ASX Announcement

Company Announcements Office
Australian Securities Exchange

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6 August 2010

(ASX Code GRK)

Substantial Inferred Geothermal Resource for Green Rock's Alkimos Permits

Highlights

- Substantial geothermal resource at Alkimos confirmed by independent estimate.
- Further definition of the resource through two exploration wells to be located in discussion with land owner LandCorp.

Green Rock has engaged Hot Dry Rocks Pty Ltd (HDR), a leading Australian geothermal consulting company, to provide a Geothermal Resource estimate for its Alkimos Permits GEP2 and GEP39 north of Perth.

HDR reports that the Permits, covering 340 square kilometres, contain estimated Geothermal Resources amounting to 61,000 PJ of stored heat (equivalent to1.9 million MT_{th}.yrs). A summary of HDR's full report is attached. While this estimate was determined specifically for the purpose of a potential district cooling project, production of the stored heat could be used for other direct use purposes including district heating, sea-water desalination and purification of waste water by distillation.

Richard Beresford, Green Rock's Managing Director, said "Ten production projects of $10MW_{th}$ each running for 50 years would use less than one percent of the stored heat right beneath this major new community development. We are very excited by the potential for geothermal to supply a large part of the community's energy needs with this renewable and continuously available resource."

Green Rock Energy Limited: Unit 6, 38 Colin Street, West Perth WA 6005, Australia. Postal Address: PO Box 1177, West Perth WA 6872, Australia
T **(+61 8) 9482 0482** F (+61 8) 9482 0499 E info@greenrock.com.au W www.greenrock.com.au ABN 59 094 551 336

Further definition of the resource and targeting of the best production locations will be assisted by the drilling of two 500m exploration holes which will be 50% funded by the WA Government this year through its Exploration Incentive Scheme. Green Rock announced this award on 2nd June 2010.

The WA Government announced on 20th July that the Development Agreement had been signed with Delfin Lend Lease to begin the first stage and master planning of the Alkimos project. The 710 hectare community will include a major regional town centre and a coastal village centre. Green Rock will be discussing the locations of the two exploration holes with land owner LandCorp with reference to future sites of energy demand in commercial and high-density residential areas.

Nigel Hodder
Company Secretary

Investors and Media

T: +61 (0) 9482 0482

E: info@greenrock.com.au

APPENDIX

Statement of estimated Geothermal Resources
Alkimos Geothermal Play, GEP 2 & GEP 39, 06 August 2010

The Alkimos Geothermal Play, Western Australia

The Alkimos Geothermal Play lies in Geothermal Exploration Permits GEP 2 and GEP 39 (total 340 km^2) approximately 40 kilometres north of Perth, Western Australia (Figure 1), and represents a Hot Sedimentary Aquifer (HSA) target. GEP 2 and GEP 39 are 100% controlled by Green Rock Energy Ltd (GRK). The licence holder aims to produce geothermal fluids from the target reservoir primarily as a source of thermal power for absorption chiller air conditioning systems.

