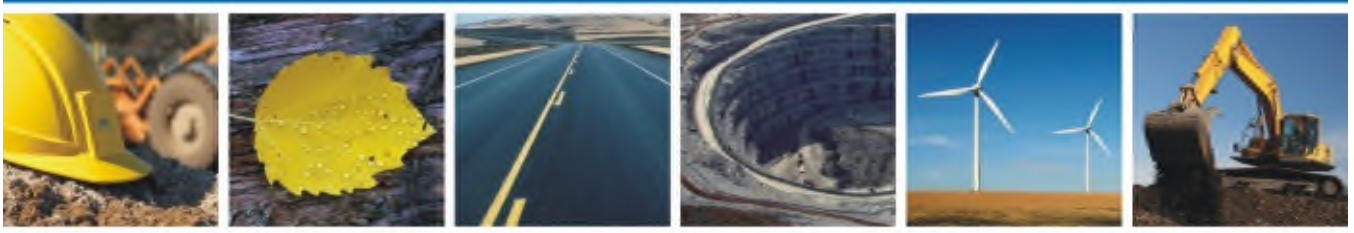


GOVERNMENT OF YUKON, COMMUNITY SERVICES

GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM, BURWASH LANDING, YUKON



REPORT

JUNE 28, 2013
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EXECUTIVE SUMMARY

Introduction

EBA Engineering Consultants Ltd., operating as EBA, A Tetra Tech Company (EBA) was retained by the Government of Yukon, Community Services, Infrastructure Development C-13 (YG) on behalf of the Kluane First Nation (KFN) to prepare a guidance document for the development of a cold and warm water well system in Burwash Landing, Yukon. Figure 1 shows the study area, key landmarks and the three existing water wells considered in this study (KFN-F, KFN-K and KFN-L).

This desktop study had the following main objectives:

- Summarize conditions at existing water supply wells;
- Evaluate projected drinking water demand, evaluate potential for using heat energy from deep warm water well (KFN-L);
- Provide Class-D costs for water treatment, water distribution, and geexchange energy system;
- Clarify permits and approvals required;
- Identify potential funding sources; and
- Incorporate findings from KFN Energy Summit (held March, 2013).

KFN’s priorities are primarily for water supply, treatment and distribution guidance, with geexchange energy system secondary, and with a simple, reliable and sustainable approach.

Water Demand

To predict water demands, we used a future water demand rate of 125 litres per capita per day (L/c/d) and considered three scenarios for population growth and predicted water demand over 20 years:

- **Low Growth:** 7% growth every five years.
- **Moderate Growth:** 30% growth every five years.
- **High Growth:** 7% growth every five years, plus 2000 people added by 2018 (from mining activity).

Tables ES1 and ES2 below show projected population growth and water demand under the three scenarios for 20 years.

Table ES1: Population Growth Scenarios

Population Growth Scenario	YEAR				
	2013	2018	2023	2028	2033
Low	95	102	109	116	125
Moderate	95	124	161	209	271
High	95	2102	2109	2116	2125

Table ES2: Forecasted Water Demand Scenarios

Population Growth Scenario	Forecasted Water Demands				
	Population (2033)	Future ADD (L/c/d)	ADD (m ³)	ADD (L/s)	ADD (USgpm)
Low	125	125	16	0.18	2.8
Moderate	271	125	34	0.39	6.2
High	2125	125	266	3.07	48.6

Water demands not factored into the above include a proposed greenhouse, a community pool, school and light industrial area.

Water Supply

Table ES3 summarizes key points for the three water wells considered (KFN-F, KFN-K and KFN-L).

