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Status of the South Meager Geothermal Project British Columbia, Canada: Resource Evaluation and Plans for Development

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ABSTRACT

Potential resources of geothermal power in Canada are principally found in British Columbia, along the costal range, associated with young volcanic activity in the so-called "circum-pacific ring of fire". Other Pacific Rim states have already developed highly commercial geothermal power facilities. Canada has been lagging behind, mostly due to the presence of cheap hydropower in British Columbia. With escalating energy demand and prices, geothermal appears to be the most practical and environmentally clean option to the Province. Early geological, geophysical and gradient drilling activities in the 1970s identified several interesting prospects." Meager Creek" located 170 km north of Vancouver became the selected site for detailed exploration and deep drilling. Despite encouraging data, the project was frustrated by economical downturns during the early 1980's and low energy prices. The South Meager project has the goal of becoming the first Canadian commercial geothermal power development. MT surveys followed by three deep slim holes discovered a high-temperature permeable zone associated with the volcanic vents connected to Pylon peak. This information identified a target for two deep production-size wells to be completed in 2004. The capacity of the reservoir is estimated at 100 MW (net), while the probable capacity of the South Meager site is believed to be about 250 MW. The first phase of commercial production is planned to come on line by mid-2007.

Background

Canadian geothermal exploration started three decades ago in response to the 1970's energy crisis. The federal government and the government-owned utility, B.C. Hydro, sponsored the work. Regional exploration activities targeted young volcanic features in the British Columbia Coastal Range, which is part of the circum-pacific volcanic belt (Figure 1). These activities identified several potential sites, among which the Meager Creek area (located 170 km north of Vancouver) was

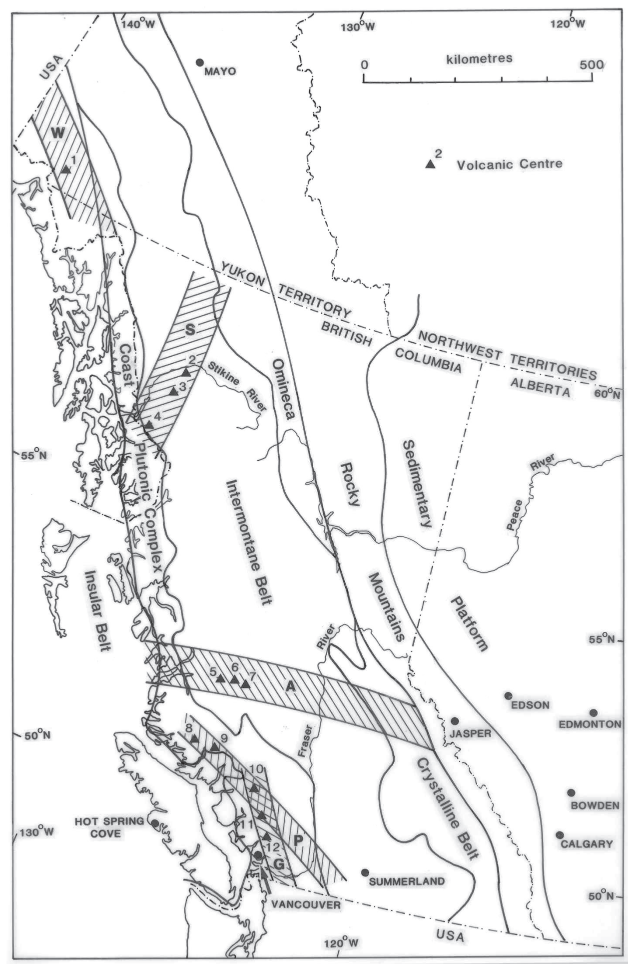

Figure 1. Young Volcanic centers in the British Columbia Coastal Mountains. Meager Complex is situated at the intersection of Garlibaldi and Pemberton ranges. Volcanic belts are labeled: W- Wrangell, S- Stikine, A- Anahim, P-Pemberton, and G-Garibaldi.

