

INQUIRY INTO WATER AUGMENTATION

Organisation:

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Local Aquifer Trusts

Submission to The NSW Upper House

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Background

The NSW Upper House has called for submissions relating to NSW water management initially closing at June 1st. The *multi-party committee* has extended the deadline to August 2016, with a Federal Election now due in July. This submission outlines some ideas for change, with a new driver for innovation via *Local Aquifer Trusts*, to test on a failing NSW aquifer.

Recent History: In 2013, the Menindee Lakes in western NSW were drained by the *Murray Darling Basin Authority* (“MDBA”), into the Darling River (around 370 gigaLitres), to flush out the lower river system. This was part of new *water sharing agreements* between Federal and State government to attempt a better balance between environmental flows, irrigators, upper and lower catchment users, and salt accumulation in the lake and river system. There followed a period of lower than expected inflow into Menindee Lakes. The lakes dried up, and so too did Broken Hill's primary *urban water supply*. Alarm escalated, and *NSW Water* rapidly moved to find an underground source. “Plan B” emerged and in the nick of time a *low salinity aquifer* near the lake, adequate for around 2 years supply to Broken Hill was found, developed, tested, piped and delivered. It needed expanded *desalination* at Broken Hill, but as of last November, restitution of reasonable water security to the city appears to have occurred. Meanwhile in Canberra, ACTEW has spent around \$605 million to increase Canberra's water security by around 70 gigaLitres - only a modest return on major investment. At Menindee, the MDBA basically performed an *uncontrolled test* with an embarrassing result.

Both examples above show good, solid 19th century thinking applied in the 21st century (draining of lakes, building of dams, diverting rivers). Both exhibit a disconnection between the old, and new trends in coordinated management of surface and underground water. South Australia and Western Australia lead the way locally, with poor water supplies demanding *early adoption* of new technologies. Within the Canberra region, the towns of Yass, Murrumbateman, Gundaroo, and Bungendore suffer insecure, poor quality water supplies. These towns must appear insignificant compared to Canberra, but this writer believes they hold a key to improving aquifers

Proposed herein is a test model to improve a *failing aquifer* involving a change of management strategy. This proposal emerges from analysis of *knowledge gaps* between different regions, different players and different disciplines. Such *knowledge gaps*, are often the underlying drivers of poor decisions. They also include fundamental views of the world that generate conflicts by choosing between *aquifer repair*³ OR *economic development*, not requiring *aquifer repair WITH economic development*. This second possibility is a new model which I suggest needs to be adopted - made possible by rapid advances in multiple disciplines. Many advances have not yet made it to mainstream thinking, and this is the hallmark of *continuing knowledge gaps*. The bridging of these gaps is central to this submission.

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Glossary of Key Concepts

<i>aquifer repair</i>	for this submission: the improvement of all or part of an aquifer in water quality, or storage capacity, leading to growing <i>aquifer valuation</i> ;
<i>Aquifer Storage and Retrieval (“ASR”)</i> :	the storage of surface waters (usually treated) into an aquifer for later retrieval by pumping either locally or at a distance ;
<i>Aquifer Storage and Transfer Retrieval (“ASTR”)</i>	ASR where there is separation by distance of the storage point, and the retrieval point. The water travels underground and is used elsewhere (like an underground pipe)
<i>aquifer valuation</i> :	for this submission, the total estimated volume in an aquifer, valued at nearest local market water price, less the estimated cost to remove salt or pollutants (the value may be negative);
<i>aquifer:</i>	an underground strata of rock or sediment that holds and transmits water ;
<i>aquitard</i> :	an underground strata of rock or sediment that impedes water flow;
<i>bridging of knowledge gaps</i> :	communication of ideas such that knowledge gaps are reduced
<i>desalination</i> :	the removal of salt from water to produce fresh water supplies;
<i>early adoption</i> :	adoption of new concepts and practice shortly after it becomes proven, or reported. These organisations may be small, agile and characterised by cutting edge thinking. They also may be large and drive innovation themselves.
<i>failing aquifer</i> :	For the purposes of this submission, an aquifer that has known widespread contamination, of limited economic benefit, freshwater storage use, or emptied to the point of impairing use as a water source;
<i>GigaLitres</i>	1,000,000,000 litres or 1 billion litres, or 1,000 megaLitres. Or 1 million cubic metres;
<i>halocline</i> :	Variation of salt concentration over distance in a water body;
<i>knowledge gaps</i> :	where there is a difference in knowledge underlying human behaviours- the gaps may be across or within organisations, disciplines, or countries and states, and time
<i>Local Aquifer Trust (“LAT”)</i> :	for this submission, a local organisation for part or all of an aquifer, committed to the joint principles of both improving their aquifer, and generating new local economic activity that will continue aquifer repair into the future;
<i>pilot trials</i> :	a small scale test, or controlled experiment, of a new strategy wherein costs, benefits and unforeseen consequences can be better understood, and then applied in the light of new knowledge. (in Broken Hill's case, the emptying of the lakes was an uncontrolled experiment, without a backup <i>urban water supply</i> in place).
<i>self-funding aquifer repair</i> :	for this submission: a process whereby local community and enterprise fund repair of a failing aquifer;
<i>threatened aquifer</i> :	for this submission: an aquifer under threat of reduced valuation by a decision, process or development
<i>urban water supply</i> :	water supplies for towns and cities (for Broken Hill, this should have been protected as the highest priority within current best practice water resources principles of management – the MDBA ignored the risk)
<i>water security</i> :	the capacity of a system to deliver continuous, reliable supply
<i>water sharing agreements:</i>	recent Australian agreements between state and federal governments to redistribute water resources, sharing between environmental, agriculture, upper and lower river users.

Executive Summary

Australia faces major problems in water supplies, and this has recently generated increasing conflict and tensions. At the same time, new technologies in energy, irrigation, transport, desalination, viticulture, aquaculture and agroforestry, to name but a few, are generating new solutions for old problems.

These solutions need testing at a local aquifer level with safe, affordable *pilot trials*. Climate changes are a cyclical geological fact and our focus on sensible water reforms will be central to future prosperity. Sensible engineering investment in aquifers, driven by good research, is a needed reform.

Competing interests, uses and conflicts over aquifers, have led to emerging salinity and aquifer crises. “Fracking” and its attendant conflicts has raised the stakes and potential for both conflict and wasted effort in legal red tape. Strategies to meet these issues have driven an emerging legislative complexity that as a result risks obstructing progress. The Murray Darling shared water resource models, now show a willingness of Australian government, business and community to cooperate and change. That cooperation and how to foster it, is critical to success from change.

Proposed herein is a test model for *failing aquifers* involving local aquifer management including:

1. a pilot *Local Aquifer Trust (LAT)*, and
2. a related *Aquifer Construction Authority (ACA)* for that example aquifer;
3. engaging communities in developing a *local aquifer repair plan*, sequencing the enterprises needed for *self-funding aquifer development* ;
4. converting current enterprise to an LAT approved model that both grows new enterprise in scale, AND repairs the aquifer for the long term;
5. Constructing and testing pilot trials from generated new data.

The separate bodies of LAT and ACA arise because while the Management Trust may become permanent if successful, a Construction Authority would have a natural lifecycle ending after aquifer development, providing a body of expertise to move to other aquifers if required.

Major difficulties in improving Australian Aquifer management are widely identified:

- 1) lack of accurate specific knowledge and ongoing research data for a given aquifer;
- 2) A multitude of interested parties that can compete and paralyse progress;
- 3) limited opportunity to establish reasonably isolated case studies to inform future work
- 4) Lack of a clear set of priorities for a given aquifer;
- 5) Lack of income for aquifer management & development so that it is of neutral cost to the host state.

With an experimental pilot project, NSW could lead by example in Australia. A ***Lake George Aquifer Trust*** would apply the ideas in this submission. This aquifer is a *failing aquifer* isolated from others, controlled by one authority, with major potential for improvement.

