The New South Wales Government
Independent Planning Commission NSW
Level 3, 201 Elizabeth St.
Sydney
N.S.W. 2000

21 McBrien Drive
Kelso
N.S.W. 2795
27-7-20

Re, My objection to the approval of
The Santos Narrabri Gas Fracking Project

Commission Members,
I am an Australian citizen with no connection to the Pilliga area, other than my passionate resolve in regard to protecting the whole of Australia for the future, from projects, which, in my opinion, will damage the environment permanently, causing major problems for the present and future population of our country. I do feel I know the area well from my reading of, and referral to, the immensely descriptive book "A Million Wild Acres" researched and compiled by Eric Rolls, who lived in that area. A book I respectfully commend, to anyone wishing to absorb both the history and the incredible diverse natural biodiversity of that area. My credentials to make the objections which follow, include a career in the construction industry, involving project management of major projects in the Sydney CBD and North Sydney, and fifteen years as the principal of a building consultancy, operating mainly as an expert witness in legal matters. My major client over a number of years was Alliance Insurance. I have lectured by invitation at The University of Technology, and presented a paper there on project management..
I wish to render my objections to the approval of the above project for the following reasons:

The most important reason is one, which, in my opinion, has not been considered in the Santos submission, and, if I am correct in my assumptions, could cause a major disaster to the environment which the area could not recover from. To appreciate the matter, it is necessary to consider together, both the Santos submission, and also another major project under assessment in the same area, namely, The N.S.W. Great Artesian Basin Shallow Water Resource Plan. The latter being a plan to control water sharing between New South Wales, Victoria, and South Australia, with the intentions of using the water in the shallow water aquifer, which exists in the top sixty metres below ground level, for agricultural , environmental, and business use. The intention, to use up to 20% of the water available. This water has no connection with the waters of The Great Artesian Basin, which lies at a much greater depth, separated by rock strata from the sub surface water. This sub surface area of sixty metres in depth, consists of unconsolidated sediments of sandstone, mudstone, siltstone, and shale, which, being unconsolidated, allows for the space for water to accumulate in the ground, to form The Great Artesian Shallow Water Resource.
The water table of this resource, can be as near as ten metres from the surface, and existing bores are utilised for water for towns in the area, and for agriculture. Both of whom depend on it. The natural situation which exists to focus on, is the sub surface material of this resource, being unconsolidated, and the fact that under certain conditions, any unconsolidated material can be consolidated by vibration, and thus occupy a smaller space. In my opinion, there is a risk of such an action occurring, if

the Santos project is approved and allowed to proceed.
To appreciate the philosophy of my contention, it is necessary to consider the history of fracking in other areas of the world, and to consider the knowledge and reactions in other countries and communities, to events which have occurred as the result of fracking procedures to the detriment of those areas, principally, fracking causing earthquakes in surrounding areas, which are large enough to cause damage to buildings and the terrain many kilometres away, and the tremors continuing for long periods after the initial fracking has been accomplished. Currently as a result of such events occurring, fracking has been banned in Canada, the states of New York, in 2015, Vermont in 2012, Maryland, in 2017, Pittsburgh Pennsylvania in 2010, Philadelphia in 2012, Beverley Hills California in 2014, Ohio City, Bradview Heights, Mansfield, Oberlin, and Yellow Springs, Ohio, in 2012, Denton, Texas, Boulder County Colorado , Mora County, New Mexico in 2014, Hawaii County, in 2013. In Europe, France in 2011, The Netherlands, Germany, in 2012, Bulgaria, in 2012, Spain in 2012/13, Switzerland, Italy, Northern Ireland in 2017, Scotland, in 2017, Wales, and recently on 2-11-19, in England, based on scientific investigations involving earthquakes, caused by only one fracking installation in Lancashire, which caused earthquakes with a 2.9 M/L force. (M/L figures are similar to the Richter scale)
Refer to the attachment "A" for the scientific analysis which states, "*That it is not currently possible to accurately predict the probability or magnitude of earthquakes linked to fracking operations*". In The U. S. there have been earthquakes linked to fracking up to 5.7 on the Richter scale, near Prague Oklahoma, and in China, some of a 4.9 force.
There is then, scientific analysis and recognition, that fracking can cause earthquakes, with significant earthquakes occurring in the Lancashire, England fracking process, while scientists were analysing the situation, leading to the UK government abandoning fracking support altogether. This, from only one fracking well site.
Reports on the web, describe swarms of earthquakes occurring in the areas of the US where fracking is taking place.

Earthquakes cause damage to terrain and structures in various ways. Some by direct ground movement, both vertical and horizontal. The salient one, with respect to my objection to the Santos project, is that of liquefaction. This phenomenon can occur under the influence of an earthquake, and or, ground tremors, in water saturated unconsolidated soils. In such a situation, the material constituting the unconsolidated ground, under vibration, flows as a liquid, and consolidates in the process, thus collapsing and decreasing the overall volume of the soil, causing amongst other alterations, the water content to be pushed out vertically to the surface. Refer to the attachment "B", A scientific report titled "Liquefaction Induced Flooding in Christchurch New Zealand" by C.A. Davis, S. Giovinazzi and D. Hart, a paper presented to the 61CEGE 6th International Conference on Earthquake Geotechnical Engineering, held on 1-4 November 2015 in Christchurch New Zealand.

I have no geotechnical education, however, In the subject matter, I consider that it is logical to consider the Santos proposal, together with the NSW Great Artesian Basin Shallow Water Resource Plan, and the effect that seismicity induced by fracking, could have, on an unknown area possibly large scale. The tremors from the single fracking site in Lancashire, impacted only some eight kilometres away with a 2.9 Richter scale earthquake. The earthquake of February 2011described in the Christchurch situation was 6.2 in intensity, and was felt 150 kilometres away. My concerns follow. Neither the Santos submission or The Great Artesian Basin Shallow Water Resource Plan, considers the risk of fracking induced earthquakes affecting the upper 60 metres of ground over the Great Artesian Basin. In fact, In The NSW GAB Shallow Groundwater Sources, Resource Description Report, (NSW Department of Industry 2018A) with regard to The GABSWR proposal, refer in clause 4.3 of their risk assessment, in regard to unconsolidated sediments, that "*sediment compaction can lead to impacts on surface water users, and that sediment compaction can lead to subsidence.*" The report then states, "*that sediment compaction is outside the report's scope of risks*".

The scientific report in relation to the fracking induced earthquakes at Preston New Road, Lancashire, U.K. states, "*that it is not possible with current technology to accurately predict the probability or intensity of tremors associated with fracking.*"

That conclusion was from scientific investigation of the results from just one well. The Santos plan is to drill 850 wells over a large area. It is logical to state that;

(a) Although geotechnical surveys have been carried out, there is no complete knowledge of the ground/water make up in that and other areas, which could be affected.

(b) It is impossible to forecast what effect 850 wells collectively will have, in regard to induced seismic activity, and to what distance such activity might extend.

(c) A major earthquake could affect a very large area, and the known ground situation of water saturated unconsolidated ground, could be prone to liquefaction.

