Supplementary Submission No 13a

INQUIRY INTO WATER AUGMENTATION

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Cooperative Aquifer Shepherding at Menindee.

Supplementary Submission to NSW Upper House Water Augmentation Inquiry

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Background

The NSW Upper House has established an inquiry into NSW water management, triggered by the controversial drawdown of Menindee Lakes in 2013 by The M*urray Darling Basin Authority* ("*MDBA*"). This led to the loss of Broken Hill's water security following unexpected drought, and successful emergency development of a backup water supply by *NSW Water*. The writer has made a submission to the committee related to a pilot trial of community level aquifer management at Lake George NSW. [1] This supplementary submission, focuses on the Menindee Lakes example applying similar analysis to that context.

The above title has three intended meanings-

1. enabling *a Menindee Aquifer Council with NSW Water*, to act as the good Shepherd and control Drought Water Security at Menindee, ***until*** the MDBA and its operant rules can deal effectively with drought water supplies, and Menindee is drought proofed;
2. The real-world transfer of water from the river and lakes to *drought reserve aquifers* via a recharge "s*hepherd aquifer*", using passive *Managed Aquifer Recharge* or "MAR";
3. further shepherding of water over distance by linking aquifers with other aquifers, via aquifers, river and short pipelines (Aquifer Storage and Transfer Retrieval or "ASTR");.

Drought-proofing community water is a short term imperative of the highest priority. Re-balancing water use in the Murray Darling Basin is a long term process, and just as important on a longer term time scale. *Geoscience Australia's* drought proofing proposal for Menindee (BHMAR) [2] highlights our errors in creating Broken Hill's water crisis: conflicting needs from water and the timescales to solve them. We ***can*** do both. The unexpected drought placed a spotlight on trying to do everything too quickly. MAR and ASTR[3] methods at Menindee have the potential to solve both problems together. The research demands we try to understand a new way of thinking applicable to much of inland Australia. It deserves a rapid pilot test installation at Menindee to confirm its accuracy, specifically for salinity levels[4] and bore-proven water reserves. Some of this new knowledge to understand is set out below.

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1 *Local Aquifer Trusts (Lake George Aquifer Trust)* Peter R Main 26th May 2016
2 *Broken Hill Managed Aquifer Recharge project (BHMAR)* report 2013 Geoscience Australia (BHMAR)
3 Aquifer Storage and Transfer Retrieval
4 Salinity levels of bore-water are a critical unknown determining cost of planned supply

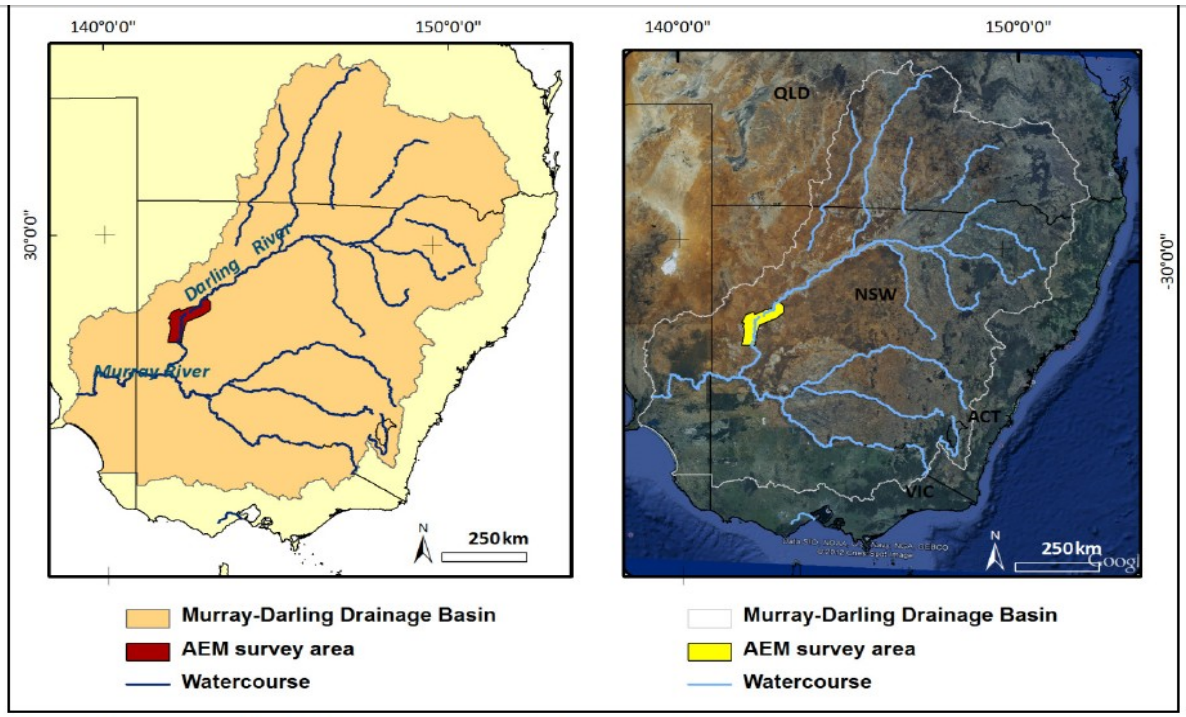

Figure 1-1. *Location of the BHMAR project area in relation to the Murray-Darling Drainage Basin in south-eastern Australia.*

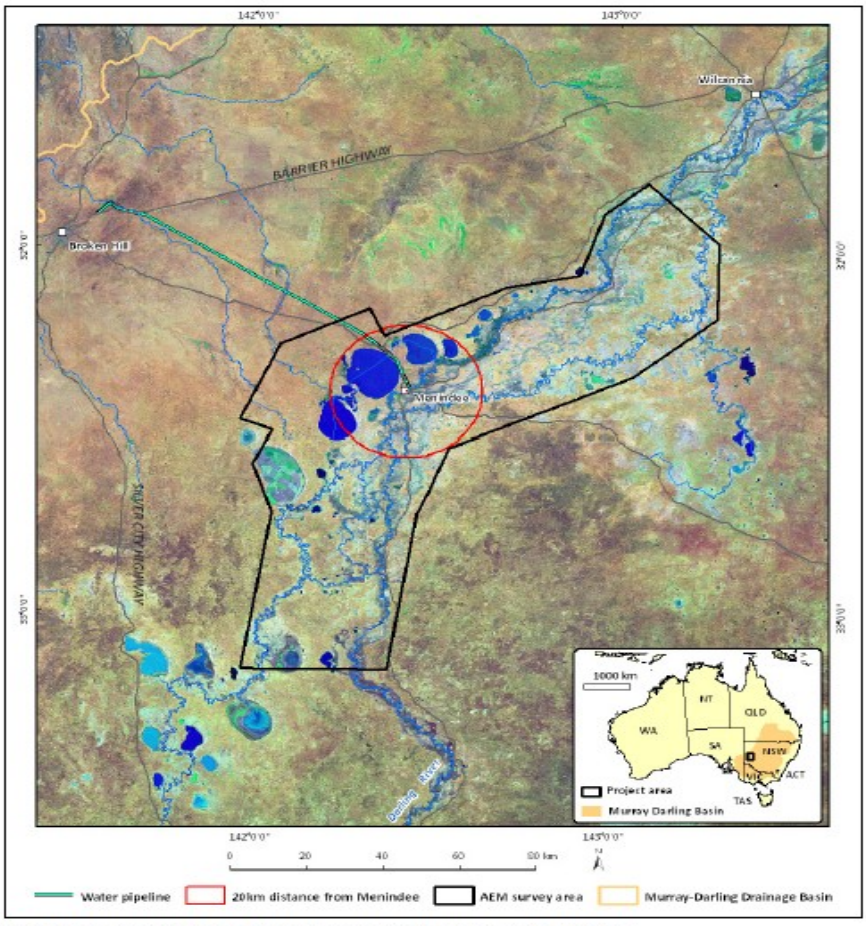

Figure 2-1. Location of the BHMAR project area relative to Menindee and Broken Hill.

Managed Aquifer Recharge Scoping Maps from *Geoscience Australia* BHMAR Report 2013

New Water Knowledge and its impact.

New Knowledge of Bores, Aquifers and Drought-proofing

1. We now drill bores to both pump water into aquifers not just to take it out *(Aquifer Storage and Retrieval or "ASR"*)
2. We can then take water out of aquifers as a drought *reserve water bank* – this reserve does not rapidly evaporate, and with care can be a permanent feature integrated with river and lake storage and environmental restoration;
3. The technology is well proven, not experimental, outside of NSW but mostly in urban areas.
4. There are few non-urban functional ASR projects in Australia -a Queensland Burdekin River [5] project and a South Australian wine district project[6] but they both have external economic funding for the projects, and both came about for salt control (Fig 4 P. 21)
5. The Geoscience report is ground-breaking research insofar as it uses multiple methods to take much of the guesswork out of where to drill bores, and what we will find ;
6. ASR systems are designed for the priorities of the local context: minimum cost and maximum long term water security are the highest drought priorities at Menindee;
7. We are now 100% sure that there are large stores of water and salt within 20km of Menindee Pipeline end [7] , sufficient for up to 5 years supply of the design requirements for drought-proofing the district (See Table 2 Page 29);
8. There are even larger stores up and down the Darling, and these can be delivered via river, canal, aquifer, or pipeline ;
9. The new Geoscience Australia knowledge needs physical confirmation by pilot test installations at Menindee (water quality, quantity, storage and retrieval behaviours all need testing to verify the BHMAR work);

The impact of new water knowledge at Menindee and elsewhere.

