ENVIRONMENTAL IMPACT REPORT

Enhanced Geothermal Systems

Reservoir Stimulation & Evaluation

August 2010

Geodynamics Limited

GEODYNAMICS
LIMITED

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1 INTRODUCTION

Geodynamics Limited (Geodynamics) plans to construct a number of geothermal power plants in the Cooper Basin using Enhanced Geothermal Systems (EGS) to generate electricity.

EGSs involve injecting water (geofluid) deep into a well where it passes through fracture systems in the rock, extracting heat from the rock mass. The heated water is returned to the surface through a production well where the heat is transferred to a secondary working fluid and used to drive a turbine power generator.

The development of an EGS requires the artificial stimulation of a hot rock mass (usually found at significant depth) to develop an extensive zone of permeable fractures that can hold a significant quantity of stored water (geofluid). The fracture zone must be sufficiently permeable to allow injected water to flow through the hot zone into a production well/s where it can be returned to the surface and the heat extracted to use for power generation.

An EGS must be carefully studied and evaluated over a significant period (typically up to 12 months), to ensure that it can support economic heat extraction over the long term and warrant significant investment in power station and electricity distribution infrastructure. In particular, an EGS must be tested and evaluated to prove it can support a sufficient and stable flow of hot water – in terms of both temperature and flow rate – over the long term (20 plus years).

Geodynamics has been developing and evaluating EGSs in the hot basement granites underlying the Cooper Basin since 2002. The main activities (previously referred to by Geodynamics as the *Diagnostic Phase*), have been carried out under the combined *Environmental Impact Report/Statement of Environmental Objectives for Diagnostic Phase covering: Diagnostic Flow, Simulated Circulation Test, Enhancement & Demonstration Circulation (October 2004)* prepared by Geodynamics.

Under Regulation 14 of the *Petroleum and Geothermal Energy Regulations 2000* (SA), an approved SEO must be reviewed at least once in every five years. The scope of the review is based on the requirements of Regulation 14(2) of the *Petroleum and Geothermal Energy Regulations 2000*, which requires the following to be taken into account or addressed:

(a) changes in information or knowledge in relevant areas

(b) community expectations in relation to relevant environmental issues

(c) changes in the use of land

(d) changes in operational practices; and

(e) other matters determined to be relevant by the Minister.

Accordingly, the purpose of this new EIR is to evaluate the environmental impacts of both the stimulation/injection process used to create an EGS and the subsequent evaluation phase (previously referred as the *Diagnostic Phase*).

This EIR also addresses the requirements of section 97 of the *Petroleum and Geothermal Energy Act 2000* and Regulation 10 of the Regulations to the Act in relation to the content of

an EIR.

2 CURRENT APPROVALS

A combined EIR and SEO (*Environmental Impact Report/Statement of Environmental Objectives for Diagnostic Phase covering: Diagnostic Flow, Simulated Circulation Test, Enhancement & Demonstration Circulation)* was prepared in 2004 by Geodynamics for the stimulation and evaluation testing of the Habanero 1 & 2 doublet the following year.

The 2004 EIR/SEO was subsequently used for the stimulation and evaluation testing phase of the Habanero 1 & 3 doublet in 2008.

The activities covered by the 2004 EIR/SEO include:

- Diagnostic flow test
- Simulated circulation phase
- Enhancement (stimulation) phase
- Demonstration circulation phase
- Onsite storage of water produced from the wells
- Installation of high pressure/temperature pipework between wells & choke & separator
- Installation of acoustic monitoring wells and monitoring devices
- Drilling of shallow water bores to provide water used in diagnostic tests
- Well and water bore abandonment activities

3 PROPOSED ACTIVITY AND LOCATION

The regional location of Geodynamics' geothermal retention licence areas (GRLs) in the Cooper Basin is shown in Figure 1 below. Geodynamics proposes to continue to undertake activities associated with the stimulation and evaluation testing of EGSs within its Cooper Basin GRLs. This is likely to occur at an increased intensity over the next few years due to the introduction of a second geothermal well drilling rig in the Cooper Basin scheduled for late 2010.

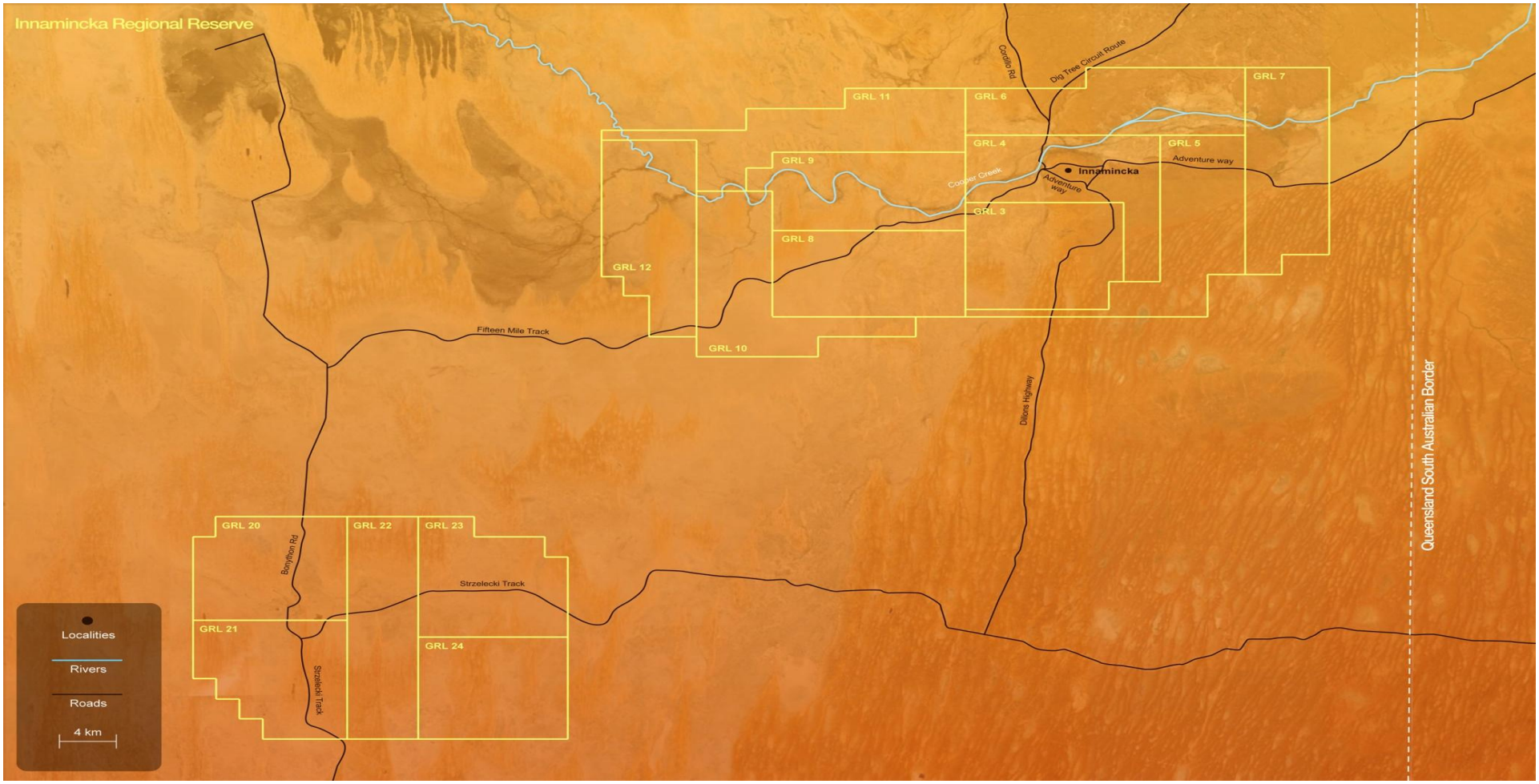

Figure 1. Geodynamics geothermal retention license areas in the Cooper Basin

The stimulation and evaluation of an EGS typically comprises the following stages:

1. **Stimulation/Injection**: to enhance the capacity of the existing fracture network in the hot rock mass and create a stimulated fracture zone reservoir
2. **Production Testing:**: to evaluate the capacity of the stimulated fracture zone reservoir created by the stimulation/injection phase to produce (flow) geofluid
3. **Open Loop Testing:**: to establish fluid circulation between injection and production wells and test the flow rate between these wells
4. **Closed Loop Testing:** to evaluate the performance of the EGS over the long term and forecast resource degradation and the potential lifespan of the system

The footprint of the stimulation/evaluation activities would remain within the area bounded by the original drilling pad/s (other than high pressure pipelines & water holding ponds/dams). Its visual profile and impact would be similar to that of the drilling rig (or less once the rig is relocated).

Further details on these stages are provided below.

3.1 Stimulation/Injection

The stimulation/injection process involves injecting water into a well at as high a pressure and flow rate as possible in order to enhance the capacity of the fracture network within the hot rock mass to flow at as higher rate as possible.

The injected water is typically sourced from water bores or from the basement granite (left over from previous diagnostic phase testing). Subject to approval, water from Cooper Creek or the Great Artesian Basin may also be used.

Prior to injection the water is treated with small amounts of polyelectrolytic and cationic coagulants to flocculate clay and silica colloids which could reduce flow rates in the fracture zone. These benign chemicals are added to the injection water at low concentrations (2 ppm) and the resulting water is contained within lined, impervious, treatment ponds and not discharged into the environment outside the stimulation/evaluation system.

Approximately 20 – 40 megalitres (ML) of water is used in the stimulation/injecting process to create each EGS reservoir. The stimulation/injection process takes approximately 2 to 3 weeks for each EGS reservoir. A number of oil industry frac pumps are used in the process and these would be located on the existing drill pad. The injected water remains underground in the stimulated fracture zone until the subsequent steps in the diagnostic test phase are carried out.

3.2 Production Testing

Using the overpressure in the fracture zone, flow is produced to the surface from a single well and passed across a choke to drop the pressure to near atmospheric pressure. This causes the highly pressured geofluid to flash to a mix of water (85%) and steam plus non condensable gases (15%).

The flow is separated into water and vapour fractions in a steam separator vessel with the steam and non-condensable gases vented upwards into the atmosphere and the liquid fraction sprayed across a lined collection pit (Plate 1). This production to atmosphere is typically carried out from 1-3 weeks. Less than 10 ML is produced over this time and the water is stored at the surface in a lined pond. The flow rate is controlled by the choke and varies depending on the productivity index of the well (a relationship of pressure drop to flow rate).

Plate 1 – Steam separator vessel used in Production & Open Flow testing (Habanero 3).

3.3 Open Loop Testing

In open loop testing, water from the production water pond (filled during Production Testing) is flocculated to remove silica colloids and pumped into the injection well at approximately the same rate as the rate of production.

As some steam is lost during the Open Loop Testing process (approx 15% is vented to atmosphere), make-up water is required to be added. This make-up water can be sourced from water bores or, subject to approval, from Cooper Creek or the GAB.

The Open Loop Test takes approximately 1 – 2 weeks to complete.

3.4 Closed Loop Testing

In closed loop testing, water from the production well is flowed along a high pressure pipeline via an air cooler to an inline pump. This pump is capable of accepting the water at high pressure and boosting it to an even higher pressure into the injection well.

The pump pressure differential controls the flow rate around the system. For closed loop testing a choke is not used, and the pressure is too high for any steam to form.

No steam, water or non-condensable gasses are lost or discharged to the surface during the Closed Loop Test which can take up to 12 months to complete.

Non toxic and non carcinogenic, environmentally benign organic tracers such as naphthalene sulfonate or fluorescein (or similar) may be used during the Closed Loop Test process. These are contained within the testing system and not released into the surface environment.

3.5 Ancillary Activities

The following activities and facilities are typically required for the stimulation and evaluation phase:

- Construction of impermeable (eg HDPE lined) ponds/dams up to 20ML capacity for the storage of water (including production water) and smaller impermeable collection pits used in Production Testing
- Installation and use of high pressure/temperature pipelines and pumps
- Construction of water bores to access shallow aquifers and, subject to (Department for Water) DFW approval, the Great Artesian Basin (GAB)
- Use of low pressure HDPE pipelines to transfer water between ponds/dams/collection pits and to supply water from approved sources
- Pressure vessels/chokes
- Acoustic and seismic monitoring
- High pressure pumps
- Chemistry/testing facilities
- Installation and use of high pressure/temperature chokes & separators
- Installation and use of acoustic and seismic monitoring wells and monitoring devices
- Well and water bore abandonment activities
- Site offices, accommodation, storage facilities and amenities (typically already in place from previous drilling activities)

4 OPERATIONAL CHANGES SINCE 2003

4.1 Management System Changes

Since 2003 Geodynamics has taken a number of key steps in terms of environmental management. The most significant of these is the development and implementation of an Environmental Management System (EMS) and the engagement of a full time Environmental Manager.