Writer's interest

My interest in this topic comes from having grown up on the land, and my past studies in geology and engineering. I also now have a longstanding study interest in *computer-assisted bridging of knowledge gaps*, both in my profession as community GP, and in a general interdisciplinary science sense. Interdisciplinary studies are often a Cinderella of research work, yet topics such as Aquifer management demand inclusion of multiple disciplines.

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(further analysis of the example can be made available on request)

Format: pdf format is provided.

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Introduction

Drought affects us all at times, but whilst the urban Australian may experience water shortages, farmers and their families with livestock face bleak times. I grew up on the land, and experienced the effects of drought and failed irrigation projects on the family.

An essential need for any commercial breeding herd of cattle is to preserve the herd genetic base through drought. The herd represents many years of imported bloodlines, bull and cow purchases, observation and culling. Losing the nucleus of a herd in drought is a depressing disaster. Feeding stock is expensive, and small rotated irrigation supplementary grazing a farm saver. Tanks and troughs, pest and wildlife fence control, bores, pumps, theft, and dispatching a prized cow, are all part of the farmer's life. Failure of any one of these can mean the difference between making it to the next rains, or selling the herd.

Now a city dweller, I have for some years pursued a study interest in *computer-assisted bridging of knowledge gaps*, both in my profession as community GP, and in a general interdisciplinary science sense. The trigger for this interest, was treating a patient that displayed unusual response to treatment, outside the accepted model for her condition. This eventually proved to be a significant *knowledge gap* between basic biomedical research, and conventional medical practice. For many reasons this knowledge was not adopted by routine, accepted clinical practice.

One factor in this was some government policy dating back 40 years that was simply wrong. What the policy did not accept was the need to cope safely with *outliers-* or *unusual contexts*. Most rules and policies have exceptions, and it is a mark of our mastery of a challenge if we can recognize these and deal with them effectively. Water management exhibits similar features, with local community knowledge a likely key to reliable success. Ignoring the local's viewpoint risks needless failure, as at Broken Hill recently.

It is thus with interest I noted the NSW Upper House call for public submissions on water management, as part of a broader spectrum of Australian community focus on water. I reviewed some of the many relevant disciplines as an outsider, and generated the concepts in this submission, as a possible model to better engage communities in looking after their own water.

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Lake George Knowledge base for a pilot Aquifer management

Lake George is a large, shallow, old and isolated NSW lake without a surface drainage or aquifer outlet ⁽¹⁾. It used to drain into the Yass River via a valley exiting through Geary's Gap. The Lake was isolated by the thrusting up of the Lake George Range about 2 million years ago. About 20,000 years ago it is thought to have last overflowed into the Yass Valley during the last major wet period.

It has an area of about 160 sq Km when full, but regularly empties, and is 4 to 5 metres deep when full. There is about 150metres of sediment of three types in the lake bed, deposited since the lake was isolated. The upper fine clay and silt sediment layer (an *aquitard* ⁽²⁾) seals off the two lower gravel and sand layers. The geology is reasonably characterised by past studies. The Lake's filling and emptying appears adequately explained by a large shallow lake, high winds, small catchment, and absence of external drainage. The salt movement has been examined reasonably well in 1982. Multiple test bores exist because of general interest in what is one of the oldest lakes on Earth.

There is a band of high salinity about 10metres below the lake bed, maintained by a complex pressure interaction between the fresh water lake surface, and deep aquifer waters pressurized by recharge waters entering at the perimeter of the lake. This salinity band appears to be maintained by oscillation between a full and empty state. When empty it acts as a dry salt lake, with some of the salty deposit at the surface lost to wind-blow. The salt appears to be renewed by windblown precipitation from the sea to the East. The salinity of Lake George varies from fresh water when full, to greater than sea-level saline when nearly empty ⁽³⁾. Its Aboriginal name is Weerewa or : "bad waters" reflecting this feature as historical fact.

In 1902 a regular ferry traveled between Bungendore and Geary's Gap. Murray Cod were caught on the banks near Bungendore, and huge flocks of waterfowl were a regular feature for the inhabitants.

When full, the lake surface waters hold about 500 gigaLitres or 1 Sydney Harbour (*SydHar*). The gravel and sand *aquifer* ⁽³⁾ beneath the *aquitard* has a partially mapped salinity, but unknown volume and porosity. A rough estimate of around 100 gigaLitre is probable. (10km*10km *0.2 porosity *50m depth) with salinity between twice to a third of seawater. The upper *saline aquitard* is unlikely to participate in storage or yield.

Other community uses:

- There are no trees on Lake George as regular flooding and salt probably kills them.
- There is no building or agriculture establishment for similar reasons.
- There is no aquaculture (saline or fresh) or major irrigated horticulture (grazing poor quality salt affected grasses is the major use when the lake is dry)
- There are no recreational fisheries or hatcheries.
- Recreation is limited as fences prevent sailing and water sports, and the lake is often dry.
- Stunning morning views from Geary's gap and other observation¹ points along the Highway are a tourist attraction .
- There are a number of gravel and sand quarries near the lake's top water level.

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1. No proof of aquifer outflow to Yass has been found, but outflow is acknowledged as probably minor
2. An *Aquitard* is a non-permeable layer of strata that obstructs water flow in an aquifer
3. Since salinity varies widely over time, place and depth, there is insufficient detail for re-engineering.

Potential Participants

Nearby relevant parties and their interests that might be involved (not in order of importance) are:

• Bungendore township	(water limits urban amenity and town development)
• Collector	(limited water supplies and economic development)
• Palerang Shire Council	(local government- to merge with Queanbeyan Council)
• Lake George Wineries	(possible expansion, reliability of supply and cost)
• Yass valley settlements and agriculture (wineries)	saline, poor water supply,
• Yass Township and Murrumbatemen water supplies	poor water supplies(weir and bores)
• Burrinjuck dam flood mitigation, irrigation MIA, water sports	(may improve water control, add to storage, seasonal flow)
• NSW Water	(State administrative authority for lake)
• Graziers who graze animals on the dry lake bed	(improve fodder, water, stocking rates)
• Local Landcare groups	(grassroots enthusiasm for restoring environment)
• Canberra – ACTEW water supply, dams and lakes	(adequate supplies – until 2030 – limited storage options)
• Queanbeyan and Googong	(adequate supplies)
• Gunning & upper Lachlan	(poor water quality, limited)
• Goulburn	(water (poor) supply secured by pipeline)
• Wind Farm to east of Lake George	(unrestricted wind precinct)
• Lake Bathurst and Taralga	(may have some water -use interaction potential)
• University of NSW (Defence school), Canberra University, ANU, Wollongong University	(research and student courses)
• Current Lake enterprises	(gravel & sand, bore drilling, developers, gardeners, tourism and others)

Nearby River systems include:

1. Yass River
2. Queanbeyan and Molonglo Rivers
3. Goodradigbee and Murrumbidgee
4. Shoalhaven

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Some Questions for a Lake George Aquifer Management Trust

Realistically the issue is too complex to address in this submission, however a simple provocative approach may illustrate some themes. These are the type of questions needing exploration:

- Can any part of the lake be safely rendered a permanent freshwater waterway ? If so which part(s) ?
- Can any part of the lake be safely rendered into a saltwater waterway ? Which parts? Would a tidal flow /filling pattern be desirable or possible ?
- Can any treatment of the underground aquifer render it safe for high quality freshwater storage ?
- Can the lake waters be used to stabilize the Yass Valley water flows ?
- Can any part of the lake be isolated for fresh water fishery and aquaculture ?
- Can any part of the lake be established for salt harvesting ?
- Can any part of the lake be used for a solar farm(s) and related electricity infrastructure ?
- Can any new permanent freshwater wetlands be established to purify part of the lake waters ?
- Is there any external source of water that could be used to render the lake permanently filled or partly filled? If so from where ?
- What income can be derived in the medium term for development and aquifer management ?
- What sources of establishment investment loans could be sourced for a new water bank ?
- What prospects for bypass storage of ACT or Googong excess water exist ?
- What raw materials to seal any western edge canal are available for construction ?
- What monitoring system would be required for the Yass River if supply to Yass occurred ?
- What period would the pilot trial run for?
- What flow rates could be practical ?
- Where would the fresh water to pump be sourced from ?
- Where would the energy come from for pumping ?
- What treatment to a level of potable or irrigation supply for Lake George water would be required to Yass, Collector, Bungendore or Canberra ?
- How can infrastructure be concealed from affecting the views of Lake George ?

