futurewateroptions

FOR THE ACT REGION IN THE 21ST CENTURY

ACTEW CORPORATION

THE TANTANGARA DAM OPTION

A report assessing various alternatives
for the use of Tantangara Dam
for future ACT water supply

April 2005

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Executive Summary

Context and Purpose

This report is part of a Future Water Options project established under the 2004 initiative "Think water, act water – a strategy for sustainable water resource management". The project's aim is to identify a reliable, sustainable, and cost- effective source of water that will serve the ACT region over the long-term. Initially, ACTEW selected three options (including multiple alternatives and combinations) for detailed assessment including:

- *enlarging the existing Cotter Dam;*
- *constructing a new dam on the Gudgenby River (the Tennent Dam); and;*
- *water Transfer to the ACT from NSW's Tantangara Dam on the Murrumbidgee River.*

Each option includes the following assumptions:

- *high population growth.*
- *reduced per capita demand – 12 per cent by 2013 and 25 per cent by 2025.*
- *climate change – lower supply and higher water demand.*
- *environmental flows –delivered from each water supply.*

This report assesses the Tantangara Option, short-listed to its Tantangara long tunnel and Murrumbidgee River flow alternatives.

Despite proposed water efficiency measures population growth forecasts indicate that a major new water source will be required. According to ACTEW, there is no alternative "unless the ACT is willing to accept the regular occurrence of water restrictions of a severity and frequency unprecedented in planning elsewhere in Australia."

Canberra's Water Cycle

Unchanged by the development of new water sources, the ACT's status as a net water exporter will continue to support downstream economic activity while contributing to environmental and amenity flows. Figure ES1 below shows the inflows and outflows from the ACT.

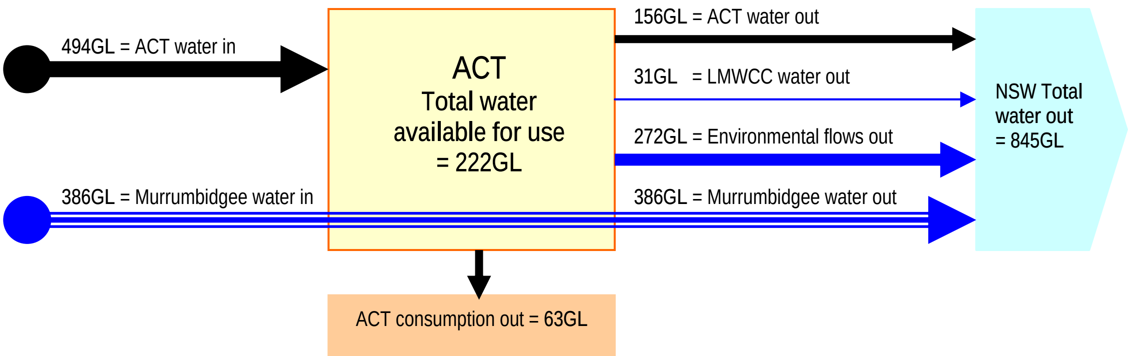


Figure ES1: ACT Water Inflows and Outflows

Tantangara Alternatives

The Tantangara Option proposes to transfer water from the Tantangara Reservoir to Corin or Googong Reservoir. A Tantangara water transfer involves the following main actions:

- *purchasing water;*
- *storing water in Tantangara Reservoir; and*
- *transporting water from Tantangara to the ACT.*

Under this option, ACT would buy the water from NSW, VIC or SA while paying Snowy Hydro for storage and a loss of generating capacity.

When ACT needed the water, Tantangara Dam releases would flow down the Murrumbidgee for transfer to the ACT via:

- *pipes and tunnels about 20 to 30 km to Corin Reservoir; or*
- *a pipe to Googong Reservoir near Angle Crossing, 100 km downstream.*

Studies undertaken in this project show that most of the proposed tunnel and pipe alternatives could severely affect the environment through excessive discharges at the top of the Cotter catchment – a significant wilderness area. Heritage values in some of the region's more culturally sensitive areas would also be at risk. Finally, social and amenity values would be compromised by many of the pipe and tunnel alternatives where pipelines and infrastructure intruded into highly valued public and private lands. These considerations ultimately exposed the "long tunnel" and "Murrumbidgee River flow" as the final two alternatives examined in this option report.

In the first alternative, a 20km-long tunnel would link the Murrumbidgee just outside Kosciuszko National Park, to the Cotter, three kilometres upstream from Corin Reservoir's headwaters. Water flowing down the tunnel could power a hydro plant at the Cotter end to offset costs.

In the second alternative, a pipeline connecting the Murrumbidgee with Googong Reservoir would convey pumped water via Burra Creek. This alternative has comparatively lower risks and represents the most effective version of the Tantangara Option. Figures ES2 and ES3 show the two alternatives.

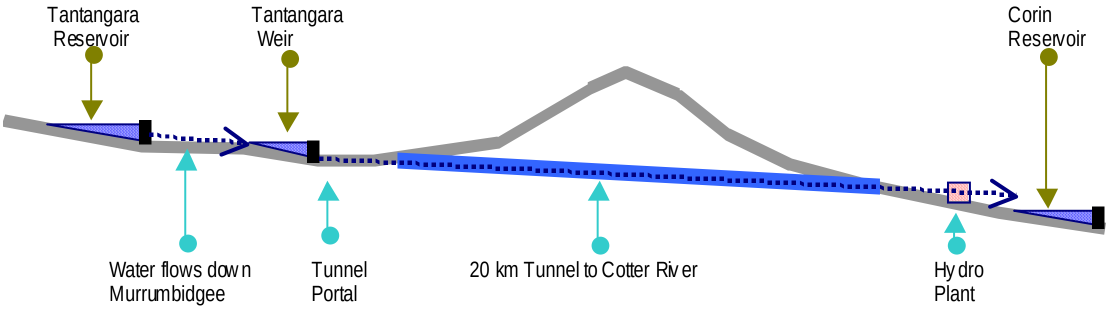


Figure ES2: Tantangara *long tunnel* Alternative

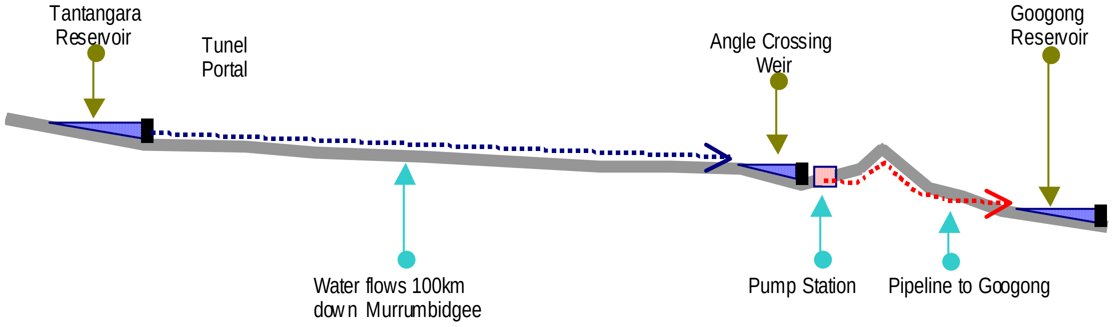


Figure ES3: Tantangara *"Murrumbidgee River flow"* Alternative

Planning and Approvals

Both Tantangara alternatives would initiate a complex web of approvals and consent processes that include NSW, ACT and Commonwealth jurisdictions. Local, state and federal laws, regulations, policies, and protocols would apply to environmental, heritage, land use, and economic elements in the option's construction and operation. These could also include participation within the Murray Darling Basin (MDB) Water Cap, its associated trading scheme, and operating rules that govern the Cap and Snowy Hydro activities.

Documentation and approval processes would likely accompany an environmental impact assessment that could be coordinated between jurisdictions complimented by integrated approvals and their attached conditions.

Sustainability concepts embedded within these assessment and approval processes also feature in ACTEW's corporate controls and legal obligations. Sustainability issues embody environment, social and economic factors to include much of the philosophy behind ecologically sustainable development and its triple bottom line analyses. The most relevant water criteria are protection of public health, reliability of water supply, and effects on the aquatic environment.

Recent focus group discussions confirmed that 72 per cent of participants were willing to pay more for water to limit demand, increase supply and reduce water restrictions consistent with the sustainable construction and operation of a new water source.

Steps to Developing the Tantangara Option

Following widespread public consultation and environmental impact assessment, the Tantangara option could follow two separate development processes:

1. *A long tunnel alternative including weir, connecting tunnel, outflow pipes, and hydropower plant construction to link the Murrumbidgee with Corin Reservoir.*

2. *A Murrumbidgee River flow alternative including weir, pumping station and pipeline construction to link the Murrumbidgee with Googong Reservoir.*

Both alternatives use existing storages and are subject to similar operating procedures, water purchases, licenses, and approvals necessary to deliver the water from NSW to the ACT. The main differences lie in their respective delivery methods, costs and environmental impacts.

There are two possible water-trading processes for the Tantangara option. In the first process, purchased NSW water would be stored in Tantangara for release to the ACT under NSW control. This involves significant sovereignty risks because the water is largely controlled by NSW and cannot be guaranteed for delivery to ACT.

In the second process, the Territory's participation in the MDB Cap would enable it to purchase "Cap Water". This lowers the "sovereignty" risk by transferring "Cap Water" control from NSW to the ACT. Nevertheless, neither process can absolutely guarantee water delivery because in an extreme drought the ACT would share limited "high security (water) entitlements" with other high security MDB users. Figure ES4 below shows five major administrative steps associated with these processes.

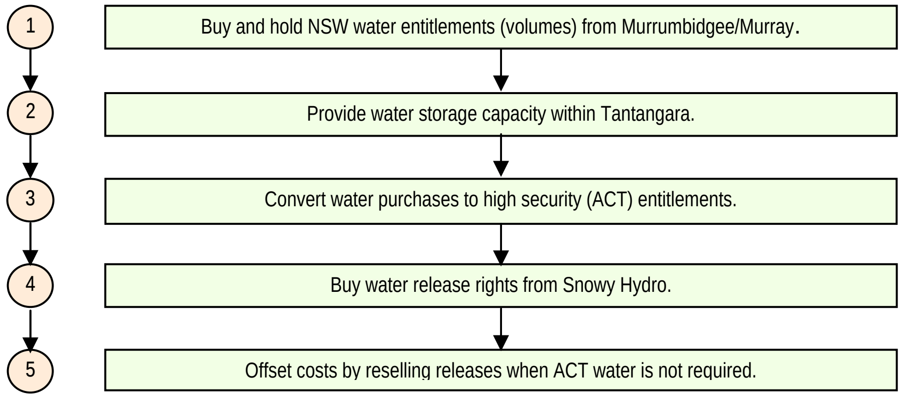


Figure ES4: Tantangara Water Transfer Arrangements

ACTEW can purchase (and hold) NSW water entitlements from downstream users in the following ways:

- *purchase entitlements via a water broker;*
- *purchase an irrigation property with its attached water entitlement;*
- *purchase by electronic exchanges; and*
- *bilateral negotiation.*

Under the proposed (still under review) Murrumbidgee Water Sharing Plan (WSP) and Water Management Act (2000) ACTEW can obtain a holding licence with:

- *approval for the purchase (subject to trading rules) from a private extractor; and*
- *approval for the purchase from a single privatised irrigation district.*

If ACT participated in the Murray Darling Basin Cap it could purchase "Cap Water" from a variety of NSW, Victorian, or South Australian sources. The Territory could then transfer that *water, and permanently hold the water rights under ACT control. In other words, the purchase would increase the ACT Cap while reducing the seller's Cap.*

Tantangara has the capacity to store ACT water without fundamentally changing the reservoir. Subject to negotiation with NSW and Snowy Hydro, this water could be stored within the reservoir and still meet existing and proposed business needs, operational rules, and statutory obligations. Negotiations for storage and release would also be subject to a NSW environmental flows strategy due in 2005. This could involve other stakeholders including environmental agencies and downstream catchment management authorities.

An ACTEW purchase of a general security water entitlement would need conversion to a high security entitlement. High security entitlements provide virtually guaranteed water access (currently subject to the NSW Minister's discretion). Converting entitlements and their respective conversion rates are subject to:

- *NSW Government and Minister's explicit approval of conversion rates under the current trading regime;*
- *ACT ratification of the National Water Initiative under a proposed trading regime; and.*
- *participation by ACT in the Murray Darling Basin Cap to convert NSW entitlements to ACT entitlements under a proposed trading regime.*

If the ACT participated in the Cap through a proposed trading regime the conversion rates would be determined through endorsed schedules. It is possible that even with high security entitlements under ACT control the Territory may not have complete access to its water. This situation could occur when extreme drought conditions left a shortfall of high security water to be spread amongst competing high security users. Under this situation, water access would be rationed between users.

The NSW Minister currently must approve a water transfer from the lower Murrumbidgee (covered by the Murrumbidgee Water Sharing Plan) to Tantangara because it lies outside the Water Sharing Plan boundary. Including regional water supply initiatives (e.g. Queanbeyan and Yass supplies) and specific issues related to irrigation efficiency could encourage NSW Department of Infrastructure Planning and Natural Resources support and influence Ministerial deliberations.

If ACT participates in the Cap then the water transfer would be subject to finding a willing seller with trading rules related to existing technical and financial considerations.

NSW controls water entitlement volumes in Snowy catchments but Snowy Hydro has obligations and rights in the collection, storage and timing of water releases[1]. Under the Corporatisation Act, Snowy must consider requests for water but Snowy Hydro must also release a minimum 1,026 GL annually for the Murrumbidgee (below target water). Snowy Hydro may also release discretionary volumes (above target water) averaging about 254 GL per year. Snowy Hydro's limited flexibility for "below target water" release contrasts with "above target water" releases timed to coincide with high electricity prices.

ACT water transfers involving both water release types would change the opportunity cost (and purchase price). Murrumbidgee high security water entitlements come from the below target

[1] Snowy Corporatisation Principles, 1997

water. If ACTEW purchases high security entitlements it would divert below target water (or lower cost water) to Snowy Hydro's advantage.

Under the Snowy Hydro Corporatisation Act 1997 [NSW] extractive entitlements to water stored in the Snowy Scheme can only be granted by the NSW Water Ministerial Corporation. The Act enables Snowy Hydro Company to charge a fee for taking extractive water that can either be negotiated with the extractor or determined by the NSW Water Ministerial Corporation.

The key negotiating issue for the ACT is the opportunity cost of foregone electricity from:

- *water taken (volumes);*
- *whether the water is below or above target water;*
- *impacts on Tantangara operations particularly in relation to spills and losses;*
- *the value of Snowy Hydro's power in the National Electricity Market (NEM) or in contracts with distributors and other NEM parties; and*
- *value of renewable energy certificates for that part of Snowy Hydro's generation eligible under the Renewable Energy (Electricity) Act.*

Final price negotiations and agreements involving Snowy Hydro and NSW would need to consider factors such as off-take arrangements, pipeline design, identified risks and liability. Some of these costs could be offset by:

- *negotiating with Snowy Hydro to sell back releases when Tantangara water is not required in ACT;*
- *establishing internal ACTEW rules for trading water to irrigators when water is not required in ACT; and*
- *refining and implementing operating rules for ACT and NSW storages and transfers.*

Water Resources and Quality

Around 300GL average yearly flow is potentially available from Tantangara Reservoir. Nearly all of this supply is currently diverted to Lake Eucumbene for Snowy Hydro operations with about 9 per cent of the flow scheduled for environmental releases commencing in 2005. The Tantangara Option proposes to use about 7 per cent of the Upper Murrumbidgee flow in tandem with these releases. Both these contributions account for less than 16 per cent of the river's natural flow but Tantangara is only partially filled. Modifications now under construction, will allow storage and delivery of ACT and NSW water as required. Modelling indicates that releases for ACT would probably occur on average about three to four years each decade.

CSIRO has predicted that likely climate changes could potentially reduce water yields up to 50 per cent relative to historic patterns by 2070. Responding to warmer temperatures, per capita demand could rise to 16 percent by 2070. Such projections have serious implications for future water supply decisions but do not rule out the possibility of securing Tantangara water.

Water Quality within Tantangara is reasonably high with some nutrient and dissolved oxygen impacts due to catchment characteristics and land use. The catchment's location within Kosciusko National Park provides high water quality security with existing storage detention and treatment plants virtually guaranteeing consistently clean and safe water.

Key Issues

Tantangara short-listed alternatives are subject to the same key environmental, social and economic issues but their exposure to these issues and their associated risks varies. While the long tunnel maximises supply and water delivery performance, it also has higher environmental, social and economic risks through its location and cost characteristics. The Murrumbidgee River flow has a relatively lower supply and delivery performance but its environmental, social and economic risks are comparatively lower. Figure ES5 summarises the main issues.

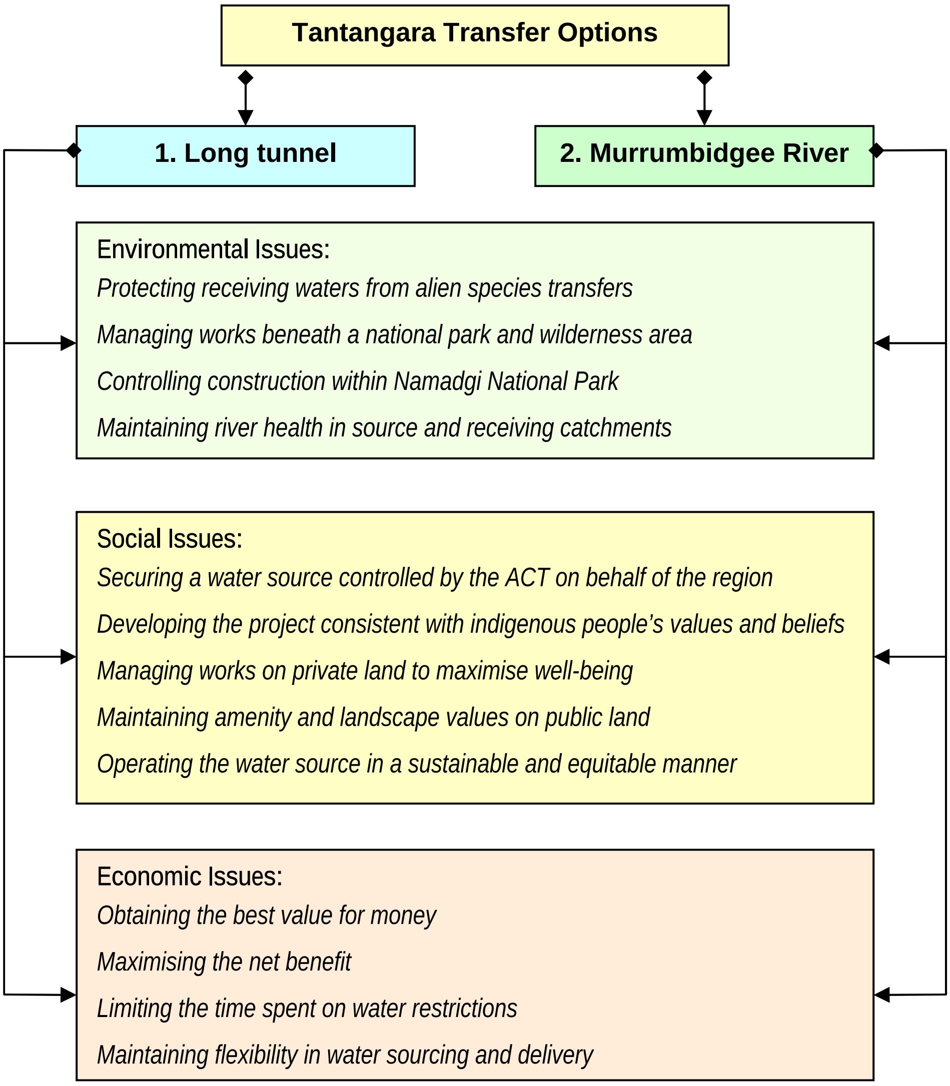


Figure ES5: Key Tantangara Option Issues

Environmental Issues

Tantangara releases with proposed NSW environmental flows could significantly improve Murrumbidgee River health. Enhanced water quality and ecological diversity is likely to have important benefits well downstream of the Territory. Proposed releases would also recharge adjoining aquifers and floodplains remerging as persistent low flows during droughts.

Maintaining Googong capacity could encourage more frequent "spilling" and provide additional environmental flows benefiting Queanbeyan and Molonglo River health, amenity, and recreation opportunities.

These advantages are counterbalanced by environmental risks associated with transferring water between basins, site works and pipeline construction.

The long tunnel option also has potential benefits for Murrumbidgee river health but only for the 16km reach between the dam and proposed tunnel. Conversely, the tunnel has comparatively greater environmental risks including high conservation values in the Upper Cotter, high quality receiving waters in Corin Dam and potential site impacts related to tunnel, associated facilities, and access construction.

Social Issues

Both Tantangara Option alternatives are compromised by their current inability to source ACT-controlled water. Ultimately, the ACT cannot secure a future water supply through Tantangara unless it participates in the Murray Darling Basin Cap. There is also a possibility that competing high security users may have to ration water in extreme drought conditions. For these reasons the option should be considered less desirable than its Cotter and Tennent Dam counterparts in the short to medium term.

On the other hand, a resolution of the Cap coupled with additional security provided through ACT water sources in the "Murrumbidgee River flow" alternative could render it as one of the more sustainable and cost effective options.

Both options also have potential impacts on heritage values. Investigations have yet to identify any significant constraints related to site activities but Indigenous groups have indicated that the Upper Cotter and Murrumbidgee Valley has a high cultural significance.

Works, additional flows, and transport activities could affect local community and residential amenity along the Murrumbidgee. Some of these effects could be beneficial while others may require mitigation, especially over the short term.

Activities and operations within Namadgi national park could potentially impinge on public recreation and landscape values that define the character of these wild areas. Mitigation measures over the short, medium and long term could be required to ameliorate these potential impacts.

Economic Issues

Capital costs for the long tunnel and Murrumbidgee River flow alternatives amount to about $141M and $70M respectively. Apart from Tantangara releases, the Murrumbidgee River flow alternative could also source ACT water from the Gudgenby, Naas, or other catchments. Separate water sourcing gives ACT authorities more flexibility in optimizing water supply and specifically Googong Reservoir's role in that process. It also places less pressure and by implication, a potentially lower premium on securing a water supply from NSW.

Both alternatives potentially limit the impact of water restrictions consistent with the objectives in Think water act water. The Murrumbidgee River flow provides an immediate and cost effective short-term solution while the long tunnel is an effective medium to tong term solution. Compared *with other options Tantangara is very cost effective and in the case of the long tunnel, offers high sustainability through hydropower generation.*

Finally, both alternatives maximise net benefits to water users through their comparatively low cost, effective water delivery, and integration into existing water supplies.

Conclusions

Both alternatives feature this option's main advantage – the use of existing dams and treatment plants at relatively low cost. Both alternatives are also limited by the option's main disadvantage - Tantangara water is currently controlled by NSW. This could mean ACT is denied water at a crucial time when supplies are most limited.

Apart from Tantangara releases, the Murrumbidgee River flow could also source ACT water from the Gudgenby, Nass or other catchments. Supply from 2 separate sources gives ACT authorities more flexibility in the role of Googong for regional supply and places less pressure on securing a water supply from NSW.

The Tantangara Option is compromised by the inability to source ACT-controlled water but this could be resolved by ACT participating in the Murray Darling Basin Cap. Nevertheless, competing high security users (like ACT) may still have to ration water in extreme drought conditions and this presents risks for a significant capital investment like the long tunnel. Consequently, this alternative should be considered less desirable than its Cotter and Tennent Dam counterparts.

Of the two Tantangara alternatives, the proposed Murrumbidgee River flow has comparatively low environmental, social, and heritage impacts, potentially higher environmental benefits and superior flexibility that makes it better value for money.

For these reasons the Murrumbidgee River flow alternative represents a superior Tantangara Option that should be considered as possible water source for future ACT needs, especially in the short term.

1 Introduction

1.1 Purpose of Report

In April 2004, the ACT Government released *Think water, Act Water - a strategy for sustainable water resources management*[2]. The strategy defined actions to achieve sustainability objectives for water use in the ACT to 2050. A dedicated project, *Future Water Options,* responds to the strategy objective: *to provide a long-term reliable source of water for the ACT region.*

Nearly 30 possible options for boosting Canberra's water supply have been investigated in a report commissioned by ACTEW for *Think water, Act water*[3]. This report identified three options (including several alternatives and variants) for more detailed assessment:

- enlargement of the existing Cotter Dam;
- construction of a new dam on the Gudgenby River (the Tennent Dam); and
- transfer of water to the ACT from Tantangara Dam on the Murrumbidgee River in NSW.

Under *Think water, act water,* the assessment process must develop the three main options and provide recommendations on a new water source for the ACT region. This report assesses the Tantangara water transfer option. Companion reports review the other two options and a summary report provides a final recommendation to the ACT Government on new water sources for the ACT.

1.2 Water Supply in the ACT

Two catchments currently supply Canberra's water (see Figure 1.1):

- Cotter catchment with three storage dams (Cotter, Bendora and Corin) and Mt Stromlo Water Treatment Plant (WTP) supplies about 60 per cent of Canberra-Queanbeyan's water needs; and
- Googong Dam (and WTP) supplies the rest.

Historically, water supplies maximised the use of Bendora and Corin Dams. Bendora Dam water (fed by the Corin Dam), gravity fed through the Bendora Gravity Main to Stromlo Water Treatment Plant, traditionally required only disinfection and fluoridation before distribution.

Prior to the 2003 bushfires, a protected catchment in the Namadgi National Park ensured high water quality and gravity mains reduced energy costs. Residual energy used to generate hydroelectricity minimised water production costs while yielding environmental gains through greenhouse gas reductions and renewable energy production.

[2] ACT Government (2004), *Think water, act water,* Vol 1 "Strategy for sustainable water resource management in the ACT;" Vol 2 "Explanatory document;" Vol 3 "State of the ACT's water resources and catchments," April 2004.
[3] ActewAGL (2004), *Options for the Next ACT Water Source*, report for ACTEW Corporation by Technical and Consulting Services Branch, ACTEWAGL Water Division, April 2004.

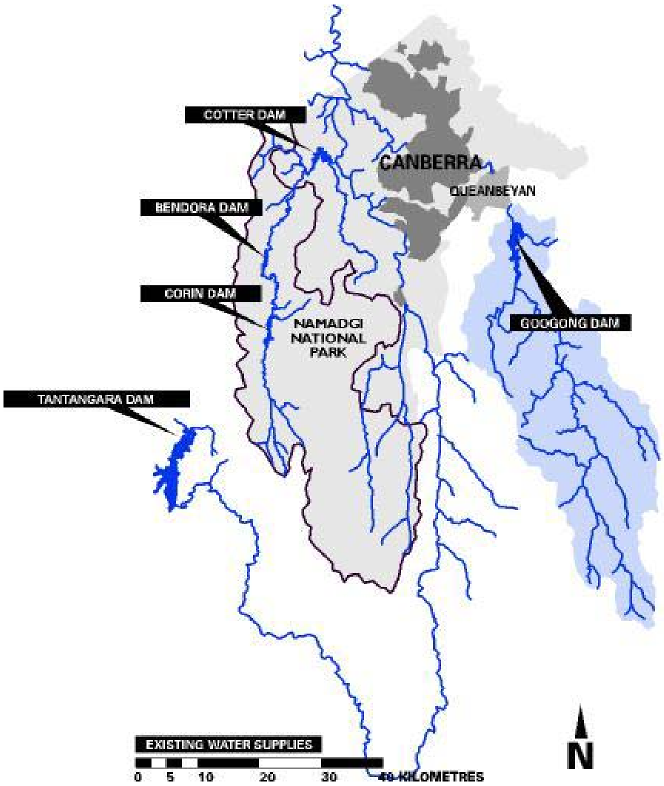


Figure 1.1 Canberra's Water Supply

Cotter Dam has not supplied water for the last 20 years for several reasons:

- limited storage capacity;
- poor water quality from the lower Cotter catchment due to development and forestry practices;
- no water treatment facility before 2004; and
- Cotter water needs treatment and pump from Cotter dam more than 150 metres to the Stromlo WTP (completed in 2004).

Cotter catchment receives relatively high rainfall (approximately 950 mm annually) compared with 600 mm at Canberra Airport) particularly above Bendora Dam in the Brindabellas.

In January 2003, bushfires severely burnt the Cotter catchment leaving long-term water quality impacts through vegetation destruction and soil destabilisation. Several storms following the fires have already washed large amounts of sediment into the Bendora and Corin Dams demonstrating a pressing water treatment need. Accordingly, ACTEW commissioned a water treatment plant at Stromlo with a capacity to purify 250 ML per day. This investment was completed in late 2004.

Googong Reservoir lies about 20 kilometres southeast of Canberra on the Queanbeyan River.[4] Flowing through forests, grazing land, and rural residential areas, Queanbeyan River water requires significant treatment to meet drinking water standards. Googong catchment receives

[4] Under the *Seat of Government Acceptance Act 1909,* the Commonwealth was granted the rights to use water from the Molonglo and Queanbeyan Rivers for Canberra's water supply.

less rainfall (650 mm) and has higher evaporation rates than the Cotter catchment. Yields are comparatively low for Googong despite being three times larger than the Cotter catchment.

Googong water must be pumped 50 metres to the Googong WTP and fully treated before distribution. The Reservoir's water treatment plant has recently been upgraded from 180 ML per day to 270 ML per day. This treatment and pumping requirement means that water from Googong dam is significantly more expensive to supply than Cotter water.

Tantangara Reservoir, while not part of ACT's water supply, has delivered water to Territory in the past. During the 1962 drought, the ACT government used water released from Tantangara to supplement a dwindling water supply. Following drought breaking rains, the temporary Murrumbidgee River Weir and pump station was decommissioned.

Average annual water available from ACT controlled catchments (excluding water in the Murrumbidgee River as it flows into the southern ACT from NSW) is around 494 GL.[5] Environmental flows require 272GL with 222GL potentially available for water supply. Consumption in recent years has averaged about 65 GL, with over half of this (35 GL) returned to the Murrumbidgee River after treatment at the Lower Molonglo Water Quality Control Centre.

A further 386 GL per year enters the ACT from via the Murrumbidgee River. This water is not used by the ACT and flows back into NSW. A total of 845 GL in an average year flows from the ACT into Burrinjuck Reservoir. This discharge supports downstream economic activity including Murrumbidgee Irrigation Area, town water supplies and environmental flows.

These water flow data are based on historical stream flow records collected across the catchments. Hydrological modelling discussed in Chapter 4, and used as a basis for determining future water needs, has shown that when factors such as allowance for worst possible drought events and climate change are taken into account, future water flows are likely to be reduced.

The Territory's main water aggregates are depicted diagrammatically in Figure 2.3.

1.3 Think Water Act Water Context

Think water, act water – a strategy for sustainable water resources management released on 28 April 2004, constitutes the ACT's Water Resources Management Plan under the *Water Resources Act 1988*, and supercedes a previous version published in August 1999. *Think water, act water* is a legal instrument responding to community objectives for water supply security; water use efficiency, water quality and community participation (See Appendix A).

International, national, and ACT studies indicate the most cost effective and sustainable short-term option is first to implement water efficiency measures. The ACT Government has set targets to reduce per capita mains water consumption by 12 per cent by 2013 and 25 per cent by 2023. These targets could be achieved through:

- water efficiency actions;
- sustainable water recycling;
- enhanced use of stormwater and rainwater; and

[5] ACT Government (2004), *Think water, act water, Vol 1, op cit,* p 21. April 2004.

- increasing reclaimed water use from the present five per cent to 20 per cent.

Despite these efficiencies, official population growth forecasts still require a new major water source. In December 2004, ACTEW Corporation reported to the ACT Government that:

"unless the ACT is willing to accept the regular recurrence of water restrictions of a severity and frequency unprecedented in planning elsewhere in Australia, then additional water storage will be needed in the ACT." [6]

The Tantangara water supply option is particularly relevant to the *Think water, act water* strategy because it:

- satisfies the need for increased water supply;
- offers a flexible response to water reuse challenges;
- could play an important role in meeting ACT responsibilities for a cross-border water supply strategy based on sustainability principles and water supply security;
- provides a responsive approach to Water Sensitive Urban Design by allowing flexible supply and discharge options from existing storage reservoirs;

1.4 Study of Future Water Options

ActewAGL's options report[7] identified new water supply options and contingency planning for a continuing drought. It re-assessed previously proposed schemes and developed new options in a three-staged approach illustrated in Figure 1.2.

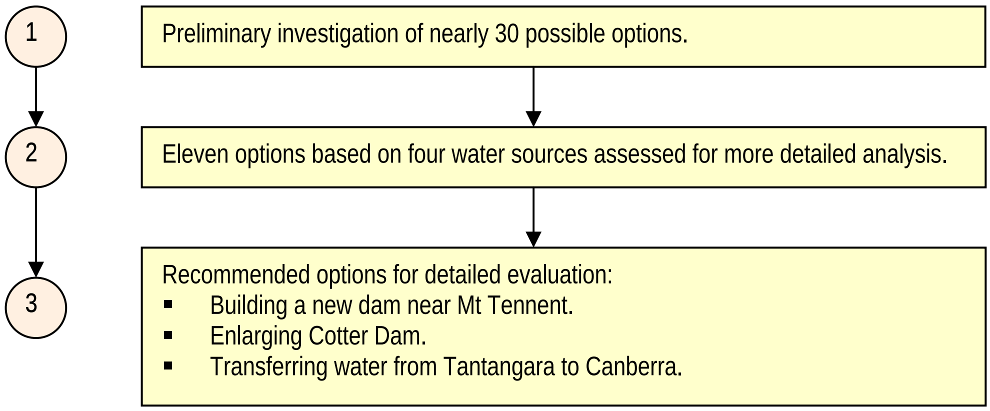


Figure 1.2: Assessing Options For The Next ACT Water Source

Four options were identified for further investigation. The Coree dam option with no significant advantages over Cotter and some disadvantages was not pursued following confirmation of the Cotter enlargement engineering/geological feasibility.

[6] ACTEW Corporation (2004), *An Assessment of the Need to Increase the ACT's Water Storage*, December 2004, p 20.
[7] ActewAGL (2004), *Options for the Next ACT Water Source*, report for ACTEW Corporation by Technical and Consulting Services Branch, ACTEWAGL Water Division, April 2004. *op cit*.

Three selected options were:

1. Tennent Dam;
2. enlarged Cotter Dam; and
3. Tantangara Transfer.

The options report concluded:

"1. Whilst Tennent Dam has a large capital cost, it would provide significant storage and the options of feeding water to either a new water treatment plant at Tuggeranong or to the new Stromlo treatment plant.

2. Enlarging Cotter Dam also has a number of advantages that should be examined in detail. These include that it is an existing dam which would be enlarged, it is in a high rainfall catchment area and the river is already regulated.

3. The Tantangara option is attractive enough to warrant further investigation. From an engineering perspective the Yaouk Valley pipeline route, discharging into Porcupine Creek, should be examined in more detail. The other three pipeline options could be discarded because of their high operating cost (pumped option) or capital cost (tunnel option), but further examination of the social and environmental factors need to be considered." [8]

Following preliminary investigation, eleven alternatives were short-listed and ranked according to cost per gigalitre (GL) of yield. Additional analyses, including a timetable for providing water, provided further variants to the initial eleven. These 25 variants are summarized in Appendix B.

Water sources assessed in this process but excluded from further consideration include:

- a water farm (advanced effluent treatment);
- cross border supplies (other than Tantangara);
- groundwater;
- stormwater reuse (other than that considered in proposed 25 per cent demand reduction);
- using existing urban lakes to supplement supply;
- enlarging other existing storages in the ACT;
- raising spillways on existing storages thus increasing effective capacity;
- transferring water from existing storages in NSW;
- potential dam sites within the ACT; and
- potential dam sites in NSW near the ACT[9].