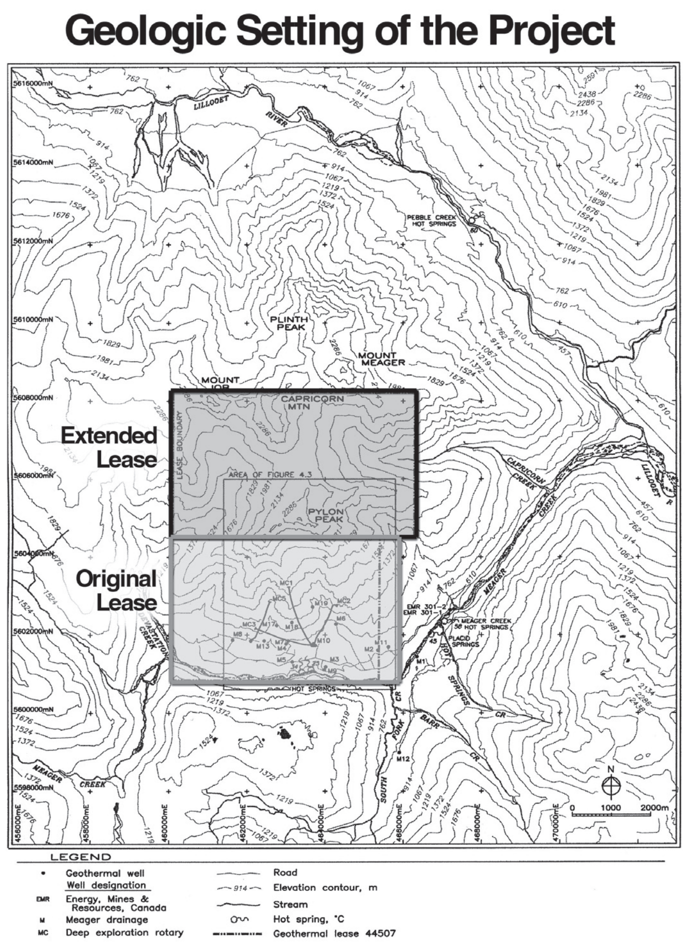

Figure 2. Geothermal lease area of the South Meager Creek Geothermal Project; also showing location of major drill holes.

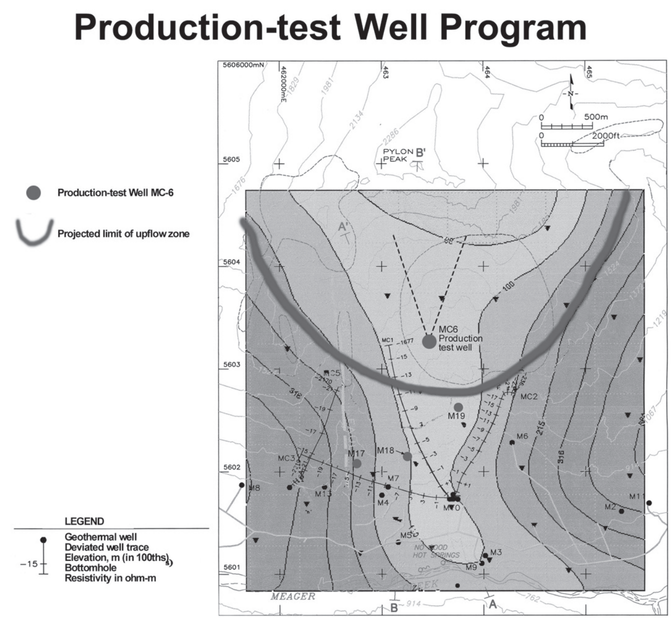

Figure 3. MT anomaly; also showing location of deep drill hoes and the production test wells (planned for 2004).

