Response to Ecological issues raised within DPIE's letter to IPC "Response to Independent Planning Commission Questions" (14th August 2020).

David C. Paull (MRes Sc, Dip Hum)

21 August 2020

The Department of Planning Industry and Environment's (DPIE) letter to the Independent Planning Commission (IPC) in response to evidence presented at the public hearing for the Narrabri Gas Project (Project) outlined a number of issues in relation to the principle of Ecological Sustainable Development (ESD) as an objective of the *Environmental Planning and Assessment Act 1979* and the adequacy of the proponent's proposals to deal with impacts on the environment and biodiversity in a way which is consistent with this principle.

In relation to ESD, DPIE states:

"Based on its detailed assessment and subject to the recommended conditions, the Department has concluded that the Narrabri Gas Project represents ESD as it:

- *would not cause serious or irreversible environmental damage;*
- *would not adversely affect the biological diversity and ecological integrity of the region, including the Pilliga State Forest;*
- *is consistent with the principle of internalising the environmental costs of development as Santos would be liable for meeting all the costs associated with avoiding and/or minimising the impacts of the project, with monitoring and reporting on its environmental performance during operations, and with fully rehabilitating the site following operations.*

Consistent with my evidence presented to the IPC, I will outline here how none of the above assertions in relation to biodiversity can be substantiated within the proponent's application documents, in the evidence presented by Santos or by the DPIE in their recommended Conditions of Consent or Assessment Report.

In summary:

- Lack of certainty regarding the location and extent of the gasfield infrastructure and indirect impacts has hindered a detailed assessment of this Project's impacts on biodiversity. Nevertheless, cases of 'serious or irreversible impact' to a number of key, sensitive species are identified here. These include the Black-striped Wallaby, Pilliga Mouse, Eastern Pygmy-possum, Koala and Five-clawed Worm-skink.
- Internal forest fragmentation and increasing patch isolation are key threats to biodiversity worldwide, facilitating weed and feral animals penetration of forest remnants, increasing feral predator hunting success, increasing 'edge-effect' on forest communities, increasing traffic, noise, light and dust pollution, all matters poorly dealt with in the EIS documents and in the Framework for Biodiversity Assessment (FBA) methodology. This and current methodology for assessing biodiversity impacts in NSW does not adequately cater for the scale of indirect impacts that arise from large diffuse developments such as gasfields. In fact, the proposal will trigger a number of key threatening processes that will not be adequately offset in the existing Conditions of Consent, or be limited to 20 years as well sites and access tracks will need to maintained into the future.
- DPIE has claimed Santos will be able to internalise costs partly by 'fully rehabilitating' damage by infrastructure. However, DPIE rejected Santos' request for upfront biodiversity

credits for site rehabilitation. Santos has not demonstrated that recreating natural ecosystems at well sites is feasible. Well and spill site rehabilitation currently show poor natural re-growth with a low native plant diversity and high levels of weed infestation, even after 20 years at some sites. Previous efforts at planting natives has resulted mostly in failure. This has been documented by citizen scientists in submissions to the DPIE (PEG 2018).

Precautionary principle and impacts on biodiversity values

DPIE states in its letter of 14 August 2020, that it remains unconvinced of any serious or irreversible harm occurring and that speakers at the hearing,

"… focussed primarily on some of the scientific uncertainties associated with the assessment, without providing any new information that materially changes the Department's assessment of these uncertainties, rather than identifying and providing clear evidence of the specific serious or irreversible environmental damage that may or would occur as a result of the project and how likely (sic) the threat of this damage is."

My scientific assessment of the extent of likelihood of impacts of the Project on key threatened species, based on the known scientific literature, data provided in the EIS and associated documents, in the context of the precautionary principle as described in section 6(2) of the *Protection of the Environment Administration Act 1991* (NSW) (POEA Act), is summarised below in Table 1.

Table 1. Susceptibility to threat - key threatened species

	Risk of threat type (serious or irreversible impact)			
Species	***Habitat loss***	***Fragmentation***	***Feral Predators***	***Other Indirect***
Pilliga Mouse	*Potentially over 380 ha of breeding habitat*	*Highly sensitive to reduced cover*	*Yes, susceptible to increased risk*	*Yes, light, noise, dust, fumes*
Eastern Pygmy-possum	*Unknown*	*Highly sensitive to reduced cover*	*Yes, susceptible to increased risk*	*Yes, light, noise, dust, fumes*
Black-striped Wallaby	*Unknown, 19 ha of preferred Brigalow habitat to be removed*	*Increased risk due to loss of Brigalow, vehicle collisions*	*Yes, susceptible to increased risk*	*Yes, vehicle strike, Infrastructure obstruction. Light, noise, dust, fumes*
Koala	*95 ha of preferred habitat to be removed (according to new SEPP44 guidelines)*	*Increased risk of vehicle collisions*	*Yes, susceptible to increased risk*	*Yes, vehicle strike, Infrastructure obstruction, Light, noise, dust, fumes*
Five-clawed Worm-skink	*Unknown extent*	*Further clearing on black soils may increase level of habitat loss.*	*Unknown*	*Soil compaction*

Consideration should also be given to the principles applicable to the determination of "serious and irreversible impacts on biodiversity values" of the Project for the purposes of the NSW Biodiversity Offset Scheme. In this regard, cl 6.7 of the *Biodiversity Conservation Regulation 2017* (NSW) (BC Regulation) provides, relevantly:

"(1) This clause applies for the purposes of determining whether an impact on diversity values is a serious and irreversible impact for the purposes of the biodiversity offsets scheme.

(2) An impact is to be regarded as serious and irreversible if it is likely to contribute significantly to the risk of a threatened species or ecological community becoming extinct because—

> *(a) it will cause a further decline of the species or ecological community that is currently observed, estimated, inferred or reasonably suspected to be in a rapid rate of decline, or*
> *(b) it will further reduce the population size of the species or ecological community that is currently observed, estimated, inferred or reasonably suspected to have a very small population size, or*
> *(c) it is an impact on the habitat of the species or ecological community that is currently observed, estimated, inferred or reasonably suspected to have a very limited geographic distribution, or*
> *(d) the impacted species or ecological community is unlikely to respond to measures to improve its habitat and vegetation integrity and therefore its members are not replaceable.*

(3) For the purpose of this clause, a decline of a species or ecological community is a continuing or projected decline in—

> *(a) an index of abundance appropriate to the taxon, or*
> *(b) the geographic distribution and habitat quality of the species or ecological community.*

…"

I outline my scientific assessment of the impact of the Project on biodiversity values in accordance with cl 6.7(2) of the BC Regulation below in Table 2. I note that only one of the four criteria under cl 6.7(2) needs to be met for an impact to be regarded as serious and irreversible.

Table 2. Assessment of serious and irreversible impact on biodiversity values - key threatened species

Species	***Criteria under Clause 6.7***				***Serious and Irreversible Impact?***
	1 Rapid decline	***2 Small population size***	***3 Limited range***	***4 Ability to respond***	
Pilliga Mouse	*Unknown. Recent drought is likely to have reduced numbers. Vulnerable under Biodiversity Conservation Act 2016* (NSW) *(BC Act)*	*Yes. Population size fluctuates markedly. Recent dry conditions do not favour this species*	*Yes. Restricted to Pilliga Forests*	*Populations can respond to favourable habitat and climatic conditions, though it is unknown if rehabilitation will achieve this*	*Meets 2 out 4 criteria, 2 unknown*
Eastern Pygmy-possum	*Unknown. Vulnerable under BC Act*	*Yes. Surveys undertaken show this species occurs at a low density*	*Yes. Known mainly from large public lands in Brigalow Belt South (BBS). Possible unique genotype*	*Unknown*	*Meets 2 out 4 criteria, 2 unknown*
Black-striped Wallaby	*Yes. Endangered under BC Act*	*Yes. This species has a small population size compared to other macropods*	*Unknown number of populations in BBS, found throughout northern Pilliga*	*Unknown*	*Meets 2 out 4 criteria, 2 unknown*

Koala	*Yes, considered to have undergone overwhelming recent population crash*	*Yes. Pilliga Koalas are at a critically low population size*	*Yes. A critically small population which may have unique genetic characteristics*	*Animals will occupy areas of regeneration. It is unknown if gas rehabilitation can achieve this*	*Meets 3 out 4 criteria, 1 unknown*
Five-clawed Worm-skink	*Yes. Endangered under BC Act*	*Unknown. Remaining populations are scattered and difficult to locate. Habitat subject to ongoing clearing*	*Unknown*	*Unknown*	*Meets 1 out 4 criteria, 3 unknown*

If each of these species is considered in the context of clause 6.7 of the BC Regulation, the best available scientific understanding of these species' habitat preferences and current conservation status shows that one species, the Koala, meets three of the four criteria with the fourth unclear due to lack of scientific certainty. Another three species, Black-striped wallaby, the Pilliga Mouse and Eastern Pygmy-possum met two of the criteria with insufficient information to accurately determine the other two, and a fifth, the Five-clawed Worm-skink, meets one of the criteria though little is known of the biology or the ecology of this species in the Project Area.