Figure 1.3 shows the proposed three main water supply option locations. These represented the initial assessment of water supply option that would be short listed after further evaluation.

[8] *Ibid,* p 27.
[9] *Ibid,* pp 30-35.

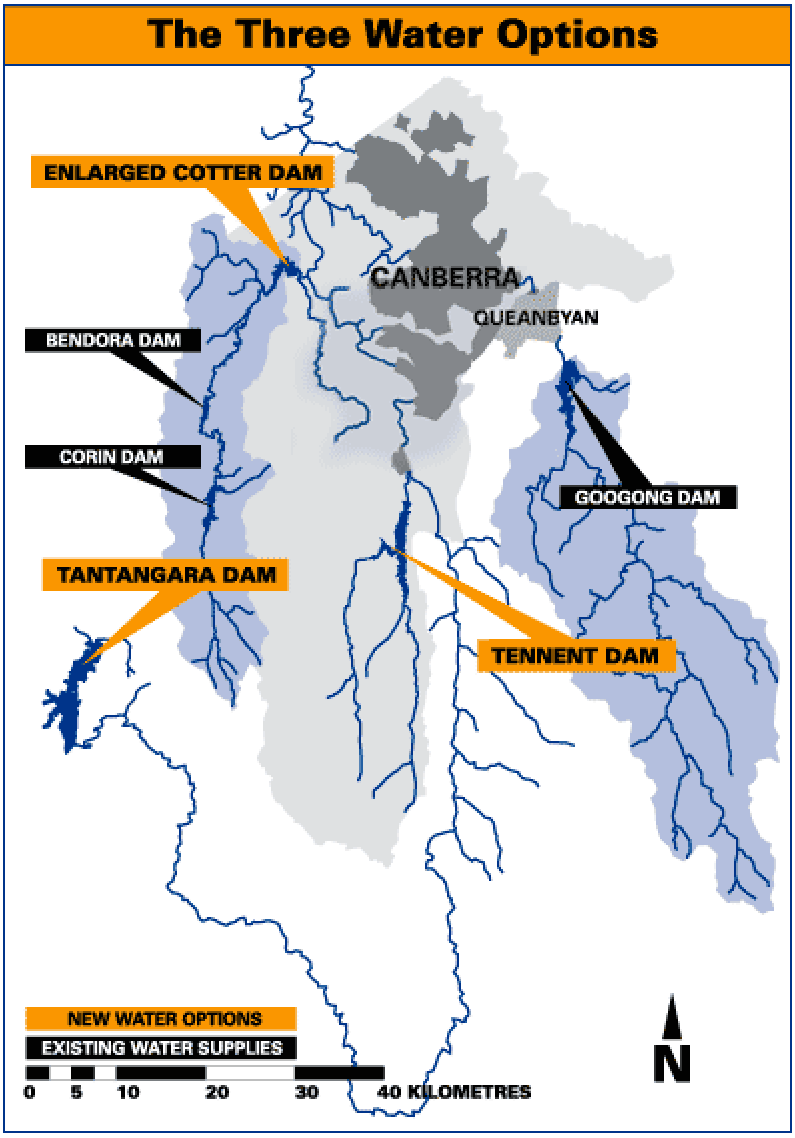


Figure 1.3: Options For The Next ACT Water Source - Main Supply Options

1.5 Study Procedure

This phase of the water supply options study has the following approach:

- conduct wide-ranging, comprehensive and robust technical studies and consultations into all relevant aspects of each of the investigated options;
- investigate and report on the need for, and likely timing of, a new ACT water supply – this was ACTEW Corporation's December 2004 report[10];
- prepare a report on each of the investigated options using results from technical and consultation work while objectively setting out all the relevant option characteristics; and
- compare and contrast the options in a combined report that summarises their costs, benefits and impacts - leading to a preferred option selection or option combinations.

Technical studies providing input to this part of the work include:

[10] ACTEW Corporation (2004), *op cit*.

- Fish Impact Study, by Environment ACT;
- Murrumbidgee Transmission Losses Report, by Marsden Jacob Associates;
- Ecological Risk Assessment, by the CRC for Freshwater Ecology;
- Aquatic Ecology, by the CRC for Freshwater Ecology;
- Flora and Fauna, by Biosis Research;
- Cultural Heritage, by Navin Officer;
- Land Ownership, by KMR Consulting and Guildin Consultants;
- Catchment and Landscape Analysis, by Ecowise Environmental/Barry Starr;
- Water Quality (six studies), by ActewAGL/Ecowise Environmental;
- Technical Advice on ACT Reservoir Recreational Water Use Options, by ActewAGL and Water Futures;
- Infrastructure Reports, by GHD and SMEC;
- Geotechnical Investigation, by Coffey Geosciences;
- Social Impact Analysis, by Tania Parkes/Ernst and Young;
- Economic Impact, by the Centre for International Economics;
- Hydrology, by ActewAGL;
- Tantangara Options Water Quality Report, by ACT Future Water Options Integrated Project Team
- Greenhouse Gas Emissions, by ActewAGL;
- Consultation Framework, by Purdon and Associates, Clarity Communications and Swell Design;
- Community Values and Sustainability Assessment, by Consulting Environmental Engineers; and
- Sustainability Assessment, by the Institute of Sustainable Futures/University of Technology, Sydney.

These technical studies are summarised and cited as appropriate throughout this report.

1.6 Contents of Report

This report includes a review and synopsis of the technical studies listed above targeting recommendations relevant to the Tantangara Option. Drawing on these recommendations this report evaluates the initial option alternatives and through an iterative process, short-lists those to a final preferred alternative. The short-listing process compares the alternatives' performance against criteria in the following broad content areas:

- Background and context information including introduction, Tantangara transfer options, Planning, water resources, infrastructure. These chapters outlines this report's purpose, project alternatives, design assumptions and proposal characteristics, relevant laws policies and regulations, existing water quality and quantity, and proposed site conditions.

- Environmental, social and economic effects including environmental impacts, heritage and cultural implications, costs and benefits, and sustainability issues. These chapters review and compare potential impacts of the two, short-listed alternatives.

An executive summary outlines the key recommendations in this report and a rationale for the decision process.

2 Tantangara Transfer Options

2.1 Existing Tantangara Dam and Operations

Tantangara Dam lies on the Murrumbidgee River about 6 km downstream of the Gurrangorambla Creek confluence in Kosciuszko National Park. Part of the Snowy Mountain Scheme, Tantangara Dam impounds Murrumbidgee headwaters for diversion through the Murrumbidgee to Eucumbene Tunnel.

The upper Murrumbidgee catchment covers about 13,000 km^2 (ACT occupies around 18 per cent of the catchment area) but most of the reservoir's natural inflow diverts to Lake Eucumbene.

Constructed in 1959, the reservoir's minimum operating level is substantially below its crest height. Currently, the reservoir maintains this level through a fixed discharge point but intake structure changes (under construction) will permit specific withdrawal at various depths[11].

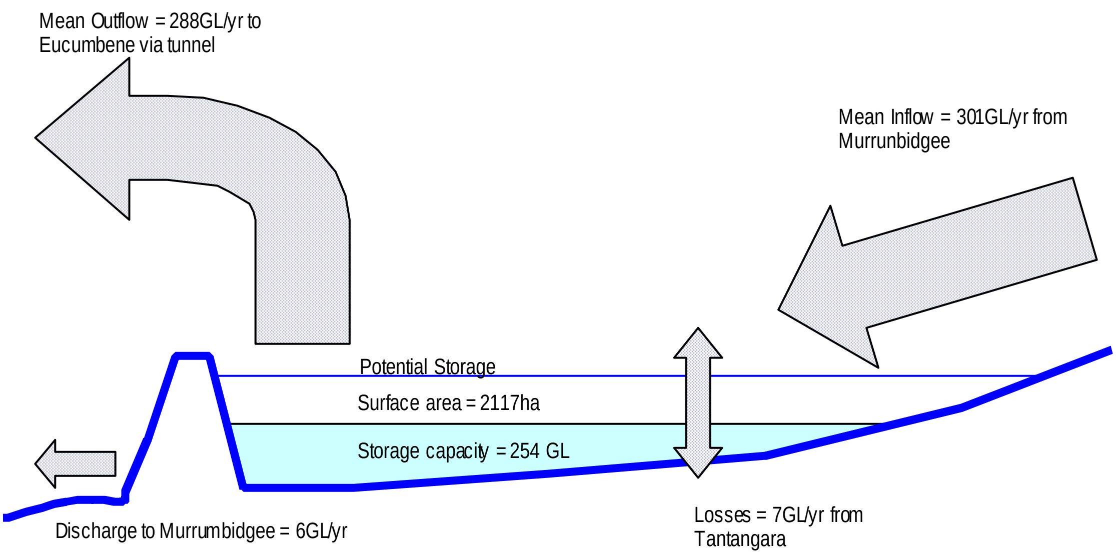


Figure 2.1: Tantangara Reservoir Characteristics

Tantangara continuously receives inflows and diverts outflows to Lake Eucumbene leaving the reservoir only partly filled at significantly less than its potential maximum volume.

Catchments downstream of Tantangara Dam supply nearly all flows for the ACT and beyond with current operations providing no reservoir release for several months each year. Tantangara discharge to the Upper Murrumbidgee currently accounts for about two percent of the natural flow[12].

NSW and Australian Government agreements will mandate Tantangara environmental flows to improve river health by June 2005. Current offtake upgrades to meet the new flow requirements

[11] Snowy Mountains Engineering Corporation (2005) ACT *Future Water Options Tantangara Option.* 2005
[12] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682. Preece (2004) cited in.

would also allow water extraction from surface and other water levels to reduce downstream impacts.

2.2 Alternative Transfer Routes and Sizes

Initially, consultants[13] considered four Tantangara transfer options at flow capacities of 60 ML/d, 180 ML/d and 360ML/d. The most likely flow capacity of 180ML/d was applied to the following options.

Option A - Water pumped from directly below Tantangara through two pumping stations and 30km of pipeline across the Bimberi Range at Murrays Gap to discharge into the Cotter River upstream of Corin Dam.

Option B - Water flows 10 km down the Murrumbidgee from a reconstructed Tantangara Dam outlet to a diversion weir with a tunnelled discharge into Porcupine Creek flowing into the Cotter River.

Option C - Water flows 17 km down the Murrumbidgee to a diversion weir at the Yaouk Valley for pumping up the valley to a tunnel into Porcupine Creek.

Option D – Water flows through a 17 km pipeline along the Murrumbidgee River corridor to allow gravity flow from Tantangara to Porcupine Creek (within the same Yaouk Valley pipeline route as Option C).

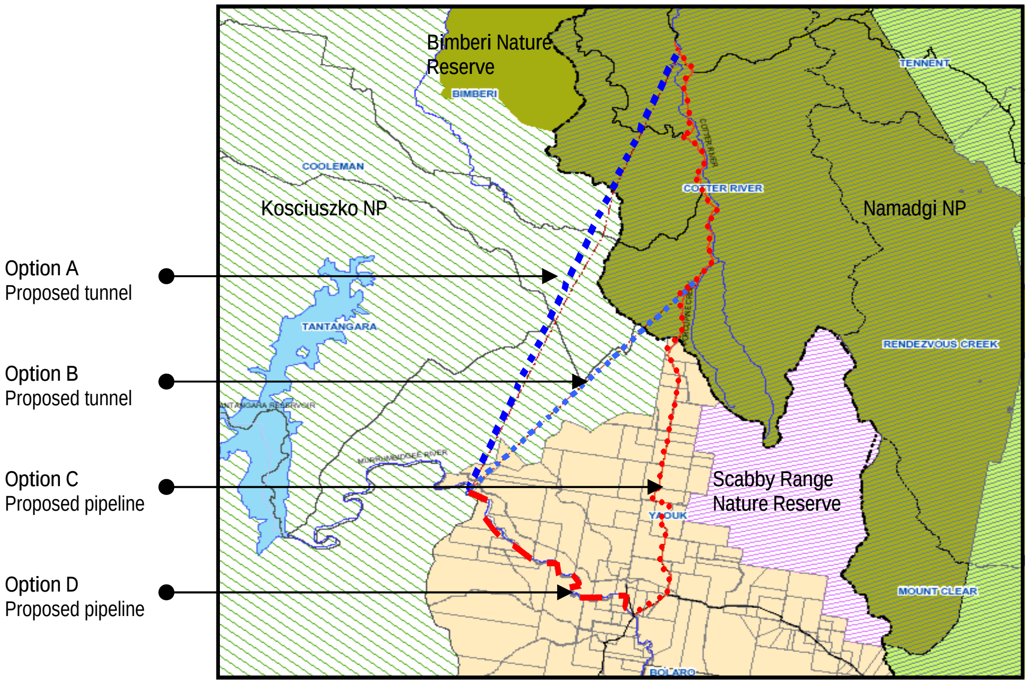


Figure 2.1: Preliminary Short-Listed Tantangara Transfer Options

[13] Snowy Mountains Engineering Corporation (2005) ACT *Future Water Options Tantangara Option*, *p2-2*. 2005

All of these options include the following elements:

- obtaining water rights;
- storing water in Tantangara Reservoir; and
- transporting water from Tantangara to the ACT.

2.2.1 Further Options and Alternatives

In their further investigations SMEC consultants and ACTEW also discussed:

- two further tunnel alternatives with downstream portals in the Cotter River valley;
- alternative transfer capacities at:
  - 60 ML/D (24 hour pumping);
  - 360 ML/D (12 hour off peak pumping); and
  - 180 ML/D (24 hour pumping).
- a pipeline along the Cotter River fire trail to avoid discharge in catchment headwaters;
- three Murrumbidgee River weir site alternatives; and
- a hydropower station at the downstream discharge point(s).

Consultants tested the main options and their variants applying environmental, economic and service delivery considerations. The tests provided comparisons for initial short-listing.

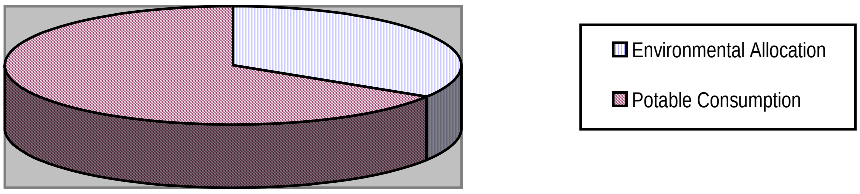
2.3 Environmental Flow Assumptions

The *Water Resources Act 1998* requires Environment ACT to produce a Water Resources Management Plan that specifies environmental flows and management of remaining water resources. Water allocations are central to this plan. Allocations cannot be created or licenses to take water granted unless they are provided for by the Plan.

Environment ACT's (1999) guidelines define environmental flows as the *"streamflow necessary to sustain habitats (including channel morphology and substrate), encourage spawning and the migration of fauna species to previously unpopulated habitats, enable the processes upon which succession and biodiversity depend, and maintain the desired nutrient structure within lakes, streams, wetlands and riparian areas."*[14]

From 2000 to 2003, the Territory averaged 62 GL/yr potable consumption ranging from 54 GL in 2003, to 69 GL in 2002[15]. Environmental allocations averaged 31.775 GL (about a third) of the region's yearly water allocations ranging from 13.5 GL in 2003, to 41.5 GL in 2000. Current rules preclude hydropower operations, dam spills, and treated wastewater discharges as environmental flows so total ACT outflows are significantly larger than average yearly allocations of around 94 GL. Figures 2.2 and 2.3 show the ACT water balance and relationships between environmental flows, potable consumption and total flows.

[14] Environment ACT (1999), *Environment Flow Guidelines*, 27 May 1999, p 3.
[15] ACT Government (2004), *Think water, act water, Vol 1, op cit,* p 21.



Source: Think water, act water 2004

Figure 2.2: Average Environmental Allocation and Potable Consumption 2000-2003

ACTEW calculations show that current environmental allocations are equivalent to the requirements of about 75,000 residents – implying that a new water storage facility will be required earlier under the current environmental flow regime.

There are four elements of environmental flows:

- **Low flows** based on the 80th percentile flows (i.e. flows exceeded 80 per cent of the time). In other words, flows below the 80th percentile are all required for environmental purposes. The guidelines enable a reduced low flow not below the 50th percentile if the water service provider can demonstrate the need for additional supply.
- **Flushing flows** to maintain water channel structures and their dependent ecological processes. The critical discharge is the 1 in 1.5 to 2.5 years flood event. In ACT rivers (other than water supply catchments) the short duration of high volume flows and a limit on abstraction of 10 per cent of flows above the 80th percentile ensure that flushing flows occur with this frequency.
- **Special purpose flows** include a requirement for Cotter River spawning flows. A flow adequate for spawning is defined as the 50th percentile monthly flow during spring (September, October and November) and the 80th percentile monthly flow for the months of August and December to March inclusive. In two out of every five years, flows must be at or above the spawning level for each month in the August to March period, regardless of prevailing seasonal conditions. ACTEW would prefer to have this requirement conditional on the previous 12 months flow into Corin Dam being in excess of 60 GL.

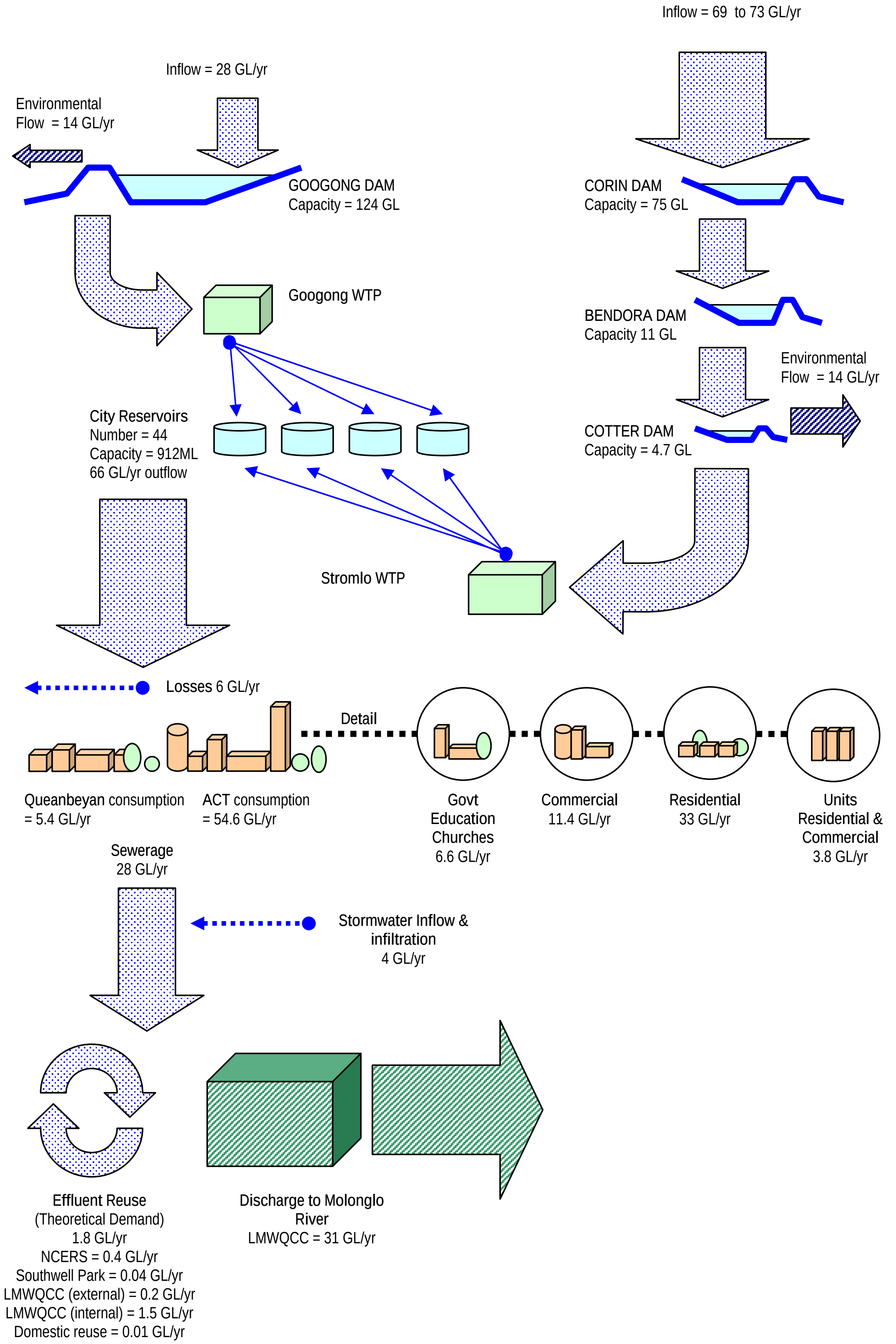


Figure 2.3: ACT Water Balance July 2001 to June 2002

Source: Think water, act water 2004

Maintenance of impoundment levels is required to protect macrophytes (water plants). For urban lakes and ponds the maximum draw down as a result of abstraction is 0.20 m below spillway level.[16]

While most sub catchments are restricted to having no more than 10 per cent of flows above the 80th percentile abstracted, “water supply catchments” can have 100 per cent of flows above the 80th percentile utilised.

Ten percent of flows above the 80th percentile traditionally created a threshold for suitable abstraction in most sub catchments. This 10 per cent threshold was determined in 1999 from factors including habitat diversity and quality, nutrient and sediment cycling, movement of biota and connectivity between aquatic and terrestrial habitats. These flow requirements have recently been modified to account for recent scientific knowledge.

ACTEW’s water licence requires that reservoir releases for environmental flows mimic natural flows as far as possible. This particularly applies to water temperature.

The guidelines also reduced releases based on “drought” conditions to ensure water supply security. Under these provisions “Drought” occurs when:

- nine of the preceding 12 months flows into Corin and Googong are less than the median monthly inflows; and
- total reservoir storage is less than 50 per cent .

Environment ACT’s Environment Management Authority (EMA) can permit reduced releases on a case-by-case basis but not below the 50th percentile flows.

Assumptions on future environmental flow releases fundamentally support the demand assessments for new water options. ACTEW sought EMA advice on the following potential environmental flow scenarios[17]:

- scenario 1 – current environmental flows;
- scenario 2 – preliminary modified environmental flows; and
- scenario 3 – modified environmental flows.

Investigators consider scenario 3 to be the least flow needed to sustain ecosystems. Further research may support these assumptions but in the meantime, both the preliminary and modified scenarios reduce environmental flow releases below the current regime.

Environmental flows for the Tantangara Option discussed here are largely related to ACT requirements through potential discharges to the Upper Cotter (under the Long tunnel option) and Googong Reservoir (under the Murrumbidgee River flow option). Additional supplies from Tantangara could support environmental flows released via Cotter Reservoir but this complex

[16] ACT Government (2004), *Think water, act water,* Vol 3, *op cit,* p 6.
[17] ActewAGL (2004), *Environmental Flow Scenarios.* 2004

supply route would support environmental flows for only a small distance between Dam and the Murrumbidgee River.

Similarly, pumping to Googong may facilitate additional environmental flows but ultimately those releases would benefit the Queanbeyan River reaches. Both Tantangara alternatives could service Murrumbidgee environmental flows with substantial benefits to the upper reaches especially through ACT releases riding on proposed NSW discharges.

The NSW government effectively controls environmental releases for much of the Upper Murrumbidgee but ACT reaches could be extracted at rates up to the 95-percentile flow during wetter months. Snowy Hydro has agreed to a 26 GL annual environmental flow release adding to current commitments for a minimum 32 ML/d flow at Mittagang Crossing and 17 ML/d at Cotter Crossing. These existing commitments are largely derived from catchments (including ACT catchments) downstream of Tantangara Dam. The environmental flow release pattern would be negotiated between SnowyHydro and DIPNR.

The Upper Murrumbidgee Expert Panel[18] recommended reinstating an annual minor flood event peaking daily at 4,000 - 5,000 ML/d over 6-7 days during August to October. This 30 GL event would exceed the entire agreed release and is unlikely to be implemented in the short-term.

The expert panel also recommended maintaining higher August to October flows at 300 to 530 ML/d, or natural, whichever is lower. ACTEW expects Tantangara Dam releases for Canberra's water supply (30-100 ML/d) to be included in Snowy Hydro releases for environmental flows. Allowing for these proposed releases each of the Tantangara supply options would remain at a total 20 GL/yr.

2.4 Murrumbidgee River flow Alternative

The Tantangara option also includes scope for downstream pumping alternatives including:

- release Tantangara water down Murrumbidgee River to a 20 km pipeline linking the River at Angle Crossing in the ACT with Googong Dam; and
- release Tantangara water down the Murrumbidgee to the existing Cotter pumping station connected to Stromlo water treatment plant.

These alternatives provide for three downstream pumping variants (see Figure 2.4):

1. Off-take near Angle Crossing for pumping via Rob-Roy and Mt Campbell Districts to Onion Farm at Burra Creek upstream of Googong Reservoir;
2. Off-take near Angle Crossing for pumping via Rob-Roy and Googong Districts direct to Googong Reservoir; and
3. Off-take near Cotter Pump Station for pumping to Mt Stromlo Treatment Works via the existing pipe network.

[18] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682. Murrumbidgee Expert Panel (1997) cited in.

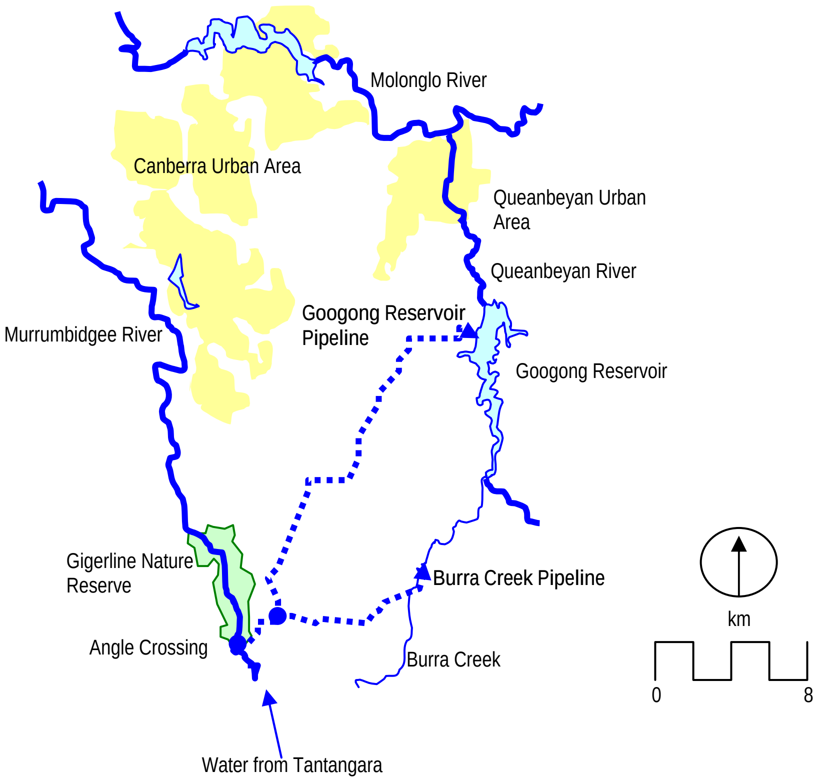


Figure 2.4: Proposed Murrumbidgee Water Transfer Alternatives

In the first instance, the scheme would require pumping stations and a possibly a tunnel through the Mt Campbell ridge. The second alternative uses a pipeline located along the Monaro Highway and Old Cooma Roads for delivery through the Googong rural residential area. Both alternatives could deliver flows for storage to augment the Googong supplies and reduce dependence on the less reliable Queanbeyan River catchment. Treatment and distribution would be through the existing Googong infrastructure.

In the third instance, the scheme could use recently completed infrastructure at Cotter. This pumping infrastructure, designed for temporary drought contingencies, could be upgraded to allow larger volumes to be fed into the existing Canberra supply on a more permanent basis.

All three alternatives could facilitate the proposed 60ML/day and 180ML/day extraction rates depending on Murrumbidgee River flows and pumping duration.

2.5 Refinement of Alternatives

Tantangara short-listed options include significant parts within or adjacent to national parks. The reservoir and its catchment lie within Kosciuszko National Park (KNP). Upper Cotter Catchment works would lie inside Namadgi National Park and both parks form part of the Bimberi Wilderness Area. Potential environmental, heritage and landscape impacts would require considerable management planning to mitigate possible impacts within these areas.

Under these circumstances:

- weir construction should occur outside KNP on privately owned downstream sites;
- underground pipelines would be necessary over their entire route; and

- tunnel portals (entrances) would lie outside national parks except where no alternatives exist. This means that tunnel-boring machines (TBM), drilling rigs, and servicing equipment would be delivered and serviced beyond the park boundaries and importantly, all tunnel spoil excavated and transported well beyond park habitats.

These considerations excluded the following alternatives:

Pressure pipeline from Tantangara Dam

A pipeline from the Tantangara Dam outlet along the Murrumbidgee to turn north up the Yaouk River Valley through a tunnel at Yaouk Gap would be costly and seriously affect national park and wilderness areas.

Discharge into Porcupine Creek

A Porcupine Creek discharge would degrade Upper Cotter environmental flows and their dependant habitats. Potential discharges between 60 ML/D and 360 ML/D would represent significant increases in the catchment's base flow causing bank erosion, bed degradation, and habitat changes in addition to significant risks through disease and exotic fish transfers.

Following the refinement of alternatives consultants[19] short-listed the remaining options for more detailed study. Including a consideration of 60 ML/D, 180 ML/D and 360 ML/D flow rate alternatives the four short-listed options[20] are:

- Option 1A – pumping main and penstock (downhill pipeline and "gate" valve);
- Option 1B – pumping main, short tunnel and penstock;
- Option 2A – long tunnel and short penstock; and
- Option 2B – short tunnel and long penstock.

2.5.1 Option 1A - Pumping Main and Penstock

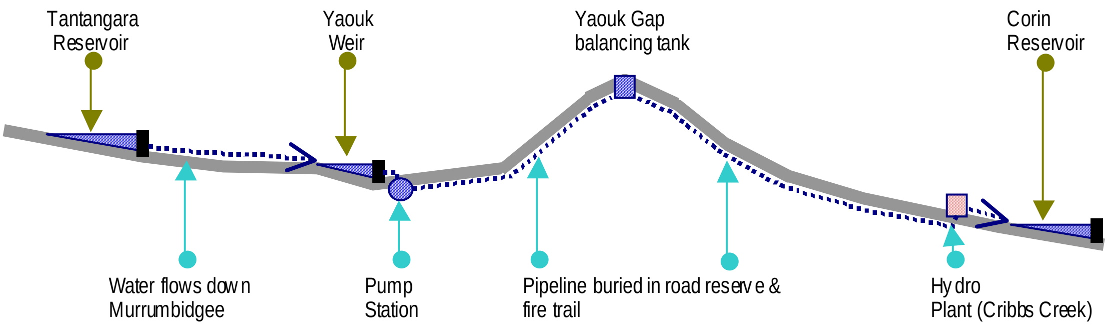


Figure 2.5: Pumping Main Option

[19] Snowy Mountains Engineering Corporation (SMEC) (2005) ACT *Future Water Options Tantangara Option*, *p2-4*
[20] Option titles as nominated by SMEC Consultants

This option's main elements include (see Figure 2.5:

- Tantangara Dam releases from existing outlet works into the Murrumbidgee to a constructed Yaouk Weir (25 km downstream);
- pumping station with a 14 km pipeline to a Yaouk Gap balancing tank;
- diversion into a 12 km penstock discharging about 1 km upstream of Cribbs Creek confluence with Cotter River;
- mini-hydro power station at the discharge into Cotter River;
- power line (6 km submerged, 3 km buried) from the hydro station to Corin Dam; and
- power line (20 km) from Adaminaby to Yaouk Pumping Station.

2.5.2 Option 1B - Pumping Main, Tunnel and Penstock

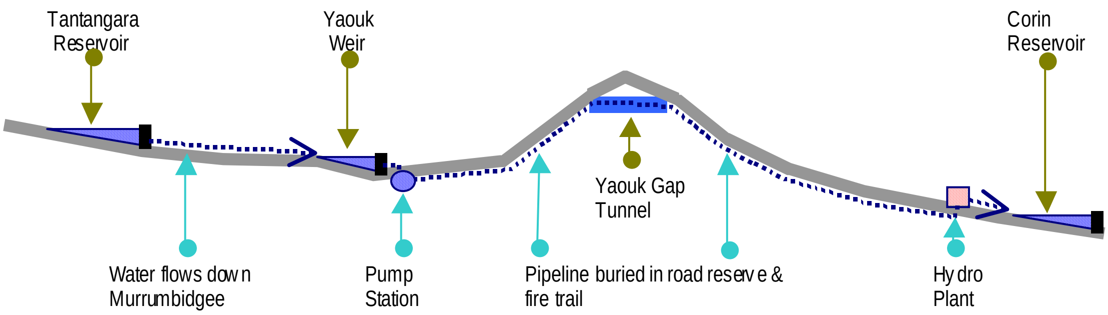


Figure 2.6: Pumping Main & Tunnel Option

This option's main elements include (see figure 2.5):

- Tantangara Dam release from existing outlet works into the Murrumbidgee to a constructed Yaouk Weir (25 km downstream);
- pumping station with a 13 km long pipeline to a tunnel near Yaouk Gap;
- diversion through 1.6 km Long tunnel under Yaouk Gap to a balancing tank;
- diversion into an 11 km long penstock discharging about 1 km upstream of Cribbs Creek confluence with Cotter River;
- mini-hydro power station at the discharge into Cotter River;
- power line (6 km submerged, 3 km buried) from the hydro station to Corin Dam; and
- power line (20 km) from Adaminaby to Yaouk Pumping Station.

2.5.3 Option 2A - Long tunnel and Short Penstock (Gravity Option A)

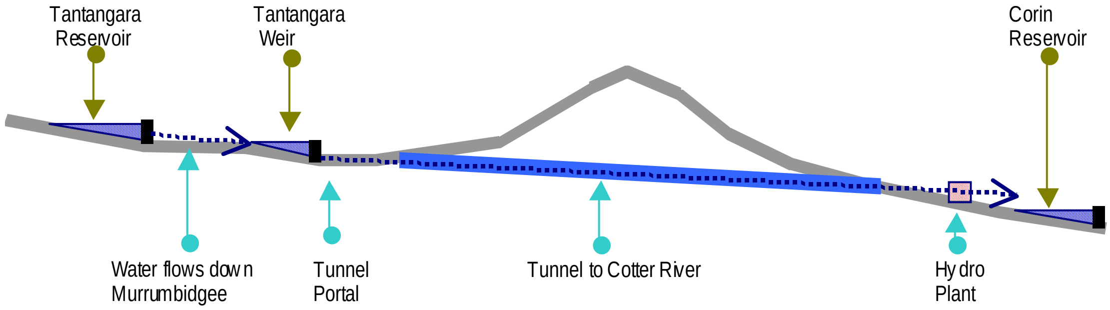


Figure 2.7: Long Tunnel Option

This option's main elements include (see Figure 2.7):

- Tantangara Dam release from existing outlet works into the Murrumbidgee to a constructed Tantangara Weir (16 km) downstream;
- diversion through a 20 km long gravity tunnel discharging about 1 km upstream of Cribbs Creek confluence with Cotter River;
- balancing tank storage with release into 0.8 km penstock and mini-hydro station;
- mini-hydro power station at the discharge into Cotter River; and
- power line (6 km submerged, 3 km buried) from the hydro station to Corin Dam.

