REGIONAL WATER SECURITY PROGRAM

Greater Hunter regional water strategy

Securing the future water needs of the Hunter, Central Coast and Mid-Coast areas

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Abbreviations

AWD	available water determination
AWRA-R	Australian water resources assessment river model
BLR	basic landholder rights
CCC	Central Coast Council
CHPP	coal handling and preparation plant
CNAF	Catchment Needs Assessment Framework
CSIRO	Commonwealth Science and Industrial Research Organisation
DPC	Department of Premier and Cabinet
DPI	NSW Department of Primary Industries
ECA	environmental contingency allowance
ECL	East Coast Low
EOS	end of system
EPA	NSW Environment Protection Authority
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
GDE	groundwater-dependent ecosystem
GRP	gross regional product
GHR	Greater Hunter region
HEVAE	high ecological value aquatic ecosystems
HWC	Hunter Water Corporation
INSW	Infrastructure NSW
IPART	Independent Pricing and Regulatory Tribunal
IWCM	integrated water cycle management
LTAAEL	long-term average annual extraction limit
MCA	multi-criteria assessment
MCC	Mid-Coast Council
MDBA	Murray–Darling Basin Authority
ML	megalitre
Mt	mega tonne
MW	megawatt
NWIDF	National Water Infrastructure Development Fund
OEH	Office of Environment and Heritage
ppt	parts per thousand
SIS 2014	*State Infrastructure Strategy 2014 Update*
UNSW	University of New South Wales
UNSW WRL	University of NSW Water Research Laboratories
WMA	*Water Management Act 2000*
WSP	water-sharing plan

Summary

The Greater Hunter Region lies to the east of the Great Dividing Range from the Manning River Valley in the north, to the Central Coast in the south. The region is home to over a million urban and rural residents. It's also Australia's largest regional economy, with local industry contributing over $50 billion to the NSW economy every year. Much of the region's economic contribution comes from electricity generation, coal mining and agriculture. All of these industries rely heavily on secure water supplies. The region is also a popular tourist destination, partly because of its high-quality water environments.

It has been over 20 years since the last water strategy was developed in the Greater Hunter region. In that time, the region has quadrupled its output of coal, experienced the deregulation of the power and dairy industries, and suffered a major drought that exposed significant water and energy security risks. Significant water reforms have also occurred, including the establishment of water as a property right separate from land entitlement, the introduction of legally binding water-sharing arrangements between consumptive users and the environment, and trading of water between different water users. With water-sharing plans designed to protect important environmental values in the Greater Hunter, the water trading market is the primary mechanism for economic growth.

Water is managed in the Greater Hunter through seven water-sharing plans, three major water utilities and numerous categories of licences within the region. Water is also transferred between different water-sharing plan areas while some utilities store water on behalf of others in the region. Water supply and demand issues faced by the many different water users in the region are often so complex that they can't be dealt within a single water-sharing plan. This strategy was developed to address these issues using a risk assessment and evidence-based process.

A central issue for the Greater Hunter region is its inability to achieve a diverse mix of industries due to the available water resources being fully allocated with large entitlements, especially water of higher reliability, restricted from being traded between different users. This was particularly the case in drought, where less than 10 per cent of the available water was able to be traded. A number of factors have also affected the efficiency of the water trade market, including physical barriers preventing water being moved from one source to another, as well as water licence exemptions and special-purpose licence restrictions. This strategy considers infrastructure solutions to overcome the physical barriers preventing water from moving to its highest need.

Regional water strategies use a systems approach to water planning that recognises the interdependencies of the different sources and management of water within a region. The NSW Government is developing strategies to ensure infrastructure funding is targeted to achieve the greatest benefit and to distribute these benefits to achieve the optimum economic and community outcome. To achieve this, strategies consider a broad range of water management issues, including planning and regulation, the water trading market, and commercial and community viability. In developing this strategy the community, stakeholders and experts helped to identify the risks to water security in the Greater Hunter region, including:

- extended periods of severe restrictions for urban centres during drought
- managing a range of droughts, including those worse than has been recorded
- prolonged periods of reduced water availability impacting on the diversity of industries
- Australia not being able to meet its international obligations under various signed conventions
- the quality of the water cannot sustain environmental and human needs
- competing uses of water will place stress on environmental assets.

How those risks change in the future is dependent on five drivers, including:

- continued population growth within the region's major urban centres
- the planned closure of the two thermal power stations
- reductions in base flows from the interception of groundwater and surface runoff

- increasing demand for agricultural products
- climate change.

Numerous hydrologic, environmental and economic studies were undertaken to inform and assess the current risks, and how those risks change with combinations of drivers and infrastructure. The key findings from this analysis are:

- Drought security was confirmed as the primary economic risk facing the Upper Hunter. This risk extends to all sectors, including urban, agriculture, mining and power generation.
- Analysis of historical rainfall patterns shows that droughts have been under-estimated in the Upper Hunter and a stronger variation in rainfall occurs across the Greater Hunter region.
- A repeat of the 1940s drought (the worst on record) would see general security water allocations reduced to zero for approximately 12 consecutive years.
- Analysis of the variability of climate indicates that the 1940s drought may occur on average 1 in 40 years.
- Reductions in the base flows of rivers have occurred, and will continue to occur, as mining intercepts surface runoff and lowers groundwater levels near rivers.
- The proposed closure of Liddell Power Station in 2022 will not significantly mitigate the risk of failure of supply to water users in the Hunter Regulated River.
- Infrastructure options that increase the connectivity of water across the Greater Hunter region will deliver the most benefit and could significantly delay the next supply augmentation for both Newcastle and Central Coast, potentially mitigating the need for water restrictions.
- Most of the scenarios involving infrastructure were found to be beneficial and a multi-criteria analysis identified the following infrastructure options for further investigation:
  - construction of a two-way pipeline between Lostock and Glennies Creek Dam.
  - construction of a potable pipeline from Hunter Water Corporation (HWC) infrastructure to Singleton.
  - a large-scale water reuse scheme.
  - continued operation of the Barnard Scheme after Liddell Power Station closes.
- The wetlands of the Hunter River estuary are of international importance and are listed under the Ramsar Convention. Hydrologic modelling of the Hunter River estuary indicated that the options investigated could be managed to maintain the wetland's characteristics, and in doing so, meet Australia's international obligations under the convention.
- To maximise the economic and environmental benefits of these infrastructure priorities, the water-sharing plans and administrative arrangements within the Greater Hunter region will need adjustment.
- Large-scale recycled water options associated with AGL Macquarie had high economic value. Further analysis of recycling options is recommended.

To achieve an improvement in drought security, promote economic growth and better protect environmental assets, the strategies and actions in Table 1 are recommended.

This regional strategy is the tool for an ongoing conversation about the direction of water management within the region. This strategy outlines the major risks and drivers that everyone as water managers will face over the next 20 to 30 years. It is important that industry, state and local government, water utilities and the community are engaged in active discussion and debate on the key strategies and actions that have been identified as a result of technical investigations and studies. This document has been produces as a tool for this important discussion to take place.

Table 1. Strategies and actions

No.	Existing management	Proposed strategy	Action to implement strategy	Responsibility
1.	**Managing the Upper Hunter, Manning and Lower Hunter/Central Coast separately, with varying degrees of drought risk and water utilisation.**	**Invest in infrastructure to physically link the region to utilise the benefits from climatic variation.**	**Action 1:** Prepare business cases for: • Constructing a potable pipeline between Hunter Water Corporation (HWC) and Singleton Council. • Pipeline connecting Lostock and Glennies Creek Dams. Infrastructure NSW (INSW) has recommended in the State Infrastructure Strategy (SIS) Update 2018 that these two business cases be prepared by both WaterNSW and HWC in order to achieve the objective of longer-term water security for the Hunter region.[1]	Hunter Water Corporation and Singleton Council WaterNSW
2.	**Switching off water-sharing plans (WSPs) in extreme events. The Hunter Regulated River is managed within the bounds of the historical climate record.**	**Document rules for water-sharing during extreme events based on probability of supply.**	**Action 2:** Develop Drought Contingency Plan for the whole region including: • Operating rules when entering a drought. • Current operating rules for known droughts. • Operating rules for beyond the worst drought on record. The contingency plan will incorporate and review existing arrangements and allow for the movement of water to mitigate drought if infrastructure is built.	NSW Government
3.	**Giving privileged access to major water utilities during extreme events, with water only used for the purpose of the utility.**	**Review AGL entitlements as their generating capacity reduces.**	**Action 3:** Work with AGL to review water-sharing arrangements by early 2019 to enable an informed response to the closure of power-generation plants in the Greater Hunter region.	NSW Government

[1] NSW 2018 State Infrastructure Strategy 2018:
https://insw-sis.visualise.today/documents/INSW_2018SIS_BuildingMomentum.pdf
Water Chapter 11: https://insw-sis.visualise.today/chapters/Water.pdf

No.	Existing management	Proposed strategy	Action to implement strategy	Responsibility
4.	**Establishing individual agreements between utilities with physical infrastructure links.**	**Advance water governance arrangements that optimise water management outcomes.**	**Action 4:** Develop agreements between water utilities/providers on how infrastructure will be managed and operated. This will ensure optimal reliability and security for users within the context of reviewing and improving environment risk. Noting that the financial arrangements are a matter for the utilities.	NSW Government with water utilities
5.	**Sharing of water through water-sharing plans based on existing infrastructure and operational rules.**	**Optimise sharing with new infrastructure, including during periods of varying degrees of drought.**	**Action 5:** Review water-sharing arrangements in line with new infrastructure to address reliability of supply.	NSW Government with water utilities
6.	**Basing water trade markets around individual water-sharing plans with extraction limits.**	**Broaden and deepen the water trade market by allowing transfers between WSPs within a framework that protects third parties.**	**Action 6:** **6.1:** Adjust water-sharing arrangements to ensure the water trade market can maximise the benefits of investments in infrastructure while protecting the environment and other water users from third-party impacts consistent with the principles of the National Water Initiative Agreement. **6.2:** Inform users of current levels of risk on their modelled reliability of supply and explain possibility of conversions.	NSW Government
7.	**Discharging waste water to rivers and ocean.**	**Improve the water trade market opportunities for recycling by introducing recycling and incentives.**	**Action 7:** **7.1:** Hunter Water Corporation further investigates opportunities for a major recycling project consistent with the Lower Hunter Water Plan. **7.2:** Investigate the potential of reuse schemes generally.	Hunter Water Corporation with NSW Government NSW Government with water utilities
8.	**Protecting environmental values through addressing high and low flow events.**	**Review and improve environmental obligations.**	**Action 8:** **8.1:** Monitor and see Action 4. **8.2:** Clarify environmental rules during extreme events and remove uncertainty from WSPs	NSW Government

Part 1: Development of the strategy

Photograph 1. Farmer in Morpeth, Maitland (Maitland City Council)

This Greater Hunter regional water strategy has been designed to set the context and build on the work being undertaken by many of the agencies that manage water within the region. It combines the water resources knowledge of the NSW Department of Industry's Land and Water Division with comprehensive water demand and supply forecasting, industry insights and expert advice on project population and economic growth.

The strategy has used a systems approach to water planning within the region to ensure it is considered as a whole rather than as individual components. This involved:

- using *2014 State Infrastructure Strategy Key Issues* as a starting point
- identifying and quantifying the risks
- identifying the drivers of change
- setting future direction for water-sharing and infrastructure to reduce the level of risk.

This initiative is capable of being carried out due to the advances in the understanding of systems, improvements in hydrologic modelling and a whole-of-government approach sponsored by Infrastructure NSW.

Hunter River catchment key issues

- Forecast Low Drought Security with expected increased demand for water for mining and population growth.
- Low flow utilisation.
- The Upper Hunter has low water reliability because although Glenbawn and Glennies Creek Dams are large they only regulate a small proportion of the valley. Also Lostock, which has the potential yield, is a small dam. The eastern catchment is high yielding but largely unregulated and disconnected from the demands for mining and power stations located in the central catchment.
- Newcastle is the second largest city in NSW. Other major towns include Maitland, Singleton, Cessnock, Muswellbrook and Raymond Terrace.
- The Hunter supports a large population and a diverse range of important water users including Hunter Water Corporation, local councils, power generators (providing most of the electricity of NSW), major coal mines (Newcastle Port is one of the largest coal facilities in the world), other heavy industry, world renowned horse and cattle studs and wineries, as well as other agriculture and dairy farms.

Infrastructure NSW
Extract from *State Infrastructure Strategy Update 2014*

The following stakeholder engagement occurred during the development of this strategy:

- The mining industry was involved through a 2012 mine survey on water usage and a workshop to discuss the results within the mining industry. This provided a better understanding of the volumes of water taken and used by mines.
- Water users and the community were involved in the review of the regulated river water-sharing plan in exploring water-sharing arrangements that could assist with managing drought risk.
- Universities provided scientific and evidence-based information:
    - The University of Newcastle was engaged to provide hydrology, climate change and variability.
    - The University of New South Wales was engaged to carry out estuary hydrodynamic modelling.
- Investigations into the security of water in the Upper Hunter were undertaken through the Upper Hunter Priority Catchment (UHPCP) project funded by Infrastructure NSW. This was undertaken via a steering committee led by the Department of Premier and Cabinet, with the following agencies involved in the steering committee and working group:

  - NSW Department of Premier and Cabinet (DPC)
  - NSW Department of Primary Industries (DPI)—Agriculture
  - NSW Office of Environment and Heritage (OEH)
  - WaterNSW
  - DPI Regional Development
  - NSW Department of Industry—Lands & Water
  - Upper Hunter Shire Council
  - Singleton Council
  - Muswellbrook Shire Council
  - Hunter Water Corporation.

  Following these investigations, INSW requested further consideration of linkages with the Lower Hunter and other areas of the GHR.

- The water utilities were involved by contributing information to support the development of the strategy and as members of the Upper Hunter Water Issues Steering Committee that oversees the program.
- Support of the Department of Premier and Cabinet Upper Hunter Industries Scenarios Project that promotes regional development within a changing industry environment. This was a research project covering the future of the area's agribusiness, coal production and power-generation sectors. It involved collaboration between the Department of Premier and Cabinet (DPC), NSW Department of Primary Industries and NSW Department of Planning and Environment.
- Two industry leaders' forums were held on 30 May and 10 June 2016 to identify opportunities for agribusiness development and to establish industry development scenarios for resource, energy and agribusiness development.

  The forums also included participants from the Singleton, Muswellbrook and Upper Hunter Councils, NSW Office of Environment and Heritage, Australian Trade and Investment Commission, Hunter Research Foundation, Newcastle University, Australian Bureau of Agricultural and Resource Economics and Sciences, Regional Development Australia Hunter, Jobs for NSW, HunterNet, Newcastle Airport, Hunter TAFE, Hunter Business Chamber and leading coal mining, power generation and agribusiness companies with an interest in the Upper Hunter.
- In-depth interviews with leaders from government, industry and research organisations with an interest in the Upper Hunter was undertaken by the economic and regional development consultants Michael Connell and Associates to assess coal, power generation and agribusiness industry opportunities.
- Collaborating with Hunter Water Corporation, and other agencies, on the development of a single platform estuary model required to meet Commonwealth requirements for cumulative assessment of the coal mining industry on the Ramsar wetlands.

In addition, the Commonwealth has undertaken studies within the region to provide scientific information associated with coal seam gas and large coal mines.

These technical studies, together with community and industry consultation, provided a solid foundation for making risk-based decisions about how best to meet industry and population growth forecasts, manage the downsizing of mining and power generation and allow for new water-based industries to emerge whilst preserving existing water users' security and protecting environmental and cultural assets.

Risks were identified from community consultation in the development of the water-sharing plans; from agreements and legislative obligations with the Commonwealth Government and consideration of the results of technical studies undertaken to support water management in the region. The future scenarios considered for the Hunter Valley were chosen from a combination of what the community and industry were saying.

This strategy is the tool for an ongoing conversation about the direction of water management within the region through the evaluation and monitoring of the major issues facing current water management arrangements.

Major issues and risks identified in many public forums are listed in Table 2. The column on the right highlights the issues and risks addressed in this strategy (highlighted in blue). Issues that are not being addressed in this strategy are covered in other water initiatives. This strategy can help in discussions relation to those initiatives.

Table 2. Issues and risks raised by the community

Issues and risks raised by community	Considered in strategy
Aboriginal cultural issues	No
Broadening the water trading market	Yes
Buybacks of licences	No
Climate variability	Yes
Connecting groundwater and surface water	Yes
Connections between water-sharing plans	Yes
Controlled allocations	Yes
Conversions	Yes
Cumulative environmental impact	Yes
End of system flows and estuary	Yes
Environmental flow requirements	Yes
Exemptions	Yes
Extraction of high-flows	Yes
Generic approach in rule development	No
Groundwater dependent ecosystems	No
High-flow extractions	Yes
Hunter Salinity Trading Scheme	Yes
Infrastructure—large scale existing and new	Yes
Infrastructure—farm dams—location and funding	No
In river dams	No
Interception and diversion of base flows from mining	Yes
Introduction of new industries	Yes
Metering	No
Minister's Dealing Principles	No
Monitoring program	No
Natural pools in systems	No
Protection of biodiversity and overall catchment health	Yes
Recycling of water	Yes
Stormwater harvesting	No
Stranded assets	Yes
Substitution	Yes
Third-party impacts	Yes
Tidal pool extraction	Yes
Water quality	Yes
Water-sharing rules	Yes

Part 2: The Greater Hunter region

The Greater Hunter region (GHR) is the area to the east of the Great Dividing Range in New South Wales, from the Manning River catchment in the north to the Mangrove Creek and Mooney Mooney Creek systems in the south (see Figure 1). The three main catchment areas referred to in this document are the Hunter Valley, Mid-Coast catchments and Central Coast catchments. Jointly these cover 37,000 km^2.

Photograph 2. Aerial view of Hunter River at Morpeth (NSW Trade & Investment)

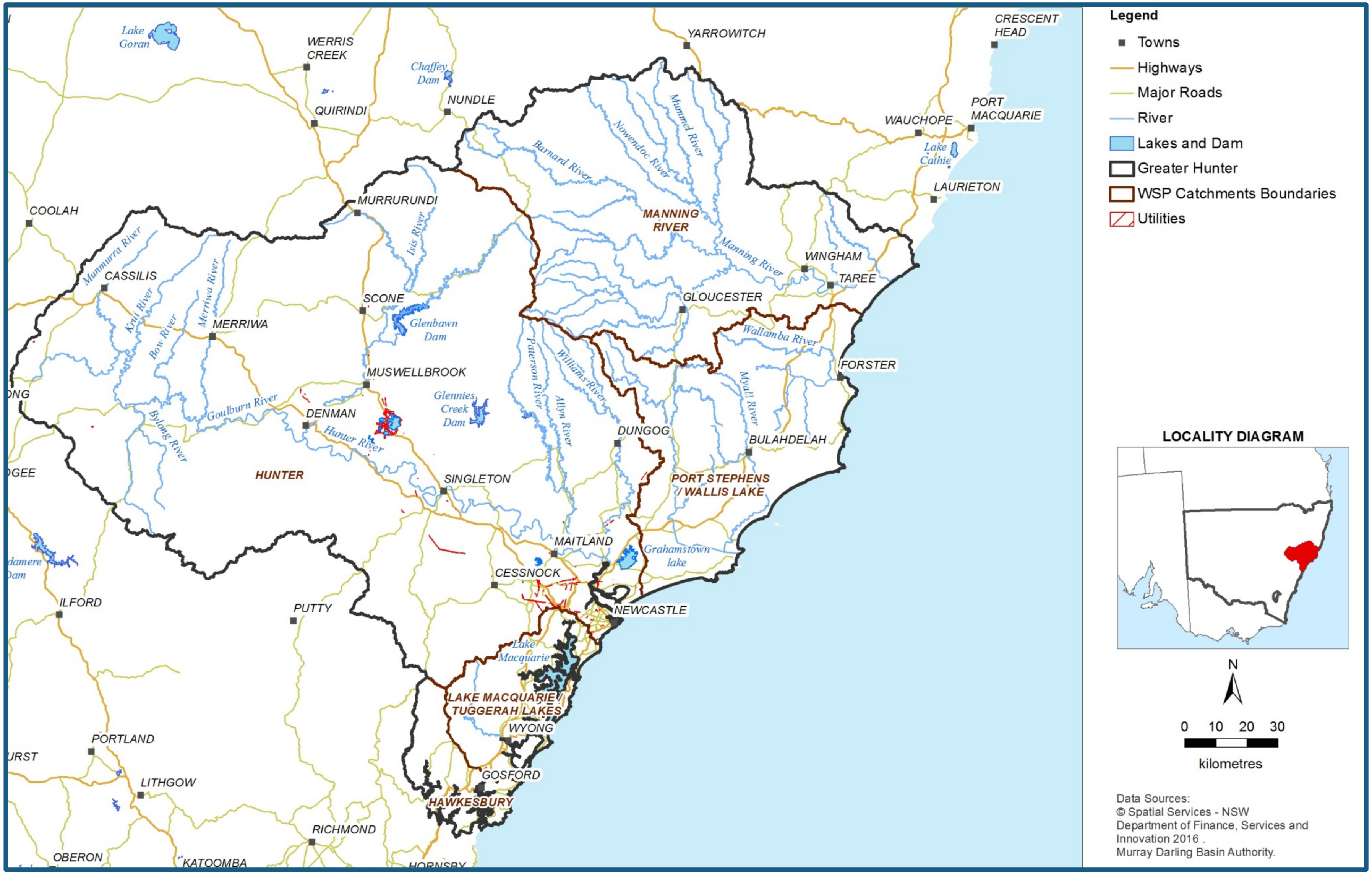

Figure 1. The Greater Hunter region

History of Indigenous communities

The first peoples of the Hunter comprised approximately seven different cultural groups. The language and tribal groups of the Hunter include the Kamilaroi and Wiradjuri in the Western Valley, Geawegal to the north-west, Wanaruah in the central valley, and Worimi to the north-east with the Darkinjung in the south.[2]

The Awabakal are the traditional owners of land from the Hunter River in the north to Tuggerah Lake in the south. The Awabakal are people of the coast, estuaries, lakes and wetlands, but also had an attachment to the rugged sandstone country of the Sugarloaf and Watagan Ranges. They lived by fishing and gathering shellfish, as well as hunting animals and collecting fruits and tubers.

Belmont Lagoon is a place of cultural and spiritual significance, being the site of a major annual corroboree and the subject of a traditional story about the formation of the lagoon. Jewells Swamp near Redhead provided a rich food source including emus, waterbirds, kangaroos, shellfish and fruit from burrawang palms. Middens in the area provide evidence of thousands of years of Aboriginal occupation.

The Worimi are the traditional owners of the Great Lakes and Port Stephens area between the Hunter and the Manning rivers. The landscape includes an abundance of Aboriginal cultural sites including burials, campsites and middens. Traditionally, the Worimi people used the beaches to travel between the northern and southern parts of their country. The Worimi people manage the Stockton Bight areas (known as Worimi Conservation Lands) through a joint agreement with NSW National Parks and Wildlife Service.[3]

Aboriginal communities have a spiritual and customary living relationship with water in all its forms, through creation stories, use of water as a resource, and knowledge about sharing and conserving water.[4] The Hunter River was called Coquun, Myan or Coonanbarra for the Aboriginal nations of the Hunter Valley. *Biame* is the Supreme Being. In the Dreaming Stories of the Wonaruah people, all things were created by Biame and the valley floor parted and what was to be the keeper of life was formed. The river now flowed. The land was ready. Both man and animal descended from the spirits and moved over the earth. This shows the importance of the river to the Aboriginal people. Reports from the early 1800s suggest that the river provided an important source of food, as fishing with lines, nets, fishing spears and weirs was observed as well as the collection of shellfish such as mussels.[5]

Although Europeans visited the Hunter region as early as 1790, and cedar getters travelled up the river from this time, European settlement of the Hunter River did no commence until a convict camp was established in 1801 to exploit coal supplies at a place called Muloobinbah (*place of ferns*) by the Awabakal people, on the site of present day Newcastle. Expansion through the valley was swift and 245,000 hectares land had been claimed by 1825. The pattern of clearing occurred along the rivers as a result of the fertility of the alluvial plans and access to fresh water. Expansion continued throughout the 19th century. The resulting displacement of the Aboriginal people from the best land in the district, conflict with settlers and convicts, and sickness took a severe toll on the Aboriginal population.[6]

The importance of the region to NSW

The Hunter Valley has the largest regional economy in Australia, ranking above Tasmania, Northern Territory and the Australian Capital Territory in terms of economic output. It drives around 28% of regional NSW's total economic output. It is the largest regional contributor to gross state product ($38.5 billion), has the largest share of regional population (21%) and accounts for the highest share of

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[2] DPI Water, *Water-Sharing Plan for the Hunter Unregulated and Alluvial Water Sources: Background document 2016*, August 2016
[3] DPI Water, *Water-Sharing Plan for the Hunter Regulated River Water Source: Background document*, March 2017
[4] NSW Office of Water, *Our Water Our Country: An information manual for Aboriginal people and communities about the water reform process*, NSW Department of Primary Industries, Sydney, 2012
[5] Brayshaw, *Aborigines of the Hunter Valley – a study of colonial records*, 1987
[6] DPI Office of Water, *Water-Sharing Plan evaluation report 2004 to 2012, Hunter Regulated River Water Source, draft* November 2014, unpublished.

employment (22%). Newcastle is the nation's seventh largest city and the Port of Newcastle is Australia's largest port[7].

The relative value of Hunter Regulated River water-based production relative to other major NSW regulated river catchments is given in Figure 2.

The GHR has the largest share of both regional population and regional employment and is located in the state's fastest growing corridor. The projected population along this corridor is predicted to be 1.1 million by 2036. The GHR has NSW's most productive coal mining region, most productive wine producing area, the largest equine industry in Australia and produces 30% of the electricity needs of NSW.[8]

The Mid-Coast catchments generate $3.265 billion to the gross regional product (GRP) of NSW that represents 0.006% of NSW Gross Product ($524,459 million) in 2016.[9]

The Central Coast generates $10.8 billion in gross regional product, representing 8% of regional NSW's total GRP. This subregion offers connectivity to key labour and consumer markets and a key viable alternate business and residential location for Sydney[10].

The value of the water-related economic production in the Hunter Regulated River system in comparison to other regulated systems within NSW is illustrated in Figure 2. This demonstrates the consequences (and therefore risk) to the economy of NSW of the impact of a failure to supply adequate water.

Coal mining

Coal mining is the region's largest primary industry. The Hunter Valley contains significant reserves of export quality, low-ash, high-energy thermal coals and low-ash, soft coking coals. Most mines are large-scale, multi-seam, open-cut operations with a number of underground operations. The Hunter Valley Coal Chain is the largest coal export operation in the world, with rail and port infrastructure servicing approximately 1,400 export vessels per year.

Over 80% of NSW thermal coal is exported from the GHR (around 142 Mt in 2013–14) and the balance (25 Mt) are used in domestic power generation. Over 80% of power generation in NSW is currently coal-fired. The NSW coal industry directly employs 21,863 people, with an estimated 90,000 related jobs. Around 90% of production is exported into Asia.[11]

In 2014–15 the Hunter Coalfields produced 149.4 million tonnes (59% share of NSW production), with saleable coal valued at $8.38 billion. With direct on-site employment of 11,028 people, the Hunter accounted for 55% of NSW coal industry employment.[12] In 2015–16, the NSW Government received $1.19 billion in royalties from mining, of which coal contributed 91%.[13]

From a survey of 23 out of 29 companies in 2014–15, mining accounted for 22.9% of the region's gross regional product (GRP)[14]. It supported 11,189 direct full-time resident employees. Direct expenditure was calculated at $4.8 billion within the region. This direct expenditure generated:

- $6.4 billion in additional supply chain goods and services
- $3.1 billion in wages and salaries associated with 52,225 additional jobs supported in the region.

The total economic contribution also included:

- $9.6 billion in supplying business purchases

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[7] Department of Trade and Investment, *Economic Profile, Hunter Valley, prepared for the economic development strategy for regional NSW,* February 2015

[8] agl.com.au/about-agl/how-we-source-energy/thermal-energy/agl-macquarie

[9] Id economic profile Mid-Coast Council

[10] Department of Trade and Investment, *Economic Profile, Central Coast, prepared for the economic development strategy for regional NSW*, February 2015

[11] Department of Trade and Investment, *NSW Coal Industry Profile 2014 Volume 1 Incorporating commentary and Coal Services Pty Ltd, 2011-12, 2012-13 & 2013-14 Statistical Supplement*, 2014

[12] Michael Connell and Associates, *Upper Hunter Diversification Energy Sectors Issues Paper*, June 2016

[13] resourcesandenergy.nsw.gov.au/miners-and-explorers/enforcement/royalties

[14] Note: this does not include the former Greater Taree local government area

- $4.5 billion in total wages and salaries paid to workers
- 63,414 jobs (20.9% of the entire workforce in this region)[15]
- $1.3 billion in royalties to the NSW Government.

Coal mining will continue as a major industry in the medium to longer term with the demand for thermal coal in Asia and India for power generation; the high-quality thermal coal deposits; an efficient supply chain; and the current approvals for mine extensions. However, in the medium- term even with a future lift in coal prices, employment levels will not return to the peak levels of the investment and mining boom.

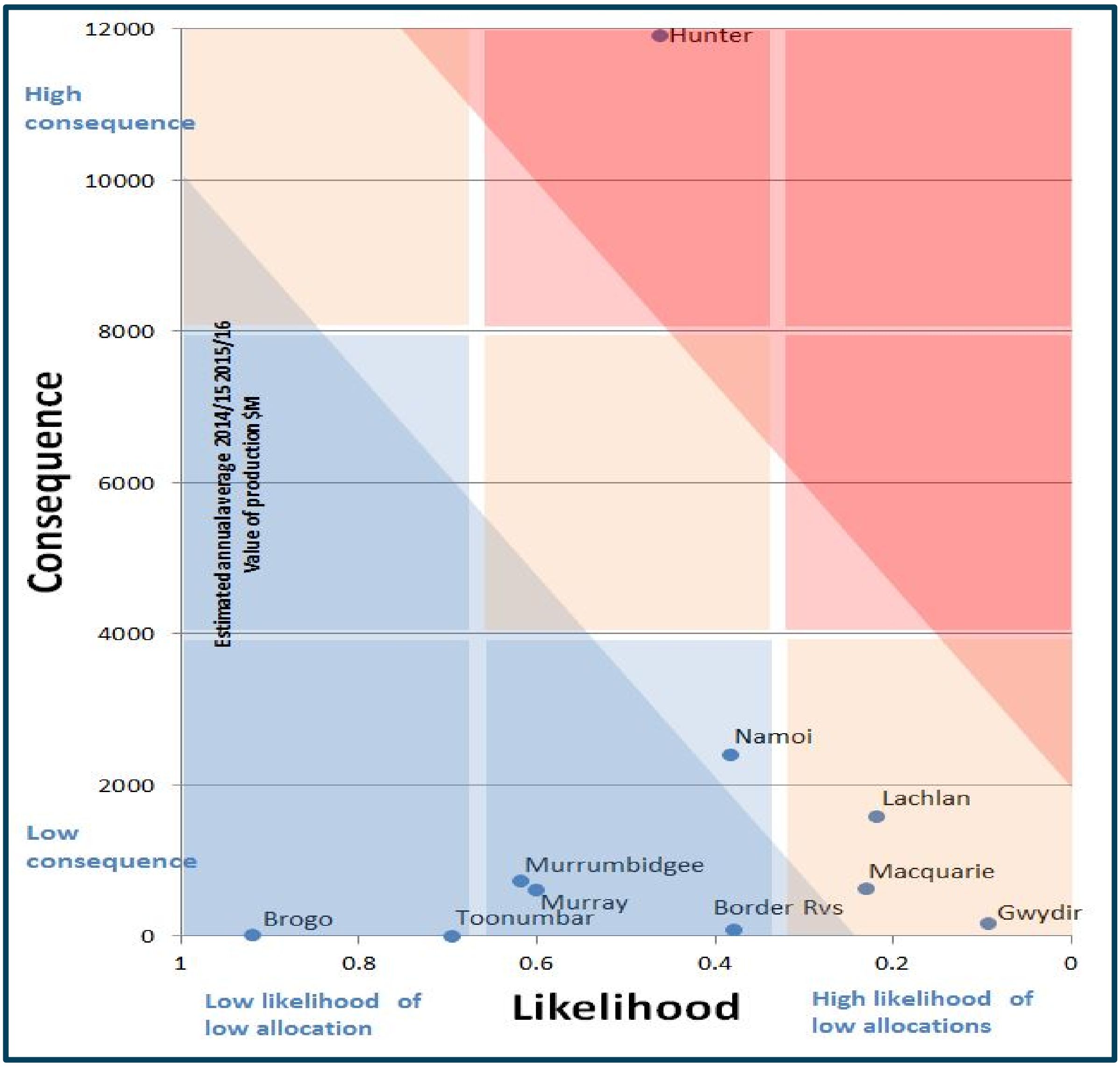

Figure 2. Risk to value of water-related production in major NSW regulated river catchments

Power generation

Coal-fired power generation has been the predominant source of electricity supply in NSW. The share of electricity generation from coal increased from 91% in 2000–01 to 97.1% in 2007–08. However, coal-fired electricity generation, as a share of total generation, has decreased over the past six years to 87.5% in 2013–14, mainly due to the commission of several gas-fired generators over this period.[16]

[15] University of Wollongong, *NSW Mining Industry Economic Impact Assessment 2014/15*, prepared for NSW Minerals Council January 2016

[16] Department of Trade and Investment, *NSW Coal Industry Profile 2014 Volume 1 Incorporating commentary and Coal Services Pty Ltd, 2011-12, 2012-13 & 2013-14 Statistical Supplement*, 2014

AGL Macquarie currently has around 30% of NSW's electricity capacity and is the largest domestic buyer of NSW coal (for power stations). Employment at the Upper Hunter sites is currently over 650 and the two power stations occupy a total area of 10,000 hectares.[17]

The region is now in the process of an energy transition. Liddell Power Station (PS) is planned for closure in 2022 and Bayswater in 2035. AGL has made a commitment to be carbon dioxide emission neutral by 2050. Their strategy is to transition to low emission baseload power generation using renewables. The energy grid distribution network in place for the existing power stations is also highly valuable and likely to be essential in the transition to a low emissions energy future. In addition to AGL, there are currently two early stage renewable energy projects in the GHR: the Liverpool Range Wind Farm and Kyoto Energy Park at Scone.[18]

Agriculture

The GHR has significant agricultural production able to service the major centres of Sydney, Central Coast and Newcastle due to their proximity. Agribusiness includes traditional irrigated cropping, grazing, grapes, nurseries as well as abattoirs, chicken and egg production and piggeries, fodder production and turf production on alluvial soils.

The GHR is a significant contributor to the agricultural industry in NSW. For example, the Upper Hunter represents only around 2% of the area of agricultural holdings in NSW. However, it is specialised in a number of sectors and produces 11% of the state's milk; 17% of commercial pasture seed in NSW; 20% of the state's olive production; 8% of the pastures cut for hay; 6% of NSW pecan production; and 7% of NSW beef cattle for slaughter.

Significant primary industries on the Central Coast include turf growing, fruit (primarily citrus), vegetable production, poultry and water bottling. The latter two industries utilise mainly groundwater, not water from the surface streams.[19]

Table 3. Gross value irrigated production against total production

Commodity	Gross value of product 2015–16 in $[20]	Gross value of irrigated production 2014–15 in $[21]
Cereals for grain and seed	6,516,883	44,192
Nurseries, cut flowers and cultivated turf	33,097,835	32,051,715
Other broad acre crops	1,995,386	17,437
Hay	19,116,378	5,970,043
Vegetables	4,295,880	2,790,388
Fruit and nuts (excluding grapes)	2,580,631	1,082,198
Grapes	1,871,208	975,548
Dairy production	88,609,970	70,635,070
Production from meat cattle	234,625,580	30,911,561
Production from sheep and livestock	239,944,619	48,222,056
Totals	**632,654,370**	**192,700,206**

Equine industry

The equine industry is a major industry in the GHR. The Upper Hunter is one of three international centres of equine excellence and an internationally acclaimed thoroughbred breeding area. The region is ranked second only to Kentucky, USA in terms of concentration of thoroughbred stud properties and the quality and number of bloodlines. The Hunter Thoroughbred Breeders Association identified the Hunter Valley as:

[17] agl.com.au/about-agl/how-we-source-energy/thermal-energy/agl-macquarie
[18] ABARES Department of Agriculture and Water Resources, *Regional Profile Hunter Valley (excluding Newcastle) New South Wales*, 2017
[19] DPI Water, *Water-Sharing Plan for the Central Coast Unregulated Water Sources 2009: background document for amended plan 2016*, August 2016
[20] Source ABS Cat. No. 7503.0 Provided by Market and Analysis, Strategy and Policy, DPI
[21] Source ABS Cat. No 4610.0.55.008. Provided by Market and Analysis, Strategy and Policy, DPI

- the largest domestic producer of thoroughbreds, producing around half of all thoroughbred horses born in Australia
- the largest source of thoroughbred exports, with 67% of all Australian thoroughbred horse exports in 2008-09 and 80% to 90% of total value of all Australian thoroughbred exports, sired or bred
- exported Hunter Valley sired or bred yearling foals in 2011 was estimated at over $100 million in total estimated value
- producing 63% of the world's top Australian racehorses
- a significant contributor to the regional economy, with 85% of all operating expenses spent within the Hunter Valley
- contributing over $2.4 billion to the NSW economy and $5 billion to the national economy
- employing thousands of people across its value chain nationally.

The Upper Hunter also supports other equine industries including stock horses, polo, hay and lucerne production. There is a concentration of other services including a specialist equine hospital at Scone, a research centre, associated veterinarian and training facilities and a series of specialist horse transport, feed companies and specialist breeding, rearing, training, spelling and competition facilities. [22]

Population

The total population of the region in 2016 was 1,071,850. This is approximately 14% of the population of NSW at the time.

