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Date: 8 August 2020

An Expert Review of the Narrabri Gas Project Environmental Impact Statement and Response to Submissions

Introduction

I have been briefed by the Environmental Defenders Office (EDO) acting on behalf of the North West Alliance to provide expert advice relating to the Narrabri Gas Project Environmental Impact Statement (EIS), Response to Submissions and associated documents. My review specifically addresses the following issues in relation to Aquatic Ecology, Groundwater Dependent Ecosystems (GDEs) and specifically Stygofauna or subterranean Aquatic Ecosystems.

Issues to address in my expert report include:

a) In your opinion, is the assessment of any aquatic and Groundwater Dependent Ecosystem impacts arising from the Project adequate?
b) In your opinion, has the assessment material appropriately identified the potential impacts on aquatic and Groundwater Dependent Ecosystem as a result of the Project?
c) Do the recommended Conditions of Consent adequately address any of the concerns you have raised above?
d) Provide any further observations or opinions which you consider to be relevant.

Key documents relating to the Project that I examined include the following:

Environmental Impact Statement	a) Executive Summary:
	b) Table of Contents
	c) Chapter 7 - Produced water management
	d) Chapter 11 – Groundwater and Geology
	e) Chapter 12 - Surface water quality
	f) Chapter 16 – Aquatic ecology: Aquatic Ecology and Stygofauna Assessment
	g) Chapter 29 - Cumulative impact
	h) Chapter 30 - Environmental management and monitoring
	i) Appendix C - Field Development Protocol
	j) Appendix F Groundwater Impact Assessment – Appendix B - "GDE Impact Assessment Report
	k) Appendix G1 - Managed release study _Bohena Creek
	l) Appendix G3 - Water monitoring plan
	m) Appendix G4 - Water baseline report
	n) Appendix H - Hydrology and geomorphology
	o) Appendix J1 - Ecological impact assessment 1 of 2
	p) Appendix J1 - Ecological impact assessment 2 of 2
	q) Appendix V - Rehabilitation strategy
Response to Submissions	a) Response to Submissions (Executive Summary (pp 5-8 of 482), The Project (pp 38-47 of 482), Aquatic ecology (pp 334-344 of 482)
	b) Appendix D – Water Baseline Report (pp 220-327):
	c) Supplementary Response to Sub (Produced water management 2-24 - 2-28, Appendix A -Water baseline report addendum pp 67-74 of 92)
	d) EPA - Final Advice on Fugitive Emissions:
Department's Assessment Report	a) DPIE Final Assessment Report (Executive Summary pp 3-19 of 392, Aquatic species 94 of 392, Biodiversity 102-118 of 392)::
	b) Recommended Conditions

I declare that I have made all the inquiries which I believe are desirable and appropriate (subject to any qualifications in this report), and that no matters of significance which I regard as relevant have, to my knowledge, been withheld. I have read and I agree to be bound by the Expert Witness Code of Conduct contained in Schedule 7 of the *Uniform Civil Procedure Rules 2005*.

Disclaimer
The opinion provided is based on a combination of field-based examination of the project area and my experience and expertise in surface freshwater ecology and groundwater dependent ecosystems. The review and opinions presented here are solely my own.

Qualifications as Expert
Annexure A to this report has a copy of my curriculum vitae.
I have the following qualifications:

a. 2015 - PhD, the University of New England. Title Taxonomy and Systematics of the Anaspidacea.
b. 1988 - Bachelor of Science. Honours, the University of Tasmania.
c. 1986 - Bachelor of Science. Majoring in biology and geology, the University of Wollongong.

Executive Summary

The review of the above documents has highlighted a number of issues with the execution of the aquatic and groundwater assessments, interpretation of findings and thus the final conclusions. These issues include:

- In summary, the consent authority cannot make an appropriate assessment of the impact of the proposed operation on the Groundwater Dependent Ecosystems (GDEs), including the subterranean Stygofauna community based solely on the data and interpretation of the data provided by Santos in the relevant sections of the EIS.
- It is recommended that due to the deficiencies in the EIS to adequately assess the ecological values of the groundwater and surface water ecosystems and the potential impacts of the proposed operation to these water sources, their associated biodiversity and the dependent Landholders dependent on the level and quality of these water sources it is imperative to utilise the 'Precautionary Principle' to reject the proposal outright or require significant additional work and mitigation to be conducted to address the deficiencies outlined in this review.
- The GDE section of the EIS (Chapter 11) presented an over-simplification of what constitutes a GDE by reliance on the classification described in Eamus and Froend 2006. Serov et al 2012 provides a far more detailed GDE classification that would enable the GDEs to be divided into not only more types but subtypes. This is important in that each type and subtype of GDE has varied environmental requirements that are impacted to differing degrees by potential changes in water chemistry, water levels, water pressure and aquifer structure that would enable a more effective impact assessment.
- A misinterpretation of groundwater cues in the landscape and a downplaying of the ecological values within a sand-based ecosystem as well as neglecting important groundwater habitats and dependant organisms. This will require the assessment to be re-examined in detail.
- The inappropriate use of satellite imagery to determine groundwater dependency of wetlands. Although informative on the general physical characteristics of the wetlands, it is not an effective or appropriate method for assessing groundwater dependency.
- There was a lack of appropriate interpretation of the ecology of water dependent flora and fauna present in relation to groundwater dependency.
- There appears to be no recognition in the assessments that the Pilliga forest is covered by the Lowland Darling aquatic endangered ecological community (EEC) listed under the *Fisheries Management Act 1994* or that the Pilliga contains significant recharge zones for the Great Artesian Basin groundwater source. These important components of ecological value were not included in either the surface aquatic ecosystem assessment or the GDE assessments. This is important in the process of assignment of ecological value of the GDEs using the NSW GDE Risk Assessment Guidelines (Serov 2012). The 2012 GDE Assessment Guidelines stipulate that the first stage of assigning ecological value is to determine if the GDE already occurs within a recognised area of High Ecological Value (HEV). If they do then all GDEs occurring within the zone of investigation are automatically assigned a HEV. Therefore, all GDEs listed within the Pilliga are of High Ecological Value.
- The presence of significant recharge zones of the Great Artesian Basin highlights the value of keeping the Pilliga Forest pristine and unimpacted. Any impacts to the water entering the Great Artesian Basin has the potential to significantly impair the largest groundwater source in Australia.
- In addition, the Pilliga area and its waterways have been acknowledged recently by the CSIRO (2018) in the 'Namoi Bioregional Assessments' to be a unique and separate ecosystem within the region due to its unique geomorphology. The "Upland Riverine Landscape Class in the Pilliga region" was addressed within a separate modelling exercise due to the streams in this region having a unique set of conditions. These streams were characterized as having sandy beds, temporary flow with some permanent pools above highly stratified sandstone. Therefore, the streams and aquatic biodiversity cannot be compared with the surrounding region. For this reason, the aquatic ecosystems (streams and wetlands) should be recorded as having high ecological value.

