Appendix 5.10
Geothermal Review and Site Inventory
(KGS 2016)

YUKON
ENERGY

Geothermal Review and Site Inventory

FINAL – REV 0

KGS Group 16-1404-001
August 2016

Prepared By

Joel Lambert

Joel Lambert, P.Eng.
Senior Mechanical Engineer

PROFESSIONAL
YUKON
J.C.J. LAMBERT
TERRITORY
Sept 8, 2016
ENGINEER

Approved By

Jason Mann, P. Geo
Senior Hydrogeologist

KGS Group
Winnipeg, Manitoba

Kontzamanis Graumann Smith MacMillan Inc.

KGS GROUP
CONSULTING ENGINEERS

3rd Floor
865 Waverley Street
Winnipeg,
Manitoba
R3T 5P4
204.896.1209
fax: 204.896.0754
www.kgsgroup.com

September 8, 2016

File No. 16-1404-001

Yukon Energy Corporation
2 Miles Canyon Road
Whitehorse, Yukon
Y1A 6S7

ATTENTION: Mr. Marc-André Lavigne
Resource Planner

RE: Geothermal Review and Site Inventory
Final – Rev 0

Dear Mr. Lavigne:

Please find enclosed a PDF version of our revised draft report for the Yukon Energy Corporation Geothermal Review and Site Inventory. The primary objective of this study was to develop potential geothermal projects at a conceptual level. This study included identifying potential sites and providing economic analysis for these sites to determine whether a geothermal project was feasible in the Yukon. This revision addresses the comments received from Yukon Energy Corporation on the Draft B report.

After reviewing past reports and performing a volumetric assessment; the Vista Mountain and McArthur Springs locations were determined to have the largest production capacity for sites located near Yukon Energy Corporation's existing or planned infastructure. As the exact amount of production capacity is unknown, we have considered alternatives for both sites. The best and worst case senario in terms of production from the geothermal wells were considered for our analysis. For each alternative, we have developed monthly generation profiles and cost estimates including the construction and long term costs for developing these geothermal projects.

Please review the report and provide any comments you may have. We thank you for the opportunity to work on this project.

Sincerely,

Joel Lambert

Joel Lambert, P.Eng.
Senior Mechanical Engineer

JCL/ama
Enclosure

EXECUTIVE SUMMARY

Yukon Energy Corporation retained the engineering services of KGS Group to develop conceptual designs for geothermal projects in the Yukon. KGS Group retained Mannvit hf from Iceland to perform the final review of the site selections, assessment of geothermal well field needs, plant sizing, and determination of the appropriate technology and process to be used for the selected sites. KGS Group also retained InterGroup Consultants to perform the economic evaluation of the concepts developed. The study includes identifying potential sites and providing cost estimates and energy generation profiles for these sites to determine whether a geothermal project is feasible.

KGS Group and Mannvit hf reviewed the memoranda and reports provided by YEC and established a ranking of the sites from most favourable to least. The terms of reference for the project were to consider only sites that were located within 25 km from existing or future planned infrastructure.

Of the sites within the geographic location criteria, the Vista Mountain site was the most attractive because it is located on crown lands, close to the load centre of Whitehorse, has a relatively high inferred temperature, and it is very close to the North Klondike Highway and the Takhini substation.

The most promising site reviewed was McArthur Springs. Although it does not lie within the corridor 25 km on either side of existing or planned infrastructure, it has the highest inferred temperature. Unfortunately, the length of the access road and transmission lines required to develop this site increase the expected project costs considerably.

Since no exploration wells have been drilled at any of the sites reviewed, including the Vista Mountain and McArthur Springs sites, there is considerable uncertainty regarding the actual reservoir temperature, chemistry and production index (PI) of the geothermal wells. This report presents optimistic and pessimistic cases for the PI at each site and the resulting plant capacities were determined using the geothermal fluid temperature that was inferred using geothermometer calculations.

The expected plant capacities from the Vista Mountain site range from 0.9 MW net output to 2.3 MW net output. The expected plant capacities from the McArthur Springs site range from 2.1 MW net output to 5.5 MW net output. The actual plant capacity that can be developed will be dependant on the actual geothermal fluid temperature and the PI values encountered once the wells are drilled. The plant capacities being limited by the estimated capacity of the geothermal resource.

The Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC) for the Vista Mountain site are shown in the Table below.

Geothermal Cases	**Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)**					
	3.38% Real WACC		**4.61% Real WACC**		**8.82% Real WACC**	
	LCOE (2015$)	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**
	$/kW.h	**$/MW**	**$/kW.h**	**$/MW**	**$/kW.h**	**$/MW**
A	**B**	**C**	**D**	**E**	**F**	**G**
Vista Mountain Case 1: 0.9 MW	$0.368	$2,330,074	$0.412	$2,658,409	$0.577	$3,901,681
Vista Mountain Case 2: 2.3 MW	$0.194	$1,094,589	$0.214	$1,248,829	$0.290	$1,832,876

The Vista Mountain Case 1 with 0.9 MW net development scale shows about two times higher LCOE and LCOC under each WACC scenario compared to the higher scale capacity and energy Case 2 [with 2.3 MW]. This highlights that any small scale version of the project is likely not financially attractive.

The Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC) for the McArthur Springs site are shown in the Table below.

Geothermal Cases	**Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)**					
	3.38% Real WACC		**4.61% Real WACC**		**8.82% Real WACC**	
	LCOE (2015$)	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**
	$/kW.h	**$/MW**	**$/kW.h**	**$/MW**	**$/kW.h**	**$/MW**
A	**B**	**C**	**D**	**E**	**F**	**G**
McArthur Springs Case 3: 2.1 MW	$0.469	$3,220,803	$0.527	$3,674,652	$0.746	$5,393,197
McArthur Springs Case 4: 5.5 MW	$0.225	$1,388,937	$0.250	$1,584,655	$0.343	$2,325,759

The McArthur Springs Case 3 with 2.1 MW net development scale shows more than two times higher LCOE and LCOC under each of the WACC scenarios compared to the higher scale Case 4 capacity and energy. This highlights that any small scale version of the project is likely not financially attractive.

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

FIGURES
DRAWINGS
APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF APPPENDICES

1.0 INTRODUCTION

Yukon Energy Corporation (YEC), established in 1987, is a publicly owned electrical utility which provides reliable electricity to close to 15,000 consumers. The hydro facilities at Whitehorse, Mayo, and Aishihik Lake provide 92 megawatts of power to the surrounding communities. With 39 megawatts produced by diesel generators (currently used for back up) and 0.65 megawatts by a small wind turbine on Haeckel Hill near Whitehorse, Yukon Energy has the capacity to generate close to 132 megawatts. In support of Yukon's long term load forecast, YEC seeks to refine the knowledge and determine the feasiblity of potential geothermal generation projects in the Territory.

Yukon Energy Corporation retained the engineering services of KGS Group and indirectly, KGS Group's subconsultants, Mannvit hf of Iceland and InterGroup Consultants, to review existing reports and data, identify preferred sites, and develop conceptual designs for geothermal projects in the Yukon. The study includes cost estimates and energy generation profiles for these sites as well as the expected levelized costs of energy and capacity. The results of this study will be used to support Yukon Energy Corporation's planning process to look at potential resource options to meet the long term load forecast for 2016-2035.

1.1 TERMS OF REFERENCE

The scope of work for this study included the following:

- Attend a project kickoff meeting with YEC by conference call.
- Project Management.
- Review the 26 memoranda and reports previously completed by YEC on the available geothermal resources available in the Yukon.
- Identify all potential geothermal sites within 25 km of existing and/or planned infrastructure as illustrated by Figure 1 from the RFP.
- Employing the above information, select the best three (3) sites. Evaluate the site-specific requirements (procurement of land, # of wells, and type of equipment and cost of transmission/distribution) and develop conceptual level geothermal projects for various generation capacities, namely 5 MW, 10 MW and 20 MW.

- Develop monthly generation profiles for the three sites based on the projected capacities.
- Develop AACE Class V cost estimates (-50% to +100%) for the three sites based on the projected capacities.
- Identify preliminary risks and potential "Show Stoppers" for the three sites. However, it is noted that the evaluation of the three geothermal projects against the environmental and socio-economic attributes will be completed as a separate project.
- Identify and evaluate potential O&M costs for operation of the three sites based on the various generation capacities.
- Generate high-level project schedules (including provisions for further exploratory work, data collection, effects assessment, permitting and the like) from the early planning/exploration phase through to the project commissioning phase.
- Evaluate the earliest possible in-service date and potential project life for each of the three sites.
- Prepare a report detailing the study process and findings.

The items identified below were excluded from the scope of work:

- Collection of any additional environmental, geotechnical, or physical data; and
- Evaluation of the three geothermal projects against any environmental and socio-economic project attributes.

1.2 MODIFICATION TO THE ORIGINAL TERMS OF REFERENCE

Given the budget set aside by Yukon Energy Corporation to complete the study, the KGS Group proposal indicated that there would be greater value to Yukon Energy Corporation in developing fewer concept designs and providing a more in-depth review of fewer design options, than could be done if the 9 scenarios requested in the RFP were pursued. It was decided at the kick-off meeting that the existing data would be reviewed and the sites ranked from most to least attractive. From these intial rankings, a determination was made as to the number of total sites to be evaluated, and for the range in generating capacity for each site.

As described in Section 2, two sites were selected for concept design development and two different capacity levels were considered at each site; thus resulting in a total of four concept designs and cost evaluations.

2.0 REVIEW OF EXISTING INFORMATION AND RANKING OF SITES

KGS Group collected and reviewed pertinent documentation, reports, drawings, surveys and other data, assessed the available information, and identified the additional information required to effectively complete the study. The reports received from Yukon Energy Corporation are listed in Appendix A – Bibliography**.**

Information from CanGEA/Energy Branch was also used in this assessment. The information had not yet been published but Yukon Energy Corporation provided “early access” to assist with this work.

2.1 COMMENT ON AVAILABLE INFORMATION

In general, the reports provided by YEC were compiled over a number of years of study (typically between 2009 and 2012), and for the most part by the same engineering consultant. Some of the reports, such as more broadly based, sub-regional to regional aerial photography interpretation reports and/or other geophysical studies, for example, are of general interest in defining possible geothermal source signatures over larger areas, but did not factor directly into assessments and calculations necessary for completion of the current study. As such, these more regionally based reports were not reviewed in detail, other than to provide some context if/as necessary in relation to site terrain or general geological conditions of the region of interest.

Key data sources necessary for developing the current study included:

- Basic details associated with the overall geological setting and geological structure(s) of the potential geothermal resource;
- Measured surface spring temperature data;
- Measured water quality data to infer the possible relationship of the flow system(s) to deeper seated plutonic heat sources;
- Calculation of geothermal source temperatures via geothermometer calculations (typically SiO2 geothermometer techniques);
- Isotope signatures of source waters to infer residence times and possible deep-seated geothermal sources;

- Measured or estimated geothermal gradients (if any were available); and
- Typical ground temperatures for the region, and climate normal data, used to assess heat exchange processes necessary with the power generation schemes assessed in the study.

Each of the potential geothermal resources, ranked into the project shortlist during the course of this study, included some basic understanding of the geological framework and hydrogeological setting within which the possible geothermal resourse is hosted. This is of importance as there must be a conduit through which groundwaters can circulate to depth, become heated, and return back toward surface, to provide a signature for a possible geothermal resource target. The geochemistry of these heated spring waters will vary, depending on the geology, residence times, and flow path length/depths to which these groundwaters circulate. These signatures, in absence of direct measurements of a possible geothermal resource, are important in deducing the potential for a viable geothermal system.

Those resources in the vicinity of Whitehorse (e.g. Vista Mountain, Takhini, Stinky Lake and Versluce) are hosted within fault zones and ancillary fault zones of the “Whitehorse Trough”. The Whitehorse Trough is associated with an intermontane setting, comprised of an intensely folded, faulted and metamorphosed geology, and is juxtaposed along the Nahlin Fault zone, and south of the Tintina Fault, which is a significant, territory-wide structural feature.

Other short-listed geothermal features, namely Jarvis River, Partridge Creek, and the McArthur spring, are associated with a valley setting comprised of thick sediment cover, though bounded by assumed deep and sub-vertical fault zones; a zone of intense fracturing, faulting, and shearing along the Tintina Trench; and within the Selwyn Fold Belt, respectively. The Tintina Trench is associated with a massive Territory-wide fault zone, extending continuously for hundreds of kilometers, and the Selwyn Fold Belt formed during a phase of basin folding and during large scale mobilization of regional fault structures.

It is important to note that the evaluation of all of these potential geothermal resource sites as necessary for the current study are being completed using inferred data. None of these geothermal resources have been measured directly, and it is possible that direct measurement of these geological and geothermal features at depth could result in a different conclusion.

Site rankings and interpretations of possible geothermal resources are discussed in the following report sections.

2.2 SITE LOCATION CRITERIA

The terms of reference for this study stipulated that sites located within a 25 kilometre range of existing and planned future Yukon Energy Corporation infrastructure (i.e. transmission & distribution lines, substations, switchyards, etc.) would be considered for evaluation. This is due to the relatively high additonal costs of support infrastructure such as construction of access roads and interconnections via new transmission lines. This was the first screening criteria applied to all target geothermal resources, and several of the sites discussed in the reports and memos were eliminated from consideration based only on this proximity criteria. Figure 1 is a map of the geographical area in question, which includes the locations of the potential geothermal sites. Table 1 lists the longitude and latitude of the sites that meet the location criteria, as well as the "straight-line" distance to the existing or planned infrastructure and estimates of the transmission line and access road lengths that would be necessary to develop the site.

TABLE 1
SITES LOCATED WITHIN 25 KM OF EXISTING OR PLANNED INFRASTRUCTURE

NAME OF SPRING	LATITUDE	LONGITUDE	STRAIGHT LINE DISTANCE TO TRANSMISSION LINE	ESTIMATED ACCESS ROAD LENGTH	ESTIMATED TRANSMISSION LINE LENGTH
	[deg - min]	[deg - min]	[km]	[km]	[km]
Takhini	60 52	135 22	1	1	1
Versluce	60 46	135 09	1	1	1
Mayo well	63 36	135 53	1	1	1
Stinky Lake	60 45	135 08	1	1	1
Vista Mountain	60 55	135 11	4	2	5
Jarvis Creek	60 54	137 57	5	5	5
Partridge Creek	63 41	137 18	15	20	20
Atlin	59 24	133 35	20	1	22
Morin North	59 59	134 13	22	33	33
Morin Middle	59 58	134 13	22	33	33
Jones Lake	59 53	134 00	22	22	22
Morin South	59 58	134 13	25	30	30

Of these sites, the Takhini, Versluce, Vista Mountain and Stinky Lake sites are attractive from a geographical location point of view because of their proximity to Whitehorse and the major load centre in the Territory.

There were a few sites that, while not within the area of interest, were reviewed. These sites are listed in Table 2.

TABLE 2
SITES LOCATED CLOSE TO LOCATION CRITERIA

NAME OF SPRING	LATITUDE	LONGITUDE	STRAIGHT LINE DISTANCE TO TRANSMISSION LINE	ESTIMATED ACCESS ROAD LENGTH	ESTIMATED TRANSMISSION LINE LENGTH
	[deg - min]	[deg - min]	[km]	[km]	[km]
McArthur	63 04	135 42	37	43	43
McPherson	61 52	129 37	41	50	50
Volcano Mountain	62 54	137 20	33	35	35

2.3 SITE RANKINGS

Once the location screening criteria was applied, the available information for the remaining sites was reviewed. This amount of information available for each site varied. Some sites had almost no information at all (e.g. Volcano Mountain and the Sites near Atlin), while reports contained water temperature, groundwater chemistry, spring flow rates and isotope analyses for some of the other sites.

The following sites were eliminated from consideration from this study based on the lack of available information.

- Volcano Mountain.
- Atlin.
- Jones Lake.
- Morin (South, Middle and North).
- Mayo Well.

Further investigation/exploration may indicate geothermal resources worth developing at these sites, but there is not sufficient information available at this time to make this determination.
The remaining sites, each including enough base information for a cursory resource evaluation, were ranked as follows (Refer to Appendix B – Site Ranking Summary for further details):

- Vista Mountain Warm Spring.
- Takhini.
- Stinky Lake Warm Springs.
- Versluce.
- Jarvis Creek (Jarvis River) Warm Spring.
- Partridge Creek.
- McArthur Spring.

Interestingly, based on the available data, the McArthur Spring, although not in accordance with the proximity to existing/future infrastructure criteria, appears overall to be the site with the greatest inferred potential for a “low temperature” geothermal source. It was ranked at 7 due to its distance from the nearest transmission line (Carmacks-Stewart line), and associated complexities in constructing road access and power transmission interconnections in a rugged terrain setting.

Vista Mountain ranks high due to its close proximity to infrastructure and the main load center of Whitehorse, location on Crown lands, and relatively high inferred resource temperature (110°C, or “low temperature” geothermal) in comparison to other possible Whitehorse region sites which have an inferred temperature of <100°C (Klump and Dennett, December 2012). The Takhini geothermal resource is also in a good geographical location, however it is situated on private land and it is currently being operated as a recreational “Hot Spring” business, which is a major destination in the Whitehorse area. The inferred temperature of the Takhini geothermal resource is just below the “low temperature” geothermal resource threshold cutoff, at an inferred resource temperature of approximately 96°C (Klump and Dennett, December 2012).

It should be noted that, of the remaining sites in the Whitehorse region (i.e. Stinky Lake, Versluce, and Jarvis River), there is not one site that is siginificantly better than the others, and the associated inferred maximum resource temperature of these sites is approximately 100°C. Partridge Creek, while in accordance with the transmission right-of-way screening criteria, is further from the main Territory load center of Whitehorse, located approximately 115 km southeast of Dawson City. The inferred resource temperature of Partridge Creek is somewhat low, with geothermometer readings as low as 95°C, though depending on the geothermometer calculation used, reported estimates on reseource temperature vary between approximately 100°C and 120°C (Klump and Dennett, April 2012). Access/transmission construction to Partridge Creek is overall within rugged terrain, thus increasing site development logistical complexities, and overall associated costs as compared to possible geothermal resources located closer to Whitehorse. The difference in the current site rankings is within the expected margin of error, and given more information from further investigations or explorations, the site ranking order may vary.

All the reviewed sites for this report are low/medium temperature resources. Low/medium temperature resources have temperature less than 150°C. The fluid is usually pumped from the wells as a liquid. The heat from the fluid is used for generating electrical power in a binary power cycle as described in Section 3.2.1. For comparison, the temperature in high temperature resources are typically over 200°C. The fluid from the wells is usually in two phases, liquid and steam, but in some cases dry steam. The steam can be used directly in turbines. The efficiency and feasibility of such power plant is usually better than for a power plant using low/medium temperature resource in a binary power cycle.

2.4 PREFERRED SITES AND POTENTIAL PLANT CAPACITIES

Given that there was not a marked difference between the attractiveness of the Whitehorse region potential geothermal resource sites (other than for inferred resource temperature), the KGS Group team and Yukon Energy Corporation decided to develop concept designs for only one of these sites. Due to the limited baseline data available, there is little to no difference in the concept design that would apply to any of these sites. However, it was decided that a site with the highest inferred geothermal resource temperature, and relatively straightforward construction considerations (i.e. Vista Mountain), would form the best base case for assessment in the Whitehorse region. The Vista Mountain concept design is in general representative of the concept that could be developed for the remainder of these Whitehorse region sites.

The Vista Mountain Warm Spring site was selected because it:

- Ranked better that the other Whitehorse region sites, based on inferred geothermal resource temperature.
- Is geographically located near Whitehorse and near the Takhini substation.
- Is located near the North Klondike Highway.
- Has a relatively gentle surrounding terrain with good access; and
- Is located on public (Crown) land.

Regarding the resource capabilities, the main assumption for the preferred sites is that each geothermal resource capacity declines annually by 2%, as a “natural” decline. As a face value, the lifetime of each project is just over 30 years, if no new make-up wells are drilled. For the range of the selected Productivity Indices (PI) and temperatures, as well as assuming the power generating processes presented in the following report sections, each well power output was estimated to be 0.6 to 3.5 MW_e. The annual well decline would be approximately 0.02 to 0.1, depending on the PI and temperature.

The annual production decline of 2% is taken from the world literature and it applies to high temperature geothermal projects with successful reinjection. For the Yukon projects which are assumed to be operated at much lower temperature, the 2% annual decline is a reasonable estimation.

For this type of reservoir, reinjection will boost the reservoir pressure by providing an extra mass flow. Ideally the reinjection strategy is to locate the injection and production wells close together to provide pressure support, but far enough apart to prevent premature thermal breakthrough. Without any reservoir simulations in hand, the minimum distance between a production and a reinjection well is considered to be about 1,000 m. The world average between production and reinjection wells for this type of reservoir is about 1,300 m.

The two cases at Vista Mountain are primarily based on two assumptions for PI. Case 1 has a PI of 1 kg/s/bar, producing 1.2 MW gross and 0.9 MW net. Case 2 has PI of 5 kg/s/bar, producing 3.1 MW gross and 2.3 MW net. The number of wells and completion depth of the wells are the same for both the cases and the expected geothermal resource temperature is estimated at 120°C. The only difference between the cases is the PI value which results in different mass flow from the production wells. Wells with less mass flow like in Case 1 do not need as powerful well pumps as Case 2 and other parasitic load for such a plant (e.g. power to run well pumps and condenser fans, etc.) is also less. The two PI values are estimates of likely ranges estimated for the McArthur reservoir as well.

The McArthur Warm Spring site was also selected for assessment. Although it is situated outside the geographical proximity to transmission tie-in screened within this study, and while the terrain/access conditions appear difficult, it was the only site where the available raw data showed a geothermal resource that was of significantly higher temperature than all other potential geothermal resource sites studied to date. In fact, based on the raw water quality data provided, a recalcuation of the silica geothermometer for this resource indicates it may be inferred to be as high as approximately 155°C – 160°C. While not included in the current assessment, it is important to note that the site is located on land that has significance to the local First Nations community.

The two cases at McArthur are, as in the Vista Mountain case, primarily based on two assumptions for PI. Case 3 has PI of 1 kg/s/bar, producing 2.8 MW gross and 2.1 MW net. Case 4 has PI of 5 kg/s/bar, producing 7.0 MW gross and 5.5 MW net. The number of wells and depth of the wells are the same for both the cases, and the expected temperature value is estimated at 160°C. The only difference betweem the cases is the PI value which results in different mass flow from the production wells. Wells with less mass flow like in Case 3 do not need as powerful well pumps as Case 4 and other parasitic load for such a plant is also less.

Drilling of make-up wells is usually a part of the normal operation of a geothermal power plant in order to replenish the reduced capacity of the production wells. How frequently make-up wells are drilled depends on the decline rate as well as number of wells. The cost of drilling one make-up well can, however, be a large part of the total cost for power projects with few wells making the make-up drilling less feasible. In the case of the Vista Mountain and McArthur Springs sites, it is expected that the drawdown in the wells will be governed by the general drawdown in the resource. As the temperature decline and degradation of equipment are also independent of the wells, we conclude that make-up wells will not remedy the output degradation.

Due to lack of geophysical data, the actual size of the geothermal resource could not be delineated. Therefore, a conventional volumetric capacity estimate was not possible. The approach here was to use the length of the mapped faults to determine how many wells could be drilled in each area. The assumption is that the faults are the main providers of the necessary permeability to sustain the proposed geothermal production. The second assumption is that 1000 m spacing is required between the wells. These assumptions lead to the conclusion that both the areas (Vista Mountain and McArthur Springs) could each sustain two production wells and one injection well. The limited number of wells that could be sustained at each site limit the plant capacities that could be developed at these sites to the values included in this report.

Dissolved solids and/or gases may require water treatment mitigations, such as relatively high plant operation pressure and/or necessary chemical treatment. The nature of geothermal plants is such that these problems are normally inherited and unavoidable, but mitigatable. The mitigation methods depend on the nature of the geothermal fluid (like chemical composition, temperature and pressure). Since little is known about the nature of the geothermal fluid in these resources which are being dealt with here, the extent of the mitigation process is unknown. Possible problems and mitigations for geothermal fluids are listed in Table 3.

TABLE 3
WATER TREATMENT MITIGATIONS

PROBLEM	MITIGATION
High CO_2 gas content of the fluid leads to high CO_2 emission into the atmosphere.	Keep the CO_2 dissoved in water by relatvely high wel head pressures and reinject it back into the reservoir.
Low pH (acid geothermal fluid) which can be corrosive for wells and pipelines.	Injecting a solution with high pH value into the well to neutralize its acidity.
Mineral scaling due to silica (SiO_2) and/or calcite ($CaCO_3$).	Inhibitors injected into the well, high operation pressures, repeated cleaning.

2.5 FURTHER EXPLORATION

The geological information available for the Vista Mountain site is general and further work is needed to assess the geothermal potential of the area. The assessment should be divided into two phases.

The first phase should focus on the surface geology, structural arrangements and geochemistry in the Vista Mountain area. The target of the work is to estimate the resource temperature and to delineate the geothermal area. With this information, the power capacity can be estimated. The estimated power capacity value will be used as a go/no-go decision for further work.

If the decision is to continue the investigation, the assessment will move to phase two. The work in this phase mainly focuses on geophysical surveys. There are several geophysical surveys which can be utilized. Normally two to three individual surveys are recommended. Typical surveys are resistivity surveys (for this area, Transient Electro-Magnetic (TEM) surveys are ideal and Magnetotelluric (MT) surveys are less so due to the low probability of adding information on the resistivity structure of the area), gravity surveys and magnetic surveys. Surface surveys, like soil temperature and soil gas mapping are also ideal, as well as thermal gradient drilling. The soil/gas temperature mapping measures the temperature and the gas flow in the soil down to 1 meter depth. Soil temperature/gas mapping will find anomalously hot areas, which are normally tied to permeable structures. These permeable structures could be then targeted at greater depths. Prior to drilling thermal gradient wells, the regional gradient must be known so anomalous areas can be delineated. In other words, the proposed thermal gradient survey will focus on finding anomalously hot areas. In low temperature areas, the thermal gradient wells only need be 30-60 meters deep, if the permeability is low. The number of wells will vary greatly, but 10-15 wells are not an unrealistic number of thermal gradient wells.

If after the completion of the assessment, deep drilling is still considered too risky, one option is to drill “slim” exploration wells (i.e. test boreholes with diameters less than 150 mm, or 6 inches) which are deep enough to penetrate into the top of the geothermal resource. Slim wells offer cost effective solution compared to a full diameter research well. The resource temperature can be measured in slim wells and short production/injection testing can be carried out as well. Nevertheless, slim well drilling is risky, particularly with deep wells, and it is highly unlikely they can be used as either production wells or reinjection wells.

