring discussions with clients and ACCC<br>• Tendering for Construction (or as per alternate strategy) | Detailed design established. Post-design estimate (pre-tender for construction estimate) and an approved budget for construction.<br>Planning approvals in place.<br>Contract for construction ready to award. | August 2017 to January 2021 |
| Phase 6 – Construction | Construction including environmental management and consultation | Asset creation | January 2021 to June 2024 |
| Phase 7 – Commissioning and handover | Operation activities including:<br>• First fill<br>• Handover of Asset from Project team to Asset Management & Operations teams | Asset operation | June 2024 onwards |
| Phase 8 - Operation | Operations | | |

The potential scope and costs associated with Phase 2 activities is set out in Table 17. These costs are indicative only and will need to be market tested.

**Table 17: Phase 2 Investment Requirements**

| Investigation | Amount $'000 (ex GST) |
|---|---|
| *Stakeholder Engagement* | |
| Initial public consultation on the broad investment proposal | $200 |
| On-going landholder consultations | $150 |

| Investigation | Amount $'000 (ex GST) |
|---|---|
| Agency engagement and approvals path planning | $250 |
| Customer engagement, funding sources and delivery model preliminaries | $150 |
| *Engineering Feasibility Assessment* | |
| In-situ investigations and feasibility study in the vicinity of Cranky Rock | $2,000 |
| Structural assessment to investigate feasibility of raising Wyangala Dam and impacts on the existing arch dam | $300 |
| Engineering and feasibility design for the purposes of a high level budget (preliminary estimate) | $1,000 |
| *Hydrologic modelling and planning optimisation of operations and optimisation of storage size* | $300 |
| *Cost-benefit analysis* | |
| Parallel consideration of demand-side options in addition to storage (Water NSW related options only. Town demand, irrigation on farm demand and other options to be investigated by other stakeholders) | $150 |
| Cost benefit assessment including willingness and capability to pay considerations | $250 |
| **TOTAL** | **$4,750** |

**Box 7: Potentially Impacted Landholders**

The key concerns of the potentially impacted landholders consulted during this study were:

- Having certainty, in a timely manner, about whether their property is impacted: landholders are always making investment decisions that might change if the land is to be resumed. Similarly, any sale of land is difficult during the planning phases when a site is not yet chosen.
- Clarity of the resumption process and timing: how will resumption processes work? When will they occur? How long they take? Will the farmland left be economic?
- Fairness in resumption dealings: the land has economic value and personal value to the landholders and they expect to be fairly compensated for the loss.
- Operational interfacing with a storage and the existing uses of their properties: How

the storage inundation area be operated? Will there be recreational use? How will we access all of our property and our water? How will our stock access water?

- Ongoing consultation and advice on progress prior to media releases is important.

As noted in Table 16, identification of a final site is still several years away and resumption processes are unlikely to commence before the end of 2016.

The *Land Acquisition (Just Terms Compensation) Act* 1991 provides the mechanism for acquiring land and can be accessed through www.austlii.edu.au


# 8. Recommendations

This section sets out the recommendations of this scoping study.

## 8.1 Recommendation

The following recommendations are made in relation to next phases of planning:

- Progress with in-field investigations in the vicinity of Cranky Rock. Investigations should focus on establishing the potential foundation and storage integrity risks.
- Undertake a cost-benefit analysis to determine the economic value of the investment in water security improvement in the region.

**Box 8: Funding New Infrastructure**

Whilst technically feasible, availability of funds can limit investment, even in those projects that have a demonstrably positive cost-benefit ratio. Funding sources, including potential private sector arrangements and identification of a paying customer base, will need to be examined as part of the next phases of planning.

The Agricultural Competitiveness White Paper (Commonwealth, 2014) identified the Federal government's positions:

- The Federal Government view water as predominantly a State issue, but will consider co-funding projects that are nationally significant and in the national interest.
- The Federal government also advocates for strong capital contribution and involvement from the private sector and Local Government where appropriate.

## 8.2 Next Steps

The next steps for planning are:

- Implement Phase 2 as set out in Table 17, which includes in-situ investigations, in field environmental assessments and cost-benefit assessment.
- As requested by stakeholders, make this study available to the public.

**Box 9: A Project Reference Group?**

Stakeholders have requested ongoing consultation and involvement in decision-making throughout any further investigations or planning processes for a dam. Many of the stakeholders suggested that a steering committee or project reference group was required:

- Belubula Landholders Association requested involvement in any options on the Belubula River.
- Centroc requested involvement in a steering committee (whether the recommendations of this report include town water storage or not) as the organisation brings significant expertise and value to water management including:
    - Skilled at working with and communicating to our communities
    - Understanding of water and regional development needs
    - Experienced in town water management
    - Understanding the bigger picture and are strong strategic planners
- Lachlan Valley Water requested involvement in any ongoing project planning group or committee.
- Orange Speleological Society requested involvement in any ongoing consultation processes.

Water NSW, as part of project management activities, often puts in place community reference groups for the delivery of infrastructure.

# 9. References

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- 20 June 2014 – Preliminary Concept Estimate for New Belubula River Dam – Potential 90,000 ML storages at Cranky Dam Sites
- 19 June 2014 – Preliminary Concept Estimate for New Belubula River Dam
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# Appendix A: Stakeholder Consultation Outcomes

This appendix details the outcomes of consultation with key stakeholders for this study.

## Approach

As illustrated below, against the International Association for Public Participation spectrum of engagement, 'Consult' was selected as the appropriate level of engagement for the purposes of this project. The goal and promise of consult level engagement was shared with the stakeholders engaged.

| Inform | Consult | Involve | Collaborate | Empower |
|---|---|---|---|---|
| **Goal of engaging the stakeholder** | | | | |
| To provide the stakeholder with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions. | To obtain stakeholder feedback on analysis, alternatives and/or decisions. | To work directly with the stakeholder to ensure that stakeholder issues and concerns are consistently understood and considered. | To partner with the stakeholder in each aspect of the decision including the development of alternatives and the identification of the preferred solution | To place final decision-making in the hands of the stakeholder |
| **Promise to the stakeholder** | | | | |
| We will keep you informed. | We will keep you informed, listen to and acknowledge concerns and provide feedback on how stakeholder input influenced the decision. | We will work with you to ensure that your concerns and issues are directly reflected in the alternative developed and provide feedback on how stakeholder input influenced the decision. | We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible. | We will implement what you decide. |

## Key Stakeholders

The key stakeholders engaged as part of this study, and the consultation activities undertaken, are set out in the following table.

| Key Stakeholder | Consultation |
|---|---|

| Key Stakeholder | Consultation |
|---|---|
| Belubula Landholders Association | 29 October 2014: joint briefing meeting with the Belubula Landholders Association in Canowindra to introduce the project scope, options and evaluation criteria.<br><br>20 November 2014: presented preliminary findings to Lachlan Customer Service Committee which includes representatives of Belubula Landholders Association and Lachlan Valley Water.<br><br>25 November 2014: combined meeting with Centroc to discuss shared views on water security issues and potential solutions. |
| Lachlan Valley Water | |
| Central NSW Councils (Centroc) | 6 November 2014: briefing meeting with the elected representatives and staff of the member councils at Forbes to introduce the project scope, options and evaluation criteria.<br><br>24 November 2014: briefing meeting with and staff of the member councils at Forbes to present shortlisted options and consider Centroc views on the relative weightings of desirable criteria.<br><br>25 November 2014: combined meeting with Belubula Landholders Association and Lachlan Valley Water to discuss shared views on water security issues and potential solutions. |
| Government agencies:<br>• Bureau of Meteorology<br>• Central Tablelands Local Land Service<br>• Central West Local Land Service<br>• Commonwealth Environmental Water Holder<br>• Department of Planning<br>• Department of Primary Industries<br>• Department of Trade and Investment<br>• Murray Darling Basin Authority<br>• Office of Environment and Heritage<br>• Regional Development Authority Central West<br>• State Emergency Services | October 2014: letter advising of the scoping study and seeking agency advice on their involvement in subsequent planning efforts and matters for consideration. Subsequent emails and telephone conversations with agencies as required. |
| Lachlan Riverine Working Group | 2 December 2014: teleconference to brief members on the study scope, options, evaluation criteria and potential solutions. |
| Lake Cargelligo community | 20 November 2014: meeting with the elected representatives of Lake Cargelligo in Condobolin to introduce the project scope, options and evaluation criteria. |

| Key Stakeholder | Consultation |
|---|---|
| Potentially impacted landholders near The Needles | 29 October to 4 November: individual meetings on the various farms or other locations of their choice with potentially impacted landholders.<br><br>19 November: phone calls with other self-identified potentially impacted landholders associated with Cranky Rock and The Needles. |
| Speleological interests (Orange Speleological Society, Australian Speleological Federation) | 4 November 2014: meeting with representatives of the society and federation in Orange to introduce the project scope, options and evaluation criteria. |
| Water NSW Lachlan Customer Service Committee | 20 November 2014: briefing at standing meeting in Condobolin to introduce the project scope, options, evaluation criteria and preliminary findings. |
| Wiradjuri land council region (Cowra) | October 2014: letter advising of the scoping study and seeking advice on their involvement in downstream planning efforts and matters for consideration. |

### Consultation Outcomes

The issues raised through stakeholder consultation process have been considered closely by Water NSW in undertaking this assessment and in making recommendations. The following table provides a response as to how these issues raised have been considered in the assessment to date.

The views represented are divergent in a number of respects and this was considered by the project team.

Also, it is acknowledged that the views are those of key stakeholders and this may not be representative of the community at large.

A number of issues raised related to matters not directly relevant to the scoping study, or that will be addressed at a later phase of project development. These have been considered and, where appropriate, included in the identification of the subsequent phases of the project.

## Considering Stakeholder Feedback

| Topic | What we heard | Considered in Assessment |
|---|---|---|
| Alternative approaches | • Need more demand management and recycling<br>• Has there been talk of transfers in system, such as from Oberon following the slow down at Delta Electricity?<br>• Irrigators use groundwater as an alternative source but it is an expensive source and harder to user for flood irrigation<br>• Could we establish a 'medium security' licence type? Perhaps people would buy shares in the dam?<br>• Bores are going in at a very fast rate. Brown's Creek aquifer seems to have been impacted by the mine. The issues of groundwater need looking at as well as dams<br>• Lake Rowlands is a good option, saves on building new infrastructure<br>• What about water in the other catchments, what about helping out with water in Lithgow instead?<br>• What about using the Lithgow mine water instead?<br>• In QLD, piping of channels is providing savings in water of up to 80%. This is a better cost benefit<br>• Have re-regulation sites down the system been considered in terms of their ability to improve security? This should be considered in the cost-benefit analysis<br>• Are other water savings and efficiency measures being considered? Including operational efficiency options such as those being considered under the Basin Plan?<br>• Is the do nothing option being considered? | • Study scope limited to storage options however, alternatives for improving water supply security, including demand management, were documented as these can be investigated in parallel with phase 2 activities. |

| Topic | What we heard | Considered in Assessment |
|---|---|---|
| Cost effectiveness of option | • New storage is not a cost-effective solution to water security<br>• Cost-effectiveness and cost-benefit, including ensuring the storage is of an appropriate scale to deliver benefit, are important to general security irrigation customers | • Levelised comparative whole of life cost assessment was undertaken as part of study<br>• Desktop consideration of economic benefit was undertaken, but detailed cost benefit analysis is recommended as part of subsequent phases. |
| Efficient use of water | • Options to reduce demand and recycle water should be considered<br>• Water efficiency, demand management and recycling are cheaper and less environmentally harmful than dams<br>• The potential for water efficiency works as opposed to building a new dam<br>• Implementation of CARM and improved efficiency of operation of Mid-Lachlan creeks, by automating privately owned structures<br>• Transmission losses – can the river be run with less loss? Should we be investing in using piping to improve water security?<br>• Is there a potential for more efficient agriculture – are we optimising what we already have before we invest in more storage? Are there incentives for on farm efficiency?<br>• Transmission losses in the Belubula River need to be considered<br>• Transmission losses downstream of Canowindra are high<br>• We are locking up water for our needs when we need to be more efficient with water. People need to manage with less water. If there were no dams, we would still live and we would survive | • Study scope limited to storage options however, alternatives for improving water supply security, including demand management, were documented as these can be investigated in parallel with the phase 2 activities. |

| Topic | What we heard | Considered in Assessment |
|---|---|---|
| Evaluation considerations | • What weighting are given to the criteria?<br>• The flood mitigation benefit of the dam should be considered<br>• Consider inundation of prime land<br>• Consider the opportunity for hydro-electricity, as there is a quite significant fall from the Needles site downstream if that is what is needed<br>• Is the limestone an issue?<br>• No public roads on the site<br>• Environmentalists, no one sees the caves<br>• Topography: there is a basalt lava flow cap from Mount Canobalas on the edge of the Needles. This makes for high value agricultural land and is also a source of blue metal for a dam<br>• Cranky Rock would flood a lot of good farmland<br>• Will Wyangala option really fill? It seems odd to have looked at sites upstream of Wyangala<br>• Is hydro-electricity a consideration?<br>• Junction Reefs site, a gorge near the small dam. Would have 50GL and be a good hydro-electricity site as there was an old hydro scheme up there and there is a high voltage power line up there put in by the mine<br>• Who would own Carcoar?<br>• There is concern about the potential for land slippage in the Cadia Valley and the potential of the tailings dam to fail<br>• The small Junction Reeds dam had issues with heavy metals in the water associated with mining. There is a contamination risk | • These issues were considered in assessing the potential dam sites at both short-listing and in recommending preferred options<br>• Many of these aspects were part of the defined mandatory and desirable evaluation criteria utilised in the assessment<br>• Pairwise comparison of the objectives was utilised by the project team to establish weightings and this was also explored with some key stakeholders |

| Topic | What we heard | Considered in Assessment |
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| | • Hydro electricity - will be difficult to get a significant benefit<br>• Perspective on lead times changes depending on whether we are in drought or not | |
| Flood mitigation | • Needles dam would provide flood mitigation for the Belubula valley downstream including Canowindra | • Flood mitigation was considered in the desirable criteria for option selection. |
| Funding and ability to pay | • Are you considering private sector funding?<br>• Is there another body of work, for those who are going to invest, on cost benefit analysis?<br>• Irrigators will feel the cost impact of any dam as general security licences pay for water whether it is available or not and want to see a cost-benefit analysis<br>• Is the dam to be a user pays system? | • Funding and ability to pay will be considered in Phases 2 and onwards in the next stages of this project. |
| Impact on environmental assets | • Dams cause environmental problems such as degrading the river system<br>• Caves contain 32 species of fossil corals and scientifically significant fossils such as trilobites, brachiopods, bryozoa, echinoderms and graphtolites<br>• Needles will wipe out recovering Murray cod populations in the Belubula River. The dam will stop fish from moving up and down the river to breed<br>• River will degrade and the flows will have to be adjusted to suit the fish<br>• Sites between Carcoar and Canowindra would impact on the Cliefdon Caves inundating thermal spring, most of the fossil sites, and large areas of the rich alluvial agricultural flats. The caves are caused by the Thermal Spring, not connection to the River<br>• First limestone caves discovered in NSW, over 100 of them, will be lost, as will internationally significant fossil sites. Pristine state of the caves, decorations that rival Jenolan, recently listed on the National Trust. Caves have not been properly | • The environmental values of each of the sites were considered in the assessment of the short-listed options.<br>• These issues would also be considered in any future environmental assessment process. |

| Topic | What we heard | Considered in Assessment |
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| | documented and studied. Water will bring silt which will erode the features.<br>• Will the water travel through the caves and along the limestone belt/fault system - where will it go? Concerned about impact on caves<br>• Region is generally supportive of a new dam, but it would also be preferable to protect the caves<br>• Cliefden Caves and the Fossil Hill are world famous and visited by geologists from China and Canada<br>• Caves are in the poor agricultural country. There are only about 40-50 cavers a year who use the site. The caving society in Orange manages access.<br>• If it did not take out the caves and fossil hill could be protected, that would be a good outcome. 'Bat ladies' (scientific study) have been coming to the site lately<br>• There are two platypus colonies near the Needle site. What happens to the platypus in the river, do they move?<br>• Does the channel get scoured out all the time by the dam?<br>• There are many caves in the area including Wellington, Jenolan, Abercrombie, Boorowa and each is special. These caves are particularly so because of the caves themselves and Fossil Hill<br>• There are grass box woodlands that will be lost, including red gums that it would be sad to see lost<br>• Concerned about leakage from the tailings dam at Cadia<br>• There are native fish including red fin and yellow fin in the Belubula River<br>• How does this fit in with the MDB plan? Are we are taking water from the environment?<br>• The aesthetic and scientific values of the caves would be lost | |

| Topic | What we heard | Considered in Assessment |
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| | • Threatened species database may not record the bats in the caves as the studies to confirm the extent of their range have not been completed<br>• OSS documents all the karst features (caves are part of karst landscapes). There are 60 caves in the area and 121 features (including the caves). The caves range from 10m-3km (features are smaller caves that do not have a dark zone). The entrance to the cave can be in the hill, but they then mainly go down to the river level. There was some mapping done in the 1960s and 70s, but they were plans not vertical reliefs. We are now mapping both. NPWS 2012 did an assessment in NSW of all the 'off park' karst areas and it viewed Cliefden as the most significant. The International Union of Speleology will have its annual conference for a week in Sydney at Panthers in 2015 and they want to see the fossils. The scientific value of the area is beyond the value of the water<br>• Lake Cargelligo is the most important environmental wetland in the whole of the Lachlan Valley. It has migratory birds and waterfowl and it is a bird refuge. The lake is not just for recreational use. There have been fish kills in the lakes from the cold emergency releases from Wyangala<br>• Environmental impacts in terms of how the assets are operated and the impact on environmental assets needs to be considered. Have you assumed translucency?<br>• There is a 7 GL limit for the Belubula so there would be a need to reconsider both the Belubula and Lachlan water sharing plans. The environmental water from the Belubula is in the un-regulated water and this will need to be considered<br>• What guidance framework being used to shape the study? Are ANCOLD guidelines being used, especially around fishways and cold water pollution? | |
| Impact on landholders<br>(these comments were | • Our concern is it would inundate all our river frontage when it is full, which we know is once every 20 years. How would our pump work – it would be in the | • Land acquisition processes will form part of later phases of the project after |

| Topic | What we heard | Considered in Assessment |
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| hand recorded in interviews with potentially impacted landholders and should not be attributed to any given landholder) | reservoir when full, would need to go on a pontoon?<br>• Our allocation will still be in Carcoar, so we need our water supply to be maintained. How do we get access to our water?<br>• Management of our property is a concern, we would lose land, how would we manage our stock. Cattle bog up water lines.<br>• Will this be a recreation area? Who will manage weeds and fire risks?<br>• We would lose a lot of river flats which is the good production land<br>• What is the lead time? Selling or buying land at the moment is difficult as we are under a cloud of uncertainty. How long for the land acquisition, timing and process?<br>• There is an equity issue in that we have to pay the consequence of storage when it is downstream users who benefit. It would be fairer if we could also harvest more water locally as we are currently limited to 10%.<br>• The storage would take out our access road<br>• The financial impact is of concern to us. Succession planning for the farm. It is not our intention to sell. Of our 5,000 acres, 3,000 would be affected. Loss of history, geology and beautiful river<br>• Does the government have a power to acquire?<br>• Is it going to happen? What is the timeframe?<br>• Do not try to take it from us without compensation, fair compensation. It is our home and we do not want to go<br>• How big the dam is changes how much land will we lose?<br>• Where will the wall be built? Will people be coming past our home every day? We like our privacy, it is why we live here | a site has been selected. |

| Topic | What we heard | Considered in Assessment |
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| | • If there is a feasibility study, will people come in and out of our property?<br>• Will there be an exclusion zone? Would it be a public recreation dam?<br>• We invest in weed control – should we keep doing this?<br>• We need water security for our stock – how will stock access?<br>• We want to be fairly compensated.<br>• Fertilising is a 5 year investment. We are investing in fencing and weed control. Management and investment into the property now – do we just do short term things or continue to look long term (we've been thinking for the long term until now)?<br>• We own country on both sides of the river, most is on the other side of the river from our home and therefore, access is an issue for us. At the moment we access right through the bottom of where the dam would go. Will the wall be accessible? Access is steep which is not ideal for stock access to water, the land adjacent was bought to have good stock water access<br>• The dam essentially separates the land into two lots of smaller parcels of land that become uneconomic (decreases the economy of scale of the farm) except for our neighbours to buy<br>• Will there be speedboats on the water – we do not want to have a Wyangala recreation area. Is it possible to have legislation put in place to ensure the dam is not used for recreation? Are there any dams that have no access?<br>• How much land will you resume?<br>• How does our land integrate with the dam? Do our stock just go down to the water? Who would pay for pumps for our stock to access water? | |
| Impact on | • Cliefden Caves at Needles have Aboriginal cultural value and the site of the first | • The recreational and cultural values of |

| Topic | What we heard | Considered in Assessment |
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| recreational/cultural assets | Ordovician limestone discovery in NSW in 1815<br>• Area is listed on the Register of National Estate but is not protected under national or state environmental law<br>• Destruction of heritage-listed limestone caves<br>• Lake Cargelligo – the community is concerned about environmental flows into the lake and want allocations into the lake protected. Amenity of the lake has a value in the local economy of Lake Cargelligo. Eco-Tourism businesses would establish if they knew there was water going to be in the lake. Locals struggle with the idea of having water restrictions when they see irrigation water running down the river<br>• There is a social impact from poor water security. It impacts mental wellbeing when there is not enough water for people to visit the town<br>• Aboriginal access to heritage, habitats and other values as a result of development needs to be considered<br>• Need to contact Aboriginal interests in relation to next steps<br>• Need to consult on Indigenous linkage to fishing and the need to consult with recreational fishing associations/representatives as part of next stages | the sites were considered in the evaluation of the shortlisted options.<br>• These issues would also be considered in any future environmental assessment process. |
| Impact on river flows | • Impact on the hydrology of Belubula River<br>• Potential impact on Lake Cargelligo | • Options were considered consistent with current water sharing plans to ensure water for the environment. |
| Impact on water quality | • Proposed dam is downstream of Cadia Valley operation's tailings dam | • Water quality considerations will be assessed as part of any future environmental assessment process. |
| Job creation/economic | • Solving the water security issue of the region creates jobs and boosts confidence<br>• The project will increase employment, provide economic stimulus and increase | • Desktop consideration of economic benefit was undertaken, but detailed |

| Topic | What we heard | Considered in Assessment |
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| stimulus | water-based tourism and recreation in the Central West.<br>• Potential impact on Lake Cargelligo community and their economic viability if the Lake is negatively impacted<br>• Irrigation and three mining projects in the region need water<br>• Productive water has significant economic value<br>• This will create jobs. Building infrastructure helps the economy<br>• The dam is not a lot of money compared to the $1bn spent on Sydney hospital. The dam is a long term investment<br>• Water is essential. The Macquarie pipeline for Orange is not enough to support the population growth and need for water in the Orange area<br>• When you inundate productive land to build the dam to provide water for irrigation, how can there be an agricultural advantage of the water? Major agricultural cropping flats at Taplow will be lost. Is there a net benefit for primary production?<br>• Regis Gold pulled their planned mining project because the price of gold has fallen<br>• Important not to talk the Lachlan down and drive down confidence. Careful use of the word 'problem'<br>• There will be a need for Aboriginal access to employment from any development | cost benefit analysis is recommended as part of subsequent phases. |
| Likely performance of dam | • Needles is a large dam with a small catchment. Cranky Rock is a slightly smaller dam with a greater catchment<br>• Carcoar does not fill due to limited inflows. Carcoar has very little catchment<br>• Needles dam is an opportunity to provide water security for the whole of the Central West area<br>• Dam unlikely to perform due to close proximity to Carcoar Dam, Lake Rowlands | • Considered in the process of evaluating the long-list and the short-listed options. |

| Topic | What we heard | Considered in Assessment |
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| | and Flyers Creek dam<br>• Farming practices have changed, farmers are more efficient with water, but changes in farming practices have changed runoff, there is not less rainfall<br>• How well do each of the options secure carry over water for dry years?<br>• Does the modelling account for the changing farming practices above Wyangala Dam and the reducing performance of the catchment? Is it more susceptible to risk?<br>• The Needles site appears to tick most of the boxes: water security, flood mitigation, economic benefits not only for mining but irrigation and town water, most environmental, and in conjunction with Carcoar and Lake Rowlands locally, and later stages connected to a regional water supply network of pipelines i.e, Burrendong, Wyangala, and Chifley dams, where may it stop, if we had the cash.<br>• Will the dam fill?<br>• Pride of Oak (another name for Cranky Rock) catches Limestone Creek and Fire Creek, there are more streams<br>• Concern about the availability of water, why this river when it already has so many dams?<br>• Needles is a good spot. Steep country, good place to build a dam. If the site is technically feasible, Needles is a good site<br>• Cranky Rock looks like a saucer compared to Needles and you can see why Needles is of interest as it would need a relatively small wall and would be a deep dam<br>• You can only go as high as the Needles, not sure that more than 500GL can go in<br>• Volume of water on the Belubula is large and the river provides a lot of water | |

| Topic | What we heard | Considered in Assessment |
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| | • Cranky Rock is a bowl and the walls would not be high, there would be a lot of evaporation loss<br>• Catchment area of Wyangala is bigger, how can the Belubula river add this much water?<br>• Lower Cranky Rock site was preferred in 1960s with Conobadine Creek providing additional water. However, evaporation loss has to be considered<br>• You would need to go 25m at the Needles to get below the shales to a foundation<br>• Will the storages flood Cadia tailings dam?<br>• A 90GL storage is not enough for irrigation needs. We want to ensure there is a positive cost-benefit for any storage and we want to ensure the investment can meet our needs if we are expected to pay for it<br>• Can Carcoar support more than just the needs identified in the Centroc Water Security Study? | |
| Location of option | • Supportive of Needles location<br>• Alternative of Cranky Rock dam due to impacts of Needles on Cliefden Caves<br>• Suggestion of a storage in the Mandagery Creek area<br>• Many members of the local community have been involved in identifying potential options since 1980s. There is a strong degree of ownership of particular sites in the region.<br>• Raised Roaring Rock option as one discussed in the community<br>• Want to ensure that Cranky Rock is considered as a location, not just the Needles<br>• Towns are supportive of 'win-win' options with irrigation water needs, but towns only require small volumes of water compared to irrigation and town water is critical to provide service needs for the whole region (e.g. hospitals). No point | • Perspectives on locations were considered in the evaluation process |

| Topic | What we heard | Considered in Assessment |
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| | having town security without economic security.<br>• Carcoar was a poor, politically motivated, choice for a dam and is not achieving enough water security<br>• Cranky Rock looks preferable as it can meet town, irrigation and mining demands in the region whereas options in the South cannot<br>• Pretty keen to see a dam somewhere, but it has to be the right site<br>• Not concerned about the leakage from the dam. Happy for a dam to go in at the Needles<br>• Do not spend too much time on augmenting Carcoar, but to the extent it is examined, consider linking it to Lake Rowlands and using it to provide town water supply.<br>• Consider using two dams together, one for irrigation and one for town supplies eg. Carcoar for towns | |
| Ongoing consultation | • Belubula Landholders Association requested being involved in any future project committee<br>• Centroc requests being involved in any future steering committee (whether the recommendations include town water storage or not) as the organisation brings significant value to water management. Centroc would like the opportunity to positively influence the process by brining to the table expertise:<br>  o We are very good at working with and communicating to our communities<br>  o We understand water and regional development needs<br>  o We are experienced in town water management<br>  o We get the bigger picture and are strong strategic planners<br>• Centroc will provide further advice on how it would like to be represented as | • For Water NSW and the NSW Government to determine. |

| Topic | What we heard | Considered in Assessment |
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| | opportunities arise, but considerations would initially include<br>o o Involvement of key expertise from across the membership<br>o o Involvement of the individual council(s) where any proposed development would occur<br>o o Involvement of Central Tablelands Water<br>• Potentially impacted landholders request to be actively engaged on a one-to-one basis<br>• OSS request to be actively involved in any future consultation and engagement processes<br>• Suggest two levels of consultation going forward: informed stakeholders on a steering committee (generally, the approach used for Lake Brewster worked) and wider consultation and information for the general public (public meetings or feedback opportunities) | |
| Publication of the report and findings | • Stakeholders including Belubula Landholders Association, Centroc, Lachlan Valley Water, Orange Speleological Society, and some of the potentially impacted landholders requested publication<br>• These stakeholders would also prefer advice on recommendations prior to public announcement | • For the NSW Government to determine |
| Security of water entitlement | • Generally agree the security problem for towns is as per the Centroc Water Security study<br>• The new NOW modelling and guidelines, which have not been formally released, seem to show supplies are less secure than thought. Could be as much as 20% less secure<br>• Parkes and Forbes rely on groundwater as backup supply. A recent study done by | • Perspectives considered in formulating the definition of the water security problem |

| Topic | What we heard | Considered in Assessment |
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| | NOW on groundwater suggests that these resources might be more secure than first thought although there is still debate about this conclusion. There have also been changes to the water sharing plans that may result in a better balance with other extractors and a higher priority for town water supplies in the plan<br>• Has there been conversion of general security to high security licences?<br>• Continuous accounting in the Belubula River is not working as illustrated by the current lack of water in Carcoar when accounts have water in them.<br>• Continuous accounting does help irrigators (where it works) to manage water between years<br>• There is concern that the general security water in the Lachlan Valley in 2015/16 may not be deliverable<br>• To improve security for irrigation, reduce the sequences of years with zero allocation<br>• Irrigators know it is not about more water, it is about water security<br>• Minimising the number of zero allocation years<br>• Impacted by the Millennium drought. High security was cut back by 50% in 2009<br>• Cadia will still have to have their water too from Carcoar. The dam will also impact their pump at the Oaky Creek Site too<br>• Carcoar is only 30% full and will shortly be only stock and domestic. We have no run off dams. There is a need for water in the area<br>• Water security in Canowindra and down the Lachlan is an issue<br>• We do need more water storage on this side of the divide. Many of the people against the dam are from the other side of the divide (Sydney)<br>• What size will the dam be? Minister said 600 GL. River flows a lot, hell of a lot of | |

| Topic | What we heard | Considered in Assessment |
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| | water 90 GL does not sound big enough<br>• Who are you improving the water for? Orange? Kings Plain Mines cannot go ahead because they do not have water security<br>• The problem that needs solving is greater than 90 GL<br>• Hillston relies on the river water and it is the largest citrus growing are in NSW. It also grows cotton and potatoes<br>• How did we run out of water for Condobolin in the Millennium drought?<br>• Carcoar Dam and Lake Rowlands to be linked to provide 40,300 ML for town water if Needles built. No upgrade of Rowlands then needed<br>• Water security is a major concern facing many regional communities<br>• Lack of water security for consumptive users and feel that sourcing water from the Lachlan valley is limiting economic growth.<br>• Want town water security as well as irrigation security. Will consider Carcoar as an option for towns, but are concerned around licensing of water allocation from Carcoar, the volume of water, ownership of the water (can they on-sell it) and how will it be managed? There is also a view that State Water's Wyangala failed, as did the operations of water in the valley in the Millennium drought<br>• Towns only use 2% of the water in the valley<br>• Without water security, there is no food bowl and this is our livelihood. Our shire provides 38% of the oat crops of the state.<br>• For the Belubula River irrigators, removing years with a zero allocation improves security.<br>• Perhaps we should use the language 'increasing the reliability of productive water'<br>• The options will not solve all town water issues. These remaining issues, such as | |

| Topic | What we heard | Considered in Assessment |
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| | Boorowa are very real concerns from our perspective | |
| Water sharing | • Important to realise the historically, there has been some conflict between urban and non-urban water users in the valley.<br>• Licencing, MDB plan, should there be a push back on MDB plan? Is there scope in advice to government that can assist with advocacy on MDB plan? Can we change the size of the bucket, the SDL for the Lachlan valley? Suggest Water NSW include in the report "other learnings" which might include such commentary.<br>• Towns, irrigators and mining activities in the Lachlan Valley need improved water security and should work together on this issue<br>• There is a need to reconsider the translucent flow rules in the water sharing plans<br>• Concern that town water needs may be prioritised over irrigation water<br>• Need more working together: irrigators, towns and mines<br>• Cadia dries out the area. Cadia east has a lot of water intercepting their mine – where is the water coming from? How do they use this? Is it drying out other water sources?<br>• No new water licences would be available, is that correct?<br>• Towns water priority use of water, but they sell it to mines, but probably would not share it with irrigators<br>• The Macquarie River Water Sharing Plan says we cannot build new in stream dams without Ministerial approval. Is this the same in the Lachlan?<br>• Concern that Lachlan Valley water is going to provide for the towns, not all area in the Lachlan. Taking security out of our valley. Carcoar could be used to help keep the river moving rather than exporting the water from there to towns<br>• Frustrated that it is difficult to work out who to talk to in order to have the water | • Water sharing arrangements will be considered in Phases 2 and ongoing |

| Topic | What we heard | Considered in Assessment |
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| | for the environment recognised in the Lachlan Water Sharing Plan. We want the important natural environment of Lake Cargelligo recognised<br>• Security for all of the Lachlan Valley is important. Equity upstream and downstream. We were on level 7 restrictions when the top of the valley was only on level 2.<br>• Is supplying towns about extra water or water security? Will new towns that do not currently draw on the Lachlan, draw on the Lachlan<br>• Equity along the river is important. Intergenerational equity is also important<br>• We need to reconsider the water sharing rules for the Lachlan<br>• We currently struggle to use water fairly in the valley | |

Feedback from the various State and Federal Government agencies was also considered in undertaking this scoping study. This is set out in the table below.

**Considering Agency Feedback**

| Agency | Response | Considered in Assessment |
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| Bureau of Meteorology | • With respect to the hydrological investigation and assessment of dam yields and spillway design discharges, the Bureau does not have experience in this area and I do not see us being directly involved in these studies.<br>• The Bureau provides a flood warning service for the Belubula River to | • Flood warning matters can be addressed as part of the concept and detailed design processes in Phases 4 and 5.<br>• Preliminary consideration of flood mitigation |

| Agency | Response | Considered in Assessment |
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| | Canowindra when river levels are expected to exceed minor flood level. This can be extended to a high flow advisory/warning service during the construction phase of the dam. The Bureau can also develop a short term flow forecasting service for the dam after completion. Both of these services would be provided on a commercial and cost recovery basis respectively.<br>• The Bureau will need to adjust its flood forecasting model for the Belubula River to accommodate a new dam in the catchment. This will require us to receive details of the dam capacity versus height and spillway discharge rating table. The assessment process can also include an evaluation of any flood mitigation benefits from the proposed dam for Canowindra and the Belubula River and, to a lesser extent, the Lachlan River. | potential was undertaken in this study but it would be confirmed in Phases 2 and 3. |
| Commonwealth Environmental Water Holder | • The Commonwealth Environmental Water Holder has considerable water holdings in the Lachlan catchment. Use of these holdings is governed by statutory frameworks, including the *Water Act 2007* and delivery is provided by State Water. Construction of a new dam in the Lachlan catchment will affect our water management options and potentially the environmental outcomes that could be achieved. As such, the Commonwealth Environmental Water Office (CEWO) would like to be engaged by State Water throughout the scoping study and any future feasibility studies.<br>• The CEWO has developed a set of principles that is used for assessing activities which may impact on Commonwealth environmental water holdings (provided). We request that these principles be considered during the ongoing assessment process for the water storage | • The scoping study assumed the existing water sharing plan and Murray-Darling Basin Plan rules remain as is.<br>• Flexible carry over provisions were implicitly considered as part of the Mandatory criteria for security improvement, but will also be considered in Phase 2 and ongoing optimisation of a selected option.<br>• Assessment of the potential alternations to water sharing will form part of Phases 2 and ongoing. |
| Department of Planning and | • The Western Region office of DP&E is keen to be kept aware of progress in regard to the site investigations and site selection process. We would welcome | • Preliminary consideration of impacts of the dams on road infrastructure was considered in the |

| Agency | Response | Considered in Assessment |
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| Environment – Western Region | being invited to any agency discussions that may be held in the process, and would appreciate being able to provide comment on the regional and local land use planning implications for the project.<br>• We are currently preparing Regional Growth, Environment and Infrastructure Plans across Western NSW, and water security is a major issue flagged in our preliminary issues investigation and analysis.<br>• Some preliminary matters for consideration include:<br>o any impacts on existing infrastructure networks, including transport, electricity, utilities and telecommunications<br>o impacts on productive rural lands, and the contribution to the local economy of these lands<br>o the economic benefits for the broader region of the project proceeding | engineering assessment. Other impacts on electricity, utilities and communications would be assessed in Phases 2 and onwards.<br>• Only desktop consideration of economic benefits was undertaken for this study. A cost-benefit analysis is recommended as part of Phase 2. |
| Environment Protection Authority (EPA) | • The EPA has no role in the scoping study or any feasibility studies.<br>• Should a site for the new dam be selected, and an Environment Assessment (EA) be undertaken in support of the Project, the EPA would then have a role in assessing the EA for licensing requirements and such things as sediment and erosion control, the handling of waste etc during construction. | • EA considered in the development of the timeline for subsequent stages of study. |
| Lachlan Riverine Working Group | • The need to contact Aboriginal interests in relation to next steps.<br>• The need to consult on Indigenous linkage to fishing and the need to consult with recreational fishing associations/representatives as part of next stages<br>• Does the study only look at water balance?<br>• Who undertook the hydrology?<br>• What guidance framework being used to shape the study? Are ANCOLD | • Desktop consideration of Indigenous heritage and environmental and recreational assets has been undertaken in this study. More detailed assessments and consultation will be undertaken in subsequent phases.<br>• The cost of fish passage and management of the storage have been considered in the |

| Agency | Response | Considered in Assessment |
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| | guidelines being used, especially around fishways and cold water pollution?<br>• Are other water savings and efficiency measures being considered? Including operational efficiency options such as those being considered under the Basin Plan?<br>• Is the 'do nothing' option being considered?<br>• Will the report be made available to government agencies to comment on before it goes to the NSW government?<br>• How will cost benefit analysis be done? What will happen if the costs equal the benefits?<br>• A new dam will diminish the share of water going to the environment (ie high flows will be captured and stored and allocated to consumptive use and some will evaporate). How will the relative share between consumptive use and the environment which has been established by the Basin Plan Sustainable Diversion limit be maintained?<br>• Abercrombie River sites – very significant threatened species (Macquarie Perch) issues to be overcome.<br>• To achieve greater water security, apart from the "Do nothing" option, there is also the "Operational option" – ie change the water allocation rules and keep more water in storage so that water security during dry years is improved. Extremely cost effective in comparison to building a new dam!<br>• A new dam will invoke the fish passage provisions of the Fisheries Management Act – so the cost of a fishway on the dam or offset fishways on other structures will need to be factored in. The cost would likely be different depending on the site chosen.<br>• What reference there is to NSW's Dams and Weir policy? | comparative costs developed in this study. However, detailed consideration would form part of the design phases.<br>• The 'do nothing' option is considered in that it may have been infeasible for any of the options to address the water security problem. The 'do nothing' option will continue to be explored in the downstream phases including cost benefit analysis and environmental impact assessment. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | • This still leaves us in a bit of a wait and see in terms of how social and environmental assessment might look. Approaches such as willingness to pay and existence values are proposed. In the end, and as we discussed, whatever weightings are applied will be value-driven and are difficult to measure. And how decisions are made will be an interesting discussion. For example, one hypothetical acceptable solution was a $2M loss to local communities around the dam would be acceptable if there is a $6M gain for downstream users.<br>• If possible, could SWC clarify why Aboriginal communities in those identilfied sites (e.g. the six that made it past First Pass Criteria to multi-criteria Second Pass assessment) not included as key stakeholder for consultation at this stage? Is that because according to WSP there are currently no extractions for native title rights from the water source?<br>• Recognise that this is not a new process, so would be following a process already done (best practice), so what is the context of that? Is that straight a consultant brief and where do these Best practice guidelines come from, and how do they fit into (i.e. consistent with) agency frameworks/practices?<br>• There is a national committee on large dams (Australian National Committee on Large Dams (abbreviated as ANCOLD) and they have their own standards which relate to assessment impacts on various aspects of community (e.g. guidelines on risk assessment) – are SWC following those standards? ANCOLD have guidelines for minimal impacts on fish and cold water impact<br>• In addition, while understand and acknowledge points reiterated bout this being only an initial first step desktop assessment designed to eliminated the 'obvious no-starters' [there are still a large number of different ways (even if recommend a site) that a dam may still fall over as a concept in downstream planning activates], there appears to be an underlying message or assumption that some | |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | of the potential barriers to a dam can be 'off-set' or mitigated. Recommend that any cost benefit also take into account potential threats of a dam to threatened species populations, and the considerable investment already made into research/restoration achievements in some of the proposed sites by a range of stakeholders including community and private landholders (e.g. Abercrombie River and Macquarie Perch, and re-snagging project for fish habitat). In addition, recommend consider and detail how dam proposal relates to the intent of biodiversity conservation legislation and investment (e.g. Fisheries Management Act 1994, Environmental Protection Biodiveristy Conservation Act 1999, Threatened Species Conservation Act 1995).<br>• There are other options outside of building structures that should be further investigated in parallel with any recommendations in the SWC Report, and included in the detailed cost-benefit analysis. For example, upgrading weirs along the Lachlan River system so they can operate as re-regulating storages or structures. | |
| Murray Darling Basin Authority | • I recognise the NSW Government's objective of constructing the dam is to improve water security for communities and irrigators in the Lachlan valley/ water resource plan area.<br>• The proposed Belubula River Dam is in the Lachlan surface water resource plan area (WRPA) of the Murray- Darling Basin, which also intersects with seven groundwater resource plan areas. I note that the Lachlan WRPA has a number of wetlands of national significance such as the Booligal Wetlands, the Great Cumbung Swamp and Lake Ita.<br>• It will be important that any new dam is consistent with the Murray-Darling Basin Plan 2012, and in particular that it does not impact on: | • The scoping study assumed the existing water sharing plan and Murray-Darling Basin Plan rules remain as is.<br>• Assessment of the potential alternations to water sharing will form part of Phases 2 and ongoing. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | o the accreditation of the Lachlan water resource plan under the Basin Plan, including the ability to achieve relevant Sustainable Diversion Limits<br>o delivering the Basin Plan's environmental and water quality objectives, including protecting planned environmental water in the dam's catchment area at the 2012 level.<br>• MDBA would appreciate being kept up to date on matters associated with the "Belubula River Dam Investigation" project that may impacts on the above issues, particularly in terms of:<br>o Preliminary engineering assessments and hydraulic studies;<br>o Environmental impact assessments;<br>o Identifying statutory constraints, requirements and assessment; and<br>o Peer reviews of the assessment report. | |
| National Parks and Wildlife Service | • Belubula options do not directly impact any national park or reserve<br>• The central tablelands and slopes have a highly fragmented and highly disturbed native vegetation. Developments that impact on existing remnant vegetation communities can have a significant overall impact on the region<br>• Riparian gallery forest in the Belubula catchment appears to be largely intact from the Burnt Yards area west to Canowindra. Damming at any of the sites would split this ecosystem in two, placing an obstacle for fauna species utilising the riparian gallery forest moving up and down the Belubula River. While riparian gallery forest (usually dominated by Casuarina cunninghamiana) is not a threatened ecological community, it is highly modified in many parts of the central tablelands, so intact high quality riparian habitat is an important ecological niche. Species such as platypus, water rat, golden whistler and many other bird species are known to utilise this riparian habitat. The quality of the | • Potential impact on national parks, reserves, vegetation and habitat considered for all options in the desktop environmental assessment of each short-listed option. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | riparian gallery forest and the impact on fauna movement caused by a dam should be one of the factors considered in any dam proposal<br>• There appears to be a relatively large (but still small) patch of remnant vegetation south of the Needles proposal which may be impacted by rising water levels. Box woodland EEC is known from the Burnt Yards area to the east. Belubula catchment options be assessed for impact on extant white box, yellow box, Blakeley's red gum grassy woodland communities as this is a threatened ecological community under both federal and state legislation | |
| Office of Environment and Heritage | • Cliefden caves contain abiotic and biotic values of state, national and international significance | • Potential impact on caves considered in the desktop environmental assessment and social assessment of the short-listed options. |
| Office of Water | • Interest in exploring opportunities for town water supply security to be recognised as an important part of the customer base<br>• Existing adopted strategy for towns of the region is additional storage in the Belubula catchment (augmentation of Lake Rowlands Dam) | • Consultation with Central NSW Councils.<br>• Consultation with Office of Water.<br>• Consideration of Carcoar as a potential for town water in options assessment. |
| Office of Water | • It is recommended the scoping study include:<br>o Justification of the proposed dam/s operation and consideration of alternatives. This is to also include consideration of the potential role of this dam to support water security in the broader Central West. Proposed methods to determine water supply availability and security is recommended.<br>o Conceptual dam designs and related infrastructure.<br>o Details of the existing environment at the proposed dam sites and identification of potential impacts through dam construction, dam filling and | • Alternative sites considered in the study.<br>• Details of the hydrological assessment, including recognition of the water sharing plan and Murray Basin Plan are presented in Appendix D.<br>• Proposed dam operations would be considered in Phases 2 and onwards.<br>• Concepts of the dams are presented in Appendix C. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | full supply design level during normal operating conditions and during flood events. This is to consider potential changes for water users and the environment.<br>o Identification of potential impacts on:<br>▪ surface and ground water sources (both quality and quantity)<br>▪ related infrastructure<br>▪ adjacent licensed water users and basic landholder rights<br>▪ reliability for downstream valleys and water users<br>▪ watercourses, riparian land, and geomorphic impacts (including erosion and bank stability)<br>▪ local and downstream environment<br>▪ groundwater dependent ecosystems<br>▪ downstream flood height<br>▪ landuse, and<br>▪ concepts to reduce and mitigate these impacts<br>o Recognition of the Water Sharing Plan (WSP) for the Belubula River Regulated Water<br>o Source and the key measures of how this WSP is currently implemented. Any new structure would require amendment to this WSP which is a separate process that includes a consultation process. Consideration of potential implications to the Water Sharing Plan for the Lachlan Regulated River Water Source is also requested.<br>o Consideration of relevant policies and guidelines, including the Murray-Darling Basin Plan and the Murray-Darling Cap. | • Preliminary desktop assessment of the environment at the dam sites was assessed as part of this study. Detailed assessments would form part of Phases 2 and onwards.<br>• More detailed consideration of water sharing arrangements would form part of considerations in Phases 2 and onwards. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| Regional Development Australia - Central West | • Over recent years, Regional Development Australia Central West (RDACW) has participated in Murray Darling Basin Plan stakeholder engagement activities and is mindful of the importance of water security to communities across the Lachlan catchment area. As part of our charter, RDACW works with local communities and the three levels of Government to, amongst other things, determine economic development and infrastructure priorities.<br>• Water security and supply is an integral part of ensuring sustainable, prosperous communities in the Central West. Through our consultations with local communities, RDACW is keen to ensure that viable, sustainable and economic solutions are identified that provide assurity of supply. We support the development of water security feasibility studies that not only provide sound engineering and environmental solutions but also optimise the likelihood that the local economies in the catchment can support population growth and development of agricultural and other economic activities.<br>• In other words, dam and other water security infrastructure should not only provide the necessary security of supply for local communities but should also enable and facilitate the development of irrigation, farming and other activities. A sustainable system which can provide the appropriate degree of redundancy and encapsulate future forecast population growth, as well as provide flexibility as to sourcing options, will provide greater certainty to businesses by reducing risk around fluctuations in available supply.<br>• Where the underlying water security risks are mitigated, increased business confidence should lead to greater investment in the region, the creation of new jobs, and increasing population. They are the objectives that RDACW believes are key to providing sustainable, long term futures for communities within our region. | • Factors raised considered in the multi-criteria assessment of the short-listed options which considers economic, social and environmental aspects of water security. |

| Agency | Response | Considered in Assessment |
|---|---|---|
| | • RDACW is keen to support the work undertaken by State Water in this area. We would seek to be included in stakeholder briefings or updates and we would also ordinarily attend community consultations on issues of importance such as this. Our main interest is being kept informed of developments in respect of project scoping as they unfold. We would need to have a high level, not detailed, understanding of the potential engineering, environmental, heritage, social and economic factors of options under consideration. | |
| State Emergency Service | • The main implications dams have on NSW SES are the changes to flood behaviour (upstream and downstream) through mitigation or increased flows and failure/overtopping consequences<br>• The SES utilises Dam Safety Emergency Plans to inform their operational response. Of particular importance is maximising the available time to respond to an emergency through the use of white, amber and red alerts with appropriate defining conditions<br>• Suggested consultation with Bureau of Meteorology and Dam Safety Committee | • Considered in the development of the timeline for subsequent stages of study.<br>• Bureau of Meteorology consulted.<br>• Dam Safety Committee appraised during regular meetings with Water NSW. |

# Appendix B: Data

This appendix details the key data gaps in available information for this study and sets out the management strategies deployed.

