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Submission to Santos Narrabri Gas EIS

Review of Santos Environmental Impact Statement (EIS) for an 850 well coal seam gas production project in the Pilliga forest and adjacent farmland near Narrabri.

The members of the Northern Inland Council for the Environment object to this project and believe for the reasons given below that it should be rejected.

The Proposal

The proposal includes;

- a gas processing facility for compression dehydration and treatment of gas,
- a water management facility for storage and treatment of produced water and brine,
- possible additional power generation on site,
- continual flaring (burning off of gas) at two locations,
- an infrastructure corridor through the forest between Leewood and Bibblewindi,
- expansion of worker accommodation,
- discharge of waste water into Bohena Creek,
- irrigation with treated water and landfill burial of tens of thousands of tonnes of salt.

The project is more than four times the size of either of the previously approved CSG projects in NSW. It requires the clearing of 988.8 ha of Pilliga Forest to construct up to 850 wells on 425 well pads over 95,000 hectares.

The project will impact on;

- 7 migratory species listed in the EPBC Act 1999
- 27 threatened animals species listed in the TSC Act 1995 and EPBC Act 1999– of those 13 species are tree hollow dependent, 16 species are threatened by feral predators, and 23 species are threatened by inappropriate fire,
- 10 threatened plants species listed in the TSC Act 1995 and EPBC Act 1999 - 5 of those plants are threatened by frequent fire
- 3 endangered ecological communities listed in the TSC Act and EPBC Act

Summary of objections

If this development is given approval it will pave the way for a larger scale of development than that considered in the EIS. It is likely that the scale of development required to justify the infrastructure proposed will require more well heads, which will have a significantly greater

impact on the Pilliga Forest, Agriculture, and the Narrabri regional community. Also not considered is the impact of the proposed pipeline through western NSW.

It should not be approved base on the evidence of impacts observed in Queensland and lack of consideration for;

- the negative impact of the pipeline, it is integral to the project that must be included in EIS.
- the negative impact to human health, as has been observed in Queensland and overseas
- the negative impact to the regional community, as observed in Queensland
- the potential impact to food security
- the amount of fugitive emissions has not been properly assessed, as seen in Queensland
- the impact that those emissions will have on Climate Change, methane is 80 times worse than Carbon dioxide
- the potential impact to water, both above and below ground, in the short and long term.
- the potential impact of lowering of water tables on ground water dependent ecosystems and dependent stygofauna
- the very high conservation value of the Pilliga Forest. It is incompatible to locate an industrial gas field in the largest remnant of inland woodland most capable of supporting viable populations of numerous threatened species into the future. It is the largest remnant within the 4% of the bioregion that is crown lands and conservation reserves.
- the actual impact to the flora and fauna resulting from the project is still largely unknown as the locations for the well heads, roads and pipelines have yet to be determined. The public cannot review an EIS that is based on a hypothetical impact.
- The offsetting of that impact is also unknown, won't be known until it is known what offset land is available. The public have no idea of where offsets will be located or what condition they are in, of even if they occur.
- Feral animal and weed control is to be considered 30% of the offset strategy. Using feral control programs should not be allowable as control should be happening now under State Forest management as their duty of care.
- The loss of forest integrity. The forest would not be cut up like a draft board by well pads, tracks and pipe lines that will destroy habitat, fragment habitat, increase edge effects that modify flora and fauna species composition, increase predation of wildlife, increase feral animal invasion, increase weed invasion.
- The threat of fire and how the risk is to be managed. Lacks detailed Bush Fire plans about frequency and extent of hazard reduction that will be applied to protect infrastructure. Any increase of fire frequency, even cool burns, would be a significant and widespread impact to flora and fauna.

In general the risks have not been fully acknowledged. The EIS is based on simplistic assumptions that fail to consider the complexity of the risks involved and the very long term impact and very high cost of those risks should they eventuate. The past pollution event from Eastern Star gas water holding pond is a classic example of how plans do fail.

The EIS fails to justify the project and its significant impacts and long term risks;

There's no justification for:

- The need for the gas. The whole Santos gas development is based on a false assumption that NSW has a gas supply shortage that cannot be met by limiting gas export from the existing fields to retain enough for domestic supply. Now a well-established fact.

- The significant harm that this project will inflict on social, environmental, and economic values of the Narrabri Shire and New South Wales needs to be weighed up against the economic justification for the project. There is no such economic justification.

Santos is one of several large gas companies that threw the east coast gas market and the industries that rely on it into turmoil by opening up CSG fields in Queensland and contracting to sell more gas than those fields can produce to overseas customers. They drove up the price of gas and are plundering supplies previously available to domestic manufacturers and power stations.

The gas produced at Narrabri might be as little as 4.9% of the volume contracted for sale out of Gladstone. Opening up another gas field at Narrabri is not going to bring down prices. In fact, it will force prices up, because unconventional gas like CSG is so expensive to produce and yields are so low.

Research undertaken by gas company AGL shows that gas from the Pilliga would be the most expensive gas of anywhere in the current east coast gas market. The number of jobs the project will support once the construction is over is just 145. Weighed against damage to the land, and the Great Artesian Basin, this makes no sense. We need sustainable jobs, not plunder for profit.

Gas was once considered to be the energy source to bridge the gap from coal to renewables. We now know that gas can potentially contribute more to Climate Change than coal through fugitive emissions, and we have seen in Queensland that CSG poses a significant risk to water tables, human health and communities.

The supposed critical gas shortage that caused the price rise was the result of government failure to regulate gas export. There is plenty of gas available for domestic supply if the governments decided to bring in regulations to ensure gas is reserved for Australian use. Presently the profitability of overseas companies is considered a higher priority than domestic supply.

We believe the energy debate has been biased toward coal and CSG due to their strong political influence over both NSW and Federal governments. We believe that further government investment into roof top solar, battery systems, wind, hydro, tidal, wave, concentrated solar thermal, and geo thermal systems can supply the energy requirements of NSW.

The gas industry claims are misleading that unconventional gas development brought an economic and jobs boom to Queensland, and promises to do the same for New South Wales. Santos media article Appendix 2 shows their attempt to mislead the public.

The impact of unconventional gas and mining development on communities and local businesses in the Darling Downs region.

Source: CSRM University of Queensland

In contrast to the economic benefits promised, recent gas industry funded studies of the economic and social impacts of gas in Queensland's unconventional gas fields have found:

Local business stakeholders reported deterioration in:

- Financial capital
- Local Infrastructure
- Local skills
- Social cohesion
- The local environment
- Real estate values post construction

Unconventional gas has affected community wellbeing:

- Fewer than one in four local people approved of the unconventional gas industry, with less than 6% believing it would "lead to something better".

Unconventional gas creates few additional jobs:

- There was virtually no spill over jobs created in local retail or manufacturing.
- Gas jobs will be slashed by 80% at the end of the construction period.

For every 10 unconventional gas jobs created, 7 service sector jobs were lost.

There have also been few economic benefits for the wider economy. The industry emphasises the high value of the gas it exports, but the value of gas exports largely flow to the gas companies rather than to the Australian community.

As the Reserve Bank of Australia concluded:

> The effect on Australian living standards will be less noticeable than [the increase in gas production] given the low employment intensity of LNG production, the high level of foreign ownership of the LNG industry and, in the near term, the use of deductions on taxation payments.

Queensland's experience shows that reality does not match the unconventional gas industry's claims. Few benefits are realised outside the gas industry, and there are serious social and economic effects on local communities and existing businesses.

In addition to the fact that the Narrabri Gasfield cannot be justified economically it would impact the largest inland forest that supports the highest diversity of threatened plants and animals.

Rural landholders and the public have been surveyed throughout the Narrabri region; over 90% say they don't want CSG mining in the region. Their wish should be respected, as it is their lives and communities that will be affected the most.

Why then is the Narrabri CSG project even considered when you consider that it will expose the region to very high long-term risks for an unnecessary and uneconomic energy source?

- the existing gas fields can supply the domestic market if regulated to do so
- the supposed economic and jobs benefit doesn't stack up,
- significant potential impacts to the environment, agriculture and people from CSG production

We don't need it.

Renewable Options For Energy

There are numerous renewable energy options that can be used to decrease our reliance of fossil fuels. They are not all limited to daylight hours; they can provide baseload power 24 hours per day. See Appendix 1 for alternative sources for renewable energy.