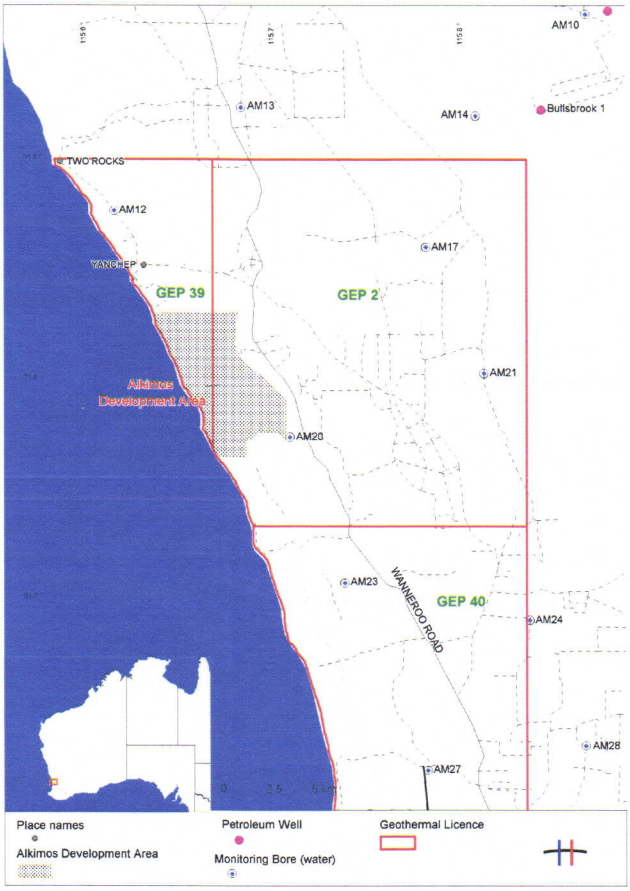

Figure 1. Location of the Alkimos Geothermal Play and geothermal licences GEP 2 & GEP 39 in Western Australia (red). Water bores (white/blue points) and petroleum wells (pink points) used to constrain the geological structure are also shown.

Water bore and aquifer observation bore drilling activity (Figure 1) provided information on shallow lithology, while precision temperature logs recorded by GRK provided temperature gradient data. Temperature was directly measured by GRK within eight wells (AM12, AM13, AM17, AM20, AM21, AM24, AM27 and AM28) at different locations and stratigraphic depths. These surveys and bores generated data of relevance to geothermal exploration. There have been no significant historical petroleum exploration activities within the Permits from which to directly derive deeper temperature and stratigraphic information. Information about lithologies and temperature at depth were, however, derived from the Bullsbrook 1 petroleum well to the northeast of the area.

Hot Sedimentary Aquifers – Yarragadee Formation and Cattamarra Coal Measures

The Perth Basin is a north-northwesterly oriented rift basin comprised of a series of sub-basins, troughs, shelves and ridges containing predominantly Early Permian to Late Cretaceous sedimentary sequences up to 15 km thick. The Alkimos Geothermal Play overlies the central southern part of the Dandaragan Trough, a major structural subdivision within the Perth Basin.

Surface outcrop is mostly flat-lying Tertiary and Quaternary limestone; sand, silt and clay in varying proportions. The shallow geology of the Alkimos area is constrained by a number of groundwater and aquifer monitoring and production bores, with deeper units inferred by projecting distal 2D reflection seismic data and petroleum borehole stratigraphic intersections.

The Yarragadee Aquifer is a major confined aquifer system in the greater Perth Region and consists of the permeable beds of the Gage and Yarragadee Formations and the Cattamarra Coal Measures. The South Perth Shale (where present) is the top confining bed with aquifer units interconnected between the other formations of the system. Sedimentary aquifers are naturally porous and permeable rocks from which water can be extracted without the need for 'enhancing' their permeability. When aquifers are buried beneath thick sections of thermally insulating rocks, the natural heat of the earth can warm the contained water above normal expected temperatures. Such Hot Sedimentary Aquifers (HSAs) are attractive geothermal energy targets. The Yarragadee Formation and Cattamarra Coal Measures in GEP 2 and GEP 39 represent such targets.

The principal target reservoir in the Alkimos Geothermal Play is the base of the Yarragadee Formation and the Cattamarra Coal Measures to a maximum depth of 4,000 m. All sand-prone units from the basal sections of the Yarragadee Formation to the Cattamarra Coal Measures are considered viable reservoir targets. Figure 3 includes a map of the Inferred Geothermal Reservoir thickness, comprising the aquifer system between the Yarragadee Formation and Cattamarra Coal Measures, from a cut off temperature of 75°C (see below) to the maximum target depth of 4,000 m.