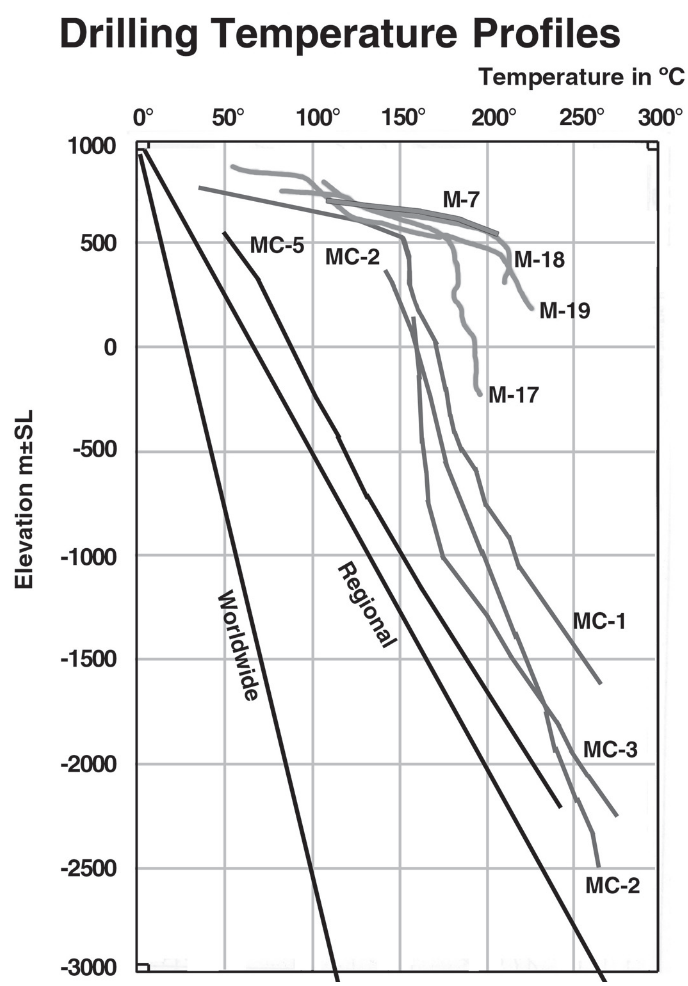

Figure 4. Temperature profiles obtained from major drill holes within the South Meager Creek Project area.

considered as the best prospect. Geophysical and geochemical exploration was followed by slim whole gradient drilling in the North (Pebble Creek) and South Meager areas.

In the early 1980s, three deep exploration holes (MC1, MC2 and MC3) were drilled to a maximum depth of 3500m at the South Meager site (Figures 2 and 3). The test holes resulted in the discovery of fluid temperatures as high as 270°C at a depth of 3000 m. These wells, however, did not prove to be viable for commercial power production, for two reasons: 1) they were not drilled into high permeability zones and 2) well completions were designed for exploration purposes and were not therefore adequate for production. One of the three wells (MC1) proved to have a potential of about 3 MW, had it been adequately completed (Ghomshei and Stauder, 1989; Ghomshei et al, 1992).

Despite the encouraging results, the project was halted by the end of 1985. In 1989 the geothermal lease at the Meager site was granted to Meager Creek Development Corporation (a subsidiary of the present owner, Western GeoPower Corp). Activities started again (under the new owners) in the early 1990s and culminated in 1995 with the drilling of a fourth deep exploratory hole. This well was not productive but proved to be useful for construction of a sub-surface temperature model. The most recent phase of activity started in 2000 under Western Geopower Corp., which extended exploration activities to higher elevations (i.e. further north), where higher temperatures and permeability were expected to be present. MT surveys (Figure 3) and temperature models based on existing well data (Figure 4) suggested that the core of the geothermal system is under Pylon Peak (Figure 5). Three deep slim holes (to a maximum depth of 1200 m) targeted the hot zones identified by the MT and temperature model (see location of M17, M18 and M19 in Figure 3). The results were very encouraging. Temperature gradients of about 150 °C/km were encountered. The wells also provided information on permeabilities at depths below 600 m. Temperature profiles of all wells, including the previous and recent holes (M17, M18 and M18) are presented in Figure 4.

Two deep production-size confirmation wells will be drilled and completed in the year 2004. These wells will target the high-temperature and permeable zones identified by the deep slim holes and the MT data (Figure 3 to 6). At this stage, reservoir models suggest that the reservoir could produce at least 100 MW (net). The area has an estimated capacity of 250MW. Plans are in place to start commercial production in the year 2007. This paper provides a summary of the project, including plans for development.