10. A pipeline similar to the current Broken Hill pipeline, constructed around 10km south from Menindee, and then a smaller pipeline grid, will connect the key Jimargil borefield area to the Menindee pipeline end (See Fig 1 page 18);
11. The pipeline can take flow both ways -to the borefield for recharging the aquifers and from the borefield for water draw-down;
12. The overall project can start and be incrementally developed in staged construction, with each zone piped in via a local grid, sized according to volume to and from each aquifer;
13. The BHMAR report cautions that distance from Menindee will prevent ASTR development – this is is challenged, as using river flows to deliver water downstream without a pipeline is applicable to this design requirement (outside the 20km brief given to GA);
14. A lower-cost option is for the construction of a passive recharge ASR borefield upstream of Menindee, adjacent to newly found existing river bank-recharge beds;[8]
15. If the BHMAR methods are confirmed at Menindee, extending the practice up to the Middle Darling could integrate use of both surface aquifers and the Great Artesian Basin ("GAB") for Bourke and Wilcannia and communities between;
16. Similar ASTR projects down the Darling together with drought-time artesian water release maintained by the *GAB bore capping project*[9] could then drought-proof the entire Darling by combining proven technologies;

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5 Qld Lower Burdekin MAR project from 1960s success in preventing saline aquifer contamination
6 SA Wine district MAR Angus and Bremer Rivers South Australia
7 BHMAR Project 2015 Geoscience Australia
8 See herein option 4 for community driven change
9 Great Artesian Basin ("GAB") Cap the bores project

Executive Summary

In 2013 at Menindee, the operations of the *Murray Darling Basin Authority* (MDBA) and *NSW Water* under the current rules, failed to safely control Broken Hill's *drought water supply.* Until a permanent solution is installed, sole control by NSW Water, with consent of local community groups could render drought supplies as secure as possible.(Wincen Cuy page 17).

Broken Hill is not the only water user in the district, and drought-secured supply for household, stock, and fixed plantings are a minimum expectation from secure water supplies throughout the Darling Basin. The strategies in place to date cannot resolve both unexpected drought, and ad hoc water release from the upper Lakes.

NSW has announced a new pipeline from the Murray River to Broken Hill, however this will not resolve a number of issues relating to Menindee: i) drought supplies to Lower Darling; ii) restoration of normal flows to the Darling Anabranch; iii) drought stabilisation of rural industry and tourism at Menindee; iv) enabling the Lakes' separate use for *all* community, river and enterprise, and v) trialling a consensus environmental pattern use of the lower two lakes, enabling future RAMSAR listing.[10] External sources or new local storage are needed, and both have been considered by NSW Water , the CSIRO and *Geoscience Australia*.

There already exists a comprehensive research report on Menindee drought water supplies, by Geoscience Australia in 2013, based on earlier work. The research appears to have been ignored for unknown reasons [11], and some of the key new knowledge emerging is summarized herein. It is a major exemplar body of research, providing a knowledge base for rapid engineering translation to *staged installations*. It has a potential to resolve drought water supplies crisis in the region permanently, without a Western Murray to Broken Hill Pipeline. The potential may have been misunderstood with significant *knowledge gaps* evident in multiple interested parties.

The e*mergency water supply aquifer* is now 1) developed but untested in a full cycle of practice 2) at risk of further salt damage in an unknown manner 3) has no infrastructure to confirm that ASR methods can be applied to speed its recharge after a drought draw-down of volume, and 4) has no installation to reduce salt loads in the aquifer. At the time of writing this, water down the Darling from recent rains has reached Wilcannia indicating thanks are due to NSW Water for a rescue job well done (but incomplete).

DARLING@WILC. MAIN C (425008) Sun 17/Jul/2016 17:00:00 Flow (ML/day) 5193

Menindee Lakes and the above unfinished drought-proofing, allows a second focus on *salt removal* from the Darling and Menindee. A focus on salt removal is worthwhile, as the demand for flow volumes is only half the story when many of the problems relate to salt accumulation at threatened catchment locations. New strategies to permanently reduce the Darling's salt load can complement benefits from increasing environmental water flows.

A rapid investment in field-testing Geoscience Australia's work is reviewed, with a short list of possible strategies to choose from. *Field testing* is required, to *validate the research*, with a test of accuracy of the combined methods in predicting where to site production bores, and to choose appropriate aquifer recharge methods.

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10 RAMSAR listing requires restoration of natural flow patterns- Lakes Cawndilla and Menindee appear possible;
11 Lack of time, and unresolved salinity issues may have led to NSW Water choosing a north Lake Menindee borefield;

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Format: pdf format is provided.

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Introduction

Menindee Lakes and their drawdown in 2013 could be described as *"A singular Australian exemplar of inadvertent bad government using misplaced confidence in incomplete science",* but I would prefer to think of it as: "A *good example of immature governance using incomplete science, providing a unique opportunity for us all to learn about new research".* It is a monumental failure of *Translational Science* [12], likely to cost around $500 million, without solving the related challenges.

The event generated conflict, disorder and unexpected cost, placing at risk a major inland town and its mining industry, together with destruction of drought water security for the region. Whilst specific remedies for Menindee and Broken Hill can be recommended by the NSW Parliamentary Committee, a more general review for the rest of NSW drought impacts on constituents in the MDB is deserved. The MDB Authority needs to rebuild trust damaged by confusing long term water use re-balancing, with critical short term drought water security imperative.

The breadth and depth of flaws in the underlying processes leading to the crisis may relate to how politics, law and government understand and use applied science. It is an irony that the CSIRO and the States of South Australia and Western Australia have world reputations of expertise in water management, and yet we have a government-fostered decision committing a simple error- not having a *backup drought water supply,* in a drought-prone area, by mixing two conflicting desires, without prior investment in resolving the conflict by new strategies. New water strategies are available, yet not in progress before the 2013 event, leaving little time for NSW Water to respond and prevent damage.

There is even a comprehensive, forgotten script published in 2013 from Geoscience Australia for drought-proofing Menindee with Managed Aquifer Recharge [13] -the *BHMAR project*. The absence of an expert appeal body that might have prevented the crisis, is another key to events: a national body with such potential shield effect was abolished by The Abbott government as a cost-saving mechanism. With hindsight, this may have been at best an exercise in *cost-shifting*.

The science underlying the MDBA activities appears sound but incomplete. One *red flag* is the lack of *transparency* and *error estimates* in the use of models (SDLs), to decide on change. This is inconsistent with the honest use of applied science. The local application of SDL's in each district become more challenged when we find that the Geoscience research provides a new model for aquifer recharge along the Darling, and that the SDL estimates for Menindee is wrong. The MDB Authority needs to recalibrate the Menindee SDL with this new knowledge.

Rewriting promises of THE PLAN :
We can restate the above failure by rewriting some of the MDBA's reassuring words : "There is to be no social or economic impact on regional communities through recovery of the additional 450 GL". This applies to the additional recovered volumes for environmental flow to 2024, but it could equally be rewritten to reflect a real-world imperative : "There is to be no social or economic impact on regional communities *during drought, through recovery of SDL targets during a transition to secured drought water supplies*".

Drought water security for communities and established enterprise needs to be at the top of our list for improving rural water.

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12 *Translational Science* - Science that studies the translation of new research to real world applications
13 *Broken Hill Managed Aquifer Recharge project (BHMAR)* Geoscience Australia 2013

The Anatomy of error at Menindee Lakes

The errors made in emptying Menindee Lakes appear to be multifactorial, and in my view reflect the immaturity of the MDBA control system, and lack of local integrative cohesive control:

1. The knowledge base for draw-down of the Lakes seems inadequate for drought water security, both in science, and the breadth of predictive analysis needed for equal care of environment, social, and economic parts of a sustainable nation;
2. A degree of hubris occurred in predicting weather and absence of drought after emptying;
3. No prior commencement of pilot installation testing of the Geoscience Australia's MAR research [14] (the prior CSIRO work identified the potential, ***with*** a caveat for MAR first);
4. The lack of an *expert appeal body* was one key to the mistake (local community objections have no natural forum);
5. The lakes are ideal evaporating pans – some more so than others, yet this remains an inexact part of estimates. [15] The accelerated evaporative losses were part of the unexpected inadequacy of reserves
6. Significant sediment deposition plays a role in worsening evaporative losses;
7. The aquifer used for Broken Hill's reserve water supply is saline and inadequately tested for recharge, desalination, and protection from damage when they are pumped down (this may accelerate salt recharge not freshwater recharge if Lake Menindee is full). This did not impair the work proceeded with, due to the expanded capacity of desalination at Broken Hill;
8. Distribution of local fresh water is already enabled via pipelines that could be further developed with a network, enabling multiple small scale landuse that requires reliable water supply of a modest volume, changing the water market (Western Victorian Wimmera-Mallee example) [16]

How should we really treat "scientific error"

Transparency is needed to allow a diversity of audit methods to cross-check a claim or decision. In applied science this can be called *triangulation*- we use many different methods to reality check a conclusion. This does not appear to be the science's fault, but the political use of data in a manner that implies accuracy for methods that in reality have large error estimates attached. (The aim for the Geoscience project was to use multiple research methods to pioneer a new way of mapping aquifers more precisely, and thus decide where to place bores and choose recharge methods)

Error estimates represent the realistic level of certainty of a method applied to a problem. They can be confusing, but a simple rule of thumb is that if good error estimates are used, most past , current and future events will fit within the modeled prediction plus its errors. A numerical range in a figure such as Sustainable Diversion Limits (SDLs) can help. It is common for many domains to remove error estimates, and quote only a crisp number. This often requires explanation from expertise familiar with the *assumptions and methods that underly the measurement*s. Such expertise is not always readily available.

With government, finding an example that fits outside predictions calls into question the whole process- if it is wrong in this example, where else is it wrong? How can we sort out the good from the bad to prevent more mistakes? This is the case in Menindee : the predictions of water supply have a large error to do with the uncertainty of drought. This error underlies the use of SDLs as a foundation for change, and needs honest expression.