- The inference of groundwater dependency is an essential component of determining the presence of GDEs, however this is described in Serov et al 2012 as an early stage in the assessment process that is intended to highlight potential GDEs but not to be used to cut out potential sites altogether. The process of confirmation of groundwater dependency requires a field-based hydrogeological investigation of this dependency before sites are classed as not being a GDE. The investigation would normally use a combination of: an examination of groundwater depths from nearby bores in relation to the water levels in the wetlands and streams; comparing the water chemistry and water quality of the groundwater and surface water for groundwater chemical signatures such as a number of isotopes, as well as aquatic faunal composition. Temperature variation of the groundwater and surface waters over time is also an effective method for determining groundwater connectivity. Considering the time available for this predevelopment study there was ample time to conduct a more effective longer-term monitoring of these variables. Without this data it is not possible to rule out any particular wetland as being a GDE. As the detailed confirmation of GDE dependency was not done even after the limited field confirmation, the conclusions of this EIS cannot be substantiated.
- Inappropriate and insufficient sampling of stygofauna within and downstream of the project and over a sufficient time period.
- Although no stygofauna were collected in the Santos EIS study, **a significant stygofauna community exists within the shallow alluvial aquifers and the deeper sandstone aquifers across the Pilliga and adjacent aquifers** and have been recorded on multiple occasions (2007, 2011, 2012. 2013, 2015, 2017 and 2020) by Dr Peter Serov.

Detailed Review of Appendix B - "GDE Impact Assessment Report":
The following policy should be included under section 2.2, page 2-2. It should be noted that the activities undertaken and the assessments are compliant with this additional policy: 'NSW Groundwater Quality Protection Policy, Department of Land and Water Conservation, 1998.' http://www.water.nsw.gov.au/Water-Management/Law-and-Policy/Key-policies/default.aspx

1. Section 6.2 "Potential Impacts to GDEs" (pg. 6-5) does not identify all the relevant potential impacts. The following potential impacts should be included and assessed as required.

a. Contamination of lands surface and streamways from gas well wastewater spills as well as leakage of well wastewater from the earlier evaporation/holding dams into the very porous alluvial sediments and Pilliga sandstone aquifer.

b. Contamination of aquifers from damaged or incorrectly installed or aging gas wells.

c. Contamination of naturally isolated aquifers during the drilling process by creating connectivity through leakage between aquifers that had previously been isolated through poorly constructed or aging wells. The connection between shallow aquifers with deeper aquifers or aquifers with surface waters can cause the introduction of waters with significantly different water chemistry such as higher or lower dissolved oxygen levels and higher salt loads into the receiving aquifers. This connectivity can also allow the introduction of foreign organisms such as surface sulphur reducing bacteria and surface invertebrates into aquifer ecosystems that were previously isolated thus impacting on the endemic fauna through invasion or impact to the water chemistry or habitat structure via clogging of the flow pathways.

d. The impact of drawdown on the biodiversity of water level sensitive taxa, such as mussels in refugial baseflow pools within the streams such as Bona Ck and Coghill Ck, has not been considered in the assessment process.

e. There is no discussion at all of speed or timing of drawdown or frequency of drawdown of the alluvial and Pilliga Sands aquifers. This is a significant factor that needs to be considered as the rate of drawdown is a critical factor for terrestrial vegetation communities dependent on groundwater as well as the water level sensitive surface aquatic fauna and the stygofauna present in thin water bearing zones.

2. The assessment does not appear to have used a robust methodology in ecological value assignment. GDEs have been assigned a lower ecological value as a result. It is recommended that a comprehensive ecological assessment is conducted that compares and ranks the aquatic ecosystems solely within the Pilliga. The Risk Assessment process appears to have made some incorrect assumptions on groundwater dependency and associated risks. It is recommended that this process is re-examined as some of the outcomes are questionable and will need to be reconsidered.

Pg. 8-1, section 8 “Conclusions”: It is concluded that “all type 2 GDEs have low ecological value”. This is based mainly on whether there is any listed threatened species. There needs to be a far more detailed on-ground ecological assessment conducted to refine this valuation based on the characteristics of aquatic habitats across the Pilliga. The invertebrate identification for the aquatic taxa also needs to be at the species level as family level is only used in rapid condition assessments and is not very informative for assessing conservation value.

The Pilliga forest (except for the southern margin which is in the upper catchment of the Castlereagh River) is covered by the Lowland Darling aquatic endangered ecological community (EEC) listed under the *Fisheries Management Act 1994*. This does not seem to have been included in either the surface aquatic ecosystem assessment or the GDE assessments. Within the GDE assessment, the first stage of assigning ecological value asks if the GDE occurs within a recognised area of high ecological value and, if it is, then all GDEs in that area are automatically assigned a High Ecological Value. Therefore, all GDEs listed within the Pilliga are of High Ecological Value. In addition, the Pilliga area and its waterways have been acknowledged recently by the CSIRO (2018) in the ‘Namoi Bioregional Assessments’ to be a unique and separate ecosystem within the region due to its quite unique geomorphology. The “Upland Riverine Landscape Class in the Pilliga region” was addressed with a separate modelling exercise due to streams in this region having a unique set of conditions. There streams were characterized as having sandy beds, temporary flow with some permanent pools above highly stratified sandstone. Therefore, the streams and aquatic biodiversity cannot be compared with the surrounding region. For this reason, these aquatic ecosystems should be recorded as having high ecological value.

The EIS also reports that the Pilliga streams are considered to be not disturbed or impacted compared with the Namoi River and wetlands to the west of the area. Therefore, in terms of overall condition they must be considered to have high ecological value. This is not reflected in the EIS assessment. There must be a comprehensive ecological assessment conducted that compares and ranks the aquatic ecosystems solely within the Pilliga. It is only then that an adequate and representative ecological value can be assigned to each location. If this is done many of the aquatic habitats will be classed as having a much higher ecological value and ecosystem condition.