3.0 VISTA MOUNTAIN

3.1 SITE DESCRIPTION

Vista Mountain is located approximately 4 km North of Takhini Substation and approximately 1 km West of the North Klondike Highway, as shown on Figure 2. Access to the site is good. Most of the distance between the North Klondike Highway and the spring is generally flat, with a rise in elevation on approach to the spring site itself. It is estimated that the optimum transmission line route will follow the access road from the plant to the North Klondike Highway. The line would then follow the existing right of way to the Takhini substation.

3.1.1 Regional Geology and Site Observations

Site visits were not included in the scope of this project, therefore the Vista Mountain site, and any geological observations are based on the available reports (e.g. Klump and Dennett, December, 2012), and satellite/aerial images of the surrounding landscape. Review of aerial photography indicates a relatively flat (+/- 2 m elevation variation) rock outcrop south of the spring site suitable for construction of the powerhouse and condenser. There is strong evidence of glacial scouring, with most exposed outcrops with a smooth and rounded morphology. The rock is generally of low relief, with fluted outcrops trending in a northwest-southeast orientation, separated by narrow shallow depression areas. Limited overburden stripping and minimal bedrock excavation is estimated to be necessary to prepare the preferred construction site, south of the spring. Based on the extents of visible bedrock, it is estimated that all major structures can be founded on concrete slabs cast directly on the prepared bedrock surface, with smaller components such as pipe supports or doweled directly to the rock surface. Rock types in the area include massive to thickly bedded limestones, and sandstones, shales, and conglomerates. Specifically, outcrops of limestones and shales are observed at the spring site itself. As reported by Klump and Dennett (December, 2012), typical slopes are gentle (e.g. 15% to 26%), to moderate in other site areas (i.e. 27% to 49%) away from the relatively flat location that would be targeted for construction of any facility, and as described above.

As described by Klump and Dennett (December, 2012), two regional fault trends are typical in the study area, subsidiary zones associated with the more regional Whitehorse Trough. These faults trend in a northwesterly direction, and in a north-northeast, to northerly direction. The spring site itself is located at the intersection of two prominent faults. Dominant jointing directions measured at the site are generally in a north-south direction, dipping to the west, with secondary discontinuity orientations northwest-southeast (dipping southwest) and/or oriented northeast-southwest with a sub-vertical dip. The project area includes zones of glaciolacustrine deposits, overlying the bedrock.

The project site as well lies within the zone of discontinuous permafrost in Canada, where frozen ground is scattered throughout these kinds of glaciolacustrine fine sediments. In general permafrost is most common within poorly drained and low-lying bog areas where layers of peat and vegetation insulate the ground and prevent permaforst thaw. At this time, permafrost design issues are not included within the conceptual assessments. However, based on the extents of visible bedrock at the site it is not estimated that permafrost issues would be significant for development at this site.

3.1.2 Availability of Construction Material

Construction materials would need to be sourced to provide for aggregates for access road construction as well as concrete production. From a review of satellite photography, established aggregate sources are located within 15 km of the site which could likely provide all aggregate needs for the project. If the available local aggregate sources are not sufficient or accessible, other established aggregate sources in the Whitehorse area would provide the required construction materials.

3.2 PLANT ARRANGEMENT

3.2.1 Organic Rankine Cycle (ORC) Power Plant

The Vista Mountain site was estimated to produce geothermal liquid at 120°C. The design concepts for the site are comprised of ORC geothermal plants for both cases where the geothermal fluid is kept as single phase liquid. An ORC plant uses the high temperature steam and/or water from the production wells to heat a binary fluid, which most often is a hydrocarbon, with a low boiling point in a heat exchanger. The heat absorbed from the geothermal source causes the hydrocarbon fluid to evaporate, producing the high-pressure vapor that is then expanded through a turbine. The turbine drives a generator to produce electrical power. The low pressure turbine exhaust vapor is then condensed to be recirculated through the system repeatedly. The lower boiling point and higher molecular weight of the hydrocarbon fluid allows the use of smaller equipment than a conventional steam cycle operating at low temperatures. After the geothermal fluid has heated the hydrocarbon fluid in the heat exchanger, it is reinjected into the reservoir through a reinjection well. Figures 3 and 4 demonstrate schematically how an organic rankine cycle (ORC) functions for different PI values.

For both Case 1 and Case 2, it is proposed that the arrangement consist of two production wells and one injection well. All wells were assumed to be 2700 metres deep and they would be located approximately 1000 m apart. The wells will have ø13 ⅜" anchor casings down to approximately 400 m depth and a ø9 ⅝" production liner from 300 m down to approximately 1000 m. The production part of the wells will be drilled with a ø8 ½" drill bit and a ø7" slotted liner will be run in the production part down to the bottom of the well or 2700 m depth. Installed in the wells will be ø8" line-shaft pumps. A small building covering the well head and associated equipment would be equipped with either a roof hatch or a completely removable roof to allow for easy installation and maintenance of the pumps. Buried insulated pipe would connect the wells to the plant. Although the exact location of the plant relative the wells cannot be determined without further field investigations, the preferred option is to locate the plant close to the reinjection well, even within the well field.

Figure 5 and Figure 6 show the proposed plant layout. The turbine, generator and control rooms will be housed in a powerhouse due to the local climate. The heat exchangers and condensing equipment are located outdoors adjacent to the powerhouse.

3.2.2 Transmission Line

The transmission line for the Case 1 and 2 is 34.5kV which will follow the Vista Mountain access road until it dead ends to Highway #2. It will then follow Highway #2 and interconnect with the transmission line at the Takhini Substation. The proposed transmission line path does not interfere with any Ta'an Kwach'an First Nation settlement land.

With little site specific geological or terrain information evaluated, the exact construction location within the Vista Mountain region may vary along with the required transmission line alignment. For cost estimating purposes, the transmission line length is estimated to be 5 km from the geothermal plant to the Takhini Substation.

There has been no consideration to the overall grid capacity at the tie-in locations, and any constraints or limitations of the existing or future grid extensions have not be evaluated. Costs for upgrades that may be required have not been carried in the estimates in this report.

3.3 POWER AND ENERGY POTENTIAL

3.3.1 Estimates of Potential Energy

The efficiency of an ORC geothermal power plant is inversely proportional to the ambient temperature. In other words; the efficiency of the plant decreases as the the ambient temperature increases. Also, as the ambient temperature increases, more power is needed to condense the working fluid. This results in a lower plant capacity during the summer. In the winter months, the efficiency increases and less power is required to condense and a higher plant capacity is achieved. The following tables show the gross and net plant capacity ranges for both cases.

CASE #1

	T_{amb}	P_{gross}	P_{net}
	[°C]	**[MW]**	**[MW]**
	15	1,1	0,7
Design case:	**8**	**1,2**	**0,9**
	0	1,4	1,1

CASE #2

	T_{amb}	P_{gross}	P_{net}
	[°C]	**[MW]**	**[MW]**
	15	2,7	1,9
Design case:	**8**	**3,1**	**2,3**
	0	3,6	2,8

As mentioned earlier, a constant decrease of 2% per year has been assumed. The actual performance of the wells would depend on the local conditions. Monitoring of the well production rates and drawdown values would be required during the operation of the station.

3.3.2 Case 1 - Monthly Generation Profile

The energy production was estimated using monthly climate normals recorded from 1981 to 2010 at the Whitehorse A station which were provided by weather records of Government of Canada.

The assumptions used for this estimation of the average annual energy production are:

- The plant net capacity was linearly interpolated between 1.1 MW – 0.9 MW for monthly climate normals between 0°C - 8°C.
- The plant net capacity was linearly interpolated between 0.9 MW – 0.7 MW for normals between 8°C and 15°C.
- The plant net capacity is 1.1MW for any monthly climate normal under 0°C.
- Plant availability of approximately 95%.

The monthly generation profile for Case 1 is shown in Figure 7.

The maximum energy production would occur in between the months of December and March. The following table summarizes the monthly generation profile resulting with an initial yearly total of 8.15 GWh. As discussed, the capacity and yearly energy production of the plant decreases over time; therefore, after 30 years, it is expected that the annual energy production will be decreased to 4.54 GWh.

TABLE 4
CASE 1 SUMMARY OF INITIAL AVERAGE MONTHLY ENERGY

	MONTHLY AVERAGE ENERGY (MWh)
January	777
February	702
March	777
April	735
May	648
June	532
July	509
August	543
September	629
October	769
November	752
December	777
Yearly Total (MWh)	**8150**

3.3.3 Case 2 - Monthly Generation Profile

For Case 2, the plant net capacity was linearly interpolated between 2.8MW – 2.3MW for monthly climate normals between 0°C - 8°C and 2.3MW – 1.9MW for normals between 8°C and 15°C.

The assumptions used for this estimation of the average annual energy production are:

- The plant net capacity was linearly interpolated between 2.8 MW – 2.3 MW for monthly climate normals between 0°C - 8°C
- The plant net capacity was linearly interpolated between 2.3 MW – 1.9 MW for normals between 8°C and 15°C
- The plant net capacity is 2.8MW for any monthly climate normal under 0°C.
- Plant availability of approximately 95%, to account for inspection/repair time.

The monthly generation profile for Case 2 is shown on Figure 8.

The maximum average energy production would occur in between the December and March months. Table 4 summarizes the monthly generation profile resulting with a yearly total of 20.95 GWh. The capacity and yearly energy production of the plant decreases over time; therefore, after 30 years, it is expected that the annual energy production will be decreased to 11.66 GWh.

TABLE 5
CASE 2 SUMMARY OF INITIAL AVERAGE MONTHLY ENERGY

	MONTHLY AVERAGE ENERGY (MWh)
January	1,979
February	1,788
March	1,979
April	1,872
May	1,657
June	1,405
July	1,371
August	1,440
September	1,607
October	1,957
November	1,915
December	1,979
Yearly Total (MWh)	**20,950**

3.4 COST ESTIMATES

Costing for both cases was completed for comparison. The total 0.9 MW net plant, Case 1, is estimated at approximately $37,800,000, as summarized in Table 5. The total 2.3 MW net project cost, Case 2, is estimated at approximately $45,200,000, as summarized in Table 5. Detailed estimates of the project direct costs have been provided in Appendix C – Detailed Cost Estimates. This appendix also include a brief discussion of the basis for the cost estimate.

TABLE 6
VISTA MOUNTAIN SUMMARIZED COSTS

ITEM			CASE 1 0.9 MW COST (2015 $)	CASE 2 2.3 MW COST (2015 $)
Contractor Direct Costs			**$15,130,000**	**$18,160,000**
Site Work			$100,000	$120,000
Structures & Excavation			$930,000	$1,190,000
Power Plant			$2,900,000	$5,400,000
Wells & Water Supply System			$9,070,000	$9,320,000
Transmission Line & Interconnection			$990,000	$990,000
Access			$640,000	$640,000
Environmental & Mitigation Items			$500,000	$500,000
General Contractor Indirect Costs	*35%*	of Directs	**$5,300,000**	**$6,360,000**
Travel and Accommodation Costs	*6%*	of Directs	**$910,000**	**$1,090,000**
Subtotal			**$21,340,000**	**$25,610,000**
Contingency	*30%*	*of Subtotal*	**$6,400,000**	**$7,680,000**
Total Construction Cost			**$27,740,000**	**$33,290,000**
Contractor Markups			**$5,600,000**	**$6,720,000**
Profit	12%	of Const.	$3,329,000	$3,995,000
Head Office Overhead	7.0%	of Const.	$1,942,000	$2,330,000
Bonding & Insurance	1.2%	of Const.	$333,000	$399,000
Total Contractor Price			**$33,340,000**	**$40,010,000**
Owner Costs			**$4,440,000**	**$5,180,000**
Environmental Licencing/Consulting	3.0%	of Directs	$454,000	$545,000
Prefeasibility Study	0.5%	of Directs	$76,000	$91,000
Feasibility Study	1.5%	of Directs	$227,000	$272,000
Final Design	9.0%	of Directs	$1,362,000	$1,634,000
Site Assistance & Quality Assurance	6.0%	of Directs	$908,000	$1,090,000
Owner's Administration	2.0%	of Contract	$667,000	$800,000
Pre-Drilling Go/No Go Exploration			$750,000	$750,000
Total Project Cost			**$37,800,000**	**$45,200,000**

The total project costs shown are expected to be inclusive of all project costs. Given the limited amount of design work performed to date, a contingency of 30% has been included. Also, the allowances for contractor indirect costs, travel and accommodation, profit, overhead, etc. are based on KGS Group's recent experience on hydroelectric development projects in various remote locations in Canada (including the Mayo B Hydroelectric project).

3.5 CONSTRUCTION SCHEDULE & LIFE OF THE PROJECT

The preliminary construction schedule is shown on Figure 9. A pre-design phase including the test well drilling and confirmation of plant capacity has been considered in the context of the total project schedule. If the pre-design phase where to start immediately, site works and transmission line construction would start 1ST quarter 2018. The earliest possible in service date would be 1ST quarter 2019.

The potential life span for both Case 1 and 2 are estimated at 30 years.

3.6 OPERATION AND MAINTENANCE COSTS

At this early stage of design, it is difficult to estimate the operation and maintenance costs, but generally, an ORC geothermal plant of the sizes in question here can be operated by one person working approximately half-time. On top of this, scheduled and unscheduled maintenance needs to occur. The O&M cost includes all expenses that are related to the operation and maintenance of the power plant like overhead costs, supervision of equipment (turbine, generator, heat exchangers, buildings, pipes, wellhead etc.), maintenance (both work and material) and monitoring. Besides the labor cost, the other costs include some consumable goods (lubricants, spare parts, etc.), taxes and other expenses such as waste disposal.

To estimate yearly average maintenance costs, published data for ORC geothermal plants was used. Costs per kW of capacity from the report “Assessment of Current Costs of Geothermal Power Generation in New Zealand (2007 Basis)”, by Sinclair Knight Merz, 2009, was used as a basis. The published data was for 20 MW plants, therefore, the values obtained were scaled up to account for the anticipated increase cost per kW for the significantly smaller Vista Mountain cases. The O&M costs were estimated at:

- Case 1 (0.9 MW net plant): $350,000 per year.
- Case 2 (2.3 MW net plant): $800,000 per year.

3.7 LEVELIZED COSTS

The Levelized Cost of Energy (“LCOE”) and Levelized Cost of Capacity (“LCOC”) are a useful means of comparing energy options based on financial attributes, providing the levelized cost of a unit of energy or capacity of a resource option at the point of interconnection with the Yukon power grid. The LCOE and LCOC estimates adopted for this assessment assume a full utilization of the energy and capacity of the reviewed option.

The following financial assumptions are used for LCOE and LCOC analysis ($2015) of the Vista Mountain geothermal resource option:

- The capital costs, including transmission/interconnection costs identified during the review and provided in this report;
  - Vista Mountain case 1 at $37.0 million.
  - Vista Mountain case 2 at $44.4 million.
- Annual fixed operating and maintenance costs identified during the review and provided in this report;
  - Vista Mountain case 1 at $0.350 million/year.
  - Vista Mountain case 2 at $0.800 million/year.
- Annual energy output [KWHr] and capacity [MW] outputs are based on evaluation of each option provided in this report, including the assumed 2% yearly degradation over the life;
- Expected life of all options is assumed to be 30 years and the in-service date is assumed to be the start of 2019.
- Inflation rate of 2%.
- Weighted average cost of capital (WACC) as specified by YEC.
- Rate of 5.45% (nominal) and 3.38% (real), assuming 2% inflation.
- The options are also reviewed using higher WACC (assumed to be used in the assessments of independent power producers [IPP] options):
  - Rate of 6.7% (nominal) and 4.61% (real).
  - Rate of 11% (nominal) and 8.82% (real).

Table 7 below provides a summary of the LCOE and LCOC for each scale of Vista Mountain development cases under each of the WACC scenarios.

TABLE 7

LCOE AND LCOC FOR VISTA MOUNTAIN CASES

Geothermal Cases	Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)					
	3.38% Real WACC		4.61% Real WACC		8.82% Real WACC	
	LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)
	$/kW.h	$/MW	$/kW.h	$/MW	$/kW.h	$/MW
A	B	C	D	E	F	G
Vista Mountain Case 1: 0.9 MW	$0.368	$2,330,074	$0.412	$2,658,409	$0.577	$3,901,681
Vista Mountain Case 2: 2.3 MW	$0.194	$1,094,589	$0.214	$1,248,829	$0.290	$1,832,876

The Vista Mountain Case 1 with 0.9 MW net development scale shows about two times higher LCOE and LCOC under each WACC scenarios compared to the higher scale capacity and energy Case 2 [with 2.3 MW]. This highlights that any small scale version of the project is likely not financially attractive.

Refer to Appendix D - Financial Tables for further details.

4.0 McARTHUR SPRINGS

4.1 SITE DESCRIPTION

McArthur Springs is located approximately 42 km East of North Klondike Highway southeast of Stewart Crossing, and approximately 75 km south of Mayo, as shown on Figure 10. The site is located within the Ddhaw Ghro Habitat Protection Area, and is designated for mineral exporation development by the Selkirk First Nation. With the remote location of the springs, current site access conditions are challenging, due to overall rugged terrain. As a result of this, a longer access road is necessary to access the geothermal plant site. It is therefore assumed that the optimum transmission line route will follow the access road from the plant to interconnection along the North Klondike Highway.

4.1.1 Regional Geology and Site Observations

Site visits were not included in the scope of this project, therefore the McArthur Springs site and geology observations are based on available reports (e.g. Schillereff, Johnston, and Dennett, February, 2009; Dennett and Klump, April, 2010; Menzies and Dennett, October, 2009; Carlson and Zondervan, September, 2009; Carlson and Zondervan, June, 2009), and satellite/aerial images of the surrounding landscape. The springs are associated with an intensely folded geological terrane, within the Selwyn Fold Belt. The McArthur Pluton, a major intrusive body, is also a significant feature in the McArthur springs area, and is oriented relatively parallel to the Tintina Trench (which is located 8 km south of the spring site). The springs exit at the southwest margin of the pluton, where it had intruded sedimentary and meta-sedimentary bedrock at the margin of the basin. These bedrock units include siltstones, mudstones and chert, with interbedded sandstones and schists. Based on the orientation of the creek where the springs are located, the spring site is assumed to be hosted within a subsidiary fault zone, trending at approximately 60° to the main regional fault trend.

The spring discharges at 18 individual vents, distributed over an area of approximately 150 m x150 m, and exiting from river valley fill overburden deposits. Variation in the preciptates from groundwater flows at the discharge areas, suggest that there have been changes in flows, or variation in discharge sites, over the life of this spring. Unique to this site is the relatively fesh spring groundwater geochemistry, which suggests short residence times within the subsurface circulation system.

A relatively flat area will be selected near the spring site, suitable for construction of the powerhouse and condenser. Limited overburden stripping and rock excavation in the form of local chipping rather than blasting is anticipated to prepare the site for construction. Due to the extents of bedrock visible, it is expected that all major structures can be founded on slabs cast directly to rock with smaller components such as pipe supports or doweled directly to the rock surface.

While the project site lies within the zone of discontinuous permafrost in Canada, in general permafrost is most common within fine grained glaciolacustine soils that are poorly drained and where layers of peat and vegetation insulate the ground and prevent permaforst thaw. At this time, permafrost design issues are not included within the conceptual assessments.

4.1.2 Availability of Construction Material

Construction materials would need to be sourced to provide for access road construction, as well as for concrete production. From a review of satellite photography, existing rock outcrops and talus materials could be developed to produce all aggregate needs for the project. Importantly, the cut-fill balance of the road design would require optimization, as best possible, to mitigate the need for significant importation of construction materials, and enhance efficient and cost effective utilization of materials available within the project footprint and along the access road alignment. A Geotechnical investigation of the surrounding area could be required to optimize the road alignment, and also confirm sources of additional construction materials, if the available local sources are insufficient, or otherwise difficult to develop for construction use. Some photos of the McArthur site that show the typical valley rockfills and bedrock outcrops in the project area are contained within reference reports such as Schillereff, Johnston, and Dennett (February, 2009).

4.2 PLANT ARRANGEMENT

4.2.1 Organic Rankine Cycle (ORC) Power Plant

The McArthur Springs site was estimated to produce geothermal fluid at 160°C; which is significantly higher than Vista Mountain. The higher water temperature delivers more heat for the hydrocarbon fluid to absorb in the heat exchanger. The more heat absorbed by the working fluid, the higher pressure flowing through the turbine-generator unit which results in a higher plant capacity. The ORC components are similar to both cases at Vista Mountain, only the system size is larger. For further details on functionality of the ORC, refer to Section 3.2.1. Figures 11 and 12 demonstrate the organic rankine cycle schematic for the different PI values.

For both Case 3 and Case 4, it is proposed that the arrangement consist of two production wells and one injection well. All wells were assumed to be 2700 metres deep and they would be located approximately 1000 m apart. The wells will have ø13 ⅜" anchor casings down to approximately 400 m depth and a ø9 ⅝" production liner from 300 m down to approximately 1000 m. The production part of the wells will be drilled with a ø8 ½" drill bit and a ø7" slotted liner will be run in the production part down to the bottom of the well or 2700 m depth. Installed in the wells will be ø8" line-shaft pumps. A small building covering the well head and associated equipment would be equipped with either a roof hatch or a completely removable roof to allow for easy installation and maintenance of the pumps. Buried insulated pipe would connect the wells to the plant.

Figure 13 and Figure 14 show the proposed plant layout. The turbine, generator and control rooms will be housed in a powerhouse due to the local climate. The heat exchangers and condensing equipment are located outdoors adjacent to the powerhouse.

4.2.2 Transmission Line

The transmission line for Case 3 and 4 is 138kV which will follow the McArthur Springs access road until it dead ends onto the North Klondike Highway. Located north of the Pelly and MacMillan rivers, the proposed transmission line path lies entirely within Nacho Nyak Dun First

Nation and Selkirk First Nation traditional territory and the westernmost portion of the line is within the Selkirk First Nation settlement land.

With relatively little geological or site specific information, the exact transmission line corridor within the McArthur Springs region is undetermined at this time, along with the required length of transmission line. For cost estimating purposes, an approximated transmission line length of 42 km is assumed.

Similar to the Vista Mountain location; there has been no consideration to the overall grid capacity at the tie-in locations, and any constraints or limitations of the existing or future grid extensions have not be evaluated. Costs for upgrades that may be required have not been carried in the estimates in this report.

4.3 POWER AND ENERGY POTENTIAL

4.3.1 Estimates of Potential Energy

The efficiency of an ORC geothermal power plant is inversely proportional to the ambient temperature. In other words; the higher the ambient temperature, the lower the efficiency and more power is needed to condense the working fluid. This results in a lower plant capacity during the summer. In the winter months, the efficiency increases and less power is required to condense and a higher plant capacity is achieved. The following tables show the gross and net plant capacity ranges for both cases.

CASE #3

	T_{amb} [°C]	P_{gross} [MW]	P_{net} [MW]
	15	2,6	1,9
Design case:	**8**	**2,8**	**2,1**
	0	3,1	2,4

CASE #4

	T_{amb} [°C]	P_{gross} [MW]	P_{net} [MW]
	15	6,4	4,9
Design case:	**8**	**7,0**	**5,5**
	0	7,7	6,2

As mentioned earlier, a constant decrease of 2% per year has been assumed. The actual performance of the wells would depend on the local conditions. Monitoring of the well production rates and drawdown values would be required during the operation of the station.

4.3.2 Case 3 - Monthly Generation Profile

The energy production was estimated using monthly climate normals recorded from 1981 to 2010 at the Whitehorse A station which were provided by weather records of Government of Canada.

The assumptions used for this estimation of the average annual energy production are:

- The plant net capacity was linearly interpolated between 2.4 MW – 2.1 MW for monthly climate normals between 0°C - 8°C
- The plant net capacity was linearly interpolated between 2.1 MW – 1.9 MW for normals between 8°C and 15°C.
- The plant net capacity is 2.4 MW for any monthly climate normal under 0°C.
- Plant availability of approximately 95%.

The monthly generation profile for Case 3 is shown on Figure 15.

The maximum energy production would occur in between the months of December and March. Table 8 summarizes the monthly generation profile resulting with an initial yearly total of 18.62 GWh. As discussed, the capacity and yearly energy production of the plant decreases over time; therefore, after 30 years, it is expected that the annual energy production will be decreased to 10.37 GWh.

TABLE 8
CASE 3 SUMMARY OF INITIAL AVERAGE MONTHLY ENERGY

	MONTHLY AVERAGE ENERGY (MWh)
January	1,696
February	1,532
March	1,696
April	1,616
May	1,503
June	1,352
July	1,357
August	1,391
September	1,457
October	1,683
November	1,642
December	1,696
Yearly Total (MWh)	**18,620**

4.3.3 Case 4 - Monthly Generation Profile

The assumptions used for this estimation of the average annual energy production are:

- The net plant capacity was linearly interpolated between 6.2 MW – 5.5 MW for monthly climate normals between 0°C - 8°C
- The plant net capacity was linearly interpolated between 5.5 MW – 4.9 MW for normals between 8°C and 15°C
- The plant net capacity is 6.2 MW for any monthly climate normal under 0°C.
- Plant availability of approximately 95%, to account for inspection/repair time.

The monthly generation profile for Case 4 is shown on Figure 16.

The maximum average energy production would occur in between the December and March months. Table 9 summarizes the monthly generation profile resulting with a yearly total of 48.24 GWh. The capacity and yearly energy production of the plant decreases over time; therefore, after 30 years, it is expected that the annual energy production will be decreased to 26.85 GWh.

TABLE 9
CASE 4 SUMMARY OF INITIAL AVERAGE MONTHLY ENERGY

	MONTHLY AVERAGE ENERGY (MWh)
January	4,382
February	3,958
March	4,382
April	4,181
May	3,931
June	3,510
July	3,506
August	3,609
September	3,810
October	4,351
November	4,241
December	4,382
Yearly Total (MWh)	**48,240**

4.4 COST ESTIMATES

Costing for both cases was completed for comparison. The total 2.1 MW net plant, Case 3, is estimated at approximately $114,000,000, as summarized in Table 10. The total 5.5 MW project cost, Case 4, is estimated at approximately $127,000,000, as summarized in Table 9. Detailed estimates of the project direct costs have been provided in Appendix C – Detailed Cost Estimates. This appendix also include a brief discussion of the basis for the cost estimate.