The EMS establishes a set of processes and practices which ensure that Geodynamics minimizes its adverse environmental impacts, meets the commitments of its environmental policy and achieves its objectives and targets. The EMS applies to all of Geodynamics' operations, sites and offices.

Staff and contractors working for Geodynamics are required to comply with the EMS in relation to all day to day activities undertaken for and on behalf of Geodynamics.

In October 2009, Geodynamics' EMS was independently certified by SAI Global as complying with the requirements of ISO/ANZ 14001:2004.

4.2 Operational Changes

Geodynamics has drilled 5 deep (over 4000m) geothermal wells in the Innamincka area since 2003 and in March 2009 the company announced that it had successfully proven its ability to extract heat from hydraulically stimulated hot fractured rock to create power (Proof of Concept). This announcement followed the completion of a successful six week closed loop test between Habanero 1 & 3.

In its 2009 Annual Report, Geodynamics estimated its Cooper Basin tenements had inferred geothermal resources of approximately 230,000PJ.

Over the next few years Geodynamics intends to demonstrate it can produce power on a commercial basis at a competitive price from its geothermal resources in the Cooper Basin.

This next phase will involve the drilling of additional doublets and further stimulation and evaluation activities to develop and test thermal reserves and commercial flow rates (2nd drill rig to be on site in late 2010).

5 DESCRIPTION OF ENVIRONMENT AND NEW INFORMATION

5.1 Surrounding land use

The dominant land uses surrounding Geodynamics' operations in the Cooper Basin are associated with the conservation of wildlife, landscape and historic features of the area, petroleum and natural gas production, tourism and pastoral production.

The proposed pumping activity is located adjacent to Cooper Creek within the Innamincka Regional Reserve (Figure 2).

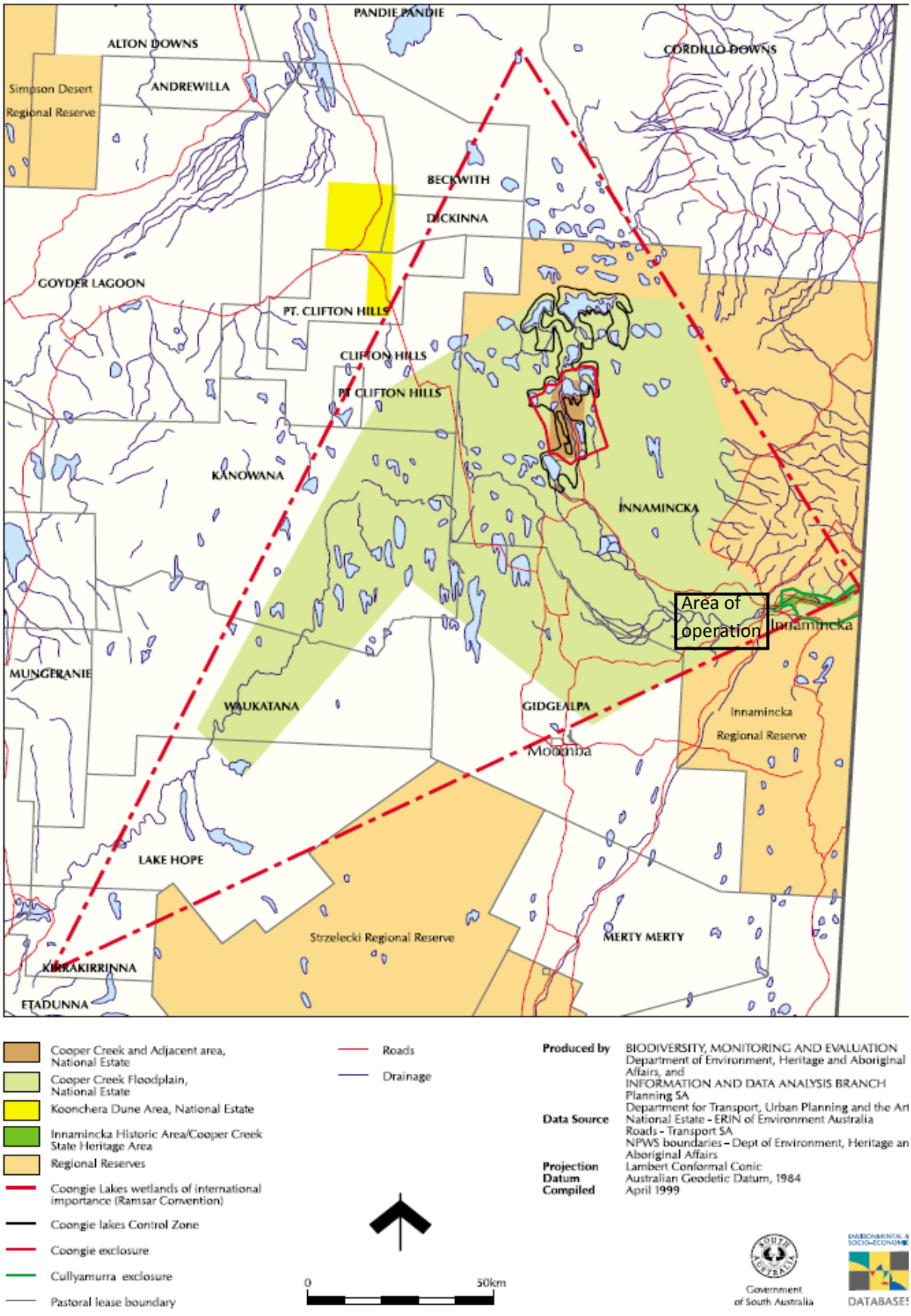

Figure 2-Innamincka Regional Reserve & Coongie Lakes wetland area

The *National Parks and Wildlife Act 1972* (South Australia) provides for the establishment and management of reserves for public benefit and enjoyment, to provide for the conservation of wildlife in a natural environment, and for other purposes.

In South Australia, Regional Reserves provide for the conservation of wildlife or the natural or historic features of that land while, at the same time, permitting the utilisation of the natural resources of that land.

Under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth) a referral of a proposed activity to the Commonwealth Department of Environment Water Heritage and the Arts is required for actions that may have a significant impact on matters of national environmental significance. These are:

- World Heritage properties
- National heritage places
- Ramsar wetlands
- Threatened species and ecological communities
- Migratory species
- Commonwealth marine areas
- Nuclear actions (including uranium mining)

As Geodynamics' GRLs overlap both the Regional Reserve and the Coongie Lakes area, it is likely that stimulation and evaluation activities will take place within these areas from time to time.

The conservation status of the general area has not changed since the last EIR was prepared in 2004 and the surrounding land uses are still primarily concerned with the conservation of wildlife, landscape and historic features of the area, petroleum and natural gas production, tourism and pastoral production.

The stimulation/evaluation testing activities are not inconsistent with the maintenance of the conservation status of the Innamincka Regional Reserve and the Coongie Lakes RAMSAR wetland. Geodynamics has been undertaking stimulation/evaluation activities in this area since 2005 with no recorded adverse environmental impacts made by the public or regulatory authorities in that time.

5.2 Climate

Innamincka Regional Reserve is located in one of the most arid areas in Australia and the world. The long-term average annual rainfall (110 years of records) is 172.5 mm but the area is renowned for its unpredictable and highly variable rainfall (80.7% variation). Over the last 110 years average or above average rainfall has been received 39% of years and droughts (less than 75 mm in summer and 50 mm in winter) 29% of years. On average 42% of rain is received in the summer months January to March.

5.3 Land systems

Most of the GRLs fall within the Interim Biogeographic Regionalisation for Australia (IBRA) Coongie sub-region. There are three land system habitats within the Coongie sub-region these being: Cooper (floodplain), Merninie (gibber tableland) and Tingana (sand dunes).

To provide an indication of potential clearance or disturbance of land system habitats in the GRL areas EBS (2009) estimated a worst case clearance footprint of 250Ha based on estimates of the possible total project footprint of all potential Geodynamics infrastructure activities (excluding transmission lines).

If all of this clearance was distributed evenly within the Cooper, Merninie and Tingana land systems this would represent less than 0.05%, 0.5% and 0.6% of each system the GRLs respectively (EBS 2009).

As the stimulation and evaluation activities represent only one small component of the total Geodynamics' activities being carried out within its GRL, the impacts of this particular activity on the land systems will be negligible.

5.4 Surface water

The major wetlands, swamps and lakes in the area derive water from flow events in Cooper Creek. The majority of these flows result from summer monsoonal rainfall in central Queensland. Local runoff from the stony tablelands also supplies water to waterholes and swamps but on a less frequent and more erratic basis.

During periods of low flow, most water flows through the North West Branch of Cooper Creek into the Coongie Lakes and Lake Goyder. If flows are large enough to fill these lakes, additional water flows down the main branch of the Cooper toward Lake Hope and eventually into Lake Eyre.

The main channel of Cooper Creek is well defined and connects a series of ephemeral swamps and permanent and semi-permanent waterholes. During floods, the main channels overflow and floodwaters spill into the vast floodplain via numerous distributor channels.

Cooper Creek flows are unregulated (ie no human intervention via dams or other regulatory structures) and extremely variable. Flow occurs in one or more discrete pulses each year and several months may pass without flow. Flow occurs in almost every year, and in most years it reaches the Coongie Lakes.

Flows and flood peaks have been recorded at the Cullyamurra streamflow station near Innamincka since 1973 by the South Australian Department of Water Land and Biodiversity Conservation (DFW).

According to DFW records, the mean annual flow in Cooper Creek at Innamincka is in the order of 1, 065,836 ML/year with a median annual flow of 379,700 ML. Flows can occur (or not) at any time of the year and based on the stream discharge duration curve for Cullyamurra streamflow station (DFW), flow in the Creek occurs for nearly 70% of the time.

Approximately 20 – 40ML of water is required in the stimulation/injection phase for each EGS reservoir. This water is drawn from approved sources including shallow aquifers and the granite reservoir itself. Approval has been sought to extract water from Cooper Creek and the GAB for use in the stimulation/evaluation phase if additional water is required.

5.5 Hydrogeology

The project area is underlain by Eromanga Basin sediments which are part of the GAB.

The alluvium along Cooper Creek is a source of sub-artesian water and in particular sandy sequences underlying the Creek provide a baseflow to semi permanent waterholes during extended dry periods.

Shallow groundwater quality in the project area is variable. Water from bores in the shallow (water table) aquifers in the vicinity of Jolokia, Savina and Habanero ranges from fresh to brackish (i.e. <1,000 to 10,000 mg/L) and some of these bores are suitable for drinking or stock water supply.

Depending on its availability, shallow bores are used by Geodynamics to access this water for use in the stimulation/injection phase and also to make up water lost during open loop testing. The salinity of this water is not important, but the calcium content is required to be low to minimize calcite scaling in the deeper parts of injection wells and in the granite reservoir. If saline water in the shallow aquifers is too high in calcium to be used alone; it would need to be diluted with fresh water for stimulation/injection.

As the use of shallow bore water during the stimulation/testing phase and as make up water during open loop testing is a once off activity for each EGS reservoir, the impact on shallow groundwater resources in the area is likely to be negligible. However, the impacts of any long term shallow groundwater extraction during the operational phase of power stations utilising EGS derived energy would need to be further evaluated in the relevant EIR for that activity.

The GRLs also lie within the Far North Prescribed Wells Area (FNPWA), which is managed by a Water Allocation Plan under the *Natural Resources Management Act 2004*. Under the Plan, approval is required to extract and use water from the GAB. Geodynamics made an application to DFW as an existing user in September 2003, seeking an allocation to use artesian water for stimulation and evaluation activities. At the time of preparing this EIR the application was still under consideration by DFW.

The naturally occurring water in the granites that form the hot fractured rocks (referred to as 'geofluid') is highly saline, with measured concentrations of total dissolved solids from the Habanero-3 well in the order of 25,000 mg/L. Analyses of the chemical composition of the geofluid from various samples taken from the Habanero-3 well on 17 March 2008 (Table 1) indicate that the water has elevated concentrations of metals and metalloids including antimony, arsenic, boron and barium.

Additional geofluid constituents other than those reported in Table 1 have also been analysed but have not been included as they were well below concentrations of concern (or below laboratory detection limits), including benzene, toluene, ethylbenzene, xylene, polynuclear aromatic hydrocarbons, total petroleum hydrocarbons, cadmium, cobalt, manganese and nickel.