Table ES3: Key Information for Wells KFN-F, KFN-K and KFN-L

	KFN-F (town well in use)	KFN-K (new cold water well)	KFN-L (new warm water well)
Well Depth	60.96 m (200 ft.)	73.5 m (241 ft.)	387.4 m (1,271 ft.)
Well Yield	0.23 L/s (3.7 USgpm)	9.5 L/s (150 USgpm)	3.5 L/s (55 USgpm)
Water Level/ Artesian Pressure at Wellhead	Not artesian (SWL ~12 m (39 ft) bgs)	3 psi (SWL ~2.1 m (6.9 ft) ags)	1 psi (SWL ~0.7 m (2.3 ft) ags)
Water Temperature	~2°C	1.9°C	15.9°C
Water Quality Summary	Meets all GCDWQ MACs; Manganese (0.07 mg/L) slightly exceeds AO (0.05 mg/L)	As (0.012 mg/L) slightly exceeds MAC (0.01 mg/L); hard (150 mg/L CaCO ₃); pH (up to 8.8) exceeds MAC (6.5-8.5)	As (0.075 mg/L) exceeds MAC (0.01 mg/L); exceeds AO for TDS, Fe, colour; very hard (406 mg/L CaCO ₃)

Notes: GCDWQ – Guidelines for Canadian Drinking Water Quality; USgpm = US gallon per minute; SWL = static water level; bgs = below ground surface; ags = above ground surface; AO = aesthetic objective; MAC = maximum allowable concentration

Subsurface Conditions

The Burwash Landing area is underlain by a thick sequence of heterogeneous glacio-lacustrine sediments (primarily clay, silt and sand) with no bedrock encountered up to 374 m depth. Discontinuous permafrost exists in the area to a depth of 30-50 m, with an active zone up to several metres thick. Building foundation design must assume that there is permafrost in the subgrade, and designs prepared accordingly.

Hydrogeologically, groundwater flow is generally to the northeast toward Kluane Lake. Confined and semi-confined sand aquifers exist with apparently irregular distribution within the sediments. Groundwater is cold (2°C or less) in aquifers within 75 m of surface, but substantially warmer (about 16°C) in a deep sandy aquifer (of unknown thickness) encountered at 387 m depth at KFN-L. The measured geothermal gradient is about 4.4°C rise per 100 m depth, 1.8 times greater than the normal gradient (2.5°C per 100 m depth).

KFN Energy Summit

Key points from the Energy Summit highlight that there is a general dissatisfaction with using diesel fuel for building heating (the primary energy demand), and that any renewable energy projects would be

beneficial. KFN is pursuing wind and solar pilot projects, and improving energy efficiency through demand side management. Wood heating as the primary heating source for homes is considered successful, so based on this, geexchange is not considered further in this study for potential district residential heating. Finally, due to remoteness, harsh climate and a potential lack of trained resources for complex system operations, it is very important to minimize the complexity of water or geexchange systems.

Options Overview

Three broad options were considered here (Options 1, 2 and 3), with increasing relative cost and overall complexity. Option 2 is subdivided into two sub options (2a and 2b). Table ES4 presents key aspects for each option, along with the evaluation summary.

Newly proposed back-up supply wells are included (KFN-M for Option 1 and KFN-N for Option 2a and Option 3). A new shallow injection well (labelled KFN-O) is considered for water disposal in Options 2a and 2b. A new deep injection well (labelled KFN-P) is considered in Option 3.

Heat recovery from KFN-L increases with each successive option, and is used only for individual building or greenhouse heating in Options 1, and 2a/2b, but could support a small district energy system to heat proposed new water treatment plant (WTP), greenhouse, 4-plex, school and swimming pool in Option 3. The options evaluation is presented further below.

Backup Water Well Considerations

For Yukon community water systems, a minimum of two water supply wells are recommended to provide redundancy (in the case of a pump failure or for well maintenance). Backup water supply wells should be:

- Located as close as practicable to the WTP to minimize piping length and freeze protection.
- Far enough away from the primary well to avoid unacceptable well interference.
- Located cross-gradient with the primary well in case of contamination up-gradient of that well.
- Sited with appropriate setbacks from contamination sources (e.g., septic systems).
- Constructed according to pertinent Yukon and Canadian well construction guidelines.

