NSW Department of Planning & Infrastructure

MACQUARIE RIVER TO ORANGE PIPELINE PROJECT

Independent Review of Hydrological Modelling

Looking downstream from Cobbs Hut Hole on 5 March 2013. The flow at this time was approximately 2000ML/d and occurred after moderate rain in the previous week. This was a relatively high flow which could be expected to be exceeded less frequently than 20% of the time if the past climate repeats itself in the future. The proposed extraction point for the new pipeline is in the centre left of the photograph immediately upstream of a rock bar that is almost completely submerged (although some high rocks on the left side and a few low rocks on the right side of the main flow are visible).

Final Report

8 April 2013

Bewsher

NSW Department of Planning & Infrastructure

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1. INTRODUCTION

1.1 BACKGROUND

Orange City Council proposes to improve its water supply by pumping water from the Macquarie River. The extraction is proposed to occur from a waterhole known as the Cobbs Hut Hole approximately 30km upstream of the Burrendong Dam impoundment. This location is referred to as MR5a and is located adjacent to the recently established streamflow gauging station (GS 421192) and about two kilometres downstream of the location of the previous Dixons Long Point Gauging Station (GS 421080).[1]

The proposal is a key outcome of Council's Water Supply Management Strategy and an Integrated Water Cycle Management Evaluation Study (IWCMES) which Council has been conducting in accordance with best practice guidelines prepared by the NSW Government (refer Document No 17 in **Table 1.2**).

The Project is being assessed under the provisions of Part 3A of the Environmental Planning and Assessment Act 1979.[2] The assessment is to be carried out by the NSW Planning Assessment Commission (PAC).[3]

This review has been commissioned by the Department of Planning and Infrastructure (DP&I) in order to provide an independent and unbiased review of hydrological modelling issues associated with the Project. The review was commissioned on 1 February 2013 after both the:

(a) *Macquarie River to Orange Pipeline Project Environmental Assessment* (EA) prepared by GHD in August 2012; and

(b) *Macquarie River to Orange Pipeline Project Preferred Project Report* (PPR) prepared by GHD in 2013,

had been submitted by the Council (who is the Proponent). In addition, various community submissions had been received, a number of which raised matters relating to hydrology.

1.2 SCOPE OF THIS REVIEW

The science of hydrology concerns itself with many aspects of water in our environment. Whilst there are numerous fields of hydrology, this current review has focussed on consideration of streamflows in the Macquarie River adjacent to the proposed extraction at

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[1] The Dixons Long Point gauging station was decommissioned in 1978. It operated for a 7 year period from 1971.

[2] More correctly, the project is being assessed as a transitional Part 3A project because the original provisions of the Act have now been repealed. However the provisions of Part 3A in force immediately before its repeal on 1 October 2011 and as modified by Schedule 6A to the Act, continue to apply to transitional Part 3A projects.

[3] The Minister for Planning and Infrastructure has delegated his functions for Part 3A projects other than those made by or on behalf of a public authority. As Orange City Council is not a public authority in accordance with the Act, the project will be determined by the Planning Assessment Commission under delegated authority.

Cobbs Hut Hole, and surface water issues within Orange itself including the Summer Hill Creek catchment into which the extracted river water is proposed to be pumped, prior to flowing into Suma Park Dam.

Computer model simulations of hydrological behaviour have been used to inform key components of the Project as described in the EA and the PPR. This hydrological modelling allows the behaviour of the Macquarie River streamflows and the surface water characteristics of the catchments within Orange to be explored under various alternative project configurations and climatic conditions. This hydrological modelling also allows the potential effects of climate change to be considered.

The rigor of this hydrological modelling is the principal focus of this review.

The streamflow hydrology which is the subject of this review relates to both existing and future conditions, noting that Orange's water supply demand will alter as the city grows, as other water management projects are implemented, as part of normal fluctuations in weather patterns or as part of potential longer-term changes in the climate. The hydrologic data which has been used comprises that obtained from existing records of past behaviour as well as synthetically generated data.

1.3 DOCUMENTS PROVIDED FOR REVIEW

The documents provided for review are listed in **Table 1.1**. Other documents that were provided for reference are listed in **Table 1.2**.

1.4 TERMS OF REFERENCE (TOR)

The terms of reference for this review require:

TOR 1. *An independent review of the hydrological modelling contained within the EA and the PPR including:*
- *(i) Strategic Planning and Project Justification (Molino Stewart);*
- *(ii) Hydrology and Water Security Assessment (Cardno),*
- *(iii) Decision Support Tool Framework (Geolyse);*
- (iv) *Hydrology and Water Security Assessment (Geolyse);*

TOR 2. *Consideration to the alternatives described in the above documents and raised in submissions received.*

TOR 3. *Consideration of the Proponent's response to issues raised in submissions received such as those from:*
- *(i) Office of Environment and Heritage;*
- *(ii) Department of Primary Industries;*
- *(iii) Orange and Regional Water Security;*
- *(iv) Orange Rate Payers Association;*
- *(v) Macquarie Marshes Environmental Landholders Association.*

TABLE 1.1: DOCUMENTS PROVIDED FOR REVIEW

Doc No	Date	Title	Author / Agency
1	January 2013	Macquarie River to Orange pipeline project. Preferred project report. Main report. Final Draft. Particularly: • Decision Support Tool Framework (Geolyse); • Hydrology and Water Security Assessment (Geolyse)	GHD
2	August 2012	Macquarie River to Orange pipeline project. Environmental assessment. Particularly: • Appendix B: Strategic planning and project justification (Molino Stewart) • Appendix D: Hydrology and water security assessment (Geolyse)	GHD
3	Various	Submissions and advices received relating to hydrology including, but not limited to, those provided by: • Friends of the Macquarie, 21 March 2013 • Sofala Branch of Central Acclimatisation Society (CAS) • Individual submission, 10 March 2013 • Individual submission, 15 February 2013 • Friends of the Macquarie, 18 February 2013 • Orange and Region Water Security Alliance, 1 February 2013 • Friends of the Macquarie, 30 January 2013 (containing February edition of the NSW Council of Freshwater Anglers newsletter) • Department of Primary Industry, 23 October 2012 • Inland Rivers Network, October 2012 • Mudgee District Environment Group, 12 October 2012 • Office of Environment and Heritage (including Attachment A), 19 October 2012 • Orange and Region Water Security Alliance, 14 October 2012 • Orange and Region Water Security Alliance, 21 November 2012 • Individual submission, 18 October 2012	Various individuals, private groups and associations, government agencies

TABLE 1.2: DOCUMENTS PROVIDED FOR REFERENCE

Doc No	Date	Title	Author / Agency
4	21 March 2013	Letters to DP&I	OCC and Geolyse
5	February 2013	Macquarie River to Orange Pipeline. PowerPoint Presentation	Haege, M. Geolyse
6	October 2012	Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources 2012	NSW Gov't
7	July 2012	Impact of Global Warming and Climate Variability on Secure Yield of Non-metropolitan NSW Water Supplies. Pilot Study Assessing 11 Systems. Presentation by Peter Cloke, NSW Water Solutions (WS) to LGSA Water Management Conference	WS, NSW Dept of Comm.
8	October 2011	Geolyse memo to Council: Existing system secure yield	Geolyse
9	August 2011	Macro water sharing plans - the approach for unregulated rivers. A report to assist community consultation.	NOW
10	June 2010	Macquarie / Castlereagh / Bogan Valley - Independent Audit of Cap Model	Bewsher Consulting, MDBA
11	November 2009	REF: Ploughmans Creek Stormwater Harvesting Scheme	Geolyse
12	November 2008	Browns Creek Mine Water Supply to Orange. Transfer System Desktop Study. Draft Report	NSW Dept of Commerce
13	February 2008	Orange Water Supply Yield Study: Progress Report. (Memo to Council)	WS, NSW Dept of Comm.
14	July 2008	REF: Blackmans Swamp Creek Stormwater Harvesting Scheme	Geolyse
15	June 2008	Climate data for hydrologic scenario modelling across the Murray-Darling Basin. Murray-Darling Basin Sustainable Yields Project	Chiew, F, et al. CSIRO
16	June 2008	Future climate and runoff projections (~2030) for New South Wales and Australian Capital Territory	Vaze, J, et al. DWE
17	August 2007	Best-Practice Management of Water Supply and Sewerage, Guidelines	NSW DWE
18	August 2002	No. 6 Daily extraction management in unregulated rivers (2002 version). Advice to Water management Committees.	NSW Gov't

TOR 4. *Preparation of a report providing independent expert advice and commentary on the:*
(i) applicability of the chosen models;
(ii) assumptions made;
(iii) results obtained and interpretation of those results.

TOR 5. *A statement from the reviewer about the level of confidence and justification of the project considering the above mentioned data.*

1.5 ACTIVITIES UNDERTAKEN

In addition to consideration of the documents listed in **Tables 1.1** and **1.2**, this review has also involved:

(a) discussions and correspondence with personnel of the Department of Planning and Infrastructure (DP&I);

(b) attendance at a presentation by Geolyse at the DP&I's Sydney office on 15 February 2013 which was also attended by Orange City Council;

(c) inspection of the Cobbs Hut Hole on the Macquarie River, Suma Park Dam, and the Blackmans Swamp and Ploughmans Creek stormwater harvesting schemes in conjunction with staff of Orange City Council on 5 March 2013;

(d) discussions on hydrological issues at Geolyse's Orange office on 5 March 2013;

(e) various telephone discussions with staff from Geolyse and the NSW Office of Water (NOW) during February and March 2013; and

(f) written comments and discussions from Council, Geolyse and the DP&I following provision of an initial draft of this review report

The reviewer acknowledges the useful assistance provided by the Proponent, their consultant, Geolyse, and NOW during the course of the review. Further the discussions with the Proponent and Geolyse have been carried out in a frank and open manner, the reviewer's requests for further information have been addressed promptly and the reviewer has had no reason to suspect that information was being unreasonably withheld.