Given the elevated concentrations of salinity and some metals in the geofluid its release into the surface environment, including soils, surface and shallow potable groundwater aquifers, must be prevented. This will be achieved by ensuring all structures that store or receive geofluid are lined with high density polyethylene (HDPE) with a minimum thickness of 2mm.

Table 1-Granite reservoir geofluid composition

		1	2	3	4	5
Reservoir pH at 250 DegC		5.92	5.94	5.96		
Ammonia (total as NH3)	mg/L	1.96	2.0	2.0		
Antimony	mg/L	3.1	2.6	2.6		
Arsenic	mg/L	2.6	2.7	2.7		
Barium	mg/L	3.1	3.2	3.2		
Boron	mg/L	196	204	204	208	199
Calcium	mg/L	23.9	22.7	22.7	30	32
Cesium	mg/L	41.8	43.7	43.7		
Chloride	mg/L	7346	7754	7754	7336	7654
Fluoride	mg/L	15.6	16.1	16.1		
Lithium	mg/L	187	189	189	191	202
Magnesium	mg/L	0.23	0.24	0.24		
Potassium	mg/L	569	558	558	627	638
Rubidium	mg/L	14.6	15.3	15.3		
Silica (as SiO2)	mg/L	457	449	449	474	462
Sodium	mg/L	3759	3835	3835	3898	4044
Sulphate	mg/L	36.7	31.9	31.9		
Uranium	mg/L	< 0.00036	< 0.00036	< 0.00036		
Carbon Dioxide(total)	mg/L	18286	16538	17212		
Hydrogen sulphide	mg/L	80.3	96.3	84.3		
Argon	mg/L	8.5	7.4	7.1		
Helium	mg/L	19.0	18.8	18.4		
Hydrogen	mg/L	0.41	0.29	0.29		
Methane	mg/L	971	1008	989		
Nitrogen	mg/L	567	560	543		
Wellhead temperature	°C	198	205	205		
Separator pressure	bg	1.24	1.33	1.33		
Calculated steam fraction		0.1472	0.1594	0.1594		

Sample 1: Combined chemistry of separator water and steam samples collected at ~1.30am
Sample 2: Combined chemistry of separator water and first steam sample collected at ~7.50pm
Sample 3: Combined chemistry of separator water and second steam sample collected at ~7.50pm
Sample 4: Chemistry of wellhead sample collected at high pressure at ~ 1.30am
Sample 5: Chemistry of wellhead sample collected at high pressure at ~ 7.20pm

5.6 Threatened fauna

Environmental and Biodiversity Services (EBS) was commissioned by Geodynamics to undertake a flora and fauna survey within their South Australian geothermal exploration sites near Innamincka. The initial ecological survey was conducted within four separate survey areas by EBS and completed in March 2009.

Subsequent to this survey EBS was commissioned by Geodynamics to consider additional impacts on threatened species and communities associated with activities in the GRLs, in particular habitat clearance and other effects associated with the construction of powerlines, power plants and associated buildings and facilities (*Flora and Fauna Impact Assessment for Geodynamics Geothermal License Area September 2009, Report prepared by Environmental and Biodiversity Services for Geodynamics Ltd).*

Overall, three key potential impacts were identified by EBS as potentially resulting from geothermal operations including:

- Habitat clearance
- Bird collisions with transmission lines
- Potential for the creation of artificial waterbodies attracting birds from Cooper Creek and Coongie Lakes areas

EBS identified 37 threatened fauna species under South Australian and Commonwealth legislation (2 mammals, 33 birds, 2 reptiles) as potentially impacted by Geodynamics' activities within its GRLs (Table 2).

Table 2. Threatened fauna species that occur or may occur within Geodynamics' GRLs

Family	Species name	Common name	AUS	SA	Source
AVES	*Actitis hypoleucos*	Common Sandpiper		R	BDBSA
AVES	*Amytornis barbatus barbatus*	Grey Grasswren (Bulloo)	VU	R	EPBC BDBSA
AVES	*Amytornis barbatus diamantina*	Grey Grasswren		R	BDBSA
AVES	*Anas rhynchotis*	Australasian Shoveler		R	BDBSA
AVES	*Anhinga novaehollandiae*	Australasian Darter		R	BDBSA
AVES	*Aprosmictus erythropterus*	Red-winged Parrot		R	BDBSA
AVES	*Apus pacificus*	Fork-tailed Swift	Mm, Lis		EPBC
AVES	*Ardea alba*	Great Egret,	Mi, Mm, Lis		EPBC
AVES	*Ardea ibis*	Cattle Egret	Mi, Mm, Lis		EPBC
AVES	*Ardea intermedia*	Intermediate Egret		R	BDBSA
AVES	*Ardeotis australis*	Australian Bustard		V	BDBSA
AVES	*Biziura lobata*	Musk Duck		R	BDBSA
AVES	*Cacatua leadbeateri*	Major Mitchell's Cockatoo		R	BDBSA
AVES	*Cladorhynchus leucocephalus*	Banded Stilt		V	BDBSA
AVES	*Egretta garzetta*	Little Egret		R	BDBSA
AVES	*Elanus scriptus*	Letter-winged Kite		R	BDBSA
AVES	*Falco hypoleucos*	Grey Falcon		R	BDBSA
AVES	*Falco peregrinus*	Peregrine Falcon		R	BDBSA
AVES	*Grantiella picta*	Painted Honeyeater		R	BDBSA
AVES	*Grus rubicunda*	Brolga		V	BDBSA
AVES	*Hamirostra melanosternon*	Black-breasted Buzzard		R	BDBSA
AVES	*Lophoictinia isura*	Square-tailed Kite		E	BDBSA
AVES	*Microeca fascinans fascinans*	Jacky Winter		R	BDBSA
AVES	*Merops ornatus*	Rainbow Bee-eater	Mt, Lis		EPBC
AVES	*Myiagra inquieta*	Restless Flycatcher		R	BDBSA
AVES	*Ninox connivens*	Barking Owl		R	BDBSA
AVES	*Oxyura australis*	Blue-billed Duck		R	BDBSA
AVES	*Phaps histrionica*	Flock Bronzewing		R	BDBSA
AVES	*Pedionomus torquatus*	Plains-wanderer	VU	E	EBS
AVES	*Plegadis falcinellus*	Glossy Ibis		R	BDBSA
AVES	*Podiceps cristatus*	Great Crested Grebe		R	BDBSA
AVES	*Stictonetta naevosa*	Freckled Duck		V	BDBSA
AVES	*Rostratula australis*	Australian Painted Snipe	VU	V	EPBC
MAMMALIA	*Notomys fuscus*	Dusky Hopping-mouse	VU	V	BDBSA EPBC EBS
MAMMALIA	*Pseudomys australis*	Plains Mouse (Plains Rat)	VU	V	BDBSA
REPTILIA	*Aspidites ramsayi*	Woma		R	BDBSA
REPTILIA	*Emydura macquarii*	Macquarie Tortoise		V	BDBSA

KEY: Regions:
AUS: Australia (*Environment Protection and Biodiversity Conservation Act, 1999*)
SA: South Australia (*National Parks and Wildlife Act, 1972*)

Conservation Codes:
En or E: Endangered **Vu or V:** Vulnerable **R:** Rare
Mm: Migratory Marine species **Mi:** Migratory wetland species, **Lis:** Listed overfly marine area **BDBSA** – Threatened species records detailed within the Biological Database of South Australia **EPBC** – Threatened species identified within the EPBC Act Protected Matters Database Search **EBS** – Threatened species observed or captured within the EBS March 2009 survey

Table 3. Potential for occurrence of threatened species on-site considering habitat preferences (from EBS 2009)

SPECIES NAME	COMMON NAME	STATUS		PRIMARY HABITAT	IDENTIFIED LAND SYSTEM HABITAT	LIKELIHOOD OF OCCURRENCE ON SITE
		AUS	SA			
Notomys fuscus	Dusky Hopping-mouse	VU	V	Dusky Hopping Mice inhabit soft sandy habitats, preferring dunes with Sandhill Canegrass, Sandhill Wattle, Nitrebush, Sticky Hopbush and other ephemeral plants (Moseby *et al.* 1999).	Tingana (sand dunes)	**High -** This species was detected during survey and has been recorded 12 times on the BDBSA.
Pseudomys australis	Plains Mouse (Plains Rat)	VU	V	Cracking clay habitats in northern South Australia. Plains Rats are found on stony (gibber) plains and mild slopes that have gilgais, predominantly within chenopod shrubs as well as ephemeral plants that require good rains to flourish. In very good years they can occur on adjoining sandy plains and may also occur on gypsum clay soils with deep cracks and sparse perennial vegetation (Ehmann, 2005; Menkhorst & Knight 2004; Moseby, 2006; Bandle & Moseby, 1999).	Merninie (gibber tableland)	**Very Unlikely, but possible** – One record of the species has been recorded within the BDBSA previously in 1957. Most of the project area does not support 'preferred habitat'; however, the gibber tableland in the northern section of the project area could potentially provide suitable habitat.
Aspidites ramsayi	Woma	n/a	R	Woma Pythons are found in desert dunefields and on sandy plains, usually with hummock grasses but also other natural vegetation. They often inhabit rabbit burrows but may also shelters under hummock grasses or dense bushes.	Tingana (sand dunes), Mernine (gibber tableland)	**High –** This species has been recorded 4 times on the BDBSA and the project area is within their known distribution.
Emydura macquarii	Macquarie Tortoise	n/a	V	Murray / Darling River System. Restricted to larger rivers and associated large waterholes on floodplains (Cogger 2000).	Cooper (floodplain)	**Very Unlikely, but possible -** This species has been recorded 6 times on the BDBSA and the project area is within their known distribution; however, the species inhabits major channels and waterholes, which will not be cleared by geothermal operations.

EBS also identified the potential for occurrence of threatened species within the GRLs considering habitat preference (Table 3 above).

As the EGS stimulation and evaluation activities would only be undertaken adjacent to existing geothermal wells, which would not be located on sand dune systems or adjacent to large water bodies such as Cooper Creek for logistical reasons, it is considered that the only fauna species likely to occur in the GRLs that could potentially be affected by stimulation and evaluation activities is the Plains Mouse.

The EBS report (2009) considers that given the huge extent of available and preferred habitat for the Plains Mouse (gibber tableland of the Merninie land system), the overall habitat loss associated with all of the likely activities being undertaken by Geodyamics in its GRLs would still be *'very unlikely'* to have a significant impact on this species. In any case, Geodynamics' expected main developments are located to the west of the local Merinie land system areas in the Cooper land system.

The main potential impact associated with birds is related to the impact of creating artificial water sources that could attract resident and migratory birds to the holding ponds/dams associated with the stimulation and evaluation activities. It has been observed during previous stimulation/evaluation testing that birds do not drink the water as it is too saline. There is no danger from the temperature of the water as once the steam has discharged to atmosphere the fluid phase collected in the ponds is close to ambient and not hot enough to cause any risk to flora or fauna or the safety of workers in the area.

Bulk water held in these constructed ponds/dams is, only required for the first two months of the stimulation/evaluation process as the most time consuming stage of the process – Closed Loop Testing – does not require significant water for the process.

Any excess water held in the pond/dams after the completion of the first three stages of the process would be gradually lost through evaporation thus removing any permanent substantial source of water that could attract birds.

5.7 Threatened flora

The EBS surveys commissioned by Geodynamics identified 12 flora species and 3 ecological communities of state conservation significance as requiring impact assessment. No flora species or ecological communities of national significance were recorded or identified within the GRLs by EBS. Table 4 details the threatened flora species assessed by EBS.