(d) The results of liquefaction could include
  (1) Temporary surface flooding. With the water lost by evaporation
  (2) Ground level subsidence.
  (3) Irreversible ground compaction, making it impossible for the shallow water aquifer to be recharged in the future.
  (4) Rivers and current bores drying up permanently.
  (5) The great Artesian Basin Shallow Water Resource or part, could be lost for ever
  (6) Agriculture and complete biodiversity over a large area lost for ever

My request is for the commission to seriously consider this possibility, after confirmation by geotechnical experts that this risk is indeed present. I am aware of the type of risk assessments quoted by assessment reports i/e low, medium, and high. I consider the effects of a serious earthquake induced by fracking, causing liquefaction to this area, are of such magnitude, as to mean no possible risk of such a happening should be contemplated, or allowed at all, however small.

Is there any risk that fracking can damage the existing regime in The Great Artesian Basin area?

A report entitled "The Independent Scientific Enquiry into Hydraulic Fracture Stimulation in Western Australia, was commissioned by The Western Australian State Government in 2017, prepared by a panel appointed by the Government, consisting of Dr. Tom Hatton, (Chair), Phillip Commander, Dr. Ben Clennell, Professor Fiona Haslam McKenzie and Dr. Jackie Wright. The final report was presented to the Western Australian Government in September 2018. This inquiry report is extensive in addressing every aspect of the fracking industry, including risks. In addressing, *Is there any risk that fracking can damage the existing regime in The Great Artesian Basin area,* I quote some of the findings of that inquiry report.
The full enquiry document is available on the web.

In Clause 6-12-3 Page 185, **Induced Seismicity,** it states in part; *Human activities are not capable of creating entirely new large faults in an intact rock mass, but they can influence patterns of natural seismicity in several ways; A large increase in fluid pressure in the subsurface from injection of significant volumes of fluids, (generally water but can be gas storage) The fluid pressure reduces the effective stress acting to resist fault slip, such that the forces needed for the fault to move eventually decrease below the strength of the fault and it moves.* and following, on page 186, *This may lead to an increase in seismicity and has been documented in several states in the United States, where very large volumes of wastewater from oil and gas production have been deposed of in surface wells.* and, *The induced seismicity that is well documented from North America, can generally be shown to be associated with large cumulative volumes of injection, and to require some months or years after the injection of fluid ceases.*

A further reason for induced seismicity is given on page 186. Reason being;
A large decrease in fluid pressure from the withdrawal of large quantities of water or hydrocarbons from a sub surface reservoir. Owing to the complex of interplay of forces in the sub surface and the fact that a reservoir is both porous and elastic, the reduction in fluid pressure can change the stress balance such that a fault already near the failure can reactivate. This may occur gradually (a seismic slip), or rapidly enough to produce microseismicity or, very rarely, a felt earthquake. Typically, this scenario leading to felt seismicity is associated with very large and long term withdrawal of large fluid volumes from a reasonably deep but still compressible rock reservoir. (Gonzalez et al 2012) examined how the 5.1 magnitude 2011 Lorca earthquake in Spain, which led to nine deaths, was probably caused by extensive withdrawal of groundwater for agricultural use. and further on page 186, *The Groningen conventional gas field in the Netherlands is an example of an area where decades of gas production has led to tens of centimetres of cumulative ground subsidence, the reactivation of faults and sporadic felt seismicity in the vicinity. (Van Wees et al. 2017) and references therein.*
On page 187;*Conditions in the Appalachian region of North East United States*

where the Utica and Marcellus shale is encountered, have been considered to have a somewhat higher risk owing to greater complexity of structures (Arthur, Bohm & Layne 2008). Indeed, a series of induced earthquakes, including a felt magnitude event, was recorded in the heart of the producing region of the Utica Shale in Youngstown, Ohio in 2011 (Skoumal, Brudzinski & Currie 2015) and further on Page 187; *Public attention was drawn on the topic of induced seismicity outside of North America following an earthquake of =2.3 Mw close to the site of a hydraulic fracture stimulation operation near the city of Blackpool in Lancashire in the United Kingdom (UK) in 2011 (Clarke et al. 2014) This gave rise to a series of investigations by government agencies and eventually to changes in regulations by The United Kingdom Oil and Gas Authority.* and, in part page 187; *There have been more reports of seismicity induced by hydraulic fracture stimulation operations.* and; on pages 187/188: *There is evidence from the Duverney Shale in Alberta, that the extent and size of seismic events increases in line with the amount of fluid pumped during a series of hydraulic fracture stimulations in a field (Schultz et al. 2018); This study noted that there can be a delay of months or years from the commencement of hydraulic fracture stimulation operations, to the point where enough fluid has built up to have a noticeable effect on seismicity in a particular field. Follow up investigations by Eaton & Schultz (Eaton & Schultz 2018) showed that the induced seismicity was concentrated where a high level of overpressure already existed within the shale formation, that is, the extra fluids injected during hydraulic fracture stimulation tipped some faults within these zones over the edge into a condition of failure.* and on page 188; *A combination of many factors is necessary for injection to induce felt earthquakes. These include, faults that are large enough to produce felt earthquakes; Stresses that are large enough to produce earthquakes; and The presence of fluid pathways from the injection point to faults, and fluid pressure changes large enough to induce earthquakes.*

In ***Triggered Seismicity,*** *Clause 6.12.4 pages 189, and 190, it states; Triggered seismicity is a term used to describe an earthquake that occurs at a particular time owing to a distant external event disturbing an already unstable fault, leading it to reactivate. This is distinct from induced seismicity, where local changes in stress and fluid pressure directly lead to an earthquake happening. With regard to hydraulic fracture stimulation, this induced seismicity is usually within a few kilometres of an injection well. On rare occasions, seismicity can be induced up to tens of kilometres away from the area of fluid source when the cumulative volumes and consequent changes in the state of stress around a field of injection wells are very large and propagate along faults and fracture corridors over a period of years (Peterie et al. 2018)* and further;

It is possible that the build up of pressure and stresses caused by human activity could place a nearby fault close to it's failure condition, and then an external event such as a large earthquake could tip that fault into an unstable state wherein it does fail and produce a new rupture. While it could be argued that the earthquake was triggered, the conditions preparing for failure are man made, so it still would be seen as an induced event. This is the case even if it was one of a series of earthquakes associated with human activity that appeared to elevate the level of seismic activity over that previously recorded in the area. Van Der Elst et al. (van der elst et al. 2013) report an *increase in the incidence of remote triggering within areas of suspected anthropogenic earthquakes in the American Mid West .*

In my opinion, the scientific evidence proves that earthquakes can result from fracking operations, and that the behaviour of the ground can not be predicted, even with one well, with 850 wells there is then a definite risk of environmental damage. The ground conditions are evidently a complex issue, with unknown values, making positive prediction of ground behaviour virtually impossible.

My further reasons for objecting to approval of the Santos submission

The possibility of polluting of the Great Artesian Basin waters, which, although at a great depth below the rock fracking area, could be polluted by the chemicals used in the fracking. There is no way of knowing the composition of the ground between the fracking area and the waters below. There are likely to be faults in the rock which could be affected by the seismic effects described previously. Such tremors could cause crack and movement in existing faults in the rock strata, between the fracking area and the artesian basin, allowing free access for polluted waters to flow in to the basin This surely is logical reasoning. Again, in my opinion, a no risk at all strategy should be the case for this matter. Such a happening simply can not be repaired and would be the ultimate in environmental damage.