Major population centres in the Central Coast include Gosford and Wyong and a number of smaller urban centres close to the ocean and Tuggerah Lakes. Seasonal populations increase significantly from tourism due to the natural beauty of the area and the close proximity to major urban centres such as Sydney and Newcastle. The population of the Central Coast in 2016 was 339,600.

Major population centres in the Hunter catchment include Newcastle, Lake Macquarie, Maitland, Cessnock, Singleton, Kurri Kurri, Muswellbrook, Scone and Branxton–Greta. Total population for the Hunter catchment was 641,050 in 2016 with the majority of the population residing in the Lower Hunter area (584,400) compared to the Upper Hunter (56,650).

Major population centres in the Mid-Coast area includes Gloucester, Wingham, Taree, Karuah and Foster–Tuncurry. Seasonal populations increase significantly in the coastal and mountainous areas from tourism due to the natural beauty of the area and close proximity to Sydney and Newcastle. Total population for the Mid-Coast area was 91,200 in 2016.

[22] Department of Primary Industries, *Upper Hunter Region Equine Profile*. Fact Sheet No. 6 June 2013

Part 3: The water management framework

Photograph 3. Glenbawn Dam (NSW DPI)

The framework

Numerous NSW Government agencies, state-owned corporations and local councils are responsible for administering, protecting, regulating and supplying water (as shown in Figure 3).

The Commonwealth, state and territory governments recognise the:

- continuing national imperative to increase the productivity and efficiency of Australia's water use
- need to service rural and urban communities
- need to ensure the health of river and groundwater systems.

To establish clear pathways to return all systems to environmentally sustainable extractions limits, all governments therefore signed an Intergovernmental Agreement on a National Water Initiative. This is to provide greater certainty for investment and the environment and to underpin the capacity of Australia's water management regimes to deal with change responsively and fairly. That agreement sets out how the risk of changes in water reliability is managed.

A schematic diagram of how the different water-sharing plans and water utilities administratively relate is given in Figure 4. For example:

- water is taken from the Lower North Coast Unregulated and Alluvial WSP
- transferred via AGL Macquarie's Barnard Scheme
- into a dam managed by WaterNSW through the Hunter Regulated River WSP to supply to AGL Macquarie's Power Stations.

NSW Department of Industry's role is to:

- ensure the potential options are considered in the context of overall water management within a strategic regional framework
- consider the water needs for all water uses in the region, that is, irrigation, industry, town water and the environment
- manage competing priorities from various water uses
- consider third party impacts of any potential options
- consider water-sharing arrangements
- assign the task of developing/managing the infrastructure to the appropriate water provider.

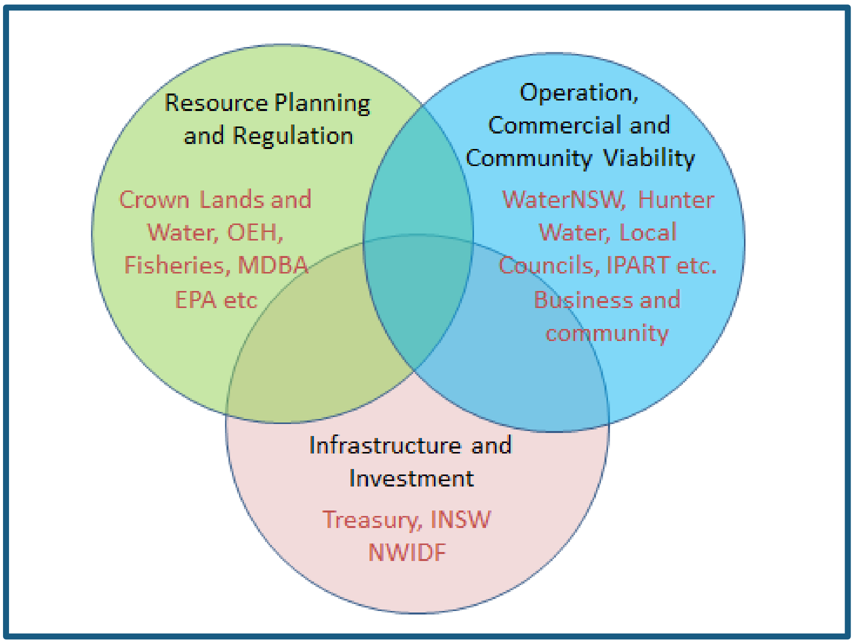

Figure 3. Current water resource managers

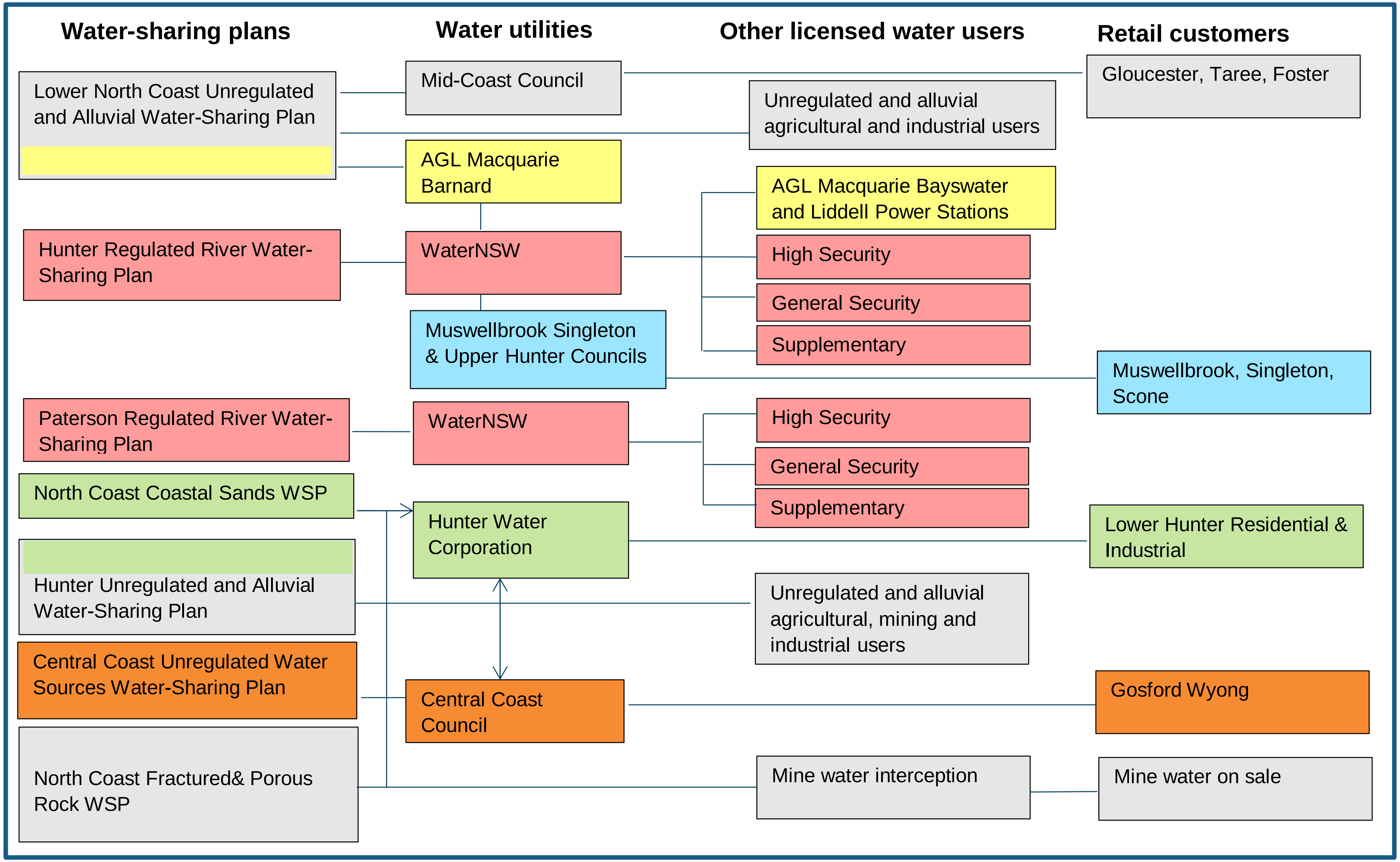

Figure 4. Existing management arrangements within the Greater Hunter region

Types of surface and groundwater

The primary sources of water are:

- surface water regulated by the operation of WaterNSW water storages
- surface water that is unregulated (some rivers maybe controlled by weirs and in-stream dams)
- groundwater contained beneath the earth's surface in alluvial, fractured and porous rock and coastal sand aquifers
- recycled water from mines and major water utilities
- water intercepted from groundwater and surface runoff.

Regulated rivers

Regulated rivers are gazetted streams that have flows controlled by state-owned water storages. There are two rivers in the GHR that are regulated by major headwater storages—the Hunter and Paterson Rivers. The two storages in the Upper Hunter are Glenbawn Dam and Glennies Creek Dam. These are operated by WaterNSW to supply bulk, raw water for irrigation, towns and stock and domestic needs as far downstream as Maitland. Lostock Dam, also operated by WaterNSW, is a smaller storage that provides water supply to users along the Paterson River until its tidal limit downstream from Gostwyck Bridge.

The yield of Glenbawn and Glennies Creek Dams is heavily dependent on tributary inflows from the upstream, unregulated rivers. During normal years, the storages only top up the difference between water orders and tributary inflows. During drought, tributary inflows diminish and the percentage of storage contribution to fill water orders increases.

Unregulated rivers

The majority of the GHR surface water resources are unregulated rivers not controlled by water being released from state-owned water storages. Water availability in these systems varies between seasons and years as they do not have major storages that capture and control their flows. Flow is dependent on rainfall runoff and groundwater seepage. Long periods of no flow make extraction opportunities in these systems highly unreliable. Hunter Water Corporation, Mid-Coast Water, Central Coast Council and AGL Macquarie have all constructed infrastructure to extract water from the unregulated rivers.

Groundwater

Aquifers are underground layers of water-bearing permeable rock or unconsolidated materials (gravel, silt or clay) and can store large volumes of water accumulated over thousands, or tens of thousands of years. Water recharges aquifers from rainfall, surface flows from rivers and lakes, or flow from adjacent aquifers. The GHR contains the following aquifer types:

- porous rock aquifers found in rock formations such as sandstone or limestone. Fractured rock aquifers found in rock formations such as granite or basalt.
- coastal sand aquifers.
- alluvial aquifers.

Groundwater resources in the GHR are used for town water supplies, agriculture, mining, power and other industries as well as parks and gardens. Groundwater also maintains wetlands and supports the base flow of many of the region's unregulated rivers.

Groundwater is often considered an alternative water supply and only accessed during drought conditions when surface water is unavailable or restricted. Water utilities maintain groundwater supplies for drought security and access it for potable water supply when required.

Recycled water

Total recycled water supplied is the sum of all treated sewage effluent that is used by either the utility or businesses supplied by the utility, or supplied through a third-pipe system for urban re-use. Water utilities operate some recycled water schemes. The volume of recycled water supplied is affected by a number of factors, including the availability of potable water, the size of the utility, its proximity to potential customers (such as agricultural users, major industrial customers and recreational facilities), fluctuations in sewage received and therefore effluent available for recycling and government policy.[23] In 2015–16:

- Central Coast Council (CCC) recycled 895 ML of water
- HWC recycled approximately 5,373 ML[24]
- Mid-Coast Council (MCC) recycled 944 ML.[25]

Water interception

Interception is an activity that intercepts surface or ground water that would otherwise flow, directly or indirectly, into a watercourse, lake, wetland, aquifer, dam or reservoir.[26]

Under the Harvestable Rights—Eastern and Central Division Order 2006, a landholder has the right to capture 10% of the average regional rain water run-off on their land by means of a dam or dams. This water may be used for any purpose except where it is licensed:

- under the *Water Management Act 2000* for domestic and stock purposes
- a right to take water under Part 2 of the *Water Act 1912* which restricts its use to stock or domestic or
- a right to take water from a river or lake under Part 2, Chapter 3 of the *Water Management Act 2000*.

Exempt classes of dams under Schedule 2 of the Harvestable Rights Order include:

> *'Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a Government agency or Local Government Council to prevent the contamination of a water source.'*

Mining are allowed the harvestable rights exemption for the containment of contaminated water.

Table 4 shows the estimated runoff capture by harvestable rights-exempt dams by mining operations within the Hunter Regulated River catchment area.

Table 4. Estimated runoff capture by harvestable rights-exempt dams on Hunter Regulated River[27]

Management zone	Runoff in above- median rainfall year (ML)	Runoff in 10% dry year (ML)	Runoff in driest recorded rainfall year (ML)
Zone 1	20,483	10,244	5,950
Zones 2 And 3	25,011	13,686	5,385
TOTALS	**45,494**	**23,930**	**11,335**

Basic rights under the *Water Management Act 2000* is defined as domestic and stock rights, harvestable rights or native title rights. Domestic and stock rights are defined in section 52 of the Act and allows a landholder without an access licence, water supply work or water use approval:

'a) to take water from any river, estuary or lake to which the land has frontage or from any aquifer underlying the land, and

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23 Bureau of Meteorology, National Performance report 2015-16: Urban Water Utilities, Part A
24 DPI, Water, *Lower Hunter Water Plan 2016 Evaluation* – Draft, 2016
25 Mid-Coast Water, *Our Water Our Future*, April 2008 Superseded
26 Water Act 2007, Commonwealth
27 DPI Water, *Upper Hunter Valley Preliminary Drought Risk Report,* July 2013

(b) to construct and use a water supply work for that purpose, and

(c) to use the water so taken for domestic consumption and stock water, but not for any other purpose.'

Table 5 shows the estimated volume by Basic Landholder Rights at the time of the development of a water-sharing plan. The tidal pool estimations were not completed at the time of the relevant WSP and have since been estimated and incorporated into the table.

Table 5. Estimated basic landholder rights[28]

Area	Basic landholder rights annual ML
Hunter Regulated River	5,515
Paterson Regulated River	548
Hunter Unregulated and Alluvial	14,341
Wallis Creek	26
Hunter River Tidal Pool	58
Paterson River Tidal Pool	58
Wybong Creek	274
Lower North Coast (Mid-Coast catchments)	5,050
Central Coast	298
TOTAL	**26,168**

Interactions between water types

Many of the GHR ground and surface water resources are highly connected. These hydraulic connections are known to occur where streamflow recharges aquifers in some river reaches (losing river reaches), while groundwater delivers base flows in others (gaining river reaches). Figure 5 illustrates this relationship.

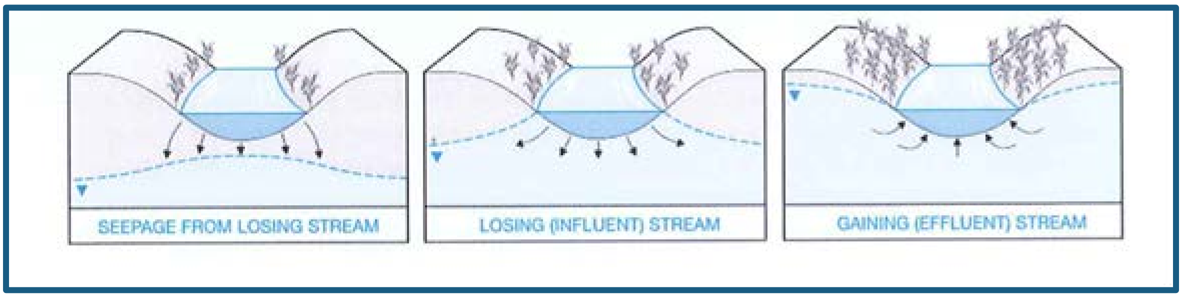

Figure 5. Relationship between surface and groundwater

The region's up-river alluvial and coastal sand aquifers have a significant level of connection to adjacent surface water sources. The estimated travel time between the two sources can range from days to months. Pumping of surface water or groundwater can alter this relationship. The connectivity between surface and groundwater resources is described in Table 6.

Table 6. Interconnections

Aquifer type	Water sources	Level of connection between surface and groundwater	Estimated travel time between surface and groundwater
Coastal sands	Hawkesbury to Hunter Coastal Sands Manning Coastal Sands	Significant (tidal section only)	Days to months

[28] At time of WSPs plus estimates for tidal pool BLR.

Aquifer type	Water sources	Level of connection between surface and groundwater	Estimated travel time between surface and groundwater
Up-river alluvial	All unregulated rivers and the regulated Hunter River	Significant	Days to months
Coastal floodplain alluvial	Hunter catchment floodplain Central Coast Floodplain Manning Coastal Floodplain	Low–moderate (tidal section only)	Days Season Season
Fractured rock	New England Fold Belt	Low–moderate	Years to decades
Porous rock	Sydney-Gunnedah Basin Sydney Basin Sandstone Clarence-Moreton Basins	Low–moderate	Years to decades

Water storage and delivery

Historical drought issues in the GHR have influenced government and industry to invest heavily in storing water. The total storage capacity of infrastructure able to hold 100 ML or more in the GHR is 1,672,478 ML. The storage capacity in the Upper Hunter Valley available for bulk water supply is 1,053,000 ML, five times the annual water requirement of downstream water users.

Table 7 shows the capacity of current infrastructure to provide access to most of the water provided to regulated river users, local and major water utilities for town water supply and power generation within the GHR. The major infrastructure and ownership is illustrated in Figure 6.

Utilities are responsible for the capture, storage and delivery of water. The GHR has the following water utilities:

- **WaterNSW**—A state-owned corporation providing bulk water to customers from Glenbawn, Glennies and Lostock Dams through releases to the river systems below these dams (regulated river). This water is used primarily by mining, agribusiness and to service some town water supplies. After major and local water utilities water demand is met, water is provided (in order of priority) to high security, general security and supplementary supply access licence holders.
- **Hunter Water Corporation (HWC)**—provides urban water supplies to Newcastle, Lake Macquarie, Maitland, Cessnock, Port Stephens and Dungog. Chichester and Grahamstown Dams and Seaham Weir provide reticulated water to the Lower Hunter. The water supply system covers an area of 5,366 km^2 from Branxton in the north-west, to the Central Coast in the south.[29] The Lower Hunter Water Plan 2014 has identified that HWC's supplies are vulnerable to droughts because the storages are relatively small, or shallow, and water levels can fall quickly.
- **Central Coast Council (CCC)**—has the third largest urban water supply system in NSW, after Sydney and the Hunter. CCC supply network is linked to the Hunter Valley via a 12,800 ML per year connection to HWC. The CCC supplies approximately 93% of water used by 300,000 residents. Mangrove Dam is the major dam in the network. During the 2007 drought it dropped as low as 10.27%.
- **Mid-Coast Council (MCC)**—provides reticulated water to about 40,000 homes and businesses in the Lower North Coast. It operates five water supply schemes: the Manning, Gloucester, Bulahdelah, Stroud and Tea Gardens. It sources water from both surface and groundwaters. Bootawa Dam is their largest storage being an off-river dam with a capacity of 2,250 ML. 90% of water is sourced from this dam.
- **Local councils**—also provide reticulated water to various townships within the Upper Hunter. Raw water for Singleton town water supply runs under gravity from Glennies Creek off-take. Similarly, Scone has a pipeline to Glenbawn Dam. Muswellbrook, Denman and of Jerrys Plains take their

[29] NSW Department of Finance and Services, *2014 Lower Hunter Water Plan*

water from the Hunter River, or its associated alluvium. Cassilis takes its water from groundwater. Murrurundi takes its water from an unregulated river. Plans are progressing to connect to Scone.

- **AGL Macquarie**—owns Lake Liddell and Plashett Dam. These are filled primarily from water pumped from the Hunter River to supply the two power stations. In addition, a weir on the Barnard River in the Manning Valley allows for up to 20,000 ML per year to be transferred over the Mount Royal Range into the Hunter River above Glenbawn Dam for use by AGL Macquarie.

Table 7. Existing water infrastructure storage capacity

Dam	Capacity (ML)	% of total resource	Owner	Major use
Glenbawn Dam	750,000+ 120,000 Flood Storage	45%	WaterNSW	Flow regulation providing for river users downstream
Glennies Creek Dam	283,000	17%	WaterNSW	Flow regulation providing for river users downstream
Lostock Dam	20,000	1%	WaterNSW	Flow regulation providing for river users downstream
Chichester	18,000	1%	HWC	Reticulated water supply
Grahamstown Dam	182,000	11%	HWC	Reticulated water supply
Seaham Weir[30]	1,200	0.07%	HWC	Reticulated water supply
Liddell Cooling Water Dam	148,000	9%	AGL	Cooling water
Plashett Reservoir	65,000	4%	AGL	Power generation
Mangrove Creek Dam	190,000	11%	CCC	Reticulated water supply
Mardi Dam	7,400	0.5%	CCC	Reticulated water supply
Mooney Mooney Dam	4,600	0.3%	CCC	Reticulated water supply
Bootawa Dam	2,250	0.1%	MCC	Reticulated water supply
Lower Mangrove Creek Weir	300	<1%	CCC	Reticulated water supply
Ourimbah Creek Weir	100	<1%	CCC	Reticulated water supply
Lower Wyong River Weir	300	<1%	CCC	Reticulated water supply
Murrurundi	100	<1%	UHSC	Reticulated water supply
Buladelah	228	<1%	MCC	Reticulated water supply
Total	**1,672,478 + 120,000 flood storage**			

Water entitlements

The total volume of licensed water extraction across the region is estimated at 826,579 ML per year[31]. Table 8 summarises how licensed water entitlements are distributed across the region. It shows that the regulated arm of the Hunter River is the single largest provider of water in the region (28%), while the Hunter Valley's unregulated rivers and alluvial collectively account for 35%. This table does not include Basic Landholder Rights as they are not licensed.

The distribution of access licence entitlements for 2017 is shown in Figure 7. The smallest volumes of entitlement are held in the North Coast Coastal Sands aquifers (4%), the Paterson Regulated River water source (1%) and the Lower North Coast Unregulated River aquifers (0.3%).

Figure 8 shows a comparison of the end-of-system flows to the level of entitlement and the long-term average annual extraction limit for each of the sub regions. The Mid-Coast catchments have been further broken into the Manning River Catchment and the Karuah/Great Lakes. Figure 8 shows that the end-of-system flow is greatest in the Manning River, closely followed by the Hunter River. The greatest extraction to end-of-system flows is in the Central Coast. For the Manning this was 4% and 3% respectively.

More detail on water entitlements is given in Appendix 1: Water entitlements.

30 Seaham Weir is not a permanent storage. It only holds back water for the purposes of pumping to Grahamstown Dam during periods of high flows as per the WSP.

31 As at January 2017

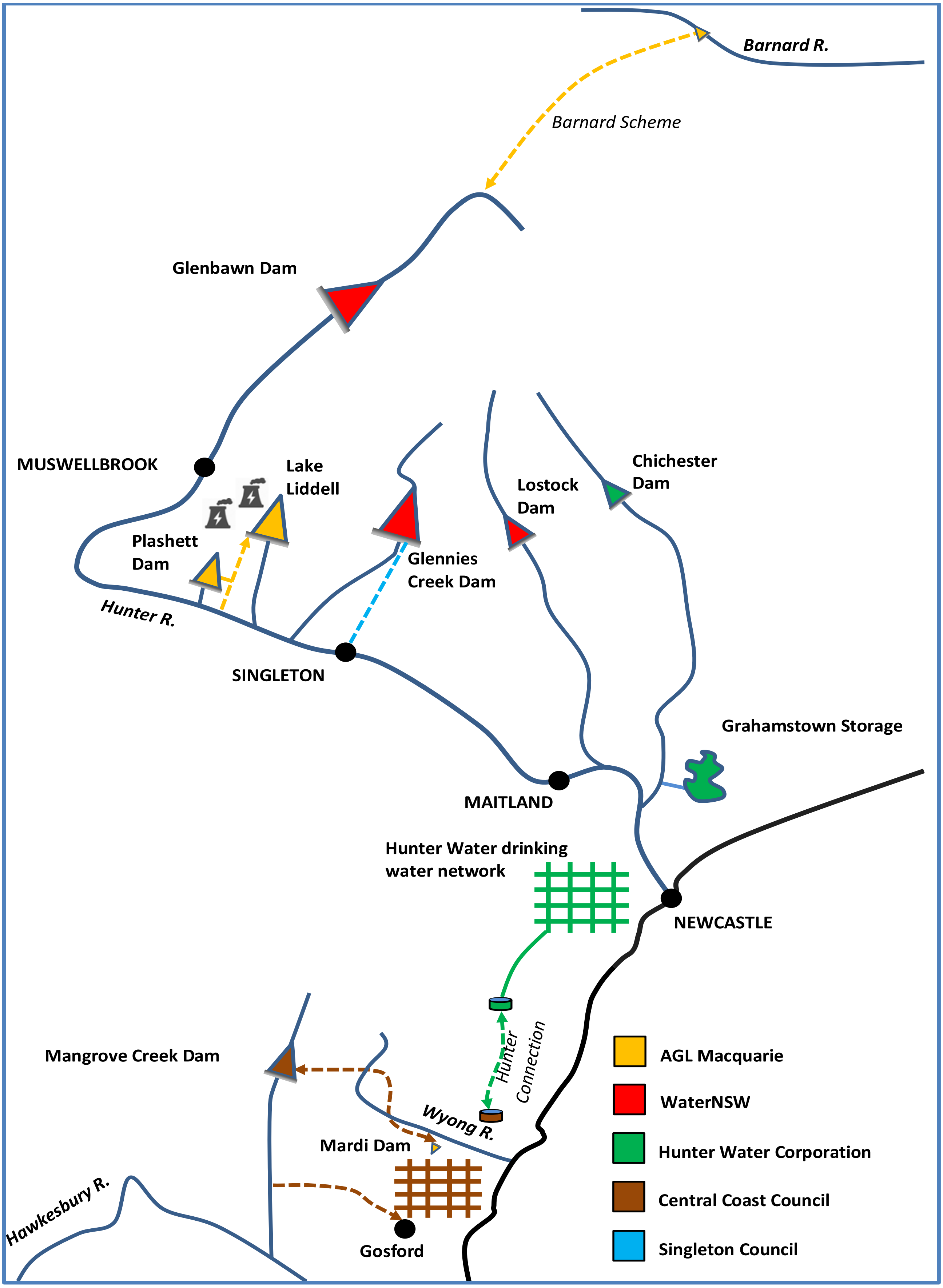

Figure 6. Hunter valley and Central Coast infrastructure schematic and ownership

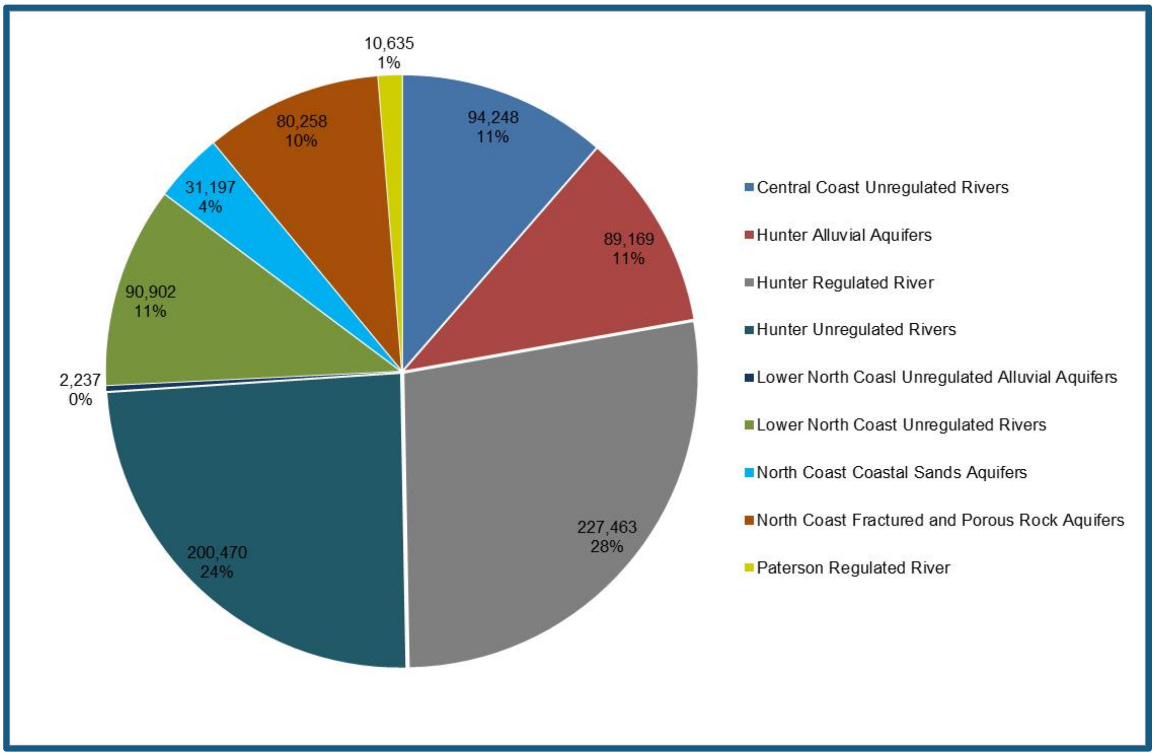

Figure 7. Distribution of water access entitlements at January 2017

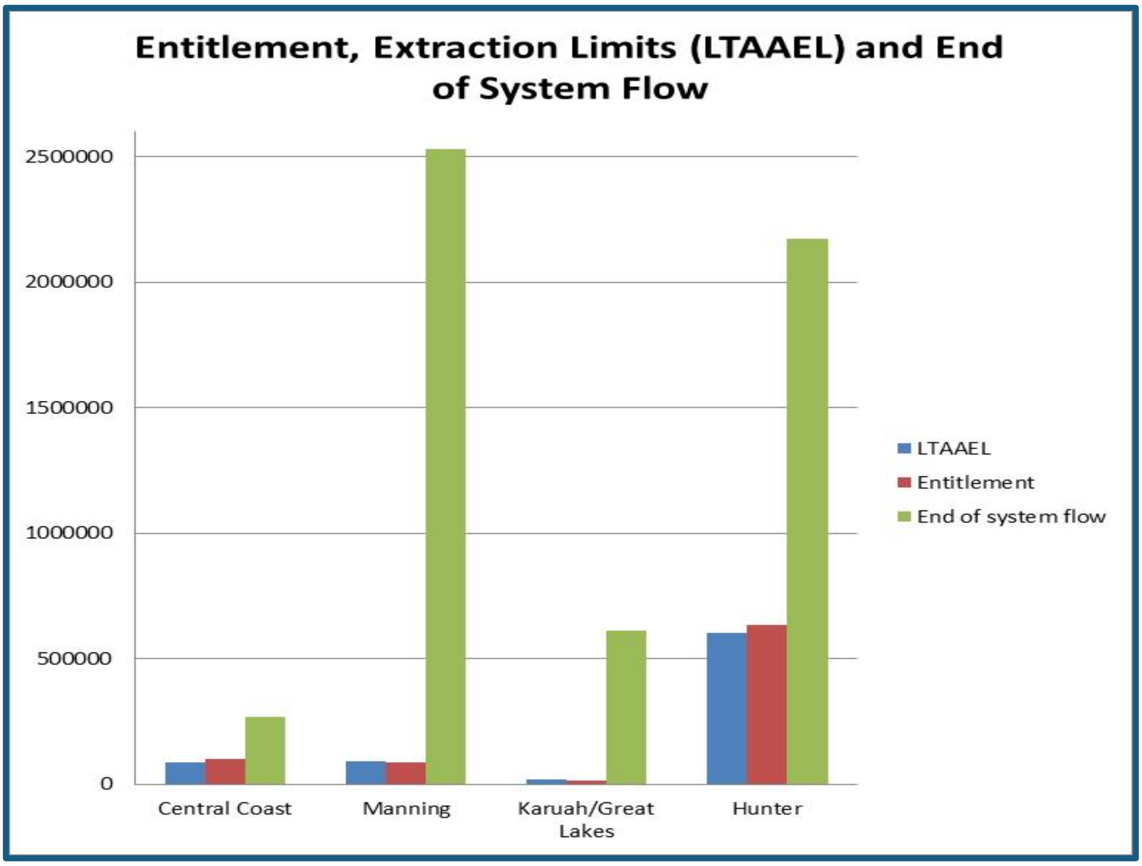

Figure 8. Entitlement to average annual flow[32]

[32] The comparison of entitlement to average annual flow for the Mid-Coast and Central Coast catchments is based on end of system flows post extraction whereas in the Hunter Valley the end of system flows is pre-extraction

Table 8. Annual water access entitlement volumes/plan limit volumes estimated at January 2017 for the Greater Hunter region

Hunter Valley		
Water resource	**Level of entitlement (ML per annum)**	
Hunter Regulated River	General Security	128,544
	High Security	21,740
	Town Water Supply	10,832
	Major utility	36,000
	Supplementary	48,519
	Domestic and Stock	1,828
	Total	**247,463**
	The WSP limit	*217,000*
Unregulated River above Regulated River	Unregulated	84,854
	Alluvial	65,037
Hunter Regulated Alluvial	Alluvial	24,132
Groundwater	Fractured and Porous rock	69,689
Barnard Scheme for AGL Macquarie		-20,000
Total Hunter Arm		**471,175**
Williams River	Unregulated	8,322
	Hunter Water	78,500[33]
Total Williams River Arm		**86,822**
Paterson River	General Security	9,565
	High Security	265
	Domestic	49
	Supplementary	756
	The WSP limit	*11,175*
	Unregulated	4,120
Total Paterson River Arm		**14,755**
Hunter unregulated residual		22,542
Tidal Pool		23,932
Return WWTP (define) flows		-21,800
Coastal Sands groundwater		29
Tomago (MWU)		25,300
Total Hunter Valley residual		**50,003**
Total Current Hunter Valley		**622,755**

Mid-Coast catchments		
Water resource	**Level of entitlement (ML per annum)**	
Manning River catchment	Unregulated	48,106
	Alluvial	1,932
	Domestic and Stock	97
	Major Water Utility	20,000[34]
	Local Water Utility	16,715
Total Manning River		**86,850**
Non Manning catchment	Unregulated	5,406
	Alluvial	305
	Domestic and Stock	37
	Local Water Utility	541
Total Non-Manning Surface Water		**6,289**
Groundwater	Coastal Sands	61
	Tomaree	13
	Tomaree (MWU)	3,700
	Fractured and Porous rock	5,760
Total Groundwater		**9,534**
Total Mid-Coast catchments		**102,673**

Central Coast Catchments		
Water resource	**Level of entitlement (ML per annum)**	
Unregulated Rivers	Unregulated	14,269
	Domestic and Stock	229
	Major Water Utility	79,750[35]
Groundwater	Coastal Sands	2,094
	Fractured and Porous Rock	1,335
	Kulnura Mangrove Mountain	3,474
Total Central Coast catchments		**101,151**

[33] WSP extraction limit. Entitlement is 346,700ML of which 100,000 ML from Newcastle water source, 239,000 ML from Williams River including 189,000 ML at Balickera Pumping Station and 50,000ML at Chichester and 7,700ML from Jerrys Water Source (sect 29. WSP)

[34] Average 3 year rolling entitlement

[35] Water-sharing plan limit. Entitlement is 105,865 ML—only 36,750ML can be supplied for urban use, while further water may be pumped into storage when there is adequate flow in streams (background document)

Water-sharing plans

Sharing of the region's water resources between users (including the environment) is defined in statutory water-sharing plans (WSP) that are prepared in accordance with *the Water Management Act 2000*. They apply for ten years.

The following five surface water and two groundwater-sharing plans operate in the GHR:

- Hunter Regulated River Water Source 2016
- Paterson Regulated River Water Source 2007
- Hunter Unregulated and Alluvial Water Sources 2009
- Lower North Coast Unregulated and Alluvial Water Sources 2009
- Central Coast Unregulated Water Sources 2016
- North Coast Coastal Sands Groundwater Sources 2016
- North Coast Fractured and Porous Rock Groundwater Sources 2016.

The WSP boundaries for the region's regulated, unregulated and alluvial aquifer water sources are shown in Figure 9. The planning boundaries for the NSW Coastal Sands and NSW Fractured and Porous Rock water sources are shown in Figure 10.

Table 8 provides additional detail on how volumes of surface water and groundwater that is held in entitlements for consumptive use fits within the Hunter Valley, Mid- Coast catchments and Central Coast catchments. It does not include estimates of the volume of water that is currently captured or used by basic landholder rights (BLR) users and exempt activities in each water source. These uses, which do not require a water access entitlement, include basic rights such as stock and domestic use, native title and harvestable rights, and water interception by mining activity.