Table 4. Threatened flora species that occur or may occur within the Geodynamics' GRLs (from EBS 2009)

Family	Species name	Common name	Status	
			AUS	SA
CALLITRICHACEAE	*Callitriche sonderi*	Matted Water Starwort	n/a	R
CHENOPODIACEAE	*Osteocarpum acropterum var. deminutum*	Wingless Bonefruit	n/a	R
CHENOPODIACEAE	*Osteocarpum pentapterum*	Five-wing Bonefruit	n/a	E
CRUCIFERAE	*Phlegmatospermum eremaeum*	Spreading Cress	n/a	R
ELATINACEAE	*Bergia occultipetala*		n/a	V
FRANKENIACEAE	*Frankenia cupularis*		n/a	R
LEGUMINOSAE	*Acacia tenuissima*	Slender Wattle	n/a	R
LEGUMINOSAE	*Swainsona oligophylla*		n/a	R
MYOPORACEAE	*Eremophila polyclada*	Twiggy Emubush	n/a	R
STERCULIACEAE	*Gilesia biniflora*	Western Tar-vine	n/a	R
THYMELAEACEAE	*Pimelea penicillaris*	Sandhill Riceflower	n/a	R
ZYGOPHYLLACEAE	*Zygophyllum humillimum*	Small-fruit Twinleaf	n/a	R

KEY
Regions:
AUS: Australia (*Environment Protection and Biodiversity Conservation Act, 1999*)
SA: South Australia (*National Parks and Wildlife Act, 1972*)

Conservation Codes:
V: Vulnerable
R: Rare
E: Endangered

The only potential impact of the stimulation/evaluation phase on threatened flora species or ecological communities is associated with the clearance of habitat during the construction of bulk water storage dams/ponds used to provide 20 - 40ML of water used during the stimulation phase. Typically, two turkey nest dams, each approximately 100metres square, are constructed for this phase.

EBS (2009) assessed the potential for occurrence of threatened flora species within the GRLs (Table 5).

Table 5. Potential for occurrence of state threatened flora species occurring on-site considering habitat preferences (from EBS 2009)

SPECIES NAME	COMMON NAME	STATUS		PRIMARY HABITAT	IDENTIFIED LAND SYSTEM HABITAT	LIKELIHOOD OF OCCURRENCE ON SITE
		AUS	SA			
Callitriche sonderi	Matted Water Starwort	n/a	R	A rarely collected species, it has been generally recorded in inundation areas such as creek banks	Cooper (Floodplain)	**Unlikely** – This species was not detected during the March survey and the single record on the BDBSA is adjacent to the main channel of the Cooper Creek which will not be impacted upon by geothermal operations
Osteocarpum acropterum var. deminutum	Wingless Bonefruit	n/a	R	Wingless Bonefruit are found in a variety of habitats, often found in Bladder Saltbush and Bluebush communities on scalds or slightly saline locations	Cooper (Floodplain)	**Unlikely –** not recorded during the March survey, one record on the BDBSA approximately 30km north of Moomba well outside the likely impact area
Osteocarpum pentapterum	Five-wing Bonefruit	n/a	E	Similar to the Wingless Bonefruit, with regional records in close proximity to major creeks or tributaries	Merninie (Gibber Tableland); Cooper (Floodplain)	**Unlikely –** not recorded during March survey, however, two records on the BDBSA, one several km south-west of Innamincka and one approximately 15km north east of the town, both records adjacent to the Cooper Creek or major tributaries
Phlegmatospermum eremaeum	Spreading Cress	n/a	R	Generally occurs on heavier soils associated with floodplain areas, however, has also been recorded chenopod shrublands	Cooper (Floodplain)	**Likely** – not recorded during the March survey, however, one record on the BDBSA on the Strzelecki Track between Transmission Line Options 1 and 2
Bergia occultipetala		n/a	V	Limited information on the species, appears to prefer wetter areas	Cooper (Floodplain); Tingana (Sand Dunes)	**Unlikely, but possible** – not recorded during the March survey, one record on the BDBSA approximately 15 km east of Innamincka.
Frankenia cupularis		n/a	R	Limited information on the species, Frankenia's in general can occupy a range of habitat types	Cooper (Floodplain) – based on previous record	**Unlikely –** based on the previous record (one) of the species on the BDBSA, approximately 30km north west of Innamincka. It was not recorded during the March survey. Little is known about the preferred habitat of the species.
Acacia tenuissima	Slender Wattle	n/a	R	Only one record of the	Cooper (Floodplain);	**Unlikely, but possible –** not recorded in the

SPECIES NAME	COMMON NAME	STATUS		PRIMARY HABITAT	IDENTIFIED LAND SYSTEM HABITAT	LIKELIHOOD OF OCCURRENCE ON SITE
		AUS	SA			
				species in SA, several km's south west of Innamincka, common in northern states. Found on red sandy plains.	Tingana (Sand Dunes)	March survey, but one recorded in close proximity to the geothermal project area (only known record for SA).
Swainsona oligophylla		n/a	R	Occurs on sandy soils of sand dunes and swales	Cooper (Floodplain); Tingana (Sand Dunes)	**Likely –** a total of 10 BDBSA records within or adjacent to project area, likely to be present when rainfall stimulates germination
Eremophila polyclada	Twiggy Emubush	n/a	R	Found on clay and duplex soils of floodplain areas	Cooper (Floodplain)	**Unlikely, but possible –** total of three BDBSA records, all of which occur adjacent to the Cooper Creek or a major tributary, potential habitat across the lower lying floodplain areas
Gilesia biniflora	Western Tar-vine	n/a	R	Has been recorded on saline stony soils, possibly restricted to saltbush communities	Tingana (Sand Dunes); Merninie (Gibber Tableland)	**Unlikely –** two BDBSA records for the region, both approximately 25km east of Dillons Highway
Pimelea penicillaris	Sandhill Riceflower	n/a	R	Occurs on sand dunes with deep sandy soils	Tingana (Sand Dunes); Cooper (Floodplain)	**Unlikely, but possible** – previously recorded close to Innamincka (two records), extensive available habitat within project area
Zygophyllum humillimum	Small-fruit Twinleaf	n/a	R	Recorded growing on red-brown cracking clay and sandy loam with gypsum	Tingana (Sand Dunes); Merninie (Gibber Tableland); Cooper (Floodplain)	**Unlikely, but possible –** a total of seven records in close proximity to project site, all outside the potential infrastructure areas

KEY

Regions:
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Conservation Codes:
V: Vulnerable
R: Rare
E: Endangered

The following species listed as 'likely' to be present by EBS in Cooper or Merninie land systems could be affected by the construction of water storage dams/ponds for the stimulation/evaluation activity:

- ***Phlegmatospermum eremaeum***
- ***Swainsona oligophylla***

EBS (2009) considered that, even considering the full extent of Geodynamics' activity within its GRLs, the potential for a significant impact to occur on either of these species would be unlikely (but possible).

The only way to eliminate any impact on these species would be to undertake a flora assessment on the actual area to be cleared for dam/pond construction as part of the Activity Notification process.

Within the GRLs, three vegetation communities listed as *'of concern'* in South Australia were identified by EBS and are detailed in Table 6.

Table 6. Threatened ecological communities that occur within the Geodynamics' GRLs (from EBS 2009)

Threatened Ecological Community	Conservation Status	Source
	SA	
Eucalyptus coolabah ssp. *arida* (Coolibah) Woodland on levees and channel banks of regularly inundated floodplains	**Of concern**	EBS Neagle (2003) DEH (2005)
Atriplex nummularia (Old-man Saltbush) Open Shrubland with occasional emergent *Eucalyptus camaldulensis* (River Red Gum) or *E. coolabah* ssp. *arida* (Coolibah) on low sandy rise of floodplains	**Of concern**	Neagle (2003) DEH (2005)
Chenopodium auricomum (Golden Goosefoot) Shrubland on cracking clay depressions subject to periodic waterlogging	**Of concern**	EBS Neagle (2003) DEH (2005)

KEY

EBS – Threatened species observed or captured within the EBS March 2009 survey

Neagle (2003) – An inventory of the Biological Resources of the Rangelands of South Australia

DEH (2005) - Provisional List of Threatened Ecosystems of South Australia (unpublished and provisional)

Coolibah Woodland is typically found on levees and channel banks and regularly inundated floodplains within the Cooper Creek system. As regularly inundated areas are highly unlikely to be considered suitable sites for geothermal wells and power plants this particular community would not be impacted by the stimulation/evaluation activities.

Old-man Saltbush Open Shrubland is generally found on low sandy rises of floodplains, floodouts and swamps and in areas that are only occasionally inundated. According to EBS (2009) because this community is so widespread within the Channel Country Bioregion, its clearance on the scale likely to be required for all of Geodynamics' activities within its GRLs (of which stimulation/evaluation activities are a very minor part), would be unlikely to have a significant impact.

Golden Goosefoot Shrubland is generally found on cracking clay depressions subject to periodic waterlogging and less frequently flooded areas of the Cooper Creek system. Similar to Old-man Saltbush Open Shrubland, EBS considers any impacts by Geodynamics' activities on Golden Goosefoot Shrubland unlikely due to the minor scale of clearance possible within such a widespread community.

5.8 Heritage

The area has many sites and stories of particular significance to Aboriginal people. Prior to European colonisation the fresh and often abundant water in a desert environment sustained relatively high populations of Aboriginal people from the Yandruwandha, Yawarrawarrka and Dieri Aboriginal groups.

The level of occupation is indicated by the many large midden, burial and other sites to be found on the periphery of water bodies. The area also provided materials for tools; particularly grinding stones which were valuable trading items.

The non-aboriginal cultural heritage of the area is also of significance. The first graves of the ill-fated explorers Burke, Wills and Gray occur on the reserve. The Australian Inland Mission nursing home building, a ruin since the 1950s is now restored as the Regional Reserve office.

As specific locations of the future stimulation/evaluation sites within Geodynamics' GRLs are not known at this time, to ensure there any impacts on heritage are minimized and avoided wherever possible, prior to undertaking any site clearance/disturbance Geodynamics would ensure Aboriginal and heritage work area clearances are undertaken on sites identified for stimulation/evaluation activities. In particular, any sites required for construction of water storage dams/ponds and pipelines would require heritage clearance by appropriately qualified specialists.

5.9 Noise & air quality

The existing noise environment in the GRL areas is expected to be typical of sparsely populated pastoral areas, with generally low levels of background noise dominated by natural sources (e.g. wind, animals and insects).

The South Australian Environment Protection (Noise) Policy 2007 (the Policy) provides goal noise levels based on the Development Plan Zones in which the noise source and the noise receivers are located. The most appropriate noise goals for this activity are the *Rural Living* levels of 47dB(A) during the daytime (7am-10pm) and 40dB(A) during the nighttime (10pm-7am).

Power generators and water pumps used in the stimulation/evaluation process would temporarily affect background noise in the area surrounding any stimulation sites. A noise assessment of a stimulation (fracking) process carried out by Acoustic Dynamics (Appendix A) at a fracking operation near Camden (NSW) in 2007 found that the noise level associated with a fracking operation utilizing 5 pumps and blender) at average revs is approximately 80 dB(A) at a distance of 50 metres from the source. As Geodynamics proposes to operate only 3 pumps at average revs with no blender for most of the time this level is likely to represent a worst case scenario under typical operating conditions. For short periods (approximately 15 minutes in duration) while pumps are being changed over they will be operated at maximum revs, producing a noise level of approximately 90 dB(A) at 15 metres from the source.

The relationship between noise level and distance is well established with a doubling of distance equating to a reduction in the level of noise of 6dB. Table 7 sets out the noise levels expected with each doubling of the distance from the most prevalent fracking phase of the stimulation activity (3 pumps operating with no blender at average revs) with a direct line of sight between the source and the receiver location.

The insertion of a physical barrier such as a shipping container or purpose built noise barrier would typically result in a reduction of 5 dB in the noise level at the receiver. The presence of a significant topographic feature such as a sand dune, hill or creek bank breaking the line of site between the source (fracking pumps) and the receiver location would result in an even greater reduction in the noise level and in most cases would eliminate the fracking pump noise entirely at the receiver location.

Table 7 Noise levels at distance from a typical fracking operation

Distance from noise source (metres)	Noise level (dB(A)) at receiver	Distance from noise source (metres)	Noise level (dB(A)) at receiver
50	80	800	56
100	74	1600	50
200	68	3200	44
400	62	6400	38

As terrain between a stimulation and receiver sites will change considerably, noise impacts will need to be assessed on a case by case basis as part of the activity notification for each new stimulation site using the information in Table 7 (or new noise data if a different fracking process is proposed), to calculate the likely noise impacts on the nearest receivers and identify any mitigation measures that may be required to meet the *Rural Living* noise goals.

The air quality in the vicinity of the stimulation/evaluation activity is expected to be typical of a remote rural environment and influenced primarily by dust from high winds.

6 ENVIRONMENTAL RISK ASSESSMENT & MITIGATION MEASURES

This section outlines the methodology used to assess the environmental risks associated with the stimulation/evaluation activities and details and discusses the mitigation measures proposed to treat and manage these risks.

6.1 Risk Assessment Process

An assessment of the likelihood and consequences of environmental harm occurring from activities associated with the stimulation and evaluation phases provide an objective basis for the management of risks.