Water Treatment and Distribution for Options

In general, potable water treatment objectives for this project include:

- Meets all Guidelines for Canadian Drinking Water Quality (GCDWQ), including aesthetic objectives.
- Turbidity generally less than 1 NTU and at all times less than 5 NTU.
- Hardness of less than 200 mg/L.
- Provide primary disinfection treatment to 4-log removal of viruses.
- Chlorine residual to be at least 0.4 mg/L for truck fill and at least 0.2 mg/L at all points of a distribution system.

Table ES4: Summary and Evaluation of Options

	Option 1	Option 2 a	Option 2 b	Option 3
Water Supply	KFN-F and KFN-M	KFN-K and KFN-N	KFN-K and KFN-L	KFN-K and KFN-N
Water Treatment	Existing WTP ¹ with expansion and improvements	New WTP – As reduction and chlorination	New WTP – Greensand/As reduction, chlorination, and RO	New WTP - As reduction and chlorination
Water Distribution	Truck only	Truck and piped distribution	Truck and pipe distribution	Truck and piped distribution
Geoexchange	Closed-loop with "convection promoter"	Closed loop with artesian flow or moderate pumping	Semi-open loop standing water column	Open loop
Water Disposal	No water disposal required	Shallow injection well or surface water	Shallow injection well or surface water	Deep injection well
Potable Water Demand Scenario	Low – 2.8 USgpm ADD ²	Moderate – 6.2 USgpm ADD	Moderate – 6.2 USgpm ADD	High – 49 USgpm ADD
Geoexchange Water Demand	None	Moderate – 10 USgpm	Moderate – 10 USgpm	Up to 100 USgpm
Overall Complexity	Low	Moderate	Moderate	High
Technical / System Complexity	<ul style="list-style-type: none"> Lowest overall complexity. Similar to existing system using much of the existing infrastructure. Requires new backup well KFN-M. Water supply and geoexchange systems are completely separated and independent. Simple closed-loop geoexchange system for small greenhouse. Low permafrost risk/ complications. 	<ul style="list-style-type: none"> Moderate overall complexity. Requires new backup well KFN-N. May require shallow injection well. New WTP required. Water supply and geoexchange systems are separated but share some of the infrastructure. Moderately complex geoexchange system for heating of large greenhouse. Requires water disposal. Low permafrost risk/ complications. 	<ul style="list-style-type: none"> Moderate to high overall complexity. No new backup well required. May require shallow injection well. New WTP required. Additional complexity for treatment of KFN-L water to meet GCDWQ³. Water supply and geoexchange systems could be fully integrated. Piped distribution to eastern-end of community. Complex geoexchange system including greenhouse, WTP and 4-plex. Requires water disposal. Moderate permafrost risk/ complications. 	<ul style="list-style-type: none"> High overall complexity. Requires new backup well KFN-N and deep injection well. New WTP required. Water supply and geoexchange systems are separated but share some of the infrastructure (TP, common trenching). Piped distribution system. Complex open-loop geoexchange system including WTP, 4-plex, school, swimming pool, with potential additional capacity. Requires water disposal. Moderate permafrost risk/ complications.
Regulatory	<ul style="list-style-type: none"> "Approval to Modify" from YG-EHS⁴ to upgrade WTP. Assessment under YESAA⁵ for activities related to drilling of KFN-M No Water Licence required. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS⁶). Type A Water Licence for water disposal may be required depending on disposal option and system design. Surface water disposal would likely require additional baseline data collection and fisheries assessments. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS). Type A Water Licence for water disposal may be required depending on disposal option and system design. Surface water disposal would likely require additional baseline data collection and fisheries assessments. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS). Type A Water Licence for water disposal.
Operator Skill Requirement	<ul style="list-style-type: none"> System would likely be classified by EOCP⁷ as "Small Water System" (serves <500 people). Lowest operator skill requirements (Certified SWS⁸ Operator). Operator would likely not have to be Level 1 certified. Simple geoexchange system with relatively low skill requirements. Knowledge of circulating pumps and heat pumps. 	<ul style="list-style-type: none"> System would likely be classified by EOCP as "Small Water System" (serves <500 people). Low operator skill requirements (Certified SWS Operator). Operator would likely not have to be Level 1 certified. Low to moderate skill requirements for geoexchange system. Knowledge of circulating pumps and heat pumps. Must deal with water disposal. 	<ul style="list-style-type: none"> System would likely be classified by EOCP as "Small Water System" (serves <500 people). Low operator skill requirements (Certified SWS Operator). Operator would likely not have to be Level 1 certified. Moderate skill requirements for geoexchange system. Knowledge of circulating pumps; heat pumps, "bleed" controls. Periodic heat exchanger maintenance may be required. Must deal with water disposal from well. 	<ul style="list-style-type: none"> System would likely <u>not</u> be classified by EOCP as "Small Water System" (serves >500 people). Considerable operator skill requirements (likely at least Level 1 certification). Moderate skill requirements for geoexchange system. Knowledge of circulating pumps; heat pumps, controls. Periodic heat exchanger maintenance may be required. Must deal with water disposal from well.