Damage to the environment at surface level

I understand that there no plans are in place to remove the large quantities of salt which result from the drilling of the wells. Each well is required to have a bund to store the salt water adjacent to the well. The water also contains chemicals which are known to be dangerous to the environment. There are bound to be spills of this water and other liquids used in the process. The United States E.P.A. in The Journal Environmental Science and Technology, states that up to 16% of wells spill liquids in the USA, and between 2005 and 2014, there were 6648 such spills at fracking well sites.. The ground and environment around wells where spills occur, is likely to be irremediable. A further issue is, that each well site covers around 2 hectares, and 850 wells separated by 750 metres. There will be a network of roads connecting the drill sites, cutting up the area into a large number of blocks separated by the roads for the length of the project over 20 years. This will effect the biodiversity of those areas to a great degree, in my opinion. Birds and animals will leave these areas for good. They will not be around to come back in twenty years. The idea that such a development can be repaired back to the original, is untenable. Once an environment is destroyed, logic says, that any environment the subject of remediation, will never be the same. The environment will alter from what is prevalent now, and no amount of rehabilitation of the area will bring it back to what exists currently. There is a large diversity of bird, animal, and plant life in the Pilliga, as described by Eric Rolls, in his book, “A Million Wild Acres“, Refer to attachments “C” and “”D” from that book, which lists the birds and plant life which exists there, and under threat. There are 222 species of birds, and about a thousand species of plants in The Warrumbungle National Park, The Pilliga Nature Reserve, and State forests, some rare in the 14000 square kilometres, surely an environment requiring the ultimate in protection.

The Great Artesian Basin and The Great Artesian Basin Shallow Water Resource are unique national assets to Australia of huge proportions, natural wonders which could never be replaced. Assets which need to be protected from any threat to their viability as a resource. Fracking is a threat, which scientists state, is an operation where it is not possible to predict ground behaviour which can result from fracking, creating a risk which should not be contemplated, in my opinion. The Precautionary Principal should surely apply to this proposal.
I trust that my submission against the approval of this Santos project will be treated seriously by the Independent Planning Commission.

Yours sincerely

John Eccles

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Press release

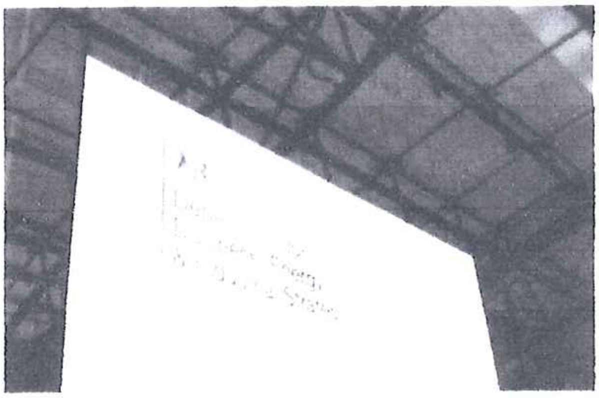
Government ends support for fracking

Government ends support for fracking in England on the basis of new scientific analysis, published today.

Published 2 November 2019

From:

Department for Business, Energy & Industrial Strategy (https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy), Oil and Gas Authority (https://www.gov.uk/government/organisations/oil-and-gas authority), The Rt Hon Kwasi Kwarteng MP (https://www.gov.uk/government/people/kwasi-kwarteng), and The Rt Hon Andrea Leadsom MP (https://www.gov.uk/government/people/andrea-leadsom)



- Oil and Gas Authority report published today concludes that it is not possible with current technology to accuratel predict the probability of tremors associated with fracking
- Separate proposals to change the planning process for fracking sites will no longer be taken forward at this time

Fracking will not be allowed to proceed in England, the government has announced today, following the publication of new scientific analysis.

Ministers took the decision on the basis of a report by the Oil and Gas Authority (OGA) (https://www.ogauthority.co.uk/exploration-production/onshore/onshore-reports-and-data/preston-new-road-pnr-1z-hydraulic-fracturing-operations-data/), which found that it is not currently possible to accurately predict the probability or magnitude of earthquakes linked to fracking operations.

Fracking already takes place across the world including in the US, Canada and Argentina. However, exploratory work to determine whether shale could be a new domestic energy source, delivering benefits for our economy and energy security, has now been paused - unless and until further evidence is provided that it can be carried out safely here.

Ministers have always been clear that the exploration of England's shale gas reserves could only proceed if the science shows that it is safe, sustainable and of minimal disturbance to those living and working nearby. For that reason, government introduced tight planning controls through the Infrastructure Act 2015 and set strict limits on seismicity, in consultation with industry.

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6ICEGE
6th International Conference on Earthquake Geotechnical Engineering
1-4 November 2015
Christchurch, New Zealand

Liquefaction Induced Flooding in Christchurch, New Zealand

C. A. Davis[1], S. Giovinazzi[2], D.E. Hart[3]

ABSTRACT

Large, low-lying tracts of eastern Christchurch, New Zealand, were inundated multiple times with water several centimeters deep as a result of earthquake-induced liquefaction processes initiated by the main events in the 2010-2011 Canterbury earthquake sequence. The water and soil ejection process from liquefaction is well understood. However, the extent of possible ejecta and the resulting impacts on communities are neither understood nor documented. This paper presents observations and some lessons learned from the liquefaction-induced flooding and sedimentation experienced in Christchurch. These processes resulted in costly damages to private properties and to the water, sewer, storm water, and transportation lifelines systems as well as hindering people's mobility and access to emergency services in the earthquake aftermath. Additionally, emergency response and recovery activities were delayed or hindered. Results of this initial investigation identify the need for better understanding of the conditions leading to severe liquefaction-induced flooding and sedimentation to allow for improved public policy and engineering mitigations.

Introduction

Between Sept. 4, 2010 and Dec. 23, 2011, the Canterbury, NZ region was shaken by a historically unprecedented earthquake sequence which caused extensive liquefaction in and around Christchurch. In many areas the liquefaction was so severe it resulted in flooding across large areas for many hours to days following the earthquake. This water and soil ejection process from liquefaction is well understood. However, the extent of possible ejecta and resulting community impacts is not well understood or well documented. The 2010-11 earthquake sequence provides unique examples of extensive liquefaction in numerous communities who suffered flooding primarily from water and soil being ejected from the ground as a direct result of the liquefaction process. The purpose of this paper is to provide initial documentation of these examples and the resulting impacts to infrastructure. The study summarized herein is part of a much broader on-going international project investigating earthquake-flood multihazard impacts to lifeline systems.

Canterbury, New Zealand, Earthquake Sequence of 2010-2011

The Canterbury, New Zealand region was struck by a sequence of earthquakes in 2010 and 2011; the most significant being: M_w 7.1 on Sept. 4, 2010; M_w 6.2 on Feb. 22, 2011; M_w 5.8 and M_w 6.0 on June 13, 2011; and M_w 5.8 and M_w 5.9 on Dec. 23, 2011. The 2010 earthquake epicenter

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was located 45 km west of Christchurch while the 2011 earthquakes were about 6 to 10 km from the Christchurch city center. This earthquake sequence resulted in significant seismic-induced geotechnical mechanisms increasing flood susceptibility in the Christchurch area, including vertical tectonic movements, liquefaction induced settlement, and lateral spreading. This paper focuses on liquefaction-induced flooding and sedimentation. Other geotechnical aspects are part of on-going earthquake-flood multihazard studies (e.g., GEER, 2014).