**Sources**

The sources of information for this project are set out in Section 9.

**Data Gaps and Management Strategies**

This study was a desktop exercise in the relative ranking of options for a dam and there are limitations in terms of available information to support decision-making. The information was suitable for relative ranking of the options, but further investigation of several areas, as set out in Section 7, will be required in subsequent phases to ensure sound-decision making. Sound dam planning requires detailed information and site investigations to be conducted covering the full range of issues including risk management, environmental management, construction and operation and asset management.

The key data gaps, and the strategies to manage these for this scoping study, are set out in the table below.

**Key Data Gaps and Management Strategies**

| Category | Data Gap | Management Strategy |
|---|---|---|
| Demand data | • Project specific information on town water demands were not available<br>• Current, user-specific licence and demand information (i.e. volume and spatial distribution within the Lachlan Valley) for all GS irrigation users were not available. | • Publicly available annual forecasts of demand for towns from the 2009 Centroc Water Security Study were assumed<br>• Basin Plan quoted total long-term diversion was adopted with total river reach licence and planted area details in Lachlan Valley IQQM reduced to match this value. Approach was adopted consistent with MDBA methodology utilised in SDL assessment underpinning the Basin Plan |
| Public option | • In assessing the social desirability of the sites, there is incomplete information on the public opinion around all options. | • Consultation was undertaken with key stakeholders, including local government, to broadly gauge acceptability of options, and, in particular the short-listed options.<br>• The recommended next phases of the |

| Category | Data Gap | Management Strategy |
|---|---|---|
| | | project include public consultation |
| Customer willingness/ability to pay | • There is presently no information about the willingness or ability of potential customers of any investment in new assets to identify users to pay for the service. | • The recommended next phases of the project include cost-benefit analysis and assessments of willingness and ability to pay |
| Environmental assets | • It is observable in the environmental assessment that there is more detailed information available for Wyangala dam than some of the other sites. This is likely to be as this site has been studied in greater depth historically. | • The assessment of environmental performance included recognition of this limitation in formulating recommended scores for the various options<br>• The recommended next phases of the project include more detailed environmental assessment of recommended sites. |
| In situ site conditions, particularly at The Needles, Cranky Rock and Abercrombie | • It is observed that the presence of faulting near the dam site could introduce the potential for seismic ground displacement, strong shaking or leakage.<br>• The presence of calcareous materials in the reservoir and their reaction (solubility) to inundation in and around Needles and Cranky could also be a problem. | • The recommended next phases of the project includes a detailed geotechnical analysis, seismology and hydrology study. |
| Feasibility assessment of augmentation of Wyangala | • The impact of raising the dam by buttressing of the existing embankment could overstress the existing concrete arch. | • The recommended next phases of the project includes a detailed finite element analysis. |

# Appendix C: Engineering Characterisation and Assessment of Options

## Introduction

This engineering assessment was undertaken in three main stages, consistent with the overall planning process:

- Development of a short-list of options through application of a set of mandatory criteria (stage 1).
- Evaluation of the short-list against a set of desirable criteria (stage 2)
- Costing (stage 3).

## Stage 1 Short-Listing

The objective of this stage of the assessment is to identify a short-list of viable water security options for the Lachlan Valley using agreed mandatory criteria. The mandatory criteria are listed in table below.

In order to compare storage options at the various sites, the options will need to be modelled to show that it provides the same or similar reliability and security of water resources. This hydrological assessment is detailed in Appendix D.

The short-listed options will be recommended for detailed assessment (Stage 2) in order to determine a preferred servicing option(s) and could include a combination of options at various locations.

## Mandatory Criteria

| Mandatory | Sub-Criteria | Measurement |
|---|---|---|
| Technically potentially feasible solution | Water Reliability and Security | Yield Assessment and Performance of each option on security of supply (through hydrologic modelling, see Appendix D)<br><br>Stage 1 assessment examines dam options based on the performance of each dam size at the various locations. The performance will take consideration of an additional volume of water (e.g. 20 GL) that will be made available for extractive use thus improving their security. More details are available in the hydrology report in Appendix D. |
| | Dam size and High Level Comparative Cost ($HLCC) | $(HLCC)/GL (estimation of high level cost comparatives based on previous similar projects) |

| Mandatory | Sub-Criteria | Measurement |
|---|---|---|
| | Engineering Constraints | Any fatal flaws e.g. ability to locate dam site and build a large reservoir, potential size of dam in regards to geomorphology of the site and valley configuration |
| | Environmental Impacts (see Appendix E) | Any fatal flaw issue e.g. endangered species or other which would not be feasible to manage the impacts. Other environmental issues will include:<br>• Aboriginal and European heritage<br>• Flora, fauna and ecological communities<br>• Waterways<br>• Extent to which locals will need to be relocated and/or land acquired through compensation |
| | Geology and Material Availability | Any fatal flaw issue e.g. Foundation limitations or interstratal Karst, which would be impracticable to manage the impacts.<br>Availability and suitability of material to build a dam. |
| Regulatory compliance | | Statuary compliances |
| Consistent with the Basin Plan | | Consistent with the sustainable diversion limit (SDL) targets at end of basin (see Appendix D) |

**Previous Studies**

The following studies have been reviewed as part of this study:

1. Lachlan Valley Dam Sites Preliminary Estimates of Stream flow and System Yields, September 1980
2. URS Cranky Rocks and Needles Reports:
   - 20 June 2014 – Preliminary Concept Estimate for New Belubula River Dam – Potential 90,000 ML storages at Cranky Dam Sites
   - 19 June 2014 – Preliminary Concept Estimate for New Belubula River Dam
   - 19 June 2014 – Needles Dam – Geology
   - 19 June 2014 – Needles Dam Site Study – Site Selection
   - 19 June 2014 – Summary of Works – Belubula River CFRD Dam
   - 19 June 2014 – Needles Dam Site A – Cost Estimates
   - 18 June 2014 – Belubula River Dam – Preliminary Concept Estimate Meeting
   - 16 June 2014 – Needles Dam Site Study Scope (Draft for SWC Comment)
3. Preliminary investigation for additional storage in Lachlan Valley
4. Stage-storage information for all sites provided by Water NSW

5. Hydrological Data: Storage/Yield
6. Geological and Geotechnical Data:
   - Geological GIS maps (provided by Water NSW)
   - 1:100,000 Maps publicly available from NSW Government http://www.resourcesandenergy.nsw.gov.au
7. Material Quarries: Based on Aerial Images, Google, Yellow pages

**Potential Dam Sites**

The potential dam sites are set out in the figure below.


**Potential Dam Storage Sites**

**Long List of Option Description**

The table below sets out a summary of the potential storage sites.

**Summary of Potential Dam Storage Sites**

| Site | Description |
|---|---|
| **LACHLAN RIVER CATCHMENT** | |

| Site | Description |
|---|---|
| Wyangala Dam Raise | This option includes raising the existing dam by 20 m to meet water security needs. The capacity is expected to increase by 780 GL. |
| Abercrombie Dam – Abercrombie River | This option includes a new dam on the Abercrombie River upstream and east of Wyangala Dam. There is a potential storage of approximately 1,100 GL. |
| Hillandale Dam – Lachlan River | This option includes a new dam on Lachlan River, upstream and south of Wyangala Dam at Hillandale. There is a potential storage of approximately 1,480 GL. |
| Narrawa Dam – Lachlan River | This option includes a new dam on the Lachlan River upstream and south of the Hillandale Dam site. There is a potential storage of approximately 1,000 GL. |
| Badgery Dam Site | The option includes a dam on the Lachlan River, 18 km downstream of Wyangala Dam. There is a potential storage of approximately 45 GL. |
| **BOOROWA RIVER CATCHMENT** | |
| Battery Hill Dam – Boorowa River | This option includes a new dam on the Boorowa River, upstream of its confluence with the Lachlan River and upstream of Cowra. There is a potential storage of approximately 1,100 GL. |
| Harry Darts Dam – Boorowa River | This option includes a new dam on Boorowa River, upstream of the Battery Hill Dam site. There is a potential storage of approximately 380 GL based percentage of contributing catchment. |
| **BELUBULA RIVER CATCHMENT** | |
| Cranky Rock Dam 1 (Previously named site D or Oak Pride) | This option includes a new 700 GL dam on the Belubula River, approximately 15 km east of Canowindra. There is a potential storage of approximately 1,000 GL. |
| Cranky Rock Dam 2 (Previously named Site 5 or E) | This option includes a new dam on the Belubula River, about 2km downstream of Cranky Rock Dam site 1 and about 13km east of Canowindra. There is a potential storage of approximately 1,000 GL. |
| The Needles Dam A (Site C or P) | This option includes a new dam on the Belubula River about 10 km upstream of Cranky Rock Dam site. There is a potential storage of approximately 800 GL. |
| The Needles Dam B (Site R) | This option includes a new dam on the Belubula River about 10-11 km upstream of Cranky Rock Dam site. There is a potential storage of approximately 700 GL. |
| The Needles Dam C (Site S) | This option includes a new dam on the Belubula River about 12 km upstream of Cranky Rock Dam site. There is a potential storage of approximately 700 GL. |

| Site | Description |
|---|---|
| Carcoar Dam Raise | This option includes raising the exiting dam to meet water security needs. The capacity is expected to increase to total of ab approximately out 220 GL from existing 35.8 GL. |
| Junction Reefs | This option includes a new dam on the existing heritage listed dam structure. There is a potential storage of approximately 90 to 350 GL. |
| **MANDAGERY / BOREE CREEK CATCHMENT** | |
| Murga Dam | This option includes a new dam on the Mandagery Creek about 2.5 km northwest of Murga adjacent to Mandagery Creek and The Escort Way. There is a potential storage of approximately 1,200 GL |
| Boree Creek Dam | This option includes a new dam on the Boree Creek upstream of Cudal. There is a potential storage of approximately 500 GL. |

### Lachlan River Catchment

The Lachlan River Catchment has a number of sites that have been investigated. Currently there is one large dam on the Lachlan River (Wyangala Dam). Along with a proposal to raise Wyangala Dam, three additional dam sites on the Lachlan and Abercrombie Rivers are proposed.

*Wyangala Dam*

Wyangala Dam was completed in 1935, and further upgraded in 1971. The dam upgrade was undertaken over the existing arch dam completed in 1935. It is a major reservoir situated below the confluence of the Lachlan and Abercrombie rivers, located approximately 48 km upstream of Cowra. It is an earth and rockfill dam with a central clay core and has a height of approximately 85m. The existing dam capacity is 1,220 GL. The existing spillway includes eight tainter gates with a total capacity of approximately 272,000 ML/d.

There are two outlets with capacity of 6,700 ML/d and two power stations with a maximum output of 22.5 MW.

The proposal is to raise the exiting dam to meet the water security needs of the irrigators. The future potential capacity is expected to be between 2,000 - 2,400 GL.

### Wyangala Dam

| Catchment | Lachlan River |
|---|---|

| | |
|---|---|
| Potential Storage (GL) | 2,400 |
| Catchment Area ($km^2$) | 8,300 |
| Latitude (approx.) | 33°58'24.54"S |
| Longitude (approx.) | 148°57'8.04"E |

*Geology*

The dam is typically founded on alluvial materials associated with Lachlan River with the abutments of the dam keyed into granite of the Wyangala Granite formation. An inferred fault feature is mapped adjacent to the dam site. The most significant issues for development of the existing dam appear to be the presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage which could be compounded by a dam raise.

*Site Suitability*

The current rockfill dam is approximately 1.3km in length and 85 m high. The raising of the dam will require significant earthworks and a large volume of rockfill. Although these costs will be high it would be feasible to raise the dam. Costs associated with raising the spillway, and the dam's other appurtenances will need to be factored in when determining whether a raise is cost effective.

There are four options of raising the dam based on the proposed height:

- Option 1 - adding rockfill materials on top of and on the downstream face of the existing embankment;
- Option 2 - adding rockfill materials on top of and on the upstream face of the existing embankment;
- Option 3 - adding rockfill materials on top of and on both the upstream face and the downstream face of the existing embankment; and
- Option 4 - construction of a reinforced earth block on top of the existing dam crest.

Option 1 appears to be the most technically viable option but among the most expensive as it will require an enormous amount of rockfill to raise and buttress the existing embankment. This option will, however, have the added benefit of making the existing embankment more stable. The new spillway on the left abutment could be a suitable source of rock and will also assist with achieving additional spillway capacity for the PMF condition.

The existing gravity arch dam (built 1935) immediately upstream of the embankment may render Options 2 and 3 infeasible as thickening the upstream shoulder might destabilise the arch.

The feasibility of Option 4 will require further investigation. Vertical reinforced earth block raising by approximately 4.5m has been successfully applied in the raising of Googong Dam near Canberra, and currently a 6.5m vertical raising is proposed for raising Chaffey Dam in Tamworth. At Wyangala it appears that a maximum vertical raising of approximately 5m is the technical limit due to embankment stability issues. The existing embankment has relatively low factors of safety against slope failure under the seismic loading due to the Maximum Design Earthquake. The design of vertical raising will likely be controlled by seismic stability requirements.

**Abercrombie Dam**

This is a new dam proposed on the Abercrombie River. There is a potential storage of approximately 1,480 GL based on previous assessments undertaken. However the storage of approximately 1,100 GL is more feasible based on the stage curve developed.

**Abercrombie Dam**

| Catchment | Abercrombie River |
|---|---|
| Potential Storage (GL) | 1,480 |
| Catchment Area ($km^2$) | 2,635 |
| Latitude (approx.) | 33°57'10.46"S |
| Longitude (approx.) | 149°19'38.73"E |

*Geology*

The dam site is underlain by rock of the Kangaloolah Volcanics. Aerial photographs indicate rock exposure in parts of the stream channel with some accumulation of sediments in the low speed inside corners of river bends. Abercrombie cave is located about 3-4 km north of inundated area and the calcareous material may extent to the reservoir or dam site. An inferred fault feature is mapped through or adjacent to the dam site. The most significant issues for development of a dam on the site appear to be:

- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- Abutment stability for a gravity dam.

*Site Suitability*

The storage potential for Abercrombie Dam is 1,100 GL. The valley in which the proposed dam would be located has a low point of 420 mAHD, a high point of 540 mAHD and an approximate length of 800 m.

A dam constructed at this location is likely to be founded on the volcanic rock andesite which is shown to be at or near the surface on geological mapping for the site, with potential outcrops identified in the steam channel. The andesite would provide a suitable foundation stratum for either a concrete or embankment dam due to its low compressibility and typically high rock strength. The degree of weathering and number of fractures present in the bedrock would need to be determined.

An embankment dam with a clay/concrete cut off into the andesitic rock could be constructed. The materials could be stripped from within the footprint of the proposed catchment area. Shallow bedrock could limit the availability of site won materials for the construction of an earthfill dam; however a rockfill dam may be a possibility.

No existing quarry of significant size has been identified close to the proposed site. As such, importing aggregate and other materials required for the construction of a concrete dam could be expensive. The timing of a proposed auxiliary spillway at Wyangala Dam's left abutment, as part of a required Flood Security Upgrade, could be a factor in sourcing material for the dam.

In summary, the likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filters and blanket filter underneath the downstream shoulder;
- Option 2 - an earth and rockfill embankment dam
- Option 3 - a concrete faced rockfill embankment dam; and
- Option 4 - a gravity dam built of wet mixed concrete or roller compacted concrete.

The viability of the Options 2 and 3 will depend on the availability of rockfill materials from potential quarries within a close distance otherwise the construction costs will be prohibitively high. The viability of Option 4 will also depend on finding rock with good bearing strength at reasonably shallow depth.

**Hillandale Dam**

This is a new dam proposed on the Lachlan River upstream and south of Wyangala Dam at Hillandale. There is a potential storage of approximately 1,480 GL based on previous assessments undertaken.

**Hillandale Dam**

| Catchment | Lachlan River |
|---|---|
| Potential Storage (GL) | 1,480 |
| Catchment Area ($km^2$) | 3,910 |
| Latitude (approx.) | 34° 2'34.39"S |
| Longitude (approx.) | 149° 2'48.03"E |

*Geology*

The dam site and reservoir extent appear to lie within Blanket Flat Granite. Aerial photographs indicate the accumulation of sediments within the river channel. The most significant issues for development of a dam on the site appear to be removal of sediment accumulated in the river channel to form a dam foundation.

*Site Suitability*

The valley in which the proposed dam would be located has a low point of 378 mAHD, a high point of 600 mAHD and an approximate length of 3.0 km.

The geological map infers that granite and sandstone are at or near the surface however as discussed in the geological section there appears to be a large accumulation of sediment/alluvial material in the river channel and its surrounding areas.

The required length of a proposed dam across this valley, to provide the desired storage, is likely to rule out a concrete gravity dam due to the costs involved. The thickness of the alluvial materials in the river channel would also compound on this cost if identified to a significant thickness. Outcrops of rock can be seen across the site, indicating the possible presence of shallow bedrock however they are not consistent.

There may be sufficient site won materials to construct an earthfill embankment dam particularly if the alluvial material contains high clay content. There may also be the possibility of quarrying the rock required for a rockfill dam from outcrops identified in the catchment area.

There is no quarry of significant size in close proximity to the proposed site. There are however a number of borrow pits in the area which look to be comprised of sand/sandstone.

In summary, the likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder; and
- Option 2 - an earth and rockfill embankment if suitable rockfill materials can be sourced from within a close distance, or at the location of the new spillway.

**Narrawa Dam**

This is a new dam proposed on the Lachlan River upstream and south of Hillandale Dam. Based on the previous studies the potential storage of this site is approximately 1,000 GL, however based on the percentage of contributing catchment and impacts to Wyangala reservoir the storage capacity could be as low as 500 GL.

**Narrawa Dam**

| Catchment | Lachlan River |
|---|---|
| Potential Storage (GL) | 1,000 |
| Catchment Area ($km^2$) | 2,258 |
| Latitude (approx.) | 34°17'17.03"S |
| Longitude (approx.) | 149° 5'58.54"E |

*Geology*

The dam site and reservoir extent would be located in Abercrombie Formation sandstone, interbedded with laminated siltstone and mudstone. The watercourse on which the dam would be constructed is inferred to have resulted from faulting. The most significant issues for development of a dam on this site appear to be the presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.

*Site Suitability*

The valley where the proposed dam would be located has a low point of 435 mAHD, a high point of around 510 mAHD and an approximate length of 1.0 km.

The geological map infers that sandstone, interbedded with laminated siltstone and mudstone are at or near the surface. The bedrock materials, if identified near the surface, could provide a suitable foundation stratum for either a concrete or embankment dam. As discussed in the geology section the degree of weathering and faulting in the bedrock materials would need to be determined.

A concrete dam could be very expensive to construct due to the remote location of the dam and the width of the valley floor. Mudstone, if found in the dam foundation, may not provide adequate bearing capacity to support a gravity dam.

An embankment dam with a clay/concrete cut off into the underlying bedrock could be constructed. The materials could be stripped from within the footprint of the proposed catchment area. Shallow bedrock could limit the availability of site won materials for the construction of an earthfill dam; however, a rockfill dam may be a possibility.

No quarry of significant size has been identified close to the proposed site as such importing aggregate and other materials required for the construction of a concrete dam could be expensive.

In summary, the most likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder; and
- Option 2 - an earth and rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.

**Badgery Dam Site**

The dam is proposed on the Lachlan River, 18 km downstream of Wyangala Dam. It has a catchment of 9,200 km$^2$ and its potential yield was not investigated.

**Badgery Dam Site**

| Catchment | Lachlan River |
|---|---|
| Potential Storage (GL) | 45 |
| Catchment Area (km$^2$) | 9,200 |
| Latitude (approx.) | 33°55'34.02"S |
| Longitude (approx.) | 148°47'27.22"E |

*Geology*

The dam is typically founded on coarse alluvial materials associated with Lachlan River; abutments are on Whistle Waa Granite formation. The Woodstock (thrust) fault is located downstream from the dam site. The most significant issues for development of a dam on the site appear to be:

- Establishing the extent of recent alluvium and whether it presents a potential leakage path from the reservoir.
- Removal of sediment accumulated in the river channel to form a dam foundation.
- There are no visible outcrops of rock in areas close to the proposed dam that would indicate shallow bedrock.

*Site Suitability*

This dam site is located immediately downstream of the confluence of the Boorowa and Lachlan Rivers just downstream of Wyangala Dam. The storage potential on the Badgery site is governed by the level of the outlets on the Upstream Wyangala Dam. The difference between levels of the site location and the outlet is approximately 10-15 m. To avoid impacts on the outlets of Wyangala Dam, this will limit the storage volume to approximately 45 GL.

The valley where the proposed dam could be located has a low point of 290 mAHD, a high point of 320 mAHD and an approximate length of 1.0 km. It also requires a saddle dam on the right abutment with an approximate length of 400 m.

The abutments of the dam are likely to be founded in granite outcrops observed in the hillside on the right abutment of the valley. Alluvial materials associated with the Lachlan River can be seen in the river channel which has a width of approximately 700 to 800m.

A number of properties and local roads are located immediately downstream of the dam site. A number of properties are also located upstream which could be inundated by the reservoir.

It may be possible to construct a concrete gravity dam at this location. The strength of the bedrock materials and the degree of weathering will need to be determined. There is the possibility that alluvial materials are located in the main river channel. There are no visible outcrops of rock in areas close to the proposed dam that would indicate shallow bedrock.

It would be possible to construct an embankment dam across the valley. Clay soils may be present in above the bedrock materials. An earthfill dam with a cut-off trench constructed in the underlying bedrock may be a possibility although the nature of the granite would need to be determined. If shallow bedrock is encountered then the use of the materials in a rockfill dam may also be a possibility.

**Boorowa River Catchment**

Two dam sites are proposed at different locations on the Boorowa River.

**Battery Hill Dam**

This is a new dam proposed on the Boorowa River upstream of its confluence with Lachlan River and downstream of Cowra. There is a potential storage of approximately 1,100 GL based on previous assessments undertaken.

**Battery Hill Dam**

| Catchment | Boorowa River |
|---|---|
| Potential Storage (GL) | 1,100 |
| Catchment Area ($km^2$) | 1,820 |
| Latitude (approx.) | 33°57'44.91"S |
| Longitude (approx.) | 148°50'8.94"E |

*Geology*

The dam site is located near the boundary of Olivine Basalt, Whistle Waa and Wyangala Granite and covered with alluvium and the depth of alluvial materials underlying the proposed dam is uncertain. Based on the 1:100,000 geological maps, the Wyangala granite is located mainly on the eastern side of Boorowa River and Olivine Basalt is on the western side. The Olivine Basalt is susceptible to weathering and if the spillway will be located on the left abutment, further investigation on the quality of rock will be required. The most significant issues for development of a dam on the site appear to be establishing the extent of recent alluvium and whether it presents a potential leakage path underneath the proposed dam.

*Site Suitability*

The storage potential for Narrawa Dam is approximately 1,100 GL. The valley where the proposed dam could be located has a low point of 301 mAHD, a high point of 400 mAHD and an approximate length of 1.5 km.

The abutments of the dam are likely to be founded in either granite or basalt with outcrops observed in the hillside either side of the valley. Alluvial materials associated with the Boorowa River can be seen in the river channel which has a width of approximately 250-300 m.

A concrete gravity dam could be expensive to construct, and also not technically viable if there is significant alluvial deposit in the dam foundation. The valley is relatively wide and as such a large volume of concrete would be required to construct the dam. The cost of excavating the alluvial materials from the river channel would also be expensive if encountered to a significant depth.

An embankment (rockfill) dam could be constructed with rock stripped from within the footprint of the proposed catchment area. Shallow bedrock could limit the availability of site won materials for the construction of an earthfill dam.

The nearest quarry to the site is Glenella quarry (<1km) and provides products including sand, clay and basalt which could be utilised for either a concrete or embankment dam.

In summary, the most likely options for this site are:

- Option 1 - an earth and rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.
- Option 2 - a concrete faced rockfill embankment if the concrete slab can be founded on reasonably good quality rock at shallow depth.

**Harry Darts Dam**

This is a new dam proposed on the Boorowa River, upstream of the Battery Hill Dam site. There is a potential storage of approximately 380 GL based on the percentage of contributing catchment. However the valley is wide and extensive materials will be required.

**Harry Darts Dam**

| Catchment | Boorowa River |
|---|---|
| Potential Storage (GL) | 380 |
| Catchment Area ($km^2$) | 1,277 |
| Latitude (approx.) | 33°59'18.47"S |
| Longitude (approx.) | 148°49'33.90"E |

*Geology*

The dam site is located on Wyangala Granite and covered with alluvium and the depth of alluvial materials underlying the proposed dam is uncertain. The most significant issues for development of a dam on the site appear to be:

- Establishing the extent of recent alluvium and whether it presents a potential leakage path underneath the proposed dam.
- Volcanic Granite if found at shallow depth, can provide sufficient foundation bearing capacity for both gravity and embankment type dams.

*Site Suitability*

The main valley where the proposed dam could be located has a low point of 304m, a high point of 330m and an approximate length of 970m. The abutments of the dam are likely to be founded in granite.

The granite would provide a suitable founding stratum for a concrete or embankment dam if it is not too fractured or weathered. The alluvial materials located to the western side of the valley could be an issue. If a significant thickness of alluvium is encountered the excavation costs to provide a stable foundation within the granite would be expensive. It is not possible to confirm whether shallow bedrock exists at this site as no outcrops of rock can be observed in the aerial mapping.

Assuming a shallow alluvium profile, clay soils may be present allowing for the construction of an earthfill dam with a cut-off trench constructed in the underlying granite.

Glenella quarry is in close proximity to the site (<3km) and provides products including sand, clay and basalt which would be required for either a concrete or embankment dam.

In summary, the most likely options for this site are:

- Option 1 - an earth and rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.
- Option 2 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.

**Belubula River Catchment**

The Belubula River Catchment has a number of sites that have been investigated. The Cranky Rock proposal looks at two dam sites, 2 km away from each other. The Needles proposal looks at three dam sites of varying sizes, close to each other. It is expected that during the option assessment phase, 1 or 2 dam sites will be identified for short list. The Carcoar dam option looks at raising the existing dam. Yield, constructability and safety will be a key component of this dam proposal. One of the issues for all dams in the area is the presence of calcareous materials in the reservoir and their reaction (solubility) to inundation.

**Cranky Rock Site Option 1 (D or Oak Pride)**

The dam is proposed on the Belubula River, about 13-15 km east of Canowindra. The site looks suitable for a dam site with a comparatively narrow valley of approximately 70m wide. The right abutment has a height of approximately 425 mAHD and left abutment has a height of approximately 450 mAHD.

**Cranky Rock Option 1 (D or Oak Pride)**

| Catchment | Belubula River |
|---|---|
| Potential Storage (GL) | 1,000 |
| Catchment Area ($km^2$) | 1,758 |
| Latitude (approx.) | 33°31'59.27"S |
| Longitude (approx.) | 148°47'32.49"E |

*Geology*

The dam site is underlain by sandstone/siltstone of the Millambri Formation with, as per previous site investigations, depth of alluvium in the river channel of approximately 6 m (20ft). It appears that the reservoir would inundate the same formation. A small inferred fault feature is mapped nearby the site. The most significant issues for development of a dam on the site appear to be:

- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- The presence of calcareous materials in the reservoir and their reaction (solubility) to inundation.
- The need to cut off seepage flows through the alluvium at the dam site.

*Site Suitability*

The main valley where the proposed dam could be located has a low point of 333 mAHD, a high point of 365 mAHD and an approximate length of 700m. The proposed dam is likely to be founded in sandstone/siltstone.

It may be possible to construct a concrete gravity dam at this location. The strength of the sandstone/siltstone and the degree of weathering/fracturing of foundation would need to be determined. The alluvial materials located in the main river channel could be an issue if a significant thickness is encountered. The geological mapping for the site infers that the alluvial materials/river channel is approximately 200 m wide. There appears to be outcrops of rock in the area which indicate that shallow bedrock is present.

It should be possible to construct an embankment dam across the valley. Clay soils may be present in the alluvium allowing for the construction of an earthfill dam with a cut-off trench in the underlying sandstone/siltstone. If shallow bedrock is encountered the construction of a rockfill dam may also be a possibility.

A quarry has been identified on George Russel Drive, 10km southeast of Canowindra and approximately 20km south of the proposed dam site. A number of borrow pits can also be seen on aerial mapping which look to be typically comprised of sand.

Previous investigations have identified potentially 3.9 million cubic yards (3 million $m^3$) of material is available at this site.

Cadia Valley Gold Mine is located approximately 20km northeast of the proposed site. The mine has a large opencast pit over 1.5km wide, the depth of which is unknown.

There is the possibility that blasting and other practices at the mine may cause seismic instability along any fault lines and a study would need to be undertaken to determine this.

The likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.
- Option 2 - an earth and rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.
- Option 3 - a gravity dam built of wet mixed concrete or roller compacted concrete if rock bed of sufficient strength and orientation/morphology (if a rock foundation of sufficient strength and orientation/morphology).

**Cranky Rock Dam Option 2 (site E or 5)**

The dam is proposed on the Belubula River, about 2 km downstream of Cranky Rock Site 1. This site has a wider valley.

**Cranky Rock Option 2**

| Catchment | Belubula River |
|---|---|
| Potential Storage (GL) | 1,000 |
| Catchment Area ($km^2$) | 1,944 |
| Latitude (approx.) | 33°31'30.92"S |
| Longitude (approx.) | 148°46'15.86"E |

*Geology*

The dam site is underlain by sandstone/siltstone of the Millambri Formation with an unknown depth of alluvium in the river channel. The reservoir has the potential to inundate calcareous siltstone/sandstone/limestone of the Melongull Formation and Canomodine Limestone. An inferred fault feature runs through the dam site. The most significant issues for development of a dam on the site appear to be:

- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- The presence of calcareous materials in the reservoir and their reaction (solubility) to inundation
- The need to cut off seepage flows through the alluvium at the dam site.

*Site Suitability*

The main valley where the proposed dam could be located has a low point of 345 mAHD, a high point of 408 mAHD and an approximate length of 450 m. The proposed dam is

likely to be founded in sandstone/siltstone with limestone also shown to be present on the geological mapping for the site.

Limestone in particular can be subject to weathering with voids often present leading to a low compressive strength. The alluvial materials located in the main river channel could be an issue if a significant thickness is encountered. The river channel in this area is not very wide however and as such it is unlikely that a significant proportion of alluvial material will be encountered. There appears to be outcrops of rock in the area which indicate that shallow bedrock is present.

It should be possible to construct an embankment dam across the valley. Clay soils may be present in the alluvium allowing for the construction of an earthfill dam with a cut-off trench in the underlying sandstone/siltstone. If shallow bedrock is encountered the construction of a rockfill dam may also be a possibility.

A quarry has been identified on George Russel Drive, 10 km southeast of Canowindra and approximately 25km south of the proposed dam site. A number of borrow pits in the area can also be seen on aerial mapping which look to typically be comprised of sand.

Previous investigations have identified potentially 3.9 million cuYr (3 million $m^3$) of material is available this site.

Cadia Valley Gold Mine is located approximately 20km northeast of the proposed site. The mine has a large opencast pit over 1.5km wide the depth of which is unknown. There is the possibility that blasting and other practices at the mine may cause seismic instability along any fault lines and a study would need to be undertaken to determine this.

The likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.
- Option 2 - an earth and rockfill embankment or a concrete faced rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.

If any of the Cranky Rock sites are shortlisted for further study, it is important to carry out sufficient geological investigations to ensure that the presence of calcareous materials will not adversely impact the watertightness of the reservoir, or may cause foundation problems if soluble rock or cavities are found under the footprint of the proposed dam.

**The Needles Dam A (site C or P), and C (Site S)**

This site is about 8 km upstream of Cranky Rock Site 1.

**Needles Dam A, B and C**

| Site | A (Site C or P) | B (Site R) | C (Site S) |
|---|---|---|---|
| Catchment | Belubula River | Belubula River | Belubula River |
| Potential Storage (GL) | 811 | 700 | 700 |
| Catchment Area ($km^2$) | 1,523 | - | - |
| Latitude (approx.) | 33°34'37.9"S | 33°34'33.08"S | 33°34'41.05"S |
| Longitude (approx.) | 148°51'24.96"E | 148°51'10.23"E | 148°51'02.21"E |

*Geology*

The dam site is underlain by sandstone of the Macquarie Group Formation and sandstone/ siltstone/ shale of the Woree Creek Formation, the two units being separated by a thrust fault. The river channel contains an unknown depth of alluvium. The reservoir appears to inundate sandstone and calcareous siltstone of the Angullong Formation. The most significant issues for development of a dam on the site appear to be:

- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- The presence of calcareous materials in the reservoir and their reaction (solubility) to inundation.
- The need to cut off seepage flows through the alluvium at the dam site.

Previous investigations have identified potentially 6.5 million cuYr (5 million $m^3$) of material is available this site.

*Site Suitability*

The valley at Needles Dam is approximately 500 m wide. The low point of the valley is 393 mAHD with the highest point at an elevation of approximately 500 mAHD. The proposed dam is likely to be founded on sandstone/siltstone. Alluvial materials associated with the Belubula River can be seen in the river channel which has a width of approximately 70 m.

If designed conservatively to overcome the soft and friable shales and downstream dip of 20 degrees it may be possible to construct a concrete gravity dam at this location. The strength of the sandstone/siltstone and the degree of weathering/fracturing would need to be determined. The alluvial materials located in the main river channel could be an issue if a significant thickness is encountered. There appears to be outcrops of rock in the area which indicate that shallow bedrock is present.

It should also be possible to construct an embankment dam across the valley. Clay soils may be present in the alluvium allowing for the construction of an earthfill dam with a cut-off trench in the underlying sandstone/siltstone. Signs of rill erosion at the site suggest that the clays might be very erodible and possibly dispersive. With proper compaction control and properly designed filter zones, even dispersive clays can be used for building the core of an earth and rockfill dam. If shallow bedrock is encountered the construction of a rockfill dam may also be a possibility.

A quarry has been identified on George Russel Drive, 10 km southeast of Canowindra and approximately 60km by road from the proposed dam site. A number of borrow pits in the area can also be seen on aerial mapping which look to typically be comprised of sand.

Cadia Valley Gold Mine is located approximately 20 km northeast of the proposed site. The mine has a large opencast pit over 1.5 km wide, the depth of which is unknown. There is the possibility that blasting and other practices at the mine may cause seismic instability along any fault lines and a study would need to be undertaken to determine this.

The likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.
- Option 2 - an earth and rockfill embankment or a concrete faced rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.
- Option 3 - if designed conservatively to overcome the soft and friable shales and downstream dip of 20 degrees, a gravity dam is feasible.

If this site is shortlisted for further study, it is important to carry out sufficient geological investigations to ensure that the presence of calcareous materials will not adversely impact the watertightness of the reservoir, or may cause foundation problems if soluble rock or cavities are found under the footprint of the proposed dam.

**Carcoar Dam Raise**

An option to improve the water security of the Lachlan catchment is to raise the existing Carcoar Dam. Carcoar Dam is 57 m high and 187 m long, and is a concrete double arch dam which was built in 1970. The dam is located about 6 km north of the village of Carcoar and south of the town of Blayney. The dam has a catchment area of approximately 230 $km^2$ with an existing storage capacity of 35.8 GL. The existing spillway has a total capacity of approximately 105,000 ML/d and the outlet capacity is 1,470 ML/d. Carcoar Dam road crosses the dam via a bridge (over the spillway) and connects Midwest Highway to Barry Road (Barry, NSW).

It is estimated that the catchment upstream of the dam has a potential to store 217 GL. However, raising the existing dam height will be very technically challenging and costly.

**Carcoar Dam**

| Catchment | Belubula River |
|---|---|
| Potential Storage (GL) | 217 |
| Catchment Area ($km^2$) | 230 |
| Latitude (approx.) | 33°37'8.27"S |
| Longitude (approx.) | 149°10'49.14"E |

*Site Suitability*

There is potentially a quarry source for Carcoar Dam along Brown Creek Road, 26 km from the dam site. The specific materials produced by the quarry would need to be identified however the underlying geology comprises the volcanic rocks basalt, volcanic sandstone and Hornblendes.

Options for raising Carcoar Dam include:

- Option 1 - Modifying the existing dam to a gravity arch dam by downstream buttressing using wet mixed concrete; and
- Construction of a new dam immediately downstream of the existing dam. The likely options for the new dam are:
  - an earth and rockfill embankment
  - a concrete faced rockfill embankment, or
  - concrete gravity dam built of wet mixed concrete or roller compacted concrete

**Junction Reefs**

This site is upstream of the Cliefden Caves and downstream of Carcoar Dam. The dam has a catchment area of approximately 1,200 km$^2$. The site is located near an old dam site which is heritage listed. It has a wide valley adding significant cost to the overall dam costs.

It is estimated that the catchment upstream of the dam has a potential capacity to store 240 GL.

**Junction Reefs**

| Catchment | Belubula River |
|---|---|
| Potential Storage (GL) | 240 |
| Catchment Area (km$^2$) | 1,200 |
| Latitude (approx.) | 33°37'14.68"S |
| Longitude (approx.) | 148°59'5.09"E |

*Site Suitability*

There is potentially a quarry source for this Dam along Brown Creek Road, within 100 km from the dam site. The specific materials produced by the quarry would need to be identified however the underlying geology comprises of volcanic rocks basalt, volcanic sandstone and Hornblendes.

The current Junction Reefs Dam at Mandurama is a dam with State heritage significance built in 1898 and is currently a NSW LPI asset. It is a 19 m high and 126 m long concrete masonry gravity dam with multiple sloping arch buttresses. It is a prescribed structure with a unique design and was the first of its type to be built in Australia.

The concrete structure is silted up and faces stability issues and a reassessment of sliding resistance during normal and unusual loading conditions showed it still required some stabilisation works and it is particularly vulnerable to earthquake loads.

### Mandagery and Boree Creek Catchment

#### Murga Dam

The dam is proposed on the Mandagery Creek, some 2.5 km northwest of Murga adjacent to Mandagery Creek and The Escort Way. It has a catchment of 1,500 km$^2$ and potential storage of approximately 1,200 GL.

#### Murga Dam

| Catchment | Mandagery / Boree Creek |
|---|---|
| Potential Storage (GL) | 1,200 |
| Catchment Area (km$^2$) | 1,500 |
| Latitude (approx.) | 33°21'55.20"S |
| Longitude (approx.) | 148°31'46.77"E |

*Geology*

The dam site is underlain by alluvial deposits, the in-filled valley being approximately 200m wide at the proposed site. The right abutment would be founded on Mandagery Sandstone (sandstone, siltstone, shale) and the left abutment either on the same unit or alluvial material depending on the dam geometry. A fault is mapped crossing the valley within 200 m of the dam site and an inferred fault feature located within the reservoir is trending towards the dam site. The most significant issues for development of a dam on the site appear to be:

- The need to cut off seepage flows through the alluvium at the dam site.
- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- Potential alluvial material on left abutment.

*Site Suitability*

The main valley at the proposed location of Murga Dam is approximately 1.25 km in length. The dam is likely to be founded in sandstone/siltstone.

It may be possible to construct a concrete gravity dam at this location. This option however may not be economically viable if the length of the gravity structure is too long. The strength of the sandstone/siltstone, the degree of weathering/fracturing and strike and dip so as to confirm no unfavourable foundation bedding conditions would need to be determined. The alluvial materials located in the main river channel and the left abutment could be an issue if a significant thickness is encountered. There appear to be outcrops of rock in areas close to the proposed dam indicating shallow bedrock.

It should be possible to construct an embankment dam across the valley. Clay soils may be present in the alluvium allowing for the construction of an earthfill dam with a cut-off trench constructed in the underlying sandstone/siltstone. If shallow bedrock is encountered then the use of the materials in a rockfill dam may also be a possibility.

The nearest large scale quarry looks to be Millers Metals in the town of Forbes approximately 56 km from the dam site.

The likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.
- Option 2 - an earth and rockfill embankment or a concrete faced rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.
- Option 3 - a gravity dam built of wet mixed concrete or roller compacted concrete if rock bed is found at shallow depth, and the length of the dam is not excessive.

### Boree Creek Dam

The dam is proposed on the Boree Creek, upstream of Cudal. It has a catchment of 254 $km^2$ and has a potential yield of 12.8 GL per annum.

**Boree Creek Dam**

| Catchment | Boree Creek |
|---|---|
| Potential Storage (GL) | 500 |
| Catchment Area ($km^2$) | 254 |
| Latitude (approx.) | 33°16'39.07"S |

| | |
|---|---|
| Longitude (approx.) | 148°44'58.88"E |

*Geology*

The dam site is underlain by rock of the Garra Formation (limestone, sandstone, shale, siltstone). The Cudal (thrust) fault is located approximately 600 m downstream from the dam site. The most significant issues for development of a dam on the site appear to be:

- The presence of faulting near the dam site introducing the potential for seismic ground displacement, strong shaking or leakage.
- The potential for limestone to be within the inundation zone with possible solubility issues.

*Site Suitability*

The valley at Boree Creek Dam is quite shallow with a depth of 20 m over a distance of approximately 1.25 km. The dam is likely to be founded in sandstone/siltstone with limestone also indicated on geological mapping for the area.

It may be possible to construct a concrete gravity dam at this location. The strength of the bedrock materials and the degree of weathering (particularly in the limestone) will need to be determined. There is the possibility that alluvial materials are located in the main river channel. There are no visible outcrops of rock in areas close to the proposed dam that would indicate shallow bedrock.

It would be possible to construct an embankment dam across the valley. Clay soils may be present above the bedrock materials. An earthfill dam with a cut-off trench constructed in the underlying limestone may be a possibility although the nature of the limestone would need to be determined. If shallow bedrock is encountered then the use of the materials in a rockfill dam may also be a possibility.

The nearest large scale quarry looks to be Bald Hill Quarry on The Escort Way, 26 km from the dam site.

The likely options for this site are:

- Option 1 - a zoned earthfill embankment with chimney filter and blanket filter underneath the downstream shoulder.
- Option 2 - an earth and rockfill embankment or a concrete faced rockfill embankment if suitable rockfill materials of sufficient hardness can be sourced from within a close distance.

- Option 3 - a gravity dam built of wet mixed concrete or roller compacted concrete if rock bed is found at shallow depth, and the length of the dam is not excessive.

If this site is shortlisted for further study, it is important to carry out sufficient geological investigations to ensure that the presence of calcareous materials will not result in a leaky reservoir, or cause foundation problems if solution cavities are found under the footprint of the proposed dam.

**Screening of Options**

A three stage process was adopted when assessing the long-list of options for performance and feasibility. The process included:

Step 1 of Screening - Assessing dams against engineering constraints. This looked at the feasibility of a new, or upgrade to an existing, dam based on engineering challenges.

Step 2 - Yield Performance – This looked at available yield at each dam site and its potential storage capacity.

Step 3 - High level cost estimation – This assumed all new dams as earth fill dams with a cost unit rate which was applied to the overall material quantity to look at the relative cost effectiveness.

**Engineering Constraints Assessment**

The following dams were removed from the long list for further assessment based on an engineering constraints assessment.

*Raising Carcoar Dam*

The Carcoar Dam is a double arch dam and any augmentation to upgrade this dam will face significant technical challenges. It has a relatively low yield in comparison to the other sites due to the size of contributing catchment.

*Badgery Site*

This dam site is close to Wyangala Dam on the Lachlan River, downstream of the proposed Battery Hill Dam. Investigation on the levels shows that a new dam would inundate the Wyangala outlets thus impacting the performance of the Dam and hydropower generation. Locating Badgery site in series downstream of existing Wyangala dam would also raise safety concerns due to the potential of cascade failure scenarios.

*Boree Creek, Cudal Site*

This dam site is upstream of Cudal township. The key issue from a dam safety perspective is the risk to the population downstream of the dam. It also has a small yield providing minimal reliability and security.

*Junction Reefs*

The dam is heritage listed. Upgrade to the structure of the dam is not viable due its age and stability. If a new dam is built downstream at either location identified, it would flood an old gold field area (primary reason for the construction of the existing dam). Also, the site would provide a small security improvement compared to other options.

**Yield Performance**

The results from the hydrologic assessment, namely yields for various dam sizes, were plotted and assessed to determine the performance of each dam. The table below shows the modelled capacity and equivalent yield at each dam location and figure below shows the performance of the various dam sizes. The shortlisted options are shown with a red circle around the optimal dam size in the figures below. Options that have been shortlisted are based on the highest equivalent yield with the lowest comparative cost estimate.