The risk assessment in this EIR uses a risk matrix and definitions for consequences and likelihood derived from Geodynamics' corporate risk management system and procedures. These are based on the Australian Standard AS/NZ 4360: 2004 Risk Management.

Geodynamics' risk assessment process involves:

- identifying the potential hazards or threats posed by the activity/s
- categorising the potential consequences and their likelihood of occurring
- using a risk matrix to characterise the level of risk.

The results of the risk assessment undertaken for the project are summarised in Appendix B and the proposed management measures are discussed in Section 6.2.

The level of risk identified in Appendix B assumes that the proposed management measures will be fully implemented by Geodynamics. Where procedures in Geodynamics' EMS are identified it assumes that these will also be implemented in their entirety.

The definitions for consequences and likelihood, and the risk matrix used in the assessment are outlined below.

6.1.1 Definition of Consequences

To describe the severity, scale and duration of potential impacts associated with the activity, five categories of consequence have been used (Table 7) based on the risk consequence definitions in Geodynamics' risk management process.

Table 7 – Risk Consequences

Descriptor	Environment	Reputation
Catastrophic	Permanent impact long term (decades) regional impact.	Adverse global media coverage. Major stakeholders terminate. Company at stake.
Major	Long term (decades) local area impact. Medium term (years) regional impact.	Adverse national media coverage. Company on notice.
Moderate	Medium Term (years) local area impact. Short term (months) regional impact.	Long term (weeks), local media and local interest.
Minor	Short term (months) local area impact.	Short term (days), local media and local interest.
Insignificant	Temporary impact (days/weeks) to immediate area.	Local interest only, quickly forgotten.

6.1.2 Definition of likelihood

The likelihood of environmental consequences occurring was defined using the five categories shown in Table 8 consistent with Geodynamics' corporate risk process. The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring.

Table 8 – Risk Likelihood

Descriptor	Probability	Frequency	Historical
Almost Certain	> 1 in 10	Several times per year	Has occurred frequently in the company
Likely	Between 1 in 10 and 1 in 100	About once per year	Has occurred once or twice in the company
Possible	Between 1 in 100 and 1 in 1,000	Once in a 1 - 10 years	Has occurred many times in the industry
Unlikely	Between 1 in 1,000 and 1 in 10,000	Once in 10 - 100 years	Has occurred once or twice in the industry
Rare	< 1 in 10,000	< Once in a 100 years	Unheard of in the industry

6.1.3 Risk Ranking

The risk associated with each hazard is characterised using the matrix in Table 9 below.

Risk reduction measures are applied to reduce risks to tolerable levels and risks are considered acceptable if they can be managed and maintained via mitigation measures into the low category.

Table 9 – Risk Ranking Matrix

	RARE	UNLIKELY	POSSIBLE	LIKELY	ALMOST CERTAIN
CATASTROPHIC					EXTREME
MAJOR				HIGH	
MODERATE			MEDIUM		
MINOR		LOW			
INSIGNIFICANT					

An assessment of the level of environmental risk identified for activities associated with the stimulation/evaluation activities carried out in Geodynamics' GRLs is provided in Appendix B.

6.2 Environmental Management & Mitigation

The mitigation and management measures to be implemented during the stimulation and evaluation phases will ensure that the level of environmental risk associated with these activities can be maintained at the 'low' levels identified in Appendix B.

6.2.1 Stimulation/Injection

One of the main risks associated with the stimulation/injection phase is the potential for induced seismicity due to the activation of existing deep faults in the area being stimulated.

In an evaluation of the risk of artificially induced seismic activity in the Cooper Basin due to the stimulation of EGSs, Hunt and Morelli (2006), found that the seismic events generated during stimulation testing by Geodynamics at Innamincka fall below the background coefficient of ground acceleration which is 0.05 g.

Because ground acceleration is not easily measured it is proposed to apply the ANZECC Guidelines to Minimise Annoyance due to Blasting Overpressure & Ground Vibration (1990) which set a peak particle velocity criteria of 10 mm/sec at the nearest sensitive receiver as the maximum level not to be exceeded.

Hunt and Morelli (2006) made a number of recommendations regarding the monitoring of seismic activity and the identification of levels that would trigger certain management responses in the event of elevated levels of seismic activity. In particular, it was recommended that Geodynamics introduce a "traffic light" seismic hazard control system for all current and future geothermal reservoir development operations, particularly during initial fluid injection phases.

Accordingly, it is proposed that a site specific seismic analysis study be carried out by an external expert to define the event magnitude compared to the nearby sensitive receivers or infrastructure (including in-ground). The study would identify the event magnitude that will result in the peak ground velocity of 10 mm/sec being exceeded.

The process would involve injection pressures and volumes being reduced or shut down in a stepwise manner if seismic event magnitudes are raised above predetermined levels identified in the seismic analysis. Microseismic monitoring will be undertaken in real time and seismic monitoring will commence before the start of stimulation operations to obtain baseline information.

6.2.2 Production & Open Loop Testing

The main difference between Production and Open Loop testing and the other phases involve the discharge of geofluid in both liquid and gaseous states into the environment. The main risks are associated with:

- radioactive elements present in geofluid and steam vented to atmosphere
- contamination of soil and shallow potable groundwater aquifers by highly saline geofluid or other chemicals

The concentration of the radioactive element radon in the atmosphere will be monitored in the vicinity of any Production and Open Loop tests to ensure that levels of radon do not exceed 1000 Bq/m3[1]. Continuous radon monitoring during Habanero 2 flow testing from 11 – 14 April 2005 found levels did not exceed 140 Bq/m3.

The levels of the radioactive elements uranium and thorium in the geofluid will also be tested offsite in NATA registered laboratories to determine if any special management measures are required to be implemented during the testing phase. Uranium levels in geofluid tested to date are less than those in seawater and thorium is undetectable. The level of radium in geofluid has not been measured in the past but will be measured in future tests.

To minimise any potential for defoliation damage to vegetation from condensate in steam vapour during Production or Open Loop testing these tests will be carried out in areas largely devoid of vegetation (eg over the top of ponds). If the wind is causing vapour to drift over vegetation it will be redirected away from the vegetation or stopped altogether if necessary. Monitoring of nearby vegetation will also be undertaken to check for any adverse effects.

[1] 'Action level' for Australian workplaces - from *National standard for limiting occupational exposure to ionizing radiation*, Radiation Protection Series RPS1, NOHSC & ARPANSA, 2002

All geofluid discharges will be directed into HDPE lined (minimum thickness of 2mm) ponds/pits to ensure that contamination of soil or shallow potable groundwater aquifers is avoided. Splashboards will be installed if required to ensure no overspray of ponds/pits occurs.

6.2.3 Closed Loop Testing

As Closed Loop testing does not involve any discharges to the environment the risks of contamination are significantly reduced. However, as the process takes up to 12 months to complete and involves fluids under very high temperature and pressure, there is a risk of well or pipeline failure occurring that could result in a significant pollution/safety incident occurring.

The May 2009 incident at Habanero 3, while not related to Closed Loop testing per se, resulted in an estimated discharge of 14 ML of geofluid onto the surface. While in this instance the geofluid was contained within an adjacent borrow pit, if a similar incident was to occur at a more remote site closer to Cooper Creek, in the absence of any environmental controls, the impacts on Cooper Creek or other waterbody within the Innamincka Reserve or Coongie Lakes RAMSAR area could be serious.

Pipelines will be designed and maintained to the relevant Australian standard (AS 4041-2006 and NACE for H2S & CO2) and relevant engineering specifications.To manage the risk of an uncontrolled discharge of geofluid into a nearby water course in the event of a well or pipeline failure it is proposed to construct temporary diversion bunds/drains to direct any such discharge into a holding area where it can be contained for testing and management as required.

As the potential exists for scale containing radioactive elements to occur in pipelines used to convey geofluid these scales will be tested for radioactivity and reported to PIRSA.

If, at the end of the Closed Loop testing phase, the water dam/pond is not be required to store water it may be allowed to evaporate, exposing the sediments that have deposited at the base of the dam over the stimulation/evaluation testing phases.

As these sediments could contain chemicals (including flocculant wastes) and elements that, if dispersed in the wind or improperly disposed of may cause hazards to workers or the environment, it is proposed that the sediments be tested prior to being exposed to determine the necessary management and/or disposal measures.

6.2.4 Other risks

The stimulation/evaluation phase requires the use of a large number of chemicals used as flocculants, anti scaling agents, tracers etc. The storage and handling of these chemicals and any fuels and oils used on site shall be managed in accordance with Geodynamics' Chemical and Fuel Storage Environmental Guidance Note and in accordance with the South Australian EPA's bunding guideline 080/07 Bunding & Spill Management (June 2007).

In addition, Material Safety Data Sheets shall be available on site for all chemicals used in the stimulation/evaluation process.

To avoid any unnecessary disturbance or damage to heritage sites or environmentally sensitive areas it is proposed that surveys be undertaken of proposed stimulation/evaluation sites and in particular, any areas required for water storage ponds/dams, in the early design phase so any sensitive areas can be avoided wherever possible.

A small camp (less than 10 staff) would be required for Closed Loop testing over a 12 month period. Typically the necessary facilities required to accommodate this number of staff – including a package effluent treatment system designed and maintained in accordance with SA Department of Health requirements – would either be retained from the earlier drilling phase or installed as required (subject to any new Activity Notification requirements that may be necessary).

Other risks associated with stimulation/evaluation phase and their proposed mitigation measures are identified in Appendix B.

6.2.5 Community Consultation

Geodynamics has conducted a number of information sharing / consultation events in the past. The most recent event was held on 2 August 2010. It was hosted by Dr Doone Wyborn, Geodynamics Chief Scientist and Andrew McMahon, Geophysicist. The presentation covered the background of the company, work to date, immediate work program, road to commercialisation of the resource and hydraulic stimulation activities to be completed at Jolokia 1. A copy of this presentation can be found on the Geodynamics website at www.geodynamics.com.au .

The event was well received by the local community with only a small number of issues raised, specifically around the impacts of micro-seismic activity on the local buildings. In response to these issues, Geodynamics has arranged for the attendance of a building engineer prior to the hydraulic stimulation activities at Jolokia (2010) to undertake a baseline assessment of the local buildings.

Geodynamics has also arranged for the installation of a seismic monitoring device in the township close to the hotel to inform the local residents of seismic activity in the area. Following the hydraulic stimulation of Jolokia 1, Geodynamics will arrange for the building engineer to re-assess the local buildings for any effects of the stimulation activities.

Geodynamics maintains a good relationship with the local community and will seek to keep them informed of the results of the Jolokia 1 hydraulic stimulation and any future stimulation and evaluation activities in the area.

7 REFERENCES

Environmental Impact Report/Statement of Environmental Objectives for Diagnostic Phase covering: Diagnostic Flow, Simulated Circulation Test, Enhancement & Demonstration Circulation (October 2004) prepared by Geodynamics.

EBS (2009). Flora and Fauna Impact Assessment for Geodynamics Geothermal License Area September 2009, Report prepared by Environmental and Biodiversity Services for Geodynamics Ltd.

Cooper Basin HDR Seismic Hazard Evaluation: Predictive modelling of local stress changes due to HFR geothermal energy operations in South Australia. Dr Suzanne P Hunt and Mr Cameron P Morelli, The University of Adelaide (2006)

Occupational Health & Safety Noise Assessment, "Fracking" Noise Emission, November 2007 (Acoustic Dynamics)

Recommendations for Limiting Exposure to Ionizing Radiation (1995)(Guidance Note NOHSC:3022(1995)) and National Standard for limiting ionizing radiation [NOHSC:1013(1995)} Radiation Protection Series Publication No.1 Republished March 2002

ANZECC Technical Basis for Guidelines to minimize annoyance due to blasting overpressure and ground vibration, September 1990

Appendix A

Noise Assessment

BJ SERVICES COMPANY – "FRACKING" OPERATIONS

OCCUPATIONAL HEALTH & SAFETY NOISE ASSESSMENT
"FRACKING" NOISE EMISSION - OCTOBER 2007

Prepared for:

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Project 2595
14 November 2007

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MEMBER FIRM
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OF AUSTRALIAN
ACOUSTICAL
CONSULTANTS

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1 INTRODUCTION

Acoustic Dynamics is engaged by BJ Services Company (herein referred to as BJ Services) to provide an assessment and report on occupational noise levels, received by personnel working on or near the equipment used and associated with "fracking" (or "fracturing") operations. This report is prepared for BJ Services, in accordance with their Occupational Health and Safety (OH&S) policies, systems and procedures.