Biased Planning Process

The decision whether to approve the Santos EIS must be based on the opinions and evidence expressed by the majority of submissions received. It is a very concerning trend that public concerns expressed through submissions and Planning Assessment Commission hearings for large mining developments are constantly ignored. For too long the political influence of large mining companies has over ridden public concerns.

The EIS process should not be about refining a project to make it acceptable to the government. It should not be a foregone conclusion that it will go ahead with some tweaking, as recent comments from Kevin Humphries suggest.

An EIS should be the decision point where all the scientist and expert opinions about likely impacts get weighed up to determine how much of the likely impact can be mitigated and if the residual impacts and risks are acceptable to the public for the project to go ahead.

A clear example that Santos assumes the EIS will be approved is that the pipeline planning is going ahead before the Pilliga Gasfield is approved.

FURTHER REASONS WHY WE OPPOSE THE NARRABRI GAS PROJECT:

Air quality:

The air quality assessment fails to include health-damaging fine particulate pollution with a diameter of 2.5 microns or less (known as PM2.5). With diesel generators at each well pad and at the water treatment and gas compression plants, there will be significant PM2.5 emissions. The air quality assessment and greenhouse gas sections also fail to model the likely substantial escape of fugitive methane emissions.

Fugitive Emissions

Surveys of Queensland and USA gas fields have found much high methane emissions than what have previously been reported. Such high emissions will contribute more to Climate Change than coal fired power stations, as methane is 80 times more powerful than carbon dioxide. Surveys found methane escapes via cracks to the soil surface, through equipment joints, out of vents and water piped to treatment plants. These are not hypothetical instances – all have occurred either in Australia or overseas. Both public and professional awareness and understanding of fugitive emissions is limited.

Salt:

The water removed from the ground will be treated; however the disposal of the salts is a very significant long-term problem. Peak salt production at Narrabri CSG will be 115 tonnes per day, which equates to two and a half B-double truckloads per day. In the peak year, this would mean the creation of 41,900 tonnes of salt for disposal, which Santos says will be placed in landfill.

Cultural heritage and the Pilliga:

The Pilliga is a spiritual, cultural and social icon for Gomeroi/Gamilaraay people. Fragmentation and industrialisation will cut people off from their heritage and connection to country.

Biodiversity and the Pilliga:

The Pilliga is also the largest temperate woodland in New South Wales. Santos propose clearing nearly 1,000ha of the Pilliga, including habitat for 39 threatened plants and animals including the critically endangered Regent honeyeater and Koala, which are already in decline in the Pilliga. Spread across the 95,000ha of forest, this clearing will fragment a much larger area of habitat than the 988 ha cleared.

The Pilliga forest is the cornerstone of conservation for western woodland fauna, its significance is illustrated in Appendix 3.

The gasfield will clear breeding habitat for the Pilliga Mouse, which lives nowhere else, and breeding habitat for other wildlife. It will fragment and degrade the forest.

Without specific information about where the wells and lines will be located, a proper ecological impact assessment can't be completed. The Pilliga is renowned as natural and cultural icon and must be protected from becoming an industrial gasfield.

Environmental impacts of clearing

Clearing causing fragmentation of remnants into smaller remnants, linear strips, or edge effects adjoining cleared areas effectively diminishes forest integrity and modifies fauna species composition of native species and favours exotic fauna species. It is well documented that clearing disturbance and tracks favours feral animals, resulting in increased grazing of plants and predation of native fauna.

The increase of vehicles also increases the likelihood of road kill and injured animals.

The increase of vehicle and machinery movements into the forest from other areas increases the likelihood of weed introduction and invasion.

The EIS survey identified eight serious weeds to be controlled – Coolatai grass, African Lovegrass, Green Panic, African boxthorn, Prickly Pear, Tiger Pear, Lippia and Noogoora burr. Control must also be carried out for all other weeds that occur or are new introductions that can displace native plants e.g. Buffel grass, Velvet Tree Pear, Mother of Millions and the other tropical pasture grasses.

Social and health impacts:

The social impact assessment is three years old and inadequate. The regularly updated compendium of health studies produced by the Concerned Health Professionals of New York show there is mounting evidence that unconventional gas operations impact human health through water contamination and respiratory illness. The Government must insist that Santos conduct a proper health impact assessment including modelling exposure pathways, reviewing literature, and engagement with the Narrabri community.

In Narrabri, this project will have negative impacts on cost-of-living, increased cost of labour, and a boom and bust to the housing market. The boom is cited in the EIS as a benefit of the project, but it will not benefit low-income renters. Many of the Queensland towns such as Roma and Chinchilla have become ghost towns of empty houses after the construction boom.

The effect of the project on cost-of-living in the Shire needs to be modelled, assessed and considered, as do the labour dynamics of the project. The project entirely surrounds Yarrie Lake, and Santos propose that wells might come as close as 200m from the Lake.

Groundwater and the Great Artesian Basin:

Santos' project is expected to remove 37.5GL of groundwater over the life of the gasfield, mostly in the early years. It's possible this amount could be as high as 87.1GL. In years 2-4, the company is expecting to extract 10ML water per day or 3.65GL per annum. This is close to 16% of the current licenced extraction from the Oxley-Gunnedah groundwater source. The coal seam needs to be dewatered to release the gas, but this aquifer lies beneath the Pilliga Sandstone, part

of the Great Artesian Basin recharge. Santos' EIS admits that over time, the project will result in a loss of water from the GAB recharge aquifer, but downplays the scale of this loss. CSG in Queensland has drawn down GAB aquifers already. We can't afford to risk this crucial resource.

Water Contamination

The area that this EIS covers is termed the Southern Recharge of the Great Artesian Basin and is a major recharge area for that basin; otherwise it would have another descriptive terminology.

The proposed CSG area in the Pilliga Forest is largely sandy soil, and the vegetation is dependent on the underground water table, any lowering or contamination of the surface aquifers is likely to have impact on the vegetation.

Bushfire

On page 59, the EIS states that "the proponent would prepare a bushfire management plan". The EIS should already have a draft plan for consideration. Given that Santos are already flaring in a high bushfire risk forest, how is it that they do not already have a bushfire management plan?

The current Narrabri /Moree BFMC Bush Fire Risk Management Plan 2010, lists the threat to the existing 26 Gas Well Sites as Extreme 1C T16, it also lists the Westport / Rockdale Road (Jacks Creek) Human Residential area as Extreme 1A T1;2;3. There is no reference to the proposed fire management or hazard reduction plans in place to provide protection from the extreme threat.

The EIS states;

Bushfire risk would be made as low as reasonably practicable through the implementation of a Bushfire Management Plan prepared in conjunction with landholders, the Forestry Corporation of NSW and the NSW Rural Fire Service. The Plan would formalise and build on measures informed by the participation in the Resource Industry Fire Management Group.

The Plan would include: formal preparedness procedures for staff and contractors, appropriate work practices and restrictions responsibilities and actions in the event of a bushfire outbreak or warning, asset produced zones, fuel reduced areas, evacuation procedures and routes exercised and drills for staff and contractors. Bushfire risk would also be reduced through features incorporated into the design of the project include remotely operated well infrastructure with fail safe valves, buried gathering lines and appropriately rated electrical instrumentation and equipment.

Fires can occur at any time of year however the official Bushfire Danger Period generally commences in October and runs to the end of March each year. This may be bought forward depending on seasonal conditions.

End of excerpt.

Bushfire is a major concern as the Pilliga forest is highly susceptible to fires. Activities associated with CSG mining will likely increase the risk of bushfires, and the need for asset and human life protection will likely result in more frequent hazard reduction fires.

Frequent fire is listed as a key threatening process because it can change the composition of the plant community, cause the local extinction of some plants, and destroy log and hollow habitat that is critical to 13 threatened species. It is potentially a greater impact than the clearing, as it will affect a larger area. See Appendix 4.

Inappropriate fire regimes were identified as the second-highest threat to threatened fauna species in the study region, and the third-highest threat to threatened flora species.

For the majority of flora and fauna species threatened by inappropriate fire regimes, it is high-frequency fire regimes that are detrimental. High frequency fire can lead to direct mortality, food deprivation, and an increase in predation levels on native fauna, a reduction in the availability of critical habitat features such as hollow-bearing trees or an inability to attain a critical lifecycle before the next fire event (Gill &Bradstock, 1992; Gill, 1975; Whelan, 2002). For some species, the suppression of fire is also a threat to their survival (e.g. *Rulingia procumbens, Bertya opponens, Tylophora linearis).*

The EIS optimistically says that the "Total length of fallen logs is unlikely to change as a result of the project and is more likely to increase due to the respreading of felled timber".