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14 Broken Hill Managed Aquifer Recharge project BHMAR 2013 Geoscience Australia

15 The accelerated evaporative losses (heat, wind, low humidity) were part of the unexpected inadequacy of reserves

16 Wimmera-Mallee pipeline grid www.vic.pipeline.au

An example at Lake George, NSW

Applying the above to Lake George, the Lake George SDL is set at 1.2 GL pa[17]. A major study into a more accurate SDL, funded by real estate development pressure, concluded a figure of 0.75 GL pa was more realistic.[18] The appropriate response was to tap into the Eastern Fractured Rock Aquifer at Butmaroo Creek to temporarily solve the water supply problem. Notwithstanding these two figures, a back of envelope calculation using the Southern part of basin rainfall, evaporation, and Lake George's historic water levels, indicate a more realistic figure of around 5-20GL pa with a minor and achievable change of assumptions about the way the Lake works.[19]

An example of "scientific error"

If we take as example the Lake George SDL affecting Bungendore, the current crisp number of 1.2 GL is challenged. The final SDL could have been better expressed as 1.25 +18.75 -0.5 GL, or "0.75 to 20GL pa" as a range. Even though SDLs are intended to give long term averages, they still need to include a sense of the expected accuracy of the methods used. Each of the catchments in the MDB Plan probably have similar errors – certainly the underground SDLs associated with rivers similar to the Darling, have a new Geoscience Australia model to be revised.

Opinion:

Whilst the MDBA has not yet demonstrated the expertise for safe drought decisions within its current ruleset, few would disagree with an aim for long term change. A healthy, balanced, sustainable *triple bottom line*, [20] that eventually delivers water security for all three foundations of community, river and enterprise is achievable. Confusing short term, medium term and long term problems and solutions is likely to lead to flawed decisions. Long term re-balancing of flows that achieve this, is still needed in the MDB.

Historically the environmental flow base for a healthy river system has been abused, over the last century. Assuming that a rapid return to balance can be done safely in a short or medium term, risks unforeseen results such as events at Menindee. This brings into disrepute what needs to remain a consensus process, given sufficient imagination, re-engineering, and ongoing community consultation.

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17 MDB Plan Lake George Basin SDL

18 Bungendore bore development project report

19 Available on request from the writer

20 Originally from environmental concepts of joint care for social, business and environment

Some Alternatives for Menindee Drought-Proofing.

There are four options outlined herein including the one apparently chosen by the NSW Government, (Option1).

Option 1: Direct Western Lower Murray to Broken Hill Pipeline

POSITIVES:

1. Provides a known secured water source for Broken Hill
2. likely cost of around $500million (?)
3. reasonably estimated completion time of a few years
4. modern pipeline technology providing long term solution
5. political certainty for NSW government for an embarrassing issue

NEGATIVES:

6. ignores the 50GL drought reserve aquifer developed and wastes the work to date
7. ignores the potential for ASR applied to aquifer development
8. does not contribute to salt management of MDB
9. transfers water load of about 10GL pa from a Darling to Murray source
10. does not drought proof the lower Darling
11. May be overly sensitive to BH and mining community objection to having a bore water source for their supply (it is the quality and quantity that matter);
12. Does not have a known water price base for all water users in the district
13. Does nothing to revise the overall dynamics of Menindee Lakes water management (eg. enable full draining the lower two lakes, leaving the upper lakes full)
14. Does not change Menindee Lakes salt accumulation.
15. May lead to the permanent destruction of community water amenity at Menindee .

Option 1 has been recently announced as a decision to be proceeded with. To comment, we would need transparent, published cost comparisons between the top few most effective choices examined by NSW Water, and published water supply cost comparison for the affected local communities.

RECOMMENDATION: *The committee could advise NSW Water liaising with the Victorian Government on their experience with the Wimmera-Mallee Pipeline Grid to offset infrastructure pipeline costs, and include this in further community consultation.*

Option 2 : Upgraded Anabranch Darling Pipeline to the Murray

Upgrading of the current partial pipeline from the Murray towards Menindee is possible. This would enable a ready expansion of water-grid connection secured supplies to the Lower Darling, for alternative economic development long term. The proposal solves a number of problems :

1. It could drought-proof the lower Darling and the Western Darling Anabranch
2. It could enable a revised balanced sustainable flow-model and economic social environmental use for the Menindee Lakes
3. It could assist in desalinating the aquifers with ASTR borefield development;
4. It enables use of the borefield development to date (shandying and ASTR aquifer desalination)
5. It would economically use the current BH pipeline for the rest of its lifetime
6. it could establish new enterprise in the region to secure the economic base for the long term.

If linked to MAR projects South of Menindee, a grid of pipelines that connects to the current pipeline, could secure modest-volume water use for agriculture. There is a good model for such a project in the Wimmera-Mallee Victorian Pipeline Grid, complete with infrastructure cost-recovery, and reasonable water use charges.

RECOMMENDATION : *the committee could advise NSW Water to seek expert MAR advice, to be included in community consultation process with cost/benefit analysis for the new MAR methods and how they might interact with an Upgraded Darling Anabranch-Murray Pipeline grid.*

Option 3 : Staged implementation of the MAR project.

In my view, the Geoscience Australia Research proposal really needs translation to a multi-staged engineering project, suited for graduated implementation in the field. This is complex engineering project management. A basic, no frills, part implementation as Stage 1 could verify or disprove key aspects of the research to date. The whole project needs re-focus on agricultural, environmental and community water markets, not town water for Broken Hill. Expensive water treatment and injection is probably out, and extensive passive MAR options in. Option 4 canvasses some simplified issues that might be of interest to the Menindee community, if a failure of governments to act occurs.

RECOMMENDATION*. That the committee requests NSW Water liaising with MAR expertise, develop a greatly simplified indicative sequence of works, for some pilot, lower cost Menindee MAR developments. Such a simplified plan would need to maximally use available bores, minimise cost, and link this with BHMAR new knowledge, to implement part of the plan as a pilot project.*

Option 4 : Community Funded, Pilot scale, passive MAR projects.

Possible sources of self-funding development exist, if no action occurs on MAR from relevant governments. The Western Pipeline alone leaves multiple issues unresolved, and private enterprise and community actions are possible. In particular it leaves unresolved Menindee district and lower Darling drought water supplies, Darling Anabranch flow restoration, and reconciliation of RAMSAR listing with other needs. Careful selection of bore and MAR targets to maximise returns, together with sales of new water enabled by desalination of MAR aquifers by cyclic flushing, are likely to succeed. A new focus on pumping out salt from mobile aquifer zones, not pumping in fresh water may provide a major change to low-cost potential.[21]

The SDL for underground water at Menindee needs re-calculating, and this could occur with liaison between the MDBA and Geoscience Australia. This should also acknowledge the importance of fostering MAR progress, regardless of government action or inaction.

"New" water enabled by community-level funded projects could be equitably split between community amenity, environment, and new or expanded enterprise. Intermittent flow regimes in drought are a practical alternative employed by NSW Water to recharge downriver surface water stores. This system works, but it needs a source of external water in times of drought. About 4 to 10 bores, carefully selected passive recharge sites, solar power and pulsed releases from upstream, are a probable minimum for some impact. A small weir above Menindee could maintain water up the Darling for some distance, including two bank-recharge areas found by the Geoscience Work. Refilling of the borefield water-bank would occur during riverflow, and water return back to the river from the borefields in drought (this is just amplifying what happens naturally – Fig 5 page 22)

21 Why is the salt there anyway in an aquifer -because it has nowhere to go. If we actively remove it and make room for fresh water, we may also prevent new salt contamination of an aquifer. Salt concentrated in *aquitards* will only be released slowly.

Persisting inaction from government needs to be prevented from demoralizing the Broken Hill and Menindee districts – drought itself is enough of a challenge. The Murray Darling Basin Authority could help redeem itself in Menindee by an SDL revision in the light of new research, and assisting in a pilot MAR project. It might even chip in money for a bore or two.

Victoria and South Australia could assist by acknowledging the need for transitional work at Menindee for drought provision, salt control, pulsed drought water flows from MAR aquifers, and MAR validation applicable everywhere. They might contribute a few quid since they have helped develop a flawed MDBPlan in drought water security transitions. The Federal Government might consider paying for a couple of bores and avoid the embarrassment of wasting their investment in the Geoscience Australia's MAR research project.

The NSW Government could assist with expanded water treatment at Menindee, and perhaps a small ASTR pipeline at the current Menindee Lake emergency borefield to test the research there. Construction of minor earthworks upstream of Menindee could establish conditions for good passive aquifer recharge, using the GA new knowledge about stream-bank aquifer recharge. It could also assist by ensuring NSW Water undergoes a rapid cooperative re-education about new knowledge in MAR methods via Western Australia, South Australia and Geoscience Australia.

Cooperatively resolving Menindee and Broken Hill drought water is a central challenge to the whole MDB Plan, participating governments, communities and the MDBA. Some of the parties that might participate in option 4 are listed below.

8. Potential Aquifer Participants for self-funded MAR at Menindee

• Salt Harvesters of Australia	Mentoring expertise to establish a new pilot salt farming site at Menindee if opportunity is found
• Broken Hill Council	Water supply :Purchase of some part of new water for greening Broken Hill
• Menindee Lakes Aboriginal council	Environment, water supply, economic , tourism and traditional interest – advice on potential wetlands development to enable ASTR and use some water for environmental purposes
• Pipeline dependant enterprises	Water supply, salinity, cost, security, fixed-planting activity
• Small local towns and communities	Pipeline potential for water security and economic stability and development; town amenity
• NSW recreational fishers	Local branch – recreational advice and use for enhanced native fish supplies
• Menindee South irrigators	Current lake source of intermittent supply
• NSW Water & NSW Government	Expertise and resources to build infrastructure Minor works (Block earthworks) to enable recharge, and coordinate releases better; good government ;
• Menindee Community Water Council	Really a collection of community representatives that have been meeting with NSW Water to solve the long term drought water and Lakes future water problems.

DISCUSSION

The recent events of Menindee, taken with timely but untested new research, create a unique opportunity to build on the emergency borefield work to date, and drought-proof the lower Darling region. To drought-proof the region, temporary control of the water storage and flow at the Lakes may need to revert to NSW Water and the local community, until further works are completed.