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Some Answers to be explored.

These have emerged from review of the knowledge gaps in a diversity of disciplines, and querying new knowledge found :

- 1) **Can any part of the lake be safely rendered a permanent freshwater canal or waterway? If so which part(s) ; PROBABLY:** eg. if some of the lakes South-western shore-water is converted to a lagoon and fresh water is sourced from the lake surface when full, or retrieved from a repaired stored deep aquifer when empty, and/or external flow from other catchments.
- 2) **Can any part of the lake be safely rendered into a saltwater lagoon? Which parts? Would a tidal flow or filling pattern be desirable or possible/? PROBABLY:** but some economic benefit would need to be enabled. The lake bed structure is suited for isolation of a sea level saline pond with its *aquitard*, but mixing of surface and deep waters occurs at the lake-shore;
- 3) **Can any treatment of the underground aquifer render it safe for high quality freshwater storage? PROBABLY- BUT IT DEPENDS ON COST:** if it is pumped out and replaced by fresh water from a diversity of sources it is likely to be partly maintainable as a freshwater source – proof of this would need pilot controlled trials.

- 4) **Can the lake waters be used to stabilise the Yass Valley water flows ? POSSIBLY:** pumping over Geary's Gap to restore what was an historic flow pattern would require a 37 metre lift into the Yass River Valley. The energetics of this seem possible, for flow rates that would change the Yass River Valley, and permanently stabilize supplies. A pulse flow regime supply of say 100megL/day would be significant (36gigL pa) Sourcing this in drought times may be from a repaired deep aquifer. A seasonal flow itself would be useful.
- 5) **Can any part of the lake be isolated for fresh water fishery and aquaculture? YES:** freshwater fishery could be part of creek outlet lagoon developments. Aquaculture areas may be a spin-off nearby but they may have different requirements. A circulation of water into a wetlands would be one solution potentially controlling both pollution and turbidity (but not salinity).
- 6) **Can any part of the lake be established for salt harvesting? YES:** Lake George has large reserves of ancient salt in the saline *aquitard*. Any parts of the lake bed with sealing aquitard are likely to be suitable and shallow ponds there could be set up to evaporate salt. Wind control by trees and windbreaks may be required.
- 7) **Can any part of the lake be used for a solar farm (s) and related electricity infrastructure PROBABLY:** a small part of the flat dry lake bed is a good starting point. Permanent control of flooding with levees , and drainage with pumps would be required. The levees could hide these from lakeside view.
- 8) **Can any new permanent freshwater wetlands be established to purify part of the lake water YES :** if a flow is established by pumping with a gradual drop a series of wetlands could be established. These would require permanent level control to prevent prolonged flooding.
- 9) **Is there any external source of water that could be used to render the lake permanently filled or partly filled? If so from where? POSSIBLY:** Googong, Queanbeyan and Molonglo rivers, and Cotter via Googong, Shoalhaven, however none appear likely as each would involve major infrastructure, and some quid-pro trade off for the construction;
- 10) **What income can be derived in the short, medium and long term for development and aquifer management ? UNKNOWN BUT SIGNIFICANT:**
- a) this question is an early basic function of a local aquifer management trust
 - b) expansion of wineries with related tourist presence of the LGAT could generate increased economic activity- these are established enterprises;
 - c) A fresh water lagoon at a creek outlet with bores, may have potential for water sales to Bungendore and to fully cater for its planned growth (currently over-committed).
 - d) the activities could generate significant tourist interest. A tourist centre with displays, tours, info, and participation would be an early part of the project ;
- 11) **What establishment loans could be sourced for LAT developments? UNKNOWN:** secured infrastructure loans by the future water bank income may be a target (if pilot trials are successful). The two likely freshwater water-banks are of around 500GL surface and 200GL (deep -including creek aquifers) with full repair and control of both.
- 12) **What prospects are there for freshwater bypass storage of ACT or Googong water into Lake George? UNLIKELY:** The ACT now has an underground pipeline linking Murrumbidgee water to Googong dam. Pipelines can also deliver Cotter water to Googong. A pipeline could deliver from Googong catchment into the southern Lake George Catchment and this would

increase the flow to Bungendore and improve the quality of water entering the lake. Benefit for the ACT would need to be in some sort of economic activity (eg share of the output for a large solar farm, or return of water from the upper Yass Valley to Lake Gungahlin, or additional potable water storage to the East of Canberra). ACTEW delivers to Canberra expensive water and further high cost infrastructure or change to volume markets seems unlikely. ²

13) **What raw materials to seal any western edge ponds are available for construction? PROBABLY LOCAL;** the aquitard upper silt/clay layer is likely to be good starting point, additional gravel/rock fill would be available at nearby quarries (Sutton or Lake George Range). Additional clay to seal may need to be sourced somewhere off the lake bed;

14) **What monitoring system would be required for the Yass River if water bypass/supply to Yass occurred MAJOR CHANGE:** A lack of historical data was identified as a critical issue in the report on Western Palerang water in 2012 ³. A system is needed of new monitoring and production bores, together with some key flow monitors. The bores should enable saline monitoring, level, and draw down behaviour. They could be the basis for selected irrigation activities in the Yass Valley. Joint ventures with landowners may be a possible start up model.

15) **What period of time would a pilot project run? 5 to 10 Years for interim reporting;** 25 years would be a reasonable time frame as infrastructure construction does not occur overnight. A staged approach may work, and annual report of water volumes, quality, income and research to parliament would be required. Published external auditor reports on a water bank operation would be needed regularly.

16) **What flow rate would be practical into the Yass valley? UNKNOWN;** but even a relatively small flow rate may provide major benefits to

- a) Yass water supply,
- b) Yass river salinity control
- c) Yass Valley viticulture
- d) a small number of rural developments that would not otherwise occur due to lack of water.
- e) Tourist interest in Lake George and Geary's Gap projects.

17) **Where would the fresh water be sourced from SURFACE** water when LG is full, possibly a repaired deep aquifer when LG is empty, and possibly a South-West lake edge lagoon.

18) **Where would the energy come from for pumping and desalination? SOLAR FARM(s)** are likely, as there are potential tradeoffs and interested parties that may invest. Grid power or the Eastern Lake George Wind Farm would be other sources.

19) **What treatment to a level of potable supply for Lake George water would be required to Yass, Collector, Bungendore, Canberra, VERY LITTLE** when LG is full for surface water source; When LG is near empty, surface water is not suited to export, but deep aquifer may be a source.

20) **What opportunities to conceal any infrastructure from effect on the vista of Lake George ? TREES and DYKES** could conceal low lying infrastructure. Solar arrays could be sunk below horizon if a guaranteed sub-lake drainage is locally established with fail-safe pumping.

² The Murrumbidgee to Googong Pipeline, Cotter dam expansion, and Googong Dam Spillway cost cost around \$605 million with a modest increase in ACT water reserves (a population of 500,000 by 2050 will need more).

³ Water resources of the western catchments of Palerang Local Government Area: by Sarah Beavis

Some visible presence of the activities would probably be acceptable, but the preservation of a vista would be a foundation priority.

21) **Is it possible for the whole of Lake George to be maintained as a permanent freshwater lake ?** **NOT WITH THE CURRENT CLIMATE:** unless external freshwater is bypassed from another catchment. The evaporation rate of around 50" pa exceeds the 25" rainfall.

22) **Is it possible to maintain part of Lake George as permanent freshwater lake?** **YES** – with basin segmentation and a graduated retreat into the freshwater zones probably around the creek outlets, plus selective desalination, permanent surface fresh water is possible. The cost of the various strategies and their benefits, is unknown, but is central to a role for *Lake George Aquifer Trust*.