3. Inappropriate methodologies have been employed to assess aquatic ecosystem conditions and this should be rectified.

The surface water aquatic assessment of aquatic ecosystem condition used the AUSRIVAS technique to sample the macroinvertebrates. This is a rapid aquatic ecosystem condition assessment technique developed to give a quick condition assessment using a snapshot of aquatic biodiversity from only two habitat types i.e. pool edge and riffle zone. It is not an adequate aquatic biodiversity assessment of each location and cannot be used as a comprehensive biodiversity assessment. This is particularly the case as the base identification level is only to family level. They have not sampled all available aquatic habitats or niches present or identified the taxa to species. They therefore would be unable to determine if there were any threatened species, short range endemic species, groundwater dependent species or species sensitive to habitat disturbance such as water level or water quality change. It is noted that a number of the sites assessed for groundwater dependency and ecological value were not sampled for aquatic macroinvertebrates and water quality, but instead relied solely on satellite imagery. This is by no means adequate to effectively assess the aquatic biodiversity and its ecological value of an area.

4. The GDEs are generally not well categorised and/or characterised or the following requires consideration.

a. The GDEs presented here are either off river springs and wetlands or terrestrial vegetation. There is no consideration of river-based pools, or off channel pools which are recognised to be present.

b. There also appears to be a complete lack of understanding of which terrestrial vegetation is considered to be groundwater dependent. The EIS does not relate the dependency of the surrounding GDE or other vegetation e.g. rooting depths of known groundwater dependencies of terrestrial species such as. Red Gum and Rough-barked Apple (known as phreatophytes with specific rooting depths) to actual groundwater depths.

c. Only limited attempts appear to be made to determine groundwater depth at or near wetlands and terrestrial GDE location even though there are bores in close proximity to many of these potential GDEs. The significance of this is that in order to determine if an aquatic or terrestrial ecosystem is potentially connected to groundwater it is essential to know what the surrounding groundwater level is. In regards to streams and wetlands if the groundwater level is the same or above the surface water levels or within the root zone or vadose zone (semi saturated zone) in these habitats then they are gaining aquatic systems which means the groundwater is draining into them or assessable to the root zone (Serov et al 2012). The opposite is a losing system where the groundwater level is significantly lower than the surface water levels or tree root zone and the surface water is draining into the groundwater. Groundwater dependency can only be positively determined when there is an adequate understanding the relationship between the surface water levels, tree zone levels and the groundwater levels.

d. There was also only limited water quality data collected as one-off data points. Given the length of time Santos has had to prepare the EIS there should have been a time series of water quality monitoring conducted over the last 3-4 years to: 1) establish the pre-development water chemistry levels and natural annual fluctuations and to compare water physio-chemical fluctuations between the surface habitats and the groundwater. Additional water chemical parameters should have included a full water chemistry assessment (including metals, isotopes and BTEX chemicals) of each water source (wetlands and the nearest groundwater bore in order to determine 1) hydrologic connectivity between the water sources and 2) as a benchmark for future monitoring of any water chemistry changes that are outside the natural thresholds. If this is not done then it will be very difficult if not impossible to determine if there has been any impact through contamination or groundwater level change from the installation and operation of the gas wells.

5. The following comments relate to “Appendix B – GDE characterisation sheets”:

a. Some comments and assessments are contradictory to the water quality data i.e. in Yarrie Lake it is stated that “as the water is extremely turbid (469 NTU), it has prevented sunlight penetration and kept the temperature low (12 C). The low temperature and freshness of the water (184.1 µS/cm) make it unlikely that groundwater makes a significant contribution to the hydrology of the lake”. The interpretation of the water quality data is not correct as cold water is usually considered a sign of active groundwater discharge. They did not stipulate if the cold water was a result of thermal stratification which is usually caused by high turbidity or whether they simply measured the temperature from the bank. Given that the normal measuring regime for the AUSRIVAS protocol stipulates that measurements are taken from the edge of the pool or the riffle, it is assumed that this is how it was taken. Therefore, they could not have inferred that the low temperature was the result of thermal stratification and the statement is wrong. It is also unusual that other sites with a high turbidity did not record similar significantly lower temperatures. There was no comparison of the temperature ranges of the nearby bores. This lower temperature of the wetland is likely to be a characteristic of the local groundwater source. The deficiencies noted needs to be rectified.

b. The location and surface area of each groundwater source and the GDE’s dependent on each was not determined. One of the first steps in identifying and valuing a GDE is to understand which aquifer or groundwater source it is connected to. This is essential in determining the risk level of impact on individual aquifer water level and water chemistry changes to a GDE Therefore, as this delineation and separation of aquifers was not done the assessment of value and risk assumes that there is only one aquifer across the area and the ecological value and risk will be uniform across the whole area. As the groundwater report lists a number of geological units and aquifers across the project area the risks to each aquifer and its associated GDEs from drawdown or water contamination will vary and has not been correctly calculated. Indeed, the statement repeated continuously throughout the document that "there will be only less than 0.5m drawdown of the aquifers over the life of the operations" indicates that this drawdown is uniform across the area i.e. is the same for each of the different aquifers irrespective of connectivity, porosity and transmissivity. This assessment therefore completely ignores the potential differential impacts on water levels, water pressure, and water chemistry on the GDE's within each aquifer. Consequently, GDE values and risk needs to be reassessed using a more detailed assessment of each aquifer and its associated GDEs.

c. Round Swamp Summary Sheet page 2: Round Swamp is assessed as not being groundwater - fed based on satellite imagery and was not visited. As this lake is not on a water course, is permanent and has extensive macrophytes developed, it is inferred to be spring fed. Without additional groundwater data the satellite imagery used it is not sufficient to test this groundwater dependency. Therefore, additional data/information is required to reassess ground water dependency of Round Swamp.

6. The following comments relate to "Table A3: Assessment of likelihood of feature being a GDE and decision to proceed to next stage of works". (Appendix A – Potential GDE reference tables, pgs. 65-71)

a. Pg. 68: The statement referring to Site 41 – "Pool is located in watercourse; water is very murky which suggests it is surface water" is inappropriate. Although the clarity of the water in fast/active springs can be very clear (and cold) in most cases where there is slow discharge of groundwater, particularly through clay based soils which are easily disturbed, the water can be very turbid therefore water clarity should only be used as an general indicator of groundwater discharge where the there is a fast discharge through sand/gravel/bedrock substrate. In addition, many of the wetlands are reported to be impacted by stock or feral animals such as pigs which significantly damage the banks and pool bottoms resulting in very turbid waters. Unless each wetland has been fenced off from these animals it is not possible to use turbidity in the assessment of groundwater dependency except in the case noted above. The wetland groundwater dependency assessments using water clarity as a determinant should be retracted and reassessed.

b. Pg. 68: The comment relating to Site 52 - "(Wetland) Located on a creek line, (therefore) likely to be surface water fed" is an incorrect assumption that precludes the presence of riverine baseflow supporting instream pool as refugia. The wetland groundwater dependency assessments using stream bed location as a determinant should be retracted and reassessed.