Resource estimation

Stored heat assessment

Hot Dry Rocks Pty Ltd (HDR) used a 'stored heat' method to estimate the Geothermal Resource in the target reservoir. The method requires the estimation of the **volume**, **density**, **specific heat capacity** and **temperature** of the target reservoir formations, a consideration of the realistic lowest economically extractable temperature ('**cut-off temperature**') and the amount of thermal energy that might be extracted from the resource fluids (related to the '**base temperature**').

HDR constructed a numerical 'earth model' to estimate the stored heat within the target reservoir(s), based on gridded lithology data from water bores in the Alkimos area. The earth model extended to a depth of 5,000 m and divided the stratigraphy of the Geothermal Play into six (6) units: **Tertiary, Coolyena Group, Warnbro Group (including Leederville Formation and Gage Formation), South Perth Shale, Yarragadee Formation (including the Cadda Formation)** and **Cattamarra Coal Measures.** Note that although the earth model extended beyond the boundaries of GEP 2 and GEP 39, the Geothermal Resource was estimated **only within the tenement boundaries of GEP 2 and GEP 39 and to a depth of 4,000 m.** Figure 2 shows the depth to the top of the Yarragadee Formation within the earth model of the Alkimos Geothermal Play.

HDR assigned thermal conductivity and heat generation values to the units, based on lithological proportions and 'mixing laws'. Derived thermal conductivity values are summarised in Table 1. HDR considers the values assigned in this study to be reasonable averages for the formations under consideration, but the number of measurements made on actual samples of the formations is currently insufficient to determine potential lateral and vertical variation. Uncertainties in projected temperatures and Geothermal Resource estimates therefore increase with distance from, and depth beneath, borehole control points. Thermal conductivity is assumed to be isotropic for all units.

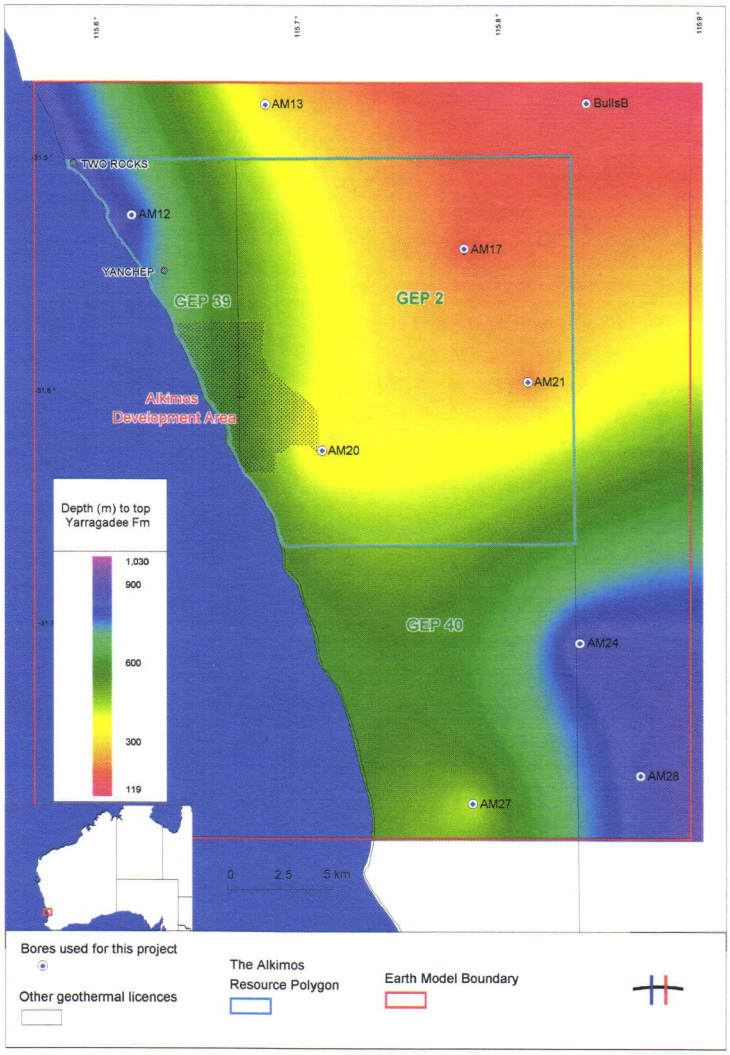

Figure 2. Depth to the top of the Yarragadee Formation across the area of the earth model (red square), with the Alkimos Geothermal Play shown as the light blue polygon. Bores used to constrain the thermal models (white/blue points) are also shown.