Should fire frequency increase due to hazard reduction to protect assets, log and hollow tree habitat will surely decline.

Santos does not appear to have a clear bushfire strategy, without a detailed plan it is not possible to evaluate the risk and the pending threat to flora and fauna and the public.

The EIS states; Should prescribed burning be identified as a priority supplementary measure, then a detailed prescribed burning management plan will be prepared.

Santos should not be allowed to operate in such a vulnerable forest with a large risk of fire from flaring, particularly as flares are exempt from fire bans.

All those living in the vicinity have just cause to be concerned about more flares being installed, as more wells are proposed in the fire-prone area.

The table below was taken from the EIS, it indicates hazard reduction is part of the fire plan but does not specify what hazard reduction activities will be used.

Bushfire preparedness and seasonal activities

Activity	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Monitor and Communicate	■	■	■	■	■	■	■	■	■	■	■	■
Detail budget for implementation	■											
Review / update fire competency training		■	■									
Assess Asset Protection Zones			■	■								
Assess seasonal fuel hazard risks		■	■	■	■							
Map hazard reduction program			■	■	■							
Review field signage and replace as necessary				■	■							
Update maps for emergency response use					■	■						
Update Contact Lists					■	■						
Implement hazard reduction program					■	■						
Check and service equipment						■						
Pre-fire season meeting with STO rep, FCNSW and RFS							■					
Declaration Fire Season (typically)								■				
Implement seasonal permit and reporting controls								■				

The NSW Rural Fire Act exemption allows mining companies to burn gas flares during intense fire conditions when farmers are forced to cease harvest.

Locating gas wells and collection lines in such a large forest with a history of extreme fires, defies logic.

Page 8 section 3 of Appendix J2 Biodiversity offset package

The Biodiversity Offset Package for the project will contain a combination of

Like-for-like offsets secured via an appropriate conservation mechanism (including purchase and retirement of biodiversity credits (where available), protection under Biobanking Agreements, or reservation under the NSW *National Parks and Wildlife Act 1974*).

Supplementary measures developed and funded through Planning Agreements (PAs) under the NSW *Environmental Planning and Assessment Act 1979* (EPA Act).

Compensatory measures such as Koala research.

NSW Biodiversity Offsets Fund for Major Projects will be used for remaining offset liability (when established).

Comments Re Offset Package

The Biodiversity Offset Strategy refers to the NSW and Commonwealth requirements for offsetting and calculates species credits required and offset areas per ecosystem/vegetation community required. All of which will be identified at some point in time in the future.

We find it perplexing that the actual area of each community and ecosystem can be known when the locations for the infrastructure remain unknown. Also perplexing is the flora species credit Table 4 page 3 that includes numbers of plants impacted by the proposal. Question how the number of plants impacted can be known when the actual infrastructure locations are not known.

Approvals cannot be granted on open ended assumptions, the public have a right to be informed in the EIS process how offsetting is to be achieved on the ground. We have seen the worst case scenario of abuse of offsetting for the Maules Creek mine. Where the consultant Cumberland Ecology claimed that Stringybark open forest at high altitude was like for like White box woodland. Approval cannot be granted until the public have been shown on maps where the offsets will be located, so they can independently review that they are what the consultant claims.

The offset strategy also identifies that 10% of the offset requirement will be a Koala research proposal. It seems ironic that the Koala is in serious decline in the Pilliga largely due to the impact of Climate Change which can only be controlled through reducing greenhouse gas emissions. The Koala research offset cannot be serious, as the CSG proposal is going to result in increasing methane emissions and the impacts of Climate Change, as well as direct impacts of habitat loss and roadkill. Approval cannot be granted for the Koala research offset proposal.

The offset strategy also identifies that 33% of the offset requirement will be a feral animal and weed control strategy. Whilst it is acknowledged that such a control plan would benefit both flora and fauna, it should not be allowed as an offset, as that control should already be conducted by State Forests as their duty of care to manage the land.

The offset strategy identifies that the loss of hollow trees will be compensated at a 1:1 ratio presumably using nest boxes?

Section 2.3.4 Hollow-bearing trees

"The removal of large hollows (>300 mm) will be compensated for by at least a 1:1 replacement. Specific detail regarding offset ratios, locations for hollow re-instatement and an implementation strategy will be developed as part of the Biodiversity Offset Package for the project".

"The number of trees with hollows will be reduced to '0' in development areas as a result of the project. The installation of nest boxes is not currently a supported method for the replacement of hollows in the FBA".

These statements are vague and perhaps contradictory as to what will be used to compensate for the loss of tree hollows. Thirteen of the threatened species impacted are tree hollow dependent. Hollows should be replaced by at least a 1:2 ratio to accommodate loss of hollow recruitment as well.

HAZARDS TO ASTRONOMY

Ref: EIS Appendix Q (GHD) and section 5.3.3; SSD 14_6456

Light pollution from flares, compressor stations and the water treatment plant will ruin the dark night needed by the internationally renowned Siding Spring Observatory.

Santos has failed to ensure that vital astronomical assets of the Commonwealth of Australia, and 50 other international research institutions, are not detrimentally impacted by the operation of a large gas field and gas processing equipment to the north of Siding Spring.

Over the years, major public funds have been invested in these world class facilities for astronomy. Australian taxpayers and science institutions are rightly deserving of protection of this asset.

There is no recognition of the cumulative impact of future expansion from PEL238 to other gas licence areas much closer to the observatory.

Santos has not proposed adequate mitigation measures to protect the observatory operations, particularly in not ensuring the clarity of the night sky from light pollution impacting negatively on visible light telescopy, and from not preventing an increase in chemical air pollution impacts on delicate instrumentation and mirror surfaces. It has also not recognised or mitigated chemical air pollution impacts on the Narrabri radio telescope facilities.

There is no recognition in the Santos EIS that air pollution (Chapter 18) at times will concentrate in certain weather conditions, such as during temperature inversions or cloudy, still nights and drift southward towards the observatory. Air pollution from gas fields is well-documented but has not been correctly identified in Chapter 18. It comprises methane, ethane, butane, and some higher hydrocarbons that can form ozone smog in sunlight, especially mixed with flaring combustion products like nitrous oxide. There is also hydrogen sulphide. This air pollution is not documented in the EIS by Santos. Gas field smog is highly corrosive on delicate instrumentation and can cause smog haze.

Santos have failed to propose adequate mitigation measures to minimise the impact of light pollution from flaring operations - in fact, no flare shielding is proposed. Two major flare stacks will likely operate continuously at Bibblewindi and Leewood. Santos has under-estimated the likely continuous operation of these stacks and not proposed adequate shielding.

Santos has under-estimated the amount of light pollution and has contradictory statements in the EIS about the number of flares – at one point it is stated that there will be 'up to 6' (5.3.3) pilot well flares, but in other parts of the EIS it is estimated over 25 pilot flares (Greenhouse Gas Chapter 24) will be operational at any time.

The NSW EPA recommends that flare stacks be shielded.

Chapter Q mentions the potential high light pollution impact of major flare events but 'talks down' the frequency of such events. This is NOT the experience in the QLD coal seam gas

fields. The Santos EIS does not reflect practical on the ground experience of coal seam gas field operations.

The reality of gas fields is that gas supply restrictions mean that gas flaring can occur whenever the market is not drawing gas from the Project. This means that flaring can be a constant feature of an operational gas field. Claims by Santos that flaring will be minimal are simply not supportable.

It is inconceivable that the negative impacts of the Project on Siding Spring would be acceptable to Australian and international astronomers nor to the Australian public who have heavily invested in

APPENDIX 1.

Renewable Sources of Energy that if maximised could negate the need for Narrabri Gas.

Tidal energy - Tidal energy can be generated in two ways, tidal stream generators or by barrage generation. The power created though tidal generators is generally more environmentally friendly and causes less impact on established ecosystems. Similar to a wind turbine, many tidal stream generators rotate underwater and are driven by the swiftly moving dense water. Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power. Historically, tide mills have been used both in Europe and on the Atlantic coast of the USA. Can provide off peak power during the night.

Wave energy - Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work — for example for electricity generation, water desalination, or the pumping of water (into reservoirs). Wave energy can be difficult to harness due to the unpredictability of the ocean and wave direction. Wave farms have been created and are in use in Europe, using floating Pelamis Wave Energy converters. Most wave power systems include the use of a floating buoyed device and generate energy through a snaking motion, or by mechanical movement from the wave's peaks and troughs.