This appears to be possible simply by keeping Menindee Lakes below the trigger required to transfer control to the MDBA. The MDB Plan itself appears flawed insofar as safe transition to drought provisions are not provided for, but is assumed to be reliable (an unstated assumption). Broken Hill's experience shows it is not safe, and suggests some rewriting of the MDB Plan for transitional arrangements in NSW may be warranted.

We can restate the above failure in simple terms from rewriting the MDB reassurances as a core promise: "There is to be no social or economic impact on regional communities *during drought through recovery of SDL targets during the transition to eventual permanent MDBA water governance as decided by State Water Authorities*".

The MDBAuthority has not demonstrated sufficient experience to yet be entrusted with safe decisions for drought-proof water supplies. NSW Water also does not appear to have sufficient experience yet in key knowledge of MAR applicable to drought proofing the lower Darling. This knowledge is, however, readily available in Australia. Absence of such expertise may have limited NSW Water's development of alternative permanent strategies for Menindee. If NSW Water becomes familiar with planning, installing and supervising successful MAR projects, their field-level skills would be available for application in the rest of NSW. Menindee has a best-case available data to give NSW Water a good chance of success.

If further work is based on spring-time emptying of the lower Menindee Lakes, together with saline emptying of the aquifer, and recharge from the lake being emptied, gradual progress in basic secure water supplies can proceed. Currently the Lower Darling is not drought proof for domestic, stock and permanent plantings – a major failure of water supply distribution. Ample water sources are available, they need to be linked and managed differently in concert with underground water environmental repair,

Expenditure of a large sum on solely providing a new Broken Hill pipeline, may represent a major *opportunity cost* error unless spin off benefits occur. The Wimmera pipeline grid in Victoria provides a working example of what is possible given clear thinking and commitment to provision of modest water security of a region.

Linking this concept to annual environmental flows could keep Lakes Menindee and Cawndilla lakes empty in Summer -thereby providing permanent new water to the lower Darling for further aquifer repair, and local water-based enterprise growth. Payment for the water would go some way to permanently offset construction cost. The lifetime of the current Menindee-Broken Hill pipeline is unclear, nor is the cost of remedial work to extend it. If the currently proposed Western Murray-Broken Hill pipeline goes ahead, alternate use of the existing pipeline to grow enterprises needs to be considered.

CONCLUSIONS:

Broken Hill's recent experience suggests local Australian communities will need to pro-actively secure their own town or agriculture water security. A thorough consultative process examining the best reasonable permanent choices for Menindee drought-proofing needs to occur for permanent conflict resolution.

The Murray Darling Basin Authority and its current operating rule-set appear have not proved safe to control drought-proofing water supplies at Menindee. Sole control by NSW Water, with local community consent, could help pending stabilisation of drought-proofing strategies and works.

NSW Water, with rectification of its knowledge gaps in MAR borefield development seems an appropriate body to safely administer Menindee fully during any such transitional period. These knowledge gaps are likely to be bridged by liaison with expertise in Geoscience Australia, the CSIRO, SA Water, WA Water and private consultants. When Menindee and its district are reasonably drought proof, return of control to the MDBA under new rules would be reasonable.[22]

RECOMMENDATION : The committee could consider recommending the application of the above change to drought reserve water control, where conflict exists, throughout the Murray Darling Basin, as a reasonable provision for a safe transition phase to future improved governance.

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2: Essential Water : Forum for Water Security Meeting Minutes – 4 June 2015
Date:Thursday, 4 June 2015 Time:10.30 am CST
Location: Barrier Social Democratic Club, Meeting Room 218 Argent Street, Broken Hill

3. Parsons Brinckerhoff Australia Pty Limited authored for
NSW Office of Water Characterisation of hydrogeochemistry and risks to groundwater quality
Impact of groundwater pumping on groundwater quality:
National Water Commission - Raising National Water Standards Programme December 2011

22 The required rule changes are minor, but work to enable 12GL/day discharge from the lower lakes is required.(see the CSIRO reports on MAR 2011)

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https://www.environment.gov.au/.../sustainable-diversion-limit-adjustment-mechanism *T*he 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*.

2. 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

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4.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.

5.floodplain_harvesting_policy.pdf modified: 2016-04-27 21:15:46, size: 337309 bytes
floodplain_harvesting_policy

Glossary of Key Concepts

aquifer repair	for this submission: the improvement of all or part of an aquifer in water quality, or storage capacity, leading to growing *aquifer valuation*;
***Aquifer* Storage and Retrieval ("ASR") :**	the storage of surface waters (usually treated) into an aquifer for later retrieval by pumping either locally or at a distance ;
Aquifer Storage and Transfer Retrieval ("ASTR")	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)
aquifer valuation :	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);
aquifer:	an underground strata of rock or sediment that holds and transmits water ;
aquitard :	an underground strata of rock or sediment that impedes water flow;
aquiclude :	Strata of rock or sediment completely impervious to water (required at floor of saltpan)
desalination :	the removal of salt from water to produce fresh water supplies;
failing aquifer :	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;
GigaLitres	1,000,000,000 litres or 1 billion litres, or 1,000 megaLitres. Or 1 million cubic metres;
halocline :	Variation of salt concentration over distance in a water body;
knowledge gaps :	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
pilot trials :	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 *urban water supply* in place).
Salt slug	Applied by MDBA to a body of saline water moving downriver, often under fresh water
SDL	Sustainable Diversion Limit – basis for water re-allocation in the Murray Darling Basin.
self-funding aquifer repair :	for this submission: a process whereby local community and enterprise fund repair of a failing aquifer;
Translation Science	Science that studies the translation of new research to real world applications
water security :	the capacity of a system to deliver continuous, reliable supply

QUOTES WORTHY OF REVIEW.

1. 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.."

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. 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"

3. Brief for the BHMAR Project
" - Alternative groundwater-related water supply options for Broken Hill that could provide enhanced drought security for periods up to 3 years (~30 GL), within 20 km of existing water and energy infrastructure at Menindee.
- Potential MAR opportunities and groundwater resources that could provide enhanced drought security and promote regional development for communities and industries (eg. agriculture and mining) across a larger area (~7,500 km2) of the Darling Floodplain."

4. Parsons Brinckerhoff Australia Pty Limited authored for
NSW Office of Water Characterisation of hydrogeochemistry and risks to groundwater quality
Impact of groundwater pumping on groundwater quality:

“Project objective
As a result of drought and climate change, surface water availability and reliability in some parts of the Murray-Darling Basin are declining and groundwater is being pumped in increasing quantities as an alternative water source. As pumping can lead to water moving within and across aquifers, it can cause deteriorating groundwater quality either through changing salinity or chemical composition. The NSW Office of Water (NOW) commissioned Parsons Brinckerhoff to characterise the hydrogeochemistry and investigate the risks posed by groundwater pumping on groundwater quality in six alluvial groundwater systems so that a risk assessment

5. Essential Water community forum minutes

04.06.2015-Forum-for-Water-Security-Meeting-Minutes.pdf

“ ACTION: Wincen Cuy (from meeting held on 12 March 2015) 480 GL stays in the upper Lakes until we come up with a long term solution. Can we have an understanding that the 480 GL stays in the upper Lakes from this point forward? Can we talk to the MDBA about this? It needs to be forcefully emphasised to the MDBA. Looking at a five year plan, but if we can look at the 480 GL and have a commitment that the 480 GL can be kept in the upper Lakes then we have mutual agreement and understanding to move forward. Wincen Cuy said that he would be happy to sit down with the MDBA and put that forward”

Comment: In the absence of change, the BHCC and other community interests could consider seeking a court injunction for relief from *perverse drought damage* [23] :
The court could order

1) NSW Water and the MDBA to maintain not less than 480 GL in the upper Menindee lakes at all non-drought times, until permanent solution for drought water security is installed

2) If a declared drought, consent from all parties (to the order) be required for downstream release.

NSW Water and MDBA could consent to such court intervention, unless they wish to to modify it;
If they wish to modify it, rewriting it in a form of agreement suited to all sides should be possible. If the agreement is breached, the BHCC and community councils could apply for relief to the court.
If NSW Water and the MDBA wish to oppose such a court motion, the community at least knows they are still in hostile hands.

6. Quote from the editor AJ van Someren Boyd
Editors note: An important aspect of restoring water security to agricultural areas is that of ensuring *food security* for the whole of Australia. This suggests a need for Federal Government as well as State and Local Governments, and community (including farmers) involvement in decisions.

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23 “Perverse” in the meaning of no legal intent to increase drought damage on community or enterprise by the MDBPlan.