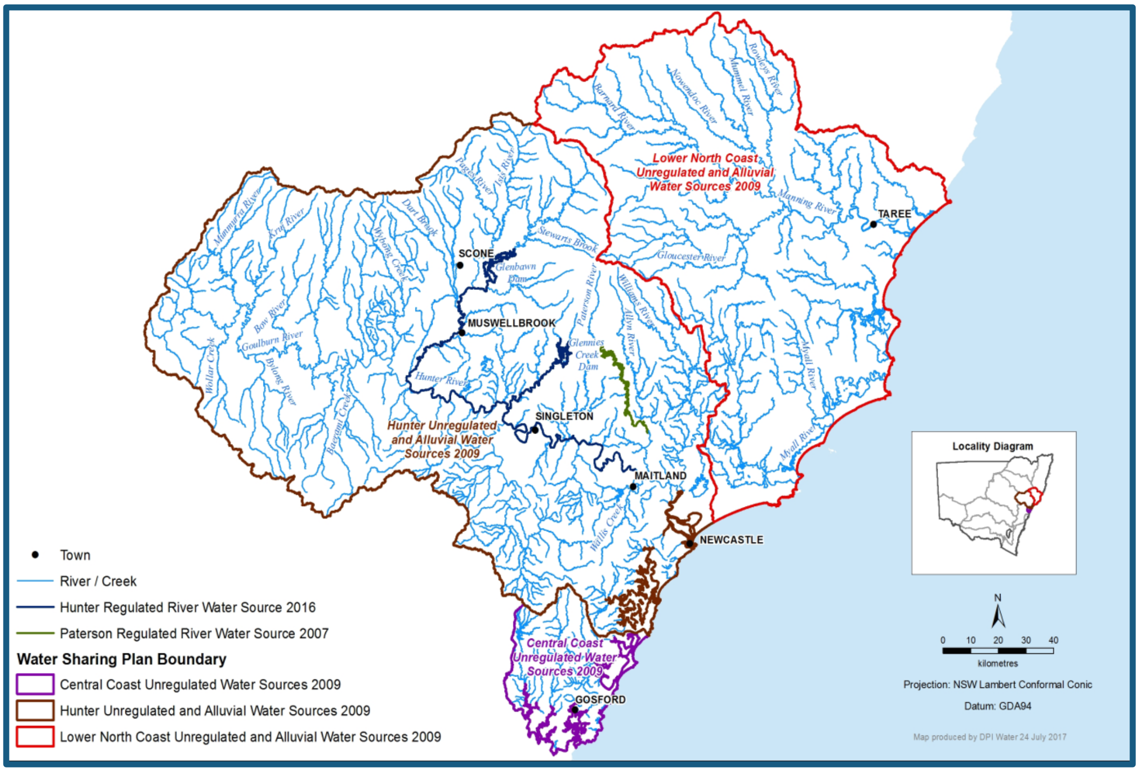

Figure 9. Current surface water and alluvial aquifer water-sharing plan

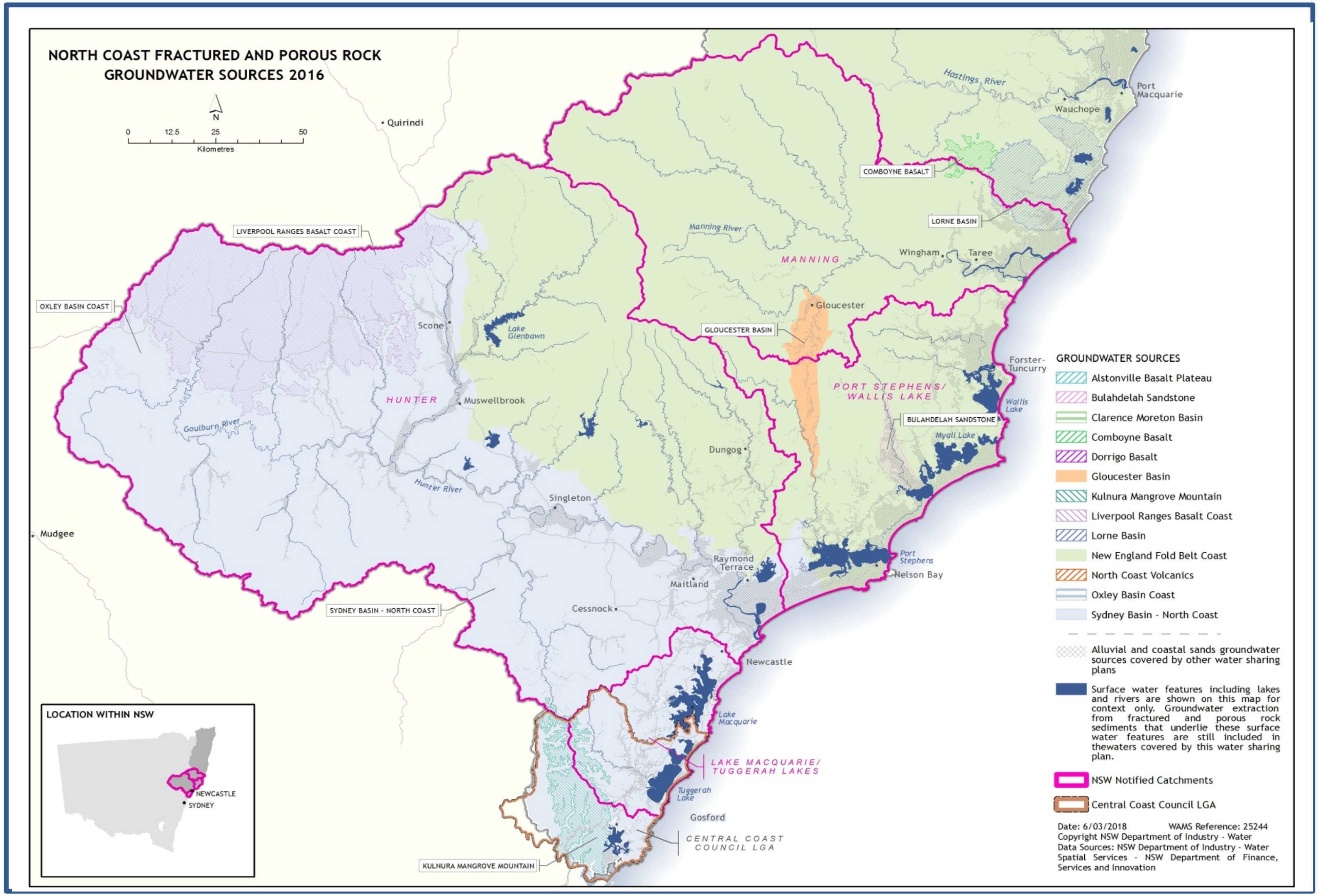

Figure 10. Current groundwater sources

Part 4: Environment and water quality

Photograph 4. Lakes and reeds (E. Harris)

The Hunter's riverine ecological values are shown in the region-wide map in Figure 11. These ecological values have been classified according to their diversity, distinctiveness, naturalness, representativeness and the presence of vital habitat under the High Ecological Value Aquatic Ecosystems Tool (HEVAE). The application of HEVAE assists in identifying water sources and river reaches where there may be risk to instream values. It also allows for the protection of ecological values, such as threatened species, by applying trade rules to encourage the reduction of entitlement in high instream value river reaches. From Figure 11 it can be seen that the:

- Manning and Karuah River catchments are classified as having high to very high values
- headwaters of the Williams River and southern Hunter River catchment are classified as having high to very high values
- northern and western upper catchment areas of the Hunter are generally classified as having low values
- Central Coast catchments' rivers contain a mix of medium to high values.

Groundwater dependent ecosystems (GDEs) are a diverse and important component of biological diversity. GDE's are ecosystems that use groundwater as part of their survival strategies and can include wetlands, vegetation, mound springs, river base flows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems.

The groundwater dependence of ecosystems can range from complete to partial reliance on groundwater, such as might occur during droughts. The degree and nature of groundwater dependence will influence the extent to which they are affected by changes to the groundwater system, both in quality and quantity.

Extensive studies have been conducted on the Tomago and Tomaree groundwater sources to identify vegetation types and determining their level of groundwater dependence. These studies found that 80% of the vegetation in Tomago had some level of dependency on groundwater. Above the Tomaree aquifer around 50% of the vegetation had some level of groundwater dependence.

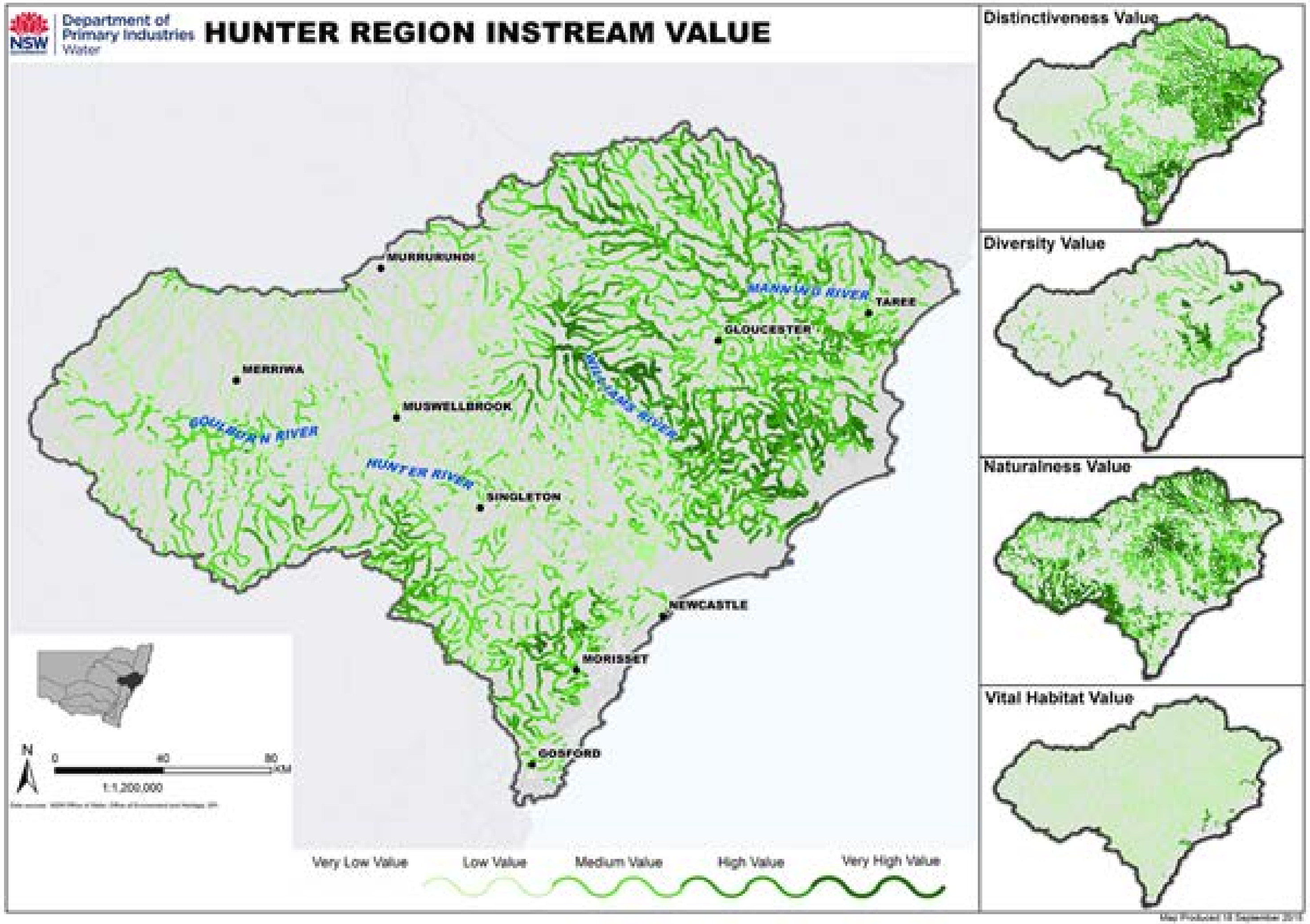

Figure 11. Ecological value classification of rivers

Planned environmental water

Reducing stress on the environment has been the major focus of water planning since the *Water Management Act* was introduced in 2000. A series of water-sharing and operating rules (see Table 9) have been designed to provide water for the environment across a range of flow events from floods to very low flows. These rules also ensure that water is not completely taken by upstream users and provides benefit to downstream water users.

A proportion of flow ultimately reaches the estuaries. The estuaries within the GHR have been shown to be some of the most sensitive estuaries in NSW from changes in inflows from either groundwater, low flow and high flow inflows. [36]

The Hunter River estuary and its dependent wetlands have been the focus of water planning decisions since 2004. For the Hunter Estuary the environmental flow rules for the Hunter Regulated River, the Paterson Regulated River, the Williams River and other unregulated rivers entering the estuary all contribute freshwater to the estuary. The upper half of the estuary is fresh water and is known as the Hunter Tidal Pool. During times of low river flows saline water penetrates higher into the estuary. The Hunter Tidal Pool supports agricultural, stock and domestic needs and many aquatic and marine animals.

Environmental baseline

The Kooragang Wetland located in the lower Hunter estuary is a nationally and internationally significant wetland listed under the Ramsar Convention. This wetland is a key site for migratory and resident shorebirds providing roosting and feeding resources to a large seasonal population of shorebirds and as a waylay site for transient migrants.

Under the *Ramsar Convention 1971* (amended 1994), countries agreed to establish and oversee a management framework aimed at conserving wetlands that are representative, rare or unique or are important for conserving biological diversity by maintaining the ecological character of the wetland at the time that it was listed. The Commonwealth Government reviewed and documented the characteristics of the Hunter Wetlands National Park in 2012.[37] This ecological description is used by the Commonwealth to measure whether developments will impact adversely on the wetlands.

Ramsar wetlands are recognised as a matter of national environmental significance under the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act, 1999*. Consequently, an action that has, or is likely to have, a significant impact on the ecological character of a Ramsar wetland must be referred to the Commonwealth for environmental assessment and approval process (Parts 7-9 EPBC Act). In addition, since June 2013 all NSW coal seam gas and large coal mining developments that is likely to have a significant impact on water resources require approval from the Commonwealth Government's Environment Minister (that is known as the water trigger). [38]

Due to these environmental obligations, the 2012 characterisation has been set as benchmark to assess future changes. This is referred to in this document as the 2012 Base Case.

[36] Sourced from the various background documents to the unregulated water-sharing plans in the Greater Hunter region
[37] For further information see the report *Kooragang Ramsar Wetland Ecological Description*, Commonwelath Government, 2012
[38] Commonwealth Government, *Environment Protection and Biodiversity Conservation Act*, 1999 (EPBC Act)

Table 9. Environmental flow rules

Type of rule	Details
Environmental contingency allowance (ECA)	Water is set aside at Glenbawn Dam, Glennies Creek Dam and Lostock Dam for environmental contingencies. The Office of Environment and Heritage (OEH) is responsible for operational decisions on the management and use of environmental water in NSW in consultation with relevant agencies/stakeholders. Both the Hunter and Paterson regulated systems provide environmental water allocations (ECAs) that require active management (20,000 ML/year for the Hunter River and 2,000 ML/year for the Paterson River). At the time the ECA was developed, the Hunter River had experienced several years in which there were algal blooms and high salinity levels For the Williams River HWC operates to pass a fresh of 500 ML at Seaham Weir approximately once per year.
On-river dam release rules	2016 agreed Chichester Dam environmental flow rules: 20 ML/day when no water restrictions apply 14 ML/day when moderate restrictions (level 1 and 2) apply 7 ML/day when severe restrictions (level 3 and 4) apply Central Coast Mangrove Creek Dam flows be released, if and when required, shall be the lesser of: a. inflow, or b. an average flow of 2.7ML/day during the months of September to July inclusive, or c. an average flow of 2.0ML/day during the months of May to August inclusive, or d. a sufficient release to maintain a visible flow in Mangrove Creek immediately above its junction with Warren Warren Creek and at the bridge over Mangrove Creek immediately above its junction with Dubbo Creek. Release rules from Mangrove Creek Weir require that releases shall be made from Mangrove Creek Weir, such that when inflows minus the releases from Mangrove Creek Dam down Mangrove Creek are equal to or less than 3 ML/day then the release must be equal to or greater than the inflow minus the releases from Mangrove Creek Dam down Mangrove Creek. There are no release rules for Glenbawn Dam, Glennies Creek Dam and Lostock Dam. These dams are operated to achieve the end of system flow requirements.
Cease-to-pump rules	In most unregulated rivers it is during drier periods when flows are naturally low and there is generally greatest concern for the health of the river. This is when pools contract, water quality deteriorates and fauna compete for reducing food supplies. The WSPs for these systems then require licence holders to stop pumping when the river falls below a certain level. These are called cease to pump rules. The most significant cease to pump rules are: 1) The Lower Barnard River Upper Reaches Management Zone 13 ML/day at Weir gauge 208027 2) The Wyong River 4 ML/day at gauging stations 211009 and 211010)
Annual limits (LTAAEL)	WSPs set the long-term average annual extraction limit (LTAAEL) to ensure that extractions do not reduce water for the environment and the security of supply to water users. The LTAAEL is less than entitlement in regulated systems. Entitlement is set so that more water can be extracted in wetter years but entitlement holders are still bound by this LTAAEL over a period of years (usually averaged over three years). The Hunter Regulated has an entitlement of 247,463 ML/year with an LTAAEL of 217,000 ML/year.

Type of rule	Details
	Central Coast catchments have an entitlement of 101,151 ML/year with an LTAAEL of 88,043 ML/year plus basic landholder rights (BLR). Paterson Regulated has an entitlement of 10,635 ML/year with an LTAAEL of 11,175 ML/year. This LTAAEL includes BLR. Hunter Unregulated has an entitlement of 117,850 ML/year and the LTAAEL is for all licences plus basic landholder rights except the major water utility. Hunter Unregulated Hunter Water Corporation Corporate entitlement is 346,000 ML/year with an LTAAEL of 78,500 ML/year (assessed over 10 years) The Lower North Coast WSP has an entitlement of 93,139 ML/year and the LTAAEL is the sum of all share components plus BLR.
Daily flow sharing	Where large volumes are extracted on a daily basis the WSPs establish the percentage of flow that can be extracted. The three most significant extraction percentages are: 1) Hunter and Paterson regulated rivers allow extraction of 50% of high flows 2) The Williams River agreed operating rules. HWC must pass: a. 30% when no water restrictions apply, b. 20% when moderate restrictions (level 1 and 2) apply and c. 10% when severe restrictions (level 3 and 4 apply) 3) Wyong River: for the Local Water Utility: a. 80% of remaining flow when the combined storage level of local water utility is less than 40% full capacity b. 80% of remaining flow when the combined storage level of local water utility is between 40 and 60% c. When the combined storage level is equal to or greater than 60% of full capacity then: i. A Class it is 0% or remaining flow ii. B Class it is 60% of remaining flow iii. C Class it is 60% of remaining flow
End-of- system flow	For the Hunter and Paterson Regulated Rivers, a daily end-of-system flow needs to be passed downstream. Unless dry condition targets apply, the following below falls must be maintained for the Hunter Regulated River: a. 17 ML/day from 1 Dec to end of February at Liddell & 36 ML/d at Greta b. 18 ML/day from 1 Mar to 31 May at Liddell & 40 ML/day at Greta c. 56 ML/day from 1 June to 31 August at Liddell & 73 ML/day at Greta d. 38 ML/day from 1 September to 30 November at Liddell & 61 ML/day at Greta For the Paterson Regulated WSP (clause 14). When flows at Halton gauge exceed 95^{th} %, must ensure flows at Gostwyck exceed: a. 10 ML/day from 1 December to end of February b. 7 ML/day from 1 March to end of May c. 32 ML/day from 1 June to end of August d. 3 ML/day from 1 September to end of November For the Williams River HWC must pass 20ML per day at Seaham Weir, plus the daily flow share set out above.

Water quality

Water quality and quantity are closely inter-related and variations in one can significantly affect the other. Therefore both need to be carefully coordinated.

Several studies were undertaken to assess the impact of river regulation on the rivers ecology to understand the role of running water ecosystem and algal blooms.

In particular, these studies were used to gain an understanding how the Environmental Contingency Allowance (ECA) could be used to suppress excessive algal growth. One study focused on phytoplankton, nutrients and flow in the Hunter[39] and another undertook a post-flood event high resolution study of water quality and phytoplankton[40].A major conclusion from the studies undertaken was that 400 ML per day of flow would suppress algal growth during months when water temperature exceeded critical temperatures.[41] Therefore water needs to be held in storage in case algal blooms occur.

HWC holds 18 Environmental Protection Licences that cover the operation of all of their 19 wastewater treatment works, one water treatment plant and one for Balickera Canal. HWC are now building an enhanced water quality model for the Hunter River Estuary. Initial results from this model indicate the close interaction between the quantity of water flowing down the Hunter River, and its major tributaries, and seasonal and event-based water quality outcomes in the estuary. The major water quality issues in the estuary are increasingly blue-green algae blooms (related to high nutrient loads from diffuse and point sources), water clarity (turbidity) and heavy metals (from various industrial sources).

The Hunter Salinity Trading Scheme was introduced in 2002 to address salinity issues in the Hunter River. The scheme allows saline water accumulating in mines and Lake Liddell to be discharged at times of high river flows and low background salinity levels. The amount of salt the river can accommodate without impacting on other users is determined daily via an extensive and continuous real-time monitoring network. Individual dischargers can discharge a proportion of salt during high rainfall events according to the tradeable salinity credits they hold. This scheme is rarely used during drought periods due to a lack of high rainfall events. Water quality during drought periods can be generally expected to decline as the concentration levels of individual pollutants increases in water bodies in response to reduced dilution. Mine owners and AGL Macquarie need to consider the risk of holding water against the risk of uncontrolled discharge to waters.

[39] Avery, E , *Phytoplankton, nutrients and flow in the Hunter River,* Department of Infrastructure, Planning and Natural Resources, 2004

[40] Sanderson B G and Redden AM*, Examination of post-flood event in the Hunter River: a high resolution study of water quality and phytoplankton*, University of Newcastle, 2004

[41] Avery, E , *Phytoplankton, nutrients and flow in the Hunter River,* Department of Infrastructure, Planning and Natural Resources, 2004

Part 5: Water use and drought management

Photograph 5. Hunter River at Aberdeen (NSW DPI)

Current water use

The previous section outlined the maximum available water take from the various water sources. This does not mean, however, that this amount of water is always taken. For example, agriculture industries that use water for irrigating crops may not use their total entitlement because it rains, or on-site storages do not have the capacity to hold total volumes of entitlement. Similarly, mining may not use all of its entitlement because the level of production does not require it. In addition, AGL Macquarie has entitlements from both the Hunter Regulated River system and the Barnard Scheme but may choose to use only one of these sources of water.

Mining

The Hunter Valley's mining industry has an estimated combined annual water entitlement of 118,489 ML/year. The combination of differing methods of coal extraction, variability of climate-driven contributions to mine site supply, site specific responses to groundwater ingress, connectivity to rivers and other surface water sources creates an extremely complex mosaic of water take. Mining operations take water from a number of supply sources that may be categorised by the mechanism by which water is taken. This includes:

- direct take (externally sourced and pumped to the mine site)
- incidental take (that is, water draining into a mine excavation from the surrounding porous rock matrix and without intervention driving its interception)
- interception take (such as rainfall/runoff capture on-site or harvesting from sediment basins constructed and maintained on-site)
- indirect take (i.e. where a connection is established between a mining operation and an external water source whether by cracking, conduit drainage or pressure displacement driving surface/ground waters towards or into the mining operation)

Demand to maintain coal operations require both baseline (continuing) and variable (contingent) water. Baseline demand maintains the essential operations of the mining project and includes:

- coal handling and preparation plant (CHPP) to process coal for sale
- vehicle and plant wash-down and maintenance
- haul road dust suppression
- raw and product coal stockpile management
- internal water supply to maintain access to operational areas.

Contingent demand includes climate-related water management and supply requirements. This includes:

- rehabilitation water supply (that is additional to incidental rainfall to active and completed rehabilitation areas)
- site dam maintenance and enhanced evaporative losses
- contingent needs including firefighting, dust storm recovery and other incidents

Baseline water demands are relatively inflexible and are required on a continual basis to maintain mining operations. Contingent supply requirements are additional to baseline supply requirements. Therefore, water demands will generally be greater during extended dry periods.

Power generation

The main NSW power stations in the GHR are coal-fired varying in the following locations:

- Vales Point (1,320 MW) on the Central Coast is owned and operated by Delta Electricity (NSW Government).
- Liddell (2,000 MW) and Bayswater (2,640 MW), located between Singleton and Muswellbrook are owned and operated by AGL Macquarie Ltd (acquired from the NSW Government in September 2014).
- Eraring Power Station (2,880 MW) near Wyong is owned and operated by Origin Energy.

Vales Point and Eraring Power Station are sea water cooled rather than sourcing water from the river system/catchment.

AGL Macquarie has five sources of water for a shared water supply system for Liddell and Bayswater Power Stations.

1. A Major Water Utility Licence of 36,000 ML/year.
2. A supplementary water access licence that is limited to an average of 36,000ML/year.
3. The Barnard River Scheme.
4. Water caught from the catchment of its dams.
5. Other general and high security licences that AGL has purchased from other users (2,908ML/year General Security and 1,754ML/year High Security)

This water is used for cooling water, boiler water, fire water, domestic water and equipment wash-down. Most of this water is extracted from the Hunter River. The variation in supply is buffered by two large storages Lake Liddell and Lake Plashett.

Water demand is variable depending on climate with evaporation from storages and cooling water towers being the main demand. In dry, hot conditions the evaporation rate increases, driving higher demand for water. Lake Liddell is also used as a means of cooling water released to Liddell Power Station. Hot water from Liddell Power Station is also discharged to Lake Liddell thereby increasing its overall temperature and evaporation rate. Since water is being constantly lost through evaporation the concentration of salt in the water increases. To manage this, Lake Plashett is kept as a fresh-water storage and Lake Liddell is used to store salt. Salt is removed from Lake Liddell either through processing of water or discharging into the Hunter River under the Hunter River Salinity Trading Scheme. The Power Stations therefore must balance their water and salt budgets.

Agribusiness

Irrigated agriculture is licensed to access approximately 326,000 ML of the region’s total water entitlement. Much of the water used by agribusinesses is opportunistic. In-crop rainfall is a major input for irrigated agriculture producers and has a strong influence on decisions to use water and participate in water trading markets. Land and water use may be significantly impacted upon by varying rainfall and storage levels.

For example, use of water in 2005-06 followed a period of variable rainfall and lower storage levels. 2014-15 water use followed a period with high levels of water in storages but variable rainfall. Analysis suggests that there have been declines over the past decade in:

- irrigated pasture
- plantings of grapevines and other cereals
- land use by horticulture.

Figure 12 shows the major land use activity and water entitlement levels in 2012.

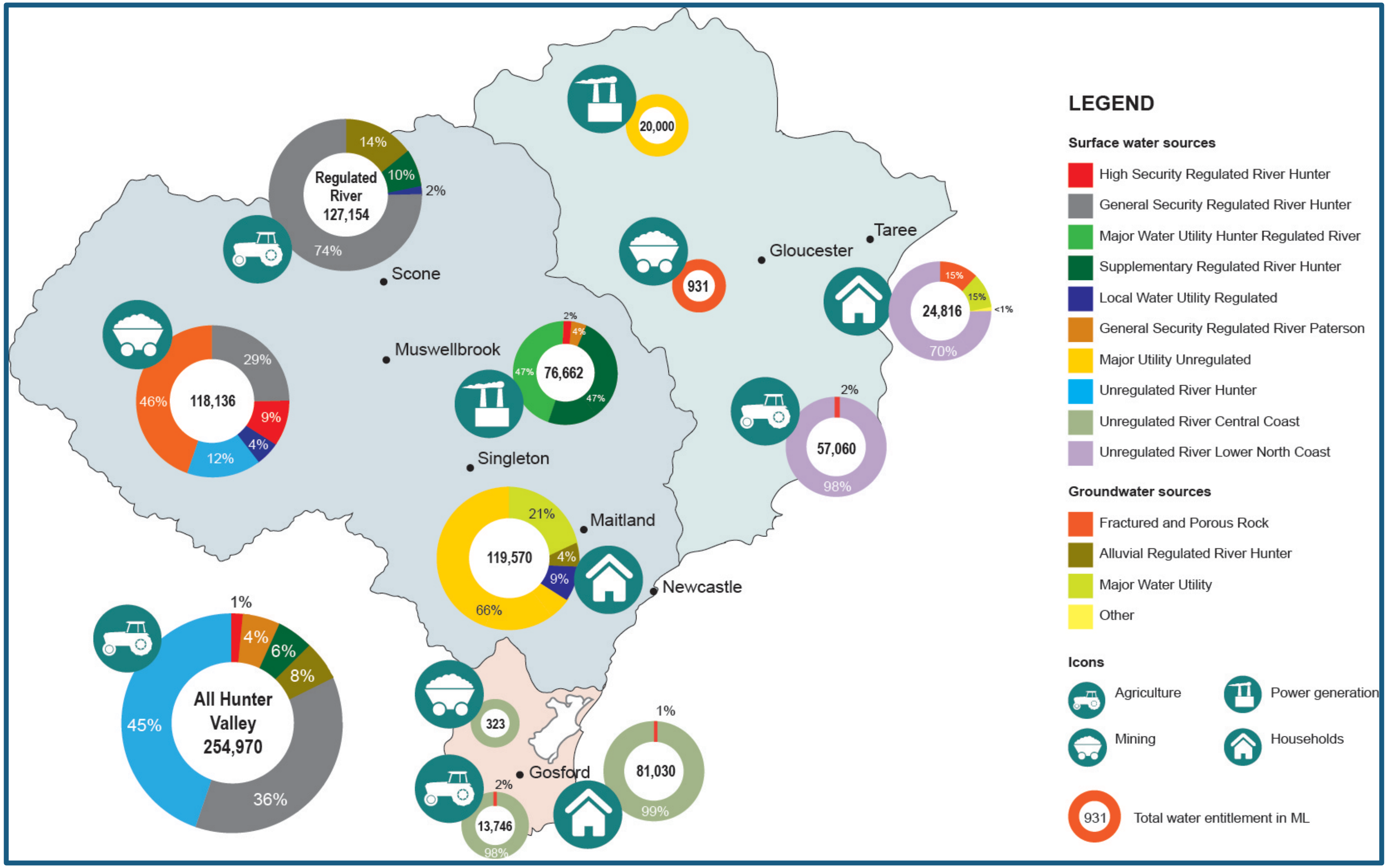

Figure 12. Major activity with source of water and entitlement levels at 2012 or time of WSP

Droughts—operation and management

The Hunter Valley has periods of severe drought and flood. The region sits in a transitional zone between the winter-dominated rainfall in the south and summer-dominated rainfall in the north. There can be periods of both wet winters and summers or periods of dry summers and winters.

One significant climate factor that affects the Hunter Valley's rainfall is East Coast Lows (ECL). These develop over the Tasman Sea close to the NSW coast and can intensify rapidly in the overnight period. ECLs are driven by the temperature gradient between the Tasman Sea air and cold air in the high levels of the atmosphere over Australia. In June 2007, an ECL resulted in the bulk carrier *Pasha Bulker* running aground at Nobbies Beach. Rainfall induced by ECL and related weather systems has been identified as important events that generate significant inflows into major storages along coastal NSW.

Part of a water utilities' responsibility is to undertake long-term strategic planning of their water services. HWC has undertaken this through the *Lower Hunter Water Plan 2014* and Central Coast Council has the *Water Plan 2050*. Other utilities have developed Integrated Water Cycle Management (IWCM) strategies linking urban water supply, sewerage and stormwater. For example, Mid-Coast Council's *Our Water Our Future 2045*.

The Hunter Regulated system

The large storages that supply water to the Hunter Regulated River are sufficient to buffer for short drought periods. As shown in Figure 13, the system is affected by extended periods of below average rainfall. The worst drought on record was 1936 to 1948. During this 12-year period, this drought would have led to persistent zero allocations for general security licence holders, reduced allocations for high-security licences and water shortages for utilities (urban water and power). Mining and agriculture relying on the Hunter Regulated River would be severely affected during a sustained drought such as this.

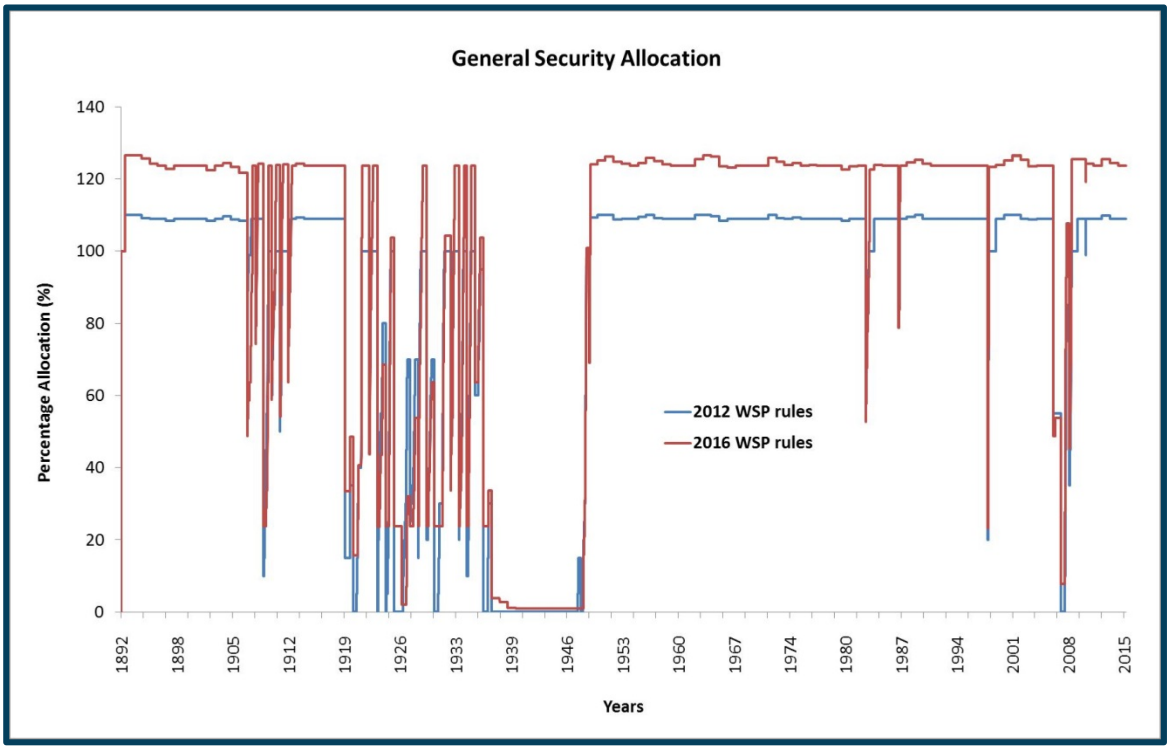

Figure 13. Effect of drought on general security allocations

The Hunter Regulated River Water-Sharing Plan (WSP) 2016 sets out general rules for the amount of water available at any time through the Available Water Determination (AWD). As shown in Figure 14 when dam storage levels diminish the AWD:

- first reduces General Security allocations; then
- both general security and high-security allocations are reduced with general security being reduced at twice the rate until it becomes zero; then
- high-security water allocations continue to decrease until they too become zero; then
- the remaining water is provided to major water utilities, local water utilities of Upper Hunter, Singleton and Muswellbrook and environmental contingency water volumes to account for transition losses and end of system flows.

The WSP specifies that the water supply system must be managed as represented in flow information held by the department when the first WSP for this water source came into force (2004).

The water-sharing plan also specifies that major water utilities, local water utilities, environmental contingency transition losses and end of system flows are provided through the worst drought on record at the time of making the first plan.

The *Water Management Act 2000* provides that the minister can suspend a WSP or parts of it, and undertake critical water planning to prioritise water availability to critical human uses. This in effect creates a 'two-tier' water policy framework:

- Tier 1: Water availability is better than the drought of record: Policy and management arrangements are predictable and transparent within a WSP.
- Tier 2: Water availability is as per the drought of record or worse: Parts of the WSP are suspended and policy and management arrangements rest on the Minister's discretion under 'critical water planning; arrangements (usually involving consultation).

The Upper Hunter historical climate 'drought of record' is a drought of approximately 12 years from 1936 to 1948. General security water users would reduce to zero or limited water allocations during that period of time. This will have an impact as it is estimated that 38% of agriculture is reliant on general security water as is 28% of mining[42].

During the millennium drought of 2006–07, the AWD reached zero allocations for general security and 75% allocations for high-security users. The WSP was suspended and NSW Government Cabinet approval was required to use the environmental contingency allowance (ECA). The millennium drought of 1999–2000 was not as severe as previous historical droughts but the WSP was suspended in anticipation that it may have become as severe.

Hunter Water Corporation

HWC water supplies are sufficient to provide water to the community for the medium-term but supplies are vulnerable to droughts because their storages are relatively small or shallow and water levels can fall quickly. Over the last 120 years, there have been four severe coastal droughts—in the 1900s, the 1940s, the 1960s and the 1980s. The lower Hunter area was not affected as badly as most other parts of NSW during the 1990s and 2000s. Water restrictions were avoided in the Millennium drought as a result of a series of localised storms, including the Pasha Bulker storm in 2007.

[42] Data from Upper Hunter Drought Risk Report, 2013

Hunter Water Corporation's approach to managing the supply demand balance includes:

- A strong focus on reducing demand for potable water through the implementation of an integrated water conservation strategy. Key initiatives include:
  - engaging with the community on the value of water, through the Love Water campaign, to drive behavioural change in water consumption
  - actively reducing leaks across Hunter Water's water network
  - implementing water efficiency programs for non-residential customers as part of business as usual, to reduce demand from the non-residential sector by 10%
  - development of alternative water supplies for non-potable sue (such as industry and irrigation)
  - exploring new technologies that may reduce our future reliance on bulk water supply.
- Undertaking 'readiness activities' for temporary desalination so that the lower Hunter valley is better prepared in the unlikely event of a severe drought.
- Water transfers between Hunter Water and the Central Coast, including upgrades to increase the capacity of transferred water and developing a combined model of the systems to optimise water transfers for the benefit of both.
- Investigating the feasibility of new water supplies, for both ongoing supply and as a drought response, through the major review of the Lower Hunter Water Plan.

These elements supplement the proactive management of existing surface water and groundwater sources at Chichester Dam, Grahamstown Dam, Tomago and Tomaree bore fields and, in the event of drought, implementation of staged water restrictions, additional water conservation measures and targeted awareness campaigns.