Earthquake-Induced Liquefaction Process Leading to Flooding

Figure 1 shows flooding after the February 22, 2011 Christchurch earthquake resulting from large volumes of liquefaction-induced water bubbling out from the ground in portions of the city, which was compounded by water flowing from broken pipes and groundwater wells. The liquefaction process is well understood and can be found in numerous references (e.g., Idriss and Boulanger, 2008). This section does not provide new information on the liquefaction process, but instead summarizes the process as it relates to the flooding observed in the Canterbury region, using surficial flooding and erosion as an analogy, and provides a technical context for the impacts on community and lifeline systems.

Figure 1. Typical liquefaction induced flooding of Christchurch suburbia from Feb. 22, 2011. (a) Aerial view of estuary-proximal suburb of Bexley (Crown Copyright 2011, NZ Defence Force – Some Rights Reserved). (b) Flooding of Anzac Dr. (courtesy T. O'Rourke).

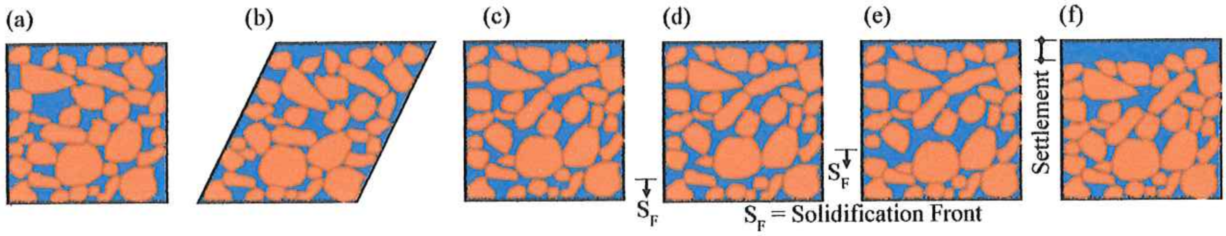

Figure 2. Saturated soil element experiencing undrained shear strain from earthquake shaking, liquefaction, and solidification. (a) Initial un-sheared state with particles supported by grain-to-grain contact. (b) Element experiencing shear deformation rearranging the soil particles. (c) Element returned to un-sheared condition after developing maximum pore pressure (liquefaction) with particles in a suspended condition. (d) Particles in liquefied element begin to fall out of suspension showing initiation of solidification front S_F. (e) Solidification front propagating upward. (e) Element with particle arrangement in final solidified state showing final settlement.

Figure 2 diagrams the liquefaction process. Liquefaction generally occurs in loose, saturated or partially-saturated non-cohesive soils. During earthquake shaking, the granular soil contracts decreasing in volume. The volume decrease occurs as the soil particles move and attempt to fill the void spaces within the loose soil mass. In saturated soils, the void space is filled with water. If drainage is unable to occur during the shearing and contraction process (Fig. 2b) the incompressible water temporarily prevents the soil grains from contracting (Fig. 2c). As the soil void space attempts to decrease, the load is transferred from the soil structure to the water mass, resulting in an increase in pore water pressure and stress reduction on the soil grains. Water pressure can build up to a value equal to the overburden pressure, at which point the effective stress drops to zero, creating a liquefied condition, and the soil grains are put in a state of suspension (Scott, 1986) as shown in Figure 2c.

The excess water pressures generated in the soil mass are dissipated by solidification and water flow. The water flow tends to move upward due to an upward hydraulic gradient (Idriss and Boulanger, 2008). The water flow initiates from the bottom of liquefied soil layers as the particles settle by falling out of suspension (Scott, 1986) as shown in Figure 2d, and creates an intra-layer water gap or loose soil zone as shown in Figures 2d and 2e. Figure 2e shows the upward propagation of a particle solidification front through a soil element, which eventually results in total settlement within the element as shown in Figure 2f. This is a constant volume process which is understood by comparing Figures 2a and 2f. These figures show how the soil particles are rearranged within the same unit volume and during settlement the water moves upward relative to soil particles, but the top of water gap or water film shown in Figure 2f is the same elevation as the original top of the soil grains shown in Figure 2a.

As shown in Figure 3, in large soil deposits intermediate soil layers having lower permeability (e.g., a very thin silty layer above a massive sand layer) may reduce the rate of flow causing build-up of a water film and lateral water flow. The generation of water films add to the potential ground instability which may already exist due to reduced soil strength. The unstable condition results in ground deformations and cracking. Tension cracks provide a low resistance path for water to escape during the pore water pressure dissipation process. As the pressures dissipate, the natural subsurface variability results in changes to the hydraulic gradient.

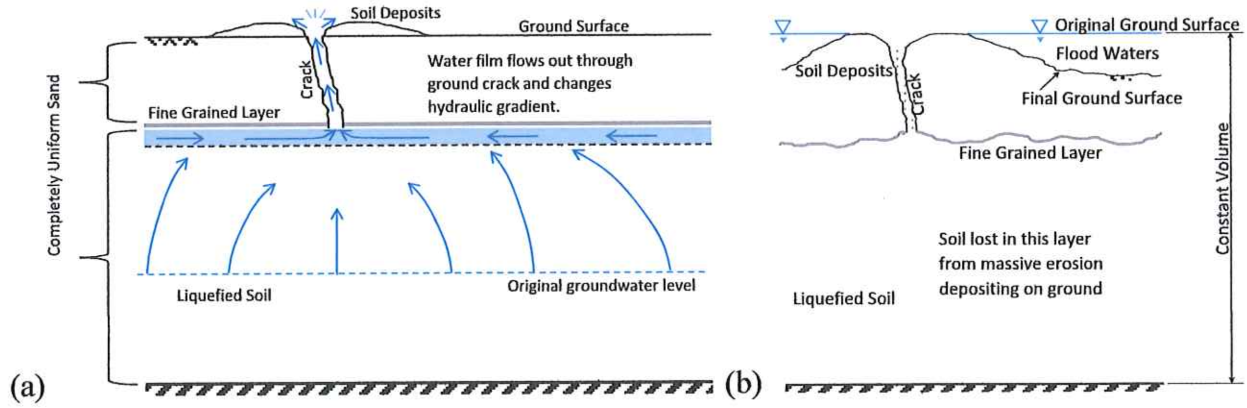

Figure 3. Continuous fine grained layer within otherwise uniform sand. (a) Upward water flow slowed at fine grained layer forming a water film; crack focuses soil-water slurry ejection on ground surface and changes hydraulic gradient. (b) Final state of uneven ground conditions.