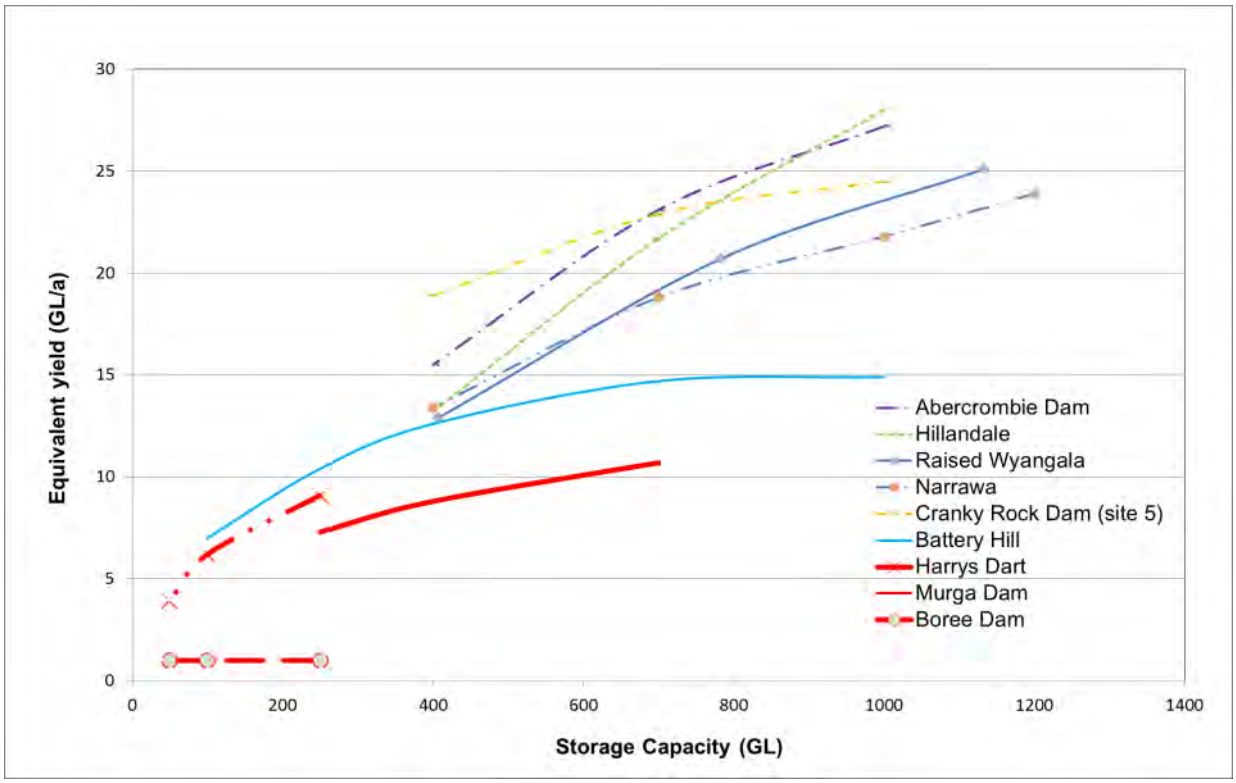
**Modelled dam size and equivalent yield**

| Dam | Capacity (GL) | Equivalent yield (GL/a) |
|---|---|---|
| Cranky Rock Dam | 400 | 18.9 |
| | 700 | 22.9 |
| | 1,000 | 24.5 |
| Needles Dam | 700 | 22.9 |
| Raised Wyangala | 400 | 12.9 |
| | 780 | 20.7 |
| | 1,000 | 25.1 |
| Abercrombie Dam | 400 | 15.5 |
| | 700 | 23.1 |
| | 1,000 | 27.2 |
| Hillandale | 400 | 13.2 |
| | 700 | 21.7 |
| | 1,000 | 28.0 |

| Dam | Capacity (GL) | Equivalent yield (GL/a) |
|---|---|---|
| Narrawa | 400 | 13.4 |
| | 700 | 18.8 |
| | 1,000 | 21.8 |
| | 1,200 | 23.9 |
| Battery Hill | 100 | 7.0 |
| | 250 | 10.4 |
| | 400 | 12.6 |
| | 700 | 14.7 |
| | 1,000 | 14.9 |
| Harry Dart | 50 | 3.9 |
| | 100 | 6.2 |
| | 250 | 9.1 |
| Murga Dam | 250 | 7.3 |
| | 400 | 8.8 |
| | 700 | 10.7 |
| Boree Dam | 50 | 1.0 |
| | 100 | 1.0 |
| | 250 | 1.0 |

The figure below shows that a number of dam sites have low yields. Sites with low yield (dark red lines) have been excluded from further assessment as they do not provide the security required when compared to the other sites. The dam sites excluded from further assessment include:

- Boree Dam
- Murga Dam
- Harry Darts Dam




**Equivalent Yield (EY) vs Storage Capacity**

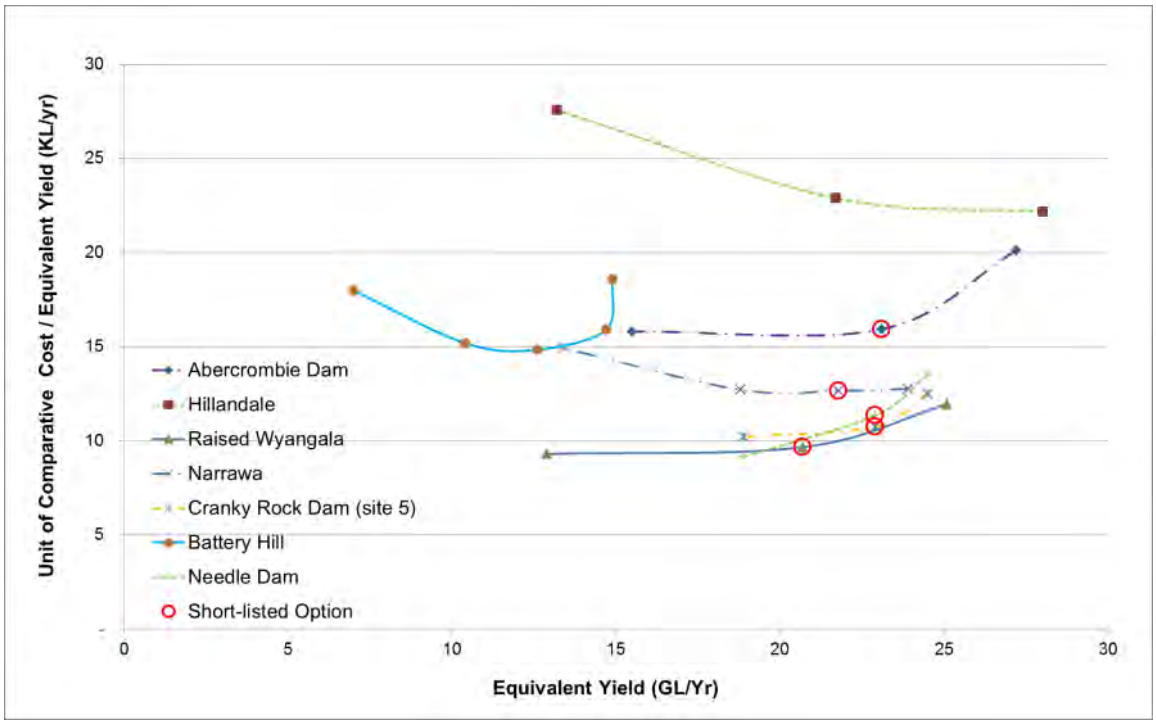
### High Level Comparative Cost Assessment

At this screening level, the main objective is to identify the appropriate dam size at each location. A high level cost estimation was undertaken to determine the quantity of material required to build an earthfill dam. This high level cost estimate was based on the following assumptions:

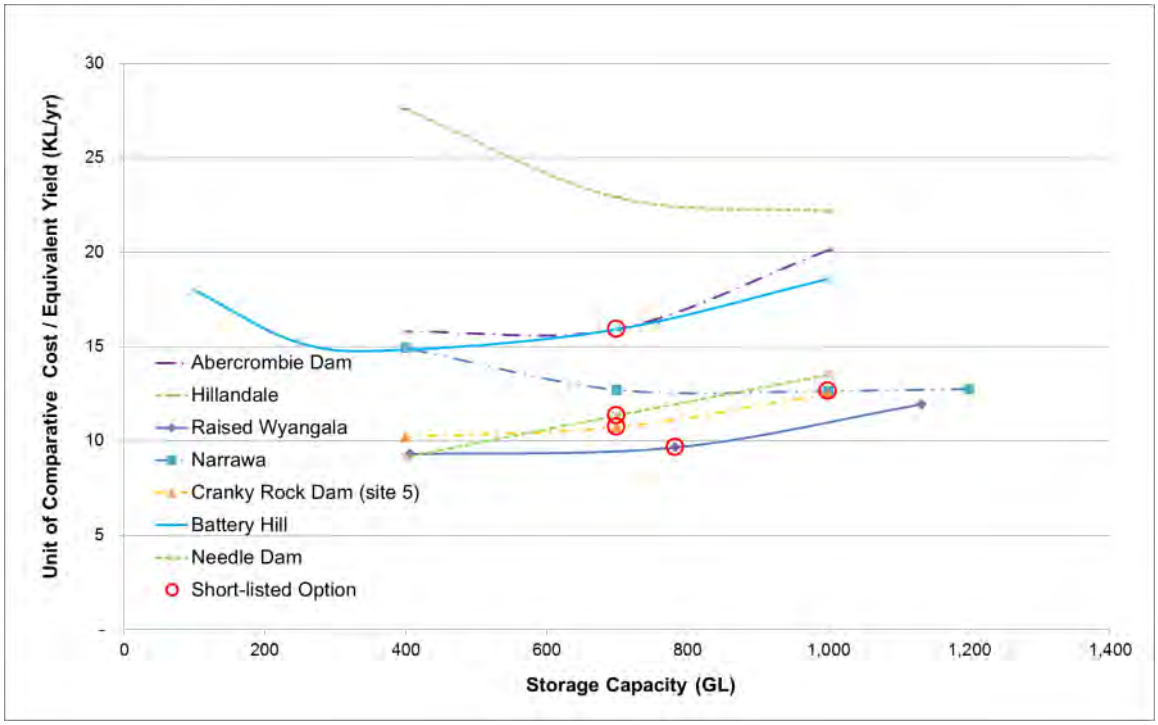
- Dam type – All dams were assumed as earth fill dams for costing purposes
- All characteristics associated to earthfill dams are similar for all sites

The figures below show the unit cost per equivalent yield for each dam against equivalent yields and dam storage respectively. A lower value of unit cost highlights a more cost effective option. These options were shortlisted to be further assessed during the next stage.

As Hillandale dam site is located in a wide valley, the results show it to have a relatively higher unit cost in comparison to the other sites. This site was removed for further consideration. The other 5 sites (Abercrombie, Narrawa, Battery Hill, Needles and Cranky Rock) were shortlisted for further investigations. An optimal size highlighted in red circle was selected for the 5 dam sites. The shortlisted sites are listed in Section 4.




**Unit of Comparative Cost / EY vs Equivalent Yield**




**Unit of Cost/EY (KL/yr) vs Storage**

**Short-List Options**

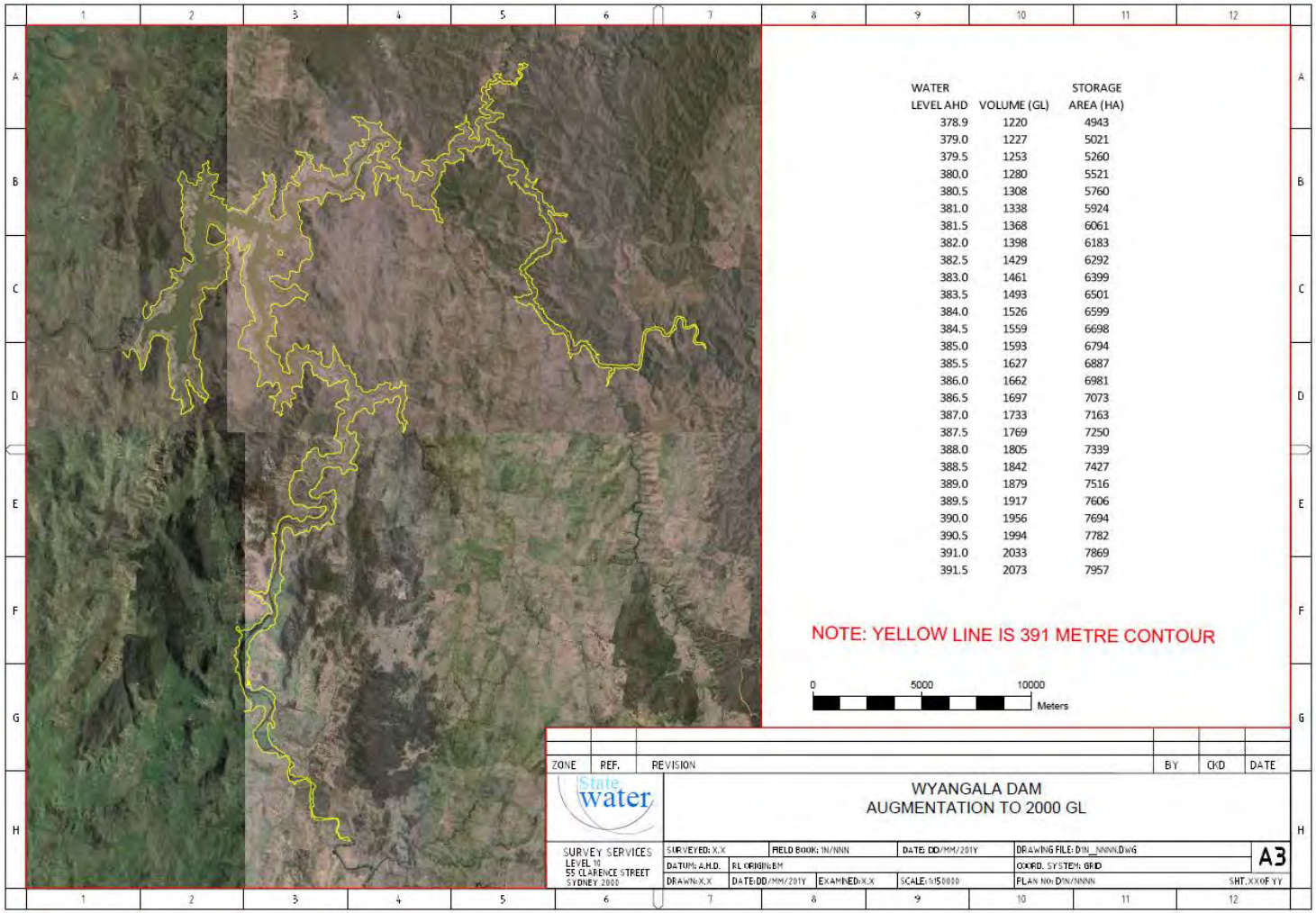
Based on the engineering and hydrologic assessment undertaken the recommended short listed options include:

**Short Listed Options**

| Options | Dam Site |
|---|---|
| 1 | **Raise Wyangala Dam** |
| 2 | **Abercrombie Dam**<br>700 GL |
| 3 | **Narrawa Dam**<br>1,000 GL. |
| 4 | **Cranky Rock**<br>700 GL |
| 5 | **Needles Dam**<br>700 GL |
| 6 | **Battery Hill**<br>400 GL |

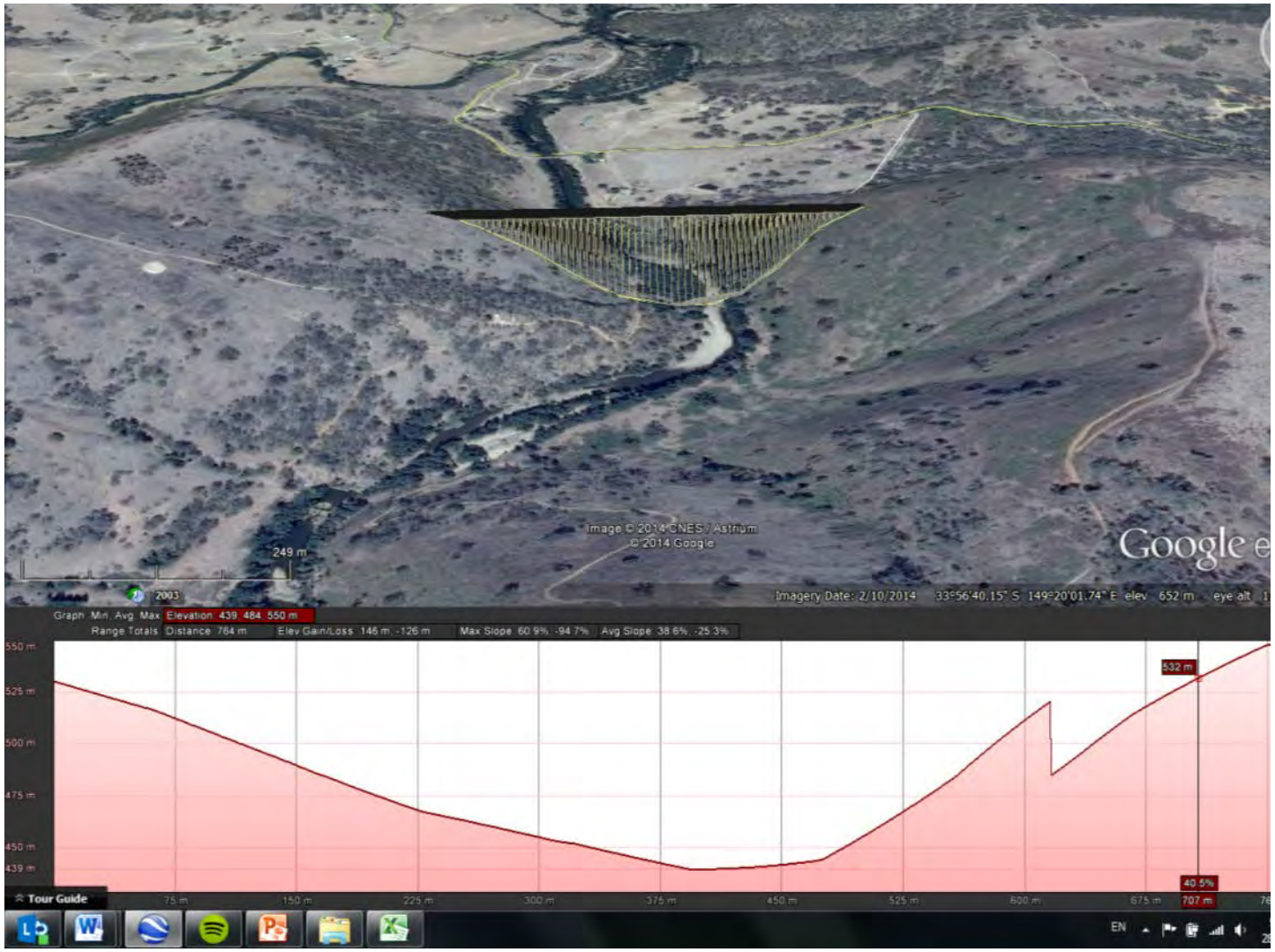
## Supporting Documents and Figures for Shortlisting of Options

### Staged Storage - WYANGALA DAM

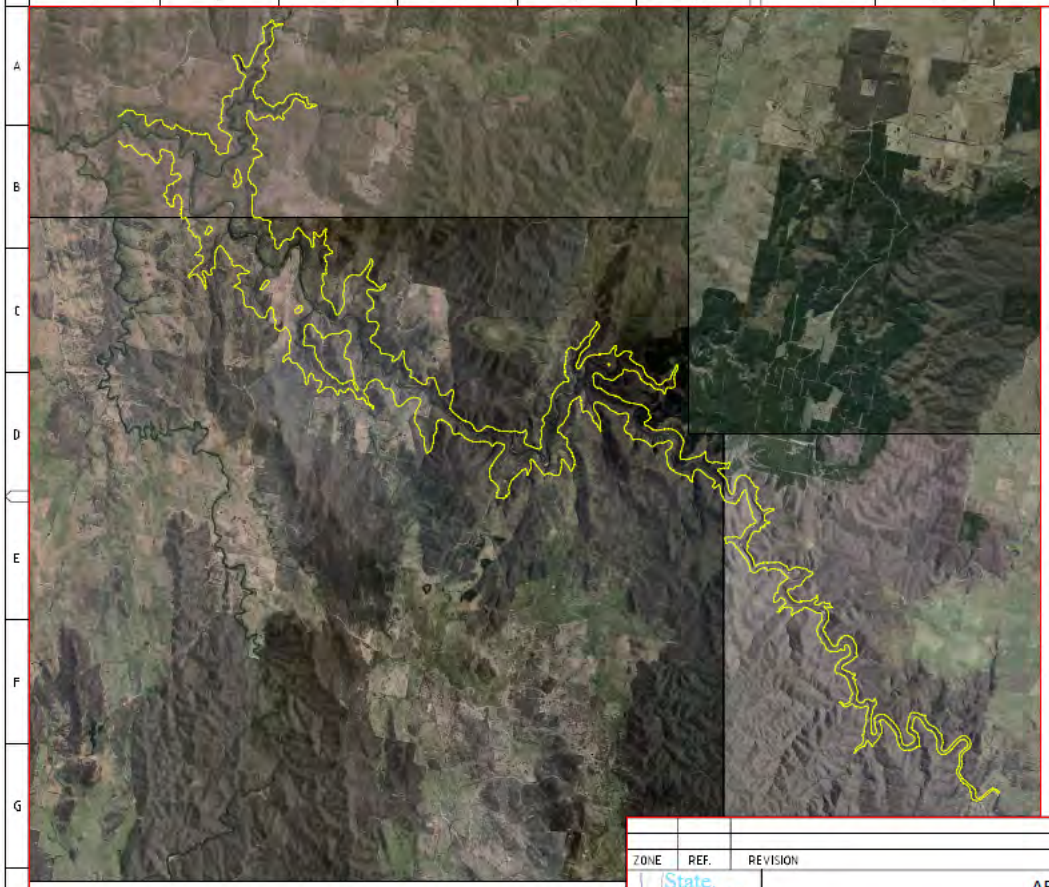


| WATER LEVEL AHD | VOLUME (GL) | STORAGE AREA (HA) |
|---|---|---|
| 378.9 | 1220 | 4943 |
| 379.0 | 1227 | 5021 |
| 379.5 | 1253 | 5260 |
| 380.0 | 1280 | 5521 |
| 380.5 | 1308 | 5760 |
| 381.0 | 1338 | 5924 |
| 381.5 | 1368 | 6061 |
| 382.0 | 1398 | 6183 |
| 382.5 | 1429 | 6292 |
| 383.0 | 1461 | 6399 |
| 383.5 | 1493 | 6501 |
| 384.0 | 1526 | 6599 |
| 384.5 | 1559 | 6698 |
| 385.0 | 1593 | 6794 |
| 385.5 | 1627 | 6887 |
| 386.0 | 1662 | 6981 |
| 386.5 | 1697 | 7073 |
| 387.0 | 1733 | 7163 |
| 387.5 | 1769 | 7250 |
| 388.0 | 1805 | 7339 |
| 388.5 | 1842 | 7427 |
| 389.0 | 1879 | 7516 |
| 389.5 | 1917 | 7606 |
| 390.0 | 1956 | 7694 |
| 390.5 | 1994 | 7782 |
| 391.0 | 2033 | 7869 |
| 391.5 | 2073 | 7957 |

**ABERCROMBIE DAM**



## Staged Storage - ABERCROMBIE DAM



| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 420 | 0.0 | 0 | 462 | 109.50 | 645 | 504 | 584.5 | 1753 |
| 421 | 0.1 | 11 | 463 | 116.05 | 664 | 505 | 602.2 | 1787 |
| 422 | 0.2 | 14 | 464 | 122.78 | 682 | 506 | 620.2 | 1820 |
| 423 | 0.3 | 16 | 465 | 129.69 | 700 | 507 | 638.5 | 1853 |
| 424 | 0.5 | 19 | 466 | 136.78 | 718 | 508 | 657.2 | 1887 |
| 425 | 0.7 | 24 | 467 | 144.04 | 735 | 509 | 676.3 | 1922 |
| 426 | 1.0 | 32 | 468 | 151.48 | 753 | 510 | 695.7 | 1956 |
| 427 | 1.4 | 38 | 469 | 159.10 | 771 | 511 | 715.4 | 1989 |
| 428 | 1.8 | 44 | 470 | 166.90 | 789 | 512 | 735.5 | 2023 |
| 429 | 2.3 | 55 | 471 | 174.88 | 807 | 513 | 755.9 | 2057 |
| 430 | 2.9 | 63 | 472 | 183.04 | 826 | 514 | 776.6 | 2093 |
| 431 | 3.5 | 73 | 473 | 191.40 | 845 | 515 | 797.7 | 2129 |
| 432 | 4.3 | 81 | 474 | 199.96 | 865 | 516 | 819.2 | 2166 |
| 433 | 5.2 | 89 | 475 | 208.72 | 889 | 517 | 841.0 | 2205 |
| 434 | 6.2 | 103 | 476 | 217.73 | 913 | 518 | 863.3 | 2247 |
| 435 | 7.3 | 116 | 477 | 226.99 | 940 | 519 | 886.0 | 2290 |
| 436 | 8.5 | 136 | 478 | 236.53 | 969 | 520 | 909.1 | 2337 |
| 437 | 9.9 | 150 | 479 | 246.36 | 998 | 521 | 932.7 | 2384 |
| 438 | 11.5 | 168 | 480 | 256.49 | 1029 | 522 | 956.8 | 2436 |
| 439 | 13.3 | 189 | 481 | 266.94 | 1061 | 523 | 981.2 | 2486 |
| 440 | 15.3 | 217 | 482 | 277.70 | 1090 | 524 | 1006.1 | 2535 |
| 441 | 17.7 | 243 | 483 | 288.73 | 1117 | 525 | 1031.3 | 2584 |
| 442 | 20.2 | 267 | 484 | 300.03 | 1142 | 526 | 1057.0 | 2583 |
| 443 | 23.0 | 287 | 485 | 311.58 | 1168 | 527 | 1083.0 | 2622 |
| 444 | 25.9 | 304 | 486 | 323.38 | 1193 | 528 | 1109.4 | 2660 |
| 445 | 29.1 | 322 | 487 | 335.43 | 1218 | 529 | 1136.2 | 2700 |
| 446 | 32.4 | 339 | 488 | 347.73 | 1243 | 530 | 1163.4 | 2739 |
| 447 | 35.8 | 357 | 489 | 360.29 | 1269 | 531 | 1191.0 | 2781 |
| 448 | 39.5 | 374 | 490 | 373.10 | 1294 | 532 | 1219.0 | 2824 |
| 449 | 43.3 | 391 | 491 | 386.18 | 1321 | 533 | 1247.5 | 2866 |
| 450 | 47.3 | 407 | 492 | 399.53 | 1349 | 534 | 1276.3 | 2908 |
| 451 | 51.5 | 423 | 493 | 413.15 | 1377 | 535 | 1305.6 | 2951 |
| 452 | 55.8 | 439 | 494 | 427.07 | 1406 | 536 | 1335.4 | 2995 |
| 453 | 60.3 | 457 | 495 | 441.27 | 1435 | 537 | 1365.5 | 3040 |
| 454 | 64.9 | 474 | 496 | 455.77 | 1466 | 538 | 1396.2 | 3086 |
| 455 | 69.7 | 492 | 497 | 470.55 | 1498 | 539 | 1427.3 | 3136 |
| 456 | 74.7 | 511 | 498 | 485.74 | 1532 | 540 | 1458.9 | 3191 |
| 457 | 80.0 | 532 | 499 | 501.24 | 1568 | 541 | 1491.1 | 3248 |
| 458 | 85.4 | 556 | 500 | 517.12 | 1608 | 542 | 1523.8 | 3300 |
| 459 | 91.1 | 579 | 501 | 533.40 | 1647 | 543 | 1557.1 | 3350 |
| 460 | 97.0 | 604 | 502 | 550.06 | 1685 | 544 | 1590.8 | 3397 |
| 461 | 103.1 | 626 | 503 | 567.09 | 1720 | 545 | 1625.0 | 3444 |

NOTE: - YELLOW LINE IS 539 METRE CONTOUR

0 3000 6000 Meters

ZONE | REF. | REVISION | BY | CKD | DATE

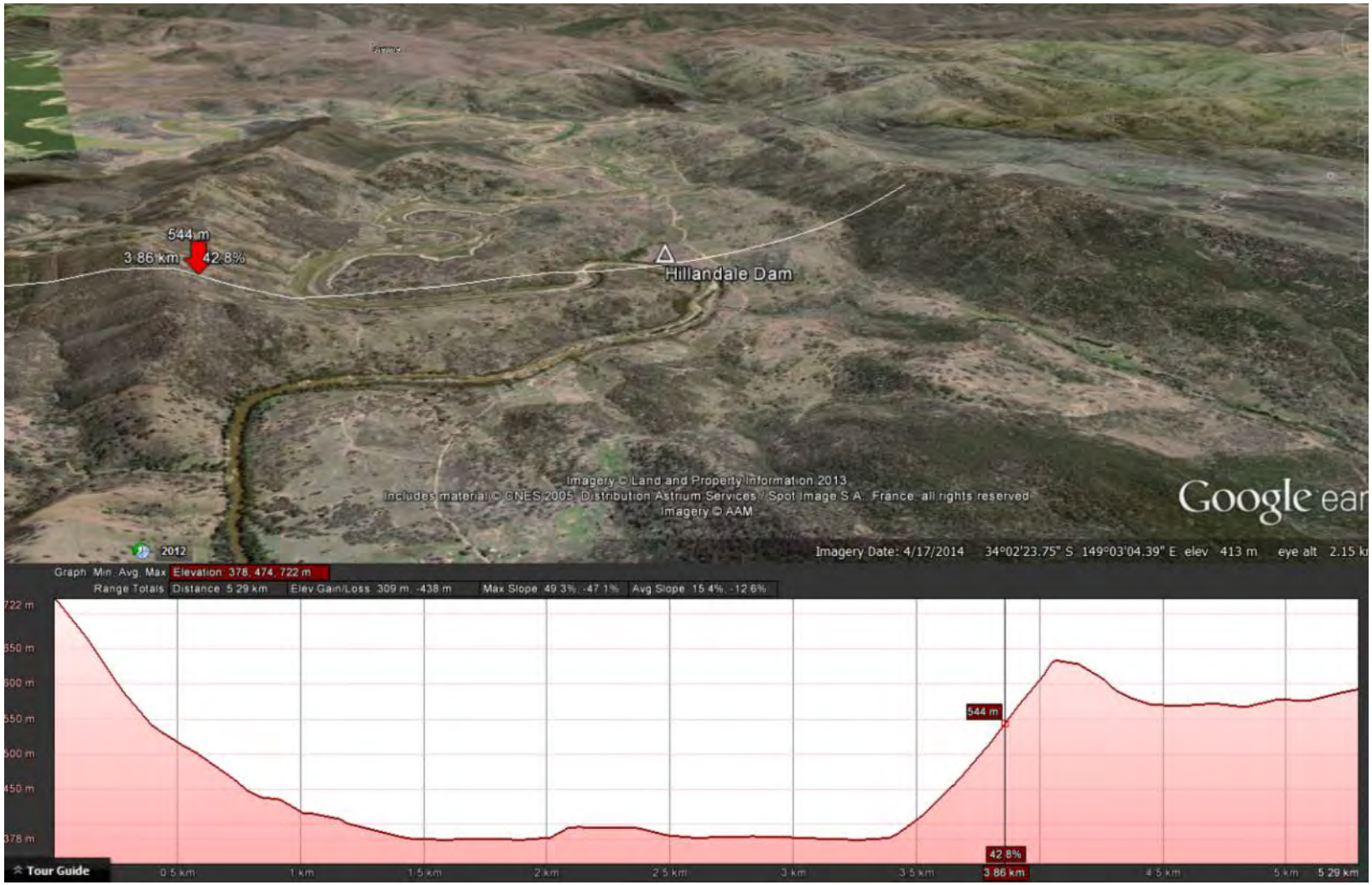
State water

ABERCROMBIE DAM
1400 GL STORAGE

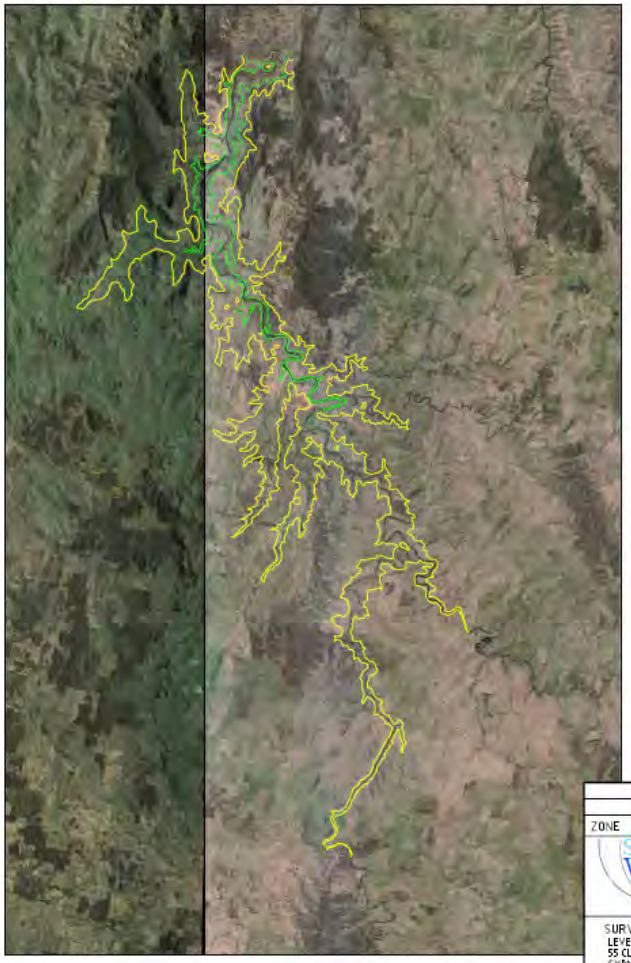
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

SURVEYED: X.X | FIELD BOOK: IN/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: MGA 55
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:100000 | PLAN No: D1N/NNNN | SHT. XXOF YY

**HILLANDALE DAM**



## Staged Storage – HILLANDALE DAM



| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 368 | 0.0 | 0 | 397 | 123.8 | 1214 | 426 | 987.3 | 5141 |
| 369 | 0.0 | 0 | 398 | 136.3 | 1300 | 427 | 1039.5 | 5292 |
| 370 | 0.0 | 7 | 399 | 149.8 | 1398 | 428 | 1093.2 | 5446 |
| 371 | 0.1 | 10 | 400 | 164.4 | 1527 | 429 | 1148.4 | 5596 |
| 372 | 0.2 | 13 | 401 | 180.4 | 1679 | 430 | 1205.1 | 5750 |
| 373 | 0.4 | 16 | 402 | 197.9 | 1814 | 431 | 1263.4 | 5906 |
| 374 | 0.6 | 19 | 403 | 216.7 | 1944 | 432 | 1323.3 | 6066 |
| 375 | 0.8 | 21 | 404 | 236.7 | 2063 | 433 | 1384.8 | 6233 |
| 376 | 1.0 | 24 | 405 | 257.9 | 2172 | 434 | 1447.9 | 6408 |
| 377 | 1.2 | 27 | 406 | 280.2 | 2275 | 435 | 1513.0 | 6597 |
| 378 | 1.5 | 31 | 407 | 303.4 | 2379 | 436 | 1579.9 | 6796 |
| 379 | 2.3 | 107 | 408 | 327.7 | 2481 | 437 | 1649.0 | 7010 |
| 380 | 3.7 | 188 | 409 | 353.0 | 2583 | 438 | 1720.2 | 7248 |
| 381 | 6.2 | 294 | 410 | 379.4 | 2686 | 439 | 1794.0 | 7514 |
| 382 | 9.5 | 357 | 411 | 406.8 | 2792 | 440 | 1870.7 | 7837 |
| 383 | 13.3 | 411 | 412 | 435.3 | 2902 | 441 | 1950.8 | 8170 |
| 384 | 17.7 | 461 | 413 | 464.8 | 3012 | 442 | 2033.9 | 8458 |
| 385 | 22.6 | 514 | 414 | 495.5 | 3125 | 443 | 2119.8 | 8722 |
| 386 | 28.0 | 567 | 415 | 527.3 | 3244 | 444 | 2208.3 | 8961 |
| 387 | 33.9 | 621 | 416 | 560.4 | 3369 | 445 | 2299.0 | 9184 |
| 388 | 40.4 | 675 | 417 | 594.7 | 3502 | 446 | 2391.9 | 9399 |
| 389 | 47.4 | 728 | 418 | 630.5 | 3646 | 447 | 2487.0 | 9610 |
| 390 | 55.0 | 784 | 419 | 667.8 | 3836 | 448 | 2584.1 | 9820 |
| 391 | 63.1 | 838 | 420 | 707.4 | 4096 | 449 | 2683.4 | 10027 |
| 392 | 71.7 | 891 | 421 | 749.6 | 4331 | 450 | 2784.7 | 10238 |
| 393 | 80.9 | 945 | 422 | 793.9 | 4518 | | | |
| 394 | 90.7 | 1005 | 423 | 839.9 | 4686 | | | |
| 395 | 101.0 | 1067 | 424 | 887.5 | 4839 | | | |
| 396 | 112.0 | 1136 | 425 | 936.7 | 4991 | | | |

NOTE:- YELLOW LINE IS 450 METRE CONTOUR
GREEN LINE IS 400 MTRE CONTOUR

0 5000 10000 Meters

ZONE | REF. | REVISION | BY | CKD | DATE

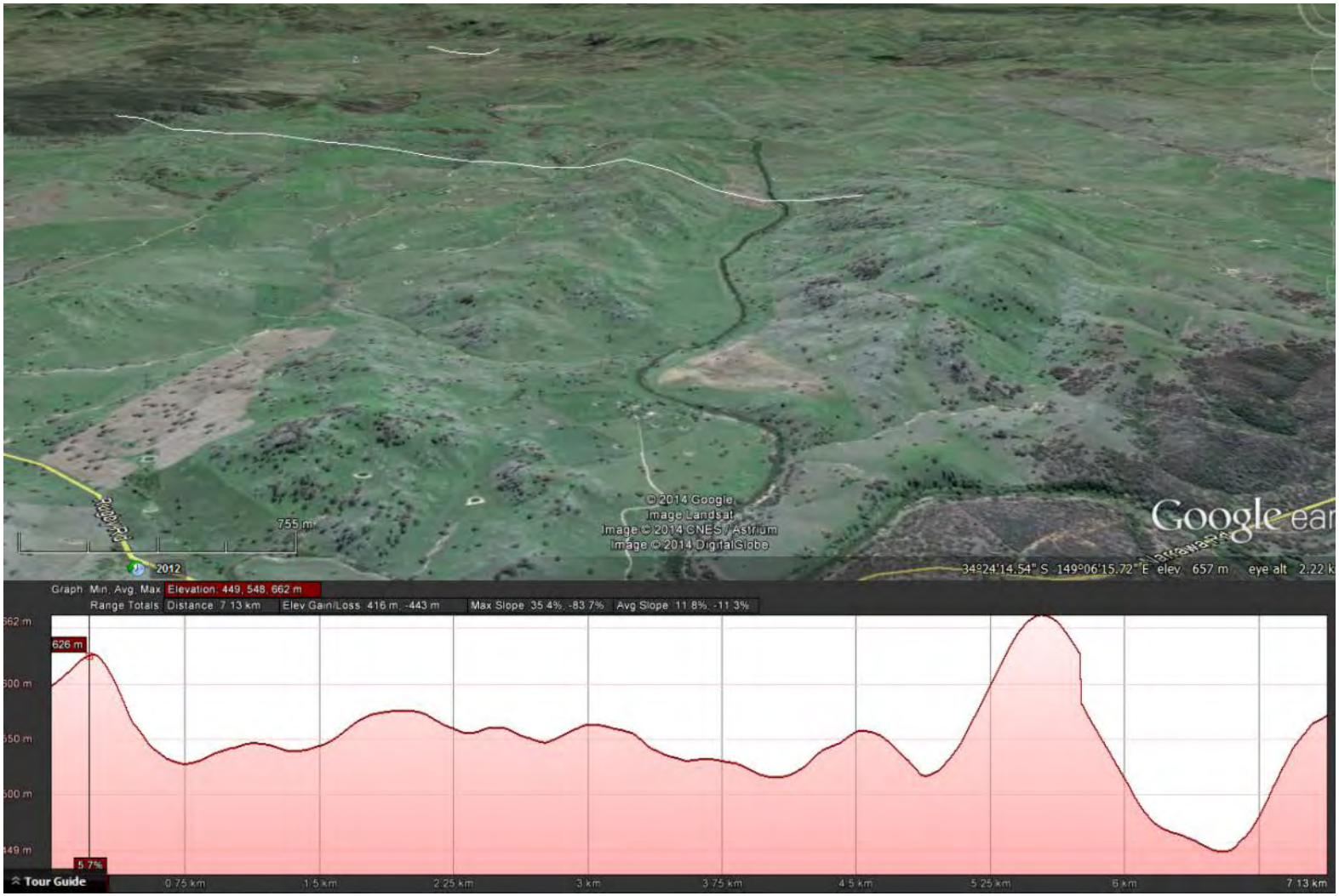
State water

HILLANDALE DAM
PROPOSED STORAGE

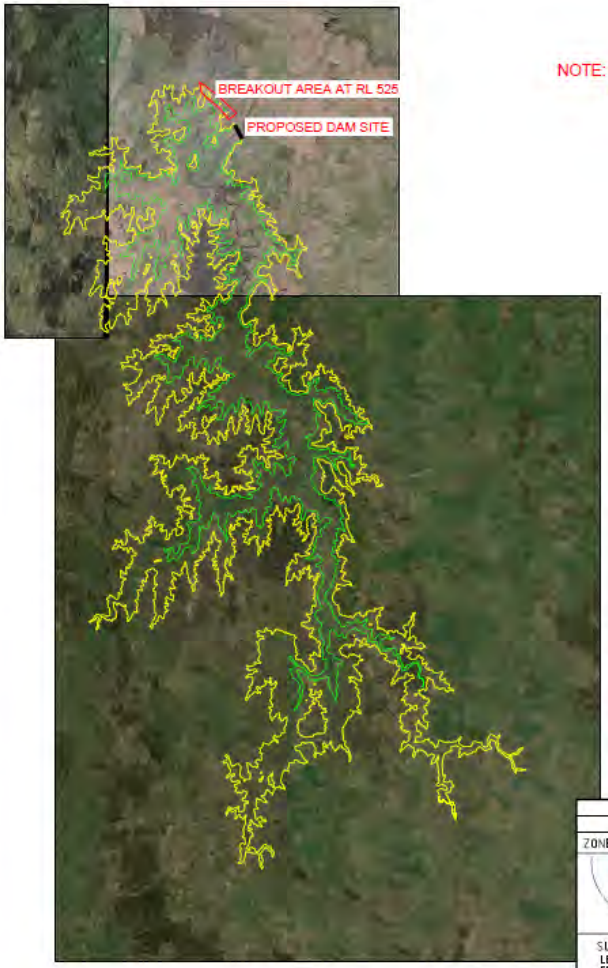
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: MGA 55
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:200000 | PLAN No: D1N/NNNN | SHT. XXOF YY

**NARRAWA DAM**


© 2014 Google
Image Landsat
Image © 2014 CNES / Astrium
Image © 2014 DigitalGlobe
755 m
2012
Google earth
34°24'14.54" S 149°06'15.72" E elev 657 m eye alt 2.22 k
Graph Min, Avg, Max Elevation: 449, 548, 662 m
Range Totals Distance 7.13 km Elev Gain/Loss 416 m, -443 m Max Slope 35.4%, -83.7% Avg Slope 11.8%, -11.3%
662 m
626 m
600 m
550 m
500 m
449 m
5.7%
Tour Guide
0.75 km
1.5 km
2.25 km
3 km
3.75 km
4.5 km
5.25 km
6 km
7.13 km

## Staged Storage - NARRAWA DAM




NOTE: YELLOW LINE IS 525 METRE CONTOUR
GREEN LINE IS 560 METRE CONTOUR

| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 439 | 0.0 | 0 | 480 | 146.2 | 1129 | 521 | 2076.7 | 10477 |
| 440 | 0.0 | 6 | 481 | 158.1 | 1256 | 522 | 2184.1 | 10997 |
| 441 | 0.1 | 11 | 482 | 171.3 | 1386 | 523 | 2296.4 | 11451 |
| 442 | 0.2 | 16 | 483 | 185.8 | 1510 | 524 | 2413.0 | 11857 |
| 443 | 0.4 | 22 | 484 | 201.5 | 1620 | 525 | 2533.5 | 12239 |
| 444 | 0.7 | 30 | 485 | 218.2 | 1724 | 526 | 2657.7 | 12613 |
| 445 | 1.0 | 39 | 486 | 236.0 | 1831 | 527 | 2785.7 | 12984 |
| 446 | 1.5 | 48 | 487 | 254.8 | 1935 | 528 | 2917.4 | 13354 |
| 447 | 2.0 | 59 | 488 | 274.7 | 2040 | 529 | 3052.8 | 13726 |
| 448 | 2.7 | 69 | 489 | 295.6 | 2148 | 530 | 3192.0 | 14109 |
| 449 | 3.4 | 79 | 490 | 317.7 | 2263 | 531 | 3335.0 | 14498 |
| 450 | 4.2 | 89 | 491 | 340.9 | 2384 | 532 | 3482.0 | 14897 |
| 451 | 5.2 | 102 | 492 | 365.4 | 2514 | 533 | 3633.0 | 15315 |
| 452 | 6.3 | 114 | 493 | 391.2 | 2649 | 534 | 3788.3 | 15746 |
| 453 | 7.5 | 128 | 494 | 418.4 | 2796 | 535 | 3948.0 | 16205 |
| 454 | 8.8 | 141 | 495 | 447.2 | 2961 | 536 | 4112.5 | 16697 |
| 455 | 10.3 | 155 | 496 | 477.7 | 3151 | 537 | 4282.1 | 17231 |
| 456 | 11.9 | 171 | 497 | 510.2 | 3351 | 538 | 4457.3 | 17826 |
| 457 | 13.7 | 190 | 498 | 544.8 | 3573 | 539 | 4638.9 | 18518 |
| 458 | 15.7 | 212 | 499 | 581.8 | 3832 | 540 | 4828.2 | 19380 |
| 459 | 18.0 | 239 | 500 | 621.7 | 4165 | 541 | 5027.1 | 20397 |
| 460 | 20.6 | 277 | 501 | 665.2 | 4521 | 542 | 5235.8 | 21322 |
| 461 | 23.5 | 313 | 502 | 712.0 | 4844 | 543 | 5452.9 | 22069 |
| 462 | 26.8 | 350 | 503 | 762.0 | 5136 | 544 | 5676.9 | 22709 |
| 463 | 30.5 | 383 | 504 | 814.6 | 5374 | 545 | 5906.9 | 23306 |
| 464 | 34.5 | 416 | 505 | 869.4 | 5588 | 546 | 6143.0 | 23899 |
| 465 | 38.8 | 447 | 506 | 926.3 | 5799 | 547 | 6384.9 | 24482 |
| 466 | 43.4 | 476 | 507 | 985.4 | 6010 | 548 | 6632.6 | 25067 |
| 467 | 48.3 | 506 | 508 | 1046.5 | 6220 | 549 | 6886.2 | 25645 |
| 468 | 53.5 | 536 | 509 | 1109.8 | 6433 | 550 | 7145.5 | 26219 |
| 469 | 59.1 | 568 | 510 | 1175.2 | 6651 | 551 | 7410.6 | 26802 |
| 470 | 64.9 | 601 | 511 | 1242.8 | 6873 | 552 | 7681.6 | 27397 |
| 471 | 71.1 | 639 | 512 | 1312.7 | 7103 | 553 | 7958.6 | 28008 |
| 472 | 77.7 | 677 | 513 | 1384.9 | 7343 | 554 | 8241.8 | 28641 |
| 473 | 84.7 | 715 | 514 | 1459.6 | 7599 | 555 | 8531.6 | 29315 |
| 474 | 92.0 | 754 | 515 | 1537.0 | 7879 | 556 | 8828.3 | 30036 |
| 475 | 99.7 | 795 | 516 | 1617.3 | 8179 | 557 | 9132.5 | 30815 |
| 476 | 107.9 | 841 | 517 | 1700.7 | 8507 | 558 | 9444.9 | 31678 |
| 477 | 116.6 | 889 | 518 | 1787.6 | 8891 | 559 | 9766.5 | 32668 |
| 478 | 125.7 | 945 | 519 | 1878.7 | 9335 | 560 | 10099.0 | 33885 |
| 479 | 135.5 | 1014 | 520 | 1974.7 | 9902 | | | |