Solar power - Photovoltaic (PV) Solar power is harnessing the suns energy to produce electricity. One of the fastest growing energy sources, new technologies are developing at a rapid pace. Solar cells are becoming more efficient, transportable and even flexible, allowing for easy installation. PV has mainly been used to power small and medium-sized applications, from the calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array.

Wind power - Wind power is the conversion of wind energy by wind turbines into a useful form such as electricity or mechanical energy. Large-scale wind farms are typically connected to the local power transmission network with small turbines used to provide electricity to isolated areas. Residential units are entering production and are capable of powering large appliances to entire houses depending on the size. Wind farms installed on agricultural land or grazing areas, have one of the lowest environmental impacts of all energy sources. Although wind produces only about 1.5% of worldwide electricity use, it is growing rapidly, having doubled in the three years between 2005 and 2008. In several countries it has achieved relatively high levels of penetration,

accounting for approximately 19% of electricity production in Denmark, 11% in Spain and Portugal, and 7% in Germany and the Republic of Ireland in 2008.

Concentrated solar power - Concentrated solar thermal (CST) technology harnesses the sun's power to generate electricity. It uses lenses and reflectors to concentrate sunlight, heating a fluid such as water or oil and producing steam to drive a turbine.

The advantage of concentrated solar thermal technologies is that they provide a dispatchable energy supply – that is, their power output can be adjusted based on grid demand. This makes them more flexible than traditional solar PV plants.

Globally, solar thermal technology is being deployed on a large scale to provide electricity, and storage systems are also being investigated.

Abundant sunshine and plenty of open space means Australia is ideally placed to take advantage of solar thermal technologies for energy generation.

Hydro power - Hydroelectricity is electricity generated by hydropower, i.e., the production of power through use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy. Once a hydroelectric complex is constructed, the project produces no direct waste. Small scale hydro or micro-hydro power has been an increasingly popular alternative energy source, especially in remote areas where other power sources are not viable. Small scale hydro power systems can be installed in small rivers or streams with little or no discernible environmental effect or disruption to fish migration. Most small scale hydro power systems make no use of a dam or major water diversion, but rather use water wheels to generate energy. This was approximately 19% of the world's electricity (up from 16% in 2003), and accounted for over 63% of electricity from renewable sources.

Geothermal power - Geothermal energy is a very powerful and efficient way to extract renewable energy from the earth through natural processes. This can be performed on a small scale to provide heat for a residential unit (a geothermal heat pump), or on a very large scale for energy production through a geothermal power plant. It has been used for space heating and bathing since ancient roman times, but is now better known for generating electricity. Geothermal power is cost effective, reliable, and environmentally friendly, but has previously been geographically limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for direct applications such as home heating.

APPENDIX 2. The story behind Santos attempt to influence the government and public

Media article 20th March 2017 - www.theaustralian.com.au/.../santos...narrabri-csg-project-will...nsw-gas.../3708a2296...

Santos has warned there could be job losses and industrial closures if its controversial $3.6 billion Narrabri coal-seam gas project, which could supply half of NSW's gas demand, does not go ahead.

In its environmental impact statement, Santos says Narrabri, which has faced strong community opposition, is an economic project that could be safely producing in 2019 to ease a looming east coast shortage, if environmental approvals can be secured.

The Adelaide-based oil and gas company has challenged the NSW government to push through approvals as markets grow tighter in the face of exports from its Gladstone LNG project that have sucked up former NSW supply from the Santos-operated Cooper Basin.

If Narrabri, which was previously forecast to cost $2bn, does not go ahead, there could be job losses, industrial closures and shortages, Santos says.

"The Narrabri Gas Project could supply up to 50 per cent of the natural gas needs of NSW and deliver substantial benefits to the local community and the state," Santos chief Kevin Gallagher said in the project's environmental impact statement, which is currently open for submissions.

"The EIS concludes the project can be developed safely with minimal and manageable risk to the environment," he said, adding there would be minimal risk of impact on agricultural and domestic water sources.

The project, largely in the Pilliga state forest, has been on the drawing board since 2011 when Santos bought the John Anderson-chaired Eastern Star Gas for $920 million.

But Narrabri suffered setbacks in the form of strong environmental and farming opposition, state government restrictions and a reserve downgrade because the coal- seam gas was not as easily produced as previously thought.

While Santos has labelled the project as "non-core" and slowed development, and its 20 per cent partner Energy Australia has written the project value down to zero, it last month surprised the market by declaring it would submit a 7000-page environmental impact statement and had struck a deal with APA Group to link the project to market through a 400km pipeline.

The Santos-led Gladstone LNG project in Queensland has come under the spotlight after Malcolm Turnbull's emergency meeting with gas producers last week because it is buying the equivalent of about one-third of east coast domestic gas consumption because it does not have enough gas reserves to support the two LNG export trains it built at Curtis Island.

The other two projects at Curtis Island, Shell's Queensland Curtis LNG and the Australia Pacific LNG plant run by Origin Energy and ConocoPhillips, are net suppliers to the domestic market.

In the Narrabri EIS, Santos explains the impact that LNG exports are having on the domestic market, where buyers are complaining of shortages and big price hikes.

"From 2017, a major shift will occur when all three liquefied natural gas facilities in Queensland will reach more stable production levels," the EIS says.

"The majority of the gas that was previously contracted from the Cooper Basin will no longer be available to supply NSW, as it has been contracted from 2016 to meet some of the supply requirement of these Queensland natural gas facilities." Santos says NSW will have to get its gas from Victoria, raising supply risk if there is an outage.

"Should the project not proceed, and if a feasible alternative to current gas supply is not found in the short term, there is a risk that jobs may be lost, large industrial gas users may close and there may be gas shortages," Santos says.

The project is expected to cost $3.6bn to develop in nominal terms, require another $1.9bn of operating costs and deliver its owners a net present value of $2bn. As under previous plans, 850 wells will be drilled over 20 years, producing peak production of 200 terajoules a day.

"Construction of the project is expected to commence in early to mid-2018 with first gas scheduled for 2019-20, subject to obtaining regulatory approval and a final investment decision," Santos said.

Mr Gallagher said the project would provide 1300 jobs during a three-to-four year construction period, 200 ongoing jobs and would generate $1.2bn in state royalties.

While NSW was the leader in restricting onshore gas production in the east coast, followed up by Victoria and the Northern Territory, in 2014 it listed Narrabri as a "key strategic entry project in its state Gas Plan, after NSW chief scientist and engineer Mary O'Kane declared the technical challenges and risks of the industry could be managed.

But opposition has not really eased, with the Wilderness Society declaring the largely unchanged plans in the current EIS puts Santos "on a collision course with the Narrabri community and people across NSW". How the project will be funded, if it is approved, is also unclear, with Santos in no position to embark on the project on its own.

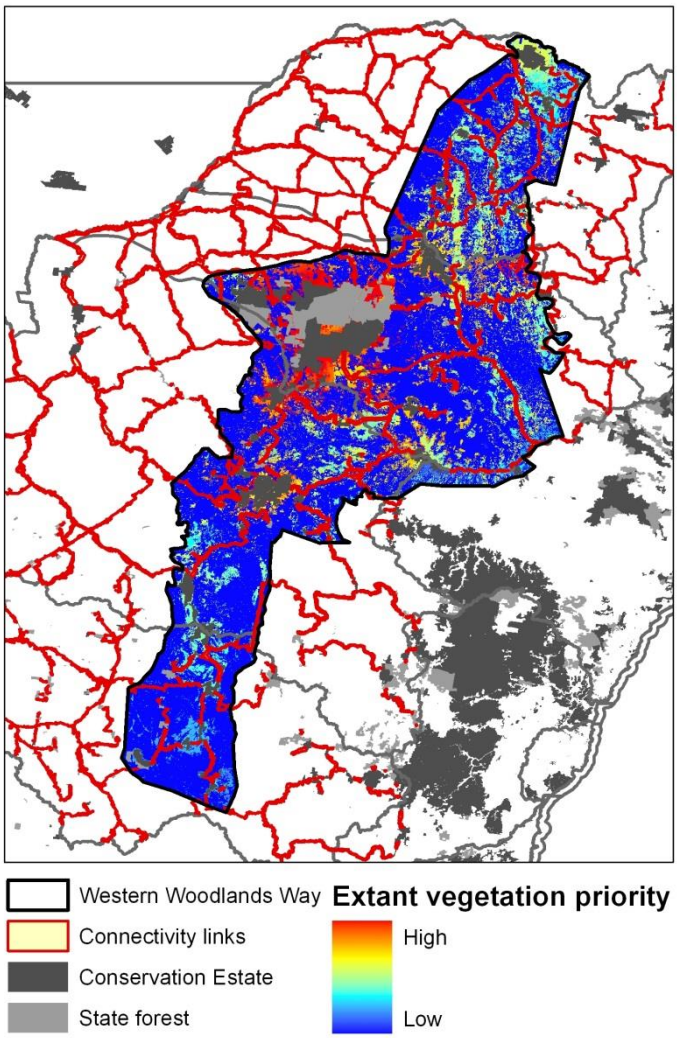
The east coast gas crisis is being made worse by sliding oil prices that sapped funding options and shareholder excitement for new gas projects.