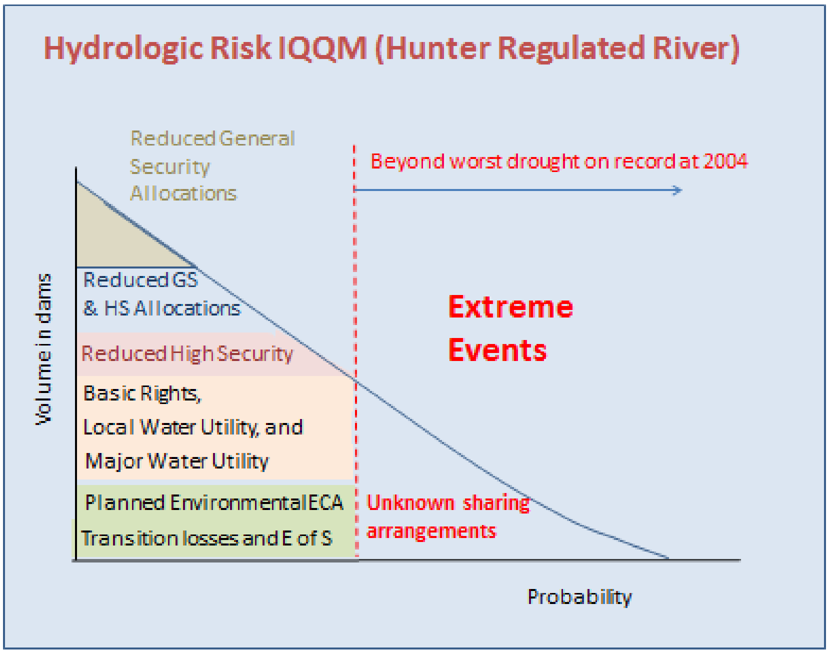

Figure 14. The available water determination (AWD) and extreme events

Central Coast Council

In the 2000s the Central Coast catchment experienced its worst drought since records began there in 1885. The water level in the main storage, Mangrove Creek Dam, dropped to approximately 10% in early 2007. HWC storages were relatively full due to a series of localised ECLs. HWC was able to supply water to the Central Coast Council to help maintain supplies through that drought. An agreement was signed in 2006 to transfer water between the regions with daily transfer rates dependent on the storage levels in each sub-region.

Since the last drought, over $100 million has been invested by the Central Coast Council and Commonwealth Government to improve the security of the Central Coast's water supplies. A new pipeline and pumping stations that allow water to be pumped into Mangrove Dam from Wyong River and Ourimbah Creek was completed in 2012.[43]

Mid-Coast Council

Droughts have been a major factor in the development of infrastructure supplying water to the towns within the Mid-Coast catchments. Over time town water supply schemes have become networked in response to either water quality or the river systems dropping too low to pump. This also includes the development of storages such as Bootawa Dam and extending the schemes to cover more towns with the joining of Lower Manning Supply to Bootawa Dam in 1976.[44]

Throughout the drought of the 2000s, there was concern that there would not be enough water in the Manning River to meet demand. In 2009 and 2010, Mid-Coast Water (now Mid-Coast Council) did not have a water treatment plant and the valley experienced several 'wet droughts' of periods when the river was too turbid and nutrient-laden to pump without risking algae blooms in Bootawa Dam. Dam levels in these times fell to critical levels three times.[45]

Mid-Coast Council is continuing to address drought by developing a bore field in the Nabiac aquifer (due for completion in 2018) and a new water treatment plant as a supplementary supply for the Manning Water Scheme. This will reduce pressure on the Manning River during drier times. However, secure yield investigations completed as part of the IWCM process confirmed that the supply will still not meet NSW Department of Industry's *Assuring Future Urban Water Security* guidelines. Council's strategy commits to investigating additional options such as enhanced storage or recycled water within five years.

[43]NSW Department of Finance and Services, Lower Hunter Water Plan 2014, January 2014
[44] Mid-Coast Water Services, *Who we are and what we do, Community Information Booklet*, 2018
[45] Mid-Coast Water, *Working with our Catchment Manning River Catchment Management Program*, 2011

Part 6: The water trading market

Photograph 6. Hunter vineyard (NSW Trade & Investment)

This regional water strategy provided an opportunity to identify:

- how the water trading market has performed to date
- how markets can be more effective
- whether market-based solutions are a viable, non-build alternative to infrastructure.

Water trading markets are based on the concept of establishing the limit for extraction of water (known as the long-term average annual extraction limit—LTAAEL) and trading within that limit. In setting the LTAAEL, water-sharing plans (WSPs) ensure water is reserved for use by the environment to maintain environmental values. Water markets were designed to:

- manage the impacts of drought by trading water to the greatest need
- enable growth in new industries by providing access to water.

Improving both understanding of, and confidence in, markets can enhance participation and therefore trading of water. This trading amongst different users and uses can help take advantage of new opportunities and generate greater returns from water.[46]

[46] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

Water markets allow water users, rather than the government, to make seasonal and longer-term decisions about how and where water is used. Water trading is a process that allows water to be used most productively by allowing users to redistribute their share of the resource from lower value to higher value uses.

The development of the WSPs enabled a market in water entitlements and allocations as well as a range of tools that allowed water managers and water users to manage their risk and respond to variations in water availability. However, this is based on the objectives, conditions and assumptions prevailing in the 1990s–2000s (with minor 2016 revisions for the Hunter Regulated), including contemporary climate knowledge, public ownership of power utilities, energy policy and regional economic circumstances (balance of mining to agriculture). Events and improved knowledge suggest reconsideration may be appropriate for the strategic planning horizon of 30 to 40 years.[47]

Trends in movement of water between sectors

Figure 15 and Figure 16 show the changes in water use by the different types of users in the Hunter Valley between 2004 and 2013.

From 2004 to 2013, with the increasing development of the mining industry in the Upper Hunter, mines bought up all the high security water that was available on the market. When this was exhausted new mining developments started to access the less reliable general security water to meet demand. As mining developed further up the Hunter Valley, the major source of water became the porous and fractured rock groundwater and some of the regulated river alluvial groundwater. To gain additional water, some of the mines required water from the unregulated river systems. This means that during periods of drought mines are vulnerable to insufficient supply of water. [48] In addition mines have taken advantage of the available water from porous and fractured rock aquifers.

As illustrated in Table 10, mining and power generation have nearly 83% of high-security entitlements and 28% of general security entitlement in the regulated river system, totalling approximately 34% of all water entitlements.

[47] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

[48] DPI Water, *Upper Hunter Valley Preliminary Assessment of Drought Risk Report*, July 2013

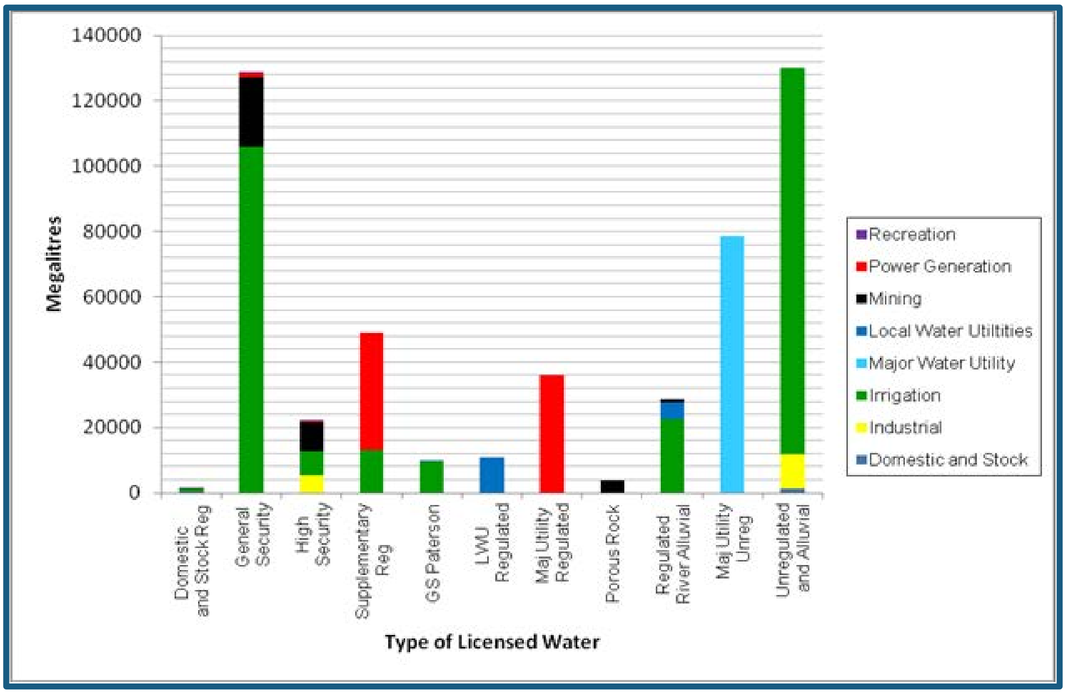

Figure 15. Hunter valley water entitlements held by water use sectors 2004[49]

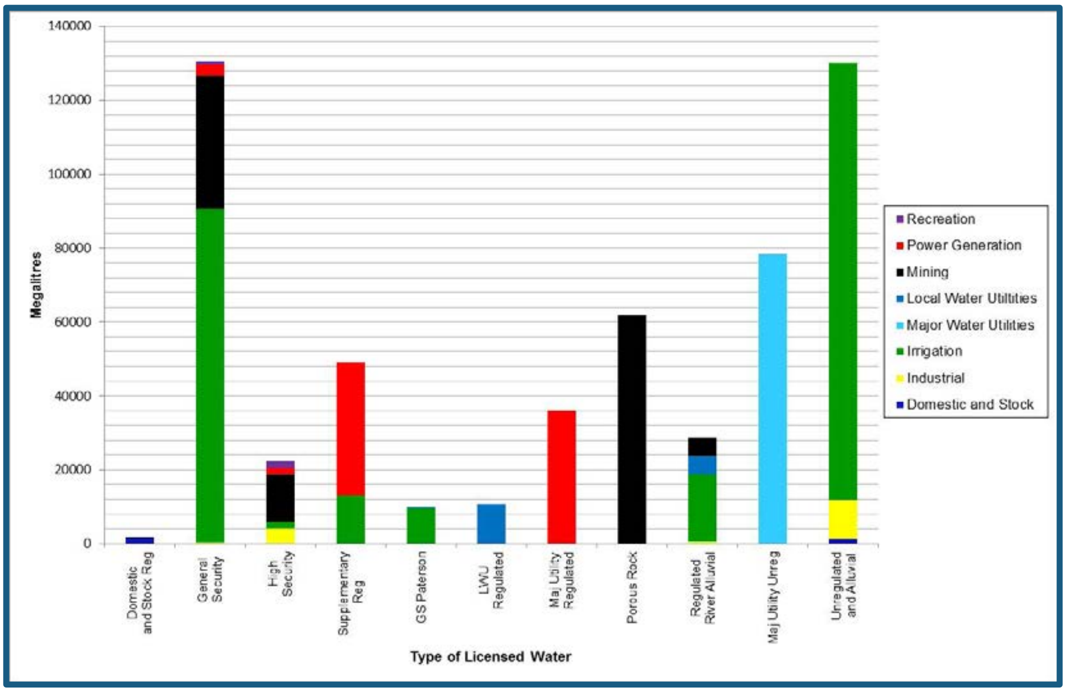

Figure 16. Hunter valley water entitlements held by water use sectors 2013

[49]Note that HWC entitlement is actually 396,700ML but is limited to 78,500ML per year under the WSP. It is anticipated that the entitlement for HWC will be adjusted during the review process for the Hunter Unregulated and Alluvial Water-Sharing Plan due in 2019.

Table 10. Total share components issued in the Hunter Regulated River water source and ownership[50]

Product	Management zone	Shares Allocated	Shares owned by mining interests	Shares issued to Power Generation	Combined shares	Proportion (%)	Remaining shares
High Security	Zone 1	10,378	7,606	1,751	9,357	90.2	1,021
	Zone 2	10,016	4,410	3,400	7,810	78.0	2,206
	Zone 3	1,765	1,149		1,149	65.1	616
	Subtotal	**22,159**	**13,165**	**5,151**	**18,316**	**82.7**	**3,843**
General Security	Zone 1	75,035	27,814	2,908	30,722	40.9	44,313
	Zone 2	47,078	1,127.4		1,127.4	2.4	45,950.6
	Zone 3	6,050	1,462		1,462	24.2	4,588
	Subtotal	**128,163**	**30,403.4**	**2,908**	**33,311.4**	**26**	**94,851.6**
TOTAL SURFACE WATER		**150,322**	**43,568.4**	**8,059**	**51,627.4**	**34.4**	**98,694.6**
HRR Alluvial	U/S Glennies	20,341	5,559.6		5,559.6	27.3	14,781.4
	D/S Glennies	8,714	191		191	2.2	8,523
	Glennies	0				0	
	TOTAL HRR ALLUVIAL	**24,132**	**5,750.6**		**5,750.6**	**23.8**	**18,561.4**
Note: Available water determinations (AWDs) reach full allocation at 1ML/unit share. However, AWDs are frequently less than 1ML/unit share, when water availability is constrained.[51]							

Trading of water

Trading rules for the regulated rivers

For the Hunter Regulated River the trading rules allow trades to occur within the regulated river system as follows:

- Zone 1A and 1B within each management zone so long as they also meet specific conditions;
- Zones 2A and 2B they can trade within each zone but not between; and
- Zone 3A can trade into management zones so long as they also meet specific conditions.
- The current trading rules do not allow water from zones 2 or 3 to be traded into zone 1. The WSP sets a limit regarding how much water can be held in each zone. At present zone 1 is effectively at full capacity.

Table 11 details the tradeable and non-tradeable water entitlements in the Hunter Regulated River. This shows that overall, 61% of water is tradeable and in zones 1A and 1B only 48% is tradeable. Figure 17 illustrates the major trading zones in the Hunter Regulated River. There are no zones within the Paterson Regulated River.

Trading rules for unregulated rivers

Trading rules under the macro planning process are guided by the following principles:

- Where instream values are considered, high trades are either not permitted or only allowed into high flows.
- Where a water source is under high hydrologic stress, no trades are permitted into the water source.
- Trades into downstream water sources are permitted regardless of stress or instream value, provided the water sources have a direct hydrologic connection.

[50] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

[51] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

- Trading within water sources is generally permitted; however, in some areas trading may be restricted to protect high-value areas, or to limit demand in areas where competition for water is already high.

As a result of these principles, trades are not permitted into many unregulated water sources across many of the plans' areas. High instream value water sources are protected by prohibiting trades or limiting trades into only higher volumes flows. Trades are allowed into some water sources with lower value to encourage the movement of extraction from higher to lower environmental value areas.

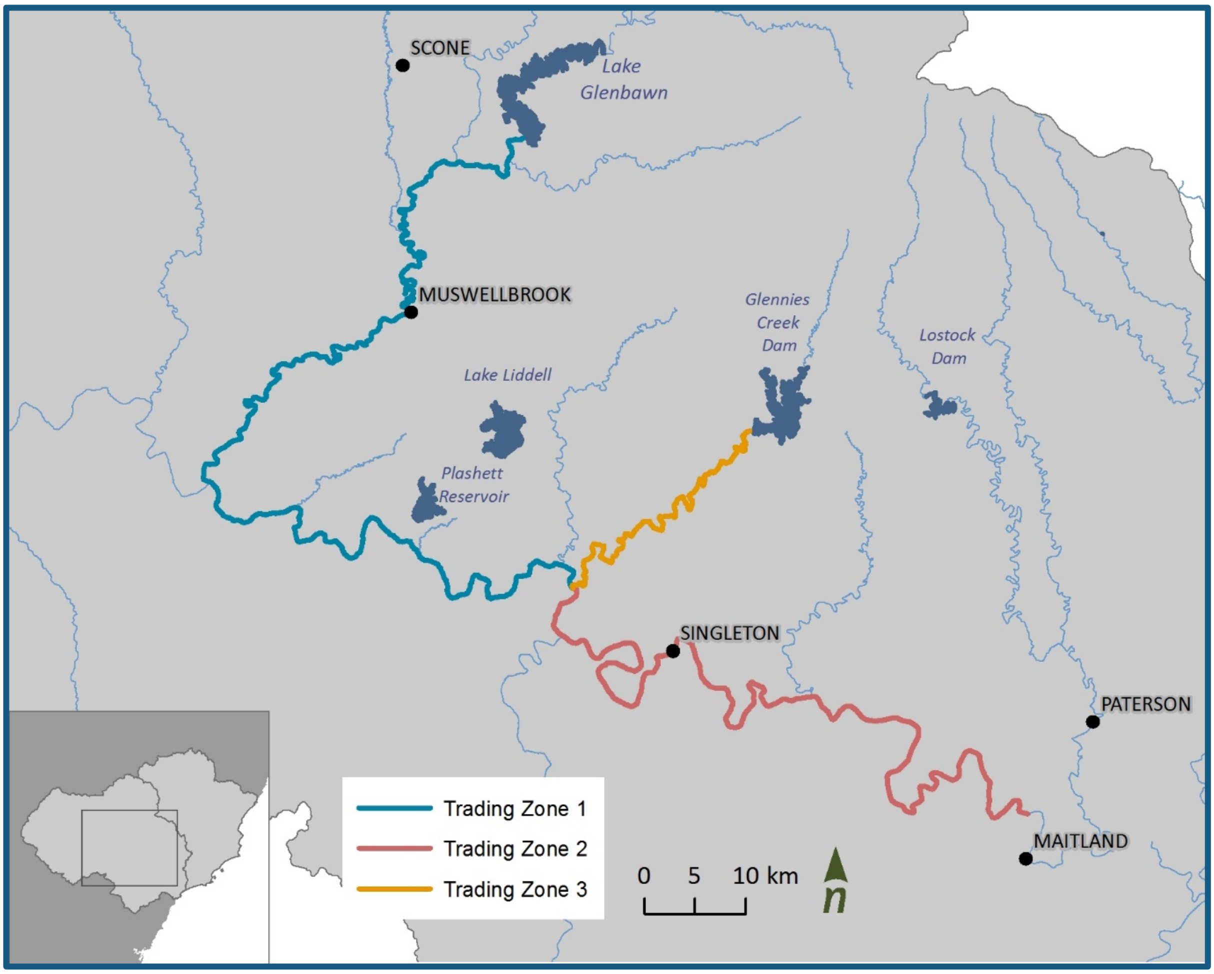

Figure 17. Overview map of trading zones in the Hunter Regulated River WSP 2016

Conversion of a water licence from one category to another

Regulated river

Within the Hunter Regulated River WSP, all zones and management zones allow conversions from high security to general security and general security to high security.[52] In the case of converting from general security to high security, a conversion factor of 1:3 is used where 1 ML of high security is a result of 3 ML of general security share component. Conversions to general security are also limited to a total volume within the system.[53] The Paterson Regulated River Water Source WSP allows conversions. Neither WSP for the Paterson or the Hunter allows for supplementary water to be converted for high or general Security water.

[52] Water-Sharing Plan for Hunter Regulated River Water Sources, 2016, section 59 conversion of access licence to new category.
[53] Water-Sharing Plan for the Paterson Regulated River Water Source, 2007, section 49 Rules for conversion of access licence category

Unregulated river

By changing water use from occurring during periods of low flow to periods of relatively higher flow, over time, streams may be de-stressed and river conditions may improve. To promote this shift in water use, the following conditions have been applied:

- Karuah River WSP applies a conversion rate of 1:2. That is, for every 1 unit of unregulated river licence share surrendered, 2 unit shares of high flow access will be granted
- Hunter Unregulated and Alluvial WSP allow pumpers to convert to higher flows in 5 of the 39 water sources.

In the Central Coast catchments none of the water sources were considered suitable for conversions.

How much trading has occurred

Permanent water trade market

On the permanent market, high security entitlements are rarely traded. These licences are mainly owned by mining or energy companies, who are unlikely to offload these assets whilst they have active operations in the Hunter. This is because high security entitlements, as outlined in the water-sharing plan, provide a minimum of 75% annual allocation even during exceptionally dry years. Therefore, even though in an average year they prefer to use general security entitlements (if they have any) for their water needs, mining and energy companies want to keep high security water as a back-up as they cannot afford to risk water security.[54] The general security permanent market has been more active in the Hunter though this has generally been lower compared to other markets in NSW. Prices for general security permanent transfers peaked during the drought but since then prices have been declining.[55]

Temporary water trade market

Historically, the performance of the temporary water market in the Hunter has been characterised by low levels of trading activity and prices. The one exception to this was seen during the peak of the Millennium drought when the market witnessed sporadic bursts of high demand and consequently very high market prices. Since the drought broke, temporary water prices in the Hunter have not exceeded $60 per ML with the average price for the whole time period being slightly above $30 per ML. This is a very low price in comparison to other catchments in NSW.

The total volumes traded on the temporary market have varied but generally have been low. This can be partly explained by the high water availability in the Hunter catchment for both high and general security entitlements. Only once since 2004 have the final allocations of each water year been less than 100% for entitlement classes and during most years the initial allocation for the season on 1 July has been the full 100% for both classes. In an average year, less than one-third of the water allocated against general and high security entitlements is actually used. [56]

[54] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

[55] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

[56] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

Table 11. Summary of tradeable and non-tradeable water entitlements Hunter Regulated River[57]

Water product	Management zone/river	Volume	Unit
Major utility (Barnard access licences)	Barnard	20,000	ML per year
Major utility (Liddell and Bayswater)	1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)	36,000	ML per year
	Supplementary	36,000	ML per year
Major utility sub-total (non-tradeable)		**92,000**	
Local water utility	1A (Hunter River from Glenbawn Dam to Goulburn River Junction)	5,800	ML per year
	1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)	32	ML per year
	2A (Hunter River from Glennies Creek Junction to Wollombi Brook Junction)	0	ML per year
	2B (Hunter River from Wollombi Brook Junction to Downstream extent of the Hunter River)	0	ML per year
	3A Glennies Creek	5,000	ML per year
Local water utility sub-total (non-tradeable)		**10,832**	
TOTAL NON- TRADABLE		**102,832**	
High Security	1A (Hunter River from Glenbawn Dam to Goulburn River Junction)	5,182	Unit shares
	1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)	5,128	Unit shares
	2A (Hunter River from Glennies Creek Junction to Wollombi Brook Junction)	2,809	Unit shares
	2B (Hunter River from Wollombi Brook Junction to Downstream extent of the Hunter River)	6,971	Unit shares
	3A Glennies Creek	1,650	Unit shares
High Security sub-total (tradeable)		**21,740**	
General Security	1A (Hunter River from Glenbawn Dam to Goulburn River Junction)	46,925	Unit shares
	1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)	29,475	Unit shares
	2A (Hunter River from Glennies Creek Junction to Wollombi Brook Junction)	3,053	Unit shares
	2B (Hunter River from Wollombi Brook Junction to Downstream extent of the Hunter River)	43,298	Unit shares
	3A Glennies Creek	5,793	Unit shares
General Security sub-total (tradeable)		**128,544**	
Supplementary	1A (Hunter River from Glenbawn Dam to Goulburn River Junction)	4,441	Unit shares
	1B (Hunter River from Goulburn River Junction to Glennies Creek Junction)	4,166	Unit shares
	2A (Hunter River from Glennies Creek Junction to Wollombi Brook Junction)	505	Unit shares
	2B (Hunter River from Wollombi Brook Junction to Downstream extent of the Hunter River)	3,289	Unit shares
	3A Glennies Creek	117	Unit shares
Supplementary sub-total (tradeable)		**12,518**	
Total Regulated System (tradeable)		**162,802**	

[57] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017 (table 6)

Table 12. Summary of tradeable and non-tradeable water entitlements unregulated and groundwater

Water Product	Catchments	Water resource	Level of entitlement (ML per annum)
Major utility(urban water)	Central Coast	Unregulated	105,865[58]
	Hunter	Unregulated	78,500[59]
	Mid-Coast	Tomaree Groundwater	3,700
	Hunter	Tomago	25,300
Major Utility	Mid-Coast	Unregulated	20,000[60]
Major utility sub-total (non-tradeable)			**233,365**
Local Water Utility	Mid-Coast	Unregulated	17,256
Local Water utility sub-total (non-tradeable)			**17,256**
Domestic and Stock	Central Coast	Unregulated	229
	Mid-Coast	Unregulated	134
Domestic and Stock (non-tradeable)[61]			**363**
TOTAL NON TRADEABLE			**250,984**
Unregulated	Central Coast	Unregulated	14,269
	Hunter	Unregulated	143,770
		Alluvial Unregulated	65,037
		Alluvial Regulated	34,561
	Mid-Coast	Unregulated	53,512
		Alluvial Unregulated	2,237
TOTAL UNREGULATED TRADEABLE			**313,386**
Groundwater	Central Coast	Coastal Sands	2,094
		Porous and Fractured Rock	1,335
	Hunter	Coastal Sands	29
		Porous and Fractured Rock	69,689
	Mid-Coast	Coastal Sands	61
		Tomaree	13
		Porous and Fractured Rock	5,760
TOTAL GROUNDWATER TRADEABLE			**78,981**

[58] Note the maximum that can be extracted in a single year is 79,750 ML—only 36,750 ML can be supplied for urban use while further water may be pumped into storage when there is adequate flow in streams.
[59] WSP limit
[60] Average 3-year rolling entitlement
[61] Note this is an underestimation as there will be domestic and stock entitlement volumes within the unregulated tradeable component

Table 13. High security entitlement trades in the Hunter Regulated River water source 2004-17[62]

Date	Volume (ML)	Price ($/ML)
23/12/2005	1,135	2,795.05
07/08/2006	150	3,000.00
18/08/2006	150	3,000.00
22/12/2006	8	9,000.00
16/01/2008	180	8,000.00
14/02/2008	150	7,210.00
21/10/2008	500	1,000.00
04/12/2009	400	4,500.00
05/03/2012	229	5,750.00

Table 14. General security entitlement trades in the Hunter Regulated River water source 2004-17

Season	Number of trades	Total volume traded (ML)
2005/06	5	1,108
2006/07	17	2,162
2007/08	14	2,619
2008/09	5	284
2009/10	4	272
2010/11	3	263
2011/12	9	1,590
2012/13	13	1,355
2013/14	6	549
2014/15	8	1,200
2015/16	2	75.7
2016/17	5	473

Effectiveness of the market

A number of factors can effect the effectiveness of the water market as shown in

Table 15. The underutilisation issue highlighted by Infrastructure NSW and outlined in the *State Infrastructure Strategy 2014 Update* is attributed to two key factors:

1. demand behaviour by businesses holding onto water for security of supply
2. the ineffectiveness of the market due to water not being able to be physically moved to where it is required.

From available information it has been concluded that:

- the market is active in droughts but not at other times.

As shown in Table 13 and Table 14, within trades occurred primarily during the 2006–07 drought.

For example, in the last trading year of 2017-18, approximately 150 trades in the Hunter River Regulated system occurred. Approximately 11% of general security allocations had been temporarily traded and 10% of high security. Only general security allocations had been permanently traded amounting to approximately 1%.

- The major growth areas in water have been through exemptions from the market.

[62] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017

The major area of growth in exemptions has occurred through the increase in volumes in mainly access licences within the fractured and porous rock groundwater. The difference between 2004 and 2013 as shown in Figure 15 and Figure 16 shows the significant increase in volumes in the Hunter Valley. Volumes in the Hunter Valley have increased from 3,821 ML in 2004 to 65,432 ML in 2013 to 69,689 ML by January 2017 with some applications still to be processed. In addition, the rest of the region has an additional 7,095 ML of entitlement with applications still to be processed.

- The licensing system for special purpose licences[63] limits the pool of water in the market.

As shown in Table 11 the total volume of Special Purpose Licences is 102,832 ML out of a total of 265,634 ML of entitlement. This means that 39% of entitlements are not available to the market in the Hunter Regulated System. In the Hunter Unregulated system a total of 250,984 ML is held in Special Purpose Licences out of a total of 564,370 ML. This means that approximately 45% of entitlements are not tradeable.

- The pool of water is very limited during times of drought.

As an example, within the Hunter Regulated system during a drought when general security reaches zero only high security entitlements can be traded. By the time general security reaches zero, high security available water determinations have been reduced to 75% allocation. Therefore, during a drought only 16,305 ML of high security is available for trade (see Table 11 for figures). This means that, at this point in time only 10% of the water designated as tradeable can actually be traded.

- Protection of third-party interests limits trade.

As shown previously in this section, trading rules are designed to protect third-party impacts by ensuring the movement of water access licences are not to the detriment of an existing user. This is built into the trading rules and trading zones for the regulated system as well as the trading rules within the unregulated water-sharing plans and the Dealing Principles (Appendix 2). Trading rules do not allow for trades between water- sharing plans. These limitations to meet third party impacts create a limited market.

[63] Major utility specific purpose licence such as power generation that are issued by the minister for a specific purpose only. When no longer required the licence is cancelled.

Table 15. Factors affecting the water market in the Greater Hunter

Factor	Comments
Exemptions	Exemptions under the *Water Management Act* that may impact on the performance of the market include: • Harvestable Rights exemptions • Basic landholder rights • Growth in Local and Major Water Utilities
Growth within plan limits	Groundwater licences under the North Coast Fractured and Porous Rock WSP can continue to be issued outside of these zones if there is any unassigned water. This unassigned water can be made available through a controlled allocation order made under section 65 of the WMA 2000 by Ministerial discretion.
Plan suspension	The Hunter Regulated River Plan commenced on 1 July 2004. It was suspended on 29 December 2006 and recommenced 20 February 2009. The Wybong Creek Plan commenced on 1 July 2004 and was suspended on 18 August 2006. The main reasoning behind suspension of the Hunter Regulated River Plan was that water users did not have sufficient time between commencements of the plans to make adjustments to their businesses. At the same time the then Macquarie Generation (now AGL Macquarie) was being asked to increase power production to make up for shortfalls from other drought affected generators, even though it had not pumped any water from the Barnard River. The environmental water within the Hunter Regulated River WSP could not be used without Cabinet approval given the seriousness of the risks
Special purpose licence restrictions	Major utility specific purpose access licences are issued by the Minister for the specific purpose only. They cannot be traded, nor can their annual allocations be traded. When no longer required, the licence must be cancelled.[64]
Physical barriers to trade.	There may be adequate water available but the water may be located in the 'wrong' location that may be constraining market performance. The water systems are currently not connected. That is, for example, the Upper Hunter and the Lower Hunter operate as two separate systems and the water cannot physically be transported to other areas.
Trading between water-sharing plans	Trading between water-sharing plans is limited. Water cannot be traded between: • Regulated and Unregulated systems • Hunter Regulated River and the Paterson Regulated River.
Substitution	Substitution is using recycled water as opposed to using water currently in the system. Recycled water is not currently part of the water market. This means that water utilities such as Hunter Water Corporation cannot offer recycled water on the market.

[64] Alluvium Marsden Jacob Associates, *Hunter Distribution of Benefits Assessment, and Hunter Preliminary Economic Appraisal including Strategic Policy Review and Modelling Review*, Final report for Upper Hunter Priority Catchment Program Steering Committee, August 2017.

Part 7: Major risks and drivers

Photograph 7. Bayswater stacks with surrounding lake (Industry & Investment)

Identifying the major risks

Major risks were identified through:

a) the state-wide assessment undertaken for the *State Infrastructure Strategy 2014 Update* (SIS 2014). This assessment used a needs identification framework for regulated river valleys. This identified that drought security and flow utilisation were issues within the Hunter valley.

   Using the Catchment Needs Assessment Framework (CNAF) for Unregulated Catchments, an assessment was made based on the then local government areas (LGA) of the security of water supply of different local water utilities. It identified that many of the former local government areas within the Greater Hunter region have a high likelihood of water supply deficiency.

b) the Commonwealth Government agencies, including the CSIRO, undertook studies within the region to provide scientific information associated with coal seam gas and large coal mines at the regional scale.

c) community concerns raised by water users during the development and review of WSPs[65] and the Upper Hunter Diversification Project.

[65] NSW Department of Industry, Water, community submission database for Water-Sharing Plans

Risk 1: Extended periods of severe restrictions for urban centres

HWC and CCC have identified that drought security is their primary risk. HWCs area of operation is vulnerable to drought because water storage levels can fall quickly in prolonged periods of hot dry weather.[66].

The Central Coast catchments' total storage levels dropped to just over 10% in 2007. Level 4 restrictions were enforced banning all outdoor water use.[67]

Throughout the drought of the 2000s there was concern there would not be enough water in the Manning River to meet demand for Mid-Coast Council.[68]

A study was undertaken by NSW Department of Industry on the relative security of urban centres reliant on regulated rivers by extending the approach used in the most recent drought operations to the 120 years of historical record. In this study, drought is defined as when high security allocations are less than 100%. It was identified that the five longer duration events in the historical record would only impact on urban centres receiving their full allocation entitlement.

There is a higher risk for the urban centres supplied via the Hunter Regulated River as the Hunter system has fewer contingencies than many inland regulated rivers because of its many large inflexible demands. [69]

In droughts worse than those in recorded history there would be no guarantee of supply for these areas.

Risk 2: Droughts including those worse than recorded severely impacting the economy

As shown in Figure 16, water entitlements shifted from agriculture to mining during the period 2004–13. The demand for water access for mining outstripped the availability of high security access rights. As a result, the majority of mines in the upper catchment have developed with general security access licences. This means there is a significant risk that these mines will not have enough allocation available during drought periods and mine operations and output will be constrained and/or deferred.

Risk 3: Prolonged periods of reduced water availability impacting on the diversity of industries

The Greater Hunter region supports many diverse industries as discussed in Part 1. During a period of major drought the water market should transfer water to the greatest economic need. Whilst this is desirable in the short term, the longer term outcome will be that many established businesses may leave the region and establish elsewhere. For globally competitive industries they may not re-establish elsewhere in NSW or Australia.

The longer-term reduction in coal-based industries, coupled with a major drought, could leave the region in a situation where other industries cannot fill the void.

Risk 4: Not meeting international environmental obligations

Changes in water management have the potential to affect the region's wetlands and jeopardise Australia's obligations under the Ramsar Convention.

Australia is meeting its international environmental obligations through current water management arrangements. Changes to these water management arrangements such as, but not limited to, additional infrastructure, changes in water-sharing rules and/or the extent of the interception of base flows into

[66] NSW Department of Finance and Services, *Lower Hunter Water Plan*, January 2014
[67] Wyong Shire Council, *The Mardi-Mangrove Link Pipeline, the largest water infrastructure project on the Central Coast in 25 years*, 2009-2011
[68] Mid-Coast Water, *Working with our Catchment Manning River Catchment Management Program*, 2011
[69] DPI Water, Hunter IQQM: Drought reliability assessment, August 2015

rivers as a result of mining activities could result in Australia not meeting its commitments to the Kooragang Wetland.

Risk 5: Quality of the water cannot sustain environmental and human needs

There is a close interaction between the quantity of water flowing in rivers and streams and the seasonal quality of water. This interaction is emphasised in the estuaries as they are the focus of the end of the water system.

Major quality issues may arise from blue-green algal blooms as a result of high nutrient loads, water clarity from turbidity and heavy metals from sewage effluent discharges. Significant population is projected within the area serviced by Hunter Water Corporation and Central Coast Council. This increase in growth will require investment to ensure the quality of water can continue to sustain environmental and human needs.

Future drivers

Drivers are factors that can change risk levels into the future. For example, from 2000 to 2014, the rapid expansion of coal mining was a major driver.

Driver 1: Population growth in urban centres

Population growth is expected throughout the entire region and the current water management framework allows for growth in urban water use. If this growth in use occurs in fully-allocated systems it can reduce the water reliability of other users and the environment.

Some important urban water sources may no longer be reliable/accessible because of water quality issues. Urban water secure yields may be reduced and alternative supplies or demand measures will be required to identify water supply options to support this growth.

To map out future needs the water service utilities have each developed 50-year plans that forecast scheme water demand, set water use efficiency targets and identify supply options to continue to ensure high quality water supplies to the region's towns and cities. Lands and Water has analysed these plans to confirm water efficiency targets and growth projections and identify the timeframe and options to meet future water supply needs.

The population within the Hunter Valley and Central Coast catchments are expected to continue to increase over the next 20 years due to their proximity to Sydney and continued economic activity. Current population and projections to 2036 are illustrated within Figure 20. [70] These figures are the mean series. Department of Planning and Environment (DPE) also have low and high series of population projections.

HWC, CCC and MCC have undertaken long-term planning to estimate future urban water demands. These estimates are based on expected growth and efficiency targets.

The population within the HWC's area of operations is expected to reach around 701,000 by 2036. The current water supply system can supply an average of around 76,000 ML/year to the people of the Lower Hunter. Taking into account the forecast increase demand for water due to population growth, it is expected there will be enough water to supply the lower Hunter area until 2037–38 under typical climate conditions.

The yield of 76,000 ML/year is based on current water sources, water access/transfer rules and the existing transfer capacity constraint from the Central Coast. With increased northward capacity and

[70] DPE main series population figures from planning.nsw.gov.au/Research-and-Demography/Demography/Population-projections?acc_section=2016_nsw_population_projections_data|2016_nsw_household_and_dwelling_projections_data|2016_nsw_projection_data_by_lga|nsw_projections_user_guide|projections_archive.
Upper Hunter includes LGAs of Muswellbrook, Singleton and Upper Hunter Shire.
Lower Hunter includes Newcastle, Lake Macquarie, Maitland, Cessnock, Port Stephens and Dungog

Mangrove Creek Dam at full operating level, the yield is estimated at 79,000 ML/year. This is illustrated in Figure 18.

Hunter Water is actively seeking to reduce the demand for potable water in the short term through an integrated water conservation strategy, to extend these timeframes and delay the decision on future source augmentation. This will allow for the opportunity to take advantage of future opportunities such as behavioural change in water consumption and technological change.

Mid-Coast Council's strategic planning confirms that a long-term solution for the Manning scheme, based on secure yield modelling, is required by approximately 2030. This is as a result of a combination of population growth and the need to improve current reliability of supply.

For the Manning scheme, there will still be a shortfall in secure yield of approximately 1,000 ML once the Nabiac scheme is commissioned, or 12% of annual demand. The shortfall is the difference between the annual demand and the calculated secure yield. The implications are that, in the worst case scenario such as severe drought the 5/10/10 rule would not be able to be met.[71] This is illustrated by the lower bound (blue line) in Figure 19. The short term shortfall is anticipated to be met by continuing demand management strategies and an acceptance of more frequent water restrictions.

Figure 19 also includes an upper bound (blue line) for potential system yield, if water quality constraints were able to be removed for the purposes of water extraction from the Manning River. Mid-Coast Council's existing water quality risk management strategy takes a cautious approach to water quality extraction to minimise the risk of adverse water quality impacts within Bootawa Dam such as potentially toxic blue-green algae blooms.