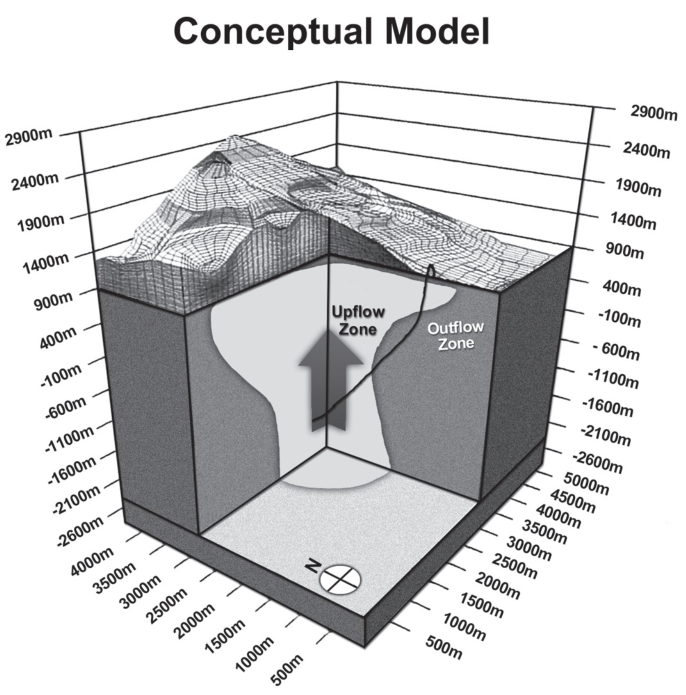

Figure 5. Conceptual Geothermal Model based on temperature and MT surveys, showing the upflow and outflow zones.

Geological Setting

British Columbia is located on the circum-pacific volcanic belt, where active subduction of the ocean floor under the continent gives rise to marginal volcanism. Along the British Columbia Coastal Range there are several active volcanic complexes of andesitic and dacitic composition. Several gas vents and about 100 hot springs are among the surface manifestations of the British Columbia active volcanism. The Meager Creek

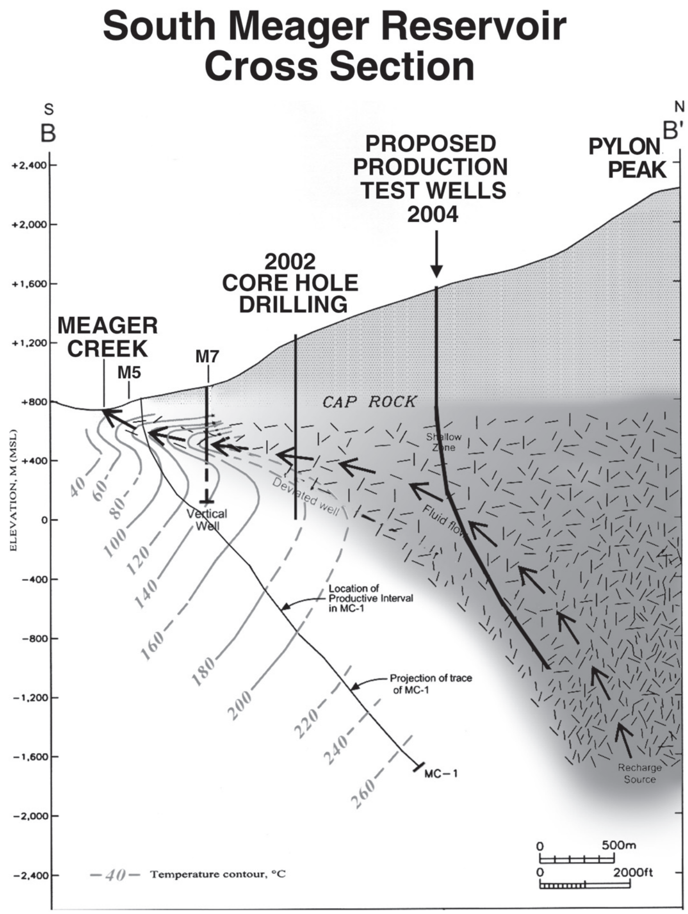

Figure 6. South Meager Creek Reservoir Cross Section; showing location of Meager Creek, Pylon Peak, deep rotary hole MC1, core holes and proposed deviated test hole.

geothermal complex is located in the southwestern corner of the British Columbia, at the intersection of the Pemberton and Garibaldi Volcanic Ranges (Figure 1). The Meager Complex consists of a series of late Tertiary to Quaternary andesitic to rhyodacitic volcanic centers, which intrude plutonic rocks of Jurassic to Cretaceous age (Reed, 1979). These rocks have low permeabilities, except in the fractured areas. Permeability in these rocks is commonly associated with either fault zones or volcanic vents. Fault zones including the Meager Creek fault, which strikes east-west (along Meager Creek) and dips about 50 degrees north, provide conduits for rising geothermal fluids. More pervasive permeability is believed to be associated with fractures around the volcanic vents, beneath Pylon Peak in the South Meager area (Figure2 and 3).