Origin's economic Ironbark coal seam gas project in Queensland is up to five years behind schedule and Mr Gallagher, since taking the reins at the debt-laden Santos early last year, has slashed spending.

APPENDIX 3.

SUMMARY OF

WESTERN WOODLANDS WAY REPORT THAT HIGHLIGHTS THE SIGNIFICANCE OF THE PILLIGA FOREST FOR THE CONSERVATION OF WESTERN WOODLAND FAUNA



NSW GOVERNMENT Office of Environment & Heritage

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

This document is a summary of the two volumes of the Western Woodlands Way report:

Fuller, R.A., Drielsma, M.J., Watson, J.E.M., Taylor, R., Sushinsky, J., Smith, J. and Possingham, H.P. (2011) *Western Woodlands Way. Volume 1: Priorities for Ecological Restoration*. Spatial Ecology Laboratory, University of Queensland, Brisbane, and the Landscape Modelling and Decision Support Section, New South Wales Office of Environment and Heritage, Dubbo.

And

Taylor, R. and Drielsma, M. (2012) *Western Woodlands Way. Volume 2: Priorities for Investment in Remnant Vegetation and Connectivity* New South Wales Office of Environment and Heritage, Dubbo.

INTRODUCTION

- Recent research points to the need for an integrated landscape approach to biodiversity conservation to tackle the large scale impacts of threatening processes such as habitat loss, fragmentation and climate change.
- The Western Woodlands Way (WWW) is a large scale response to the serious and ongoing declines in biodiversity in the sheep-wheat belt of New South Wales, the most highly cleared region in NSW. This decline results principally from loss and fragmentation of native vegetation and will be exacerbated in the future by climate change.
- The WWW covers an area from the Queensland border at Dthinna Dthinnawan National Park through a string of conservation reserves in a north – south axis ending at Weddin Mountains National Park and Dananbilla Nature Reserve in the south, comprising an area of 75,425 km^2 (Fig. 1).
- This report develops the scientific basis for prioritizing
  - conservation and repair of extant vegetation,
  - ecological restoration of areas that have been cleared and
  - connectivity links (both existing and areas where revegetation could improve connectivity).
- This proposed methodology is suitable for "landscape species" whose status is primarily impacted by the amount and spatial arrangement of habitat (assessed through the surrogate of vegetation in this project).

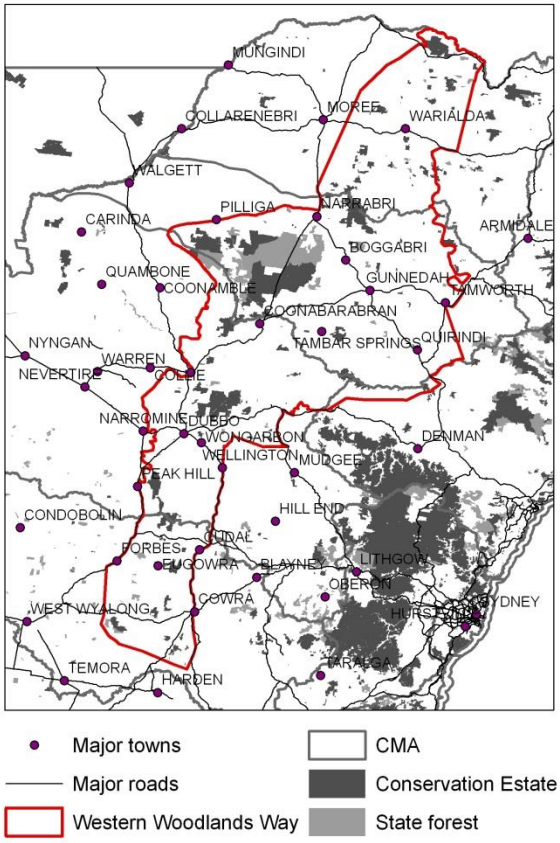


Fig. 1. The location of the Western Woodlands Way.

PRIORITISATION OF INVESTMENT IN EXTANT VEGETATION
(see Volume 2)

- Priority areas for investment in remnant vegetation to improve the viability of declining fauna species were identified using the Rapid Evaluation of Metapopulation Persistence (REMP) methodology. This population viability modelling framework was developed for 35 declining fauna species that were all limited by the amount, configuration, connectivity and / or condition of vegetation (habitat).

- A grid size of 1 ha was used in the analysis. The main data inputs used are a map of existing vegetation communities (Regional Vegetation Communities for Border Rivers/Gwydir and Namoi catchments and Broad Vegetation Types for Central West and Lachlan catchments), an estimate of the pre-1750 area of these communities and a map of current vegetation condition along with an index of the habitat value of all condition states (=7 land use categories) of all vegetation communities and movement abilities of fauna species.

- The analysis provided four outputs:
    - An occupancy map for each species that indicates the proportion of time that each location across the region is expected to be occupied based on the biology of the species and landscape habitat characteristics.
    - Metapopulation capacity (MPC) which describes the ability of the region to support a viable population.
    - Priorities for management: Conservation. The grid cells with higher 'Conserve' values are those that, if they were cleared, would have the greatest adverse impact on the Region's biodiversity. They generally represent vegetation in relatively good condition that is of high conservation value for declining fauna. In these areas future threats should be circumvented through incentives and investment to ensure their long-term value to biodiversity persistence in the region.
    - Priorities for management: Repair. Priorities for repair were considered to be locations with higher MPC, but where significant improvement to habitat quality is attainable. Preventing the future degradation of these areas from predicted threats and restoring or improving their condition will have a significant contribution to the overall biodiversity of the region.

- Maps for each of the 35 species were prepared. Two examples are shown in Fig. 2. Five of the species (Barking Owl, Gilberts Whistler, Regent Honeyeater (breeding), Superb Parrot (breeding), Superb Parrot (non-breeding)) were found to have insufficient habitat to support viable populations within the region. A number of other species were found to be viable within the region but with drastically reduced occupancy from the pre-European state.

- In the figures the ellipses represent the most robust metapopulations for the WWW region. However, the MPC can vary across a region because the region incorporates more than one metapopulation, each with its own MPC. Within a large region, such as the WWW, where distinct clusters of habitat are functionally disconnected for a species, there can be more than one metapopulation present. A separate analysis for each cluster would be required to determine the viability of the other 'lesser' metapopulations.