2. HYDROLOGICAL MODELLING REVIEW

2.1 MODELS USED TO INFORM THE PROJECT

Four different hydrological models have been used by the Proponent and their consultants as part of the Project. Within this report these models are referred to as:

(a) *River flow model* − which was established by Kozarovski and Partners (under the direction of Geolyse) to analyse and extend the available daily flow records at the pump site on the Macquarie River;

(b) *Water balance model* − which was prepared by Geolyse to simulate the water supply system within Orange itself including the behaviour of Council's storages and the operation of its stormwater harvesting schemes;

(c) *Secure yield model* − which was undertaken by NSW Water Solutions (WS) within the NSW Department of Public Works in order to determine the secure yield[4] of the water supply system; and

(d) *IQQM* (i.e. integrated quantity and quality model) – this model was used to assess impacts to water users and the environment below Burrendong Dam. IQQM has been widely used by government water agencies in NSW and Queensland.[5]

In addition to these hydrological models, the proponent has also used the HEC-RAS hydraulic model[6] to investigate water levels within the River and other potential changes to the hydraulic behaviour of the River downstream of the pump site. Some limited comments on this hydraulic assessment are provided in **Section 3.1**.

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[4] Consistent with the approach adopted in the EA and the PPR, the term 'secure yield' has the special meaning given to it by NSW best practice. This practice and the determination of secure yield is described in Appendix B of Appendix D of the EA, and in Document Nos. 7 and 13. A further description is provided in **Appendix A**. Whilst not specifically referred to in the NSW guidelines in Document No 17, the reviewer understands application of the secure yield approach is considered by NOW and the NSW Public Works as an essential component of determining a robust security of supply basis for urban water supply headworks in NSW.

[5] The Macquarie Valley IQQM has been the primary simulation tool used in all major water resource planning in the Valley for over a decade. As it has been the subject of independent auditing carried out for the Murray-Darling Basin Authority and numerous internal assessments by NOW, its credentials are well established and it has received only cursory attention in this review. (Refer Document No 10).

[6] Broadly speaking 'hydrology' describes the process under which rainfall is converted into surface water flows and the manner in which these flows might be altered (e.g. hydrologic routing) as they travel across the landscape or within a river network. 'Hydraulics' has to with the physics of the passage of flows over the ground including flow depth, velocity, water level, energy losses due to bed friction, etc. There is considerable overlap between these two disciplines and the distinction becomes blurred on occasions, particularly in common usage. For example the Macquarie River IQQM which covers the majority of the Macquarie Valley is normally referred to as a 'hydrologic model' despite it containing simulation of some hydraulic characteristics.

2.2 KEY CHARACTERISTICS OF THE MODELS

The key characteristics of each of the four hydrological models described in the previous section are summarised in **Table 2.1**.

One of the wetlands within the Ploughmans Creek system. The stormwater harvesting scheme implemented in this area has created a very attractive open space asset for the local community. Flows are captured at downstream weirs and pumped to a water treatment plant and thence to Suma Park Dam. This scheme can operate whenever Suma Park Dam is less than 100% full.

TABLE 2.1: SUMMARY OF MODEL CHARACTERISTICS

Description	River Flow Model	Water Balance Model	Secure Yield Model	IQQM
Author	Kozarovski and Partners.	Geolyse.	NSW Water Solutions (WS).	NOW and Qld DSITIA[7].
Software used	WATHNET and Monash rainfall-runoff model.	Excel spreadsheet.	Unknown, possibly a version of Basic.	Fortran.
Documentation of model	No formal documentation provided by Author. Limited description provided by Geolyse in Appendix D of EA.	Appendix D of EA.	No formal documentation provided by Author but some characteristics are described in memos to OCC and a separate technical paper appended to the EA.	Documentation of the application of IQQM to the Water Sharing Plan and Murray-Darling Basin 'cap' issues in the Macquarie Valley and beyond, in addition to independent reviews and auditing of the model, are available.
Purpose/description of model	Generate synthetic daily flows at pump site on Macquarie River. Includes model of entire upstream catchment including water use and storages. (Few details of the model configuration are available).	Simulates components of key water supply infrastructure with Orange including inflows to dams, water demand, stormwater harvesting, storage behaviour, evaporation and seepage losses. No allowance for flow routing or lagging is included.	Not as detailed as water balance model. E.g. does not directly simulate stormwater harvesting (utilises data from water balance model to allow for these effects). Demand to vary until 'secure yield' criteria are met. Yield determination to be repeated with 15 climate change data sets. Intensive, iterative calculations are performed.	Simulates the unregulated and regulated portions of the Valley under specified water management conditions, on a daily basis for a period in excess of 110 years.
Catchment conditions considered	A: historical catchment. B: recent catchment. C: future climate.	Various combinations of river pumping, stormwater harvesting, bores, water demands, existing and enlarged Suma Park dam capacities.	Existing conditions with provision for stormwater harvesting, river pumping, bores, modified Suma Park Dam capacity. Future climate scenarios are also considered.	A range are available including current, water sharing plans and 'cap', in addition to dozens (or possibly 100s) or other scenarios that have been investigated by NOW over the last decade.
Climatic data used	SILO.[8]	SILO.[8]	SILO. [8]	Historical and SILO. [8]

[7] Queensland Department of Science, Information Technology, Innovation and the Arts
[8] See *http://www.longpaddock.qld.gov.au/silo/*

TABLE 2.1: SUMMARY OF MODEL CHARACTERISTICS (Continued)

Description	River Flow Model	Water Balance Model	Secure Yield Model	IQQM
Streamflow data used	Historical streamflow records used to calibrate 'Monash' rainfall runoff model. NSW climate change data sets (see Doc No 16) used to determine impact of climate change on streamflows at pump site.	River flows at pump site based on river flow model. Identical inflows to OCC storages as for the secure yield model.	River flows at pump site based on river flow model. Inflows to OCC storages generated from AWBM model. Suma Park Dam inflows from stormwater harvesting and bores based on results of water balance model.	Historical where available otherwise inferred from adjacent streamflow records or synthesized using Sacramento modelling based on rainfall and other climatic data.
Calibration and validation. Robustness of model to operate outside calibration period.	Largely unknown. Ability of model to replicate observed streamflows is reported by Geolyse in Appendix D of the EA.	Largely unknown however it is understood that results are similar to secure yield model which adds confidence to its use.	Largely unknown however it is understood that results are similar to water balance model which adds confidence to its use. Model used elsewhere in NSW which has likely provided opportunity for any deficiencies in model to be identified.	Separate calibration of flow, diversions, crop areas and storages are carried out, in addition to validation. A specific methodology has been developed by NOW to consistently assess the quality of calibration of IQQMs across the State.
Simulation period	1889-2009 (i.e. 121 years)	1890-2007 (i.e. 118 years)	1890-2007 (i.e. 118 years) 1896-2006 (i.e. 111 years) for climate change runs	Varies for different runs but for the Water Sharing Plan model comprises January 1890 through December 2007, or longer.
Orange water demands	n.a.	Demand increased at 0.8% per year from base demand of 5400ML/yr in first year of simulation.	Fixed monthly pattern of demand assumed. Overall level of demand varied to determine secure yield.	Not explicitly simulated. Indirect allowance made through use of tributary inflows to Macquarie River which include for town water extractions.

2.3 ESTABLISHMENT AND OPERATION OF MODELS

Each of the models provides for the simulation of hydrological behaviour on a daily basis for a period in excess of 100 years. The climatic conditions over the simulation period are either the historical climate or the historical climate adjusted for potential climate change. A key assumption in the use of these two climate conditions is that the sequences of dry and wet years within the historical climate will be representative of those sequences that might reoccur in the future (albeit with some adjustment in magnitude for climate change).[9]

The hydrological models can also include different assumptions about water management infrastructure, the level of water usage by irrigators and the use of water for environmental purposes. These assumptions are often referred to as 'development levels'.

The normal practice is for hydrologic models to be run for the 100+ years' simulation period with the assumed climate conditions and development levels remaining constant for the entirety of the simulation.[10] In this manner the model results provide the range of likely outcomes that could occur in the future. The results are normally analysed to prepare statistics of the likely occurrence of simulated circumstances, on the assumption that the past climate (or adjusted climate) is reflective of the future.[11]

Hydrological models are only approximate representations of reality and in common with all modelling it is always possible to improve the model simulation by additional effort. The extent to which model upgrades and improvements are carried out is therefore subjective and based on the intended use of the model and the 'return for effort'.

It is normal practice in Australia for all important hydrologic models to be peer-reviewed.

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[9] This assumption is consistent with the approach adopted in the CSIRO Sustainable Yields Project (see Document No. 15) which has also been referred to in the EA. The state of current climate science suggests that the sequences of wet and dry will likely change if climate change occurs however the science has not progressed sufficiently to allow new sequences to be generated for use in hydrological modelling in Australia. The reviewer therefore concurs with the use of the historical climate and the historical climate adjusted for climate change which were adopted in the EA noting that this approach is the best available, despite its shortcomings.

[10] The reviewer notes that this has not been the case with the Project's water balance model where demands have been assumed to increase progressively under 'Scenario 2' – refer page 25 of Appendix B of the EA. These annually increasing demands mean the results of the model can't be interpreted in the manner results of hydrological models are normally interpreted because the level of demands have not remained constant over the simulation period. For example the results of the water balance model which have been used to inform the Suma Park Dam's spill analysis (see Section 4.3.7 of Appendix D of the EA) and to prepare Figs 54−56 and Tables 4.10−4.13 aren't for a constant demand level but one that is increasing. Further the very driest conditions (i.e. 1894-1900) which occur at the beginning of the simulation will occur when the demands are lowest. This will likely introduce some small statistical bias into the results.