A more detailed discussion of the susceptibility of each species, citing scientific literature, is provided in the following text.

The Pilliga Mouse

The endemic Pilliga Mouse *Pseudomys pilligaensis* is restricted to public lands in the public Pilliga forests (Appendix 2 of this report). While the Pilliga Mouse habitat is more limited in extent on the western side of the Newell Highway, it would seem the eastern side of the highway could be a core area for this species, judging by the extent of suitable habitat (Paull 2009). The current status of this species in the Pilliga is not known, with no field work to my knowledge undertaken within the Project Area since 2014. This species responds well to wet conditions, though how well this species has persisted during the recent drought is not known.

Santos has been allowed to clear up to 380 ha of potentially suitable habitat in this core area, based on my own published studies on the ecology of this species (see Appendix 1 to this report), much of which may be breeding habitat for the Pilliga Mouse. Paull et al. (2014) described breeding habitat for this species within the Project Area and while some key habitat features and ecological communities could be identified as being preferred by the Pilliga Mouse for breeding purposes during spring, this is also the time of year of population dispersal, leaving most areas of potential habitat apparently vacant. Therefore, presence/absence of this species at any location cannot be used as a measure of site suitability.

Santos presented an analysis of habitat modelling for this species in its EIS, to show that due diligence would be exercised during well site and infrastructure location. There are some constraints to the accuracy of this modelling, and how well it would predict breeding habitat for this species, outlined in my previous submission to IPC, including a failure to refer to the scientific literature on the known habitat preferences of this species.

In addition, this species is very susceptible to internal habitat fragmentation from increasing levels of road and other gas infrastructure through the forest, for two reasons. (a) It is a cryptic species avoiding exposed areas and roads, and (b) these will increase feral predator activity in areas not previously subject to clearing. Santos has not proposed any mitigating measures in relation to this increased feral predation, a key threatening process in NSW. (These matters are explained more fully in my previous submission).

Given this state of knowledge on the Pilliga Mouse, in my scientific opinion, under cl 6.7(2) of the BC Regulation two of the criteria for serious and irreversible harm as a result of the Project will be met, with the further criteria undetermined due to insufficient information. It is also scientifically likely this species will suffer serious or irreversible impact and there is a lack of full scientific uncertainty as to the environmental damage under the precautionary principle as expressed in section 6(2) of the POEA Act.

Eastern Pygmy-possum

The Eastern Pygmy-possum *Cercartetus nanus* would be subject to the same types of threat as the Pilliga Mouse, except that very little is known of the habitat selection of this species in the Pilliga forests Large public land remnants of the Pilliga and Goonoo forests seem to be its main refuge in the BBS bioregion (Appendix 2).

Pygmy-possums are rarely encountered and difficult to observe and trap unless targeted techniques are used. Low numbers of captures of this species by Santos reflect poor survey methodologies (Landmark and TWS 2012). My own experience with this species shows it is most effectively caught with pit-traps, a technique not utilised in the EIS, and that gullies zones appear to be favoured. However, such little information in the EIS regarding this species in terms of presence or habitat selection has severely hindered an adequate impact assessment.

For the Pygmy-possum, the current status of local populations is also uncertain. Severe drought conditions over the last two-three years (2017-2019) has hindered normal growth, water availability, insect activity, flowering and seed production in the forest. These may have serious consequences for the survival of local populations of small mammals and an assessment of the current status of both these species is urgently required, prior to any further disturbance.

Like the Pilliga Mouse, in my scientific opinion, under cl 6.7(2) of the BC Regulation two of the criteria for serious and irreversible harm as a result of the Project will be met, with the further two criteria undetermined due to insufficient information. It is also scientifically likely this species will suffer serious or irreversible impact and there is a lack of full scientific uncertainty as to the environmental damage under the precautionary principle as expressed in section 6(2) of the POEA Act.

Black-striped Wallaby

Black-striped Wallabies *Macropus dorsalis* are more or less constrained to public land areas in the bioregion where it forages widely into adjoining private lands to feed (Jarman et al 1991). While NPWS has undertaken monitoring of this population in the Brigalow Park reserves in the past, there is little indication of current numbers. Recent work by the Australian Wildlife Conservancy (2016-19) show this species is widely distributed in Pilliga National Park. Other than their current conservation status, which is endangered under the BC Act*,* there is little indication of current population trends. The status and distribution of this species west of the Great Dividing Range requires urgent attention. This Black-striped Wallaby is also found in wetter forest on the north coast ranges, though their survival and persistence following the recent bushfire episodes is now uncertain.

Despite some recording success by Santos (17 records of this species in EIS) and existing records, no analysis of preferred habitat or movement patterns in the forest has been completed by Santos and so no information has gone into informing Santos of any habitats preferred by this species in their Ecological Scouting Framework. In fact, these wallabies are known to prefer forest with dense understorey, Brigalow and areas with moister soils and move considerable distances at night into open country to feed (Evans 1996; Jarman et al 1991).

Santos has also increased the amount of Brigalow forest they could clear to 19 ha from 7 ha in the EIS, with no explanation given. Any further loss of preferred habitat of this species is likely to exacerbate its current trend towards extinction.

The configuration, density and extent of fencing in the proposed gas field north of the forest and around the Brigalow Park reserves is not known. However, these have the capacity to provide significant impediments to dispersal and qualitative changes to habitats occupied by this species as a result of location of gas infrastructure and their impacts on this species' essential behavioural patterns.

Based on these assessments, in my scientific opinion, under cl 6.7(2) of the BC Regulation two of the criteria for serious and irreversible harm as a result of the Project will be met. It is also scientifically likely this species will suffer serious or irreversible impact and there is a lack of full scientific uncertainty as to the environmental damage under the precautionary principle as expressed in section 6(2) of the POEA Act.

Koala

For Koalas *Phascolarctos cinereus*, extinction risk is already high due to a very low population size, any additional impacts could prove detrimental to the survival of this once important population. The low numbers and severely contracted range of the Koala in the Pilliga Forests were described by Lunney et al. (2017). Severe drought in following years raised concerns around the survival of this population (see Final Report of NSW Upper House Koala Inquiry 2020). However, new evidence has come to light in 2020 on the status of some areas where Koalas still reside in the broader forest (presented in my previous submission to IPC).

Data presented in the new Koala Habitat Protection SEPP (March 1, 2020) show a number of species of eucalypt species of equal high importance to the Pilliga Koalas including Red Gums (*E. blakelyi, E. chloroclada*), Pilliga Box (*E. pilligaensis*) and Poplar Box (*E. populnea. ssp. bimbil*). The allowable clearing limits in these communities add up to some 95 ha (see Appendix 1 to this report), not counting some of the associations with red gums in nutrient-poor, heathy areas. None of this information has been updated in the proponent's submissions on this Project. Added to this unaccounted impact is an array of indirect impacts expected to arise as a result of the Project.

Santos' consultants, Niche, conducted a Koala survey in 2014 across the Pilliga and made a statement that the Project Area is unlikely to harbour any suitable refuge habitat for the Koala in times of population contraction. However, evidence of Koala within the Project Area in 2016 by community surveys (submitted with my last submission to the IPC) would suggest this is not the case. Persistence of Koalas in the area of Pilliga National Park to the west of the Project Area (2016-18, Rod Kavanagh, pers.com.) also suggest northern areas of the forest are indeed refuges for this species.

As Koalas are in a critical state of decline in the Pilliga forest, first priority would be to investigate extent and health of populations. The best outcome for these struggling Pilliga animals would be to not have a gasfield to contend with and to have an independent, government or community-sponsored Koala monitoring and survey program.

Based on these assessments, in my scientific opinion, under cl 6.7(2) of the BC Regulation three of the criteria for serious and irreversible harm as a result of the Project will be met for the Koala. It is also scientifically likely this species will suffer serious or irreversible impact and there is a lack of full scientific uncertainty as to the environmental damage under the precautionary principle as expressed in section 6(2) of the POEA Act.

Five-clawed Worm-skink

Habitat for the Five-clawed Worm-skink *Anomalopus mackayi* was identified in the Project Area according to the EIS, though the extent of this was never properly acknowledged or mapped in any of the species assessments undertaken by the proponent. For Santos, this is particularly derelict in its statutory obligations as this species is endangered in NSW and was identified as a 'matter for further consideration' under the FBA methodology. Any assessment of the impact on this species from the Project is therefore mired in uncertainty, though given the assessment in Table 2, it clearly meets one of clause 6.7 criteria, being a population in severe decline given ongoing threatening processes on this species in the region, particularly from land-clearing and cropping. .