Excerpts from Serov et al (2012) – "*Most streams that drain the eastern and western margins of the Great Dividing Range originate as spring or seepage fed watercourses and have a significant groundwater baseflow component downstream*."

"*Base flow, by definition, is stream flow that is supported entirely by groundwater discharge, Wilson and Moore, 1998. Strong interactions between streams or rivers and the groundwater system are usually associated with shallow aquifers. If the water table or groundwater level in an aquifer is higher than the running level in a stream, groundwater will flow or discharge to the stream. In this case, the stream is defined as a 'gaining stream', and the groundwater discharge is called 'baseflow'"*

"*Streams that begin in extensive permeable aquifers generally have a stable point of origin and sustainable discharge from their headwaters and throughout the aquifer."*

"River base flow ecosystems include a combination of subsurface and surface ecosystems depending on the structure of the river bed sediments. Groundwater base flow in sand-bed and gravel-bed rivers support both riparian vegetation and in-stream macrophyte communities, surface water aquatic

invertebrate communities, and a specialised community of invertebrates (termed hyporheos) that exist below the river bed / substrate surface in the hyporheic zone."

The presence of permanent wetlands is termed 'Window Wetlands' where the water level is a reflection of groundwater levels. These wetlands (and streams) are occupied by organisms that require permanent inundation. In the case of a number of Pilliga wetlands this includes large populations of freshwater mussels, crustaceans, sponges and aquatic invertebrate groups that have limited dispersal capabilities and are therefore very sensitive to water level (and quality) variation.

c. Pg. 68: The comment relating to Site 56 – "Dark murky water suggests no groundwater influence". Again, this is false assumption. See above comment.

d. Pg. 68: The comment relating to Site 58 – "Wetland vegetation but most likely pooled surface water". This statement needs clarifying in terms of wetland vegetation type. Wetland vegetation generally implies that there is a relative permanence to the water within the wetland and can in itself imply a groundwater connection. In addition, it is the wetland vegetation type and species that give a more direct indication whether there is a groundwater contribution. Therefore, additional information is required to clarify the statement.

7. The following comments should be rectified and/or noted as appropriate:
a. Pg. 5-5, section 5.1.4 "Summary" states that "Bohena Ck and Coghill Ck have perennial flow regimes and are more likely to recharge groundwater than receive groundwater". This is an incorrect statement as perennial streams are far more likely to be receiving groundwater as gaining streams. Indeed, even during dry periods when there is no flow or water in the main channel there is permanent riverine pools and a baseflow under the sand substrate. Under these observations it must be inferred that these streams are a significant GDE along their length. This GDE type was not included in the Type 2 GDEs listed. It is recommended that it be included and assessed as appropriate.
b. Pg. 5-9: The first paragraph confuses type 2 and type 3 GDEs.
c. Pg. 5-9: The location of both type 3 and 2 GDEs is a function of topography and geology.

Detailed Review of EIS Chapter 11. Groundwater and Geology

1. Appropriate GDE classification has not been used. It is recommended that Santos consider using the GDE classification system outlined in Serov et al. 2012
Pg. 11.41, section 11.4.6 "Environmental Values" - While two methodologies are stated to be used i.e. (Richardson et al. 2011) and (Serov et al. 2012) the classification of GDEs adopted in the EIS i.e. (Eamus and Froend (2006)) was not used within Serov et al. 2012. Serov et al. 2012 divides GDEs into 7 broad types. Under the 2012 classification the area encompassing the Santos development would have 5 major GDE types. These are:
a. Subsurface phreatic aquifer ecosystems (Stygofauna).
b. Baseflow stream (hyporheic or subsurface water ecosystems – Hyporheic/stygofauna).
c. Groundwater dependent wetlands.
d. Baseflow streams (surface water ecosystems).
e. Phreatophytes – Groundwater dependent terrestrial ecosystems.

Pg. 11.41. Potential Type 2 GDEs exist at nine sites and are assessed to have low ecological values due to the absence of protected or important wetland species, and heavily or moderately modified conditions.

Under the definition of Type 2 GDEs as defined by Eamus and Froend (2006) there are actually three distinct ecosystem types. These being 1) groundwater wetlands, 2) instream surface pools and surface flow and 3) subsurface hyporheic ecosystems. The ones listed by EcoLogical only take into account waterholes therefore they are under-representing the number of ecosystems present. The issue with the classification presented by Eamus and Froend (2006) is that it is an outdated and overly simplified classification that gives a false representation of the number of GDE types present, allowing for the misidentification and under representation of the number and diversity of GDEs within a defined area. More recent classifications such as Serov et al 2012 give a more comprehensive and ecologically relevant classification system. In assessments such as this, using the Eamus and Froend classification allows for important, sensitive ecosystem types to be ignored and therefore not included in the assessment. An example of this misrepresentation is the lack of reference to the Subsurface Hyporheic Ecosystem (GDE Type 1.2 in Serov, et al, 2012). This ecosystem is a vital and distinct component of the baseflow riverine environment that in this case has been grouped with the obligate aquifer stygofauna community and in so doing has led to a misrepresentation of what stygofauna actually is. It has also degraded the value and inherent natural composition of this community through poor sampling design and an insufficient number of sampling sites. The condition of these ecosystem types has not been conducted in relation to the natural state within this area.

2. The report needs to reconsider the assignment of GDEs as 'heavily or moderately impacted' within the site

"The condition of these GDEs is heavily or moderately impacted". In my opinion this is an incorrect assessment of the condition of these streams. The reason for this opinion is based on the following facts. The sand-based stream ecosystems present in this area are a unique ecosystem type. While generally having a lower biodiversity than other regions, they are unique in their geomorphology and faunal associations; are part of an EEC; have water level sensitive fauna and locally restricted fauna; have fauna that occur at the edge of their ranges; have a higher biodiversity in some groups than the rest of the region; and have habitats that are regional refuges, and therefore of high value.