This report is to be reviewed by the BJ Services HSE Coordinator, along with representatives of the company management and representatives of any safety committees or employee representatives, as part of BJ Services' commitment to continual improvement of its OH&S policies, systems and procedures.

In this report, Acoustic Dynamics establishes and details the relevant OH&S noise criteria for personnel. This report also presents the measurement results, findings and recommendations following a survey of occupational noise exposure levels and the associated (calculated) Daily Noise Exposure experienced by personnel working within close proximity to the fracking equipment, following a survey of typical fracking operations, taken on-site near Camden, NSW, on 17 October 2007.

This report has been prepared in accordance with the requirements and principals of:

- The Occupational Health and Safety Act 2000;
- The Occupational Health and Safety Regulation 2001;
- Australian Standard AS 1259-1990 "Sound Level Meters" (Parts 1&2);
- Australian Standard AS 1269-1998 "Occupational Noise Management" (Parts 0-3); and
- The Workcover NSW Code of Practice 2004 "Noise Management and Protection of Hearing at Work".

Acoustic Dynamics' noise measurement survey was carried out on Wednesday 17 October 2007, adjacent to equipment used for normal fracking operations, which mainly comprised of:

- 5 pumps; and
- 1 blender (or mixer).

Various other ancillary equipment was in use during our noise survey, including several smaller pumps and a hose nozzle squirting water, however the noise emission from these items of equipment was significantly lower than the noise from the equipment specifically associated with the fracking (pumps and blender).

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2 DESCRIPTION OF BJ SERVICES FRACKING OPERATIONS

As part of BJ Services' OH&S policies, systems and procedures, the company has an ongoing commitment to the health and safety of its employees, including measurement and documentation of noise emission and noise exposure levels within areas where employees may experience high noise levels.

BJ Services provides services largely to the extractive industry sector. The fracking operations being undertaken during Acoustic Dynamics recent survey, measured and assessed within this report, were specifically for the gas industry.

The fracking process for the gas industry is a highly technical process whereby a mixture of water and chemicals is forced into a gas well (or pipeline) under extremely high pressure levels, forcing the ground adjacent to the shaft to fracture (hence "fracking"), thereby releasing greater quantities of gas into the pipeline for extraction. This process increases the yield from a gas pipeline/well.

BJ Services provides fracking services throughout Australia and the Asia-Pacific region requiring the company to transport its equipment and personnel throughout the region, as required. Fracking is carried out at the location of gas wells, which are located outdoors on public, privately owned and leased land, generally in rural or semi-rural areas.

BJ Services' personnel and some visitors are generally required to work within close proximity to the fracking equipment to enable the equipment and processes to be monitored and adjusted, as required.

BJ Services' personnel generally work during daytime (light) hours, however fracking operations are unpredictable and can be undertaken in periods as short as a few hours or as long as several days. Typically, BJ Services' personnel would not be exposed to the noise associated with fracking for longer than 12 hours in any one day, and as such, this period shall be conservatively used as the typical maximum shift duration for noise exposure calculations.

Various supervising personnel and visitors may access and move around the fracking equipment during its operation. A basic layout diagram, showing the basic layout of the fracking equipment is presented as our Measurement Location Plan within **Appendix A**.

The following sections provide the relevant OH&S noise criteria, along with measurement results, findings and recommendations following our survey of occupational noise exposure levels. Also presented are the associated Daily Noise Exposure levels experienced by personnel and visitors working adjacent to the fracking equipment during its operation.

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3 PROCEDURES AND INSTRUMENTATION

The procedures for noise exposure level measurements throughout the survey were in accordance with AS 1269-1998 "Occupational Noise Management".

Sound pressure measurements were carried out using a precision sound level meter conforming to the requirements of AS 1259-1990 "Sound Level Meters".

The survey instrumentation used during the survey is set out in **Table 3.1**.

Table 3.1 Noise Survey Instrumentation

Type	Serial Number	Instrument Description
2260	2413547	Brüel & Kjær Modular Precision Sound Level Meter
4189	2395414	Brüel & Kjær 12.5 mm Prepolarised Condenser Microphone
4231	2412578	Brüel & Kjær Calibrator

The L_{Aeq} (A-weighted equivalent continuous) sound pressure levels were measured at positions representative of the noise exposure experienced by or as near as possible to the various operators and personnel while they were performing normal duties. At each position surveyed, levels were sampled over a sufficient duration to provide a representative indication of employee noise exposure.

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4 RELEVANT OH&S NOISE CRITERIA

In NSW, the Occupational Health and Safety (OH&S) (Noise) Regulation 2001 (effective 31 May 1997) sets the following limits for occupational noise exposure, above which either administrative or engineering noise control measures are required to be implemented:

- The 8 hours exposure to a continuous L_{Aeq} level of 85 dB(A); and
- The level of noise to which persons employed are exposed shall not peak at more than 140 dB(C).

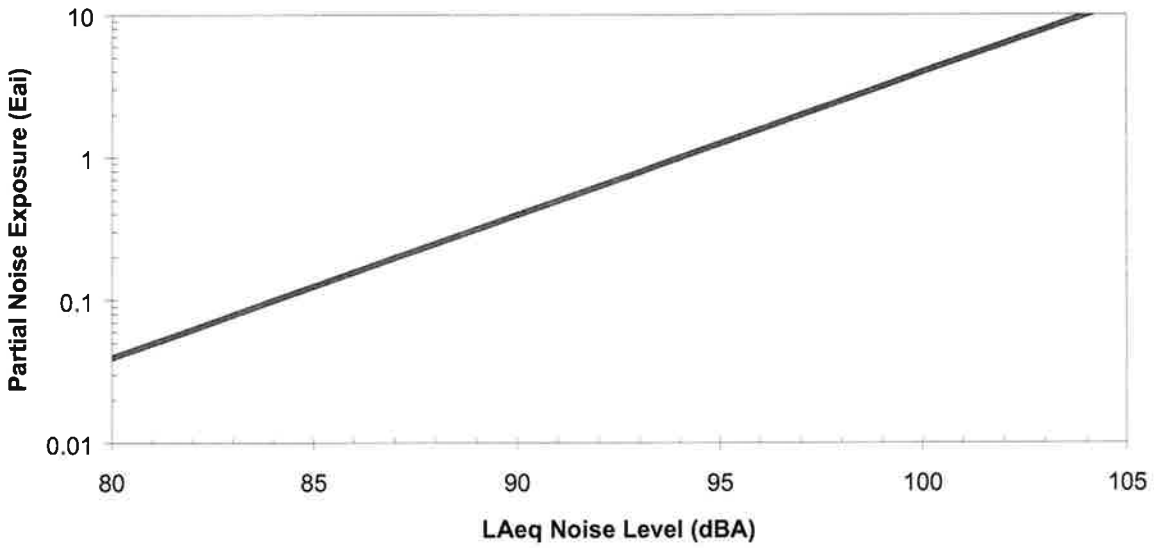
Recent changes in the regulation are now consistent with the recommendations of the National Health and Medical Research Council (NHMRC) of the Australian Department of Health and the Department of Industrial Relations and Employment (NSW).

These criteria are generally consistent with the OH&S noise emission criteria for other states within Australia and for other countries within the Asia-Pacific region, however these should be checked with the relevant authorities for each different country or region.

Although the NSW Regulation detailed above sets an L_{Aeq} maximum exposure limit of 85 dB(A), hearing damage has been shown to occur in some individuals at levels as low as 75 dB(A). Ultimately, the OH&S standards and regulations may be reduced to reflect this knowledge. As such, when designing noise controls to reduce noise emission from various items of plant or equipment, a maximum noise emission level of 75 dB(A) should be set as an objective.

An employee's Daily Noise Exposure ($E_{A,T}$) is a function of noise exposure levels (L_{Aeq}) and duration of exposure. Each segment of exposure is considered to be a Partial Noise Exposure ($E_{A,Ti}$). The Daily Noise Exposure is the sum of all Partial Noise Exposure's received throughout the working day. **Figure 4.1** contains calculated values of Partial Noise Exposure for various L_{Aeq} levels.

Figure 4.1 Calculation of Partial Noise Exposure ($E_{A,Ti}$)



For example, a person exposed to an L_{Aeq} of 85 dB(A) for 3 hours and L_{Aeq} of 89 dB(A) for 5 hours during a working day would have a Daily Noise Exposure calculated as follows:

3 hours at 85 dB(A) = 3 x 0.13	=	0.39
5 hours at 89 dB(A) = 5 x 0.31	=	1.55
Daily Noise Exposure	=	1.94

In this instance, the resultant Daily Noise Exposure of 1.94 is equivalent to an L_{Aeq} of 88 dB(A) over a continuous period of 8 hours.

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5 NOISE MEASUREMENT RESULTS AND FINDINGS

5.1 BJ Services Personnel

The L_{Aeq} noise exposure levels for various personnel exposed to the noise emission resulting from the fracking operations were measured at various operator and supervisor locations and are presented in **Table 5.1.1**.

Table 5.1.1 Noise Measurement and Exposure Details

Meas't Number	Loc'n Number	Dist. to Centre of Noise Source [m]	Description of Location and/or Noise Source	L_{Aeq} of Operation (dB(A))	$E_{A,T}$ (10 to 14 Hrs)	Max Exposure to Activity to Achieve Daily Exposure = 1 (Hours)	Required Hearing Protection Classification[1]
2	S5	10	Blender only (Operating at average revs)	94	10.4	1.0	1
3	S2	6	Blender only (Operating at average revs)	98	27.2	0.4	2
4	A0	50	Blender only (Operating at average revs)	79	0.3	Continuous	-
4	A0	10	Calculated level of blender only (Operating at average revs)	93	7.7	1.3	1
22	A10	50	Blender only (Operating at average revs)	79	0.3	Continuous	-
22	A10	10	Calculated level of blender only (Operating at average revs)	93	7.8	1.3	1
41	B10	50	Only pump 1 operating (Blender not operating)	80	0.4	Continuous	-
41	B10	10	Calculated level of only pump 1 operating (Blender not operating)	94	9.1	1.1	1
50	C10	50	Fracking with all 5 pumps and blender (Not operating at max revs)	81	0.5	19.0	-
50	C10	10	Calculated level of fracking with all 5 pumps and blender (Not operating at max revs)	95	13.3	0.8	1
70	A10	50	Fracking with all 5 pumps and blender (Operating at max revs)	90	4.3	2.4	1
70	A10	10	Calculated level of fracking with all 5 pumps and blender (Operating an max revs)	104	106.8	0.1	3
71	S5	10	Fracking with 3 pumps and blender (Operating at max revs)	102	61.6	0.2	3
72	S3	5	Fracking with 3 pumps and blender (Operating at max revs)	103	78.2	0.1	3

Meas't Number	Loc'n Number	Dist. to Centre of Noise Source [m]	Description of Location and/or Noise Source	L_{Aeq} of Operation (dB(A))	$E_{A,T}$ (10 to 14 Hrs)	Max Exposure to Activity to Achieve Daily Exposure = 1 (Hours)	Required Hearing Protection Classification[1]
73	S3	5	Fracking with 3 pumps and blender (Operating at max revs)	101	46.8	0.2	2
74	S3/S5	8	Fracking with 3 pumps and blender (Operating at max revs)	99	30.5	0.3	2
75	S6	5	Fracking with 3 pumps and blender (Operating at max revs)	101	50.5	0.2	3
76	S1	15	Fracking with 3 pumps and blender (Operating at max revs)	90	3.9	2.6	1

Note: 1) Conservatively based on 10 to 14 hour shift lengths for all personnel.

A Measurement Location Plan is attached within **Appendix A** showing measurement locations.

Table 5.1.1 presents the average Daily Noise Exposures of employees working without hearing protection (conservatively based on a 10 to 14 hour exposure level), together with the maximum number of hours of exposure of noise per day permissible without exceeding a Daily Noise Exposure value of 1.0.

For workers who have daily exposure periods other than 8 hours (for example people on shift work and as presented in the table above for BJ Services' personnel) their Daily Noise Exposure is be calculated by the use of **Table 5.1.2**, given the L_{Aeq} and exposure time of the operation.

Table 5.1.2 Adjustments to Normalised Noise Exposure Level $L_{Aeq(8hour)}$ for Extended Shifts

Shift Length (Hour)	Adjustment to $L_{Aeq(8hour)}$ (dB)
<10	+0
≥10 to <14	+1
≥14 to<20	+2
≥20 to 24	+3

This principle has conservatively been used in **Table 5.1.1**, as Acoustic Dynamics understands that personnel may sometimes be exposed to noise associated with the fracking equipment for longer periods than 8 hours.