Table ES4: Evaluation of Options (cont'd)

	Option 1	Option 2 a	Option 2 b	Option 3
Sustainability	<ul style="list-style-type: none"> ▪ Sustainable with respect to groundwater quantity because extraction of groundwater for water supply is low and no water is extracted for geexchange (closed-loop system). ▪ Proper design of geexchange system is important to ensure thermal sustainability. 	<ul style="list-style-type: none"> ▪ Water supply is sustainable due to relatively small extraction rate and high-yield well KFN-K. ▪ Moderate sustainability of geexchange system because water is not re-injected into same aquifer; however, relatively small extraction rate from deep aquifer is likely viable. 	<ul style="list-style-type: none"> ▪ Water supply is sustainable due to relatively small extraction rate and high-yield well KFN-K. ▪ Moderate sustainability of geexchange system because water is not re-injected into same aquifer; however, relatively small extraction rate from deep aquifer is likely viable. 	<ul style="list-style-type: none"> ▪ Maximized sustainability of geexchange system with respect to aquifer pressure and water quantity because water is re-injected into same aquifer. ▪ Water disposal at surface or to different aquifer would likely be unsustainable and cause depletion of deep aquifer. ▪ Proper injection well design is important to ensure thermal sustainability.
Timeframe – design / approval / tendering/ construction / commissioning process	<ul style="list-style-type: none"> ▪ Shortest timeframe. ▪ Design, approval, and tendering in spring/summer 2013. ▪ Possibly construction in late summer 2013 and commissioning in the fall of 2013. 	<ul style="list-style-type: none"> ▪ Moderate timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process. 	<ul style="list-style-type: none"> ▪ Moderate timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process. 	<ul style="list-style-type: none"> ▪ Longest timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process.
Environmental	<ul style="list-style-type: none"> ▪ Lowest heat energy extraction from KFN-L. ▪ Lowest hydrocarbon offset. ▪ No water disposal required. 	<ul style="list-style-type: none"> ▪ Low to moderate heat extraction from KFN-L. ▪ Low to moderate hydrocarbon offset. ▪ Requires water disposal to shallow aquifer or surface water. ▪ Disposal to surface water may have adverse environmental effects. 	<ul style="list-style-type: none"> ▪ Moderate heat energy extraction from KFN-L. ▪ Moderate hydrocarbon offset. ▪ Requires water disposal to shallow aquifer or surface water. ▪ Disposal to surface water may have adverse environmental effects. 	<ul style="list-style-type: none"> ▪ Very environmentally sound. ▪ Maximum heat energy extraction from KFN-L. ▪ Offsets most hydrocarbon reliance. ▪ Water disposal back to same aquifer.

Notes:

- ¹ WTP – Water treatment plant
- ² ADD – average daily demand
- ³ GCDWQ – Guidelines for Canadian Drinking Water Quality
- ⁴ YG-EHS – Government of Yukon – Environmental Health Services
- ⁵ YESAA – Yukon Environmental and Socioeconomic Assessment Act
- ⁶ LPDWS – Large Public Drinking Water System (definition by Yukon Public Health and Safety Act)
- ⁷ EOCP – Environmental Operators Certification Program
- ⁸ SWS – Small Water System (EOCP definition)

In addition, water from KFN-L used for geexchange may need conditioning to mitigate parameters that might lead to performance problems during heat recovery or water disposal (e.g., well or heat exchanger fouling). This would be determined in future when assessing engineering prefeasibility.