DISCUSSION AND CONCLUSIONS:

The accompanying Appendices contain more detailed aspects related to the above. These are a speculative set of views, however they emerge from examination of the current knowledge base on Lake George, and new ideas from multiple disciplines affecting aquifer practices. Many prospects that might have seemed fanciful a few years ago, now to me seem inevitable.

Counter-intuitively, future change might bring some major surprises: Bungendore may need to water its gardens daily from surface waters when the lake is above 2 metres; “Lake Bungahlin”⁴ might save the town's water quality for good; the Turallo Creek wetlands experiment may need extension along the creek's entire course, and Bungendore Gravel may need to dig much bigger holes for a future Bungendore Lagoon.

Accurate, cheap data gathered from our waterways and aquifers, will become ubiquitous, real-time and web-distributed. Transferring clean water between catchments for long term freshwater underground storage will become reality, and regional cooperation more precise and fruitful.

An empirical approach to this and other proposals before the Upper House is probably deserved. Such pilot trials need to include local communities, enterprise and government , with relevant oversight by expert disciplines. Lake George is unusual, in that it: i) does not participate in the Murray Darling Basin, ii) has a large salt-damaged aquifer that is probably repairable; iii) nearby significant population of Canberra paying high water prices, and iv) nearby established Wineries with limited water supplies. It has negligible current value in its aquifer,⁵ and resources to repair it.

Broken Hill's recent experience suggests local communities cannot trust remote, complex government processes to deliver town or agriculture water security. All local councils probably need at least a liaison officer at the *Local Aquifer Trust*, to communicate and listen effectively

In my view the mechanisms for such long term local co-operation needs to be fostered and tested by the NSW Parliament. Some form of aquifer-wide, long term local management is needed. Even if this is locally funded, encouragement alone from the Parliament itself may suffice for a self-organizing community driven, *Local Aquifer Trust*.

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4 A web-propagated cynical local term for a Gungahlin-like lake development in Bungendore

5 At *aquifer valuation* $100 \times 10^6 \times \$3$ to desalinate directly + borewater supplies : around -\$300 million.

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www.groundwater.com.au/.../Groundwater%20movement%20in%20heterogenous%2... Ander Guinea,
3. *Aquitards | UNSW Connected Waters Initiative*
www.connectedwaters.unsw.edu.au/research/projects/aquitards Timms WA; Crane R; Anderson DJ; Bouzalakos S; Whelan M; McGeeney D; ... the Southern Liverpool Plains, New South Wales - implications for groundwater ...
4. *NSW government threatens \$1 million fine in ... - Canberra Times*
www.canberratimes.com.au > News > ACT News Nov 6, 2015 - "Previously stripped bare of vegetation and ravaged by gully erosion, "The Gib" now has a green ribbon along *Turallo Creek* from leaky weirs ...
5. *Rehydrating the Floodplains: Turallo Creek Open Day | Murrumbidgee ...*
murrumbidgeelandcare.asn.au/node/2903 Time: 10.00am - 3.00pm. Visit *Turallo Creek* where it runs through The Gib property and see a holistic farm ... *Canberra Urban & Regional Futures Seminar*
6. *Sustainable Diversion Limit Adjustment Mechanism | Department of ...*
<https://www.environment.gov.au/.../sustainable-diversion-limit-adjustment-mechanism> The Basin Plan's Sustainable Diversion Limit (SDL) adjustment mechanism ... The SDLs are set for each catchment and

aquifer, as well as the Basin-wide ... Instead the SDLs represent limits on average water diversions over the long-term.

7. [Enlarged Cotter Dam water security project - Independent Competition ...](#)
www.icrc.act.gov.au/wp-content/uploads/2013/.../Report_9_of_2010_June_2010.pdf ICRC independent competition and regulatory commission Final Report Enlarged Cotter Dam Water Security Project Report 2010 by EC Dam – 2010
8. [Code of Practice for Aquifer Storage and Recovery – EPA](#)
www.epa.sa.gov.au/files/4771454_cop_aquifer.pdf Web site: www.epa.sa.gov.au *aquifer* aquitard artesian *aquifer* storage and recovery (ASR) 4771454_cop_aquifer.pdf
9. Climatic influence on shallow fractured-rock groundwater systems in the Murray–Darling Basin, NSW [Climatic influence on shallow fractured rock groundwater systems in the Murray-Darling Basin ...](#) www.environment.nsw.gov.au/resources/salinity/09108GroundwaterMDB.pdf by A Rančić - 2009 - Related articles
10. Department of Environment and *Climate Change NSW* (DECC). 2 School of of rainfall time series based on *hydrologic* analysis of *Lake George* levels.
11. <http://www.wrl.unsw.edu.au/centrifuge-permeameter> Centrifuge Permeameter - Water Research Laboratory - UNSW Australia www.wrl.unsw.edu.au/centrifuge-permeameter The Water Research Laboratory *centrifuge* permeameter facility constructed for the National Centre for Groundwater Research and Training (NCGRT) is one of ...
12. <http://www.water.nsw.gov.au/water-management/law-and-policy/national-reforms/murray-darling-basin-plan> The Basin Plan for the Murray-Darling - NSW Office of Water www.water.nsw.gov.au › *Water management* › *Law and policy* › *National reforms* An *SDL* adjustment mechanism is included in the *Plan* which potentially allows for ... Inland NSW makes up the largest proportion of the *Murray-Darling* Basin.
13. BULK WATER ALLIANCE - ACT Auditor-General's Office <http://www.audit.act.gov.au/auditreports/reports2015/Report%20No%206%20of%202015%20Bulk%20Water%20Alliance.pdf> Jun 24, 2015 - *reports* the results of the audits directly to the *ACT* Legislative *ACTEW's* selection of alliance contracting for the *water security* projects .Water security for the ACT projects
14. Botany-Sand-Beds-aquifer.htm modified: 2016-04-24 15:44:24, size: 68249 bytes [Botany-Sand-Beds-aquifer](#)
15. [floodplain_harvesting_policy.pdf](#) [floodplain_harvesting_policy](#)
16. Measurement of aquifer storage change and specific yield using gravity surveys_951561681_Arizona.PDF [Measurement of aquifer storage change and specific yield using gravity surveys_951561681_Arizona](#)
17. The Importance of Overbank Deposition on a Floodplain Adjacent to a Filling Reservoir_krallaguposterlatest.pdf [The Importance of Overbank Deposition on a Floodplain Adjacent to a Filling Reservoir_krallaguposterlatest](#)

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QUOTES WORTHY OF REVIEW.

===== 1. Cotter to Googong

<https://www.iconwater.com.au/Community-and-Education/Our-projects/Other-Projects/Cotter-to-Googong-Bulk-Transfer.aspx>

"Cotter to Googong Bulk Transfer

In April 2005 Icon Water began work to implement the Cotter Googong Bulk Transfer program, an innovative way of utilising existing infrastructure to increase the ACT's water supply in the immediate future. The scheme has been operational since 2005/06.

Icon Water developed the scheme during its comprehensive study of Future Water Options that was completed in early 2005. The scheme works by drawing water from the reservoirs in the Cotter Catchment, treating it at the Mt Stromlo Treatment Plant and after meeting town demand, using the largely existing water supply distribution network to transfer surplus water to the Googong Reservoir — up to 150 Megalitres per day."

<https://www.iconwater.com.au/Community-and-Education/Our-projects/Other-Projects/Lower-Molonglo-Augmentation.aspx>

"The Murrumbidgee to Googong Pipeline cost \$140.5 million, less than the final estimated cost of \$154.5 million and was overdue by three months. And the Googong Dam Spillway cost \$54.0 million, less than the final estimated cost of \$56.0 million and was overdue by eight months. The combined cost of the three projects cost \$605 million, an increase of 5.5 per cent over the combined final budgeted costs.

It involved the construction of a pipeline and associated infrastructure to facilitate the transfer of up to 100 megalitres of water per day from the Murrumbidgee River, through a 12 kilometre underground pipeline to Burra Creek in NSW. The water would then flow approximately 13 kilometres along Burra Creek into the Googong Dam."