Based on these assessments, in my scientific opinion, under cl 6.7(2) of the BC Regulation one of the criteria for serious and irreversible harm as a result of the Project will be met for the Five-clawed Worm-skink. It is also scientifically likely this species will suffer serious or irreversible impact and there is a lack of full scientific uncertainty as to the environmental damage under the precautionary principle as expressed in section 6(2) of the POEA Act.

Adversely affecting biological diversity and ecological integrity

DPIE also states that the Project:

> *"… would not result in any significant impacts on listed threatened species or communities, principally because Santos can avoid and/or minimise the impacts of the project on these species and communities during the detailed design and implementation of the project, and that any residual impacts can be significantly reduced by the progressive rehabilitation of the site and offset in accordance with the requirements in the NSW Government's Major Projects Offsets Policy."*

As native vegetation removal and fox predation are Key Threatening Processes (KTPs) in NSW, the exacerbation of these impacts would be expected to degrade ecosystems and the habitat of species for at least the life of the Project. The life of the Project is said to be 20 years, though well sites will remain in place after this time, and as ongoing maintenance will be required, tracks are also likely to be maintained, even after 20 years. At any rate, 20 years of continuous increased levels of key threatening processes itself may be enough to have a significant impact, as outlined above, to the point of causing serious or irreversible harm to sensitive species.

Given these threats, impacts of the Project will most certainly *adversely affect the biological diversity and ecological integrity* of the local region. For DPIE to state otherwise suggests it has not given sufficient regard to the ecology of these species or the types of impacts they would be subject to given the nature of the development. An example is the extensive literature on the effects of internal forest fragmentation on wildlife, which should have been comprehended to inform an adequate assessment of this Project. If 'black box' assessment methodologies (eg. FBA) do not take into consideration these factors adequately, then that is the failing of the NSW Government. Scientific opinion is not constrained by 'black-boxes' but by the level of published, expert knowledge.

Adaptive Management shortcomings

Santos' approach to mitigating impacts on sensitive or threatened species and ecological communities, one endorsed by DPIE, centres around a flexible approach to the location of the siting of infrastructure, what Santos call 'micro-siting' with a 'Field Development Protocol' and an 'Ecological Scouting Framework'.

The Recommended Conditions of Consent specify the production of a Biodiversity Management Plan that would detail the protocols for the Field Development Protocol. However, no other guidance has been given in the Recommended Conditions, other than to say the Protocol is for, " ... *managing any threatened species or ecological communities identified during the investigations, including measures to avoid disturbance of threatened species or ecological communities where reasonable and feasible*".

In fact, the ability of Santos to avoid sensitive matters is constrained by the design of the gasfield itself and Santos has been given considerable scope to clear sensitive areas if required, in the form of the upper disturbance limits allocated to all ecosystem types. No upper limits have been proposed for threatened species habitat in the Project Area. This is compounded by the fact that the habitat preferences of the key threatened species identified here have not been well-defined by Santos, making further unaccounted-for loss of habitat for these species entirely possible. While new information can be fed into an 'adaptive framework', questions remain as to the suitability of this approach given the large amounts of new information which would need to be incorporated, information that has previously not been considered by a consent authority. There is no further requirement for Santos to fill knowledge gaps for key species in the Recommended Conditions of Consent, other than to undertake specific site assessments. This itself is not enough to properly inform a meaningful avoidance strategy for these key species.

The use of modelled upper disturbance limits in fact is contrary to the principle of avoidance enshrined in the NSW Biodiversity Offsets Policy for Major Projects (2014). It is actually a response to the inflexibility of gas field design and its limited ability to avoid sensitive areas. While DPIE has accepted Santos' contention that the extent of clearing is not going to be as extensive as first indicated in their EIS, Santos has doubled the allowable extent of clearance of Brigalow endangered ecological community (EEC) from 7 ha to 19 ha in the Recommended Conditions of Consent. This strongly indicates that rather than promoting avoidance of sensitive ecosystems and habitat, Santos has in fact been granted the necessary clearance allowances such that avoidance would largely not be necessary and that any fine tuning of design would be very minor.

Offset uncertainty

All of the sensitive, affected species listed above are more or less restricted to public lands, ie. areas not available for land offset. Given 70% of offsets are to be sourced from land offsets questions as to the feasibility of the retirement of biodiversity credit liability remain. None of the 'species credits' have been given any pathway for retirement of credit liability nor is there any suggestion of how they could be retired.

The exception would be the Koala, where suitable habitat may exist in quantities within the Project Area on private land, though an assessment of Koala habitat availability on private lands has not been provided by Santos. This is because it is impossible to verify the actual vegetation communities on any private land without onsite inspection. Clearly, Santos has not invested any effort to do so and so assurances by DPIE and Santos on the success of their offset strategy amount to little.

DPIE simply does not know whether successful site rehabilitation, where it replicates target ecosystems, can be achieved. This has yet to be proved by Santos despite a Rehabilitation Strategy being submitted with their EIS. Santos has twice been refused to have its current state of rehabilitation accredited as achieving offset level habitat restoration either for species or ecosystems credits during the process of the EIS and DPIE and OEH assessments. For DPIE to claim these outcomes can be expected to have an offset standard is a statement not backed by any evidence.

The current state of rehabilitation success at well and spill sites in the forest was examined in detail by Pilliga Environment Group (PEG 2018) who measured native plant presence and cover, weed presence and top-soil conditions. The Group found low native species diversity, depauperate groundstorey layer, high levels of weed invasion and low success rates for plantings. Some sites with historic spill zones have not rehabilitated after 20 years to anywhere near their original condition. Sites show ongoing issues with soil suitability with elevated pH. This study (attached) showed from an examination of 63 well sites in the Pilliga, only one showed some resemblance to the original vegetation cover.

Inter-generational equity

DPIE claims it is providing an approval that will be consistent with the principle of inter-generational equity, but closer examination shows this not to be the case. In particular DPIE states in its Assessment Report that,

" .. all the land disturbed by the project would be progressively rehabilitated to a high standard and returned to its previous use".

As previously discussed, this is an unsubstantiated claim. In relation to equity for future generations, DPIE states,

"the project would not have significant impacts on any of the region's natural or cultural resources (gas, water, land, air, flora and fauna, cultural heritage or built environment, including the Siding Springs Observatory) either now or in the future, and it would not prevent future generations from being able to inherit and benefit from a region that has extensive and diverse natural and cultural resources".

The claim in relation to significant impacts, as discussed above, for some key species, is unlikely to be true. In my opinion, the possible loss of the Black-striped Wallaby, Pilliga Mouse, Eastern Pygmy-possum and Koala populations from within the Project Area would have potentially serious consequences for the ultimate survival of these populations in the Pilliga and would rob future generations of a *natural* legacy more rich.

Appendix 1

(a) Clearance Upper Limits for Koala Habitat in Project Area (as per DPIE Assessment Report and expert knowledge, SEPP 44, March 1 2020)