0 8000 16000 Meters

| ZONE | REF. | REVISION | BY | CKD | DATE |
|---|---|---|---|---|---|

State water

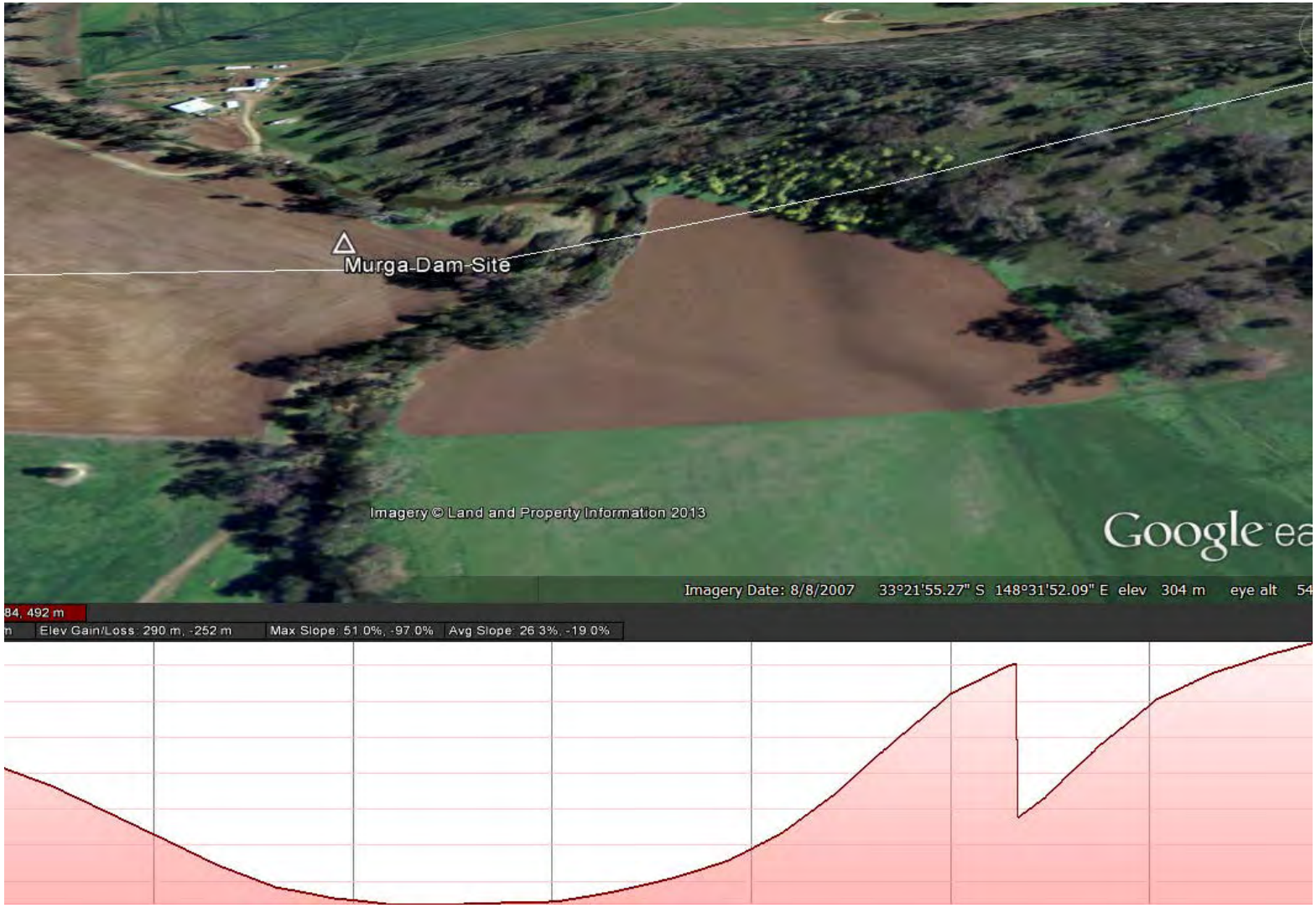
NARRAWA DAM
PROPOSED STORAGE

SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

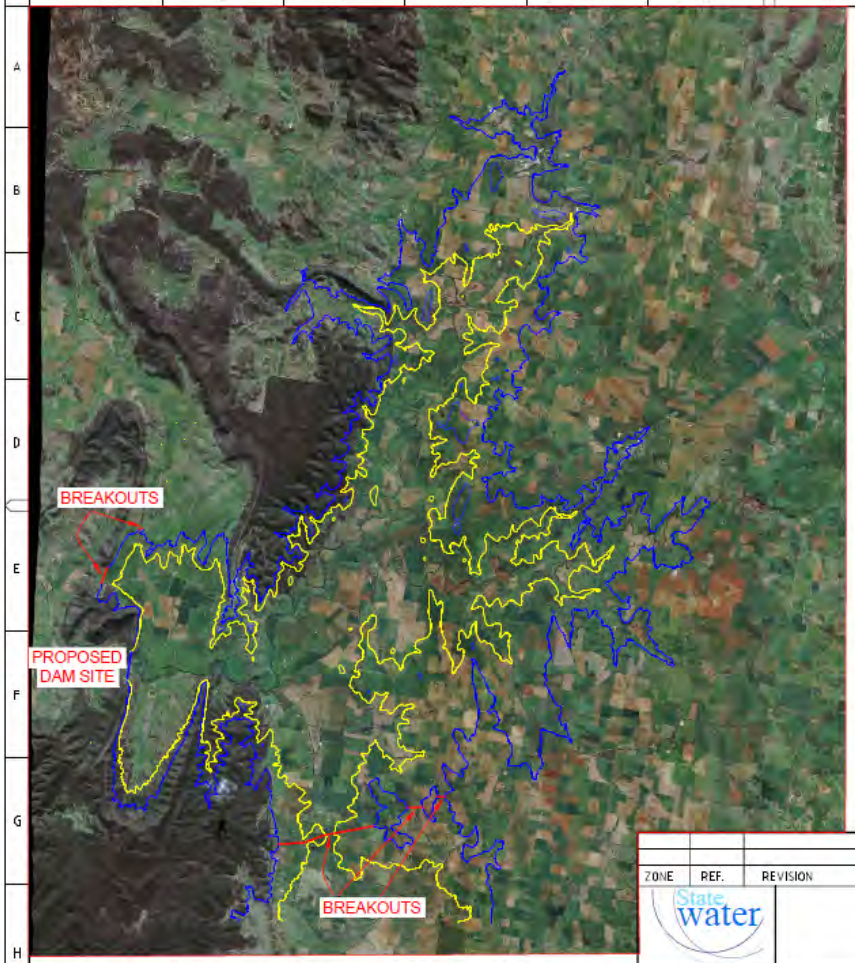
SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: MGA 55
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:250000 | PLAN No: D1N/NNNN | SHT. XXOF YY

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

**MURGA DAM**


Murga Dam Site
Imagery © Land and Property Information 2013
Google ea
Imagery Date: 8/8/2007 33°21'55.27" S 148°31'52.09" E elev 304 m eye alt 54
84, 492 m
Elev Gain/Loss: 290 m, -252 m
Max Slope: 51.0%, -97.0%
Avg Slope: 26.3%, -19.0%

## Staged Storage – MURGA DAM




| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 301 | 0.0 | 0 | 348 | 419.4 | 2681 | 395 | 3724.4 | 12479 |
| 302 | 0.0 | 1 | 349 | 446.7 | 2788 | 396 | 3850.4 | 12724 |
| 303 | 0.0 | 4 | 350 | 475.1 | 2896 | 397 | 3979.0 | 12986 |
| 304 | 0.1 | 9 | 351 | 504.7 | 3014 | 398 | 4110.2 | 13270 |
| 305 | 0.2 | 15 | 352 | 535.5 | 3141 | 399 | 4244.5 | 13588 |
| 306 | 0.4 | 22 | 353 | 567.5 | 3268 | 400 | 4382.2 | 13978 |
| 307 | 0.7 | 33 | 354 | 600.8 | 3398 | 401 | 4524.2 | 14414 |
| 308 | 1.0 | 46 | 355 | 635.5 | 3527 | 402 | 4670.4 | 14810 |
| 309 | 1.6 | 61 | 356 | 671.4 | 3662 | 403 | 4820.2 | 15148 |
| 310 | 2.3 | 79 | 357 | 708.7 | 3807 | 404 | 4973.2 | 15446 |
| 311 | 3.2 | 102 | 358 | 747.6 | 3968 | 405 | 5129.1 | 15721 |
| 312 | 4.3 | 129 | 359 | 788.2 | 4153 | 406 | 5287.5 | 15974 |
| 313 | 5.8 | 159 | 360 | 830.8 | 4386 | 407 | 5448.5 | 16220 |
| 314 | 7.5 | 194 | 361 | 876.0 | 4637 | 408 | 5611.9 | 16462 |
| 315 | 9.7 | 236 | 362 | 923.5 | 4861 | 409 | 5777.8 | 16703 |
| 316 | 12.2 | 276 | 363 | 973.1 | 5075 | 410 | 5946.0 | 16945 |
| 317 | 15.2 | 317 | 364 | 1025.0 | 5290 | 411 | 6116.7 | 17189 |
| 318 | 18.6 | 360 | 365 | 1078.8 | 5473 | 412 | 6289.8 | 17437 |
| 319 | 22.4 | 407 | 366 | 1134.4 | 5652 | 413 | 6465.4 | 17692 |
| 320 | 26.7 | 466 | 367 | 1191.8 | 5829 | 414 | 6643.7 | 17955 |
| 321 | 31.8 | 545 | 368 | 1251.0 | 6014 | 415 | 6824.6 | 18233 |
| 322 | 37.6 | 608 | 369 | 1312.1 | 6196 | 416 | 7008.3 | 18523 |
| 323 | 44.1 | 677 | 370 | 1374.9 | 6374 | 417 | 7195.1 | 18830 |
| 324 | 51.1 | 732 | 371 | 1439.6 | 6551 | 418 | 7385.0 | 19162 |
| 325 | 58.7 | 785 | 372 | 1506.0 | 6730 | 419 | 7578.5 | 19537 |
| 326 | 66.8 | 838 | 373 | 1574.2 | 6913 | 420 | 7776.1 | 20016 |
| 327 | 75.5 | 891 | 374 | 1644.3 | 7101 | 421 | 7979.2 | 20596 |
| 328 | 84.6 | 944 | 375 | 1716.2 | 7298 | 422 | 8187.8 | 21114 |
| 329 | 94.3 | 996 | 376 | 1790.3 | 7507 | 423 | 8401.1 | 21533 |
| 330 | 104.6 | 1050 | 377 | 1866.4 | 7731 | 424 | 8618.2 | 21876 |
| 331 | 115.4 | 1106 | 378 | 1944.9 | 7976 | 425 | 8838.5 | 22170 |
| 332 | 126.7 | 1163 | 379 | 2026.1 | 8259 | 426 | 9061.5 | 22442 |
| 333 | 138.6 | 1221 | 380 | 2110.4 | 8625 | 427 | 9287.3 | 22706 |
| 334 | 151.1 | 1282 | 381 | 2198.8 | 9053 | 428 | 9515.6 | 22968 |
| 335 | 164.3 | 1345 | 382 | 2291.2 | 9420 | 429 | 9746.6 | 23228 |
| 336 | 178.1 | 1412 | 383 | 2387.1 | 9745 | 430 | 9980.2 | 23491 |
| 337 | 192.5 | 1482 | 384 | 2485.9 | 10017 | 431 | 10216.5 | 23759 |
| 338 | 207.7 | 1558 | 385 | 2587.3 | 10263 | 432 | 10455.4 | 24025 |
| 339 | 223.7 | 1645 | 386 | 2691.2 | 10497 | 433 | 10697.0 | 24298 |
| 340 | 240.7 | 1755 | 387 | 2797.3 | 10723 | 434 | 10941.4 | 24579 |
| 341 | 258.9 | 1885 | 388 | 2905.6 | 10941 | 435 | 11188.6 | 24872 |
| 342 | 278.4 | 2008 | 389 | 3016.1 | 11156 | 436 | 11438.9 | 25182 |
| 343 | 299.0 | 2123 | 390 | 3128.7 | 11371 | 437 | 11692.3 | 25509 |
| 344 | 320.8 | 2238 | 391 | 3243.5 | 11585 | 438 | 11949.1 | 25859 |
| 345 | 343.8 | 2351 | 392 | 3360.4 | 11800 | 439 | 12209.6 | 26253 |
| 346 | 367.9 | 2467 | 393 | 3479.5 | 12020 | 440 | 12474.4 | 26727 |
| 347 | 393.1 | 2576 | 394 | 3600.8 | 12245 | | | |

NOTE:- YELLOW LINE IS 400 METRE CONTOUR
BLUE LINE IS 440 METRE CONTOUR

| ZONE | REF. | REVISION | BY | CKD | DATE |
|---|---|---|---|---|---|

State water

MURGA DAM
PROPOSED STORAGE

SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

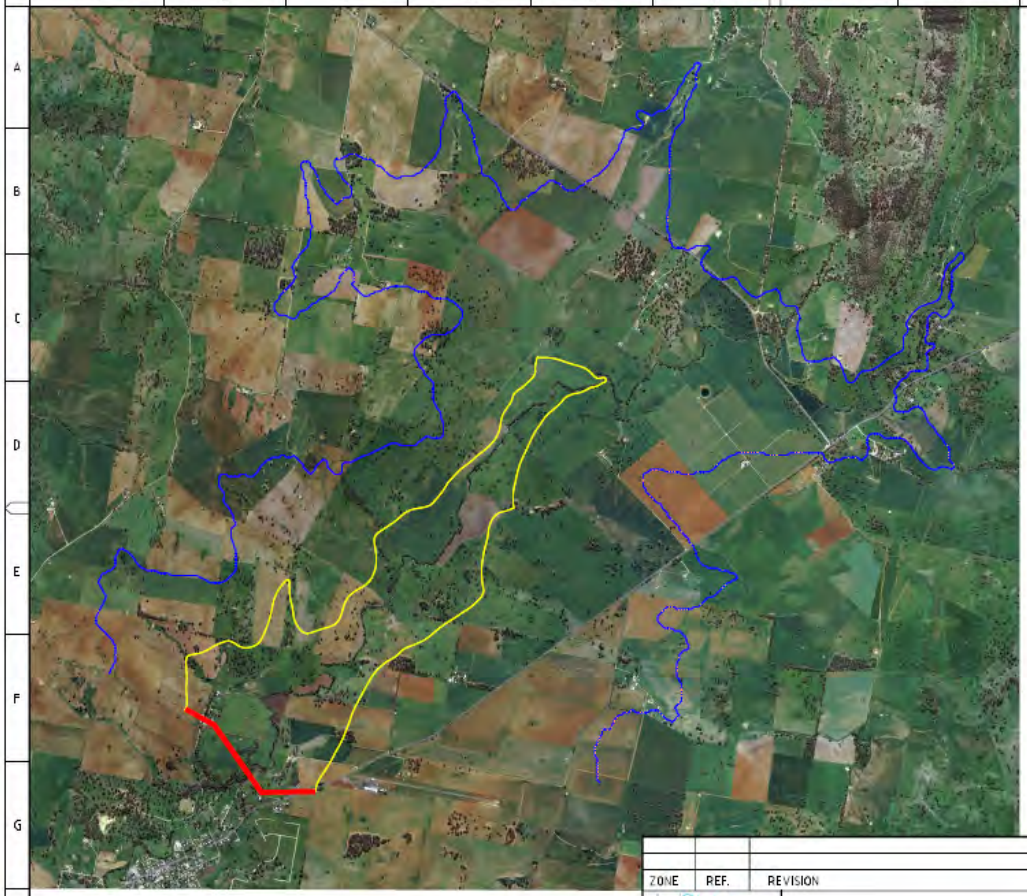
SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: MGA 55
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:50000 | PLAN No: D1N/NNNN | SHT. 1 OF 1

A3

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

**BOREE CREEK DAM**

## Staged Storage – BOREE CREEK DAM (CUDAL)



| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|
| 441 | 0.00 | 0 | 471 | 44.56 | 530 |
| 442 | 0.00 | 0 | 472 | 50.05 | 568 |
| 443 | 0.01 | 1 | 473 | 55.92 | 607 |
| 444 | 0.03 | 3 | 474 | 62.21 | 651 |
| 445 | 0.07 | 5 | 475 | 68.96 | 699 |
| 446 | 0.13 | 9 | 476 | 76.20 | 749 |
| 447 | 0.25 | 13 | 477 | 83.96 | 803 |
| 448 | 0.40 | 18 | 478 | 92.27 | 860 |
| 449 | 0.61 | 24 | 479 | 101.19 | 926 |
| 450 | 0.88 | 30 | 480 | 110.87 | 1020 |
| 451 | 1.22 | 37 | 481 | 121.80 | 1163 |
| 452 | 1.61 | 43 | 482 | 134.11 | 1292 |
| 453 | 2.08 | 50 | 483 | 147.58 | 1400 |
| 454 | 2.62 | 58 | 484 | 162.08 | 1500 |
| 455 | 3.24 | 66 | 485 | 177.57 | 1595 |
| 456 | 3.94 | 75 | 486 | 193.97 | 1685 |
| 457 | 4.74 | 86 | 487 | 211.26 | 1773 |
| 458 | 5.66 | 98 | 488 | 229.45 | 1865 |
| 459 | 6.71 | 113 | 489 | 248.55 | 1955 |
| 460 | 7.93 | 135 | 490 | 268.53 | 2041 |
| 461 | 9.44 | 168 | 491 | 289.37 | 2126 |
| 462 | 11.31 | 206 | 492 | 311.04 | 2209 |
| 463 | 13.60 | 251 | 493 | 333.54 | 2292 |
| 464 | 16.29 | 286 | 494 | 356.89 | 2378 |
| 465 | 19.32 | 319 | 495 | 381.11 | 2467 |
| 466 | 22.66 | 351 | 496 | 406.24 | 2558 |
| 467 | 26.33 | 384 | 497 | 432.30 | 2654 |
| 468 | 30.34 | 418 | 498 | 459.35 | 2757 |
| 469 | 34.71 | 455 | 499 | 487.49 | 2874 |
| 470 | 39.44 | 492 | 500 | 516.91 | 3021 |

NOTE: - YELLOW LINE IS 470 METRE CONTOUR
BLUE LINE IS 500 METRE CONTOUR

ZONE | REF. | REVISION | BY | CKD | DATE

State water

BOREE CREEK DAM
(CUDAL)

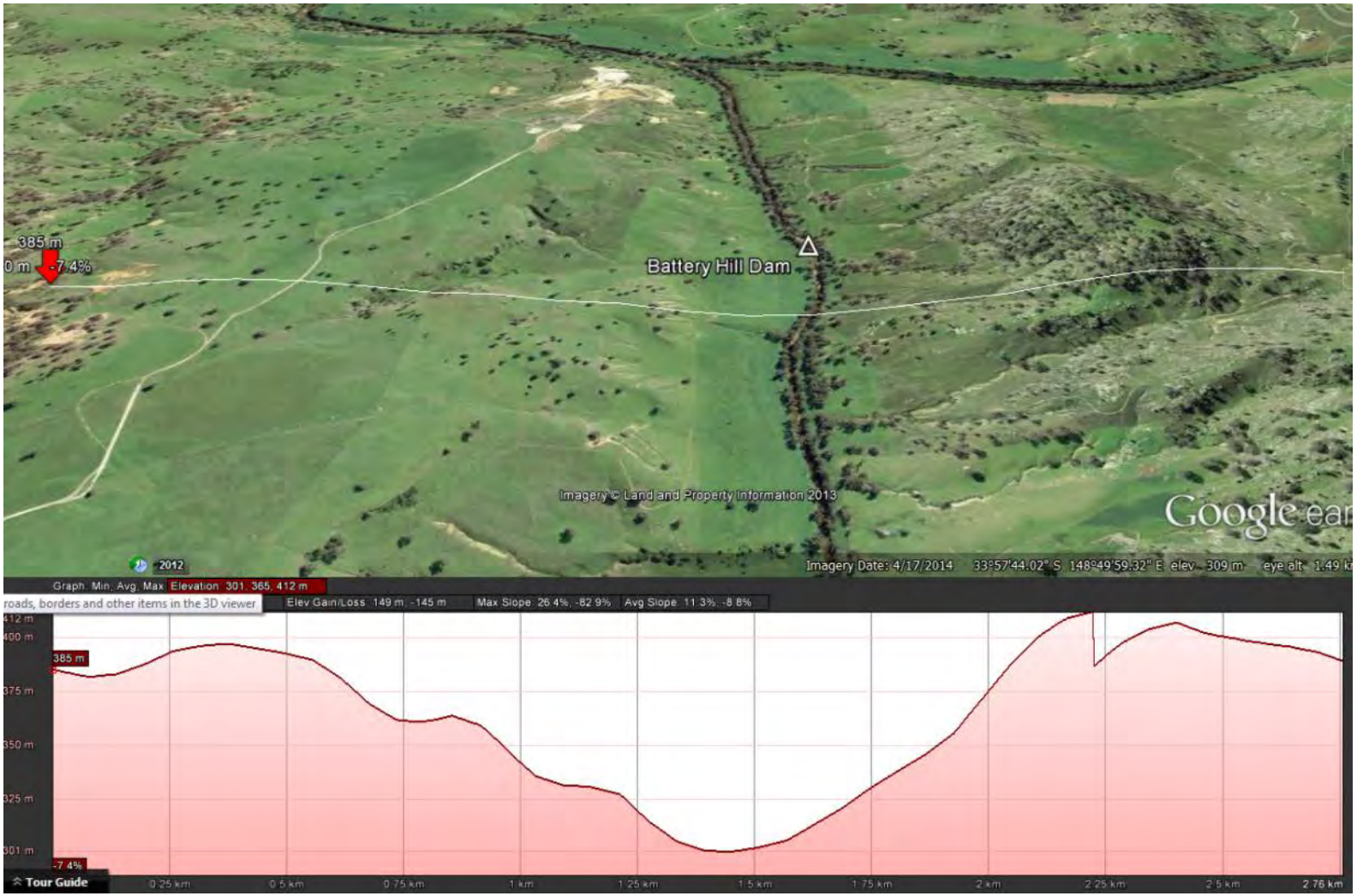
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: GRID
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:40000 | PLAN No: D1N/NNNN | SHT. XXOF YY

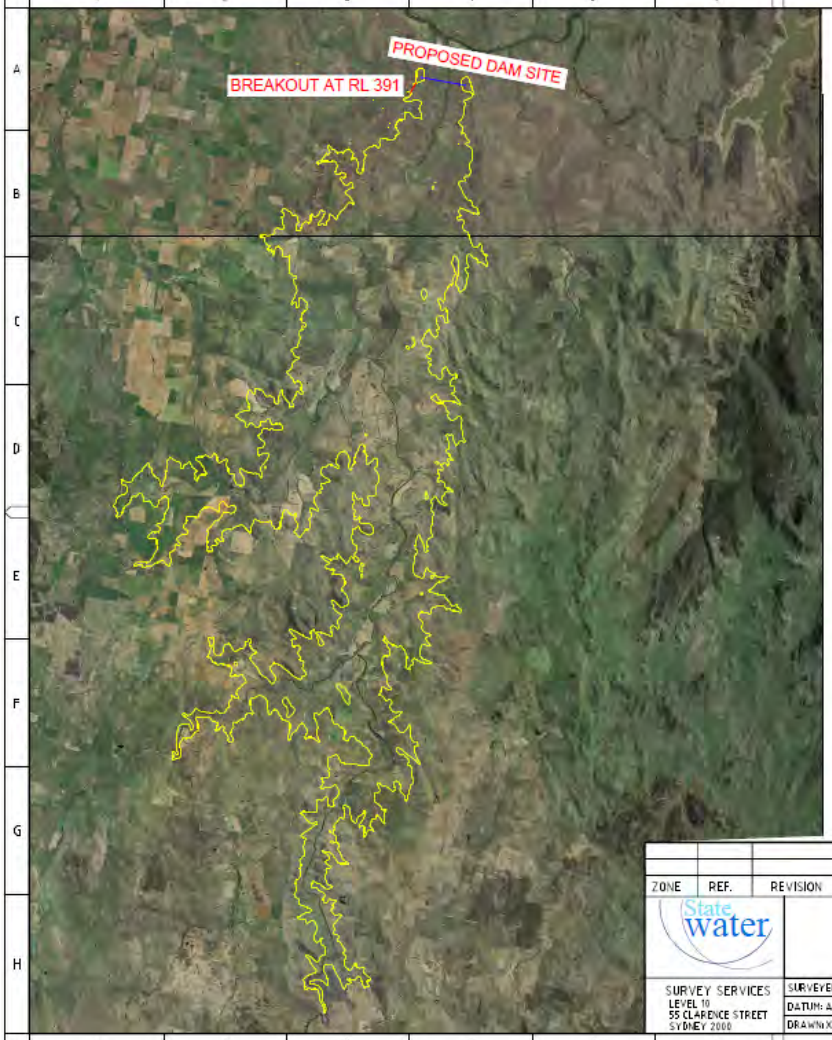
A3

0 1200 2400 Meters

## BATTERY HILL DAM



## Staged Storage – BATTERY HILL DAM




| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 295 | 0.0 | 0 | 331 | 230.7 | 2120 | 367 | 2108.6 | 8632 |
| 296 | 0.0 | 0 | 332 | 252.5 | 2239 | 368 | 2195.7 | 8788 |
| 297 | 0.0 | 3 | 333 | 275.5 | 2366 | 369 | 2284.3 | 8946 |
| 298 | 0.1 | 11 | 334 | 299.8 | 2493 | 370 | 2374.6 | 9105 |
| 299 | 0.3 | 27 | 335 | 325.4 | 2627 | 371 | 2466.4 | 9264 |
| 300 | 0.7 | 59 | 336 | 352.4 | 2774 | 372 | 2559.9 | 9426 |
| 301 | 1.4 | 82 | 337 | 380.9 | 2922 | 373 | 2655.0 | 9593 |
| 302 | 2.3 | 102 | 338 | 410.9 | 3084 | 374 | 2751.7 | 9764 |
| 303 | 3.4 | 122 | 339 | 442.6 | 3270 | 375 | 2850.3 | 9945 |
| 304 | 4.7 | 141 | 340 | 476.4 | 3514 | 376 | 2950.7 | 10136 |
| 305 | 6.3 | 160 | 341 | 513.1 | 3809 | 377 | 3053.0 | 10335 |
| 306 | 8.0 | 180 | 342 | 552.6 | 4095 | 378 | 3157.4 | 10545 |
| 307 | 9.9 | 202 | 343 | 594.7 | 4304 | 379 | 3264.0 | 10773 |
| 308 | 12.0 | 225 | 344 | 638.6 | 4477 | 380 | 3373.0 | 11037 |
| 309 | 14.4 | 253 | 345 | 684.2 | 4635 | 381 | 3484.8 | 11314 |
| 310 | 17.1 | 281 | 346 | 731.3 | 4784 | 382 | 3599.2 | 11563 |
| 311 | 20.0 | 311 | 347 | 779.8 | 4932 | 383 | 3715.9 | 11787 |
| 312 | 23.3 | 344 | 348 | 829.9 | 5078 | 384 | 3834.8 | 11987 |
| 313 | 26.9 | 380 | 349 | 881.4 | 5220 | 385 | 3955.6 | 12174 |
| 314 | 30.9 | 420 | 350 | 934.3 | 5361 | 386 | 4078.3 | 12360 |
| 315 | 35.3 | 464 | 351 | 988.6 | 5500 | 387 | 4202.8 | 12544 |
| 316 | 40.2 | 514 | 352 | 1044.3 | 5642 | 388 | 4329.2 | 12727 |
| 317 | 45.6 | 574 | 353 | 1101.5 | 5792 | 389 | 4457.4 | 12911 |
| 318 | 51.7 | 643 | 354 | 1160.1 | 5944 | 390 | 4587.4 | 13092 |
| 319 | 58.5 | 721 | 355 | 1220.4 | 6103 | 391 | 4719.2 | 13275 |
| 320 | 66.2 | 826 | 356 | 1282.2 | 6270 | 392 | 4852.9 | 13456 |
| 321 | 75.2 | 957 | 357 | 1345.8 | 6449 | 393 | 4988.4 | 13640 |
| 322 | 85.4 | 1086 | 358 | 1411.3 | 6645 | 394 | 5125.7 | 13829 |
| 323 | 96.9 | 1219 | 359 | 1478.8 | 6869 | 395 | 5265.0 | 14027 |
| 324 | 109.7 | 1338 | 360 | 1548.8 | 7144 | 396 | 5406.3 | 14235 |
| 325 | 123.6 | 1453 | 361 | 1621.9 | 7460 | 397 | 5549.7 | 14456 |
| 326 | 138.7 | 1557 | 362 | 1697.9 | 7731 | 398 | 5695.5 | 14694 |
| 327 | 154.8 | 1668 | 363 | 1776.3 | 7953 | 399 | 5843.7 | 14957 |
| 328 | 172.1 | 1786 | 364 | 1856.8 | 8142 | 400 | 5994.7 | 15263 |
| 329 | 190.5 | 1896 | 365 | 1939.1 | 8312 | | | |
| 330 | 210.0 | 2007 | 366 | 2023.0 | 8473 | | | |

NOTE:- YELLOW LINE IS 400 METRE CONTOUR

0 5000 10000 Meters

ZONE | REF. | REVISION | BY | CKD | DATE

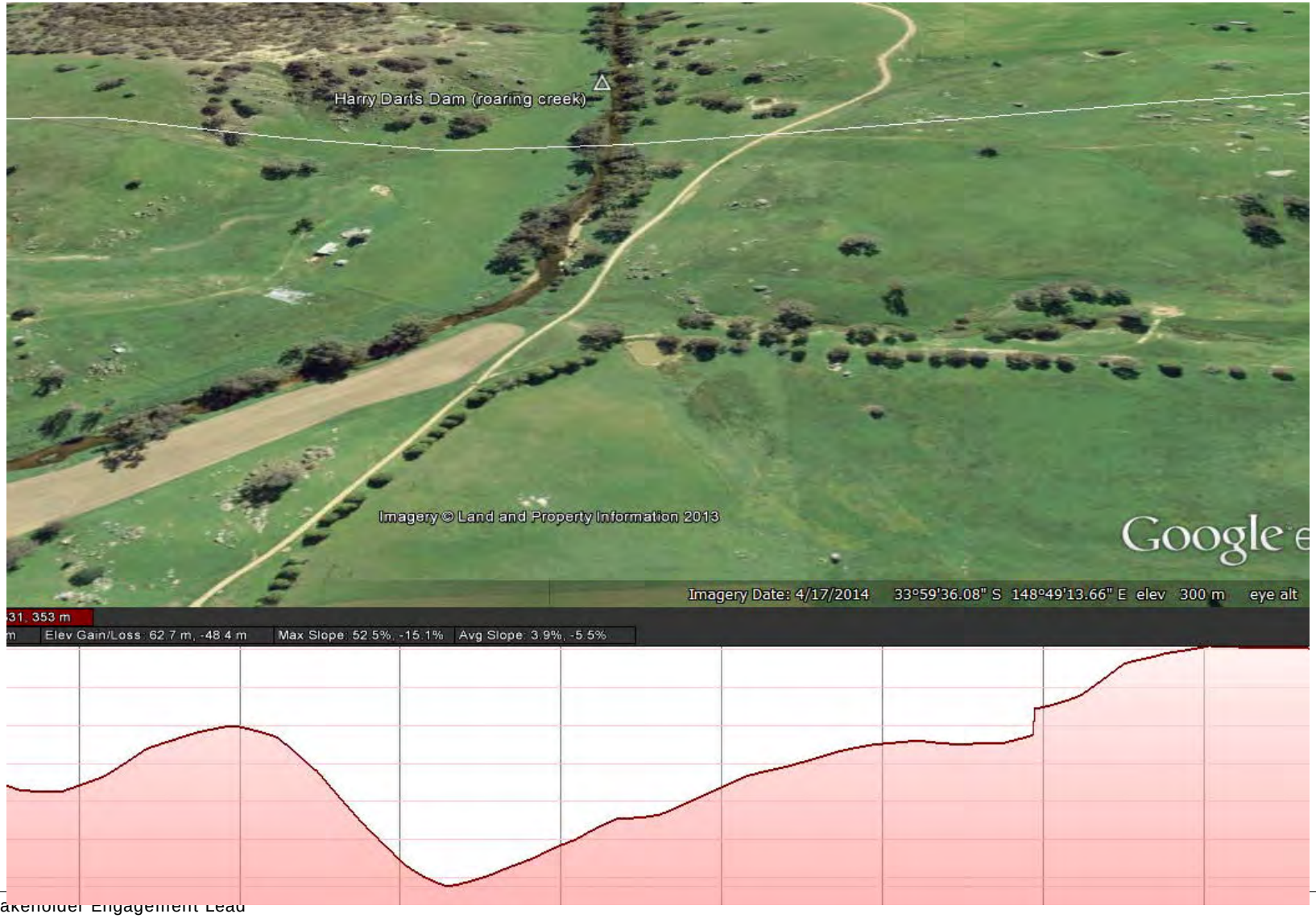
State water

BATTERY HILL DAM
PROPOSED STORAGE
RL 400 METRES

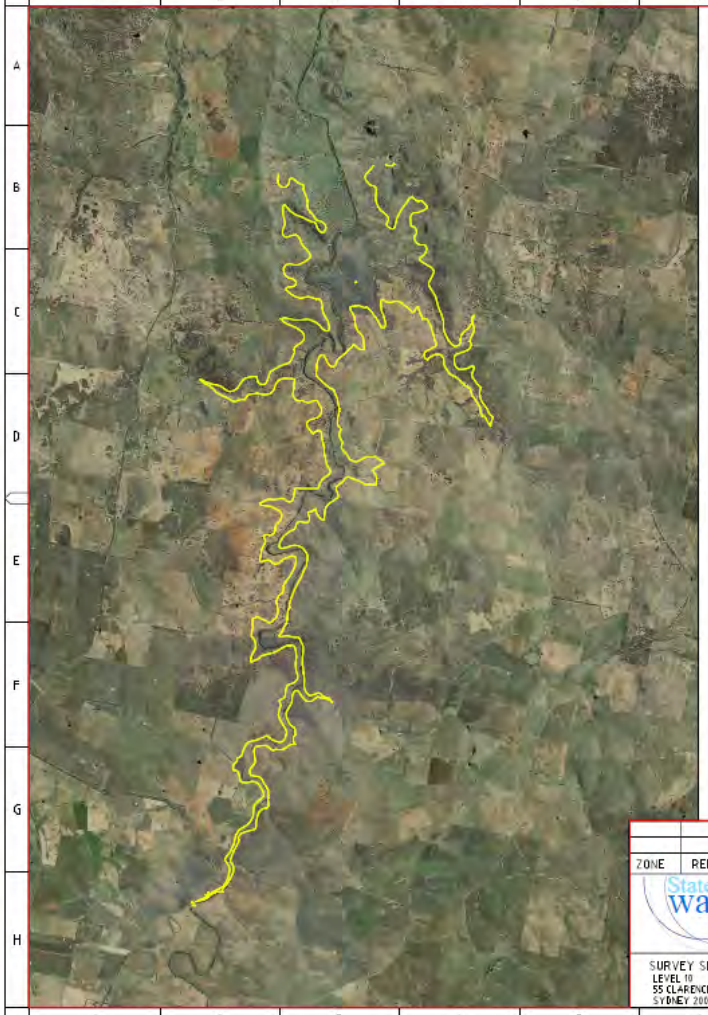
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: GRID
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:150000 | PLAN No: D1N/NNNN | SHT. XXXOF YY

**HARRY DARTS DAM**



## Staged Storage – HARRY DARTS DAM



| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 354 | 0.0 | 0 | 384 | 11.4 | 99 | 414 | 71.3 | 340 |
| 355 | 0.0 | 0 | 385 | 12.4 | 104 | 415 | 74.8 | 355 |
| 356 | 0.0 | 0 | 386 | 13.4 | 108 | 416 | 78.4 | 370 |
| 357 | 0.0 | 0 | 387 | 14.6 | 113 | 417 | 82.2 | 386 |
| 358 | 0.0 | 0 | 388 | 15.7 | 118 | 418 | 86.2 | 404 |
| 359 | 0.0 | 5 | 389 | 16.9 | 123 | 419 | 90.3 | 423 |
| 360 | 0.1 | 10 | 390 | 18.2 | 128 | 420 | 94.6 | 444 |
| 361 | 0.2 | 13 | 391 | 19.5 | 134 | 421 | 99.2 | 467 |
| 362 | 0.4 | 16 | 392 | 20.8 | 139 | 422 | 104.0 | 488 |
| 363 | 0.5 | 18 | 393 | 22.3 | 145 | 423 | 108.9 | 510 |
| 364 | 0.7 | 20 | 394 | 23.7 | 151 | 424 | 114.2 | 532 |
| 365 | 0.9 | 22 | 395 | 25.3 | 157 | 425 | 119.6 | 554 |
| 366 | 1.1 | 24 | 396 | 26.9 | 164 | 426 | 125.2 | 577 |
| 367 | 1.4 | 26 | 397 | 28.6 | 171 | 427 | 131.1 | 600 |
| 368 | 1.7 | 29 | 398 | 30.3 | 179 | 428 | 137.2 | 623 |
| 369 | 2.0 | 31 | 399 | 32.1 | 188 | 429 | 143.6 | 647 |
| 370 | 2.3 | 34 | 400 | 34.1 | 198 | 430 | 150.2 | 673 |
| 371 | 2.7 | 38 | 401 | 36.1 | 209 | 431 | 157.0 | 700 |
| 372 | 3.1 | 41 | 402 | 38.3 | 218 | 432 | 164.2 | 727 |
| 373 | 3.5 | 45 | 403 | 40.5 | 227 | 433 | 171.6 | 756 |
| 374 | 4.0 | 49 | 404 | 42.8 | 236 | 434 | 179.3 | 787 |
| 375 | 4.5 | 54 | 405 | 45.2 | 245 | 435 | 187.3 | 819 |
| 376 | 5.0 | 59 | 406 | 47.7 | 254 | 436 | 195.7 | 854 |
| 377 | 5.7 | 63 | 407 | 50.3 | 264 | 437 | 204.4 | 893 |
| 378 | 6.3 | 68 | 408 | 53.0 | 274 | 438 | 213.6 | 935 |
| 379 | 7.0 | 74 | 409 | 55.8 | 284 | 439 | 223.2 | 983 |
| 380 | 7.8 | 80 | 410 | 58.6 | 295 | 440 | 233.3 | 1039 |
| 381 | 8.6 | 85 | 411 | 61.6 | 305 | 441 | 244.0 | 1100 |
| 382 | 9.5 | 90 | 412 | 64.8 | 317 | 442 | 255.2 | 1158 |
| 383 | 10.4 | 94 | 413 | 68.0 | 328 | 443 | 267.1 | 1219 |
| | | | | | | 444 | 279.6 | 1278 |

NOTE: - YELLOW LINE IS RL444 METRE CONTOUR

0 2400 4800 Meters

| ZONE | REF. | REVISION | BY | CKD | DATE |
|---|---|---|---|---|---|

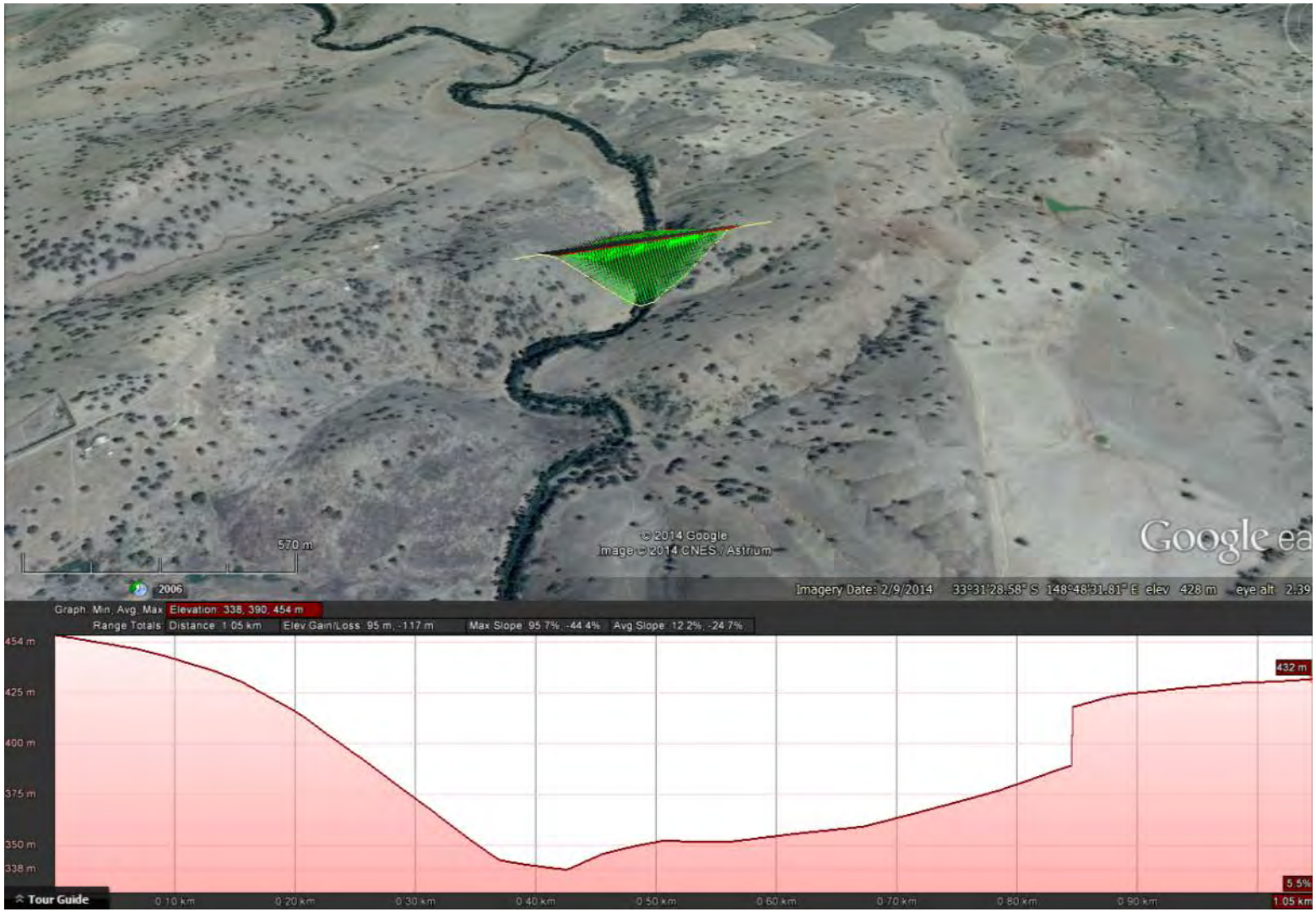
State water

HARRY DARTS DAM
PROPOSED STORAGE

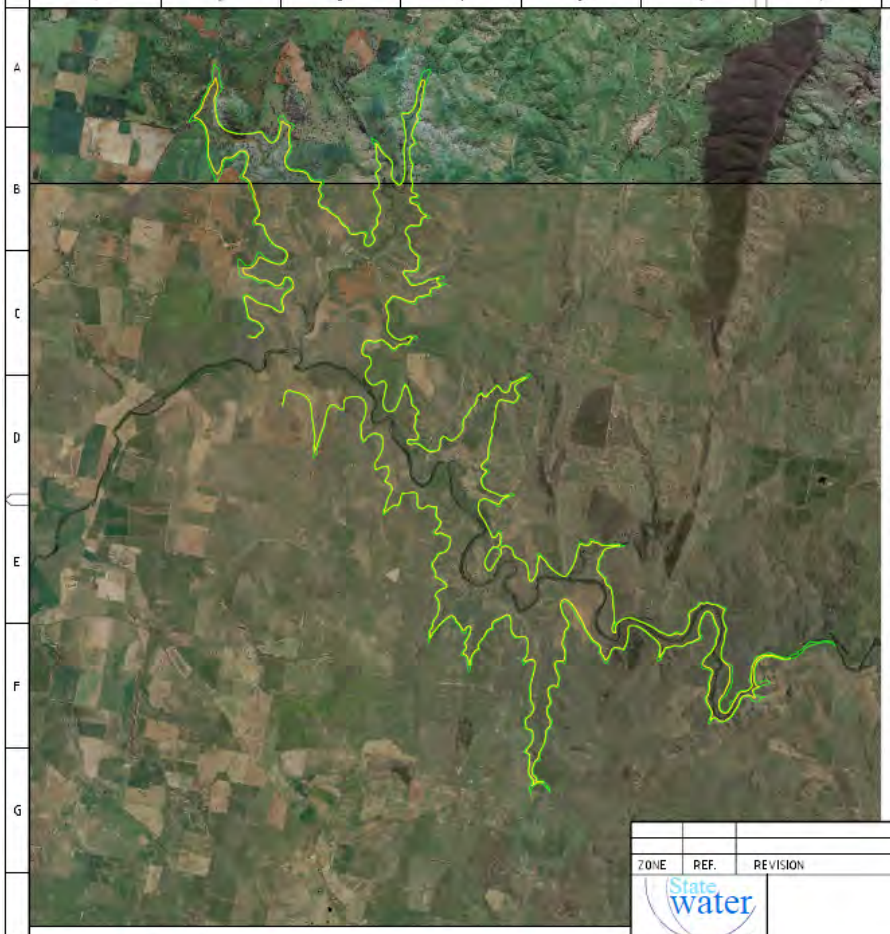
SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: MGA-55
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:40000 | PLAN No: D1N/NNNN | SHT. XXOF YY

**CRANKY ROCK 1 (UPSTREAM – 700 GL)**



**Staged Storage – CRANKY ROCK 1**




| Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) | Water Level | Total Volume (GL) | Water Surface Area (Ha) |
|---|---|---|---|---|---|---|---|---|
| 319 | 0.0 | 0 | 346 | 24.7 | 301 | 373 | 236.6 | 1402 |
| 320 | 0.0 | 0 | 347 | 27.9 | 324 | 374 | 250.8 | 1452 |
| 321 | 0.0 | 1 | 348 | 31.2 | 348 | 375 | 265.6 | 1503 |
| 322 | 0.0 | 3 | 349 | 34.8 | 375 | 376 | 280.9 | 1557 |
| 323 | 0.1 | 4 | 350 | 38.7 | 401 | 377 | 296.7 | 1614 |
| 324 | 0.1 | 7 | 351 | 42.9 | 428 | 378 | 313.2 | 1676 |
| 325 | 0.2 | 11 | 352 | 47.3 | 456 | 379 | 330.3 | 1743 |
| 326 | 0.3 | 15 | 353 | 52.0 | 484 | 380 | 348.1 | 1820 |
| 327 | 0.5 | 20 | 354 | 57.0 | 514 | 381 | 366.7 | 1900 |
| 328 | 0.7 | 26 | 355 | 62.3 | 546 | 382 | 386.1 | 1983 |
| 329 | 1.0 | 33 | 356 | 67.9 | 582 | 383 | 406.3 | 2057 |
| 330 | 1.4 | 40 | 357 | 73.9 | 621 | 384 | 427.2 | 2125 |
| 331 | 1.9 | 48 | 358 | 80.3 | 662 | 385 | 448.8 | 2188 |
| 332 | 2.4 | 57 | 359 | 87.2 | 709 | 386 | 471.0 | 2251 |
| 333 | 3.0 | 67 | 360 | 94.5 | 767 | 387 | 493.8 | 2314 |
| 334 | 3.7 | 78 | 361 | 102.5 | 829 | 388 | 517.3 | 2379 |
| 335 | 4.6 | 89 | 362 | 111.1 | 880 | 389 | 541.4 | 2441 |
| 336 | 5.5 | 100 | 363 | 120.1 | 930 | 390 | 566.1 | 2503 |
| 337 | 6.6 | 113 | 364 | 129.7 | 978 | 391 | 591.4 | 2565 |
| 338 | 7.8 | 127 | 365 | 139.7 | 1025 | 392 | 617.4 | 2629 |
| 339 | 9.1 | 143 | 366 | 150.2 | 1071 | 393 | 644.0 | 2694 |
| 340 | 10.7 | 166 | 367 | 161.1 | 1116 | 394 | 671.3 | 2761 |
| 341 | 12.4 | 192 | 368 | 172.5 | 1162 | 395 | 699.3 | 2833 |
| 342 | 14.5 | 213 | 369 | 184.4 | 1209 | 396 | 728.0 | 2908 |
| 343 | 16.7 | 234 | 370 | 196.7 | 1257 | 397 | 757.4 | 2990 |
| 344 | 19.2 | 256 | 371 | 209.5 | 1305 | 398 | 787.8 | 3080 |
| 345 | 21.8 | 279 | 372 | 222.8 | 1353 | | | |