===== 2. Yass

"Table 1. Reticulated water sources, Yass Valley Local Government Area, July 1999 to June 2004

Source of reticulated water	Town or village supplied	Capacity	
		1999–2000	2003—04
Yass dam	Yass, Bowning and Binalong	875 ML	876 ML
Murrumbateman bore	Murrumbateman	3.5 L/sec	3.5 L/sec

ML = megalitre; L/sec = litres per second; Source: Yass Valley Council

How much water was available?

The Yass dam level dropped in the summer months from the end of 2001 to a low of 58% in February 2003 and 64% in May 2004 (see Figure 1) when about 550 megalitres of water were available. The fullness of the water supply reflects climatic variability and the amount of water used.

Figure 1. Percentage fullness of Yass Weir, July 1997 to June 2004

Graph showing that there were more level 2 water restrictions in Gunning in 2002-03 than in other years in the reporting period. Source: Yass Valley Council"

3. Lake George-Yass (salt dust, levels)

Getting to the bottom of the Lake George mystery – smh.com.au

<http://www.smh.com.au/articles/2002/11/29/1038386313869.html> [www.smh.com.au](#) › Home › "National News" › The Big

Dry Nov 30, 2002 - The draining of *Lake George*, says government ecologist Justin

Getting to the bottom of the Lake George mystery

By James Woodford

November 30 2002

"It is the perfect time to fathom the depths of the enigmatic and spectacular Lake George.

For the first time in nearly 60 years the 25-kilometre long and 10-kilometre wide lake, beside the highway near Canberra, is absolutely bone-cracking dry, navigable by motor car from one end to the other and generating clouds of dust storms.

.....

This time there is not a drop."

4. Water Prices Canberra

<https://www.iconwater.com.au/My-Home/My-account/Pricing-and-your-Customer-Contract/Residential-waterprices.aspx>

2016 "ACT residential water prices

A summary of our standard water prices can be found below.

Standard charge Cost

Supply fee (\$/year) \$101.14

Usage rate (\$/kL) Based on average daily usage in billing period

- For the first 0.548 kL/day \$2.60
- Thereafter \$5.22 “

5. Water Prices Sydney uses a primary and recycled water areas

<https://www.sydneywater.com.au/SW/accounts-billing/understanding-your-bill/our-prices/index.htm>

“ If you have a meter, you pay for the amount of water you use. If you're in a recycled water area, you'll also pay for the recycled water you use.

Usage 2014 - 2015 charge 2015 - 2016 charge

Your water usage \$2.232 a kilolitre \$2.276 a kilolitre “

6. Water Prices Melbourne

<http://southeastwater.com.au/Residential/Pages/WaterPricesCharges.aspx>

“ Melbourne Water Usage Charge

Tier 1 for the first 440 litres of water usage per day \$2.5877 per kilolitre

Tier 2 for water usage above 440 and up to 880 litres per day \$3.1426 per kilolitre

Tier 3 for water usage above 880 litres per day \$3.7494 per kilolitre “

7. Water Prices Palerang

<http://www.palerang.nsw.gov.au/council/council-documents/fees-and-charges/fees-and-charges-2015/16>

“DETERMINATION OF USAGE CHARGES 6.1

Pricing Structure 2013-14

As part of its annual budgetary deliberations Council shall determine the fee scale for the sale of water through its connected reticulation network. This may include a tiered structure.

For the 2013/14 financial year Council's fee structure is as follows (all schemes):

\$2.08/kL ≤ 200 kL annually

\$3.28/kL > 200 kL annually

The 200 kL threshold is not applied equally across each quarter but cumulatively throughout the billing year."

8. West Palerang Water Futures Report Series 2012.

1a water report June 2012 part 1 main report p1-62.pdf

Water resources of the western catchments of Palerang Local Government Area: a report to

Palerang Shire Council : Sara Beavis Fenner School of Environment and Society, Australian National University, Canberra. Main report p1—62. Report prepared for Palerang Council June 2012

" Spatial and temporal variability of flow regimes

Lake George is a terminal system with surface water inflows from Collector Creek in the north; Allianoyonyiga, Taylor and Butmaroo Creeks in the east and Turallo Creek from the south. The only stream gauge for this catchment is located on Butmaroo Creek immediately adjacent to the Kings Highway. Within the other relevant catchments of the Palerang LGA, gauging stations are located on the Yass, Molonglo and Queanbeyan Rivers as well as Burra Creek which is an important tributary of the Queanbeyan River (Figure 7). "

.....
"When the data at a sub catchment scale are examined, the implications of farm dam development on surface water diversions become especially apparent (Table 6). The highest density of dams occurs in the Burra/Googong and Upper Yass subcatchments, associated with rural residential development."

9. "THE GEOCENTRIFUGE

UNSW "A new geocentrifuge commissioned by the National Centre for Groundwater Research and Training is one of only two of its kind in the world, and is used for assessing porous materials including geological core samples. Located at the University of New South Wales, the geocentrifuge acts as a sort of environmental time machine — by speeding up gravity to about 550 times normal, the geocentrifuge accelerates water movement through core samples. Centrifugation can directly address questions about subsurface flow at scales that are not otherwise possible, simulating thousands of years within weeks or months."

10. SDL Sustainable Diversion Limits

<http://www.water.nsw.gov.au/water-management/law-and-policy/national-reforms/murray-darling-basin-plan>

"Sustainable Diversion Limit Adjustment Mechanism

The Basin Plan's Sustainable Diversion Limit (SDL) adjustment mechanism enables the Basin-wide SDL for surface water (10 873 gigalitres per year) to be changed up or down by no more than five per cent, as long as environmental, social and economic outcomes are not compromised. "

.....
SDLs are long-term averages - - - -

SDLs are not fixed amounts. Instead the SDLs represent limits on average water diversions over the long-term. The actual limits on water use will vary according to water availability in that year, in line with State water resource plans. This ensures sufficient flexibility to adapt with Australia's highly variable climatic conditions.."

11. Volume 78, Oceans and Atmospheres Pages 6341–6353

Coupled salt and water flows in a groundwater basin

Authors James A. Greenberg, James K. Mitchell, Paul A. Witherspoon

First published: 20 September 1973 Full publication history

DOI: 10.1029/JC078i027p06341

“Abstract

The postulates of irreversible thermodynamics and the law of conservation of mass were combined to yield two simultaneous partial differential equations describing the simultaneous transient-state flow of salt and water in fine-grained sediments. Chemico-osmotic coupling may induce a small chemico-osmotic consolidation of the aquitard (0.3mm) over a period of about 25 years, but the aquitard should act as an effective pollution barrier to the movement of NaCl into a freshwater aquifer below. “The ‘tightness’ of the aquitard to salt movement depends mainly on aquitard thickness, hydraulic permeability, and drawdown in overlying and underlying aquifers”.

12. New model of water flows under pumping

FROM : Guinea, A, Timms, W, Hartland, A, Acworth, RI, 2013 under review, ‘Hydrogeological processes in a clay dominated alluvial deposit, Hydrogeology Journal National Centre for Groundwater Research and Training

"New model of water flows under pumping

Ander Guinea, an NCGRT postdoctoral fellow at the University of New South Wales, has been studying whether there is indeed sometimes significant water movement in a variety of directions due to pumping. - - - - "

classical layered concept of aquifers and aquitards, where the movement of water is limited. These results show that this traditional model can be applied to some regions.

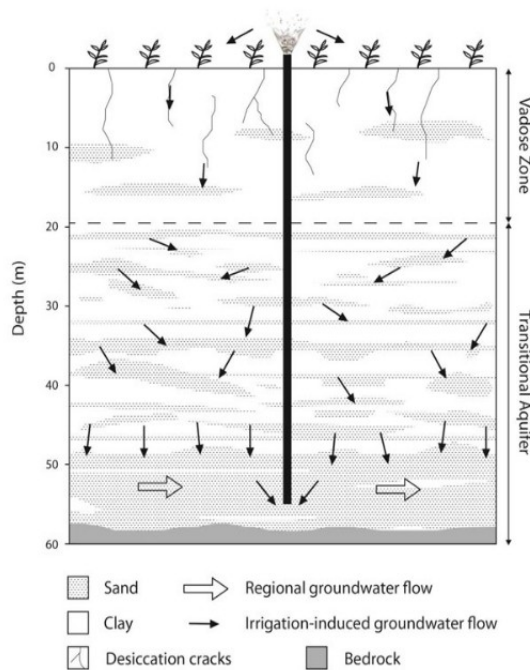
However, his results from Breeza show that some clayey groundwater systems respond quickly to changes in pressure – both lowering in response to pumping and recovering when pumping ceases. This suggests that water is able to move through this system.