For Option 1, water system improvements would include improvements to the existing WTP to address deficiencies and the operational issues with the current system, and to support the increasing demand in the low growth scenario. These improvements would include:

- A new well (KFN-M) to provide water supply redundancy.
- A new delivery truck with a larger capacity (15,500 litres; 4,100 US gallons).
- An expanded WTP to accommodate the larger delivery truck and operational changes to better align water delivery with well recharge rates.
- Treatment for manganese (Mn) removal including either aeration or oxidation to reduce and/or eliminate the sulfur smell in the water.
- Replacing all system controls and also providing control and monitoring in the site office. Upgrades would be operator-friendly and reduce needs for operator intervention.
- Data loggers for water level and flow placed in KFN-F and KFN-M, with data monitored to manage well and system performance.
- Installing a redundant chlorination system with isolation valve, relief valve, level sensor with alarm and static mixer.
- Cleaning and rehabilitation of the online free chlorine analyzer.

To provide sufficient storage and to improve chlorine contact time to meet disinfection targets, additional storage capacity of 56,500 L (14,925 US gal) would be required, for a total WTP storage capacity of 75,500 L (19,950 US gal).

Water treatment and distribution would be similar for Options 2 and 3. KFN-K would be the primary supply well with KFN-N as backup for Option 2a and 3, while Option 2b uses KFN-L as back-up to KFN-K. For Options 2 and 3 in general, the water system improvements would include:

- A new WTP building (~186 m²; 2000 sq. ft.) near KFN-K/L to accommodate treatment, storage and larger sized bulk delivery truck.
- A new 3,800 L (1,000 US gal) raw water feed tank to prevent excessive cycling of the well pump.
- Ferric based media for arsenic removal and a sodium hypochlorite chlorination system.
- Treated water stored in polyethylene tanks in the new WTP; storage capacity similar to Option 1.
- A backwash water system for system maintenance.
- Full redundancy from the well pump to the bulk truck fill point.

For Option 2a, water treatment would include an arsenic adsorption filter unit followed by sodium hypochlorite injection. The filter unit would utilize ferric-based media to remove arsenic and other metals (including iron and manganese).

For Option 2b, water treatment would be more complex due to higher arsenic concentrations, hardness and TDS in KFN-L water. The conceptual treatment would include the following:

- Hypochlorite injection for the oxidation of dissolved metals.
- Iron reduction in manganese green sand plus media filter unit.
- Arsenic adsorption filter unit.
- TDS reduction unit using reverse osmosis (RO).
- Hypochlorite injection.

Water distribution would include both piped and trucked distribution for Options 2 and 3. The trucked distribution would be similar to the current operation, only with a larger truck and tank. The proposed piped system would consist of a distribution loop serving the eastern end of village (existing residences and future residential development), installed within the “active layer” above permafrost.

Heat Transfer Options, Resource and Demands

Four methods of extracting heat from KFN-L were examined. Table ES5 summarizes characteristics, heat recovery values and potential heating uses for each of these cases. The geexchange cases range from simple in-well closed-loop with low heat production (case 1) up to an open loop configuration with highest heat production that could support a small district energy system (case 3). The maximum net heat available from KFN-L is ~420 kW (1.4 million Btu/hr). Groundwater disposal requirements range from none (case 1), to minor (~10 US gpm in case 2a and 2b), to major (~100 US gpm in case 3).

Table ES6 summarizes estimated heating demand for various building types and sizes considered here. Prioritized heating loads are as follows (in order): greenhouse, well pump house (Option 1 only), water treatment building (Option 2 and 3), 4-plex, school, and swimming pool.