NOTE: YELLOW LINE IS 395 METRE CONTOUR
GREEN LINE IS 398 METRE CONTOUR

ZONE | REF. | REVISION | BY | CKD | DATE

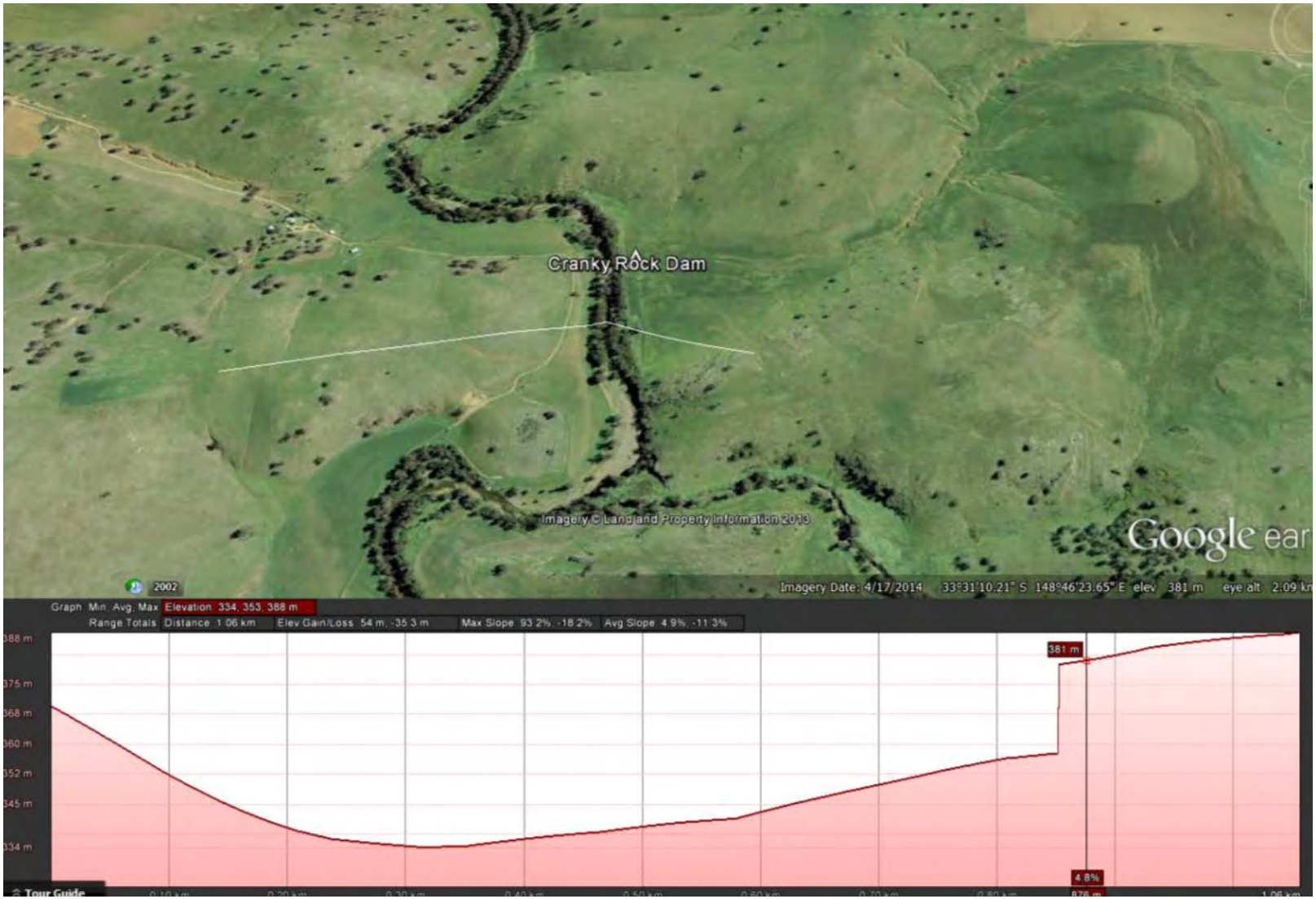
State water

CRANKY ROCK DAM
SITE 1

SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

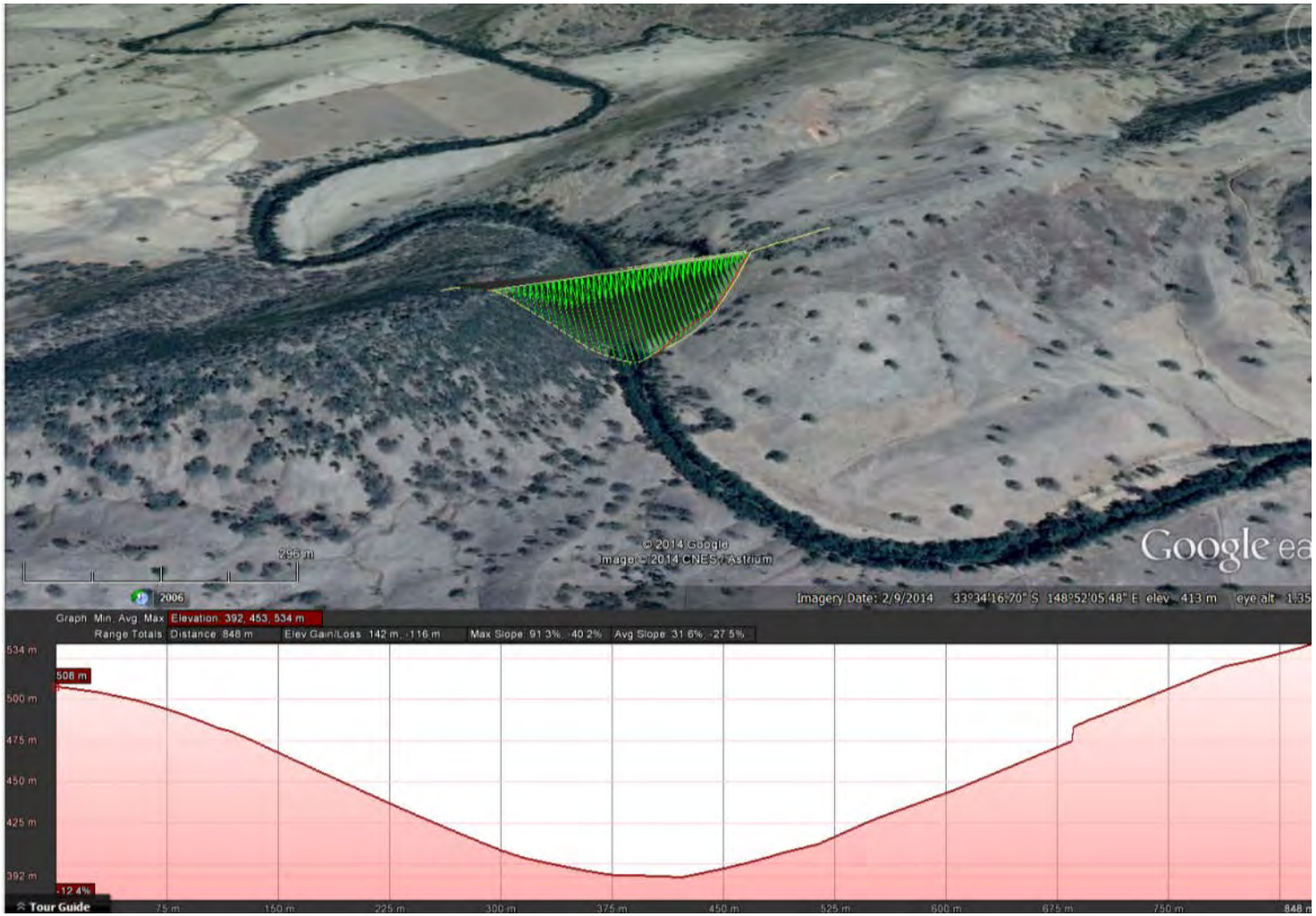
SURVEYED: X.X | FIELD BOOK: IN/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3
DATUM: A.H.D. | RL ORIGIN: BM | COORD. SYSTEM: GRID
DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1:40000 | PLAN No: D1N/NNNN | SHT. XX OF YY

## CRANKY ROCK 2 (DOWNSTREAM)

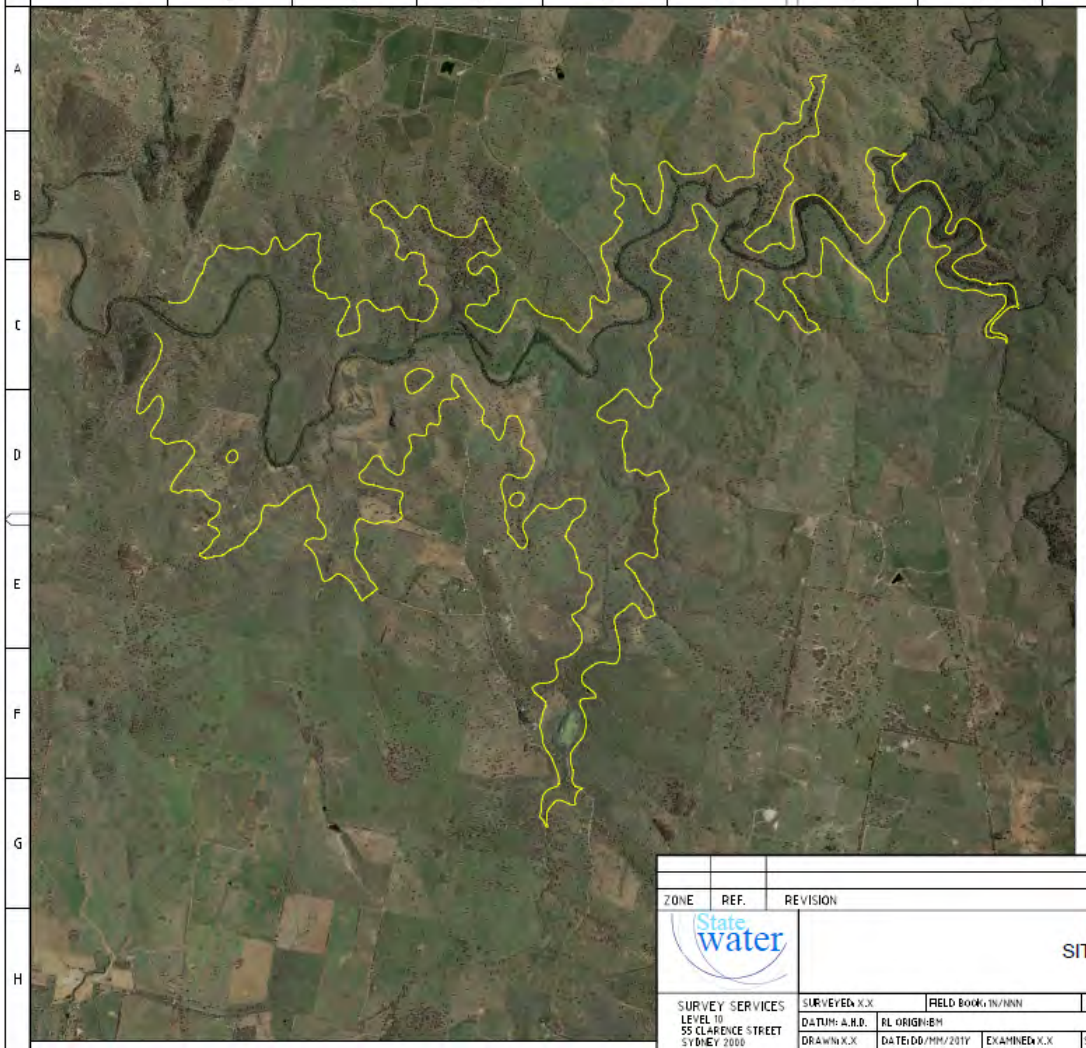



Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

**NEEDLES DAM**


© 2014 Google
Image © 2014 CNES / Astrium
Google ea
2006
Imagery Date: 2/9/2014 33°34'16.70" S 148°52'05.48" E elev 413 m eye alt 1.35
Graph Min, Avg, Max Elevation 392, 453, 534 m
Range Totals Distance 848 m Elev Gain/Loss 142 m, -116 m Max Slope 91.3%, -40.2% Avg Slope 31.6%, -27.5%
534 m
500 m
475 m
450 m
425 m
392 m
508 m
-12.4%
Tour Guide
75 m
150 m
225 m
300 m
375 m
450 m
525 m
600 m
675 m
750 m
848 m

## Staged Storage – NEEDLES DAM



| Water Level | Total Volume (GL.) | Water Surface Area(Ha.) | Water Level | Total Volume (GL.) | Water Surface Area(Ha.) | Water Level | Total Volume (GL.) | Water Surface Area(Ha.) |
|---|---|---|---|---|---|---|---|---|
| 374 | 0 | 0 | 406 | 34 | 344 | 438 | 255 | 1100 |
| 375 | 0 | 0 | 407 | 37 | 361 | 439 | 266 | 1135 |
| 376 | 0 | 1 | 408 | 41 | 379 | 440 | 278 | 1176 |
| 377 | 0 | 2 | 409 | 45 | 397 | 441 | 290 | 1213 |
| 378 | 0 | 4 | 410 | 49 | 415 | 442 | 302 | 1248 |
| 379 | 0 | 6 | 411 | 53 | 432 | 443 | 315 | 1282 |
| 380 | 0 | 9 | 412 | 57 | 451 | 444 | 327 | 1315 |
| 381 | 0 | 12 | 413 | 62 | 469 | 445 | 341 | 1348 |
| 382 | 0 | 15 | 414 | 67 | 488 | 446 | 354 | 1380 |
| 383 | 1 | 19 | 415 | 72 | 508 | 447 | 368 | 1416 |
| 384 | 1 | 23 | 416 | 77 | 529 | 448 | 383 | 1453 |
| 385 | 1 | 29 | 417 | 82 | 550 | 449 | 397 | 1489 |
| 386 | 1 | 36 | 418 | 88 | 574 | 450 | 413 | 1526 |
| 387 | 2 | 44 | 419 | 94 | 600 | 451 | 428 | 1563 |
| 388 | 2 | 55 | 420 | 100 | 629 | 452 | 444 | 1601 |
| 389 | 3 | 64 | 421 | 106 | 662 | 453 | 460 | 1639 |
| 390 | 4 | 73 | 422 | 113 | 690 | 454 | 477 | 1680 |
| 391 | 4 | 82 | 423 | 120 | 714 | 455 | 494 | 1723 |
| 392 | 5 | 92 | 424 | 127 | 736 | 456 | 511 | 1768 |
| 393 | 6 | 101 | 425 | 135 | 760 | 457 | 529 | 1816 |
| 394 | 7 | 112 | 426 | 143 | 784 | 458 | 547 | 1868 |
| 395 | 8 | 123 | 427 | 151 | 809 | 459 | 566 | 1924 |
| 396 | 10 | 135 | 428 | 159 | 834 | 460 | 586 | 1988 |
| 397 | 11 | 149 | 429 | 167 | 858 | 461 | 606 | 2053 |
| 398 | 13 | 165 | 430 | 176 | 883 | 462 | 627 | 2111 |
| 399 | 14 | 183 | 431 | 185 | 907 | 463 | 648 | 2165 |
| 400 | 16 | 208 | 432 | 194 | 932 | 464 | 670 | 2213 |
| 401 | 19 | 247 | 433 | 204 | 957 | 465 | 693 | 2260 |
| 402 | 21 | 269 | 434 | 213 | 984 | 466 | 715 | 2306 |
| 403 | 24 | 288 | 435 | 223 | 1011 | 467 | 739 | 2351 |
| 404 | 27 | 308 | 436 | 233 | 1039 | 468 | 762 | 2396 |
| 405 | 30 | 327 | 437 | 244 | 1069 | 469 | 787 | 2441 |
| | | | | | | 470 | 811 | 2486 |

NOTE:- YELLOW LINE IS 467 METRE CONTOUR

0 2000 4000 Meters

| ZONE | REF. | REVISION | BY | CKD | DATE |
|---|---|---|---|---|---|

State water

NEEDLE GAP DAM
SITE A 700 GL STORAGE

SURVEY SERVICES
LEVEL 10
55 CLARENCE STREET
SYDNEY 2000

| | | | | |
|---|---|---|---|---|
| SURVEYED: X.X | FIELD BOOK: 1N/NNN | DATE: DD/MM/201Y | DRAWING FILE: D1N_NNNN.DWG | A3 |
| DATUM: A.H.D. | RL ORIGIN: BM | | COORD. SYSTEM: GRID | |
| DRAWN: X.X | DATE: DD/MM/201Y | EXAMINED: X.X | SCALE: 1 | PLAN NO: D1N/NNNN SHT. 1 OF 1 |

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

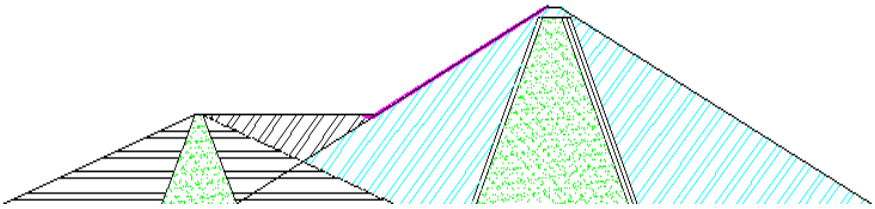
**Stage 2 - Detailed Assessment**

The objective of this stage of the assessment was to identify the most appropriate dam type for each site to undertake further cost comparative estimation. The short-listed options identified during Stage 1 have been further reviewed against other available information.

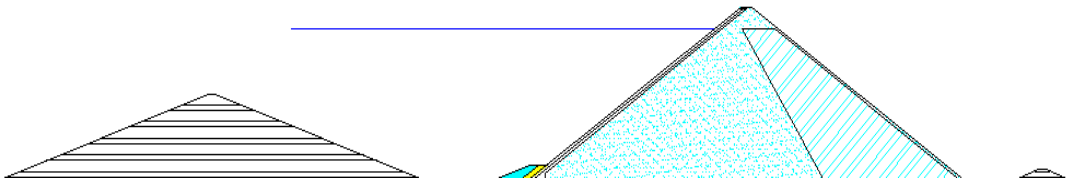
The short-listed sites include:

- Abercrombie
- Battery Hill
- Cranky Rock
- Narrawa
- Needles
- Raising Wyangala

The dam types for individual sites have been collaboratively determined with relevant Water NSW stakeholders. Data used for the assessment includes information provided by Water NSW, other publicly available data and best engineering judgement. Due to the nature of the study and lack of detailed field data, the proposed type may not be an optimised engineering solution. However for this level of comparative assessment, the dam type identified in this study is deemed adequate.



**Zoned Earthfill Dam (showing upstream cofferdam)**



**Concrete Face Rockfill Dam (showing upstream cofferdam)**

Detailed assumptions and outcomes of the cost comparative assessment are presented in later sections of this report.

**Abercrombie Dam**

To store 700 GL, the full supply level (FSL) will be at approximately 510 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately 520 m AHD.

**Abercrombie Dam dimensions**

| Height of Dam (m) | Length of dam (m) |
|---|---|
| 100.2 | ~ 600 |

Locally available materials:

- Alluvial deposits, possible shallow and unknown quantity.
- Rock is likely to be at a shallow depth with quantity unknown. Rock (andesite) should be of good quality.
- The nearest quarry is at considerable distance from the dam site. However material obtained from excavation of the spillway can be utilised for the dam construction. In addition, the new auxiliary spillway at Wyangala could be a good source of rock depending on the timing.

Assumptions:

- A Roller Compacted Concrete (RCC) dam is feasible if good quality rocks are available locally. If rocks can be found at a relatively shallow depth, the grade of batter can be 0.7H:1V. Part of dam crest could be shaped as an overflow stepped spillway. A RCC dam is less susceptible to scour and erosion during construction. The design of the size of cofferdam and flood diversion can be reduced which impacts the overall cost.
- A concrete face rock fill dam (CFRD) is a good alternative if foundation for a gravity dam (RCC) is uncertain. A CFRD generally has higher construction cost when compared to a RCC dam. For comparative purpose, a CFRD has been considered for this site. Should this site become favourable, both RCC and CFRD dam options need to be further investigated.
- The right abutment appears to be a suitable site for the spillway, chute and dissipating basin.

**Battery Hill Dam**

To store 500 GL, the FSL will be at approximately 337.6 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately 349.6 m AHD.

**Battery Hill Dam dimensions**

| Height of Dam (m) | Length of dam (m) |
|---|---|
| 54.6 | ~ 908 |

Locally available materials:

- Alluvial deposits to unknown depth.
- Rock is likely to be at a shallow depth with quantity unknown. Rocks are likely to be granite and basalt.
- Quarries are within 1 km from the dam site.

Assumptions:

- An earth and rockfill dam appears to be the appropriate dam choice for this site. This is due to the probable foundation rock and geomorphology. Availability of suitable local rock as fill material needs to be confirmed.
- A concrete gravity section may be required at the spillway where alluvial deposit is most shallow.
- An unlined diversion tunnel may be required.
- If an embankment dam is selected, the right abutment appears to be a suitable location for a spillway, chute and dissipating basin.

**Cranky Rock Dam Site 5 (Oak Pride)**

To store 700 GL, the FSL will be at approximately +395 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately +406 m AHD.

**Cranky Rock Dam dimensions**

| Height of Dam (m) | Length of dam (m) |
|---|---|
| 87 | ~ 657 |

Locally available materials:

- Alluvial deposits to unknown depth.
- Rock is likely to be at a shallow depth with quantity unknown. Rocks are sandstone/siltstone/limestone of unknown strength.
- Previous geological assessments (e.g. Geological Surveyor Report (1946), Chief Engineer Report (1967)) described 20 ft to 40 ft of alluvial deposits in the river bed.
- The Geological Surveyor's report (1946) described the foundation rock being fine grained tuffs with beds of coarser felspathic tuffs and cherty shale. Seven boreholes were drilled along the centreline of the proposed dam. Greater depth of weathering was found in the upper slopes where drilling was down to 21 m without getting satisfactory cores.
- The nearest quarry is about 25 km from the dam site. Some old borrow pits can be found in the area.

Assumptions:

- An earth and rockfill dam appears to be the appropriate dam choice for this site. Availability of suitable local rock as fill material needs to be confirmed.
- The underlying siltstones and shales, which seem to have an unfavourable strike and dip and potentially low strength characteristic, covered with deep alluvial deposits do not favour the construction of a gravity dam.
- A lined diversion tunnel may be required.
- The right abutment appears to be a suitable location for a spillway, chute and dissipating basin.

**Narrawa Dam**

To store 1,000 GL, the FSL will be at approximately +507.3 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately +515 m AHD.

**Narrawa Dam dimensions**

| Height of Dam (m) | Length of dam (m) |
|---|---|
| 79.2 | ~ 897 |

Locally available materials:

- Alluvial deposits, possible shallow and unknown quantity.

- Rock is likely to be at a shallow depth with quantity unknown. Rocks are sandstone/siltstone/mudstone of unknown strength.
- The nearest quarry is at considerable distance from the dam site.

Assumptions:

- An earth and rockfill dam appears to be the appropriate dam choice for this site. Availability of suitable local rock as fill material needs to be confirmed. Depending on the geomorphology, strike and dip, siltstone and mudstone material may pose some risk to the foundation stability for an embankment dam.
- Foundation with siltstone and mudstone may not have high strength to support a gravity dam.
- A lined diversion tunnel may be required.
- The right abutment appears to be suitable location for a service spillway.
- The left abutment appears to be suitable for a spillway, chute and dissipating basin.

**Needles Dam Site A**

To store 700 GL, the FSL will be at approximately +465.4 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately +473 m AHD.

Needles Dam dimensions

| Height of Dam (m) | Length of dam (m) |
|---|---|
| 101.3 | ~ 485 |

Locally available materials:

- Alluvial deposits to unknown depth.
- Rock is likely to be at a shallow depth with quantity unknown. Rocks are sandstone/siltstone/shale/limestone of unknown strength.
- The presence of limestone and calcareous materials may adversely impact the watertightness of the reservoir, or cause foundation problems if soluble rock or cavities are found under the footprint of the proposed site.
- URS (June 2014) commented that the upper slope may contain quartzitic sandstones and conglomerates partly metamorphosed with high strength which could be suitable as rockfill material. The Macquarie Park sandstones have a high to very high strength.

- The nearest quarry is about 60 km from the dam site. Some old borrow pits can be found in the vicinity. URS (June 2014) highlighted a potential borrow site 2 km northeast of the dam site with tertiary sand and gravels which could serve as filters for an earth and rockfill dam.
- A geological assessment report dated 1966 identified alluvial flats upstream and downstream of the dam site.
- Geological assessment in the 1960s also highlighted the foundation rock as being predominantly shale which is soft and friable.

Assumptions:

- An earth and rockfill dam appears to be the appropriate dam choice for this site. Availability of suitable local rock as fill material needs to be confirmed. It appears that materials for the construction of the clay core and filter zones are available locally.
- The URS report (2014) recommended a CFRD. This could be feasible on the assumption that the concrete face is founded on soft rock.
- The foundation with siltstone and shale may not have adequate strength to support a gravity dam.
- A lined diversion tunnel may be required.
- The left abutment appears to be a suitable location for a spillway, chute and dissipating basin.

**Wyangala Dam**

To store 2,000 GL, the FSL will be at approximately 390.9 m AHD. To provide sufficient freeboard to safely convey the PMF, the dam crest level will be at approximately 399 m AHD. Also a new saddle dam will be required north of the existing dam.

Other key issues:

- Impact to upstream residents and amenities including two caravan parks and the small township of Reids Flat at the southern side of reservoir.
- Raising by forming a rockfill buttress on the downstream side of the dam is preferred as it could stabilise the existing dam (e.g. by flattening the gradient of the upper part of the embankment).
- Raising by buttressing on the upstream side of the existing embankment could overstress the existing concrete arch thus making it technically unfeasible.
- The existing spillway will need to be extensively modified by raising the sill level (by approximately 12 m).
- An auxiliary spillway will be required to safely convey the PMF. The rockfill for the raised embankment could be sourced from the excavation of the new spillway.

- The control room for the spillway gates which is currently at about the same level as the spillway bridge deck will need to be rebuilt at a higher level.
- The intake towers may need to be strengthened and raised.
- The access bridge to the towers will need to be raised and extended due to the new raised embankment crest.

**Conclusions**

The following can be concluded from the assessment:

- Only Abercrombie could qualify for a RCC dam due to strong rock type and abutments within a relatively steep and narrowing valley. The key risk is the availability of rocks at the site to produce concrete. Also the rock foundation depth is unknown. For comparative purposed a CFRD has been considered for this site. Should this site become favourable, both RCC and CFRD dam options need to be further investigated.
- Most of the other sites have sandstone, siltstone, mudstone or shale in their foundation. Sandstone foundations are not ideal; however some are strong enough to withstand the loading from a gravity dam. Siltstones, mudstones and shale are not considered suitable for a gravity dam.
- Material availability is a crucial aspect of dam type selection. The availability of rock material will be investigated during the detailed planning/concept stage of the project after this study.
- Core of the embankment dam shall be fine material. An asphaltic concrete core can be an alternative if fine materials are not available.
- If the rock foundation is shallow, a concrete faced rockfill dam may be an appropriate option.

**Proposed Dam Type at each site**

| Dam | Site | Type | Comment |
|---|---|---|---|
| 1 | Abercrombie | ER | Concrete-faced rockfill dam (CFRD) |
| 2 | Battery Hill | TE | Zoned Embankment |
| 3 | Cranky Rock | ER | Concrete-faced rockfill dam (CFRD) |
| 4 | Narrawa | TE | Zoned Embankment |
| 5 | Needles | ER | Concrete-faced rockfill dam (CFRD) |
| 6 | Raise Wyangala | RB | Downstream rockfill buttressing |

**Stage 3 - Costing**

The objective of this stage is to highlight the performance of the dams in respect to high level comparative cost estimates, yield and security. The performance was largely based on:

- Fine-tuning the storage capacity at the dam sites, and
- Comparative cost estimation of the shortlisted dams.

The six shortlisted dam sites were assessed in more detail and were based on a number of key assumptions that are listed below.

**Assumptions**

*Dam Type*

The type of dam was developed based on details that were provided in Stage 2. Details of the dam geometry used for the comparative costing purpose are provided in the table below.

**Dam size**

| Dam | Zoned Earthfill (TE) | Concrete Face Rock Fill (ER) | Raising Wyangala |
|---|---|---|---|
| Batter Slopes | 2.2:1 | 1.5:1 | 1.7:1 |
| Crest Width (m) | 8 | 8 | 10 |

*Outlet Offtake*

The size of Diversion Capacity was assessed in the Hydrological study. The required capacity was assessed to be about 7000 ML/d which being similar for all sites was therefore not been included in the comparative cost estimate. For the existing Wyangala dam, the total cost of these outlet offtakes has been deducted from its total estimate to enable comparison.

*Spillway*

Spillway capacity is based on the PMF provided. A high level flood routing was undertaken to determine the spillway, chute and stilling basin sizes. All sites assumed to have a non-gated ogee spillway. It is assumed the specific flow rate over the Ogee is about 40 $m^3/s/m$. It is also assumed a 6 m wide bridge with piers (15 m span) is required over the spillway length.

**Spillway size**

| Dam | Abercrombie | Battery Hill | Cranky Rock | Narrawa | Needles | Wyangala Dam |
|---|---|---|---|---|---|---|
| PMF ($m^3/s$) | 16,500 | 13,000 | 13,500 | 15,000 | 12,000 | 14,722* |
| Routed Peak ($m^3/s$) | 15,500 | 12,400 | 13,000 | 13,300 | 11,600 | |

* Note that Wyangala Dam is not currently PMF compliant, but would possibly need to be made to be PMF compliant following augmentation under current NSW Dams Safety Committee requirements [viz: DSC guidance sheet, DSC3B].

*Free board*

The size of free board was estimated based on fetch of the reservoir, likelihood of settlement and type of dam. The outcome of freeboard assumption is provided in the table below.

**Freeboard**

| Dam | Abercrombie | Battery Hill | Cranky Rock | Narrawa | Needles | Wyangala Dam |
|---|---|---|---|---|---|---|
| Height of Freeboard (m) | 2 | 4 | 3 | 3 | 2 | 3 |
| Water Depth over spillway | 8 | 8 | 8 | 8 | 8 | 6 |
| FSL depth (m) | 90 | 43 | 76 | 68 | 91 | 12 (increment) |
| Total dam Height (m) | 101 | 55 | 87 | 80 | 102 | 105 |

*Cofferdam*

Cofferdam height is based on 1:500 AEP flood in accordance with NSW DSC requirements, and assuming a constant flow diversion during flood. Adopted details are provided in the table below.

**Cofferdam size**

| Dam | 1:500 Volume (GL) | Duration of Hydrograph (hr) | Outlet size ($m^3/s$) | Volume reduction of storage (GL) | New Storage Volume (GL) 1:500 | 1:500 Min. Cofferdam height (m) |
|---|---|---|---|---|---|---|
| Abercrombie | 250 | 310 | 80 | 89 | 161 | 49 |
| Battery Hill | 185 | 250 | 80 | 72 | 113 | 29 |
| Cranky Rock | 200 | 200 | 80 | 58 | 142 | 46 |
| Narrawa | 230 | 225 | 80 | 65 | 165 | 43 |
| Needles | 150 | 165 | 80 | 48 | 102 | 46 |

*Access Road*

Roads that are likely to be inundated have been identified and two rates for arterial and local roads have been used for rerouting options. No upgrade has been considered for the existing roads.

*Reservoir clearing, Land acquisition and Vegetation offset*

Reservoir clearing and vegetation offset were based on a single rate as provided by Water NSW which was based on recent experience. The vegetation offset have been taken as 3 times the actual impacted area identified in the environmental assessment, consistent with Water NSW recent experience.

*Fish-ways*

The estimates for fish-ways have been based on a uniform rate of linear height of dam for comparative costing purpose.

*Other Costs*

Other relevant costs have been determined as a percentage of the total construction cost. The following has been adopted for all sites:

**Other costs**

| Other Costs | % of construction cost |
|---|---|
| Profit | 10.0 |
| Detailed Design (including site investigations) | 5.0 |
| Site Supervision | 3.0 |
| Unlisted Items | 5.0 |
| Overheads | 10.0 |
| Owners Representative Services | 2.0 |
| Contingency | 40.0 |
| Legal Costs | 0.5 |
| Communications | 0.5 |

*Hydropower*

Hydropower generation (MW per annum) is based on the height and average outlet flow rate. The release from each site was based on the information provided in from the hydrological analysis in Appendix D.

**Hydropower**

| Dam | Abercrombie | Battery Hill | Cranky Rock | Narrawa | Needles | Wyangala Dam |
|---|---|---|---|---|---|---|
| Average Release ($m^3/s$) | 20 | 11 | 34 | 21 | 34 | 32 |
| Capacity (MW) | 548 | 602 | 1,362 | 103 | 1,506 | 109 |

*Whole of Life Cost*

The performance for each dam was based on a high level comparative cost estimate. Items considered similar were excluded in the comparative cost estimate. Operation and maintenance costs are generally included as a percentage of the capital cost in a strategic planning process. As the assessment was based on a comparative estimate it

was deemed appropriate to exclude the operation and maintenance costs from the assessment. Inclusion of the values will not make a difference to the ranking of the dams.

*Exclusions*

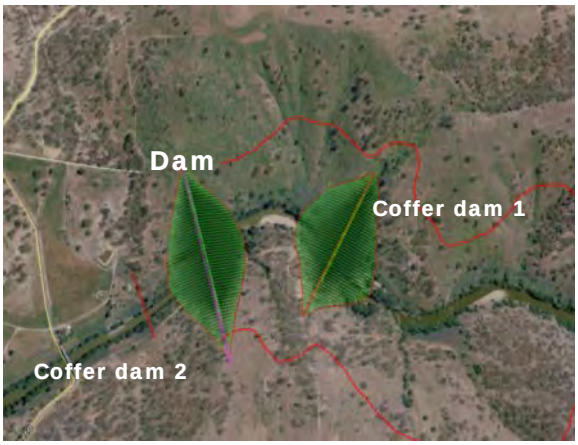
The following are considered similar for all options and has been excluded from the cost estimate:

- Tunnel and diversion structures (cofferdam is included)
- Gates and other mechanical equipment,
- Instrumentations and electrical works,
- Site security, office, Shed, O&M facilities,
- Decommissioning of downstream lakes/ storages,
- Hydropower and associated M&E ancillaries,

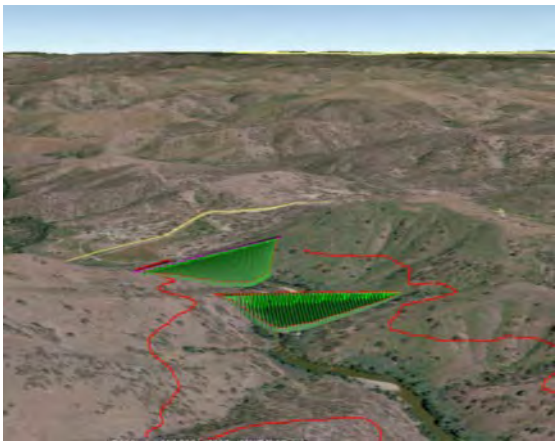
## Short-Listed Options

*Abercrombie Dam*

The figures below show the Abercrombie Dam and upstream and downstream coffer dams. The tables below present the key dam components.




Abercrombie Dam, Plan



Abercrombie Dam

**Abercrombie Dam Details**

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Abercrombie | 700 | 23 | ER (CFRD) | 1960 | 11 | 90 | 101 |

**Abercrombie Spillway Details**

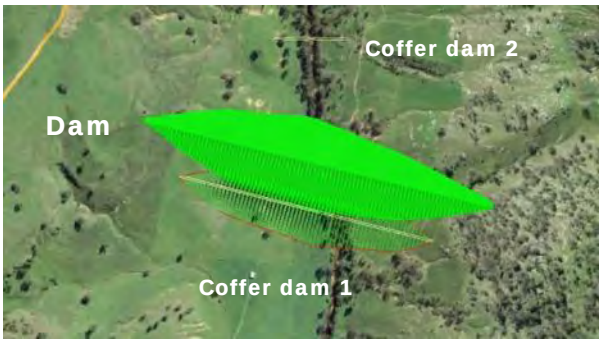
| Name | PMF (Spillway) m3/sec | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Abercrombie | 15,500 | 387 | 40 | 280 | 250 | 470 | 380 | 96 |

**Abercrombie Coffer Dam and Other Estimate**

| Name | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of properties inundated | Vegetation offset (ha) | Hydro plant capacity |
|---|---|---|---|---|---|---|---|---|---|
| Abercrombie | 161 | 49 | 5 | 2.7:1 | - | - | 1 | 777 | 548 |

*Battery Hill Dam*

The figures below show the Battery Hill Dam and upstream and downstream coffer dams. The tables present the key dam components.




Battery Hill Dam, Plan

Battery Hill Dam

### Battery Hill Dam Details

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Battery Hill | 400 | 12.6 | TE (Earthfill) | 3020 | 12 | 43 | 55 |

### Battery Hill Spillway Details

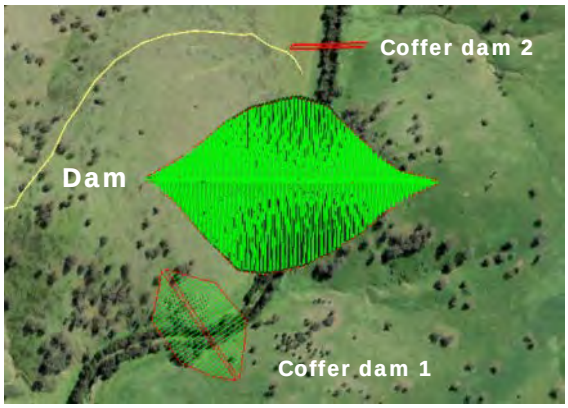
| Name | Design Flow (m3/sec) | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Battery Hill | 12,400 | 309 | 40 | 300 | 248 | 420 | 300 | 96 |

### Battery Hill Coffer Dam and Other Estimate

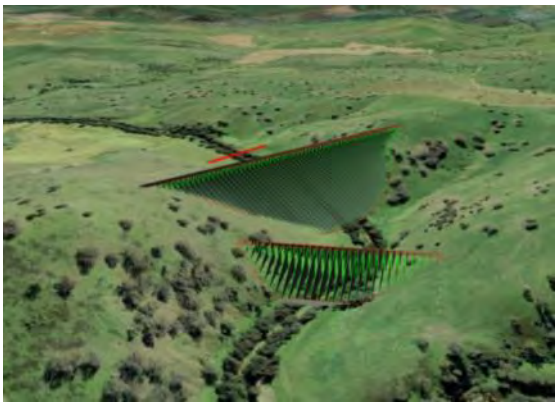
| Name | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of property inundated | Vegetation offset (ha) | Hydroplant capacity (MW) |
|---|---|---|---|---|---|---|---|---|---|
| Battery Hill | 113 | 29 | 5 | 2.7:1 | 8 | 30 | 15 | 429 | 602 |

### Cranky Rock Dam Site 5 (Oak Pride)

The figures below show the Cranky Rock Dam site 5 (Oak Pride) and upstream and downstream coffer dams. The tables below present the key dam components.




Cranky Rock Dam, Plan



Cranky Rock Dam

### Cranky Rock Dam Details

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Cranky Rock | 700 | 23 | ER (CFRD) | 2,835 | 11 | 76 | 87 |

### Cranky Rock Spillway Details

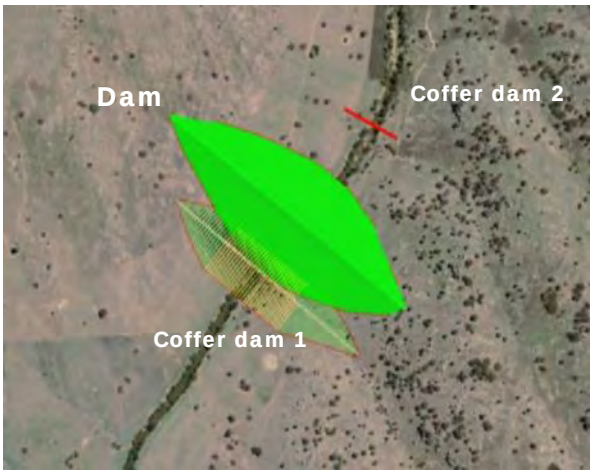
| Name | Design Flow (m3/sec) | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Cranky Rock | 13,000 | 324 | 40 | 280 | 260 | 380 | 320 | 96 |

### Cranky Rock Coffer Dam and Other Estimate

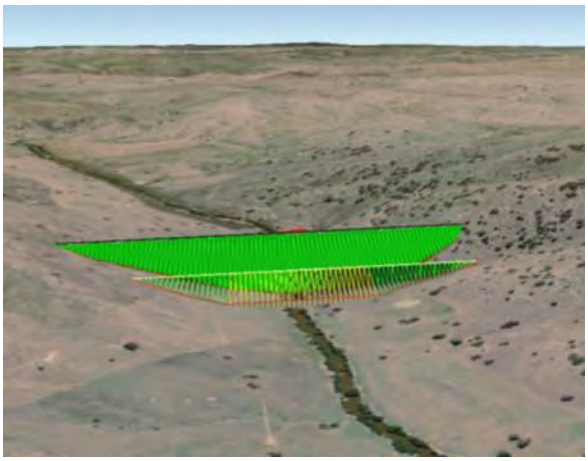
| Name | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of property inundated | Vegetation offset (ha) | Hydro plant capacity |
|---|---|---|---|---|---|---|---|---|---|
| Cranky Rock | 142 | 46 | 5 | 2.7:1 | - | - | 7 | 246 | 1,362 |

*Narrawa Dam*

The figures below show the Narrawa Dam and upstream and downstream coffer dams. The tables show the key dam components.




Narrawa Dam, Plan



Narrawa Dam

## Narrawa Dam Details

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Narrawa | 1,000 | 22 | TE (Earthfill) | 6,032 | 12 | 68 | 80 |

## Narrawa Spillway Details

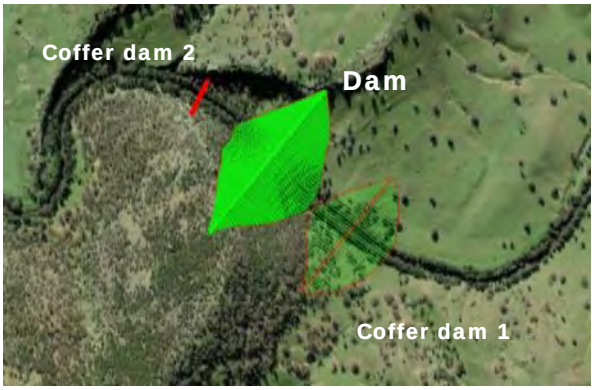
| Name | Design Flow (m3/sec) | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Narrawa | 13,300 | 332 | 40 | 400 | 266 | 450 | 330 | 96 |

## Narrawa Coffer Dam and Other Estimate

| Name | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of property inundated | Vegetation offset (ha) | Hydro plant capacity (MW) |
|---|---|---|---|---|---|---|---|---|---|
| Narrawa | 165 | 43 | 5 | 2.7:1 | 67 | 25 | 28 | 1,683 | 103 |

*Needles Dam Site A*

The figures show the Needles Dam Site A and upstream and downstream coffer dams. The tables show the key dam components.




Needles Dam, Plan

Needles Dam

**Needles Dam Details**

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Needles | 700 | 23 | ER (CFRD) | 1,341 | 11 | 91 | 102 |

**Needles Spillway Details**

| Name | Design Flow (m3/sec) | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Needles | 11,600 | 289 | 40 | 180 | 232 | 300 | 280 | 96 |

**Needles Coffer Dam and Other Estimate**

| Name | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of property inundated | Vegetation offset (ha) | Hydro power capacity |
|---|---|---|---|---|---|---|---|---|---|
| Needles | 102 | 46 | 5 | 2.7:1 | - | 1.6 | 3 | 219 | 1,506 |

*Wyangala Dam*

The figure below shows the existing Wyangala Dam that is proposed to be raised by 20 m. The tables show the key dam components.

**Wyangala Dam**

### Wyangala Dam Details

| Name | Storage (GL) | Improved Yield (GL/yr) | Dam Type | Inundated Area (Ha) | Free Board + Water height over spillway + Settlement (m) | FSL Depth (m) | Dam Height (m) |
|---|---|---|---|---|---|---|---|
| Wyangala | 2,000 | 21 | DS Buttress | 2,921 | 8 | 12 | 105 |

### Wyangala Spillway Details

| NAME | Design Flow (m3/sec) | Spillway width (m) | Discharge (m3/sec/m) | Spillway Length (m) | Chute Width (m) | Chute Length (m) | Dissipator Width (m) | Dissipator Length (m) |
|---|---|---|---|---|---|---|---|---|
| Wyangala | 14,722 | 367 | 40 | 150 | 294 | 400 | 360 | 96 |

### Wyangala Coffer Dam and Other Estimate

| NAME | Volume of 1:500 Flood (GL) | Coffer Dam height (m) | Top width (m) | Batter slopes (H:V) | Arterial Road (km) | Local Council Road (km) | No of property inundated | Vegetation offset (ha) | Hydro plant capacity (MW) |
|---|---|---|---|---|---|---|---|---|---|
| Wyangala | - | - | - | - | 2 | 6 | 25 | 900 | 109 |

## Cost Estimation

*Cost Estimate*

The comparative estimate provided for each dam in this section was used during the Multi-Criteria Analysis (MCA) process (Appendix F). Table below shows a high level comparative cost estimate for the various components of the dams.