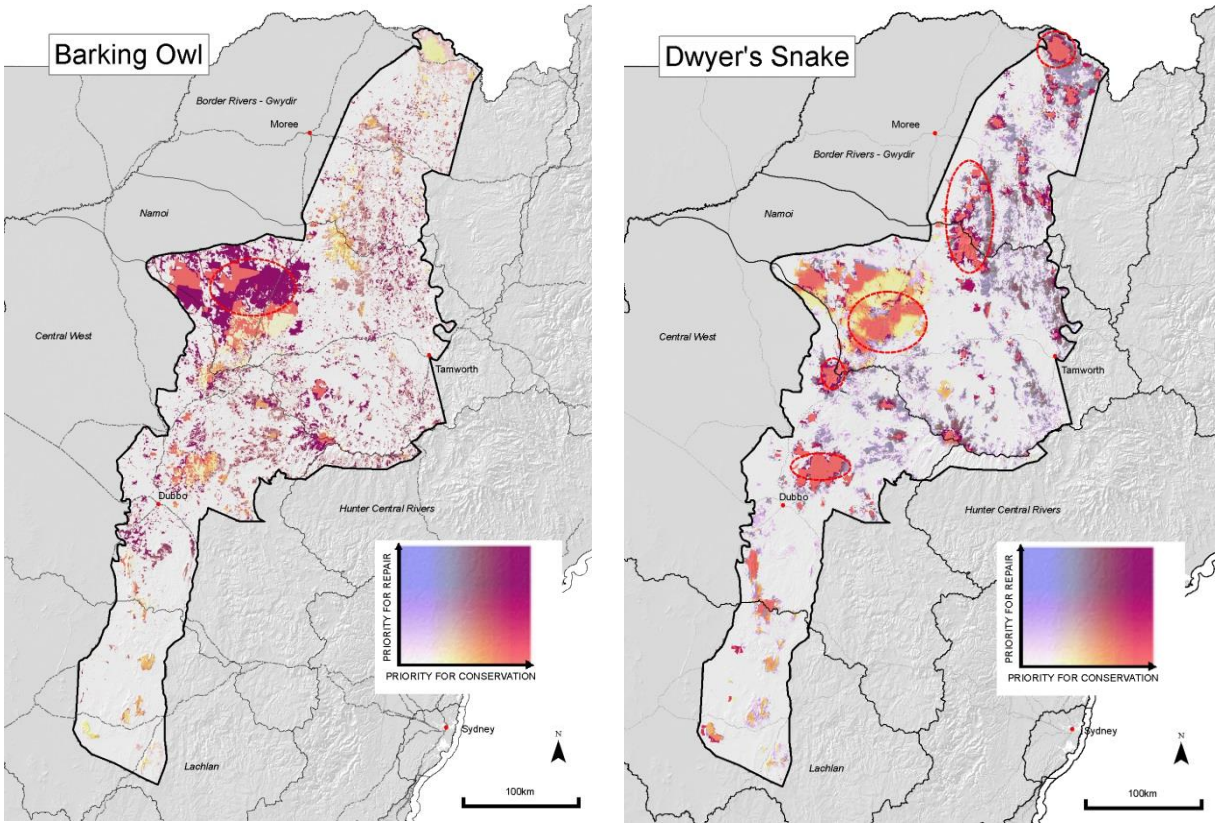


Fig. 2. Conserve / repair priority for vegetation for the Barking Owl *Ninox connivens* and Dwyer's Snake *Parasuta dwyeri*. Areas enclosed by the red dotted line support the most robust long-term viable metapopulations.

- The priority maps for individual species have been aggregated into a single priority map (Fig. 3).
- The differences between the conservation and repair layer are highly influenced by the condition of a particular site. Because the condition of the vegetated areas on private property is not accurately mapped the differences between these two layers may not be particularly informative. For this reason the two layers have been combined to produce a single priority map for vegetation investment after weighting of a species' contribution to the overall priority value (Fig. 4) based on:
  - the percentage of the predicted pre-European occupancy that is presently occupied;
  - The threat status of the species
  - The current percentage of the Metapopulation Capacity threshold.
- A greater area of priority locations occurred in the north where a higher proportion of the landscape retained native vegetation than in the south where clearing has been more extensive.

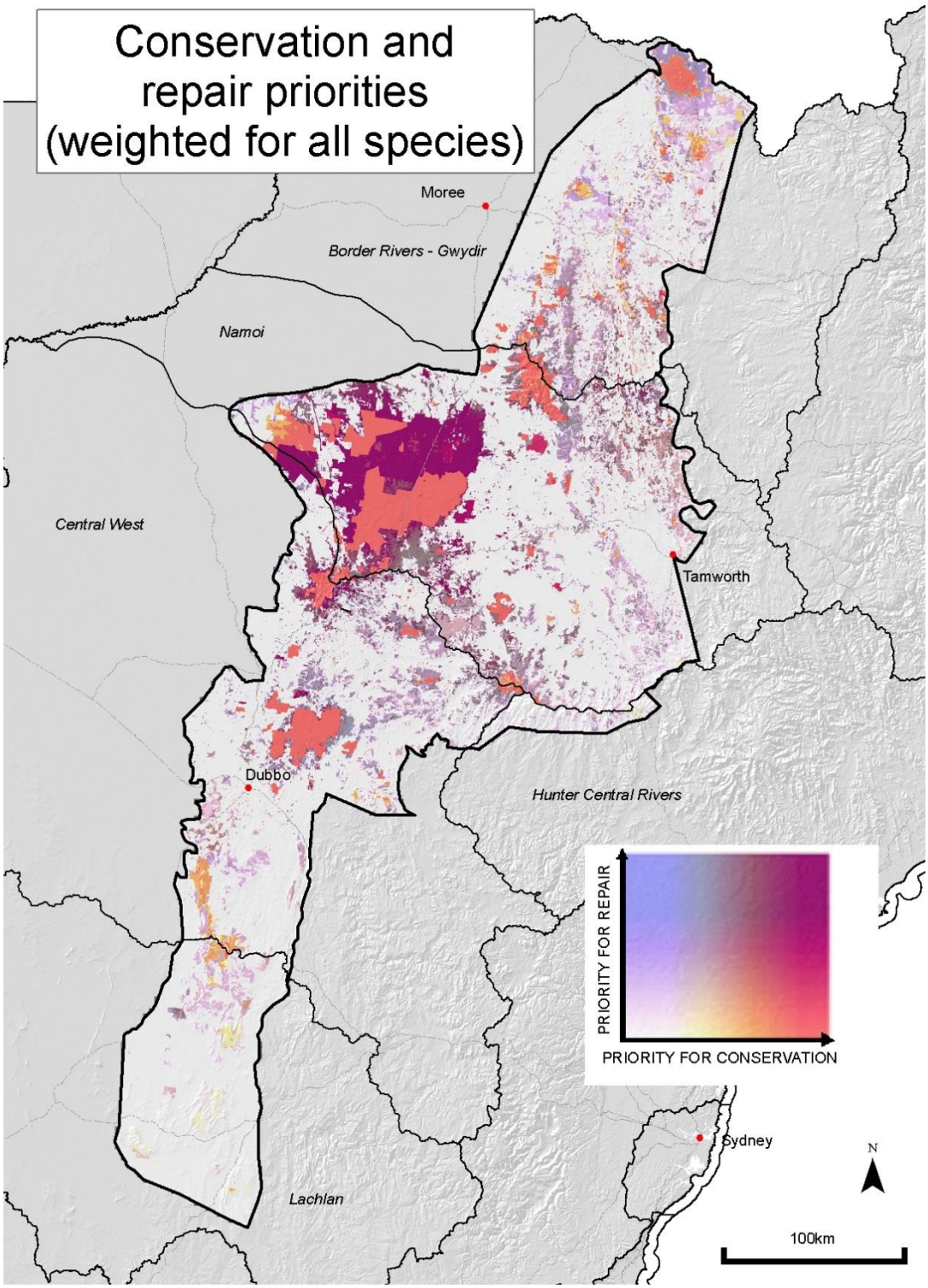


Fig. 3. Combined conserve/repair priority for vegetation based on requirements of all declining fauna species included in the analysis.