3. The following comments should be rectified and/or noted as appropriate:

a. The statement regarding type 3 GDE's being able "to source soil water from rainfall recharge and surface flow events within alluvial settings", while true in respect of the fact that all terrestrial vegetation communities use rainfall, is used here to down play the role of groundwater to these ecosystems. The definition of a GDE within Serov et.al. 2012 is "'Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater." This indicates that these ecosystems would not be present without the access to groundwater. The proponent's statement must therefore be removed because it is misleading.

b. The statement that "Groundwater dependent ecosystems are protected through both State and Federal Government legislation" is true at a broad conceptual level. The same legislation also acknowledges the lack of information currently available and stipulates a methodology for assessing the ecosystems. Within NSW, high priority sites are listed under Water Sharing Plans enacted through the *Water Management Act 2000*. This classification is often misunderstood and confused with the threatened species legislation. It refers to a first stage listing of groundwater ecosystems which are considered high priority for management action. This listing includes only those known GDEs that are either or already protected under other legislation, occur within a protected area or are specific types of GDEs (have an obligate groundwater dependency) such as springs and caves. It is not a high ecological value classification until an appropriate ecological and conservation assessment has been conducted. As these assessments have not been done for the identified GDE types in this area the use of this classification here is only to acknowledge the presence of the springs. It should not be used to discredit the value of the other identified GDEs because they had not been listed. The value of the High Priority listing is to demonstrate that spring ecosystems are protected in NSW.

c. Water level sensitive threshold species have not been established.

4. Threatened species and threatened communities potentially present at the site have not been adequately recorded/identified/assessed.

The use of Threatened Species and Threatened Community lists for assessing many GDEs, in particular subterranean and river baseflow communities, is completely inadequate and misleading as the lists disregard those communities that rely on groundwater for survival. Most (~99%) of the fauna associated with many GDE types but particularly subterranean GDEs have never been described. The few species that have been listed are from caves and these are very few in number. In addition, most subterranean fauna typically has small ranges and are highly endemic and most areas have not been sampled previously. Therefore, the fact that there is currently no listing of threatened species in an area that has had very limited surveys conducted does not mean there are no potential threatened species. In contrast, the fact that there have been so few surveys indicates that any fauna found there in the future will most likely new to science, be of high conservation value and, as the threat from CSG increases, would therefore likely be added to the threatened species lists.

On page 11-42 it is stated that - "None of the identified GDE sites exhibit characteristics of Matters of National Environmental Significance under the EPBC Act and are not considered to support species dependent on groundwater from the Great Artesian Basin. As such, the sites are not considered to represent a threatened ecological community under the EPBC Act".
There are several issues with this statement.
1) This statement in nonsensical in that it relates to an ecosystem type (i.e. mound springs) not present within the area of investigation or previously identified within the EIS.
2) It implies that the identified Springs are of lesser value because they are not mound springs even though they have been identified previously as 'High Priority' GDEs under the Water Sharing Plans and within the NSW GDE Register. This approach is entirely incorrect.
3) They refer to 'spring' species dependent on groundwater without actually collecting or identifying any animal species from the mentioned springs. Therefore, it is not possible to know that the springs are not artesian and that if there are species present that they are not artesian species.

Detailed Review of Appendix C - "Aquatic Ecology and Stygofauna Assessment"

1. Stygofauna sampling approach is not adequate and requires a more comprehensive sampling regime to collect representative samples from appropriate locations within each aquifer/geology type and depths.

Stygofauna sampling regime included "Nineteen samples collected from the following locations, where no stygofauna was found:

a. two monitoring bores in the colluvium at Leewood;
b. four production bores;
c. three monitoring bores in the Bohena Creek alluvium;
d. five hand-dug pits in the Bohena Creek alluvium."

The following points are noted from the above sampling regime and site selection:

a. The number of samples taken were insufficient to adequately survey the area surrounding and within the proposed area of operation.
b. The sites with the colluvium were unsuitable due to the fine clay matrix as reported in the Groundwater and Geology Chapter.
c. The production bores sampled were within two coal seams, which typically have high salt loads and have been shown repeatedly not to contain stygofauna. It is fine to have sampled these bores as a broad cross-section of bores from each aquifer and geology type, however to only sample these as examples of general groundwater is completely wrong and misleading. In subterranean biodiversity studies coal seam aquifers are generally typically avoided.
d. The sampling techniques for the bores was standard and correct however the sampling technique for the Bohena Creek alluvium is ineffective.
e. They also omitted the locations of the previously collected rich stygofauna community at Maules Creek. They refer to two dates (2007, 2008) with no author names and which are not referenced. In terms of a chronology for the discovery of stygofauna in the upper Maules Creek Alluvial, it was initially conducted by Dr Peter Serov and Dr Dawit Berhane then with NSW Office of Water in 2006-7 with further sites sampled in 2008. This location has also had follow on positive surveys in 2011, 20015 and recently in 2020. These surveys have been conducted by Dr Peter Serov. The results of the 2007, 2008 studies were not mentioned or cited in their assessments.
f. The stygofauna sampling site selection had the following specific issues:
    - There is no appropriate description of the sites. The sites listed in table 4 (pg. 20.) give no information about the bore details including water table depth, total depth of the bore,

diameter and type of bore, and water quality. It appears there was no water quality data recorded or water samples analysed for water chemistry.