At this highly heterogeneous site, the classical model of confining clay aquitards does not work well.

Ander has proposed a new conceptual model for this type of landscape, as seen in the diagram to the right, where water moves in a variety of directions but with a delayed response to groundwater pumping.

THE IMPLICATIONS

This research underscores the importance of understanding the mechanisms at work in any particular location, and that well-established models may not always be appropriate. In particular, this research shows the importance of



www.groundwater.com.au/.../Groundwater%20movement%20in%20heterogenous%2

"Ander has proposed a new conceptual model for this type of landscape, as seen in the diagram , where water moves in a variety of directions but with a delayed response to groundwater pumping."

13. The Basin Plan for the Murray-Darling

<http://www.water.nsw.gov.au/water-management/law-and-policy/national-reforms/murray-darling-basin-plan>

"The Basin Plan for the Murray-Darling

The Basin Plan was signed into law by the Commonwealth Parliament in November 2012.

Overview of the Basin Plan

The Basin Plan includes enforceable limits on the quantities of surface water and groundwater that can be taken from the Murray-Darling Basin.⁶ The sustainable diversion limits (SDLs) are set initially at 2,750 gigalitres less than current diversions in the rivers. This is to be achieved by 2019 with the water being recovered by the Commonwealth to provide additional water for the environment.

An SDL adjustment mechanism is included in the Plan which potentially allows for some 650 GL of environmental outcomes to be delivered through improved use and management of environmental water rather than recovery of water. The Basin Plan also allows for additional 450 GL of water to be recovered by 2024 potentially increasing the water recovered for the environment to 3,200 GL if operational constraints in the system are removed. There is to be no social or economic impact on regional communities through recovery of the additional 450 GL"⁷

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⁶ Lake George is not a hydrogeological part of the Murray Darling Basin (except via bedrock aquifers)

⁷ Broken Hill citizens are never likely to believe this assertion in the future.

One key issue for Lake George water management is the salt-filled *aquitard* below the lake waters, a 50m thick water obstructing layer of clay and silt, that is full of salt. For this aquifer, it is proposed that experimental knowledge could progress with pilot projects that meet three basic criteria: a) yield improved ongoing data, b) improve waters above and below ground, and c) generate new economic activity. Where successful these could be multiplied to a larger scale.

Aquitards are more complex than once thought, with new concepts emerging from research into the aquifer effects of *fracking* for natural gas.⁸ The potential value in converting Lake George to a freshwater body is large, with establishment of a permanent freshwater lake body of around 1 SydHarb, and a converted freshwater under-lake and creek aquifer of as yet unknown volume.

Dry time access to the under-lake aquifer could drought proof land around the lake's perimeter. Some of that water could be made available for the Yass valley and Canberra in periodic dry times (via Geary's Gap). A permanent change in *Sustainable Diversion Limits ("SDL")* for the Lake George basin would result if supplementary water was transferred from other catchments.

Knowledge Base

1. Aquitards transmit water and salt slowly, hence there is interest in how to keep the current salt in the aquitard away from the mobile waters of the lake proper, or the aquifer below the aquitard. Recent proposals for different models have recognised that many underground water storage aquifers are not as simple as a sheet like layer structure as traditionally modeled, but the upper large LG aquitard appears to be simple large and thick (around 50metres). *"The 'tightness' of the aquitard to salt movement depends mainly on aquitard thickness, hydraulic permeability, and drawdown in overlying and underlying aquifers"* (quotes P.18)
2. Samples of the Aquitard drilling cores were taken by the BMR in the 1980s and may be now testable with new technology.⁹
3. Caution is obviously required: *"Clay-rich sediments must be managed to prevent release of salts that have been deposited and accumulated over geological time."*¹⁰
4. Pockets of lower aquitards are thought to lie within the lower two formations of the aquifer: *"a new conceptual model for this type of landscape,where water moves in a variety of directions but with a delayed response to groundwater pumping."*^{1,10}
5. Lake George Alluvium SDL area has a potential water use of 1.2GL/year (Total 2007/2008 Entitlement*). Total Current Use is 0.23GL¹¹. Sub lake aquifer volume is unknown but probably around 1-200GL, with a drought draw down of an unknown value pa from the water bank.
6. Storage of significant volumes in the valleys of feeder creeks is now understood to occur by raising the water tables, and delaying outflow (as per Turallo Creek experiments)¹². The volume is not measured, nor saline improvement in water quality documented due to the absence of flow gauging¹³
7. There is a high concentration of salt about 10metres below the lake bed, thought to have occurred because of a balance between lake water pressure from above, and aquifer pressure below.¹⁰

8 Hydrogeological processes in a clay dominated alluvial deposit, Hydrgeology Journal National Centre for Groundwater Research and Training Ander Guinea

9 The Geocentrifuge National Centre for Groundwater Research and Training University of NSW

10 Liverpool Plains aquifer research

11 See Murray Basin SDL risk assessment for the Lake George basin

12 The Canberra Times Turallo Creek conflict

13 Palerang Shire Water report 2012 ANU

Knowledge Gaps.

1. What isolation of the lake surface waters from the aquitard, is needed to limit salt transfer upwards into the lake bed surface? (probably nil provided the lake water is kept above 2 metres)
2. What depths would be suited to pump out the aquifer below the aquitard creating a part of the aquifer that is fresh? (unknown however the under-lake aquifer waters and salt appear ancient ¹⁴)
3. What is the aquitard's *hydraulic resistance* under different conditions? (unknown but testable ¹⁵ - in practice it is likely to be dynamic testing by pump-down and monitoring levels and salt);
4. Where are the aquitard edges and what difference does this make? (The aquitard is thought to leak around the perimeter of the lake bed)¹⁰
5. Can brine be re-injected into the Aquitard to dispose of desalination byproduct? (probably not, as *fracturing the aquitard* is a risk inversely dependent on its *plasticity* ¹⁶)
6. What potential enterprises could use the saline aquifer waters? (mariculture, saline aquaculture, evaporation pond salt production,
7. What methods are there for desalinating the lake bed to rectify the topmost soils to enable agriculture when the lake is dry ? (saline species plantings, pond isolation of small test areas, maintaining periodic fresh water over the test lake bed, -advice from Holland about successful past practices of sea bed reclamation for agriculture could be a source of practical strategies.)
8. How long would it take to convert Lake George and its aquifer to fresh water? (Unknown but probably in the region of 2 years for partial pockets of conversion, with an eventual time scale of possibly 20 years dependent on aquifer behaviour from data tests).

Ongoing Data needed in operation.

1. As the *saline aquifer* is pumped out and replace with fresh water, data from bore water salinity and volume with aquifer levels would be required;
2. a one off solution for the initial saline load needs to be found, and then after that a solution for probably around 30kg/hectare/per year of the total catchment salt loading ¹⁷
3. Periodic water testing for continual supply, and estimates of total aquifer filling from bore levels.

Conclusions.

Whilst ignoring the aquifer and merely keeping Lake George surface waters fresh by external catchment supplementation could work, in times of drought a reserve freshwater storage in the *aquifer water bank* would remain a reasonable ambition. Such a project would be major and must be based on known aquifer and aquitard behaviours, or it risks failure. Removing salt from the upper few metres of the lake bed is probably a prerequisite to any such change, and this would require testing of the lake bed behaviour via small isolated ponds, a freshwater source and drainage method trials.