*Level of Accuracy*

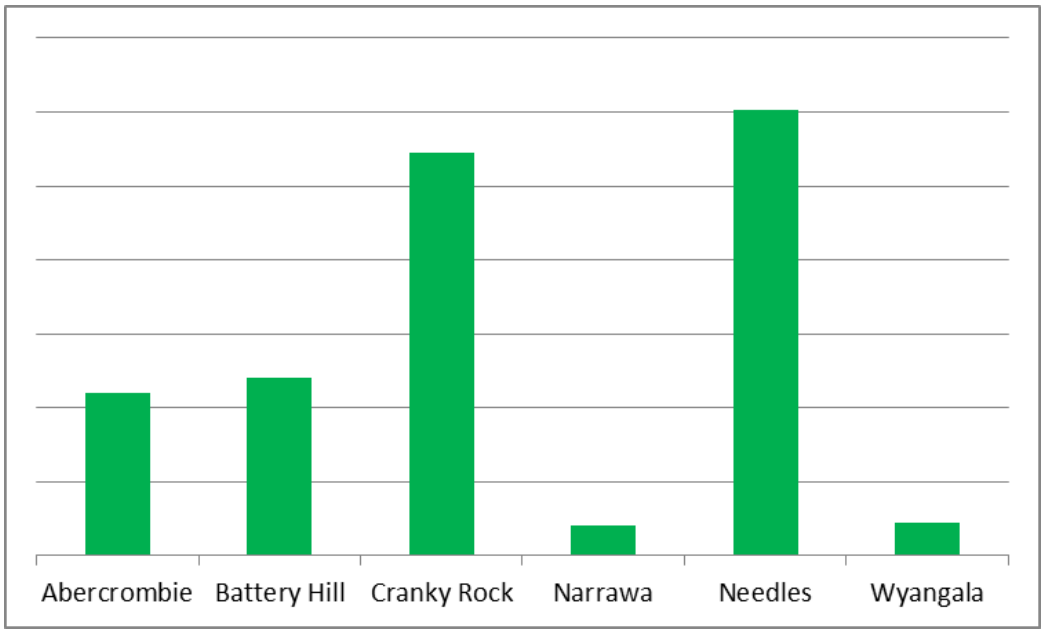
The material estimates developed for the report are prepared in accordance with engineering experience and available information from similar projects, and are intended to provide a comparative cost estimate for high level optioneering purposes. The resultant values should not be used for any budgetary planning.

**Summary of Costs**

| | | Abercrombie | Battery Hill | Cranky Rock | Narrawa | Needles | Wyangala |
|---|---|---|---|---|---|---|---|
| 1 | Preliminary and General | 7,015,200 | 7,672,400 | 7,557,700 | 9,539,840 | 6,631,420 | 7,611,020 |
| 2 | Environmental Controls | 6,000,000 | 6,800,000 | 6,000,000 | 8,000,000 | 6,800,000 | 5,600,000 |
| 3 | Construct and Maintain Access Roads | 4,100,000 | 11,920,000 | 11,100,000 | 9,400,000 | 14,920,000 | 2,940,000 |
| 4 | Reservoir Cleaning | 29,400,000 | 45,300,000 | 42,525,000 | 90,480,000 | 20,115,000 | 43,815,000 |
| 5 | Coffer Dam- Upstream | 22,949,348 | 18,924,510 | 21,368,355 | 35,182,054 | 17,470,094 | 2,282,500 |
| 6 | Coffer Dam Downstream | 429,444 | 706,322 | 401,191 | 689,370 | 339,034 | 395,540 |
| 7 | Foundation | 16,333,333 | 16,333,333 | 10,308,333 | 13,075,000 | 14,050,000 | 7,250,000 |
| 8 | Quarry | 4,700,000 | 4,700,000 | 4,700,000 | 4,700,000 | 4,700,000 | 4,700,000 |
| 9 | Dam Body | 163,636,600 | 187,455,400 | 163,198,800 | 266,169,400 | 143,321,400 | 92,818,500 |
| 10 | Spillway | 144,659,500 | 150,458,000 | 129,876,000 | 198,967,000 | 100,082,500 | 133,182,000 |
| 11 | Fish Passage | 27,060,000 | 12,780,000 | 22,800,000 | 20,460,000 | 27,390,000 | 31,500,000 |
| 12 | Lump Sum Items (power, instrumentation, site security, demobilisation, site rehabilitation, landscaping, documentation, commissioning and training (outlet and diversion for Wyangala ) | 14,250,000 | 14,250,000 | 14,250,000 | 14,250,000 | 27,390,000 | -45,250,000 |
| 13 | Public Roads and Private Properties | 5,927,500 | 137,917,500 | 2,545,000 | 451,222,500 | 7,942,500 | 40,170,000 |
| a | Saddle Dam | - | - | - | - | - | 1,200,000 |
| b | Modification to outlet structure | - | - | - | - | - | 8,450,000 |
| | **Total Contract Cost** | **446,460,925** | **610,834,132** | **436,630,379** | **1,122,135,164** | **378,011,948** | **336,664,560** |
| 14 | Other Costs (profit, detailed design, site supervision, overheads, contingency. Legal costs, communication etc) | 339,310,303 | 464,233,940 | 331,839,088 | 852,822,725 | 287,289,081 | 255,865,066 |
| | **Total Cost** | **785,771,228** | **1,075,068,072** | **768,469,467** | **1,974,957,889** | **665,301,029** | **592,529,626** |

*Hydro Power Investigation*

The hydro power generation (MW per annum) assessment was based on the height of respective dams and average flow release rate. The figure below shows the comparative hydro generation potential at the various dam locations.



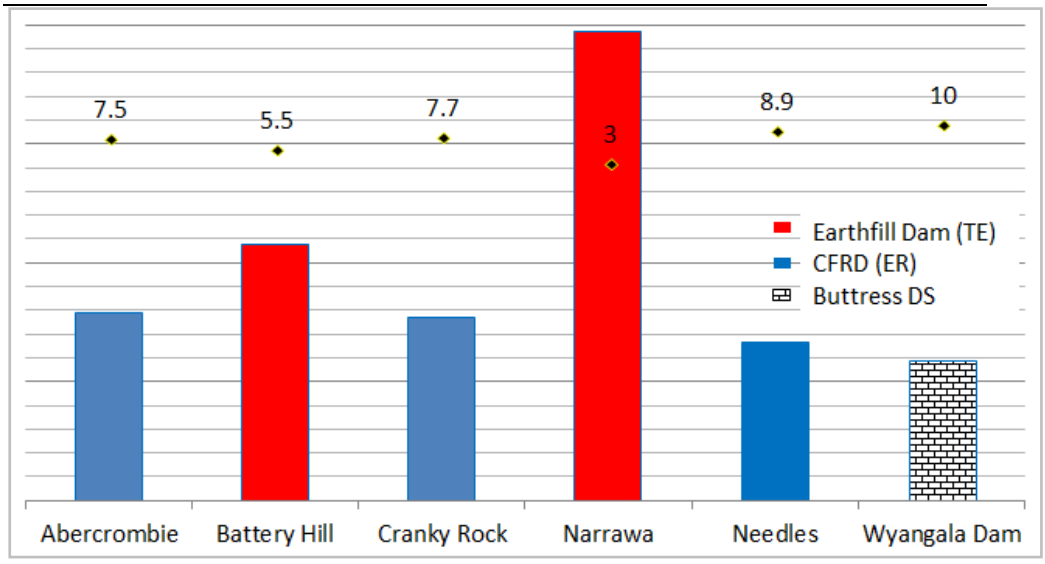

**Hydro Power Comparison**

Hydro power is currently being generated at Wyangala. The increase in height will only have a marginal improvement as shown in the above figure. The low value associated with the Narrawa Dam is due to its relatively lower dam height.

*Comparative Estimate Discussion*

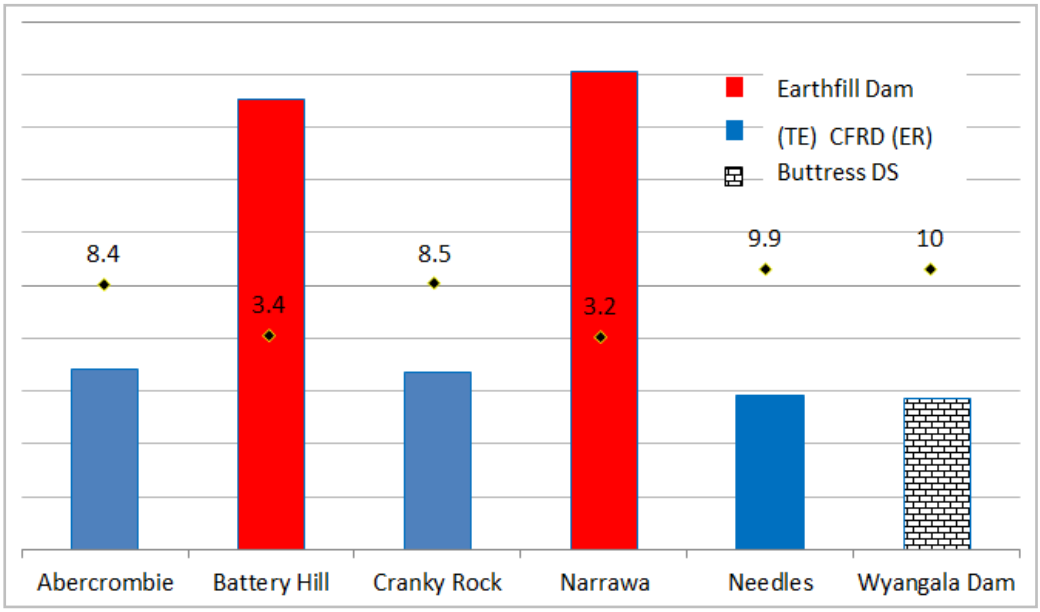
To enable ease of scoring during the MCA process, each dam site's comparative estimate was factored to get a maximum value of 10. The lowest cost dam received the highest score; others were based on a percentage of its cost with respect to the total. The comparative cost per unit yield is determined by taking the comparative cost and dividing by improved yield. A similar approach is adopted for the comparative cost per unit storage.

The following figure shows the comparative cost between dams. The factors show the cost performance. Wyangala performs best as it has the lowest cost. Narrawa performs the worst as it is the most expensive dam.




**Comparative Total Cost**

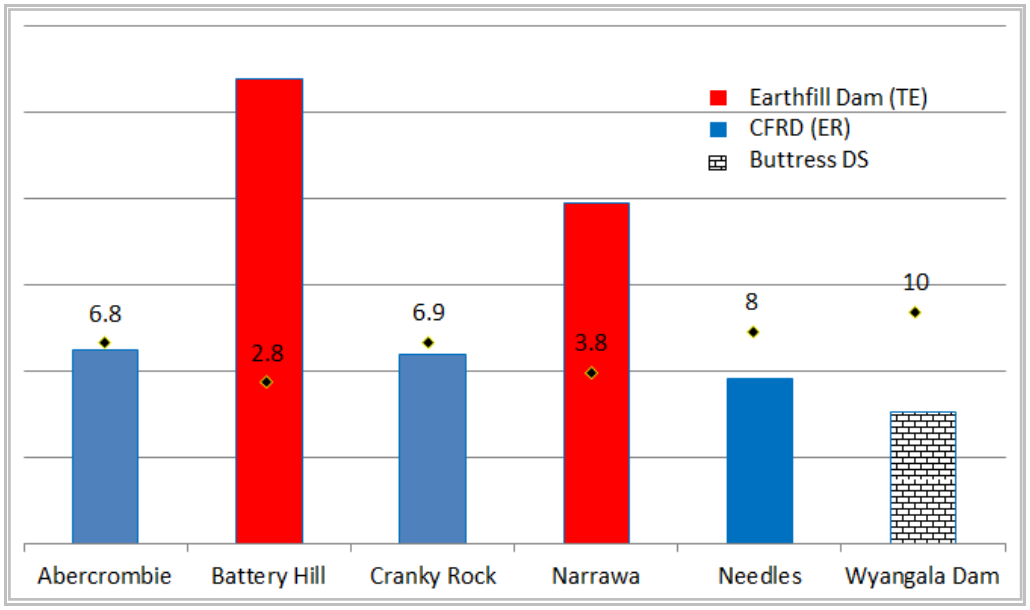
The following figure shows the comparative cost performance per improved yield. The graph below shows that Narrawa and Battery Hill has the lowest performance as they are expensive and provide the least yield. Abercrombie, Cranky Rock, Needles and Wyangala performance is very similar.




**Comparative Cost per Improved Yield (CC/(GL.Yr$^{-1}$))**

The following figure shows the dam performance with respect to the storage volume. The graph below shows that Narrawa and Battery Hill has the lowest

performance as they are the most expensive for their respective storages. Abercrombie, Cranky Rock, Needles and Wyangala performance is very similar




**Comparative Cost per Storage volume (CC/GL)**

**Potential Risks**

The table below shows the general dam risks and the following table shows site specific risks.

**General Risks**

| Type | Risks | Design Actions |
|---|---|---|
| Hydrologic | • Potentially inaccurate hydrological modelling and inaccurate yield estimation<br>• PMF estimations | • Review the hydrological model, access more updated data<br>• Design to meet guideline – appropriate type of dam |
| Foundation | • Foundation instability or failure | • Undertake thorough geotechnical site investigations<br>• Insitu and laboratory testings |
| Dam Material | • Availability of suitable material<br>• Rapid weathering of material | • Topographical mapping and surveying of site<br>• Geological studies<br>• Geophysical investigations<br>• Site investigations |
| Seismic | • Cracking<br>• Activating of existing faults and displacement<br>• Liquefaction | • Assess fault activity and seismicity<br>• Define maximum credible earthquake and design to meet seismic safety guidelines |

| Type | Risks | Design Actions |
|---|---|---|
| Stability | • Piping, slope instability<br>• Overturning or sliding<br>• Overtopping and erosion<br>• Instability of abutments<br>• Landslide in reservoir area | • Design for foundation treatment<br>• Strict design requirement – appropriate type of dam<br>• Independent expert review of design<br>• Strict quality requirements for materials and construction |
| Stakeholder | • Impact to roads and services<br>• Impact to towns and properties<br>• Dam break and population at risk | • Develop safety procedures for town that will be impacted<br>• Design the apparatus according to the Dam safety category<br>• Undertake stakeholder consultation |
| Construction | • Difficult terrain<br>• Material<br>• Waste haulage | • Major access to dam will be Battery Road<br>• Strict quality requirements for material and construction |
| | • Major flood during construction | • Monitor weather<br>• Develop safety procedures and emergency action plan. |
| | • Failure of diversion works | • Optimse diversion tunnels and coffer dams using probability of flooding |
| | • Blasting and misfire (flying Rock – hazard) | • Safety procedures to be developed |

## Site Specific Risks

| Dam Location | Specific Site Risks |
|---|---|
| **Abercrombie Dam** | **General Impact –** 2,000 ha will be inundated and 13% of that area is covered with significant flora which may require environmental offset.<br>**Flooding** – The most notable impact will be to the combine effect of dam break with downstream dam of Wyangala, and the impact on Population at Risks (PAR) in downstream predominantly township of Cowra.<br>**Technical –** Foundation stability.<br>**Geology** – The presence of faulting near the dam site introduces the potential for seismic ground displacement, strong shaking or leakage. Abercrombie Cave is located North of the site and extent of calcareous material to be mapped. |
| **Battery Hill Dam** | **General Impact –** A number of arterial Roads will be impacted by the dam.<br>**Flooding** – The most notable impact will be to the town of Cowra<br>**Technical –** Foundation stability, deep bed rock, seepage through foundation, Zone 1 material may require to borrow from distance.<br>**Geology** – The key risk is establishing the extent of recent alluvium and whether it presents a potential leakage path underneath the proposed dam. |

| Dam Location | Specific Site Risks |
|---|---|
| **Cranky Rock Dam** | **General Impact -** There will be a number of local roads that will be impacted by the new dam.<br><br>**Flooding** - The most notable impact will be to the town of Canowindra about 20 km from the dam site.<br><br>**Technical** - Foundation stability, seepage through foundation, watertightness of reservoir.<br><br>**Geology** - The presence of faulting near the dam site introduces the potential for seismic ground displacement, strong shaking or leakage.<br><br>The Cliefden Cave entrance point may not be impacted; however the extent of cave shall be mapped and assessed against inundation area. |
| **Narrawa Dam** | **General Impact -** Dam is away from any major towns. Only local unsealed roads will be impacted, however the inundation area is about 6000 ha and about 1600 ha of that may is covered by significant flora.<br><br>**Flooding** – The most notable impact will be to the combine effect of dam break with downstream dam of Wyangala, and the impact on Population at risks in downstream predominantly township of Cowra.<br><br>**Technical** –wide valley which will require extensive material which may not be available locally. Foundation stability, deep bed rock, seepage through foundation.<br><br>**Geology** -The presence of faulting near the dam site introduces the potential for seismic ground displacement, strong shaking or leakage. |
| **Needles Dam** | **General Impact -** There will be a number of local roads that will be impacted by the new dam.<br><br>**Flooding** - The most notable impact will be to the town of Canowindra about 30 km from the dam site.<br><br>**Technical** - Foundation stability, seepage through foundation, watertightness of reservoir.<br><br>**Geology** -The presence of faulting near the dam site introduces the potential for seismic ground displacement, strong shaking or leakage. The presence of calcareous materials in the reservoir and their reaction (solubility) to inundation could also be a problem.<br><br>The Cliefden cave is likely be inundated which is valued by the community and other stakeholders. |

| Dam Location | Specific Site Risks |
|---|---|
| **Wyangala Dam** | **General Impact -** There will also be impacts to upstream residents and amenities including two caravan parks and the small township of Reids Flat at the southern side of reservoir.<br><br>**Flooding** – The most notable impact will be to the town of Cowra, upgrade of the existing spillway can be undertaken simultaneously with the dam upgrade, which is an opportunity.<br><br>**Technical** - Raising by buttressing of the existing embankment could overstress the existing concrete arch, therefore detailed structural analysis is required. The outlet structure has already raised once and the new upgrade may also impact the foundation of the tower outlet.<br><br>**Geology** - The presence of faulting near the dam site introduces the potential for seismic ground displacement, strong shaking or leakage which could be compounded by a dam raise. |

## Engineering Forward Planning

Some the specialist studies required to undertake the engineering design of a dam will include but not be limited to the following table. The other studies such as socio-economic analysis, environmental investigation, legal and approval requirements and similar are not included in the following list.

*Engineering Forward Planning*

| No. | Study |
|---|---|
| 1 | Detailed survey – topography |
| 2 | Geomorphology - existing environment condition assessment<br>• Impact assessment, flows, ponded areas |
| 3 | Geology in and around the dam and inundation areas |
| 4 | Geotechnical Investigations:<br>• Identification of areas of mass movement – field work and laboratory assessment<br>• Soils – field work and laboratory assessment<br>• Rock - field work and laboratory assessment |
| 5 | Existing/new quarry investigations for materials |
| 6 | Dam siting: finalisation of location of dam alignment based on the detailed site and desktop investigations |
| 7 | Detailed optioneering on dam type based on foundation and material availability |
| 8 | Detailed hydrologic and system supply modelling |

| No. | Study |
|---|---|
| 9 | Inundation of lands and infrastructure |
| 10 | Surface water resources and water quality |
| 11 | Reservoir sedimentation and water quality at the outlet structures (including measures for cold water pollution) |
| 12 | Selection of the Hazard Category of dam and potential impact assessment |
| 13 | Optimisation of reservoir operation |
| 14 | Concept and detailed design of dam body, spillway, and other apparatuses. |

# Appendix D: Hydrologic Modelling

Assessment of the hydrology for a number of proposed surface water supply sources within the Lachlan Valley was undertaken in the study (see Figure 1). The supply sources identified for assessment were:

1. Belubula River:
   - Dam located at Cranky Rock (2 sites) located on the Belubula River: Series of potential dam capacities between 400 and 1,000 GL
   - Dam located at 'the Needles' (3 sites) on the Belubula: Series of potential dam capacities between 400 and 1,000 GL.

   For the purposes of the initial high-level stage of options assessment, and based on the relatively proximal location of dam-sites, hydrological outcomes for all Belubula River options are based on assessment of Cranky Rock dam-site 1 ("D" or "Oak Pride Dam").

2. Abercrombie River:
   - Dam located on Abercrombie River upstream of Wyangala Dam: Series of potential dam capacities between 400 and 1,000 GL
3. Lachlan River:
   - Raising of Wyangala Dam: Series of potential raises to provide total dam capacities of between 1,624 and 2,350 GL (i.e. provide total additional capacity of between 407 and 1,133 GL)
   - Narrawa dam-site located on the Lachlan River upstream of Wyangala Dam: Series of potential dam capacities between 400 and 1,200 GL
   - Hillandale dam-site located on the Lachlan River upstream of Wyangala Dam: Series of potential dam capacities between 400 to 1,000 GL

4. Boorowa River:
   - Harrys Dart dam-site located on the Boorowa River: Series of potential dam capacities between 50 and 250 GL
   - Battery Hill dam-site located on the Boorowa River: Series of potential dam capacities between 100 and 1,000 GL
5. Mandagery/Boree Creek:
   - Dam located on Boree Creek: Series of potential dam capacities between 50 and 250 GL

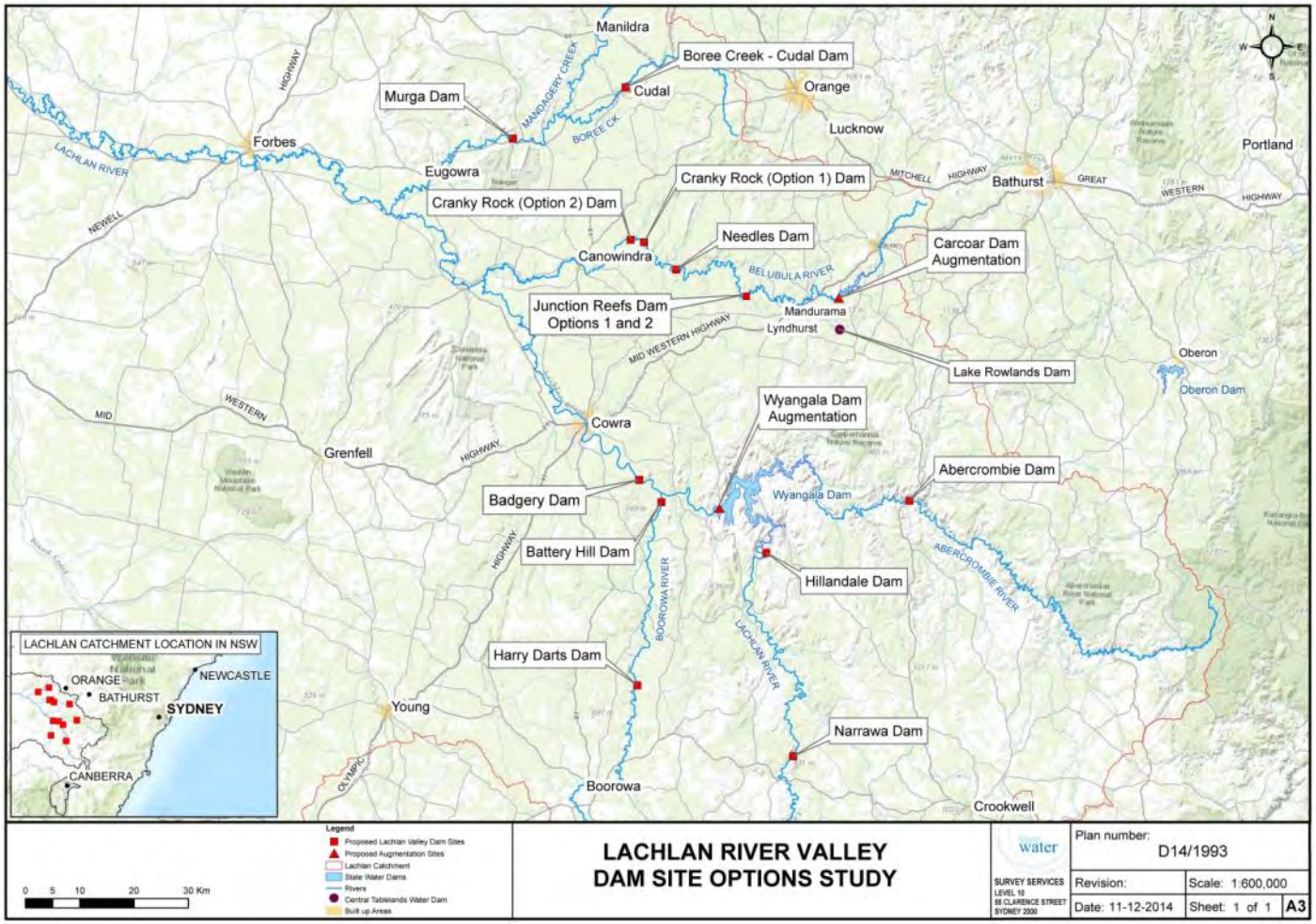
- Murga Dam located on Mandagery Creek: Series of potential dam capacities between 250 and 700 GL

The modelling assessment was undertaken as a high-level, comparative assessment of the potential for the above options to provide improved water security within the Lachlan Valley, including for General Security (GS) and High Security (HS) irrigators and Town Water Supply (TWS). The high-level hydrological assessment reported here has been aimed at providing information at the level of 'proof of concept' and comparative option ranking.

The key focus for the hydrological assessment in supporting the wider options study was to provide a clear measure of the potential improvement in water security provided by a wide range of dam options within various watercourses of the Lachlan Valley. By definition the term 'water security' will have a different meaning for different stakeholder groups (town water supply, irrigators, environmental flow regulators, etc). Further, individual users within any single stakeholder group may have different specific needs in terms of improved security (e.g. for GS irrigators an increased frequency of maximum or overall Announced Allocations (AA) versus a decreased frequency of minimum/zero AA).

As an initial measure of the potential for the system to provide improved water security in whatever final form that stakeholder needs determined, options assessment has been based on a measure of 'additional equivalent yield' (defined further below) which provides a consistent measure of additional total long-term system resource provided under each individual option. The specific, and likely varying, security requirements across the Lachlan Valley will be an important next step towards final option selection and the development of an optimised set of operating and water sharing rules for the proposed augmented/improved water supply system.

This report provides a succinct summary of the key characteristics of the surface water options described above, the catchments within which they are/would be located, comparative water supply performance results for all options and discussion regarding factors for consideration when using this information.




**Lachlan River Valley dam site options study**

**Assessment methodology and assumptions**

Modelling assessment was undertaken using the Integrated Quantity-Quality Model (IQQM), which is used extensively through NSW, Queensland and the Murray Darling Basin for water resource planning assessment and support. Models used in the assessment has been developed and used for supporting the development of:

- Water Sharing Plan for the Lachlan Regulated River Water Source 2003, (NSW Government 2003) ('Lachlan WSP')
- Water Sharing Plan for the Belubula Regulated River Water Source 2012, (NSW Government 2012) ('Belubula WSP')
- Basin Plan 2012 (Commonwealth of Australia, 2012) ('Basin Plan')

Specifically, two key Lachlan Valley specific models were used as the basis for assessment:

- the most recent version of the NSW Office of Water (NoW)-developed Lachlan Valley WSP case ('WSP model'); and,
- the MDBA-development Sustainable Diversion Limit (SDL) case for the Lachlan Valley used in support of the development of the Basin Plan ('SDL model').

Both the WSP and SDL models includes catchment inflows, existing key water supply infrastructure, environmental release rules as well as TWS and irrigator demand throughout the Lachlan Valley.

At the initiation of the assessment, the WSP and SDL models provided included climatic/hydrologic data for the period 1/1/1895 to 30/6/2009. In order to include the most recent drought period ('Millennium Drought'), the most recent climatic/hydrologic input data sequences were obtained from the NoW, providing for a simulation period of 1/1/1898 to 30/06/2013.

For each of the options and sizes assessed, an 'equivalent yield' was determined based on operation of the augmented system under Base Case water entitlement conditions, water sharing/resource assessment rules and environmental flow requirements. The equivalent yield was then defined by the additional average annual GS irrigator diversions available due to the augmentation options, whilst still meeting all other existing user and environmental requirements. This value effectively represents the potential additional resource for GS irrigators provided

by each option net of any release to maintain (or improve) town water supply, high security irrigator and environmental outcomes.

The potential additional resource can then (in later, more detailed phases of final option assessment and design) be used to provide increased availability via a general increase in Announced Allocations from year to year (i.e. reliability improvement) or, as is more likely to be the focus within the Lachlan Valley, improved availability during more extreme dry conditions (i.e. security improvement).

Modelling assessment was undertaken in three stages comprising:

- Base case development: to provide a reference case representing (as closely as possible) current conditions within the Lachlan Valley;
- Options assessment (Equivalent yield): to provide directly comparable potential resource able to be provided by the full set of options defined above.
- Whole-of-catchment impact reporting: to provide direct measures and outcomes regarding impact of short-listed options on other water users and environmental flow outcomes.

The following sections provide a summary of each of these stages of assessment.

**Base case development**

In order to ensure all assessment outcomes are directly comparable and consistently described, an assessment Base Case was developed to, as appropriately as possible, represent current conditions within the Lachlan Valley, including levels of diversion and water entitlement buy-back to date. The assessment Base Case was developed using the WSP model as the initial basis with:

- Inclusion of all SDL model environmental flow rules (see Section 4 below); and,
- Reduction of active GS irrigation entitlement volumes and crop areas to simulate long-term total diversions consistent with estimated June 2012 levels quoted within the Basin Plan (Item 13 of Schedule 2).

Key Base Case infrastructure and water entitlement characteristics and assumptions are summarised in the tables below. All other assumptions/inputs, including catchment characteristics, infrastructure details, operational and water

sharing rules are consistent with the NoW base models and requirements of the Lachlan Valley WSP (2003) and Belubula River WSP (2012).

### Characteristics of existing water storages

| Storage | Full supply volume (ML) | Dead storage (ML) |
|---|---|---|
| Wyangala Dam | 1,217,000 | 1,000 |
| Carcoar Dam | 36,000 | 200 |
| Lake Cargelligo | 60,000 | 17,000 |
| Lake Brewster | 155,000 | 18,000 |
| Brewster Weir | 5,500 | 865 |

### Base case water entitlements

| Entitlement type | ML/a |
|---|---|
| TWS | 17,500 (based on projected 2040 demands from MWH 2009) |
| HS Irrigator | 41,600 |
| GS Irrigator | 478,618 |
| Environmental (as purchased GS ) | 149,140 |
| ECA | 10,000 |
| Water quality | 20,000 |

Environmental water requirements from both the WSP and SDL models were incorporated into the assessment Base Case, as summarised in the table below.

**Base case environmental release/flow rules**

| Rule | Requirements |
|---|---|
| *From WSP model* | |
| Wyangala Dam minimum release | 70 ML/d |

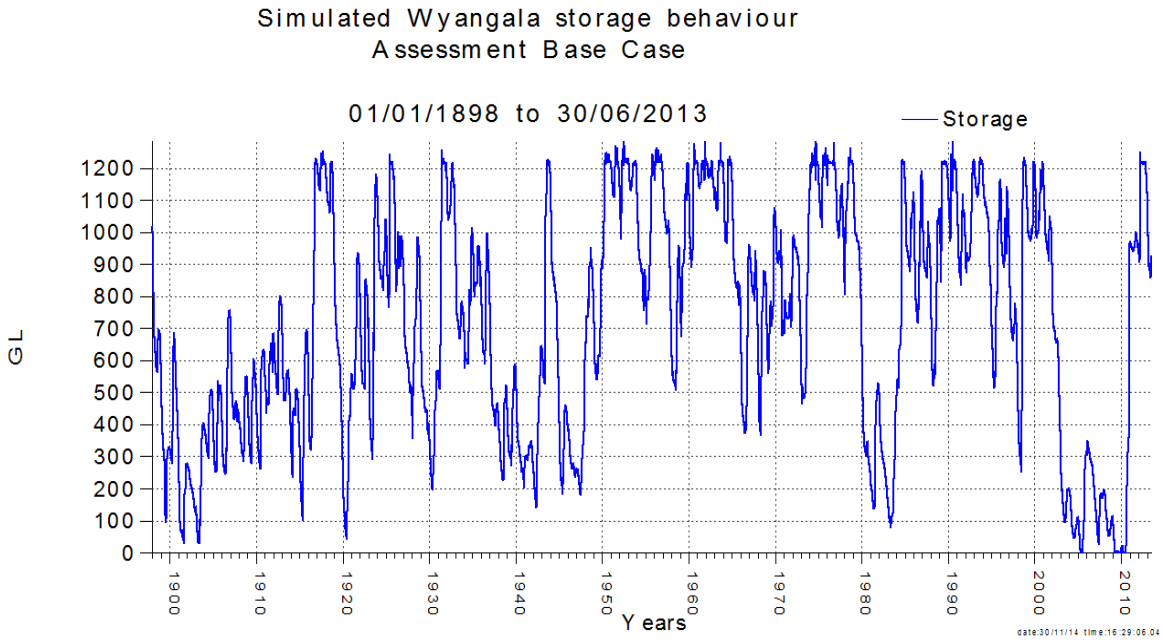
| Rule | Requirements |
|---|---|
| Carcoar Dam minimum release | 2 ML/d |
| Belubula River minimum end of system flow (at Bangaroo) | 10 ML/d |
| Brewster Weir minimum release | 20 ML/d |
| Lachlan River minimum end of system flow (at Booligal) | 100 ML/d |
| Water quality | 20,000 ML/yr |
| Environmental Contingency Allowance (ECA) | 10,000 ML/yr |
| Translucency Requirements | As per Section 13 of the Lachlan Valley WSP |
| *From SDL model* | |
| Wyangala Key Environmental Flow (KEF) | Time series minimum flow as provided with SDL model |
| Carcoar KEF | Time series minimum flow as provided with SDL model |
| Belubula River minimum end of system flow (at Bangaroo) | 60 ML/d |
| Minimum flow at Nanami | 300 ML/d |
| Minimum flow at Jemalong | 250 ML/d |
| Minimum flow at Condobolin | 200 ML/d |
| Minimum Brewster Weir inflow | 150 ML/d |
| Minimum flow at Hillston | 100 ML/d |
| Booligal Environmental Wetland Requirement (EWR) | Time series minimum flow as provided with SDL model |
| Minimum flow at Booligal | 50 ML/d |
| Minimum flow at Willandra | 55 ML/d |

**Base case outcomes**

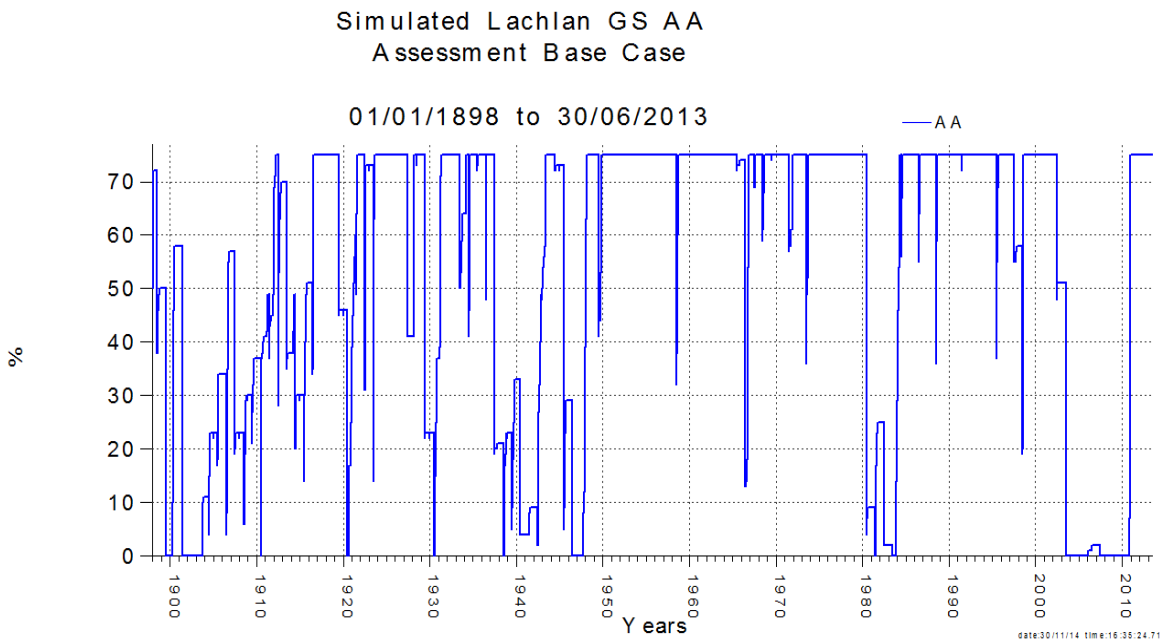
As an illustration of the underlying security issues relevant to the Lachlan Valley water supply system, the figures below show simulated storage behaviour and GS irrigator performance under the range and pattern of climate and streamflows experienced over the past approximately 125 years.

The first figure shows simulated Wyangala Dam storage behaviour, with clear illustration of the wet/dry cycles experienced within the Lachlan Valley, and South Eastern Australia generally. The second figure shows the AA behaviour that would result from the climatic (and consequent storage) conditions, with extended periods of both good (i.e. high) AA outcomes as well as poor (i.e. low) AA outcomes.

Of note are the extended period of below average conditions in the early 1900's (the 'Federation Drought') as well and the shorter, more extreme dry conditions in the early 2000's (the 'Millenium Drought). Developing an understanding of the potential range of climatic/hydrologic variability that can lead to these differing types of drought (i.e. extended, chronic below average, and short, sharp, extreme dry) and the options for system augmentation and operation to improve the ability of the system to maintain supply during these periods.




**Simulated Wyangala storage behaviour (Base Case)**




**Simulated Lachlan GS irrigator AA (Base Case)**

**Long-list options assessment**

The total set of dam options to be assessed comprised a total of ten (10) dam locations with a range of size sub-options as summarised in the table and shown graphically in the figure below.

An important distinction between the Belubula River options and all other options is the additional potential yield benefit for Centroc communities. System augmentation via a Belubula River option would provide for supply of all Belubula River water user demand downstream Cranky Rock/The Needles from the new dam, with subsequent significant reduction in demand on Carcoar Dam. Assessment of this substitution of supply indicates that maintenance or improvement of supply performance to all existing Belubula River users upstream of the potential new dam could be maintained with an additional 5 GL/a of high security supply to augment future Centroc community TWS requirements. This 5 GL of potential additional high security yield has been included within the equivalent yield outcomes to ensure consistent comparison of potential resource between all options.

On the basis of the comparative equivalent yield outcomes applied on a levelised cost basis (Appendix C), a series of options ('short-list') was selected for further, more detailed assessment. These short-listed options comprise:

- 700 GL Cranky Rock Dam (noting that for high-level nature of assessment, option hydrological outcomes assumed applied equally to all Cranky Rock and Needles Dam options).
- 1,000 GL Narrawa Dam
- 2,000 GL Raised Wyangala Dam
- 700 GL Abercrombie Dam
- 400 GL Battery Hill Dam

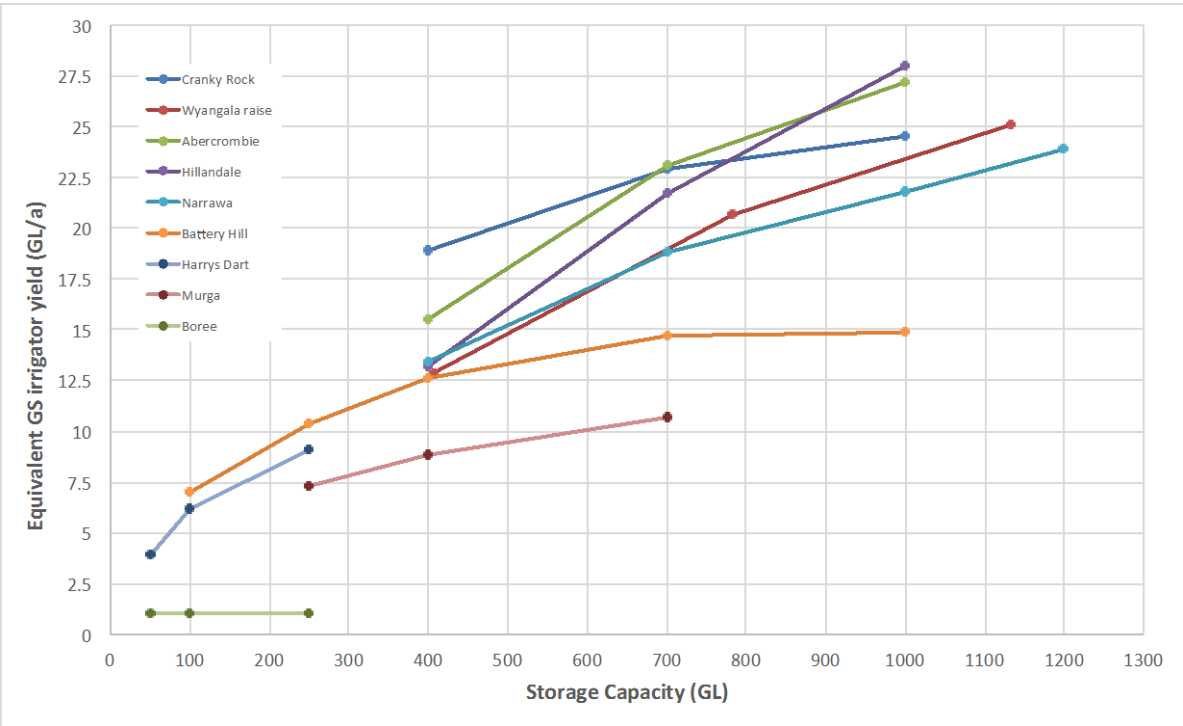
Assessment outcomes associated with each of these options with respect to equivalent GS yield, impact on other users within the Valley and Basin Plan environmental flow outcomes are described further below. The outcomes from this stage of Short-listed Options assessment were used as inputs to support Multi-Criteria Analysis (MCA) in Appendix F being undertaken for the over-arching options assessment process.

**Table 4 - Comparative Long-list options assessment results**

| Watercourse | Option | Storage capacity (GL) | Average annual Lachlan Valley GS irrigator diversion (GL/a) | Equivalent yield (GL/a) |
|---|---|---|---|---|
| Base Case | Existing conditions | Current | 208.9 | - |
| Belubula River | Cranky Rock Dam | 1,000 | 228.4<br>+ 5 Centroc | 24.5 |
| | | 700 | 226.8<br>+ 5 Centroc | 22.9 |
| | | 400 | 222.8<br>+ 5 Centroc | 18.9 |
| Lachlan River | Raised Wyangala Dam | 2,350<br>(i.e. +1,133) | 234.0 | 25.1 |

| Watercourse | Option | Storage capacity (GL) | Average annual Lachlan Valley GS irrigator diversion (GL/a) | Equivalent yield (GL/a) |
|---|---|---|---|---|
| | | 2,000 (i.e. + 780) | 229.6 | 20.7 |
| | | 1,624 (i..e +407) | 221.8 | 12.9 |
| | Hillandale Dam | 1,000 | 236.9 | 28.0 |
| | | 700 | 230.6 | 21.7 |
| | | 400 | 222.1 | 13.2 |
| | Narrawa Dam | 1,200 | 232.9 | 23.9 |
| | | 1,000 | 230.7 | 21.8 |
| | | 700 | 227.7 | 18.8 |
| | | 400 | 222.3 | 13.4 |
| Abercrombie River | Abercrombie Dam | 1,000 | 236.1 | 27.2 |
| | | 700 | 232.0 | 23.1 |
| | | 400 | 224.4 | 15.5 |
| Boorowa River | Battery Hill Dam | 1,000 | 223.8 | 14.9 |
| | | 700 | 223.6 | 14.7 |
| | | 400 | 221.5 | 12.6 |
| | | 250 | 219.3 | 10.4 |
| | | 100 | 215.9 | 7.0 |
| | Harrys Dart Dam | 250 | 218.0 | 9.1 |
| | | 100 | 215.1 | 6.2 |

| Watercourse | Option | Storage capacity (GL) | Average annual Lachlan Valley GS irrigator diversion (GL/a) | Equivalent yield (GL/a) |
|---|---|---|---|---|
| | | 50 | 212.8 | 3.9 |
| Mandagery/Boree Creek | Murga Dam | 700 | 219.6 | 10.7 |
| | | 400 | 217.7 | 8.8 |
| | | 250 | 216.2 | 7.3 |
| | Boree Creek Dam | 250 | 209.9 | 1.0 |
| | | 100 | 209.9 | 1.0 |
| | | 50 | 209.9 | 1.0 |




**Long-list equivalent GS irrigator yield**

## Short-listed Options results

A set of short-listed options was determined from assessment as described in Appendix C and F. The following summarises hydrological assessment undertaken for these short-list options.

*Equivalent GS yield*

Equivalent yield outcomes, including levelised cost from the engineering assessment (see Appendix C), for each of the short-listed options are summarised in the table below. The following figures show comparative Lachlan GS AA outcomes as an indication of the potential improvement in performance/security under each short-listed option.

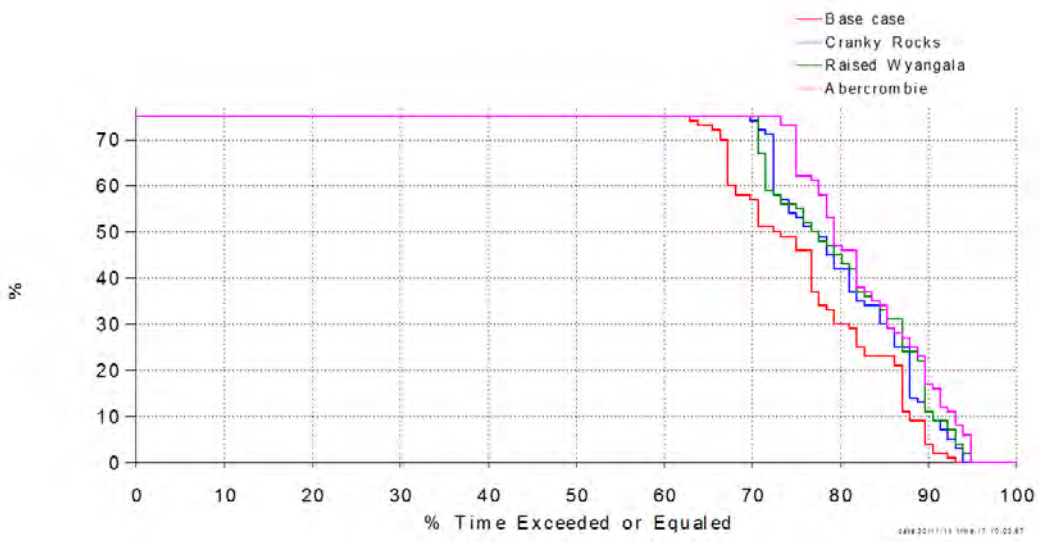
### Short-list Option GS supply outcomes

| Option | Lachlan Valley GS irrigator average annual diversion (GL/a) | Equivalent yield (GL/A) | % years with maximum end of year AA(1) | % years with zero end of year AA |
|---|---|---|---|---|
| Base case | 208.9 | - | 63% | 7% |
| Cranky Rock Dam (700 GL capacity) | 226.8 | 17.9 (GS) + 5 (Centroc) | 70% | 6% |
| Raised Wyangala Dam (2000 GL capacity) | 229.6 | 20.7 | 70% | 5% |
| Abercrombie Dam (700 GL capacity) | 232.0 | 23.1 | 73% | 5% |
| Narrawa Dam (1,000 GL capacity) | 230.7 | 21.8 | 71% | 5% |
| Battery Hill Dam (400 GL capacity) | 221.5 | 12.6 | 71% | 6% |

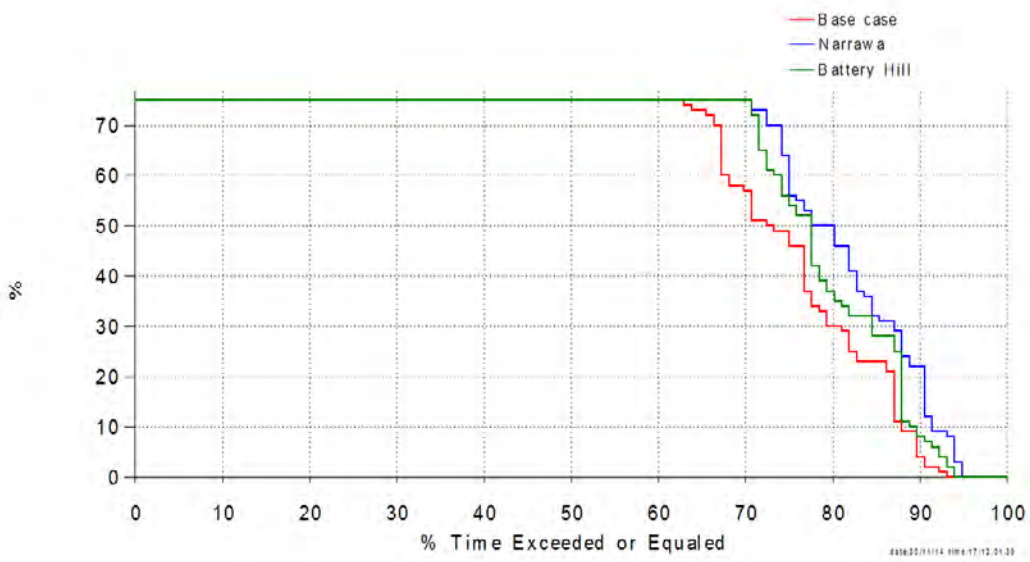
**Notes: (1)** Current Lachlan Valley water sharing rules set a maximum AA of 75%

As described above, it is important to re-iterate that the results summarised in the table are based on a continuation of current system operation and resource assessment/water sharing, and provide an indication of the magnitude of

potential additional GS irrigator resource available ensuring provision for all other water requirements within the Lachlan Valley. The optimisation of how this additional resource was to be utilised (e.g. increased diversions versus increased security, sharing between different water user types, etc) would be the subject of further detailed assessment on the basis of stakeholder feedback regarding desired outcomes and operational considerations for the specific preferred option(s).