Table 1. Values for thermal conductivity (at 25°C) and heat generation assigned to earth model units

Unit	Thermal conductivity (W/mK)	Heat generation ($\mu W/m^3$)
Tertiary Units	2.30	0.0
Coolyena Group	2.32	0.0
Warnbro Group	2.67	0.0
South Perth Shale	1.71	0.0
Yarragadee Formation	3.12	0.0
Cattamarra Coal Measures	2.39	0.0

Cut-off and base temperature

For the purposes of this stored heat assessment, HDR defined the cut-off temperature as *the minimum economic reservoir fluid temperature for commercial energy extraction*, and the base temperature as *the temperature of the geothermal fluid once it has passed through the absorption chiller, prior to re-injection.*

HDR assumed a **cut-off temperature of 75°C** and a **base temperature of 55°C.** These are appropriate for the absorption chiller technology that the licence-holders propose to use for air conditioning systems. Should technological advances decrease the base temperature, the estimated Resource may increase over time.

Reservoir volume

For the purpose of estimating reservoir volume, all of the Yarragadee Formation and Cattamarra Coal Measures (and intervening Cadda Formation should it exist in this area) were included. The top of the reservoir was defined by the cut-off isotherm (75°C; see below), and the maximum economic drilling depth of 4,000 m defined the base of the reservoir. The predicted depth and thickness of the reservoir interval varies according to the distributions illustrated on Figure 3. The total estimated reservoir volume is **536 km^3**.