Table ES5: Summary of Geexchange Cases for Heat Extraction from KFN-L

Case	Description of Technology	Relative Install Cost	Maintenance/Complexity	Groundwater Disposal Quantity	Estimated Thermal Output
1	<ul style="list-style-type: none"> ▪ See Figure 2 and 3. ▪ Heat exchange accomplished with closed-loop, durable plastic pipe heat exchanger placed in well KFN-L. ▪ Heat carrier fluid is an environmentally-safe antifreeze-water solution. ▪ An open-ended “convection promoter” pipe is necessary to keep water passively circulating vertically in the well. 	Low	<ul style="list-style-type: none"> ▪ Relatively low. ▪ Knowledge of circulating pumps and heat pumps. 	None	<ul style="list-style-type: none"> ▪ ~15 kW (~50,000 Btu/hr) ▪ Could provide base load soil heating for a ~900 sq. ft greenhouse.

Table ES5: Summary of Geoexchange Cases for Heat Extraction from KFN-L

Case	Description of Technology	Relative Install Cost	Maintenance/Complexity	Groundwater Disposal Quantity	Estimated Thermal Output
2a	<ul style="list-style-type: none"> ▪ See Figure 4. ▪ Heat exchanger system same as Case 1. ▪ Additional feature: Well is allowed to flow artesian. This artesian flow moderates the well water with warm groundwater entering at the well bottom. 	Low to Moderate	<ul style="list-style-type: none"> ▪ Relatively low to moderate. ▪ Knowledge of circulating pumps and heat pumps. ▪ Must deal with water disposal. 	~10 USgpm	<ul style="list-style-type: none"> ▪ ~53 kW (~180,000 Btu/hr) ▪ Could provide base load soil heating for a 3,000 sq. ft greenhouse.
2b	<ul style="list-style-type: none"> ▪ See Figure 5 ▪ “Semi-open” loop (standing column well). ▪ The heat transfer fluid is the well water itself, circulated through surface heat exchanger and disposed of back into the top of well KFN-L. ▪ It is necessary to “bleed” some well water out of the system to moderate well water temperature and prevent freezing. ▪ Well water is isolated from heat pump equipment to prevent possible scale, fouling of the heat pump(s). 	Moderate	<ul style="list-style-type: none"> ▪ Moderate. Need “bleed” controls. ▪ Knowledge of circulating pumps; heat pumps. ▪ Periodic heat exchanger maintenance may be required. ▪ Must deal with water disposal from well. 	~10 USgpm	<ul style="list-style-type: none"> ▪ 73 kW (~250,000 Btu/hr). ▪ Could provide base load soil heating for a 3,000 sq. ft greenhouse, <u>plus</u>. ▪ 100% peak load for space heating of new WTP + tempering of recirculated drinking water + ~45% peak load of new 4-Plex.
3	<ul style="list-style-type: none"> ▪ See Figure 6. ▪ Open loop. ▪ The heat transfer fluid is groundwater. ▪ All water must be used or disposed. ▪ Well water is isolated from heat pump equipment to prevent possible scale, fouling of the heat pump(s). 	High. Need an injection well.	<ul style="list-style-type: none"> ▪ Relatively moderate to high. Need “bleed” controls. ▪ Knowledge of circulating pumps; heat pumps, control and management of district heating systems. ▪ Periodic heat exchanger maintenance may be required. ▪ Must deal with water disposal from well. 	Up to 100 USgpm	<ul style="list-style-type: none"> ▪ 410 kW (1.4 million Btu/hr). ▪ Could provide 100% base load soil heating for 3,000 sq. ft greenhouse, <u>plus</u>. ▪ 100% peak load of space heating for greenhouse + water treatment building + tempering of recirculated drinking water + new 4-Plex + swimming pool + school + additional ~200 kW.