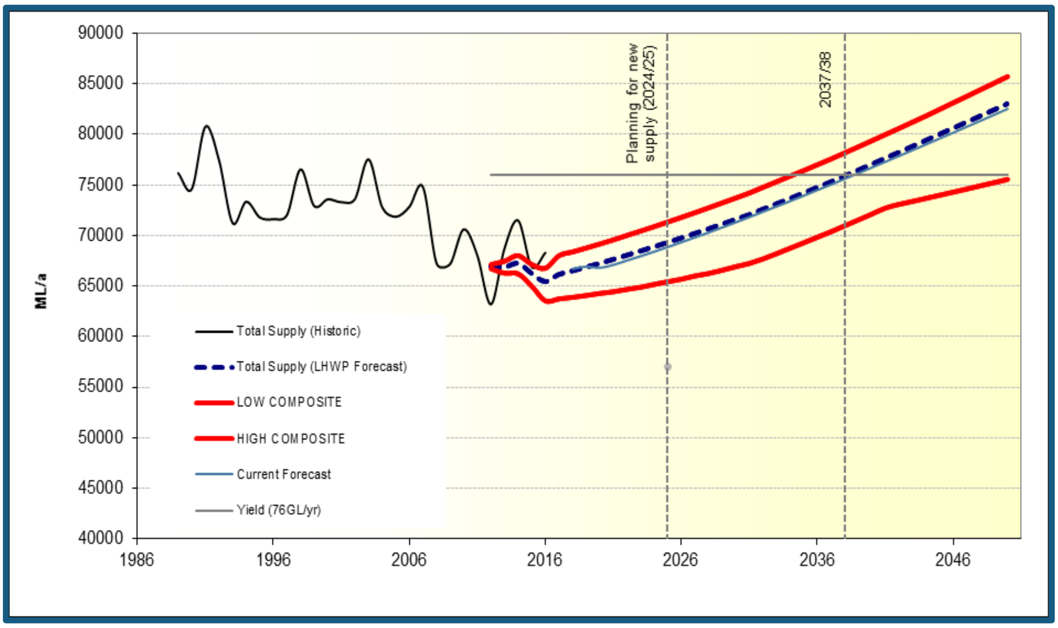

Figure 18. Hunter Water Corporation demand forecast and system yield to 2046

[71] Mid-Coast Water Services (a division of Mid-Coast Council) *Integrated Water Cycle Management Strategy*, 2015

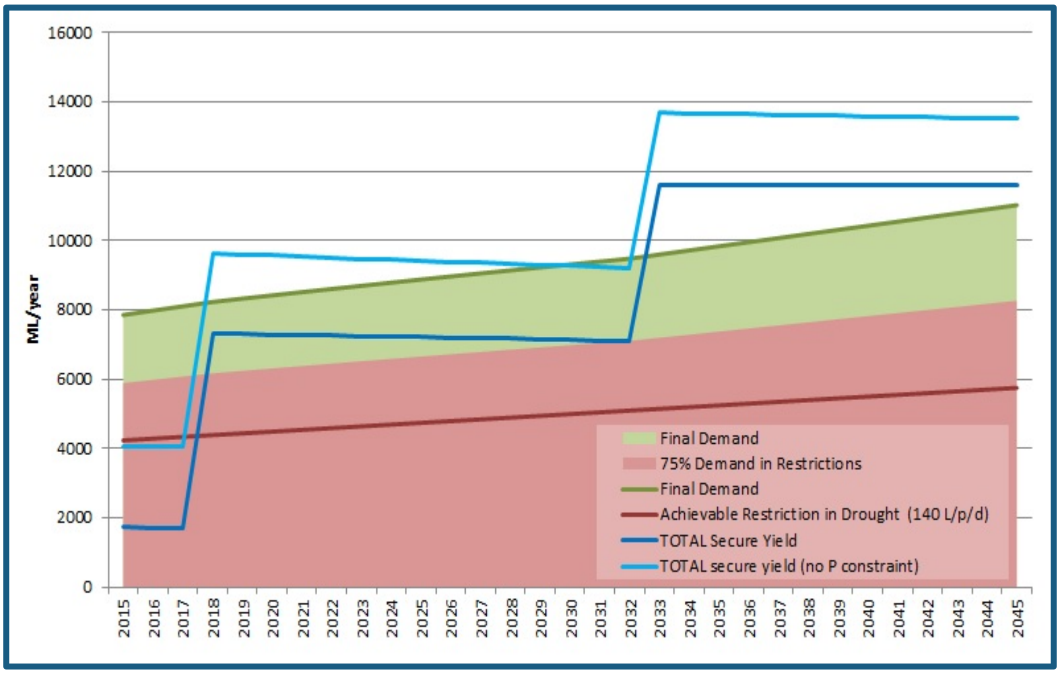

Figure 19. Manning water supply scheme demand forecast and secure yield to 2045

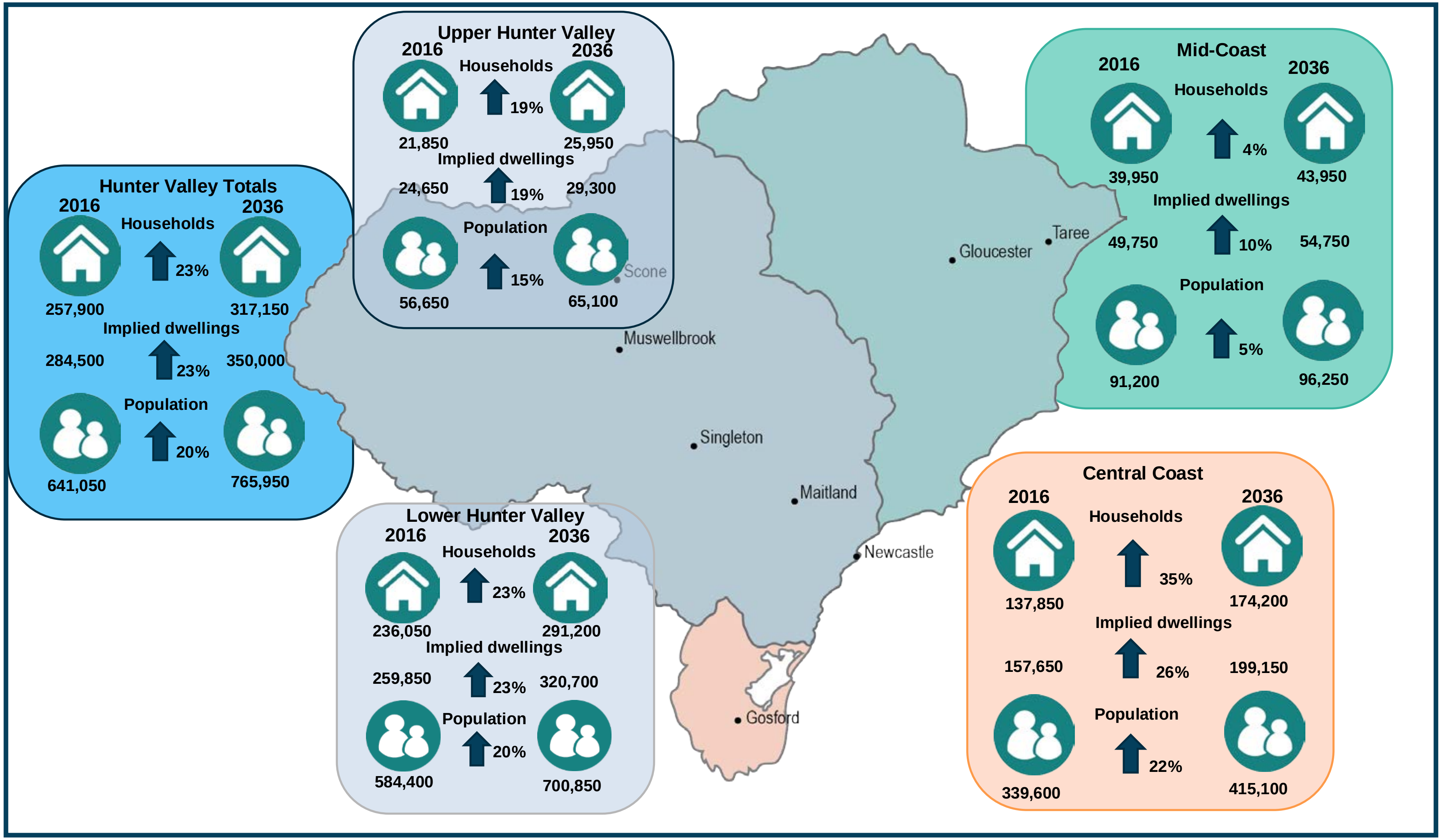

Figure 20. Population trends

Driver 2: Reduction in base flows from interception

The Commonwealth Government, in a scientific collaboration between the Department of Environment and Energy, Bureau of Meteorology, CSIRO and Geosciences Australia, has undertaken a water balance assessment for the Hunter subregion[72] as part of their Bioregional Assessments.

This research shows that there has been, and will continue to be, an impact on surface water base flows from mines through interception of groundwater aquifers, draw down of water tables near rivers and interception of surface water runoff. The year of maximum change varies throughout the study area though it most likely occurs during the decades after mining activity ceases.

The focus of Bioregional assessment was impacts that will occur as a result of approvals for mining since 2012. It found changes in water availability in the Hunter Regulated River at Greta ranges in potential impacts. It is likely that losses will exceed 5,000 ML per year but very unlikely to exceed 12,000 ML per year.[73] In unregulated and alluvial water sources there is the possibility (at least 5% chance) of reductions in water availability of 3,000 ML to 6,000 ML per year in the Singleton, Muswellbrook, Jerrys and Wyong River water sources.

In addition, there are potentially significant impacts on reliability of supply indicated by an increase in cease-to-pump days per year for the Wyong River and some creeks in the Singleton, Jerrys and Muswellbrook water sources.[74]

The Bioregional Assessment concluded that, when considering the Hunter Regulated River, these changes need to be interpreted with caution since the Australian Water Resources Assessment river model (AWRA-R) had not been constructed to specifically represent operational management of releases from Glenbawn and Glennies Creek storages. Therefore, to better understand the impact on the Regulated River System the Bioregional Assessment results including predictions of losses from activities that predated 2012 were modelled in the context of the storage operation and other drivers for this strategy.

Driver 3: Planned closure of thermal power stations

AGL Macquarie has announced plans to close Liddell Power Station in 2022 and Bayswater Power Station in 2035. The closure of Liddell Power Station will not significantly improve the risk of failure of supply to water users in the Upper Hunter valley.

The NSW Government is aware that the closure of the power stations will have a significant impact on economic activity within the Hunter region. Nor does it want to have a repeat of the effect of not planning for the economic and community impact that was experienced within Victoria with the closure of La Trobe power station.

There is a possibility of stranded infrastructure assets and water access entitlements when the Hunter's power stations close. AGL Macquarie holds a considerable volume of high security water entitlement which would assist with economic growth/industry diversification if it could be redistributed.

AGL has a commitment to advancing alternate/renewable energy generation options and has a strategy that all power generation will be carbon zero by 2050. Power plants have a technical life of 50 years and Liddell is planned to close in 2022 and Bayswater in 2035. AGL is working on transition plans for these closures.

[72] Herron NF, Crosbie R, Peeters L, Pena-Arancibia J, Viney N, Wilkins A, Zhang YQ and Marvanek SP*, Water balance assessment for the Hunter subregion. Product 2.5 for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment*, Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia

[73] Note: the term *'very likely'* is used to describe whether there is a greater than 95% chance of something occurring and *'very unlikely'* is used where there is a less than 5% chance

[74] *Assessing impacts of coal resource development on water resources in Hunter subregion: key findings. Product 5: Outcome synthesis for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment*, A scientific collaboration between the Department of Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia 2018

AGL have plans to upgrade Bayswater Power Station that will be completed and fully operational by 2022. This increases capacity but will not involve any significant change in water management.

As part of the transition plans for the Upper Hunter, AGL formed the Hunter Energy Transition Alliance to work with the community to identify opportunities for new energy investment, future jobs and skill requirements/developments to re-equip the thermal generation workforce.

The land occupied by the two power stations and buffer zones totals around 10,000 hectares. AGL and the Hunter Energy Transition Alliance are investigating future options for the site. The water held by AGL will also come into play with the closure of the power stations. A switch to new energy production sources means that water consumption for power generation is uncertain and could either fall or remain the same.

Driver 4: Increased demand from agriculture and industry

Emerging opportunities for agribusiness development for regional NSW is one of five key industry sectors providing Australia's strongest prospects for sustainable economic growth based on predicted global demand. New free trade agreements, and other market developments combined with natural competitive advantages in the Upper Hunter such as access to markets, skills and smart technologies underpin these opportunities.

This is particularly relevant with the continuing urban expansion of the Sydney region creating potential conflicts with existing agribusinesses and processing plants. The transport infrastructure links between Sydney and the region provide an added mechanism for promoting regional development.

The agribusiness industries identified at national and state level as having major opportunities in global markets include industries that are currently major activities (beef and dairy) and sectors that are small in the region (oil seeds, legumes) but have potential to expand. New opportunities that could be introduced or expanded include additional food processing plants such as eggs and poultry and production linked to a regional food and wine experience and the tourism market.

With a combination of the slowdown in the mining sector and medium to long-term plans for the power station closures, the agribusiness sector has started to consider opportunities for an expansion in agriculture, horticulture and processing operations. All sectors identified the potential opportunity to use mining land (rehabilitated sites and buffer lands) for agribusiness activities in the future.[75] Industry groups highlighted that a combination of lower current/future water demand from mining and power generation creates opportunities for expansion and diversification of agribusiness in terms of land and water availability.[76]

Coal mining will continue in the region. Coal production has flattened out since 2014. Exports continued to grow but rates have slowed over the 2 years to 2014–15. The long-term situation will depend on market factors including demand levels from China but even with a major lift in coal prices, employment levels will not return to the peak levels of the boom as coal companies have restructured operations and improved productivity.[77]

Driver 5: Climate change

NSW Department of Industry undertook studies to assess the potential effects of drought by adopting the Office of Environment and Heritage east coast climate change scenario[78]. This scenario included an increase in evaporation of between 5 and 20% and a +15% to -15% rainfall variation range.

The department adjusted their IQQM model to increase evaporation by 10% that would reduce flow to rivers and storages. At the same time, no variations were made to rainfall in the model. The study assessed evaporation at less than the mid-range point of 17.5%. The results indicate that the river systems and storage water levels are sensitive to changes from increasing evaporation.

[75] Michael Connell & Associates *Upper Hunter Diversification: Agribusiness Issues Paper*, May 2016
[76] Michael Connell & Associates *Upper Hunter Diversification: Agribusiness Issues Paper*, May 2016
[77] Michael Connell and Associates, *Upper Hunter Diversification Energy Issues Paper*, June 2016
[78] Office of Environment and Heritage, *Eastern Seaboard Climate Change Initiative East Coast Lows (ECL) Research Program Synthesis for NRM Stakeholders,* 2016

This means that shallow HWC storages and Lake Liddell would be highly sensitive to changes from drought. Glenbawn Dam would be influenced by reduced inflows from unregulated systems during periods of drought. Lostock and Glennies Creek Dams are also sensitive to changes in evaporation. The Central Coast and Mid-Coast Councils' infrastructure are in a similar position given their proximity to the Hunter Valley infrastructure and relative size.

Quantifying the major risks and benefits

To quantify the risks to water users dependent on the regulated river system and the potential costs and benefits, the following steps were undertaken, as shown in Figure 21. Traditionally planning has only been undertaken to Step 5 in this process.

Step 1 Update and improve records

Watermation P/L was commissioned to update data on rainfall, evaporation and runoff used for hydrologic modelling. The purpose of this was to accurately convert below average rainfall into commensurately low flows. The existing rainfall runoff models were calibrated prior to the recent drought of 2007, so the accuracy of the models required review, and where necessary, recalibrated.[79] This new data provides a climate record based on the 122 years of recorded data. It showed that the inflows into Glenbawn Dam from unregulated streams are lower than originally thought. The outcome was that the droughts in the IQQM have been under-estimating the level of drought in the Upper Hunter.

Step 2 Expand the coverage of the model

NSW Department of Industry improved its surface water capabilities for the Hunter region. It expanded the Hunter Regulated River IQQM to include the Paterson and Barnard Rivers. This model allows for daily water balance simulations over a long-term climatic period based on contemporary levels of water supply and demand infrastructure, water access and entitlements and water-sharing plan rules.

Step 3 Establish 2012 base case for ensuring that Australia's international obligations are met

NSW Department of Industry established a base case of 2012 within the hydrologic model to ensure that Australia's international obligations were met and to assess whether any potential infrastructure solutions would need to be referred to the Commonwealth under the requirements of the *Environment Protection and Biodiversity Conservation Act (1999).* This is the critical date for the Kooragang Wetlands as this is the time when the characteristics of the wetlands have been described and against which all changes are compared.

Step 4 Establish 2016 base case for ensuring there are no adverse third-party impacts

NSW Department of Industry r established a base case of 2016 within the IQQM to ensure that there would be no adverse third-party impacts as a result of changes in water management including operational changes to existing infrastructure or the introduction of new infrastructure. This aligns with the Hunter Regulated River Water-Sharing Plan of 2016.

[79] Watermation, *Technical Report for DPI Water Rainfall Runoff Modelling for Hunter Water Security Investigations*, 2017

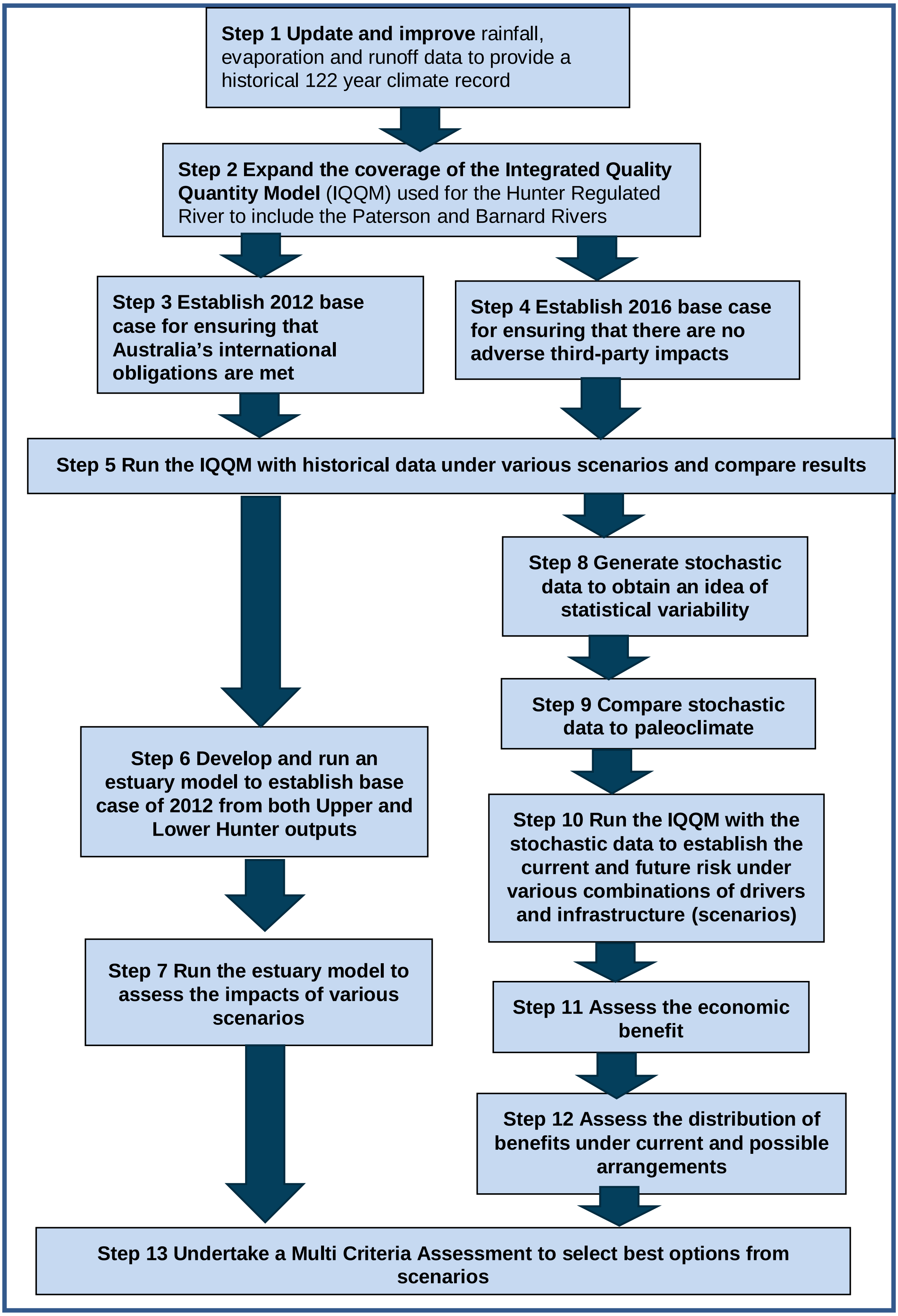

Figure 21. Methodology for quantifying and assessing risks for the Upper Hunter

Step 5 Run the IQQM with historical data under various scenarios and compare results

NSW Department of Industry ran the IQQM model with the updated historical data from Step 1. [80] Changes in the Hunter Regulated River Water-Sharing Plan of 2016 were made to incorporate the non-build options such as increased carry-over which allows water users to manage their own risk. The IQQM model was updated to include these options. These were found to be effective in small droughts only (see Appendix 3).

The 2013 Upper Hunter Drought Report[81] also identified a broad range of infrastructure options. This group of options were evaluated against a series of criteria such as capacity to meet demand, lead time, cost, environmental, social and reliability of supply to form the basis of options in Table 16.

Modelling scenarios were chosen to answer key questions as outlined in Table 17. The 15 scenarios are a mix of do nothing, individual infrastructure options and logical combinations of options. Scenarios were built starting with the 2012 and 2016 base cases and then adding in the individual infrastructure options with and without use of the Barnard Scheme. Likely combinations of options were added to assess how they could work together to provide optimal outcomes.

Interception of base flows was added in to some scenarios to assess its likely impact and whether the infrastructure options would still be viable.

Step 6 Develop and run an estuary model to establish base case of 2012

The University of New South Wales (UNSW) was commissioned to build an estuary model that would allow all stakeholders involved in water management in the Hunter to understand impacts on the Hunter estuary. In addition, NSW Department of Industry r commissioned UNSW to incorporate the data from the Upper and Lower Hunter models, using historical data, to assess possible impacts on the estuary to ensure that Australia's commitments are met. The model was limited to historical data because the level of computation of the stochastic data.

Step 7 Run the estuary model to assess the impacts of various scenarios

UNSW WRL ran the estuary model for each scenario to assess the impact on the estuary. The results show that the variation in salinity concentrations in the estuary from the various scenarios is similar across the model with changes generally lower than 2 parts per thousand (ppt) and rarely exceeding 5 ppt in the estuary. Changes in salinity concentrations exceeding 5 ppts are observed occasionally over the 113-year simulation period but only for short durations (for example, a few days).

Similar to the overall estuary, changes at the Hunter Wetlands National Park are mostly insignificant over the simulation period of 113 years. However, changes over a short duration (say a few weeks) may be sufficient to have an impact on the site. Changes in salinity that exceeded 3 ppt for a period of approximately 12 days occurred for scenarios 13 to 16 over the studied period of 16 June to 26 July 1958. Changes in salinity of more than 2 ppt are generally of short duration (that is, less than a month) and tend to occur during or after a dry year .[82]

[80] NSW Department of Industry, *Hunter Valley Water Security Modelled Scenario Runs*, January 2018, unpublished.
[81] DPI, Office of Water, *Upper Hunter Valley Preliminary Assessment of Drought Risk*, July 2013
[82] Glamore WC, Deiber M, Rahman PF and Howe D, UNSW WRL, *Hunter River Estuary Tidal Dynamic Assessment*, WRL Technical Report 2017/01 January 2017

Table 16. Assessed infrastructure option

No.	Option	Description
1.	Do nothing—no intervention	• No new infrastructure • 75% rule High Security Announced Allocation relaxed under the 2016 WSP rules (OD Hydrology)
Raw Water Options		
2	Transfer via pipeline from existing Lostock Dam to Glennies Creek Dam—7,500 ML/yr	• Existing Lostock Dam size retained • 2-way pipeline transferring 7,500 ML/yr
3.	Pipeline from existing Lostock Dam to Glennies Creek Dam—15,000 ML/yr	• Existing dam size retained • 2-way pipeline transferring 15,000 ML/yr
4.	Pipeline from Lostock direct to Singleton Treatment Plant—7,500 ML/yr	• 7,500 ML/yr transfer direct to Singleton
5.	Pipeline Paterson to Singleton (7,500 ML/yr) with an enlarged Lostock Dam (67,000 ML)	• 7,500 ML/yr 2-way transfer • Dam wall raised to 14.4 m and 67,000 ML capacity
6.	Pipeline Lostock Dam to Glennies Creek Dam with an enlarged Lostock (67,000ML) —15,000 ML/yr	• Pipe size allowing 2-way transfer of 15,000 ML/yr • Dam wall raised to 14.4 m and 67,000ML capacity
7.	Pipeline from existing Lostock Dam to Glenbawn Dam—15,000 ML/yr	• Pipe size allowing two-way transfer volume of 15,000 ML/yr • Existing dam size retained
8.	Pipeline from existing Lostock Dam to Glennies Dam to Lake Liddell—15,000 ML/yr	• Pipe size allowing two-way transfer of 15,000 ML/yr • Existing dam size retained
9.	HWC to Singleton potable two-way water pipeline	• Lochinvar to Rixs Reservoir (above Singleton) as costed in NSW Water Solutions Report • 4,000 ML/yr transfer via 2-way pipeline
10.	Paterson (Vacy) to Maitland to Singleton potable 2-way pipeline	• 4,000 ML/yr two-way pipeline transfers as in 9 above.
Water reuse and enhancement of existing schemes		
11.	Large scale reuse scheme transfer from HWC to Lake Liddell	• Effluent reuse from HWC waste water treatment (WWTP) at Farley, Kurri Kurri, Morpeth and Raymond Terrace and piping 17,000 ML/yr to Lake Liddell
12.	Large scale reuse scheme transfer from HWC west Lake Macquarie WWTPs to Lake Liddell (large scale reuse)	• 20,000 ML/yr piping of reused effluent from Belmont ocean outfall, Dora Creek, Toronto and Edgeworth WWTPs to Lake Liddell
13.	Large scale reuse scheme transfer from HWC Burwood Beach WWTP to Lake Liddell (large scale reuse)	• Delivers 30,000 ML/yr via a 90 km pipeline from Burwood Beach to Lake Liddell • Requires a pipeline via Newcastle city and further water treatment
14.	Large scale reuse scheme from HWC to Lake Liddell (large scale reuse)	• Combine Options 11 to 13 = 47,000 ML/yr via multiple pipelines to Lake Liddell • Requires pipeline via Newcastle city and further treatment
15.	HWC small scale recycling scheme	• 5,000 ML/yr recycled effluent piped from HWC WWTPs below Branxton for small scale recycling scheme
16.	Glenbawn Dam Airspace Management	• Requires Glenbawn Dam be filled above its normal flood storage level by up to 120,000 ML before onset of drought • Can deliver 5,000 ML/yr

Table 17. Scenarios and key questions

Scenario No.	Scenario details	Key questions
01	2012 Base case—do nothing.	What was the regime at the time of the 2012 Ramsar listing characterisation?
02	2016 Base case—do nothing.	What is the situation now following the 2016 water-sharing plan rule changes? Can AGL–Macquarie still receive 100% allocation through the worst drought on record, given the decreased predicted inflow into Glenbawn Dam as a result of a better understanding of the historical drought from updating the rainfall records?
03	Base Case (2) plus Liddell PS closed in 2022 with Barnard Scheme operating.	What is the difference in the risk to, and the security of supply of, water from the closure of the thermal power station (Liddell) with the Barnard Scheme operating?
04	Base Case (2) plus Liddell PS closed in 2022 with the Barnard Scheme closed.	What is the difference in the risk to, and the security of supply of, water from the closure of the thermal power station (Liddell) without the Barnard Scheme operating?
05	Scenario 3 with interception losses downstream of Glenbawn dam due to mining take impacts (CSIRO). Liddell PS closed. Barnard Scheme operating.	How does the reduction in base flows from interception by mining impact users with the Barnard Scheme operating and the thermal power station (Liddell) closed? Can the 2016 WSP provide 100% allocation to AGL Macquarie through the worst drought on record?
06	Scenario 4 with system losses downstream of Glenbawn dam due to mining impacts. Liddell PS closed. Barnard Scheme closed.	How will a reduction in base flows from interception by mining impact users without both the Barnard Scheme operating and the thermal power station (Liddell) closed?
07	Scenario 3 with HWC >> Singleton potable pipeline supplying 5000 ML/yr. Liddell PS closed. Barnard Scheme operating.	What is the impact from the Williams River of extraction to meet extended periods of severe restrictions for urban centres or population growth in urban centres?
08	Scenario 3 with small scale HWC effluent reuse scheme. 5,000 ML/yr. recycled effluent piped from HWC Waste Water Treatment Plants below Branxton for small scale recycling. Liddell PS closed. Barnard Scheme operating.	What is the impact of a small reduction of effluent discharge from HWC on the estuary on meeting international environmental obligations and maintaining the quality of the water to sustain environmental and human needs?
09	Scenario 3 + large scale HWC effluent reuse scheme. 17,000 ML/yr. recycled effluent piped to AGL Macquarie from HWC Waste Water Treatment Plants located below Branxton. Liddell PS closed. Barnard Scheme operating.	What is the impact of a large reduction of effluent discharge from HWC on the estuary whilst the Barnard Scheme is operating on meeting international environmental obligations and maintaining the quality of the water to sustain environmental and human needs?
10	Scenario 4 + large scale HWC effluent reuse scheme. 17,000 ML/yr. recycled effluent piped to AGL Macquarie from HWC Waste Water Treatment Plants located below Branxton. Liddell PS closed. Barnard Scheme closed.	What is the impact on the estuary of a large reduction of effluent from HWC without the Barnard Scheme operating? What is the impact on meeting international environmental obligations and maintaining the quality of the water to sustain environmental and human needs?

Scenario No.	Scenario details	Key questions
11	AGL reduced major utility water take due to Liddell PS closed. Barnard Scheme closed.	Can AGL Macquarie maintain their water supply with reduced allocation after Liddell Power Stations closes?
12	Scenario 5 + Lostock >> Glennies Dam pipeline transfer. Existing Lostock dam size retained. Pipe size allowing transfer volume of 7,500 ML/yr. Mining impact losses included. Liddell PS closed. Barnard Scheme operating.	Do small water transfers between Lostock and Glennies Creek Dams reduce the risk to, and improve security of, water supply to current entitlement holders?
13	Scenario 5 + Lostock >> Glennies Creek Dam pipeline transfer. Existing Lostock dam size retained. Pipe size allowing transfer vol. of 15,000 ML/yr. Mining impact losses included. Liddell PS closed. Barnard Scheme operating.	Do large water transfers between Lostock and Glennies Creek Dams reduce the risk to, and improve security of, water supply to current entitlement holders?
14a	Scenario 3 + Lostock >> Glennies Creek Dam pipeline transfer. Lostock dam size expanded to 67 GL. Pipe size allowing transfer volume of 15,000 ML/yr. Not including mining impact losses. Liddell PS closed. Barnard operating.	Is an enlargement of Lostock Dam required in addition to a pipeline between Lostock and Glennies Creek Dam with the Barnard Scheme operating to reduce the risk to, and improve security of, water supply to current entitlement holders?
14b	Same as 14a except Barnard Scheme closed.	Is an enlargement of Lostock Dam required in addition to a pipeline between Lostock and Glennies Creek Dam to reduce the risk to, and improve security of, water supply to current entitlement holders, if the Barnard Scheme is not operating?
14c	Scenario 13 + Lostock water transfer >> Glennies Creek Dam to max of 15,000 ML/yr. Lostock dam size enlarged to 67 GL. Barnard Scheme operating.	Is an enlargement of Lostock Dam required with a pipeline to Glennies Creek Dam and the Barnard Scheme operating going to reduce the risk to, and improve security of, water supply to current entitlement holders?
15	Scenario 2 plus Liddell PS closed. Small scale water recycling = 5000 ML/yr. Potable water pipeline – HWC >> Singleton supplying 5000 ML/yr. Scenario 3 with Lostock >> Glennies Creek Dam pipeline transfer. Pipe size allowing transfer volume of 15,000 ML/yr. System losses from mining. Barnard Scheme operating.	Can international obligations under current WSP rules be met after taking into account interception of base flows, the closure of the thermal power station (Liddell), the Barnard Scheme operating and major infrastructure developed?

Step 8 Generate stochastic data to obtain an idea of statistical variability

University of Newcastle was commissioned to undertake stochastic data (probability) to simulate variability by producing 10,000 years of records based on historical records. This broadens statistically the probability of climate variability including whether there are changes in such things as averages. As a result it demonstrates that that there is probability of significantly dryer and wetter conditions than were experienced in the 122 years of record. This was done within the context of ensuring some key long-term historical characteristics.[83]

Step 9 Compare stochastic data to paleoclimate

OD Hydrology was engaged to analyse and compare the data to see if the stochastic data was showing the same order of drought as the paleoclimate data (i.e. pre-climate record). This was to ensure that there is robustness in the stochastic data for soundness of method.

Figure 22 illustrates the last 1,000 years of wet and dry periods. It shows that since the 1500s the region has been experiencing 500 years of average to wet periods of climate. Prior to this there were periods of dryer or average years of rain.[84] [85]Analysis indicates there is a likelihood that dryer conditions will return and will need to be factored into management.

Paleo-climate analysis of the last 10,000 years and stochastic generation of rainfall and evaporation data suggests droughts of 15 to 20 year duration (as well as extended wet periods) may occur in the future.[86] Hydrological analysis has suggested that in this context, the 1936–46 drought may represent a recurrence event of 1 in 40 years, rather than a 1 in 100, when considered in the context of a longer timeframe.[87] Therefore, existing climate variability poses potentially higher risks security of water supply than was previously understood.

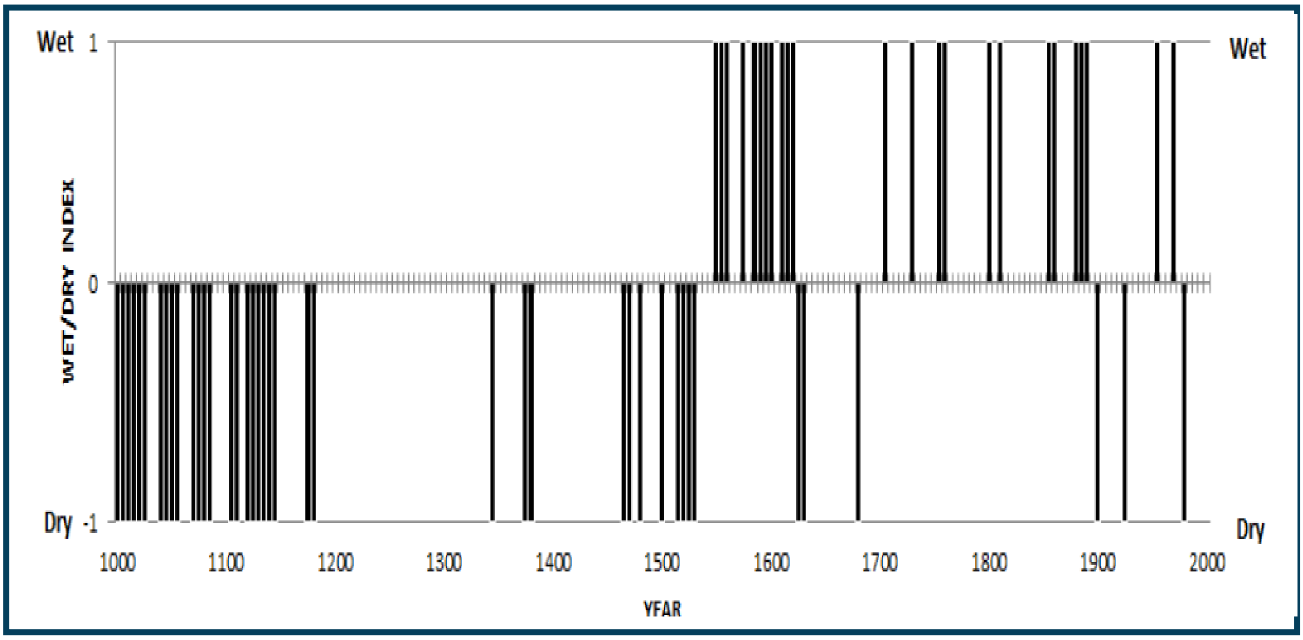

Figure 22. Wet and dry periods over the last 1,000 years

[83] University of Newcastle, *Multi-site rainfall and evaporation data generation report*, 2016

[84] Flack A.L*. Investigating pre-instrumental hydroclimatic records relevant to eastern Australia and what this means for water resource management*. Honours Thesis, University of Newcastle, Australia, 123 pages, 2015

[85] Flack, A.l., Kiem, A.S., Tozer, C.R., Vance, T.R. and Roberts, J.L., *Multiproxy paleoclimate reconstructions for eastern Australia confirm instrumental records misrepresent hydroclimatic variability: implications for water resource management and planning*, Water Resources Research, In Review, 2018

[86] Kiem, A.S. University of Newcastle, *Multi-site rainfall and evaporation data generation for the Hunter Water Infrastructure Project: Final Report for NSW DPI Water*, 2016

[87] OD Hydrology Hunter Valley Water Infrastructure Project, *Stochastic hydrologic/water supply assessment – Scenario assessment outcomes: Final report for DPI Water, Brisbane*, January 2017

Step 10 Run the IQQM with the stochastic data to establish current and future risk under various combinations of drivers and infrastructure (scenarios)

OD Hydrology was commissioned to run the IQQM with the probability data against various scenarios that covered the identified drivers and potential infrastructure opportunities to see how risk changed. The scenarios and results are shown in Table 23 in Appendix 4: Statistical hydrological assessment. To understand the role of climate change OD Hydrology also ran the model with the stochastic data using a mid-range outcome with an increased evaporation rate of 10%.