Monitoring and control of the rate of salt loss under the aquitard would be required, however this is likely to be small once the initial process occurs, as the salt appears to have accumulated over 2 million years. Overall pressure maintenance of fresh water recharge into the aquifer to keep the system balanced at the 10m aquitard high salt mark would be required to keep the salt stationary.

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14 Water levels, balance, and chemistry of Lake George, New South Wales G. Jacobson & A. W. Schuett 1979

15 The Geocentrifuge National Centre for Groundwater Research and Training University of NSW

16 Contaminant Transport Through Aquitards: Technical Guidance for Aquitard Assessment K.R. Bradbury et al Awwa Research Foundation

17 Groundwater and surface water interaction at Lake George, New South Wales G. Jacobson I, et al 1991

The recent new bore for Bungendore's water identified future potential at Butmaroo Creek.¹⁸ Whilst both areas are unproven in *Aquifer Storage and Recover* ("ASR") behaviour, there are likely methods to develop the aquifer consistent with current principles of best practice for ASR.¹⁹ The \$1m works improved Bungendore's water security, added recycled treated effluent irrigation to Bungendore Oval, and *partly* provided for future and committed urban growth.

The bore pump down behaviour and salinity data suggest a sustainable flow rate from the new bore of 1.2L/sec. The market for the water is high \$/litre, although not as high as ACTEW water charges in Canberra.²⁰ Assertions as to sustainability of the new bore are currently based on aquifer models not *long term full aquifer data*, and remain open to criticism that catchment behaviour may not be as assumed. The absence of *halocline* and *aquifer level* data up the catchment is the same problem identified for much of the region.²¹ The data needed are long term aquifer pump down levels and salinity levels from multiple bores, to adjust water and salt flow models to guide aquifer use.

Consider now a different model of aquifer testing, for further securing Bungendore's water. If we add a number of bores both upstream and downstream to the lake, and link the most saline bores to a modular desalination unit, we should have both permanent water security, and gradually reduce the salinity of the aquifer under Bungendore. The brine bypass could be used to pilot a salt farm or saline aquaculture, or pumped to the lake. Energy cost is the major issue at around \$3-\$4 per kLitre, however if a low cost secondary supply fit for gardens and small scale agriculture is implemented, this may offset costs by increasing demand and a providing secondary income stream.

Irrigation with brackish water is possible as the MIA experience shows, allowing further bores to be brought into action, as the local aquifer loses salt. If we take this further, and convert more of Turallo creek upstream to leaky weirs or a lake, we may increase the total fresh water stored around Bungendore for dry times. When demand is low, recharge of fresh water into brackish bores could occur. When Lake George is above 2 metres, pumping fresh water direct from the lake into the aquifer around Bungendore would further lower the salt levels.

Such a project would need data on both *pump-down* and *aquifer recharge* behaviours, together with salinity movement - the *halocline changes* (variation in salt levels). Enterprise around Bungendore could include swale based trees and wetland, public access to freshwater foreshore, irrigated forest plantation, irrigated fodder, irrigated vine crops and horticulture. Some of these enterprises have well-understood economics, but their co-location needs to provide *comparative advantage*. The scale of each joint venture activity would depend on the results, with only small pilot studies for long term enterprise, changing the mix according to results.

Similar to Bungendore's growth, until better data exist for pumping, aquifer behaviour cannot be presumed. What can be presumed is at minimum, a large supply of *brackish water*. Desalination plants could rectify this, however the long term cost of the water is critical to enterprise viability. Real benefit of the above could be a partial restoration of *Bungendore Billabong* for water -based enterprises, urban amenity and recreation, and a renewal of Bungendore as the best-watered Gardening Town of the Region.

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18 Final report into Bungendore Water supply enhancement 2012

19 See: South Australian principles of best practice in Aquifer Storage and Recovery

20 ACTEW charges are now around \$5 /litre over a nominal consumption -see ACTEW website

21 See ANU water resources report to Palerang Council 2012 Sara Beavis

Geary's Gap Wetlands and Visitor Centre

For Lake George, the three equal needs from demonstration projects are: 1) to yield ongoing data, 2) to improve the surface and aquifer waters, and 3) to generate new economic activity. Thus some effort spent on the potential at Geary's Gap would be worthwhile. Creation of a new wetlands along the base of the Lake George Range both North and South of the *Anderson VC Rest Area* are possible. Rising biodiversity, bird-life, wildlife, and rest area amenity may creatively use nearby land.

Knowledge Base

Geary's Gap is a good location for testing of *Aquifer Storage Transfer and Retrieval (ASTR)* at Lake George. Based on the geology of buried upper Yass Valley stream-beds, these *palaeovalleys* have recently been mapped near Bungendore. They *should* lead downstream to the fault line at Geary's Gap where the Lake George Range upthrust blocked water outflow into Yass River.²²

Aquifer Storage and Retrieval (ASR) uses the same or adjacent bores to tap an aquifer. With Lake George, recharging the aquifer under the lake bed *aquitard* could occur at a distance (even at Bungendore if its aquifer is desalinated). The *Anderson VC Rest Area* is a small area to the East of the highway at the base of the Geary's Gap on the lake side of Lake George Range. Access South or North of the current site would allow a small tourist facility providing refreshments, information centre and local tourist sales outlet. With the water from a production bore (with desalination if required), potential for a new Wetlands, walking and bike trails, sheltered palaeoforest (reconstruction of a flora representing species in wet times at Lake George), permanent freshwater recreation pond and pilot aquaculture, could all be considered.

Knowledge Gaps.

1. What level of bore pumping can be maintained for permanent wetlands, within the limits of brackish water quality, aquifer pump-down, and any desalination?
2. What level of hydraulic connectivity exists between the buried stream-beds at the lake's edge (eg Bungendore and Collector) and Geary's Gap aquifer?
3. What supply level and desalination are needed for each planned activity?
4. What other local markets are there for any fresh water pumped from this location?
5. What sources of local renewable energy to pump water would be feasible?

Ongoing Data needed in operation.

1. Bore water salinity and volume with periodic aquifer bore testing;
2. Real time water levels of bore, ponds and storm-water;
3. Periodic water testing for continual supply;
4. Pond local storage could establish a permanent local fresh or brackish water at the site.

Conclusion.

Whilst some of the above may be possible alone, development is likely to be most successful when sharing infrastructure, creating competitive advantage. Lake George's mysterious emptying and filling may be explicable by hydrology analysis, but it remains a tourist attraction with minimal facilities for the traveler to date. Joint venture activities between *NSW Parks and Wildlife*, and private sector investors is likely to succeed. Anderson VC Rest Area is well sheltered, pleasant and has splendid lake views. Nearby sensitive development could significantly improve the area's use.

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²² Groundwater and surface water interaction at Lake George, New South. Wales. G. Jacobson et al 1991

APPENDIX 4 Geary's Gap Flood and Storage Control.

Geary's Gap represents the old Yass River outflow from Lake George, before a geological upthrust of Lake George Range created the Lake. The Lake George basin then filled with sediment- separated into 3 classes, the lowest Geary's Gap Formation, mid Ondyong Point formation, and upper Bungendore Formation of clay and silt.²³ The upper formation is a saline *aquitard*, or water resistant layer that only slowly transmits water. The lower 2 formations are likely to transmit water readily, with sand, gravel and silt filling the lowest along the buried Upper Yass River valley. If so the waters would probably arrive at Geary's Gap and thence flow in an as yet unknown manner.

Lake and Aquifer Storage and Recovery

Aquifer Storage and Recovery or "ASR", is an established method of water storage used to augment supplies in Australia and elsewhere. In Lake George's case, the aquifer under the lake is saline, and we need to add a concept of *Lake Storage and Recovery*, or "LSR" to discuss the topic. In flood, Lake George could receive water bypass from Googong or Cotter, with such flows reducing the peak water load on Burrinjuck Dam. If the surface waters of lake George were kept at fresh water status (above 2 metres), this body of around 500gigaLitres could be available for transfer to Burrinjuck via Yass River valley later. A 1 metre rise at Lake George stores around 120GL, a significant volume. The 140megaL/day bypass from Murrumbidgee to Googong would take around 2 years to increase the lake level by 1 metre so it would not be an overnight event. Peak flow rates for catchment transfer is not a trivial issue, but the upper Yass River catchment has high transient flows consistent with an elevated old river valley truncated by uplift⁽²⁾.