- The consideration and sampling of Bohena Creek hyporheic environment was entirely inadequate both in terms of number of samples, technique and discussion. The hyporheic ecosystem is an important feature of sand-based river systems. Groundwater base flow in sand-bed and gravel-bed rivers supports both riparian vegetation and in-stream macrophyte communities, surface water aquatic invertebrate communities, and a specialised community of invertebrates (termed hyporheos) that exist below the river bed / substrate surface in the hyporheic zone (Serov et al 2012). Many surface aquatic macroinvertebrates and aquatic vertebrate species rely on base flows for a variety of functions such as:
    - reproduction by utilising the stable flow either within the surface substrate or through the hyporheic zone to lay eggs.
    - a crèche environment for larvae / juvenile stages of macroinvertebrates.
    - a refuge zone during periods of extreme flows (both low and high flows).
    - a supply of nutrients from upwelling zones. (Serov, et.al., 2012). The author of the EcoLogical report has used the Bou Rouche hyporheic pump (Bou & Rouch, 1967, Boulton & Foster 1998, Boulton, et al. 2004) extensively in the past to sample deep into a river beds of many sand beds streams including extensively along the Hunter River for a PhD, and yet does not use it here in a similar habitat. The value of using the Bou Rouche pump technique is that it allows the deeper (0.5-1.5m depending on the length of the pipes used) sediments within a river bed to be sequentially sampled at different depths where obligate groundwater fauna (permanent hyporheos or phreatobites) are most likely to be found. It is in effect a temporary piezometer or monitoring bore. The pit sampling technique that was used would only be sampling the top 0-30cm of sediment which is typically occupied mainly by surface macroinvertebrates (Stygoxenes) or soil invertebrates (Edaphobites) unless there was a significant localised spring head or upwelling zones. The question has to be therefore raised as to why the Bou Rouche Pump technique was not used to adequately sample this habitat, even though is the superior technique to use. In addition, sufficient numbers of samples are not collected to adequately characterise the fauna longitudinally or at varying depths or at control sites versus impact sites.
- The fauna collected in the hyporheic samples were not described in any sufficient way. The fauna collected are common in the hyporheic zone and provide indications of stream health. This was not discussed.
- The aquatic mite fauna collected in the hyporheic fauna (and macroinvertebrate sampling) has been disregarded as not important. However, there is a considerable literature both in Australia and overseas highlighting the ecological importance and the rich biodiversity of the water mites within baseflow streams and the hyporheic zones (Chappius, 1942, Karaman, 1935, Boulton & Foster. 1998, Di Sabatino et al 2003, Boulton et al 2010). In Australia, Professor Andrew Boulton, an eminent aquatic ecologist, has written several papers on the value and importance of this fauna in rivers, groundwater and the hyporheic zone (Boulton et al 2010. They have also been collected extensively from riverine sediments and bores across NSW and Queensland by myself and other consultants. They are also considered as sensitive indicators of aquatic ecosystem impacts.
- The terrestrial fauna collected in the hyporheic sampling was also dismissed by EcoLogical as not being of any importance. However, they are important components of the Vadose Zone fauna. This fauna occurs in the moist unsaturated zone above the water table particularly in baseflow rivers. They are a distinct ecotone and need to be considered in any ecological assessment of mine discharge.
- The bores sampled in the Black Jack and Maules Creek seams were located in coal measures which are typically very salty and completely unsuitable for stygofauna. The proponent stated "Although some of the bores sampled are probably too deep and isolated from sources of organic matter to support stygofauna". The results of sampling these bores should be disregarded because they acknowledged that stygofauna would not be present.

- The sampling did not include the Pilliga sandstone aquifers. These aquifers had been reported earlier (2012, 2013, and 2017) to have repeated positive records of stygofauna and yet this aquifer was not sampled.
- Therefore, it would appear that the sample sites chosen were non-representative of the major aquifers, very limited in aerial coverage and number of sites, and used inappropriate methods to sample the baseflow hyporheic environment of the main streams i.e. Bohena Creek.
- They did not sample the other major streams for hyporheic fauna either.
- **An important point here is that a request was made by the author to Santos to re-examine the bores used in the stygofauna report and access was denied.**

g. Methodology used was inappropriate

- The control and impact sites for bores appear not to have been established in regard to the groundwater flow paths for contaminants and water level changes i.e. east and south east side compared with northern and north west sides.
- The sites do not appear to have been selected to represent the aquifers within each geology type.
- Within the macroinvertebrate's discussion there is no identification of species, therefore no identification of water level threshold taxa, taxa sensitivity to water quality change, or taxa longevity. The parameter of taxa longevity is an important measure of the aquatic macroinvertebrate community's adaptation to environmental change. If a community is composed of mostly or entirely of short lived (1-12 months) species this water source is generally intermittent or ephemeral. If the community composition is composed of long-lived species (1-10 years plus) that water source is considered to be permanent and usually highly dependent on groundwater.

2. A number of macroinvertebrates were collected but have not been included in the assessments. The report needs to be amended to include these.

The following macroinvertebrate fauna was collected but was not mentioned in the results and discussion. These particular groups however are strong indicators of water permanence and possible groundwater dependence (Williams, 1980). They are also indicators of good water quality and good ecosystem condition. The highlighted fauna has associations with groundwater:

a. Coleoptera: Hydraenidae, Hydrochidae, Elmidae
b. Crustacea: Parastacidae, Atyidae, Palaeomonidae
c. Diptera: Ceratopogonidae, Dixidae, Orthocladinae
d. Ephemeroptera: Leptophlebiidae, Baetidae, Caenidae
e. Gastropoda: Ancylidae, Planorbidae
f. Odonota: Gomphidae, Aeshnidae, Libellulidae, Protoneuridae, Hemicordulidae.
g. Trichoptera: all families

3. Important sensitive species known to be present in the region have not been considered in the sampling and/or assessments. It is highly recommended that this deficiency is rectified for the reasons set out below.

a. Fauna not recorded or even mentioned are the two species of freshwater mussels that occur along Bohena Creek. These species (*Velesunio ambiguous* and *V. wilsonii*) can live in excess of 20 years and occupy the deeper sections of the permanent pools and are very susceptible to water level changes as they are unable to move from the location and die once they are exposed. An examination in 2016 of wetland pools in the Pilliga conducted by the author and Ecologist Dr David Paul identified that the mussels only occurred at approximately 0.3 – 0.6m depth thus making them very susceptible to water level fluctuations as they are generally unable to move from their positions

b. One of the major deficits in the aquatic and terrestrial surveys presented in the EIS is the examination of the highly diverse and potentially very sensitive aquatic and terrestrial molluscs that include snails and bivalves. Murphy and Shea (2013) conducted "a field survey of the area in 2006–2012 and identified a surprisingly rich and relatively intact aquatic native molluscan fauna with five species of bivalves in three families and nine species of freshwater gastropods (four families), including some rare species and range extensions. The native land snail fauna comprised 18 species (six families), including an unusually rich pupillid fauna with nine species. Some range extensions are recorded and some species are narrow-range endemics. The distributions of many aquatic and terrestrial species were correlated with geology or soil type. Introduced molluscs were predominantly found in anthropogenic habitats and include two freshwater gastropods (two families) and nine terrestrial snails and slugs (eight families). This study provides insight into the original molluscan fauna of the western slopes prior to landscape-scale agricultural development and provides a benchmark for future reference" (Murphy & Shea, 2013). This study was not included in the assessment at all and there was no discussion of mollusc biodiversity or disturbance sensitivity. It also highlights a rich terrestrial snail community that is very localised and endemic. These were not included in the terrestrial assessments.

c. A similar deficit is highlighted with the lack of discussion on the decapod Crustacea. Murphy 2011 reported that although the decapod diversity was low within the Pilliga at the species level, it was high at the family level. The paper highlighted that this group of invertebrates is very susceptible to water quality and, in particular, water level impacts, and were dependent on the permanence of pools (which are highly likely to be groundwater fed). "*Caridinia mccullochi, Paratya australiensis* and *Macrobrachium australiense*, in contrast, are dependent on surface water at all life cycle stages, and their survival in the Pilliga Scrub relies on the few small permanent waterholes along the larger intermittent streams or, if these dry out, re-colonisation from downstream perennial river channels during occasional stream flow events. An increase in aridity due to anthropogenic climate change could result in the local extinction of these three species, representing a 60% reduction in local decapod species diversity" (Murphy 2011).