[11] Given this basis for modelling, it is not uncommon for model results to be used inappropriately or misunderstood by lay people. For example if the model's results indicate, say, that a storage spills in year 30 of a simulation, it would be a fallacy to conclude that after commencement of the project the storage will spill in 30 years' time. The models are not to be used to predict behaviour on specific days or years. Rather the model's results should be used to indicate the statistical range of behaviour that could occur. For example, if over 100 years of simulation the storage spills in 20 of the years it would be more appropriate to say the chance of spilling will be 5% in any one year. Special care must therefore be used in interpreting the results of hydrologic models.

2.4 MODEL CALIBRATION AND VALIDATION

The model calibration and validation phases are the most critical in establishing the rigor and 'credentials' of a hydrologic model. Most hydrologic models have key parameters which cannot be determined based on empirical formulae. This is because the physical processes involving the conversion of rainfall into streamflow, and the translation of flows along a waterway, are extremely complex and it is not possible or practical to represent many of these processes by exact mathematical equations. Rather the models contain more general relationships[12] with a variety of parameters which must be adjusted to suit each catchment.

Model parameters are normally adjusted during the model calibration phase so that the model replicates observed behaviour. Further the model is usually then validated by comparing the results of the model with observed behaviour outside the period used for calibration. This provides some independent checking of the calibration. The calibration and validation periods should ideally contain representative sequences of the climate (e.g. wet and dry periods) over which the model is required to simulate behaviour.

It is almost invariably the case that the calibration and validation of models are strongly constrained by the availability of accurate streamflow and climatic records. Consequently the establishment of models involves considerable hydrologic judgement and experience on the part of the modellers.

The above discussion is of most relevance to the Project because its secure yield appears to be dominated by behaviour of the system over the drought from 1894 to 1900 and there are no streamflow records for this period. Thus the streamflows used to predict the volumes pumped from the River and the local inflows to Suma Park Dam (and other Council's storages) for this critical drought period, have all been synthetically generated.

In particular:

(a) the river flow model has been used to set the 80th percentile cease-to-pump flow trigger and to define the river flow series which was subsequently utilised in both the water balance model and the secure yield model to determine the volume of water pumped from the River; and

(b) within the secure yield model, the inflows from the local catchments to all of Council's storages including Suma Park Dam, were obtained from AWBM rainfall-runoff modelling.[13]

Consequently the ability of the river flow model to accurately predict river flows and the ability of the secure yield model to accurately predict local catchment inflows are key considerations for this review as they will strongly influence the simulated behaviour of the Orange water supply system during a repeat of this drought. As noted above, the abilities of the models to replicate this drought behaviour are dependent on the models' calibrations. Further as there has been limited attention given to the documentation of the models' calibrations, it is difficult to infer the models' robustness to operate over such a dry period. In addition from the information provided it appears that the models' validations have been limited or is absent.

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[12] These are sometimes referred to as 'black boxes'.

[13] In addition to these local catchment inflows, there are also inflows to the storages from the stormwater harvesting schemes. These inflows are also synthetically generated and are determined within the water balance model.

It is the reviewer's opinion that considerable uncertainty remains with the models' results that form the basis of some of the hydrological performance quoted in the EA and PPR including the determination of the 80th percentile river flow at the pump site.[14]

Nevertheless Geolyse have been aware of these potential uncertainties and have carried out various sensitivity tests. Many of these examine the potential for the uncertainties to alter the principal hydrological characteristics and operation of the Project. Some of these relate to the simulated streamflows in the Macquarie River which constrain the potential for pumping to occur.

These sensitivity tests are important additions to the hydrologic modelling that has been carried out.

2.5 RIVER FLOW MODEL ASSESSMENT

2.5.1 'Recent' and 'Past' Catchment Approach

The EA and PPR place considerable weight on the prediction of streamflows at the pump site and the frequency at which these flows occur. This information is derived in large part from the river flow model and therefore it warrants closer attention in this review.

As noted above, the current review is significantly hampered by a lack of documentation by the model's developers and operators. This includes details of the model's calibration and its validation (if any).

The documentation provided by Geolyse states that:

> *"The calibration process revealed a change in runoff conditions post 2000. The flow duration curves at the Bruinbun and Sofala gauging stations showed a significant difference between the recorded and simulated flows for the post 2000 period. These changes were more than could be explained by climate alone"*.

Further as explained by Geolyse at the presentation that was made to the reviewer and the DP&I on 15 February 2013, the model developer has considered there to be significant physical changes in the catchment which produced different runoff responses post-2000. Accordingly he has developed a 'past catchment' (i.e. pre-2000) model[15] and a 'recent catchment' (i.e. post-2000) model. Further, because the recent catchment 'changes' were considered to be permanent, the recent catchment model was used to derive the 118 years of streamflows at the pump site which were utilised in both the water balance model and the secure yield model. This means that the estimate of the 80th percentile flow of 22ML/d which is referred to in a number of places in the documentation is also based on the assumed recent catchment conditions.

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[14] As models do not perfectly reflect reality, some uncertainty in any model results is to be expected. However for the project's models, the level of uncertainty is increased because of the calibration and validation issues discussed above.

[15] The EA refers to the 'past catchment' as the 'historical catchment'. The reviewer has chosen not to use the term 'historical catchment' in order to avoid any confusion with the 'historical model' referred to in the EA (and which is described more fully in Document No 4). This model utilises the 'past catchment' for the entirety of the 121 year simulation but also includes for increasing development levels (irrigation, town water supply extraction, construction of storages etc) as they happened in the catchment in times past.

In the reviewer's opinion it is most unlikely that the failure of the pre-2000 model to replicate post-2000 conditions is as a consequence of physical changes to the catchment but rather it reflects the inability of the model itself to respond to the substantially drier conditions which occurred post-2000. The reviewer has had considerable experience in reviewing hydrological models across the Murray-Darling basin and does not believe the explanation offered in the EA is credible.[16] Rather the persistently drier conditions are likely to have produced changes in runoff response, groundwater interaction and losses which are beyond the capabilities of the pre-2000 model to adequately simulate.

The reviewer also notes that Geolyse appears to have had some reservations[17] having classified the approach as "conservative" thus erring on the side of caution in establishing a secure yield for the Council.[18] Whilst this position is understandable, it does not allow an accurate assessment of the likely hydrological behaviour and its associated environmental impacts.

2.5.2 Suggested Flow Frequency at Pump Site

The flow frequencies at the pump site have been discussed in a number of places within the EA and the PPR. Note that there were some typographical errors in Figures 25 and 26 of Appendix D of the EA and these figures have since been revised by Geolyse and amended figures reproduced in **Appendix C**.[19]

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[16] The reviewer also notes that there is no description in the EA as to what actual physical changes occurred within the catchment around the turn of the century. The fifth paragraph on Page 20 of Appendix D of the EA states that "*this phenomena*" has been observed in other studies for Orange and Bathurst but these studies do not appear to be independent and may also be subject to the same inappropriate conclusions regarding catchment change.

[17] i.e. reservations concerning the extent to which the generated river flow time series was representative of the likely hydrological variability at the site.

[18] It would appear that Geolyse considered that the simulated river flows generated by the Scenario B river model may have been a little drier than may occur in the future, thus reducing the volumes that could be pumped to Suma Park Dam and resulting in an under-estimate of the secure yield. Such an approach would be "conservative" because the justification of the project is dependent on its secure yield. However there are two other nuances to the claim that the approach is "conservative" that warrant brief comment:

(a) firstly, a consequence of using the Scenario B river flows is that the 80th percentile of the flow series will be too low. If the Project is approved as proposed this would result in the pumps operating at river levels lower than would otherwise occur if a more accurate 80th percentile flow had been determined. From the point of view of aquatic ecology, there will likely be greater impacts on the River by having the pumps switch on at a lower river level than at a higher level. Consequently from this ecological perspective the adoption of Scenario B flows may not be a "conservative" outcome;

(b) secondly, the aquatic ecology impact assessment reported in the EA and PPR has been undertaken assuming the pumps switch on at low river flows based on the Scenario B flow series. If the Project is approved with the pumps switching on at higher river flows, the ecological impacts at the higher flows will likely be less than those reported in the EA and PPR. Consequently under these circumstances the aquatic impact assessment in the EA and PPR will be "conservative".

[19] The reviewer understands the label "Historical" on Figure 27 of Appendix D of the EA should be "Scenario B". Geolyse advised the reviewer that the historical model includes increasing development levels (irrigation, town water supply extraction, construction of storages etc) as they happened in the historically catchment. The EA historical model was run over the full 121 years and included increasing catchment development through this period. (This model "ends" with the current catchment development level). Further Geolyse has also clarified that the discussion about "Scenario A" in their

In the absence of more rigorous modelling, the reviewer considers the frequency of flows at the pump site are more likely to follow the current/past catchment conditions (on the assumption that the catchment response has not altered post-2000), except for the changes in water management infrastructure that have occurred as development and irrigation has proceeded in the upstream catchment. Whilst the "Historical" or "Scenario A" data sets reported by Geolyse[19] could be used to approximate this catchment state, or alternatively the recorded flows at Bruinbun and Sofala could be used to infer flows at the pump site, a more appropriate data set would be to use the 117 year data set derived by NOW using the Macquarie IQQM for the period from 1890 to 2007.[20]

On 15 March 2013 the reviewer obtained a copy of the river flows simulated by NOW using IQQM for current conditions assuming implementation of the relevant water sharing plans.[21] This data was analysed by the reviewer and the following statistics were obtained, some of which are very similar to the information presented by Geolyse for NOW's "macqw079" data set that is reproduced in **Appendix C**:

(a) 97th percentile flow = 22ML/d;
(b) 95th percentile flow = 30ML/d;
(c) 93rd percentile flow = 38ML/d;
(d) 80th percentile flow = 92ML/d; and
(e) 77th percentile flow = 108ML/d.