5.2 Personnel with Intermittent Noise Exposure Patterns

Rather than being exposed to continuous or constant levels of noise, most of the personnel (and visitors) are subject to varying levels and durations of noise exposure due to the nature

of their job functions and the fracking operations. Most of the personnel are only exposed to the highest noise levels for short periods of time. The noise exposure level and the duration of exposure for all personnel varies from day to day and it is not practical or possible to directly measure or assign Partial Noise Exposure or Daily Noise Exposure for all or each of these personnel.

It is considered appropriate and conservative that all such personnel wear hearing protection based on their normalised equivalent 8 hour noise exposure, for the particular area they are working in, or for the activity being undertaken, even if their noise exposure is limited to a duration shorter than this.

5.3 Noise Description of Various Operations

During a fracking operation there are three distinct noise types. These can be described as steady-state noise, intermittent and impulsive noise.

Steady-State Noise

Steady state noise is typical of mechanical plant items and electro mechanical devices, where noise emission levels have only small variations with time. Examples of steady state noises include generators and the pumps and blender during warm-up or at idle.

Intermittent Noise

Intermittent noises occur for relatively short periods of time. To be readily identified, the levels are generally higher than the ambient noise environment. Examples include many of the noise emissions from the various activities observed during our noise survey, including the pumps and blender during fracking operations.

Impulsive Noise

An impulsive noise is a high level noise source of very short duration. Examples of impulsive noises include air pressure discharges or pneumatic valves, impacts such as the use of a hammer and the dropping of heavy items onto hard surfaces such as timber being dropped onto concrete, however the distinction between intermittent noise and impulsive noise is not always readily discernible.

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6 DISCUSSION AND RECOMMENDATIONS

6.1 OH&S Noise Management Policies Systems and Procedures

Although the Regulation detailed in section 3 sets an L_{Aeq} maximum exposure limit of 85 dB(A), hearing damage has been shown to occur in some individuals at levels as low as 75 dB(A). Ultimately, the OH&S standards and regulations may be reduced to reflect this knowledge. As such, when determining noise management policies, systems and procedures and when designing noise controls to reduce noise emission from various items of plant or equipment, a maximum noise emission level of 75 dB(A) should be set as an objective.

Acoustic Dynamics has reviewed the Workcover NSW Code of Practice 2004 for "Noise Management and Protection of Hearing at Work" and provides the following relevant information from this review.

"The law requires employers to:

- *identify hazards at workplaces*
- *assess the risks*
- *find ways to eliminate the hazards or control the risks that they present*
- *consult with employees on health and safety matters.*

Controllers of work premises have a duty to ensure that premises are safe and without risks to health.

Information should be provided to employees, taking language and literacy into account, to familiarize them with:

- *what noise is*
- *the range of health effects due to noise*
- *the social handicaps of noise-induced hearing loss and tinnitus*
- *the sources of exposure to noise in their particular workplace*

The prime responsibility for ensuring that a safe working environment is established, and safe work practices are implemented and maintained, resides with the employer. Employers should ensure that:

- *statutory requirements are complied with*
- *a noise control policy and program of action are developed*
- *all levels of management and employees are aware of the control measures to reduce exposure to noise*
- *all employees are encouraged to cooperate in using agreed safe work practices*
- *information on noise, the risks of exposure to noise and the appropriate control measures are disseminated in a manner appropriate to the workplace*

- *a comprehensive personal hearing protection program, including the selection of personal hearing protectors, and instruction of employees in their correct use and maintenance, is implemented*
- *employees receive appropriate training and education when it is required.*

Employers should recognise the supervisor's role in the management of noise and the protection of hearing at work. There should be close liaison between supervisors and employees."

The Code of Practice discusses engineering noise control measures, in particular:

- ❑ New plant and workplaces;
- ❑ Existing plant and workplaces;
- ❑ Engineering treatment of the source;
- ❑ Engineering treatment of the noise transmission path; and
- ❑ Inspection and maintenance of controls.

Also addressed within the Code of Practice are *"administrative noise control measures"*. The Code of Practice states:

"Where it is not practicable to comply with the standard set by the Regulation solely through engineering noise control measures, administrative noise control measures may also be used. Administrative noise control measures may include job rotation, job redesign or rosters which are designed so that as few employees as possible are exposed to noisy operations."

Following the above sections, the Code of Practice goes on to discuss personal hearing protectors. The Code of Practice states:

"When engineering and administrative noise control measures do not reduce the exposure to noise below the standard set by the Regulation, employees should be supplied with, and wear, effective personal hearing protectors.

Personal hearing protectors should not be used when noise control by engineering or administrative noise control measures is practicable. They should normally be regarded as an interim measure while control of noise exposure is being achieved by these means.

The removal of personal hearing protectors for even short periods of time can significantly reduce their effectiveness and result in inadequate protection. The difficulties of wearing personal hearing protectors for long periods of time in certain environments should be considered under the program of action developed in accordance with section 3.2 of this code of practice. Regular brief periods in quiet areas, without personal hearing protectors, should be included as part of the personal protection program."

The Code of practice also discusses:

- ❑ Hearing protection areas;
- ❑ Selection of personal hearing protectors;
- ❑ Inspection and maintenance; and
- ❑ Education.

Acoustic Dynamics advises that BJ Services' OH&S policies, systems and procedures should not only incorporate a mechanism for inspection and maintenance of hearing protection as indicated above, but also a mechanism for enforcing the use of hearing protection devices while an employee undertakes noisy activities or is within close proximity of noisy activities. Penalties could be imposed upon personnel who are identified as consistently failing to adhere to the hearing protection procedures determined.

Further to the above information, Acoustic Dynamics provides the following information for incorporation into BJ Services OH&S policies, systems and procedures.

6.2 Noise Reduction

In general, where the Daily Noise Exposure exceeds 1.0 and/or where the upper limiting noise level exceeds 140 dB(C), there is a statutory obligation upon the occupier of the premises *".....unless he has reasonable excuse....."* to carry out engineering noise reduction and/or restriction of the periods or situations in which persons are exposed to potentially harmful noise levels such that the statutory criteria are complied with.

Further investigation could be carried out to determine whether noise emission levels from various noisy activities associated with fracking could be reduced, however considering the scale and nature of the operations, and the variety of noise sources, it is clear that large noise reductions by engineering noise control are unlikely to be practical or cost effective at this stage.

Enclosures

Enclosures can be used to reduce noise emission from certain items of plant or for particular employees. Acoustic Dynamics notes that an enclosure is used for the fracking control room. Acoustic Dynamics understands that enclosures could net easily be adapted to the other operator positions associated with the fracking operations.

Barriers / Screens

Barriers and sound absorbing screens can be used to quieten direct noise between personnel or between working areas, however considering the scale and nature of the operations, the effect of such barriers and screens would be negligible. As such, barriers and screens are unlikely to be suitable for use with the fracking operations.

General / Maintenance

Generally, proper, regular maintenance including oiling, greasing and replacement of bearings results in quieter, more effective operation of a machine, with less vibration. Where an item of equipment has notably increased in noise level over time, maintenance should be undertaken to reduce noise emissions.

Further to this, and considering the extremely high noise emission levels experienced during fracking operations, such maintenance is unlikely to significantly alter the noise emission received by personnel.

6.3 Education

Personnel need to be educated about the desirability of noise reduction and the importance of hearing protection. In addition, personnel should be educated about the social and other difficulties encountered by individuals who have noise-induced hearing loss, and advised that once an individual has some hearing loss, hearing cannot be regained.

6.4 Hearing Protection

With knowledge of the information provided above, including the noise measurement results presented within **Table 5.1.1**, until such time as noise levels during fracking operations are shown to be below the objective noise level at all times, it is important to ensure that employees are protected from noise emission, which may cause damage to their hearing.

Further to Acoustic Dynamics' OH&S noise survey, the following recommendations are made with regard to the use of hearing protection.

Personnel Exposed to Noisy Activities

Personnel must wear hearing protection at all times, regardless of the duration they expect to be exposed:

- When within 25 metres of the blender operating at average revs;
- When within 25 metres of an operating pump at low revs or warming up;
- When within 25 metres of the fracking equipment when 5 pumps and the blender are operating at low revs or warming up; and
- When within 100 metres of the fracking equipment during fracking operating at high revs (regardless of the number of pumps).

Personnel working inside the insulated mobile control room need not wear hearing protection, however hearing protection should not be removed until within the control room and prior to exiting the control room during the above activities.

Impulsive Noise

It is mandatory that personnel who experience noise levels that peak above 140 dB(C), for even a short period of time, wear hearing protectors at all times during these activities. As the noise level to which personnel are exposed while undertaking impulsive activities can vary greatly, based on our noise survey, it is recommended that personnel who experience L_{Cpeak} levels of noise greater than 105 dB(C) wear hearing protectors.

Although no high impact noise sources were identified during Acoustic Dynamics' survey, personnel must wear hearing protection at all times while exposed to high impact noise, in particular while undertaking the following activities:

- ❑ whenever hammering; and
- ❑ any other impulsive noise generating activities including during any high pressure valve discharges.

Selection of Hearing Protectors

The highest measured L_{Aeq} noise level during Acoustic Dynamics' OH&S survey was **104 dB(A)**, therefore the 8-hour equivalent L_{Aeq} noise exposure level for all personnel is likely to be below 104 dB(A) (the highest noise level measured during Acoustic Dynamics' noise survey). Based on these noise levels, a **moderate** grade (class 3) of acoustical performance would be required for hearing protectors to be used by all personnel.

The use of the classification method is intended to simplify the process of the selection of appropriate hearing protectors for those working in the field. With the classification method the only required information is the normalised $L_{Aeq(8hour)}$. The relationship between class and SLC_{80} is given in **Table 6.4.1**.

Table 6.4.1 Relationship between Class and SLC_{80} of Hearing Protector

Class	SLC_{80} Range[1]
1	10 to 13
2	14 to 17
3	**18 to 21**
4	22 to 25
5	26 or greater

Notes: 1) The SLC_{80} values are rounded to the nearest integer.
2) For further information on SLC_{80} refer to AS 1270.

The SLC_{80} (Sound Level Conversion) value is a single number rating of hearing protector noise reduction, permitting selection of required degree of protection with an appropriate level of confidence. This SLC_{80} value is defined as the difference between the C-weighted sound level impinging on the hearing protector and the A-weighted sound level reaching the wearer's ears and incorporates a "mean minus one standard deviation" correction to ensure that the stated degree of noise reduction is obtained on 80% of occasions.

The required Hearing Protection Classification for each assessment location is presented in **Table 5.1.1**, with the highest classification shown being class 3. Acoustic Dynamics recommends that selection of Hearing Protection Classification 3 (or higher) hearing protectors for all personnel. Such hearing protection will adequately reduce noise emission levels received at the ear, when used correctly.

The following companies (in alphabetical order) are just some of the companies that supply hearing protectors, warning signs, safety posters and general advice in this regard:

Company	Products/Services	Telephone
Earmold Pty Ltd	Hearing tests, audiometry and personalised moulded earplugs	02 9671 5301
Klenall Industrial Suppliers	Hearing protectors and safety equipment	02 4732 1771
MSA (Aust) Pty Ltd	Hearing protectors and safety equipment	02 9688 0333
Protector Alsafe	Hearing protectors and safety equipment	132 832
Safeman Australia	Hearing protectors and safety equipment	02 9609 7960
Safetymart (Aust) Pty Ltd	Hearing protectors and safety equipment	1300 305 220
Safety Store	Hearing protectors and safety equipment	07 5445 4667

Various types of ear muffs and earplugs, including mounded earplugs are available. Acoustic Dynamics advises that in order to ensure a greater level of acceptance of the hearing protectors by employees, it is recommended that when providing earmuffs and/or earplugs, employees be allowed to choose from a range of products. When selecting hearing protectors, beyond achieving the required classification, emphasis should be placed upon comfort and correct fitting so as to improve the likelihood that they will be used and maximise the benefit gained.

Identification of Noise Zones

Typically, where noisy areas or zones can be identified, signs should be erected at critical entry and exit points and at locations within each zone where considered appropriate, and the model(s) of hearing protector and SLC_{80} performances required of those protectors should be specified. The signs should be mounted at head height above the floor level so that they are easily visible.

Acoustic Dynamics advises that noisy activities and areas should be identified for all fracking operations. Any signs erected should be focused on the use of hearing protectors by all personnel exposed to noisy activities.