The formation of cracks and water films in the subsurface tend to focus the flow paths and create complicated flow conditions and hydraulic gradients. The hydraulic gradients commonly have sufficient velocity and force to erode subsurface soils. The soil particles in a liquefied state are in a buoyant condition and highly susceptible to erosion. In fact, the initial hydraulic gradient set up in a liquefied soil mass is analogous to initiating piping erosion or quick conditions (Idriss & Boulanger, 2008). Soil erosion takes place along the subsurface water flow paths. Rapid flowing water picks up soil particles along its course. In some cases the soil being eroded may not have been liquefied, but simply located on the path of least resistance for pore water pressure dissipation. This erosion process creates a soil-water slurry, which flows as described above for subsurface water paths.

The water or a soil-water slurry flow is ejected from the earth, either onto the ground surface, or into some subsurface cavity such as an underground vault, cracked or open pipe or other space. The observable ejecta are shown in Figure 3 as a water flow, often accompanied with soil when erosion takes place. Soil ejected onto the ground is commonly referred to as "sand boils", "mud spouts", or "sand volcanos" as a result of the ejection process looking like material boiling up or spouting from the ground, with resulting deposits forming cone-shaped mounds with central craters akin to mini-volcanos as shown in Figure 3 and Figure 5a presented in a later section.

Because liquefaction is a constant volume process, as the ground settles the water and soil sedimentation deposition depth above the ground increases and inundates the surface as shown in Figure 3b. In the absence of surface drainage, the water surface elevation after the liquefaction process is completed remains approximately the same as the original pre-earthquake ground surface elevation. The variation in subsurface conditions and erosion process results in differential settlement across the ground surface. The inundation depth of flooding is approximately equal to the settlement when original groundwater is near the surface.

Analog with Surface Water Flooding

The liquefaction-induced flooding from the groundwater has an analogy with surface water flooding. Flooding occurs from the accumulation of source water of sufficient volume to inundate areas of land. Normally this occurs from water above ground such as rain, snow melt, dam/levee failure, etc. The hydraulic gradient created from water flow may be sufficient to erode soil and move other materials, which can then be transported and deposited downstream as debris. During the liquefaction process the groundwater serves as the source water, which can erode the subsurface soils and deposit them where the water is ejected from the ground. This analog is useful for relating the liquefaction-induced flooding and sedimentation to other more common flood events created from surface waters and associated sediment and debris deposition.

Liquefaction-Induced Settlement and Flooding in Christchurch, NZ

Ground settlements resulted from multiple geotechnical mechanisms including: (1) head ward vertical slumping from lateral spread movements, (2) solidification of liquefied soils, and (3) loss of ground from the subsurface soil erosion and ejection process. Approximately 87% of the settlement is estimated to be associated with the ejecta (Van Ballegooy et al., 2014). These settlements increased the flooding opportunity by providing lower laying areas for water to pond as shown in Figure 1b. Settlements from solidification and soil ejection occurred as the liquefaction-induced floodwaters were ejected to the ground surface; that is, the ground was settling as water was ponding on the lowered ground surface. In a sense, a bowl shape was formed giving an area to hold the ejected water. As shown in Figure 1, many streets were inundated with water several tens of centimeters deep. Vast volumes of surface deposits were removed after each event, combining with the accumulation of the three primary settlement mechanisms to enhance the liquefaction-induced flooding potential for each subsequent earthquake event. Cumulative settlement reached 0.3 to 1 m in different areas (GEER, 2014).

Liquefaction-induced flooding occurred in Christchurch city and nearby towns in all the previously identified significant earthquake events within the sequence. Figure 4 presents some examples of liquefaction-induced flooding in different locations and earthquakes. Not all liquefied areas sustained flooding following the earthquakes. Many areas experienced liquefaction-induced water and soil ejecta at the ground surface, without experiencing flooding, due to insufficient water spouting from the ground, little or no damage to pipelines, and/or sloped ground allowing ejected water to drain rapidly. Some areas experienced liquefaction induced flooding from several of the earthquakes, while other areas only experienced flooding from a single event. Those areas which experienced liquefaction-induced flooding were generally low-lying and relatively flat, underlain by thick soil deposits having a relatively high liquefaction potential and, crucially, featured shallow groundwater. Communities suffering significant liquefaction-induced flooding in at least one earthquake include: Aranui, Avondale, Avonside, Bexley, Bromley, Burwood, Central City, Ferrymead, Halswell, New Brighton, Parklands/Queenspark, Richmond, Shirley, Wianoni, and Woolston/Brookhaven. Large inhabited areas were inundated, as seen in Figure 1, in all events resulting in liquefaction-induced flooding of streets and properties, including homes and businesses. In total these areas directly impacted at least tens of thousands of people multiple times resulting in extensive infrastructure and property damages and associated economic impacts. Observations were also made in large open park spaces and rural fields, where no developments or underground piping exist. While these rural areas may have suffered little-to-no economic impact, they do provide evidence for the source of flooding coming from the liquefaction process. Further evidence comes from flooding in urban areas at elevations above river level, and in backyards contained by walls and fencing (e.g., Figure 4b; https://www.youtube.com/watch?v=gDkLPLCC_Ok).

Figure 4. Liquefaction-induced flooding impacts. (a) Feb 22, 2011 flooded street in Aranui suburb. (b) June 13, 2011 flooded property in Aranui suburb. (c) June 13, 2011 flooding streets and property in Bromley. (Photos courtesy M. Lincoln, nzraw.co.nz)

Figure 1b shows a photograph of flooding on Anzac Dr. following the Feb. 22, 2011 earthquake in the Bexley suburb. The water depth at time the photograph was taken is estimated as 200 to 300 mm based on curbs completely covered with water and the car bumper in the background above water. Settlement in Bexley was about 300 mm for this earthquake. The reported settlement and observed flood depths are consistent with liquefaction ejecta causing flooding, as seen in Figs. 2 and 3. Further investigations are warranted to confirm these initial observations.

Damaged infrastructure contributed to the liquefaction-induced flooding in several ways. Damaged pressurized water pipes and wells added to the volumes of flood water, and in some cases created localized flooding. The damaged sewer and storm water drainage pipes were filled with sands, reducing or completely eliminating their ability to drain water. Upstream wastewater flows were either: (1) backed-up and flooded upstream at points where the hydraulic head reached the ground surface elevation, or (2) discharged at the point of damage adding to local flood conditions.

Impacts From Liquefaction-Induced Flooding and Sedimentation in Christchurch

Damaged non-pressurized pipes from sanitary sewer and storm water drainage networks created open void spaces into which the subsurface liquefied soils flowed. Additionally, the increased hydrostatic pressures placed buoyant forces on buried pipes, potentially displacing and opening the pipe joints and/or causing the pipes and appurtenant structures to float. Sewage water discharge contaminated some flooded areas causing health concerns. The flood water eventually drained to rivers, estuaries and the ocean, thereby spreading the contamination. Also, as part of the immediate response, raw sewage was pumped into local rivers within the city.

Figure 5 presents example impacts from liquefaction-induced sedimentation. Large volumes of soil were ejected onto the ground surface and flowed considerable distances which: (i) blocked drainage paths, (ii) filled catch basins, (iii) blocked streets, and (iv) trapped vehicles. Items (i) and (ii) prevented drainage of liquefaction-induced inundation while items (iii) and (iv) reduced or eliminated street functionality. The damaged pipes eroded large holes in the streets and further impacted transport capabilities through (1) soil flowing into non-pressurized sanitary sewer and storm water drainage pipes and (2) pressurized water pipes jetting and eroding holes.