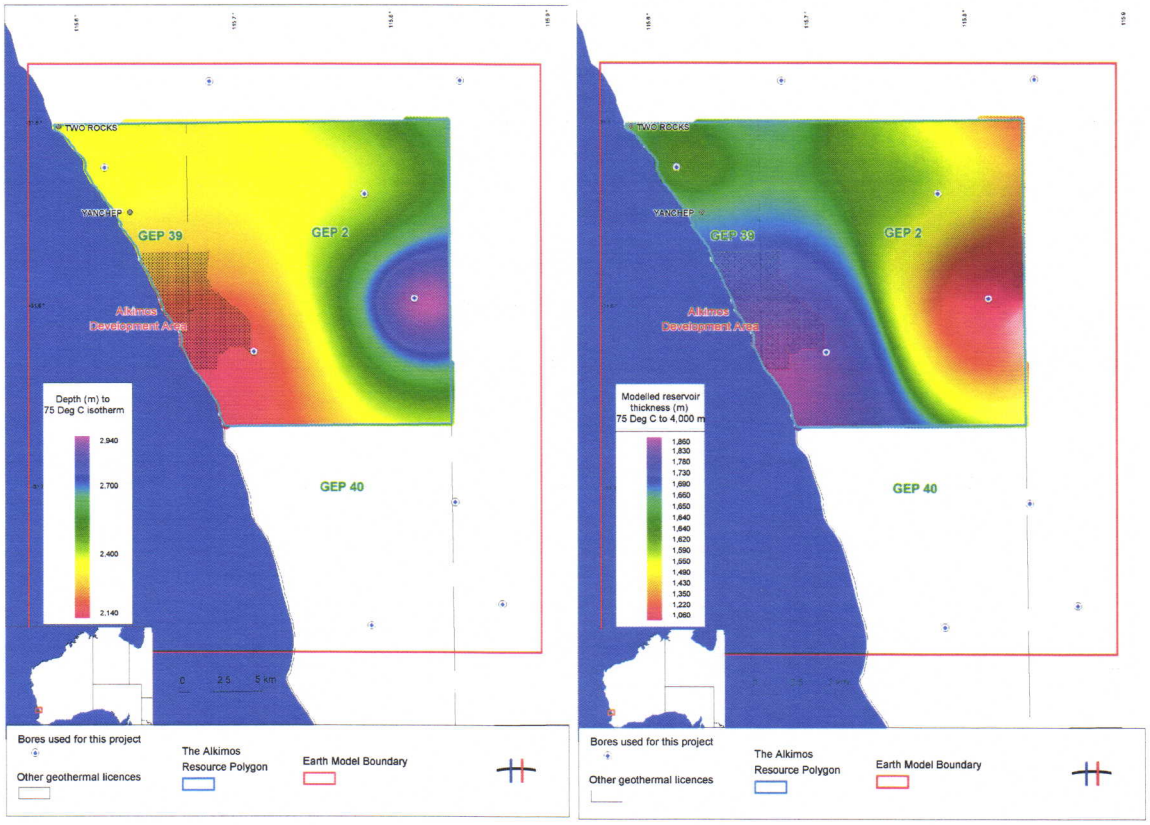

Figure 3. *Left:* Modelled and gridded depth to the 75°C isotherm beneath the Alkimos Geothermal Play area. *Right*: Modelled and gridded reservoir thickness from minimum cut off temperature of 75°C to maximum depth of 4,000 m. Latitude and longitude are in projection GDA94.

Reservoir density and specific heat

The density and specific heat of the Yarragadee Formation (and deeper reservoir units) were estimated based on a simple quartz-water mix in the ratio 95:05, with 0.75% total coal. The density of a 95:05 quartz-water mixture with additional 0.75% coal is about **2580 kg/m^3**. The specific heat of a 95:05 quartz-water mix over the temperature range **T** = 50–250°C is approximated by the equation:

$$c_p = 913.6 + 1.228 \times \mathbf{T} \quad \text{J/kgK}$$

Reservoir temperature

Surface heat flow was constrained by one-dimensional heat flow models (e.g. Figure 3) of six water bores and one petroleum well for which measured borehole temperature and lithology data were available. The

available temperature data fit a conductive model (within uncertainty limits) through the full depth of six of the water bores and the one well, suggesting that the thermal state of those bores was conductive, with no evidence of convection or advection. The modelling revealed, however, anomalously low heat flow values for the two bores AM24 (47 mW/m^2) and AM28 (51 mW/m^2). These values may suggest localised advective influence of shallow groundwater flow affecting the temperature logs at these locations. Heat flow estimates from AM24 and AM28 were not used in the resource calculation.

The locations and depths of the bores, and their modelled heat flow values, are presented in Table 2.

Table 2. Heat flow constraints on the temperature modelling. Uncertainty values were derived from uncertainty in thermal conductivity estimates. Coordinates are in projection MGA94 Zone 50 (GDA94).

Bore	East	North	TD (m)	Estimated Heat Flow (mW/m^2)
AM12	368581	6511653	838	65 ± 2.4
AM13	374909	6516946	798	70 ± 1.6
AM17	384288	6510078	301	68 ± 2.7
AM20	377567	6500435	467	74 ± 2.3
AM21	387307	6503748	464	60 ± 1.5
AM24	389763	6491300	908	47 ± 1.9
AM27	384680	6483682	762	75 ± 1.7
AM28	392620	6485039	625	51 ± 1.8
Bullsbrook	390085	6517019	4257	60 ± 2.5

Temperature was predicted using 1D conductive heat flow models to a depth of about 4,000 m below each well on Figure 2 (eg Figure 4), based on the observed surface heat flow (Table 2) and the predicted stratigraphic column derived from the earth model. The temperature dependence of thermal conductivity was also taken into account, using a formula published by Sekiguchi (1984)[1]. Target isotherms were then gridded across the licence.