If the Proponent's proposal to pump when flows exceed the 80th percentile is implemented then based on these revised flow statistics the cease-to-pump flow trigger would be 108ML/d.[22]

Whilst 108ML/d is approximately three times higher than the 38ML/d flow trigger proposed in the PPR the potential implications to the Project may not be as dramatic as the above flow ratio suggests. In particular consideration has been given to how the Project's secure yield

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Section 4.3.8 is meant to be a discussion about use of "Historical" flows (i.e. replace references in this section to "Scenario A" with "Historical").

[20] Nevertheless even this approach has some deficiencies. The Macquarie IQQM makes use of Sacramento modelling for much of its streamflow extension. As noted in the review of this model that is reported in Document No 10, the Sacramento models and transmission loss relationships were calibrated on pre-2000 data and are in need of revision themselves. However in the opinion of the reviewer the results of IQQM can be used with more confidence than the results presented in the EA and should be used in the interim until such time as the river flow model can be revised and an updated river flow series prepared which overcomes the identified deficiencies. Most importantly the reviewer considers that the 80th percentile flow of 22ML/d reported in the EA is inaccurate.

[21] This is the "*macqw120_dixons*" data set. The IQQM used for this run is understood to be very similar to the IQQM model that was separately reviewed and has been described in Footnote 20. It also appears similar to the "*macqw079*" model run reported in the EA and shown in the revised Figure 25 in **Appendix C.**

[22] As described in the PPR, if 12ML is to be pumped in a day (when unconstrained by low river flows or Suma Park Dam levels), and the pump is to be operated only 19 hours per day, then the instantaneous pump rate when operating will need to be 12*24/19=15.2ML/d. As 92+15.2=107.2ML/d and if this flow is rounded up (as per the PPR approach) then 108ML/d will need to be the cease-to-pump trigger in order to ensure that the pumps do not operate when river flows are below the 80th percentile. Thus, in summary, it's the reviewer's opinion that until such time as better hydrologic modelling becomes available, an interim flow at the pump site of 108ML/d should be used in lieu of the 38ML/d trigger proposed in the PPR. (This opinion is expressed having regard to hydrologic issues only based on continuation of the 80th percentile approach, and separate environmental constraints may dictate a different cease-to-pump trigger).

might alter if a different cease-to-pump flow trigger was adopted and this is discussed further in **Section 2.7.3**.

2.6 WATER BALANCE MODEL

The spreadsheet model which Geolyse has developed appears to have been a very valuable tool for exploring Orange's water management system. One of its main benefits is the ability to simulate and integrate water supplies from stormwater harvesting and other sources.

In the time available for the current review, an in-depth assessment of this model has not been carried out.[23] The main significance of the water balance model to the current review is that its results have been used to determine:

(a) the time series of flows harvested from the Blackmans Swamp Creek and Ploughmans Creek stormwater harvesting schemes;[24]

(b) the days on which river flows at the pump site exceed the cease-to-pump trigger, and as a consequence, the time series of flows delivered to Suma Park Dam;

(c) the storage volumes in Suma Park Dam (which if above the 90% trigger, may constrain pumping from the river); and

(d) the spill from Suma Park Dam.

Consequently these aspects of the model have been given closer consideration in this review. In particular it is noted that the time series from (a) is utilised directly in the secure yield modelling. Further the inflows to the Council's storages used in the water balance model were derived from estimates prepared for the use in secure yield model. Thus any errors in these data sets will affect the results of both models.

2.7 SECURE YIELD MODEL

'Secure yield' is a key consideration within the Project's documentation. **Appendix A** provides further details of the concept including its application to Orange.

2.7.1 Secure Yield Estimates for Current Climate

The modelling of secure yield for Orange City Council has been undertaken by the NSW Water Solutions (WS) group within the NSW Department of Public Works. The reviewer understands the modelling undertaken for Council has been applied across NSW for a number of water utilities which adds confidence that the modelling procedures have been appropriately and consistently applied. Nevertheless the reviewer is surprised that there

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[23] The reviewer does not believe this to be a significant shortcoming of the Terms of Reference for the review. The spreadsheet model has been utilised for a number of projects over some years and any significant programming errors would likely have emerged and been corrected over this period.

[24] The runoff from these catchments has been derived using the rainfall-runoff relationships in MUSIC (a model developed by eWater) which have been calibrated to the available data. No obvious errors were found in the calibration of these relationships. Nevertheless this received only limited attention during the current review.

appears to be little documentation of the modelling details that have been applied except for those provided in a few memos to Council.[25]

Information provided by Geolyse to the reviewer indicates that an earlier estimate of secure yield prepared in 1990 was approximately 8000ML/yr. This was prepared at a time prior to any stormwater harvesting or groundwater supply schemes, and the yield estimate was dominated by the estimation of catchment inflows to Council's main storage at Suma Park Dam. These inflows at that time were prepared based on correlation with streamflows beyond the Orange area and as a result of revisions carried out by WS in 2008, a significant reduction in inflows and secure yield occurred. (Refer discussion in Document No 13).

The revised inflows were computed from an AWBM model but few details of the calibration and validation of the model are available. The reviewer considers it appropriate for the Council to request further details of the calibration and validation used by WS in their model. It would also be wise to request WS to provide an estimate of the uncertainty they expect to be present in their secure yield estimates for Orange.

WS's secure yield estimate prepared using these revised inflows was 3500ML/yr when calculated in 2008 using the '5/10/20' secure yield methodology that was in place at the time. The reviewer understands that the current estimate of the secure yield using the present '5/10/10' methodology is 3400ML/yr.[26]

The PPR quotes the current secure yield of the existing system (i.e. without the Project) to be 4750ML/yr and this is comprised of the secure yield of:

(a) 3400ML/yr from the existing local catchment inflows;[27]

(b) 900ML/yr from the stormwater harvesting schemes;[28] and
(c) 450ML/yr from groundwater pumping.

With implementation of the Project, an additional 2700ML/yr of secure yield would be provided from the river pumping thus increasing the total secure yield to 7450ML/yr (i.e. 4750+2700=7450).

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[25] Further the reviewer anticipated that the model might have been subjected to independent peer review but could find no reference to this having been carried out.

[26] Advice received from Geolyse on 15 March 2013 indicated that they believed the estimation of local catchment inflows had not altered since 2008. Further the 2008 value of 3500ML/year was based not only on the 5/10/20 rule but it also used a Suma Park Dam volume of 18,000ML rather than the 17,290ML capacity currently adopted. (Given the rule and the Suma Park Dam volume, the reviewer would have expected a bigger reduction in the secure yield than has been reported).

[27] During the review Geolyse advised that the 3400ML/yr yield was calculated by WS as part of the IWCMES. This appears consistent with Appendix A of Appendix D of the EA which reports that WS calculated the existing catchment yield as 4600ML/yr on the assumption that 75ML/yr groundwater pumping was provided and that Stage 1b of the Blackman Swamp Creek stormwater harvesting scheme was also implemented. (Appendix B of the EA reports that this latter scheme provides a 1100ML/yr increment in secure yield). It is noted that numerically 4600-75-1100 approximates 3400ML/yr.

[28] This comprises the Blackmans Swamp Creek (Stage 1a) scheme which is currently approved only to operate when Suma Park Dam is below 50% full, and the Ploughmans Creek scheme which can operate wherever Suma Park Dam is below 100%.

2.7.2 Secure Yield Estimates with Climate Change

Allowance for the impacts of climate change on secure yield have been made using the 2008 climate change data sets that were referred to in **Section 2.3** and Footnote 9. The reviewer endorses the approach which has been undertaken and notes that climate change could be expected to reduce yield by 6 to 8%.[29]

2.7.3 Secure Yield Estimates with Altered Pumping Triggers

Using the revised river flow sequence and the interim pump trigger of 108ML/d discussed in **Section 2.5.2** the reviewer has estimated the secure yield would likely increase by a small amount of approximately 100−200ML/yr.[30] This is because despite pumping now occurring at a higher river flow, the occurrence of higher flows improves the opportunities to pump during the critical drought period prior to 1900.[31]

2.8 IQQM MODELLING OF IMPACTS BELOW BURRENDONG DAM

In the reviewer's opinion, the Macquarie IQQM is the appropriate hydrologic modelling tool from which to assess the impacts of the Project below Burrendong including changes to the water deliveries to the Macquarie Marshes.
Given the relatively small extraction volumes and the large 'buffering' of flows that is provided by the Burrendong Dam impoundment it is unsurprising that IQQM indicates the hydrologic impacts below the dam are very small.

It is unfortunate that the operation of the IQQM to assess the impacts of the Project in the EA was carried out using only the extractions from the River at the pump site without allowance for the additional return flows to the River which would occur because of the increased spills from Suma Park Dam. This matter has been raised in a number of the submissions where it is demonstrated that on average, the additional return flows will be about four times the net

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[29] The reviewer understands that in considering climate change, the local catchment inflows were adjusted by WS and that the river flows at the pump site were adjusted by Kozarovski and Partners. Whilst the manner in which the stormwater harvesting yields were adjusted is not reported in the EA, Geolyse subsequently advised that a methodology based on the 2008 climate change data sets was utilised. (The actual method for adjusting stormwater flows was not investigated during the review. Further the manner in which stormwater flows might alter as the City grows has also not been reviewed).

[30] The reviewer's assessment is approximate as it does not allow for the marginally higher Suma Park Dam levels which would result from the extra pumping. These higher Dam levels could cause the occurrence of 90% levels within in the Dam to increase marginally, which in turn would act to limit pumping. This 'second order effect' is not included in the reviewer's assessment.