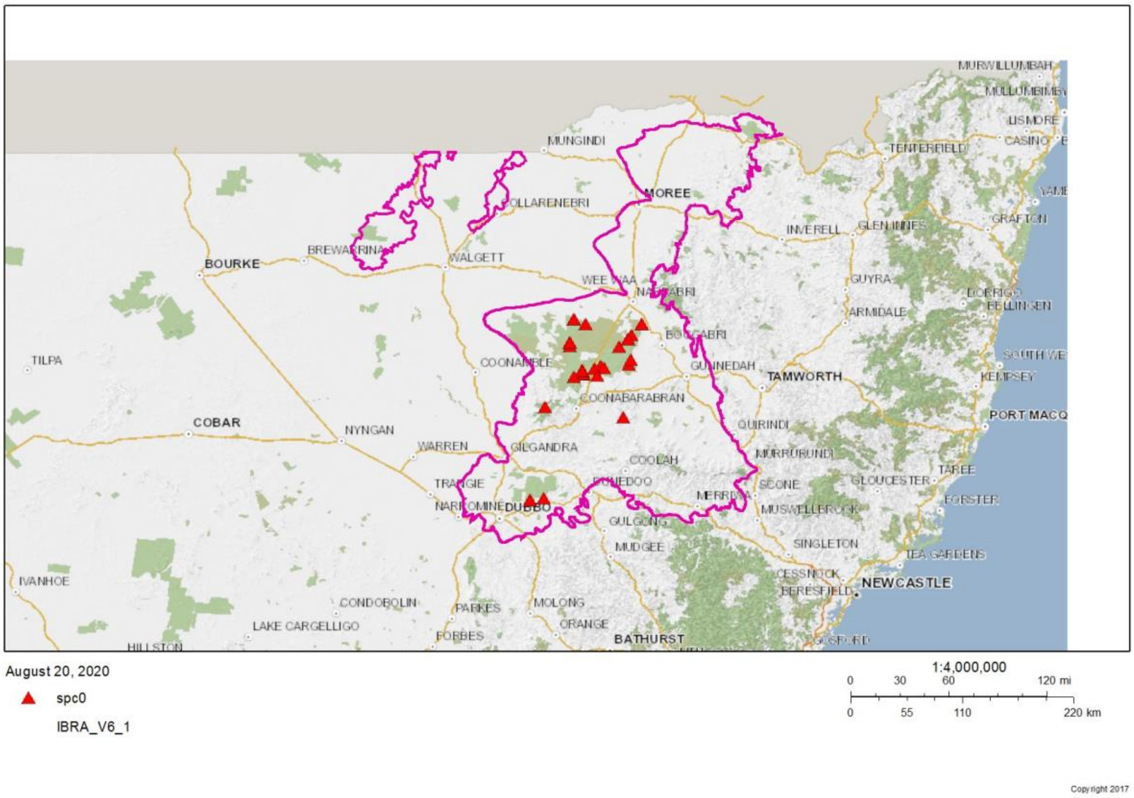
Preferred Koala habitat in Project Area to be cleared	Upper clearance limit
88 Pilliga box - white cypress pine – Buloke shrubby woodland in the Brigalow Belt South Bioregion – Woodland Native vegetation	40.8
202 Fuzzy box woodland on colluvium and alluvial flats in the Brigalow Belt South Bioregion (including Pilliga) and Nandewar Bioregion Native vegetation	5.9
399 Red gum - rough-barked apple +/- tea tree sandy creek woodland (wetland) in the Pilliga - Goonoo sandstone forests, Brigalow Belt South Bioregion- Woodland Native vegetation	3.4
397 Poplar box - white cypress pine shrub grass tall woodland of the Pilliga – Warialda region, Brigalow Belt South Bioregion – woodland Native vegetation	1
401 Rough-barked apple - Blakely's red gum - black cypress pine woodland on sandy flats, mainly in the Pilliga Scrub region – woodland Native vegetation	46.4
	95.5 ha

(b) Clearance Upper Limits for Pilliga Habitat in Project Area (as per DPIE Assessment Report and expert knowledge (Paull 2009l Paull et al 2014)

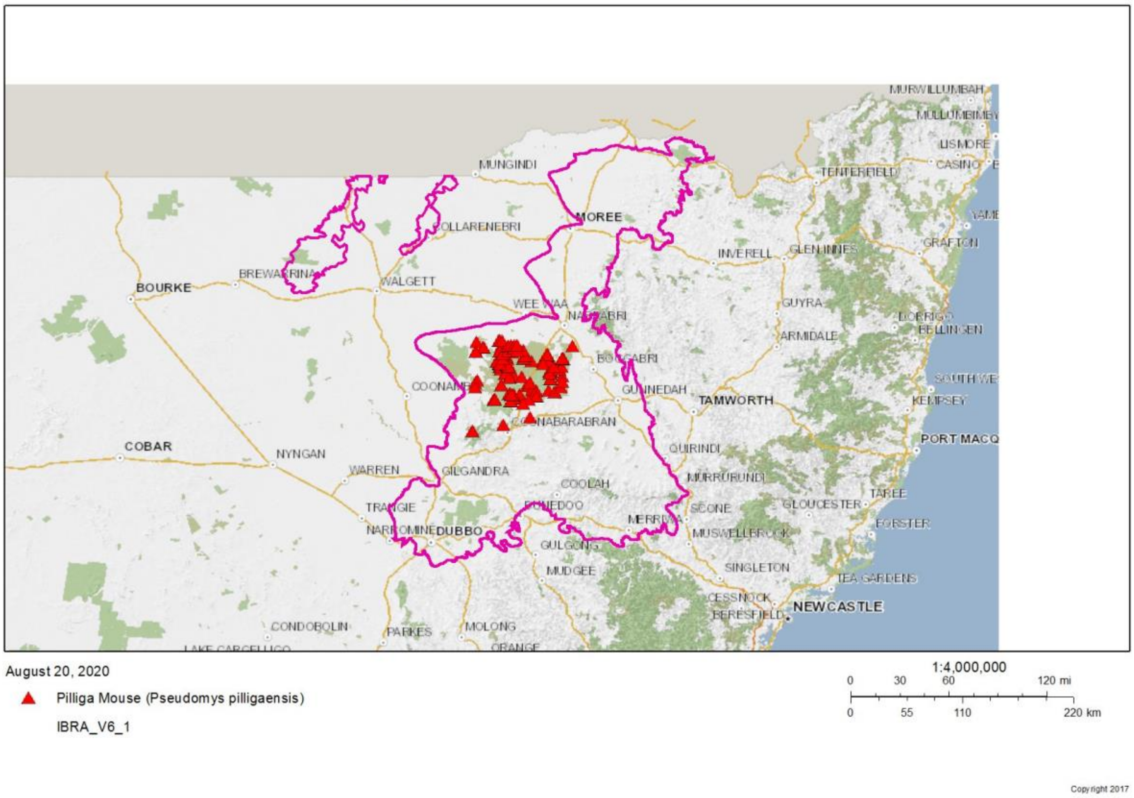
Potential Pilliga Mouse habitat in Project Area to be cleared	Upper clearance limit
141 Broombush - wattle very tall shrubland of the Pilliga to Goonoo regions, Brigalow Belt South Bioregion Native vegetation 1,035.60 19.5	19.5
408 Dirty gum (Baradine gum) - black cypress pine - white bloodwood shrubby woodland on of the Pilliga forests and surrounding region – Woodland Native vegetation 3,084.80 33.3	33.3
404 Red ironbark - white bloodwood +/- burrows wattle heathy woodland on sandy soil in the Pilliga forests – woodland Native vegetation 9,993.90 86.6	86.6
405 White bloodwood - red ironbark – black cypress pine shrubby sandstone woodland of the Pilliga Scrub and surrounding regions – Woodland Native vegetation 6,652.10 108.7	108.7
40X1 White bloodwood – dirty gum – rough barked apple – black cypress pine heathy open woodland on deep sand in the Pilliga forests Native vegetation 7,534.90 138.4	138.4
	386.5 ha

Appendix 2. Distribution Maps

Eastern Pygmy-possum BBS(NSW)



Pilliga Mouse Records BBS(NSW)



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Study on the success of rehabilitation at gas infrastructure within PEL238

Bohena 11 regeneration site

Pilliga Environment Group

25 June 2018

Summary

Results of an examination of all well sites (63) within forested areas of PEL238 show:

- In terms of both vegetation cover and species diversity, two thirds of the well sites subject to natural regeneration are currently in a poor quality with low to no vegetation cover to speak of and a poor species diversity. Many sites are supporting significant amounts of weeds.

- 20 well sites show a high plant cover in at least one layer, generally the mid-storey, which is usually dominated by *Acacia spectablis* and/or *A. deanii.* Groundstorey is usually the poorest component, though some sites show good recovery. Only one site Dewhurst (DH) 09 was found to be on a trajectory to become self-sustaining and meeting benchmark criteria. The soil conditions at this site were normal.

- Most sites showed sub-surface pH levels above the background levels of the reference system. High levels of pH at well sites will inhibit the development of the naturally occurring ecological community. Double the background levels of salt in the sub-surface soil at the spill sites may also inhibit the recovery in these areas. Site rehabilitation should also include soil restoration with targets to achieve more acidic top-soils.

- Sites subject to active regeneration are young and given constraints associated with soil conditions at these spill sites, their success remains unresolved.

- Claims made by Santos in the environmental assessment documentation for the Narrabri Gas Project (Project) as to the effectiveness of their current rehabilitation at well sites should be rejected by consent authorities pending independent assessment.

- Santos' request for additional biodiversity credits for their rehabilitation activities as part of the Project should not be supported.

Background

Claims have been made in the Santos Narrabri Gas Project (Project) Environmental Impact Statement (EIS) Rehabilitation Strategy and the Response to Submissions documentation about the high 'site quality' observed at well sites in PEL238. The Pilliga Environment Group Inc (PEG) has subsequently investigated vegetation and soil conditions associated with well sites in the Project area to test these claims.

Santos have repeatedly stated that current rehabilitation is on track to meet completion targets, in terms of species composition and vegetation structure at the sites, for example; "*Rehabilitation to date shows similar numbers of native species to reference sites, is dense shrub layer, relatively low weed cover and regeneration of overstorey through coppice regrowth.*"

The only evidence presented in the EIS to support these claims (with no further evidence presented in the RtS) is Figure 5 in Appendix V of the EIS (reproduced below). It shows a graph comparing 'site quality' against reference values at 11 sites. The meaning of 'site quality' is unclear, though shows, for example at site DH9, site quality is approximately 75% of the reference site quality. Overall, it is stated by Santos that naturally revegetated well sites on average are about 74% of the quality of reference sites (Santos 2017).