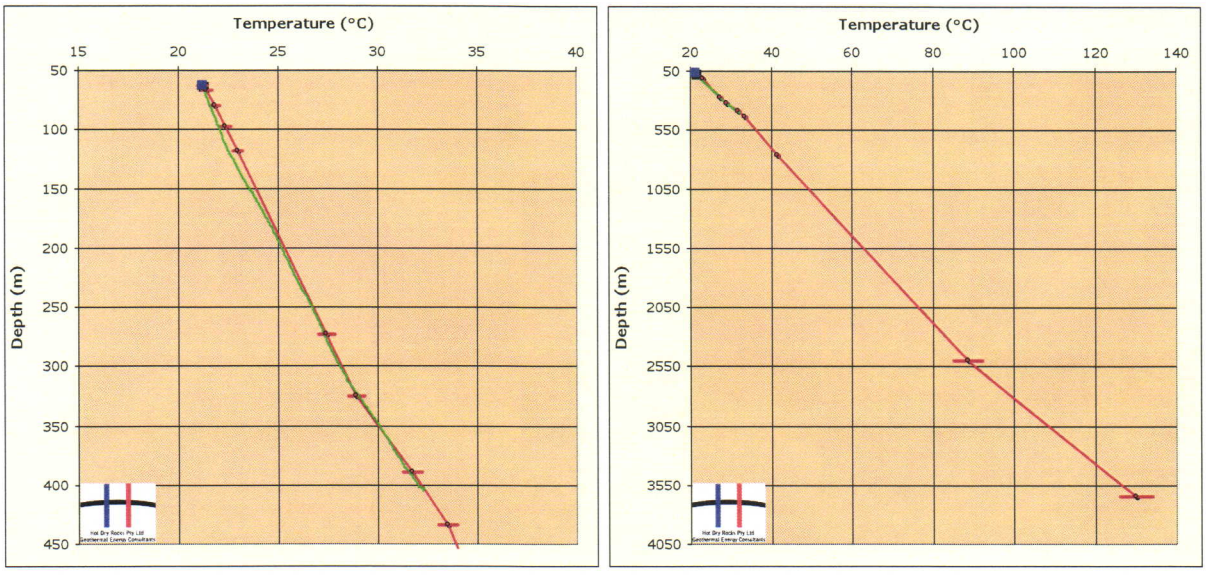

Figure 4. *Left:* 1D conductive heat flow model of water monitoring bore AM27. Green line shows measured temperature data. The red line is the predicted temperature profile for a 1D conductive heat flow model with heat flow = 75 ± 1.7 mW/m^2. *Right:* Modelled temperature profile to 130°C below AM27.

[1] **Sekiguchi, K.** (1984). A method for determining terrestrial heat flow in oil basinal areas. *Tectonophysics*, 103, 67–79.

Total Resource

The total estimated stored heat in the defined reservoir interval is 60,727 PJ (equivalent to 1,926,000 MWt.yrs) within a volume of **536 km^3**.

Classification of Resource

The Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2008 Edition) defines an 'Inferred Geothermal Resource' as "*that part of a Geothermal Resource for which thermal energy in place can be estimated only with a low level of confidence...This category of Geothermal Resource is inferred from geological, geochemical and geophysical evidence and is assumed but not verified as to its extent or capacity to deliver geothermal energy. There must be a sound basis for assuming that a Geothermal Play exists, estimating the temperature and having some indication of its extent.*"

HDR judged that **the stored heat estimated above is best classified as an Inferred Geothermal Resource**. In reaching this decision, HDR took into account the following points:

- The existence of Yarragadee Formation in the Alkimos Geothermal Play is based on lithological data from the water bore drilling logs.
- The existence of the underlying reservoir units (Cadda Formation and Cattamarra Coal Measures) is inferred by analogy with nearby deep petroleum drilling operations (wells Bullsbrook 1 and Eclipse 1), 2D seismic interpretations and generalised Perth Basin stratigraphy.
- The temperature and depth of the reservoir is inferred from 1D conductive heat flow models.