2.5.4 Option 2B - Short Tunnel and Long Penstock (Gravity Option B)

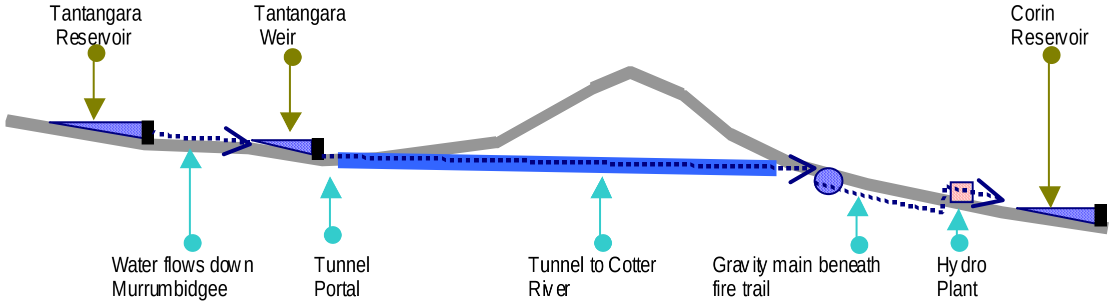


Figure 2.8: Short Tunnel with Gravity Main Option

This option's main elements include (see Figure 2.8):

- Tantangara Dam release from existing outlet works into the Murrumbidgee to a constructed Tantangara Weir (16 km) downstream;
- diversion through a 12 km-long tunnel about 1.5 km below Yaouk Gap;
- diversion through a 12 km-long penstock discharging near Cribbs Creek;
- mini-hydro power station at the discharge into Cotter River; and
- power line (6 km submerged, 3 km buried) from the hydro station to Corin Dam.

Following an assessment of all the options, ACTEW[21] reviewed the major development issues and their consequent constraints as follows:

- The main problem (in a Tantangara to Cotter system transfer) is transferring EHN virus and alien species (particularly redfin) infected with EHN.
- Proposed discharge impacts rule out the options of pumping water to either Murrays Gap or Porcupine Creek.
- The long tunnel options involve substantial construction beneath a NSW National Park, and some construction within Namadgi National Park. Energy generation was a positive but the major concern was the risk of EHN transfer to the Cotter system. Current knowledge indicates no EHN in Tantangara. Any Tantangara transfer option could introduce EHN to the Cotter system through future infections at Tantangara by fishers. *(ACTEW had major reservations about the risk of future transfer of EHN virus but determined that this option had potentially significant impacts that could be managed).*
- A pipeline to Corin Dam would involve major construction impact in Namadgi National Park that could possibly be managed but would be expensive. The need to cross many waterways, steep and fragile land, and cold temperatures would extend the construction process while not resolving the problems with transferring water from one catchment to another. (*ACTEW had major reservations about the effects of pipeline construction on the National Park plus the risk of future EHN virus transfers of and considered this option was highly constrained)*.
- An inter-basin transfer from the Murrumbidgee to Googong Reservoir has potential risks but the option of pumping into Burra Creek could be further explored, including required mitigation works to prevent erosion. Water transfer down the Murrumbidgee River was seen as positive. *(ACTEW considered that these options involved significant impacts, but could be managed – particularly if accompanied by increased flows from Tantangara in 100 km of river)*

2.6 Short-listed Alternatives

Considering environmental, social, and economic constraints and ACTEW deliberations the following represent the final short-listed Tantangara alternatives:

- the “long tunnel alternative” referred to as Option 2(a) above; and
- the “Murrumbidgee River flow alternative” (pumping to Googong Reservoir) from a weir near Angle Crossing using Tantangara water releases (referred to as the “virtual dam” alternative in the Tennent Dam Option).

Figures 2.9 and 3.0 illustrate the Murrumbidgee River flow and long tunnel alternatives respectively.

[21] ACTEW (Future Water Options Steering Committee) 1 December 2004 meeting

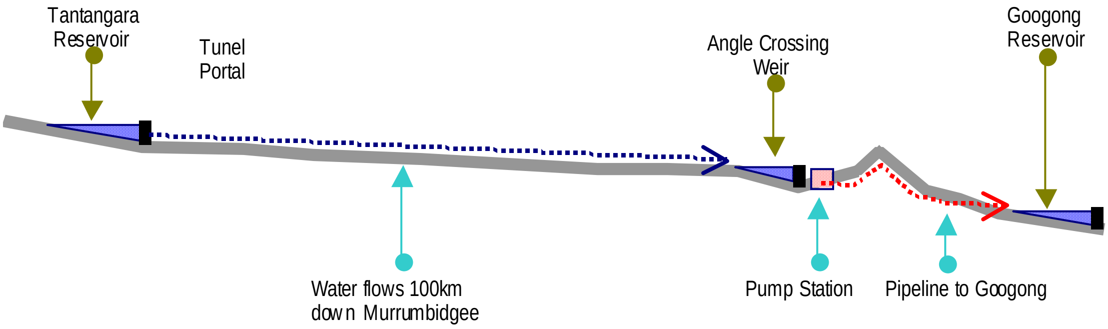


Figure 2.9: Murrumbidgee River Flow Alternative

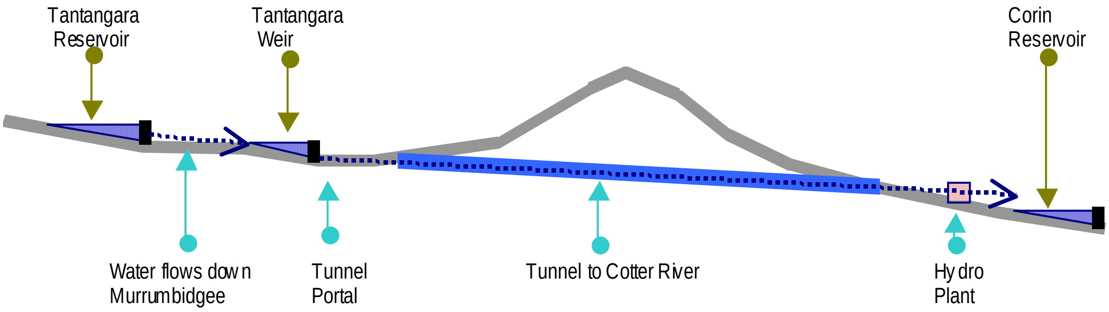


Figure 3.0: Long Tunnel Alternative

3 Planning

3.1 Statutory Planning and Legislation

The statutory framework for the Tantangara options involves complex Commonwealth Government, NSW, and ACT Government processes. These processes occur across jurisdictions both within NSW and between the Australian Government, ACT, and NSW. They include:

- water resource management policies;
- sustainability strategies, including greenhouse abatement;
- economic, social, and spatial dimensions of regional development strategies; and
- environment, land management and development control policies to manage water quality, land use, and environmental impacts.

The simultaneous application of Commonwealth, NSW and ACT laws increase complexity in negotiating, planning, investigation, assessment, review and approval activities. Each jurisdiction has significant specific and common requirements that should be coordinated to avoid process gaps and duplications.

3.2 Commonwealth Legislation and Policy

Commonwealth laws and policies establish Canberra's long-term water supplies[22] and its national capital function, engage the ACT in Murray Darling Basin issues, and set controls for environmental assessment. Appendix C summarises the important legislation.

Legislation creating the ACT provides control over water resources. These laws enable the ACT to extract water from its own catchments and include the Googong Dam outside of the ACT.

3.2.1 Murray Darling Basin and National Water Initiative

The *Murray Darling Basin Act (1993)* establishes national objectives for natural resource management, water distribution, asset management, and financial arrangements in the Murray Darling Basin. The *Act* and its consequent agreements set boundaries for ACT water planning including how much water is available under a prospective cap on extractions.

In 1998, the Territory formalised its participation in the Murray Darling Basin Initiative, committing to a cap on diversions. The ACT is currently consulting with the Murray Darling Basin Commission to set an appropriate cap but the Government has repeatedly stated it will not participate on the basis of historical use. By the end of 2005, the ACT Government expects to complete under a Memorandum of Understanding that will include a water cap provision.

In 2003, a *Murray Darling Basin Water Agreement* incorporated a five-year strategy for the implementation of water recovery measures including the recovery of 500 GL per year over five

[22] *Commonwealth Seat of Government Acceptance Act 1909* established paramount water right of the Commonwealth for the purposes of the Territory. NSW retains rights to the reasonable use of the Murrumbidgee River for conservation or irrigation. The *ACT Self Government (Consequential Provisions) Act 1988* transferred water functions to the Territory.

years for environmental purposes across the Basin. Under this agreement the ACT will contribute $5 million to recover its share of 2 GL per year.

In June 2004, the Council of Australian Governments (COAG) agreed to a National Water Initiative involving:

- expansion of permanent trading in water entitlements;
- improved water management arrangements;
- more sophisticated, transparent and comprehensive water planning;
- a commitment to address over allocated systems;
- better and more efficient management of water in urban environments;[14] and
- establishment of a National Water Commission together with an Australian Water Fund.

Tantangara alternatives have particular relationships Commonwealth water laws and policy initiatives including:

- Murray Darling Basin Commission concurrence for any major additional diversion of water, or establishment of additional storage capacity.
- A Commonwealth pre-condition to develop a regional water supply strategy before any water supply is approved. The ACT has established objectives for an integrated regional water supply strategy.[23]
- ACT participation in the National Water Initiative and the Murray Darling Basin Cap to secure ACT controlled “cap water”.

3.2.2 ACT Planning Legislation

The National Capital Plan controls the management and future development of land in the Territory.[24] The *Land (Planning and Environment) Act* mandates ACT’s Territory Plan, which must be consistent with the National Capital Plan [25].

The Tantangara long tunnel option lies within Namadgi National Park and is land identified in the NCP as *Mountains and Bushland*.

Mountains and Bushland areas feature the National Capital’s landscape backdrop, Namadgi National Park and its important, semi-wilderness character.

The National Capital Plan recognises Namadgi as part of southeast Australia’s regional alpine parks network (under the Australian Alpine National Parks Agreement) by incorporating the Namadgi Policy Plan as a special requirement for development. A new management plan for Namadgi (currently being prepared) defines policies and strategies for management over the next 10-15 years.

Mountains and Bushland areas include water supply and conservation area protection as principle considerations under the National Capital Plan, which also prescribes policies specific to Namadgi and the Upper Cotter. Relevant policies include:

[23] ACT Government (2004), *Think water, act water*, Vol 1, *op cit,* p38.
[24] *Australian Capital Territory (Planning and Land Management) Act 1988* established the National Capital Authority and National Capital Plan, which set out special requirements for development in selected areas.
[25] National Capital Authority (2002), *Consolidated National Capital Plan, including amendments*, February 2002,

- maintenance and protection of Namadgi NP water resource, conservation, wilderness and cultural values; and
- specific directions to protect Cotter Catchment's water supply values through land use controls.

The Tantangara long tunnel alternative could be consistent with these planning provisions by including mitigation measures but some risks to aquatic conservation values would remain if these measures fail to fully intercept alien species and diseases.

Proposed infrastructure, described as a *Public Utility* land use, would be permitted within Namadgi under the National Capital Plan subject to the provisions of an agreed management plan and the policies set down in the Plan's Special Requirements[26]. Namadgi's management plan is currently under review and the proposal is likely to be consistent with it and the National Capital Plan.

Appendix G in the National Capital Plan restates ecological and water quality values through objectives that also recognise Upper Cotter multiple uses that require specific management and land use controls. The Plan's objectives highlight catchment management rather than water treatment as the main water quality controls.

Upper Cotter sub-catchment policies in Appendix G emphasise water quality through tight controls on public activities to reduce pollution and bushfire risks. Similarly, any development activity associated with the proposal would be subject to tight runoff and clearing controls.

Area policies (A2)[27] also maintain ecological values in the Upper Cotter as intrinsic local characteristics and protection as a buffer for the Cotter to Gudgenby (Bimberi) Wilderness. Policies for Corin reservoir articulate its water supply role while allowing some recreation subject to controls. The proposal is consistent with these area policies.

3.2.3 Environment and Heritage Laws

Under the *Environment Protection and Biodiversity Conservation (EPBC) Act*, Commonwealth actions, activities on Commonwealth land, and actions likely to have a significant impact on national environmental significance (NES) matters are subject to a Commonwealth assessment and approval process.

"Actions" include project, development, undertaking, activity, or series of activities and the Act identifies seven NES matters listed below:

- World heritage properties.
- National heritage places (from 1 January 2004).
- Ramsar wetlands of international significance.
- Listed threatened species and ecological communities.
- Listed migratory species.
- Commonwealth marine area.

[26] National Capital Planning Authority (1990), *National Capital Plan*, 1990, as amended, Appendix G: Requirements for Namadgi National Park and Adjacent Areas.
[27] National Capital Planning Authority (1990), *National Capital Plan*, 1990, *Area Policies*

- Nuclear actions (including uranium mining).

The most likely triggers for the Tantangara Option include National heritage places, Listed threatened species[28] and ecological communities, and Listed migratory species.

Actions within the Tantangara proposal would be subject to a referral under the EPBC Act requiring Commonwealth Ministerial approval if it has, will have, or is likely to have, a significant impact on any NES matter including the introduction of invasive species[29].

The referral process is a preliminary evaluation where the Commonwealth Environment Minister decides if the proposed action requires approval and the extent of its mandatory environmental assessment. States or Territories can assess the action under the terms of a bilateral agreement or under an accredited assessment process.

If none of these assessment processes is applicable, the Commonwealth will carry out the assessment using one of the following assessment approaches:

- preliminary documentation;
- public environment report (PER);
- environmental impact statement (EIS); or
- public inquiry.

The *Australian Heritage Council Act 2003* replaces the *Australian Heritage Commission Act 1975* but final administrative arrangements have not been completed.

The Upper Cotter catchment, the Murrumbidgee River corridor and the Murrumbidgee River itself are all listed in the Register of the National Estate under this legislation. These places or sites cannot be damaged unless there are no feasible alternatives. Australian Heritage Council advice must be sought before any proposed development. Both Tantangara options would require clearance under this legislation.

Finally, species and habitats listed under the *EPBC Act* could be affected by the proposal (See Appendix E). At the least a referral under the Act with a possible EIS would be required should the Minister decide that the potential effects on NES matters (e.g. listed species) are significant.

3.3 NSW Legislation and Policy Framework

NSW laws and policies apply to those Tantangara option elements within NSW. They relate primarily to proposal's development and operational permits, approvals processes, and environmental assessment. Appendix C summarises the important legislation.

The *Environmental Planning and Assessment (EPA) Act 1979* establishes NSW's primary development assessment and land use planning system. Although the Tantangara proposals are not *designated development* under the EPA Act, the weir components could be and an

[28] See http://www.deh.gov.au/epbc/assessmentsapprovals/guidelines/administrative/index.html#threatened
[29] Introducing an invasive species into a habitat may result in that species becoming established. An invasive species may harm a critically endangered or endangered species by direct competition, modification of habitat, or predation.

environmental impact statement (EIS) is likely. The proposal is also *integrated development* requiring approval under multiple NSW consent procedures and licensing requirements.

Tantangara proposals could proceed under a formal NSW/ACT agreement covering integrated environmental assessment that also included the Australian Government and its requirements under the *EPBC A*ct. Regardless of the respective mandatory requirements, a full EIS is the most effective method for documenting development impacts and mitigation measures and would probably be completed subject to joint agreement between the jurisdictions.

To facilitate this process the NSW Minister for Planning could declare the project *"state significant".* This would avoid multiple local Councils assessing any development applications (and EIS) within NSW. Under this provision the NSW Minister would be the consent authority for Tantangara development components in NSW.

The *Environment Operations Act 1997:*

- allocates responsibilities between the Environment Protection Authority, local councils and other public authorities;
- authorises protection of the environment policies; and
- establishes licenses for activities that may impact on the environment.

Licenses would be required for water and spoil disposal, operational noise, and air quality management within NSW associated with both Tantangara alternatives.

A development application cannot be made on land within a wilderness area unless consent to the development has been obtained under the *Wilderness Act 1987*. The *National Parks and Wildlife Act 1974* defines responsibilities and management arrangements. The long tunnel traverses areas beneath these jurisdictions and although there is some ambiguity on subterranean jurisdiction, these laws probably apply.

The *Fisheries Management Act 1994* requires fish passage arrangements for a dam, weir or reservoir constructed on a waterway. The *Water Act 1912* provides for water licences, works approvals and water allocations (including their sale and transfer). *Water Management Act 2000* allows for water sharing plans and facilitates the *Water Act*. Tantangara alternatives would require permits and management responses consistent with all these Acts.

NSW and the ACT have a shared interest in management of the resources of the Murrumbidgee River since it supports regional economic development. The development of a regional integrated water supply strategy and a cap on ACT diversions will almost certainly require inter-governmental agreement. These negotiations would engage NSW agencies and Catchment Management Authorities (e.g. Murrumbidgee CMA) in their execution of the *Water Management Act 2000.*

The *Threatened Species Conservation Act 1995* would apply to all construction associated development activities specifying protection for threatened species and habitats in NSW. The *Rural Fires Act 1997* provides bushfire protection by placing a burden on prospective developers to control any fire outbreaks. The *Rivers and Foreshores Improvement Act 1948* applies to all access roads, weirs and other structures within 20m of Murrumbidgee plus other creeks and streams. The *Land Acquisition (Just Terms Compensation) Act 1991* applies to weirs, roads and pipeline routes where private landowner compensation is required for the proposal's land need. Land within the Murrumbidgee River owned by the Crown would be subject to the *Crown Lands Act 1989.*

3.4 ACT Legislation And Policy Framework

ACT laws and policies apply to those Tantangara option elements within the territory. They relate primarily to proposal's development and operational permits, approvals processes, and environmental assessment. Appendix C summarises the important legislation.

The Tantangara option would be subject to the *Water Resources Act 1998* that gives the ACT rights to the use, flow and control water of the ACT, and enables:

- preparation of environmental flow guidelines to maintain aquatic ecosystems;
- subordinate law in the form of the Water Resources Management Plan[30] to describe the ACT water resources, including the flows required for environmental needs and other water allocations, such as urban water supply; and
- creation and transfer of water allocations, licensing water use, and permits to construct water control structures;

Environmental Flow Guidelines support the *Water Resources Act,* the *Territory Plan*, and the *Water Resource Management Plan*. Importantly, the Act mandates environmental flows before any other water use.

A *Water Resource Management Plan* determines sub-catchment allocations, accounting for climate, environmental values, land use, stream flow, and environmental considerations. ACTEW Corporation has a rolling average allocation (62.7 GL/yr) limited to the Cotter and Queanbeyan River catchments. A licence authorises abstractions[31] and the Tantangara alternatives would require management plan and licence condition amendments.[32]

Environmental assessment is subject to part 4 of the Land Act. A Development Application (DA) will be required for the preferred option and this will trigger a mandatory Preliminary Assessment, which would probably lead to a requirement to prepare a full Public Environment Report (PER) or Environmental Impact Statement (EIS) and a formal Inquiry. To date the administration of this part of the Land Act has been such that usually, even for major proposals, only a preliminary assessment (albeit these are sometimes substantial pieces of work) has been required. More recent practice has been to proceed to the further levels of assessment for significant projects. This means that whilst a future water option would probably be subjected to either an EIS or a PER the administration has only minimal experience with these processes. The intent is that, depending on the option that may be selected, this report or one of its companions (which examine Cotter and Tantangara options) will serve as an appropriate document for a Preliminary Assessment and provide a basis for determining further assessment requirements. This is a practical approach that will save both time and money, without any diminution in the rigour of the assessment and approvals process.

The *Land (Planning and Environment) Act 1991* (the Land Act) establishes land use control and environmental assessment through:

[30] ACT Government (2004), *Think water, act water*, *op cit,* is the Water Resource Management Plan presented to the ACT Legislative Assembly, and now a Disallowable Instrument.
[31] Water use in 2003-2004 was 54.4 GL.
[32] Allocations and licences are sub-catchment specific and require detailed analysis.

- a *Territory Plan* determining land uses (excluding designated land covered by the National Capital Plan) and processes for Plan variations;
- procedures for development application approvals, decision reviews, and consultation requirements;
- referrals to the Heritage Council on matters of heritage significance;
- requirements for environmental assessments and inquiries; and
- land administration, including leasing and land management.

"Water Use and Catchment Policies" in the Plan's Appendix 1 define permitted uses of water within catchment areas. Permitted uses in the Upper Cotter catchment (Cotter reservoir) include land use for "water supply purposes" but exclude hydroelectric power generation. The proposed hydropower plant would require a variation to the *Territory Plan*.

Similarly, the Murrumbidgee River flow water supply proposals for would come within the definition of a "major utility installation" in the Territory Plan. "Major utility installation" is a use that can be permitted within the "mountains and bushland" and "river corridor" land use policy areas of the Territory Plan.

Consistent with the *Land (Planning and Environment) Act* the ACT Government could grant approval for Tantangara works excepting the hydro plant. Pipeline alignments traversing NSW would be subject to NSW legislation.

Table 3.1: Part B14 (Territory Plan) Controls

Control Clause	**Description and Application**
2.1 Landuse	(Schedule 1 landuse controls) permits a "major utility installation" that could include the tunnel, portals, penstock, hydropower plant and associated infrastructure subject to completion of a mandatory preliminary assessment.
2.2 Land Use Restrictions	N/A
2.3 Water Supply	The Cotter River catchment planning as multiple use subject to no water quality impacts.
2.4 Special Conditions for Environmental Protection	Requires specific ecological values protection and regeneration actions
2.5 Development Conditions	Visual assessment and management conditions for preserving visual integrity, ecology and landscape character.
2.6 Public Access and Trails	Provision of public access consistent with land use functions and risks.
2.7 Bushfire Protection	Prohibits development significantly increasing bushfire hazard.
2.8 Namadgi National Park	Notes Namadgi's inclusion in the Australian Alpine National Parks Agreement*

The Tantangara Option is generally compatible with *Part B14 Clause 1* objectives (subject to strict development controls). No area specific policies apply to the Tantangara proposal. Table 3.1 above summarises controls that apply to the B14 Policy area.

Some *Mountains and Bushlands* areas identify Public Land that provides for Plans of Management to be prepared by the Conservator of Wildlife in consultation with the public. The

Tantangara option lies beneath and within public land designated wilderness and national park and would be subject to the provisions of relevant management plans.

Under Part 4 of the *Land Act* a development application would be required for both Tantangara options. A mandatory Preliminary Assessment would probably lead to a requirement for a full Public Environment Report or Environmental Impact Statement, including a formal inquiry.

Preliminary Assessment has traditionally applied to major proposals but recent practice emphasises further levels of assessment for significant projects. While the Tantangara options would probably be subjected to either an Environmental Impact Statement or a Public Environment Report, this report (or its companions examining the Tantangara options) would provide documentation for a Preliminary Assessment.

The *Planning and Land Act 2002* accompanies the *Land (Planning and Environment) Act* requiring Territory Plan variations and possibly, design proposals to be referred to the Planning and Land Council. Providing advice to the Planning Authority and Minister the Council reviews major planning proposals.

The *Heritage Act 2004*:

- establishes a register for the recognition and conservation of natural and cultural heritage places and objects, including Aboriginal places and objects;
- establishes the Heritage Council;
- provides for heritage agreements encouraging heritage place and object conservation;
- enables enforcement and compliance to protect heritage places and objects; and
- integrates land planning and development assessments into heritage significance and heritage guidelines.

This act directs the ACT Planning and Land Authority to give the Heritage Council a copy of any development application relating to a place or object registered, or nominated for provisional registration. Conversely, the Councils must provide advice and the Authority must consider that advice. Tantangara options would require such a referral.

It is highly likely that simultaneous and overlapping reviews of the Tantangara options' heritage issues will occur under Commonwealth, NSW and ACT legislation.

The *Nature Conservation Act 1980* protects and conserves native animals and plants. It also reserves areas for these purposes and for *special protection status*. Declaration of a threatened fish or invertebrate under the Act applies this protection mandate. Two fish species listed as endangered under the *Nature Conservation Act* are automatically given special protection status. Permits would be required to take, keep, sell or otherwise trade in "animals".

Unauthorised disturbance or destruction of an animal nest including spawning sites for threatened fish is an offence under the Act, which also provides for the preparation of *Action Plans* that conserve threatened or endangered species or ecological communities.

There are prohibitions on the ACT Conservator approving certain work in wilderness areas, including Namadgi National Park. *Plans of Management* are developed for public land by the

Conservator, approved by the Minister and presented as disallowable instruments to the ACT Legislative Assembly. Tantangara options will require referral to the Conservator.

The *Environment Protection Act 1997* specifies environmental management and pollution control measures that will impact on detailed design and management, particularly during the proposal's construction phase. The *Lands Acquisition Act 1994* provides for the compulsory resumption of land for "public purposes" but potential acquisition would be limited to downstream pumping option only.

The *Independent Competition and Regulatory Commission* is a statutory body that regulates prices, access to infrastructure services, and regulated industry matters. The Commission would have a role in examining pricing changes generated by increased costs to ACTEW Corporation through the financing of infrastructure required for a preferred water option.

The ACT Government has adopted a policy on sustainability - *People Place Prosperity*[33]. Community values articulated in the sustainability policy guide development and coherence in the *Canberra Plan* and its components, the *Social Plan*, *Spatial Plan* and *Economic White Paper*.[34] Recently, the community also had an opportunity to express its views about non-urban values, issues and aspirations through the stakeholder consultation process within the major post bushfire report, *Shaping Our Territory: Opportunities for Non-Urban ACT*.[35]

Water supply reliability, availability, quality, costs, and environmental responsibility are core community values. Importantly, these values do not suggest that minimising water use should inhibit the region's natural population growth, livelihood opportunities, and lifestyle diversity.

3.5 Approvals Processes

The Tantangara long tunnel and Murrumbidgee River flow alternatives have development components that extend from respective weirs and associated facilities, through tunnels and pipelines, hydropower plant, power lines, and site access. The proposals also have operating components including water extraction, purchasing, storage, transfer, and delivery activities.

Both Tantangara alternatives would initiate complex approvals and consent processes that involve NSW, ACT and Commonwealth jurisdictions. Local, state and federal laws, regulations, policies, and protocols would apply to environmental, heritage, land use, and economic elements in the option's construction and operation. These also include potential participation within the Murray Darling Basin Cap, its associated trading scheme, and operating rules that govern the Cap and Snowy Hydro activities.

Each component requires specific approval under the laws and regulations discussed above but some coordination is possible and highly likely should the proposal proceed. For example, a coordinated assessment system could use the same or similar documentation in the Commonwealth, NSW and ACT jurisdictions. The alternatives could be deemed *state significant* making the NSW Minister for Infrastructure, Planning, and Natural Resources the consent authority instead of the respective NSW local councils.

[33] ACT Government (2003), *People, Place, Prosperity: a policy for sustainability in the ACT,* March 2003.
[34] ACT Government (2003), *The Economic White Paper for the ACT,* December 2003; ACT Government (2004), *Building Our Community: the Canberra Social Plan,* February 2004; ACT Government (2004), *The Canberra Spatial Plan,* March 2004.
[35] Non-Urban Study Steering Committee (2003), *Shaping Our Territory: Final Report: Opportunities for Non-Urban ACT,* November 2003.

As *integrated development* within NSW the Tantangara option would require a consent authority to establish general terms of any additional approvals to be issued by various responsible agencies. Regardless of the consent or licensing authority, NSW approvals processes and their documentation requirements are very complex with specific requirements extending through construction to operations including water purchase, storage and transfer arrangements.

ACT approvals processes are also complex and interrelated. Similar to NSW approvals, those in the ACT would include environmental planning, pollution control, heritage, water management and threatened species management within a simpler framework. This is partly a reflection of the Territory's more integrated approvals process but the long tunnel proposal's location entirely within Namadgi National Park simplifies agency participation. Participation within the Murray Darling Basin Cap is also likely to simplify the approvals process and its interactions with NSW.

Finally, the Commonwealth's *EPBC Act* and possibly the *Heritage Act* would require approvals for works and operations with the National Water Initiative (NWI) and Murray Darling Basin Agreements influencing the water-trading framework.

In any case, the Tantangara Option involves multiple consent authorities across several jurisdictions for both alternatives. Documentation and approvals processes are likely to extend over at least 12 months and probably beyond two years. Tables at Appendix D detail the approvals processes for each development component.

3.6 Transfer Arrangements

A Tantangara water transfer involves the following main actions:

- obtaining rights to the water;
- storing water in Tantangara reservoir; and
- transporting water from Tantangara to the ACT.

The proposal involves five major administrative steps[36] shown in figure 3.1 below.

[36] Marsden Jacobs & Associates (2003) *Tantangara Dam as an Option for Water Supply: Preliminary Business Case*

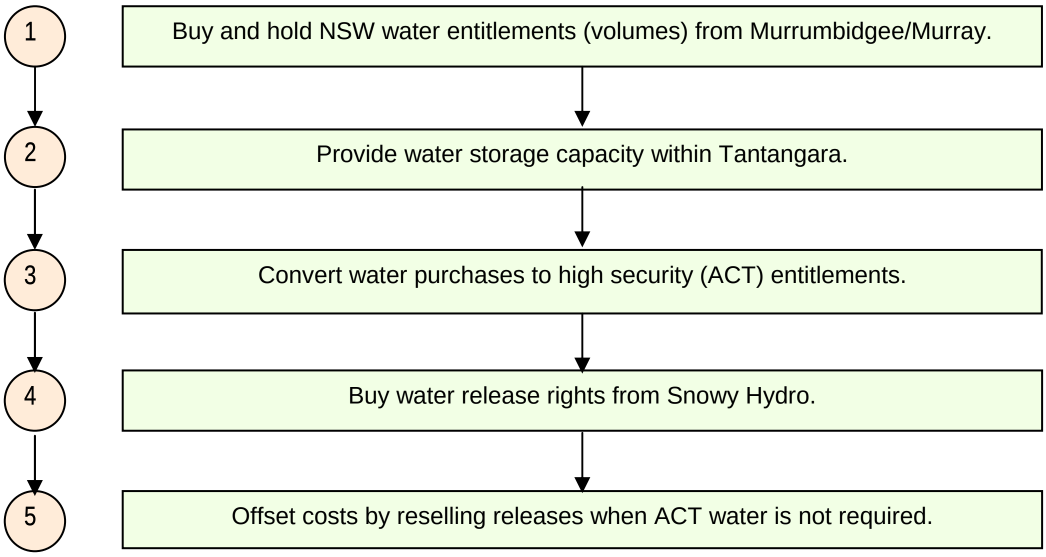


Figure 3.1: Tantangara Water Transfer Arrangements

3.6.1 Buy NSW Volumetric Entitlements from Murrumbidgee/Murray.

ACTEW can purchase (and hold) NSW water entitlements from downstream users in the following ways:

- purchase entitlements via a water broker;
- purchase an irrigation property with its attached water entitlement;
- purchase by electronic exchanges; and
- bilateral negotiation.

Under the proposed (still under review) Murrumbidgee Water Sharing Plan and *Water Management Act 2000* ACTEW could obtain a holding licence with:

- approval for the purchase (subject to trading rules) from a private extractor; or
- approval for the purchase from a single privatised irrigation district.

If ACT participated in the Murray Darling Basin Cap it could purchase "Cap Water" from a variety of NSW, Victorian, or South Australian sources, transfer that water, and permanently hold the water rights under ACT control. In other words, the purchase would increase the ACT Cap while reducing the seller's Cap.

3.6.2 Provide Water Storage Capacity Within Tantangara.

Tantangara has the capacity to store water for the ACT without fundamentally changing the reservoir. Changes to the dam's off-take structure will enable variable storage and discharge levels not currently possible and these are due for completion in 2005. Subject to negotiation with NSW and Snowy Hydro, purchased water could be stored within Tantangara and still meet existing and proposed operational rules, and statutory obligations.

Negotiations for the storage and final release would also be subject to the final environmental flows strategy[37] due in 2005. This could involve other stakeholders including environmental agencies and downstream catchment management authorities.

3.6.3 Convert Purchased Water to High Security Entitlements

ACTEW's purchase of a general security water entitlement would need subsequent conversion to a high security entitlement. High security entitlements provide greater access to water but do not necessarily guarantee a supply under the current trading regime. This is a significant issue because in a catastrophic situation (e.g. NSW water supply failure, climate change) the NSW Minister has the power to prevent ACTEW receiving its high security entitlements regardless of any contractual obligations. This is most likely to occur at a crucial time for all water users when supplies are extremely limited and conversely, demand is high.

Currently, two years supply is reserved in dams to meet the one-year demand for high security users in NSW. Converting entitlements are subject to:

- conversion rates (possibly 0.5 for conversion of general security to high irrigation security - 0.4 for conversion of general security to high security) under the current regime and the NSW Department and Minister's explicit approval of conversion rates.
- ACT ratification of the National Water Initiative under a proposed trading regime.
- participation by ACT in the MDB Cap to convert NSW entitlements to ACT entitlements under a proposed trading regime.

If the ACT participated in the Cap in a proposed trading regime the conversion rates would be determined through endorsed schedules as part of the Cap Agreement. It is possible that even with high security entitlements under ACT control the Territory may not have complete access to its water. This could occur when extreme drought conditions left a shortfall of high security water to be spread amongst competing high security users. Under this situation, water access would be rationed between users.

If the ACT does not participate in the Cap, the NSW Government must approve a water transfer from the lower Murrumbidgee (covered by the Murrumbidgee Water Sharing Plan) to Tantangara because it lies outside the Water Sharing Plan boundary. NSW approval may be supported by:

- strong support from DIPNR for regional water supply initiatives; and
- water transfer to Blowering or above relieving pressure on the Blowering Choke. Water purchase marginally benefits irrigators below the Choke by reducing required volumes.

3.6.4 Buy Release Rights from Snowy Hydro

NSW controls water entitlement volumes in Snowy catchments but Snowy Hydro holds the rights to the timing of water releases.

Snowy Hydro must release a minimum 1,026 GL annually for the Murrumbidgee (called *below target water*). Snowy Hydro may also release discretionary volumes (*above target water*) averaging about 254 GL per year.

[37] See http://www.epa.nsw.gov.au/soe/soe2003/chapter5/chp_5.2.htm

Snowy Hydro's limited flexibility for releasing "below target water" contrasts with "above target water" releases timed to coincide with high electricity prices. ACT water transfers involving both water release types will change the opportunity cost to Snowy Hydro but Murrumbidgee high security water entitlements would come from the below target water. If ACTEW purchases high security entitlements it would divert below target water (presumably at a lower cost). Under the *Corporatisation Act*, Snowy Hydro must consider requests for water.

Snowy Hydro has licensed entitlements to collect, store, and release water for power generation but it does not hold the extractive (consumptive) water entitlements.[38] Extractive entitlements to water stored in the Snowy scheme, can only be granted by the NSW Water Ministerial Corporation (s32[1] *Snowy Hydro Corporatisation Act 1997* [NSW]).

The Corporatisation Act enables Snowy Hydro Company to charge a fee for taking extractive water. The fee can either be negotiated with the extractor or determined by the NSW (S32[2] *Snowy Hydro Corporatisation Act 1997* NSW].

The key negotiating issue is the opportunity cost of foregone electricity from:

- water taken (volumes);
- whether the water is below or above target water;
- operational impacts particularly in relation to evaporation and spills;
- value of Snowy Hydro's power in the National Electricity Market (NEM) or in bilateral contracts with distributors or other NEM counterparties; and
- the value of renewable energy certificates for that part of Snowy Hydro's generation eligible under the *Renewable Energy (Electricity) Act*.

Final price negotiations and agreements involving Snowy Hydro and NSW would need to consider factors such as off-take arrangements, pipeline design, identified risks and liability sharing.