LSR Flood control mechanism - wet times and floods

If we accept the need for water transfer out of Lake George occasionally, pumping around 37metres over Geary's Gap into the Yass catchment, water could then flow to Burrinjuck for storage, useful as both flood and catchment transfer. This would allow some human controlled flexibility to balance peak flows between river catchments. No water treatment is likely to be needed, as intake from the freshwater lake surface at Geary's Gap would be away from the intake zones of the creeks flowing into Lake George.

LSR water retrieval mechanism - dry times

In dry times, retrieval of a conserved fresh water body from Lake George surface waters could occur into Burrinjuck via the Yass River. At a flow of around 200ML/day uplifted the 37m above lake level, a 6 months summer flow volume of about 36GigaLitres (0.2×180) could be transferred. This is not much as far as Burrinjuck volume goes, but it may make a large difference to the Yass Valley in drought. If we increase the flow to around 1gigaLitre per day we could make a major difference to the storage dynamics, but the Yass River valley may flood. Fail-safe operation would be mandatory, and monitoring stream levels in real time would help. The pumping station would need grid connected power to give timing control, not only solar or wind power.

Conclusion: adding ASR to a working LSR

Given the above, Lake George surface waters could act as a *Lake Storage and Retrieval water bank*, and this is a simpler engineering problem than use of a partly saline Lake George aquifer. As a drought progresses, aquifer storage of fresh water in Lake George could act as a reserve water supply for Canberra, again via Geary's Gap. This may require a pipeline or canal, and bores to tap the aquifers, and proof of water quality. One of a series of bores that tap into the old buried river stream-bed, is likely to access fresher water at some stage during aquifer salinity repair.

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²³ Jacobson et al 1991 *Groundwater and Surface water interactions at Lake George NSW*

APPENDIX 5 **Aquifer Conflicts and Local Management.**

A *failing aquifer* often generates conflict between interested parties or government, over who is to blame, and how to fix things, and who should pay. A good example at Lake George, is the Turallo creek conflict between a private landholder and the NSW government²⁴. The landholder's intent is to raise the local creek water table upstream of Bungendore and create a series of small wetlands with improved biodiversity- a limited trial of "*sequence farming*".

NSW Water has applied accepted rules that prevent upstream landholders unfairly obstructing waterways, depriving downstream users of flow. That interpretation, while usually correct for dams, seems flawed in this context since:

1. Turallo Creek's flow is transient during rainfall, ²⁵ and retaining water in an upper or middle creek aquifer would tend to integrate that flow, storing more water in the valley aquifer;
2. Retaining water in the mid to upper aquifer stores it away from the saline destination of Lake George (both surface water and aquifer);
3. The effect of wetlands is generally accepted to reduce pollution by binding it to biomass- this is a reasonable aim in current times;
4. Inspection of these small wetlands reveals clear water and regenerating biodiversity²⁶ ;
5. The creek is an *uncontrolled waterway* (no major flood control dam exists), and the effect of multiple small weirs and vegetation is likely to reduce peak flow and flooding risk for Bungendore;
6. The graduated low-level weirs are well below the old eroded creek banks ;
7. These eroded banks indicate that the old creek bed before European clearing and erosion was at a higher level than today, with a likely water table at that higher level;
8. The major long term water resource for Bungendore is from the aquifer below the creek, not from the creek surface flow;
9. increasing the aquifer level all along the creek is likely to increase a drought-protected aquifer water supply, without the cost of a dam.

Local Aquifer Trust as a Forum

A Local Aquifer Trust (LAT) could provide a forum to explore exceptions to general rules, *where conditions warrant it*. It could implement more accurate data collection that reflects the real behaviour of a creek, the lake and its aquifers. To acquire and use this data, the LAT could:

1. Monitor both salinity and flow of the creek below the wetlands to obtain objective data ;
2. Fund and install the equipment to gather data needed to resolve such issues;
3. Locally publish the data and provide expert interpretation of what it means;
4. Charge modest aquifer repair fees or receive donations from aquifer enterprises ;
5. generate alternative choices consistent with views of all local affected parties;
6. Return the issue to the state government, requesting external enforced decisions when there is data to prove that such action is justified.

Conclusion

Constructively resolving aquifer conflicts is at the heart of improving water resource use. Whilst externally imposed general principles and policies are needed, that strategy may not cope with exceptions. Enabling a local body to explore such an issue, improve data, and generate solutions, could resolve conflict and help motivate a community to fix their own aquifer.

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24 Bungendore family fights to avoid a creek tragedy : Canberra Times report Nov 7th 2015

25 Water resources of the western catchments of Palerang Local Government Area: Sara Beavis, June 2012

26 The writer attended an open day in 2015 that enabled inspection of the creek bed ,water flow and water clarity.

Central to the accompanying submission is the acknowledgment of how complex the task of *aquifer repair* is. In a perfect world, a smart Federal Government would apply a few hundred million dollars to repair the *Lake George basin*, using the underground aquifer as fresh water storage for drought times, and recharging it in good rainfall times. The tax dollars would have been excised from the exported profits of multinational companies. The Federal Government would construct a Murrumbidgee transfer pipeline into the Lake George catchment, and a large solar farm with pumping station at Geary's Gap. Canberra would then use a *reserve water bank* in drought of around 500 GigaLitres of fresh water, and the system would drought-proof the Yass Valley.

This is wishful thinking and won't happen in our foreseeable futures. Australian applied science research has been reduced to a small rump of the historical activities of organizations such as CSIRO and BMR. The new paradigm is largely joint or self-funding projects, with occasional government funding of big ticket items. Accepting this new paradigm may be difficult but this is reality. If solid data is to be generated from aquifer repair, we need to experiment safely and watch what happens. We then need to use this data to expand what works. When sufficient data exist for well informed hydrologists to agree on a strategy, the strategy should be expanded.

As an example, taking the new water supply bore at Bungendore: this has been implemented using current best practice policy, aquifer knowledge and engineering at the time. What is missing? *Dynamic data and lots of it - halocline data*²⁷ to reflect short and *long term salt and water movement*. There is no comprehensive monitoring of water level and salt data from bores in the lake bed, or serially up stream, to tell the real story of impact on the aquifer. If we aim to clean up Lake George waters, and for them to remain fresh water always, and clean up enough of its aquifer to be an effective Aquifer Storage and Retrieval *water bank*, we need to do better.

The Turallo creek story of conflict about artificial wetlands is a warning.²⁸ *NSW Water* applied rules to limit obstructions to flow down the creek, without recognising this as a form of *Aquifer Storage and Retrieval*. We know that salt washed into the lake from streams is likely to be a major source of surface water salt, and that salt can be partly bound by wetlands. We know that many Bungendore bores are salt affected, and that the creek outlets are less salty than the lake. The lowest aquifer under the lake is the least salty and mobile containerised desalination plants are now reality.

We also know salt accumulation at Lake George has been going on for about 2 million years, and the salt has become concentrated in the *aquitarid*. Therefore *all strategies* that limit salt recharge of the aquifers, and help recharge them with fresh water, need to be put on the table. This clearly includes methods of salt retention in the valleys, and altered stream flow regimes that clean up the water, and integrate flow such as "*sequence farming*". Adding a pilot trial for a time, of a desalination plant for the Bungendore aquifer to treat water from salt affected bores, would also be on the agenda.

Conclusion

Some form of organisation is needed that can help the whole local community work together, making them responsible for their own aquifer. Local management could help trial new methods such as desalination, salt farms, Aquifer Storage and Retrieval, mariculture and wetlands. Obtaining progress data over time from such a process would allow State government to know if it has delivered good government, or continuing aquifer failure.

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²⁷ Halocline : variation of salt concentration over distance in a water body;

²⁸ NSW government threatens \$1 million fine in .. - Canberra Times Nov 6, 2015 www.canberratimes.com.au