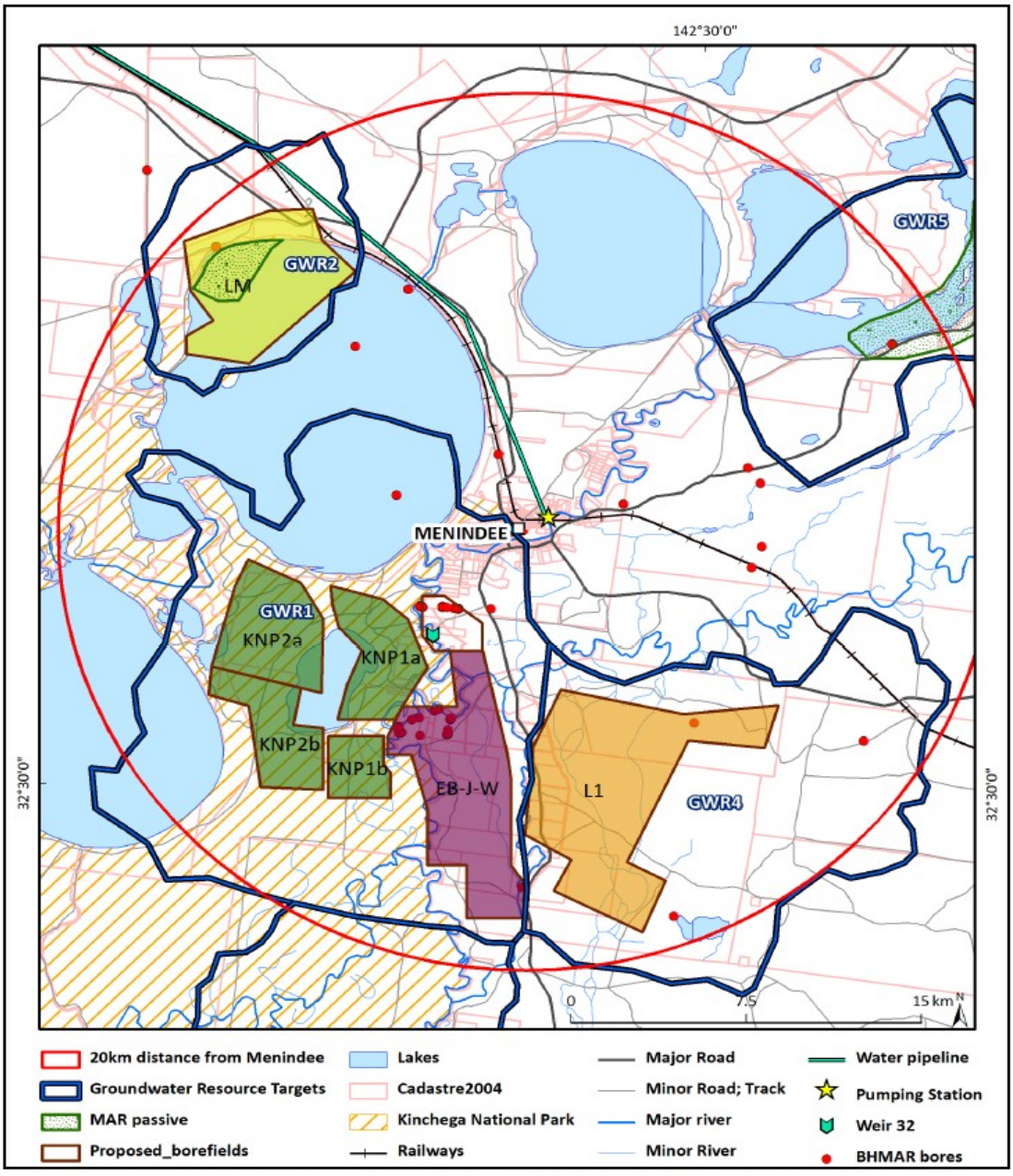

Figure A. Map of the groundwater resource and MAR targets in Pliocene (Calivil Formation and Loxton-Parilla Sands) aquifers within 20 km of Menindee township. The priority site is at Jimargil (EB-J-W), with back-up sites at the northern end of Lake Menindee (LM), Larloona (L1) and Kinchega National Park (KNP 1a, 1b, 2a and 2b).

Fig1. LOCAL GROUNDWATER MAP FROM Geoscience Australia BHMAR report 2013

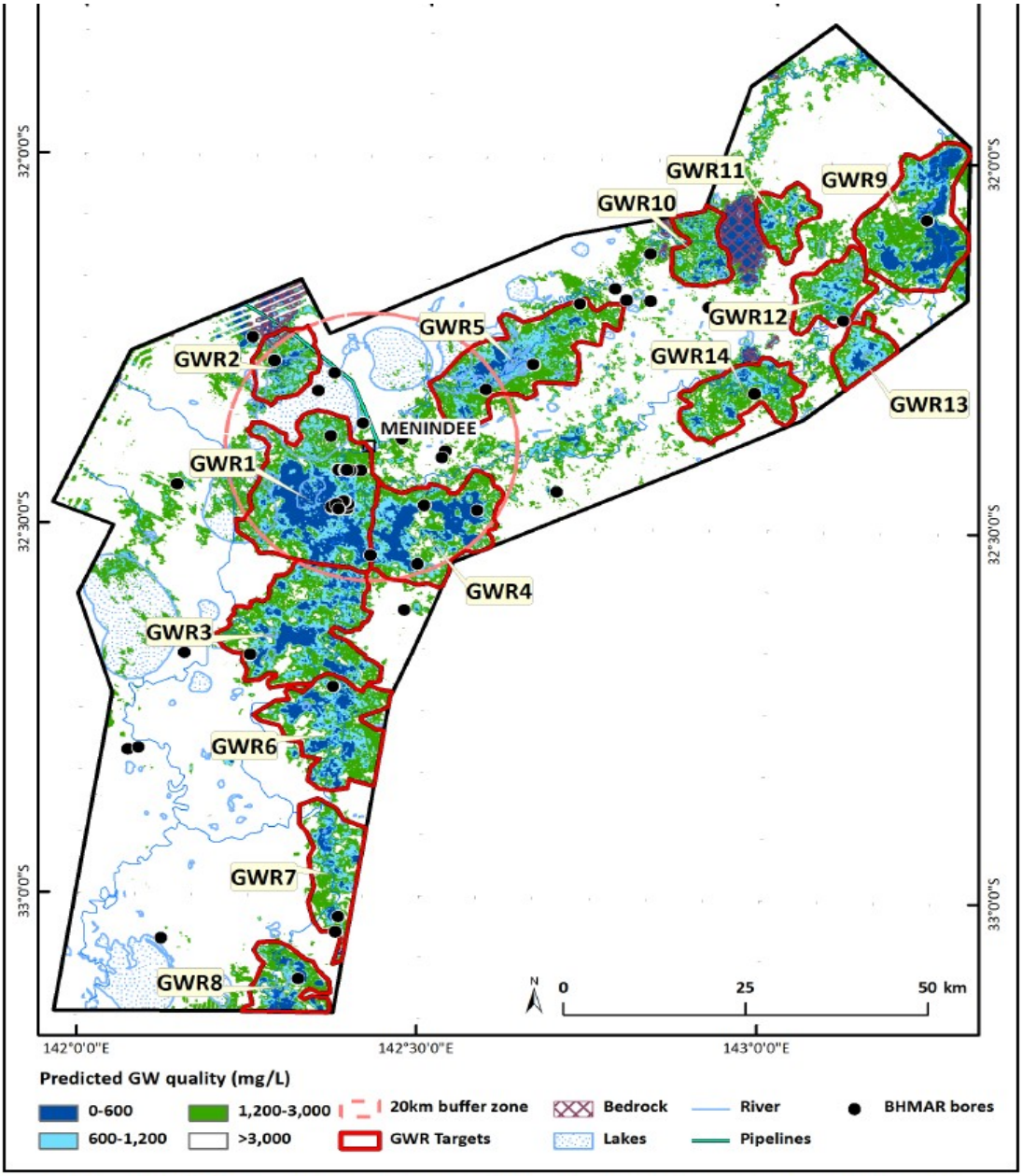

Figure B. *Map of the BHMAR project area showing the distribution of groundwater resource (GWR) targets in Pliocene (Calivil Formation and Loxton-Parilla Sands) aquifers. The boundaries marked are the maximum spatial extent of the aquifer with predicted salinities <3000 mg/L. This maximum spatial extent of fresh to brackish groundwater is defined by the combined plotting of all the AEM depth slices most relevant to the Calivil Formation (22-*

Fig 2. REGIONAL GROUNDWATER MAP FROM Geoscience Australia BHMAR report 2013

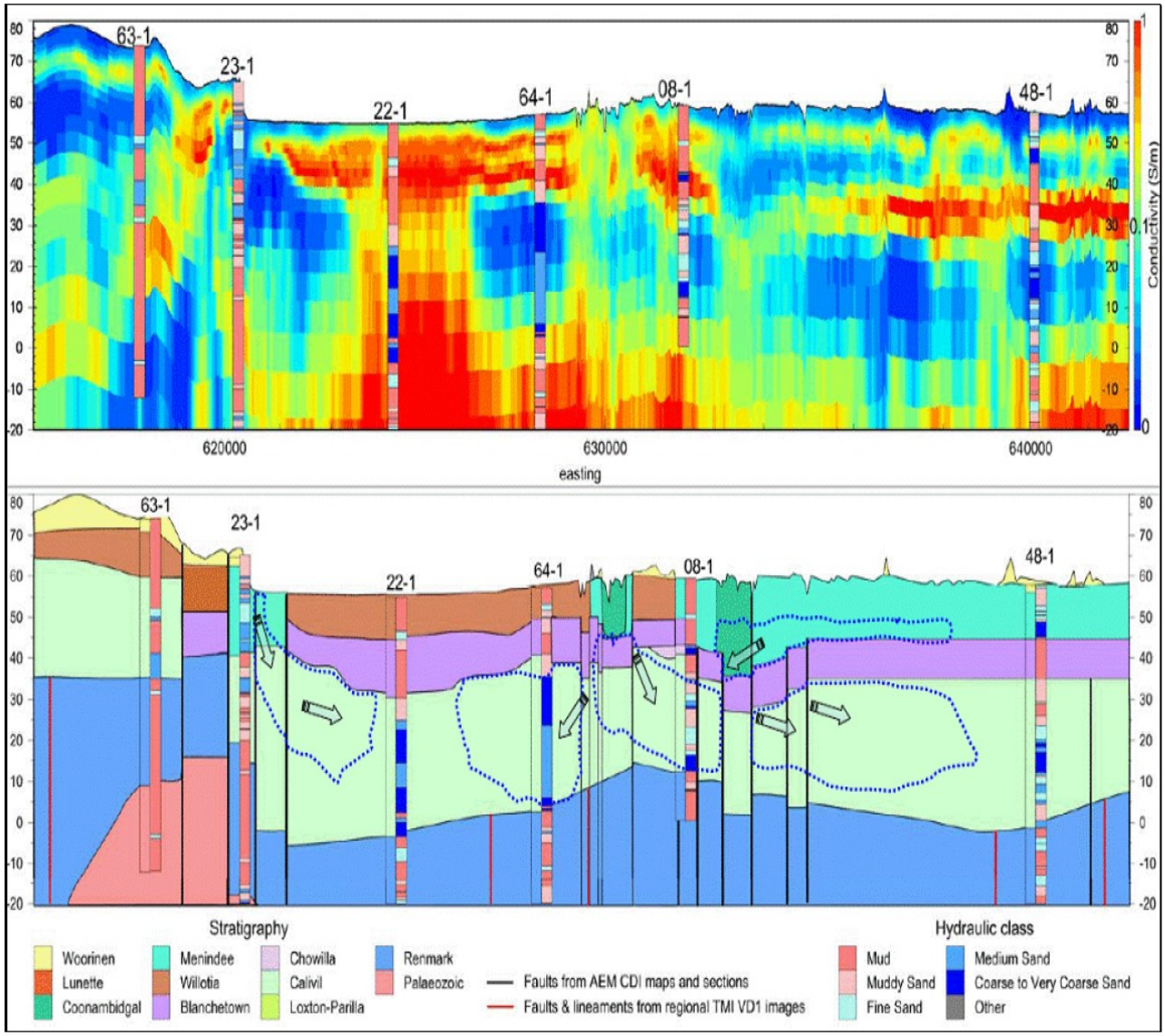

Figure F. *Geological cross-section NNW-SSE across the project area from north of Lake Menindee to Larloona Station. The top panel is an AEM conductivity depth section, with blue representing low electrical conductivity and red being high. The geological interpretation of the section is in the panel below. Boreholes are also displayed. Arrows in the lowe panel denote schematic recharge pathways to fresh groundwater resources.*