[31] This calculation was carried out over the period 1/11/1894 to 31/12/1899 based on advice and a spreadsheet from Geolyse provided on 13 March 2013. A more accurate adjustment would be available if modelled by WS. Further it is noted that application of the 108ML/d pump trigger with the time series of river flows used in the EA would result in a reduction in secure yield of about 900ML/yr. Nevertheless this estimate is inappropriate because these flows may not be accurate and, in any event, are inconsistent with the 108ML/d pump trigger. However prior to finalisation of this report, the reviewer received advice that the Proponent had determined that even with a 900 ML/yr reduction in secure yield, the project was still justified in comparison to other alternative water supply schemes that had been considered in the IWCMES.

extraction. The actual net extractions from the River are available as a time series output from the water balance model and the use of these net extractions in IQQM would have produced a more accurate assessment of the hydrologic impacts and reduced confusion amongst readers of the Project's documentation.

Nevertheless improvements to the IQQM modelling at this stage will only identify less hydrological impacts than those already presented in the EA.

Suma Park Dam was built in the 1930s and provides the main source of water for Orange. Its dam wall does not meet the requirements of the NSW Dams Safety Committee and needs to be strengthened. Raising of the dam has previously been investigated as a means of increasing the catchment yield. Unfortunately it is only cost-effective to raise the dam by about 1.0m which will increase the storage volume from 17.3GL to 19.0GL. This modest increase in capacity will lift the secure yield of the catchment by about 150ML/yr if the Macquarie River pumps are in place.

3. OTHER COMMENTS

3.1 CHANGES TO FLOW BEHAVIOUR OVER RIFFLES

The potential for pumping to alter flow behaviour between the pump site and Burrendong Dam was reported in Section 3.2 of Appendix A of the PPR and using this information the ecological impacts were inferred and were reported in Appendix D of the PPR.

3.1.1 Changes to Low Flow Rating

At the low flows at which pumping could occur, the flow behaviour within the River between the pump site and the Dam will be very complex. One would anticipate numerous rock bars, pools, riffles and other bed features to affect flow depths and velocities. Further one could expect that infrequently these features might alter and change the low flow behaviour over time. Even at the pump site where the water level is controlled by a rock bar (or series of rock bars) at the downstream end of the waterhole, and where one would expect the rating to be relatively stable, some movement in the low flow rating is expected. This is because at low flows (e.g. around 38ML/d) the flow past the rock bar(s) is likely occurring between and under gaps in the rocks as well as by overflow of the rocks. These gaps in the rocks can change over time as they become blocked with debris or other gaps open up.

The gauging station at Bruinbun has demonstrated movement in the low flow rating (see **Appendix B**) and the reviewer has been informed by NOW's hydrographers that similar characteristics exist at Bruinbun compared with the Cobbs Hut Hole where pumping is proposed.

3.1.2 Assessment of Low Flow Behaviour along the River

From the reviewer's reading of the documentation, there doesn't appear to have been any formal field inspection or survey of the low flow section of the river bed between the pump site and the Dam.[32]

The hydraulic analyses presented in Tables 3.2, 3.3 and 3.4 of Appendix A of the PPR are based only on assumptions of the low flow channel geometry rather than any real measurements. Under low flow conditions, significant portions of the total river flow may be contained within flow paths less than the 5m base width which was assumed as the minimum width in the assessment presented in the PPR.

If the cease-to-pump flow trigger for the Project is raised from 38ML/d to 108ML/d, the impact of a 15.2ML/d extraction[33] on flow characteristics will be reduced.

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[32] Nevertheless there has been survey of the Gardiners and Cobbs Hut waterholes to facilitate the establishment of HEC-RAS models but this appears principally to have been for medium and high flow purposes. The reviewer is also aware that staff from Geolyse and the Council inspected a portion of the River by canoes when flows were around 33ML/d during December 2012 but it is unclear whether this inspection has contributed to the aquatic assessment presented in Appendix D of the PPR.

[33] i.e. operating for 19 hours or 12ML/d if averaged over a 24 hour period.

3.2 INTERFERENCE WITH THE RIVER GAUGE BY THE PUMPS

Because the pumps will be located within the waterhole where water levels are recorded for Gauging Station 421192, potential exists for interference to occur with the water level recording, particularly at low flows. Based on the existing rating at the waterhole the reviewer understands water levels would drop 45mm[34] if the pumps were turned on whilst the river flow was 38ML/d. Water levels would drop only about one third of this, i.e. 15mm, if the pumps were controlled by a flow trigger of 108ML/d.[35]

Any flow gaugings at the site would always be carried out with knowledge of whether the pumps were on or not. Arrangements could no doubt be put in place so that gaugings were only carried out when the pumps were off. Ultimately this is a matter for NOW's hydrographers to advise on nevertheless the reviewer doesn't consider the proposed arrangement will present any major difficulties.

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3.3 SELECTION OF AN APPROPRIATE CEASE-TO-PUMP TRIGGER

The EA makes reference to NOW's 2002 guidelines for daily extraction management in unregulated rivers (refer Document No 18). As far as the reviewer is aware these guidelines are still in place and provide a general basis for determining an appropriate flow statistic from which to set a cease-to-pump trigger in the absence of site-specific environmental impact assessments.

The adoption of the 80th percentile flow by the Proponent is not in conflict with either the 2002 guidelines or the Water Sharing Plan, subject to the environmental assessment.

3.4 WATER LICENCING – WATER SHARES

The Water Sharing Plan makes no provision for a 'credit' for any water pumped from the River and then released into the catchment of Suma Park Dam. Whilst water pumped from the River would require a licence, the 'same' water subsequently harvested from the Dam would require a further licence.

It is unclear whether this matter has been considered in the EA and whether it has potential to cause a problem with the proposed water licencing arrangements. Nevertheless it is unlikely to present a significant impediment to the Project.

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[34] Whilst 39mm is the water level drop assumed for the aquatic ecology assessment presented in Appendix D of the PPR, as indicated in Section 3.1.3 of Appendix A of the PPR, 39mm is derived from a HEC-RAS model calibrated to the measured streamflow data at the gauging station. The NOW rating at the station shows the drop to be 45mm which will be more accurate than the estimate of 39mm derived from the HEC-RAS model.

[35] This is because as water levels rise higher in a river generally the flow occurs over a wider area and at higher velocities. Consequently for a given rise in water level, e.g. 10mm, a greater increment in flow will occur at higher water levels compared with the increment in flow that a 10mm rise would produce at lower water levels.

3.5 WATER LICENCING – ANNUAL EXTRACTION LIMIT

All water use within the catchments of the Murray-Darling Basin is constrained by the Murray-Darling Basin Cap. NSW is a signatory to these arrangements and is committed to keeping water use at the levels that would have occurred under 1993/94 levels of development in each of its valleys within the Basin. The current Water Sharing Plan (refer Document No 6) reflects the NSW Government's commitment to limiting growth in water use by constraining water use in the Macquarie Valley via the 'long-term average annual extraction limit' that is specified in Clause 32 of the Plan.[36]

It is possible that Council's current water use is below what it was in the 1990s but if water use grows as envisaged by the Project, Council's water use will exceed the 1990s levels. Purchase of water licences could offset this increased growth if the licences were active but this is unlikely to be the case as 'sleeper' licences are normally traded. Ultimately at some point in the future, the continued growth of Orange's water use will constrain or cut-back the water use of third parties in the Valley.

These matters are raised here as they don't appear to be canvassed within the EA or PPR.

3.6 ALTERNATIVE SUPPLIES FROM GROUNDWATER

The availability of additional groundwater supplies drawn from the Orange Basalts or the former Browns Creek gold mine were considered during Council's IWCMES and were the subject of a special investigation by Jewell & Associates which is reported in Appendix B of the PPR.

The groundwater consultant concluded that in respect of both potential sources there was insufficient information available to confirm that either would be able to make a reliable contribution to Orange's water supply. Further detailed studies would be required to prove the viability of either source.

3.7 DECISION SUPPORT TOOL

The reviewer endorses the proposals presented in Appendix C of the PPR for the establishment and operation of a Decision Support Tool that would allow Council to optimise the use of various external water sources (including water pumped from the Macquarie River). The implementation of the tool would facilitate 'optimum' operation of Council's overall water supply system. Of necessity this will involve trade-offs being made involving operating costs, water supply security and environmental sustainability (and the manner in which these trade-offs will be made is not documented).

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[36] The Water Sharing Plan provides a mechanism to constrain water extractions to the long-term average annual extraction limit. Clause 35 of the Plan specifies that at any time after the Plan has been operating for at least five years, the available water determinations for the unregulated river access licences can be reduced in order to return the actual average extractions to the long-term average annual extraction limit. Nevertheless in order for this mechanism to be applied, actual diversions need to exceed the long-term limit by at least 5%. Further given the lack of metering in the Valley, identification that the long-term limit has been exceeded would currently be difficult to establish. Consequently even if growth in extractions was occurring it is unlikely that unregulated river licences would be constrained in the near future.

The inclusion of probabilistic estimates of future inflows would assist in implementing the tool. These inflows should be obtained from the revised river flow model with appropriate allowances made and sensitivity tests carried out considering the potential for climate change, model uncertainties, etc.

3.8 LOSS OF LOW FLOWS BELOW BRUINBUN AND SOFALA

The reviewer understands concerns have been raised by the community that there may be significant losses into the bed of the River downstream of the Sofala and Bruinbun gauges during low flow periods.

The proponent has partially addressed this issue in Section 3.2.1 of Appendix B of the EA. The consideration of the low flow behaviour over the period from 1/11/77 through to 9/1/78 and to a lesser extent, the use of the flow duration curves, suggests that the losses may not be uncharacteristically large.

The reviewer also notes that the possible change in the cease-to-pump trigger to around 108ML/d may also diminish concerns of these potential losses.

3.9 ADDITIONAL SPILLS FROM SUMA PARK DAM

The assessment of additional spills from Suma Park Dam and changes to the flow regime within Summer Hill Creek, have been carried out by Geolyse using the water balance model. These changes are reported in Section 4.3.7.2 of Appendix B of the EA. The reviewer considers it is appropriate to use the water balance model for this purpose.