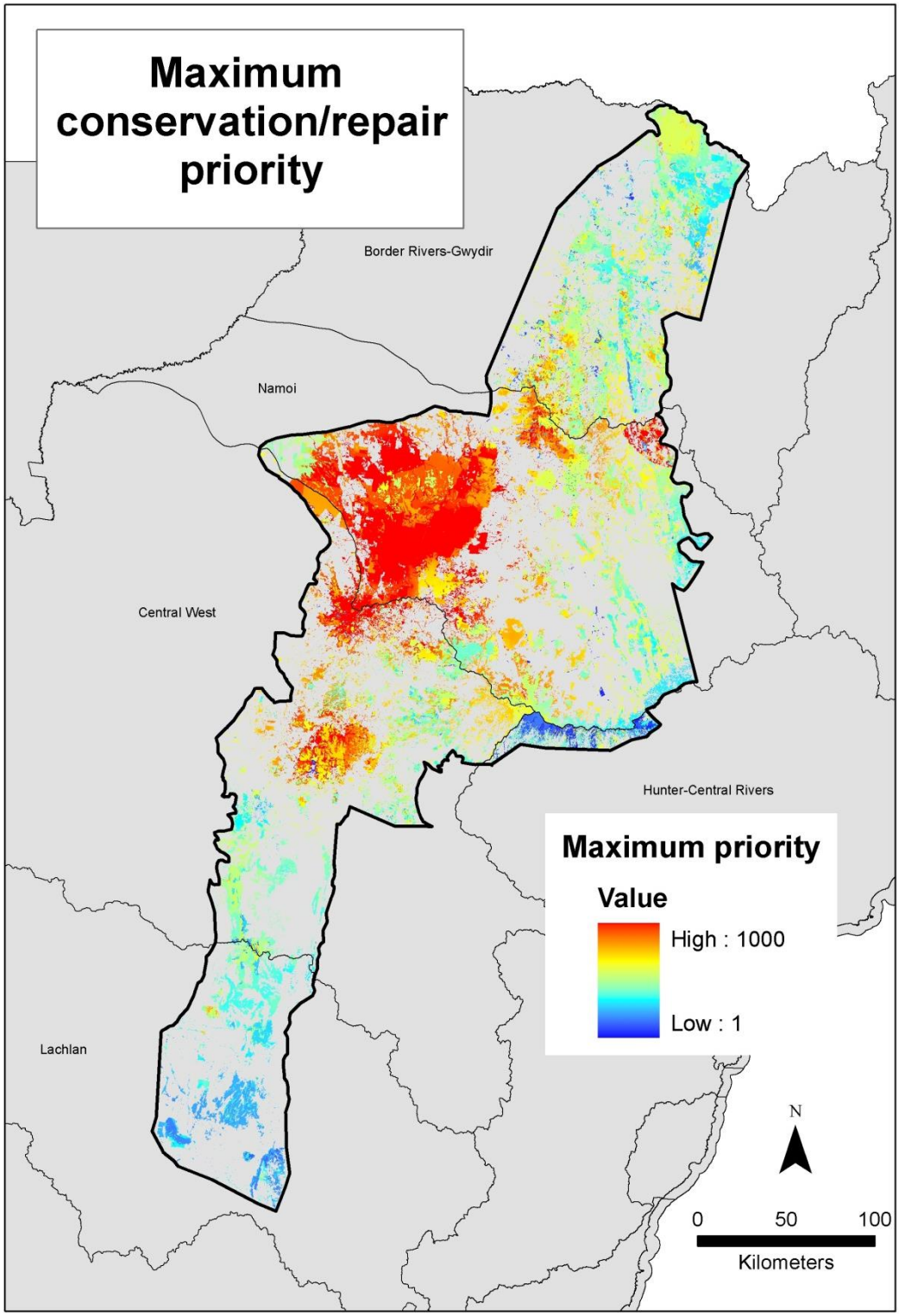


Fig. 4. Combined conserve/repair priority for vegetation based on requirements of all declining fauna species included in the analysis.

- The results indicate that the priorities for management of existing vegetation on private land involve a strategy of consolidating and building out from large existing habitat areas such as the Dthinna Dthinnawan Community Conservation Area, Mount Kaputar, Pilliga forest, Warrumbungle National Park, parts of the Liverpool Range and Goonoo and Goobang National Parks.

APPENDIX 4.
IMPACTS FROM HAZARD REDUCTION SHOULD SANTOS INFLUENCE FIRE MANAGEMENT WITHIN AND ADJOINING PEL 238 FOR ASSET PROTECTION

From NPWS Report by Dr John Hunter Vegetation and Floristics of Mt Yarrowyck NR

In summary:
1. Frequent burning causes increase stress on vegetation, and if droughts occur between fire periods these stresses are exacerbated and may lead to premature death and/or extinction due to the depletion of regenerative resources.
2. Frequent burning has been shown to increase fuel loads in the short term, while long unburnt areas become stabilised and have been shown in some locations to significantly reduce fuel loads.
3. Frequent fire promotes a young and high regenerating woodland or forest.
4. Frequent fire removes essential habitat resources for fauna such as large logs on the ground, large trees with hollows, bark resources and the functional diversity of flora.
5. Long unburnt areas are essential within the landscape and are currently a rare and significant habitat type.
6. Long unburnt vegetation is disproportionately important for fauna habitat.
7. Recently burnt patches are likely to be more heavily grazed (green pick) and may require protection.

It is important that records are kept and mapping of fire occurrences occurs. It is recommended that the following occurs:
- Collation of fire records, verbal reports and evidence from aerial photographs.
- When fires occur, accurate boundary maps of the extent of fires should be made. This needs to include accurate ground truthing.
- Map opportunistic evidence of lightning strikes.
- Site specific research needs to be conducted in each of the communities within the reserve.
- Old age stands (absence of fire) of all community types should be maintained if possible.
- Feral animal control will need to precede and follow or accompany any management burns particularly if weather conditions are dry post fire.
- Recording the fire response of individual species is needed to guide appropriate fire frequencies (in collaboration with DECC Bushfire Ecology Unit (Scientific Services Division). Specialist task that doesn't require specialist skills.

The above discussion is based on recent research much of which has been conducted within communities on the slopes and tablelands of NSW. Long-unburnt open forest and woodland is disproportionally important for fauna habitat both in communities within eastern NSW but the same processes and advantages of long unburnt vegetation occurs within semi-arid areas (such as Mallee landscapes).

In general bushfire management strategies tend to create a homogeneous fire landscape. Whereas it is a heterogeneous fire landscape (i.e. patchy burns with frequently burnt areas intermixed with long unburnt sites) that helps promote diversity at a landscape scale. Careful consideration must therefore be given to the requirements of native vegetation remnants when looking at the implementation of a non-natural fire regime.

Fire suppression for the protection of life and property has long reaching effects on biodiversity, and some recent research is discussed herewith. The efficacy of prescribed burning in reducing or eliminating the threats from wildfires has been questioned in recent research (King et al. 2008, Whelan 2002), especially in extreme weather conditions (such as high temperatures, high winds and low relative humidity). Research into litter depths is currently showing that frequent, low intensity fires cause trees and shrubs to drop damaged or stressed foliage and stimulate suckering. Thus, promoting fine fuel loads which have a greater flammability that larger woody matter.

The passage of fire also disrupts soil/litter biota causing a reduction in the amount of litter that is naturally broken down and returned to the soil. Woody debris when it breaks down provides far better soil integrity (protection from erosion) than grass and the larger the woody debris the greater the soil integrity. Furthermore frequent burning may promote fire insensitive species that often have higher oil content over less flammable fire sensitive species, again increasing the flammability of native vegetation. In combination this indicates that a program of frequent low intensity fires may in fact keep fuel loads at a high level necessarily requiring fires to be more frequent to keep such fuel loads down.

Native vegetation left long unburnt for decades (30 or more years) can have lower fuel loads than areas burnt only three to five years previously (Croft et al., in review). Fuel loads do not increase indefinitely but are constantly broken down by the ground flora and fauna. Fine fuel loads disappear to be replaced by less flammable larger woody debris. Frequent fire can also keep a woodland in a perpetual young state by stimulating germination and removing old trees (eating them out till they fall) thus reducing the number of hollows in the landscape (Croft 2013).

The effects of frequent low intensity burning on native fauna is increasingly found to have negative consequences, causing significant losses by gradual attrition of habitat. What is certain is that ecosystems in Australia have been modified by changes in fire regimes in the last 200 years (Clarke 2008, Tasker et al. 2006, Lunt 2002, Pyne 1991). Changes have occurred in the structure and floristic composition of the vegetation, and microhabitat features such as decreasing litter and logs (Spencer and Baxter 2006, Tasker et al. 2006, Gill and Catling 2002, Hobbs 2002, Russell-Smith and Stanton 2002, Catling 1991, Bell and Koch 1980; Croft et al. 2010). The impact of wildfires and prescribed burning is often a secondary consideration in fire management (Clarke 2008).

A key habitat feature that is consumed by fire is fallen timber which provides shelter for; reptiles, frogs, small mammals and numerous invertebrates (Spencer and Baxter 2006, Bowie and Frampton 2004, Michael et al. 2004, Fischer et al 2003, Lindenmayer et al. 2003). Reptile abundance and richness has been correlated with

the percentage cover of logs, their number and length (McElhinny et al. 2006). Logs provide basking sites for reptiles as well as shelter, foraging and nesting locations (Lindenmayer et al. 2005). Survival of some animal populations during and after fire is dependent on unburnt or partially burnt log refuges withstanding the passage of fire, and a fire free period to allow populations to recover.