Fig 3. CROSS SECTION FROM Geoscience Australia BHMAR report summary 2013

Fig 4. CSIRO Map of MAR projects in Australia 2015
https://research.csiro.au/mar/using-managed-aquifer-recharge/#map

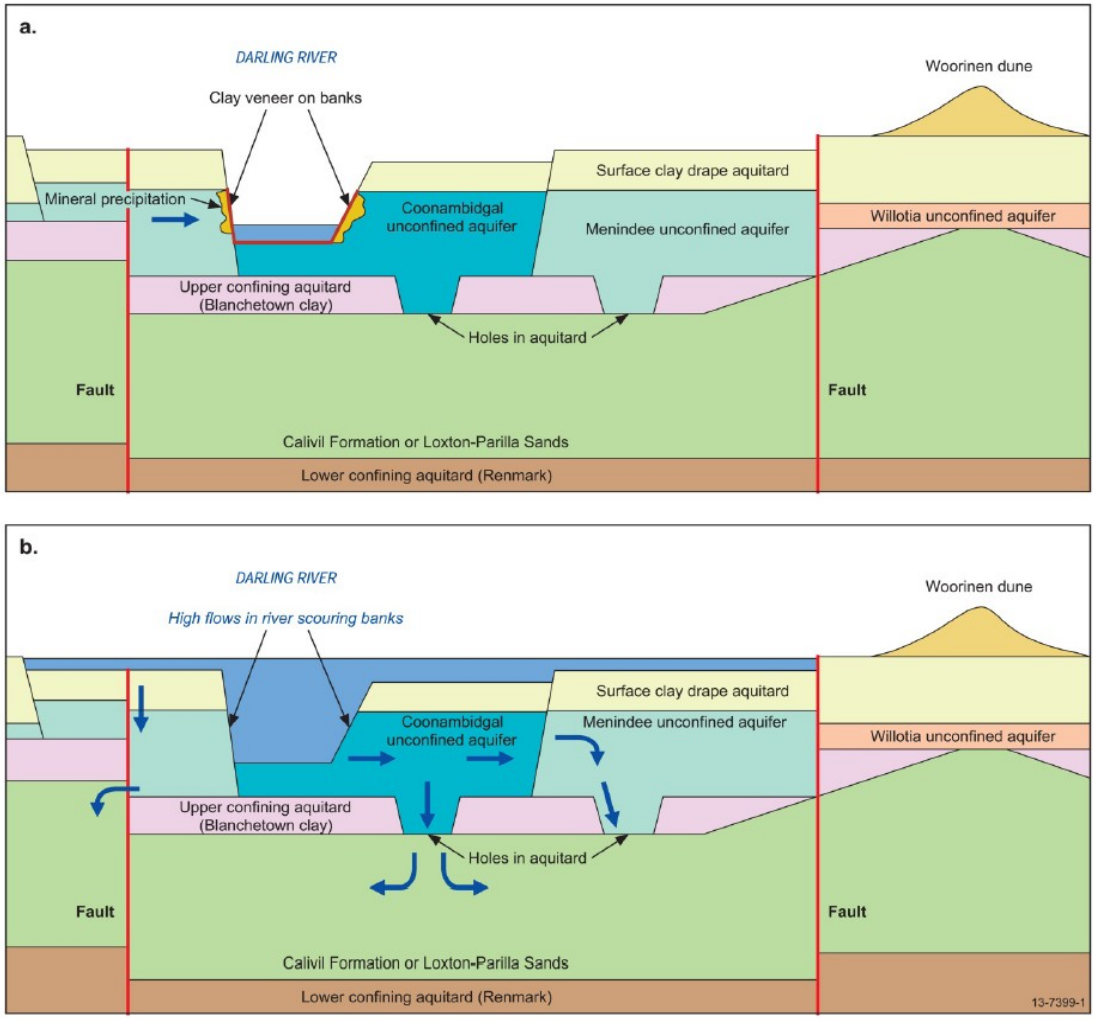

Figure H. *Conceptual model for groundwater recharge in the Lower Darling Floodplain alluvial sediments in (A) high-flow phase and (B) low flow phases.*

Fig 5 From BHMAR Report 05
Note : The text descriptor for A and B is wrong in the above diagram from the report - the loss of clay veneer allowing rapid recharge occurs in B, the High flow phase.

Appendix 1. The Menindee Aquifer Irrigation Areas

Some will see the proposed $500 million Murray River to Broken Hill pipeline as a major failure in adopting new MAR water technology at Jimargil Borefield[24]. When criticising we still need to remain constructive. The pipeline can also be seen as an opportunity to develop new enterprise in the region, based on doubling the total water supply to Broken Hill, and securing water supplies along both pipelines.

Broken Hill has suffered inadequate water volume for years, and a new corridors of economic use of reasonable cost secure water may change the region's economic base. We even have a model and example of such potential in the effects of the Western Victoria Wimmera-Mallee Pipeline Grid project. The corridor along the current pipeline may have cheaper water than the new pipeline zone.

This presents a challenge : how big should the new BH pipeline be? Certainly enough for around 30megL/day to Broken Hill, and BH's future needs, but analysis needs to occur for a bigger pipeline, enabling water sales along the pipeline to offset costs and develop the region. (The Darling Anabranch pipeline has proven inadequate for adaptation to solve the recent crisis. [25])

Broken Hill's eventual size after mining diminishes is unknown, but a well-watered oasis in the near desert is likely to remain a popular tourist location permanently. The 100 year whole-of lifetime cost/benefits of the pipeline could then look radically different, compared to spending $500 million on Broken Hill alone. Unloading the Broken Hill water supply from Menindee's pipeline will enable the similar expansion of new enterprise water use along the old pipeline.

RECOMMENDATION: That the Parliamentary committee consider recommending NSW Water and DPI Water investigate the costs and benefits of different pipeline capacities, with long term water sales to local corridor of pipeline enterprise adjacent to the pipeline, offsetting pumping and construction costs.

Passive MAR at the emergency borefield Northern rim of Lake Menindee

At Menindee, some will be disappointed with respect to NSW's choice of extraction borefield, not ASR at Jimargil. In reality, given the restricted time frame, and unknown salinity treatment cost of the water produced at Jimargil, NSW's choice of the second line aquifer at Lake Menindee was the simplest option. The water produced was unfortunately saline and needed RO desalination to use, however the size of the aquifer appears to be around the 2 to 3 years supply.

What does appear to be missing, is a published, thoroughly costed look at a *passive aquifer recharge* linked to the currently developed emergency borefield at North Lake Menindee. (see LM sub areas in Fig 1 from the BHMAR Report) . The bores drilled by NSW Water and Water NSW run in an arc around the North East edge of the lake, not over the LM zone. If these bores are operated in extraction mode, whilst there is fresh water overlying the LM porous area, an ASTR desalination of the aquifers should occur, without the need for expensive water treatment and new injection bore construction. If we focus on pumping out salt, there are very large passive aquifer beds available.

Establishing persistent water over the LM area does not require keeping Lake Menindee full – a low level canal plus pond area constructed around the arc from the inlet to the LM area should suffice. This may have the effect of retaining some shallow water adjacent to Sunset Strip, when aquifer recharge is taking place.

24 See the BHMAR Reports and quotes herein

25 Reanalysis of the problem suggests integrated lower Darling MAR aquifers along the pipeline could expand its use.

How long for an *"exchange recharge"* of the aquifers? (there are deep and shallow aquifers). This depends on the *hydraulic connectivities* of the aquifer between the recharge bed, and the pumpout bores, but a ball-park figure could be around the same projected time for emergency reserves to last- 2 ½ years of year-round or 5 years at winter-only exchange. Disposal of the underground water one off saline load is still required.

RECOMMENDATION: That the Parliamentary committee consider recommending NSW Water investigate the costs and benefits of passive MAR recharge and ASTR desalination of the currently developed emergency borefield, with long term water sales to offset pumping costs. If no funds are available, privatisation of the linked borefields in this GWR2 zone should be considered (preferably to community ownership model).[26]

Passive MAR with "shepherd aquifers" 50k upriver to Menindee

There are three easily accessible aquifers upriver to Menindee that also may lend themselves to passive MAR, with transfer to storage aquifers via ***short*** pipeline. These are GWR5 within the 20k, and GWR10 and GWR11(a palaeo-aquifer) well outside the 20k zone (Fig 1 BHMAR map).