TABLE 10
McARTHUR SPRINGS SUMMARIZED COSTS

ITEM			CASE 3 2.1 MW COST (2015 $)	CASE 4 5.5 MW COST (2015 $)
Contractor Direct Costs			**$45,010,000**	**$50,170,000**
Site Work			$110,000	$130,000
Structures & Excavation			$1,660,000	$2,550,000
Power Plant			$4,400,000	$8,400,000
Wells & Water Supply System			$8,800,000	$9,050,000
Transmission Line & Interconnection			$11,120,000	$11,120,000
Access			$18,420,000	$18,420,000
Environmental & Mitigation Items			$500,000	$500,000
General Contractor Indirect Costs	35%	of Directs	**$15,750,000**	**$17,560,000**
Travel and Camp Costs	10%	of Directs	**$4,500,000**	**$5,020,000**
Subtotal			**$65,260,000**	**$72,750,000**
Contingency	30%	of Subtotal	**$19,580,000**	**$21,830,000**
Total Construction Cost			**$84,840,000**	**$94,580,000**
Contractor Markups			**$17,140,000**	**$19,110,000**
Profit	12%	of Const.	$10,181,000	$11,350,000
Head Office Overhead	7.0%	of Const.	$5,939,000	$6,621,000
Bonding & Insurance	1.2%	of Const.	$1,018,000	$1,135,000
Total Contractor Price			**$101,980,000**	**$113,690,000**
Owner Costs			**$12,040,000**	**$13,310,000**
Environmental Licencing/Consulting	3.0%	of Directs	$1,350,000	$1,505,000
Prefeasibility Study	0.5%	of Directs	$225,000	$251,000
Feasibility Study	1.5%	of Directs	$675,000	$753,000
Final Design	9.0%	of Directs	$4,051,000	$4,515,000
Site Assistance & Quality Assurance	6.0%	of Directs	$2,701,000	$3,010,000
Owner's Administration	2.0%	of Contract	$2,040,000	$2,274,000
Pre-Drilling Go/No Go Exploration			$1,000,000	$1,000,000
Total Project Cost			**$114,000,000**	**$127,000,000**

The total project costs shown are expected to be inclusive of all project costs. Given the limited amount of design work performed to date, a contingency of 30% has been included. Also, the allowances for contractor indirect costs, travel and accommodation, profit, overhead, etc. are based on KGS Group's recent experience on hydroelectric development projects in various remote locations in Canada (including the Mayo B Hydroelectric project).

4.5 CONSTRUCTION SCHEDULE & LIFE OF THE PROJECT

The preliminary construction schedule is shown on Figure 17. A pre-design phase including the test well drilling and confirmation of plant capacity has been considered in the context of the total project schedule. If the pre-design phase where to start immediately, site works would start 3rd quarter 2018. The earliest possible in service date would be 4th quarter 2019.

The potential life span for both Case 3 and 4 are estimated at 30 years.

4.6 OPERATION AND MAINTENANCE COSTS

At this early stage of design, it is difficult to estimate the operation and maintenance costs, but generally, an ORC geothermal plant of the sizes in question here can be operated by one person working approximately half-time. On top of this, scheduled and unscheduled maintenance needs to occur. The O&M cost includes all expenses that are related to the operation and maintenance of the power plant like overhead costs, supervision of equipment (turbine, generator, heat exchangers, buildings, pipes, wellhead etc.), maintenance (both work and material) and monitoring. Besides the labor cost the other costs include some consumable goods (lubricants, spare parts, etc.), taxes, and other expenses such as waste disposal.

To estimate yearly average maintenance costs, published data for ORC geothermal plants was used. Costs per kW of capacity from the report "*Assessment of Current Costs of Geothermal Power Generation in New Zealand (2007 Basis)", by Sinclair Knight Merz, 2009,* was used as a basis. The published data was for 20 MW plants, therefore, the values obtained were scaled up to account for the anticipated increase cost per kW for the significantly smaller Vista Mountain cases. The O&M costs were estimated at:

- Case 3 (0.9 MW plant): $800,000 per year.
- Case 4 (2.3 MW plant): $1,800,000 per year.

4.7 LEVELIZED COSTS

The Levelized Cost of Energy ("LCOE") and Levelized Cost of Capacity ("LCOC") are a useful means of comparing energy options based on financial attributes, providing the levelized cost of a unit of energy or capacity of a resource option at the point of interconnection with the Yukon power grid. The LCOE and LCOC estimates adopted for this assessment assume a full utilization of the energy and capacity of the reviewed option.

The following financial assumptions are used for LCOE and LCOC analysis ($2015) of the McArthur Springs geothermal resource options:

- The capital costs, including transmission/interconnection costs identified during the review and provided in this report:
    - McArthur Springs Case 3 at $113.0 Million.
    - McArthur Springs Case 4 at $126.0 Million.
- Annual fixed operating and maintenance costs identified during the review and provided in this report:
    - McArthur Springs Case 3 at $0.8 Million/Year.
    - McArthur Springs Case 4 at $1.8 Million/Year.
- Annual energy output [KWHr] and capacity [MW] outputs are based on evaluation of each option provided in this report, including the assumed 2% yearly degradation over the life.
- Expected life of all options assumed to be 30 years [assumed in-service by the start of 2020].
- Inflation rate of 2%.
- Weighted average cost of capital (WACC) as specified by YEC:
    - Rate of 5.45% (nominal) and 3.38% (real), assuming 2% inflation.
- The options are also reviewed using higher WACC (assumed to be used in the assessments of independent power producers [IPP] options):
    - Rate of 6.7% (nominal) and 4.61% (real).
    - Rate of 11% (nominal) and 8.82% (real).

Table 11 below provides a summary of the LCOE and LCOC for each scale of McArthur Springs development cases under each of the WACC scenarios.

TABLE 11

LCOE AND LCOC FOR McARTHUR SPRINGS CASES

Geothermal Cases	**Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)**					
	3.38% Real WACC		**4.61% Real WACC**		**8.82% Real WACC**	
	LCOE (2015$)	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**	**LCOE (2015$)**	**LCOC (2015$)**
	$/kW.h	**$/MW**	**$/kW.h**	**$/MW**	**$/kW.h**	**$/MW**
A	**B**	**C**	**D**	**E**	**F**	**G**
McArthur Springs Case 3: 2.1 MW	$0.469	$3,220,803	$0.527	$3,674,652	$0.746	$5,393,197
McArthur Springs Case 4: 5.5 MW	$0.225	$1,388,937	$0.250	$1,584,655	$0.343	$2,325,759

The McArthur Springs Case 3 with 2.1 MW net development scale shows more than two times higher LCOE and LCOC under each of the WACC scenarios compared to the higher scale Case 4 capacity and energy. This highlights that any small scale version of the project is likely not financially attractive.

The detailed tables are provided in Appendix D – Financial Tables.

5.0 REVIEW OF RISKS

The process proposed for the geothermal generating plants is well established and it is not expected that there are significant risks with the availability of equipment or the technology.

The risks identified with the geothermal developments discussed in this report are related to the unknowns with the geothermal field. Namely, the temperature of the fluid, the production index of the wells, the depth of the wells required, the size of the geothermal field and the chemical properties of the geothermal fluid. Table 12 discusses the effects of these parameters.

TABLE 12
RISKS IDENTIFIED WITH THE GEOTHERMAL DEVELOPMENTS

PARAMETER	IMPACT
Temperature of fluid	Efficiency and feasibility of the power plant is directly related to temperature
Production Index	Higher the yield from the wells (L/s) results in more efficient utilization of wells (i.e. reduced drawdown and thus reduced associated pumping costs) and this makes the plant more feasible
Temperature gradient	Well depth is related to the temperature gradient and the well depth affects the cost of drilling
Size of geothermal field	The size of the power plant relative to the size of the geothermal field and can also affect life time of the plant.
Chemical properties	Dissolved solids and/or gases may require mitigation by higher plant operating pressures, and may effect a limitation on cooling of the fluid, or necessitate chemical treatment. This may increase parasitic load, reduce plant power efficiency, and/or increase operating/maintenance costs

As shown in the preliminary project schedule, one or two wells should be drilled prior to detailed design to confirm the available resource. Once the results from the exploration wells are known, a GO – NO GO decision would have to be made. The cases presented are expected to be the estimated upper and lower bounds of the potential geothermal well production capacities.

As mentioned in Table 12, the well depth affects the cost of drilling. Figure 18 shows how the drilling cost developes with the depth when drilling a vertical 2000 m deep well where the production section is drilled with a ø8 ½” drill bit. The cost does not include preparation for the drilling such as roads, drill pad, water supply, surface casingetc. From the graph, one can read that the marginal cost for depth is rather small and will be still smaller when the cost of preparation is included. The drilling risk will however increase with increased depth and the depth and strength of anchor and production castings limits the maximum depth of the well.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Frorm the information to date within the reports and information provided by Yukon Energy, it is concluded that there is a modest geothermal resource available for development in the Yukon. The inferred temperatures at all of the sites reviewed are relatively low and would therefore require the use of a binary geothermal plant arrangement (organic rankine cycle).

Of the sites reviewed that are within the 25 km corridor on either side of existing or planned transmission infrastructure, the Vista Mountain site appears to be the most promising. It is located on crown lands, close to the load centre of Whitehorse, has a relatively high inferred temperature, and is very close to the North Klondike Highway and the Takhini substation

The most promising site reviewed was McArthur Springs. Although it does not lie within the 25 km corridor on either side of existing or planned transmission infrastructure, it has the highest inferred resource temperature. Unfortunately, the length of the access road and transmission lines required to develop this site increase the estimated project costs considerably.

Since no exploration wells have been drilled at any of the sites reviewed, including the Vista Mountain and McArthur Springs sites, there is considerable uncertainty regarding the actual reservoir temperature, fluid chemistry, and production index (PI) of the geothermal wells. This report presents optimistic and pessimistic cases for the PI at each site. The resulting plant capacities were determined using the geothermal fluid temperature that was inferred using from existing geothermometer calculations. Further surveys and geophysical investigation would be required to refine the estimates presented herein.

The expected plant capacities from the Vista Mountain site range from 0.9 MW net output to 2.3 MW net output. The expected plant capacities from the McArthur Springs site range from 2.1 MW net output to 5.5 MW net output. The actual plant capacity that can be developed will be dependant on the actual geothermal fluid temperature and the PI values encountered once the production test wells are drilled and assessed.

The LCOE and LCOC analyses in this report were performed assuming full utilization of the energy option throughout each year during the 30 year life assumed under each scale of development. The following compares the financial attribute analysis of the resource options reviewed:

- The McArthur Springs option is materially larger than Vista Mountain at each of the two scales examined for each option, i.e., the smallest McArthur Springs case (Case 3) is roughly the same scale as the largest Vista Mountain case (Case 2).
- Both of these geothermal resource options are not economically attractive if the larger scale development case is not confirmed for the option through further studies, i.e., levelized unit costs per kW.h (LCOE) or per MW (LCOC) are more than twice as high for the smallest scale case versus the largest scale case for each option. McArthur Springs case (Case 3) shows the highest LCOE and LCOC reflecting high capital cost [more than 2.5 times the capital cost compared to roughly the same scale for the Vista Mountain case].
- The real LCOE ($2015) for the largest scale cases examined for each option is in the range of 19-22 cents/kW.h, i.e., $0.194/kW.h for Vista Mountain Case 2 (2.3 MW) and $0.225/kW.h for McArthur Springs Case 4 (5.3 MW). However, the McArthur Springs Case 4 option requires the larger load demand for fossil energy displacement in order to be competitive financially with the Vista Mountain Case 2 option.

McArthur Springs requires a much longer transmission line (assumed at 138 kV) to connect to the Yukon electrical grid. There could be potential financial benefits not considered in this analysis if the new transmission could be utilized by other loads or resource options.

6.2 RECOMMENDATIONS

The cost of drillling exploration wells at either of these sites is substantial. This is especially true for the McArthur Springs site, given its distance from any established access road. Therefore, further studies should be perfomed to quantify and delineate the resource at each site. The first studies should focus on the surface geology and structural arrangements and geochemistry in each area. With this, the estimated power capacity value can be used as a go/no-go decision for further work. If then, it is decided to proceed further, geophysical surveys and other surface mapping, as well as shallow drilling of smaller diamater test wells to determine thermal gradients would be required.

Following the additional studies, should either of these sites be considered further for development, at least one exploration well should be drilled at that site prior to making a final GO/NO GO decision. Since an exploration well could be developed into a production well if the project proceeds, the cost of the exploration is implicitly included in the cost estimates provided herein.

Once more precise information is known for resource temperature, fluid chemistry and well production index, the ORC process could be refined, preliminary equipment selections could be completed and the cost estimates for the project refined.

7.0 STATEMENT OF LIMITATIONS AND CONDITIONS

7.1 THIRD PARTY USE OF REPORT

This report has been prepared for Yukon Energy Corporation to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

7.2 CAPITAL COST ESTIMATE STATEMENT OF LIMITATIONS

The cost estimates included with this report have been prepared by KGS Group using its professional judgment and exercising due care consistent with the level of detail required for the stage of the project for which the estimate has been developed. These estimates represent KGS Group’s opinion of the probable costs and are based on factors over which KGS Group has no control. These factors include, without limitation, site conditions, availability of qualified labour and materials, present workload of the Bidders at the time of tendering and overall market conditions. KGS Group does not assume any responsibility to Yukon Energy Corporation, in contract, tort or otherwise in connection with such estimates and shall not be liable to Yukon Energy Corporation if such estimates prove to be inaccurate or incorrect.

FIGURES

Document Path: \\fs1\GIS Data\Project Data\Aishihik Water Licence Renewal\FIG_1_Yukon Power Grid_28Sept2015.mxd

Data Source -Main Map: Coordinate System: NAD83 UTM Zone 8
Roads -YTG SVW Roads
YEC Transmission Lines from Yukon Energy
Water 1:2M GeoYukon Dataset

Data Source -Overview Map: Coordinate System: Yukon Albers
Geobase 1:1,000,000 Place Names

*All data are limited by the date the map was printed. All spatial data subject to change.

N
W E
S

1:3,000,000

Kilometers
0 25 50 100

This drawing has been prepared for the use of Yukon Energy and may not be used, reproduced or relied upon by third parties, except as agreed to by Yukon Energy and its Partners, as required by law or for use by governmental reviewing agencies. Yukon Energy accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without Yukon Enery's express written consent.

Legend

▲ Existing Hydro Sites

YEC Transmission Lines

— 138kV Transmission Line
— 69kV Transmission Line
- - Proposed Transmission Line
▨ 25km Buffer

Roads

— Primary Highway
— Road
- - Secondary Highway
— Watercourses
▨ Waterbodies

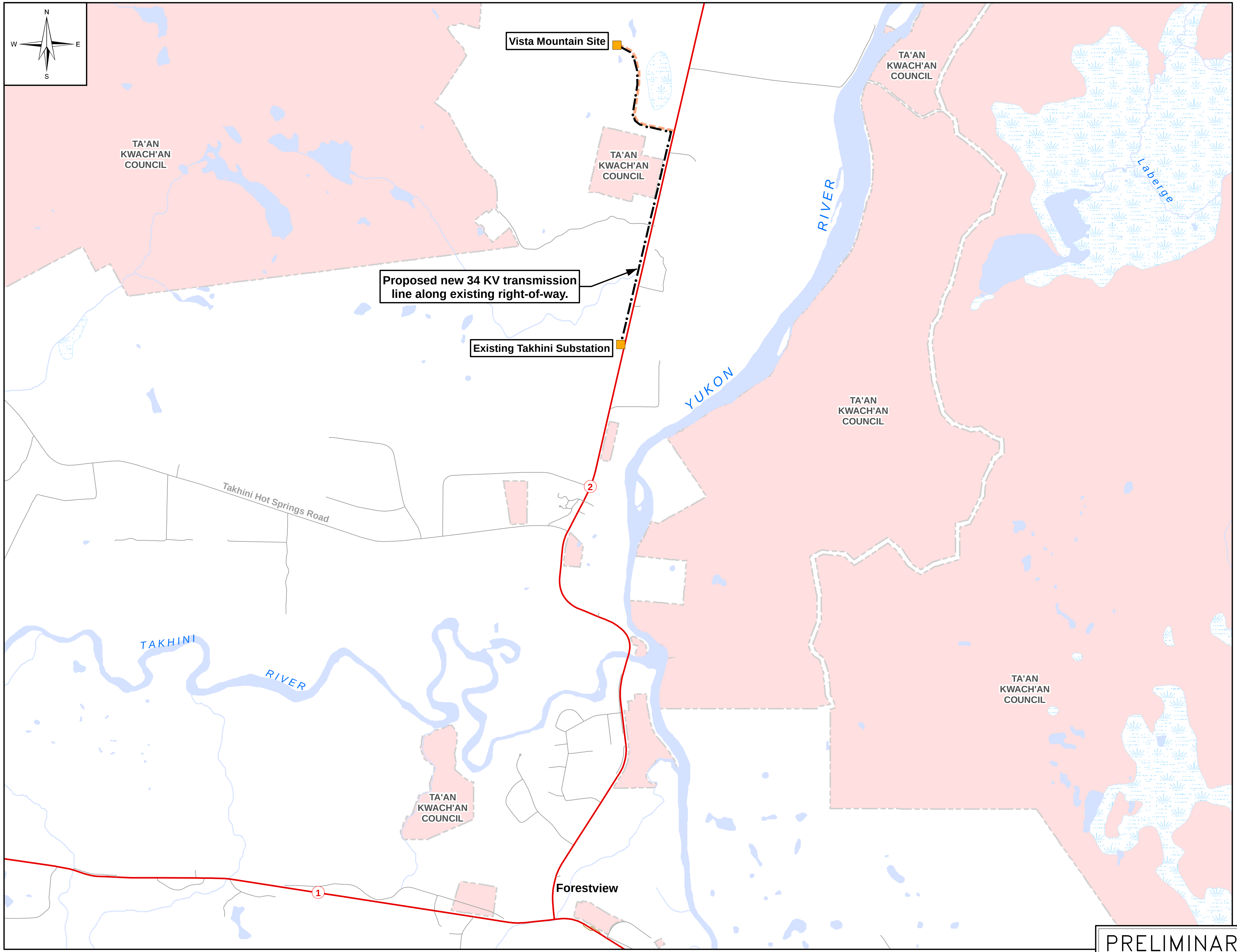
YUKON ENERGY

20 Year Resource Plan

Yukon Electrical Grid Overview and Potential Transmission Options

Date Produced: 01/12/2015

Fig 1



LEGEND:

- ▬ ▬ Proposed All–Weather Access Road
- •▬• Proposed 34.5 KV Transmission Line
- ▬ Highway
- ― Secondary Road
- ～ Watercourse
- ▬ Waterbody
- ▨ Wetland
- ▭ First Nation Boundary

NOTES:
1. Wetland, Watercourse and Waterbody layers shown were obtained from GeoYukon base data.
2. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 8. Elevations are in metres above sea level (MSL).

DRAFT

0.5 0 0.5 1 1.5 2
Kilometres

SCALE: 1:50,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/05/09	ISSUED WITH REPORT	JCL	MSW

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON ENERGY

GEOTHERMAL REVIEW AND
SITE INVENTORY

VISTA MOUNTAIN
SITE LOCATION PLAN

MAY 2016

FIGURE 2

REV: A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-1404-001\Dwg\GIS\MXDs\RevA\16-1404-001_Fig2_RevA.mxd
11"x17" PLOT SCALE 1:1

FIGURE 3
CASE 1 ORGANIC RANKINE CYLE FLOW CHART

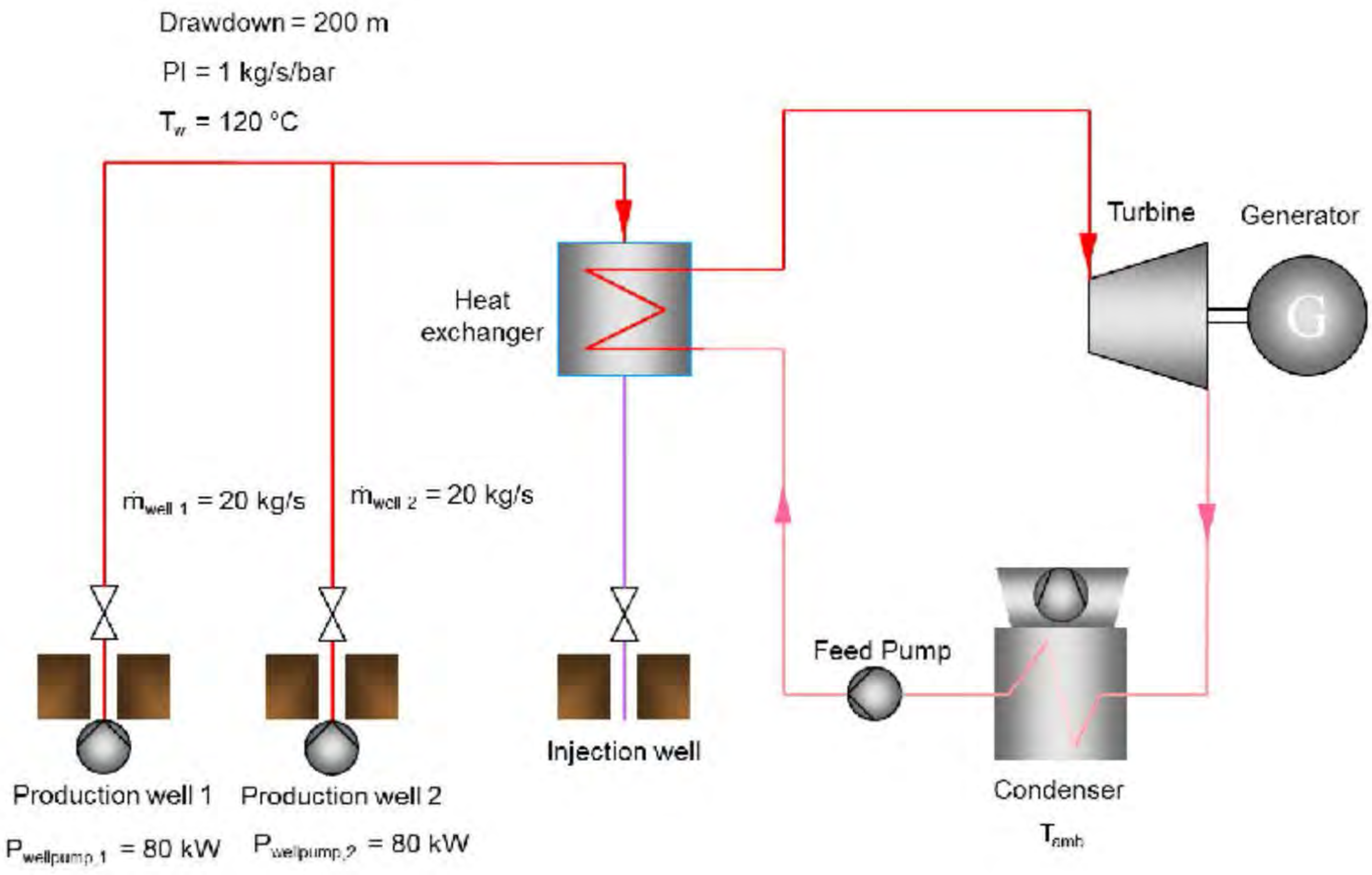
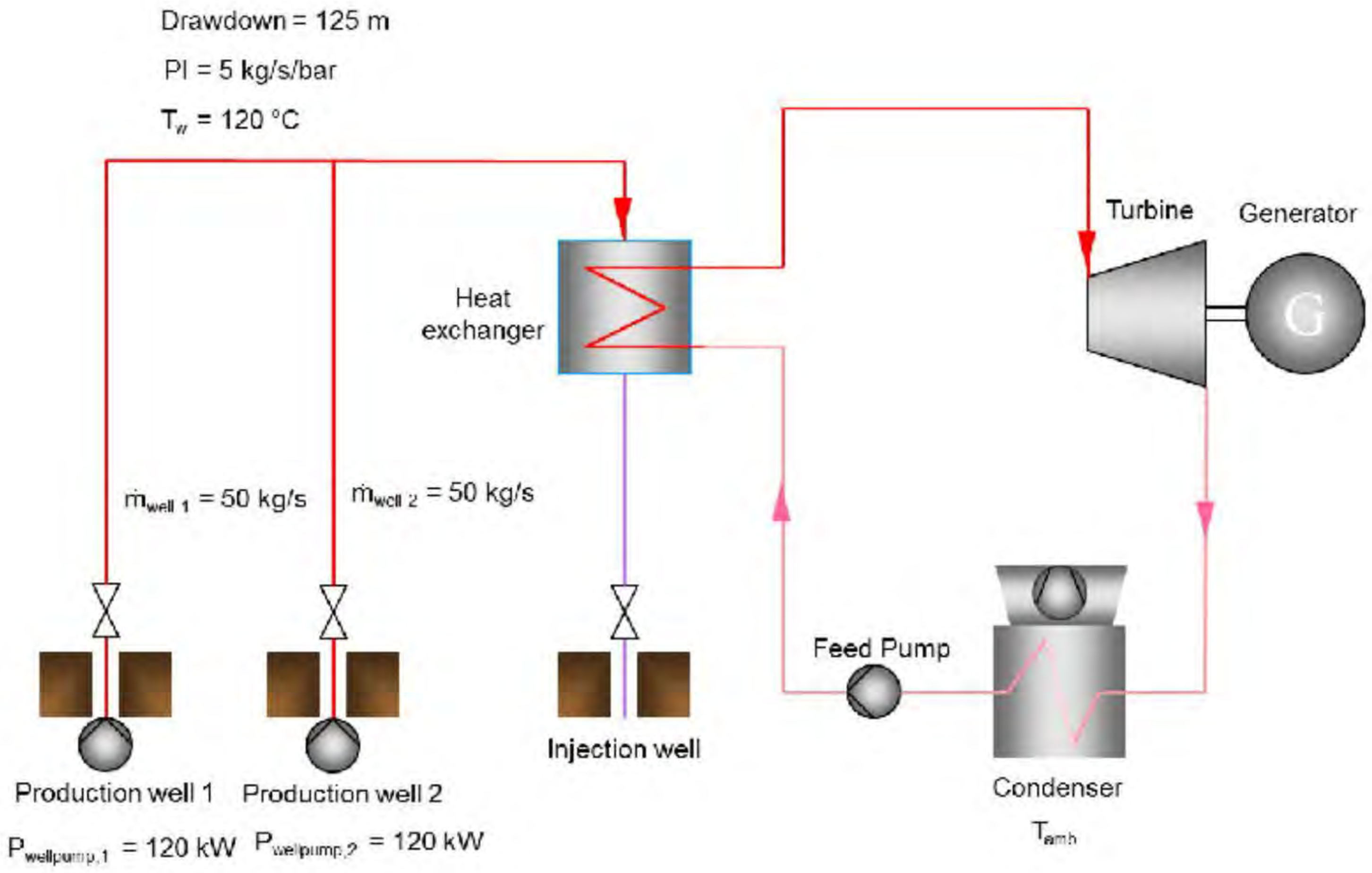
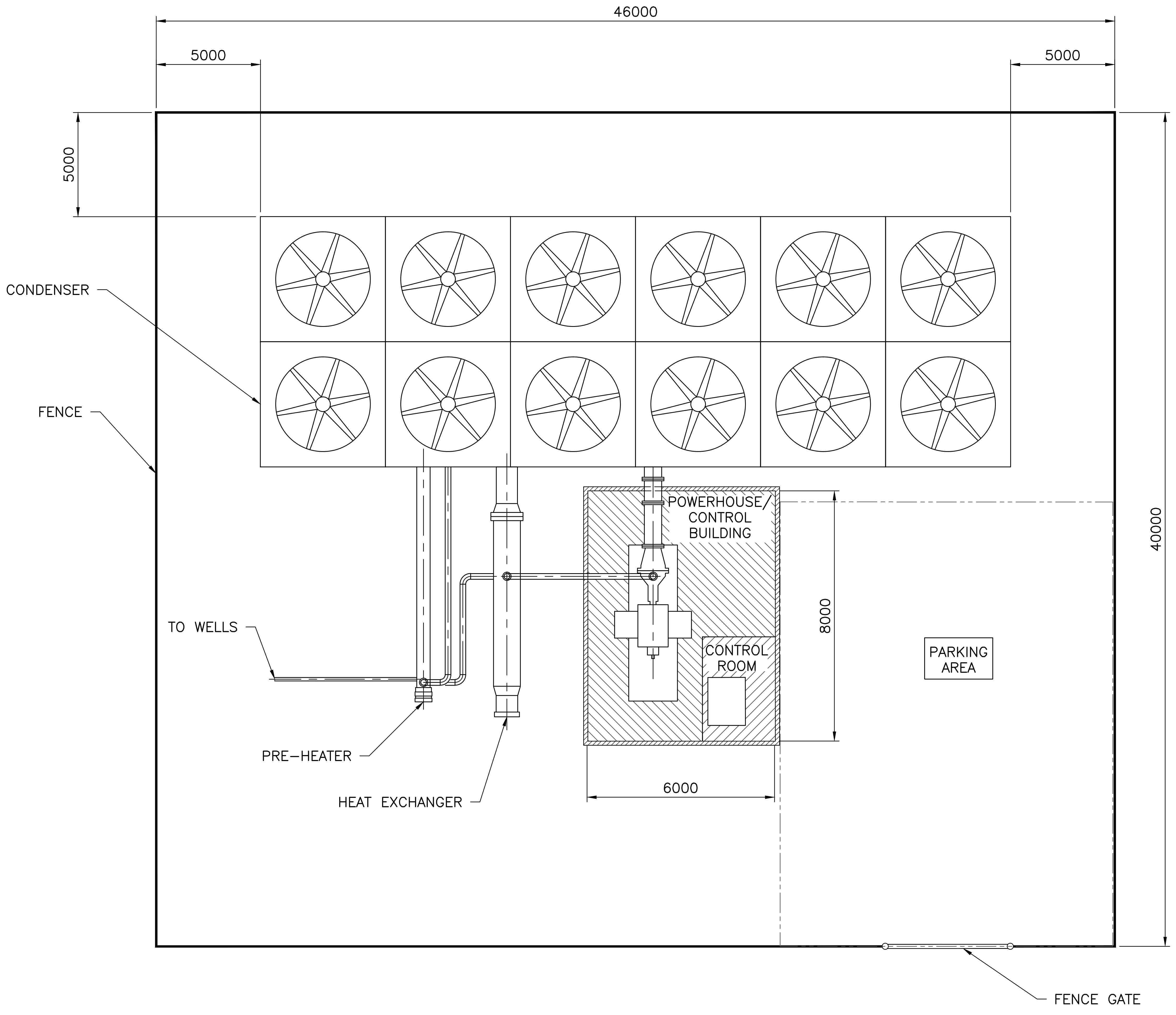