It is noted that changes to the pumping transfers from the River through adoption of the revised river flow time series suggested in **Section 2.5.2**, will alter the Suma Park Dam spills and the Summer Hill Creek flows. Nevertheless the changes are unlikely to be major.

This is the main weir pool within the Blackmans Swamp Creek stormwater harvesting scheme. This represents Stage 1a of the scheme. Flows are collected behind a gabion weir shown in the bottom left of the photograph. From here flows are pumped to a water treatment plant and then pumped to Suma Park Dam. Collection at present can only occur when Suma Park Dam is below 50% full (i.e. the stormwater harvesting scheme is viewed as an emergency drought relief project). Council has been seeking approval to operate the scheme whenever there is airspace in Suma Park Dam (i.e. Stage 1b of the scheme). Council also has investigated a further expansion of the scheme into Stage 2 which would involve considerably enlarging the storage capacity through construction of an offline storage some distance upstream of this weir. With Stage 2 in place, the secure yield of the City's water supply scheme would increase by 900ML/yr. Nevertheless harvesting water from this Creek system reduces flows in the Creek system downstream and consequently Stage 1b and Stage 2 may not be able to proceed until any potential downstream impacts are addressed.

4. SUMMARY AND CONCLUSIONS

4.1 REVIEW FINDINGS − OVERVIEW

(a) Responses to each of the terms of reference are listed in **Section 4.2** below.

(b) The most significant finding of this review is that the simulated river flows at the pump site are likely to contain a statistical bias because of the use of the Scenario B flow series in the river flow model. It is recommended that the simulation of river flows be reviewed and revised.

(c) Consequently the prediction of the 80th percentile river flow of 22ML/d, leading to a cease-to-pump trigger of 38ML/d, is likely to be unreliable.

(d) In the interim until such time as revised river flows are available, it is recommended that the Project make use of the flow series developed for Water Sharing Plan conditions using NOW's Macquarie River IQQM.

(e) Continuing with the Proponent's proposal to use the 80th percentile flow as the cease-to-pump trigger and applying the IQQM flow series indicates pumping should cease when flows entering Cobbs Hut Hole drop to 108ML/d.

(f) Changes to the flow series will alter the quantum of water simulated as being transferred to Suma Park Dam and as a consequence will likely produce small changes in the output of the water balance model used for the EA and the PPR. A small increase in the secure yield increment attributable to the Project is also likely.

(g) The environmental assessment of river impacts caused by pumping will also change and given the higher cease-to-pump flow trigger, impacts on the environment will likely reduce.

4.2 RESPONSE TO TERMS OF REFERENCE (TOR)

4.2.1 TOR 1: Review of the Hydrological Modelling in the EA and PPR

An independent review of the hydrological modelling contained within the EA and the PPR including:
(i) Strategic Planning and Project Justification (Molino Stewart);
(ii) Hydrology and Water Security Assessment (Cardno),
(iii) Decision Support Tool Framework;
(iv) *Hydrology and Water Security Assessment (Geolyse).*

(a) The review of hydrological modelling is presented in **Section 2** of this report.

(b) The four models used by the Proponent are interrelated as key parts of the models' data are shared between the models.

(c) The review has given particular emphasis to the modelling of streamflows at the proposed pump site on the River. The resultant time series of river flows has been used to assess the potential for pumping to occur and the resultant water volumes that can be delivered to Suma Park Dam.

(d) The worst drought on record commenced in the mid-1890s and this drought has a significant bearing on the calculation of the increment in 'secure yield' which the Project can deliver. The streamflows used for this period have all been synthetically generated by the Proponent's river flow model as no recorded flow data is available in the vicinity of the pump site. Consequently the rigor of these flow predictions has been an important consideration in this review.

(e) The Proponent proposes to adopt the 80th percentile river flow as the pumping trigger. To meet this requirement the EA proposed that pumping only occur when flows exceeded 38ML/d upstream of the pumps. This flow estimate was based on river flow modelling and an assumption that permanent changes in the upstream catchment's runoff response occurred around year 2000. The reviewer does not agree with this assumption and anticipates that the resultant flow series used in the EA and PPR contain statistical bias.

(f) The reviewer believes the river flow modelling used by the Proponent needs to be revised. During the review an alternative river flow time series was obtained from NOW based on their IQQM simulations under the current Water Sharing Plan. In the reviewer's opinion this flow series will likely be similar to that which would result from a revision to the Proponent's river flow model. The flow series indicated that a flow of 108ML/d should be used if the 80th percentile pumping constraint is maintained. This flow of 108ML/d should be the interim cease-to-pump flow trigger until the river flow model is improved and a more accurate assessment of the 80th percentile flow is obtained.

(g) This interim flow trigger is approximately three times that proposed in the EA and the PPR and its adoption will have implications to the aquatic ecology impacts and secure yield assessments and other components of the EA and PPR. As the new river flows suggested by the reviewer are generally higher than those in the EA and PPR, and the new cease-to-pump flow trigger will be higher than the trigger adopted in the EA and PPR, it is likely that reduced aquatic impacts will result. Further, based on preliminary calculations carried out by the reviewer, the pumped volumes available for transfer to Orange may marginally increase and there will likely be a small increase in the secure yield increment attributable to the Project.

(h) The review has also recommended that further documentation of the models' calibrations and validations be provided together with an estimate of the likely uncertainty in the Project's secure yield.

4.2.2 TOR 2: Consideration of Supply Alternatives

Consideration of the alternatives described in above documents and raised in submissions received.

(a) There is a large body of documentation of supply alternatives that has been produced as part of the Integrated Water Cycle Management Evaluation Study (IWCMES) which is currently before NOW for review (and various IWCMES supporting studies).

(b) The process has been, and continues to be, overseen by NOW. It has not been the role of this review to examine the IWCMES and the accompanying process in any detail. The reviewer notes that the process follows the Government's best practice guidelines.

(c) In response to submissions suggesting that groundwater would prove a viable supply alternative to river pumping, a brief review of the supplementary groundwater assessment provided in the PPR was carried out.

(d) This identified that there was insufficient information available to confirm that a viable groundwater supply could be made available to Orange.

4.2.3 TOR 3: Proponent’s Response to Issues Raised

Consideration of the Proponent’s response to issues raised in submissions received such as those from:
(i) Office of Environment and Heritage;
(ii) Department of Primary Industries;
(iii) Orange and Regional Water Security Alliance (and supplementary submissions);
(iv) Orange Rate Payers Association;
(v) Macquarie Marshes Environmental Landholders Association.

(a) The key hydrological modelling issues raised in these submissions have been addressed in the body of this report.

(b) The potential for significant in-stream losses to occur between the pump site and the upstream gauges at Bruinbun and Sofala cannot be entirely dismissed however based on the flow analyses using the Dixons Long Point data presented in the EA, it appears unlikely to be a major concern.

(c) The use of a higher cease-to-pump flow trigger will also reduce the importance of these potential flow losses.

(d) The implications of pumping on the flow behaviour within the River downstream of the pump site have been largely assessed within the PPR based on assumptions concerning the dimensions of the low flow channel/riffles and do not appear to have been based on field survey. The real low flow behaviour will likely be very complex. (The implications of these uncertainties on the low flow behaviour and the adequacy of the environmental assessment are a matter for others to decide).

(e) The Proponent has proposed development of a 'Decision Support Tool' to refine operation of the project works in the future in response to changing water requirements, climate and water availability. If appropriately managed and operated, the Tool has the potential to optimise the use of various external water sources for Orange. Its development is supported.

4.2.4 TOR 4: Preparation of a Report

Preparation of a report providing independent expert advice and commentary on the:
(i) applicability of the chosen models;
(ii) assumptions made;
(iii) results obtained and interpretation of those results.

(a) This report has been prepared to fulfil the requirements of TOR 4.

4.2.5 TOR 5: Level of Confidence and Justification

A statement from the reviewer about the level of confidence and justification of the project considering the above mentioned data.

(a) The hydrological modelling underpinning the justification of the Project has been reviewed. This identified a significant deficiency in the use of the river flow model to generate the 80th percentile flow from which the proposed cease-to-pump flow trigger of 38ML/d was determined. This will require revisions to the river flow time series and the cease-to-pump flow trigger.

(b) Changes to the river flow time series will alter other aspects of the environmental assessment and the secure yield assessment. These will likely diminish the environmental impacts and marginally increase the secure yield increment provided by the Project.

(c) It is not the role of this review to review the overall justification of the Project undertaken as part of the IWCMES as this justification was based on a range of considerations of which hydrology was only one. Nevertheless this review proposes amendment of the cease-to-pump flow trigger which will have flow-on effects on the secure yield increment of the Project and the minimum flows in the river at which pumping can impact on the aquatic ecology.

(d) These flow-on effects will likely alter to support the Project, i.e. the aquatic impacts are likely to be smaller and the secure yield increment will likely be marginally larger than reported in the EA and PPR.

(e) Further the changes proposed in this review are unlikely to alter the preferred option selected as part of the IWCMES.[37]

[37] This opinion is based on the information reported in Footnote 31 and relies on financial analyses undertaken by Geolyse and documented in their memo to Council on 28 March 2013. As part of these analyses Geolyse identified that even with the Scenario B flow series at the pump site and an interim cease-to-pump flow trigger of 108ML/d, the project was still favoured over other projects considered in the IWCMES.

APPENDIX A

BRIEF DESCRIPTION OF 'SECURE YIELD' CONCEPT

Secure Yield Concept:

1. 'Secure yield' defines the water delivery of a supply system under the level of performance listed in (5) below. Systems with demands equal to their secure yield can survive droughts worse than the drought of record.[38]

2. Consistent with NSW Government guidelines and best practice conditions for water supply systems across the state, the Proponent has adopted the secure yield assessment approach as the principal means of determining the adequacy of the:
   (a) *supply* including various alternatives to augment the supply; when compared with the
   (b) *demand* including various demand management alternatives.