**Simulated end-of-year Lachlan GS AA (Base case and options)**




**Simulated end-of-year Lachlan GS AA (Base case and options)**

*Other user performance*

High-level review of supply performance outcomes for other Lachlan Valley water users and Belubula Valley water users was undertaken to assessment the potential for each of the short-listed options to be undertaken with (at least) maintenance of existing supply performance for all users.

In addition to all options providing potential for maintenance or improvement of all current users, the Cranky Rocks short-list option provides for additional potential benefit specific to the Belubula Valley water users and Centroc. A point to note is that the assessment reported here provides high-level outcomes regarding potential for maintenance of performance and is based on long-term availability of water. Further, option-specific assessment, including maintenance/improvement of AA behaviour would be undertaken for more detailed design on the basis of final option selection and stakeholder feedback regarding desired water security outcomes.

**Short-list Option – other Lachlan Valley users**

| Option | HS irrigator average annual diversion (GL) | TWS/SD average annual diversion (GL) |
|---|---|---|
| Base Case | 9.1 | 17.3 |
| Cranky Rock Dam (700 GL capacity) | 9.1 | 17.3 |
| Raised Wyangala Dam (2000 GL capacity) | 9.1 | 17.3 |
| Abercrombie Dam (700 GL capacity) | 9.1 | 17.3 |
| Narrawa Dam (1,000 GL capacity) | 9.1 | 17.3 |
| Battery Hill Dam (400 GL capacity) | 9.1 | 17.3 |

**Short-list Option – Belubula River users**

| Option | HS irrigators average annual diversion (GL/a) | GS irrigators average annual diversion (GL/a) | Mining/TWS/SD (inc Centroc) (average annual diversion (GL/a) |
|---|---|---|---|
| Base Case | 0.5 | 3.5 | 4.5 |
| Cranky Rock Dam (700 GL capacity) | 0.5 | 3.6 | 10.2(1) |
| Raised Wyangala Dam (2000 GL capacity) | 0.5 | 3.5 | 4.5 |
| Abercrombie Dam (700 GL capacity) | 0.5 | 3.5 | 4.5 |
| Narrawa Dam (1,000 GL capacity) | 0.5 | 3.5 | 4.5 |
| Battery Hill Dam (400 GL capacity) | 0.5 | 3.5 | 4.5 |

**Notes: (1)** Increase includes additional Centroc supply and improvement in long-term availability for existing mine and town water supply

*Environmental flow outcomes*

*WSP flow release rules*

The Lachlan Valley WSP specifies a set of environmental flow/release rules formulated during the WSP development process to provide general environmental outcomes such as continuity of flow from the Belubula River, allowance for releases for water quality enhancement, 'translucence' flow rules in which certain natural inflow events to Wyangala Dam are effectively 'passed through' to the downstream river reaches, and minimum flows at key locations along the Lachlan River to promote continuity of flow to and from the end of the system. While the WSP does not define specific flow criteria/targets to be met, the inclusion of these operational rules within the WSP are designed to provide these important flow outcomes. As described above, all environmental and minimum flow rules specified within the WSP have been incorporated into all modelled cases reported here.

*Basin Plan environmental water requirements*

The Lachlan region includes five (5) hydrologic indicator sites (HIS) located throughout the Lachlan System comprising:

- HIS-42 Lachlan River at downstream Wyangala Dam;
- HIS-43 Belubula River at downstream of Carcoar Dam;
- HIS-44 Lachlan River at Jemalong Weir;
- HIS-45 Lachlan River at Willandra Weir; and,
- HIS-46 Lachlan River at Booligal.

Modelling undertaken by the MDBA (February 2012) to support and inform development of the Basin Plan included an assessment of baseflow at these five locations with initial analysis showing significant baseflow shortfalls at only two sites (downstream of Carcoar and Wyangala Dams). Baseflow release demand series were then developed as described in MDBA (2012) for each of these locations. These minimum required release series have been adopted within all modelling reported here.

In-stream fresh and overbank flow indicators have also been defined for the Booligal Wetlands, Great Cumbung Swamp, and the Lachlan Swamp – all wetlands of national significance in the lower sections of the Lachlan system (MDBA, February 2012).

Outcomes against Basin Plan Lower Lachlan Fresh and Overbank Flow Indicators are summarised in the table below, with a full set of tabulated results provided in Attachment A. All Basin Plan flow requirements passed under all short-listed options.

**Short-list Option Basin Plan outcomes**

| Option | Lachlan Swamp | Great Cumbung Swamp | Booligal Wetlands |
|---|---|---|---|
| Base Case | Pass (Table A-1) | Pass (Table A-2) | Pass (Table A-3) |
| Raised Wyangala Dam (2,000 GL capacity) | Pass (Table A-4) | Pass (Table A-5) | Pass (Table A-6) |

| Option | Lachlan Swamp | Great Cumbung Swamp | Booligal Wetlands |
|---|---|---|---|
| Cranky Rocks Dam (700 GL capacity) | Pass (Table A-7) | Pass (Table A-8) | Pass (Table A-9) |
| Abercrombie Dam (700 GL capacity) | Pass (Table A-10) | Pass (Table A-11) | Pass (Table A-12) |
| Narrawa Dam (1,000 GL capacity) | Pass (Table A-13) | Pass (Table A-14) | Pass (Table A-15) |
| Battery Hill Dam (400 GL capacity) | Pass (Table A-16) | Pass (Table A-17) | Pass (Table A-18) |

### Input to MCA

In order to provide input to the MCA being undertaken, a defined set of relative rankings (between zero and 10, zero being lowest and 10 being highest value) for each option was required.

Without clear definition of the specific water security improvement requirements of the stakeholders, and a quantitative measure of that requirement, a measure of comparative performance was determined based on the additional equivalent yield. This was selected as indicating a direct measure of the potential of the option to provide improved performance. While not a direct measure of all aspects of 'water security' in itself, this approach does provide the most appropriate and directly comparable measure of Option potential within the high-level approach to assessment undertaken at this stage.

Further to the direct measure, a series of supply system characteristics of importance to real-world water security during extreme dry conditions was subjectively assessed to provide support and understanding around the efficacy of the direct ranking approach being used.

The table below summarises direct ranking and supporting consideration values for each of the short-listed options. Additional equivalent yield values in the table below are as described in the section above.

Comparative ranking was undertaken using a 'normalisation' approach in which the outcomes for each Option are directly rated against the maximum value. That is, the highest value Option is given a ranking of 10 and all other options are given a ranking directly proportional to this value. For the short-listed Options the maximum additional equivalent yield value (23.1 GL/yr for Abercrombie Dam) was therefore given a value of 10 and all other options normalised against this value on the basis of their additional equivalent yield values. Outcomes from the relative ranking indicate that several options (Cranky Rocks, Raised Wyangala, Abercrombie and Narrawa) provide a similar level of potential benefit while Battery Hill shows significant less potential to provide improvement in water security.

These outcomes were then reviewed on the basis of the key storage option characteristics required to provide improved security over the existing system. The ability of a system to continue to provide water during an extreme dry is directly related to the volume stored at the beginning of the drought. Additional water in storage at the beginning of a drought means that supply has the potential to last longer under dry conditions. However, while the additional storage volume does provide an indication of potential improvement in water security, this security will also rely on the total catchment area being accessed and potential for capture of additional flows both prior to (i.e. likelihood of storage being full) and during (i.e. likelihood of receiving inflows) those periods. Therefore capture of additional catchment area and low flows during dry conditions is an important element of water security improvement.

Finally, the amount of evaporation experienced throughout the drought will also directly effect the potential for the system to maintain supply, with more efficient storages (i.e. smaller surface area for same stored volume) leading to less evaporation and therefore greater potential for continued supply under ongoing drought conditions.

Based on the above, Option characteristics considered in supporting the relative rankings above comprised:

- Additional storage volume provided by the Option;
- Additional catchment area capture by the Option;
- Additional inflow that could have been captured over the recent Millenium Drought;

- Potential additional evaporation associated with each Option, considered via the surrogate measure of total additional surface area associated with the additional storage being provided.

On the basis of these characteristics, an immediate explanation of Battery Hill relative performance is the lower storage volume provided (approximately 50% that of other Options). The underlying reason behind the selection of a 400 GL storage at Battery Hill as a short-listed option (i.e. as opposed to a larger storage at the same location) can be found in Appendix D.

For the remaining four (4) short-listed Options, advantages to Abercrombie (the highest ranking Option) are similar additional storage to Cranky Rock and raised Wyangala coupled with more efficient storage characteristics (i.e. less evaporative loss). Advantages to Cranky Rock are an increased catchment area (i.e. increased likelihood of stored water at beginning of dry conditions, as well as increased likelihood of capture of flows during a dry period), while a raised Wyangala provides slightly higher additional storage than Abercrombie or Cranky Rock options. The Narrawa Option has the advantage of greater increase in storage potential, however exhibits greater evaporative loss potential (i.e. less efficient storage) than the other options and does not provide any additional catchment.

While not intended to imply a detailed level of assessment, these subjective/reason-based outcomes generally support the direct measures and provide further depth of information for supporting MCA outcomes.

**MCA – Hydrological inputs**

| Criteria | Cranky Rock | Raised Wyangala | Abercrombie | Narrawa | Battery Hill |
|---|---|---|---|---|---|
| Direct comparison | | | | | |
| Additional equivalent yield (GL) | 22.9 (17.9 + 5) | 20.7 | 23.1 | 21.8 | 12.6 |
| *Relative/normalised performance)* | *9.9* | *9.0* | *10* | *9.4* | *5.5* |

| Criteria | Cranky Rock | Raised Wyangala | Abercrombie | Narrawa | Battery Hill |
|---|---|---|---|---|---|
| Supporting considerations | | | | | |
| Additional storage volume (GL) | +700 | +780 | +700 | +1,000 | +400 |
| Additional catchment area ($km^2$) | +1,600 | 0 | 0 | 0 | +1,800 |
| Additional minimum annual inflow (GL) | +10 | 0 | 0 | 0 | +1 |
| Maximum evaporative area (ha) | 8,100 | 8,100 | 7,300 | 11,300 | 8,300 |

## Outcomes and discussion

Key outcomes from high-level hydrological assessment comprise:

- Hydrological potential exists for significant augmentation of total system water resource via a range of dam options within the Lachlan Valley.
- Estimated scale of GS irrigator supply improvement for short-listed options is of the order of 5-10% of current estimated long-term diversions (i.e. approx. 10-25 GL/a total additional resource against existing estimated approx. 210 GL/a long-term diversion).
- Additional resource from each options appears able to be provided with maintenance or improvement of supply performance for other existing water users, noting high-level stage of assessment and requirement for further detailed studies.
- All Lachlan Valley WSP environmental release rules maintained and simulated within all short-listed options.
- Basin Plan environmental flow requirements are met under all short-listed options.
- Hydrological assessment reported here comprised high-level proof of concept/option ranking assessment. Stakeholder-specific water security

needs, measures and outcomes are to be developed/confirmed in later stages of option development studies.

Re-stating a key consideration in understanding the assessment results reported herein, results are based on a continuation of current system operation and resource assessment/water sharing, and provide an indication of the magnitude of potential additional GS irrigator resource available ensuring provision for all other water requirements within the Lachlan Valley, consistent with the stated aims of the overarching study.

The optimisation of how this additional resource could be utilised (e.g. increased diversions versus increased security, sharing between different water user groups, etc) would be the subject of further detailed assessment on the basis of stakeholder feedback regarding desired outcomes and operational considerations for the specific preferred option(s).

**Attachment A**

Lower Lachlan Fresh and Overbank Flow Indicators

## Base Case (Lachlan Swamp)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 4 | 0 | 3 | -1 | 6 | 60 | 53% | 7 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 3 | 11 | 3 | 0 | 17 | 43 | 38% | 9 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 3 | 0 | 1 | 0 | 4 | 27 | 24% | 3 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | 0 | 5 | 25 | 22% | 1 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## Base Case (Great Cumbung)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 7 | 3 | 3 | -1 | 12 | 62 | 54% | 6 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 7 | 1 | 3 | 0 | 11 | 50 | 44% | 2 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 2 | 2 | 2 | 0 | 6 | 27 | 24% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

## Base Case (Booligal Wetlands)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 19 | 5 | 2 | -1 | 25 | 82 | 72% | 4 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 3 | 11 | 3 | 0 | 17 | 43 | 38% | 9 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | 0 | 5 | 25 | 22% | 1 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 700 GL Cranky Rocks Dam (Lachlan Swamp)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 3 | 1 | 2 | -2 | 4 | 58 | 51% | 7 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 5 | 7 | 3 | -1 | 14 | 40 | 35% | 12 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 3 | 0 | 1 | 0 | 4 | 27 | 24% | 3 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

## 700 GL Cranky Rocks Dam (Great Cumbung)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event – threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 5 | 3 | 4 | -1 | 11 | 61 | 54% | 7 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 6 | 1 | 5 | -2 | 10 | 49 | 43% | 6 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 3 | 1 | 2 | -1 | 5 | 26 | 23% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 700 GL Cranky Rocks Dam (Booligal Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event – threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 19 | 3 | 2 | -1 | 23 | 80 | 70% | 6 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 5 | 7 | 3 | -1 | 14 | 40 | 35% | 12 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## Raised Wyangala Dam (Lachlan Swamp)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2-3+4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 3 | 0 | 3 | -1 | 5 | 59 | 52% | 8 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 5 | 8 | 2 | 0 | 15 | 41 | 36% | 11 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 2 | 1 | 1 | 0 | 4 | 27 | 24% | 3 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## Raised Wyangala Dam (Great Cumbung)

| Flow Indicator | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | Number of years with successful events | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2-3+4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 5 | 6 | 3 | -1 | 13 | 63 | 55% | 5 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 7 | 2 | 3 | 0 | 12 | 51 | 45% | 4 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 2 | 2 | 4 | 0 | 8 | 29 | 25% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## Raised Wyangala Dam (Booligal Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Orders and fully delivered (1) | Orders and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3+4) | Number of years with successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 17 | 7 | 2 | -1 | 25 | 82 | 72% | 4 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 5 | 8 | 2 | 0 | 15 | 41 | 36% | 11 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 700 GL Abercrombie Dam (Lachlan Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Orders and fully delivered (1) | Orders and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3+4) | Number of years with successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 3 | 0 | 3 | -1 | 5 | 59 | 52% | 8 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 4 | 9 | 2 | -1 | 14 | 40 | 35% | 13 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 2 | 2 | 1 | -1 | 4 | 27 | 24% | 2 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

## 700 GL Abercrombie Dam (Great Cumbung)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event* | Proportion of years with a successful environmental event* | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 5 | 4 | 3 | -1 | 11 | 61 | 54% | 6 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 6 | 3 | 3 | 0 | 12 | 51 | 45% | 2 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 2 | 2 | 2 | -2 | 4 | 25 | 22% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 700 GL Abercrombie Dam (Booligal Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event* | Proportion of years with a successful environmental event* | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 17 | 6 | 2 | -1 | 24 | 81 | 71% | 5 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 4 | 9 | 2 | -1 | 14 | 40 | 35% | 13 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 1,000 GL Narrawa Dam (Lachlan Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum events/years to run/save | Number of years with successful events | | | | | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rule Applied |
| Flow Event – threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | | | | | | | | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | | | | | |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 2 | 1 | 3 | -1 | 5 | 59 | 52% | 8 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 2 | 11 | 2 | -1 | 14 | 40 | 35% | 13 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 2 | 1 | 1 | 0 | 4 | 27 | 24% | 3 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 1,000 GL Narrawa Dam (Great Cumbung)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum events/years to run/save | Number of years with successful events | | | | | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rule Applied |
| Flow Event – threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | | | | | | | | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | | | | | |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 5 | 4 | 3 | -1 | 11 | 61 | 54% | 6 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 7 | 1 | 4 | -1 | 11 | 50 | 44% | 3 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 2 | 2 | 2 | -1 | 5 | 26 | 23% | 4 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

## 1,000 GL Narrawa Dam (Booligal Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 17 | 5 | 2 | -1 | 23 | 80 | 70% | 6 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 2 | 11 | 2 | -1 | 14 | 40 | 35% | 13 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 4 | 0 | 1 | -2 | 3 | 23 | 20% | 2 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 400 GL Battery Hill Dam (Lachlan Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | | | | | | | | Number of years with successful events | | | | | | | | | | |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2+3-4) | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| 1 | 850 ML/d for 20 consecutive days between Jun & Nov | 50 - 60 % | 65% | 47% | 54 | 59 | 52% | 50% | 2 | 4 | 0 | 2 | -1 | 5 | 59 | 52% | 7 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 4 | 8 | 4 | -1 | 15 | 41 | 36% | 10 | passed | S6.07 (b)(1) |
| 3 | 1,000 ML/d for 60 consecutive days between Jun & Nov | 20 - 30 % | 30% | 20% | 23 | 28 | 25% | 23% | 2 | 2 | 1 | 1 | 0 | 4 | 27 | 24% | 3 | passed | S6.07 (b)(1) |
| 4 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 3 | 1 | 2 | 0 | 6 | 26 | 23% | 0 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 400 GL Battery Hill Dam (Great Cumbung)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Number of years with successful events | | | | | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | | | | | | | | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2-3-4) | | | | | |
| 1 | 700 ML/d for 25 consecutive days between Jun & Nov | 50 - 60 % | 69% | 44% | 50 | 61 | 54% | 50% | 4 | 6 | 3 | 4 | -1 | 12 | 62 | 54% | 6 | passed | S6.07 (b)(1) |
| 2 | 1,500 ML/d for a total duration of 35 days (with min duration of 1 day) between Jun & Nov | 40 - 45 % | 55% | 34% | 39 | 51 | 45% | 41% | 4 | 6 | 3 | 3 | -1 | 11 | 50 | 44% | 3 | passed | S6.07 (b)(1) |
| 3 | 2,700 ML/d for 30 consecutive days between Jun & Nov | 20% | 26% | 18% | 21 | 26 | 23% | 21% | 2 | 2 | 2 | 2 | 0 | 6 | 27 | 24% | 3 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

## 400 GL Battery Hill Dam (Booligal Swamp)

| | | | Without Development | Baseline | | SDL Benchmark (#983) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow Indicator | | | Proportion of years with a successful event | Proportion of years with a successful event | Number of years with a successful event | Number of years with a successful event | Proportion of years with a successful event | Limits of Change (LoC) | Maximum event years to remove | Number of years with successful events | | | | | Number of years with a successful environmental event * | Proportion of years with a successful environmental event * | Number of additional years with events partially delivered (6) | Limits of Change (Result) | Rules Applied |
| Flow Event - threshold, duration, season (as gauged on the Lachlan River at Booligal Weir) | | Target Proportion of years with a successful event | | | | | | | | Ordered and fully delivered (1) | Ordered and fully delivered within 10% (2) | Other successful events (3) | Baseline events lost (4) | Total additional to baseline (5) = (1+2-3-4) | | | | | |
| 1 | 300 ML/d for 25 consecutive days between Jun & Nov | 70 - 75 % | 84% | 50% | 57 | 82 | 72% | 70% | 2 | 19 | 4 | 2 | -1 | 24 | 81 | 71% | 5 | passed | S6.07 (b)(1) |
| 2 | 850 ML/d for a total duration of 70 days (with min duration of 1 day) between Jun & Nov | 33 - 40 % | 49% | 23% | 26 | 43 | 38% | 34% | 4 | 4 | 8 | 4 | -1 | 15 | 41 | 36% | 10 | passed | S6.07 (b)(1) |
| 3 | 2,500 ML/d for 50 consecutive days between Jun & Nov | 20% | 23% | 18% | 20 | 25 | 22% | 20% | 2 | 3 | 1 | 2 | 0 | 6 | 26 | 23% | 0 | passed | S6.07 (b)(1) |

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events.

# Appendix E: Environmental Assessment of Options

This appendix describes the preliminary environmental assessment undertaken to identify the environmental issues as they relate to each potential dam option under investigation.

**Scope of Works**

The scope of works for the environmental assessment was limited to a desktop study to identify environmental constraints, relevant environmental legislation and statutory implications. Feedback from stakeholder engagement was also considered.

It is not intended to provide a comprehensive environmental impact assessment. The purpose of this study is to enable a relative options comparison and provide a high level implementation road map for the recommended option or options.

**Approach**

*Data Compilation / Literature Review*

The first step in the assessment has been to identify the technical information available regarding the environmental values and, in turn, constraints that are likely to impact on the feasibility of each water storage option.

Literature reviewed included a range of studies, reports and related documentation from past dam feasibility studies for the Lachlan Valley, environmental flow assessments and management strategies etc for the Murray Darling-Basin, Murrumbidgee and Lachlan Valley Catchments, and various environmental assessments for dam safety upgrades, water efficiency and weir remedial works within the catchment.

Data gathered was interrogated using ESRI® ArcMap™ v.10.2.2.3552 included the following:

- Office of Environment and Heritage NSW (OEH):
  - Murrumbidgee CMA vegetation mosiac map VIS_ID 3879, 2011
  - Reconstructed and Extant Distribution of Native Vegetation in the Lachlan Catchment VIS_ID 3780, 2006
  - Reconstructed and Extant Distribution of Native Vegetation in the Lachlan Catchment VIS_ID 3779, 2006
- OEH NSW National Parks and Wildlife Service (NPWS) Estate, current as at 2014

- OEH BioNet Atlas of NSW Wildlife Public Report of all valid records of threatened species (listed on TSC Act 1995), Commonwealth listed, CAMBA listed, JAMBA listed or ROKAMBA listed entities in Lachlan CMA. Report generated on 23/09/2014 3:12 PM – search area being a 10km radius from each short listed option.
- OEH Aboriginal Heritage Information Management System (AHIMS) – search areas included indicative inundation extent and a 1km buffer from each short listed option.
- Standard Instrument Local Environmental Plan (LEP) - Heritage (HER) – heritage items or heritage conservation areas data identified in Schedule 5 of relevant LEPs
- NSW Department of Planning and Infrastructure - State Heritage Register (OEH State Heritage Register and Interim Heritage Orders)
- Department of Environment Australian Heritage Database

*Options Screening*

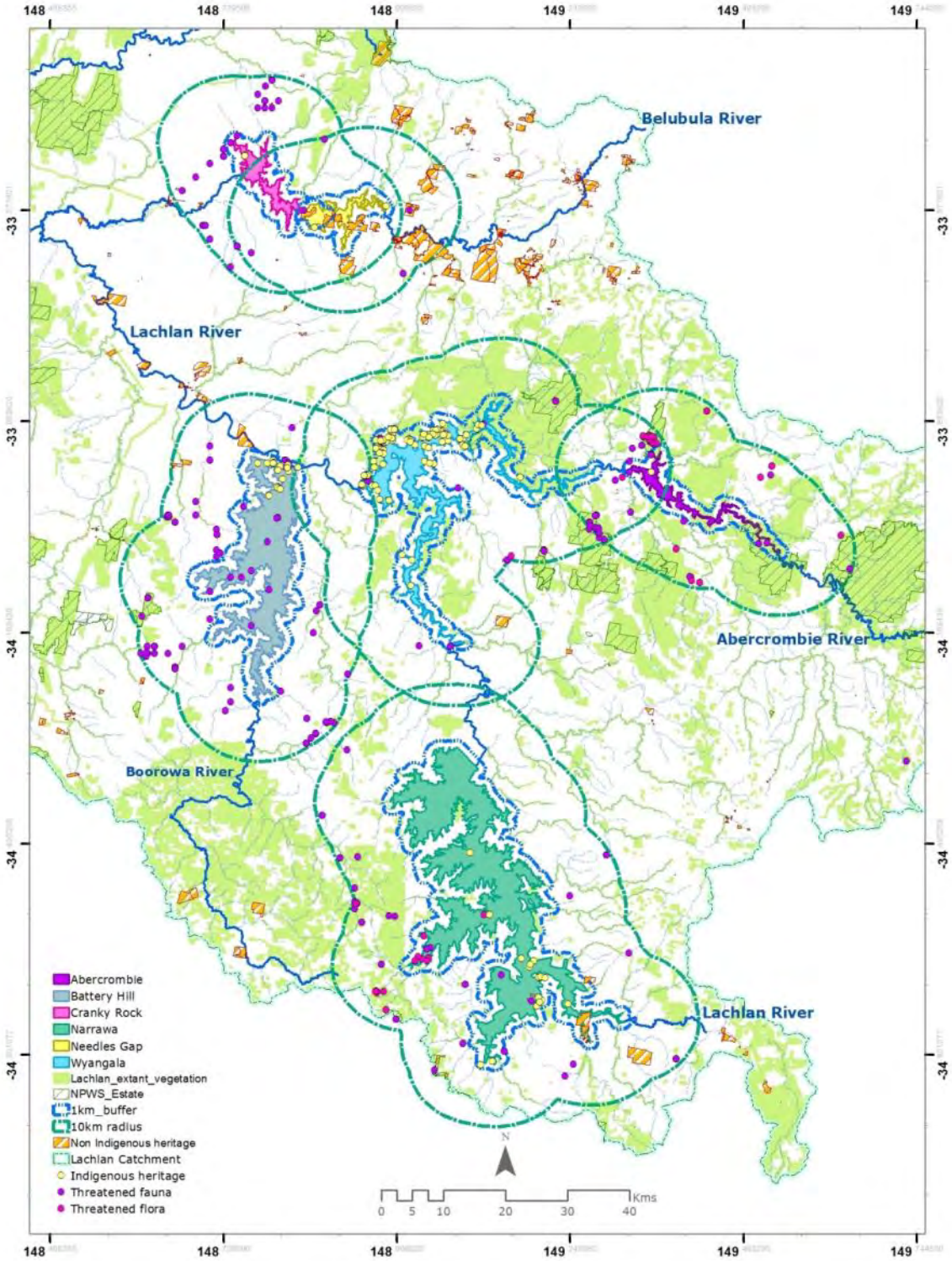
For the purpose of this study, with the exception of meeting the Basin Plan requirements, environmental constraints were considered as part of the desirable criteria and treated as a constant when assessing the long-list of options.

The short-list of options (achieved through hydrologic modelling, engineering, costing and social considerations) is set out below in the table below and shown in the following figure with mapped environmental constraints.

**Short-List of Options**

| Option | Description |
|---|---|
| Abercrombie Dam, Abercrombie River | A new dam on the Abercrombie River near Tuena and upstream of the Goulburn Road crossing of the Abercrombie River. |
| Battery Hill Dam, Boorowa River | A new dam on the Boorowa River, upstream of its confluence with the Lachlan River and downstream of Cowra. |
| Cranky Rock Dam, Belubula River | A new dam on the Belubula River, above Moorbel and approximately 15km east of Canowindra or about 2km downstream of Cranky Rock Dam site 1 and about 13km east of Canowindra. The two sites are very difficult to distinguish for the purposes of desktop assessment and hence have been considered as a single location. |
| Narrawa Dam, Lachlan River | A new dam on the Lachlan River upstream and south of Hillandale Dam site. |
| Needles Dam, Belubula River | A new dam on the Belubula River about 10 km upstream of Cranky Rock Dam site. |

| Option | Description |
|---|---|
| Raise Wyangala Dam, Lachlan River | Raising the exiting embankment dam on the Lachlan River by 20m. |




**Environmental constraints – short-listed options**

**Environmental Assessment**

*Multi-Criteria Assessment Environmental Criteria*

Environmental criteria were limited to those attributes for which data was able to be sourced via the desktop study. Factors considered include the following and are scored and ranked in the table below:

- Watercourse (relative length watercourses mapped as Perennial) – representing loss of river aquatic habitat.
- Area of disturbance (extent of inundation in hectares) – representing the loss of land and potential terrestrial habitat and the magnitude of the impact.
- NPWS estate (hectares) – loss of high conservation land reserved under *National Parks and Wildlife Act 1974* (NP&W Act)
- Vegetation (hectares) – loss of mapped native vegetation / wildlife corridor
- Heritage indigenous (number) - AHIM sites that would be inundated
- Heritage non-indigenous (hectares) - extent of land (lot no.) containing heritage sites
- Threatened flora species (number) - flora species and/or populations listed under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and NSW *Threatened Species Conservation Act 1995* (TSC Act).
- Threatened fauna species (number) - fauna species and/or populations listed under the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and NSW *Threatened Species Conservation Act 1995* (TSC Act).
- Threatened fish species (number) - of fin fish species listed under the *Fisheries Management Act 1994* (FM Act)

*Assumptions*

- The assessment area has been limited to upstream of the proposed dam wall with the exception of a one kilometre buffer zone surrounding the modelled area of inundation. Downstream impacts are assumed “able to be mitigated”.
- Areas such as Wyangala Dam and upstream Abercrombie River have been studied more intensively and therefore score more highly in areas of Indigenous Heritage and environmental flow related aspects.

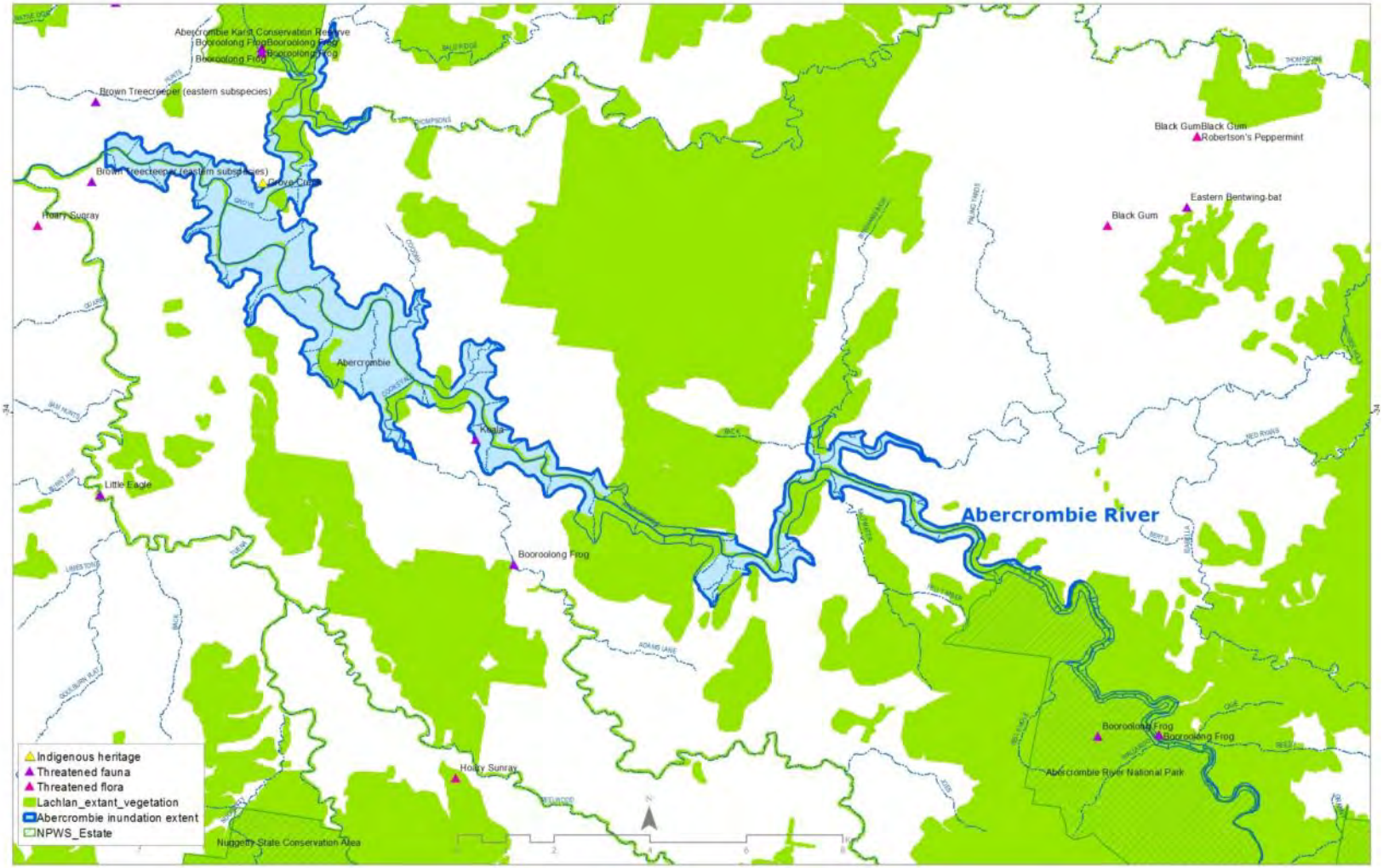
**Preliminary environmental investigations**

| Site | Waterway | NPWS Estate | Vegetation | Indigenous Heritage | Non Indigenous Heritage* | **EPBC Act** Flora & Fauna | **TSC Act** Flora & Fauna Fauna | **FM Act** Fauna & Habitat |
|---|---|---|---|---|---|---|---|---|
| **Abercrombie** | Abercrombie River | Abercrombie Karst Conservation Reserve; Abercrombie River National Park | Eastern Riverine Forests; Southern Tableland Grassy Woodlands; Upper Riverina Dry Sclerophyll Forests; Western Slopes Grassy Woodlands | Grove Creek – Carved tree | nil | Flora: Hoary Sunray E; Robertson's Peppermint V<br>Fauna: Murray cod E; Koala V; Booroolong Frog E | Flora: Robertson's Peppermint V; Black Gum V<br>Fauna: Booroolong Frog E; Brown Treecreeper V; Eastern Bent-wing Bat V; Koala V; Little Eagle V | Macquarie perch E; Silver perch V<br>EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |
| **Battery Hill** | Boorowa River | nil | Eastern Riverine Forests; Floodplain Transition Forests; Inland Riverine Forests; Southern Tableland Grassy Woodlands; Upper Riverina Dry Sclerophyll Forests; Western Slopes Dry Sclerophyll Forests; Western Slopes Grassy Woodlands | Open Sites (21) – camp sites, quarries, scarred trees other artefacts | nil | Fauna: Regent Honeyeater E; Superb Parrot V | Fauna: Regent Honeyeater CE; Superb Parrot V; Grey Crowned Babbler V; Diamond Firetail V; Barking Owl V | Macquarie perch E; Silver perch V<br>EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |
| **Cranky Rock** | Belubula River | nil | Floodplain Transition Forests; North-west Slopes Dry Sclerophyll Woodlands; Southern Tableland Grassy Woodlands; Western Slopes Dry Sclerophyll Forests | 6 in search area (open camp sites, artefact-open site) | Needles Area** | Fauna: Superb Parrot V; Brush-tailed Wallaby V | Fauna: Superb Parrot V; Brush-tailed Wallaby E | EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |

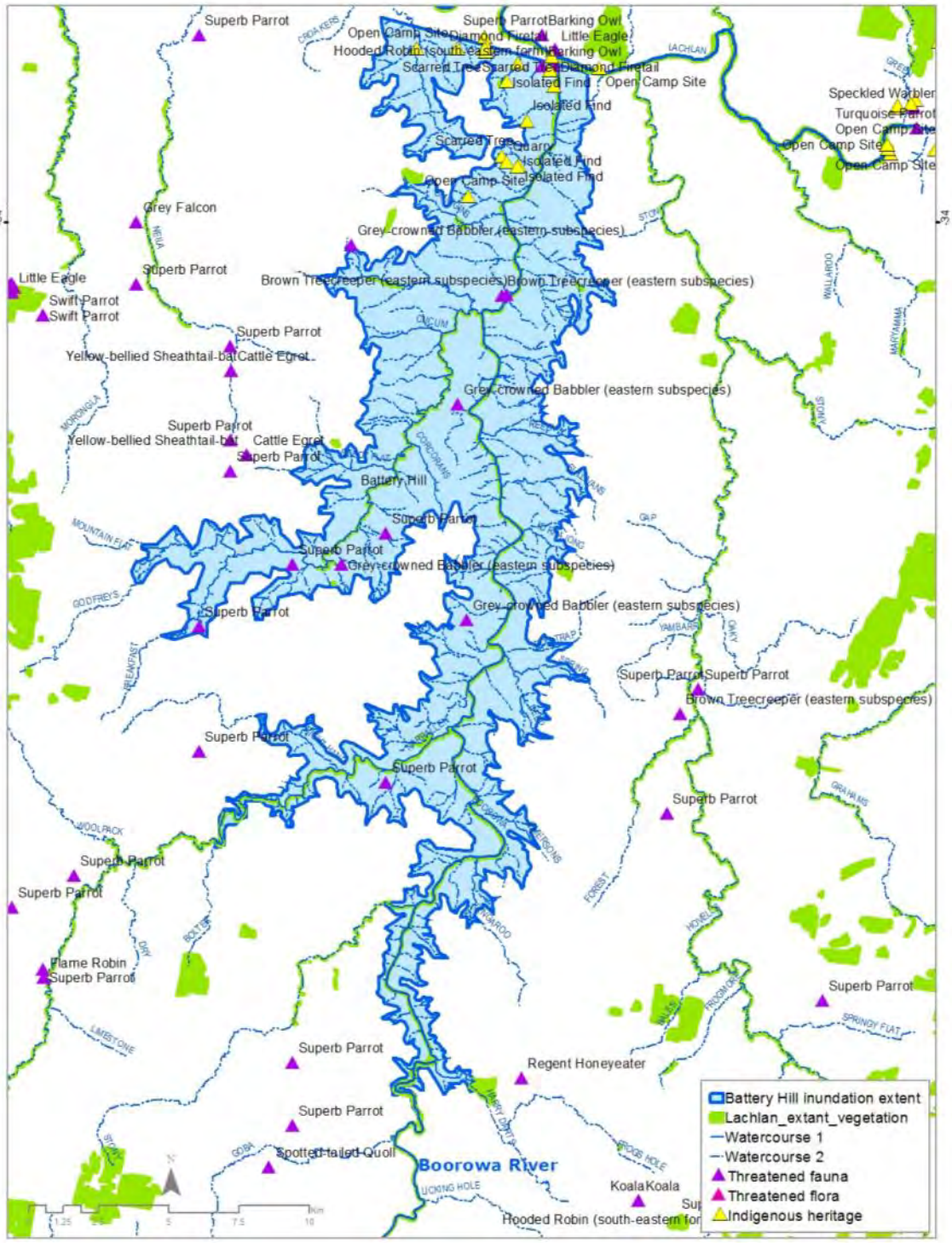
| Site | Waterway | NPWS Estate | Vegetation | Indigenous Heritage | Non Indigenous Heritage* | EPBC Act Flora & Fauna | TSC Act Flora & Fauna Fauna | FM Act Fauna & Habitat |
|---|---|---|---|---|---|---|---|---|
| **Needles** | Belubula River | nil | Floodplain Transition Forests; Southern Tableland Grassy Woodlands; Western Slopes Grassy Woodlands | Open Sites (3) – carved or scarred trees | Millamolong remnants; Cliefden Caves; Needles area** | Fauna: Brush-tailed Wallaby V | Fauna: Brush-tailed Wallaby E | EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |
| **Narrawa** | Lachlan River | nil | Eastern Riverine Forests; Inland Riverine Forests; Southern Tableland Grassy Woodlands; Temperate Montane Grasslands; Upper Riverina Dry Sclerophyll Forests; Western Slopes Grassy Woodlands | Open Sites (17) – camp sites or other artefacts | 11 x items (several buildings in Dalton, two cemeteries) | Flora: Yass Daisy V; Hoary Sunray E | Flora: Yass Daisy V<br>Fauna: Diamond Firetail V; Hooded Robin V | Macquarie perch E; Silver perch V<br>EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |
| **Wyangala Dam** | Lachlan River | Mount Davies SCA | Eastern Riverine Forests; Floodplain Transition Forests; Inland Riverine Forests; North-west Slopes Dry Sclerophyll Woodlands; Southern Tableland Grassy Woodlands; Upper Riverina Dry Sclerophyll Forests; Western Slopes Grassy Woodlands | 165 sites (burials, shelters, quarries, camp sites, scarred and carved trees, stone arrangements) | Nil | Flora: Yass Daisy V<br>Fauna: Spotted Tail Quoll E; Regent Honeyeater E; Superb Parrot V; Murray cod E | Flora: Yass Daisy V<br>Fauna: Spotted Tail Quoll V; Regent Honeyeater CE; Varied Sitella V; Little Eagle V; Turquoise Parrot V; Superb Parrot V; Diamond Firetail V; Speckled Warbler V | Freshwater catfish E (population); Silver perch V; Macquarie Perch E<br>EEC: Aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River |
| E= Endangered V = Vulnerable EEC = endangered ecological community | | | | | | | | |

* Locally significant heritage places only, no Commonwealth or State listed heritage items affected by any of the shortlisted options. ** Cliefden Caves and The Needles Areas were listed on the Register of the National Estate (RNE) in 1987. The RNE was closed in 2007 and is no longer a statutory list. Unless included in another Commonwealth statutory heritage list or owned or leased by the Commonwealth, former RNE places are no longer protected under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Places on the RNE may however, be protected under appropriate state, territory or local government heritage legislation. In this instance the Cliefden Caves and The Needles Area are listed under Schedule 5 of Blayney and Cowra Local Environment Plans.