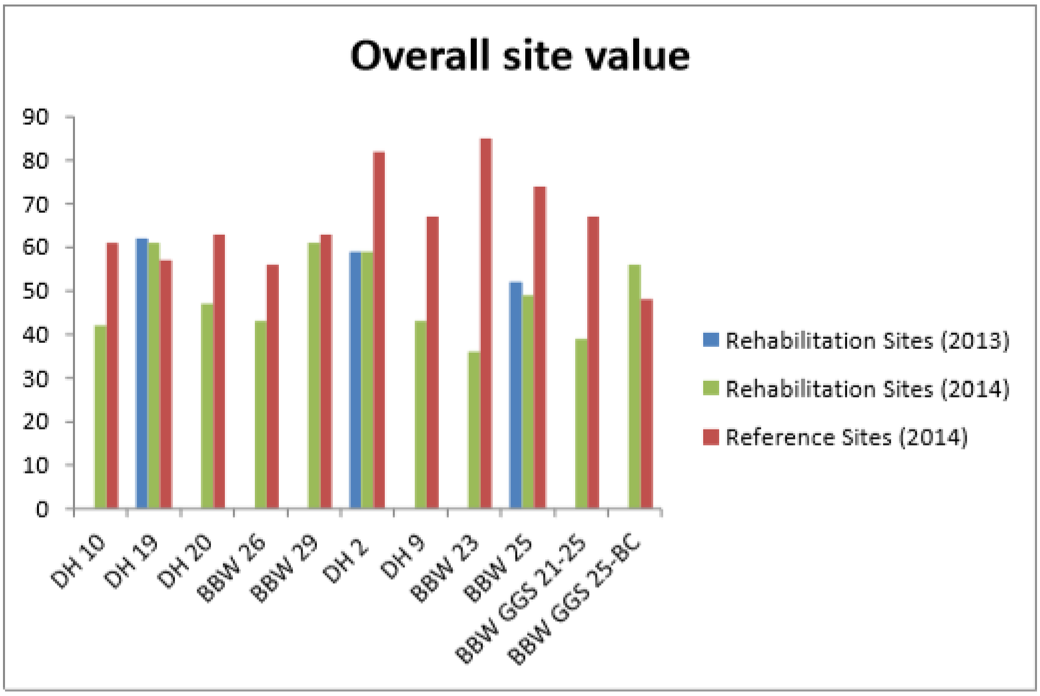

Figure 5: Overall site value in rehabilitation areas compared to nearby reference sites not disturbed by the project (2013-14)

This apparent success has led to Santos to request an additional 15% credit from rehabilitation for their offset strategy and to claim that credits generated by rehabilitation will account for some 30% of the total credit liability of the Narrabri Gas Project.

Review of existing information

The NSW Government's Sharing and Enabling Environmental Data (SEED) database shows there are 24 active production, 29 inactive (not producing), and 31 permanently sealed wells in PEL 238 (Appendix 1). A further three sites (Bohena 8, 10 and 11) are not recorded on the SEED database, though according to management plans prepared by Santos and Eastern Star Gas and obtained under the *Government Information (Public Access) Act 2009* (GiPA Act) , these have undergone rehabilitation activities over the last 20 years.

From the documents obtained, it was possible to identify six sites which have significant and recognised offsite produced water spill zones. The documents indicate a further five sites have minor offsite or onsite areas affected by spillage. All are indicated as being 'full rehabilitation' sites in the plans. The actual extent of on-site spillage within the well sites is not known.

According to the documents, since 2012, 11 sites have been subject to 'full rehabilitation' and 'soil restoration', a further 15 have been subject to 'lease size reduction' with five of these to 'partial rehabilitation'. In 2012, rehabilitation entailed removal of contaminated top-soil and sump-pits and covering the whole site with mulch and logs. This was also referred to as 'soil treatments'. 'Partial' referred to rehabilitation of only a part of the well site, leaving the rest of the site in use. Two sites in the 2012 plans (Bohena 4 and 6) were subject to 'supplementary actions' noting the failure of previous plantings at these sites (Santos 2013), entailing further mulching and soil removal at these sites.

For the most part, plant growth at well and spill sites has been due to natural regeneration and results are highly varied. 'Lease size reduction' generally incorporates areas of regrowth that have been fenced off from the rest of the site.

More recently, there has been a program of irrigation and plantings undertaken at some sites which have experienced legacy spills, (Bohena 2, 5, 6 and at the Bibblewindi facility). The detailed management plans for these activities are not publicly available though it is assumed they are being undertaken in a way consistent with the Rehabilitation Strategy as submitted in the EIS. This work has entailed a different approach of intensive irrigation, plantings and surface raking of mulch and topsoil. Gypsum is added to the irrigated water in attempt to apparently breakdown shallow clay layers. A number of other legacy sites have been subject to irrigation activity, though no plantings have yet occurred (Bohena 4, 7 and 11).

The key questions that this study will address are:

1. *Is the species composition of naturally regenerated sites consistent with bushland which occurs in adjacent bushland?*

2. *Have past revegetation efforts been successful?*

3. *Are there differences in soil condition between old and newer sites?*

4. *What, therefore, are the implications for Santos' ability to regenerate sites to a natural condition'?*

Methodology

In order to gain a better understanding of the rehabilitation at the well and spill sites in PEL238, assessments were undertaken on the vegetation cover at 63 well sites and sub-surface soil conditions at 12 sites as of June 2018.

Native vegetation

All well sites in the forest were assessed for the quality of regeneration taking into consideration vegetation cover and plant diversity. The results are shown in the last column of Appendix 1. Site inspections were generally qualitative and considered the whole site by either (a) undertaking traverses across the site or (b) walks around the perimeter of fenced sites. Overall cover of vegetation and species diversity were assessed. Sites were observed to fall within five categories of growth or site quality:

1	Little growth, weeds, poor diversity
2	Small patches of wattle and/or tree growth, low diversity
3	Partial cover of wattle and/or tree growth, some diverse understorey
4	High cover native growth, moderate-good diversity
5	Active regeneration using tubestock

How well each category meets Biometric benchmark criteria is also assessed. Santos state in their Rehabilitation Strategy that each site has as yet to be assigned a reference community, however the predominant overstorey species in the Project area are *Eucalyptus crebra* (Narrow-leaved Ironbark), *Callitris glaucophylla* (White Cypress Pine), *Allocasuarina luehmannii* (Bull Oak), *Eucalyptus chloroclada* (Dirty Gum), *Corymbia trachyphloia* (Brown Bloodwood) and *Eucalyptus pilligaensis* (Pilliga Box), probably representing a number of different communities. For this report observed site conditions, comparisons were made with the ironbark-cypress pine-bulloak community BVT398: *Narrow-leafed ironbark – White Cypress Pine – Buloke tall* *open forest on lower slopes and flats in the Pilliga scrub and surrounding lands in the central north BBS bioregion,* one of the most widespread communities in the Project Area

Soil analysis

A key component of the Rehabilitation Strategy is site soil management. Santos appear to recognise that health of the top and sub-surface soil environments and the biological activity associated with those layers are key for rehabilitation success.

Sites that Santos have cleared since taking over as owners of the Project infrastructure include the latest Dewhurst well series (26-29). However, while Santos may have stockpiled the top-soils at some of these sites, there is no documents that show how successfully these soils have been repatriated to the site. So, the proposal to do so in future Rehabilitation Strategy is not based on previous experience.

The soils in the Project area are predominately a duplex sodic type with contrasting A and B horizons. The predominately loamy A horizons are not deep, generally around 10-30cm and overlay a clay 'dome' which is the primary water-holding component of the soils.

Well site construction can heavily impact the structure of the soils. In the past, clearing of the sites scraped the top- and sub-soil, often leaving the clay layer exposed. Sites where produced water has spilled outside the well area have had their top-soils removed completely and disposed of offsite. Subsequent rehabilitation of these areas has generally involved the addition of organic matter and mulching straight on top of the clayey B Horizon, along with an intensive irrigation program, using gypsum as an additive to break down the exposed clay layer. within irrigation water applied to these sites.

The aim of this part of the study is to assess the soil health and its suitability to promote plant growth within the well sites. This assessment was undertaken by sampling the structure, pH, electrical conductivity and salinity as currently exists in the vicinity of a number of well and spill sites.

12 well sites were selected with a range of disturbance histories, including nine wells sites and three 'spill zones' and soil samples were taken (Appendix 2). At each well site, three samples were taken at equal distance (20m) from the location or likely location of the well head. At the spill zones, three samples were taken in a linear transect along the length of the disturbed area. All samples were sampled with a space of at least 20m between each. A 'control' sample was taken at each site in adjoining bushland where natural conditions were observed to exist.