3. If the normal demand on a water supply system is no greater than the secure yield then the system should be able to operate with only moderate water restrictions in the event of occurrence of droughts of similar severity to those in the historical record, including the 'federation drought' which commenced in the mid-1890s. The system should also be able to cope with significantly more severe droughts albeit with more severe water restrictions. It has been estimated that water supply systems designed in accordance with this approach would be able to cope with approximately a 1000 year drought.

4. The reviewer considers it appropriate that the secure yield approach be adopted in order to assess the adequacy of the various supply and demand management alternatives for Orange.

5. Whilst the supply conditions which define secure yield have been slightly different in the past, since February 2008 secure yield has been defined in accordance with the '5/10/10 rule' which specifies that:

   (a) *duration of restrictions* does not exceed 5% of the time; and
   (b) *frequency of restrictions* does not exceed 10% of years; and
   (c) *severity of restrictions* does not exceed 10%. This means systems must be able to meet 90% of the unrestricted water demand (i.e. 10% average reduction in consumption due to water restrictions) through a repetition of the worst recorded drought, commencing with the storage drawn down to the level at which restrictions need to be imposed to satisfy (a) and (b) above. In other words, if a water utility implemented a restriction system that provided for (a) and (b) over the long term, then if the storage was drawn down to the level at which restrictions were applied and then the worst historical drought was to repeat itself, a supply equal to 90% of the normal demand could be provided without emptying the storage.[39]

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[38] Many of the concepts presented in this appendix have been sourced from Documents Nos 7 and 13, and from Appendices A and B of Appendix B of the EA.

[39] Because the worst historical drought is assumed to commence with the storage already drawn down to the restriction level (rather than being full), this assumption will be more severe than historical and consequently the frequency of such an occurrence has been roughly estimated to be 1000 years by WS (refer Document No 7 and Appendix B of Appendix D of the EA).

6. The calculation of secure yield for this project has been carried out by NSW Water Solutions (WS) within the Department of Public Works using custom built software. The software iterates to determine the secure yield by:
   (a) initially estimating the volume (C) at which restrictions are applied such that the frequency of restrictions is less than one year in ten and those restrictions do not occur for more than 5% of the time. This is called the restriction volume;
   (b) then, assuming that the storage has been drawn down to the restriction volume C, the procedure checks whether average supplies of 90% of the secure yield could be provided if the worst historical drought then occurred.

7. **Figures A1** and **A2** below illustrate the secure yield concept and the method of calculation. The figures have been adapted from similar figures in Document No 7.

8. The above procedure is used for strategic planning assessments. The method is standardised and can be applied consistently across the State. The method may not necessarily predict the actual manner in which restrictions are applied by a water utility.

9. For the water supply system at Orange modelling by WS has shown that the critical drought period occurs over the period 31/10/1894 to 20/03/1900.[40]

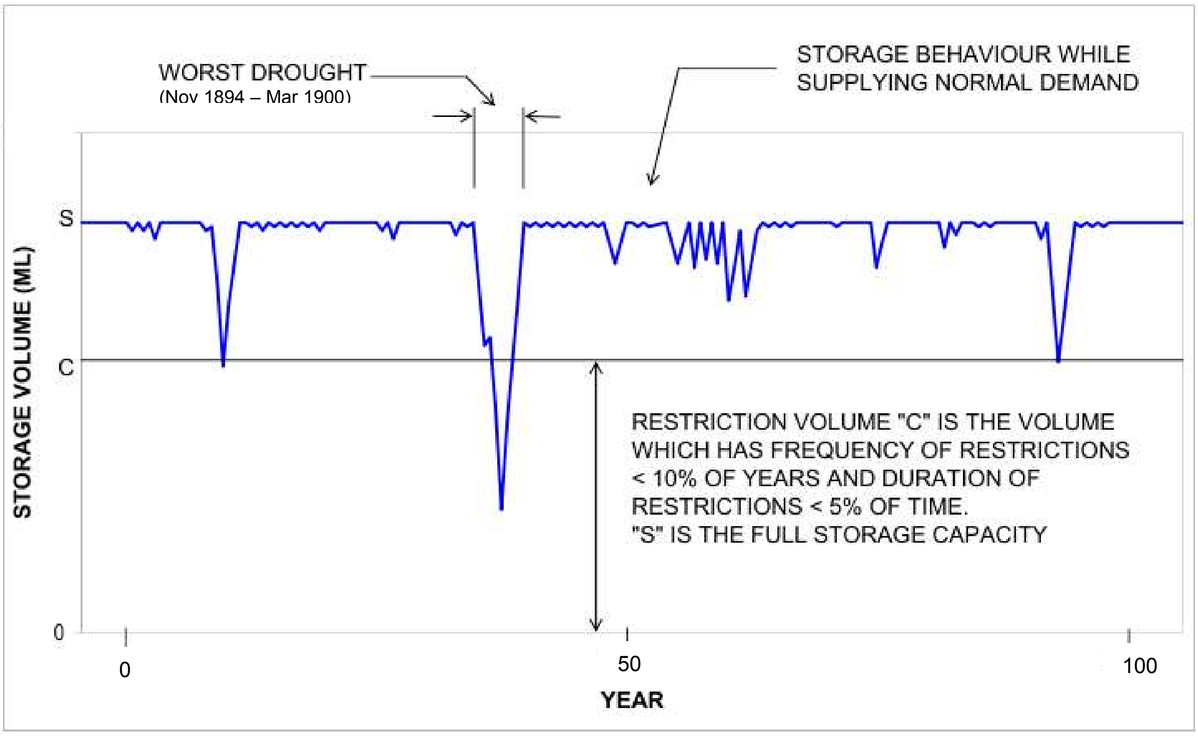

Figure A1: Step 1 – Determine Restriction Volume C

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[40] Refer secure yield summary results provided in Table 9E-2B of Appendix A of Appendix D of the EA. Note that this drought period will vary slightly depending on the system configuration. In addition, the restriction volume was determined to be 45% of the combined storage volume available in Suma Park, Spring Creek and Gosling Creek Dams.