Table 3. Estimated Geothermal Resource within the identified reservoir units for the Alkimos Geothermal Play. Resource estimate rounded to two significant figures.

Licences	Stored heat (PJ)	Volume (km^3)	Inferred Geothermal Resource (PJ)
GEP 2 & GEP 39	*60,727*	*536*	**61,000**

Key Assumptions and Geological Constraints

The following key assumptions underpin this Geothermal Resource assessment.

- The proposed use of the Geothermal Resource is in absorption air chiller technology.
- The stated Geothermal Resource does not include any additional heat that might conduct or advect into the reservoir volume during production.
- The stated Geothermal Resource assumes that advective (including convective) processes within the Geothermal Play transfer no significant heat. There is no evidence from any previous drilling or other investigations that convection plays a significant role in heat transfer within this Geothermal Play. However, if present such processes tend to suppress geothermal gradients and reduce the stored heat resource.
- The heat is stored within a combination of the matrix of the reservoir rock and the contained fluid. The calculations assume an average proportion of 5% fluid.
- This work is based on a model of a section of the Earth's crust. A model necessarily simplifies the true complexity of the Earth and as such is inherently prone to error. The results of modelling stated within this report have been generated using the best available estimates of critical parameters, but future work may yield new information that modifies or falsifies some of these assumptions. All modelling results should be treated as provisional.

This report has been prepared under the direction of Dr Graeme Beardsmore, an employee of Hot Dry Rocks Pty Ltd. Dr Beardsmore was assisted by other employees within HDR but takes sole responsibility and is accountable for the report as a Competent Person as defined by the Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (2008 Edition). Dr Beardsmore is a member of the Australian Society of Exploration Geophysicists and abides by the Code of Ethics of that organization.

Entities associated with Graeme Beardsmore hold shares in Green Rock Energy Ltd.

Dr Beardsmore consents to the public release of this Statement in the form and context in which it appears.

Glossary of terms in their context as used in this report

Base temperature	The temperature of the geothermal fluid once it has passed through a power conversion process, prior to reinjection.
Basin	A three dimensional accumulation of sediments, usually thicker on the down-thrown side of a major fault or in the centre.
Cut off temperature	The minimum reservoir fluid temperature for commercial energy extraction.
Conductivity	A measured property of a rock indicating its ability to transfer or 'conduct' heat energy, usually expressed in Watts per metre Kelvin (W/mK).
Density	A physical property of matter, such as rocks, expressed in mass per unit volume (eg kilograms per cubic metre, kg/m^3)
Earth model	A three-dimensional computer model of part the earth based on grided inputs such as depth maps from well data, gravity data or seismic mapping.
Heat Flow	The amount of thermal energy passing through a square metre at the earth's surface, usually expressed as milli-Watts per square metre (mW/m^2).
Heat Generation	The amount of heat generated by a rock through the natural decay of radioactive elements, usually expressed in micro-watts per cubic metre ($\mu W/m^3$).
Isotherm	A line or surface joining points of equal temperature.
Permeability	The ability of a rock to flow fluid, such as water, usually expressed in milli-Darcies (mD).
Play	A geothermal exploration concept or system consisting of four principle geothermal components; heat flow, thermal insulation, reservoir and access to water.
Porosity	The 'free' space in a rock, not occupied by minerals, cement or clay. A dimensionless unit, expressed as the % of rock volume that may hold fluid.
Reservoir	A body of rock with certain permeability and porosity characteristics which enable it to hold fluids of economic interest.
Sandstone	A coarse grained sedimentary rock chiefly composed of silica grains
Specific heat	The amount of energy required to raise the temperature of 1 kg of substance by 1°C; otherwise known as relative heat capacity, usually expressed in Joules per kilogram per Kelvin (J/kgK).
Stored heat	The amount of geothermal energy 'trapped' as heat within a volume of rock. Quantified as in-place petajoules (PJ).
Well	A bore hole