Figure 5. Liquefaction-induced sedimentation impacts. (a) Feb. 22, 2011 liquefaction sediments forming cones (Curtesy T. Musson, commons.wikimedia.org). (b) Feb. 22, 2011 car partially buried in sediments (Courtesy G. Gho, commons.wikimedia.org). (c) June 13, 2011 street blocked by liquefaction sediments and trapping vehicle (Courtesy M. Lincoln, nzraw.co.nz).

In addition to the drainage problems, the sediments ejected onto the ground surface built up very large sand volcanos with high, steep cones and wide, deep craters capable of bottoming out vehicles attempting to cross over them (e.g., see http://izismile.com/2012/08/31/christchurch_liquefaction_26_pics-11.htm and http://mauriroawaitaha.wordpress.com/). As seen in Figures 4b and 4c, sediment build-up was sufficient to partially bury automobiles and block streets (see also for example, http://keithwoodford.wordpress.com/2011/02/27/understanding-the-christchurch-earthquake-building-damage). Some people became temporarily trapped in their cars as a result of sediment blocking their doors (http://news.wikinut.com/Earthquake-strike-s.-February-the-22nd-2011/19occxnq/). Roadways were choked with vehicles stuck in the loose saturated sediment (http://www.stuff.co.nz/national/photos/4688271/Christchurch-aftershock-Feb-22; https://quakestudies.canterbury.ac.nz/store/part/88391).

Sediment also flowed into subsurface sewer and storm water drainage pipes as depicted in Figure 6a. This flow into pipes caused several problems, including: (1) blocking sewage flow leading to sewage flooding into streets, rivers, and estuaries causing widespread contamination, (2) blocking drainpipe flow preventing drainage of liquefaction-induced flooding and enhancing the post-earthquake flood problems, and (3) sinkholes in the streets impacting transportation, mobility, safety, other nearby utilities, private property, and emergency response. Additionally, some holes were eroded from damaged pressurized water pipes.

Figure 6. Sinkholes. (a) Car being pulled into sinkhole along with liquefaction sediment flow. (b) Dump truck stuck in sinkhole obscured by water. (c) Fire engine stuck in hole Sept. 4, 2010 (Courtesy B. Richardson, nzraw.co.nz). (d) Car drove into sinkhole previously obscured by water. (e) Large sinkhole swallowing street, vehicles, and power pole (Courtesy Perduta commons.wikimedia.org). (f) Car completely engulfed within sinkhole. All photographs except (c) are from Feb. 22, 2011. All photographs except (c) and (e) courtesy M. Lincoln, nzraw.co.nz.

The subsurface erosional flow of sediments into a pipe or other subsurface void space creates different types of impacts, as shown in 6, than when the eroded sediments are ejected onto the ground surface. The sinkholes and sediment in the streets inhibited emergency response and recovery activities ranging from emergency response vehicles shown in Figure 6c to construction equipment shown in Figure 6b to emergency water tanker trucks (e.g., http://izismile.com/2012/08/31/christchurch_liquefaction_26_pics-11.html). In many cases these sinkholes were obscured by flood waters as indicated in Figures 6b and 6d and vehicles unknowingly drove into these holes as circled in Figure 4a. As water subsided the holes retained water, and people drove into them believing they were passing over a puddle not knowing the ponding represented a deep hole (http://news.wikinut.com/Earthquake-strike-s.-February-the-22nd-2011/19occxnq/). In other cases the sinkholes developed directly below vehicles and sucked them into the formation. Figure 6e exemplifies how some sinkholes were very large and dangerous, opening entire streets, affecting not only transportation corridors and vehicle safety, but also other lifelines in the street and private properties.

In a few cases the sinkholes posed threats to lives, where vehicles either sank or drove into sinkholes, or sank into surficial liquefied soils having no bearing strength (e.g. see in Figure 6f the same car as circled in Fig. 4a). A few vehicles became engulfed to the extent drivers and passengers could have drown. Additionally, there is documentation of people being trapped in holes from the September 4, 2010 and June 13, 2011 earthquakes, and at least in one case a lady was noted to have to claw her way out of the liquefaction (see for example http://www.abc.net.au/news/2011-06-15/liquefaction-traps-christchurch-resident/2759046 and http://www.nzraw.co.nz/news/fire-engine-stuck-following-christchurch-earthquake/). There are no documented cases of severe injuries or fatalities in Christchurch resulting from this hazard.

Conclusions

Few, if any, studies have investigated liquefaction-induced flooding and sedimentation impacts on lifeline systems. The liquefaction ejecta process was well documented and observable in social media posts (e.g., youtube.com and flickr.com), providing strong evidence of liquefaction-induced flooding. The Canterbury earthquake sequence highlights the rare but extreme inundation problems that can arise from liquefaction processes. Christchurch also provides a unique opportunity to investigate and document numerous liquefaction inundation impacts on communities. Such documentation is helpful to prepare for similar potential problems in other areas. The geotechnical and urbanized development conditions leading to such extenuating situations needs further investigation so guidelines for public policy and engineering mitigations can be developed and used worldwide.

Acknowledgments

The American Society of Civil Engineers (ASCE) Technical Council on Lifeline Earthquake Engineering, ASCE Geotechnical Institute, and Los Angeles Department of Water and Power are acknowledged for their support of field investigations in Christchurch, NZ following the Feb. 22, 2011 event and as part of an earthquake-flood multihazard impacts on lifeline systems study.

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Bird List

This bird list for the Pilliga forests, Pilliga Nature Reserve and the Warrumbungle National Park has been compiled from Alan Morris's lists, from the sightings of A. R. McGill and a Gould League bird study group camped at Baradine Showground in 1975, and from my own sightings. The first column gives the familiar names as used in the text from Peter Slater's *A Field Guide to Australian Birds*. The second column gives the names recommended in 1977 by the Royal Australasian Ornithologists Union (the *Emu*, vol. 77, Supplement May 1978). I find some of these names unacceptable, especially Bush Thick-knee for the Southern Stone-Curlew. Etymologists are uncertain whether the onomatopoeia of curlew is imposed or contained but in disposing of the marvellous cry the RAOU has almost disposed of the bird. And the changing of Nankeen Night Heron to Rufous Night Heron because nankeen as a colour has become obsolete is pedantic. Let the bird preserve the old word.