Table ES6: Estimated Heating Demands

Building	Heat Load per Floor Area W/m ² (Btu/hr/ft ²)	Floor Area m ² (sq. ft.)	Comments
Future Greenhouse – Base Load	190 (60)	140 up to 280 (1,500 up to 3,000)	This load is an assumed geexchange base load at 50% peak. Geexchange would heat root zone, and a separate peaking system would be needed to heat air space.
Future Greenhouse – Full Load	280 (120)	280 (3000)	Geexchange would heat root zone, and air space. A redundant back-up system would likely still be required.
Future Community Pool	410 (130)	56 (600)	--
Future School	63 (20)	929 (10,000)	Estimated based on 5 classrooms.
Future 4-Plex Residential	38 (12)	353 (3,800)	--
Future Water Treatment Plant	63 (20)	186 (2,000)	Heating load includes tempering of water in indoor storage tanks.
Tempering of re-circulated drinking water			Approximately 10,000 Btu/hr (~3 kW).

Groundwater Quality and Geexchange

A primary consideration related to groundwater quality is the elevated arsenic concentration in water from KFN-L, the deep warm water well. If the health issues associated with long-term exposure to arsenic at the concentrations observed, water treatment and disposal could be simplified as the water used for heat extraction could then be utilized for potable water without treatment.

Groundwater quality issues (e.g., mineral scaling, biofilm formation, or metal corrosion) are a dominant reason why well or geexchange/heat exchanger systems foul, underperform or fail. Groundwater has dissolved and suspended inorganic components, dissolved gases, and bacteriological organisms which typically change their concentration or abundance during pumping, treating, exchanging heat, distributing or discharging. When groundwater undergoes a change in pressure or temperature or when groundwater is mixed with another quality of groundwater (or surface water), complex physical, hydrochemical and bacteriological changes can occur. With suitable water quality and temperature measurements, hydrochemical modelling can be used to predict how waters will likely behave during such complex changes (this would be done during later prefeasibility engineering studies).

Based on current information and experience, EBA offers these general comments to help decision-making:

- Injecting KFN-L water into a shallower, cooler aquifer would cause the greatest degree of hydrochemical/bacteriological reactions, requiring the relatively highest level of operator skill and system monitoring/management, and possibly water treatment to maintain reliable operation.
- Conveying KFN-L water (after heat exchange) back into the top of well KFN-L or injecting it back into the original deep warm water aquifer would likely cause a lesser degree of hydrochemical and bacteriological reactions, possibly requiring lesser system complexity, operator skill and management effort, and potential treatment for reliable operation.

- Exchanging heat within KFN-L, with only low flow bleed water or natural artesian discharge from KFN-L, will likely be simpler to manage, less complex and less expensive than above, due to lower flow rates and the potential to treat and blend KFN-L water into the potable water system.
- Disposal of spent KFN-L water to surface water (e.g., Pothole Lake) would be the simplest scenario, avoiding problems of fouling in an injection well or with disposal within KFN-L.

Options Analysis

Water disposal, regulatory approval requirements and permafrost conditions are important constraints that must be considered when evaluating the options. The options considered differ significantly with respect to water disposal needs, potential environmental effects and regulatory approval requirements.

Three types of water disposal were considered:

- Discharge to surface water;
- Injection into a shallow cold aquifer; and
- Injection into the deep warm aquifer.

Pending future biophysical assessments, options for surface disposal include Pothole Lake or Kluane Lake. Locations for a potential shallow (KFN-O) or deep (KFN-P) injection well are identified toward the lake from KFN-L to allow suitable hydraulic and thermal separation from KFN-L.

Non-cost evaluation factors used here included:

- Technical / system Complexity;
- Regulatory approval and permit requirements;
- Operator skill requirements;
- Sustainability;
- Timeframe (for design, regulatory approval, tendering and construction); and
- Environmental (hydrocarbon offset, extent of heat recovery from deep aquifer, potential adverse environmental effects from water disposal).

Factors not assessed were:

- System operation and maintenance (O&M) effort/costs or system life-cycle costs;
- Human resources/training issues;
- Ownership/legal liability issues; and
- System decommissioning/abandonment effort or costs.

Table ES4 (above) summarizes all of the evaluation factors for the options considered here. This table is meant to be self-explanatory, and serve as the principal basis for decisions by KFN and funding partners about which option path to pursue.

Table ES7 shows Class D (+/- 40%) capital costs for the options.