Geochemistry

Detailed major ion and stable isotope chemistry, have been reported by Ghomshei et al (1986), Moore et al.(1983), Nevin (1992), Levia, (1994) and Ghomshei and Clark (1993). Geothermal fluids from deep exploration wells and hot springs display similar geochemical characteristics. All geothermal fluids show a near-neutral pH. Average chloride of the deep fluids is about 2000 mg/l. Constant elemental ratios suggest that fluids have reached geochemical equilibrium with the reservoir rocks. Na/K and Na/Li ratios give reservoir equilibrium temperatures between 210 and 280°C, which correspond with observed down-hole temperature measurements. As for the recent (2002) boreholes, water samples from holes M17 and M18 show very low salinity and high Na/K temperatures around 270°C. The low salinities of these fluids that come from a relatively shallow depth (i.e. less than 1000m) suggest the possibility of steam heating. High temperature and low salinity waters have also been observed and reported in samples from one of the previous slim holes in the South Meager area (Ghomshei and Clark, 1993). Stable isotope data from wells and hot springs suggest a single regional origin for the entire Meager Creek Geothermal waters. The recharge is believed to be waters from relatively low elevations.

Geophysics

Previous geophysical work included a resistivity survey of the entire Meager Creek Area (Flores Lune, 1986; Frontier Geophycis, 2001; Pham, 1980; GeothermEx, 2001). This survey led to the discovery of a significant low-resistivity anomaly extended towards the north of Meager Creek. Early deep drilling (by B.C. Hydro) attempted to target this anomaly. Due to a lack of detailed information on the subsurface geometry of the anomaly, the deep directional holes (MC1, MC2 and MC3) missed the core of the anomaly. A recent MT survey (2001), revealed that the core is significantly further north (closer to Pylon Peak). Recent slim holes (M17, M18 and M19) were therefore drilled at higher elevations to the north towards the core of the MT anomaly. The high temperature gradients encountered corroborate the MT data (Figures 3 and 4). The temperature model constructed based on the down-hole temperature data (from all wells) and MT information indicate an upflow zone closer to the Pylon Peak and an outflow zone extending towards the south.

Slim Holes and Interpretation of Temperature Data

The three core-holes drilled in 2001-2002 to a maximum depth of 1200 m provided information on both temperature and permeability in the target area identified by the MT survey. M17 was the first of the three core-holes drilled in 2001-2002 to explore the southern edge of the anomaly (Figure 3). The well was completed to a depth close to 1200 m in January 2002. It reached a maximum measured temperature of 196°C. The well temperature profile (Figure 4) indicates gradients well above the average gradient in the South Meager area. A relatively constant temperature of about 190°C between depths 800 m to 1200 m (the bottom of the hole) indicates a high-temperature geothermal plume, which, in turn, strongly suggests the presence of hydraulic conductivity. Fault breccia encountered at a depth 1140 m, further supports the possibility of fracture permeability in the system. Low-permeability rocks appear to serve as a cap to the rising plume.

The high temperature fluids encountered in M17, did not flow to the surface, as is usually the case in slim holes, where fluids are subjected to extensive friction. As indicated from the measured temperature profiles (Figure 4), the invasion of some cold fluids to the well at levels above the geothermal influx, is one of the reasons that the isothermal rise of high-temperature fluids to the surface is depressed. Proper sealing of low-temperature zones and flow enhancement of high-temperature permeable zones could have improved the rise of geothermal fluids in the well.

M18 provided information on the high-temperature gradient within the area linked to the MT anomaly. Temperatures above 200°C where encountered in this well at depths of about 550 m. This is the highest temperature encountered at this depth in any well drilled in Canada. The calculated temperature gradient from this well is higher than the expected conductive temperature gradient in the area. The temperature profile therefore suggests the presence of a geothermal plume (similar to that of M17), where rising hot waters and/or steam bring heat to upper levels. M19 reached a bottom hole temperature of 224°C at a depth 913 m. The temperature profile of M19 is similar to that of M18 and indicates the possibility of permeability as the cause of a pronounced convective heat flux.

Geothermal fluid samples, collected from depth (bottom of M17) suggest that the reservoir temperature can be as high as 245 to 270 °C (based on Na, K, Ca, and Li concentrations). Hydrogeochemical data (e.g. very low salinity) also suggest the possibility of steam-heated fluids at relatively shallow depths. Water sample from wells M18 and M19 appeared to be extremely diluted and mixed with shallow circulating cold waters and drilling fluids. Overall temperature and chemical data from these wells suggest the presence of three fluid components: (i) deep geothermal waters, (ii) shallow-circulating cold influx and (iii) some steam.

In summary, temperature, lithology, and chemistry data from the three core holes have been successful in confirming:

(i) The presence of steep temperature gradients in the southern flanks of Pylon Peak.