Name according to Slater	**Name recommended by RAOU** (noted only if different)
Apostle Bird	Apostlebird
Babbler, Grey-crowned	
White-browed	
Bell-bird, Crested	Crested Bellbird
Bittern, Brown	Australasian Bittern
Blue-bonnet (Both *Northiella haematogaster haematogaster* and *N. haematogaster haematorrhous*)	Blue Bonnet
Bower-bird, Spotted	Spotted Bowerbird
Brolga	
Bronzewing, Common	
Brush Turkey	Australian Brush-turkey
Budgerigar	
Bushlark, Singing	
Butcher-bird, Grey	
Pied	
Buzzard, Black-breasted (Recorded 30 April 1977 on author's farm 16 km north-west of Baradine)	
Chat, Crimson	
Chough, White-winged	
Cicada-bird	Cicadabird
Cockatiel	
Cockatoo, Glossy	Glossy Black-Cockatoo
Major Mitchell's (No recent sightings. Last seen by author near Rocky Glen *c.* 1966)	Pink Cockatoo
Red-tailed	Red-tailed Black-Cockatoo
Sulphur-crested	
Yellow-tailed	Yellow-tailed Black-Cockatoo
Coot	Eurasian Coot
Corella, Little	
Cormorant, Black	Great Cormorant
Little Black	
Little Pied	
Crake, Marsh	Baillon's Crake
Crow, Little	
Cuckoo, Black-eared	
Brush	
Channel-billed	
Fan-tailed	

C

Golden Bronze	Shining Bronze-Cuckoo
Horsfield Bronze	Horsfield's Bronze-Cuckoo
Pallid	
Cuckoo-shrike, Black-faced	
Ground	
Little	White-bellied Cuckoo-shrike
Currawong, Pied	
Darter	
Dollar Bird	Dollarbird
Dotterel, Black-fronted	Black-fronted Plover
Red-kneed	
Dove, Bar-shouldered	
Diamond	
Peaceful	
Duck, Black	Pacific Black Duck
Grass Whistle-	Plumed Whistling-Duck
Musk	
Pink-eared	
White-eyed	
Wood	
Eagle, Little	
Wedge-tailed	
Egret, Cattle (Recorded by Alan Morris Nov. 1976)	
Little	
Plumed	Intermediate Egret
White	Great Egret
Emu	
Falcon, Black	
Brown	
Grey (Pair seen by Alan Morris 20 km west of Baradine)	
Little	Australian Hobby
Peregrine	
Fantail, Grey	
Finch, Double-bar	Double-barred Finch
Plum-headed	
Red-browed	Red-browed Firetail
Zebra	

Firetail, Diamond	
Flycatcher, Brown	Jacky Winter
Leaden	
Restless	
Fowl, Mallee	Malleefowl
Friar-bird, Little	Little Friarbird
Noisy	Noisy Friarbird
Frogmouth, Tawny	
Galah	
Goshawk, Brown	
Grey	
Grassbird, Little	
Grebe, Australian Little	Australasian Grebe
Hoary-headed	
Gull, Silver	
Harrier, Spotted	
Swamp	Marsh Harrier
Heath-Wren, Chestnut-tailed	Chestnut-rumped Hylacola
Heron, Nankeen Night	Rufous Night Heron
White-faced	
White-necked	Pacific Heron
Honeyeater, Black-chinned	
Blue-faced	
Brown	
Brown-headed	
Fuscous	
Regent	
Singing	
Spiny-cheeked	
Striped	
White-eared	
White-naped	
White-plumed	
Yellow-faced	
Yellow-tufted	
Ibis, Straw-necked	
White	Sacred Ibis
Jabiru	Black-necked Stork
Kestrel, Nankeen	Australian Kestrel
Kingfisher, Azure	

Red-backed	
Sacred	
Kite, Black	
Black-shouldered	
Whistling	
Kookaburra, Blue-winged (A pair seen often by Wilf Taylor near Bugaldi Creek 1960 to 1964, a female seen 1964 on his own property, another seen 1966. Author saw a distressed male in his homestead garden March 1975)	
Laughing	
Lorikeet, Little	
Musk	
Scaly-breasted	
Magpie, Black-backed	Australian Magpie
Magpie-lark	Australian Magpie-lark
Martin, Fairy	
Tree	
Miner, Noisy	
Yellow-throated	
Mistletoe-bird	Mistletoebird
Moorhen, Dusky	
Native Hen, Black-tailed	
Nightjar, Spotted	
White-throated	
Oriole, Olive-backed	
Owl, Barking	
Barn	
Boobook	
Masked (One brought out of a hollow tree by author on three separate occasions in 1975)	
Powerful	
Owlet-nightjar	Australian Owlet-nightjar
Pardalote, Spotted	
Striated	
Parrot, King	Australian King Parrot
Mallee Ringneck	Mallee Ringneck
Red-rumped	

Red-winged	
Superb	
Swift	
Turquoise	
Pelican, Australian	
Pigeon, Crested	
Domestic	Feral Pigeon
Pipit, Australian	Richard's Pipit
Plover, Australian Spur-winged	Masked Lapwing
Banded	Banded Lapwing
Quail, Brown	
King (Shot by Merv Goodwin of Gunnedah *c.* 1976)	
Little	Little Button-quail
Painted	Painted Button-quail
Red-chested	Red-chested Button-quail
Stubble	
Quail-thrush, Spotted	
Rainbow Bird	Rainbow Bee-eater
Raven, Australian	
Little	
Reed-warbler	Clamorous Reed-Warbler
Robin, Hooded	
Red-capped	
Rose	
Scarlet	
Southern Yellow	Eastern Yellow Robin
Rosella, Eastern	
Crimson	
Scrub-Wren, White-browed	Whitebrowed Scrubwren
Shrike-thrush, Grey	
Shrike-tit, Eastern	Crested Shrike-tit
Silver-eye, Grey-breasted	Silvereye
Sittella, Orange-winged	Varied Sittella
Snipe, Japanese	Latham's Snipe
Songlark, Brown	
Rufous	
Sparrow, House	
Sparrowhawk, Collared	
Spinebill, Eastern	
Spoonbill, Royal	

Yellow-billed	
Starling, English	
Stilt, Black-winged	
Stone-Curlew, Southern (Now rare and endangered but heard on two properties during 1980 by Mrs A. Rich and David Hadfield. Both properties are about 20 km west of Baradine)	Bush Thick-knee
Swallow, Welcome	
White-backed	
Swamphen	Purple Swamphen
Swan, Black	
Swift, Fork-tailed (Rare – seen above author's house 15 Dec. 1977)	
Spine-tailed	White-throated Needletail
Teal, Grey	
Tern, Gull-billed (Seen by author 29 Oct. 1977. Caught several insects disturbed by scarifier)	
Marsh	Whiskered Tern
Thornbill, Broad-tailed	Inland Thornbill
Buff-tailed	Buff-rumped Thornbill
Chestnut-tailed	Chestnut-rumped Thornbill
Little	Yellow Thornbill
Striated	
Yellow-tailed	Yellow-rumped Thornbill
Tree-creeper, Brown	Brown Treecreeper
White-throated	White-throated Treecreeper
Triller, White-winged	
Tropicbird, Red-tailed (Found exhausted on the ground 20 km north-west of Baradine by David Hadfield on 20 March 1978 after cyclonic rains from the east. Indentified by Alan Morris. Another found at Coonabarabran 21 March 1980)	
White-tailed (Also found 20 March	

1978. Exhausted bird was brought to Warrumbungle National Park)	
Warbler, Speckled	
White-tailed	
White-throated	
Wattle-bird, Red	Red Wattlebird
Weebill	
Whistler, Golden	
Rufous	
Whiteface, Southern	
Willie Wagtail	
Wood-Swallow, Black-faced	Black-faced Woodswallow
Dusky	Dusky Woodswallow
Little	Little Woodswallow
Masked	Masked Woodswallow
White-breasted	White-breasted Woodswallow
White-browed	White-browed Woodswallow
Wren, Purple-backed	Variegated Fairy-wren
Superb Blue	Superb Fairy-wren
White-winged	White-winged Fairy-wren

Plant List

A full list of the plants in the Warrumbungle National Parl
Pilliga Nature Reserve and State forests would take up sı
space – about a thousand species have been recorded. M
Harden of the University of New England has compiled an
list of over five hundred species for the Warrumbungle Natioı
It is available from the National Parks and Wildlife Service. A
inary list for the Pilliga Nature Reserve is also available.