Step 11 Assess the economic benefit

Alluvium and Marsden Jacobs were commissioned to assess the economic benefits of the various scenarios and the risk these options posed for the Upper and Lower Hunter regions. A preliminary Cost Benefit Analysis (CBA) was undertaken to compare the performance of various infrastructure options in scenarios using three key measures:

- Net Present Value (NPV). This is the Present Value (PV) of economic benefits delivered by the option less the PV of economic costs incurred. NPV measures the expected benefit (or cost) to society of implementing the policy expressed in monetary terms.
- Benefit Cost Ratio (BCR). This is the ratio of the PV of economic benefits to PV of economic costs. The BCR identifies the option that provides the highest benefit per unit of cost.
- Levelised Cost. This is the ratio of the PV of economic cost to PV of water usage from the hydrologic modelling.

A preliminary economic appraisal was undertaken to assess the various scenarios and their impact on the Upper and Lower Hunter valleys as well as potential benefits to various industry sectors. The preliminary cost benefit analysis focused on the benefits to major utility (energy), mining and agricultural water users. Figure 23 illustrates the net present value and benefit cost ratio of the various scenarios.

In addition, NSW Public Works (Water Solutions) were commissioned to undertake a preliminary engineering and environmental feasibility assessment of potential options. This involved identifying and preparing capital cost estimates on the infrastructure options that were considered to involve a considerable cost. These feasibility assessments were designed to be the core input into any business case developed by the relevant major water utility should any of the options be progressed.

Step 12 Assess the distribution of benefits

Alluvium and Marsden Jacobs were commissioned to undertake a distribution of benefits study under current arrangements and scenarios considered in Step 10[88]. This study analysed how the benefits of any infrastructure could be distributed. The beneficiaries could be the various categories of licences such as High Security, General Security, AGL Macquarie, the water utilities, supplementary and the environment.

The current WSP rules distribute the benefits to these users based on the historical drought sequence. The use of stochastic modelling assists with understanding how current WSP rules would distribute benefits in droughts exceeding the worse than on record.

The study found that current water-sharing plan rules limit the potential distribution of benefits from new infrastructure. By changing the WSP the government can optimise how and where these benefits flow to address the major risks and future drivers identified.

In making changes the government also needs to be mindful of any reduction or less reliable water allocation that is not previously provided for, arising from government policy (commonly

[88] Alluvium and Marsden Jacobs, *Hunter Distribution of Benefits Assessment and Hunter Preliminary Economic Appraisal, Including Strategic Policy Review and Modelling Review. Final Report for Steering Committee*, provided to DPI Water, August 2017

known as third-party impacts). Under the Intergovernmental Agreement on a National Water Initiative, a framework is provided for addressing these third party impacts.

Step 13 Undertake a multi-criteria assessment

NSW Department of Industry with guidance from NSW Water Solutions led the process of a multi-criteria assessment (MCA) on the proposed infrastructure options.[89] This provided a mechanism to bring together all the information from the previous steps with an understanding of the need to broaden the process to a regional scale that could also incorporate the drivers into an assessment of the future direction of the region.

The assessment framework, including determining weightings of objectives, was developed in consultation with the Upper Hunter Water Issues Steering Group, including the major water utilities within the Hunter valley.

The MCA considered the various infrastructure options against program objectives and goals. These infrastructure options were assessed against program objectives and goals under a consistent scoring system. The initial MCA was set up for scoring with equal weightings for each assessment criteria within a triple bottom line category (environmental, economic and social).

Each of the objectives within the MCA received individual measures and weightings. These weightings were derived through a workshop, facilitated by NSW Water Solutions, with participants from the Upper Hunter Water Issues Steering Group and Working Group.

Appendix 5: Multi-criteria assessment provides further details.

Step 14 Investigate the benefits to Lower Hunter and Central Coast

Steps 1 to 13 have focused on the Upper Hunter valley. This step explored the possibility of the benefits being distributed to a broader group of users including HWC and the Central Coast catchments. HWC undertook preliminary investigations into the potential benefits of connecting the Upper and Lower Hunter valleys primarily through a proposed Glennies Creek and Lostock Dams two-way pipeline.

This investigation indicated that:

- The networking could increase system yield in the Upper and Lower Hunter and provide additional drought resilience within the region. There are potentially other benefits, such as increased water resilience due to greater source diversification for both the Lower and Upper Hunter water supply systems. These benefits have not been modelled or explored in any great detail.
- A potential benefit to the Lower Hunter of a connection to the Upper Hunter valley is a saving in capital and operating expenditure associated with the deferral of the next major water source augmentation for the Lower Hunter. In a high demand growth scenario HWC next source augmentation is required as early as 2031-32.
- Networking the system with the two-way pipeline connection between HWC and the Central Coast and a potential line between HWC and Singleton Council may provide additional benefits to the region as a whole in terms of improving reliability and security of supply for areas particularly when in drought conditions. Further work needs to be undertaken to understand the benefits and costs to the region on both the Lostock Glennies link and the HWC Singleton link.

Alluvium and Marsden Jacobs were commissioned to reassess the benefits in step 11 with incorporating the Lower Hunter valley and Central Coast catchments. Figure 23 includes those options for connecting the region.

[89] NSW Department of Industry, *Upper Hunter Priority Catchment Options Report*, September 2017

Part 8: Key findings and actions for implementation

Photograph 8. Rural scene and thunderstorm (A. Silver)

The *State Infrastructure Strategy 2014* identified the Hunter Valley as having a high drought risk and low utilisation. Drought security was confirmed as the primary economic risk facing the Greater Hunter region. This risk extends to all sectors including urban, agriculture, mining and power generation. The Hunter Valley's economy is highly significant to NSW through mining royalties, tourism, agriculture and the thoroughbred industries.

Water planning is fragmented into many different plans (urban, regulated rivers, unregulated Rivers, and groundwater) and water is provided by multiple water utilities. This regional strategy is an overview intended to identify major risks and drivers and set the context for water planning and infrastructure development. The non-urban planning was based on the historical record with no consideration for more severe droughts. This resulted in uncertainty. This strategy has investigated the impact of severe droughts.

The Greater Hunter region has transitioned from agriculture to mining with now approximately equal use by urban, mining, power generation and agriculture. Access to reliable water is required to maintain the existing diversity of industries and to support new agribusiness and alternative energy processes. This is needed to soften the economic impact as the Upper Hunter valley transitions away from mining and coal fired power stations.

Updated rainfall and evaporation records show a stronger variation in rainfall across the Hunter Valley with the Upper Hunter likely to experience less rainfall than previously used for water supply security estimates. A repeat of the 1940s drought (the worst on record) would see General Security allocations reduced to zero for approximately 12 consecutive years. Statistical analysis and a comparison with paleoclimate studies suggest climate variability is much greater than has been observed and that drought of the intensity of the 1940s may occur more frequently than observed in the historical record[90]. Reductions in the base flows and climate change greatly increase the risk of drought. The closure of Liddell Power Station in 2022 will not significantly change the drought risks to other water users.

The low utilisation of water across the Greater Hunter region results from a combination of holding water in reserve for drought security and market restrictions. The Greater Hunter region's water market is not effective as only 10% of water is potentially available for trading during drought with the remainder being held for special purposes. Exemptions have allowed for growth to bypass the market which has further reduced drought security.

Analysis of the scenarios (combinations of drivers and infrastructure options) revealed that 'business as usual' was the single most economically, socially and environmentally undesirable scenario. The studies identified that the connectivity of water distribution systems to reduce the risk of drought across the Greater Hunter region water supply network was the most effective strategy. This strategy involves infrastructure to link the large water storage capacity of the Upper Hunter valley with the higher water yielding Lower Hunter valley. A distribution of the benefit study identified that changes to the market and water-sharing arrangements are necessary to optimise the benefit of infrastructure for both consumptive users and the environment. Any changes need to ensure there are no undesirable third-party impacts.

The strategy involves a combination of new infrastructure and better utilisation of existing assets. The Multi-Criteria Assessment (MCA) identified that the infrastructure options for further investigation:

- Construction of a two-way between Lostock and Glennies Creek Dam.
- Construction of a potable pipeline from Hunter Water Corporation (HWC) to Singleton.
- A large-scale water reuse scheme.
- Continued operation of the Barnard Scheme after Liddell Power Station closes.

The strategy also allows AGL's water infrastructure to be incorporated into a regional framework when Bayswater Power Station closes in 2035.

Some of the benefits can be transferred to HWC for urban growth in Newcastle and the Central Coast delaying the need for a major augmentation. It could significantly delay the next supply augmentation for both Newcastle and the Central Coast and mitigate the need for restrictions.

[90] For further details, refer to the *Quantifying the major risks and benefits* section in Part 6 of this report.

A large-scale water reuse scheme was shown to give the highest net present value and scored high in the MCA. However, this option was only of benefit in the short term rather than as a long-term solution and has not therefore been recommended by Infrastructure NSW (INSW) for preparation of a business case in the 2018 *State Infrastructure Strategy*. Further development of recycling opportunities is recommended.[91]

The wetlands of the Hunter River estuary are of international importance and are listed under the Ramsar Convention. Modelling of the Hunter River estuary indicated that the options investigated could be managed to maintain the wetland's characteristics and, in doing so, meet Australia's International obligations under the Convention.

Most of the scenarios involving infrastructure were found to be economically beneficial (See Figure 23). When considering networking the system to cover the whole region, the net benefit cost ratio becomes a disbenefit if only a small-scale transfer between Lostock and Glennies Creek Dams occurs. If a larger scale transfer occurs then this shows a substantial benefit.

For any subsequent assessments such as business cases for infrastructure proposals there needs to be further detailed demand assessments to confirm the beneficiaries.

This regional strategy is the tool for an ongoing conversation about the direction of water management within the region. This strategy outlines the major issues facing water management arrangements. It is important that industry, government, local government, water utilities and the community are engaged in active discussion and debate on the key strategies and actions that have been identified as a result of technical investigations and studies. This document is the tool for this discussion to take place.

[91] NSW 2018 State Infrastructure Strategy 2018:
https://insw-sis.visualise.today/documents/INSW_2018SIS_BuildingMomentum.pdf
Water Chapter 11: https://insw-sis.visualise.today/chapters/Water.pdf

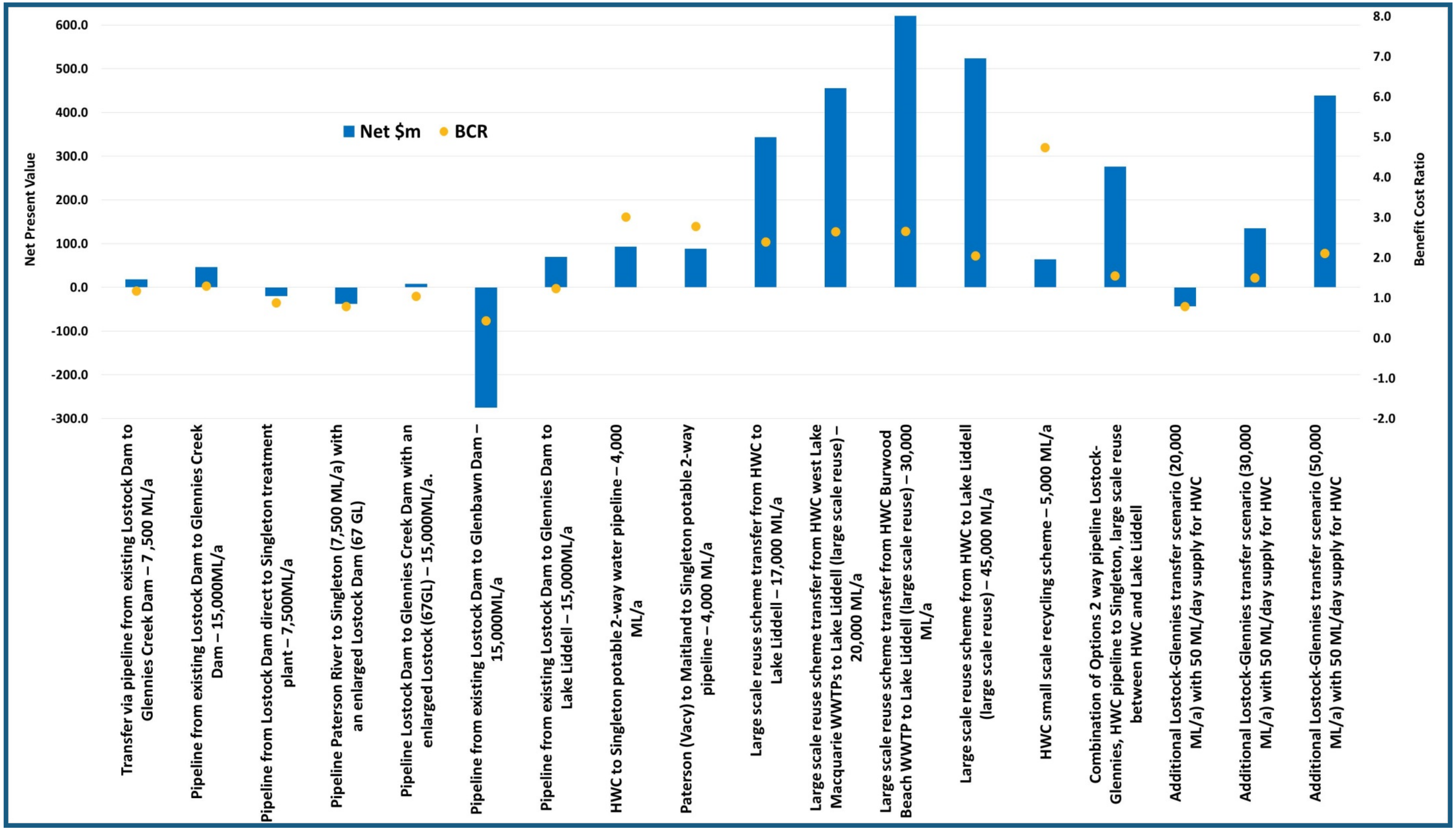

Figure 23. Comparison of net present value and benefit cost ratio, 7% discount rate for options

Glossary of terms

aquifer

rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit quantities of water to bores and springs.

consumptive pool

the portion of a water resource that is available for *consumptive use* in a water system under the rules of the relevant water plan.

consumptive use

use of water for private benefit consumptive purposes, including irrigation, industry, urban and stock and domestic needs.

drawdown

is a lowering of the groundwater level, caused, for example, by pumping.

environmental and other public benefit outcomes

is defined as part of the water planning process and specified in water-sharing plans. May include:

- *environmental outcomes*: maintaining ecosystem function (e.g. through periodic inundation of floodplain wetlands); biodiversity, water quality; river health targets;
- *other public benefits*: mitigating pollution, public health (e.g. limiting noxious algal blooms), indigenous and cultural values, recreation, fisheries, tourism, navigation and amenity values.

environmental manager

An expertise-based function with clearly identified responsibility for the management of environmental water so as to give effect to the environmental objectives of statutory water plans

- the institutional form of the environmental manager will vary from place to place reflecting the scale at which the environmental objectives are set and the degree of active management of environmental water required
- the environmental manager may be a separate body or an existing Basin, catchment or river manager provided that the function is assigned the necessary powers and resources, potential conflicts of interest are minimised, and lines of accountability are clear.

environmentally sustainable level of extraction

The level of water extraction from a particular system which, if exceeded would compromise key environmental assets, or ecosystem functions and the productive base of the resource.

exchange rate

the rate of conversion calculated and agreed to be applied to water to be traded from one trading zone and/or jurisdiction to another.

exemptions

are those activities that do not require to be licensed under the *Water Management Act 2000* and regulations. Includes harvestable rights, basic landholder rights and growth in local and major water utilities.

extraction rate

the rate in terms of unit volume per unit time that water can be drawn from a surface or groundwater system. Used in the NWI in the context of a constraint that might exist due to the impact of exceeding a particular extraction rate at a particular point or within a specified system.

general security

a form of entitlement, hence allocation, pertaining to a regulated stream for which Water Orders are accepted subject to storage/demand management. See also high security.

groundwater-dependent ecosystems (GDEs)

ecosystems that rely on groundwater for their species composition and their natural ecological processes.

gross regional product

is the net measure of wealth generated by the region. GRP can be measured by using the incomes approach, where all incomes earned by individuals (wages and salaries), firms (gross operating surplus) and governments (taxes on products or services) are added. Alternatively an expenditure approach can be taken where all forms of final expenditure, including consumption by households, consumption by governments; additions or increases to assets (minus disposals) and exports (minus imports) are added. The expenditure approach does not include intermediate expenditure, as this would lead to double counting. E.g. The wheat and flour in a loaf of bread.

harvestable rights
owners or occupiers of land can collect a proportion of the rainfall runoff from the land in one or more dams without a water licence, supply work approval or water use approval. There are restrictions on size and locations of dams. There are also exemptions.

high security
a form of entitlement, hence allocation, pertaining to a regulated stream for which the supply of water has a higher priority than general security.

lower bound pricing
the level at which to be viable, a water business should recover, at least, the operational, maintenance and administrative costs, externalities, taxes or TERs (not including income tax), the interest cost on debt, dividends (if any) and make provision for future asset refurbishment/replacement. Dividends should be set at a level that reflects commercial realities and stimulates a competitive market outcome.

metropolitan
refers to water and wastewater services provided in metropolitan urban areas having in excess of 50,000 connections.

over-allocation
refers to situations where with full development of water access entitlements in a particular system, the total volume of water able to be extracted by *entitlement holders* at a given time exceeds the *environmentally sustainable level of extraction* for that system.

overused
refers to situations where the total volume of water actually extracted for consumptive use in a particular system at a given time exceeds the *environmentally sustainable level of extraction* for that system. Overuse may arise in systems that are over allocated, or it may arise in systems where the planned allocation is exceeded due to inadequate monitoring and accounting.

regional natural resource management plans
plans that cover specific regions like those developed under the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality.

regulated river
are gazetted streams that have flows controlled by state-owned water storages. description

reliability
the frequency with which water allocated under a *water access entitlement* is able to be supplied in full.

rural and regional
refers to water and wastewater services provided for rural irrigation and industrial users and in regional urban areas with less than 50,000 connections.

sharing delivery capacity
an approach to sharing of an irrigation supply channel capacity (supplemented systems) or a water course capacity (unsupplemented) held by an *entitlement holder* and specified as a percentage share or volumetric supply rate at a particular time.

special-purpose licenses
are those licenses issued by the minister for only that specific purpose. It cannot be traded. When no longer required the licence is cancelled.

substitution
using recycled water as opposed to using water currently in the system.

surface water
water that flows over land and in water courses or artificial channels and is able to be captured and stored and supplemented from dams and reservoirs.

tidal pool
is part of the upper estuary that is essentially fresh, despite being affected by daily tidal movements. In the larger pools some commercial extraction is possible.

trading zones
established to simplify administration of a trade by setting out the known supply source or management arrangements and the physical realities of relevant supply systems within the zone. Trade can occur within and between zones without first having to investigate and establish the details and rules of the system in each zone.

upper bound pricing
The level at which, to avoid monopoly rents, a water business should not recover more than the operational, maintenance and administrative costs, externalities, taxes or tax equivalent regimes (TERs), provision for the cost of asset consumption and cost of capital, the latter being calculated using a weighted average cost of capital WACC.

water access entitlement
a perpetual or ongoing entitlement to exclusive access to a share of water from a specified *consumptive pool* as defined in the relevant *water plan*.

water allocation
The specific volume of water allocated to water access entitlements in a given season, defined according to rules established in the relevant water plan.

water irrigation area
is the area under control of an individual water service utility (e.g. an irrigation corporation, cooperative or trust, or water authority).

water plan
statutory plans for surface and/or ground *water systems*, consistent with the *Regional Natural Resource Management Plans,* developed in consultation with all relevant stakeholders on the basis of best scientific and socio-economic assessment, to provide secure ecological outcomes and resource security for users.

water sensitive urban design
is the integration of urban planning with the management, protection and conservation of the urban water cycle that ensures urban water management is sensitive to natural hydrological and ecological processes.

water system
a system that is hydrologically connected and described at the level desired for management purposes (e.g. sub-catchment, catchment, basin or drainage division and/or groundwater management unit, sub-aquifer, aquifer, groundwater basin).

water tagging
an accounting approach that allows a traded *water access entitlement* to retain its original characteristics when traded to a new jurisdiction and/or trading zone, rather than being converted into a form issued in the new jurisdiction and/or trading zone.

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Appendix 1: Water entitlements

This appendix provides greater detail on surface and groundwater resources as well as estimates of water entitlements by industry sector and sub-region.

The total volume of licensed water entitlement is 837,008 ML when taking into account water-sharing plan limits[92]. Seventy-six per cent of this volume is available from surface water resources and the remainder is available from the region's groundwater aquifers (see Figure 24).

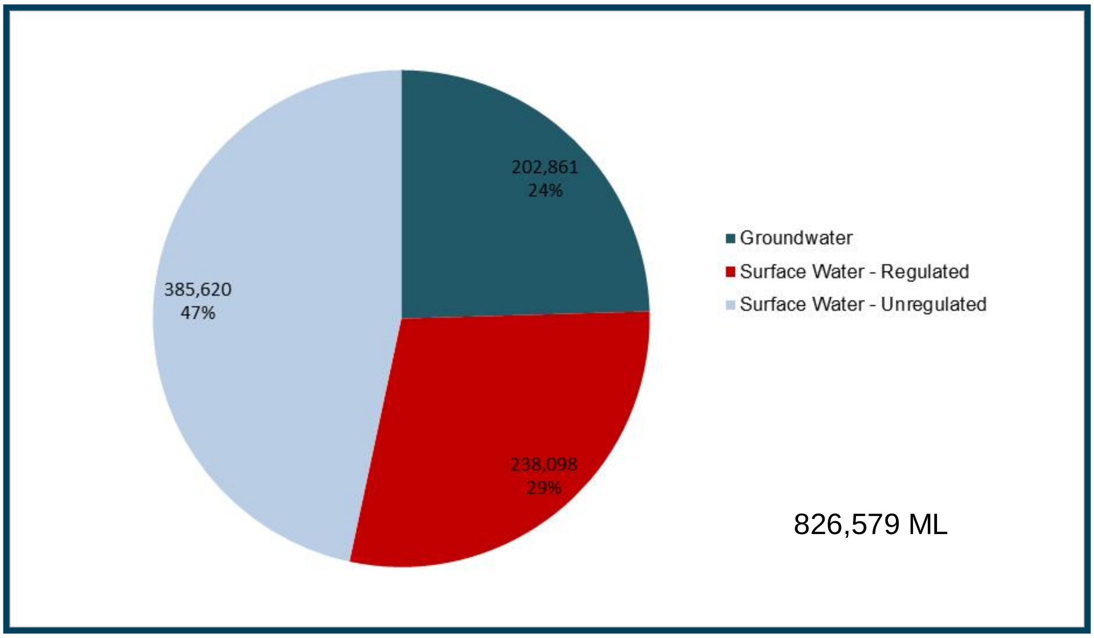

Figure 24. Annual water access entitlement volumes for whole region

The following figures show licensed water entitlements in the various valleys.

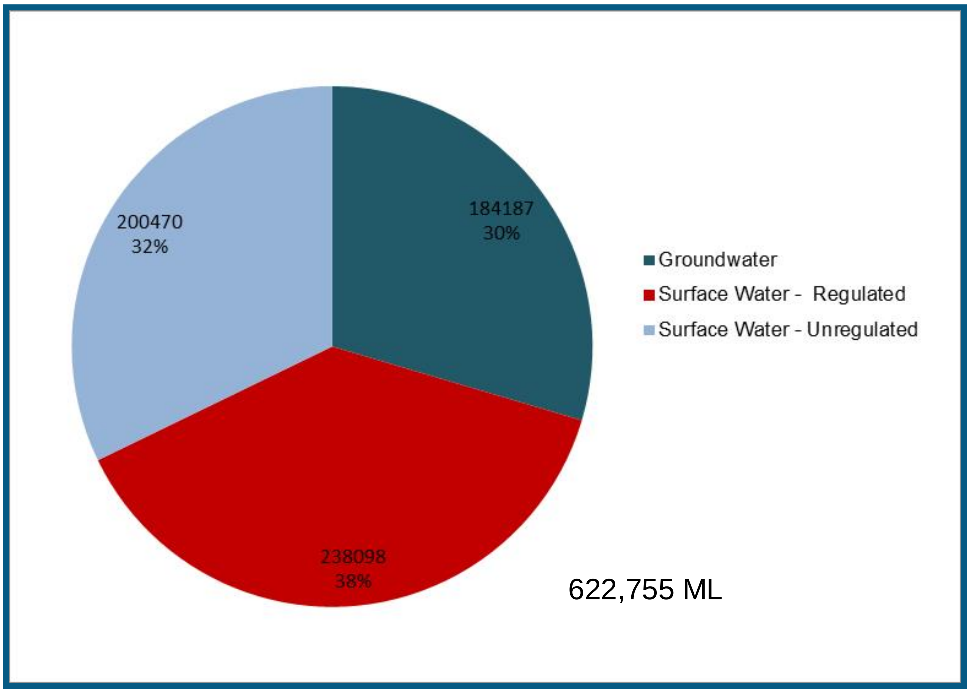

Figure 25. Annual water access entitlement volumes by source in the Hunter Valley.

92 As at January 2017

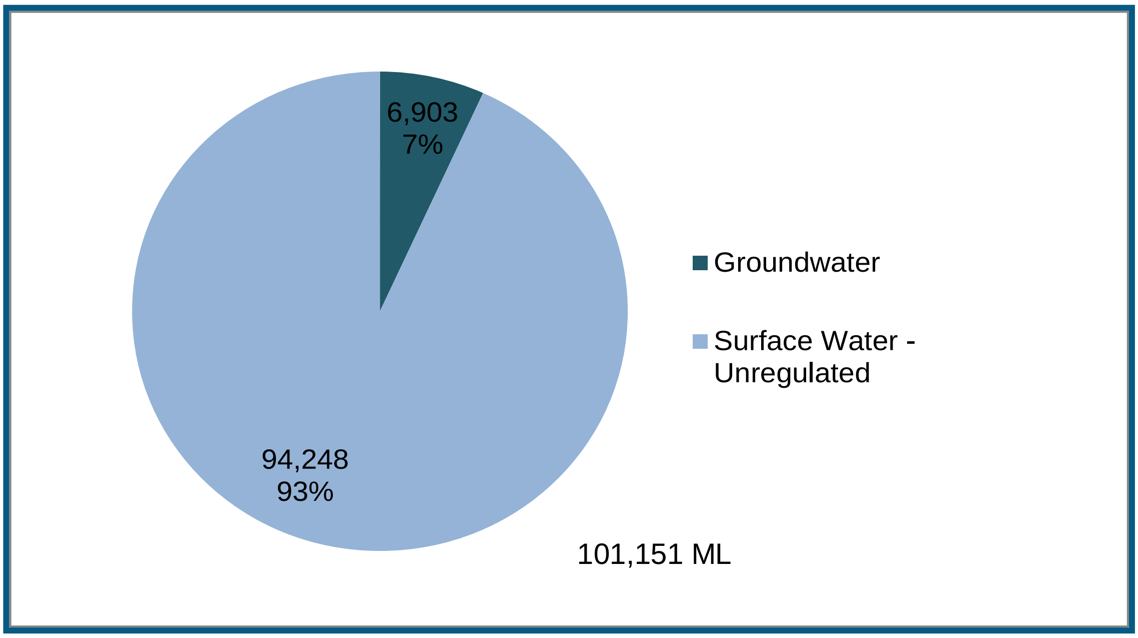

Figure 26. Annual water access entitlement volumes by source in the Central Coast catchments

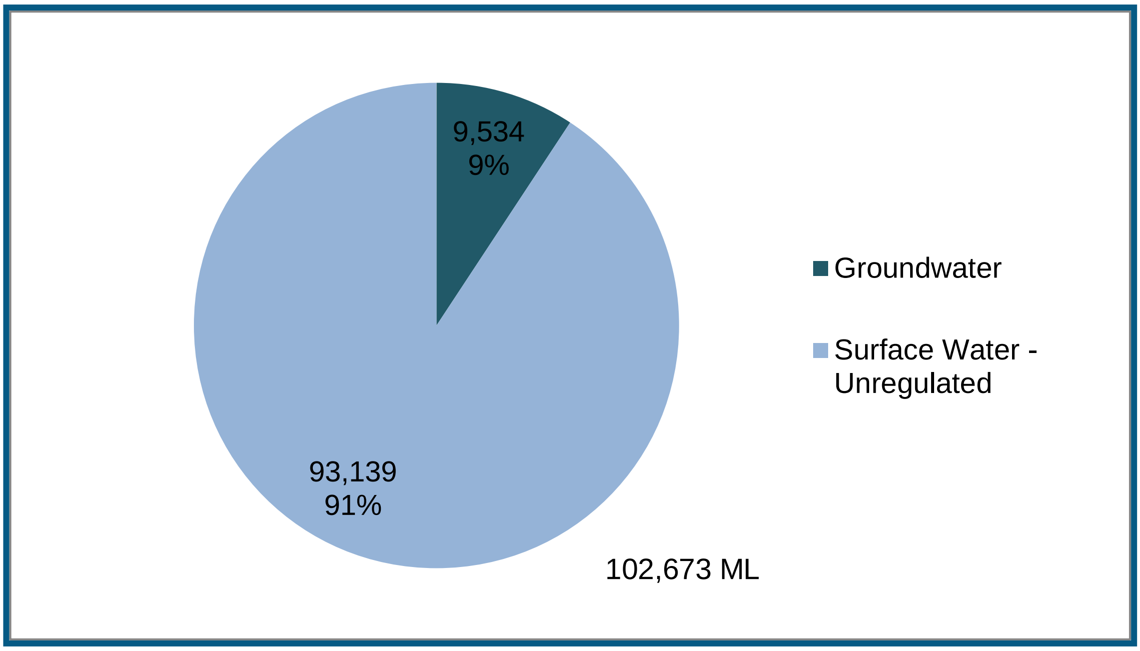

Figure 27. Annual water access entitlement volumes by source in the Mid-Coast

Appendix 2: The water trade market

This appendix provides additional information and background on the framework of the water market.

Types of dealings

Water in NSW can be traded temporarily or permanently between users, provided the transaction meets the market's rules and restrictions. Temporary water trades are a lease of a licence to another entity for a specified period of time. Permanent water trades involve a change in ownership from one entity to another.

In NSW trading of water is known as 'dealings' and water trading rules are called 'access licence dealing rules' in NSW legislation. For ease of reading these are referred to in this document as trades and trading rules. The *Water Management Act 2000* and water-sharing plans define what types of 'dealings' are possible. These are primary enablers of what types of trade is possible. The Act establishes the dealings, and the WSPs provide more specifics about whether and which types of dealings are possible in different catchments. Not all types are always possible in all catchments. The major dealings types are outlined in Table 18.

Basic landholder rights cannot be traded. Specific purpose licences also cannot be traded and must be cancelled when the purpose is no longer required.

Table 18. Types of dealings

Water Management Act section	Type of dealing
71M	Water licence transfer—change in ownership of the licence from one entity to another
71Q	Assignment of share component—sale of all or part of the entitlement of the licence
71T	Assignment of water allocations—sale or transfer of all or part of the water held in the licence holder's annual account under a trade agreement
71N	Term transfer of a water access licence—lease of a licence to another entity for a period of time
71R and 71S	Change in location where a water access licence can be used—movement of the licence to another water sources or part of the water source
71O	Conversion of a water licence from one category to another (e.g. from general security to high security)
71P	Subdivision of a water access licence—division of the licence usually so a portion can be sold
	Consolidation of water access licence—amalgamation of licences
	The exit of a co-holder from a water access licence–allowing one of the holders of a licence to sell their co-holding
71U	Interstate transfer of access licences—cancellation of access licences in one state for the purpose of granting a licence in another state
71V	Interstate assignment of allocations—sale of all or part of the water held in the licence holder's annual account to an interstate water source
71W	Nomination of water supply works—amendment of the licence for delivery of water from an alternative water supply work or group of works

Dealing Principles

The Access Dealing Principles Order 2004 (the Dealing Principles) draws on the objects and principles of the *Water Management Act 2000* and provides state-wide guidance and rules for applications to undertake water dealings including trade.

The principles specify that dealings must consider:

- the impacts on other water users;
- the impacts on the water source;
- the impacts on indigenous, cultural and spiritual matters; and
- maximising social and economic benefits.

The Dealing Principles specify rules for different types of dealings (such as conversion to a new category, subdivision, consolidation, assignment of rights or allocation, changing water sources, amending extraction component and interstate dealings). They specify the requirements that must be met for a dealing to be permitted, and the conditions under which dealing is prohibited.

Water-sharing plans and the administration of these plans must be consistent with the Dealing Principles. Water-sharing plans can contain additional rules such as restricting trade into a particular area due to its environmental values or hydrologic stress.[93]

[93] Various background documents to Water-Sharing Plans

Trading rules within water-sharing plans

Key

All ✓ are generally subject to assessment. For the Hunter Unregulated trade is generally allowed into a Water Source as long as there is no net gain trade

? means it requires further study for this to occur and may be an amendment

A ✓ and ✗ means that it is possible but there are specific trade dealings mentioned that involves specific management zones or water sources. Interpret this sequence as 'yes but'.

A ✗ and then ✓ means 'no but' which generally relates to no trades in but can trade out subject to strict criteria. The same applies to within a water source.

Table 19. Trading rules within water-sharing plans

Water source (WS)	EMU	Current shares	Within WS	BTN TRIBS	SW convert to		Into WS	Out WS		EMU	
					High flow	Aquifer access licence		SW TO SW GW TO GW	SW TO GW GW TO SW	In	Out
HUNTER VALLEY UNREGULATED											
Baerami Creek	Goulburn	4,080	✓		✗	✓	✓			?	
Black Creek		6,408.5	✓		✗	✗	✓				
Bow River		205	✓		✗	✓	✓				
Bylong River		7,808	✓		✗	✓	✓			?	
Dart Brook		29,399.5	✗		✗	✓	✓				
Dora Creek		800	✓		✗	✗	✗				
Doyles Creek		320	✓		✗	✓	✓				
Glendon Brook		1,643.5	✓		✗	✗	✓				
Glennies		456	✗		✗	✗	✗				
Halls Creek		3,940.5	✓		✗	✓	✓				
Hunter Regulated River and Alluvial		29,046	✓		✓	✓	✗				
Isis River		2,075	✓		✓	✗	✓				
Jerrys		11,053	✓	✗	✗	✓	✓				
Krui River	Goulburn	1,449	✓		✗	✓	✓			?	
Lower Goulburn River	Goulburn	17,156	✓		✗		✗			?	
Lower Wollombi R		10,447	✓		✓	✓	✓ ✗				
Luskintyre		674.5	✓		✗	✗	✓				
Martindale Creek		4,539	✓		✗	✓	✓				
Merriwa River	Goulburn	6,351.5	✓		✗	✓	✗			?	
Munmurra River	Goulburn	30	✓		✗	✓	✗			?	