3.6.5 Resell Release Rights to Snowy Hydro and Trade Water Back into the Market

Some of these purchase and transaction costs could be offset by:

- negotiating with Snowy Hydro and other water traders to sell back releases when Tantangara water is not required in ACT;
- establishing internal ACTEW rules for trading water to irrigators when water is not required in ACT; and
- refining and implementing operating rules for ACT storages and transfers including Tantangara.

3.7 Additional Requirements

ACT has an obligation under the Murray Darling Basin Cap to limit its water use. The Cap is a limit on water volumes diverted from the Basin's rivers for consumptive uses. The total cap

[38] Snowy Corporatisation Principles 1997, in Marsden Jacobs & Associates (2003) *Tantangara Dam as an Option for Water Supply: Preliminary Business Case*

amount equals *"The volume of water that would have been diverted under 1993/94 levels of development"* and it currently applies to NSW, Victoria and South Australia, with minor adjustments for each state to allow for developments since 1993/94. Rules for determining, monitoring, auditing and managing the Cap (Schedule F: Murray-Darling Basin Agreement)[39] were ratified in August 2000, following a five-year operations review.

Details of the ACT Cap are still being finalised. The ACT only uses about 0.3 per cent of the Basin's water but the cap will influence environmental flow and operating rules for all water use options.

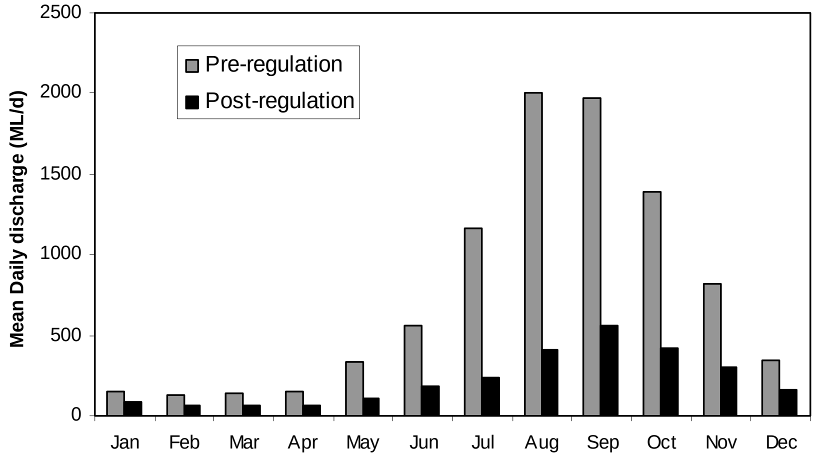
The ACT's water strategy, *Think water, act water*, states that by December 2005 the ACT will *"aim to complete a Memorandum of Understanding with the New South Wales Government and the Commonwealth Government that will include provision for a water Cap".*

[39] Murray Darling Basin Commission (2004) *Factsheet: Murray Darling Basin Agreement* 2004.

4 Water Resources

4.1 Historical Storage and Releases

Before regulation high winter-spring precipitation strongly influenced the Upper Murrumbidgee. High winter and spring flows maintained a high base flow between July and October. Tantangara Dam inflows average around 300 GL/yr with 99 per cent transferred to Lake Eucumbene as part of the Snowy Mountains Scheme[40].



Source: Snowy Water Inquiry (1998, Appendix 4, p. 30) in Marsden, Jacob 2004

Figure 4.1: Historical Murrumbidgee Flow Regime

Murrumbidgee flows currently maintain 32 ML/d at Mittagang Crossing near Cooma and 17 ML/d at Cotter Crossing in the ACT (see figure 4.1 and Table 4.1). The maximum Tantangara release is 83 ML/d or storage inflow, whichever is less but these targets are often met by downstream tributary inflows without reservoir releases. Three significant dam spills (1962, 1975 and 1992) and three minor spills have occurred since 1959.

Table 4.1: Approximate Annual Flow Currently Diverted by Tantangara Dam

Location – gauging station	Distance downstream (km)	Percentage diverted
Tantangara Dam (The Gulf)†	0 (1)	99 per cent
Yaouk	25	73 per cent
Mittagang Crossing	90	63 per cent
Billilingra	133	46 per cent
Below Lob's Hole	198	43 per cent
Pine Island	215	33 per cent
Mt MacDonald	238	30 per cent
Burrinjuck Dam	296	16 per cent

Note: Before Tantangara Dam construction a gauging station (The Gulf) operated 1 km downstream of the dam site.
Source: Marsden Jacob 2004

[40] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682. Murrumbidgee Expert Panel (1997) cited in

4.2 Environmental Flow Considerations

Investigated release rates[41] with environmental flow considerations accounted for two main scenarios:

1. Canberra water supply of 11 GL/yr with a loss allowance attributed to natural flow patterns (i.e. releases include environmental flows to maintain natural seasonality).

2. Canberra water supply of 11 GL/yr with a loss allowance supplied at a constant annual rate.

The first scenario assumes some capacity (e.g. in Googong Dam) to store water for environmental flows with a subsequent release as required. In this case, Canberra's water consumption is likely to be the reverse of environmental flows. Water demand is greatest when rainfall and streamflow is lowest. During high rainfall periods and low urban demand, environmental flow releases would mimic natural streamflow levels.

The second scenario requires no environmental flow storage with releases largely unrelated to natural flow regimes.

Investigations[42] also assumed that:

- significant water losses between Tantangara Dam and Tharwa (probably over-estimations since they were derived from calculated losses during the 1968 Tantangara Dam flow release following a significant dry period); and
- losses proportional to environmental flow releases (greater losses with greater flows is the opposite of what would actually occur but considering the conservative loss estimates is unlikely to significantly affect the estimations).

Additional flow benefits diminish by Mittagang Crossing because unregulated tributaries downstream of Tantangara supply additional flows (133 GL/yr).

Modelling predicts that a proposed 28 GL/yr environmental flow release would significantly reduce stream disturbance along this reach. These marginal volume increases (about 10 per cent of the natural flow) provide considerable improvements in flow seasonality and variability.

Modelling indicates that Tantangara releases would significantly reduce stream disturbance with the greatest improvements for water supply releases concurrent with environmental flow releases. This preserves both flow seasonality and variability.

Water supply releases at a constant annual rate significantly impact on low flows when higher than natural flow volumes would be released in the summer months (Jan – March).

Each the dam options discussed above show an increase in the hydrologic disturbance in the Murrumbidgee River downstream of the Molonglo River confluence. This is also attributed to the increases in inflows from the Lower Molonglo Water Quality Control Centre. Unlike the Cotter and Tennent options, this effect is not offset by a reduction in flow in the Murrumbidgee River

[41] Marsden Jacobs and Assoc. and Fluvial Systems (2005), *Predictions of Transmission Losses in the Upper Murrumbidgee River and Cotter River*, April 2005, ACTEW Corp Doc No. 4658
[42] *Ibid.*

upstream of the confluence but it could be mitigated if there is some attenuation capacity included at the Lower Molonglo Water Quality Control Centre.

It is clear from the options considered above that considerable environmental benefits are most likely to be achieved if the Canberra water supply requirements are released in conjunction with the environmental flow releases. Notwithstanding this consideration, downstream release to Angle Crossing and pumping to Googong is the preferred option.

4.3 Potential Transfer to ACT

Tantangara options could involve the purchase of up to 50 GL in water entitlements (2 years storage) under the Murray Darling Basin Cap on water diversions and the proposed trading scheme. Entitlements could be sourced from water users in NSW, Victoria or South Australia.

Including allowances for hydro electricity, environmental flows, losses, and consumptive use, Tantangara reservoir has the storage capacity to meet a long-term average 20GL/yr purchase and subsequent conversion into high security entitlements.

Beyond the existing system operating controls 4 new rules would apply to Tantangara Dam transfers:

1. The maximum amount that can be sourced is 20GL each October to September year (based on quantity agreed with Snowy Hydro).
2. Water cannot be used during January or February (putting cold Tantangara water into the Murrumbidgee in these months disadvantages native fish species).
3. Transfers can only occur (over the following 12 months) if the minimum system storage in October is less than the optimised trigger storage for Stage 1 Restrictions plus 30.3GL. (30.3GL is a buffer that minimises the likelihood of restrictions in the next 12 months).
4. To maximise low cost water use and minimise spills in Corin and Bendora Dams transfers can only occur in the following month if the minimum storage in Corin Reservoir at the end of the preceding month is:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
92 per cent	95 per cent	96 per cent	94 per cent	94 per cent	90 per cent	86 per cent	84 per cent	83 per cent	84 per cent	86 per cent	92 per cent

Hydrological modelling[43] suggests that under the long tunnel alternative, water releases would be needed three years out of 10. Similarly, under the Murrumbidgee River flow alternative releases would be needed four years out of 10.

4.4 Water Quality

4.4.1 Tantangara Reservoir Water Quality

Water quality for three major inflows (Murrumbidgee River, Nungar Creek, and the Goodradigbee Aqueduct) is generally good[44] with low to moderate total phosphorus

[43] Hydrological modelling ACTEW 2005
[44] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682.Maini et al (1997) cited in

concentrations, low total nitrogen (TN), low turbidity, and low dissolved salts concentrations. Water temperature mirrors the typical seasonal variation.

Compared with the major inflows sourced from national park catchments Tantangara Reservoir water quality is generally poor for the following reasons[45]:

- thermal stratification and deoxygenation of the deeper waters;
- nutrient release from reservoir sediments; and
- sediment re-suspension from shallow and exposed waters.

Reservoir studies[46] indicate:

- the storage has moderate total phosphorus and low total nitrogen concentrations.
- bottom waters were anoxic during thermal stratification;
- thermal stratification is unlikely to have had a prolonged effect on reservoir water quality because shallow storage levels, wind, and draw down encourage mixing;
- cyanobacteria (blue green algae) occurred infrequently at low to moderate cell counts;
- water levels kept low during warmer months largely prevent thermal stratification and deoxygenation that may lead to cyanobacterial blooms[47];
- reservoir waters had medium clarity; and
- high organic content may cause lower than expected surface DO concentrations.

Following the completion of the new discharge structure (scheduled for 2005), Tantangara Dam will have the ability to discharge downstream flows sourced from variable depths. This would reduce water quality impacts and enable a more controlled discharge regime.

4.4.2 Downstream Water Quality

From November 1993 to June 2004, there were no cold month water releases. Average annual Tantangara Dam releases for the remaining 9-month periods were only 27 ML/day. This creates a negligible Murrumbidgee River flow immediately downstream of Tantangara Dam compared to reservoir inflows.

Moderate nutrient concentrations downstream of Tantangara Dam are generally lower than those at the main inflows with Yaouk Total Phosphorous (TP) concentrations and turbidity exceeding dam inflow levels. Tantangara Dam releases contribute marginal downstream river flows with limited impacts on downstream water quality. Major nutrient inputs originate in catchment areas between Tantangara Dam and Cooma[48].

Murrumbidgee water quality deteriorates between Tantangara Dam and Mittagang crossing where nutrient concentrations, turbidity and electrical conductivity increase with downstream distance from the reservoir. Point sources and land use practices contribute little of the nutrient load with most nutrient inputs originating from diffuse natural sources (e.g. gully and channel

[45] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682.Maini et al (1997) cited in
[46] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682. Bowning (1995) and Maini et al (1997) cited in
[47] *Op cit*
[48] *Op cit*

erosion). Low flows may be contributing to elevated salinity between Bolaro and Mittagang Crossing.[49]

4.4.3 Water Characteristics and Treatment

The main factors that influence reservoir water quality are:

- water temperature and dissolved oxygen;
- sediment organic content; and
- Inflows from rainfall (or snowfall).

Reservoir water quality has the following characteristics:

- reservoir stratification pushes colder (and denser) water to the bottom, and warmer water to the top of the reservoir;
- sediment micro-organisms cause chemical stratification by actively reducing dissolved oxygen concentrations immediately above the substrate;
- rainfall and runoff inflows can disrupt reservoir stratification by introducing suspended material into the water column with disruptions depending on the extent, timing and existing stratification; and
- the best reservoir water quality lies 3 – 6 m level below the reservoir surface because:
  - surface water can contain significant algae and floating matter concentrations from runoff; and
  - bottom water can have elevated nutrients and metal levels, particularly when the reservoir stratifies between November and April each year.

The main factors that influence river water quality are:

- high numbers of algae and chlorophyll from low flows and high turbidity;
- darker colour and higher faecal coliform levels from higher flows; and
- highest water quality conditions during medium flows or immediately after high flows.

ACTEW analyses[50] indicate that water from the long tunnel alternative would be treatable at the Stromlo treatment plant for 95 per cent of the time.

The new (from July 2005) Tantangara Reservoir variable off-take will improve quality of water released into the Murrumbidgee River but further reservoir de-stratification may be cost effective, especially by reducing phosphorus concentration.

In about 60 per cent of cases, Tantangara water released via the Murrumbidgee River and the Cotter Pump Station would be treatable by the Stromlo facility without dilution with Bendora Reservoir water. Dilution with Bendora Reservoir water would allow Stromlo facility treatment treatable for over 95 per cent of cases.

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[49] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682.Maini et al (1997) cited in

[50] ActewAGL (2005), *Tantangara Options Water Quality Report*, April 2005, ACTEW Corp Doc No. 4663

In about 95 per cent of cases, Tantangara water released via the Murrumbidgee and pumped Googong Reservoir would be treatable by the Stromlo treatment plant or a similar facility. Reservoir de-stratification could further improve Googong water quality by reducing the concentration of nutrients and algae.

4.5 Influence of Climate Change

In its new water storage assessments, ACTEW commissioned CSIRO to analyse possible climate changes for Canberra over the next 70 years.[51]

ACTEW commented:

"with only 90 years of record of ACT climate (available) … the climate (rainfall, evaporation, temperature) records for the ACT (clearly do not) reflect the range of floods and droughts that might be experienced in the future. … The current drought is now the worst on record and would have been difficult to predict even a few years ago. … There are uncertainties in projections and new information continues to give a better understanding of the possible impacts of climate change."[52]

The results have be significant implications for the region's catchment behaviour and water demand. Regional temperature, rainfall and potential evaporation projections from global climate models indicate:

- mean annual temperature increases of 0.4 to 1.6 °C by 2030 and 1.0 to 4.8 °C by 2070, with slight seasonal variations;
- temperature increases will change the frequency of the region extreme temperatures;
- potential evaporation increases by up to 10 per cent by 2030;
- mean annual rainfall changes by between –9 per cent to +2 per cent by 2030, and –29 per cent to +7 per cent by 2070, largely over winter and spring; and
- rainfall changes significantly influencing of extreme dry and wet year frequencies (with rainfall effectiveness during wet years reduced by higher evaporation).

The evidence is not definitive but CSIRO analyses indicate atmospheric circulation patterns over the Murrumbidgee Basin have changed over the past 40 years with the following implications:

- A rainfall decline has occurred over the region, with lower variability between years since the 1980s coupled with changes in rainfall seasonality (increased winter and decreased summer rainfall).
- There may be about a 6 - 8 per cent rainfall decrease between 2035 and 2065.

Projections of water yield in the Cotter and Googong catchments and water demand within the ACT indicate:

- decreases in ACT annual run-off of up to 20 per cent in 2030 and 50 per cent by 2070;

[51] CSIRO (2003), *Climate Change Projections and the Effects on Water Yield and Water Demand for the Australian Capital Territory*, (ACTEW Corp. Doc. No. 3948).
[52] ACTEW Corporation (2004), *Assessment of the Need to Increase the ACT's Water Storage, op cit,* pp 6-7.

- changes in summer/autumn run-off (relative to 1990) of –20 to +5 per cent, and –50 to +10 per cent by 2030 and 2070 respectively;
- changes in winter/spring run-off (relative to 1990) of –20 to –5 per cent and –50 to –10 per cent by 2030 and 2070 respectively;
- projected percentage changes appear higher in the Queanbeyan River catchment than the Cotter River catchment;
- climate change, expressed as an increase in mean temperatures, predicts per capita ACT water demand will increase by 1 to 5 per cent (3 per cent for mid-range scenarios) by 2030 and 1 to 16 per cent (9 per cent for mid-range scenarios) by 2070; and
- climate change, expressed as an increase in the frequency of "hot periods", implies that the increase in demand could be approximately twice this level, 1.4 to 14 per cent by 2030 and 9 to 38 per cent by 2070.

These figures represent estimations based on complex models that should be considered as forecasts limited by the vagaries of climate prediction. Nevertheless, they imply that rainfall decline and higher evaporation is a distinct possibility for the region and water supply models for the ACT have been adjusted accordingly.

4.6 Influence of Other Variables

4.6.1 Transmission Losses

"Transmission losses" represent the water volumes lost between Tantangara and the ACT from:

- extractions for consumption;
- evaporation from water surfaces and evapo-transpiration by riparian vegetation; and
- riverbed infiltration recharging groundwater.

Initial loss occurs when flow rises and inundates to fill sediment void spaces to be subsequently lost through evaporation as the event recedes.

Estimated initial losses for the river to Burrinjuck Dam are:

- 422 ML/d for flow events rising from zero flow to baseflow level;
- 1,077 ML/d for flow events rising from zero to median flow level; and
- 655 ML/d for flow events rising from baseflow level to median flow level.

Total daily evaporation is highest in summer depending on river width with loss rates per channel length generally increasing downstream. Estimated evaporation losses for river to Burrinjuck Dam are:

- 7 ML/d in winter to 47 ML/d in summer for baseflow conditions; and
- 10 ML/d in winter to 70 ML/d in summer for median flow conditions.

Rainfall significantly contributes to volumes during low flows but the effect is brief. During median flow event conditions, rainfall contributes about 10 – 12 ML/d on average. Rainfall balances evaporative loss in winter contrasting with summer when evaporative loss greatly exceeds rainfall contributions.

Consultants[53] generated loss rate scenarios for Tantangara Dam to ACT transfer - 1GL/month and 3 GL/month plus a third release event (15GL/month) to assess loss implications for a high release rate. The scenarios in Table 4 include:

- 500 ML/day for 40 days from September to October;
- 100 ML/day for 200 days (3GL/month) from October to April; and
- 30 ML/day for 200 days (1GL/month) from October to April.

Table 4.2: Transmission Loss Scenarios For Mean, Drought, and Worst-Case Rainfalls

Rainfall Condition	Offtake location	Percent loss		
		40 days @ 500ML/d	200 days @ 100ML/d	200 days @ 30ML/d
Average Rainfall	Gulf Plain (15 km)	0.02%	0.12%	0.28%
	Yaouk (25 km)	0.04%	0.20%	0.46%
	Below Lobb's Hole (Tharwa)	2.60%	10%	24%
	Mt MacDonald (Cotter/Molonglo)	4.20%	15%	35%
	Burrinjuck Dam	6.70%	22%	52%
Drought rainfall	Gulf Plain (15 km)	0.04%	0.16%	0.37%
	Yaouk (25 km)	0.06%	0.26%	0.61%
	Below Lobb's Hole (Tharwa)	3.10%	12%	29%
	Mt MacDonald (Cotter/Molonglo)	5.00%	17%	40%
	Burrinjuck Dam	7.90%	26%	61%
Worst case rainfall	Gulf Plain (15 km)	0.05%	0.19%	0.45%
	Yaouk (25 km)	0.08%	0.32%	0.76%
	Below Lobb's Hole (Tharwa)	3.40%	14%	33%
	Mt MacDonald (Cotter/Molonglo)	5.60%	20%	46%
	Burrinjuck Dam	8.90%	30%	69%

Source: Marsden Jacob et al, 2005

Water balance models indicate that shorter-duration, higher magnitude releases (Scenario 1) are more efficient than the longer duration scenarios (Scenarios 2 and 3). In a drought year for example, a 40-day, 500ML/day release loses 5 per cent flow volume between Tantangara and Cotter/Molonglo junction area. This would require an extra 1 GL release to supply 20 GL at the downstream off take point. In comparison, a 200-day 100ML/day release loses 17 per cent , needing an extra 3.5 GL to supply 20 GL at the downstream off-take point. Releasing water at 30 ML/d loses 40 per cent to evaporation and initial loss. Regardless of the flow scenario, summertime and drought releases are relatively inefficient because of high net channel evaporation.

Transmission changes were not modeled for Cotter River because of insufficient discharge and channel data. Upper Murrumbidgee modelling provides the following indicative information:

- Cotter River would probably have comparatively lower transmission losses;
- evaporation losses would be low due to the narrow and shaded channel;
- net evaporation would be reduced within this a high altitude, high rainfall zone;

[53] Marsden Jacobs and Assoc. and Fluvial Systems (2005), *Predictions of Transmission Losses in the Upper Murrumbidgee River and Cotter River*, April 2005, ACTEW Corp Doc No. 4658

- the rate of channel bed transmission loss is unknown but it would probably be low or non-existent; and
- initial losses would be constrained by boulders and bedrock within the channel.

4.6.2 Consumptive Losses

Major diversion points include:

- 1.3 GL/yr – 1.6 GL/yr upstream of Mittagang Crossing for Cooma's water supply (maximum allocation 2.143GL/yr);
- 2 GL/yr to 4 GL/yr (estimated-un-metered extraction) on the Numarella floodplain for irrigation;
- Adaminaby floodplain water for irrigation; and
- Billilingra Gorge (marginal amounts).

Forty-four licenced water users in the Upper Murrumbidgee catchment (excluding the ACT) can extract up to 9.2 GL/yr[54] but volumes are probably lower. Extraction for large-scale irrigated agriculture occurs from the Numeralla River junction to the Bredbo River junction.

4.6.3 Catastrophic or Unforeseen Events

Catastrophic events such as bushfires, sudden climate change, or major infrastructure failures could affect both the water quality within Tantangara Reservoir and downstream flows. Additionally catastrophic failure of either Tantangara or some other element of the Snowy Scheme could impact on the ability of the reservoir to deliver its allocation to ACT.

Similarly, catastrophic events in the nation's electricity supplies or some other major influence on electricity costs and production could also influence the ability of the Snowyhydro to sacrifice generating capacity for water supplies.

The ease of disruption perhaps by terrorists of a pipeline or tunnel compared with a difficulty of sabotaging a dam is also a factor.

Regardless of these events, Tantangara water transfers are linked to the supply and trading of water and electricity within Australia, NSW and the Murray Darling Basin. As stated previously, the ability to deliver water from Tantangara is at the NSW Minister for Infrastructure Planning and Natural resources discretion until ACT signs up to the Cap. Without a full Cap water transfer, a catastrophic water supply failure that threatens NSW interests would require the NSW Minister to primarily serve his own constituents' interests that could either reduce or prevent ACT water transfers.

4.7 Expected Water Supply from Tantangara

4.7.1 Water Supply Reliability

Water supply reliability is an important consideration in selecting a preferred future water option. While guaranteeing unlimited supply is technically possible, it would be financially prohibitive. In

[54] Marsden Jacobs and Assoc. and Fluvial Systems (2005), *Predictions of Transmission Losses in the Upper Murrumbidgee River and Cotter River*, April 2005, ACTEW Corp Doc No. 4658 Snowy Water Inquiry 1997 cited in

practice, the objective is to achieve reasonable water availability at reasonable cost within environmental and social expectations that support a minimum acceptable supply.

The term "water supply reliability" means having sufficient water in storage to supply the ACT and region's urban areas without the risk of running out of water. ACTEW must be able to provide customers with water for reasonable household and commercial use, and to maintain public parks and gardens in reasonable condition.

Water restrictions may need to be imposed in prolonged droughts so that consumption is reduced. ACTEW has determined that a "reliable water supply" means that water restrictions might occur up to 5 per cent of the time. This implies restrictions of some sort (stage 1 or stage 2) could be imposed for about one summer every five years, or perhaps one full year every twenty years. Stage 3 or higher restrictions, where sprinklers are not permitted, could occur about one summer every 25 years. Ideally, stage 4 or stage 5 restrictions would never be required, but of course they may be needed in an absolutely catastrophic drought.

The water supply system would be "failing" if restrictions need to be imposed more frequently.

4.7.2 Population Growth and Other Assumptions

Failure point depends on the available water supply and demand. Demand increases as the population grows, moderated by the Government's demand efficiency targets (12 per cent reduction in per capita consumption by 2013 and 25 per cent by 2023). An option's "failure" depends on population growth rates.

For precautionary water supply planning purposes, the ACT Government's "high" growth forecast adopts a population of 500,000 persons by 2032.

A sophisticated hydrology model [55] provides calculates the comparative water supply option failure points for selected populations. Tailor-made for Canberra conditions the model predicts the response of the existing and possible future water storages to long sequences of rainfall, stream flow, temperature, water conservation and water demand scenarios.

Because existing rainfall and stream flow records for the catchments are available for only a relatively short climatic period (a maximum of 130 years), the model uses a 10,000-year synthetic record to detail the effects of climatic variability and possible climate change. This approach found the current drought is possibly the "worst on record" but may not be the "worst ever". The modelling suggests droughts have occurred in the past that were twice as bad as the current drought, lasting longer or being more severe. Such extreme and rare events may be expected to occur in the future and must be provided for in the planning process.

The modelling assumes consistent with CSIRO research that a substantial climate change has occurred and will continue. It projects that the water resources thought to be available to the ACT when the *Think water, act water* reports were published may have been optimistic. Modeled calculations with lower catchment inflow levels than those in *Think water, act water* may turn out to be overly conservative but it is considered prudent for major infrastructure planning purposes.

The concept of environmental flows has been developed to ensure that a minimum amount of flow is maintained in rivers and streams to ensure that they remain ecologically "healthy". It

[55] ACTEW Hydrology report 2005

generally requires that flows be maintained at a minimum 85th percentile of natural levels. This means that certain volumes of water must be constantly released from all dams (including Tantangara) whenever they are not overtopping. The volumes involved can be substantial and obviously reduce the amount of water remaining in the dams and available for use.

In consultation with relevant parties, including ACTEW, Environment ACT has foreshadowed the possibility that the flow levels may be modified and in some cases reduced. The modelling has assessed water supply outcomes under the current environmental flow regime and, in addition, modelling runs have been conducted for the various options under a modified environmental flow regime agreed by Environment ACT for this purpose.

Accounting for the transmission losses discussed above ACTEW expects that any releases from Tantangara Dam to the Murrumbidgee River destined for Canberra's water supply (i.e. around 30 to 100 ML/day) would include NSW releases meeting environmental flow requirements.

The average annual demand on the new water supply is likely to be around 20 GL/yr, but as the existing water supply can meet demands in all but drought years, the likely scenario for water supply augmentation is transfer of 20 to 30 GL/yr in about three to four years in 10. Snowmelt is a major source of runoff in Tantangara catchments so water transfers would most likely occur during Spring-Summer (Oct – Feb).

Modelling analyses are best presented by identifying the population level at which the system being analysed will reach the system failure point (i.e. when it can no longer supply water and meet the cities water demand. This is the year beyond which the likelihood is that restrictions will be imposed for more than 5 per cent of the time.

All other things being equal, the best option will defer system failure furthest into the future (following which further infrastructure will be required), or not at all. In reality, other factors must also be considered in the selection of a "best" option including risk, economics and sustainability. These are discussed elsewhere in this report.

With the introduction of environmental flows, assessment of climate change and climatic variability, and the impact of post bushfire vegetation recovery on water runoff, factors that were not contemplated prior to the 1990's, the existing water supply system would technically have reached failure point in 1999[56]. This is perhaps borne out by the extraordinarily long current restriction period, although this has been exacerbated by the impacts of the bushfires on the Cotter catchment.

4.7.3 Water Supply Outcomes

The outcomes of the hydrology analysis expressed in terms of projected failure points, are set out in figure 4.1 below. Key features of the results relevant to the Tantangara alternatives are:

- The long tunnel alternative as a stand-alone option fails in 2028. If this option were chosen and planning commenced immediately then the dam would be completed and filled by about 2008, giving it a "life" of only 20 years before additional infrastructure is needed.

[56] Hydrology output table, 10% time in restrictions, 25% demand reduction, optimised

- The Murrumbidgee River flow alternative (or "virtual dam"), – Angle Crossing to Googong, reaches failure point in 2018. This quicker and less costly alternative would not be a sufficient solution in isolation but could be useful as a combination with other options in the medium to long term.

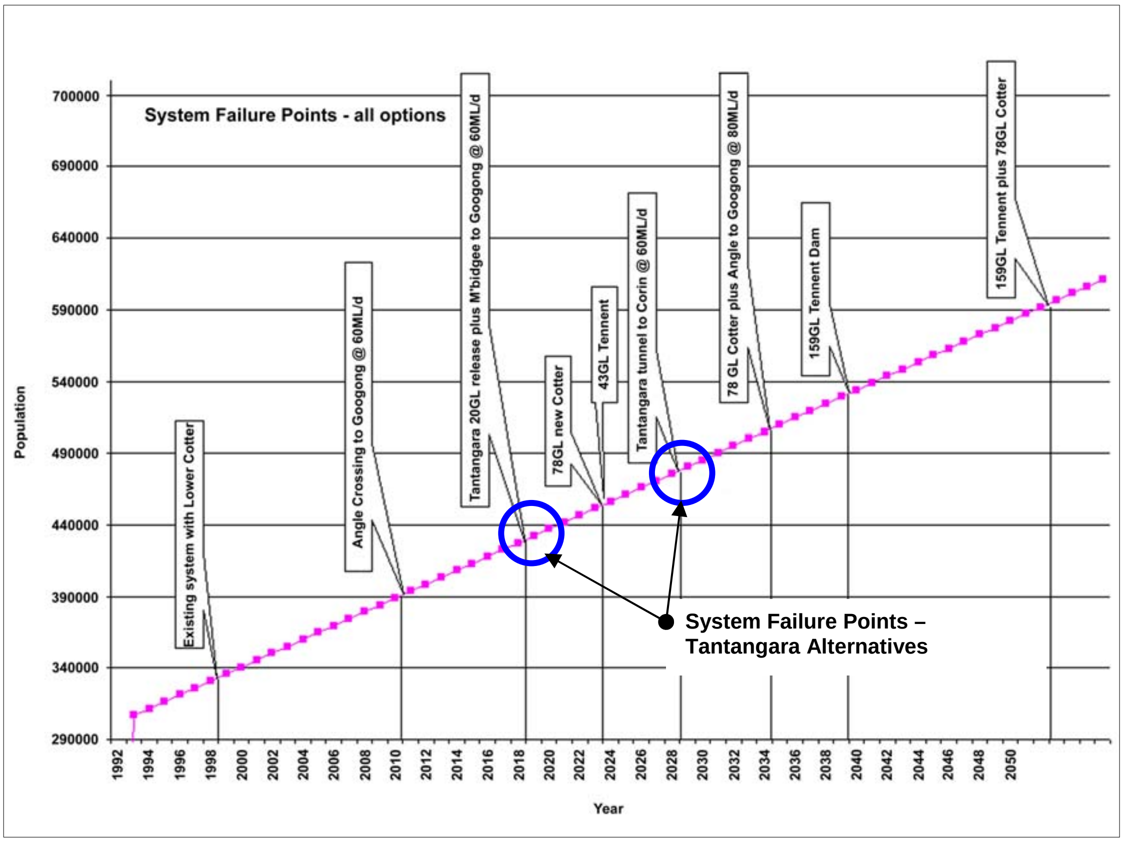


Figure 4.1: System Failure Points

* Note – The graph above shows the relative ranking of options to meet a reliability of supply for no more than 10 per cent time in restrictions. To achieve a reliability of supply of no more than 5 per cent time in restrictions, the line above would shift to the left, maintaining the same relative ranking

None of the Tantangara alternatives will adequately deliver a reliable water supply for a reasonable period into the future. It is likely that the Murrumbidgee River flow alternative, in combination of other options could deliver a better result, more sustainably, and at a comparatively low cost.

5 Infrastructure

5.1 Site and Geotechnical Conditions

Consultants[57] identified site and geotechnical conditions at the reconnaissance level for the long tunnel option including its proposed weir, tunnel, penstock, and mini-hydro plant components. These were essentially desktop surveys and should be considered as preliminary subject to further investigations.

5.1.1 Tantangara Weir

The proposed weir would impound the Murrumbidgee River about 16 km downstream of Tantangara Dam and 500 m downstream of the Kosciuszko National Park boundary.

Likely foundation conditions at the site need further investigation but “rocks” marked in this location (Yaouk 1:25 000 sheet) indicate exposed bedrock in the river with shallow residual and alluvial soils likely on the abutments.

5.1.2 Long Tunnel

A proposed 20km tunnel beneath the Gurrangorambla and Bimberi Ranges in the Kosciuszko and Namadgi National Parks would link the weir to the Cotter River.

The proposed tunnel entrance (portal) and weir lie close to a geological contact between the Gingera Batholith and the Tantangara Formation. The tunnel alignment runs:

- north east into the Tantangara Formation before passing through the Gingera Batholith contact metamorphic areole near Half Moon Peak;
- into Tantangara Formation for several kilometers and then enters the Gingera Batholith crossing several faults (Goodradigbee Fault and the northern end of the unnamed fault paralleling Bogong Creek south of Mt Morgan); and
- into the Nungar Beds after passing through a contact metamorphic areole near the granite across faults between McKennie and Mosquito Creeks and the Cotter Fault.

These geological features indicate high groundwater inflow throughout the tunnel is possible. Initial inflows would diminish as the rock voids drain but continuous pumping could be required.

5.1.3 Penstock and Mini-Hydro Station

Cotter site facilities would occupy a spur down the Cotter River left bank between Mosquito Creek and Cribbs Creek (in the Bimberi Wilderness Area of Namadgi National Park). An 800m pipe connecting the downstream tunnel exit to a mini-hydro station would follow the spur over ground conditions likely to feature shallow skeletal soils and surface rock outcrops.

The pipeline and mini-hydro plant require access upgrades and connection to a suitable capacity power line. A proposed route for these components has yet to be investigated but the power line could be submerged for 6km and excavated 3km along its alignment.

[57] Snowy Mountains Engineering Corporation (2005) ACT *Future Water Options Tantangara Option*

5.2 Construction Procedure

The Murrumbidgee site would support weir construction, tunnel excavation and spoil removal. Proposed site operations include construction services, plant operations and dismantling, pollution containment (e.g. oil and grease spills), waste treatment (e.g. drainage and soil water controls) and rehabilitation activities.

The site would require a major access upgrade for 7 km via an existing four-wheel drive track from Kennedys Road.

Subject to landowner agreement, excavated tunnel material would be transported off-site to a local area with suitable environmental controls. The tunnel spoil would be deposited, drained, shaped, top-soiled and re-vegetated.

The absence of a local power source requires generator operations at both Murrumbidgee and Cotter sites.

The Cotter site would support penstock and hydropower station construction. Location within Namadgi National Park means proposed site operations would be limited to a minimum development footprint.

An existing trail would be extended to the Cotter site servicing construction activities, site clearing, excavation and stabilisation of the tunnel exit.

The construction procedure includes the following main steps:

1. Access upgrades to construction sites.

2. Site establishment.

3. Weir, tunnel, pipeline, and hydropower station construction.

4. Site Rehabilitation.

5.2.1 Tantangara Weir

The proposed weir is a concrete dam with no floodgate. A stepped downstream face falls into an energy dissipation basin and the whole structure connects to adjoining bedrock.

Impounded river flows would divert through an intake and covered concrete pipe discharging into the tunnel entrance. A suitable fish passage would be included.

Weir construction would include the following actions:

- site works area established for environmental controls, construction equipment, servicing areas, and personnel facilities;
- temporary weir constructed of compacted fill;
- temporary diversion of the river flow;
- excavation of the permanent weir foundation;
- concrete pour and subsequent compaction;

- intake structure, energy dissipation basin and fish passage; and
- connection to the tunnel entrance;

5.2.2 Long Tunnel

The proposed tunnel is about 20km long and about 1.8m in diameter. Depth varies between 10m and 750m with at least 1 vertical shaft required for ventilation.