4. Additional information and verification are required to confirm if previously identified endangered ecological communities (EECs) within the Pilliga do not exist in the study area. Kuginis & Dabovic. (2016)

Pg. 30, section 4.1.1, "Endangered Ecological Communities" listed in the Namoi. It is stated in Table 7 that EECs are unlikely in the Study area. NSW Office of Water has listed the following EECs within the Pilliga. Therefore, Santos has failed to assess whether they exist in the Project area.

a. Brigalow - Belah open forest/woodland on alluvial often gilgaied clay from Pilliga Scrub to Goondiwindi, Brigalow Belt South Bioregion.

b. Grey Box grassy woodland or open forest of the Nandewar Bioregion and New England Tableland Bioregion

c. Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion.

5. A number of known terrestrial GDEs have not been considered in the assessment. The report requires the addition and assessment of these terrestrial GDEs such as Kuginis & Dabovic. (2016) for an appropriate assessment of terrestrial GDEs

These are known Terrestrial GDEs that have been recorded in the Pilliga but not included in the vegetation assessment. These include:

a. Coolibah - River Coobah - Lignum woodland wetland of frequently flooded floodplains mainly in the Darling Riverine Plains Bioregion

b. Poplar Box - Yellow Box - Western Grey Box grassy woodland on cracking clay soils mainly in the Liverpool Plains, Brigalow Belt South Bioregion

c. Red gum - Rough-barked Apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion

d. River Oak - Rough-barked Apple - red gum - box riparian tall woodland (wetland) of the Brigalow Belt South and Nandewar Bioregions

e. River Red Gum riparian tall woodland / open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion

f. White Box - White Cypress Pine - Rough-barked Apple shrubby open forest in the Kaputar area of Brigalow Belt South Bioregion and Nandewar Bioregion

g. Wild Quince - Mock Olive - Rusty Fig - Iamboto - Sweet Pittosporum dry rainforest of rocky and scree areas of the Nandewar Bioregion and New England Tableland Bioregion.

6. Response to section 4.4.4.1 “Rockdale stygofauna survey, Pg. 73.
The stygofauna section states that no stygofauna were collected during the sampling regime by EcoLogical. In their discussion they refer to a report (Stygoecologia, 2013 by Peter Serov) on stygofauna being collected from bores on the property known as Rockdale. This fauna compromised two families of aquatic Oligochaeta (worms) and a species of water mite. The author of this report can confirm that the taxa collected are in fact aquatic stygofauna and were not soil fauna as indicated by EcoLogical as they were alive when collected in-situ from pumped water, using a bailer or phreatobiology net, and have been repeatedly collected over 2 years from the same locations as well as from nearby properties. The fauna collected, especially the two families of worms, are entirely aquatic groups. The author of this report has over 30 years’ experience with collecting stygofauna across Australia and extensive experience collecting along the Namoi River Alluvium and has not collected these from the anywhere else in the area. There is no doubt these are stygofauna which completely refutes the claims by EcoLogical of stygofauna not being present. The species were collected in the Pilliga Sandstone aquifer from unconsolidated lenses with the sandstone at 70m depth, indicating a connectivity with the surface for the reasons outlined on page 73 of the aquatic and stygofauna report. It should be noted again that EcoLogical did not sample the Pilliga Sandstone.

7. The following comments should be rectified and/or noted as appropriate:
a. It is noted that during dry periods the water table is 2m below the riverbed. This indicates that there is a subterranean baseflow. This does not indicate that this is a fixed level.
b. There is no discussion of the flow-on effect of disturbances to the aquatic biodiversity from the flow-on of potential instream impacts downstream and outside of the area of operations.
c. Bohena Creek had higher biodiversity than the Namoi River and Narrabri Creek, and contained 11 taxa that were not found in the Namoi River sites. As the Namoi is a regulated system and highly impacted, the undisturbed Pilliga streams should be considered as refuge area for aquatic macroinvertebrates.

8. The impact to stygofauna from the proposed treated water discharge into Bohena Creek is anticipated to be low as long as the chemical composition, ionic composition and, in particular, electrical conductivity is within the natural range experienced. If, however, the water chemistry is deviated outside of the natural ranges it is highly likely that there will be a significant increase in risk of a detrimental impact.

9. It appears that the number of samples taken, the area covered and the seasons sampled are insufficient for the Leewood site operations. If the depth of the monitoring bores were relevant, then only two sampling points were used to verify stygofauna presence at Leewood. Moreover, these bores were only sampled in autumn of 2013 and 2014. Ideally most seasons (if not all) should be covered at least over the initial two-year period prior to the commencement of operation in order to determine seasonal fluctuations.

10. As stated in the reports, there is no uncertainty regarding the presence of stygofauna in the project areas, as stygofauna have previously been collected across the Pilliga in the Pilliga Sandstone aquifer and hyporheic zone Bohena Creek Alluvium by Dr Peter Serov in 2012, 2013 and 2016, it is therefore recommended, having regard to the precautionary principle, to assume that stygofauna are present in other aquifers and hyporheic zones of other streams in the area and that hyporheic sampling should be included as part of all riverine risk assessments, including Ecological Risk Assessment and Chemical Risk Assessment. Any localised impacts to the shallow aquifer water levels, changes in salinity and ionic composition, and potential leaks/spills of drilling fluids and produced water may have a significant impact to local stygofauna and hyporheic fauna communities.

11. A more comprehensive stygofauna sampling of the Leewood site as well as further sampling downstream outside the area of operation are needed as the risk of water chemistry changes that could

impact this community is highly likely. An ongoing and incident-based chemical and biological monitoring program for stygofauna should also be conducted if the presence of stygofauna is definitely found at Leewood or further downstream in Bohena Creek, and in the Namoi Alluvium downstream of the confluence.