(ii) The presence of an up-flow geothermal regime in the prospect area

(iii) Geothermal significance of the MT anomaly

(iv) The presence of fracture-related permeability at depth

Temperature Model

A temperature model was constructed by GeothermEx (2004), based mostly on temperature profiles (from old and new boreholes) and MT information (Figure 5). This model shows a significant geothermal upflow under and around Pylon Peak. This upflow zone is linked to the fractured permeability in and around the volcanic vents. Towards the southern flanks of Pylon Peak, there is evidence of an outflow regime, which carries the geothermal fluids laterally to the surface in the Meager Creek Valley. The outflow regime is evidenced by temperature profiles (especially MC1; Figures 3 to 6). The model suggests that previous deep holes have been targeting the outflow regime at shallow depth and had missed the convective plume at deeper levels (Figure 6).

One of the previous deep holes (MC1) which targeted the vicinity of the anomaly, demonstrated higher temperatures and higher permeabilities. This well produced high-temperature geothermal fluids (of about 200 to 210°C) and was used to supply a 20 kW demonstration plant in 1984. MC1 had a potential to be a productive well, had it been properly completed (Ghomshei and Stauder, 1989). It was, however, unsuccessful because of (i) inadequate well completion (leading to in well flashing) and (ii) loss of more than 500 meters of line at the bottom of the hole (in the potentially high-temperature and most productive zone).

The recent core holes were more successful than previous ones due to being closer to the upflow zone and intersecting the outflow system at deeper levels. The proposed production-size test wells are therefore designed to target the upflow zone at deeper levels (Figures 3, 5 and 6).

Plans for Deep Confirmatory Drilling and Production

Based on the volumetric heat content of the accessible portion of the upflow zone, geothermal power reserve within the lease boundaries is estimated at approximately 250 MW. This value is the output of a probabilistic approach (using Monte Carlo simulation) taking into account reasonable assumptions on (i) the percentage of the heat that is expected to be recovered at the surface, and (ii) all efficiency factors related to converting that heat to electrical energy (GeothermEx, 2004). This value is not far removed from an earlier assessment (Ghomshei and Stauder, 1989), which suggested 200 to 300 MWe for a period of at least 30 years. The most secure part of this resource is expected to provide at least 110 MW. Based on this estimate, the first phase of development has been planned for 100 MW (net) to come on line in mid-2007. Planned development of South Meager Creek is, however, based on meeting three conditions: (i) commercial well productivity can be demonstrated by drilling and testing of confirmation wells; (ii) an adequate number of drilling sites should be identified in the rugged terrain of this field and (iii)- availability of a long-term power sales contract; with an estimated price of at least C$50/MW-hr is needed to break even for a 100 MW plant (GeothermEx, 2004).

The first condition is planned to be met by drilling two directional holes from a single pad (Figures 3 and 6) into the postulated upflow zone (Figure 5) of the South Meager geothermal system. This confirmation strategy targets the deeper zone of higher temperatures (up to at least 260°C). These wells will be 2,000 m to 2,500 m deep and deviated to test the geometry and permeability of the upflow zone, which offers the best opportunity to achieve high per-well production capacities. To maximize the likelihood of demonstrating commercial production at an acceptable cost, the initial confirmation wells are expected to be followed by two additional full-diameter production wells.

As for the second condition, all production wells can be drilled from four pads (including the pad used for the confirmation wells). Anticipated well depths are shallower than about 2,500 meters. Assuming a typical minimum 300-meter well spacing, there are approximately 45 available targets. Reaching these targets will require directional drilling from the four production pads.

It is envisaged that the South Meager Project will be developed using dual-flash turbine technology with two standard 55 MW (gross) generating units. The value of this project has been estimated by conducting a conventional cash flow analysis for a 110 MW (gross) / 100 MW (net) power plants, to come on line in mid-2007 (GeothermEx, 2004).

Concerning the third condition, a wholesale power price of C$70 per MW is assumed, which is the price currently being offered by BC Hydro under the Renewables Certificate program. The power price and demand are both assumed to escalate in British Columbia. Local market for the generated power will therefore be available at well above break-even price. Considering recent re-structuring of B.C. Hydro and creation of a separate power distribution authority, possibilities also exist for the sale of the generated power directly to other users or utilities. Emerging green energy users are very keen on buying geothermal energy. The University of British Columbia has already expressed great interest in running their entire campus on geothermal power from Meager Creek.

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