Tunnel construction would include the following actions:

- upstream and downstream site establishment for tunnel access, environmental controls, equipment storage, and servicing;
- excavation using a tunnel boring machine (TBM) with drill and blast through poor ground conditions;
- excavation support combined with shotcrete to support the excavated tunnel as needed;
- groundwater control with pumping and tunnel sealing;
- groundwater drainage exiting through the Murrumbidgee tunnel entrance into a treatment facility;
- spoil removal via rail or conveyor system discharging at the Murrumbidgee entrance;
- ventilation via a vertical shaft along the tunnel alignment;
- electricity from a diesel generator established at the Murrumbidgee site and serviced with fuel and spare generator deliveries; and
- spoil disposal to nearby private land.

5.2.3 Penstock

Access to the tunnel exit would travel alongside a proposed 800m pipeline with valve (penstock). Penstock construction includes the following actions:

- clearing a 10 m-wide line 800m down the ridge to the Cotter River including soil water controls;
- spur tracks construction off the main track for access points to the penstock route; and
- rehabilitation through re-profiling, ripping, reseeding and re-vegetation.

5.2.4 Hydropower Station

The proposed hydropower station is a reinforced concrete building containing a turbine, generator, auxiliary electrics, mechanical equipment, and operator facilities. A by-pass facility would isolate the power station for maintenance or an unscheduled outage.

Power station construction includes the following actions:

- site establishment, clearing and excavation with erosion and soil water controls;
- plant building construction;
- plant installation and connection; and
- site rehabilitation.

5.2.5 Transmission Line

The proposed transmission line would power a pipeline outlet dissipator and associated works, receive energy from the hydropower plant, and supply the plant during maintenance or breakdowns. A possible 9km route from the outlet to Corin Dam could provide the necessary 11 kV transmission voltages.

Transmission line construction includes the following actions:

- clearing and access track with stabilisation as required (up to 10m wide for 3km for the buried component);
- submerge 6km of power cable on Corin Dam substrate and trench 3km of cable; and
- install a 150 kVA transformer and associated equipment (with possible increases in capacity of adjacent zone substations).

5.3 Operations

Control and communications facilities are required to block discharge unless the penstock is full of water and manage the tunnel operations.

The plant would be operated from Lower Molonglo and subject to water and plant availability the following could be started or stopped from a remote workstation:

- start system;
- open outlet gate at Tantangara Weir;
- start and operate hydropower station;
- adjust turbines to achieve flow balance between weir releases and turbine releases;
- close outlet gate at Murrumbidgee Weir; and
- shutdown turbine.

These remotely controlled operations effectively allow water to flow out of Tantangara Reservoir to flow down the Murrumbidgee and be either directed through a proposed tunnel to Corin Reservoir or continue to flow down the Murrumbidgee to Angle Crossing.

The operations involve controlling this flow through pipes, tunnels and weirs and in the case of the tunnel, discharge through a hydropower plant.

6 Environmental Considerations

6.1 Changes in Snowy Operations

A Tantangara transfer would change Snowy operations by:

- discharging up to 20 GL average per year (as required) from Tantangara to ACT via Murrumbidgee flows;
- requiring up to 40 GL (2 years) storage in Tantangara Reservoir for high security water entitlements (assuming NSW controls the high security water); and
- reducing Snowy Hydro generating capacity by an amount commensurate with the ACT water transfer.

Normally these flows would be diverted through the Snowy Scheme (See Figure 6.1) via Lake Eucumbene. There are also cumulative “losses” attributed to the additional storage and those attributed to a proposed 28 GL NSW environmental flow for the Murrumbidgee.

Overall, the average annual discharge from Tantangara to Eucumbene could be reduced by up to 46GL per year (16 per cent of current mean inflow) during a full-year ACT transfer added to NSW environmental flows. Additional losses through evaporation and infiltration are unlikely to have a significant environmental impact on Snowy operations or water availability.

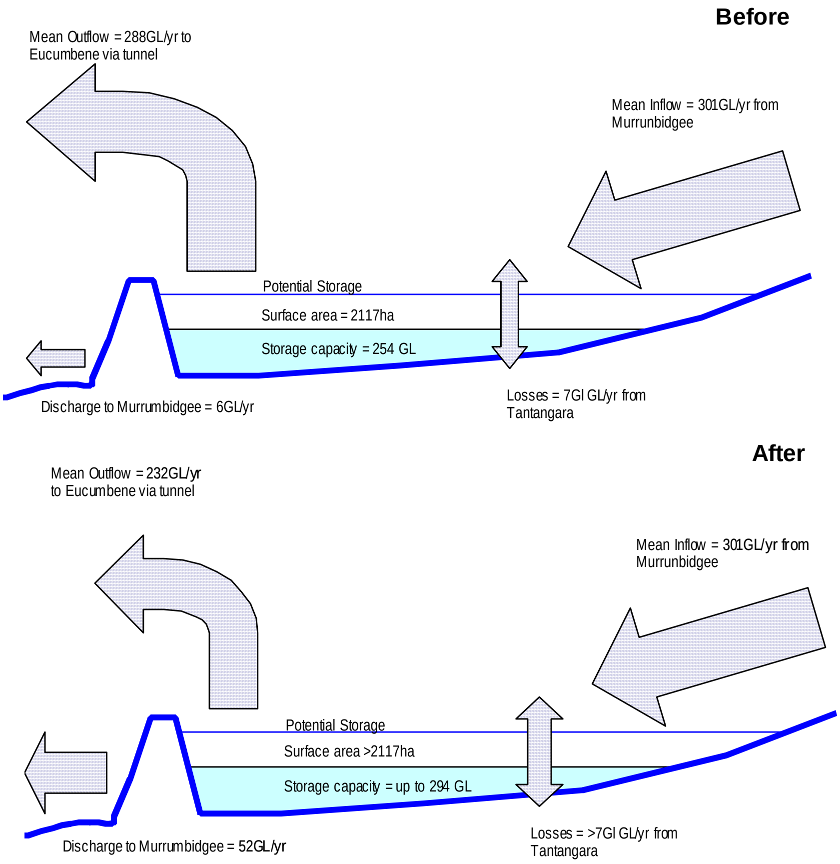


Figure 6.1: Potential Changes to Snowy Operations and Murrumbidgee Flows

6.2 Changes in ACT and NSW River Flows

The proposal would change Murrumbidgee and Upper Cotter flows with increased volumes in both rivers. NSW environmental releases would also add to Murrumbidgee flows but combined with an ACT release they are less than 20 per cent of the natural (pre-Tantangara Dam) river flow.

The proposed discharge in the Upper Cotter above Corin Dam could significantly increase natural flows depending on timing and volumes with average yearly flows up by around 50 per cent .

6.2.1 Murrumbidgee Flows

Compared with the current marginal discharge, an ACT transfer could amount to a 10-fold increase in average Murrumbidgee River flows between Tantangara Dam, the proposed tunnel entrance, and up to 100km downstream. Nevertheless, these flows remain significantly less than pre-regulation (natural flows).

A 100km Murrumbidgee flow for the Murrumbidgee River flow option would significantly increase volumes close to Tantangara declining as a proportion of total flow with downstream distance. Since regulation, flow-gauging records show reductions in flood frequency and duration with changes to low flow characteristics through reduced seasonal base flows.

Proposed Tantangara discharges are well below Murrumbidgee natural flows so the existing channel is probably large enough to cope with increased discharges in the medium to long term.

Given the current absence of an environmental flow, any release would significantly benefit Murrumbidgee river ecology notwithstanding short-term impacts on water quality and channel stability. Significant improvements in aquifer recharge, floodplain moisture, and stream reliability through larger base flows are highly likely.

6.2.2 Cotter River Flows

Tantangara options pumping water to Porcupine Creek in the upper Cotter River were excluded for their significant stream impacts. The current tunneling option to Corin Reservoir headwaters would have much lower impact on stream behaviour and sediment movement.

Nevertheless, a 20GL annual water transfer could increase river volumes by nearly 50 per cent on the current 47GL average yearly flow with significant changes to low flows.

Downstream of the proposed discharge, the transfer could increase peak flow frequency and duration with potential impacts on reaches outside areas controlled by bedrock[58]. These impacts include:

- riparian vegetation drowning;
- bank saturation and erosion; and
- increased deflected flow causing erosion.

River widening is highly likely but bedrock control would probably limit vertical channel changes.

[58] Ecowise Environmental and Starr (2005), *Catchment & Landscape Analysis of the Future Water Options for the ACT*, April 2005, ACTEW Corp Doc No. 4656

6.3 Effects on Sediment Transport

6.3.1 Murrumbidgee River

Increased flows would result in short to medium term bank erosion and scour below Tantangara reservoir. The extent of this increase would depend on riparian vegetation condition, density and composition. Bank erosion modelling suggests large increases in sediment delivery from increased bank erosion probably in the first 10 km reach below the Dam. This load increase is relatively small on a sub-catchment scale so impacts are likely to be marginal.

The River's sediment transport capacity (STC)[59] significantly exceeds modeled sediment loads so increases are not likely to impact on sand deposition in downstream channels. Tantangara Dam currently traps most coarse sediment and unless current sand deposits were mobilised by increased flows the downstream sedimentation impact would be marginal.

Modelling for a Murrumbidgee River flow increase over 100 km suggests a small sediment delivery increase that may be relatively short lived. This is unlikely to extend to any significant cumulative impact.

Modelling suggests that STC exceeds bed load for all but the last few kilometers of the 100km reach where sand accumulation could occur. Predicted flow increases would probably boost STC (compared with bed load from bank erosion) with little or no expected river impacts. Flow increases may be large enough to mobilise and remove these sand deposits with consequent improvements in channel condition and habitat.

6.3.2 Cotter River

Downstream of the proposed tunnel exit much of the Cotter River banks comprise unconsolidated sediment. Peak flows from confluent streams (e.g. Cribbs Creek) generate active erosion. The projected doubled flow rate is likely to impact to Gingera Creek, where bedrock controls the rivers' lateral movement. Impacts like riparian degradation, increased flow velocity, and bank saturation could significantly increase sediment levels especially downstream of the unconsolidated banks.

Despite the bedrock control on channel behaviour the options for managing sediment movement are limited. Bank armouring using rock or other "hard" stabilisation techniques could limit lateral channel erosion in unconsolidated sediments. If the channel was allowed to adjust to new flow regimes some additional sediment could be expected over the short to medium term.

Erosion and sedimentation in the Cotter would be subject to:

- discharge flow rates;
- discharge durations; and
- river channel morphology between the discharge point and Corin Reservoir.

[59] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682. p47

6.4 Effects on Aquatic Ecology

A Tantangara water transfer would directly affect Cotter (and Googong) aquatic ecology through the introduction of alien plants, species, and water chemistry[60]. Indirect effects through increased sediment transport, wastewater discharge during construction, riparian vegetation modification, and changes in stream behaviour are also highly likely.

Conversely, flow increases could have significant aquatic ecology benefits in the Murrumbidgee where traditional stream and floodplain behaviour is severely modified by Snowy-scheme activities. Direct benefits through higher water volumes and indirect benefits through improved water quality could favour many aquatic species. Some species adapted to the current reduced flow may be displaced.

Proposed tunnel, weir, and associated site construction all have some potential to impact on aquatic ecology. Potential impacts will vary with location, existing flow regimes, and construction methods but construction would probably generate or re-suspend sediment from in-stream sources, access tracks, and other construction activities. This may affect sedimentation rates within the weir pool, the frequency of de-silting operations, and consequent downstream impacts on fish and invertebrates. Significant impacts during and immediately after construction could be mitigated and a fish ladder would ameliorate some of the longer-term impacts.

6.4.1 Long Tunnel Impacts

Local groundwater of unknown quantity and quality could enter the tunnel over the short term[61] and this may interact with aquatic ecology through:

- draw down in local streams, bogs and water tables; and
- discharge into the Murrumbidgee.

Local groundwater testing would identify potential volumes and water quality elements but preliminary investigations indicate groundwater could contain:

- high mineral levels (excluding salts);
- high iron levels (in sandstones); and
- hydrocarbons.

Potentially large groundwater volumes would need to be pumped upslope and discharged via the Murrumbidgee tunnel entrance. Depending on groundwater volume water and quality, treatment prior to release could ameliorate short-term impacts near the weir. Tunnel sealing at groundwater ingress points should prevent downstream discharges via the Cotter tunnel exit.

The potential for adverse impacts through local groundwater drawdown would also depend on leakage rates but these would apply largely to the short-term. This short-term impact may be significant on aquatic ecology in smaller streams where base flows provide crucial habitat conditions close to the tunnel portals.

[60] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682.
[61] Snowy Mountains Engineering Corporation (2005) ACT *Future Water Options Tantangara Option*

Leachate and surface water runoff around construction sites and tunnel spoil disposal areas could also impact on aquatic ecology depending on their location, proximity to watercourses, and treatment facilities. These impacts could be managed but they are likely to be locally significant around streams and gullies with limited base flow near the spoil disposal area and construction sites.

6.4.2 Murrumbidgee River flow Impacts

Releasing water 100 km down the Murrumbidgee River has a relatively low aquatic ecology impact compared with other water supply options[62]. This option avoids national park construction impacts, minimises fragmentation through major dam construction, and improves Murrumbidgee River flows that would significantly benefit aquatic ecosystems. Like the long tunnel option, weir and associated infrastructure construction would still create some downstream hydrological disturbance and increased flows, especially near Tantangara Dam. This could favour some alien fish species like Trout.

6.4.3 Inter-basin Transfer Impacts

Tantangara options discharging water via Porcupine Creek and the upper Cotter River would significantly alter stream geomorphology, sediment movement, water quality, hydrological disturbance, and habitat availability. These options were excluded because impacts could not be sufficiently managed but directing water into Corin Reservoir headwaters (via the long tunnel alternative) still contains significant ecological risks.

The long tunnel option would need crucial safeguards to counter alien plant, animal, and pathogen transfers. These safeguards could include:

- physical barriers;
- electrical barriers;
- screens excluding animals and their eggs plus plant material; and
- UV sterilization.

None of these safeguards can be guaranteed at the catchment scale and UV sterilization is likely to create high-energy demands.

6.4.4 Effects on Amphibians

Northern Corroboree Frog or Alpine Tree Frog habitat does not occur along the proposed access routes or works areas (See Appendix E). These species occur at the following sites:

- Hanging Flat near Mt Gingera (Alpine Tree Frog); and
- Leura Gap, Murrays Gap and on Mt Bimberi (Northern Corroboree Frog).

The proposal is unlikely to directly impact on the regionally significant Cotter River Frog (*Litoria nudidigitus*- Cotter River form) population because this species occurs near the Cotter River Hut (upstream of the proposed tunnel exit). The loss of this population would be unacceptable for regional amphibian conservation programmes and any discharge to Corin Dam must consider indirect impacts from pathogens or other alien species transfers.

[62] Water Research Centre, University of Canberra (2005), *Aquatic Ecology Study*, April 2005, ACTEW Corp Doc No. 4682.

Exotic diseases could indirectly affect frog populations through transfer from construction sites on plant, personnel, equipment, spoil, and discharged groundwater. These impacts could be managed through cleaning and treatment procedures.

Under the long tunnel alternative, the proposal is unlikely to directly affect pond-breeding frog populations downstream of the proposed Murrumbidgee weir because flows along this reach are typically low. In the longer term, larger Murrumbidgee water volumes from proposed NSW e-flows and ACT water transfers may have a cumulative effect on pond breeding frogs currently adapted to minimal Dam discharges. Increased wetting along river margins creating more residual ponds and breeding areas may offset these effects.

Conversely, a water release could favour stream-breeding frogs for 100km between Tantangara Dam and the proposed weir under the Murrumbidgee River flow alternative. No threatened frog species are known from this region[63]. Increased flow along these reaches is likely to benefit in-stream amphibian habitat, provided unnaturally high summer flows do not increase water level and velocity during breeding[64]. Similar safeguards would need to apply to the upper Corin Dam and Cribbs Creek near the proposed tunnel exit.

Heavy machinery and vehicles displacing vegetation could also remove suitable habitat for amphibians along access routes, infrastructure works areas, and spoil leachate disposal sites. Management such as erosion, sediment and drainage controls could ameliorate these impacts by maintaining water quality and connecting seepages or shallow pools bisected by works.

Tunnel construction may disturb some shallow wetlands along the route where creeks, seepages and seasonally inundated pools source local groundwater. The risk to amphibians is likely to be limited depending on groundwater leakage into the tunnel.

6.4.5 Effects on Macroinvertebrates

Murrays Gap contains a population of Spiny Crayfish (*Euastacus rieki)*. Potential indirect impacts from changes to drainage patterns through either water table changes or discharges in the upper Cotter near Corin could occur. Small streams in the upper Cotter (e.g. Cribbs Creek) may contain spiny crayfish of either *E. crassus* or *E rieki*.

Improved flushing through a water transfer would improve habitat quality and diversity upstream of the proposed weir (long tunnel alternative) and over 100km further downstream under the Murrumbidgee River flow alternative.

Murrumbidgee flows would provide better habitat conditions over a longer reach than diversion and tunneling providing release controls limited constant or un-seasonally high flows with adverse consequences for macroinvertebrates.

6.4.6 Effects on Platypus

Platypus occurs at the following locations affected by the proposal:

- Casuarina Sands on the Murrumbidgee River;
- Tharwa sand-wash upstream of the Murrumbidgee and Gudgenby River confluence; and

[63] Lintermans, Mark (2004), *Review of potential impacts on fish and crayfish of future water supply options for the ACT: Stage 1* December 2004.

- Upper Murrumbidgee around Yaouk.

Beyond Yaouk, platypus is relatively unknown but high sediment loads immediately below Tantangara Dam wall probably limit abundance. Larger tributaries may provide better habitat opportunities[65].

The long tunnel option is unlikely to significantly impact on platypus habitat but the Murrumbidgee flow option could have some effect at a proposed extraction point near Angle Crossing. In any event, the possibility of increased flows and subsequent channel deepening could have a beneficial effect on platypus habitat, especially near Tantangara.

6.4.7 Effects on Fish

As previously discussed the long tunnel option could:

- change flows within Corin Dam headwaters;
- transport alien species (e.g. Brown Trout, Goldfish) from Tantangara to Upper and Middle Cotter catchment;
- transfer Epizootic Haematopoietic Necrosis (EHN) Virus to the Cotter system; and
- affect water quality through construction and operational impacts.

The Upper Cotter represents one of the few unregulated upland river segments in southeastern Australia. Discharges upstream of Corin Reservoir would change this 3km reach from a relatively undisturbed fish habitat to a regulated stream with abnormally high flows. While the proposed tunnel discharge would enter the Cotter River close to Corin Reservoir, it is likely to have significant effects through increased mean annual flow from 47GL up to 67GL.

Alien fish transfer to the Upper Cotter catchment is a distinct possibility with two Murrumbidgee species (Brown Trout and Goldfish) not present in the Upper Cotter.

Fish can survive transport via tunnels, pumps, and pipelines but effective screening could prevent fish, eggs and larval passage. Screening efficiency depends on design, species' life-cycle, and local discharge conditions. In Australia, screen performance preventing fish transfer at this scale is unknown. There is no guarantee screening would be 100 per cent effective.

The most serious threat to Upper Cotter native species could arise from EHN Virus. EHNV virus causes sudden fish-kills through renal, liver, spleen, and pancreas necrosis. Experimental work[66] indicates that Macquarie Perch is one of several extremely susceptible species.

In 1986, an outbreak in Blowering Reservoir near Tumut signaled the first EHN virus intrusion into the Canberra region with subsequent outbreaks in Burrinjuck, Burley Griffin, Ginninderra and Googong impoundments.

EHNV has not been recorded in the Cotter or the Murrumbidgee upstream of the ACT but a healthy Macquarie Perch population in both locations indicates the disease is currently not present. The absence of host Redfin species makes the disease difficult to confirm in either

[65] Lintermans, Mark (2004), *Review of potential impacts on fish and crayfish of future water supply options for the ACT: Stage 1* December 2004.
[66] Langdon 1989 cited in Lintermans, Mark (2004), *Review of potential impacts on fish and crayfish of future water supply options for the ACT: Stage 1* December 2004.

area and while testing in these areas may be possible, there is currently no adequate testing protocol.

It is possible that EHN Virus may not infect a ‘wild’ water body unless Redfin is present. Hatcheries without Redfin have recorded EHN Virus but possible “captivity stress” could be responsible. EHN Virus is robust. It can easily move around on nets, fishing lines, boats, fishing equipment, and people. Investigators[67] suspect recreational anglers could be the main disease vectors between water bodies with the virus still infectious after 113 days of drying. Researchers currently believe that EHN Virus infection in a water body is permanent.

Tantangara and nearby Lake Eucumbene are significant recreational trout fisheries and this greatly increases the chance of Redfin establishment. Anglers illegally use and discard Redfin as live bait - providing a common source of new alien fish populations in Australia[68]. If Redfin colonised Tantangara, it is likely that EHN Virus would follow.

Even without a Tantangara water transfer, it is possible that Redfin could establish in Cotter Reservoir through illegal fish transfer. Cotter River impoundments are closed to fishing so this possibility is remote but Redfin and subsequent EHN Virus transfer to Cotter Reservoir could still leave the middle and upper Cotter (above Bendora and Corin dams respectively), free of EHN Virus. Under this scenario, upstream Macquarie Perch could be isolated from the virus. A Tantangara water transfer and downstream virus migration would effectively remove this potential refuge.

Discharging Tantangara water above Corin Dam would almost guarantee that these aliens get a “free ride” into the Upper Cotter. Protecting native animals from a threat moving downstream could prove considerably more urgent and difficult than protection from the same threat moving upstream via three dams and significant obstacles.

Low flows currently restrict fish access upstream of Yaouk but proposed environmental flows would remove these existing low-flow barriers. This would enable species like Macquarie Perch and Two-spined Blackfish to access the Upper Murrumbidgee. There are no significant fish passage issues associated with the long tunnel or Murrumbidgee River flow options provided weir construction includes suitable fish ways.

There is some potential for (cold water) thermal impacts on receiving waters at Corin Reservoir if water was released from below the Tantangara thermacline. This should be ameliorated by the new intake structure currently under construction.

Higher flows may reduce thermal stress on alien trout populations in the reach immediately below Tantangara dam and this could provide enhanced conditions for Trout survival over hot seasonal conditions. Increased Trout survival could facilitate increased predation on native fish and crayfish, including Macquarie Perch. An estimated 20 GL annual release is small compared to natural flows (approximately 300 GL/yr or 25 GL/month) but significantly increases Trout survival when added to proposed NSW (26GL/yr) releases. Discharges mimicking natural flows would reduce impacts by maintaining thermal stress on Trout populations during summer.

[67] *Op cit* p79
[68] *Op cit* p79

Additional Murrumbidgee flows will scour accumulated sediments and improve habitat for Two-spined Blackfish and Macquarie Perch provided source water intake is above the thermacline to avoid downstream thermal pollution impacts.

There is potential for fish species transfer from the Murrumbidgee to the Googong catchment. One native fish and two alien fish species in the Murrumbidgee currently not present in Googong include:

- Australian Smelt (extremely rare in the Murrumbidgee upstream of Kambah Pool).
- Carp – (common near Tharwa).
- Oriental Weatherloach – (increasing abundance downstream of Angle Crossing).

The Gigerline Gorge is a natural fish barrier in most years with several species commonly encountered downstream rarely recorded upstream at Angle Crossing. Higher flows may allow fish passage through the gorge. Flows in the Gorge at Lobbs Hole are about 43 percent less than natural volumes and habitat conditions are largely unknown.

6.5 Effects on Riverine Habitat

The proposed alternatives potentially affect riverine habitat including riparian and stream bank elements flanking the Murrumbidgee and Cotter Rivers, largely due to hydrology changes.

6.5.1 Murrumbidgee River

Weir construction would have immediate and long-term effects on nearby riverine habitats from:

- direct displacement from structures and plant;
- vegetation drowning;
- flow changes;
- sedimentation within the weir; and
- erosion immediately downstream of the weir.

These changes would be permanent but restricted to the respective weir localities and generally marginal compared to the beneficial changes resulting from increased flows.

The main long-term impacts on riverine habitat are likely to result from erosive flows causing bank and channel changes. The main flow impacts are most likely to be near Tantangara Dam where limited flows since 1959 have caused sedimentation in the main channel.

Larger and more consistent flows would increase the extent and duration of wet and drying cycles with substantial benefits to riparian vegetation and its attendant habitat. While short-term instability could result in some negative impacts, the long-term benefits could be significant. These impacts will necessarily depend on release strategies with the best results coming from a flow regime that emulates natural low flows over summer and seasonal peaks during spring.

6.5.2 Cotter River

The Cotter River at Corin Dam headwaters to Cribbs Creek could be significantly affected by flow changes from the proposed tunnel discharge. These long-term changes resulting in substantial impacts on riverine ecology in the unconsolidated sediments downstream of Cribbs Creek would be contained within bedrock control areas dominating the channel.

Depending on its proposed route, an electricity line connecting the proposed hydropower plant could affect riverine ecology along the 9km route from Corin Dam. Assuming a 5m to 10m wide easement for the buried cable (3 km), the resulting riparian zone clearing could be limited to between one and three hectares. This could be locally significant.

6.5.3 Significant Wetlands

Tantangara Dam water transfers would cause changes in stream morphology, sediment dynamics, flow regimes and water quality. These could have consequent impacts on wetland water balance, species composition, and genetic intermixing. Nationally important wetlands that may be affected by a water transfer include Cotter River and Bendora Reservoir[69].

Water quality and temperature may alter habitat especially along the Corin Dam reservoir margins near the proposed discharge point. Actions that could protect the receiving waters include changing the release depth and water treatment.

The proposal could potentially affect habitat through changes in competition and food supply, zooplankton transfer, disturbance to flow-sensitive organisms, and the introduction of alien and invasive plants and animals. Nationally important wetlands that could be affected include:

- Snowy Flats (exotic species migration from Corin Reservoir to the Snowy Flats Creek Tributary); and
- Cotter Source Bog (exotic species migration from the Cotter River to its headwaters).

NSW wetlands and small creeks near the proposed tunnel alignment may also be affected by local groundwater changes. These impacts are likely to be short term and their significance would depend on groundwater ingress into the proposed tunnel, its effect on local water tables and aquifer recharge rates.

Releasing water to flow 100 km down Murrumbidgee River is unlikely to significantly impact downstream wetlands. Some beneficial impacts could occur as increased flow rates improve base flow and recharge rates in floodplains and their related wetlands.

6.6 Effects on Terrestrial Flora and Fauna

The proposal potentially affects terrestrial fauna and flora at construction sites, access roads, and power connection routes.

The long tunnel proposal directly interacts with terrestrial flora and fauna over a development footprint of approximately 12 to 20 hectares. Between 10 and 18 hectares of this footprint occupy natural habitat in 2 main areas:

- Murrumbidgee River including the weir, tunnel entrance, site facilities, and access road areas; and

[69] Biosis Research (2005), *Terrestrial Flora and Fauna and Vegetation Study*, April 2005, ACTEW Corp Doc No. 4649.

- Cotter River including the tunnel exit, pipeline, hydropower station, power line, and access road areas.

Although the development footprint for these areas is relatively small they do include significant conservation reserves in the ACT and undeveloped areas within NSW. These reserves and adjacent NSW freehold areas contain high-quality habitat.

The long tunnel proposal would require native vegetation clearing, soil disturbance, and potential weed introduction at the following locations:

- Murrumbidgee weir, tunnel entrance and adjacent construction site – 2ha disturbance of Riparian Mountain Gum Forest;
- Murrumbidgee access road – 1ha disturbance in riparian forest, 6 –12 ha disturbance in montane sheltered moist forest;
- Murrumbidgee spoil disposal site – 2ha disturbance on cleared pasture or dry tussock grasslands;
- Cotter tunnel exit, pipeline and hydropower station – 1 ha disturbance on Riparian Mountain Gum Forest; and
- Cotter Transmission line – 1 ha disturbance to Riparian Forest and *Eucalyptus Mannifera* forest.

Development activity would occur around the proposed access roads to the Murrumbidgee and Cotter portals, the pipeline route, hydro plant and transmission line. Personnel and equipment movement, habitat displacement and operational impacts are all likely to increase risks of weed and exotic plant transfer beyond those caused by initial vegetation clearing[70].

The proposed tunnel traverses areas beneath wilderness and other significant natural habitats but a proposed ventilation shaft is the only intrusion (approximately 25 square metres) into these areas. Raise-boring to prevent spoil discharge within Kosciuszko National Park would allow a possible shaft with minimal impact beneath Lone Pine trail in the Goodradigbee River Valley. The proposal is unlikely to have negative impacts on the ecological integrity of Wilderness or other significant natural areas but weed invasions and anthropogenic disturbances could occur at the tunnel portals and along their access routes.

Groundwater ingress into the tunnel could indirectly impact on some habitats depending on potential drawdown volume and water table behaviour near the tunnel alignment. The most vulnerable habitats in this case would be the Montane to Subalpine Moist Heath, Sub-alpine Bogs, and some of the wetter forest habitats including riparian forests. Geological features like faults and fractures could influence short-term impacts but groundwater drawdown is likely to be most intense near the tunnel entrances where water tables and tunnel alignments converge.

Investigators[71] found 76 dominant plant species in the study area including six exotic species. No plant species of conservation significance were recorded. Appendix F contains details on affected vegetation types.

[70] Biosis Research (2005), *Terrestrial Flora and Fauna and Vegetation Study*, April 2005, ACTEW Corp Doc No. 4649.
[71] *Op cit* p41

Investigators also recorded several animal species including two frogs, three reptiles, 19 bird and seven mammal species. Winter observations may explain lower abundances of bird assemblages.

In the western study area Richards Pipit *Anthus novaeseelandiae* is common in open areas. Murrays Gap contains a population of the Broad-toothed Rat (*Mastacomys fuscus*) - a species rare in the ACT and listed as threatened in NSW. The Broad-toothed Rat is limited to a few ACT sites all within the Cotter catchment[72] but these populations' status now requires investigation after the 2003 fires.

Over the short-term, the proposal is likely to disturb fauna habitat adjacent to the proposed pipeline, access and transmission line routes with particular impacts on fauna populations associated with creek margins and drainage lines.

Increased personnel and vehicular traffic could introduce exotic species that may affect threatened sub-alpine species such as the Northern Corroboree Frog. Bog and creek line habitats along Murray Gap Trail east of Oldfield's Hut are the most vulnerable.

Current investigations do not fully identify the significance or duration of the proposal's effects but they are likely to include:

- minor groundwater changes in the short-term;
- moderate changes around the proposed development footprint in the medium term; and
- major changes through alien species transfer and EHNV transmission in the long term.

The proposal may interact with Endangered Ecological Communities identified under the *EPBC Act* and the *Threatened Species Conservation Act.* Interactions may also occur with locally and regionally significant communities protected within conservation areas. The proposal may also impact on threatened plant and animal species listed under the *EPBC and NC Acts.* These areas and specific plants are listed in Appendix F.

The EPBC Act also requires a consideration of places listed in the Register of the National Estate. Natural places listed or interim listed on the register of the National Estate (See Appendix F) that may be affected by the Tantangara options are:

- Upper Cotter Catchment Area, Corin Rd, Tharwa, ACT;
- Bimberi Wilderness, via Kiandra, NSW; and
- Namadgi National Park, Tharwa, ACT (includes the Cotter River).

[72] Biosis Research (2005), *Terrestrial Flora and Fauna and Vegetation Study*, April 2005, ACTEW Corp Doc No. 4649.Lintermans et al ,2002 cited in

7 Effects on Cultural Heritage

7.1.1 Indigenous Heritage

The proposed long tunnel route does not affect any recorded Aboriginal sites but access roads, power lines and construction areas require more investigation to determine potential impacts.

Artefact scatters and isolated material probably occurs within these study areas. Most artefacts would most likely be manufactured from local stone occurring across the landscape from valley floors to mountains and ridgelines.

Strong links between artefact scatters on low ridges, crests and slopes overlooking creeks or swamps, are also influenced by the following factors:

- proximity to water.
- lower slope gradients; and
- available shelter.

These relationships also apply to saddles or gaps in elevated areas. Mountain peaks probably also host stone arrangements associated with substantial granite outcrops, broad rock platforms largely devoid of loose stones, and mountain summits or adjacent features such as ridge tops.

Consultants approached Indigenous groups for their views about the supply options' effects on ACT cultural heritage[73]. There is insufficient information on possible locations of a Murrumbidgee River weir and proposed Murrumbidgee River flow to fully evaluate these elements but groups were canvassed on the Tantangara Tunnel and pipeline options.

These groups include the:

- Ngunnawal Local Aboriginal Land Council;
- Ngunnawal ACT and District Indigenous Peoples Association; and
- Buru Ngunnawal Aboriginal Corporation.

Buru Ngunnawal Aboriginal Corporation representatives noted there was insufficient information for them to make detailed comments about any of the options and reserved their right to comment further.

Other groups noted:

- Tantangara pipeline options would have a significant effect considering the region's known ceremonial sites but the long tunnel option would have the least impact;
- Cotter River transfers potentially impact on significant Aboriginal cultural values depending on the tunnel alignment and its associated works; and
- Wherever possible, proposed infrastructure should lie in existing disturbance areas with works located to avoid Aboriginal sites.

[73] Navin Officer Heritage Consultants (2005), *Cultural Heritage Assessment*, April 2005, ACTEW Corp Doc No. 4651.

Namadgi National Park ranges and valleys plus adjacent NSW lands are highly significant to the Ngunnawal people with known ceremonial sites and places of spiritual significance. Mountaintops and valley approaches also hold special significance for Ngunnawal initiation rites and cosmology.

Relatively undamaged by European land use, the Upper Cotter catchment and Namadgi Ranges contain Aboriginal sites with a unique legacy for contemporary and future Ngunnawal people. These rangelands sites should be recognised as inter-related and conserved as a whole, without further degradation. This is particularly significant for the Cotter tunnel exit, pipeline, hydropower plant, transmission lines and access routes.

Namadgi National Park will formally recognise the southwestern area's natural and Aboriginal cultural values in a new classification that will acknowledge Aboriginal peoples' role. Areas between Tantangara and Corin Dam probably include a significant archaeological record that should be conserved within the park management regime rather than exposed to further pipeline or other development damage. Tunnel construction could be less intrusive but nevertheless includes impacts on the Upper Cotter Valley that if substantial, would be unacceptable.

The Murrumbidgee Corridor includes many Aboriginal sites and this is particularly relevant to proposed weirs, the tunnel entrance, site works and access roads.

Further assessment of preferred options must be informed by the results of detailed and comprehensive archaeological survey. Consultation with local Ngunnawal people would be an integral component of these assessments.

Investigations[74] indicate that of the three main options, the Tantangara Dam Tunnel (and Pipeline Options) could have the least impact on Aboriginal and non-Aboriginal culturally significant sites.

7.1.2 European Heritage

There are two recorded non-Aboriginal sites that would be directly impacted by the proposed construction route for the Tantangara Tunnel and none that will be indirectly impacted. The Upper Murrumbidgee history of low-level pastoral activity and restricted property ownership limits the likelihood of non-Aboriginal heritage sites occurring within the proposal area.

Remnant sites that may occur probably comprise isolated shepherds' or miners' huts and low-level mining operations, fence lines, and bridle trails.

7.2 Effects on Recreation

The absence of any major storage dam or other highly accessible infrastructure implies that Tantangara options would have a limited impact on recreational values and opportunities. Following the January 2003 bushfires, the ACT Government prepared and released an interim

[74] Navin Officer Heritage Consultants (2005), *Cultural Heritage Assessment*, April 2005, ACTEW Corp Doc No. 4651.