Water source (WS)	EMU	Current shares	Within WS	BTN TRIBS	SW convert to		Into WS	Out WS		EMU	
					High flow	Aquifer access licence		SW TO SW GW TO GW	SW TO GW GW TO SW	In	Out
Muswellbrook		1,894	✓		✗	✗	✓				
Newcastle		100,571	✓		✗	✗	✗				
North Lake Macquarie		1,211	✓		✗	✗	✓				
Pages River		13,550.5	✓		✓	✓	✓				
Paterson/Allyn rivers		3,924	✓		✓	✗	✗				
Rouchel Brook		1,195	✓		✓	✗	✗				
Singleton		1,413	✓		✗	✗	✓				
South Lake Macquarie		295	✓		✗	✗	✗				
Tidal Pool Water Sources		10967+ 1412.5 = **12,379.5**	✓		✗	✗	✗ ?				
Upper Goulburn River	Goulburn	1,880	✓		✗	✓	✗			?	
Upper Hunter River		4,599	✓		✗	✗	✗				
Upper Paterson		196	✓		✗	✗	✗				
Upper Wollombi Brook		2,689.2	✓ ✗ ?		✗	✓	✓ ✗				
Wallis Creek		470.5	✓		✗	✗	✓				
Widden Brook		3,218	✓		✗	✓	✓				
Williams River		24,7388.2	✓ ✗		✗	✗	✗				
Wollar Creek	Goulburn	880	✓		✗	✓	✓			?	
Wybong Creek		10,550.5	✓		✗	✓	✗			✓	✓
HUNTER REGULATED											
						HS TO GS GS to HS	**INTO MGT ZONE**				
Zone 1A		63,019.68	✓ ✗			✓	✗	✗			
Zone 1B		110,886.48	✓ ✗			✓	✗	✗			
Zone 2A		6,341.4	✓			✓	✗	✗			
Zone 2B		58,761.26	✓			✓	✗	✗			
Zone 3A		7,751.4 + (18 not	✓ ✗			✓	✗	✗			

Water source (WS)	EMU	Current shares	Within WS	BTN TRIBS	SW convert to		Into WS	Out WS		EMU	
					High flow	Aquifer access licence		SW TO SW GW TO GW	SW TO GW GW TO SW	In	Out
		stated in a zone)									
CENTRAL COAST UNREGULATED											
Brisbane Water		233.6	✓ ✗		✗		✗				
Mangrove Creek		52,410.5	✓ ✗		✗		✗				
Mooney Mooney Creek		20,260.5	✓ ✗		✗		✗				
Jilliby Jilliby Creek	Tuggerah	1,035.5	✓		✗	✓	✓			✓	
Tuggerah Lake		34	✓		✗		✗				
Wyong River		39,215	✓ ✗		✗		✗				
Ourimbah Creek	Tuggerah	7,173.5	✓		✗	✓	✓			✓	
LOWER NORTH COAST UNREGULATED AND ALLUVIAL											
Avon River		1,744	✓ ✗		✓	✗	✗	✓ ✗			
Bowman River		2,120	✓ ✗ ?		✗	✗	✗	✓ ✗			
Coolongolook River		483	✓		✗	✗	✗				
Cooplacurripa River		800	✓ ✗		✗	✗	✗	✓ ✗			
Dingo Creek		4,925	✓		✓	✗	✗	✓ ✗			
Karuah River Estuary Management		3,668	✓				✓ ✗				
Karuah Upriver Management			✓				✗				
Karuah River Management					✓	✓					
Lower Barnard River		21,369	✓ ✗		✗	✗	✓ ✗	✓ ✗			
Lower Barrington/ Gloucester Rivers		11,263	✓		✓	✓	✓ ✗	✓ ✗			
Lower Manning River		20,400	✓ ✗		✓	✗	✓ ✗	✗ ✓			
Manning Estuary Tributaries		4,212.5	✓ ✗		✗	✗	✗	✗			
Manning River Tidal Pool		3,000 (LWU)	✓		✗	✗	✓ ✗				
Mid Manning River		991	✓		✓	✗	✓ ✗	✓ ✗			

Water source (WS)	EMU	Current shares	Within WS	BTN TRIBS	SW convert to		Into WS	Out WS		EMU	
					High flow	Aquifer access licence		SW TO SW GW TO GW	SW TO GW GW TO SW	In	Out
Myall Creek		57	✓		✗	✗	✓ ✗	✓ ✗			
Myall Lakes		0	✓		✗	✗	✗	✗			
Myall River		513.5	✓		✗	✗	✗	✗			
Nowendoc River		1,274	✓ ✗		✗	✗	✓ ✗	✓ ✗			
Rowleys River		277	✓ ✗		✗	✗	✗ ✓	✓ ✗			
Upper Barnard River		1,159	✓		✗	✗	✓ ✗	✓ ✗			
Upper Barrington River		944	✓ ✗		✗	✗	✗ ✓	✓ ✗			
Upper Gloucester River		5,449	✓ ✗		✓	✗	✗ ✓	✓ ✗			
Upper Manning River		2,243	✓ ✗		✗	✗	✗ ✓	✓ ✗			
Wallamba River		1,816	✓ ✗		✗	✗	✗	✗			
POROUS AND FRACTURED ROCK											
Gloucester Basin		490	✓			✗	✗				
Kulnura Mangrove Mountain		3	✓			✗	✓				
Liverpool Ranges		2087	✓			✗	✗				
Oxley Basin		10579	✓			✗	✗				
Sydney Basin – Nth Coast		56547.5	✓			✗	✗				
COASTAL SANDS											
						Other Aquifer Licence					
Great Lakes		846.75	✓			✗	✗				
Hawkesbury to Hunter		769	✓			✗	✗				
Manning – Camden Haven		61	✓			✗	✗				
Stockton		29	✓			✗	✗				
Tomago			✓			✗	✗				
Tomaree		13	✓			✗	✗				

Appendix 3: Simulated hydrological drought assessment using historical records

To understand how rivers, dams and water allocations behave over time, computer models are used to calculate the inputs of water from rainfall and streamflow and the outputs in terms of evaporation losses from storages and rivers and transpiration from irrigation. By using the recorded rainfall these models can simulate how the systems would have behaved had the dams, water demands and water-sharing arrangements existed during historical droughts.

Rural water management has traditionally based decisions upon these simulated hydrologic assessments using simulations modes and recorded hydrologic data known as the Integrated Quality and Quantity Model (IQQM). This appendix matches with the work undertaken up to Step 5 of quantifying the major risks and drivers. These input and outputs are then simulated against the operating rules contained within the relevant water-sharing plan.

The scenarios were assessed using the simulation model to gain an understanding of the key questions.

For each scenario the following was assessed:

a) Storage levels (Glenbawn, Glennies Creek, Lostock, Plashett and Liddell)
b) Available Water Determinations (General Security, High Security, Supplementary and Major Water Utilities)
c) Diversions (the amount of water used)

Table 20 is a summary intended to provide an insight into drought behaviour[94].

The Lostock to Glennies transfer options have a very high potential to add extra water in the Hunter regulated system but the benefit is limited by an AWD based on both Glennies Creek Dam and Glenbawn Dams. As an example, in 1940 Glenbawn Dam storage is drawn down so there is not enough water to be allocated. During the same period the Lostock to Glennies transfer option keeps Glennie Creek Dam at a level that could be utilised.

Splitting the AWD could overcome this problem but the benefits would only be available to the lower section. Another option would be for water users just upstream of the Hunter River and Glennies Creek junction to shift their pumps sites. Available Water Determinations for Paterson River Water Users supplied from Lostock Dam are not significantly affected by the transfer as Lostock Dam receives a long-term average annual inflow of approximately 116,000 ML. This is nearly six times the dam's capacity.

Further modelling is required as part of WaterNSW and Hunter Water Corporation development of preliminary business cases. This includes various combinations and sizes for the preferred options and amendments to water-sharing arrangements.

[94] More details are available in NSW Department of Industry *Hunter Valley Security Modelled Run Scenarios* (to be published).

Table 20. Key questions for scenario runs

Question	Answer
Can the 2016 WSP provide 100% allocation to AGL through the worst drought on record given the decreased runoff predictions into Glenbawn Dam?	Under reduced estimates of inflows into Glenbawn Dam AGL Macquarie will continue to receive 100% of allocation through the worst drought on record (Part 6, clause 30 in the Hunter Regulated River Water Source Water-Sharing Plan 2016). This was answered by comparing Scenario 2 and 3. Refer to Figure 28 which shows that the storage can receive 100% of allocations in all years. The reduced inflows impact all other categories of licences. Note that this is not a requirement to maintain the water supply for a major utility (Barnard) access licence and supplementary through a repeat of the worst period of inflows.
What is the impact of the Liddell Power Station closure with and without the Barnard Scheme?	There is a clear benefit of having the Barnard Scheme for power generation. The benefits to other users are indirect as the Barnard Scheme's water is licenced exclusively to AGL's. It only improves the reliability of the other category of licences such as General Security indirectly if AGL then require less of their Major Water Utility allocation from Glenbawn Dam. (Scenarios 3 and 4) When Liddell Power station is closed, turning off the Barnard Scheme increases the AGL major utility diversion which reduces Glenbawn Dam storage and subsequently General Security allocations. Refer to Figure 29 which shows the difference of the effect on general security users.
In the absence of other options, how do interception activities impact users with the Barnard Scheme operating and Liddell Power Station closed? Can the 2016 WSP still provide 100% allocation to AGL through the worst drought on record?	The CSIRO reported that mining interception in the Hunter valley will result in increased system losses. There are many forms of interception that could also impact the regulated river (see exemptions in Table 15). In addition, increased licensed take from the upstream unregulated rivers or the adjacent alluvial groundwater will also reduce inflows requiring the dams to release greater amounts of water and bringing on restrictions earlier. Figure 30 shows the difference from the 2016 case and the predicted reductions in AWD for General Security licences after the closure of Liddell (Scenario 3). Any benefits from the Liddell closure are negated by possible additional losses in the system (Scenario 5).
What is the impact of supplying the Singleton town water supply from the Williams River?	This is relatively small in volume but hydrologically effective. There is a significant benefit to General Security allocation during some of the dry years. For example, General Security allocation increases from 25% to 60% from 5,000 ML of transfer into the Singleton town water supply in 1920. The reduction of the Singleton town water demand results in more water being available in storage. However, in the worst drought on record of 1940, the benefits can only be seen in the few years preceding the drought. Refer to Figure 31.

Question	Answer
What is the impact of a small-scale effluent re-use scheme?	Although the small-scale water reuse option shows some benefit, the hydrologic impact is less when compared to the option of potable water supply to Singleton despite having similar volumes. This is because the small-scale reuse option is targeted at General Security licences whilst the potable water supply option reduces demand from a higher priority category (Scenario 3 and 8). Refer to Figure 32. For AGL this provides an overall improvement though no benefit in the 1935–50 dry period. There is no significant improvement for Muswellbrook town water supply.
What is the impact of a large-scale effluent reuse scheme with and without the Barnard Scheme?	This option directly increases the volume at Glenbawn Dam by reducing demand on the Glenbawn Dam from AGL. The higher volume translates to higher allocation to other categories of Licences during dry years. In the base case of 2016 WSP rules, most years in 1940-49 are simulated to have zero General Security allocations due to dam storage levels being too low. With a large-scale reuse scheme this option is able to bring the system out of drought more quickly compared to other options. During other periods General Security allocation are also shown to be improved. (Scenario 9 and 10). Refer to Figure 33. This option also shows the biggest environmental benefit with increased end of system flow at Greta in the full historical period including the 1935-50 drought. Without the Barnard Scheme operating, the improvements are similar to when Liddell is closed and the Barnard Scheme still operating.
Can AGL Macquarie maintain their water supply with reduced allocation after Liddell Power Stations closes?	No, as the increase in risk to power generation is considered too great. This modelling did show that options for better management of the balance between supplementary and carryover of major water utility water is possible.
Does a small water transfer from Lostock Dam to Glennies Creek Dam improve security of water supply?	There are more years when General Security licences have more than 100% allocation at the start of the water year and this is reflected in long-term on-allocation diversion. In the 1920-35 period, allocation levels below 50% happened less often. However, allocation levels below 20% were not improved. There is no significant improvement in the worst drought of record period 1935–50. (Scenario 12 compared to Scenario 3). Refer to Figure 34. There is no change to AGL diversion and water availability with long-term average diversion and water availability from Glenbawn Dam similar to 2016 WSP rule arrangements with the Barnard Scheme operating.

Question	Answer
Does a large water transfer from Lostock Dam to Glennies Creek Dam improve security of water supply?	A larger water transfer from Lostock to Glennies Creek Dam suggests a significant hydrologic improvement to the Upper Hunter valley and is a better hydrologic outcome than the smaller transfer (Scenario 12 and 13 compared to Scenario 3). Refer to Figure 34. It does not however show a significant benefit during the worst drought on record period (1935-1950). In this period Glenbawn Dam had no water so water was not available to General Security users. This option is less beneficial hydrologically than a large-scale effluent reuse scheme during the worst drought on record.
Is an enlargement of Lostock Dam required?	An enlargement of Lostock Dam will not increase the hydrologic benefit to the Upper Hunter valley system as there is already a high inflow coming into Lostock Dam (Scenario 14a compared to Scenario 3). Refer to Figure 35. This also implies that the limitation of the Lostock to Glennies transfer is not the volume of the transfer itself but its tendencies towards an imbalance in the system in the Upper Hunter valley.

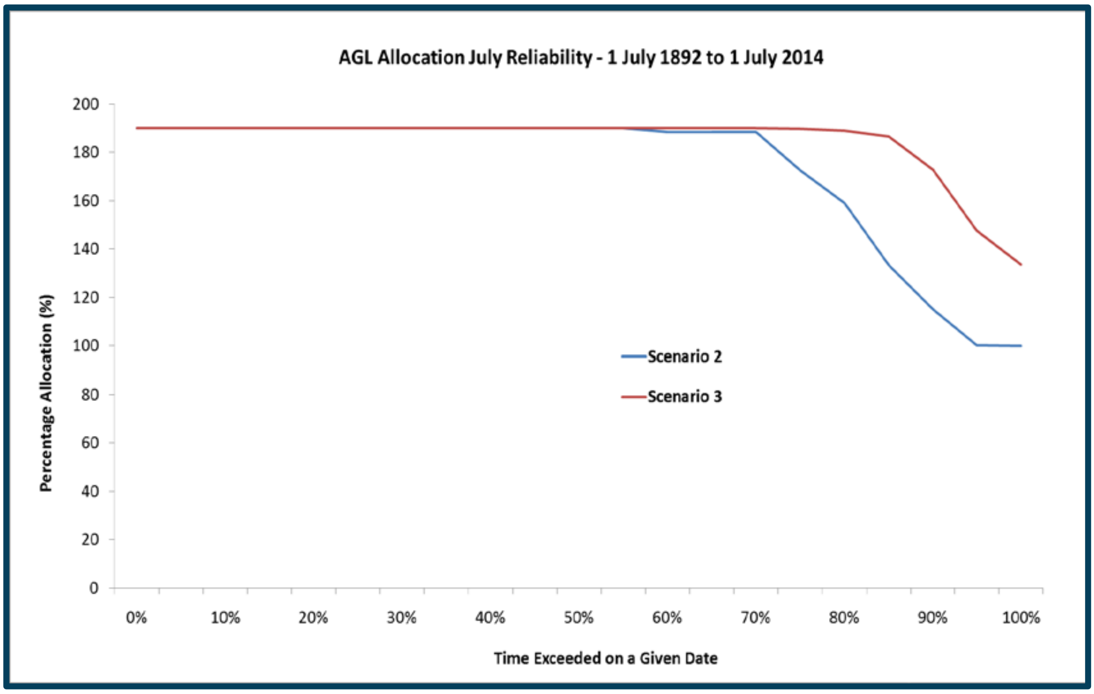

Figure 28. Comparison of 2016 Base case and Liddell Power Station closure on AGL allocation July reliability

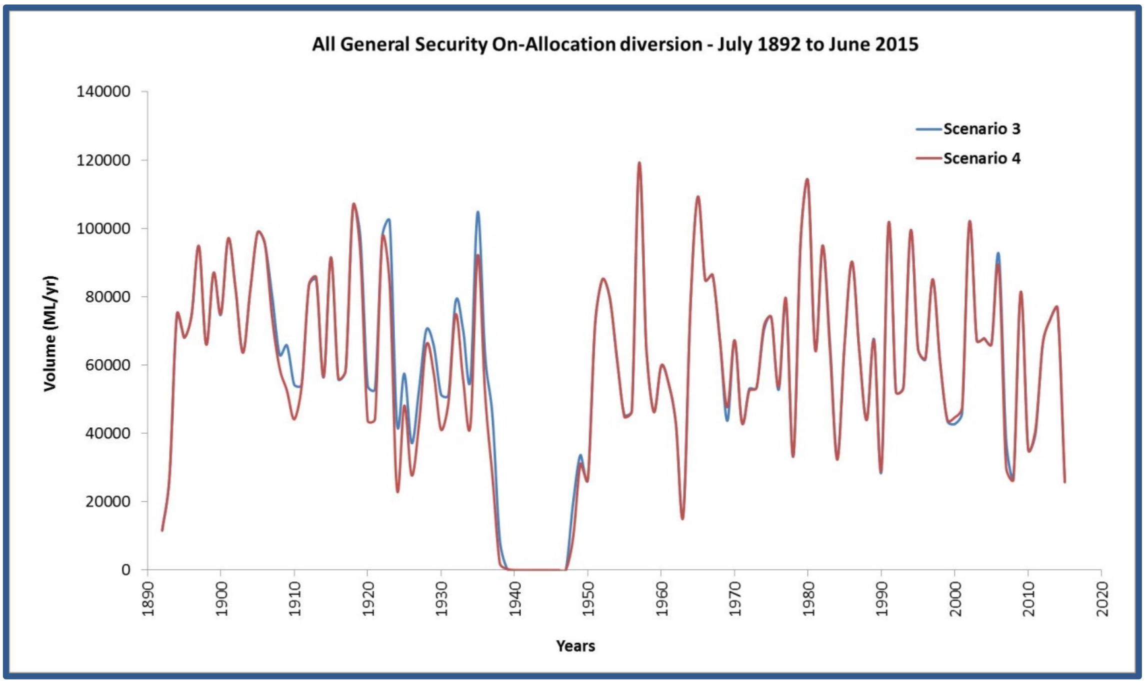

Figure 29. Impact of Liddell Power Station closure on general security on-allocation diversions

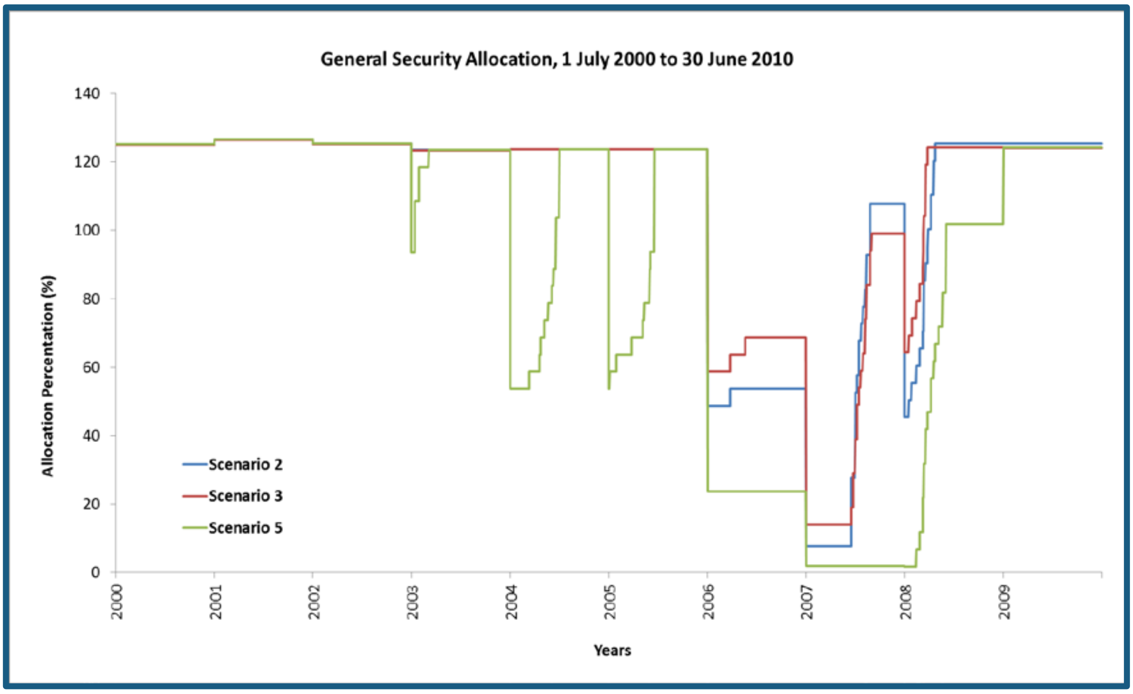

Figure 30. Impact of Liddell Power Station closure and interception on general security allocations

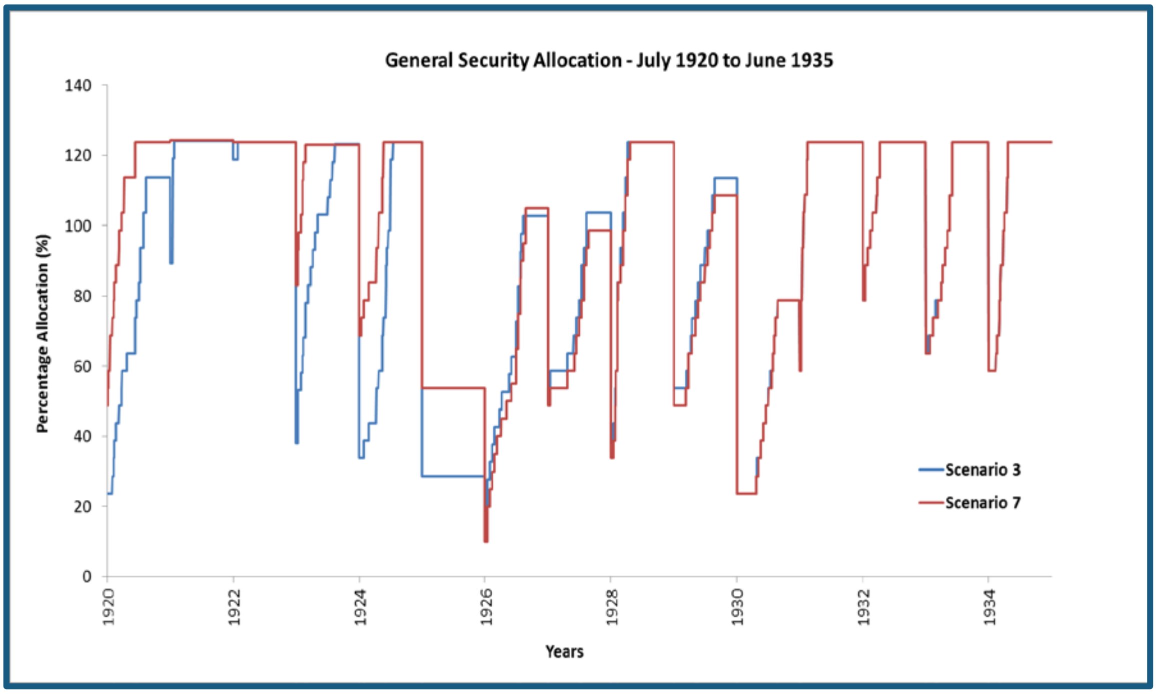

Figure 31. Impact on general security allocations from potable pipeline to Singleton (Scenario 7)

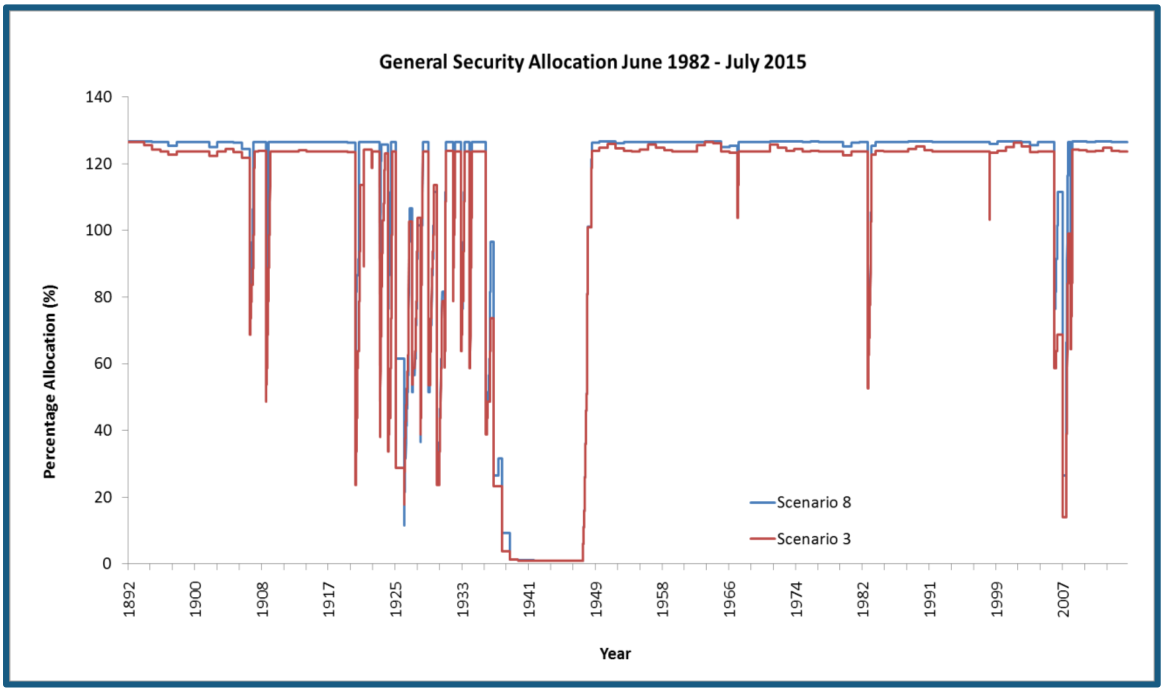

Figure 32. Impact on general security allocations comparing small-scale recycling scheme (Scenario 8) with Liddell Power Station closed and Barnard Scheme operating (Scenario 3)

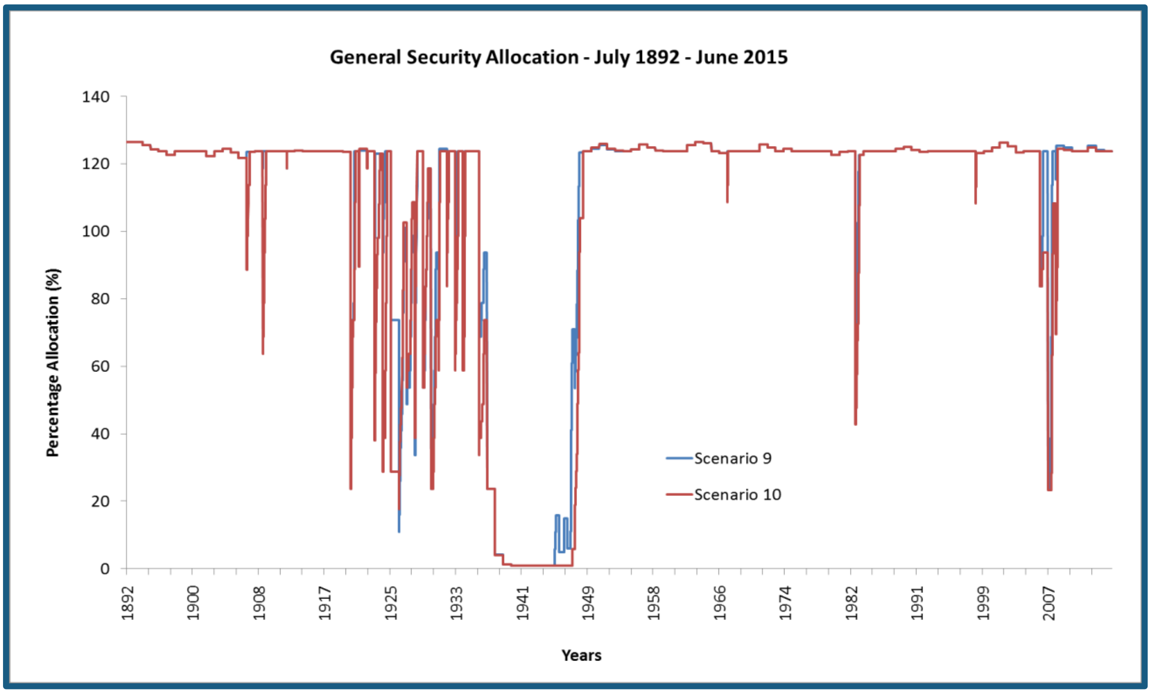

Figure 33. Impact on general security allocations comparing Liddell Power Station closed and Barnard Scheme operating with large-scale effluent reuse scheme (Scenario 9) compared to if Barnard Scheme was closed (Scenario 10)

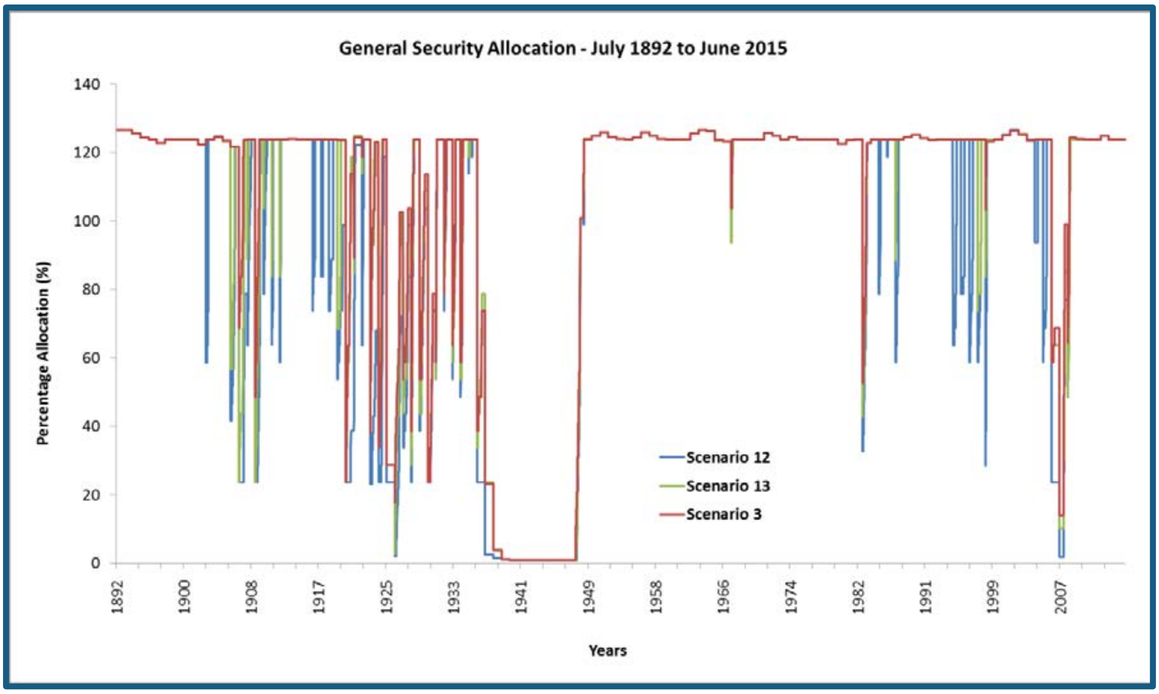

Figure 34. Impact on general security allocations with both small-scale and large water transfers from Lostock to Glennies Creek Dam (Scenario 12 and 13) compared with Liddell Power Station closed and Barnard Scheme operating (Scenario 3)

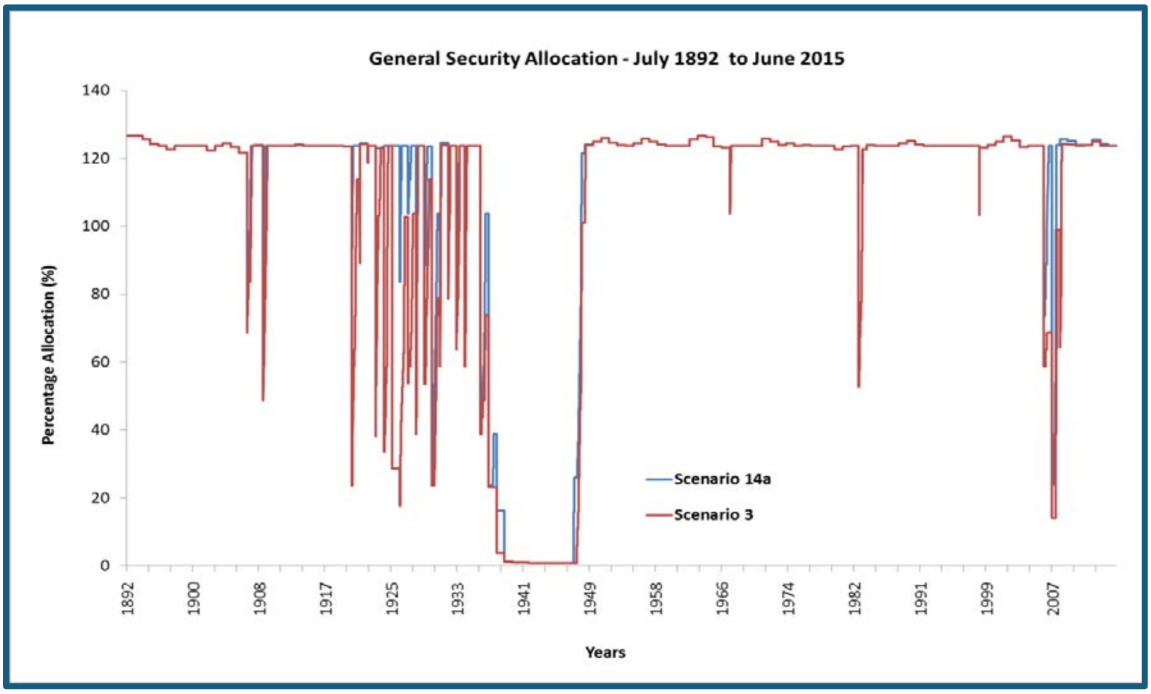

Figure 35. Impact on general security allocations with a large water transfer from Lostock Dam to Glennies Creek Dam and an enlarged dam (Scenario 14a) compared with Liddell Power Station closed and Barnard Scheme operating (Scenario 3)

Appendix 4: Statistical hydrological assessment

Stochastic hydrologic assessment

Historical weather records in Australia are generally patchy and of short duration, causing a poor understanding of pre-settlement climate. The major limitation with previous rural water planning was that the allocation of water was designed so that important industries and towns did not fail within the period of historical record. Figure 36 shows the Glenbawn Dam storage levels with the 2016 water-sharing plan rules before and after the closure of Liddell Power Station. The WSP rules allocates water out so that the system is capable of supplying essential services and environmental flows within a drought equal to the worst on record. Therefore the system is designed for the dam to just reach empty at the peak of the drought.

Beyond the worst drought on record the only water available would be natural inflows which could be extremely low. To understand what might happen in a drought beyond the worst on record, a stochastic technique was applied by the University of Newcastle (UNWC) to generate climate data.[95] This was to ensure that rare but extreme events are sufficiently represented within the modelling. This technique has been traditionally used for major urban water systems such as Sydney, Melbourne and Newcastle.

Daily rainfall and evaporation data was generated using a multi-site technique based on a lag one autoregressive model. This was then calibrated to, and verified against, the 123 years of historical daily rainfall and evaporation records to ensure that the ability of the statistical modelling could accurately reproduce key statistical characteristics of rainfall and evaporation considered important for hydrologic response and water planning outcomes.

The scenarios were run with the stochastic data using current water-sharing rules as outlined in the Hunter Regulated River Water-Sharing Plan 2016. The key results of the stochastic hydrologic assessment are detailed in Table 21. The overall results are presented in Table 23.

Points to note for the results in Table 23 are:

- **(1)** ‘Dead storage’ represents normal minimum operating level (i.e. below this level stored water is not readily accessible via existing works).
- **(2)** A ‘0%’ result effectively represents no occurrences over length of the simulation period.
- **(3)** A ‘< 0.1%’ result indicates that events have occurred, however the number of events is not statistically robust for reporting below one decimal place (e.g. 2 years in 10,000 years = < 0.1%).
- Pink is evaporation rate of 10% that is assumed to mimic climate change
- AA = Annual Allocations

[95] Kiem A.S., University of Newcastle, *Multi-site rainfall and evaporation data generation for the Hunter Water Infrastructure Project: Final report for NSW DPI Water*, October 2016

Table 21. Result of stochastic simulation on key issues

Issue	Details
General Security	• There is no appreciable difference in announced allocations between previous WSP rule arrangements and the rules under the Hunter Regulated River WSP of 2016. • The greatest risk to water users from the statistical analysis is the scenario of 2016 WSP rules with Liddell Power Station closed without the Barnard Scheme operating and accounting for losses from interception. • The best hydrologic outcome was the scenario with Liddell Power Station closed and a large-scale pipeline between Lostock and Glennies Creek Dams.
Town Water Supply	• There is no difference for Singleton Urban Water Supply UWS with the closure of Liddell Power Station or with the Barnard Scheme not operating under current WSP rules. • There is a greater future risk for Singleton UWS when taking into account both the interception losses and the Liddell Power Station closure. The impact of whether the Barnard Scheme is operating is negligible. • Muswellbrook reliability is improved after the closure of Liddell Power Station. The impact of whether the Barnard Scheme is operating is negligible. • Muswellbrook’s reliability is compromised when taking into account losses from interception of base flows. Scenario 6 results in the least reliability where under current WSP rules with Liddell Power Station closed and the Barnard Scheme is not operating and taking into account interception losses. (1 in 29 years with some shortfall)
Storage Levels	• Glenbawn Dam is estimated to fall below half full approximately 50% of the time under current WSP rules and with Liddell Power Station operating. • Glenbawn Dam is estimated to fall below half full only 44% of the time with the closure of Liddell Power Station, the Barnard Scheme operating and a large connection between Glennies and Lostock Dams. • Glenbawn Dam is estimated to fall below half full 56% of the time under the scenario where Liddell Power Station is closed, the Barnard Scheme is not operating and interception losses are taken into account.

The following graph (Figure 36) illustrates the simulated storage volumes for Glenbawn Dam with 2016 WSP rules based on historical records (Scenario 2 Base Case). This shows that, under current water-sharing arrangements, the dam is managed to the point of being empty based on the worst drought on record.

This is irrespective of whether Liddell Power Station is operational (Scenario 2) or closed (Scenario 3).

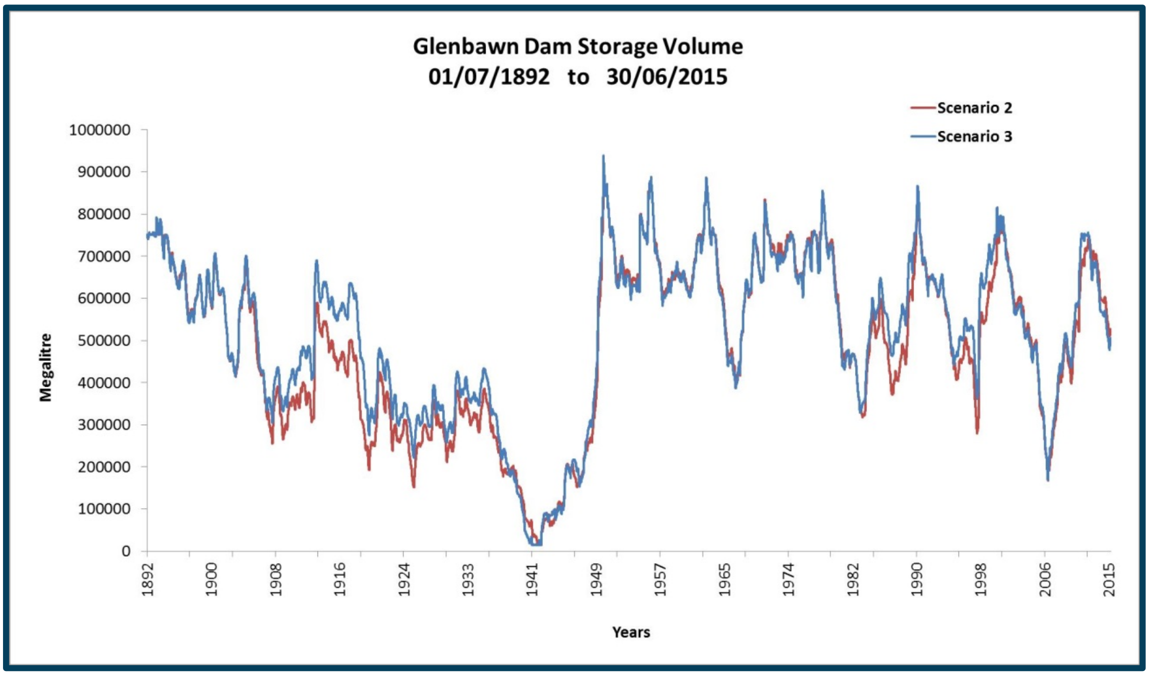

Figure 36. Simulated storage volumes under 2016 Base Case (Scenario 2) and with Liddell Power Station closed (Scenario 3) using historical records

The stochastic assessment can provide an indication of the likelihood of the length of time the dam could possibly be empty by taking into account rarer and more extreme events.