FIGURE 4

CASE 2 INITIAL MONTHLY GENERATION PROFILE



11x17



VISTA MOUNTAIN GEOTHERMAL ORC PLANT (1.2 MW)

3000 0 3000 6000 9000 12000

SCALE: 1:150mm (24"x36")

LEGEND:

ORC	ORGANIC RANKINE CYCLE

A	16/05/09	ISSUED FOR DESIGN REPORT	SBC	JCL
NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON
ENERGY

GEOTHERMAL REVIEW AND SITE INVENTORY

PLANT LAYOUT
CASE 1 (1.2 MW)
VISTA MOUNTAIN

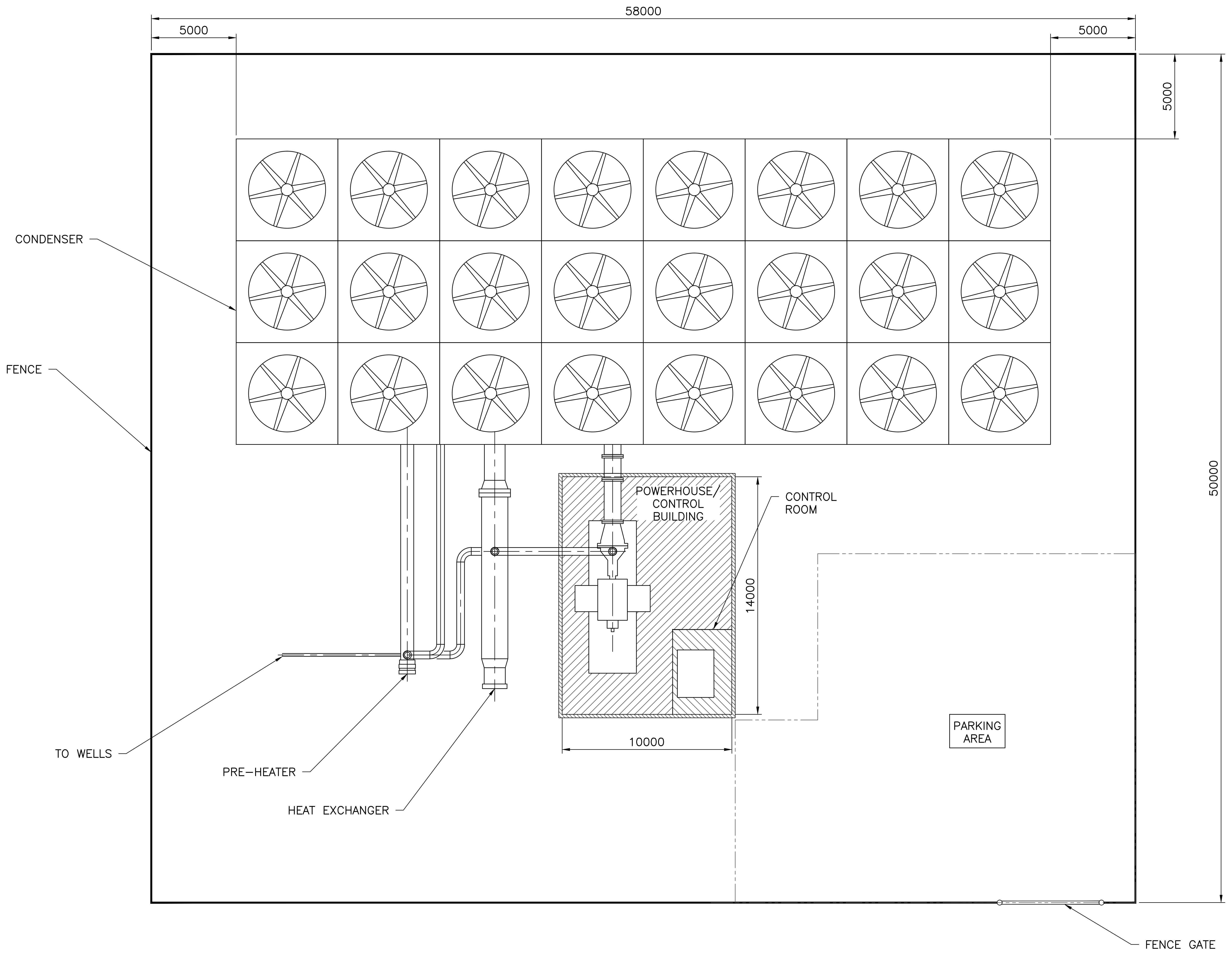
MAY_2016

FIGURE 5

REV:
A

FileName: U:\FMS\16-1404-001\16-1404-001_FIGURE 5.dwg – Tab: Rev A Plotted By: Cabellanosa 16/05/09 [Mon 2:10pm]
11"x17" PLOT SCALE: 1:2

11x17



VISTA MOUNTAIN GEOTHERMAL ORC PLANT (3.1 MW)

3000 0 3000 6000 9000 12000

SCALE: 1:150mm (24"x36")

LEGEND:

ORC	ORGANIC RANKINE CYCLE

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/05/09	ISSUED FOR DESIGN REPORT	SBC	JBC

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON
ENERGY

GEOTHERMAL REVIEW AND SITE INVENTORY

PLANT LAYOUT
CASE 2 (3.1 MW)
VISTA MOUNTAIN

MAY_2016

FIGURE 6

REV:
A

FileName: U:\FMS\16-1404-001\16-1404-001_FIGURE 6.dwg - Tab: Rev A Plotted By: Cabellanosa 16/05/09 [Mon 2:11pm]
11"x17" PLOT SCALE: 1:2

FIGURE 7

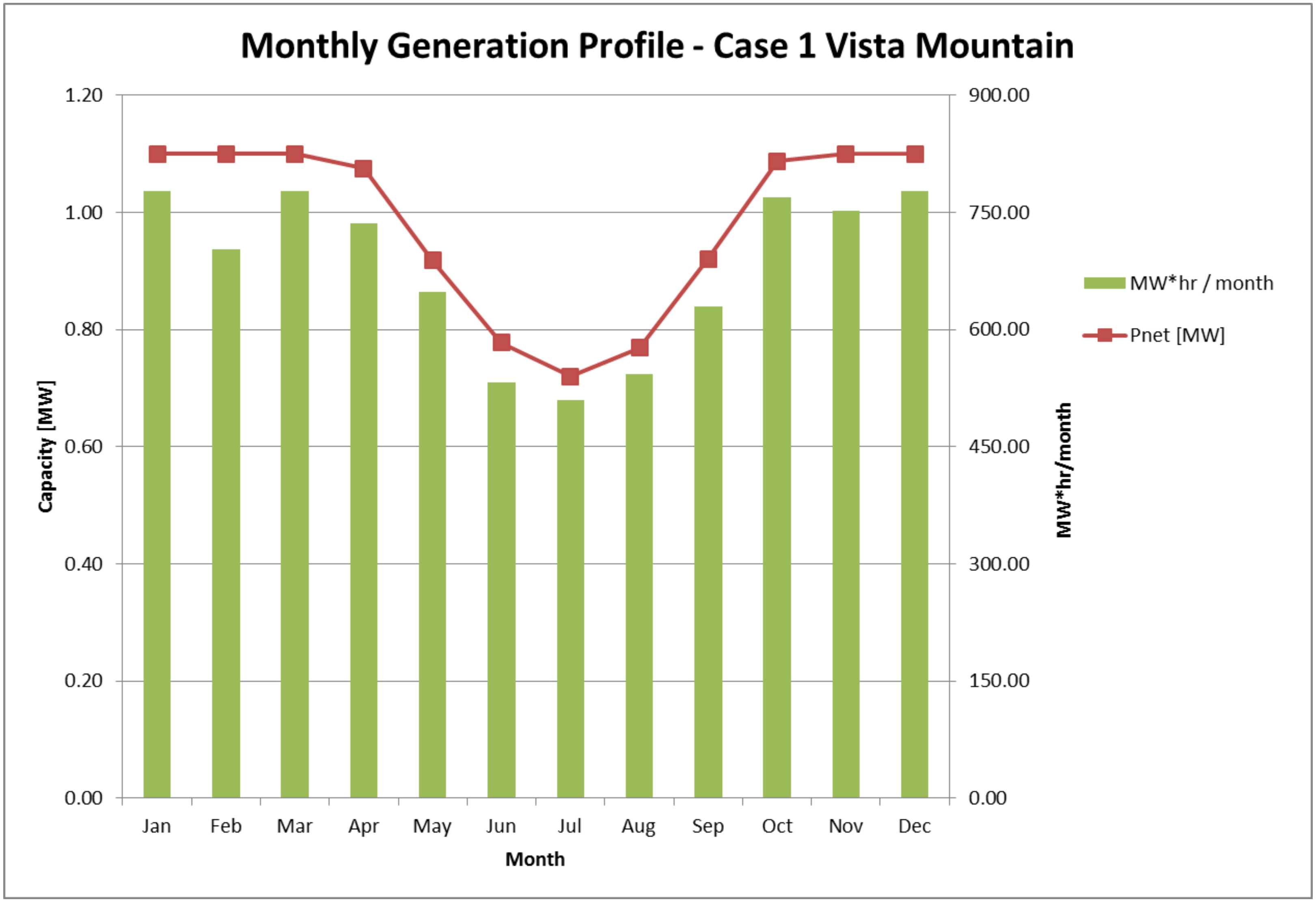

Monthly Generation Profile - Case 1 Vista Mountain
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Capacity [MW]
900.00
750.00
600.00
450.00
300.00
150.00
0.00
MW*hr/month
MW*hr / month
Pnet [MW]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

FIGURE 8

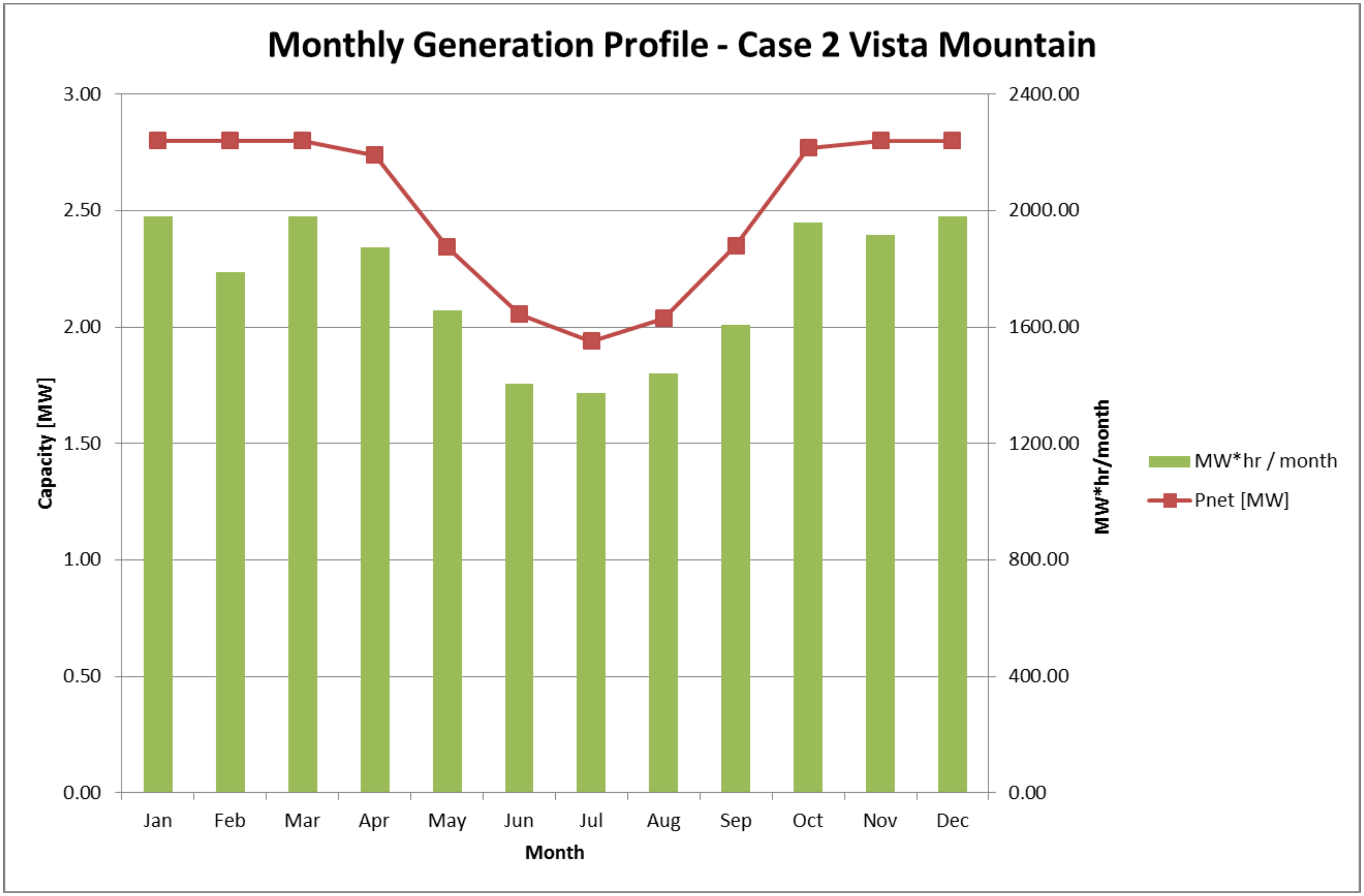
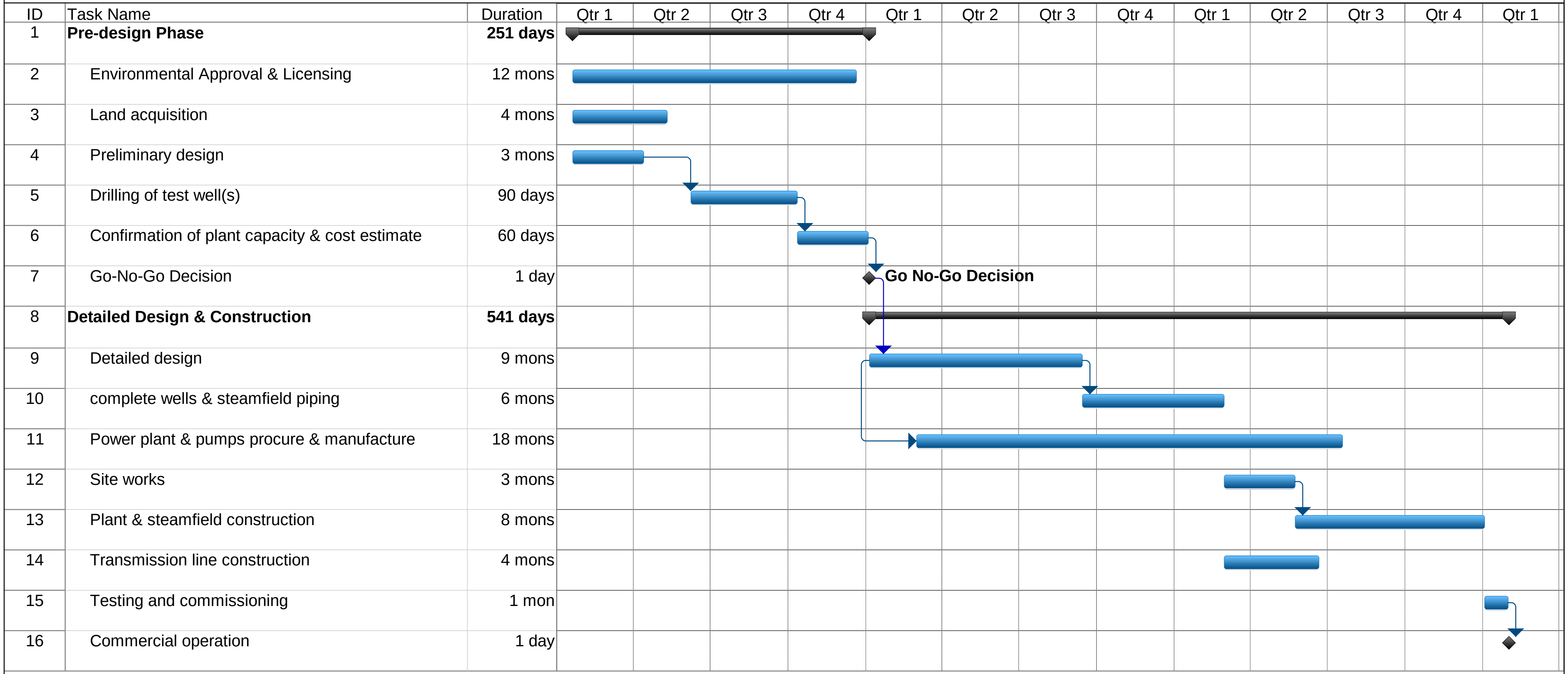

Monthly Generation Profile - Case 2 Vista Mountain
Capacity [MW]
3.00
2.50
2.00
1.50
1.00
0.50
0.00
MW*hr/month
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
MW*hr / month
Pnet [MW]

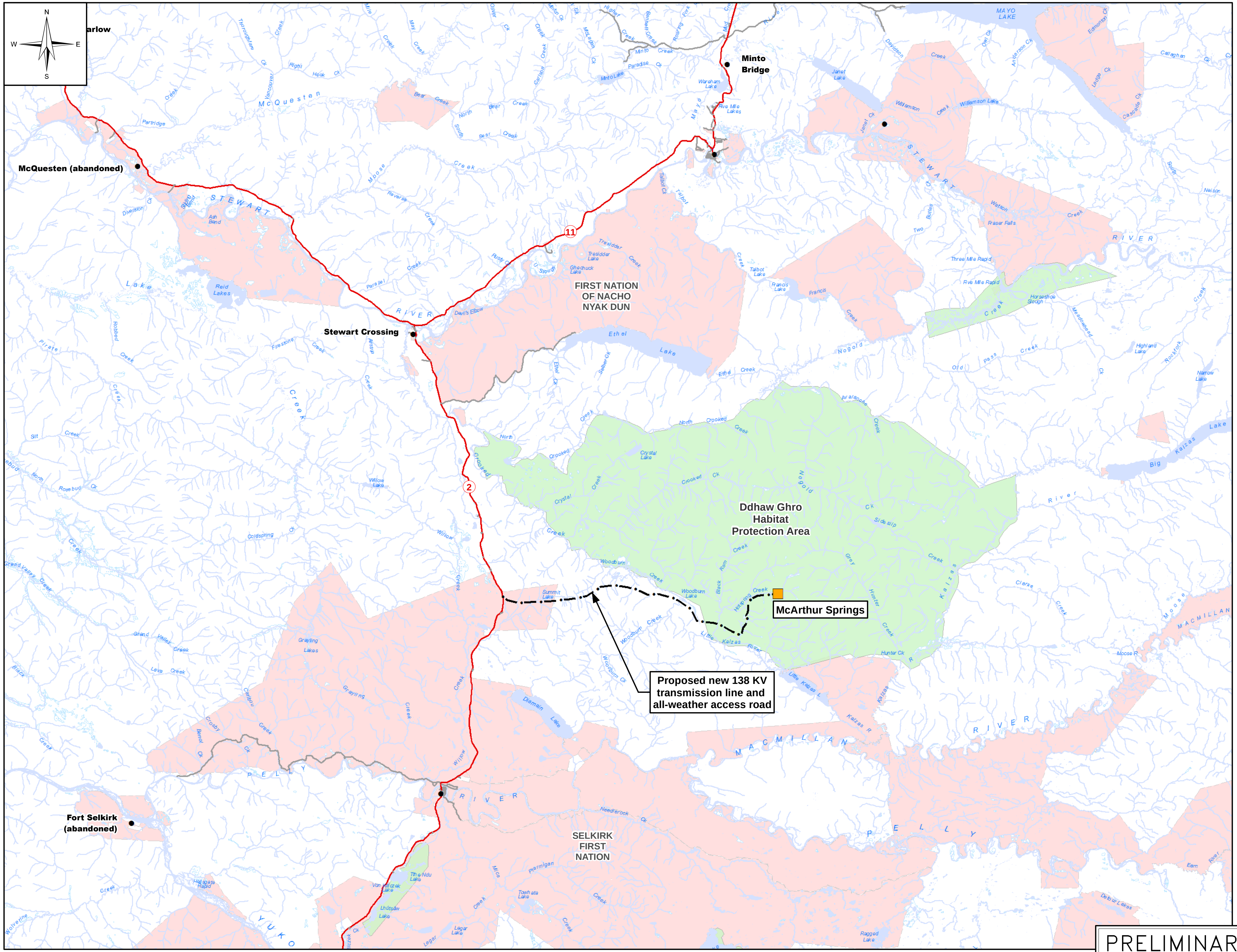
Figure 9: Vista Mountain Geothermal Plant - Preliminary Schedule

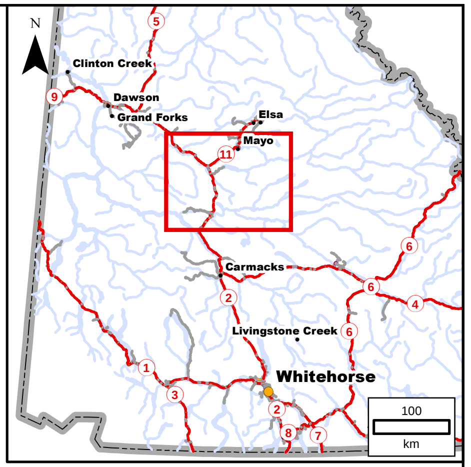


ID	Task Name	Duration
1	**Pre-design Phase**	**251 days**
2	Environmental Approval & Licensing	12 mons
3	Land acquisition	4 mons
4	Preliminary design	3 mons
5	Drilling of test well(s)	90 days
6	Confirmation of plant capacity & cost estimate	60 days
7	Go-No-Go Decision	1 day
8	**Detailed Design & Construction**	**541 days**
9	Detailed design	9 mons
10	complete wells & steamfield piping	6 mons
11	Power plant & pumps procure & manufacture	18 mons
12	Site works	3 mons
13	Plant & steamfield construction	8 mons
14	Transmission line construction	4 mons
15	Testing and commissioning	1 mon
16	Commercial operation	1 day

Date: 09/05/2016

Summary ▬ Task ▬ Milestone ◆





LEGEND:

- Proposed New 138 KV Transmission Line and All–Weather Access Road
- Highway
- Secondary Road
- Watercourse
- Waterbody
- Wetland
- Park
- First Nation Boundary

NOTES:
1. Wetland, Watercourse and Waterbody layers shown were obtained from GeoYukon base data.
2. All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 8. Elevations are in metres above sea level (MSL).