6.5 Hearing Testing

The Workcover NSW Code of Practice 2004 for "Noise Management and Protection of Hearing at Work" provides the following relevant information, relating to the testing of employees' hearing:

> *"The hearing of employees exposed to noise can be monitored through regular audiometric examinations. Such testing in itself is not a preventive mechanism, and is only relevant in the context of a comprehensive noise management program. Any changes in hearing levels over time revealed by audiometry should be thoroughly investigated as to their cause(s) and the need for corrective action.*
>
> *An audiometric testing program should be available to any employee likely to be regularly exposed to noise exposure levels in excess of the standard set by the Regulation."*

Should BJ Services wish to have hearing testing carried out for their personnel, employees should be advised that the purpose of the testing is not to see how much hearing has been lost, but rather to monitor employees' hearing to enable early notification of hearing troubles or any hearing loss and to prevent any future hearing damage. If hearing testing has not previously been carried out for an individual at the commencement of their employment, it is not possible to accurately determine whether any hearing loss pre-existed, prior to their employment for BJ Services.

Should BJ Services wish to have hearing testing carried out for their personnel, a testing programme or schedule should be determined. The following organisations (in alphabetical order) are just some, which supply hearing testing and audiometry:

Company	Products/Services	Telephone
Audio Clinic	Hearing tests and audiometry	1800 057 220
Australian Hearing	Hearing tests and audiometry	131 797
Earmold Pty Ltd	Hearing tests, audiometry and personalised moulded earplugs	02 9671 5301
Industrial Diagnostics	Hearing tests and audiometry	02 4362 2660

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7 CONCLUSION

The results of the OH&S noise exposure survey carried out represent a comprehensive coverage of BJ Services' typical fracking operations and associated activities. The noise survey and measurements form part of BJ Services' OH&S internal audit system and ensure that the statutory requirements laid down in the "The Occupational Health and Safety Regulation 2001", which became effective 31 May 1997, are met.

The survey results have permitted identification of areas and operations or activities, which expose employees to noise levels high enough to cause hearing damage. Without adequate hearing protection, employees undertaking or exposed to some noisy activities are potentially at risk of incurring hearing loss, if exposed over a sufficient period or to levels high enough. All employees exposed to normalised daily average noise levels of 85 dB(A) and above without adequate hearing protection will receive Daily Noise Exposures greater than or equal to the present recommended limit of 1.0.

In those areas or for operations or activities where daily noise exposures of personnel are likely to exceed 1.0 (during a working day where the normalised $L_{Aeq(8hour)}$ exceeds 85 dB(A)) or where the L_{Cpeak} exceeds 140 dB(C), there is a requirement to provide personnel with suitable hearing protection devices and/or implement appropriate noise control measures to comply with the relevant statutory obligations.

Table 5.1.1 illustrates the need for personnel to use appropriate hearing protection, when undertaking or exposed to certain noisy activities. The noisy activities, during which operators or nearby personnel must wear hearing protectors, are summarised within section 6.4 of this report.

We trust that the above information provided within this document meets with your present requirements and expectations. Please do not hesitate to contact us on 02 9908 1270 should you require further advice, information or clarification.

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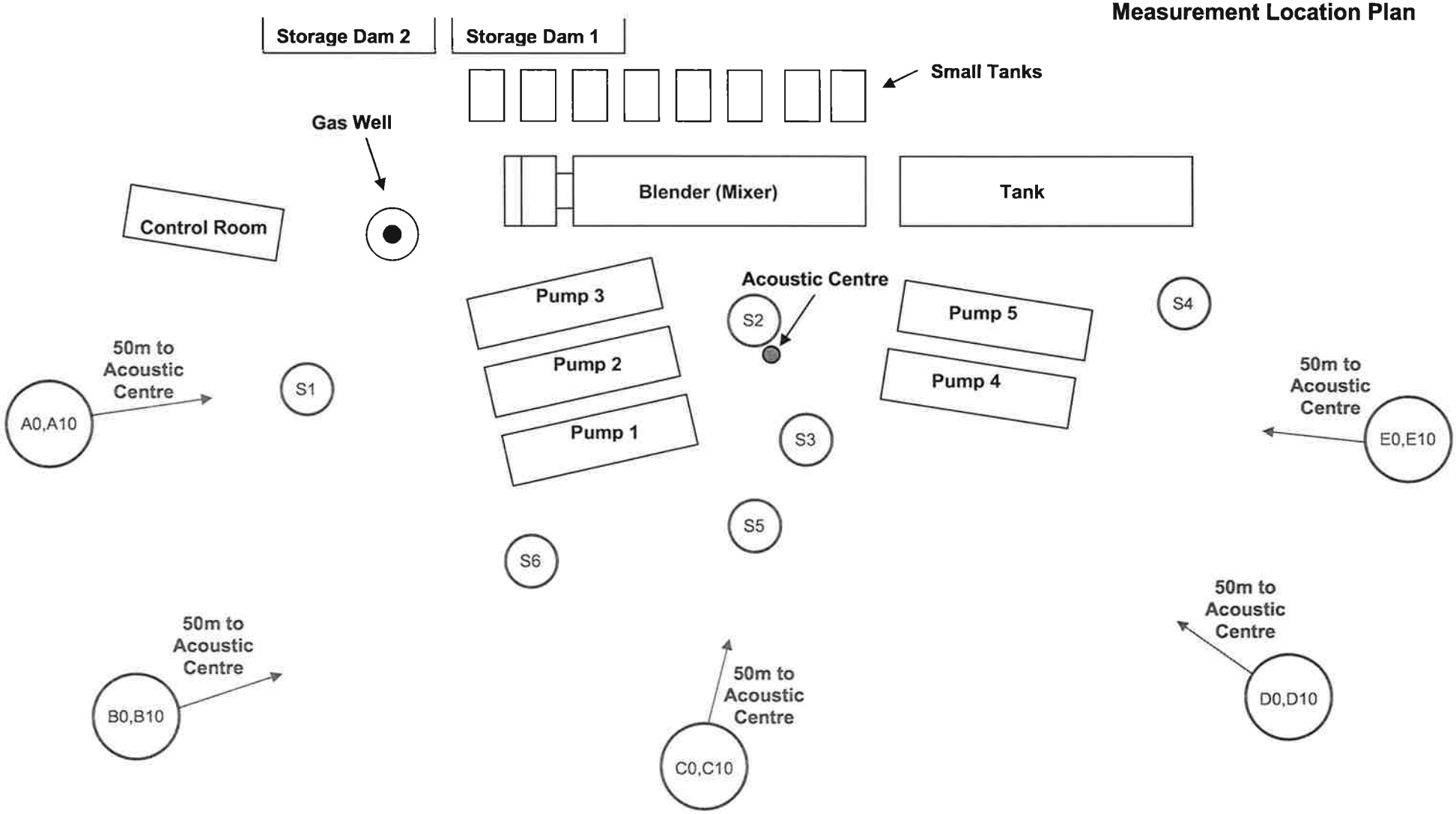
Appendix A
Measurement Location Plan



Measurement Location Plan (Not to scale)

Appendix B

Risk Assessment

EVENT/ACTIVITY	POTENTIAL ENVIRONMENTAL CONSEQUENCE/S	MITIGATION MEASURES	LIKELIHOOD	CONSEQUENCE	RISK RANKING
Siting and construction of dams/ponds, pipelines,& other facilities associated with EGS stimulation and evaluation	• Impact on threatened flora & fauna or endangered ecological communities • Damage to aboriginal or other heritage sites	• Assessment of impact on any threatened flora and fauna species to be undertaken by ecologist prior to selection of dam/pond site to avoid sensitive areas where possible • Assessment of impact on any aboriginal or other heritage sites to be undertaken by archaeologist prior to selection of dam/pond site to avoid significant heritage areas where possible •	Rare	Minor	Low
High pressure/temperature well or pipeline failure	• Contamination of soils, surface water & shallow groundwater aquifers with geofluid	• Well heads designed to 68MPa (10,000 psi) • Automated and manual shut down systems in place • High pressure failure audible alarm • Strategically located diversion bunds/drains in place to ensure high volume discharges cannot discharge into sensitive areas (eg Cooper Creek or other water courses) • High pressure/temperature pipelines designed, maintained and operated in accordance with AS 4041-2006 & NACE for H2S & CO2 and any other relevant industry standards.	Unlikely	Minor	Low

Fauna & livestock prevention	• Disturbance to natural migration or watering patterns • Mortality if fauna &livestock encounter hot or contaminated water	• Daily monitoring to be undertaken to check for fauna & livestock activity/mortality and advice from ecologist to be sought if required • Dams/ponds to be allowed to evaporate once stimulation/evaluation process complete if not required for future activities • The site will be fenced off to prevent fauna and livestock access • Escape ramp/device to be installed in ponds/sumps with vertical walls • A personnel protection fence to be erected along high pressure/temperature pipelines	Unlikely	Minor	Low

Storage and use of tracer chemicals, flocculating agents, fuels, oils etc	Contamination of soil and shallow groundwater aquifers through spills and leaks	• All fuels, chemicals, oils etc to be stored in accordance with GDY's Environmental Guidance Note for Chemical & Fuel Storage and consistent with the requirements of the South Australian EPA's bunding guideline *080/07 Bunding & Spill Management (June 2007)* • Any spills or leaks shall be cleaned up using Spill Kits available on site and reported to the GDY Environment Manager for further advice in relation to cleanup and disposal of contaminated materials • Material Safety Data Sheets shall be available at each test site for all chemicals used in the stimulation and evaluation phase and the requirements of these MSDSs shall be complied with	Unlikely	Minor	Low

Production & Open Loop Testing	• Contamination of soils or shallow groundwater by EGS geofluid discharges • Vegetation damage from boron condensate in steam vapour • Radiation hazard to workers and environment	• Continuous Radon monitoring of atmosphere in vicinity of discharges to atmosphere during production and open loop tests • Concentration of radioactive elements (Uranium Thorium & Radium) in geofluid and any scales deposited in pipelines to be tested periodically and reported to PIRSA • HDPE with a minimum thickness of 2mm will be used to line all ponds used to store geofluids • Splash board/panel to be used where necessary to ensure all geofluid discharged drains to lined pit • Wind direction to be monitored prior to and during testing to ensure drift onto soil or vegetation does not occur • Nearby vegetation to be monitored during production and open loop testing to check for damage • The f luid phase will be directed over the pond to minimize steam spray over surrounding areas	Unlikely	Minor	Low

Stimulation of granite basement	• Seismic activity causing damage to in-ground and surface infrastructure and community concern • Contamination of GAB and oil and gas resources with EGS geofluid • Airborne noise disturbance of sensitive receivers (including campers)	• A site specific seismic analysis study will be undertaken by an external expert to define the event magnitude that would result is a peak ground velocity of 10 mm/sec at the nearest sensitive receiver or infrastructure. The study will identify the seismic event levels at which the stimulation pump pressure should be reduced or the stimulation halted. • Seismic monitoring will be commenced prior to stimulation operations to obtain baseline information and will continue throughout the stimulation/evaluation phase • If magnitudes of seismic events remain above predetermined level at reduced injection rates the well shall be shut in Casing & cement shall be pressure tested to 62MPa (9000psi) • Acoustic monitoring shall be undertaken to detect the development (both extent & direction) of fracture stimulation within the granite to ensure that any impact on the overlying GAB & oil & gas reserves is avoided • Airborne noise assessment of impact of fracking operation (utilizing noise levels in Table 7 of EIR or new data where required) on nearby sensitive receivers (including campers) undertaken as part of activity notification and mitigation measures implemented (if required) to meet Rural Living goals of 47dB(A) during the daytime and 40dB(A) at nighttime • A building engineer will undertake building condition surveys of buildings in Innamincka prior to & following the stimulation of Jolokia 1 to assess any impacts of the stimulation activities	Rare	Minor	Low

		• A seismic monitoring device will be installed close to the Innamincka Hotel to inform the local residents of seismic activity in the area. • The Innamincka area community will be kept informed of the results of the Jolokia 1 hydraulic stimulation and any future stimulation activities in the area			
Flooding of Cooper Creek	Inundation of geofluid ponds, chemical and fuel stores causing pollution of surface waters	• Flooding in Cooper Creek area occurs with sufficient advance warning to allow any chemicals, fuels etc to be relocated to higher ground at GDY's warehousefacility near Innamincka • The invert level of the geofluid ponds will be higher than flood levels	Rare	Minor	Low
Wind blown dispersal of sediments in ponds/dams	• Hazard to workers & environment • Disposal of contaminated material	• Sediment deposited on dam/pond floor to be tested for contaminants prior to being exposed to air to determine risks of exposure to windblown dispersal and to identify if special management or disposal measures are required	Possible	Minor	Moderate