The following graph shows how Glenbawn Dam behaves during extreme events under various scenarios. These scenarios are all simulated under the 2016 WSP rules using the statistical generated data.

Note the years shown in the stochastic graphs are not actual calendar years but run years generated. This means that an event did not occur, say in 1340, but that this event showed up in the 1,340th year run of the model.

Figure 37 illustrates that under statistical analysis Glenbawn Dam is likely to become empty for significant periods of time under WSP arrangements (SM02). This shows that there would be multiple years in which the dam reached and stayed empty. This is no different to the previous water-sharing rules (SM01) as any benefits are given out as increased allocations as the dam levels falls. Both Scenario 1 and 2 results in zero dam storage as the benefits between the two have been given out to users as the dam level is falling.

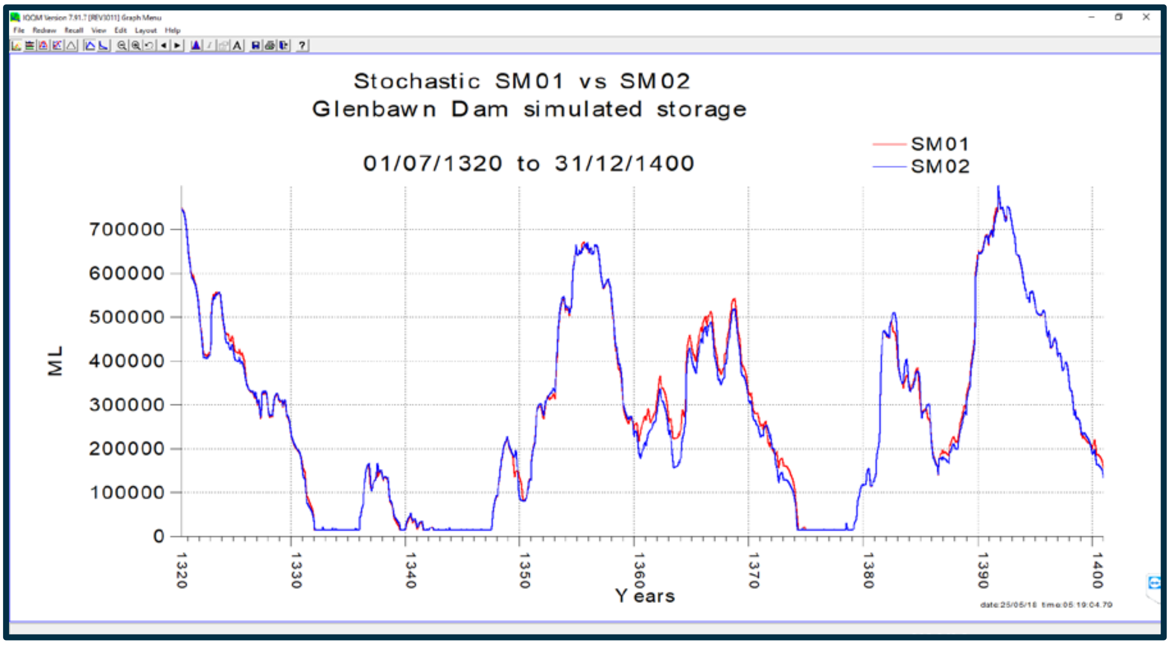

Figure 37. Simulated storage volumes under 2016 Base Case under extreme dry conditions using stochastic data

The closure of Liddell Power Station with the Barnard Scheme still operating would have no significant difference to long periods of zero storage in Glenbawn Dam as shown in Figure 38.

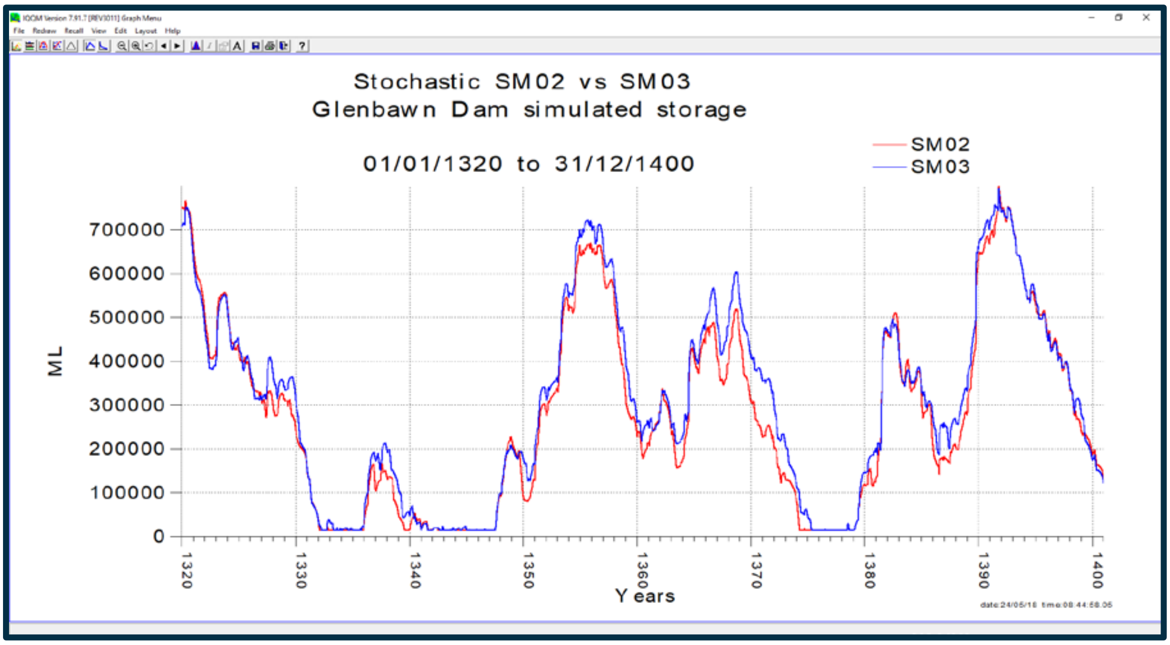

Figure 38. Simulated storage volumes under 2016 Base Case (SM2) compared to Liddell Power Station closed with the Barnard Scheme operating (SM3) under extreme dry conditions using stochastic data

In a scenario where the lower and upper Hunter Valleys were connected via a large scale recycling scheme (SM9), the number of years where Glenbawn Dam would be empty is almost halved in one drought event in the situation where Liddell Power Station has closed and the Barnard Scheme is operating (SM3). The conditions around drought events that were not improved with infrastructure can be investigated and water-sharing arrangements adjusted to better target the benefits. (Figure 39)

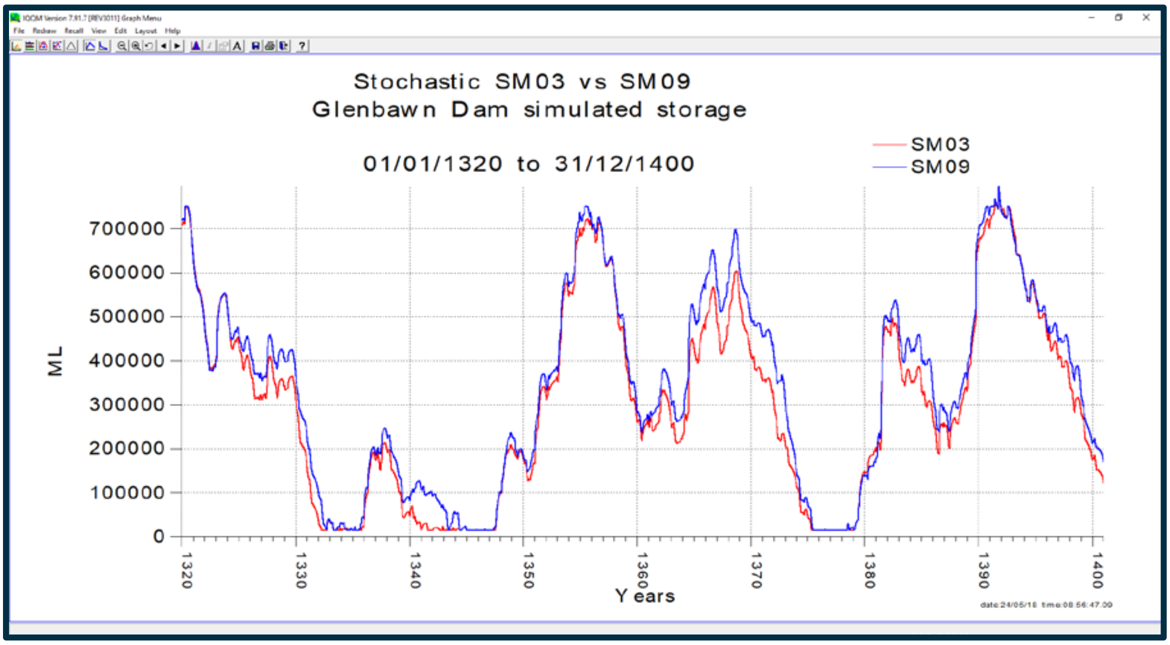

Figure 39. Simulated storage volumes under 2016 Base Case, Liddell Power Station closed and Barnard Scheme operating (SM3) compared to Liddell Power Station, Barnard Scheme operating and a large scale water recycling scheme HWC-AGL (SM9) under extreme dry conditions using stochastic data.

There are limitations to the method of stochastic data generation undertaken:

1. The method undertaken assumes that the range of variability contained in the instrumental record is representative of the full range of variability that is possible. However, recent research challenges the validity of this assumption.
2. It is not clear whether the physical characteristics and interactions between hydroclimatic variables are realistically simulated during different climate epochs (e.g. wet and dry phases, El Nino and La Nina phases, positive and negative phases of the Interdecadal Pacific Oscillation). The study to date did adequately reproduce the stochastic data for interannual to multidecadal climate variability at least in a statistical sense.
3. Possible impacts of anthroprogenic climate change are not considered or quantified in the stochastic modelling conducted in the study.

Climate change sensitivity analysis

The CSIRO have undertaken a study that predicts no strong directional change (+15% to -15%) in rainfall. It does however predict an increase an increase in evaporation of between +5% and +20% dependent on the assumed future emissions scenario.[96] To test how sensitive the Upper Hunter Valley is to evaporation an increase in evaporation of 10% was modelled.

While not intended to replace a full climate change impacts assessment this provides an indication of the sensitivity of the Upper Hunter Valley to changes in key climate characteristics and the ability of infrastructure options to mitigate these changes.

The major outcomes from climate change sensitivity analysis for their impact water users and dam levels are tabled in Table 22.

[96] CSIRO, *Climate change in Australia Projections Cluster Report - East Coast*, 2015

Table 22. Result of stochastic climate change sensitivity analysis

Issue	Details
General Security	• There is an average decrease of 19% in General Security annual water allocations across all modelled scenarios. • In scenarios where mining losses are included the general security allocations decreased by up to 24%.
Town Water Supply	• Scenario 2 (2016 Base Case) shows increased risk of reduced supply for Singleton and Muswellbrook from 1% (i.e. 1 in 100 years) to approximately 6% (i.e. approx. 1 in 15 years). • In Singleton the full annual demand is supplied 99% of years out of 10,000 compared to 97% of years after climate change adjustment. • In Singleton the percentage of years out of 10,000 where there is some shortfall in allocations increases with climate change from 0.9% to 2.4%. • In Muswellbrook the percentage of years out of 10,000 where there is some shortfall in supply increases with climate change from 1.6% to 5.7%.
Storage Levels	• For the 2016 Base Case, dam storage levels would be significantly impacted with climate change. Glenbawn Dam is currently estimated to fall below half full in approximately 50% of years, while under climate change this increased to 75% of years.

Overall, climate change impacts are likely to significantly increase risk to all users. The stochastic modelling with climate change data shows that scenario 15[97] is capable of buffering General Security users from the combined effects of the estimated mining loses and potential change in climate.

Figure 40 shows the combined impact of all the preferred infrastructure options on water allocations provided to General Security licence holders as at the 1st July each year. The red line shows scenario 3 with the 2016 water-sharing plans rules, no additional infrastructure and Liddell Power Station closed, all adjusted for climate variability and change. The black line shows scenario 15 with all the preferred infrastructure options adjusted for climate change and variability. The difference between the 2 lines shows the improvement in security of allocations to General Security users.

[97] 2016 WSP rules, Liddell Power station closed, Barnard Scheme operating, 5,000ML recycling, potable pipeline between HWC and Singleton, 15,000ML 2-way pipeline between Lostock to Glennies Creek Dam with losses from the system from mining.

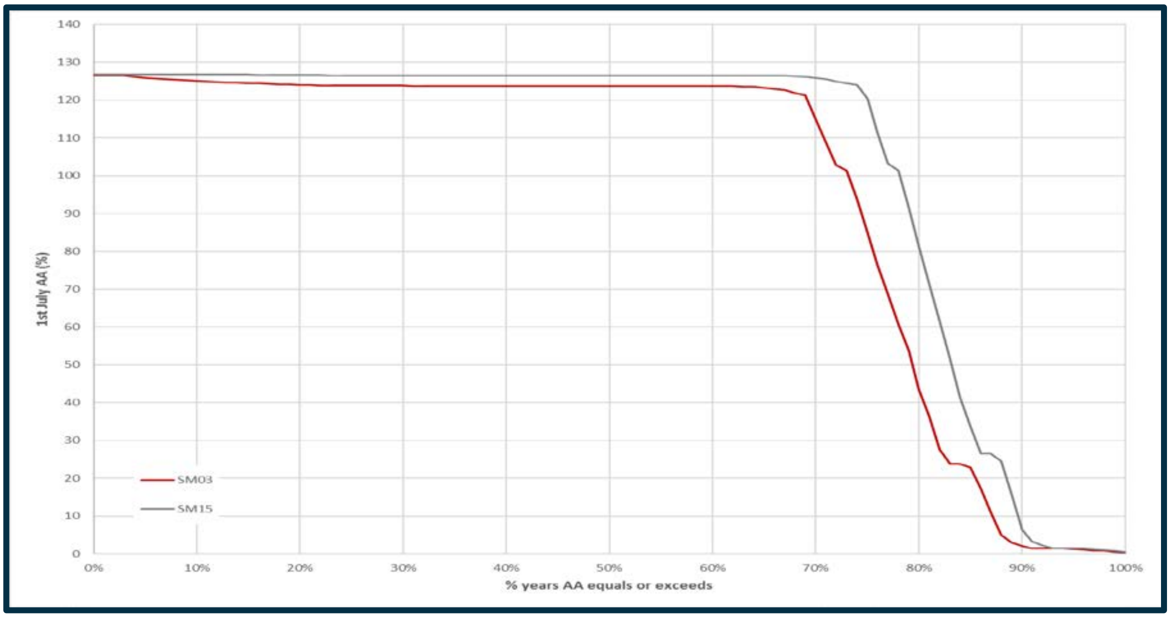

Figure 40. Climate change and variability adjusted effect of infrastructure on general security annual allocations (SM3 vs SM15)

Table 23. Results of modelled scenarios with historical and potential climate change

Case/scenario	Glenbawn Dam (750,000 ML at Full Supply Level)						% years with some shortfall				% years ≥95% AA (or greater) on 1st July							
	< 50% (375,000 ML)		< 10% (75,000 ML)		Dead storage(1) (14,710 ML)		Singleton		Muswellbrook		Gen Sec AA %		High Sec AA %		AGL %		Mining High Sec %	
	% of years (over 10,000) when storage levels fall < 50%,10% and dead storage																	
1 (Base case 1) 2012 base case	48.1	72.6	5.8	15.8	1.2	4.0	0.9	2.3	1.6	5.5	73	50	80	60	100	100	65	41
2 (Base case 2) WSP 2016	48.2	73.4	6.3	16.7	1.1	4.0	0.9	2.4	1.6	5.7	72	49	100	99.7	100	100	96	91
3 (2016 WSP with no Liddell)	44.8	69.4	4.8	13.5	0.8	3.0	0.9	2.5	1.1	3.9	74	51	100	99.6	100	100	96	91
4 2016 WSP, no Liddell, no Barnard	47.4	72	5.2	14.5	0.8	3.2	0.9	2.4	1.1	4.4	72	49	100	99.6	100	100	95	91
5 2016 WSP, no Liddell, system losses	54.1	76.8	10.7	24.5	2.3	5.7	1.7	3.7	2.9	8.2	64	41	100	99.6	100	100	95	91
6 2016 WSP, no Liddell, no Barnard and system losses	56.3	78.7	11.8	25.9	2.4	6.2	1.6	3.5	3.4	9.0	62	39	100	99.6	100	100	95	91
8 2016 WSP, no Liddell, with Barnard, with 5,000 ML/y HWC recycling small scale	42.8	68.1	4.4	12.8	0.7	2.9	0.8	2.3	1.0	3.7	76	53	100	99.6	100	100	96	91
9 2016 WSP, no Liddell, with Barnard, with 16,800 ML/y HWC recycled water to AGL	38.5	64.2	2.7	8.7	0.4	1.9	1.0	2.7	0.5	2.3	79	56	100	99.6	100	100	97	92
10 2016 WSP, no Liddell, no Barnard, with 16,800 ML/y HWC recycled to AGL	42.9	68	4.1	11.8	0.6	2.6	0.9	2.5	0.9	3.3	75	52	100	99.6	100	100	96	91
11 2016 WSP, no Liddell, no Barnard, & reduced AGL entitlement	44.4	70.3	4.5	12.8	0.7	2.9	0.9	2.6	1.0	3.7	76	53	100	99.6	100	100	96	91
12 2016 WSP, no Liddell, with system losses & 7,500 ML Lostock to Glennies	48.9	72.6	8.5	19.7	1.8	4.5	<0.1(1 y)	0.1	2.3	6.4	70	46	100	99.7	100	100	96	91
13 2016 WSP, no Liddell, with system losses & 15,000 ML Lostock to Glennies	44.0	68.6	5.7	14.9	1.1	3.3	0	<0.1 (2 yr)	1.5	4.5	74	52	100	99.7	100	100	97	92
14a 2016 WSP, no Liddell, 67,000ML Lostock &15,000 ML Lostock to Glennies	37.0	62	1.6	6.1	0.3	1.1	0	0	0.3	1.3	82	62	100	99.6	100	100	97	92
15 2016 WSP, no Liddell, with Barnard, 5,000ML recycle, HWC potable to Singleton, with system losses, 15,000ML Lostock to Glennies	40.6	65.6	4.3	12.3	0.7	2.8	Suppl. HWC	0	1.0	3.7	79	57	100	99.7	100	100	96	92

Appendix 5: Multi-criteria assessment

This appendix outlines the decision making process in meeting the needs of the Greater Hunter region. It provides background information into the critical questions that needed to be addressed as well as the information from the Multi Criteria Assessment.

The infrastructure options were evaluated against the core objectives outlined in Table 24.

Table 24. Objectives of the assessment of the Upper Hunter Priority Catchment Project

Objective	Description
Support the critical needs of regional industries and communities by ensuring water security and quality of supply	This is to ensure that critical needs can be met during periods of drought including droughts that are worse than those currently recorded. The aim is to provide water for critical needs in a drought of severity up to 1:1,000 years. To meet government statutory requirements on the provision of water for urban water supply.
To support regional development and enhance opportunities for promoting a diverse and changing economy.	The Strategy aims to improve the reliability and duration of water supply primarily for General Security users in regulated systems during periods of drought. This should also support the diversification of water-dependent industries and high security users within the region.
To provide a supply system that is responsive to changing supply and demand.	Optimise existing water infrastructure to avoid stranded assets as well as supporting a responsive and adaptable supply system to help mitigate climate variability and climate change impacts.
To provide best practice financial efficiency in the delivery of water.	To meet commitments under the *Intergovernmental Agreement on a National Water Initiative* by ensuring that the beneficiary of water delivery pays for its cost and is not passed onto other users. Strategies need to consider public and social benefit in circumstances where the beneficiary cannot afford the cost of the infrastructure and the State part subsidises the cost.
To facilitate a responsive water market within the region.	Enhance the movement of water within and between the catchments to improve adaptability to changing circumstances, improve market operation and connect rural and urban water supply systems.
To protect and maintain the certainty of user water rights.	This is essential to avoid the risk of compensation claims being triggered under the *Intergovernmental Agreement on a National Water Initiative* where changes cannot have a negative impact greater than 3%on any water users' reliability.
To provide businesses with opportunities to determine and manage their own risks.	Providing water at different levels of reliability to allow consumers to have adequate choice and potential to assess and manage individual business risk.
To maintain and improve the integrity of environmental and cultural assets to meet state and federal obligations.	The main obligation is the need to meet commitments under the *International Convention on Wetlands of International Importance especially as Waterfowl Habitat* (Ramsar) and the *Environment Protection and Biodiversity Conservation Act 1999* water trigger as well NSW legislative requirements. The characteristics of Ramsar wetlands in Kooragang National Park should not be adversely affected.

Table 25. Scenario details and key questions

Scenario No.	Scenario details	Key questions answered
01	2012 Base case—do nothing	What was the regime at the time of the 2012 Ramsar listing characterisation?
02	2016 Base case—do nothing	What is the situation now following the 2016 water-sharing plan rule changes? Can AGL–Macquarie receive 100% allocation through the worst drought on record?
03	Base Case (2) plus Liddell PS closed in 2022 with Barnard operating.	What is impact of Liddell closure with Barnard operational?
04	Base Case (2) plus Liddell PS closed in 2022 Barnard closed.	What is impact of Liddell closure without the Barnard operational?
05	Scenario 3 with system losses downstream of Glenbawn dam due to mining take impacts (i.e. CSIRO 2016 report). Liddell PS closed. Barnard operating.	How does the mining loss impact users with the Barnard operating and Liddell closed? Can the 2016 WSP provide 100% allocation to AGL Macquarie through the worst drought on record?
06	Scenario 4 with system losses downstream of Glenbawn dam due to system losses from mining impacts. Liddell Power Station closed. Barnard closed.	Does AGL Macquarie need to retain the Barnard due to mining loss? How will mining impact users without both the Barnard and Liddell?
07	Scenario 3 with HWC >> Singleton potable pipeline supplying 5,000 ML/yr. Liddell Power Station closed. Barnard operating.	What is impact of extraction from the Williams River? What is the impact of the option?
08	Scenario 3 with small scale HWC effluent reuse scheme. 5,000 ML/yr. recycled effluent piped from HWC Waste Water Treatment Plants. Liddell Power Station closed. Barnard operating.	What is impact of a small reduction in estuary discharge from HWC? What is the impact of the option?
09	Scenario 3 + large scale HWC effluent reuse scheme. 17,000 ML/yr. recycled effluent piped to AGL Macquarie from HWC Waste Water Treatment Plants located below Branxton. Liddell PS closed. Barnard operating.	What is impact of large reduction in estuary discharge from HWC with Barnard operational? What is the impact of the option?
10	Scenario 4 + large scale HWC effluent reuse scheme. 17,000 ML/yr. recycled effluent piped to AGL Macquarie from HWC Waste Water Treatment Plants located below Branxton. Liddell closed. Barnard closed.	What is impact of a large reduction in estuary discharge from HWC without Barnard? What is the impact of the option?
11	AGL reduced major utility water take with Liddell Power Station closed. Barnard closed.	Does AGL need their current full water licence entitlement in future?
12	Scenario 5 + Lostock >>Glennies Dam pipeline transfer. Existing Lostock dam size retained. Pipe size allowing transfer volume of 7,500 ML/yr. Mining impact losses included. Liddell Power Station closed. Barnard operating.	Do small water transfers improve security of water supply?
13	Scenario 5 + Lostock >>Glennies Dam pipeline transfer. Existing Lostock dam size retained. Pipe size allowing transfer vol. of 15,00ML/yr. Mining impact losses included. Liddell Power Station closed. Barnard operating.	Do large water transfers improve security of water supply?
14a	Scenario 3 + Lostock >>Glennies Dam pipeline transfer. Lostock dam size expanded to 67,000ML. Pipe size allowing transfer volume of 15,000 ML/yr. Not including mining impact losses. Liddell Power Station closed. Barnard operating.	Is an enlargement of Lostock Dam required with Barnard operational?
14b	Same as 14a except Barnard closed.	Is an enlargement of Lostock Dam required without Barnard operational?
14c	Scenario 13 + Lostock water transfer >> Glennies to max of 15,000 ML/yr. Lostock dam size enlarged to 67,000ML. Barnard operating.	Is an enlargement of Lostock Dam required with a Lostock >> Glennies Dam pipeline and Barnard operational?
15	Scenario 2 plus Liddell Power Station closed. Small scale water recycling = 5000 ML/yr. Potable water pipeline - HWC >> Singleton supplying 5000 ML/yr. Scenario 3 with Lostock >>Glennies Dam pipeline transfer. Pipe size allowing transfer volume of 15,000 ML/yr. System losses. Barnard operating.	Can all combined options work together and not cause detrimental estuary impacts?

Table 26. Key criteria in the multi-criteria assessment

Criteria	Consideration
Water supply for major and local water utilities has 100% share through a repeat of the worst drought on record	Environmental Socio/economic
Level and timing of urban water restrictions based on the 5/10/10 design rule	Environmental Socio/economic
Critical human needs are met in a drought of severity up to 1:1,000 years	Socio/economic
Reduced duration of zero allocations to General Security water users	Socio/economic
Maximises diversity of supply sources	Socio/economic
Reduces sensitivity to climate change	Environmental
Improve flow utilisation and maximises use of infrastructure assets	Socio/economic
Cost effective services (levelised costs)	Economic
Whether there is a negative change greater than 3% in reliability (compensation trigger)	Socio/economic
Maximise available choice of water products	Socio/economic
Maintain or improve characteristics of the Ramsar-listed wetlands (no salinity change of more than 4 parts per thousand	Environmental
Maintain or improve the characteristics of other key iconic environmental and cultural assets	Environmental

Table 27. Program objectives, goals and MCA criteria

Program Objective	Program Goals	MCA criteria	Triple Bottom Line Category
Objective 1. Support the critical needs of regional industries and communities by ensuring water security and quality of supply.	a) To meet the requirements of the Hunter Regulated River Water-Sharing Plan 2016 in regard to its obligations to major water utilities.	Water supply must be managed so that available water determinations for local water utility access licences and major utility access licences of 100% of share components can be maintained through a repeat of the worst drought on record as represented in the 2004 Hunter WSP.	Environmental, Socio/economic
	b) To meet the requirements of DPI Water guidelines titled Assuring Future Urban Water Security' in relation to the level and timing of water restrictions based on the 5/10/10 design rule.	Options must meet the 5/10/10 design rule.	Environmental, Socio/economic
	c) To provide water for critical needs in a drought of severity up to 1 in 1,000 years.	Does the option provide water for critical needs in a drought of severity up to 1 in 1,000 years?	Socio/economic
	d) To enable fast and easy improvements to water security and quality of supply.	Will the option enable fast and easy improvements to water security and quality of supply?	Environmental, Socio/economic
Objective 2. To support regional development and enhance opportunities for promoting a diverse and changing economy.	a) To improve drought security by reducing the duration of zero allocations to General Security users during droughts.	Reduced duration of zero allocations to General Security water users.	Socio/economic
	b) Provide reliability of water within a range of requirements for existing and emerging industries.	IQQM scenarios demonstrate that General Security water users have improved reliability and/or supply	Socio/economic
	c) Facilitate the provision of water at volumes and reliability levels matching likely future requirements	IQQM scenarios demonstrate that General Security users have improved reliability and/or supply	Socio/economic
	d) Allow opportunities for economic growth in water dependent industries.	IQQM scenarios demonstrate that General Security users have improved reliability and/or supply.	Socio/economic
Objective 3. To provide a supply system that is responsive to changing supply and demand.	a) Provide users with water from various locations and varying levels of reliability.	Maximise diversity of supply sources.	Socio/economic
	b) Ensure a responsive and adaptable supply system that can mitigate climate variability and climate change impacts.	Does it reduce sensitivity to climate change and variability?	Environmental
Objective 4. To provide best practice economic efficiency in the delivery of water.	a) Improve flow utilisation, ensuring infrastructure assets are able to be fully utilised and can be configured for maximum flexibility whilst minimising the potential for assets being stranded.	The options allow the ability to stage and/or integrate with other options in a regional approach.	Socio/economic
	b) Ensure cost effective services.	Levelised cost ($ / ML demand)	Economic
	c) Eliminate and remove perverse or unintended pricing outcomes	Economic net present value	Socio/economic

Program Objective	Program Goals	MCA criteria	Triple Bottom Line Category
Objective 5. To facilitate a responsive water market within the region	a) Allow for water to move between existing water markets to create a broader and larger water market.	Does it allow for water to move between existing markets?	Economic
Objective 6. To protect and maintain the certainty of water rights	a) To remain within government commitments to limit reductions in water supply reliability.	Whether there is a negative change greater than 3% in reliability.	Socio/economic
Objective 7. To provide businesses with opportunities to determine and manage their own risks.	a) Provide a mix of water products to allow industries to manage their own risk.	Maximise the choice of available water products.	Socio/economic
Objective 8. To maintain and improve the integrity of environmental and cultural assets to meet state and federal obligations.	a) Maintain or improve the characteristics of the Ramsar-listed Hunter Wetlands National Park to the standard it was at 2012.	No salinity change of more than 4 parts per thousand (parts per thousand) occurs more than 1% of the time compared to the baseline period.	Environmental
	b) Maintain or improve the characteristics of other iconic or key environmental and cultural assets within the region.	No significant change in stream flow as indicated by flow duration curves at relevant locations due to the infrastructure scenarios.	Environmental

Table 28. Summary of MCA results

Infrastructure option	Score results	Ranking & comments
1. Do nothing, business as usual based on 2016 Water-Sharing Plans.	4 No and 2 FAIL SCORE = 0	Rank last
2. Raw water transfer via pipeline from existing Lostock Dam to Glennies Creek Dam—7,500 ML/yr.	All Yes and Pass SCORE = 16	Rank 4
3. Raw water transfer via pipeline from existing Lostock Dam to Glennies Creek Dam—15,000 ML/yr.	All Yes and Pass SCORE = 21	Rank 2 equal.
4. Raw water transfer via pipeline direct to Singleton treatment plant—7,500 ML/yr.	All Yes and Pass SCORE = 16	High score but with weightings applied dropped to Rank 5.
5. Raw water pipeline from Paterson River to Singleton treatment plant (7,500 ML/yr.) with Lostock Dam enlarged to 67,000 ML.	All Yes and Pass SCORE = 15	Rank 7—IQQM modelling shows has insignificant hydrologic benefit
6. Raw water pipeline Lostock Dam to Glennies Creek Dam (15,000 ML/yr.) with Lostock enlarged to 67,000ML.	All Yes and Pass SCORE = 16	High score but with weightings applied dropped to Rank 6
7. Raw water transfer via pipeline from existing Lostock Dam to Glenbawn Dam—15,000 ML/yr.	All Yes and Pass SCORE = 21	Rank 2 equal but replaced by option 8 which ranked 1st. Sensitivity testing showed it remained not economically beneficial
8. Raw water transfer via pipeline from existing Lostock Dam to Glennies Creek Dam to Lake Liddell—15,000 ML/yr.	All Yes and Pass SCORE = 22	Rank 1 but replaced by option 3 which ranked 2nd because Option 8 involved two components.
9. HWC to Singleton potable 2-way water pipeline - Lochinvar to Rixs Reservoir (above Singleton). 4,000 ML/year transfer via 2 way pipeline.	All Yes and Pass SCORE = 21	Rank 2
10. Potable 2-way pipeline Paterson (Vacy) to Maitland and to Singleton. 4,000 ML/yr. 2-way pipeline transfer as in option 9	All Yes and Pass SCORE = 11	Rank 9
11. Large Scale Water Reuse Scheme transfer HWC to Lake Liddell. Effluent Reuse from 4 HWC waste water treatment plants and piping 17,000 ML/yr. to Lake Liddell.	All Yes and Pass SCORE = 17	Rank 3
12. Large Scale Water Reuse Scheme transfer from HWC west Lake Macquarie WWTPs to Lake Liddell (large scale reuse plus). 20,000 ML/yr. of effluent reuse piping from Belmont ocean outfall, Dora Creek, Toronto and Edgeworth WWTPs to Lake Liddell.	All Yes and Pass SCORE = 16	High score but with weightings applied dropped to Rank 6.
13. Large Scale Water Reuse Scheme transfer from HWC Burwood Bch WWTP to Lake Liddell. 30,000 ML/yr. via 90km pipeline from Burwood Bch to Lake Liddell.	All Yes and Pass SCORE = 14	Rank 7
14. Large Scale Water Reuse Scheme Combination from HWC to Lake Liddell. Combine options 11-13 = 45,000 ML via multiple pipelines to Lake Liddell. Requires a pipeline via Newcastle City and further treatment.	All Yes and Pass SCORE = 13	Rank 8 equal
15. Hunter Water Corporation small scale recycling scheme—5,000 ML/yr. recycled effluent piped from HWC Waste Water Treatment Plants below Branxton for small scale recycling.	All Yes and Pass SCORE = 13	Rank 8 equal
16. Barnard Scheme Enhanced Use. Can deliver net 12,000 ML/yr. from the Barnard River in the Manning catchment to Glenbawn Dam.	All Yes and Pass SCORE = 15	Rank 6 equal but leaving this option with AGL.
17. Glenbawn Dam Airspace Management. Requires Glenbawn Dam be filled above its normal flood storage level by up to 120,000ML before onset of drought. Delivers 5,000 ML/yr.	2 No and 1 FAIL SCORE = 9	Rank 9

Table 29. Option assessment criteria, measures and tools

Program goal	Assessment criteria	Measure	Tools
1a) To meet the requirements of the Hunter Regulated River Water-Sharing Plan 2016 in regard to its obligations to major water utilities.	Water supply must be managed so that available water determinations for local water utility access licences and major utility access licences of 100% of share components can be maintained through a repeat of the worst drought on record as represented in the 2004 Hunter WSP.	Yes or no	Review of WSPs
1b) To meet the requirements of DPI Water guidelines titled “Assuring Future Urban Water Security” in relation to the level and timing of water restrictions based on the 5/10/10 design rule.	Options must meet the 5/10/10 design rule.	Yes or no	Stochastic analysis
1c) To provide water for critical needs in a drought of severity up to 1 in 1,000 years.	Does the option provide water for critical needs in a drought of severity up to 1 in 1,000 years?	Pass or Fail	IQQM and stochastic analysis
d) To enable fast and easy improvements to water security and quality of supply.	Will the option enable fast and easy improvements to water security and quality of supply?	Score +3 to -3	Review details of each option.
2a) To improve drought security by reducing the duration of zero allocations to general security users during droughts.	Reduced duration of zero allocations to general security water users.	Time score +3 to -3	IQQM and stochastic analysis
2b) Provide reliability of water within a range of requirements for existing and emerging industries.	IQQM scenarios demonstrate that general security water users have improved reliability and/or supply	Percentage increase in reliability score +3 to -3	IQQM and stochastic analysis
2c) Facilitate the provision of water at volumes and reliability levels matching likely future requirements	IQQM scenarios demonstrate that general security users have improved reliability and/or supply	Score +3 to -3	IQQM and stochastic analysis
2d) Allow opportunities for economic growth in water dependent industries.	IQQM scenarios demonstrate that general security users have improved reliability and/or supply.	Score +3 to -3	IQQM and stochastic analysis
e) To enhance water security benefits on a regional scale.	Will the option enhance regional scale connectivity to optimise benefits?	Score +3 to -3	IQQM and stochastic analysis
3a) Provide users with water from various locations and varying levels of reliability.	Maximise diversity of supply sources.	Score number of independent supply sources +3 to -3	Review details of each option.

Program goal	Assessment criteria	Measure	Tools
3b) Ensure a responsive and adaptable supply system that can mitigate climate variability and climate change impacts.	Does it reduce sensitivity to climate change and variability?	Number of years with zero allocation for general security users Score +3 to -3	Review specific features of each option.
4a) Improve flow utilisation, ensuring infrastructure assets are able to be fully utilised and can be configured for maximum flexibility whilst minimising the potential for assets being stranded.	The options allow the ability to stage and/or integrate with other options in a regional approach.	Yes or No	Review specific features of each option.
4b) Ensure cost effective services.	Levelised cost (PV cost/PV ML demand)	$/ML ranking of options Score +3 to -3	State perspective over 50 years with 7% discount rate.
4c) Eliminate and remove perverse or unintended pricing outcomes.	Economic net present value	NPV > 0 ranking of options Score +3 to -3	State perspective over 50 years with 7% discount rate.
5a) Allow for water to move between existing water markets to create a broader and larger water market.	Does it allow for water to move between existing markets?	Yes or No	Distribution of Benefits and Economic Appraisal reports
6a) To remain within government commitments to limit reductions in water supply reliability.	Whether there is a negative change greater than 3% in reliability.	Pass or fail	IQQM and stochastic analysis
7a) Provide a mix of water products to allow industries to manage their own risk.	Maximise the choice of available water products.	Number of products – Score +3 to -3	Review specific features of each option.
8a) Maintain or improve the characteristics of the Ramsar-listed Hunter Wetlands National Park to the standard it was at 2012	No salinity change of more than 4 parts per thousand (ppt) occurs more than 1% of the time compared to the baseline period.	Pass or fail	Hunter River Estuary Tidal Dynamic Assessment. All “modelled” options pass.
8b) Maintain or improve the characteristics of other iconic or key environmental and cultural assets within the region.	No significant change in stream flow as indicated by flow duration curves at relevant locations due to the infrastructure scenarios.	Pass or fail	IQQM and Estuary models. Use end of system flows as a de facto measure for water available for environmental benefit.