DRAFT

5 0 5 10 15 20
Kilometres

SCALE: 1:500,000 METRIC 11"x17"

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/05/09	ISSUED WITH REPORT	JCL	MSW

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON ENERGY

GEOTHERMAL REVIEW AND
SITE INVENTORY

McARTHUR SPRINGS
SITE LOCATION PLAN

MAY 2016 FIGURE 10 REV: A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

FileName: P:\Projects\2016\16-1404-001\Dwg\GIS\MXDs\RevA\16-1404-001_Fig10_RevA.mxd
11"x17" PLOT SCALE 1:1

FIGURE 11
CASE 3 ORGANIC RANKINE CYCLE FLOW CHART

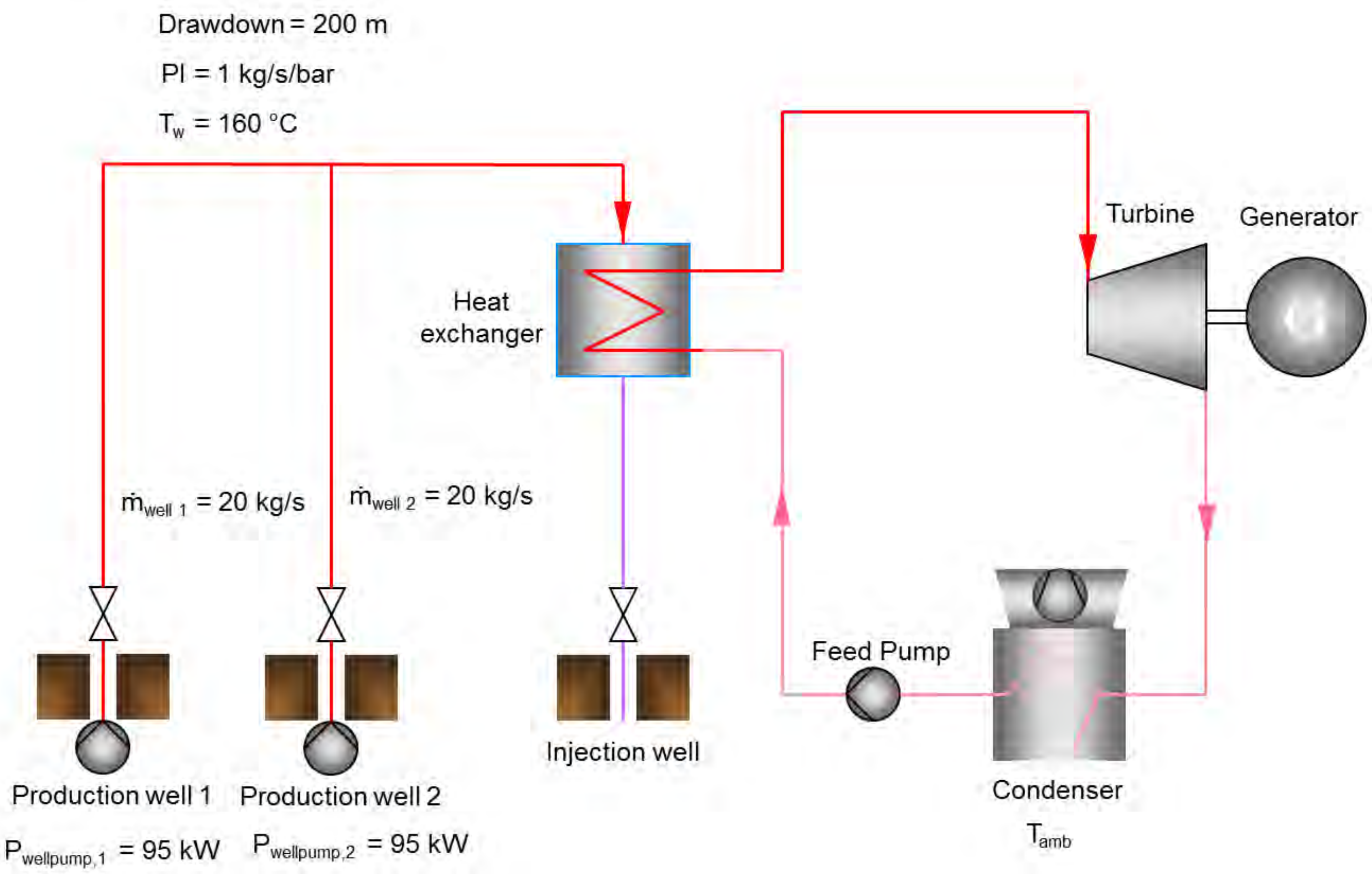
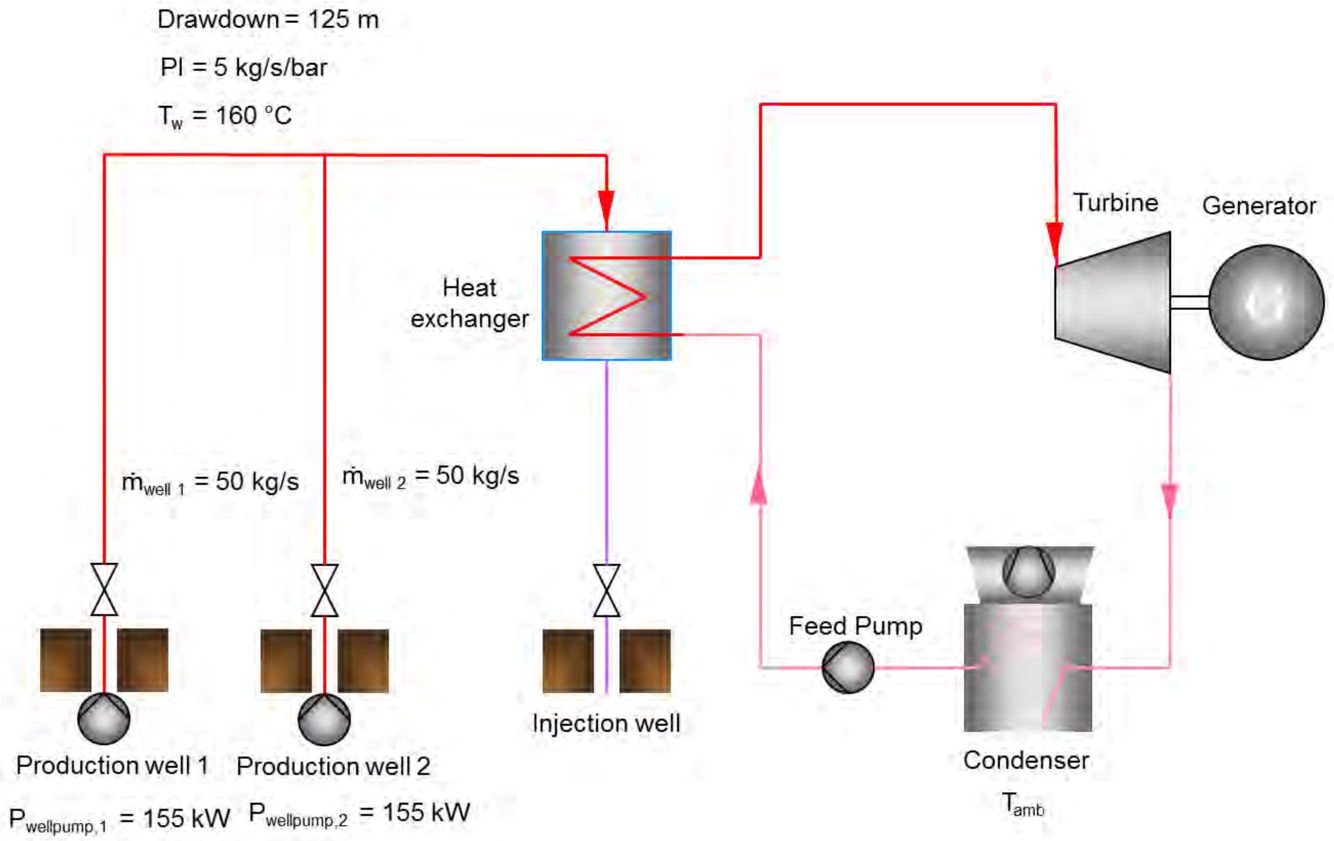
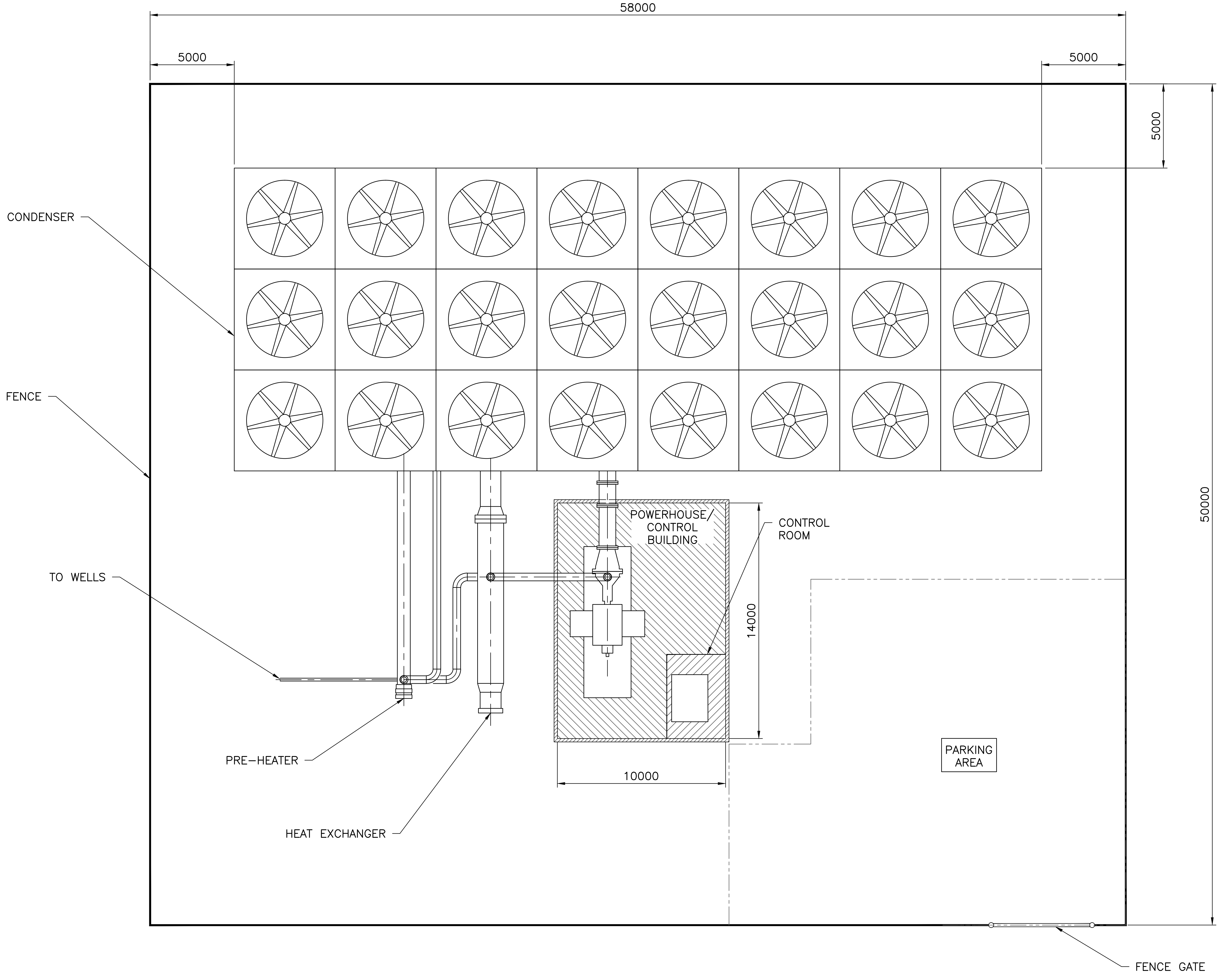


FIGURE 12
CASE 4 ORGANIC RANKINE CYCLE FLOW CHART



11x17



McARTHUR SPRINGS GEOTHERMAL ORC PLANT (2.8 MW)

3000 0 3000 6000 9000 12000

SCALE: 1:150mm (24"x36")

LEGEND:

ORC	ORGANIC RANKINE CYCLE

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/05/09	ISSUED FOR DESIGN REPORT		

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON
ENERGY

GEOTHERMAL REVIEW AND SITE INVENTORY

PLANT LAYOUT
CASE 3 (2.8 MW)
McARTHUR SPRINGS

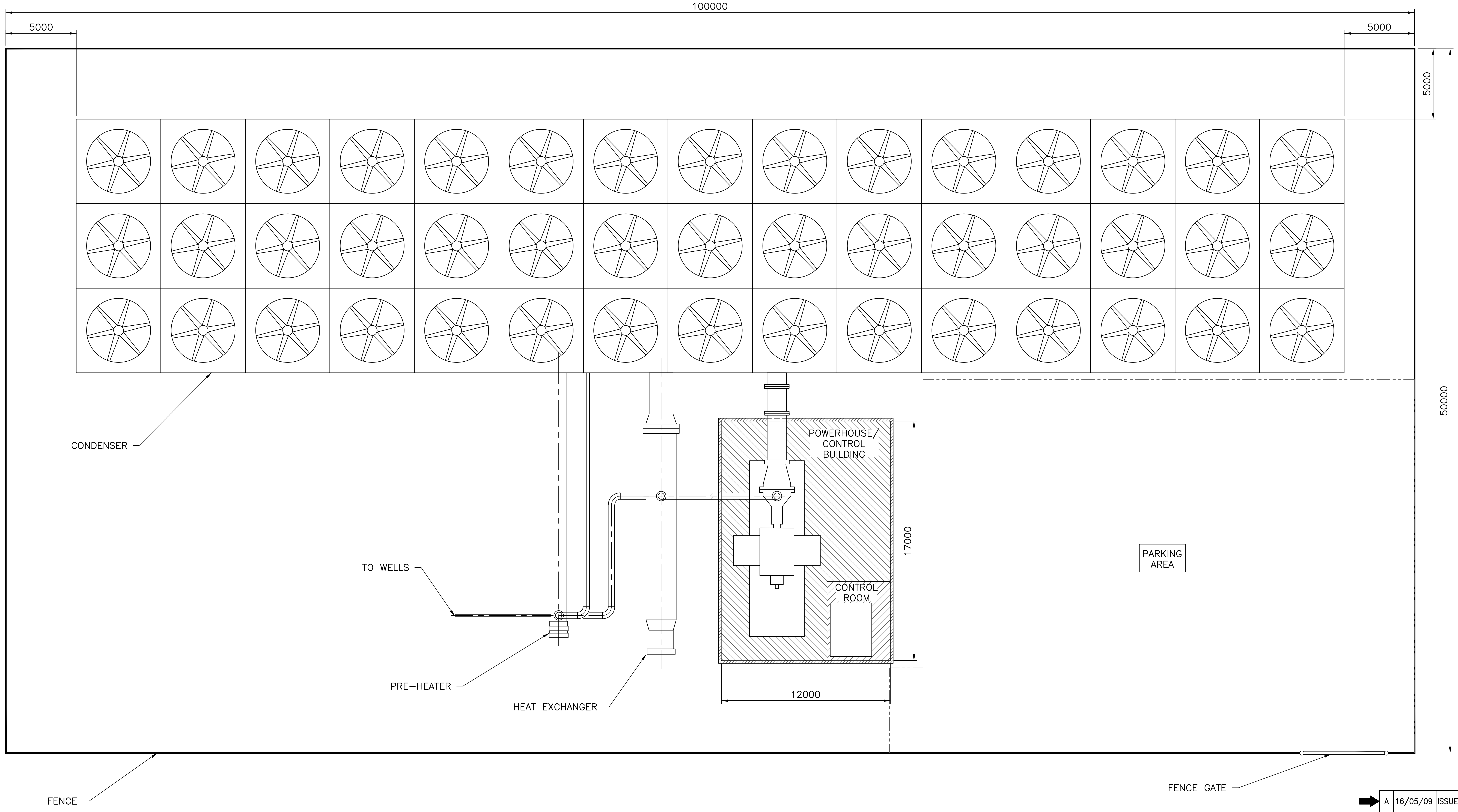
MAY_2016

FIGURE 13

REV:
A

FileName: U:\FMS\16-1404-001\16-1404-001_FIGURE 13.dwg – Tab: Rev A Plotted By: Cabellanosa 16/05/09 [Mon 2:11pm]
11"x17" PLOT SCALE: 1:2

11x17



LEGEND:

ORC ORGANIC RANKINE CYCLE

McARTHUR SPRINGS GEOTHERMAL ORC PLANT (7.0 MW)

3000 0 3000 6000 9000 12000

SCALE: 1:150mm (24"x36")

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
A	16/05/09	ISSUED FOR DESIGN REPORT	SBC	JCL

REVISIONS / ISSUE

KGS GROUP
CONSULTING ENGINEERS

YUKON ENERGY

GEOTHERMAL REVIEW AND SITE INVENTORY

PLANT LAYOUT
CASE 4 (7.0 MW)
McARTHUR SPRINGS

MAY_2016

FIGURE 14

REV: A

FileName: U:\FMS\16-1404-001\16-1404-001_FIGURE 14.dwg – Tab: Rev A Plotted By: Cabellanosa 16/05/09 [Mon 2:11pm]
11"x17" PLOT SCALE: 1:2

FIGURE 15

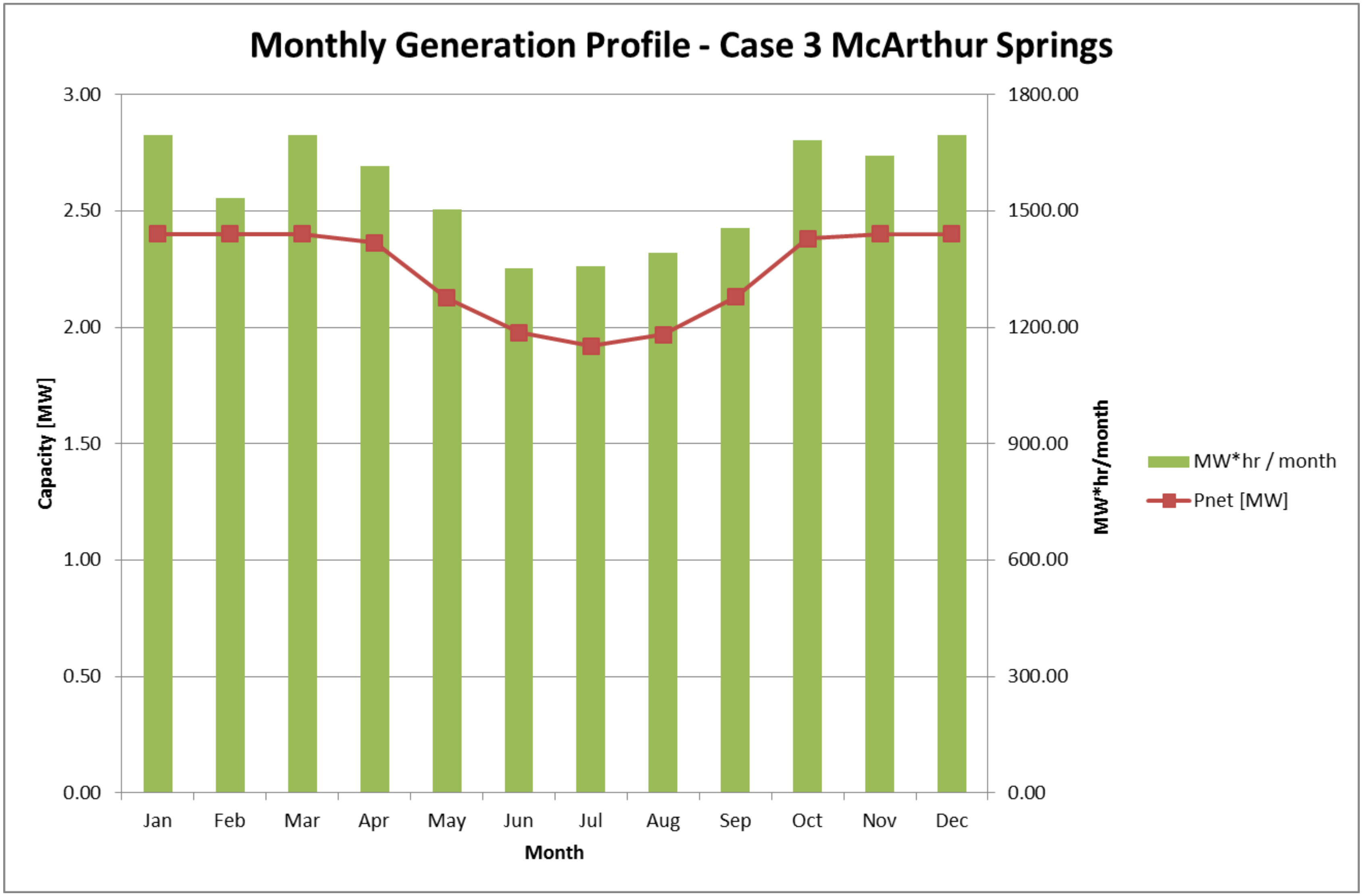

Monthly Generation Profile - Case 3 McArthur Springs
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Capacity [MW]
1800.00
1500.00
1200.00
900.00
600.00
300.00
0.00
MW*hr/month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
MW*hr / month
Pnet [MW]

FIGURE 16

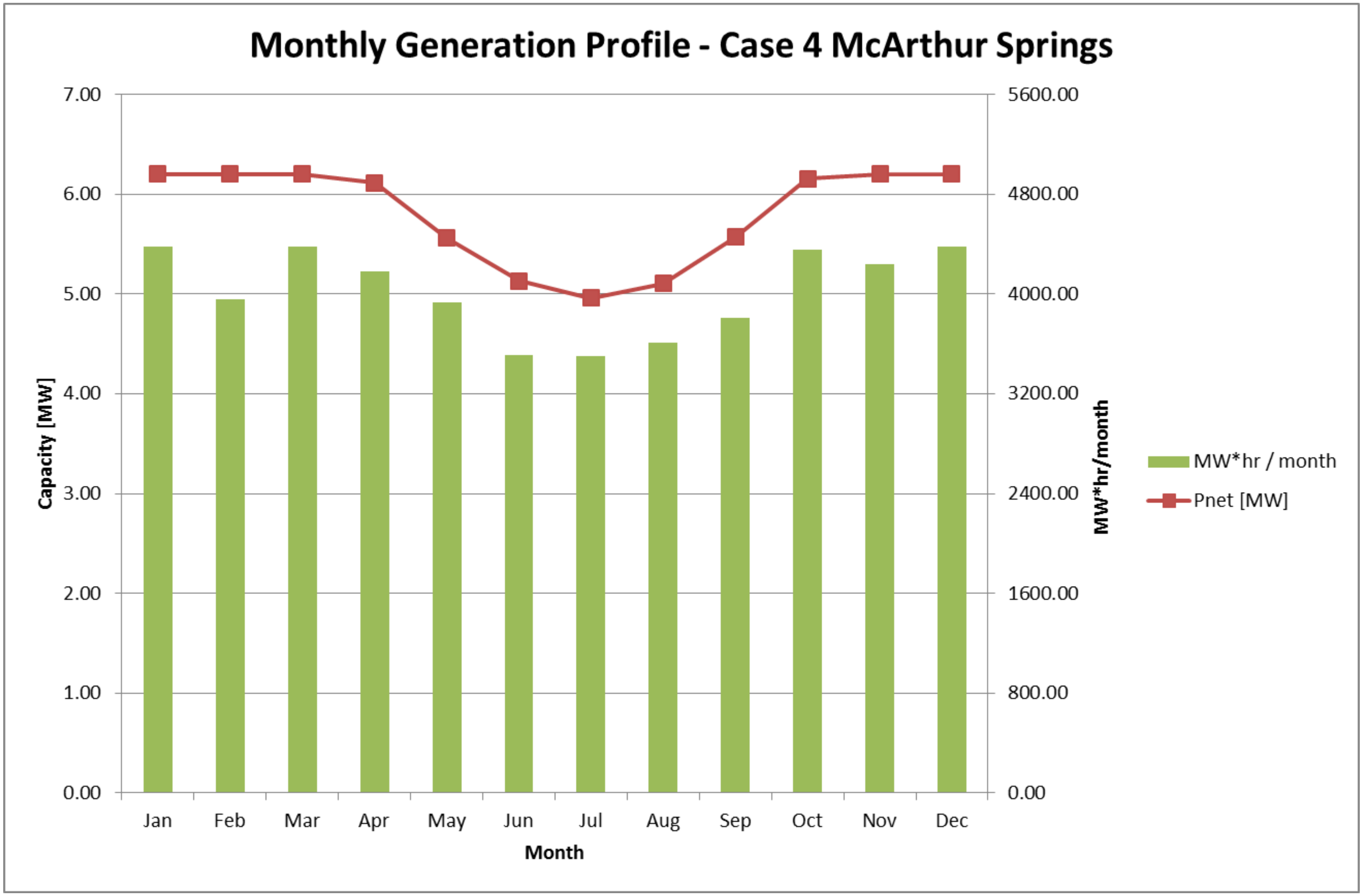
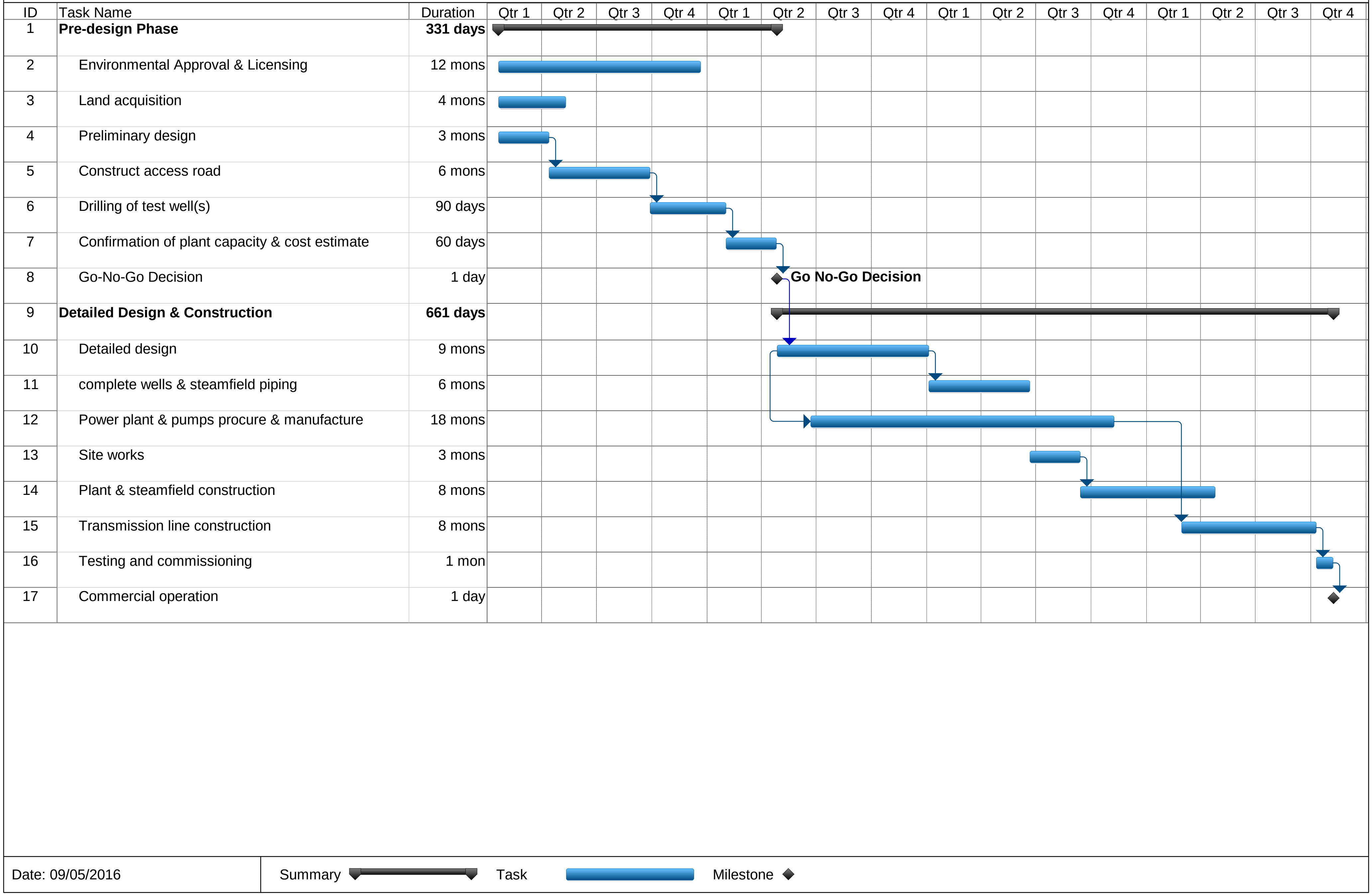