Whilst GWR10 and GWR11 are outside the brief given to Geoscience Australia for their project, they may hold another key to affordable, community funded MAR in the region.
"- Alternative groundwater-related water supply options for Broken Hill that could provide enhanced drought security for periods up to 3 years (~30 GL), within 20 km of existing water and energy infrastructure at Menindee."

Using GWR10 and 11 as *shepherd aquifers*, then transferring to nearby storage aquifers via *short* pipelines, the stored water could be recovered down to Menindee via the riverbed with pulsed flows, not expensive long pipelines. The same short pipelines to transfer *shepherded waters* can be used to recover the water when required. This uses the shepherd aquifers as a giant bank filter, and there may be specifics strategies required to get this working, given the nature of the natural recharge during floods and bank flows. [27]

RECOMMENDATION: That the Parliamentary committee consider recommending NSW Water investigate the costs and benefits of a staged development of passive MAR recharge and ASTR desalination of storage aquifers upstream to Menindee.

Three Water enterprise development regions

There are three potential low volume, moderate water cost, small scale irrigation areas – the old pipeline, the planned new western Murray pipeline, and local Menindee Lakes zone. New enterprise activity, would contribute to *aquifer repair* and maintenance at Menindee. (With ASTR, given freshwater supplies, the more the aquifer is used the better the water quality is likely to be).

With Menindee, both surface Lake Waters, River flows, wetlands and Aquifers all need to be considered as a coordinated whole as water sources and destinations, however a focus on salt harvesting to reduce the Darling's salt load appears justified. Applying the self-funding aquifer repair model[28] to Menindee Lakes it appears that for salt :

26 The GWR2 of the BHMAR project do not match the emergency bores, but the aquifers are likely to be linked
27 See the BHMAR analysis of the likely mechanism of channel bank intermittent exposure of recharge strata
28 See the main submission on Lake George

1. The knowledge base for salt impacts on the emptying of the upper and lower Lakes is unknown (the evaporation effect is to leave brine in the aquitard lake floor (hence the 2011 CSIRO proposal to revert Lake Menindee and Cawndilla to natural flows with regular emptying, matches this requirement)[29]
2. The lakes are the recipient of large flows of water, and large tonnage of salt, without as yet a clear separation of how to deal with both;
3. The lakes are ideal evaporating pans – some more so than others ;
4. The aquifer used for Broken Hills reserve water supply is saline and remains inadequately characterised for recharge, and desalination, and protection from damage when they are pumped down (this may accelerate salt recharge not freshwater recharge);
5. These are likely to be *hydraulically connected* to riverine strata entering the rim of the lake and recharging surface waters.
6. There is ample sunlight and weather conditions for salt harvesting (minimum water loss, maximum salt removal, maximum salt value, choice of sites)
7. No plans for disposal of brine via pipeline, have been found to date; (the "salt slug" method of flow down the Darling and bypassing Menindee is a current known event)
8. Distribution of brine via existing pipelines is possible using time-shared transfer and flushing, with this enabling the use of a number of localities for salt pan evaporation (multiple use of infrastructure);
9. A likely spin off from coordinated salt harvesting may be permanent, salinity controlled freshwater and marine water bodies;
10. Stable controlled salinity water bodies provide the basis for multiple new water based enterprise as economic stimulus to the region;
11. This process together with freshwater recharged aquifers to manage future drought water supplies would improve the recreational and economic life for the region and downriver.

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29 CSIRO 2011 report that led to further work on the BHMAR project

Appendix 2. The Menindee Lakes Salt Works

At Menindee, both community and small scale irrigation from secure waters cannot logically be considered without considering salt and its removal from lakes and aquifers. *Salt farming* is the process of manufacture of salt from deposits via a number of methods, and Menindee Lakes has both ancient salt and new salt from the effects of European Settlement via the Darling water flows. Maximising the price for any salt may include separating ancient salt, and new salt. Salt has widely varying applications according to contaminants and processing, and may even need disposing of in landfill if it has no economic market.

The price of salt is around $23 per tonne, with transport costs of $20 to $40 per tonne rendering many salt deposits uneconomic to mine. The diffusion of salt from the lakes and other sources is uncharacterised. (Menindee has rail transport connection already originally for watering the Broken Hill mines in the 19th century:
"Rail passenger services at Menindee were cancelled on 3 November 1989 and recommenced on 26 March 1996. The station building has undergone some changes associated with conversion to a tourist information centre c.1998, now occupied by the Menindee Regional Tourist Association.")[30]

Salt Location, Location, Location

Menindee Lakes are centrally placed for salt removal from the Darling waters, with special opportunities occurring with heavy rain after a long dry spell. The resultant *"salt slug"* presents a challenge to downstream water users, remaining separate from fresh waters until below the weir at Wentworth (at which it mixes well with fresh water). If Menindee Lakes could harvest this, and confine it to a small transition lake, thence to evaporating salt lake(s), joint benefit could accrue to the Menindee Area. There is no reason why removal of salt cannot be paid for by the MDBA, just as *lack of removal of water* is paid for. They are two sides of the same coin – successful water supply quality. Instead of the salt slug bypassing Menindee and flowing on to damage lower irrigators, interception may be possible in a safe manner.

Disposal of the brine could occur by :
6. Pumping to an unused isolated lake that has a tight aquitard, is already saline, and does not communicate with freshwater aquifers.
7. Temporary store, then desalination at Menindee with smaller volume disposal to evaporating pan (as per current practice)
8. Temporary store then transfer to Broken Hill to desalinate and dispose of as per current plans for drought emergency supply borefield (there remain some unresolved issues with this)
9. Temporary store, then transfer to an isolated saline aquifer, with gradual use over time.
10. A direct extraction small pipeline from the base of inflow weir, could also work using "saline wedging" to keep fresh and salt waters partitioned.

Receipt of "Salt Slugs" from upriver after new heavy rains, into a redistribution network, would enlarge the concentrated salt source on a renewable basis, and temporary storage and later evaporation would allow the sale of salt production to match facilities and the saline load.

With respect to aquifer salt sources, a one-off pumpout of salt water is required. Moving Broken Hill's desalination plant to Menindee would increase Broken Hill's water supply proportionately. (allowance in the emergency borefield supply was made for significant the brine bypass from RO desalination). The power source for this would be a solar farm (sized to fit desalination and pumping requirements for the BHMAR staged project implementation). Multiple small salt harvesting projects

30 http://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=4802022

such as the Pyramid Salt project may end up being most practical [31].

"A salinity audit for the whole of the Murray Darling Basin (MDBMC 1999) suggested that the salinity regime is likely to deteriorate further over the next 20 to 100 years. This resulted in the Basin Salinity Management Strategy (BSMS2001 to 2015) and triggered the Federal Government National Action Plan for Salinity and Water Quality (NAPS&WQ 2001 to 2008)"
Australian Regolith and Clays Conference Mildura 7-10 February 2012
River Murray salinity management and irrigation . Bob Newman

Some Questions for salt harvesting site choice

We need to ask the experts- there are salt farmers available for knowledge of expansion and joint ventures. There is ancient salt, isolated salt in confined aquifers (the palaeo-aquifers identified by Geoscience Australia), and annually renewed salt from the Darling Catchment. A serious look at opportunity for both salt removal from Menindee, and its harvesting is worthwhile.

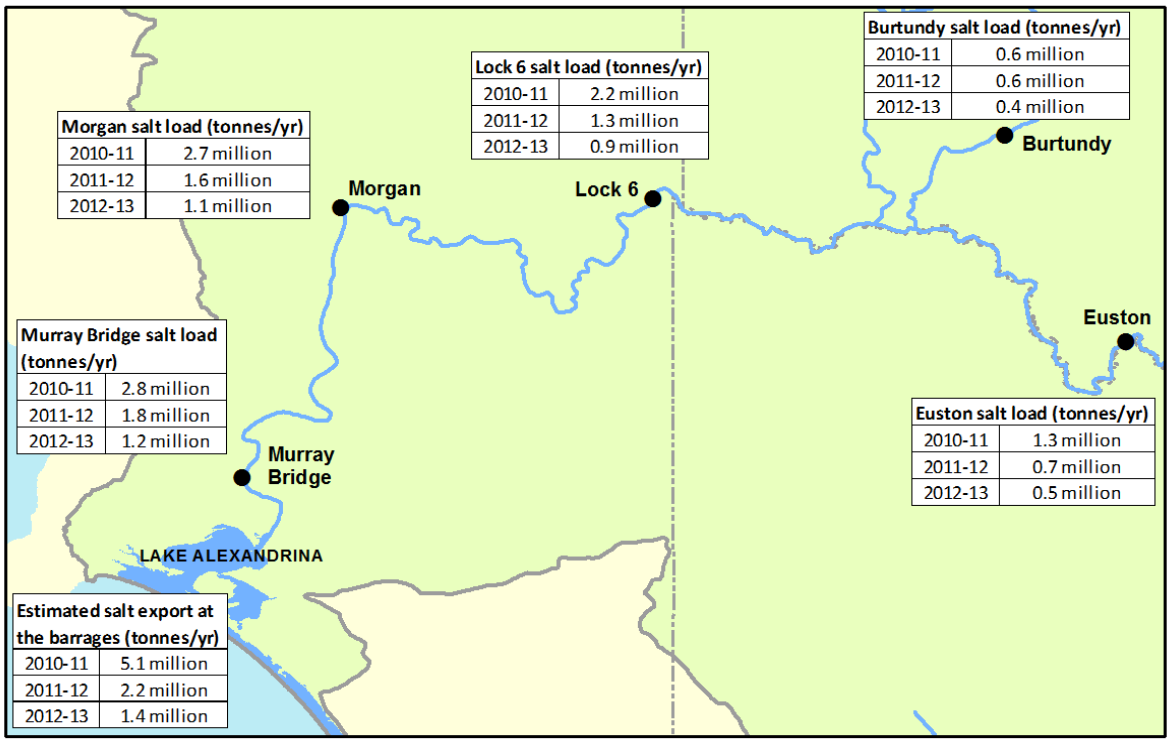

Fig 6. map from "Assessment of achievement of the salt export objective 2012-13 "
http://www.mdba.gov.au/sites/default/files/pubs/Assessment-of-achievement-of-the-salt-export-objective.docx

retrieved 19/7/16

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31 http://www.pyramidsalt.com.au/environmental_benefits.html

Appendix 3 Rural Australian ASTR in the 21st Century- all talk no water.