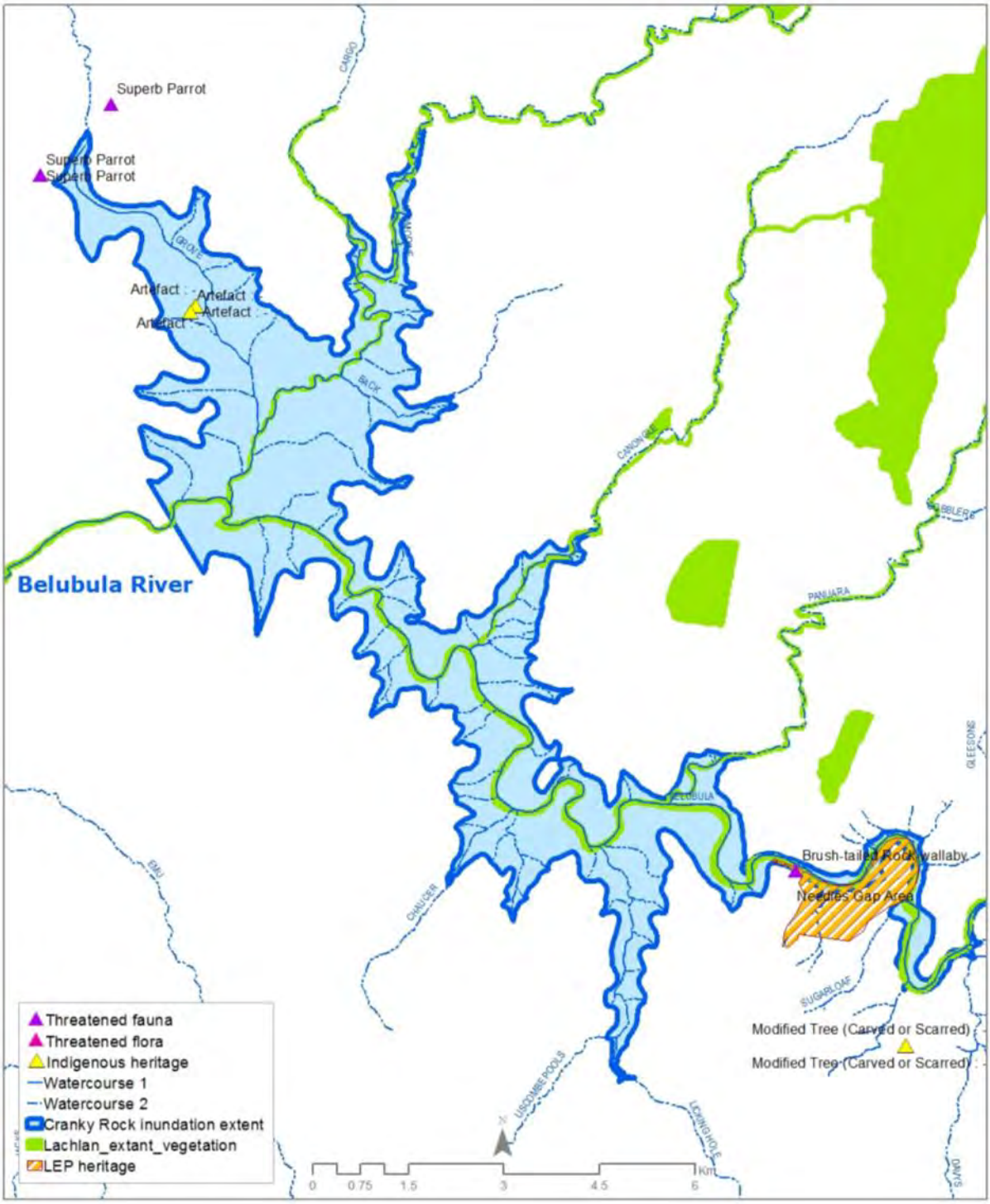
Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014



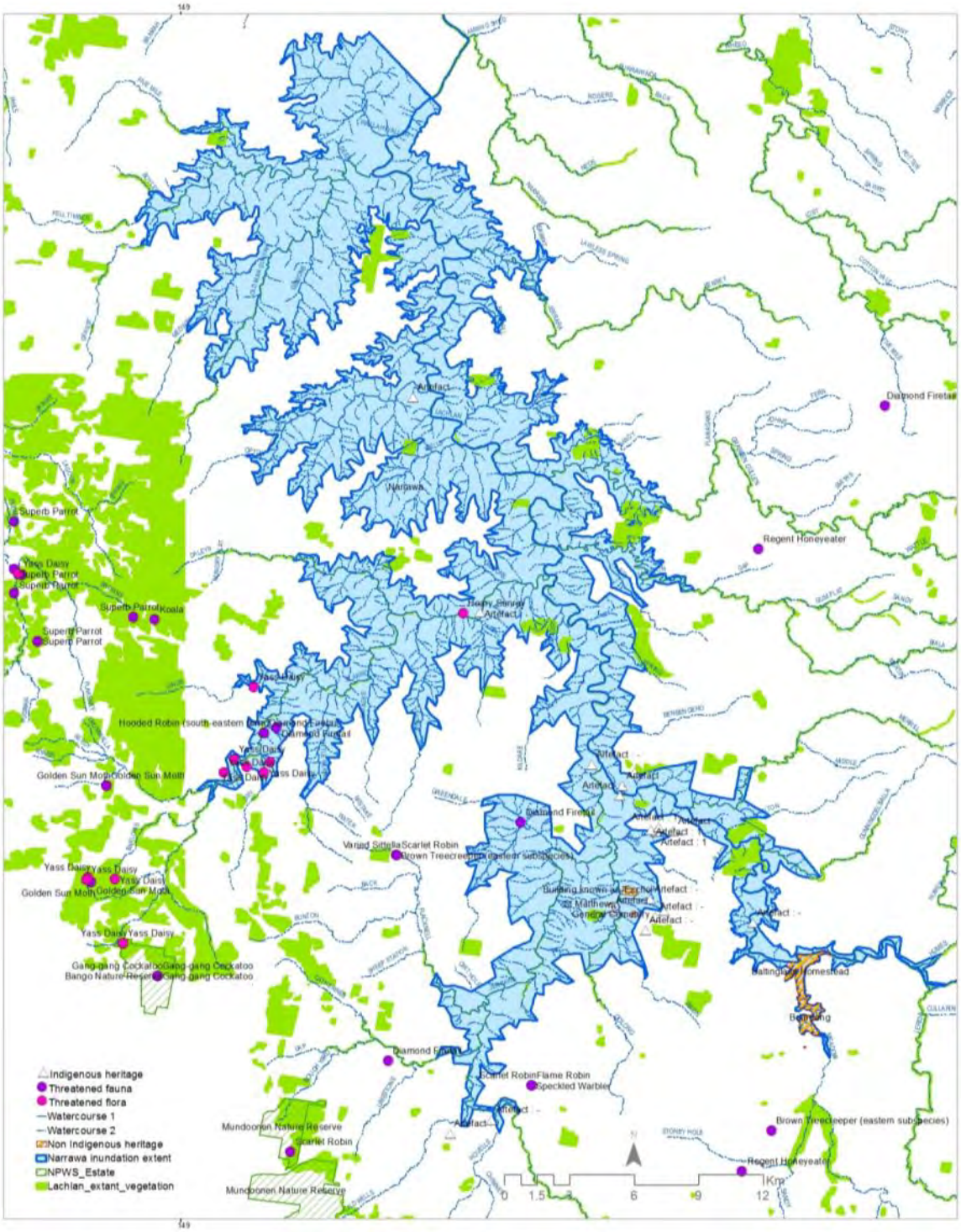

**Abercrombie Dam Constraint Mapping**



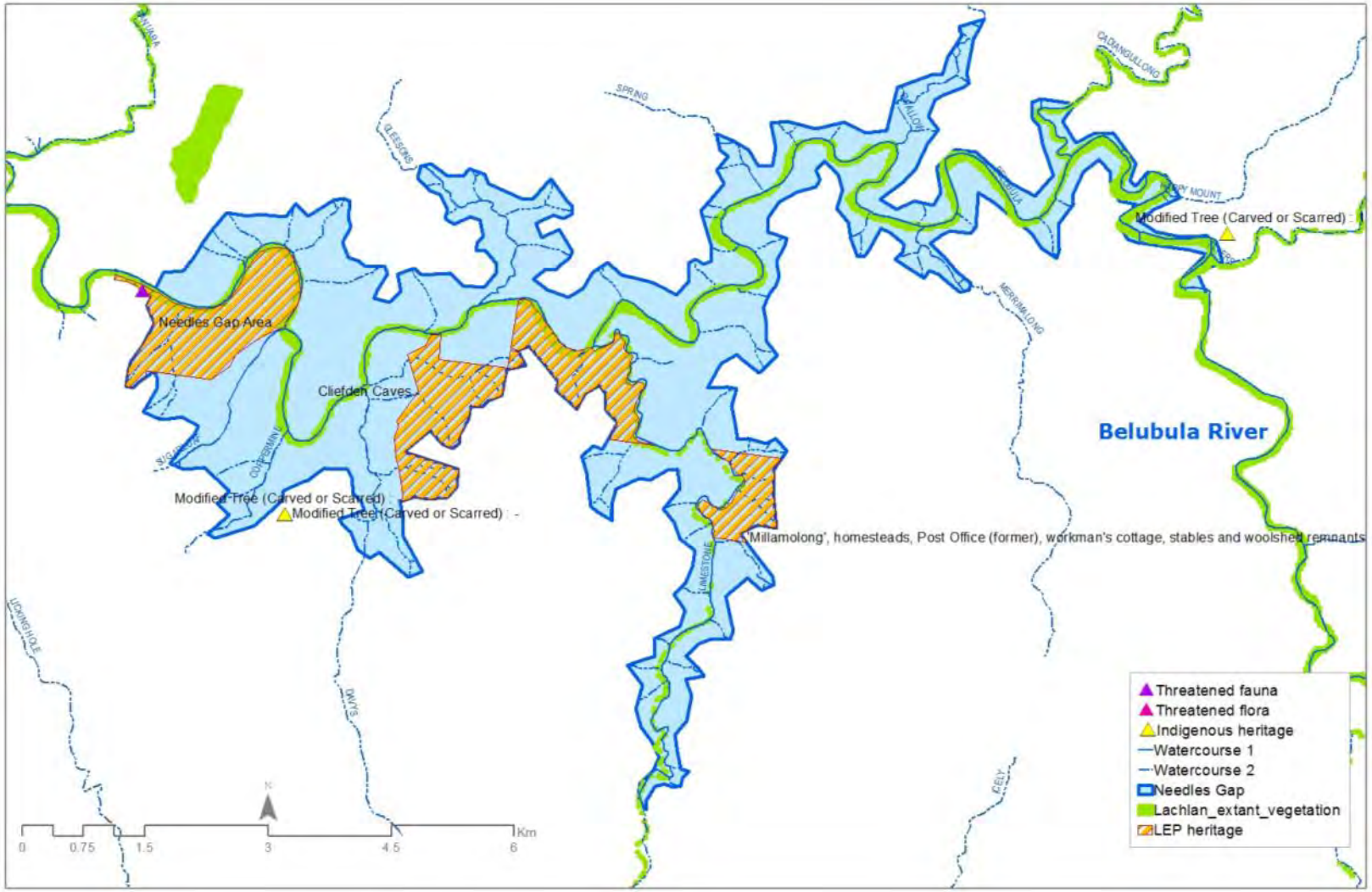

**Battery Hill Dam Constraint Mapping**



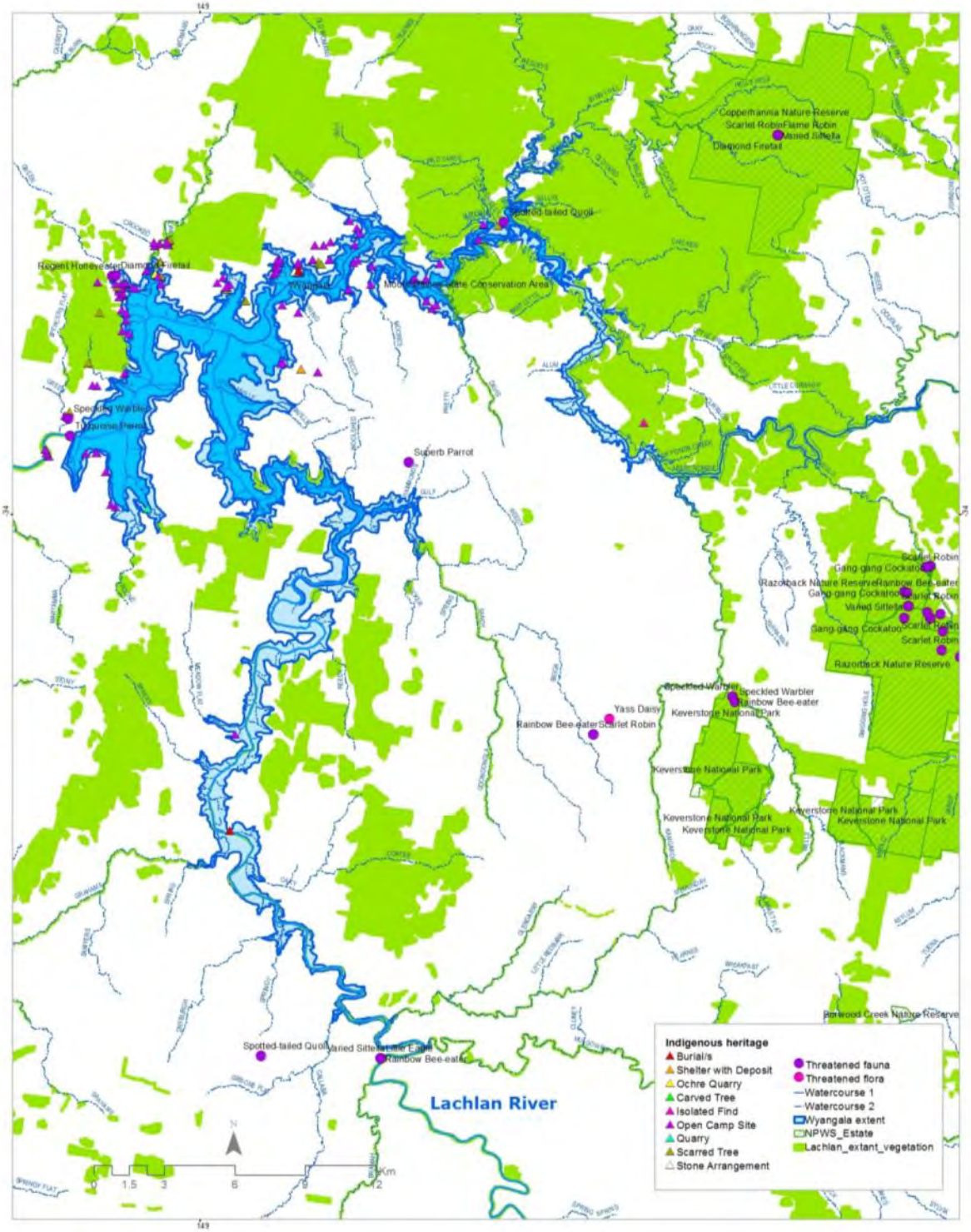

**Cranky Rock Dam Constraint Mapping**




**Narrawa Dam Constraint Mapping**




**Needles Dam Constraint Mapping**




**Wyangala Dam Constraint Mapping**

## Environmental Options Analysis

| Site | Watercourse | | Land disturbed | | NPWS | | Vegetation | | Indigenous Heritage sites | | Non Indigenous Heritage sites | | TSC Act and EPBC Act | | | | FM Act | | Rank | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length | Score | Area (ha) | Score | Area (ha) | Score | Area (ha) | Score[1] | AHIM (1km Buffer) | Score | LEP Heritage Register | Score | Flora | Score | Fauna | Score | Fish | Score | | |
| Abercrombie | 911 | **0.92** | 2,000 | **0.67** | 63 | **0.00** | 518 | | 1 | **0.99** | 0 | **1.00** | 3 | **0.00** | 5 | **0.44** | 2 | **0.00** | 4.0 | **4th** |
| Cranky Rock | 856 | **0.93** | 2,800 | **0.53** | 0 | **1.00** | 164 | | 6 | **0.96** | 145 | **0.63** | 0 | **1.00** | 2 | **0.78** | 0 | **1.00** | 6.8 | **1st** |
| Needles | 861 | **0.93** | 2,800 | **0.53** | 0 | **1.00** | 146 | | 3 | **0.98** | 394 | **0.00** | 0 | **1.00** | 2 | **0.78** | 0 | **1.00** | 6.2 | **2nd** |
| Battery Hill | 4,502 | **0.63** | 3,000 | **0.50** | 0 | **1.00** | 286 | | 20 | **0.88** | 0 | **1.00** | 0 | **1.00** | 5 | **0.44** | 2 | **0.00** | 5.4 | **3rd** |
| Narrawa | 12,081 | **0.00** | 6,000 | **0.00** | 0 | **1.00** | 1,122 | | 17 | **0.90** | 218 | **0.45** | 2 | **0.33** | 6 | **0.33** | 2 | **0.00** | 3.0 | **6th** |
| Wyangala | 3,217 | **0.73** | 2,800 | **0.53** | 35 | **0.45** | 600 | | 168 | **0.00** | 0 | **1.00** | 1 | **0.50** | 9 | **0.00** | 2 | **0.00** | 3.2 | **5th** |

Score = 0 to 1 (relative to maximum value); [1] included in cost to offset lost vegetation. Sensitivity tested inclusion and does not change rank

| **Environmental factors considered** | | **Cultural factors considered** | |
|---|---|---|---|
| Vegetation | Habitat / Wildlife corridor (ha) - scored elsewhere in terms of cost to offset all vegetation present | Land disturbed | Extent of inundation - loss of landuse (ha) |
| NPWS estate | NP&W Act - high conservation land (ha) | Heritage indigenous | NP&W Act (no. of recorded AHIM sites) |
| Flora | EPBC & TSC Acts (no. of threatened species recorded) | Heritage non-indigenous | Cabonne, Blayney & Cowra LEP heritage sites affected (ha) |
| Fauna | EPBC & TSC Acts (no. of threatened species recorded) | | |
| Watercourse | Aquatic habitat loss (km) | | |
| Fish | FM Act (no. of protected species recorded) | | |

Compiled by: Stakeholder Engagement Lead
Last updated on: November 2014

## Implementation Roadmap

*Next steps required in technical investigation and assessment*

Further investigations are required to resolve data gaps in the following areas:

- Further desktop assessment and ground truthing to determine the location of other areas of local significance identified through stakeholder engagement (e.g. European Heritage stone wall ruins in the bottom of the Needles site; Fossil Hill that has Devonian fossils);
- Vegetation mapping – refine existing GIS based mapping, determine what areas of mapping have been ground truthed and when. As a first step use high resolution aerial photography to update vegetation polygons, revisit surface areas, stratify and prioritise areas for field surveys;
- Ecology – scoping and preparation of technical briefs for investigations to determine the presence or absence of protected matters within the preferred subject area or areas;
- Heritage – scoping and preparation of technical briefs for investigations to determine the presence or absence of protected matters within the preferred subject area or areas; and
- Cliefden Caves – survey of boundaries (subterranean relative to surface) and inventory of ecological and other items of environmental significance contained within the caves.

*The approvals pathway*

Due to the value of the project (i.e. >$30million) it will require assessment as defined by the State Environmental Planning Policy (State and Regional Development) 2011 (SEPP SRD) - under the Environmental *Planning and Assessment Act 1979.*

The SEPP SRD identifies development as either State significant development (SSD) or State significant infrastructure (SSI) necessitating consultation with the Department of Planning and Infrastructure.

*Future requirements for stakeholder engagement*

During initial consultation with regulatory authorities, it was indicated that they would become more involved once the preferred option or options had been determined.

Consultation will be required with the following:

- NSW Department of Planning and Infrastructure, in relation to planning and approvals.
- NSW Office of Environment and Heritage, in relation to endangered species, populations, communities, National Parks Estate, Indigenous Cultural Heritage and National Heritage Inventory..
- Australian Department of the Environment in relation to threatened species, populations, and communities.
- NSW Office of Water, in relation to environmental flows, Sustainable Diversion Limits (SDL) and water sharing plans.
- NSW Department of Primary Industries Fisheries Unit in relation to threatened species and the Endangered Ecological Community "aquatic ecological community in the natural drainage system of the lowland catchment of the Lachlan River"
- Wiradjuri NSW Aboriginal Land Council
- Local Government, in relation to LEP heritage items, etc.

# Appendix F: Option Evaluation

To assess the short-list of options, the desirable criteria defined in Section 4.2 were applied to the short-list of options and each of the criteria was weighted. This process is discussed in this Appendix.

### Weighting Criteria

The project team undertook a pairwise analysis of the objectives to develop a weighting for each. A pairwise analysis forces each participant to choose between competing pairs of objective statements to identify which is more important. Once all possible combinations of objective pairs are assessed, the frequency of nomination of each objective as the most important becomes the weighting of that objective.

Some stakeholder input was also provided on appropriate weightings. During consultation activities with Centroc, this group developed their own objectives, which were considered by the project team before making recommendations.

### Project team weightings

| Criteria | Weighting % |
|---|---|
| Environmental sustainability: minimise environmental impacts | 5% |
| Maximise cost-effective renewable energy opportunities: energy production | 4% |
| Have regard to the interest of the community: stakeholder opinion of options | 9% |
| Operational capability to mitigate flooding: flood mitigation capability | 10% |
| Compatibility of options with Water NSW operational capability: operational compatibility | 8% |
| Compatibility of options with Water NSW strategic plans: strategic compatibility | 10% |
| Security/predictability of Water NSW revenue stream: revenue reliability | 9% |
| Maximise the net worth of the State's investment: economic benefit derived from security improvement | 13% |

| Criteria | Weighting % |
|---|---|
| Water security improvement | 19% |
| Cost-effectiveness: relative option cost performance | 14% |
| **Total** | **100%** |

### Multi-Criteria Assessment

Multi-criteria assessments such as this are only appropriate to help understand the relative performance of options and the trade-offs between criteria to assist decision-makers. In themselves, these assessments do not prescribe answers. The desktop nature of the study, and the limitations associated with data, also mean that it is important to consider, especially when there are only slight differences in options, the room for error in the desktop inputs. Further, it is also important to consider the risks associated with well performing options.

Some of the scores are derived from engineering assessments, environmental assessments and hydrologic modelling. Others are more subjective assessments undertaken by the project team reviewing all of the available information and stakeholder feedback. The scores for each option are set out in the table below.

The relative performance of shortlisted storage options is set out in the figures below.

In addition, the criteria weightings were examined to see if different weightings produced different rankings of storage options (sensitivity tested), but the results were largely insensitive to different weightings. This is also illustrated in the figures below.

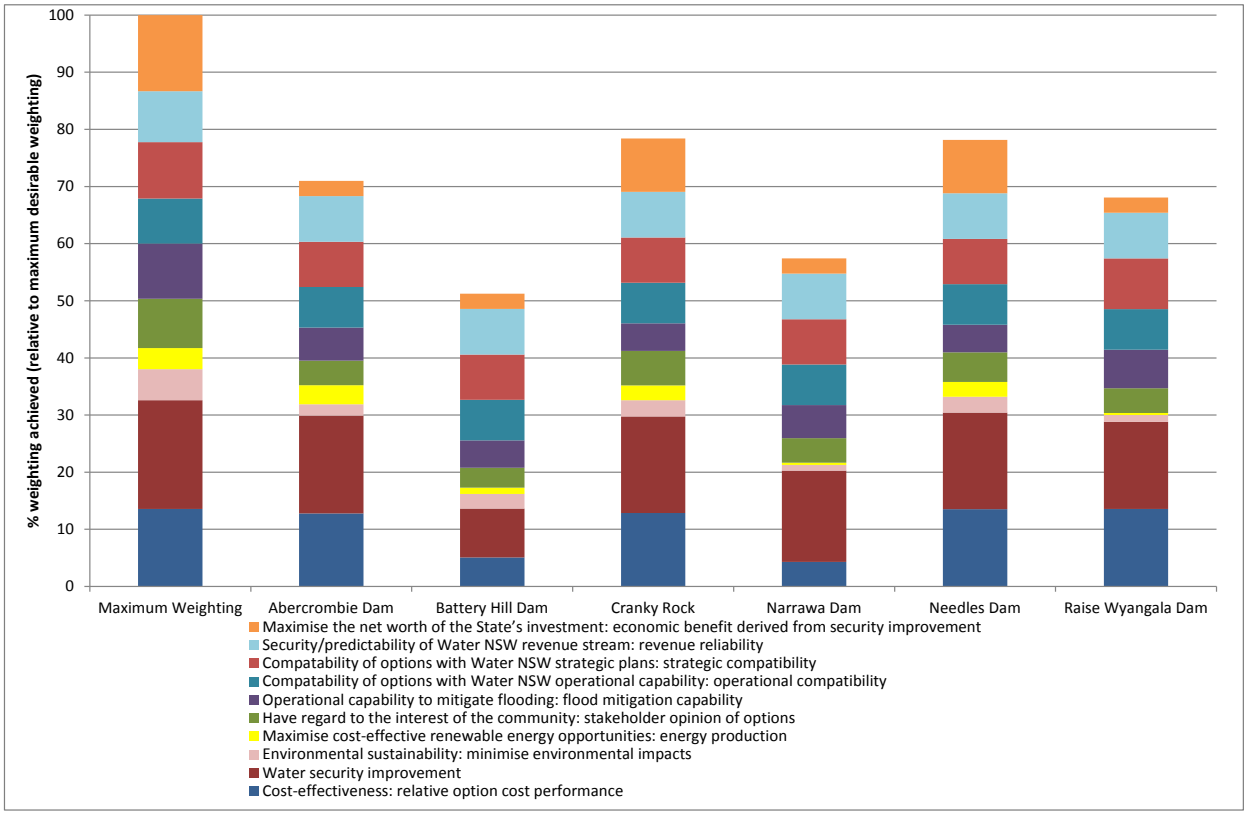
## Application of Desirable Objectives

| Option | Cost units / Equivalent Yield | Security | Economic benefit | Community interest | Renewable energy | Environmental sustainability | Predictability of revenue | Strategic plan fit | Operational capability fit | Flood mitigation |
|---|---|---|---|---|---|---|---|---|---|---|
| Abercrombie | 34.0 | 10.0 | 3.0 | 6.0 | 10.0 | 4.7 | 10.0 | 9.0 | 10.0 | 7.0 |
| Battery Hill | 85.3 | 5.5 | 3.0 | 5.0 | 4.0 | 5.7 | 10.0 | 9.0 | 10.0 | 6.0 |
| Cranky Rock | 33.6 | 9.9 | 8.0 | 8.0 | 8.0 | 6.2 | 10.0 | 9.0 | 10.0 | 6.0 |
| Narrawa | 90.6 | 9.4 | 3.0 | 6.0 | 2.0 | 2.9 | 10.0 | 9.0 | 10.0 | 7.0 |
| Needles | 29.1 | 9.9 | 8.0 | 7.0 | 8.0 | 6.1 | 10.0 | 9.0 | 10.0 | 6.0 |
| Wyangala Raise | 28.6 | 9.0 | 3.0 | 6.0 | 2.0 | 3.2 | 10.0 | 10.0 | 10.0 | 8.0 |

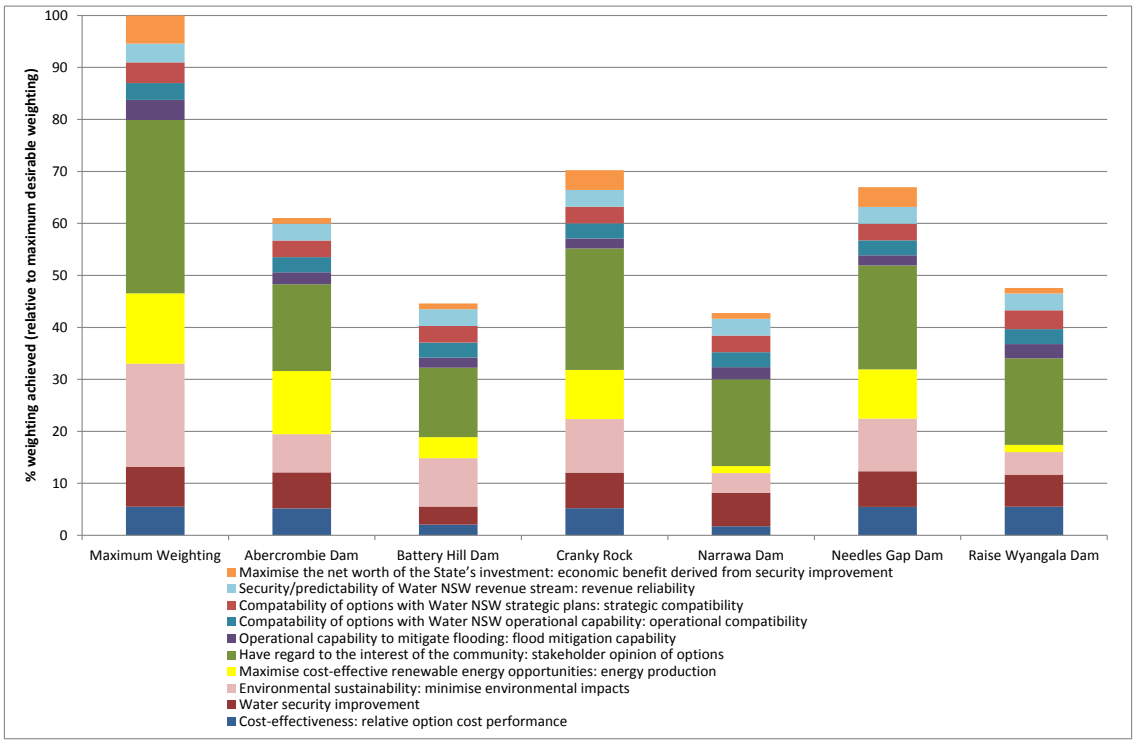
Scores for cost units, renewable energy and flood mitigation were derived from the engineering assessment in Appendix C. Equivalent yields and security were derived from the hydrologic assessment in Appendix D. Environmental scores were derived from the environmental assessment in Appendix E. Community interest scores were derived from the stakeholder engagement in Appendix A. Economic benefit was assessed through desktop examination of prices on the water market compared with the costs of recent investments made by towns in ensuring water security (this is a relatively subjective assessment of economic benefit and cost-benefit analysis is recommended). The revenue reliability, strategic and operational fit were assessed by Water NSW project team.

## Analysing the options in a multi-criteria framework

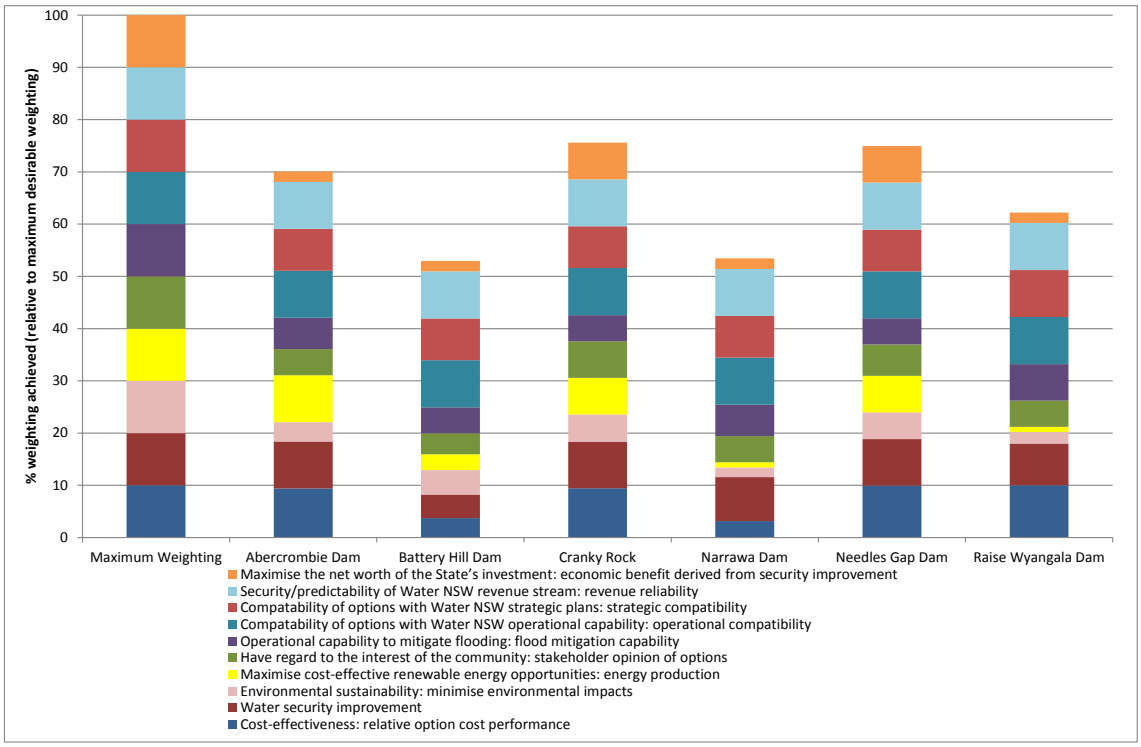
MCA results using the project team criteria weightings



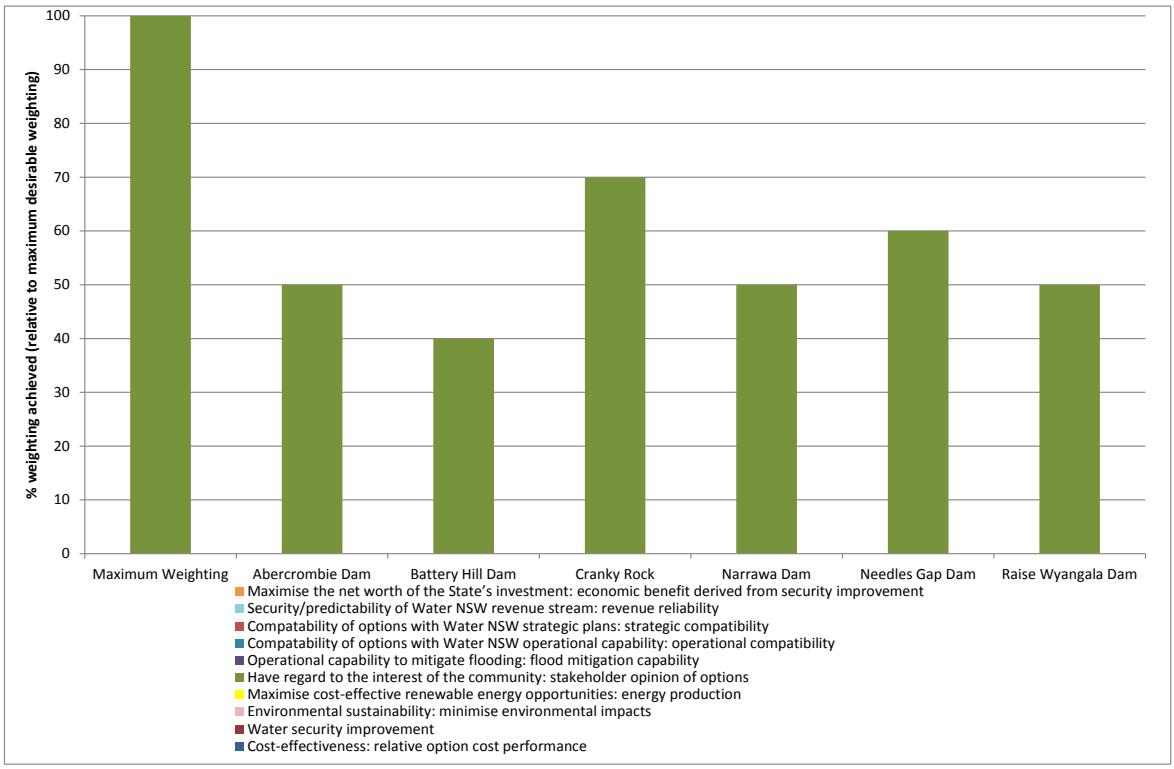
MCA results using equally weighted economic, social, environmental criteria weightings



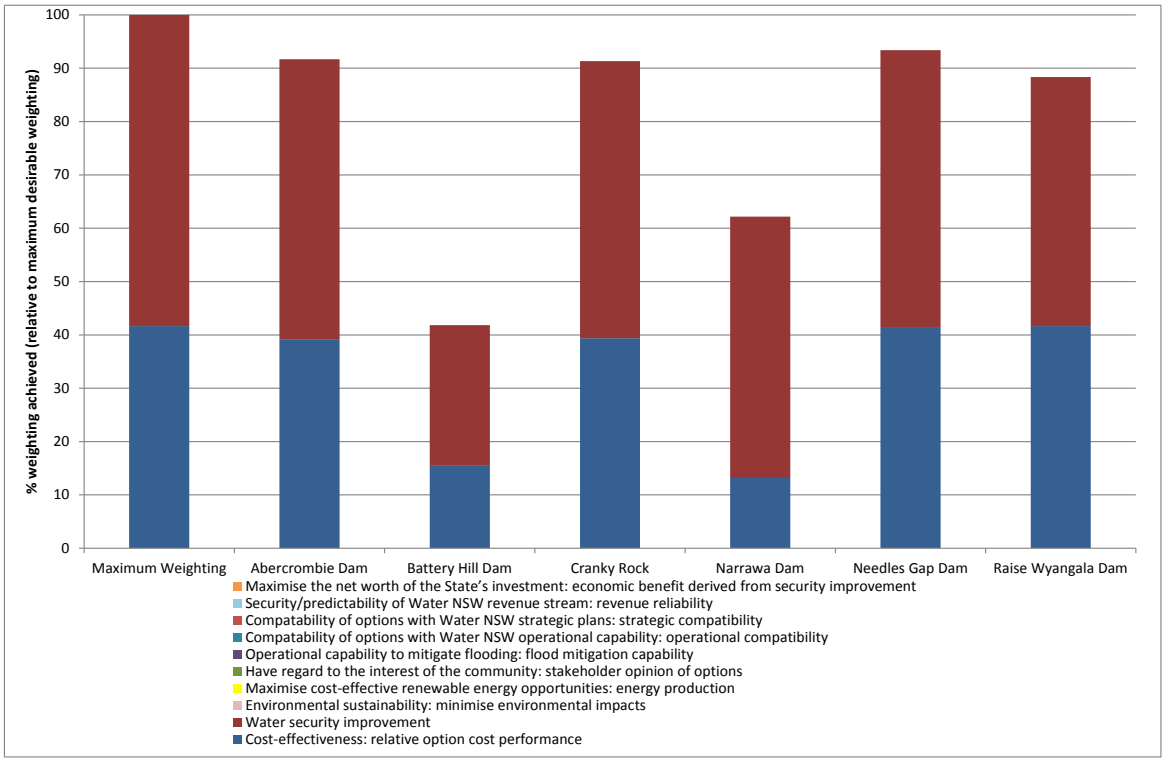

MCA using equally weighted by individual criteria



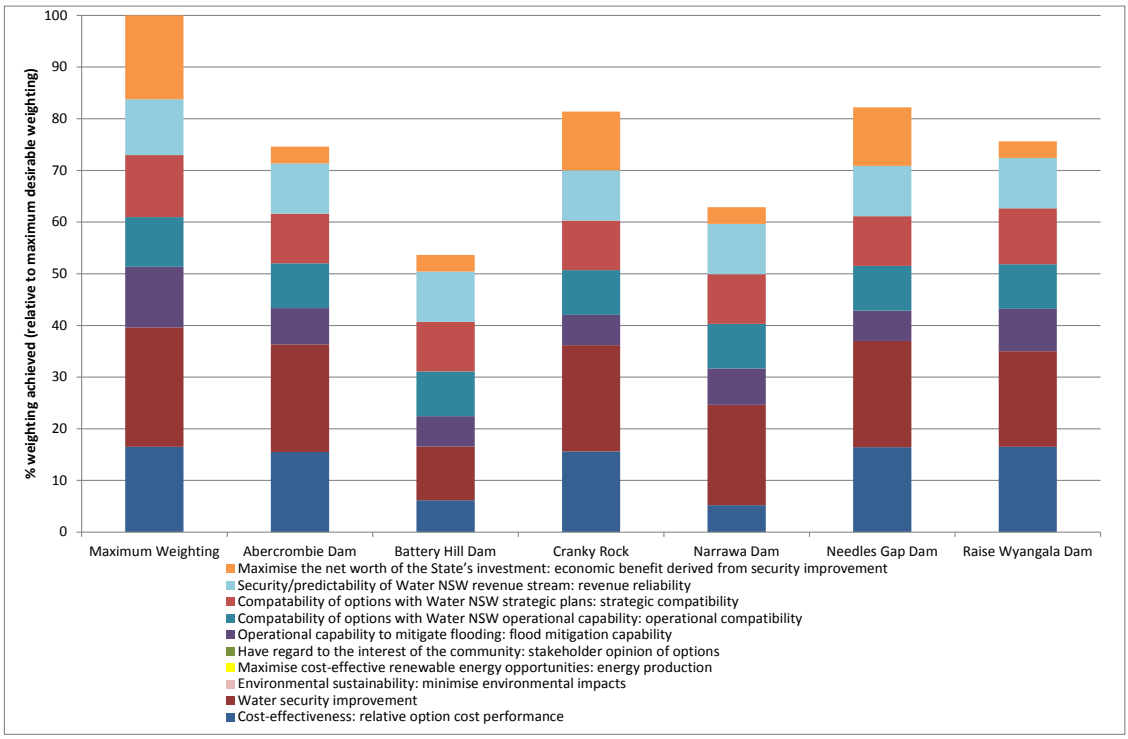
## What if only the community views mattered?



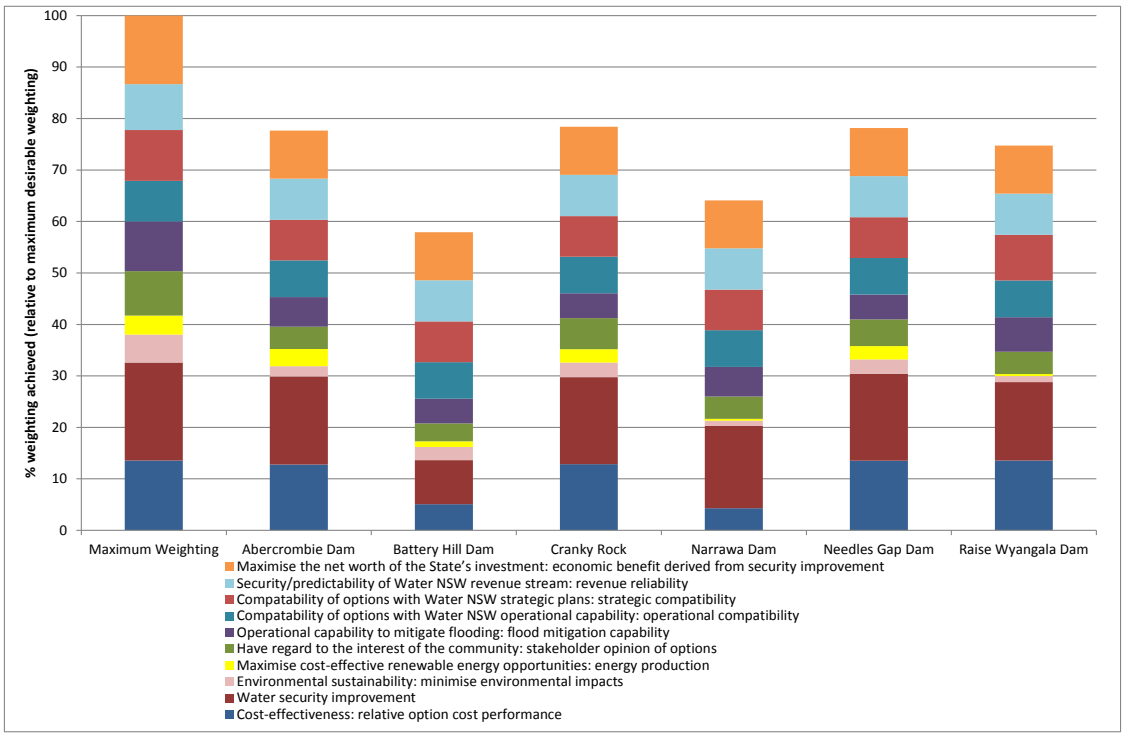

## What if only cost and water security mattered?



What if only cost, security and economic benefit mattered?




What if the economic benefit of town security is not greater than irrigation?



The assessment highlights the following:

- Four of the storage options (Cranky Rock, Abercrombie, The Needles and Wyangala raise) perform similarly in relation to cost-effectiveness and potential water security improvement.
- If it is assumed that there is greater economic benefit from increased security to towns, then the options in the Belubula (Cranky Rock and The Needles) are preferable.
- As avoiding the potential impact on the Cliefden Caves is achieved by the Cranky Rock option, but not The Needles, this option could be considered slightly better.
- The Belubula options, combined with the existing Carcoar dam, have the potential to allow for improved water security to the towns of the Central Tablelands.

Conclusions include:

- Battery Hill Dam and Narrawa Dam can be excluded from further consideration as there are better performing storage options.
- There is potential for storage to improve water security in the Belubula river. The Cranky Rock dam sites may be marginally preferred to The Needles site in that it has the potential to avoid the impact on the Cliefden Caves.
- There is potential for storage to improve water security in the Wyangala catchments. The Abercrombie dam site may be marginally preferred to raising Wyangala as this site is a more efficient dam location from an evaporation perspective.

**Potential Issues and Risks**

Each of the four remaining sites has potential issues associated with it. These were also considered by the project team as set out in the table below.

| Issue | Description | Potential Mitigation |
|---|---|---|
| Engineering | The Needles, and to a lesser extent, Cranky Rock dam sites, are located in karst landscape which includes limestone caves. There are also shales in the geology of the area. These features mean the desktop assessment of foundation efforts and costs are highly uncertain.<br><br>Raising the existing Wyangala Dam by buttressing of the existing embankment could overstress the existing concrete arch dam, therefore detailed structural analysis is required to investigate if the raising is feasible.<br><br>The presence of faulting near the Abercrombie dam site introduces the potential for seismic ground displacement, strong shaking or leakage. Abercrombie Cave is located North of the site and extent of calcareous (solubility) material would need to be mapped. | Preliminary in-situ investigations are required to understand the potential risks associated with the engineering issues. |
| Storage integrity | The Needles, and to a lesser extent, Cranky Rock dam sites, are located in karst landscape which includes limestone caves. Whilst often achievable, these types of landforms represent a risk of having a storage that loses water from the impoundment into the surrounding area. | |
| Environmental, recreational and scientific value | Whilst acknowledged as valuable in the Local Environment Plan, the Cliefden Caves are not protected under State or Federal registers or legislation. However, there is some uncertainty around the environmental, recreational and scientific value of the Cliefden Caves as their existence has not been well known and their features and habitats may not have been completely documented. This is also true of the value of Fossil Hill. | Preliminary fauna studies may be required to document the habitat significance of the caves, particularly in relation to bats.<br><br>Preliminary karst feature assessment may be required to document the significance of this landform.<br><br>Preliminary assessments of the value of fossil finds at Fossil Hill may be required to document the significance of these relics. |
| Public support | Whilst key stakeholders have been engaged, public consultation has not been undertaken as part of this scoping study. Whilst most of the key stakeholders are clear water security is an issue limiting the economic development of the region, it is difficult to ascertain the width of public support for investment in new storage | A program of opportunities for public participation during the remaining planning processes is required. |

| Issue | Description | Potential Mitigation |
|---|---|---|
| | infrastructure.<br><br>The sites identified also potentially impact on Aboriginal heritage. Stakeholders noted the need for engagement with these stakeholders to determine the impacts and mitigation strategies. Similarly, engagement with these stakeholders is important for establishing any opportunities for this disadvantaged sector of the community to directly benefit from any dam construction and or operation activities. | |
| Economic benefit | Whilst preliminary consideration of economic benefit was undertaken in this scoping study, it is not a detailed and complete cost-benefit analysis. Stakeholders, especially those likely to be customers bearing the costs of the investment, such as general security irrigators, are keen to ensure any proposed dam investment is subject to a transparent cost-benefit assessment, including differences associated with different sized storages, as there is a concern small storages will make a limited economic contribution for a large cost.<br><br>There are also potential benefits additional to water security associated with raising Wyangala dam as this dam is currently subject to dam safety upgrade requirements. It may be more economically efficient to align investments to solve multiple issues. To better understand this potential benefit, the raising of Wyangala dam should be considered as a comparison case in any subsequent cost-benefit analysis. | A cost-benefit assessment is required. |
| Potentially impacted landholder consultation | Potentially impacted landholders will want to be kept informed of the progress of detailed investigations. Consultations are most likely best to be one-to-one and concerns will include understanding project timelines and when a certain decision will be made, understanding resumption and compensation processes and understanding operational regimes between any dam operator and the on-going economic use of these properties. | Individual consultations to inform potentially impacted landholders of the planning process, timelines and opportunities for engagement is required. |

# Appendix G: Centroc Water Security Study

Water Security in the Lachlan Valley has been investigated previously by Water NSW (as discussed in this report) and by others.

In relation to town water supply security, the most recent study, the Centroc Water Security Study, was completed by the Central NSW Councils (Centroc) in 2009.

This appendix explains the link between the work of Centroc and this study.

**Scope of the Centroc Water Security Study**

In response to the worst drought on record for the region, Centroc undertook to complete a Water Security Study to investigate and recommend solutions to improve town water supply security across the Centroc region.

The scope of the study was to:

- Establish the need for water security improvement for town water supplies.
- Identify and evaluate options to improve town water supply security across the region, taking into account complementary opportunities to improve water security outcomes for other sectors.
- Recommend a regional town water security strategy which achieves the required security improvement taking into account economic, social and environmental considerations.
- Set out a plan of action for implementing the recommended strategy

The investigation included sophisticated modelling to forecast urban demand from the dozens of towns of the region, for a 50-year horizon through to 2059. These forecasts took into account projected population growth tempered by the necessity that towns become more efficient in our urban water usage.

**Outcomes of the Centroc Study**

The study determined that 29 towns across the region were at risk in respect to water supply and required substantial improvements to be made to their water security.

Over 80 potential options to improve water supply security were examined. The amplification of Lake Rowlands (Strategy 2a), and the expansion of the associated distribution network to support additional demands from Parkes, Forbes, Orange amongst others, was ultimately identified as the preferred scenario. This strategy was unanimously adopted by the Centroc Board in 2009.

In addition to the core supply and distribution network, water security to other urban centres was also addressed through:

- Pipeline connection between Bathurst and Oberon to provide supplementary water for Oberon and reduce pressure on the Fish River Water Supply, improving outcomes for Lithgow as a result.
- Pipelines from the storages of Burrendong and Chifley dams to Wellington and Bathurst respectively were recommended to save water lost in the delivery of these supplies through river channels.
- A series of local solutions, including new minor storages at Cumnock, Condobolin, Lake Cargelligo and Yeoval were recommended.
- An ongoing program of regional water conservation implementation and demand management.
- Opportunistic capital investment partnering with local irrigation operations to save water on-farm and share in the resulting water savings.
- Development of a uniform restriction trigger policy across towns connected to the same water source.

The study recognised that whilst it may take up to 10 years before the augmented Lake Rowlands will be completed, other elements of the strategy can be advanced quickly.

The study also found that connection to the Wyangala storage was uneconomic due to the distance and energy requirements to lift the water.

**Benefits to Other Sectors**

Whilst the focus of the Centroc Water Security Study was on town water supply security improvement, the study did broadly consider win-win opportunities with other water users.

Partnering with irrigators in on-farm savings, as well as the towns putting in plan demand management and uniform restriction policies would benefit the irrigation community. However, additional storage for irrigation needs was not considered.

It was also identified that there may be mutual benefit in considering the provision of some of the region's mining related water demands in association with the recommended strategy. Whilst it was noted that there was some potential to provide for some of the mining demands from the augmented Lake Rowlands storage in the Belubula River catchment, this was a secondary benefit of the recommendation, not a result of an assessment of all of the water demands in the Lachlan Valley.

**Leveraging the Centroc Study into this Study**

This study takes a broader mandate in terms of water security, than the Centroc Water Security Study. This study has considered irrigation and mining demand. In addition, the demands forecast for 2059 of the towns planned to be included in the augmented Lake Rowlands strategy, were applied to the Carcoar storage to test whether this storage has the ability to provide the towns with the same security improvement as planned through the augmentation of Lake Rowlands. This would mean any proposed new dam could be devoted to other licenced water users and there would be no need for the towns to augment Lake Rowlands.