Monthly Generation Profile - Case 4 McArthur Springs
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Capacity [MW]
5600.00
4800.00
4000.00
3200.00
2400.00
1600.00
800.00
0.00
MW*hr/month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
MW*hr / month
Pnet [MW]

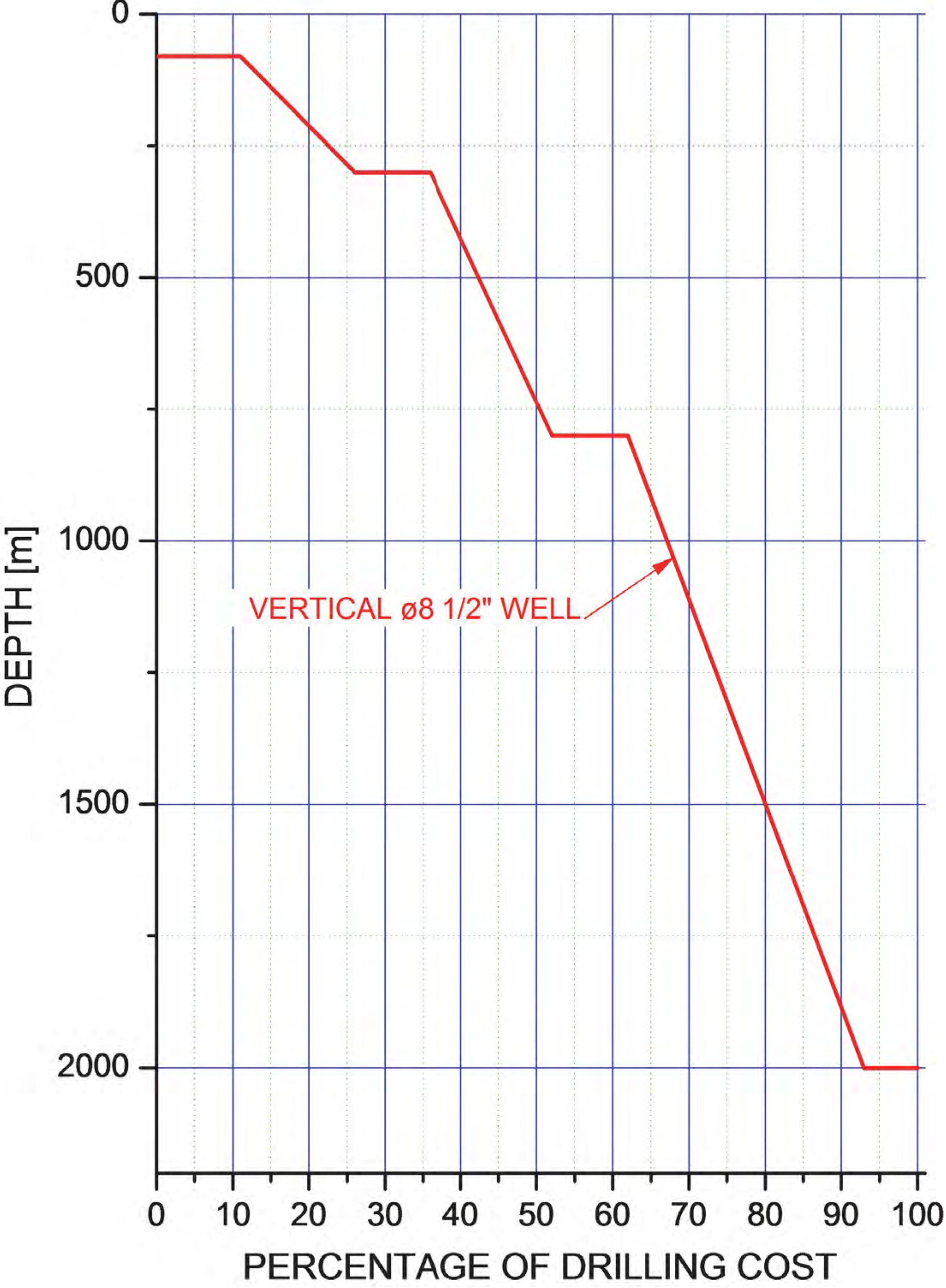
Figure 17: McArthur Springs Geothermal Plant - Preliminary Schedule



ID	Task Name	Duration
1	**Pre-design Phase**	**331 days**
2	Environmental Approval & Licensing	12 mons
3	Land acquisition	4 mons
4	Preliminary design	3 mons
5	Construct access road	6 mons
6	Drilling of test well(s)	90 days
7	Confirmation of plant capacity & cost estimate	60 days
8	Go-No-Go Decision	1 day
9	**Detailed Design & Construction**	**661 days**
10	Detailed design	9 mons
11	complete wells & steamfield piping	6 mons
12	Power plant & pumps procure & manufacture	18 mons
13	Site works	3 mons
14	Plant & steamfield construction	8 mons
15	Transmission line construction	8 mons
16	Testing and commissioning	1 mon
17	Commercial operation	1 day

Date: 09/05/2016

FIGURE 18
DRILLING COST AS A FUNCTION OF WELL DEPTH



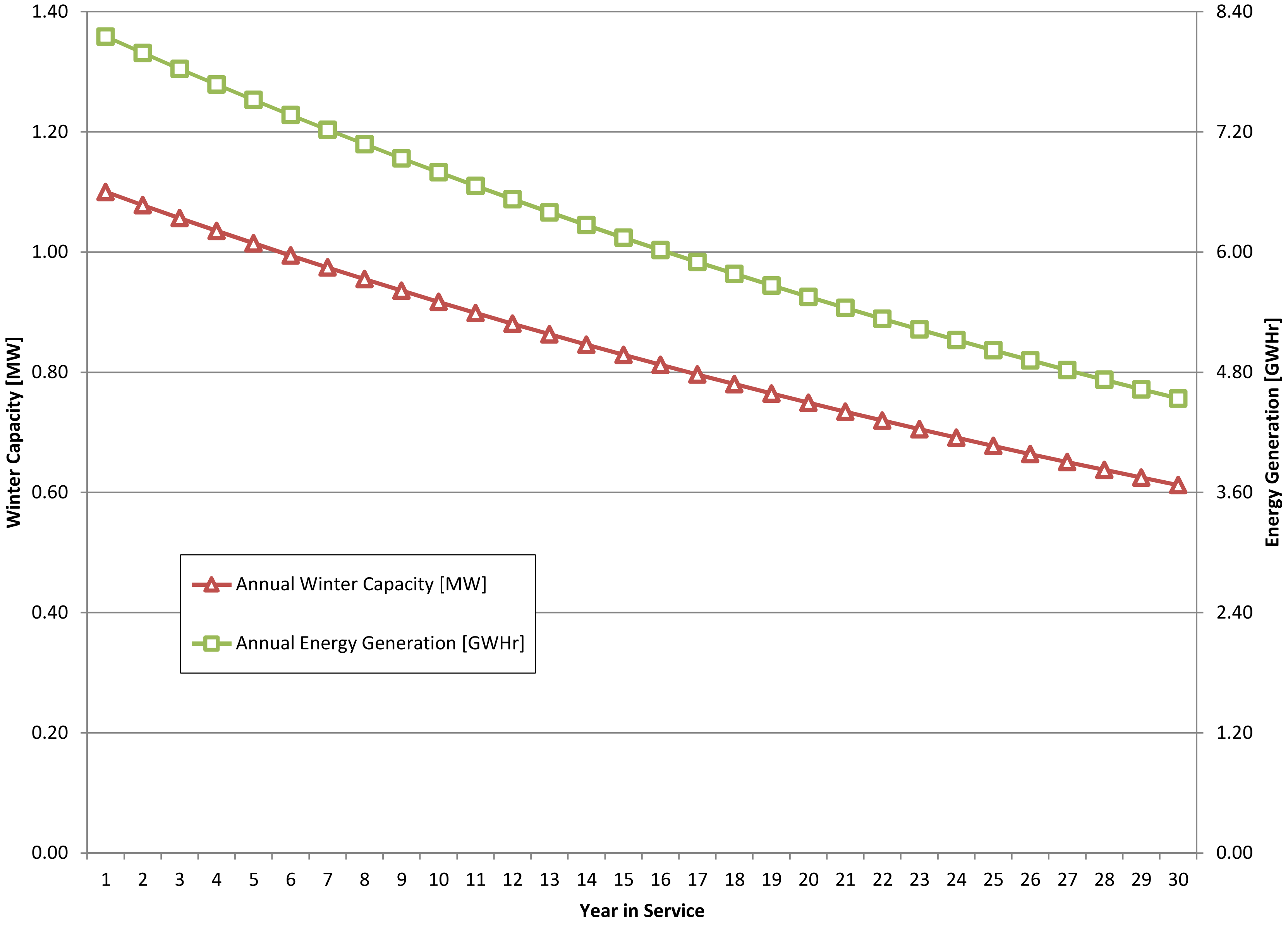


Figure 19: Energy and Capacity Degradation - Case 1 Vista Mountain

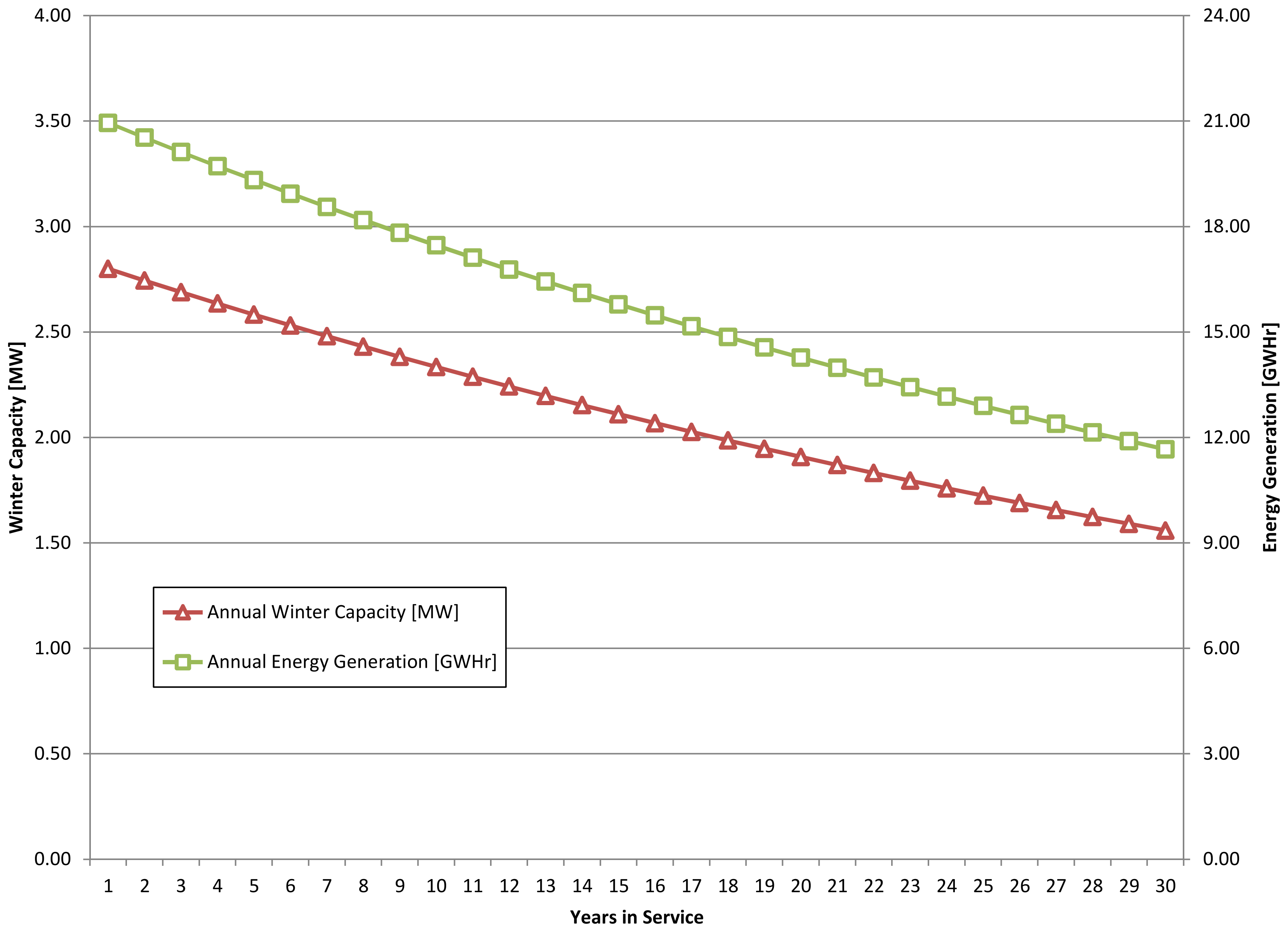


Figure 20: Energy and Capacity Degradation - Case 2 Vista Mountain

Figure 21: Energy and Capacity Degradation - Case 3 McArthur Springs

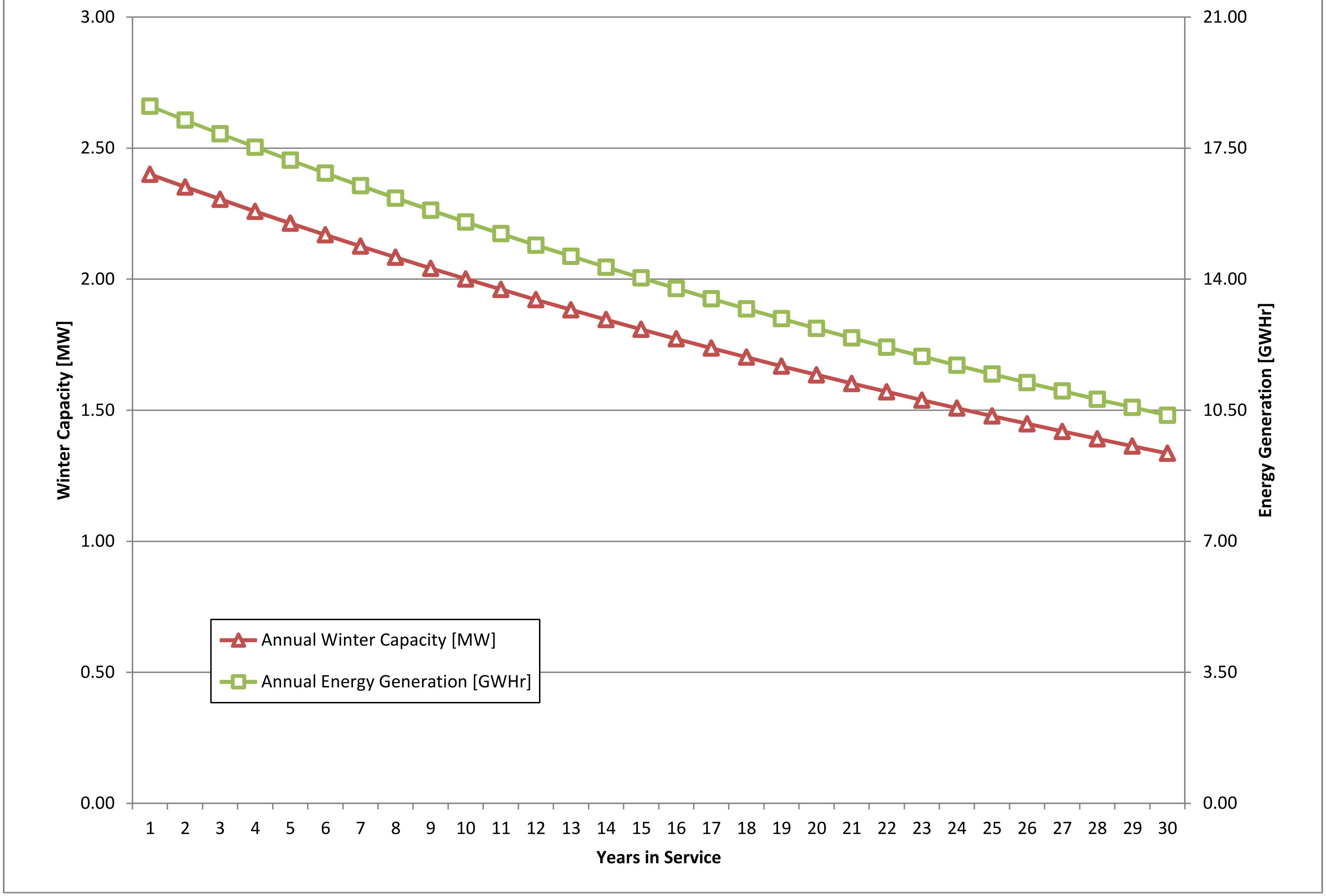
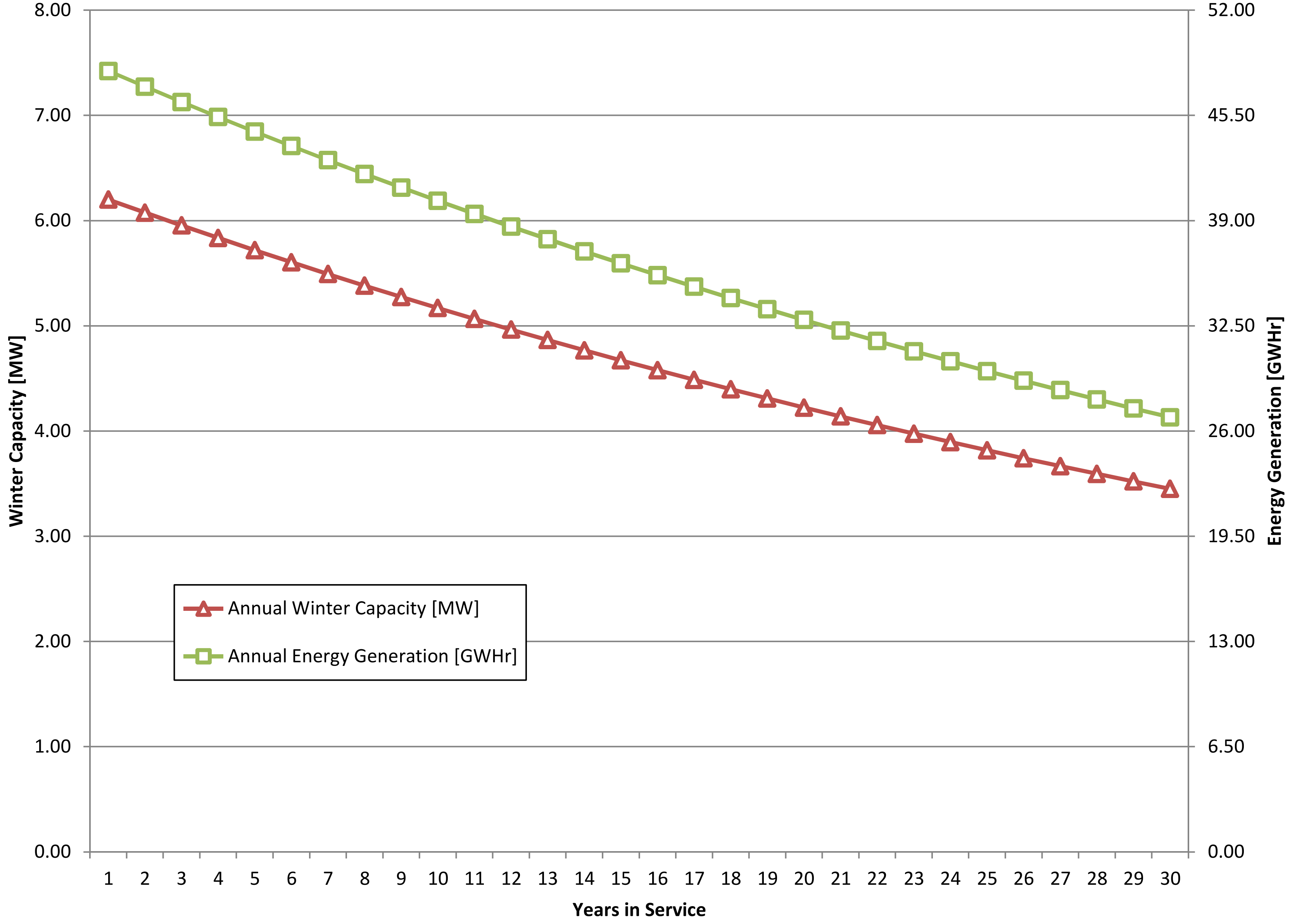


Figure 22: Energy and Capacity Degradation - Case 4 McArthur Springs



APPENDIX A

BIBLIOGRAPHY

Aurora Geosciences Ltd. (2012). Partridge Creek Elf Survey Observed Magnetic Field Tipper.

Aurora Geosciences Ltd. (2012). Partridge Creek Elf Survey Observed Magnetic Field Tipper. Partridge Creek Elf Survey Predicted Magnetic Field Tipper from Recovered 3d Conductivity Model.

Aurora Geosciences Ltd. (2012). Partridge Creek Inversion Results.

Burgess, M.M., Judge, A.S., and Taylor, A.E. (1982). Yukon Ground Temperature Data Collection – 1966 to August 1981. Earth Physics Branch Open File 82-1, Division of Seismology and Geothermal Studies, Earth Physics Branch, Energy, Mines and Resources Canada.

Carlson, George., Morgan Zondervan. (2009). Technical Memo, Yukon Geothermal Project – Results of Satellite Imagery Analysis. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Carlson, George., Morgan Zondervan. (2009). Technical Memo, Yukon Geothermal Project – Results of Thermal Infrared Imagery Analysis. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Carlson, George., Morgan Zondervan. (2009). Technical Memo, Yukon Geothermal Project– Results of Thermal Infrared Imagery Analysis. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Chaisson, Andrew., Schillereff, Scott. (2008). Groundwater Temperature, Geothermometer, and Geothermal Signature Assessment City of Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Crandall, J.T., Sadlier-Brown, T.L. (1976) Data on Geothermal Areas Cordilleran Yukon, Northwest Territoriesm and Adjacent British Columbia, Canada. Department of Supply and Services, Department of Energy, Mines, and Resources Canada.

Dennett, Jack T., Klump, Stephan. (2009). Discovery of Artesian Aquifer 30 km North of Haines Junction during the Geothermal Exploration Drilling Program. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). 2009 Air Photograph Acquisition – Jarvis River Area, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Exploration of Geothermal Potential at Jarvis River Warm Springs- 2009 Electromagnetic Geophysics Survey Program. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Exploration of Geothermal Potential at Jarvis River Warm Springs – 2009 Detailed Geological Mapping Program, Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Exploration of Geothermal Potential at Volcano Mountain – 2009 Geophysics Survey Program, Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Exploration of Geothermal Potential at Jarvis River Warm Springs – 2009 Diamond Drill Program. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Ground-Based Geothermal Reconnaissance Larsen Creek/Beaver River Area Southeast Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Report, Ground-Based Geothermal Reconnaissance Nash Creek Hot Springs Wernecke Mountains, Central Yukon, Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Summary Report 2009 Geothermal Exploration Program, Multiple Areas, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2010). Technical Memo, Desk-top Study–Geothermal Potential in the Swift River Area, Yukon and British Columbia. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Klump, Stephan. (2012). Summary of Results: Geophysics Survey of the Partridge Creek Warm Spring, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Dennett, Jack T., Martin, Ryan. (2010). Yukon Geothermal Study – Structural Inspection of Regional Aeromagnetic Mapping. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Grasby, S.E., Majorowicz, J., Ko, M. (2009). Geothermal Maps of Canada. Geological Survey of Canada Open File 6167.

Grasby, S.E., Allen, D.M., Bell, S., Chen, Z., Ferguson, G., Jessop, A., Kelman, M., Ko, M., Majorowicz, J., Moore, M., Raymond, J., Therrien, R. (2012). Geothermal Energy Resource Potential of Canada. Geological Survey of Canada Open File 6914.

Grasby, S.E., Majorowicz, J., and McCune, G. (2013). Geothermal Energy Potential for Northern Communities. Geological Survey of Canada Open File 7350.

Gross, Ashley., Dunn Craig. (2012). Whitehorse Area: Geothermal Energy Resource and Economic Assessment March 2012. Whitehorse, Yukon. Borealis Geopower.

Hildes, Dave (2013). Partridge Creek ELF 3D Inversion Memorandum. Aurora Geosciences, Northern Geological & Geophysical Consultants.

Jack Dennett. P.Geo. (2013). Summary of Results: Geophysics Survey of the Partridge Creek Warm Spring, Yukon. Whitehorse, Yukon.

Klump, Stephan., Brennwald, Matthias S., Morrison, David., Kipfer, Rolf., EBA, A Tetra Tech Company, Whitehorse, Yukon, Canada, sklump@eba.ca (* presenting author) Eawag: Swiss Federal Institute of Aquatic Science and Technology, Duebendorf, Switzerland, matthias.brennwald@eawag.ch Yukon Energy Corp., Whitehorse, Yukon, Canada, david.morrison@yec.yk.ca Swiss Federal Institute of Technology, ETH Zurich, Zurich, Switzerland, rolf.kipfer@eawag.ch. Noble Gases in Geothermal Waters as Tracers for Deep Fluid Circulation.

Klump, Stephan., Dennett, Jack T. (2011). Geology and Hydrogeochemistry of the Stinky Lake Warm Spring, Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Dennett, Jack T. (2011). Preliminary Geothermal Assessment, Partridge Creek Warm Spring, North of Stewart Crossing, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Dennett, Jack T. (2011). Subsurface Temperature Data from Borehole Measurements in Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Dennett, Jack T. (2012). Geological Mapping and Geochemistry Partridge Creekwarm Spring North of Stewart Crossing, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Dennett, Jack T. (2012). Preliminary Geothermal Assessment Vista Mountain Warm Springs North of Whitehorse, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Martin, Ryan. (2009). Gas Sampling, Jarvis River Warm Springs, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Martin, Ryan. (2009). Technical Memo, Hydrogeochemistry and Isoptope Signature of Stinky Lake and Versluce Warm Springs in Whitehorse, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Martin, Ryan. (2010). Advanced Geochemistry, Jarvis River Warm Springs and Shakwak Valley Area, Southwest, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Klump, Stephan., Martin, Ryan. (2010). Noble Gas Data from Multiple Warm and Hot Springs in Southern and Central Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Menzies, Lea., Dennett, Jack T. (2009). Technical Memo, Larson Creek/Beaver River Open Water Survey. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Menzies, Lea., Dennett, Jack T. (2009). Technical Memo, Yukon Geothermal Exploration Program - Open Water Survey. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Sadlier – Brown, T.L. (2010) A Discussion of Geothermal Resources and Their potential for Utilization in the Yukon Territory. Yukon Energy Charette.