Recreation Strategy[75] *for the Natural Areas of the ACT*. Relevant ongoing studies include the Namadgi Plan of Management Review and Cotter Precinct Masterplan.

Kosciusko National Park Management Plan and its links to other regional parks are also relevant as is the management regime for Tantangara Reservoir. The proposal is unlikely to influence recreation capacity or recreation activities in these areas.

The interim strategy recommends "key directions" in a number of areas that relate to the Tantangara option. Summarised directions relevant to the Tantangara option are:

- Corin Dam area is a popular day use and walking area, which should continue to serve this purpose.
- ACT Forests play a leading role in offering recreation opportunities like four wheel driving, cycling, horse riding, rallies and other outdoor pursuits. The integration of forests and urban areas will continue to provide community access to forest areas for walking, horse and cycle riding.
- Improved facilities for high-impact recreation activities, such as car rallies or mountain bike events should be established prior to pine replanting particularly in areas close to the Cotter precinct.

The proposal is unlikely to affect these key directions with relatively inaccessible infrastructure limited to a small area (1-2ha) above Corin Dam.

Tantangara options could provide additional recreation opportunities through higher flows especially near proposed weirs but inaccessibility is likely to constrain activity levels at the Upper Murrumbidgee site. The proposed weir site at Angle Crossing is likely to provide a more accessible and intensively used recreation resource. Recreational fishing would benefit from increased flows with amenity and water quality improvements in the Murrumbidgee encouraging more swimming, walking, and outdoor activities.

Additional water supplied through the Murrumbidgee River flow option could also extend recreational fishing and boating opportunities in the Googong Reservoir extending downstream via the Queanbeyan River to Lake Burley Griffin and the Lower Molonglo. This could have considerable water quality benefits through more frequent flushing and higher flows with significant improvement in the availability and usability of these recreation areas.

The proposal's location within Namadgi National Park is unlikely to significantly alter current recreational values except in the immediate vicinity of the Cotter tunnel exit and associated hydro plant.

7.3 Effects on Amenity

Investigations[76] indicate the Tantangara tunnel option and its associated infrastructure would have minimal impact on landscape values, access and amenity. The Murrumbidgee weir and tunnel entrance is largely inaccessible and its limited development footprint and location would not significantly affect surrounding views or the "enjoyment" of local residents or visitors.

[75] Janet Mackay, Planning for People (2004), *Interim Recreation Strategy for the Natural Areas of the ACT*, Prepared for Environment ACT, April 2004.
[76] Ecowise Environmental and Starr (2005), *Catchment & Landscape Analysis of the Future Water Options for the ACT*, April 2005, ACTEW Corp Doc No. 4656

Supporting site and access works would limit amenity in the short term but remediation and enhanced access in the long term would offset these impacts.

Proposed Cotter infrastructure would generally be limited to a minimal development footprint although some effects on views and access could be expected along the proposed transmission line, pipeline and hydropower plant. Generally these landscape and amenity impacts are unlikely to be extensive but they will be permanent.

Channel adjustment to new flow regimes could occur below the tunnel discharge but the extent will depend on flows elevations and duration. Notwithstanding the impact on water quality, channel modification and remedial works may compromise Namadgi National Park landscape values around Cribbs Creek and Corin Reservoir headwaters. These effects are likely to be limited and short term.

Landscape and amenity values along the Murrumbidgee are likely to benefit from higher flows.

7.4 Effects on Public Health

The *ACT Water Resources Management Plan* expressed through "Think water, act water"[77] aims to *"Ensure water supply and management practices are consistent with protecting public health"*. This is consistent with Commonwealth and ACT laws managing ACT water supplies[78]. The legislation requires[79]:

- a *"triple bottom line"* (environment, economic and social) approach in decision-making;
- water management within an ecologically sustainable, healthy, attractive, safe and efficient environment that provides inter-generational equity;
- reduced catchment pollution through progressive environmental improvements;
- water quality protection a higher priority than recreational access;
- waterway and aquifer protection; and
- secondary use in designated catchments permitted subject to the maintenance of primary water supply catchment values.

The ACT's drinking water management follows requirements in two key documents:

- *Drinking Water Quality Code of Practice*, published in 2000 by the ACT Department of Health and Community Care; and
- *Australian Drinking Water Guidelines*, published by the National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand in 1996 (currently under review).

These documents emphasise the importance of a catchment to consumers and the need to retain multiple barriers to prevent the transmission of microbiological or chemical contaminants.

[77] Act Government (2004), *Think water act water*, *op cit*
[78] see for example: McCann Property and Planning Pty Ltd and ACTEW (2004), *New Water Source for the ACT, Planning and Development Controls*. June 2004.
[79] adapted from ActewAGL and Water Futures (2005), *Technical Advice on ACT Reservoir Recreational Water Use Options*, April 2005, ACTEW Corp Doc No. 4671*op cit.*

A new water supply through Tantangara would be effectively managed with public health as the principal consideration while meeting the requirements of the two principal guidelines. Water quality would be consistent with *both guidelines standards* subject to treatment at Stromlo or Googong respectively.

The long tunnel option would provide very high public health security with detention (and consequent treatment) at Tantangara, discharge through a national park and further detention in Corin, Bendora, and Cotter Reservoirs prior to treatment at Stromlo. This multiple barrier approach is entirely consistent with best practice for drinking water safety.

Water quality under the Murrumbidgee River flow alternative could be compromised by catchment activities in the Upper Murrumbidgee but these effects would be offset by detention within Googong reservoir and subsequent treatment prior to delivery. Of the two alternatives, the Murrumbidgee River flow has a potentially lower water quality than the long tunnel but both can be treated to a high standard.

Finally, as a third water supply source Tantangara would add security to public health in the event of a serious contamination within the existing system.

7.5 Effects on Energy and Greenhouse Gas Emissions

Consistent with the ACT Government's energy minimisation strategies ACTEW commissioned an assessment of the energy implications of each of the water supply options.[80]

Water storage dams consume energy and produces greenhouse gas emissions in three ways:

1. construction energy and embodied energy in materials and fabrication;
2. energy and chemicals used to operate the supply system; and
3. decomposition of organic matter within reservoirs.

All reservoirs (and natural lakes) release greenhouse gases. Releases come from:

- vegetation remaining in a reservoir after construction and flooding;
- nutrients and organic matter entering the reservoir from catchments;
- organics in sediment; and
- reservoir characteristics like depth, water temperature and dissolved oxygen.

Energy used during construction is influenced by factors including:

- materials sourcing - locally sourced materials use less transport energy;
- transport mode - mass transport options like rail use less transport energy;
- waste minimisation and selective procurement processes; and
- cut and fill balancing to avoid material import and export.

[80] ActewAGL (2005), *Greenhouse Gas Emissions,* April 2005, ACTEW Corp Doc No. 4670

Blast and drill tunneling uses more energy than comparable dam construction, which uses more energy than pipeline construction. The precise quantification of these construction energy costs is difficult and accurate estimates are subject to further investigation.

Embodied energy is the amount of energy used to make a particular piece of material and this is influenced by:

- transport distances for raw materials;
- energy used on site for building or assembling;
- upstream energy inputs from fabrication; and
- materials recycling.

Direct conversion of embodied energy into greenhouse gas emissions (i.e. carbon dioxide equivalent) depends on upstream energy sources, (e.g. coal-fired power stations or hydro-power) and whether methane is incorporated in these processes.

Table 7.1 compares the greenhouse gas emissions for the Tantangara long tunnel and Murrumbidgee River flow options.

Table 7.1: Greenhouse Gas Emissions –Tantangara Options

Energy Component	Long –Tunnel	Murrumbidgee River flow
Embodied Energy over 100 yr life (tonnes/yr)	6300	450
Operating Energy (tonnes/yr)	0 (renewable energy creator)	23000
Net Sediment Release (tonnes/yr)	17	27
Total net CO_2 equivalent (tonnes/yr)	6317	23500
Total net CO_2 equivalent (tonnes/yr/GL stored)	**573**	**5340**

Source: ACTEW (2005), *Greenhouse Gas Emissions*

Measured as a CO_2 equivalent per stored GL the long tunnel alternative ranks highly compared to other options. This reflects significant energy consumption in tunnelling activities. Offset against this high construction energy are the considerable renewable energy exports created by the proposed hydropower plant. These offsets are not included in energy calculations.

Measured as a CO_2 equivalent per stored GL, the Murrumbidgee River flow alternative (and its similar “virtual dam” option) is the highest energy consumer by an order of magnitude. This reflects higher energy consumption in pumping.

Energy estimates require further investigation to make a reliable comparison between options. The absence of Tantangara hydropower contributions to renewable energy has already been discussed.

Finally, the contribution of a reliable water supply to Canberra’s parks, gardens, and streetscape and their consequent microclimate effects are significant. Potential energy savings from these microclimate effects (through reduced air-conditioning and cooling) should be considered when comparing greenhouse gas emissions.

A recently published *Tree Management and Protection Policy* for the ACT noted:

- urban trees mitigate the impact of human-induced urban heat islands, and reduce pollution (through the absorption of ozone, sulphur dioxide and nitrogen dioxide, the interception of particulate matter, and the release of oxygen);
- trees lower urban temperatures and reduce the rate of ozone formation;
- urban trees in car parks help lower the temperature of parked vehicles and reduce vehicle hydrocarbon emission;
- tree shade over roads protects weathering and reduces the need for frequent road sealing;
- urban trees reduce greenhouse gases (by storing carbon); and
- shading, wind shielding, cooling of air temperatures through evapo-transpiration, and modification of solar radiation reduce energy consumption for summer air conditioning and winter heating – saving energy costs, reducing carbon dioxide emissions and power utility investments.[81]

These effects have not been quantified, although the impact of public area street trees that have died due to water restrictions has been factored in to the benefit cost analysis discussed in the next chapter.

7.6 Effects on Landowners

Government negotiations (NSW and ACT) resolving routes and transfer arrangements would affect landowners but this is likely to be restricted to:

- landowner(s) adjacent to the Upper Murrumbidgee and Angle Crossing weir;
- landowners near the Murrumbidgee tunnel entrance;
- landowners adjacent to any NSW access roads that require realignment; and
- the NSW Government (The proposed Murrumbidgee Weir could occupy Crown Land).

Land uses affected by the Tantangara option include farming, conservation, recreation, and roads and these are considerations in determining purchase value. Where the use or loss of privately owned land occurs, a privately negotiated landholder purchase could be necessary or the NSW Government could use its compulsory acquisition powers. Compulsory acquisition is unlikely and leasehold arrangements could provide an alternative to ACTEW ownership.

The majority of land in NSW is held on a “freehold” basis and land could be purchased or acquired through negotiations under the *Land Acquisition (Just Terms Compensation) Act 1991*. Compulsory acquisition through a legislative process could occur through NSW Government agreement and legal action.

[81] Environment ACT (2001), *A Tree Management and Protection Policy for the ACT,* September 2001.

Gas pipeline legislation established a compulsory land acquisition precedent for public infrastructure but has created a legacy of negative public reaction. Further, compulsory acquisition through land acquisition or specific works legislation would still involve complex processes including landowner negotiations and a satisfaction of ‘just terms’, (i.e. a fair and reasonable amount having regard to prescribed valuation principles).

NSW Government representatives have indicated that ACTEW may be treated as a developer rather than a public utility and the NSW Government may not be prepared to use its acquisition powers for the Tantangara option. Consequently, land acquisition would need to sequentially engage individual landowners with project implementation guaranteed only after successful negotiations with all landowners. A single landowner could obstruct the proposal under these circumstances.

Several NSW State Government departments and authorities may also have an interest in a particular property depending on weir locations, the tunnel alignment and its associated site works. Each relevant agency would need to be consulted to determine their respective interests in the land and subsequent negotiation position.

Investigations[82] indicate that there is no untitled land except public roads and the riverbed in the areas affected by the proposal. Detailed designs would indicate further detailed work necessary to determine untitled land extents and their management arrangements.

NSW road reserves surveyed and registered then dedicated as a public road under the *Roads Act 1993* could provide access. Alternatively, a private road could be established either through purchase or negotiating a right of carriageway. The NSW Road Transport Authority and local Councils are principal authorities for dealing with NSW roads matters and the Tantangara proposal would require further investigation and discussions with these agencies subject to identifying access requirements.

Investigations and consultation indicates that “the Canberra community” extends well beyond the borders of Canberra and the ACT. Individual landowners, Councils, and state government agencies are likely to impose constraints on land purchase or leasing. Tantangara construction and operation would need an ongoing consultation and communication process to deal with these constraints because inadequate support from these stakeholders could result in significant impediments.

Recognition in the *Canberra Spatial Plan* that water resources management is a key sustainability issue has implications for coordination with NSW and its constituent landowners. Notwithstanding the individual rights of landowners in the acquisition and purchase process, the NSW government and catchment residents have legal obligations to maintain water quality through land use practices.

The *Spatial Plan* commits the ACT to working with the NSW Government and local councils to ensure coordinated land uses encourage sustainable development and catchment protection. The Murrumbidgee River flow option relies on NSW landowners to firstly comply with their water extraction licenses and secondly, to maintain water quality. Catchment management imperatives could reinforce existing land use controls and emphasise the need for landowner monitoring and compliance consistent with their legal obligations.

[82] KMR Consulting (2005), *Land Ownership Study*, April 2005, ACTEW Corp Doc No. 4652.

8 Economic Framework

The Centre for International Economics (CIE) undertook a benefit cost analysis of future water options using data and key assumptions provided by the Future Water Options Project Team[83]. Their *"do nothing" option* is the starting point for benefit and costs comparison. It assumes the probability of water restrictions increases over time consistent with population growth and water demand (excepting implemented or proposed demand management initiatives).

This framework examined the benefits and costs of new water supply options by comparing them with the *'do nothing'* or baseline scenario. Benefit from new supply options comes from a reduction in the expected "future cost" of water restrictions compared with *'do nothing'*. The main differences between each of the options hinge on a reduction of the expected time in restrictions compared to their respective construction and operating costs.

Complex variables supporting the framework include:

- the level of restrictions (there are five levels, each with a different target for the reduction in water demand);
- impact of restrictions on different water user types such as households, businesses, community facilities and other users;
- timing issues that discount future costs and benefits back to the present using an agreed rate to allow a net present value comparison across different options – crucially, the expected times in which water restrictions could operate compared with the water provider's service delivery obligations.
- cost components - including construction costs, environmental costs and social costs, associated with each future water supply option.
- *do Nothing* Option characteristics including population growth, income growth, climate change, and demand management.

The CIE study identifies seven main "water restrictions" costs:

- household costs;
- business and industry costs including lost surpluses from plant, garden and landscape - based industries;
- recreation costs from restrictions affecting parks and playing fields (e.g. golf courses);
- tourism costs from restrictions affecting attractions such as Floriade;
- cost of monitoring and enforcing restrictions;
- impact on ACTEW profits from reduced water sales; and
- impact on the ACT Government from reduced water extraction charge revenue while incurring fixed costs for water related activities[84].

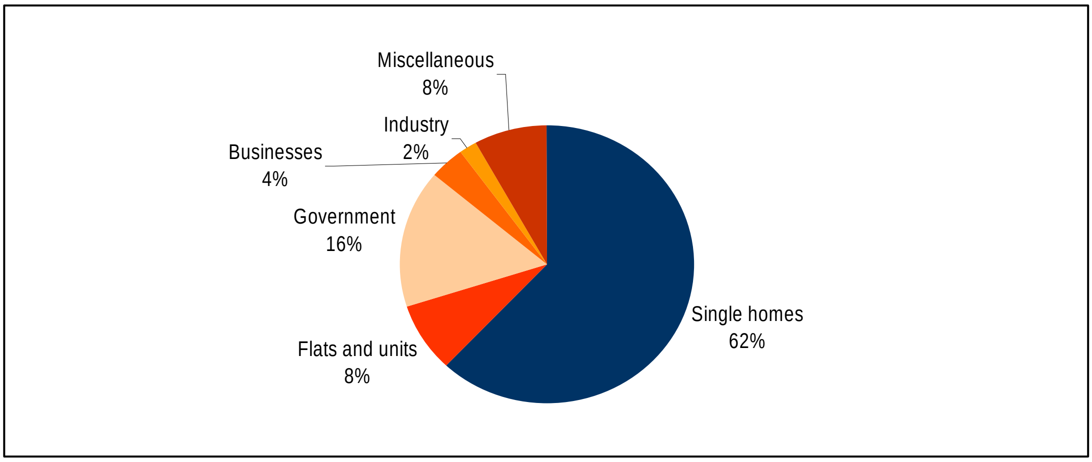
[75] Centre for International Economics (2005), *Economic benefit-cost analysis of new water supply options*, April 2005, ACTEW Corp Doc No. 4674.

[84] Prior to 1991-92 households had a "free" allowance of 455kl and were charged for water use above this; between 1991-92 and 1993-94 the free allowance was 350kl. Since 1994-95, the free allowance has been 1kl, with usage up to 350kl being charged at 28c per kl, and 64c per kl above it. An assessment showed that many

8.1 Costs to Households

Households are the Territory's biggest water users (see Figure 8.1) and most likely to bear a significant proportion of water restrictions costs. Almost 90 per cent of ACT households have a garden. This figure has not altered significantly over time but may change with future increased medium density development and urban consolidation.

Households could offset most water restriction impacts (e.g. limited times for hand held hoses on gardens) by engaging sufficient numbers of "volunteers" to use many hoses, or by paying high costs to retrofit rainwater tanks and greywater reuse systems. In practice, restrictions limit water use and dictate behavioural change.



Source: CIE report and ActewAGL

Figure 8.1: Water Use in the ACT

Household water restriction costs include the inconvenience (and time taken) of hand-watering gardens, the cost of restoring gardens following restrictions, and the cost of installing rainwater tanks, drip irrigation, reuse systems or water efficient devices adapt restrictions. In estimating water restrictions costs investigators quantify householders' willingness to pay for a reliable water supply free from restrictions on its use.

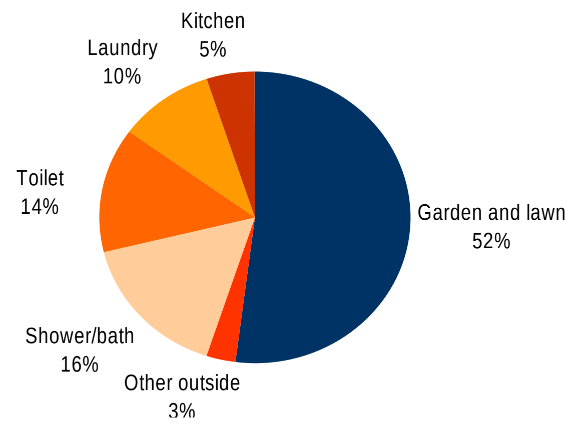
Household demand for water reflects several factors, not least the price of water. Some uses (for example, cooking and personal hygiene) are relatively insensitive to price, whereas others (such as outdoor use) are more price sensitive. The latter comprise around 55 per cent of total household water use, as shown in Figure 8.2.

Other factors affecting household water demand include:

- the number of people in the household;
- property size;
- weather conditions;
- existing appliances and investments (dishwashers, spas, swimming pools, lawns etc);

households, especially among middle-class households in older established suburbs, reduced water usage (there were no restrictions operating at the time) from 350kl to 300kl. See CIE, *op cit,* p 13.

- cost to changeover to appliances using less water; and
- the cost and availability of grey water recycling systems.



Source: CIE (2005)

Figure 8.2: ACT Household Water Use

The ACT uses a mix of price-based and quantity-based measures, community education programs, and works programs to influence water demand. The Government provides a rebate to install water saving appliances and water pricing has been modified over time to better reflect "user-pays" principles. Finally, consumer preferences change over time. Increased apartment living, individual responses to water restrictions, and the wider availability of water saving technology are all examples of changes that influence household costs.

The CIE report discussed an earlier NERA and AC Nielson studies that examined households' willingness to pay a reliable water supply[85]. Conducted before participants had extensive experience in dealing with water restrictions, these studies did not specifically target future water supply options. Nevertheless, they provide useful information about the costs that restrictions impose on households.

A total of 211 Canberra households participated in the survey (conducted in March 2003, just after the January 2003 bushfires). At the time, stage 1 restrictions (sprinklers to be used only between 6pm and 8am) applied. Although respondents did have some experience with water restrictions, the survey timing may have skewed the results. Arguably, a willingness to pay for water reliability and avoid the inconvenience of restrictions may well have increased with further exposure to more stringent (e.g. stage 3) restrictions.

The survey results indicated that:

- respondents were only willing to pay to avoid restrictions at stage 3 or above, lasting all year and applied every day;
- households were willing to pay $237 (31 per cent of the average water and sewerage bill) to reduce the frequency of these restrictions from every year to never;

[85] *Ibid p6*

- respondents were not willing to pay to avoid brown lawns in public areas; and
- the cost of stage 3 restrictions in aggregate household terms ranges between $20 and $36 million, rising to $40 - $77 million for stage 5 restrictions.

This study and other analyses allowed CIE to produce estimates for household costs of water restrictions, reproduced in Table 8.1 below.

Table 8.1: Estimated Household Costs of Water Restrictions (2005 prices and incomes)

	Lower Estimates	**Higher Estimates**
Per Household Estimates		
	$	$
Stage 1	18	24
Stage 2	80	118
Stage 3	198	360
Stage 4	224	411
Stage 5	396	769
Average for stage 3 and above	***273***	***513***

Source: CIE estimates based on water use data, a range of elasticity estimates and NERA/ACNeilson.

8.2 Other Costs of Restrictions

There are at least two effects of water restrictions on commercial and industrial activities in the ACT - the effects on businesses that use water themselves, and reduced sales from firms selling products that require water for their ultimate use.[86]

In the first instance, the CIE's economy-wide model of the ACT - Queanbeyan region assessed the cost of stage 3 and above water restrictions per average commercial water user at $1560. This is a broadly similar figure to the NERA/ACNielsen $1104 "willingness to pay" estimate for commercial customers.

The second instance includes nurseries and businesses selling lawn and other water intensive products. The overall effect here is complex because demand for native or water hardy plants may increase and consumers who do not spend money on these products will tend to spend elsewhere, with similar overall output, employment and consumption effects. In the case of nurseries, capital tied up in existing plant stocks for which demand has declined cannot easily be transformed to other stock. In addition, there is evidence of significant sales declines by nurseries due to the existing stage 3 restrictions.

In the absence of water restrictions plant sales are around $38 million per year. Estimates[87] indicate that around $11 million of this represents a fixed return to plant capital at risk from lost sales due to water restrictions.

[86] A possible third effect – reduced demand for goods and services because people are hand watering when they could be eating at restaurants, going to the movies etc – has not been taken into account in the CIE analysis. Tracing out the full effects of restrictions is complex, for example, the ACT economy may receive a boost to the extent that fewer residents choose to go to the coast at weekends because they are staying at home to keep their gardens alive.

[87] Based on ABS Data

CIE assumed that only stages 3, 4 and 5 result in lost sales and estimated[88] that stage 3 restrictions have led to a 25 per cent loss in sales. Assuming stage 4 and 5 restrictions will lead to losses of 50 per cent and 75 per cent, the potential cost for stages 3, 4 and 5 is $2.9 million, $5.7 million and $8.6 million respectively.

CIE's economy wide model of the ACT region assessed the cost of stage 3 water restrictions per average commercial water user at $1560 - broadly similar to the NERA/AC Nielsen's willingness to pay estimate for commercial customers at $1104. Table 8.2 shows the estimated costs relative to each level of water restrictions.

Table 8.2: Estimated Commercial and Industry Costs of Water restrictions

Level of Restrictions	*Reduced Welfare* [a]
	$ million
Stage 1	0.5
Stage 2	1.9
Stage 3	3.4
Stage 4	4.2
Stage 5	4.5

[a] Defined as the change in real consumption

Source: CIE estimates

The cost of water restrictions on recreation activities was estimated by noting that ACT residents spend around 164 hours per year on outdoor recreation, an implicit value of around $1600. CIE assumed that 15 percent, 20 percent, and 25 percent of this time needs to be reallocated under stages 3, 4 and 5 respectively and added a cost to restore the recreation facilities after restrictions have been lifted. This produced a total cost estimate of $8 million for stage 3 restrictions rising to around $21 million for stage 5 restrictions.

Tourism contributes about $690 million to the Territory's annual gross state product. The CIE's assumption is that stage 5 water restrictions would reduce tourism activity by 10 per cent, implying a $31 million reduction in real household welfare using the economy-wide model. Anecdotal evidence indicates that some of the existing decline in ACT tourism numbers is a response to the combined impact of drought and water restrictions but CIE has not factored it into its calculations.

Canberra's "garden city" status and the value of its urban trees are significant. Canberra Urban Parks and Places has estimated that around half of the 6000 street trees lost as a result of the drought could have been saved in the absence of water restrictions.[89] Attributing a conservative value of $1000 for each tree, the cost of stage 3 restrictions on street trees is $3 million.[90]

Water restrictions impose a range of transactions costs such as community education, monitoring compliance, and prosecuting breaches. These costs have been estimated at $1.8 million for stage 3 restrictions rising to $3.6 million for stage 5 restrictions. Stage 3 restrictions have been estimated to reduce ACTEW's profits by $3.8 million, rising to $8.4 million at stage 5.

[88] These estimates drew in part on confidential sales data from a number of representative nurseries.
[89] This section has been assisted by discussions with staff of Canberra Urban Parks and Places, part of the Department of Urban Services.
[90] There is an established methodology that values such specimen trees, with outstanding examples being attributed a value of up to $100,000 each in some circumstances.

The ACT Government would experience additional revenue loss of $1.3 million at stage 3, rising to $2.9 million at stage 5.

8.3 Overall Costs

Tables 8.2 and 8.3 draw together the material from the previous two sections while assuming one year in restrictions at the stage indicated.

Table 8.2: Total Costs of Spending One Year in Water Restrictions ($ million)

Category of cost	Stage 3	Stage 5
Household (upper estimate)	36.2	76.7
Commercial	6.3	13.1
Recreation	8.0	20.8
Tourism/street trees	3.0	37.0
Transactions costs	1.8	3.6
ACTEW profits	3.8	8.4
ACT Government	1.3	2.9
Total	**60.3**	**162.8**
Projected to 2055 (2005 dollars)	***157.6***	***428.9***

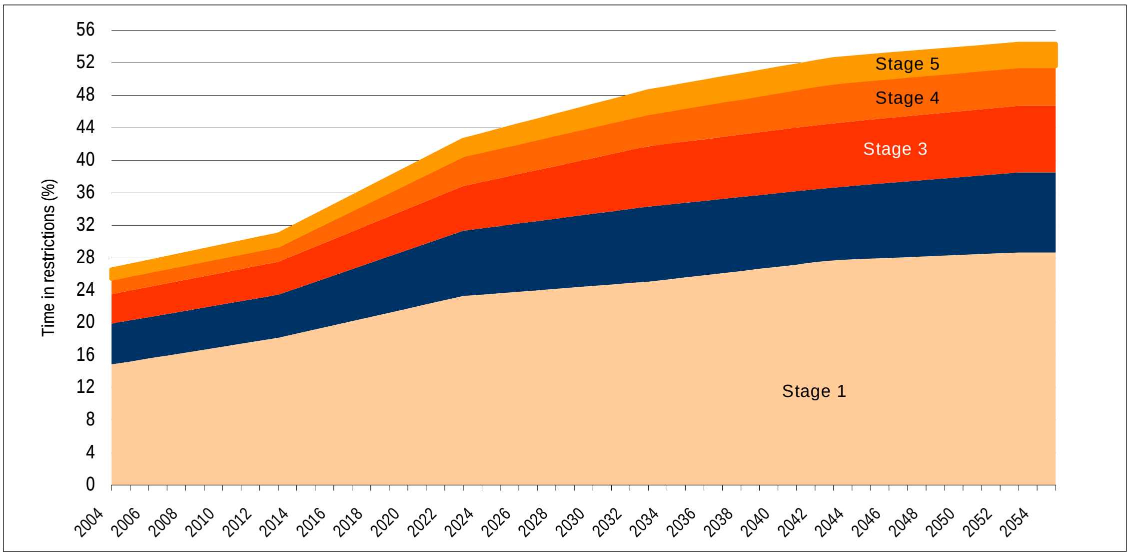
Source: CIE analysis.
Estimates for 2055 are based on assumed population and income growth, expressed in today's dollar terms

Table 8.3: Total Costs of Spending One Year in Water Restrictions by Level;

Level of restrictions	Current cost ($ million)	Projected cost in 2055
Stage 1	3.5	9.4
Stage 2	16.1	41.5
Stage 3	60.1	157.6
Stage 4	81.0	215.1
Stage 5	162.8	428.9

Source: CIE analysis.

Applying these cost estimates to the Territory's current water restriction regime indicates that since December 2002, the cost of these restrictions is around $88 million.

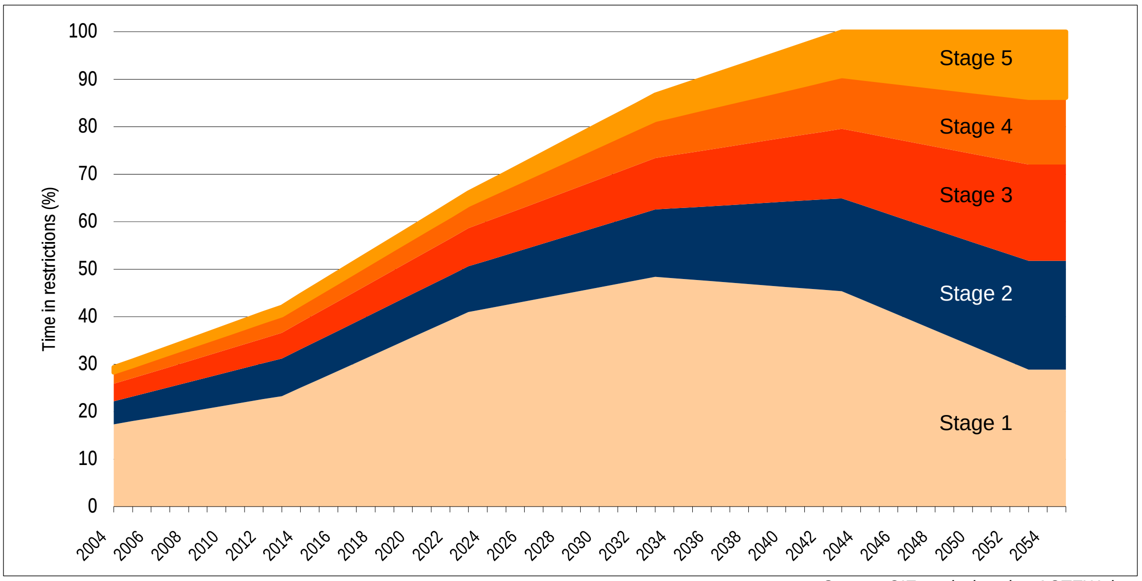


Source: CIE analysis using ACTEW data

Figure 8.3: Cumulative Time in Restrictions (medium growth scenario)

Population growth and higher net water demand increases the probability of water restrictions. A medium growth scenario (see Figure 8.3) projects restrictions from a current 26 per cent to 54 per cent by 2055. Around 15 per cent of that time would be in stage 3 restrictions or above.

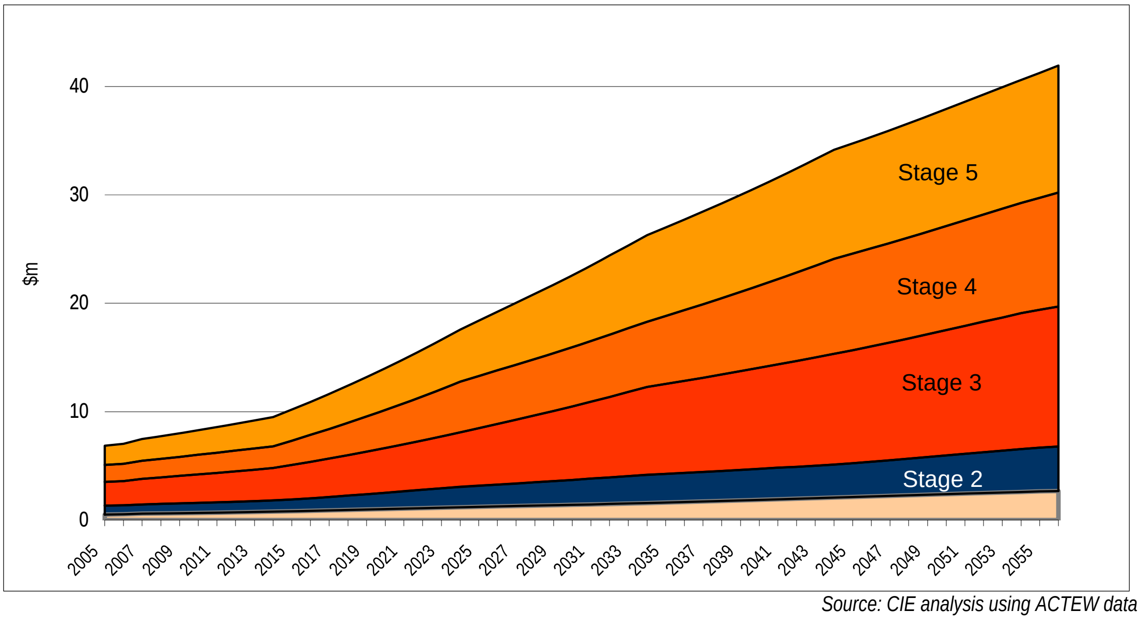
The proportion of time in restrictions hits 100 percent by 2043 under the prudent planning scenario and by 2055, the probability of stage 3 restrictions or above is 50 per cent (see Figure 8.4).



Source: CIE analysis using ACTEW data

Figure 8.4: Cumulative Time in Restrictions (prudent planning scenario)

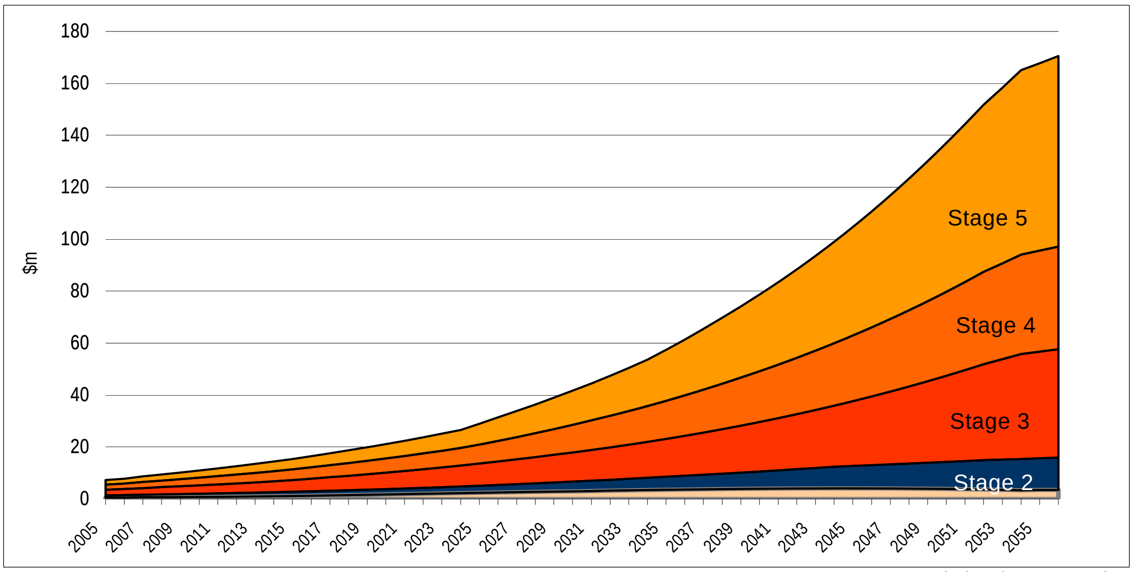
In order to estimate the costs of restrictions in the do nothing options, the cost data associated with restrictions need to be multiplied by the expected time in restrictions. This is shown in Figure 8.5 for the medium growth scenario and Figure 8.6 for the prudent planning scenario.