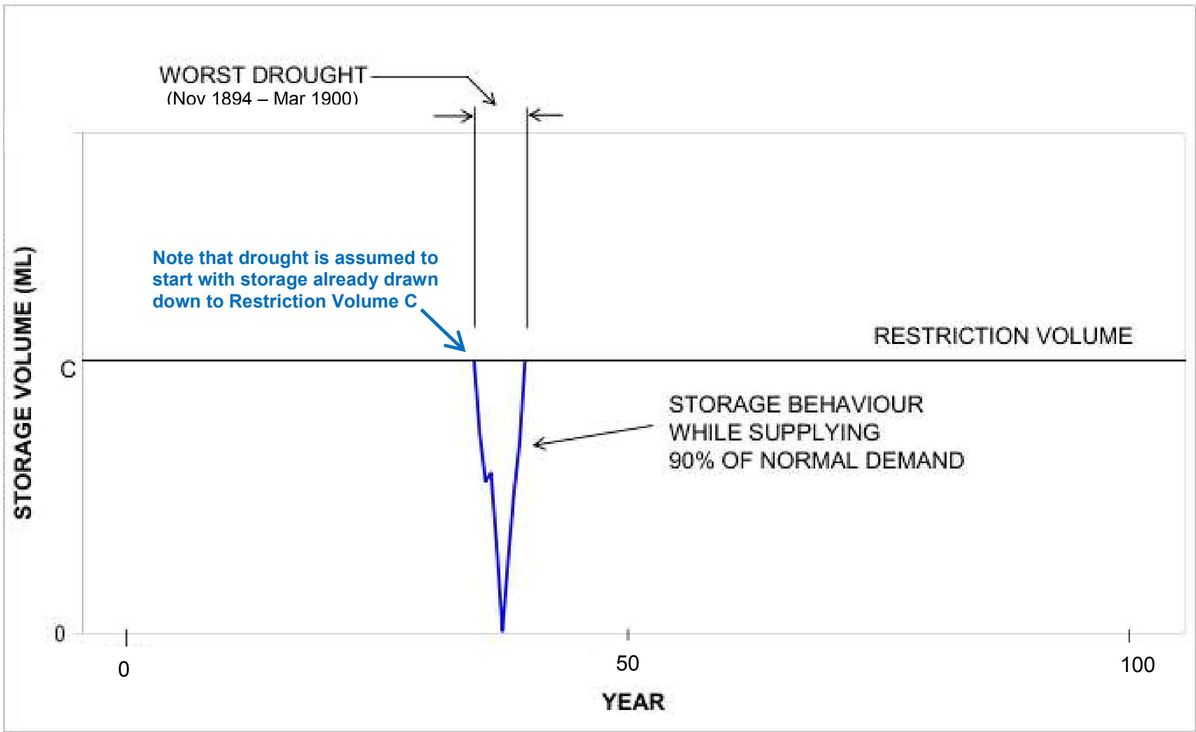


Figure A2: Step 2 – Supply during Worst Drought

APPENDIX B

RATING TABLE INFORMATION PROVIDED BY NSW OFFICE OF WATER

NSW Office of Water

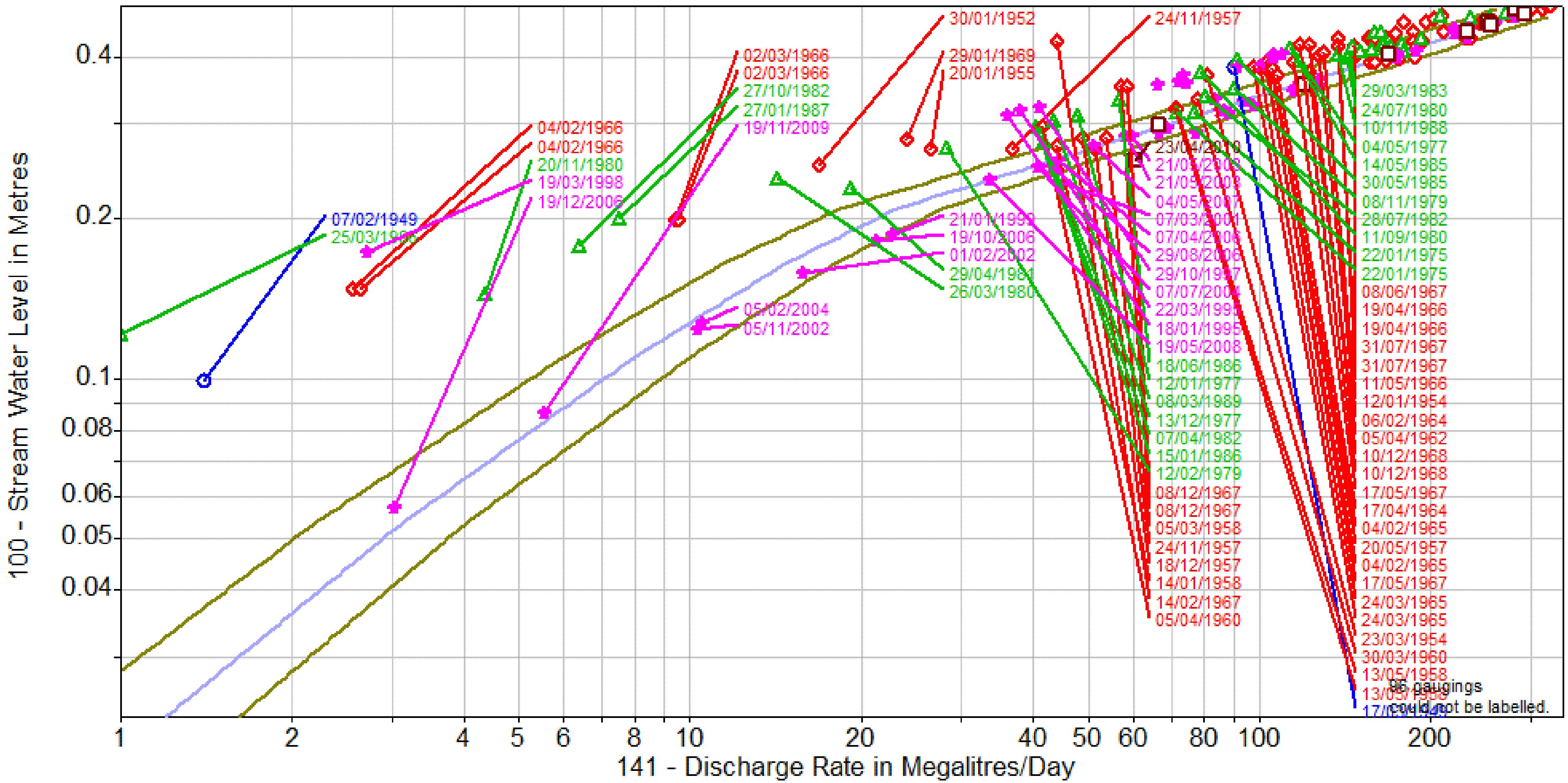
HYGPLOT V142 Output 05/03/2013

421025 MACQUARIE RIVER AT BRUINBUN

Gaugings from 11/09/1947 to 22/11/2012

○ Up to 01/01/1950 ◇ Up to 01/01/1970 △ Up to 01/01/1990 ✱ Up to 01/01/2010 □ Up to 22/11/2012

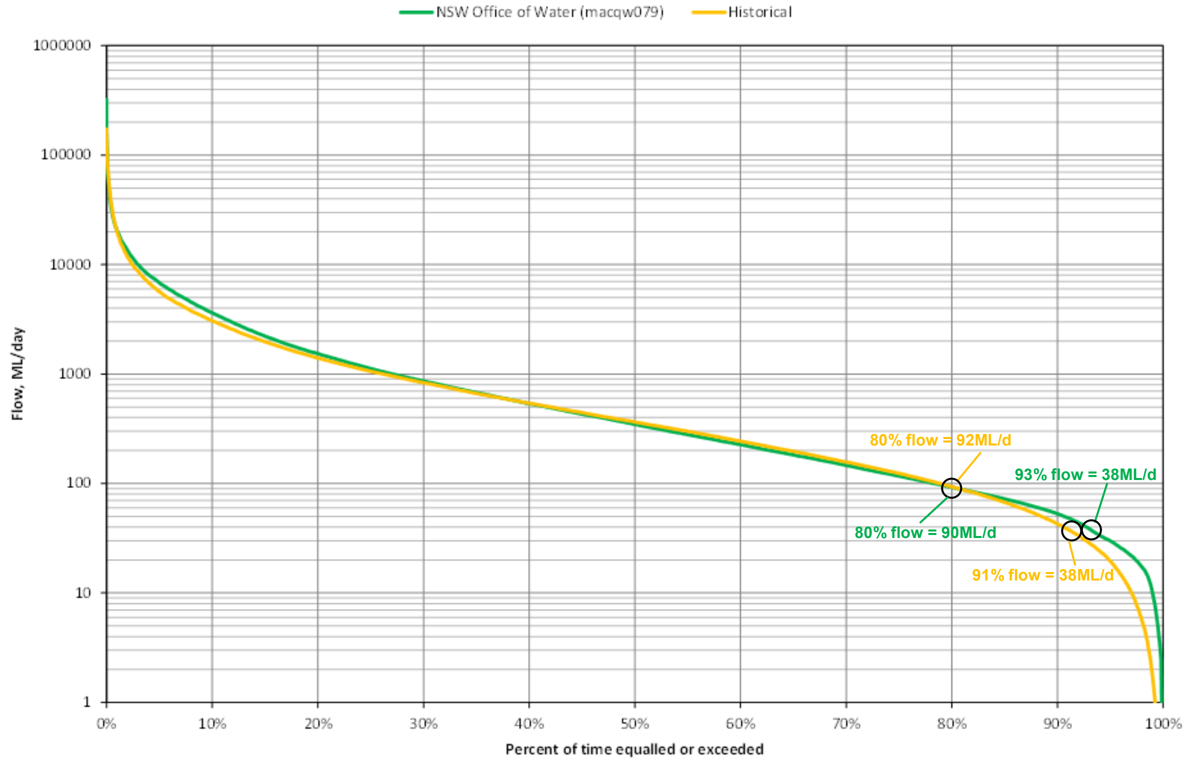
Rating Table 190.02 RT 190.02 12/12/2006 to Present



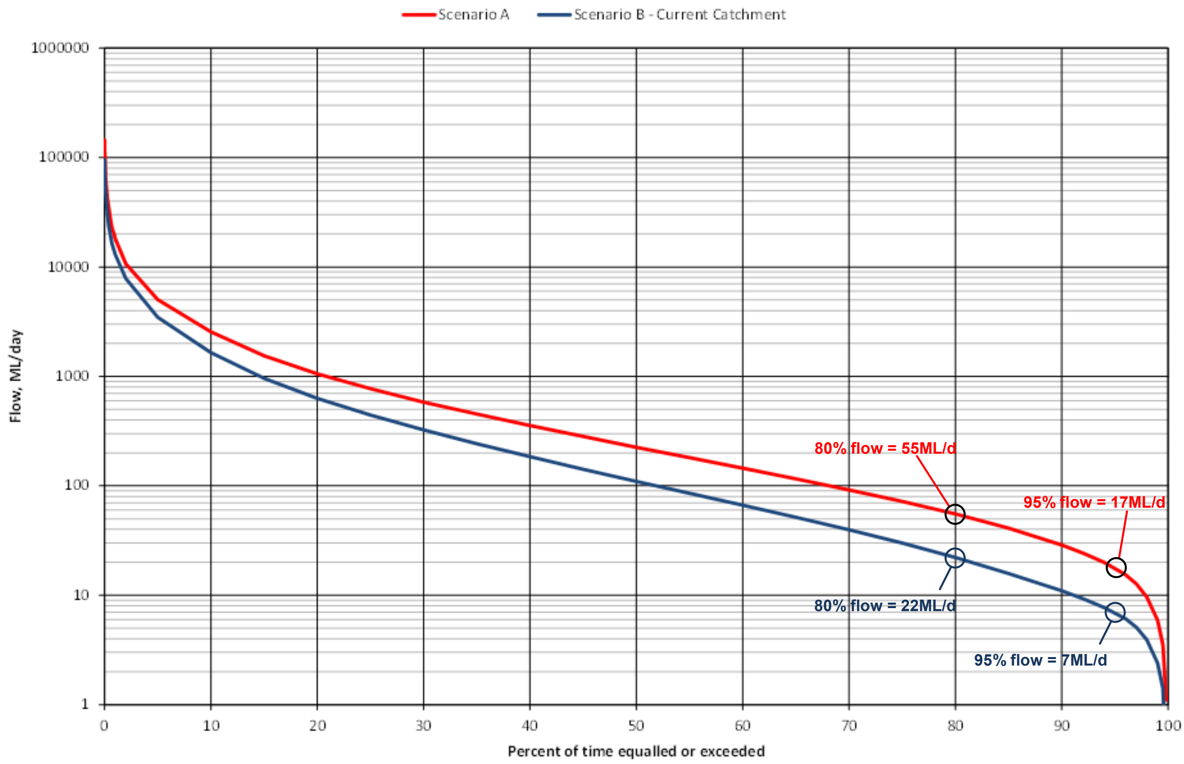
APPENDIX C

REVISED FIGURES 25 AND 26

(Provided to reviewer by Geolyse in March 2013
to rectify minor typographical errors within these
figures in Appendix D of EA).



Revised Figure 25 from Appendix D of EA (with coloured annotations by reviewer)



Revised Figure 26 from Appendix D of EA (with coloured annotations by reviewer)