Schillereff, Scott H., Johnston, Katherine. (2009). Ground Based Geothermal Reconnaissance Program Multiple Areas, Yukon. Whitehorse, Yukon. EBA Engineering Consultants Ltd.

Smith, S., and Burgess, M. (2000). Ground Temperature Database for Northern Canada. Geological Survey of Canada Open File Report 3954.

APPENDIX B

SITE RANKING SUMMARY

APPENDIX B - SITE RANKING SUMMARY

Site Ranking	Spring Name	St. Line Distance to T Line	Approx. Access Road Length, KM	Approx. T Line Length, KM	LOCATION			Site Geology (inferred)	Surface Temp.	Geothermometer	Geochemistry	Spring Flow Rate	Comments	References
	Within 50 km corridor				LAT.	LONG	Description			Estimated Temp °C				
1	Vista MT Warm Springs	1	1	1			~20 km North of Whitehorse ~1 km west of Klondike Hwy.	-Granite pluton associtated with Whitehorse trough - Thick overburden cover. Assumed deep flow system and major fault system	14	110	$CaCo_3$ + SO_4		-Meteoric water conditions, short residence time	1
2	Takhini	1	1	1	60.867	135.367	~33 km North of Whitehorse ~ 6 km North of Yukon Hwy 1	- Fractured Basalt - Whitehorse trough-fault zones - Thin sedimentary cover	47	96	$CaSo_4$	340 L/min		1,2, 4
3	Stinky Lake Warm Springs	1	1	1			~10 km North of Whitehorse	- Fractured Basalt - Whitehorse trough-fault zones - Thin sedimentary cover	19	85	CaMg HCO_3 H25 odour		-Possible origin of thermal water in sedimentary carbonate rich rocks	1, 2, 14
4	Versluce	1	1	1	60.767	135.15	~16 km North of Whitehorse	- Fractured Basalt - Whitehorse trough-fault zones - Thin sedimentary cover	13	54	CaMg HCO_3	60 L/min	- West of Porter Creek - NE of Whitehorse landfill	1,2, 5
5	Jarvis River / Warm Springs	5	5	5	60.9	137.95	Shakwak Valley ~31 km north west of Haines Junction (5 km south of Yukon Hwy 1)	- Thick overburden deep geothermal vertical faults	≤16	100	$NaHCO_3$		- Most seismicly active area in Yukon - Artesian flow from O/B at 47 m, - Possible meteroic origin difficult to seal drill hole	2, 12
6	Partridge Creek	15	20	20	63.697	137.28	~115 km SE of Dawson	Tintina Trench-Zone of intense fracturing, faulting and shearing	25	95	Na-HCO_3-SO_4		-Terrain/access challenges -Thermal water has long residence time (>>10,000 years); limited young, shallow water.	13
7	McArthur Spring (>50 km corridor)	37	45	45	60.067	135.7	Selkirk First Nation Lands ~32 km West of Yukon Hwy #2 (NW of Pelly Crossing)	- Selwin Fold belt	54	120	$NaHCO_3$		- Springs SW of McArthur Pluton	2, 10
8	Mayo Well	1	1	1	63.6	135.883	~17 km North of Mayo		15		$NaHCO_3$			6
9	Atlin	20	1	22	59.4	133.583	~165 km SE of Whitehorse		29		$Ca(CO_3)_2$			7
10	Morin North	22	33	33	59.983	134.217	~100 Km S of Whitehorse		<29		$Ca(CO_3)_2$			8
	Morin Middle				59.967	134.217								9
	Morin South				59.967	134.217								11
11	Jones Lake	22	22	22			~115 km SE of Whitehorse		<29		$Ca(CO_3)_2$			10
Sites near 50 km Corridor														
1	McPherson	41	50	50	61.867	129.617	~200 km N of Watson Lake ~30 Km NW of Yukon Hwy		N/A					12
2	Volcano Mountain	44	50	50			~40 km NW of Pelly Crossing	Volcano deposits of the Selkirk Volcanics are the youngest (<10,000 yrs)	N/A				- No Surface springs detected - Subsurface drilling required	2

Notes:

1. See YEC Figure 1: Location Plan with Grid Overview and hand marked geothermal sites.
2. Geothermometoe calculated temperatures estimated using the silica based method are considered to be a more plausible lower temperature estimate, versus the higher temperature Na-K-Ca based method.

References:

1. EBA, December 2012; Preliminary Geothermal Assessment Vista Mountain Warm Springs North of Whitehorse, Yukon
2. EBA, April 2010; Summary Report, 2009 Geothermal Exploitation Program, Multiple Areas, Yukon.
3. Borealis Geopower Inc. March 12, 2012; Whitehorse Area: Geothermal Energy Resource and Economic Assessment
4. Crandall, T. and Sadlier-Brown, T.L. , Nov 1976; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
5. Crandall, T. and Sadlier-Brown, T.L. , Nov 1977; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
6. Crandall, T. and Sadlier-Brown, T.L. , Nov 1978; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
7. Crandall, T. and Sadlier-Brown, T.L. , Nov 1979; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
8. Crandall, T. and Sadlier-Brown, T.L. , Nov 1980; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
9. Crandall, T. and Sadlier-Brown, T.L. , Nov 1981; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
10. Crandall, T. and Sadlier-Brown, T.L. , Nov 1982; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
11. Crandall, T. and Sadlier-Brown, T.L. , Nov 1983; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
12. Crandall, T. and Sadlier-Brown, T.L. , Nov 1984; Data on Geothermal Areas, Codilleran Yukon, Northwest Territories, and Adjacent British Columbia, Canada
13. EBA, April 2012; Geological Mapping and Geochemistry, Partridge Creek Warm Spring, Yukon
14. EBA, March 2011; Geology and Hydrogeochemistry of the Stinky Lake Warm Springs, Whitehorse, Yukon

APPENDIX C

DETAILED COST ESTIMATES

BASIS OF COST ESTIMATES

KGS Group has completed and is currently involved in several Canadian utility development projects. These projects are located in similarly remote locations, such as northern Manitoba, northeastern Ontario, and in northern Saskatchewan. The building and site costs for this geothermal project our based on KGS Group's recent experience.

Mannvit has been involved with the design and construction of several geothermal projects; throughout the world. The well and power plant costs, including the turbine, generator, heat exchangers, condensers, controls and pipeline costs are based from their database of projects.

Well costs included are "normal" costs for deep well drilling. Some areas in the world are currently seeing a 20% to 30 % reduction in these costs due to the slowdown in oil exploration and development. Depending on the timing of any well drilling, these savings may or may not be realized.

Direct costs include the construction expenses of the proposed geothermal development, including all temporary works such as access roads required during construction as well as all component costs needed during development. These component costs, including the turbine, generator, wells, transmission lines and interconnection have been estimated based on calculated material quantities for the arrangements and unit prices.

At this conceptual level of study the various indirect costs have been estimated as percentages of the direct costs, including the General Contractor's indirect costs, travel and camp costs, contingencies, and contractor markups. Owner's costs have also been estimated as percentages of the project direct costs, and include environmental approval studies and consultations through the approval process with all stakeholders. Owner's costs also include additional feasibility assessment costs, final design, site assistance, quality assurance and interest during construction. The Mayo B contract, as well as other more recent hydro projects, were used to develop a criteria for estimating the indirect and owner costs for the potential geothermal development for this study.

VISTA MOUNTAIN GEOTHERMAL PROJECT

DIRECT COST DETAILS

		Case 1 0.9 MW			Case 2 2.3 MW		
ITEMS	**Unit**	**Quantity**	**Unit Cost**	**Cost (2015 $)**	**Quantity**	**Unit Cost**	**Cost (2015 $)**
SITEWORK				**$100,000**			**$120,000**
Clearing	ha	1	$18,900	$19,000	1	$18,900	$19,000
Foundation Preparation							
- Powerhouse	sq metre	108	$22	$3,000	140	$22	$10,000
- Condenser	sq metre	216	$22	$5,000	756	$22	$20,000
Access road maintenance	months	12	$5,800	$70,000	12	$5,800	$70,000
STRUCTURES & EXCAVATION				**$930,000**			**$1,190,000**
Rock Excavation	cubic metre	90	$100	$9,000	140	$100	$14,000
General Excavation	cubic metre	1,840	$30	$56,000	2,600	$30	$78,000
Granular Fill	cubic metre	0	$50	$0	0	$50	$0
Reinforced Concrete							
- Pump Station	cubic metre	65	$2,200	$143,000	83	$2,200	$182,000
- Ventilator Foundations	per foundation	21	$1,500	$32,000	32	$1,500	$48,000
- Well Pump Buildings and Misc.	cubic metre	40	$2,200	$88,000	51	$2,200	$113,000
Powerhouse/Control Building							
- Superstructure Steel	cubic metre	756	$120	$90,720	1120	$120	$134,400
- Steel Cladding	sq. metre	400	$450	$180,000	500	$450	$225,000
- Architectural/HVAC/Water/Lighting	LS	1	$108,000	$108,000	1	$140,000	$140,000
Powerhouse Crane	EA	1	$150,000	$150,000	1	$150,000	$150,000
Well Pump Buildings	sq. metre	50	$1,500	$75,000	72	$1,500	$108,000
POWER PLANT				**$2,900,000**			**$5,400,000**
Turbines, Generators & All M&E Process	LS	1	$2,900,000	$2,900,000	1	$5,400,000	$5,400,000
WELLS & WATER SUPPLY SYSTEM				**$9,070,000**			**$9,320,000**
Production Wells (2700 m)	EA	2	$2,600,000	$5,200,000	2	$2,600,000	$5,200,000
Injection Well (2700 m)	EA	1	$2,600,000	$2,600,000	1	$2,600,000	$2,600,000
Mobilization of Drilling Rig	LS	1	$380,000	$380,000	1	$380,000	$380,000
Pipelines (Pre-insulated buried pipe)	LS	1	$630,000	$630,000	1	$760,000	$760,000
Well Pumps	EA	2	$130,000	$260,000	2	$190,000	$380,000
TRANSMISSION LINE				**$990,000**			**$990,000**
Transmission Line (34.5 kV)	km	5	$167,000	$835,000	5	$167,000	$835,000
Interconnection	LS	1	$150,000	$150,000	1	$150,000	$150,000
ACCESS				**$640,000**			**$640,000**
Clearing	ha	2.3	$18,900	$43,000	2.3	$18,900	$43,000
Access road	km	1.5	$400,000	$600,000	1.5	$400,000	$600,000
ENVIRONMENTAL & MITIGATION ITEMS	LS	1	$500,000	**$500,000**	1	$500,000	**$500,000**
TOTAL DIRECT COSTS				***$15,130,000***			***$18,160,000***

McARTHUR SPRINGS GEOTHERMAL PROJECT

DIRECT COST DETAILS

ITEMS	Unit	Case 3 2.1 MW			Case 4 5.5 MW		
		Quantity	Unit Cost	Cost (2015 $)	Quantity	Unit Cost	Cost (2015 $)
SITEWORK				**$110,000**			**$130,000**
Clearing	ha	1	$18,900	$19,000	1	$18,900	$19,000
Foundation Preparation							
- Powerhouse	sq metre	140	$22	$4,000	204	$22	$10,000
- Condensor	sq metre	756	$22	$17,000	1,620	$22	$40,000
Access road maintenance	months	12	$5,800	$70,000	12	$5,000	$60,000
STRUCTURES & EXCAVATION				**$1,660,000**			**$2,550,000**
Rock Excavation	cubic metre	70	$100	$7,000	102	$100	$11,000
General Excavation	cubic metre	2,740	$30	$83,000	5,204	$30	$157,000
Granular Fill	cubic metre	2,600	$50	$130,000	5,000	$50	$250,000
Reinforced Concrete							
- Pump Station	cubic metre	111	$2,200	$245,000	160	$2,200	$352,000
- Powerhouse Piles	per pile	12	$8,100	$98,000	20	$8,100	$162,000
- Ventilator Foundation Piles	per pile	32	$8,100	$260,000	64	$8,100	$519,000
- Well Pump Buildings and Misc.	cubic metre	65	$2,200	$143,000	87	$2,200	$192,000
Powerhouse/Control Building							
- Superstructure Steel	cubic metre	980	$120	$118,000	1428	$120	$172,000
- Steel Cladding	sq. metre	476	$450	$215,000	610	$450	$275,000
- Architectural/HVAC/Water/Lighting	LS	1	$140,000	$140,000	1	$204,000	$204,000
Powerhouse Crane	EA	1	$150,000	$150,000	1	$150,000	$150,000
Well Pump Buildings	sq metre	50	$1,500	$75,000	72	$1,500	$108,000
POWER PLANT				**$4,400,000**			**$8,400,000**
Turbines, Generators & All M&E Process	LS	1	$4,400,000	$4,400,000	1	$8,400,000	$8,400,000
WELLS & WATER SUPPLY SYSTEM				**$8,800,000**			**$9,050,000**
Production Wells (2700 m)	EA	2	$2,510,000	$5,020,000	2	$2,510,000	$5,020,000
Injection Well (2700 m)	EA	1	$2,510,000	$2,510,000	1	$2,510,000	$2,510,000
Mobilization of Drilling Rig	LS	1	$380,000	$380,000	1	$380,000	$380,000
Pipelines (Pre-insulated buried pipe)	LS	1	$630,000	$630,000	1	$760,000	$760,000
Well Pumps	EA	2	$130,000	$260,000	2	$190,000	$380,000
TRANSMISSION LINE				**$11,120,000**			**$11,120,000**
Transmission Line (138 kV)	km	43	$255,000	$10,965,000	43	$255,000	$10,965,000
Interconnection	LS	1	$150,000	$150,000	1	$150,000	$150,000
ACCESS				**$18,420,000**			**$18,420,000**
Clearing	ha	64.5	$18,900	$1,220,000	64.5	$18,900	$1,220,000
Access road	km	43.0	$400,000	$17,200,000	43.0	$400,000	$17,200,000
ENVIRONMENTAL & MITIGATION ITEMS	LS	1	$500,000	**$500,000**	1	$500,000	**$500,000**
TOTAL DIRECT COSTS				***$45,010,000***			***$50,170,000***

APPENDIX D

FINANCIAL TABLES

Table 1: Summary Yukon Energy Corporation Geothermal Generation Options

Step 1 - Financial analysis

Geothermal Cases	Option Assumptions										
	Capital Cost (2015$)			Annual Fixed O&M Costs (2015$)	Annual Variable O&M Costs (2015$)	Annual Average Capacity [net output] - First Year	Reliable Winter Capacity [net output] - First Year	Annual Average Capacity Factor	Annual Average Energy - First Year	Expected Life	Expected In-Service Date (January 1)
	Plant Capital Cost	Transmission Capital Cost	Total Capital Cost								
	$000	$000	$000	$000	$/MW.h	MW	MW	%	GW.h	Years	Year
A	B	C	D=B+C	E	F	G	H	I	J	K	L
Vista Mountain Case 1: 0.9 MW	$35,400	$2,400	$37,800	$350	$0	1.0	1.1	95%	8.2	30	2019
Vista Mountain Case 2: 2.3 MW	$42,800	$2,400	$45,200	$800	$0	2.5	2.8	95%	20.9	30	2019
McArthur Springs Case 3: 2.1 MW	$86,100	$27,900	$114,000	$800	$0	2.2	2.4	95%	18.6	30	2020
McArthur Springs Case 4: 5.5 MW	$99,100	$27,900	$127,000	$1,800	$0	5.8	6.2	95%	48.2	30	2020

	Levelized Cost of Energy (LCOE) and Levelized Cost of Capacity (LCOC)					
	3.38% Real WACC		4.61% Real WACC		8.82% Real WACC	
	LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)	LCOE (2015$)	LCOC (2015$)
	$/kW.h	$/MW	$/kW.h	$/MW	$/kW.h	$/MW
A	M	N	O	P	Q	R
Vista Mountain Case 1: 0.9 MW	$0.368	$2,330,074	$0.412	$2,658,409	$0.577	$3,901,681
Vista Mountain Case 2: 2.3 MW	$0.194	$1,094,589	$0.214	$1,248,829	$0.290	$1,832,876
McArthur Springs Case 3: 2.1 MW	$0.469	$3,220,803	$0.527	$3,674,652	$0.746	$5,393,197
McArthur Springs Case 4: 5.5 MW	$0.225	$1,388,937	$0.250	$1,584,655	$0.343	$2,325,759

Notes:
1. Annual average capacity is based on average available capacity throughout the year - Table 1 shows capacity and energy in year 1 of operation.
2. For each project a 3%/year degradation of annual capacity assumed over the life of project [annual energy also reduced by 3%/year].

Step 2 - Ranking

The review of Geothermal options identified two separate projects, each with 2 different scales of development.

Technical Attributes

1. Each project provides reliable energy and capacity, but is not dispatchable [technically dispatchable, however, it is not economically feasible to dispatch].
2. Each project option degrades each year in capacity and energy.
3. The only differences are:
    - in scale: McArthur Springs option is materially larger than Vista Mountain at each of the two scales examined for each project; and
    - in distance to grid: McArthur Springs requires much longer transmission line to connect to the Yukon electrical grid.

Financial Attributes

1. Vista Mountain Case 2 with 2.3 MW option shows the lowest LCOE and LCOC. This option also has a lower capital cost compared to McArthur Project with a similar scale of development option.
2. McArthur Springs Case 4 with 5.5 MW option shows the second lowest LCOE and LCOC. However, this option requires larger load demand than other cases in order to develop on an economic basis.
3. Both of the smaller scale options, Vista Mountain Case 1 [0.9 MW] and McArthur Springs Case 3 [2.1 MW], show much higher LCOE and LCOC, highlighting that small scale versions of each project are not financially attractive.
   McArthur Springs Case 3 capital cost is 2.5 times higher compared to Vista Mountain Case 2 [even though Case 3 has a slightly smaller amount of capacity and energy output].

Summary

Considering isolated nature of the Yukon Electrical grid, the best option depends on following:
- Energy demand:

    - If the energy demand requires in the range of 2.5 to 3 MW of reliable winter capacity and about 20 GW.h/year energy in near term (or less), Vista Mountain case is best option
    - If the energy demand requires in the range of 6 MW of reliable winter capacity and about 50 GW.h/year energy in near term, McArthur Springs is a competitive option only if the larger scale development is confirmed.
    - Any materially smaller load requirement than assumed in Case 2 (for Vista Mountain) and Case 4 (for McArthur Springs) will result in much higher cost per unit of energy for either option.
- Potential benefit from new transmission as regards other loads or resource options might add benefit to the McArthur Springs larger scale option that is not considered in this analysis.

Table A-1: Financial Analysis (WACC at 5.45%): **Vista Mountain Case 1: 0.9 MW**

			Average MW	Winter MW	
Capital ($000)	2015	$37,800	1.0	1.1	
Capital ($000)	2019	$40,916			
Energy		8.2	GWh/yr		
Capacity Factor		95%CF		**Load Growth**	
Fuel	2015			-2.0%	
O&M (Fixed)	2015	350.0	$000/yr	**8.2**	GW.h
O&M (Variable)	2015	0.0	$/MWh		
Life		30	years		
Salvage cost		0%			

Weighted Average Cost of Capital	5.45%
Inflation Rate	2%
Real Weighted Average Cost of Capital	3.38%

LCOE and LCOC with 5.45% WACC, Vista Mountain Case 1: 0.9 MW

Life Cycle Cost (2015$000's)	46,085
Depreciation & Return Cost (2015$000's)	39,331
Project LCOE ($/kWh)	$0.368
Project LCOC ($/MW)	$2,330,074

Year	**Vista Mountain Case 1: 0.9 MW**					
	Year-End Balance $000	**Depr $000**	**Return $000**	**O&M $000**	**Total $000**	**cents/ kW.h**
2019	39,552	1,364	2,193	379	3,935	48
2020	38,188	1,364	2,118	386	3,869	48
2021	36,824	1,364	2,044	394	3,802	49
2022	35,460	1,364	1,970	402	3,736	49
2023	34,097	1,364	1,895	410	3,669	49
2024	32,733	1,364	1,821	418	3,603	49
2025	31,369	1,364	1,747	427	3,537	49
2026	30,005	1,364	1,672	435	3,471	49
2027	28,641	1,364	1,598	444	3,406	49
2028	27,277	1,364	1,524	453	3,340	49
2029	25,913	1,364	1,449	462	3,275	49
2030	24,550	1,364	1,375	471	3,210	49
2031	23,186	1,364	1,301	480	3,145	49
2032	21,822	1,364	1,226	490	3,080	49
2033	20,458	1,364	1,152	500	3,016	49
2034	19,094	1,364	1,078	510	2,952	49
2035	17,730	1,364	1,003	520	2,887	49
2036	16,366	1,364	929	530	2,823	49
2037	15,003	1,364	855	541	2,760	49
2038	13,639	1,364	780	552	2,696	49
2039	12,275	1,364	706	563	2,633	48
2040	10,911	1,364	632	574	2,570	48
2041	9,547	1,364	557	586	2,507	48
2042	8,183	1,364	483	597	2,444	48
2043	6,819	1,364	409	609	2,382	47
2044	5,455	1,364	334	622	2,320	47
2045	4,092	1,364	260	634	2,258	47
2046	2,728	1,364	186	647	2,196	46
2047	1,364	1,364	111	660	2,135	46
2048	0	1,364	37	673	2,074	46
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		21,018	21,555	7,311	49,884	
$2015PV		19,418	19,913	6,754	46,085	
					89,734	

Year from In-service	**Annual Energy GW.h, Vista Mountain Case 1: 0.9 MW**	**Annual Winter Capacity MW, Vista Mountain Case 1: 0.9 MW**
1	8.15	1.10
2	7.99	1.08
3	7.83	1.06
4	7.67	1.04
5	7.52	1.01
6	7.37	0.99
7	7.22	0.97
8	7.08	0.95
9	6.94	0.94
10	6.80	0.92
11	6.66	0.90
12	6.53	0.88
13	6.40	0.86
14	6.27	0.85
15	6.14	0.83
16	6.02	0.81
17	5.90	0.80
18	5.78	0.78
19	5.67	0.76
20	5.55	0.75
21	5.44	0.73
22	5.33	0.72
23	5.23	0.71
24	5.12	0.69
25	5.02	0.68
26	4.92	0.66
27	4.82	0.65
28	4.72	0.64
29	4.63	0.62
30	4.54	0.61
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
Net Present Value	103	
Total energy	185	
Avg Annual energy	6	

Table A-2: Financial Analysis (WACC at 6.70%): Vista Mountain Case 1: 0.9 MW

Weighted Average Cost of Capital 6.70%
Inflation Rate 2%
Real Weighted Average Cost of Capital 4.61%

LCOE and LCOC with 6.7% WACC, Vista Mountain Case 1: 0.9 MW

Life Cycle Cost (2015$000's) 45,645
Depreciation & Return Cost (2015$000's) 39,756

Project LCOE ($/kWh) $0.412
Project LCOC ($/MW) $2,658,409

Year	Vista Mountain Case 1: 0.9 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2019	39,552	1,364	2,696	379	4,438	54
2020	38,188	1,364	2,604	386	4,355	55
2021	36,824	1,364	2,513	394	4,271	55
2022	35,460	1,364	2,422	402	4,187	55
2023	34,097	1,364	2,330	410	4,104	55
2024	32,733	1,364	2,239	418	4,021	55
2025	31,369	1,364	2,147	427	3,938	55
2026	30,005	1,364	2,056	435	3,855	54
2027	28,641	1,364	1,965	444	3,772	54
2028	27,277	1,364	1,873	453	3,690	54
2029	25,913	1,364	1,782	462	3,608	54
2030	24,550	1,364	1,691	471	3,525	54
2031	23,186	1,364	1,599	480	3,443	54
2032	21,822	1,364	1,508	490	3,362	54
2033	20,458	1,364	1,416	500	3,280	53
2034	19,094	1,364	1,325	510	3,199	53
2035	17,730	1,364	1,234	520	3,118	53
2036	16,366	1,364	1,142	530	3,037	53
2037	15,003	1,364	1,051	541	2,956	52
2038	13,639	1,364	959	552	2,875	52
2039	12,275	1,364	868	563	2,795	51
2040	10,911	1,364	777	574	2,715	51
2041	9,547	1,364	685	586	2,635	50
2042	8,183	1,364	594	597	2,555	50
2043	6,819	1,364	503	609	2,476	49
2044	5,455	1,364	411	622	2,397	49
2045	4,092	1,364	320	634	2,318	48
2046	2,728	1,364	228	647	2,239	47
2047	1,364	1,364	137	660	2,161	47
2048	0	1,364	46	673	2,082	46
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		18,616	24,418	6,374	49,408	
$2015PV		17,198	22,558	5,889	45,645	
					97,406	

Table A-3: Financial Analysis (WACC at 11.00%): Vista Mountain Case 1: 0.9 MW

Weighted Average Cost of Capital 11.00%
Inflation Rate 2%
Real Weighted Average Cost of Capital 8.82%

LCOE and LCOC with 11% WACC, Vista Mountain Case 1: 0.9 MW

Life Cycle Cost (2015$000's) 45,264
Depreciation & Return Cost (2015$000's) 41,289

Project LCOE ($/kWh) $0.577
Project LCOC ($/MW) $3,901,681

Year	Vista Mountain Case 1: 0.9 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2019	39,552	1,364	4,426	379	6,168	76
2020	38,188	1,364	4,276	386	6,026	75
2021	36,824	1,364	4,126	394	5,884	75
2022	35,460	1,364	3,976	402	5,742	75
2023	34,097	1,364	3,826	410	5,600	74
2024	32,733	1,364	3,676	418	5,458	74
2025	31,369	1,364	3,526	427	5,316	74
2026	30,005	1,364	3,376	435	5,175	73
2027	28,641	1,364	3,226	444	5,033	73
2028	27,277	1,364	3,076	453	4,892	72
2029	25,913	1,364	2,925	462	4,751	71
2030	24,550	1,364	2,775	471	4,610	71
2031	23,186	1,364	2,625	480	4,470	70
2032	21,822	1,364	2,475	490	4,329	69
2033	20,458	1,364	2,325	500	4,189	68
2034	19,094	1,364	2,175	510	4,049	67
2035	17,730	1,364	2,025	520	3,909	66
2036	16,366	1,364	1,875	530	3,770	65
2037	15,003	1,364	1,725	541	3,630	64
2038	13,639	1,364	1,575	552	3,491	63
2039	12,275	1,364	1,425	563	3,352	62
2040	10,911	1,364	1,275	574	3,213	60
2041	9,547	1,364	1,125	586	3,075	59
2042	8,183	1,364	975	597	2,936	57
2043	6,819	1,364	825	609	2,798	56
2044	5,455	1,364	675	622	2,661	54
2045	4,092	1,364	525	634	2,523	52
2046	2,728	1,364	375	647	2,386	50
2047	1,364	1,364	225	660	2,248	49
2048	0	1,364	75	673	2,112	47
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		13,161	31,531	4,303	48,996	
$2015PV		12,159	29,130	3,975	45,264	
					123,796	