Source: CIE analysis using ACTEW data

Figure 8.5: Expected Cost of Restrictions (medium growth scenario)

In the medium growth scenario, the total expected cost of restrictions increases from $7 million in 2005 to $42 million by 2055, largely arising from stage 3 or above restrictions. Consistent with the prudent planning scenario's higher expected time in restrictions, expected costs rise to $170 million by 2055, largely associated with stage 4 or 5 water restrictions.



Source: CIE analysis using ACTEW data

Figure 8.6: Expected Cost of Restrictions (prudent planning scenario)

8.4 Implications for the Tantangara Option

The new water options performance can be measured by the extent to which each option decreases the amount of time at each level of restrictions relative to the do nothing option.

8.4.1 Performance Under the Medium Planning Scenario

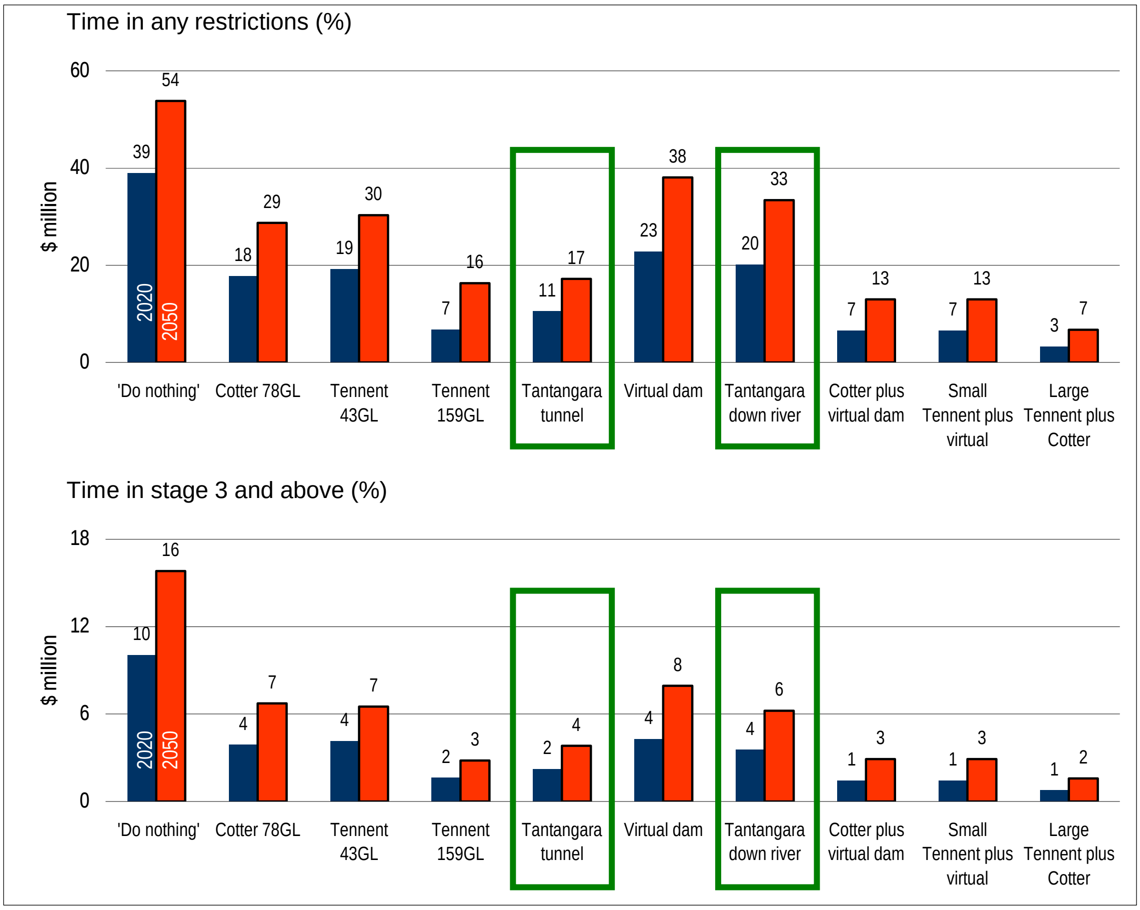
Figure 8.7 summarises each option's performance under the medium planning scenario by comparing time in restrictions for the 'do nothing' option with the time in restrictions for each of the new water supply options. In the year 2020, under do nothing option, restrictions could be expected to be in place about 39 percent of the time.

Under the Tantangara long tunnel alternative, year 2020 restrictions could be expected to be in place around 11 percent of the time. For the Murrumbidgee River flow alternative, year 2020 restrictions could be expected to be in place around 20 percent of the time. These figures place the long tunnel and Murrumbidgee River flow alternatives as middle-ranking performers.

A similar comparative analysis of the projected time in restrictions at 2050 indicates that the do nothing option would result in water restrictions in place about 54 per cent of the time.

The Tantangara long tunnel alternative again rates as moderate to higher-ranking performer with a projected time in restrictions (at year 2050) at 40 percent. The Murrumbidgee River flow alternative rates as a low-ranking performer with a projected time in restrictions at 33 percent.

Projecting the same results to time spent in stage 3 and above restriction levels reduces the time spent (2 per cent to 4 per cent respectively at 2020 and 4 per cent to 6 per cent respectively at 2050) at this restriction level but does not greatly change the comparative



performance of either alternative.

Source: CIE analysis using ACTEW data

Figure 8.7: Projected Time in Restrictions (medium planning scenario)

8.4.2 Performance Under the Prudent Planning Scenario

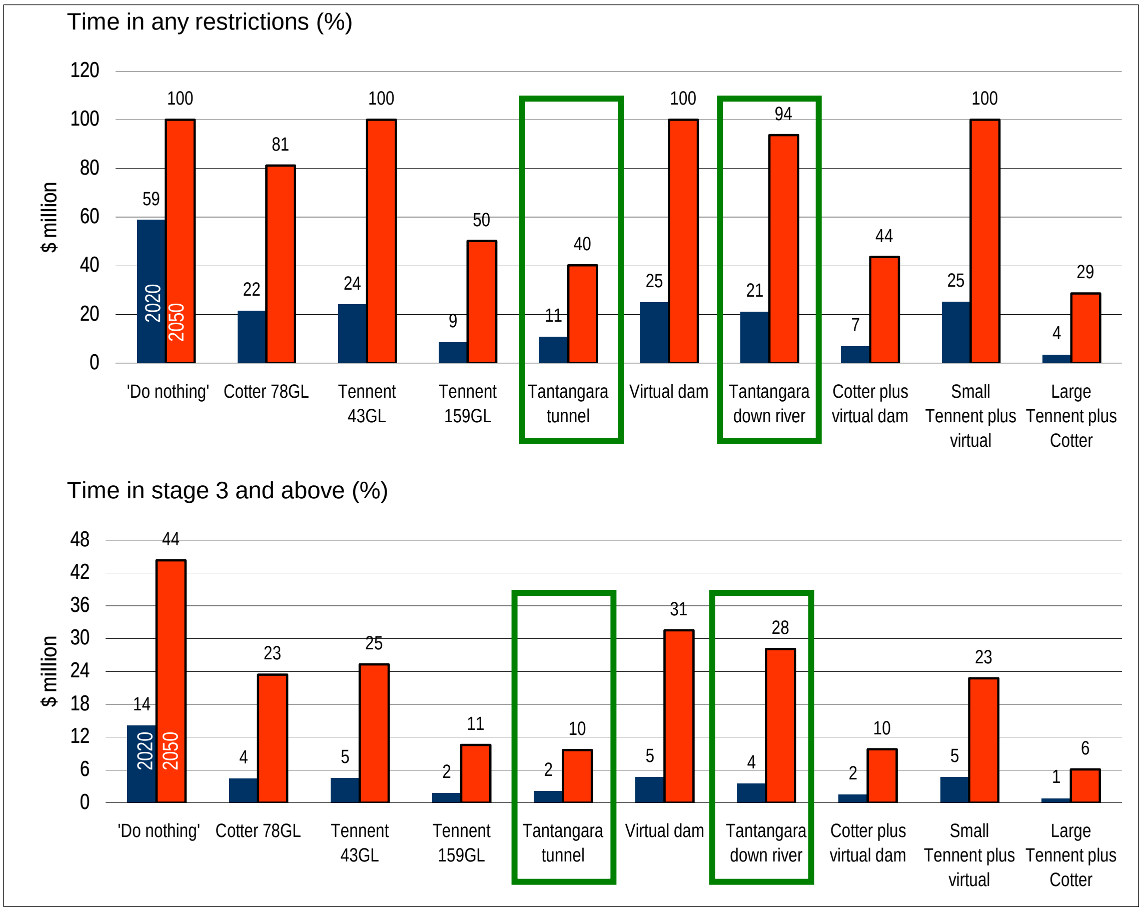
Figure 8.8 summarises each option's performance under the prudent planning scenario compared with time in restrictions for the 'do nothing' option. The green border highlights the Tantangara alternatives' comparative performance.

Under the long tunnel alternative, year 2020 restrictions could be expected to be in place around 11 percent of the time. For the Murrumbidgee River flow alternative, year 2020 restrictions could be expected to be in place around 21 per cent of the time. These figures place the long tunnel as middle to high-ranking performer and Murrumbidgee River flow alternative as middle to low ranking.

A similar comparative analysis of the projected time in restrictions at 2050 indicates that the do nothing option would result in permanent (100 per cent of the time) water restrictions.

The Tantangara long tunnel alternative again rates as a relatively strong (third highest) performer with a projected time in restrictions (at year 2050) at 40 percent. Similarly, the Murrumbidgee River flow alternative rates as a relatively poor performer with a projected time in restrictions at 94 percent.

Projecting the same results to time spent in stage 3 and above restriction levels does not greatly change the comparative performance of either alternative.



Source: CIE analysis using ACTEW data

Figure 8.8: Projected Time in Restrictions (prudent planning scenario)

8.4.3 Cost Implications

Each water supply option has specific costs including:

- capital (construction costs);
- annual operating costs (recurring running costs);
- energy costs (pumping, operating and other annual energy costs); and
- environment management costs (impact mitigation and rehabilitation costs).

The Tantangara Option requires water rights purchase, storage fees and hydro generation opportunity costs to be met. These include the following:

- water purchase – a one-off capital cost of up to $30M for 20GL that pays for the “right” or entitlement to use this water and a conversion from general to high security entitlements; and
- hydro electricity compensation – an annual operating cost between $4.6M and $5.9M composed of the following:

- Annual Option Fee (Payable on 30 January Each Year) $789,000 (this is a fixed amount regardless of whether the option is exercised);
- Option A Exercise Fee (payable only if option called) Exercise Date: By 30 April $3,840,000; and
- Option B Exercise Fee (payable only if option called) Exercise Date: By 31 October $5,120,000[91].

Judicious trading may offset some of these annual operating costs but in a year where the full 20GL was required ACTEW could expect to pay between $4.6M and $5.9M for water excluding the capital and operating costs of the transfer system infrastructure. These costs may be reduced during negotiations.

Considering the high security entitlements could be traded at any point in the future there is some likelihood that these capital costs may increase in value. Under these circumstances all the Tantangara alternatives represent good value for money compared with other options. The Murrumbidgee River flow alternative is the least expensive although its operating costs (due to pumping) are comparatively higher than the long tunnel alternative (due to gravity flow hydropower opportunities.

Even with these additional costs the Tantangara Option is comparatively inexpensive compared with other water supply alternatives.

Table 8.9 outlines the Tantangara alternatives' costs[92] compared with the other options.

Table 8.9: Tantangara Option Comparative Costs

Option	***Capital***	***Environmental management***		***Annual***	***Present value of costs in 2005***	
			Medium growth	Prudent planning	Medium growth	Prudent planning
	$m	$m	$m	$m	$m	$m
Cotter 78GL	120	5	1.2	1.4	124	127
Tennent 43GL	185	4	2.5	2.8	205	209
Tennent 159GL	250	3	2.9	3.2	265	270
Tantangara tunnel[a]	141	4	2.2	2.5	183	187
Virtual dam	40	2	1.4	2.1	55	65
Tantangara down river[a]	70	1	2.5	2.7	130	133
Cotter plus virtual dam	160	7	2.6	3.5	179	192
Small Tennent plus virtual	225	5	3.9	4.9	263	274
Large Tennent plus Cotter	370	8	4.1	4.6	392	396

[a] Capital costs include cost of purchasing high security water. Total costs include annual expected cost of water purchased from Snowy Hydro
Data source: ActewAGL, CIE calculations

Hydrological modelling suggests that Tantangara water for the tunnel would be needed 3 years out of 10 giving an expected annual water cost for this option of about $1.9 million. Under the Murrumbidgee River flow alternative, water would be needed four years out of 10, giving an expected annual water cost of $2.3 million. These costs are assumed to remain constant.

[91] Snowy Hydro (2004) Correspondence on indicative costs Feb 2004
[92] Sources include: Centre for International Economics (2005), *Economic benefit-cost analysis of new water supply options*, April 2005, ACTEW Corp Doc No. 4674 Marsden Jacobs and Assoc. and Fluvial Systems (2005), *Predictions of Transmission Losses in the Upper Murrumbidgee River and Cotter River*, April 2005, ACTEW Corp Doc No. 4658, GHD (2004)

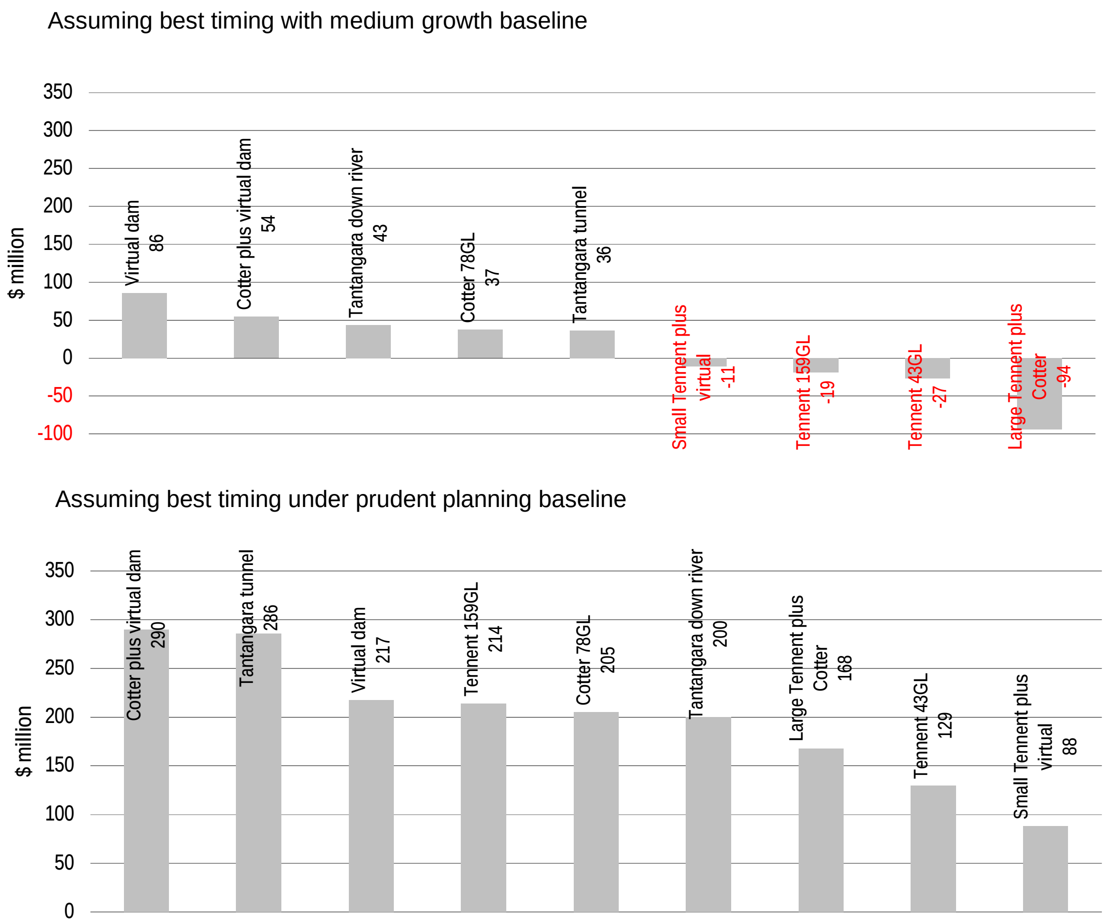
Using the CIE analysis of cost per unit of reduction (of time in restrictions for the medium planning scenario) the long tunnel alternative ranks five out of nine (moderate ranking). Under the same analysis the Murrumbidgee Flow alternative ranks second out on nine. Conversely, under the prudent planning scenario a similar analysis reverses the rankings with the tunnel scoring two of nine and the river flow scoring five out of nine. This reflects the Murrumbidgee River flow alternative's relatively low cost and poor performance under strong demand.

8.4.4 Net Benefits

The net community benefit is the reduction of the amount of time spent in restrictions and their subsequent cost savings. The magnitude of these benefits is roughly proportional to the performance of the various options. Some variation to base figures behind these estimates could change the actual dollar amount but the relative net benefits indicate Tantangara alternatives as middle to high ranking under the medium growth baseline.

Under the prudent growth baseline the tunnel has significant net benefits reflecting its relatively low cost and moderate performance.

Figure 8.10: Net Benefits of the Options (medium growth and prudent planning baselines**)**[93]



Source: CIE estimates

[93] Source: Centre for International Economics (2005), *Economic benefit-cost analysis of new water supply options*, April 2005, ACTEW Corp Doc No. 4674. p 40

The alternatives are sensitive to the baseline choice. CIE's average baseline analysis places the tunnel and river flow alternatives as second and fourth ranking options for net benefits.

Changing the timing to delay construction significantly increases the alternatives' net benefits but applying alternate environmental flows and sensitivity analyses does not significantly influence their comparative rankings. In the latter case, tunnel alternative is mostly ranked as second or third, (third highest average ranking) while the river flow alternative option frequently ranked fourth, has the fourth highest average ranking.

9 Risk Assessment

In its Future Water Options Risk Assessment[94] ACTEW qualitatively assessed risks for the main water supply options and in the Tantangara context both long tunnel and Murrumbidgee River flow alternatives. In a similar process, Cooperative Research Centre for Freshwater Ecology[95] qualitatively and more specifically assessed ecological risks.

Assessments identified risk sources from each of the final option alternatives, assessed the level of risk and described control measures to reduce risk. This rapid qualitative process is valuable for holistic consideration but constrained by high uncertainty. The assessment is indicative rather than a definitive assessment of inherent risks.

Importantly, public attitudes guided risk assessors in determining levels of concern for the consequences of various “risk events”. Community responses highlighted three main risk criteria:

- protection of public health;
- reliable future water supply; and
- effect on aquatic environment.

Public concerns were lowest for:

- recreational uses;
- National Capital lawns about Lake BG & buildings; and
- impacts during construction.

While the CRC assessment focussed on ecological risks largely generated by an expert panel, it reflects the importance of aquatic environments to the public. The Tantangara option featured the following main ecological risks associated with pipes, tunnels and inter-basin water transfers:

- loss of terrestrial vegetation;
- change in flow seasonality;
- change in flow variability;
- increased discharge; and
- pathogen transfer.

Similarly, changed operations in existing dams exposed the following main risks:

- low dissolved oxygen downstream of Tantangara Dam; and
- increased discharge (esp. in small streams) in the Murrumbidgee and Upper Cotter.

Other important ecological risks associated with the Tantangara option included:

[94] URS and ACTEW (2005), *Future Water Options Risk Assessment*, April 2005, ACTEW Corp Doc No. 4650.
[95] CRC for Freshwater Ecology (2004); *Ecological Risk Assessment*, October 2004, ACTEW Corp Doc No. 4676

- in-stream barriers (mainly to species movement), associated with weirs;
- deterioration in water quality and loss of habitat; and
- loss of terrestrial vegetation (applying largely to pipeline options).

Although not fully assessed in analyses the risks associated with securing water supplies are significant. While the likelihood may be relatively low, the possibility of not obtaining sufficient water at crucial times has severe consequences. If high security water entitlements were rationed significant economic risk particularly occurs where large capital works associated with the proposed tunnel may be under-utilised. Notwithstanding these economic risks, the consequences of committing to a water trading approach and not receiving water could have major consequences for Territory and regional water users.

9.1 Risk Assessment Approach

The risk assessment process employed workshops to identify and measure of the degree of risk by multiplying the ***likelihood*** of an event occurring and the ***consequence*** of the event. The approach was adapted from the Australian Risk Management Guidelines (AS/NZS 4360) and the US Environment Protection Agency framework.

Despite its subjectivity, this approach provides reasonable risk analyses when experienced workshop participants provide knowledge on the risk events and their characteristics. Figure 8.1 below shows the approach.

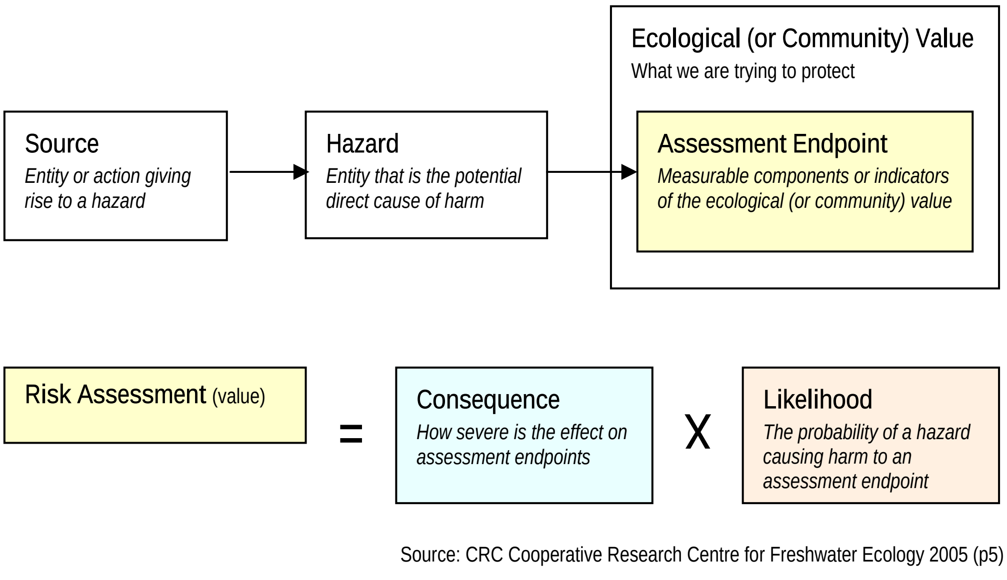


Figure 9.1: Risk Assessment Approach

9.2 Risk Assessment Results

ACTEW's risk assessment identified and characterised Tantangara Option risks for the Murrumbidgee River flow and long tunnel alternatives. Risks and their consequences are relatively benign for the Murrumbidgee River flow alternative. Conversely, the risks and consequences in the long tunnel alternative are relatively intense.

No *Extreme* risks were identified in the Murrumbidgee River flow risk assessment. Some *Very High* risks occur through the absence of a ratified ACT water Cap consistent with the National Water Initiative. This would preclude water trading between NSW and the ACT (causing a considerable loss of control over water supply and delivery) but could be mitigated by ACT signing up to the Cap. Some *Moderate* risks occur with the reliability of supply limited through rationing of high security entitlements during extreme droughts. This risk cannot be mitigated.

Table 9.1: Hazards Assessed as High Priority for Assessment[96]

Hazard	Source category	Comment
Loss of terrestrial vegetation	Pipe/tunnel	Highly likely during construction of a pipeline with associated infrastructure. *Could lead to localised loss of Alpine & Subalpine bogs & grasslands; endangered ecological communities*[97]
Change in flow seasonality	Pipe/tunnel	Operational imperatives mean it is highly likely flow seasonality would change downstream of a pipe outlet. This could disrupt spawning cues for fish.
Change in flow variability	Pipe/tunnel	It is highly likely periods of low flow would be reduced downstream of a pipe outlet. This could lead to loss of in-stream biodiversity and ecosystem resilience.
Increased discharge	Pipe/tunnel	Highly likely downstream of an in-stream pipe outlet. This could affect in-stream fauna through physical dislodgement and abrasion of substratum.
Pathogen transfer	Pipe/tunnel	Transfer of Epizootic Haematopoietic Necrosis Virus (EHNV) from Tantangara could lead to loss of species from Cotter sub-catchment
Low dissolved oxygen	Changed operations	In-stream DO moderately likely to decrease particularly with bottom releases. Could lose fish species from sub-catchments.
Increased discharge	Changed operations	Discharge highly likely to increase d/s Tantangara or Corin (for the Tantangara options). This could affect in-stream fauna through physical dislodgement and abrasion of substratum.

The long tunnel alternative included the following *Extreme* risks:

- introduction of new pests and alien species to the Cotter catchment;
- introduction of the EHN fish virus to the Cotter catchment; and
- construction in the Namadgi National Park;

These risks can be mitigated with screening and virus removal technology for waterborne species and pests. While the technology has proved successful in small applications no testing on a catchment scale has been completed. Mitigation measures do lower the risk but the consequences of a failure are significant.

Limiting the development footprint and initiating management controls (e.g. water quality and sediment management) can mitigate construction risks within the park. Some habitat would be displaced and this risk is unavoidable. Nevertheless, some habitat offsets could be established in the event that the proposal displaced critically endangered or threatened species.

[96] CRC for Freshwater Ecology (2004); *Ecological Risk Assessment*, October 2004, ACTEW Corp Doc No. 4676
[97] Applies to excluded pipeline options only

Very High and *Moderate risks* similar to the Murrumbidgee River flow alternative result from the absence of an ACT Water Cap and limitations on high security water entitlements.

CRC Freshwater Ecology included a more detailed risk assessment specific to the Tantangara option for the full range of pipeline and tunnel alternatives. Table 9.1 above is adapted from the CRC work[98] but it generally applies to the long tunnel and Murrumbidgee River flow alternatives.

9.3 Risk Management

CRC[99] recommended actions including additional ecological assessments, to manage high risks within the pipeline and tunnel alternatives excluded in this report. Nevertheless, elements of the short-listed long tunnel and Murrumbidgee River flow alternatives could be characterised under the CRC assessment and consequent management recommendations. These elements include proposed pipelines (penstock) near Cribbs Creek and Angle Crossing to Googong routes.

A high priority for risk assessment, loss of terrestrial vegetation reflected potential impacts on terrestrial and wetland biota through pipeline construction from Tantangara to the Upper Cotter. These involved a high risk to endangered ecological communities, alpine and sub-alpine bogs with CRC recommending the examination of alternative pipeline routes to avoid significant impacts to species protected under the EPBC Act. Pipeline alternatives were rejected due to their potentially high environmental impacts.

Avoiding wetlands, bogs and sensitive vegetation while using local species for re-vegetation works also could minimise terrestrial hazards.

Discharges from dams, weirs or pipe outlets could mimic natural flow regimes to minimize the risks associated with hydrological changes. Best practice environmental flow releases are required for all new dams (and discharges from the existing Tantangara Dam).

Multiple level off-takes are required to avoid the risk of oxygen depletion and downstream water quality degradation. Tantangara has a multiple level outlet currently under construction.

Fish ladders must be provided on weirs to allow migration of all native fish species.

The following risks should be specifically addressed in detailed ecological studies for the Tantangara tunnel alternative including its penstock:

- loss of terrestrial vegetation;
- change in flow;
- increased discharge (in Cotter catchment); and
- weir on Murrumbidgee River.

[98] CRC for Freshwater Ecology (2004); *Ecological Risk Assessment*, October 2004, ACTEW Corp Doc No. 4676 p19

[99] CRC for Freshwater Ecology (2004); *Ecological Risk Assessment*, October 2004, ACTEW Corp Doc No. 4676 p20

he following risks should be specifically addressed in detailed ecological studies for the Murrumbidgee River flow option:

- loss of terrestrial vegetation;
- change in flow;
- increased discharge (in Murrumbidgee River); and
- weir on Murrumbidgee River.

10 Sustainability Assessment

The sustainability concept:

- recognises that effective environmental solutions involve economic and social issues;
- refers to Ecologically Sustainable Development (ESD) defined in the 1992 National Strategy for Ecologically Sustainable Development; and
- maintains or enhances total resources without reducing any one type of natural, human, social, physical or financial capital below its “tipping point”

10.1 Sustainability Framework

Sustainability embodies *Sustainable Development*, *Ecologically Sustainable Development* (ESD) and *Triple Bottom Line* (TBL). A sustainability framework defines regulatory and policy parameters for a sustainability assessment.

ACTEW’s objectives now include ecologically sustainable development principles:

- the precautionary principle, whereby a lack of scientific certainty should not be used to postpone taking action to prevent environmental degradation;
- the inter-generational equity principle, whereby the present generation should ensure health diversity and productivity of the environment for the benefit of future generations;
- conservation of biological diversity and ecological integrity; and
- improved valuation and pricing of environmental resources.

The recommended future water option will be referred to the Commonwealth Minister for the Environment under the EPBC Act and analyses must recognise ESD principles specifically defined for the Minister’s consideration.

10.1.1 Environmental, Social and Economic Parameters

Analyses conducted for the Future Water Options project used “triple bottom line” or TBL (environmental, social and economic) assessments similar to those used by other water agencies in Australia and overseas.

The assessment criteria were developed from the eleven core sustainability dimensions set out by the ACT Office of Sustainability in the document: People Place Prosperity. From these, twelve sustainability criteria were developed with expert input, and in consultation with the community, for the evaluation of the future water options.

The 12 assessment criteria include 4 relating to each of environmental, social and economic factors, and are set out in Table 10.1. The assessment criteria are designed so that:

- there is equal consideration of economic, environmental and social factors;
- they represent the key issues involved in the comparison of Future Water Options as identified in public and agency consultation, can be measured for the different options,

and cover the sustainability areas to ensure proper account is being taken of all factors to achieve objectives;

- they are able to show a difference for the various options;
- they do not overlap, in order to avoid the problems of double counting;
- they reflect local, regional, basin-wide, national and worldwide concerns and interests; and
- they provide a direct measure of inter-generational equity.

Table 10.1: Sustainability Criteria for Evaluation of Future Water Options

Criteria	Sector
Effect on aquatic ecology	Environment
Effect on terrestrial ecology	Environment
Greenhouse gas emissions	Environment
Intrinsic value	Environment
Risk to public health	Social
Heritage and cultural values	Social
Landscape and amenity values	Social
Recreational opportunities	Social
Cost and affordability	Economic
Reliability	Economic
Employment creation	Economic
Distribution of costs and benefits	Economic

An initial set of environmental, social and economic criteria for the sustainability assessment was developed in scoping workshops involving project team members, specialist consultants and representatives of government agencies. The draft criteria were refined after discussions with the ACT Office of Sustainability and the Sustainability Expert Reference Group. To add rigour, the refined list was evaluated by interested members of the community and community groups in four workshops held in November 2004. The Institute for Sustainable Futures then reviewed these criteria to include best practice examples from sources such as CSIRO and the Institute's own experience.

Finally, the project team refined the list to ensure it incorporated the criteria the community had ranked as most important and that they corresponded to ACTEW and ACT strategy and policy documents such as '*People, Place, Prosperity*', and the *ACT Water Strategy Think water act water*, to ensure alignment with Government sustainability goals.

10.1.2 Assessment Procedure

The procedure followed to assess the various options was as follows:

1. A summary of the key environmental, social and economic issues relating to the construction and operation of each of the six options being assessed was prepared by

the environment manager, planning manager and an independent third party, summarising the findings of the specialist consultants.

2. A sheet was then prepared, summarising the key issues for each of the options, and with a column for scoring the option in the sustainability assessment workshops. The effects, levels or attributes of the options with respect to each criterion were described quantitatively.

3. At the workshops, the criteria were discussed sequentially, with the key information being read first, then questions from the participants of the appropriate specialist manager and then discussion in the workshop;

4. Workshop participants then scored each option for each criterion in turn, using an eleven-point scale: - 5 (worst) to 0 (no change) to +5 (best).

5. After each of the three groups of four criteria (environmental, social or economic) had been scored, participants weighted the criteria (so that the sum of the weights for each group of criteria added to 30). The weighting is a judgment of 'how important each criteria is relative to the others';

6. The average score for each criterion and the average weighting were then calculated.

7. The average scores were multiplied by the average weightings to derive the normalised average score for each group of criteria, and the rank of the options calculated for each group of criteria (the option with the highest normalised average score was ranked first, and so on); and

8. Calculating the normalised average score for all 12 criteria derived the overall rank of the options.

10.2 Results from Project Team Workshop

The first Sustainability Assessment Workshop involved the project team, as it was considered that members would have a good understanding of the characteristics and issues relating to the options and could provide comment on the documentation of issues as well as 'test run' the scoring and weighting procedure. There were 12 project team members present, and an independent facilitator ran the workshop. The rankings for the three groups of criteria and the overall ranking for the options are shown in Table 10.2.

Table 10.2: Sustainability Ranking of Major Options by Project Team

Option	Overall Ranking	Environment	Social	Economic
Large Cotter Dam	**1**	1	2	4
Tantangara – via river	**2**	3	1	3
Tantangara tunnel	**3**	5	3	1
Virtual Tennent Dam	**4**	2	4	2
Small Tennent Dam	**5**	4	5	5
Large Tennent Dam	**6**	6	6	6

The outcome was that the Cotter option was ranked best on the basis of least environmental impacts, and little social impact. These considerations outweighed the lower ranking of the Cotter option in terms of economic criteria.

10.3 Results from Community Perspective

The second Sustainability Assessment Workshop involved 12 community representatives, three from each of four groups (Conservation Council, Engineers Australia, commercial interests and 'concerned citizens'). These representatives had each attended a briefing on the project and the exhibition of the options, so were informed about the options and their implications. However, these persons should not necessarily be seen as representing the whole community.

The results were bi-polar with half clearly favouring the large Tennent option and the other half clearly favouring the Murrumbidgee River flow alternative. Averaging scores and weights mutes these clear preferences, leading to the overall rankings as shown in Table 10.3.

Table 10.3: Sustainability Ranking of Options by Community Representatives

Option	Overall Ranking	Environment	Social	Economic
Large Cotter Dam	**1**	1	3	4
Large Tennent Dam	**2**	4	1	1
Small Tennent Dam	**3**	5	2	3
Tantangara – via river	**4**	2	5	6
Tantangara tunnel	**5**	6	4	5
Virtual Tennent Dam	**6**	3	6	2

The Cotter option was ranked best on the basis of least environmental impacts, and this outweighed its lower social and economic rankings. The Tennent options also were ranked highly with the high volume of water available from these options was seen by most participants to have major social and economic value. Social values reflected a view about the importance of water in the urban environment, considered by some participants to offset concerns about the effects on existing leaseholders in the Gudgenby/Naas valley. Most participants saw the Tennent options as having greater environmental effects than the other options.

The Tantangara options ranked poorly despite recognition of the environmental benefits of releasing water to flow down the Murrumbidgee River. Similarly, public exhibition feedback indicated ACT residents felt uneasy about relying on NSW for the long-term water supply. Conversely, NSW residents wanted the ACT to use only Territory water resources.