The following list is selected to show some of the rarer pl
also the extraordinary numbers of the orchid family and o
within some genera confined in an area of 14,000 square kilom
is extracted from Gwen Harden's list, from Barry Fox's c
made during his study of the Pilliga Mouse, from George A
study of the genus *Prostanthera*, and from my own collection.

DROSERACEAE

Drosera auriculata — Tall Sundew
burmannii
indica

LAMIACEAE

Prostanthera cruciflora — Cross-flowered Mint Bu
denticulata sp. aff. *P. denticulata*

granitica	
sp. aff. *P. granitica*	
howelliae	
leichhardtii	
sp. aff. *P. leichhardtii*	
nivea var. *nivea*	Snowy Mint Bush
nivea var. *induta*	Snowy Mint Bush
rotundifolia	Round Leaf Mint Bush
saxicola var. *bracteolata*	Slender Mint Bush
stricta	Hairy Mint Bush (Found in one gully only in the Warrumbungles; equally restricted elsewhere.)

MIMOSACEAE

Acacia amblygona	Prickle-bush
burrowii	Burrow's Wattle
buxifolia	Box-leafed Wattle
caesiella	Blue Bush
caroleae (Formerly *A. doratoxylon* var. *angustifolia)*	
cheelii	Motherumbah
conferta	Crowded-leafed Wattle
concurrens	Curracabah
cultriformis	Knife-leafed Wattle
deanei ssp. *deanei*	Deane's Wattle or Western Green Wattle (I found one form with sensitive leaves.)
decora	Western Golden or Silver Wattle
doratoxylon	Currawong or Spearwood
flexifolia	Bent-leaf Wattle
forsythii	Forsyth's Wattle
gladiiformis	Sword Wattle
hakeoides	Western Black Wattle
harpophylla	Brigalow
implexa	Hickory
ixiophylla	
ixodes (Formerly *A. gnidium* var. *latifolia*)	Gin Gin
lanigera	Woolly Wattle

leucoclada ssp. *leucoclada*	
lineata	
mearnsii	Black Wattle
neriifolia	Silver Wattle
oswaldii	Umbrella Bush
paradoxa (formerly *A. armata*)	Kangaroo Thorn
pendula	Myall
penninervis	Mountain Hickory
pilligaensis	Pilliga Wattle
polybotrya	Coonabarabran Wattle
rigens	Needlewood
salicina	Cooba or Native Willow
spp. undescribed (*A. homalophylla-A. Pendula* group)	Wrongly called Yarran locally
spectabilis	Mudgee Wattle
stenophylla	River Cooba
subulata	Awl Wattle
tindaleae	
triptera	Spurwing Wattle, once known as Hookbill
ulicifolia	Prickly Moses
uncinata	Wavy-leafed Wattle
victoriae	Prickly Wattle
viscidula	Sticky Wattle

MYRTACEAE

Eucalyptus albens	White Box
blakelyi	Blakely's Red Gum
bridgesiana	Apple Box
camaldulensis	River Red Gum
conica	Fuzzy Box
crebra	Narrow-leaved Ironbark
dealbata	Hill Red Gum
dealbata var. *chloroclada*	Sand Red Gum (a new name suggested by Dr Johnston for this attractive small tree)
dwyeri	Dwyer's Hill Red Gum
fibrosa	Blue-leaved Ironbark
goniocalyx	Bundy or Long-leaved Box

macrorhyncha	Red Stringybark
melanophloia	Silver-leaved Ironbark
melliodora	Yellow Box
pauciflora	Snow Gum (On Mount Wambelong)
pilligaensis	Pilliga Box
populnea	Bimble Box or Poplar Box
rossii	White Gum
sideroxylon	Mugga or Red Ironbark
spp. (common intergrade between *E. microcarpa* and *E. pilligaensis*)	
spp. (probable cross between *E. crebra* and *E. melliodora*)	Gunnedah Ironbark
tessellaris	Carbeen
trachyphloia	White Bloodwood
viminalis	Ribbon or Manna Gum
viridis	Green Mallee

ORCHIDACEAE

Acianthus fornicatus	Pixie Caps (the botanical name refers to the stem jutting up from the vulva-shaped leaf)
Caladenia caerulea	Blue Fingers
catenata (Formerly *C. carnea*)	Pink Fingers
cucullata	Hooked Caladenia
dilatata	Green or Fringed Spider Orchid
filamentosa	Common Spider Orchid
reticulata	Plain-lip Spider Orchid
testacea	Honey Caladenia
Calochilus robertsonii	Purplish-beard Orchid
Chiloglottis formicifera	Ant Orchid
Cymbidium canaliculatum	Banana Orchid
Dendrobium speciosum	Rock Orchid
Dipodium hamiltonianum	Green Hyacinth Orchid
punctatum	Hyacinth Orchid
Diuris abbreviata	Donkey Orchid
platichila	Donkey Orchid
punctata	Purple Diuris

sulphurea	Tiger Orchid
Eriochilus cucullatus	Parson's Band
Glossodia major	Wax-lip Orchid
Lyperanthus suaveolens	Blady Leaf
Microtis parviflora	Slender Onion Orchid
unifolia	Common Onion Orchid
Prasophyllum rufum	Red Leek Orchid
Pterostylis boormanii	
biseta	Rusty Hood
coccinea	Red Hood
curta	Blunt Greenhood
hamata	Scaly Greenhood
longicurva	Greenhood
longifolia	Tall Greenhood
mutica	Midget Greenhood
nutans	Parrot's Beak Orchid
parviflora	Baby Greenhood
revoluta	Autumn Greenhood
rufa ssp. *aciculiformis*	Rusty Greenhood
Thelmitra aristata var. *megcalyptra*	Scented Sun Orchid
pauciflora	Slender Sun Orchid

PAPILIONACEAE

Daviesia acicularis	Prickly Bitter Pea
genistifolia	Broom Bitter Pea
latifolia	Hop Bitter Pea or Native Hops
pubigera	Bitter Pea
squarrosa	Prickly Pea
ulicifolia	Native Gorse
umbellulata	
virgata	
Pultenaea boormanii	
cunninghamii	Grey Bush-Pea
foliolosa	Small-leaved Bush-Pea
microphylla var. *microphylla*	Bush Pea
microphylla var. *cinerascens*	

RHAMNACEAE

Alphitonia excelsa	Red Ash

RUTACEAE

Philotheeca salsolifolia

SAPINDACEAE

Dodonaaea attenuata	Slender Hopbush
booroniifolia	Hairy Hopbush
cuuneata	Wedge-leaved Hopbush
fiilifolia	
ppeduncularis	Stalked Hopbush
teenuifolia	
trruncatiales	Sticky Hopbush
vviscosa var. *angustifolia*	
vviscosa var. *spathulata*	