Table B-1: Financial Analysis (WACC at 5.45%): **Vista Mountain Case 2: 2.3 MW**

			Average MW	Winter MW
Capital ($000)	2015	$45,200	2.5	2.8
Capital ($000)	2019	$48,926		
Energy		20.9	GWh/yr	
Capacity Factor		95%CF		**Load Growth**
Fuel	2015			-2.0%
O&M (Fixed)	2015	800.0	$000/yr	**20.9** GW.h
O&M (Variable)	2015	0.0	$/MWh	
Life		30	years	
Salvage cost		0%		

Weighted Average Cost of Capital	5.45%
Inflation Rate	2%
Real Weighted Average Cost of Capital	3.38%

LCOE and LCOC with 5.45% WACC, Vista Mountain Case 2: 2.3 MW

Life Cycle Cost (2015$000's)	62,469
Depreciation & Return Cost (2015$000's)	47,031
Project LCOE ($/kWh)	$0.194
Project LCOC ($/MW)	$1,094,589

Year	**Vista Mountain Case 2: 2.3 MW**					
	Year-End Balance $000	**Depr $000**	**Return $000**	**O&M $000**	**Total $000**	**cents/ kW.h**
2019	47,295	1,631	2,622	866	5,119	24
2020	45,664	1,631	2,533	883	5,047	25
2021	44,033	1,631	2,444	901	4,976	25
2022	42,402	1,631	2,355	919	4,905	25
2023	40,772	1,631	2,266	937	4,835	25
2024	39,141	1,631	2,178	956	4,765	25
2025	37,510	1,631	2,089	975	4,695	25
2026	35,879	1,631	2,000	995	4,625	25
2027	34,248	1,631	1,911	1,015	4,556	26
2028	32,617	1,631	1,822	1,035	4,488	26
2029	30,986	1,631	1,733	1,056	4,420	26
2030	29,356	1,631	1,644	1,077	4,352	26
2031	27,725	1,631	1,555	1,098	4,285	26
2032	26,094	1,631	1,467	1,120	4,218	26
2033	24,463	1,631	1,378	1,143	4,151	26
2034	22,832	1,631	1,289	1,165	4,085	26
2035	21,201	1,631	1,200	1,189	4,020	27
2036	19,570	1,631	1,111	1,213	3,954	27
2037	17,940	1,631	1,022	1,237	3,890	27
2038	16,309	1,631	933	1,262	3,826	27
2039	14,678	1,631	844	1,287	3,762	27
2040	13,047	1,631	755	1,312	3,699	27
2041	11,416	1,631	667	1,339	3,636	27
2042	9,785	1,631	578	1,366	3,574	27
2043	8,154	1,631	489	1,393	3,513	27
2044	6,523	1,631	400	1,421	3,452	27
2045	4,893	1,631	311	1,449	3,391	27
2046	3,262	1,631	222	1,478	3,331	27
2047	1,631	1,631	133	1,508	3,272	27
2048	0	1,631	44	1,538	3,213	28
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		25,133	25,775	16,711	67,618	
$2015PV		23,219	23,812	15,438	62,469	
					124,053	

Year from In-service	**Annual Energy GW.h, Vista Mountain Case 2: 2.3 MW**	**Annual Winter Capacity MW, Vista Mountain Case 2: 2.3 MW**
1	20.95	2.80
2	20.53	2.74
3	20.12	2.69
4	19.72	2.64
5	19.32	2.58
6	18.94	2.53
7	18.56	2.48
8	18.19	2.43
9	17.82	2.38
10	17.47	2.33
11	17.12	2.29
12	16.77	2.24
13	16.44	2.20
14	16.11	2.15
15	15.79	2.11
16	15.47	2.07
17	15.16	2.03
18	14.86	1.99
19	14.56	1.95
20	14.27	1.91
21	13.99	1.87
22	13.71	1.83
23	13.43	1.80
24	13.16	1.76
25	12.90	1.72
26	12.64	1.69
27	12.39	1.66
28	12.14	1.62
29	11.90	1.59
30	11.66	1.56
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
Net Present Value	264	
Total energy	476	
Avg Annual energy	16	

Table B-2: Financial Analysis (WACC at 6.70%): Vista Mountain Case 2: 2.3 MW

Weighted Average Cost of Capital	6.70%
Inflation Rate	2%
Real Weighted Average Cost of Capital	4.61%

LCOE and LCOC with 6.7% WACC, Vista Mountain Case 2: 2.3 MW

Life Cycle Cost (2015$000's)	61,000
Depreciation & Return Cost (2015$000's)	47,539
Project LCOE ($/kWh)	$0.214
Project LCOC ($/MW)	$1,248,829

Year	Vista Mountain Case 2: 2.3 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2019	47,295	1,631	3,223	866	5,720	27
2020	45,664	1,631	3,114	883	5,628	27
2021	44,033	1,631	3,005	901	5,537	28
2022	42,402	1,631	2,896	919	5,445	28
2023	40,772	1,631	2,786	937	5,355	28
2024	39,141	1,631	2,677	956	5,264	28
2025	37,510	1,631	2,568	975	5,174	28
2026	35,879	1,631	2,459	995	5,084	28
2027	34,248	1,631	2,349	1,015	4,995	28
2028	32,617	1,631	2,240	1,035	4,906	28
2029	30,986	1,631	2,131	1,056	4,817	28
2030	29,356	1,631	2,021	1,077	4,729	28
2031	27,725	1,631	1,912	1,098	4,641	28
2032	26,094	1,631	1,803	1,120	4,554	28
2033	24,463	1,631	1,694	1,143	4,467	28
2034	22,832	1,631	1,584	1,165	4,381	28
2035	21,201	1,631	1,475	1,189	4,295	28
2036	19,570	1,631	1,366	1,213	4,209	28
2037	17,940	1,631	1,257	1,237	4,124	28
2038	16,309	1,631	1,147	1,262	4,040	28
2039	14,678	1,631	1,038	1,287	3,956	28
2040	13,047	1,631	929	1,312	3,872	28
2041	11,416	1,631	820	1,339	3,789	28
2042	9,785	1,631	710	1,366	3,707	28
2043	8,154	1,631	601	1,393	3,625	28
2044	6,523	1,631	492	1,421	3,543	28
2045	4,893	1,631	382	1,449	3,462	28
2046	3,262	1,631	273	1,478	3,382	28
2047	1,631	1,631	164	1,508	3,302	28
2048	0	1,631	55	1,538	3,223	28
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		22,260	29,198	14,570	66,028	
$2015PV		20,565	26,974	13,460	61,000	
					133,226	

Table B-3: Financial Analysis (WACC at 11.00%): Vista Mountain Case 2: 2.3 MW

Weighted Average Cost of Capital	11.00%
Inflation Rate	2%
Real Weighted Average Cost of Capital	8.82%

LCOE and LCOC with 11% WACC, Vista Mountain Case 2: 2.3 MW

Life Cycle Cost (2015$000's)	58,458
Depreciation & Return Cost (2015$000's)	49,372
Project LCOE ($/kWh)	$0.290
Project LCOC ($/MW)	$1,832,876

Year	Vista Mountain Case 2: 2.3 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2019	47,295	1,631	5,292	866	7,789	37
2020	45,664	1,631	5,113	883	7,627	37
2021	44,033	1,631	4,933	901	7,465	37
2022	42,402	1,631	4,754	919	7,304	37
2023	40,772	1,631	4,575	937	7,143	37
2024	39,141	1,631	4,395	956	6,982	37
2025	37,510	1,631	4,216	975	6,822	37
2026	35,879	1,631	4,036	995	6,662	37
2027	34,248	1,631	3,857	1,015	6,502	36
2028	32,617	1,631	3,678	1,035	6,343	36
2029	30,986	1,631	3,498	1,056	6,185	36
2030	29,356	1,631	3,319	1,077	6,026	36
2031	27,725	1,631	3,139	1,098	5,869	36
2032	26,094	1,631	2,960	1,120	5,711	35
2033	24,463	1,631	2,781	1,143	5,554	35
2034	22,832	1,631	2,601	1,165	5,398	35
2035	21,201	1,631	2,422	1,189	5,241	35
2036	19,570	1,631	2,242	1,213	5,086	34
2037	17,940	1,631	2,063	1,237	4,931	34
2038	16,309	1,631	1,884	1,262	4,776	33
2039	14,678	1,631	1,704	1,287	4,622	33
2040	13,047	1,631	1,525	1,312	4,468	33
2041	11,416	1,631	1,345	1,339	4,315	32
2042	9,785	1,631	1,166	1,366	4,162	32
2043	8,154	1,631	987	1,393	4,010	31
2044	6,523	1,631	807	1,421	3,859	31
2045	4,893	1,631	628	1,449	3,708	30
2046	3,262	1,631	448	1,478	3,557	29
2047	1,631	1,631	269	1,508	3,408	29
2048	0	1,631	90	1,538	3,258	28
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
PV		15,738	37,704	9,835	63,277	
$2015PV		14,539	34,833	9,086	58,458	
					164,783	

Table C-1: Financial Analysis (WACC at 5.45%): **McArthur Springs Case 3: 2.1 MW**

			Average MW	Winter MW
Capital ($000)	2015	$114,000	2.2	2.4
Capital ($000)	2020	$125,865		
Energy		18.6	GWh/yr	
Capacity Factor		95%CF	**Load Growth**	
Fuel	2015			-2.0%
O&M (Fixed)	2015	800.0	$000/yr	**18.6** GW.h
O&M (Variable)	2015	0.0	$/MWh	
Life		30	years	
Salvage cost		0%		

Weighted Average Cost of Capital	5.45%
Inflation Rate	2%
Real Weighted Average Cost of Capital	3.38%

LCOE and LCOC with 5.45% WACC, McArthur Springs Case 3: 2.1 MW

Life Cycle Cost (2015$000's)	134,055
Depreciation & Return Cost (2015$000's)	118,617
Project LCOE ($/kWh)	$0.469
Project LCOC ($/MW)	$3,220,803

Year	McArthur Springs Case 3: 2.1 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	121,670	4,196	6,745	883	11,824	63
2021	117,474	4,196	6,517	901	11,613	64
2022	113,279	4,196	6,288	919	11,402	64
2023	109,083	4,196	6,059	937	11,192	64
2024	104,888	4,196	5,831	956	10,982	64
2025	100,692	4,196	5,602	975	10,773	64
2026	96,497	4,196	5,373	995	10,564	64
2027	92,301	4,196	5,145	1,015	10,355	64
2028	88,106	4,196	4,916	1,035	10,146	64
2029	83,910	4,196	4,687	1,056	9,939	64
2030	79,715	4,196	4,459	1,077	9,731	64
2031	75,519	4,196	4,230	1,098	9,524	64
2032	71,324	4,196	4,001	1,120	9,317	64
2033	67,128	4,196	3,773	1,143	9,111	64
2034	62,933	4,196	3,544	1,165	8,905	63
2035	58,737	4,196	3,315	1,189	8,700	63
2036	54,542	4,196	3,087	1,213	8,495	63
2037	50,346	4,196	2,858	1,237	8,290	63
2038	46,151	4,196	2,630	1,262	8,087	62
2039	41,955	4,196	2,401	1,287	7,883	62
2040	37,760	4,196	2,172	1,312	7,680	62
2041	33,564	4,196	1,944	1,339	7,478	61
2042	29,369	4,196	1,715	1,366	7,276	61
2043	25,173	4,196	1,486	1,393	7,075	60
2044	20,978	4,196	1,258	1,421	6,874	60
2045	16,782	4,196	1,029	1,449	6,674	59
2046	12,587	4,196	800	1,478	6,474	59
2047	8,391	4,196	572	1,508	6,275	58
2048	4,196	4,196	343	1,538	6,076	57
2049	0	4,196	114	1,569	5,878	57
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		64,656	66,307	17,045	148,008	
$2015PV		58,561	60,056	15,438	134,055	
					264,592	

Year from In-service	Annual Energy GW.h, McArthur Springs Case 3: 2.1 MW	Annual Winter Capacity MW, McArthur Springs Case 3: 2.1 MW
1	18.62	2.40
2	18.25	2.35
3	17.88	2.30
4	17.53	2.26
5	17.18	2.21
6	16.83	2.17
7	16.50	2.13
8	16.17	2.08
9	15.84	2.04
10	15.53	2.00
11	15.22	1.96
12	14.91	1.92
13	14.61	1.88
14	14.32	1.85
15	14.03	1.81
16	13.75	1.77
17	13.48	1.74
18	13.21	1.70
19	12.95	1.67
20	12.69	1.63
21	12.43	1.60
22	12.18	1.57
23	11.94	1.54
24	11.70	1.51
25	11.47	1.48
26	11.24	1.45
27	11.01	1.42
28	10.79	1.39
29	10.58	1.36
30	10.37	1.34
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
Net Present Value	234	
Total energy	423	
Avg Annual energy	14	

Table C-2: Financial Analysis (WACC at 6.70%): McArthur Springs Case 3: 2.1 MW

Weighted Average Cost of Capital	6.70%
Inflation Rate	2%
Real Weighted Average Cost of Capital	4.61%

LCOE and LCOC with 6.7% WACC, McArthur Springs Case 3: 2.1 MW

Life Cycle Cost (2015$000's)	133,361
Depreciation & Return Cost (2015$000's)	119,900
Project LCOE ($/kWh)	$0.527
Project LCOC ($/MW)	$3,674,652

Year	McArthur Springs Case 3: 2.1 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	121,670	4,196	8,292	883	13,371	72
2021	117,474	4,196	8,011	901	13,108	72
2022	113,279	4,196	7,730	919	12,845	72
2023	109,083	4,196	7,449	937	12,582	72
2024	104,888	4,196	7,168	956	12,320	72
2025	100,692	4,196	6,887	975	12,058	72
2026	96,497	4,196	6,606	995	11,796	72
2027	92,301	4,196	6,325	1,015	11,535	71
2028	88,106	4,196	6,044	1,035	11,274	71
2029	83,910	4,196	5,763	1,056	11,014	71
2030	79,715	4,196	5,481	1,077	10,754	71
2031	75,519	4,196	5,200	1,098	10,494	70
2032	71,324	4,196	4,919	1,120	10,235	70
2033	67,128	4,196	4,638	1,143	9,976	70
2034	62,933	4,196	4,357	1,165	9,718	69
2035	58,737	4,196	4,076	1,189	9,460	69
2036	54,542	4,196	3,795	1,213	9,203	68
2037	50,346	4,196	3,514	1,237	8,946	68
2038	46,151	4,196	3,233	1,262	8,690	67
2039	41,955	4,196	2,952	1,287	8,434	66
2040	37,760	4,196	2,670	1,312	8,178	66
2041	33,564	4,196	2,389	1,339	7,924	65
2042	29,369	4,196	2,108	1,366	7,669	64
2043	25,173	4,196	1,827	1,393	7,415	63
2044	20,978	4,196	1,546	1,421	7,162	62
2045	16,782	4,196	1,265	1,449	6,910	61
2046	12,587	4,196	984	1,478	6,657	60
2047	8,391	4,196	703	1,508	6,406	59
2048	4,196	4,196	422	1,538	6,155	58
2049	0	4,196	141	1,569	5,905	57
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		57,266	75,113	14,861	147,241	
$2015PV		51,868	68,033	13,460	133,361	
					288,192	

Table C-3: Financial Analysis (WACC at 11.00%): McArthur Springs Case 3: 2.1 MW

Weighted Average Cost of Capital	11.00%
Inflation Rate	2%
Real Weighted Average Cost of Capital	8.82%

LCOE and LCOC with 11% WACC, McArthur Springs Case 3: 2.1 MW

Life Cycle Cost (2015$000's)	133,609
Depreciation & Return Cost (2015$000's)	124,523
Project LCOE ($/kWh)	$0.746
Project LCOC ($/MW)	$5,393,197

Year	McArthur Springs Case 3: 2.1 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	121,670	4,196	13,614	883	18,693	100
2021	117,474	4,196	13,153	901	18,249	100
2022	113,279	4,196	12,691	919	17,806	100
2023	109,083	4,196	12,230	937	17,363	99
2024	104,888	4,196	11,768	956	16,920	99
2025	100,692	4,196	11,307	975	16,478	98
2026	96,497	4,196	10,845	995	16,036	97
2027	92,301	4,196	10,384	1,015	15,594	96
2028	88,106	4,196	9,922	1,035	15,153	96
2029	83,910	4,196	9,461	1,056	14,712	95
2030	79,715	4,196	8,999	1,077	14,272	94
2031	75,519	4,196	8,538	1,098	13,832	93
2032	71,324	4,196	8,076	1,120	13,392	92
2033	67,128	4,196	7,615	1,143	12,953	90
2034	62,933	4,196	7,153	1,165	12,514	89
2035	58,737	4,196	6,692	1,189	12,076	88
2036	54,542	4,196	6,230	1,213	11,638	86
2037	50,346	4,196	5,769	1,237	11,201	85
2038	46,151	4,196	5,307	1,262	10,764	83
2039	41,955	4,196	4,846	1,287	10,328	81
2040	37,760	4,196	4,384	1,312	9,892	80
2041	33,564	4,196	3,923	1,339	9,457	78
2042	29,369	4,196	3,461	1,366	9,022	76
2043	25,173	4,196	3,000	1,393	8,588	73
2044	20,978	4,196	2,538	1,421	8,154	71
2045	16,782	4,196	2,077	1,449	7,721	69
2046	12,587	4,196	1,615	1,478	7,289	66
2047	8,391	4,196	1,154	1,508	6,857	64
2048	4,196	4,196	692	1,538	6,426	61
2049	0	4,196	231	1,569	5,995	58
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		40,487	96,996	10,032	147,515	
$2015PV		36,670	87,853	9,086	133,609	
					369,375	

Table D-1: Financial Analysis (WACC at 5.45%): McArthur Springs Case 4: 5.5 MW

			Average MW	Winter MW	
Capital ($000)	2015	$127,000	5.8	6.2	
Capital ($000)	2020	$140,218			
Energy		48.2	GWh/yr		
Capacity Factor		95%CF		**Load Growth**	
Fuel	2015			-2.0%	
O&M (Fixed)	2015	1800.0	$000/yr	**48.2**	GW.h
O&M (Variable)	2015	0.0	$/MWh		
Life		30	years		
Salvage cost		0%			

Weighted Average Cost of Capital	5.45%
Inflation Rate	2%
Real Weighted Average Cost of Capital	3.38%

LCOE and LCOC with 5.45% WACC, McArthur Springs Case 4: 5.5 MW

Life Cycle Cost (2015$000's)	166,879
Depreciation & Return Cost (2015$000's)	132,144
Project LCOE ($/kWh)	$0.225
Project LCOC ($/MW)	$1,388,937

Year	McArthur Springs Case 4: 5.5 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	135,544	4,674	7,515	1,987	14,176	29
2021	130,870	4,674	7,260	2,027	13,961	30
2022	126,196	4,674	7,005	2,068	13,747	30
2023	121,522	4,674	6,750	2,109	13,533	30
2024	116,849	4,674	6,496	2,151	13,321	30
2025	112,175	4,674	6,241	2,194	13,109	30
2026	107,501	4,674	5,986	2,238	12,898	30
2027	102,827	4,674	5,731	2,283	12,688	30
2028	98,153	4,674	5,477	2,328	12,479	30
2029	93,479	4,674	5,222	2,375	12,271	31
2030	88,805	4,674	4,967	2,423	12,064	31
2031	84,131	4,674	4,713	2,471	11,857	31
2032	79,457	4,674	4,458	2,520	11,652	31
2033	74,783	4,674	4,203	2,571	11,448	31
2034	70,109	4,674	3,948	2,622	11,245	31
2035	65,435	4,674	3,694	2,675	11,042	31
2036	60,761	4,674	3,439	2,728	10,841	31
2037	56,087	4,674	3,184	2,783	10,641	31
2038	51,413	4,674	2,929	2,838	10,442	31
2039	46,739	4,674	2,675	2,895	10,244	31
2040	42,065	4,674	2,420	2,953	10,047	31
2041	37,392	4,674	2,165	3,012	9,851	31
2042	32,718	4,674	1,910	3,072	9,657	31
2043	28,044	4,674	1,656	3,134	9,464	31
2044	23,370	4,674	1,401	3,197	9,271	31
2045	18,696	4,674	1,146	3,260	9,081	31
2046	14,022	4,674	892	3,326	8,891	31
2047	9,348	4,674	637	3,392	8,703	31
2048	4,674	4,674	382	3,460	8,516	31
2049	0	4,674	127	3,529	8,331	31
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		72,029	73,868	38,351	184,248	
$2015PV		65,239	66,905	34,736	166,879	
					335,469	

Year from In-service	Annual Energy GW.h, McArthur Springs Case 4: 5.5 MW	Annual Winter Capacity MW, McArthur Springs Case 4: 5.5 MW
1	48.24	6.20
2	47.28	6.08
3	46.33	5.95
4	45.41	5.84
5	44.50	5.72
6	43.61	5.60
7	42.74	5.49
8	41.88	5.38
9	41.04	5.27
10	40.22	5.17
11	39.42	5.07
12	38.63	4.96
13	37.86	4.87
14	37.10	4.77
15	36.36	4.67
16	35.63	4.58
17	34.92	4.49
18	34.22	4.40
19	33.54	4.31
20	32.86	4.22
21	32.21	4.14
22	31.56	4.06
23	30.93	3.98
24	30.31	3.90
25	29.71	3.82
26	29.11	3.74
27	28.53	3.67
28	27.96	3.59
29	27.40	3.52
30	26.85	3.45
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
Net Present Value	607	
Total energy	1,096	
Avg Annual energy	37	

Table D-2: Financial Analysis (WACC at 6.70%): McArthur Springs Case 4: 5.5 MW

Weighted Average Cost of Capital	6.70%
Inflation Rate	2%
Real Weighted Average Cost of Capital	4.61%

LCOE and LCOC with 6.7% WACC, McArthur Springs Case 4: 5.5 MW

Life Cycle Cost (2015$000's)	163,859
Depreciation & Return Cost (2015$000's)	133,573
Project LCOE ($/kWh)	$0.250
Project LCOC ($/MW)	$1,584,655

Year	McArthur Springs Case 4: 5.5 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	135,544	4,674	9,238	1,987	15,899	33
2021	130,870	4,674	8,925	2,027	15,626	33
2022	126,196	4,674	8,612	2,068	15,353	33
2023	121,522	4,674	8,299	2,109	15,082	33
2024	116,849	4,674	7,985	2,151	14,811	33
2025	112,175	4,674	7,672	2,194	14,540	33
2026	107,501	4,674	7,359	2,238	14,271	33
2027	102,827	4,674	7,046	2,283	14,003	33
2028	98,153	4,674	6,733	2,328	13,735	33
2029	93,479	4,674	6,420	2,375	13,469	33
2030	88,805	4,674	6,107	2,423	13,203	33
2031	84,131	4,674	5,793	2,471	12,938	33
2032	79,457	4,674	5,480	2,520	12,675	33
2033	74,783	4,674	5,167	2,571	12,412	33
2034	70,109	4,674	4,854	2,622	12,150	33
2035	65,435	4,674	4,541	2,675	11,889	33
2036	60,761	4,674	4,228	2,728	11,630	33
2037	56,087	4,674	3,914	2,783	11,371	33
2038	51,413	4,674	3,601	2,838	11,114	33
2039	46,739	4,674	3,288	2,895	10,857	33
2040	42,065	4,674	2,975	2,953	10,602	33
2041	37,392	4,674	2,662	3,012	10,348	33
2042	32,718	4,674	2,349	3,072	10,095	33
2043	28,044	4,674	2,036	3,134	9,843	32
2044	23,370	4,674	1,722	3,197	9,593	32
2045	18,696	4,674	1,409	3,260	9,344	32
2046	14,022	4,674	1,096	3,326	9,096	32
2047	9,348	4,674	783	3,392	8,849	32
2048	4,674	4,674	470	3,460	8,604	31
2049	0	4,674	157	3,529	8,360	31
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		63,797	83,679	33,438	180,913	
$2015PV		57,783	75,791	30,286	163,859	
					361,760	

Table D-3: Financial Analysis (WACC at 11.00%): McArthur Springs Case 4: 5.5 MW

Weighted Average Cost of Capital	11.00%
Inflation Rate	2%
Real Weighted Average Cost of Capital	8.82%

LCOE and LCOC with 11% WACC, McArthur Springs Case 4: 5.5 MW

Life Cycle Cost (2015$000's)	159,167
Depreciation & Return Cost (2015$000's)	138,723
Project LCOE ($/kWh)	$0.343
Project LCOC ($/MW)	$2,325,759

Year	McArthur Springs Case 4: 5.5 MW					
	Year-End Balance $000	Depr $000	Return $000	O&M $000	Total $000	cents/ kW.h
2020	135,544	4,674	15,167	1,987	21,828	45
2021	130,870	4,674	14,653	2,027	21,354	45
2022	126,196	4,674	14,139	2,068	20,880	45
2023	121,522	4,674	13,625	2,109	20,407	45
2024	116,849	4,674	13,110	2,151	19,936	45
2025	112,175	4,674	12,596	2,194	19,464	45
2026	107,501	4,674	12,082	2,238	18,994	44
2027	102,827	4,674	11,568	2,283	18,525	44
2028	98,153	4,674	11,054	2,328	18,056	44
2029	93,479	4,674	10,540	2,375	17,589	44
2030	88,805	4,674	10,026	2,423	17,122	43
2031	84,131	4,674	9,511	2,471	16,656	43
2032	79,457	4,674	8,997	2,520	16,192	43
2033	74,783	4,674	8,483	2,571	15,728	42
2034	70,109	4,674	7,969	2,622	15,265	42
2035	65,435	4,674	7,455	2,675	14,804	42
2036	60,761	4,674	6,941	2,728	14,343	41
2037	56,087	4,674	6,427	2,783	13,883	41
2038	51,413	4,674	5,913	2,838	13,425	40
2039	46,739	4,674	5,398	2,895	12,968	39
2040	42,065	4,674	4,884	2,953	12,511	39
2041	37,392	4,674	4,370	3,012	12,056	38
2042	32,718	4,674	3,856	3,072	11,602	38
2043	28,044	4,674	3,342	3,134	11,150	37
2044	23,370	4,674	2,828	3,197	10,698	36
2045	18,696	4,674	2,314	3,260	10,248	35
2046	14,022	4,674	1,799	3,326	9,799	34
2047	9,348	4,674	1,285	3,392	9,351	33
2048	4,674	4,674	771	3,460	8,905	32
2049	0	4,674	257	3,529	8,460	32
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059						
2060						
2061						
2062						
2063						
2064						
PV		45,104	108,057	22,571	175,733	
$2015PV		40,852	97,871	20,443	159,167	
					452,201	