Solid logs in fire-affected areas are sometimes burnt or charred but not totally consumed, while incompletely burnt hollow logs can collapse leaving a charred log surface interface with the ground surface. The quality of these charred logs as fauna habitat appears to be reduced, with fauna surveys recording fewer animals (both invertebrates and vertebrates) recorded under this altered habitat attribute (Croft et al. 2010). This potential reduction habitat quality through partial burning is a consequence of hazard reduction burning that should be considered in fire management.

Studies have shown that in burnt forest the litter layer is often completely consumed by wildfire while in the unburnt forest there is 99% ground cover, made up mainly of grass tussocks and litter (to an average depth of 4 cm). Litter is an important habitat attribute for ground dwelling invertebrates, reptiles, frogs and mammals for foraging, shelter and basking (Clarke 2008; Taylor 2008, McElhinny et al. 2006, Majer et al. 2002).

Morrison et al.(1995) and Clarke (2008) note that it is ecologically undesirable to frequently remove ground level fuels using prescribed fire across large areas to satisfy demands for fire control. Especially considering that hazard reduction advantages of large-scale prescribed fire are not proven (Fernandes and Botelho 2003). Tolhurst et al. (1992) found that low-intensity fires reduced litter and elevated fuels and bark, but a single fire did not significantly affect coarse fuels (logs). One way to protect fallen timber habitat is to proceed with hazard reduction burning only when the drought index is low.

Climate change projections predict large increases in drought in Australia, along with more frequent fires associated with the drier and warmer conditions (Cary 2002, Australian Greenhouse Office 2003, Pittock 2005). Plants in fire and drought-prone vegetation communities may respond to these disturbances by evolving recovery mechanisms or survival strategies to persist in these environments after fire (Keith 1996, Bradstock & Kenny 2003) or drought (Davidson & Reid 1989, Morgan 2004).

Resprouting from bud reserves under the bark, from lignotubers, basal stems or rhizomes are recovery responses of many Australian plant genera in communities subject to frequent fire (Keith 1996) and also drought. However, despite an ability to recover from single fires (or other disturbance such as drought), high-frequency fire can cause some species to decline or become locally extinct if resprouters do not have time to recover a reproductive capacity.

Repeated disturbances can deplete a plant's reserves and soil seed stores. The regenerative capacity of vegetation may be affected by a combination of fire and drought (Keith 1996, Lawler et al.1998, Marod et al.2004, van Nieuwstadt & Sheil 2005), especially if inter-fire periods are short and droughts frequent. Croft et al (2007) proposed a model that predicts the decline of several rare and threatened plants subject to the combined disturbances of fire and

drought.

They concluded from observations of wattle survival after a wildfire followed by drought, that fire history should be adjusted to include severe drought when formulating fire management guidelines for vegetation.

The combined effect of drought and burning on plants' regenerative resources has not been adequately considered in fire regimes recommended for communities and species in NSW.

To avoid exacerbating the ecological consequences of frequent fire, caution is required in implementing hazard reduction burning programmes. This is especially important considering the imperative to increase the amount of prescribed burning in NSW (DECC 2009). Too-frequent fire can cause the decline of plant taxa, and fire histories should be adjusted to include the possible effects of severe drought in fire planning.

Even though there have been few studies of invertebrates on tree trunks (Bickel & Tasker 2004), the work that has been done highlights the richness of invertebrate and vertebrate fauna inhabiting different bark types. Majer et al (2002) collected over 1,200 invertebrate species on three bark types: smooth, stringy and rough. Noske (1985) determined the taxonomic composition of arthropods of the same three bark types while investigating bark-foraging by birds.

Arthropods are an important resource for feeding birds, with bark also providing nesting material (Pearce 1996,Loyn et al. 2007), nesting and foraging sites for small mammals (Dickman 1991) and shelter for bats (Lumsden et al. 2002, Vesk et al. 2008).

Michael et al (2004) warned that any management activities that reduce structural heterogeneity and complexity of habitat can also reduce faunal diversity. Fire is a natural agent, as well as management tool, that can simplify structurally complex habitat. During wildfires and hazard reduction burning, bark contributes to the fuel that promotes the spread of fire (Gill 1981, Catchpole 2002, Gould 2003).

Assessment of the fuel factors affecting fire behaviour emphasises the importance of bark in determining fuel loads and suppression difficulty (McCarthy 2002). It can take some bark types 15 to 25 years to return to pre-burning conditions (Tolhurst et al. 1992) and therefore a similar period of time to re-establish full structural heterogeneity, and possibly concomitant fauna diversity.

Land managers need to consider the potential loss of bark resources when undertaking hazard reduction burning. Burning bark reduces its structural complexity and habitat value. Burning gum trees removes decorticating bark causing a structural change that generally would be short lived, as gums usually shed bark annually. Burning bark on standing trees can cause longer term loss of habitat with a flow-on effect on resources, as they can take up to 25 years to attain the same amount of pre-fire bark structure and depth (Tolhurst et al. 1992).
A significant component of forest and woodland biodiversity is comprised of arthropods, which often have narrow habitat requirements (Recher et al. 1996).

Arthropods are a major food resource for birds, mammals and reptiles. The various forms of bark architecture take up to 20 years to develop (Vesk et al. 2008) and possibly longer to recover fully from fire (Tolhurst et al. 1992). The importance of bark as a foraging substrate for small mammals led Dickman (1991) to recommend that control burning and post-logging burning be minimised during forestry operations so that tree bark be retained.

The deleterious impact of fire on habitat resources; bark, fallen timber and litter needs to be considered in fire management prescriptions.

Frequent burning results in a relative increase in species richness in ground layer vegetation in logged and unlogged dry sclerophyll forests in south-eastern Australia (Penman et al 2008), but a decline of larger species over 1m in height. Very short or very long inter-fire periods are likely to lead to changes in species abundance (McCarthy et al. 2003, Croft et al. 2006). Whelan et al (2002) demonstrated a reduction of mean species richness per sample plot where there were very short interfire intervals.

Some studies have shown a decline in species richness with time since fire (for example Whelan et al 2002). However, a more detailed analysis of the results of this survey questions the extent of the length of time since fire as the primary determinant of the decline in species richness.

Other environmental variables, especially slope in this case, along with aspect and soil depth had a greater influence on species richness.
Long periods without burning (> 50 years) may deplete some populations locally. But as Bradstock and Kenny (2003) point out such effects may be offset if populations are intact elsewhere in the landscape and long unburnt vegetation has been found to contain species that require a long fire free periods before they become established.

Long unburnt vegetation communities (>50 years) are rare in the landscape. The substantial habitat features of these communities indicate that they are a valuable resource despite an apparent small reduction in species richness per site. The imperative to burn vegetation communities that are beyond the recommended upper fire thresholds, in order to prevent species loss, needs to be questioned in fire management planning.

Croft (2013) currently recommends that current upper fire free periods should be at least doubled to cater for fauna habitat in eastern Australia. Grazing pressure from introduced rabbits, but also from native fauna such as Kangaroos, is accentuated in small burns if dry conditions follow in the post fire environment (Cohn & Bradstock 2000). There is a need to regulate feral animals such as rabbits if good seedling recruitment is to occur in the post fire environment (Cohn & Bradstock 2000).

Although biodiversity is shown to increase after fire one should not be misled by a too great an emphasis on diversity at the cost of considering which species are contributing to the diversity and to richness at the landscape scale (Gill 1977; Noble 1981). Rigid prescriptions for fires will inevitably lead to the development of vegetation communities adapted to an inflexible fire regime with the consequent loss

of many plant species (Heislers *et al.* 1981).

For example, while fires were shown to increase local richness at Yathong it decreased the richness between sites and while richness declined with greater inter-fire periods differences between sites (beta diversity) increased (Cohn *et al.* 2002). A variety and range of age classes of each vegetation type is the most desirable outcome, with most vegetation being in the older age classes (Heislers *et al.* 1981). Variability and adaptability in fire regimes is the goal suggested by recent research (Bradstock *et al.* 1995; Conroy 1996).

Changes are known to occur in the composition of algal and bryophyte crusts on soils after fire. These crusts help stabilise the soil surface against water erosion (Eldridge & Bradstock 1994). The condition of these crusts can be crucial to soil surface regenerates and nutrient cycling (Cheal 1981; Eldridge & Bradstock 1994; Eldridge & Tozer 1997). Continued frequent burning has been shown to completely destroy cryptogamic crusts (Greene et al. 1990). Eldridge and Bradstock (1994) showed that cryptogamic crusts were best developed about 16 years after fire and that they begin to decrease after this time. The increase in litter from the overstorey species causes this reduction.