In an attempt to achieve consistency in the soil samples, the loamy sub-surface at a depth of 5 cm below the surface was targeted. At well sites however, the depth of A horizon was found to be variable and so many samples contained higher levels of clay. The soil at the spill sites under rehabilitation were found to be very different, having little of the surface loam left, these sites were found to have a highly organic and clayey sub-surface components.

pH was measured in each of the samples using the soil pH meter PH:-220S (Lutron). Electrical conductivity and associated measurements of the samples were made using the H198192 Meter (Hannah Instruments) within 24 hours of the samples being gathered.

Results: Native vegetation at the well and spill sites

Excluding the well sites subject to current active regeneration, 63 well sites located within bushland settings (mainly state forest) have been left largely to natural regeneration. Some sites have had 20 years since gas activities were undertaken at the site, though most have more recent activity, mostly 8-14 years ago. In most cases, the time since last activity has little to do with quality of existing vegetation cover with many older sites showing poor natural regeneration.

Table 1. Quality of well site rehabilitation in forested areas of PEL238

Quality	Description	Tally	%
1	Little growth, weeds, poor diversity	21	33
2	Small patches of wattle growth, low diversity	22	35
3	Partial cover of wattle and tree growth, some diverse understorey	19	30
4	High cover native growth, mod-good diversity	1	2
5	Active regeneration with tubestock	4	

1 Little growth, weeds

About one third of well sites in the forest (n=21) are largely devoid of vegetation, with scattered grasses and shrubs at some sites. These sites are also prone to weed infestation which can be significant. Various levels of mulching were observed at the sites.

DH28 typical of sites with little vegetation growth, but with some mulch.

2 Small patches of wattle and/or tree growth, low diversity

About a third of all sites (n=22) show some growth of wattles and trees in small patches. Understorey was generally found to be poor, as are overall levels of diversity. Wattles are often good colonizing species, and a few species were found to be present at the sites particularly the locally occurring Mudgee Wattle *Acacia spectablis* and Deans Wattle *Acacia deanii.*

Bohena 11 with wattle growth, some grassy patches.

3 Partial cover of wattle and/or tree growth, some understorey

Another third of well sites in the forest (n=19) show significant stands of wattle and tree growth, providing high levels of mid-storey cover. The quality of these sites varied considerably, with some showing good understorey development with a moderate diversity, while others had only scattered grasses and shrubs.

Bohena 3 with thick stands of wattle growth but with a depauperate understorey.

4 High cover native growth

Only one well site had what may be described as a good level of recruitment of locally occurring species, on a trajectory to achieve benchmark standards for composition and diversity, namely DH09 on Garlands Road. Good levels of recruitment of canopy, mid-story and groundstorey species was evident, including Bull Oak and Cypress Pine. This site had an overall good plant diversity.

DH09 showing good canopy and understorey recruitment.

5 Sites subject to active rehabilitation efforts (irrigation and plantings)

Four sites where spillage of produced water has occurred were currently found to be subject to an active rehabilitation program. This has been conducted over the last 18 months at the Bohena 2 and Bibblewindi spill sites and only recently commenced at the Bohena 5 and 6 sites.

Irrigation system at Bohena 2 spill zone

This has consisted of an irrigation system installed at each site consisting of holding tanks and a reticulated watering system. Watering of the sites has been conducted over the last 18 months, accompanied by plantings of various species.

Bohena 2 spill zone covers over 3 ha of bushland and currently shows significant effort in terms of plantings and irrigation. Prior to this current program this site would have been categorized as having a low diversity and cover. There has been significant weed removal from this site. It is too early to judge the success of this program, though some dieback is occurring, perhaps as a result of current dry conditions.

In regard to the Bibblewindi spill site, page 310 (6-122) of the Response to Submissions claims, "*Targeted surveys and monitoring at the Bibblewindi rehabilitation site undertaken by a suitably qualified ecologist during autumn and spring of 2017 have found the revegetated area is generally in a good condition and progressing on a trajectory towards self-sustaining plant communities*".

Assessment of this site in spring 2017 and June 2018 showed the 'spill area' at this site has been subject to intensive irrigation over the last year. Sedge and other wetland species have been planted which are not present in the surrounding forest community. In my opinion, if the irrigation is turned off, this 'community' is unlikely to persist. These plantings bear no resemblance to the reference community.

Results: Soil condition at the well and spill sites

Control conditions

The structure of the sub-surface' A horizon at control sites was generally a 'loam' often with a coarser sandy component on the surface of the top-soil. This merges into a 'clayey loam' the closer the contact with clay horizon. Some sites had very shallow A horizons and so samples containing clay were also obtained. At the 'spill' control sites, samples were obtained to include elements of clay so as to closer match the conditions in the rehabilitation zones.

The control sites (n=12) indicate that the loamy A horizon generally has a pH of between 5-6, with a higher pH for samples containing clay, up to about 6.3. The background electrical conductivity (EC) ranges from approximately 10-40 µs/cm and Total Dissolved Solids (TDS) at about 8-21 ppm. Background salinity levels of the soil in control areas lie in the range of 0-0.1%.

Well Sites

Some of the samples taken from well sites (n=27) showed some good retention of the top-soil, though mostly, A horizons have been lost to some extent, with shallow clay layers at some sites. This has elevated the pH readings taken at the well sites, with no sites, except two, showing a pH of less than 6 (DH09 and DH19). Sub-surface soil samples from all well sites ranged from pH 6.4 - 7.8, regardless of the clay content of the sample.

EC in the sub-surface samples from the well sites were mostly within the background levels recorded from within the control sites (9-40 µm/cm) though two samples showed double the background levels of EC and TDS. These sites also had an overall salinity level of 0.2%.

Spill Sites

At the three spill sites, the soil samples may be described as a loamy clay with very level of high organic matter. These sites all displayed a relatively high pH (6.4 - 6.9) in the 'top-soil'. EC levels varied considerably, with five of the nine samples showing double the background levels of EC and TDS with overall salinity levels of 0.2%. The rest of the samples were still seen to be higher than the normal range.

Discussion

Importance of soils in rehabilitation

Soils, especially top-soils, are key components of the ecosystem, as they supply nutrients and act as a medium for other biota, particularly bacteria and fungi needed for healthy soils and the breakdown and transmission of nutrients. Plants form symbiotic relationships with these soil fauna and flora that assist them to utilize inorganic elements.

Soil conditions (pH, EC, structure) are important to maintain this biotic-inorganic cycle which takes place in the soil. Germination is also affected by soil condition and tolerances to pH levels can affect germination potential of many species, with a variety of tolerance between species. The biggest issue which faces ecosystem restoration efforts is the biological health of soils which are stockpiled as the stockpiling process changes normal chemical and nutrient cycles and the normal growth and behavioural patterns of soil biota, such that effective soil death is usual.

Data from this and other studies show the soils of the Pilliga forest to be acidic in nature, though usually regarded as nutrient poor (OEH 2013), underlying clay layers retain water and nutrient for plant growth. The movement of nutrient through the clay layer also occurs and there it becomes available to shrub and tree growth, however, the nutrient cycle in these soils is very slow (Hart 1992). As a consequence, the vegetation communities have evolved on a nutrient poor and acidic soil. For example, the Cypress Pine can only tolerate acidic soils (Lacey 1973). It appears even with the influence of clay, which will increase pH, pH levels of the surface and sub-surface soils in the Pilliga are rarely over 6. The control site soil results obtained here compare favorably with those found by Goldey and Associates (2012) who also found an average sub-surface pH of 5.5 and an EC of <20 µS/cm at unaffected sites.

Components of produced water

The chemical composition of produced water as held in the Leewood Ponds is shown in Table 6-1 of the Water Baseline Report, provided in the Response to Submissions. pH levels of this water was found to be in the range of 8.6 – 9.8, with EC levels of 4,223 – 28,399 µS/cm and TDS of 14,000 – 40,000 ppm. The 'spill zones' were exposed to this type of water, albeit in a diluted form. The soil results shortly after the incident at Bibblewindi show a sub-surface soil pH of 8-9 and an EC up to 6,000 µS/cm (Goldey and Associates 2012). The chemical composition of this water is certainly toxic to biotic matter, judging by the rapid way vegetation die when in contact (personal observation). But produced water may also be spilled within the well-site, during routine activities while the gas well is in pilot or productive use.

While levels of pH and EC found in the samples of this study are not high when compared to raw produced water, the residual impact of this water upon the chemical nature of the soil needs to be considered. While most of the badly affected soil has been removed at the spill sites, there is still persistence of areas of relatively high sub-surface soil EC (2-3 times background levels), as demonstrated in this study.

This study showed a consistent pattern of elevated pH at well and spill sites, regardless of age since drilling completion. The highest pH readings were recorded at Bohena 3 and 2, where spill incidents have been documented and where drilling activity occurred 20 ago. While sub-surface soils at these sites have higher levels of clay on average than control sites, elevated pH (greater than 6.4) were detected regardless of it being loam or clay. Exceptions were Dewhurst 9 and 19 which had normal sub-surface readings (less than 6).