Aquifer Storage and Transfer Recovery (ASTR) is the most accurate terminology to describe the comprehensive drought-proofing of the Lower Darling proposed by Geoscience Australia at Menindee Lakes.1 The research completed in 2013 appears to have been widely ignored, in a puzzling Australian episode of failure to translate new knowledge into action. Lots of talk, many reports, but no action, and major persistent "*knowledge gaps"*.[32] Missing in action is government courage at State or Federal level to proceed rapidly with a pilot installation, to confirm key aspects of the research accuracy, on the ground at Menindee.

Commonly referenced in Australia as *MAR* or *Managed Aquifer Recharge* or *ASR (Aquifer Storage and Retrieval*), confusion between terminologies, and a daunting complexity in reporting, may have contributed to community and government ignoring the report. [33]

A review of readily available communications between government and community, social media, internet, research, agriculture, mining and news media, indicates the almost complete failure to communicate key aspects of the new knowledge. The reasons for this are not explored, but inter-organisational rivalry, competition and outright conflict between government strategy to change water use, may underlie some of this observable behaviour.[34]

The key new knowledge is that there is about 4,700 GigaLitres, or around 9 Sydney Harbours, underground within 20km of Menindee township and the current pipeline to Broken Hill . Even a small fraction of this, say 10% if reserved for drought use, is a practical permanent solution to drought-proof water supplies in the region. The water is saline affected to varying degrees, but there are about 14 "targets" or aquifers suited to ASTR methods development, and progressive desalination by pump cycling (not Reverse osmosis desalination). A small pilot project with minimal piping and bores, of some guaranteed use in drought, could be proceeded with rapidly, and extend Broken Hills current drought-reserved water supply out to around 5 years [35]. The timescale for this is small, and probably in the order of 6 to 12 months. (The key difficulty is uncertain correlation between Airborne Electro Magnetic data low and high resistivity, and fresh or saline water bodies.)

There are ample resources to implement ASTR, and the geology is well enough understood now to proceed with pilot developments. If the pilot program was successful, extending the process would progressively add to Broken Hill's water security, rapidly taking the drought protection interval out to 15 years (at 30megL/day) . Application of the project in practice should negate the need for desalination at Broken Hill, and provide for drought-proofed local community water, Lake and river environment, domestic, stock and fixed plantings of the region. This is NOT a major new irrigation scheme, but a permanent regional drought-protection project. The pilot project should enable small scale, pipeline grid-connected drought secure water sales sourced from Menindee, securing new economic activity for the region as per the Victorian experience.[36]

The water can be pumped back to the rivers and lakes during drought, to maintain water ecology, recreational, tourist, and fixed planting amenity in the district. Such a water system has the potential to provide cheap, stored water permanently.

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32 ***Knowledge Gaps*** and Information Science's use to bridge them are the writer's long term research area of interest
33 The total of the five reports is around 3700 pages.
34 These are some of the possible factors being currently explored by the writer
35 Current proven 2 years reserve plus 3 years from Jimargil pilot borefield (production only, no recharge assumed)
36 Wimmera-Mallee pipeline Victoria

Table 1. Groundwater estimates from the BHMAR Report.

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Source : BHMAR Report 5 page 14 015

"Table A. Indicative groundwater volume estimates for regional targets in the BHMAR project area. Estimates are rounded to the nearest 100 GL.

All GWR Targets

	Predicted Groundwater Salinity	Lower Quartile GwaterVolume (GL)	Median GwaterVolume (GL)	Upper GwaterVolume (GL)
All Targets Sub-total	<600 mg/L	900	1400	1900
All Targets Sub-total	600-1200 mg/L	1200	1900	2500
All Targets Sub-total	1200 - 3000 mg/L	900	1500	2000
Grand Total	<600-3000 mg/L	3000	4700	6400

Notes: These groundwater volumes are indicative estimates only. Groundwater storage volumes do not equate to extractable groundwater volumes, which would be smaller than these estimates.

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Table 2. Estimates with assumptions for drought protection periods (Spreadsheet-the writer):

Median Reserves MegL	10% reserve	MegL/day	MegL/Yr	Years	Destination
4,700,000	470,000	30	10,950	43	Broken Hill
		50	18,250	26	BH +Menindee
		70	25,550	18	BH +Menindee + Lower Darling
		90	32,850	14	BH+Men+LD+Cooyong

Assumptions:

1. 10% extraction limit
2. Desalination by pump exchange/shepherd aquifer
3. Shandying river/lake for salt discharge
4. RO only at critical salinity locations (1 off)
5. Downstream flow via river to downstream stores
6. LM NW pond/canal to provide passive recharge
7. Minimum provides for community, ecologies, stock, domestic, fixed plantings
8. Solar powered local energy source
9. Pipeline ASTR grid connecting storage aquifers
10. River delivery from upstream aquifers to lake /bypass
11. LM and Lcawdilla Lower store/release 10GL/day
12. Graduated MAR aquifer desal over 20 years

One problem from the BHMAR project's finding, is that the Sustainable Diversion Limits (SDL) used by the MDBA for the Menindee underground water resources is wrong. The current SDL is based on an assumption: that recharge to aquifers in this region occurs through dryland rainfall.[37] Rainfall recharge to Menindee Aquifers *does* appear to contribute some recharge – but only around 1%, with the rest being via flood and river processes, now better understood with the BHMAR research.

The authors of the BHMAR tiptoe around this issue, perhaps because it represents a flawed foundation of the MDBA's method of imposing reform of water use in the Murray Darling Basin. For whatever reasons, the BHMAR research is too important, and too good to allow it to be forgotten for political convenience. In my view it is a comprehensive high-quality work, of critical interest to all Australians who suffer drought. It represents a *new knowledge base* that can be rapidly adapted, and rapidly converted to real runs on the board. It can be adapted to small-scale ASTR methods anywhere, and needs to be linked to new solar energy sources, artificial wetlands, water-grid construction, and strategically selected desalination technologies.

37 See Quotes from the BHMAR Project report

The MDBA needs to admit the SDL methodology ***is*** wrong in places, correct it and move on. Furthermore, there is no real need for underground water SDLs for modern borefields with good measurements -merely knowing the aquifer levels, salinity and water quality. Such measurements can accurately drive pumping extraction and recharge of aquifers. Everyone can understand when a tank is nearly empty we need to refill it, if it's full we can use it. In applied science terms, the SDL model in use needs to be "recalibrated" with new data from new research. Recalibrating Menindee's SDL is an enabling requirement for developing the new drought-proofing proposal from Geoscience Australia.

The failure of *translational science* in this case has led to misplaced enthusiasm for an expensive but safe and probably obsolete proposal – a new long-distance pipeline from the Murray to Broken Hill touted at around $500 million. Will such a pipeline drought-proof Menindee Lakes and the Lower Darling, and provide permanently affordable drought-proof water for Broken Hill? These are the basic design briefs or "*use-cases*" for the water engineering challenge.

It is probably hard for multiple scientific authors of a very large research project, to produce a succinct, understandable and lay-person readable report. They have produced a massive work, that is probably incomprehensible to public servant advisors to Government (who no longer have time to read and understand such material in modern times anyway. Even assigning 1 or two public servants a month to read the documents and understand it, so that they can advise politicians, may not to work due to modern staff turnover. Responsibilities between departments are ferried around frequently as governments change, and key workers who understand a complex topic, are likely to be lost to other projects.

Notwithstanding all the above, there is another key problem with the BHMAR proposal -it comes from a well-funded, specific output, short time-frame group totally unaligned with the low-budget, limited resources, real-world challenge for NSW Water and contractors drilling bores in the bush. Geoscience Australia can afford cutting edge scientific complexity, but the effort is wasted unless it is simplified and prioritized for *translation* to rural Australia.

MAR standards written for cities are not directly apply in the bush without conversion for context. The water source and overall installation cost, plus running costs render many plans economically impossible. If the exchange between aquifer and river is a known natural process, we don't have to get too fussed about high quality water pre-treatment before returning it to an aquifer. We do have to get right particulates, and water incompatibility – these can damage the recharge bore/aquifer. We do have to get right prevention of other contaminants such as mine sourced heavy metals[38]

The BHMAR report has flagged limited development at more than 20kmm from Menindee due to expensive pipeline and other costs. This assumption is challenged – we can use the river to deliver pumped water from upstream, and transfer via river or aquifers to replace pipelines at low cost. We could even pump down the Great Artesian Basin (GAB) up at Bourke and Wilcannia, and with pulse-release flows expect to be able to recharge Lower Darling storages in winter. We could then recharge the GAB from future river flows if we can figure a way to pay for the energy.

We can also pump-down aquifers downstream of Menindee and use the water to recharge storages of the Lower Darling in drought. Distributed properly scaled solar farm methods are now mature technology with known costs bases, not risky experimental installations. This is why stock-water bores can be seen now throughout Australia with small solar installations, sized to fit the need.

38 See the Molonglo River , below Captains Flat and fish survival of zero at 5 days

What about salt? As a generality the more you use an ASTR aquifer within its design and borefield limits, the better the water quality retrieved. ASTR itself provides an opportunity to pumpdown an aquifer salt-affect at one end, and pump in fresh water at the other. Most urban ASR installations in Australia employ multiple cycles of injection and retrieval, with progressive salinity reduction. At Menindee, we are likely to pump out saline waters to mix with released downstream flow so that overall flow salinity is acceptable. At the same time we can pump in treated freshwater at the other end of the aquifer. The source of the water can even be an adjacent aquifer with better water, provided the waters are compatible (hence the title "Aquifer Shepherding"). Water compatibility testing is one part of the ASTR development process essential for such an installation.

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