10.4 Agency Perspectives

The third Sustainability Assessment Workshop involved mostly representatives of ACT government agencies, as it was considered that they also would have a good understanding of the characteristics and issues relating to the options. There was extensive discussion on the merits of the various options in this workshop, and additional presentations were given by the environment manager and the planning manager to clarify some issues. The rankings for the three groups of criteria and the overall ranking for the options are shown in Table 10.4.

Table 10.4: Sustainability Ranking of Options by ACT Agency Representatives

Option	Overall Ranking	Environment	Social	Economic
Large Tennent Dam	**1**	1	1	1
Large Cotter Dam	**2**	2	2	2
Small Tennent Dam	**3**	3	4	3
Tantangara tunnel	**4**	6	3	4
Tantangara – via river	**5**	4	5	6
Virtual Tennent Dam	**6**	5	6	5

The Large Tennent Option was ranked best with the Cotter option well regarded. Most participants saw the Tantangara alternatives as having a lower benefit than additional storage of water in the ACT.

10.5 Overall Assessment

The preferences and rankings developed in the sustainability workshops reflect the views of a small number of participants of generally informed people. The community has not been surveyed as a whole for the TBL assessment and it would, of course, be impossible to obtain a single answer that represents the views of "the community".

Nonetheless, the results of the sustainability assessment at the three workshops showed that there is a range of views as to the best option. No single option was favoured in all workshops although there was a slight preference for the Cotter option. The Tennent options ranked highly in one workshop and poorly in another. Similarly, the Tantangara options ranked highly by the project team but poorly by the community and stakeholder agencies.

With regard to the Tennent alternatives that are the subject of this report – the small and large Tennent dams and the virtual dam – the findings of the sustainability assessment are also ambiguous. Table 10.5 summarises the position:

Table 10.5: Summary of Tennent Alternatives Sustainability Rankings[100]

Tantangara Option Alternatives	Overall Sustainability Ranking (out of 6 alternatives) by:		
	New Water Options Project Team	Community Representatives	ACT Government Agency Representatives
Long Tunnel	3	5	4
Murrumbidgee River flow	2	4	5

This data in itself does not provide a sound basis for a decision between these alternatives. It is clear that some sectors of the community place a greater weighting on dollar costs and other sectors on environmental and social impacts. A consistent theme is the need for a reliable water supply. In this context it is apparent that all three alternatives should be carried forward for consideration either a stand-alone solutions or in combination with alternatives discussed under the Cotter and Tantangara Option investigations.

[100] Data from Tables 10.2 to 10.4

Abbreviations

°C	degrees Celsius
µg/L	Microgram per litre (equivalent to parts per billion (ppb) or one millionth of a gram per litre)
ACT	Australian Capital Territory
AS/NZS	Australian Risk Management Guidelines
CFU	colony forming units
CMA	Catchment Management Authorities
COAG	Council of Australian Governments
CO2	Carbon Dioxide
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DA	Development Application
DIPNR	The Department of Infrastructure, Planning and Natural Resources
EHN	Epizootic Haematopoietic Necrosis
EIS	Environmental Impact Statement
EMA	Environment Management Authority
EPA	Environmental Planning and Assessment Act
EPBC	Environment Protection and Biodiversity Conservation
ESD	Ecologically Sustainable Development
GL	Gigalitres (1 gigalitre = 1 000 000 000 litres)
GL/month	Gigalitres per month
GL/yr	Gigalitres per year
ha	hectares (equals 10,000 square meters)
ICRC	Independent Competition and Regulatory Commission
km	kilometres
km2	square kilometres (equal to one million square meters (m2), 100 hectares (ha))
KNP	Kosciuszko National Park
kW	kilowatts (1,000 watts)
kWh	kilowatt hours (1,000 watts for one hour)
kV	
kVA	
m	metres
m3	cubic metres
mg/L	milligrams per litre
ML	Megalitres (1 megalitre = 1 000 000 litres)
mL	millilitre
ML/day	Megalitres per day
mm	millimetres
Mt	Mount
NCA	National Capital Authority
NCP	National Capital Plan
NES	national environmental significance
NSW	New South Wales
NTU	Nephelometric Turbidity Units
NWI	National Water Initiative
PER	public environment report
Pt-Co	platinum-cobalt units
STC	sediment transport capacity
TBL	Triple Bottom Line
TBM	Tunnel Boring Machine

TP	Total Phosphorous
TN	Total Nitrogen
US	United States
WTP	Water Treatment Plant

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A P P E N D I C E S

Appendix A – Summary: Think Water Act Water Objectives

- Provide a long-term, reliable source of water for the ACT and region;
- Increase the efficiency of water usage;
- Promote development and implementation of an integrated regional approach to ACT/New South Wales cross-border water supply and management;
- Protect the water quality in ACT rivers, lakes and aquifers, so as to maintain and enhance environmental, amenity, recreational and designated use values and to protect the health of people in the ACT and down river;
- Facilitate the incorporation of water sensitive urban design principles into urban, commercial and industrial development; and
- Promote and provide for community involvement and partnership in the management of the ACT Water Resources Strategy.
- Future water resource management depends on:
- Population growth and per capita demand;
- Account for:
  - Continuing impact of 2003 bushfire damage;
  - Climate change; and
  - ‘Urban water cycle’ management.
- Satisfy future water demands by:
  - Increasing water supplies from existing or proposed reservoirs or other sources;
  - Reducing per capita mains water use; or
  - A combination of both.

Appendix B – Short-Listed Water Supply Options

Table B1: Short-listed Water Supply Option Alternatives

	Option	Alternative	Variant	Option Features
1	Cotter 78 GL			Large new dam over existing Cotter Dam. Capacity of 180 ML per day, pumped to Stromlo WTP
2	Cotter 45 GL			New dam over existing Cotter dam. Capacity of 180 ML per day, pumped to Stromlo WTP
3	Cotter 5 GL			The existing dam, with additional capture of Bendora Dam environmental flows.
4	Coree			Large new dam at Coree, alternative to new Cotter Dam options
5	Tennent 159 GL	Pipe to Stromlo WTP		Large new Tennent Dam
6		WTP at Tennent and pipe to Tuggeranong mains supply		
7	Tennent 78 GL	Pipe to Stromlo WTP		Medium new Tennent Dam
8		WTP at Tennent and pipe to Tuggeranong mains supply		
9	Tennent 45 GL	Pipe to Stromlo WTP		Relatively small new Tennent Dam
10		WTP at Tennent and pipe to Tuggeranong mains supply		
11	Tennent Murrumbidgee River flow	Weir at Angle Crossing	Pipe from Angle Crossing to Burra Creek (thence gravity flow to Googong Dam)	Water pumped from Murrumbidgee River weir at Angle Crossing, 60 ML per day. Abstraction rate equal to agreed proportion of Gudgenby River flow (which replaces the water taken from Murrumbidgee River)
12			Pipe from Angle Crossing to Googong Dam	As for 11
13		Weir at Tharwa	Pipe from Angle Crossing to Burra Creek (thence gravity flow to Googong Dam)	As for 11 but weir at Tharwa, pipe to Angle Crossing.
14			Pipe from Angle Crossing to Googong Dam	As for 11 but weir at Tharwa, pipe to Angle Crossing
15	Tantangara 20 km tunnel			Water from Tantangara Dam into Murrumbidgee River then through a tunnel into Cotter River above Corin Dam.
16	Tantangara 20 km pipeline			Release water from Tantangara Dam via pipeline to Cotter River above Corin Dam
17	Tantangara 10 km tunnel plus pipe			Combination of 15 and 16
18	Tantangara flow down river to ACT	Weir at Angle Crossing	Pipe from Angle Crossing to Burra Creek (thence gravity flow to Googong Dam)	Water stored at Tantangara Dam, released as required, pumped from Murrumbidgee River to Googong Dam
19			Pipe from Angle Crossing to Googong Dam	As for 18
20		Weir at Tharwa	Pipe from Angle Crossing to Burra Creek (thence gravity flow to Googong Dam)	As for 18
21			Pipe from Angle Crossing to Googong Dam	As for 18
22		Drought contingency Scheme or (Casuarina Murrumbidgee River flow option)	Pump directly from Murrumbidgee River	Pumping from Murrumbidgee River at Cotter pump station to Stromlo WTP (either purchased Murrumbidgee River water or proportion of Gudgenby River flow as per 11)
23			Construct weir and pump from weir	As for 22
24	Drought contingency Scheme or (Casuarina Murrumbidgee River flow option)	Pump directly from River (current scheme)		Pumping from Murrumbidgee River at Cotter pump station to Stromlo WTP (either purchased Murrumbidgee River water or proportion of Gudgenby River flow as per 11)
25		Construct weir and pump from weir		As for 24

Appendix C – Legislative Frameworks

Table C1: Relevant Legislative Instruments[101]

Commonwealth Law	Description
ACT Self-Government (Consequential Provisions) Act 1988	Water rights devolved to ACT Government from the Commonwealth
Murray Darling Basin Act 1993	Natural resource management and water distribution; caps on diversions; Water sharing
ACT (Planning and Land Management) Act 1988	Establishes National Capital Plan securing ACT water supplies; protecting catchments
Environment Protection and Biodiversity Conservation Act 1999	Provides for management of conservation issues of national significance
Australian Heritage Commission Act 1975/ Heritage Council Act 2003	Provides management of heritage issues of national significance via the Register of the National Estate; includes existing Cotter Dam
NSW Law	**Description**
Environmental Planning and Assessment Act 1979	Provides mechanisms for development and environmental assessments
Protection of Environment Operations Act 1997	Provides for the issue of environmental licences
Wilderness Act 1987	Laws protecting and managing wilderness areas
National Parks and Wildlife Act 1974	Laws managing national parks
Threatened Species Conservation Act 1995	Provides for the protection of Threatened Species
Rural Fires Act 1997	Provides for bushfire management,
Fisheries Management Act 1994	Provides for the protection of fish resources
Rivers and Foreshores Improvement Act 1948	Controls development activities and works within and adjacent to streams
Water Management Act 2000	Provides for the issue of water and infrastructure licences.
Water Act 1912	Provides for the issue of water and infrastructure licences.
Land Acquisition (Just Terms Compensation) Act (1991)	Provides for compulsory acquisition of land needed for public purposes.
Crown Lands Act 1989	Manages land owned by the Crown.
Murray-Darling Basin Act 1992	Legislation to enact the Murray-Darling Basin agreement
ACT Law	
Land (Planning and Environment) Act 1991	Establishes Territory Plan and provides mechanisms for development and environmental assessments
Nature Conservation Act 1980	Provides mechanisms and controls for nature conservation including threatened/endangered species action plans; specifies role of the Conservator of wildlife; prohibits construction in certain areas
Environment Protection Act 1997	Provides mechanisms for pollution control, including during construction
Water Resources Act 1998	Provides an ACT water management framework including environmental flows and the preparation of a Water Management Strategy
Heritage Act 2004	Empowers Heritage Council to assess impact of proposals and advise Planning and Land Authority

[101] Adapted from McCann Property and Planning Pty Ltd and ACTEW (2004), *New Water Source for the ACT, Planning and Development Controls*, Draft report for ACTEW Corporation, June 2004.

Appendix D – Approvals Processes

Table D1: NSW Approvals Process – Tunnel, Murrumbidgee Weir, and Supporting Works

Statute(s)	Approvals Process and requirements	Consent Authority	Comments
Environmental Planning and Assessment Act	State Significant Development - Development consent required under part 4	Minister for Planning	The Minister can make the proposal state significant (S88A) by declaration.
Environmental Planning and Assessment Act	Development consent required under Part 4 Permitted with consent in *Cooma Monaro LEP 1999* Zone 1(a) and unzoned land - Clause 21 (Riparian Corridors) applies. Permitted with consent in *Snowy River LEP 1997.* Zone 7 applies. Kosciuszko Regional Environmental Plan 1998 -- (Snowy River) applies.	Cooma Monaro Shire Snowy River Shire	Weir could be an artificial water body and *designated development* under EPA Regulation. DIPNR advice on EIS specifications required. Weir spans 2 local government areas (Cooma Monaro, and Snowy River) requiring consent from both Councils. Development is defined as a *utility undertaking* in Cooma Monaro LEP and *utility installation* in Snowy River LEP.
Rivers and Foreshores Improvement Act (1948)	License for works required.	DIPNR	Development proposed within 20m of watercourse.
Threatened Species Conservation Act 1995	Species Impact Statement required (S111). Licence to harm species may be required (S91).	DEC (NPWS)	Weir construction may cause harm to threatened species.
Fisheries Management Act 1999	Written notice (S199) to Minister for Fisheries for works and consideration of Minister's response required.	NSW Fisheries (Minister for Primary Industries)	Weir construction may affect fish habitat. Minister can recommend fish way construction.
Rural Fires Act 1997	Advise to authority required to light fires (s95)	Rural Fires Authority delegate (Fire Control Officer)	Cleared vegetation may require burning.
Water Act 1912	Permit to change course of a River (S18F) Application for authority to construct and use a joint water supply scheme (S20) (Works permits)	DIPNR (Ministerial Corporation)	Permit for works that affect river flows. Authority to construct and operate a joint water supply scheme (water supply for 2 or more occupiers).
Water Management Act (2000)	License to extract water, hold water or trade water. ACTEW would operate	DIPNR	Water management Act affects operations and water transfers but is intrinsically related to extraction works

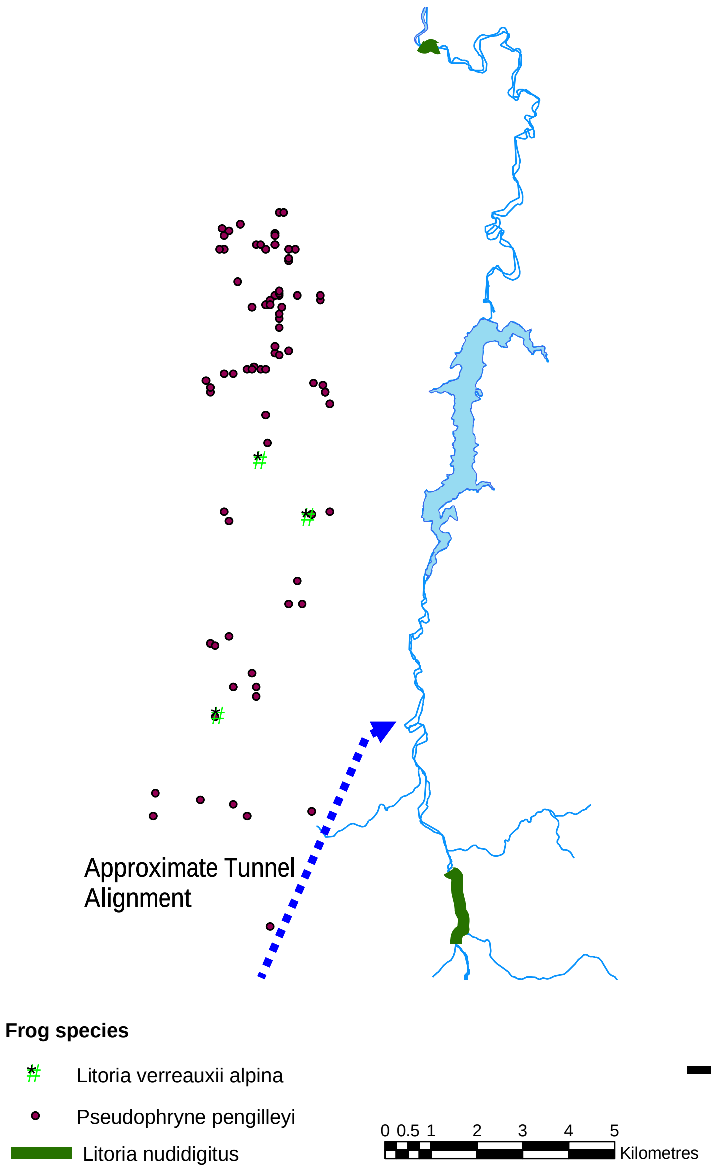
	as a private water holder rather than a water supply authority.		under the Water Act 1912.
Land Acquisition (Just Terms Compensation) Act 1991	Authorities of the state (NSW Authorities) may compulsory acquire land. (Part 2)	NSW Authority of the State (NSW Minister of delegate)	Land would be required for road access and weir construction and tunnel portal. Leases could be negotiated with landowners. ACT Government would have to negotiate with NSW to acquire land on its behalf.
Protection of Environment Operations Act 1997	License required for regulation of water pollution associated with weir and other facility construction (S43)	NSW EPA	Discharges from the constructions site(s) including roads must regulated under license.
Crown Lands Act	Lease or title required (S34) for riverbed.	Minister for Lands	Weir lies over Crown Land (Murrumbidgee riverbed)
Local Government Act (1993)	Approval required to carry out water supply work (S68)	Cooma Monaro Shire Snowy River Shire	Weir and connecting infrastructure constitutes “water supply work”.
Real Property Act 1900 (NSW).	Easements beneath private land would be required for the tunnel.	Individual landowners	Easements would be required beneath private land. Leases or easements could be negotiated with landowners. ACT Government would have to negotiate with NSW to compulsorily acquire easements on its behalf.
Wilderness Act 1987	Minister may grant consent to an easement or right of way in a national park (S153). *(There is debate over the tenure of underground land*)	Minister for the Environment or delegate (NSW NPWS)	Tunnel beneath designated Bimberi wilderness area would require consideration under the plan of management for Kosciuszko National Park
Local Government Act (1993)	Approval required to carry out water supply work (S68). Linked to weir construction.	Cooma Monaro Shire	Tunnel infrastructure constitutes “water supply work”.
National Parks and Wildlife Act 1974	Minister may grant consent to an easement or right of way in a national park (S153). *(see tenure note)*	Minister for the Environment or delegate (NSW NPWS)	Tunnel beneath Kosciuszko National Park would require consideration under the plan of management for Kosciuszko National Park.

Table D2: ACT Approvals Process - Tunnel and Supporting Works

Statute(s)	Approvals Process and requirements	Consent Authority	Comments
Land (Planning and Environment) Act 1991	Preliminary Assessment (Mandatory) required (Appendix II) Development Consent required	ACT Planning and Land Authority	Tunnel is defined as a *Major Utility Installation.* Overlay provisions for wilderness areas and national parks apply. Appendix I Water use and catchment policies apply (Water Supply). Hydropower facility requires a variation to the *Territory Plan*
Nature Conservation Act 1980	Development consent authorizes clearing. License required (Part 4) for disturbing nests, killing native animals. Commonwealth, (on Conservator's recommendation) may grant a lease of an area, or part of an area, of public land except where the area has been reserved as a wilderness area. In order to meet the Act requirements actions or protocols are required.	ACT Chief Minister (or delegate) Conservator of Flora and Fauna.	Tunnel may interact with controls for nature conservation including threatened/endangered species action plans; specifies role of the Conservator of wildlife; Prohibits construction in certain areas. Works must be consistent with Namadgi National Park Management Plan and species action plans. Management agreements can be negotiated. Plans for the protection and conservation of native animals and native plants will be identified during the environmental assessment process.
Environment Protection Act 1997	Consent required (S42) for placement of soil (class A activity). Authority may require an environmental improvement plan (S69)	Environment Protection Authority	Soil placement at tunnel portal >100m2 Provides mechanisms for pollution control, including during construction.
Water Resources Act 1998	The EPA must prepare a draft management plan for water resources management plan (Part 5)	Environment Protection Authority	Tunnel construction would influence the preparation of a Water Management Plan.
Heritage Act 2004	Discovery obligations for Aboriginal sites (S51) Referral obligations for development application (S59) Heritage direction by Minister (S62)	ACT Heritage Council	Tunnel construction could impact on heritage items. Council may direct a Heritage Management Plan (S110).

Appendix E – Potentially Affected Animal Species

Figure E1: Frog Species Detected in the Upper Cotter Catchment



Source: University of Canberra Water Research Centre (2005) *Aquatic Ecology Study*

Appendix F – Potentially Affected Vegetation

Table F1: Potential Directly Affected Vegetation Types

Community Definition	Dominant species	Location in landscape	Endangered Ecological Community?
Montane Sheltered Moist Forest	*Eucalyptus pauciflora* and/or *E. dalrympleana*	Sheltered slopes	No
Riparian Mountain Gum Forest	*Eucalyptus viminalis*	Along creek lines and some lower sheltered slopes	No
Tablelands Dry Tussock Grasslands	*Poa* spp., *Themeda triandra*	Lower valleys (e.g. Yaouk Valley)	Possibly consistent with Natural Temperate Grasslands as listed under the EPBC Act which occurs between 560m and 1200m elevation. However, is inconsistent with 'Natural Temperate Grasslands' under the NC Act, which occur below 625m elevation.

Table F2: Potential Indirectly Affected Vegetation Types

Community Definition	Dominant species	Location in landscape	Endangered Ecological Community?
Sub-alpine Bogs	Sphagnum	Permanently wet sites	Alpine Bogs have been nominated for listing on the EPBC Act and possibly consistent with the preliminary determination for 'Montane Peatlands and Swamps' under the TSC Act
Montane / Subalpine Moist Heath	*Poa* spp., with scattered shrubs	Higher valleys	May be consistent with the preliminary determination for 'Montane Peatlands and Swamps' under the TSC Act

Source: O'Sullivan and Gorrod (2004) New Water Source for the ACT – Terrestrial Flora, Fauna and Vegetation Study

Appendix G – Threatened Plant Species

Table G1: Potentially Threatened Plant Species Occurrence Within The Proposal Area

Species	NC Act	TSC Act	EPBC Act	Habitat requirements	Likely to occur in study area?
Calotis glandulosa	-	V	V	Grows in grassland and sclerophyll forest at higher altitude, from Eden to Dubbo (Harden 1992).	Possible in grassland and forest in the study area.
Rutidosis leiolepis	-	V	V	Grows in higher altitude grassland in the Cooma and Kiandra districts (Harden 1992).	Possible, in grassland vegetation in study area.
Thesium australe	-	V	V	Grows in grassland or woodland, often in damp sites; widespread but rare (Harden 1992).	Yes, in grassland and woodland vegetation in the study area.
Rutidosis leptorrhynchoides	E	E	E	Occurs in the ACT and Monaro region where it grows in grassland and woodland. This species flowers mostly in summer (Harden 1992).	Possible in grassland and woodland vegetation in the study area.
Gentiana baeuerlenii	E	E	E	Known from one location in the Orroral Valley in the Namadgi National Park. The orchid, *Spiranthes sinensis*, the herb, *Ranunculus pimpinellifolius* and the grass *Hemarthria uncinata* were found in association with the herb and this group of more widespread species may be indicators for other potential sites	Possible, although the associated species were not recorded.
Swainsona recta	E	E	E	Grassland and open woodland, often on stony hillsides (Harden 1991).	Unlikely, habitat in grassland and woodland
Muehlenbeckia tuggeranong	V	-	E	Known only from the flood terraces on the eastern bank of the Murrumbidgee R., near Tuggeranong, ACT (Harden 2000).	No, no flood terraces in study area.
Swainsona sericea	-	V	-	Grows in grassland and eucalypt woodland, sometimes with Callitris species; widespread (Harden 2002).	Yes, habitat in grassland and woodland in study area.

Key: V = Vulnerable; E = Endangered; CE = Critically Endangered; CD = Conservation Dependent; M = Migratory

Source: O'Sullivan and Gorrod (2004) New Water Source for the ACT – Terrestrial Flora, Fauna and Vegetation Study

Appendix H – Threatened Animal Species

Table H1: Potentially Threatened Animal Species Occurrence Within The Proposal Area

Common Name	NC Act	TSC Act	EPBC Act	Habitat	Habitat Opportunities
Alpine Tree Frog		E	V	This species is a high altitude frog species, occurring in the Snowy Mountains in upland bogs and rivers (Barker et al. 1995, Lintermans & Osborne 2002, NSW Scientific Committee 2002). Breeding habitats include streamside pools, bog pools, wet grassland and in deep artificial ponds (Lintermans & Osborne 2002).	Probable
Northern Corroboree Frog	E	V	V	Upland bogs and sedgelands usually above 1000m. Not recorded locally.	Highly likely
White-throated Needletail			M	An aerial species found in feeding concentrations over cities, hilltops and timbered ranges (Pizzey 1983).	Yes
White-winged Triller	V			During migration it occurs in open country with trees, from inland plains to coastal farmland. Breeds in open woodlands and scrublands, riparian woodlands, native pine and other scrub (Pizzey & Knight 1997a).	May occur in Snow Gum woodlands
Swift Parrot	V	E	E/M	The Swift Parrot occurs in woodlands and forests of NSW from May to August, where it feeds on eucalypt nectar, pollen an associated insects (Forshaw & Cooper 1981). The Swift Parrot is dependent on flowering resources across a wide range of habitats in its wintering grounds in NSW (Shields & Crome 1992). This species is migratory, breeding in Tasmania and also nomadic, moving about in response to changing food availability (Pizzey 1983).	May occasionally occur in upland forest and woodland
Satin Flycatcher			M	Migratory species that occurs in coastal forests, woodlands and scrubs during migration. Breeds in heavily vegetated gullies (Pizzey 1983).	May occur in forest/woodland habitats, particularly denser vegetation of gullies and slopes
Powerful Owl		V		Favours open forest and deep gullies. Reliance upon mature forests, which provide large tree hollows for nesting.	May be thinly distributed in the ranges. However large components of the study area would provide

Common Name	NC Act	TSC Act	EPBC Act	Habitat	Habitat Opportunities
					suitable habitat resources
Rufous Fantail			M	Migratory species that prefers dense, moist undergrowth of tropical rainforests and scrubs. During migration it can stray into gardens and more open areas (Pizzey 1983).	May occur in native forest/woodland, particularly within gully vegetation
Regent Honeyeater	E	E	E/M	A semi-nomadic species occurring in temperature eucalypt woodlands and open forests. Most records are from box-ironbark eucalypt forests associations and wet lowland coastal forests (Pizzey 1983, NPWS 1999c).	May occur in forest and woodland areas
Spotted-tailed Quoll	V	V	V	Uses a range of habitats including sclerophyll forests and woodlands, coastal heathlands and rainforests (Dickman & Read 1992). Habitat requirements include suitable den sites, including hollow logs, rock crevices and caves, and abundance of food and an area of intact vegetation in which to forage (Edgar & Belcher 1995).	Likely to occur in forest and woodlands
Koala		V		Inhabits eucalypt forests and woodlands. The suitability of these forests for habitation depends on the size and species of trees present, soil nutrients, climate and rainfall (Reed & Lunney 1990, Reed *et al.* 1990).	Possible, but distribution seems very restricted and there is low availability of preferred feed trees
Broad-toothed Rat		V		Occurs in thick undergrowth within stream and gully vegetation.	Yes
Large Bent-wing Bat		V	CD	Cave-dwelling bat that often forages above the tree canopy.	Likely
Eastern Long-eared Bat		V	V	Favours wetter habitats, ranging from rainforest and monsoon forest to riverine forests of paperbark, but are also found in open woodland, tall open forest and dry sclerophyll woodland. In northern NSW they are restricted to rainforest. The species have been recorded roosting under peeling bark, among epiphytes, in tree hollows, in the roots of strangler figs, amongst the dead fronds of a prickly tree fern and in foliage (Churchill 1998).	Likely
Brush-tailed Phascogale		V		Occurs in dry sclerophyll open forest, with a sparse ground cover of herbs,	Possible at lower altitudes

Common Name	NC Act	TSC Act	EPBC Act	Habitat	Habitat Opportunities
				grasses, shrubs or leaf litter (Soderquist 1995, NPWS 1999b). Individuals may also inhabit heathland, swamps, rainforest and wet sclerophyll forest (NPWS 1999b). Nests and shelters in tree hollows, utilising many different hollows over a short period of time. Suitable hollows are 25-40 mm wide (NPWS 1999b).	
Yellow-bellied Glider		V		Restricted to tall nature forests in regions of high rainfall. Preferred habitats are productive, tall open sclerophyll forests where mature trees provide shelter and nesting hollows. Critical elements of habitat include sap-site trees, winter flowering eucalypts, mature trees suitable for den sites and a mosaic of different forest types (NPWS 1999d).	Yes
Brush-tailed Rock-wallaby	E	V	V	Found in rocky areas in a wide variety of habitats including rainforest gullies, wet and dry sclerophyll forest, open woodland and rocky outcrops in semi-arid country. Commonly sites have a northerly aspect with numerous ledges, caves and crevices (Eldridge & Close 1995).	Possible
Smoky Mouse	E	E	E	Favours ridgetop and slopes within sclerophyll forest or heath from the coast to sub alpine regions up to 1800 m. Records from within Namadgi and Kosciusko National Parks.	Yes

Key: V = Vulnerable; E = Endangered; CE = Critically Endangered; CD = Conservation Dependent; M = Migratory

Table H2: Fish And Crayfish Known or Likely to be Present in the Proposal Area

Species		Native / alien	Tantangara -Yaouk	Yaouk-Cooma	Cooma-Gigerline Gorge	Below Gigerline Gorge (ACT)
Finfish						
Mountain Galaxias	*Galaxias olidus*	Native	✓	✓	✓	✓
Two-spined Blackfish	*Gadopsis bispinosus*	Native	✓			
Rainbow Trout	*Oncorhynchus mykiss*	Alien	✓	✓	✓	✓
Brown Trout	*Salmo trutta*	Alien	✓	✓	✓	✓
Goldfish	*Carassius auratus*	Alien	?	✓	✓	✓
Trout Cod	*Maccullochella macquariensis*	Native		✓	✓	✓
Macquarie Perch	*Macquaria australasica*	Native		✓	✓	✓
Carp	*Cyprinus carpio*	Alien		✓	✓	✓
Eastern Gambusia	*Gambusia holbrooki*	Alien		✓	✓	✓
Oriental Weatherloach	*Misgurnus anguillicaudatus*	Alien			✓	✓
Golden Perch	*Macquaria ambigua*	Native			✓	✓
Murray Cod	*Maccullochella peelii*	Native			?	✓
Redfin Perch	*Perca fluviatilis*	Alien				✓
Western Carp Gudgeon	*Hypseleotris klunzingeri*	Native				✓
Australian Smelt	*Retropinna semoni*	Native			✓	✓
Silver Perch	*Bidyanus bidyanus*	Native				
Freshwater Catfish	Tandanus tandanus	Native			✓2	✓
Crayfish						
Murray Crayfish	*Euastacus armatus*	Native			✓	✓
spiny crayfish	*Euastacus crassus*	Native		✓	?	
Yabby	*Cherax destructor*	Native		✓	✓	✓
Burrowing crayfish	*Engaeus cymus*	Native		?	?	✓
spiny crayfish	*Euastacus rieki*	Native		✓*	?	

Key
✓* = Expected to be present
= Expected to be rare vagrants
✓1 = only present in isolated farm dams
✓2 = Historical record
Source: Lintermans et al 2004

Table H3: Conservation Status Of Selected Fish And Crayfish From the Murrumbidgee

Species	ACT	NSW	National		International
	Nature Conservation Act 1980	Fisheries Management Act 1994	ASFB listing (2003)	EPBC Act 1999	IUCN Redlist (2004)
Macquarie perch	Endangered	Vulnerable	Endangered	Endangered	Data Deficient
Two-spined Blackfish	Vulnerable				
Trout Cod	Endangered	Endangered	Critically Endangered	Endangered	Endangered
Murray River Crayfish	Vulnerable				Vulnerable
Spiny crayfish, *Euastacus crassus*	Protected invertebrate				Endangered
Spiny crayfish, *Euastacus rieki*	Protected invertebrate				

Key:
ASFB = Australian Society for Fish Biology
Source: Lintermans et al 2004

Appendix I – Register of National Estate

Table I1: Relevant Places Listed On The Register Of The National Estate

Upper Cotter Catchment Area, Corin Rd, Tharwa, ACT
Class: Natural
Legal Status: Registered (27/03/1984)
Statement of Significance: This area has high ecological and aesthetic significance important for its Bogong moth aestivating sites. An undeveloped water catchment area, the Commission has determined that the place has Indigenous values of national estate significance. The Commission is currently consulting with relevant Indigenous communities on information to be placed on public record. Description: The area contains habitats from lowland to sub-Alpine with higher peaks snow-covered for extended periods. It includes: ➢ Mount Bimberi -1,911m (ACT's highest peak) . ➢ Waterfalls like Ginini Falls. ➢ East side of the Brindabella Range covered in wet sclerophyll forest. ➢ Mount Gingera –an important Bogong Moth summer camp.
Location: Approximately 40,000ha comprising the Cotter Catchment south of the northern extremity of the Tidbinbilla Nature Reserve to the junction of the Mount Franklin and Bendora Roads.

Source: O'Sullivan and Gorrod (2004) New Water Source for the ACT – Terrestrial Flora, Fauna and Vegetation Study

Bimberi Wilderness, via Kiandra, NSW
Class: Natural
Legal Status: Indicative Place
Statement of Significance: Helman Wilderness Area, already partly in a National Park and to be included in the proposed Gudgenby Park. Water catchment regulations protect the remaining area. Description: The area includes rugged mountains in the southern ACT, including the Bimberi and Scabby Ranges. The peaks are mostly granite and Ordovician sediments reaching 1,911m with local relief over 800m. Snow covers the highest peaks for several months each year. Vegetation shows marked altitudinal and topographic changes from small alpine areas through subalpine forest with dry sclerophyll forest to the east. Grassy plains in the valley surround creeks flowing west to the Goodradigbee River, and east to the Gudgenby River. The central valley contains Cotter River headwaters and Corin Dam. Condition and Integrity: Some valley areas have been grazed but abandoned due to catchment and Kosciuszko National Park controls. Access is generally limited to fire management activities.
Location: About 40000ha in the Bimberi Range in the south-western Australian Capital Territory and adjacent New South Wales, 30km north-east of Kiandra.

Source: O'Sullivan and Gorrod (2004) New Water Source for the ACT – Terrestrial Flora, Fauna and Vegetation Study

Namadgi National Park, Tharwa, ACT
Class: Natural
Legal Status: Indicative Place
Statement of Significance: Namadgi National Park contains diverse natural and cultural resources including ➢ Rugged mountain, foothill and valley terrain. ➢ ACT's highest peaks in the Australian Capital Territory. ➢ Rocky slopes and cliffs (especially over granite) with landscape significance. ➢ A wide range of vegetation types and habitats, from sub alpine communities to rocky heaths and swamps and including tall open forests of Eucalyptus delegatensis and E fastigata and dry open forest. ➢ Uncommon or rare animals (Broad Tooth Rat, River Black Fish, Macquarie Perch) and Alpine plants (Grevillea diminuta, Parautennaria uniceps and Geranium obtusisepalum) ➢ At least fifty Aboriginal heritage sites (occupation, rock painting, stone arrangement and quarry sites) ➢ European heritage sites (rural residences and outbuildings, trackways, fences plantings and evidence of timber cutting) Namadgi's natural environment is enhanced by extensions into important surrounding areas such as Tidbinbilla Nature Reserve (ACT), Bimberi Nature Reserve, Scabby Range Nature Reserve and Kosciuszko National Park (NSW). State and Commonwealth authorities manage these areas under the Australian Alps National Parks Agreement. Description: Namadgi extends over 94,000ha, (about 40 per cent of the ACT) with diverse natural and cultural values. These have not been identified, documented or assessed for national estate significance by the Commission. Condition and Integrity: Generally good. Modified by past grazing in valleys in the south, major fires (1983), pine plantations (800 ha), and dams on the Cotter River.
Location: 94,000 ha comprising the southern and southwestern parts of the ACT.

Source: O'Sullivan and Gorrod (2004) New Water Source for the ACT – Terrestrial Flora, Fauna and Vegetation Study