For EC and TDS, the highest levels observed were 2-3 times the control range (80 - 100 µS/cm and 40 - 50 ppm respectively) at two well sites and all three of the spill sites. The samples from the Bohena 2 and Dewhurst 19 well sites that contained these high levels were taken from surface depressions, possibly old sump pits or other water holding areas. The higher salt samples from the spill zones were taken from areas with no particular surface feature attached such as depressions.

These soil constraints are not favourable for the growth of locally occurring plant communities which tolerate a much more acidic soil and raises further questions concerning the ability of Santos to produce self-sustaining and locally occurring plant communities. Because of the water-holding capacities of the clay layer, contamination of the B horizons is problematic when attempting to remove these substances from the site. Spillage of produced or treated water at well sites may diminish the soil properties and plant growth potential (Echchelh et al, 2018).

Rehabilitation trajectories and completion criteria

Santos claims of a rehabilitation site quality on average being 74% that of reference site condition should be treated with caution given the following factors:

a) Figure 5 of the Rehabilitation Strategy show Santos have selectively used a number of sites with relatively good results to support their argument for wide rehabilitation success in the Project Area. However, if all sites in the PEL subject to natural regeneration are considered, success rates cannot be considered to be high, with approximately two thirds of all well sites with a low site quality, including some sites which are up to 20 years old.
b) Two sites subject to active irrigation and planting are only two years old, and given the issues associated with watering at levels greater than would be experienced naturally, species selection and high soil pH, the success of these areas remains unresolved. The Society for Ecological Restoration state that ecosystems can only be considered to be restored if they are self-sustaining to the same degree as their reference ecosystem and have the potential to persist indefinitely under existing environmental conditions. Planted systems need to demonstrate this persistence and regenerative ability, particularly under abnormal conditions associated with significant changes to the nature of the top-soil.

The benchmark conditions of Biometric Vegetation Type 398: *Narrow-leafed ironbark – White Cypress Pine – Buloke tall open forest on lower slopes and flats in the Pilliga scrub and surrounding lands in the central north BBS bioregion* specify the following criteria:

Benchmark criterion	Median Values
Native plant diversity	➢ 32±10
Overstorey cover	➢ 8.6±7.9%
Mid-storey cover	➢ 10.7±10.5%
Ground-cover (grasses)	➢ 25.2±17%
Ground-cover (shrubs)	➢ 14.6±19.2%
Ground-cover (other)	➢ 10.8±11.1%
Exotic plant cover	➢ 0.2±1.3%
Litter	➢ 52.1±28.9%
Bare ground/rock	➢ 10.3±11.6%
Cryptogram	➢ 0.6±1.2%
No trees with hollows	➢ 0.5±0.8
Length of fallen logs	➢ 45.2±31.2m

For the purposes of this report, is assumed that median levels indicated above will be the close to the approximate completion targets, though Santos have stated they will use reference sites from within the study area to create a local benchmark.

For two-thirds of the sites surveyed for this report, few if any of the benchmarks have been achieved. Of the 20 well sites where good vegetation cover was observed, very few matched the extent of groundcover specified above, while mid-storey is generally over-represented. While some sites showed good species recruitment at various levels, many did not, instead showing species and cover poor ground-storeys.

Overstorey recovery was also patchy from site to site, locally occurring eucalypt species sometimes showed good germination rates, though no site was found to have trees much over two meters. Santos also mention that coppicing stumps will provide good overstorey cover, however, most sites were observed to have their stumps removed to facilitate site activity and this component should not be relied on as a way of achieving benchmark overstorey conditions. A shortfall on relying on the Biometric benchmark approach for achieving a self-sustaining community is no specification exists for ensuring that the composition of the overstorey remains intact, and there is no requirement that all the species present in the reference sites be present at the rehab sites. During inspection of the well sites, regenerating Cypress Pine and Bull Oak were both found to be absent, except at a few sites, such as at DH09, a site with natural levels of soil pH.

In order to address some of the issues identified here, which may be particular to the type of operation being proposed, it is recommended that rehabilitation completion criteria for coal seam gas (CSG) activities specify soil pH and *Callitris* recruitment requirements.

More importantly, it is recommended that assertions made by Santos in their Project EIS and RtS regarding their rehabilitation success at well sites be independently verified prior to any approval being granted, as rehabilitation issues are key to meet specific sign-off and offset requirements in the EIS.

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Appendix 1: Site history and rehabilitation data

Site	Completion Date	Status	Depth	Impacted offsite area	Time since activity	Remediation Date	Past Actions	Rehab Rating/5
Bohena South Ponds				0.9 ha		2012	Soil Restoration, Full Rehab	3
Bibblewindi facility				1.2 ha	7 years	2014, 2017, current	Soil Restoration, Full Rehab	New plantings
Bohena 2	9-Jun-98	Permanently sealed	908m	3.1 ha	20 years	2014, 2017, current	Soil Restoration, Full Rehab	New plantings
Bohena 4/4L	15-Aug-98	Permanently sealed	910/1622m	1 ha	20 years	?, 2012, current	Soil Restoration, Full Rehab + Supplementary- irrigation	1
Bohena 5	27-Dec-98	Permanently sealed	936m		20 years	2012, current	Full Rehab - irrigation and plantings	New Plantings
Bohena 6/6H	29-Dec-98	Permanently sealed	976/691m		20 years	?, 2012	Full Rehab / Supplementary actions - irrigation and plantings	New Plantings
Bohena 8	?	Abandoned				2012	Full Rehab	3
Bohena 10		?				2012	Full Rehab	1
Bohena 11		?				2012, current	Full Rehab - irrigation	2
Bohena 14	14-Apr-10	Permanently sealed	1026.3m		8 years			1
Bibblewindi 1	8-May-00	Permanently sealed	950m		18 years			Facility
Bibblewindi 2	11-Jul-06	Permanently sealed	997m		12 years			Facility
Bibblewindi 11	24-Nov-07	Permanently sealed	1035m		11 years	2012	Lease Size Reduction	2
Burrawarna 1 e	1-Jun-00	Permanently sealed	832m		18 years			
Jacks Creek 1 e	29-Jun-00	Permanenty sealed	792m		18 years			3
Yallambee 1 e	26-Aug-09	Permanently sealed	894m		9 years			
Yallambee 2 e	21-Apr-11	Permanatly sealed	1082m		7 years			
Dewhurst 2	21-Apr-	Permanently sealed	975 m					3

Dewhurst 3	22-May-08	Permanently sealed	885m		10 years			1
Dewhurst 5	8-Oct-08	Permanently sealed	822m		10 years			1
Dewhurst 4	8-Jul-08	Permanently sealed	1038m		10 years			1
Dewhurst 7	10-Sep-08	Permanently sealed	1099m		10 years			1
Dewhurst 8/8A	20-Nov-13	Permanently sealed	1027m		5 years			1
Dewhurst 11	10-Nov-09	Permanently sealed	1038m		9 years			1
Dewhurst 19	15 May 2011	Permanently sealed	660m		7 years			4
Brigalow Park 1 e	15-Oct-04	Permanently sealed	910m		14 years			
Brigalow Park 2 e	15-Nov-10	Permanently sealed	752m		8 years			
Rosevale 1/1A e	23-Nov-10	Permanently sealed	636m		8 years			
Coonarah 2 e	20-Jan-11	Permanently sealed	1011m		7 years			
Coonarah 9 e	11-Nov-09	Permanently sealed	1023m		9 years			
Tintsfield 1	9-Oct-09	Permanently sealed	988m		9 years			
Wilga Park 4	8-Jan-99	Permanently sealed	821m		19 years			
Wilga Park 5	17-Dec-98	Permanently sealed	841m		20 years			
Bohena 3	28-Dec-98	Not producing gas	925m	0.9 ha	20 years	2012, current	Soil Restoration, Full Rehab - irrigation	3
Bohena 7	26-Dec-98	Not producing	941m	1.2 ha	20 years	2012, current	Soil Restoration, Full Rehab - irrigation	2
Bohena 9	6-Sep-04	Not producing	913m		14 years	Current	irrigation	2
Bohena South 1	19-Sep-04	Not producing	909m		14 years			3
Bibblewindi 3	20-Jun-06	Not producing	987m		12 years			2
Bibblewindi 4	1-Jul-06	Not producing	987m		12 years			2
Bibblewindi 5	28-Apr-06	Not producing	997m		12 years			1
Bibblewindi 6	25-May-06	Not producing	996m		12 years			1
Bibblewindi 7	10-Apr-06	Not producing	1005m		12 years			1
Bibblewindi 8	4-Jun-06	Not producing	997m		12 years			1
Bibblewindi 9	14-May-06	Not producing	997m		12 years			2