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Annexure A

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FIELD OF EXPERTISE

Peter is an Aquatic and Groundwater Ecologist, and Invertebrate Taxonomist who has worked in a range of environments including surface aquatic ecosystems (Rivers, Wetlands), groundwater ecosystems, marine, and terrestrial ecosystems for over 30 years. He specialises in the identification of aquatic macroinvertebrates and stygofauna (groundwater fauna) with a particular interest in the ecological condition assessments and management of Aquatic Ecosystems including rivers, wetlands and Groundwater Dependent Ecosystems. Peter has been a significant contributor in the early development of the NSW Sharing process and recognition of Groundwater Dependent Ecosystems (GDE's) in NSW government. He has been intrinsically involved in the development and implementation of NSW legislation involving High Conservation Value Rivers (HCV) Groundwater Dependent Ecosystems including actioning the NSW GDE Policy by developing and writing the NSW GDE Risk Assessment Guidelines. As a private consultant Peter has been involved in the assessment, reporting and review of aquatic and groundwater ecology components of a number of State Significant Projects in all states of Australia as well as New Zealand and California, USA. Peter has also been involved with running Citizen Science Aquatic Ecosystem education and monitoring programs for over 20 years.

ACADEMIC QUALIFICATIONS

1986 - Bachelor of Science. Majoring in biology and geology, the University of Wollongong.
1988 - Bachelor of Science. Honours, the University of Tasmania.
2015 - PhD, the University of New England.

WORK EXPERIENCE.

2012-present: Stygoecologia (Environmental Consultancy)
Owner and Director, Aquatic/Groundwater Ecologist/Invertebrate Taxonomist, specializing in all Groundwater Dependent Ecosystems including surface and subsurface ecosystems.
Website: www.stygoecologia.com.au
2016 –2019: Office of Environment and Heritage
Environmental Scientist
Aquatic/Groundwater Ecologist/Departmental Macroinvertebrate and Stygofauna Taxonomist, specializing in all Surface water and Groundwater Dependent Ecosystems including surface and subsurface ecosystems.
1999-2012 – NSW Office of Water.
Aquatic Ecologist and sole departmental Invertebrate Taxonomist and groundwater ecologist.
1997-1999: Invertebrate Identification Australasia (Environmental Consultancy)
Co-founder and Aquatic/Groundwater ecologist/taxonomist
1994-96: Australian Museum Business Services (Environmental Consultancy)
Aquatic Ecologist and Invertebrate Taxonomist.
1992 -94: Australian Museum, Marine Invertebrate Section.
1992-89: University of Tasmania, Zoology Department. Research Officer.

SUMMARY OF MAJOR PROJECTS

- Expert review of Ditchfield Contracting Pty Limited for Legal Services Branch, NSW Environment Protection Authority
- Expert review of Ridley Agriproducts Premises at Maroota to Dalgetys Creek on 19-21 June, 1 August, 17 August, 27-29 October and 20 November 2017 for Legal Services Branch, NSW Environment Protection Authority
- Review of Centennial Awaba Seep Management Stage 2 Options Report for Legal Services Branch, NSW Environment Protection Authority
- Bellingen Turtle River Health Project
- Kosciusko Resort Environmental Health Monitoring
- Qualitative Modelling Workshop for Risk Assessment Project, Coal Seam Gas and Coal Mine Developments, Namoi Bioregional Assessments, CSIRO
- University of New England, Bachelor of Zoology Review. Invited panel member.
- OEH Warrumbungles Citizen Science Project
- Central Coast Council Creek Monitoring Evaluating and Reporting Project
- King Island, NW Tasmania. Stream health education program covering all schools and classes between Year 3-9 for King Island NRM.
- Bioregional assessments – Namoi sub-region ecological receptors workshop.
- United and Wambo Open Cut Colliery, Pilot Stygofauna Assessment Study 1, Survey 1, December 2015.
- Maules Creek Coal Stygofauna Monitoring Program Survey 1, November 2015.
- NSW Major Project Assessment - Wallarah 2 Coal Mine Project, Northwest of Wyong, New South Wales (EPBC 20126388).
- Marulan Limestone Mine SSD Project Pilot Stygofauna Ecological Value and Risk Assessment Study 1, May 2015.
- Review of the Baralaba North Continued Operations Project for Depart of the Environment and the Depart of Environment and Heritage Protection, Queensland.
- Tahmoor South Project, Stygofauna Assessment, Prepared for Tahmoor Coal Pty Ltd 2013-14.
- NSW Major Project Assessment - Calga Sand Quarry Project (MP 06_0278)
- 3rd Annual Australian Environmental Assessments and Approvals, 28-30 May 2014, Sir Stamford Circular Quay, Sydney. WORKSHOP A: Improving your EIS through effective environmental monitoring, recording and management plans
- Committee member of the Coal Seam Gas Science Forum Committee and Public Workshops and Forum, Parliament House, Sydney, March 2014.
- Glenbrook Lagoon Following the Cabomba Weed Control Program 2013-16.
- A Review of Groundwater Dependent Terrestrial Vegetation and Groundwater Depth for the Namoi Catchment Management Authority, NSW. June 2013.
- Risk assessment guidelines for groundwater dependent ecosystems, Parts 1-4. Prepared for the New South Wales Government as a requirement under the NSW Water Act 2000, to assist in reporting for the Groundwater State Target, and for the Australian Government, National Water Commission, as part of the Coastal Groundwater Quality and Groundwater Dependent Ecosystems Project.
- Provide advice to the AETG (Aquatic Ecosystems Task Group and ANAE (Australian National Aquatic Ecosystems (Classification Scheme).
- Contributed to the development of the Federal Governments National Water Commission (NWC)
- Groundwater Dependent Ecosystem (GDE) Atlas.
- DECC 2010. Upland Swamp Environmental Assessment Guidelines. Guidance for the underground mining industry operating in the southern and western coalfields.
- Development of methodology for identification, valuation, classifying, risk assessment, protection and establishment of GDE database within NSW Groundwater Water Sharing Plans.

- Advising state government agency working groups on aquatic ecological issues for policy development including Aquatic biodiversity strategy, Groundwater Dependent Ecosystem Policy and High Conservation Value Rivers Assessments.
- Fieldwork for various projects conducting ecological assessments of water quality, macroinvertebrates, amphibians, reptiles and fish, including larval and adult fish studies. The field work involved working throughout NSW.
- Development of Groundwater Environmental Targets for the Natural Resource Commission (NRC).
- Advice to the National Groundwater Dependent Ecosystem Atlas (NWC)
- NSW government. Adaptive Spatial Framework Project Ecological decision support for low flows
- Monitoring River Health Initiative (MRHI) (throughout NSW)
- Snowy River Bench Marking Project
- Blue Mountain Bio-indicator Study

PUBLICATIONS,

Serov, P., Kuginis, L. 2017. A Groundwater Ecosystem Classification - The Next Steps. International Journal of Water.

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