Bibblewindi 10	26-Mar-06	Not producing	990m		12 years	2012	Lease Size Reduction	3
Bibblewindi 14	7-Feb-09	Not producing	1100m		9 years	2012	Lease Size Reduction	1
Bibblewindi 20	12 Jul 2009	Not producing,	1004m		9 years	2012	Lease Size Reduction	2
Bibblewindi 26 H	4-Jul-09	Not producing			9 years			3
Dewhurst 6	7-May-09	Not producing	1005m		9 years			2
Dewhurst 9	24 Jun 09	Not producing	1032m		9 years			3
Dewhurst 10	30 Jul 2009	Not producing	976m		9 years			3
Dewhurst 13	12-Nov-09	Not producing	1225m		9 years			2
Dewhurst 14	4-Nov-09	Not producing	1220m		9 years			1
Dewhurst 15	25-Oct-09	Not producing	1205m		9 years			1
Dewhurst 16H	18-Dec-09	Not producing	2106m		9 years			2
Dewhurst 17H	7-Dec-09	Not producing	2048m + 1 Station		9 years			2
Dewhurst 18H	26-Nov-06	Not producing	2035m + 2 laterals and 8 stations		12 years			2
Dewhurst 22	10-Dec-13	Not producing	1022m		5 years			2
Dewhurst 23	8-Feb-14	Not producing	1104m + 1 DW ~ 2km		4 years			1
Dewhurst 24	23-Dec-13	Not producing	999m		5 years			2
Dewhurst 25	17-Jan-14	Not producing	967m + 1DW ~1.8km		4 years			1
Wilga Park 3	17-Dec-98	Not producing	814m		20 years			
Bibblewindi 12	39821	Producing	1002m			2012	Lease Size Reduction	2
Bibblewindi 13	39835	Producing	1036m			2012	Lease Size Reduction, Partial Rehab	2
Bibblewindi 15	39900	Producing	1050m			2012	Lease Size Reduction	3
Bibblewindi 16	39866	Producing	1100m			2012	Lease Size Reduction, Partial Rehab	1
Bibblewindi 17	39909	Producing	1076m			2012	Lease Size Reduction, Partial Rehab	2
Bibblewindi 18 H	39888	Producing	2121m + 2 laterals, 10 stations					2
Bibblewindi 19 H	39929	Producing	2296m + 2 laterals, 6					3

			stations					
Bibblewindi 21 H	40078	Producing	2378m + 9 stations					3
Bibblewindi 22	39960	Producing	895m					3
Bibblewindi 23	39974	Producing	905m					3
Bibblewindi 24	39967	Producing	920m					3
Bibblewindi 25	39980	Producing	912m					3
Bibblewindi 27	40032	Producing	1185m			2012	Lease Size Reduction, Partial Rehab	1
Bibblewindi 28 H	40061	Producing	2364m + 3 stations					2
Bibblewindi 29	40047	Producing	1207m			2012	Lease Size Reduction	3
Tintsfield 5	40215	Producing	870m					
Tintsfield 4H	40274	Producing	1713m + 3 stations ?m					
Tintsfield 2H	40258	Producing	11712m + 4 stations					
Tintsfield 3H	40243	Producing	1492m					
Tintsfield 6	40223	Producing	871m					
Tintsfield 7	40232	Producing	870m					
Dewhurst 26	41701	Producing	1060m					2
Dewhurst 27	41733	Producing	1217m					2
Dewhurst 28	41691	Producing	1065m					1
Dewhurst 29	41779	Producing	1170m + 4DW ~ 2km					3
Core holes								
Bohena 3c	28-Dec-98	Permanently sealed	925m					
Bohena 12c	23-Jul-07	Permanently sealed	1008m					
Bohena 13c	27-Oct-07	Permanently sealed	942m					
Bohena 14c	14-Apr-10	Permanently sealed	1026m					
Bohena South 2c	26-Aug-07	Permanently sealed	906m					
Bohena South 1c	19-Sep-04	Permanently sealed	909m					
Bibblewindi 11c	24-Nov-07	Permanently sealed	1035m					

Bibblewindi North 1c	11-May-07	Permanently sealed	855m					
Bibblewindi West 1c	13-Dec-07	Permanently sealed	888m					
Wilga Park 1c	21-May-99	Permanently sealed	653m					
19 3, 22 1, 22 2, 1 4								

Appendix 2: Sub-surface soil sample data

	Site	Status	Factors	Control	1	2	3
				loam	loam	loam	clayey loam
1	Bo11	?	pH	5.65	6.88	7.73	7.03
			EC (µS)	35.5	11.6	34.21	21.41
			Res (kΩ)	28.5	86.4	27.5	46.2
			TDS (ppm)	17.52	5.8	18.91	10.88
			salinity (%)	0.1	0	0.1	0
				loam	clayey loam	clayey loam	clayey loam
2	Bo7	Sealed	pH	5.23	6.15	6.13	6.38
			EC (µS)	47.33	47.39	55.31	44.19
			Res (kΩ)	22.9	20.7	16.3	21.3
			TDS (ppm)	21.72	24.91	31.09	23.67
			salinity (%)	0.1	0.1	0.1	0.1
				loam	clayey loam	clayey loam	clayey loam
3	Bo3	Inactive	pH	5.66	7.38	7.23	6.9
			EC (µS)	29.34	21.74	25.78	13.22
			Res (kΩ)	35.8	45.5	39.2	75.8
			TDS (ppm)	13.77	11.05	12.88	6.6
			salinity (%)	0.1	0	0	0
				loam	clay	clayey loam	clayey loam
4	Bo9	Inactive	pH	5.74	6.39	6.49	7.1
			EC (µS)	22.21	11.72	9.73	23.83
			Res (kΩ)	45.1	85.5	104	41.9
			TDS (ppm)	11.1	5.84	4.83	11.93
			salinity (%)	0	0	0	0
				loam	clayey loam	clayey loam	clay
5	Bo6	Sealed	pH	5.24	6.87	6.71	6.53
			EC (µS)	32.46	22.57	22.62	9.68
			Res (kΩ)	30.3	43.7	43.4	99.6
			TDS (ppm)	17.36	12.21	11.53	4.99
			salinity (%)	0.1	0	0	0
				loam	clayey loam	clayey loam	clayey loam
6	Bo2	Sealed	pH	5.87	7.16	6.73	6.96
			EC (µS)	17.33	58.26	81.8	23.68
			Res (kΩ)	57.3	17.2	12.2	41.9
			TDS (ppm)	8.64	30.44	41.45	12.04
			salinity (%)	0	0.1	0.2	0

				loam	loam	loam	clayey loam
7	B04	Sealed	pH	6.02	6.61	6.94	6.74
			EC (µS)	24.65	19.85	28.44	25.89
			Res (kΩ)	40.3	50.6	34.5	38.6
			TDS (ppm)	12.43	9.86	14.6	13.15
			salinity (%)	0	0	0.1	0
				loam	loam	loam	clayey loam
8	DH09	Sealed	pH	5.64	5.42	5.56	6.21
			EC (µS)	33.24	25.55	56.72	15.25
			Res (kΩ)	30.1	39	17.6	65.6
			TDS (ppm)	16.49	12.87	28.67	7.58
			salinity (%)	0.1	0	0.1	0
				loam	clayey loam	clayey loam	loam
9	DH19	Inactive	pH	5.71	6.73	5.35	5.81
			EC (µS)	16.17	16.6	96.12	10.17
			Res (kΩ)	61.8	60.7	10.4	96.9
			TDS (ppm)	8.01	8.24	48.21	5.19
			salinity (%)	0	0	0.2	0
				loamy clay	organic/clay/ loam	organic/clay/ loam	loamy clay
10	BO7spill	Sealed	pH	6.14	6.44	6.54	6.67
			EC (µS)	23.79	37.06	88.13	72.67
			Res (kΩ)	43.2	27	11.4	13.7
			TDS (ppm)	11.54	19.01	43.66	39.71
			salinity (%)	0	0.1	0.2	0.1
				clayey loam	organic/clay/ loam	organic/clay/ loam	organic/clay/ loam
11	BO2spill	Watering &	pH	5.81	6.4	6.65	6.53
		planting	EC (µS)	19.56	31.36	90.3	83.62
			Res (kΩ)	51.4	30.9	11.1	11.7
			TDS (ppm)	9.67	16.41	45.81	43.74
			salinity (%)	0	0.1	0.2	0.2
				loam	organic/clay/ loam	organic/clay/ loam	organic/clay/ loam
12	Bibspill	Watering &	pH	5.91	6.43	6.84	6.5
		planting	EC (µS)	16.86	50.9	41.88	84.09
			Res (kΩ)	59.6	19	24.1	11.8
			TDS (ppm)	8.37	27.4	20.66	42.47
			salinity (%)	0	0.1	0.1	0.2