Table ES7: Class D Cost Estimate Summary for Different Options

	Option 1	Option 2a	Option 2b	Option 3
Water Supply, Treatment and Distribution	\$ 720,000	\$ 1,640,000	\$ 1,560,000	\$ 1,670,000
Geoexchange (including Water Disposal)	\$ 90,000	\$ 460,000	\$ 770,000	\$ 3,160,000
Additional Investigations and Consulting Services*	\$ 60,000	\$ 210,000	\$ 210,000	\$ 220,000
Total	\$ 870,000	\$ 2,310,000	\$ 2,540,000	\$ 5,050,000

Table ES8 summarizes financial aspects of the various heat recovery cases assigned to the options.

Table ES8: Simple Payback for Different Options

	Case 1	Case 2a	Case 2b	Case 3
Installed heating capacity (kW)	15	53	73	410
Estimated capital cost	\$ 90,000	\$ 460,000	\$ 770,000	\$ 3,160,000
Normalized cost per kW of installed heating capacity	\$ 6,000	\$ 8,679	\$ 10,548	\$ 7,707
Avoided annual diesel heating fuel cost*	\$ 5,198	\$ 18,366	\$ 25,297	\$ 142,079
Incurred electricity cost**	\$ 998	\$ 3,526	\$ 4,857	\$ 27,279
Annual energy savings	\$ 4,200	\$ 14,840	\$ 20,440	\$ 114,800
Simple payback period on energy savings (yr)	21.4	31.0	37.7	27.5

The shortest simple payback is for Option 1 (21.4 yrs) and the longest is for Option 2b (37.7 yrs). Note that the payback (27.5 yrs) for Case 3 assumes that the system would be built to full capacity with 410 kW output. This would require additional district heating demands (residential, commercial) around the proposed geoexchange loop. If Case 3 were constructed to provide heat to just the greenhouse, WTP, 4-plex, school and pool the payback would be longer than 27.5 years.

Potential Funding Sources

YG currently has money set aside for this project that was provided through the Build Canada Fund. Our understanding is that approximately **\$825,000** is remaining for this project, to be spent by March 31, 2016. This YG Build Canada funding alone would be insufficient for all but Option 1. Should Options 2a, 2b or 3 (or similar) be desired, additional funding by KFN, YG or another funding source would be required.

At the end of the report, we provide a table (Table 13) of 21 federal, territorial, institutional or private organizations, programs and grants that are applicable to First Nation water action plans, infrastructure, community improvements, alternative energy and agriculture – including funding opportunities pertinent to one or more of the project components. The table includes organization name, fund name and web link, contact information and notes on applicability.

There may also be possible opportunities related to carbon credits for offsetting reliance on fossil fuels.

Conclusions and Recommendations

EBA presents the following conclusions from this study:

- EBA has presented four options to span the breadth of “minimal” to “maximum” scope of water supply and geexchange development for KFN. The options presented were specifically selected to span the range of possible water demands as well as the range of simpler to more complex geexchange options. These options are presented with the intention that YG and KFN can consider the range of options and associated costs, and other important considerations such as system complexity and regulatory considerations.
- Although we have presented four options to span the breadth of minimum to maximum scope of development, there are several intermediate options that could also be considered. There should be sufficient information presented in this guidance document to consider and select possible intermediate combinations of options, and to make an educated decision on how to proceed with development of the cold and warm water resources.
- Option 1 could likely be completed with funding currently available; however, this option is somewhat limiting as it relies upon a water supply that has limited yield and therefore this option is only suitable for the low growth population model.
- Additional funding is required to pursue Options 2a, 2b or 3, or to pursue any intermediate combination of options.
- It is possible to reduce the costs for Option 2b and Option 3 significantly by developing the demand (i.e. the infrastructure that would utilize district heating) closer to the warm water source to minimize the development costs by reducing piping and trenching costs. This would also minimize potential risks associated with the permafrost conditions. For example, KFN could give consideration to developing the proposed 4-Plex (if Option 2b selected) and the proposed pool and school (if Option 3 selected) near the warm water resource (KFN-L).

EBA presents the following recommendations resulting from this study:

- KFN should take this guidance document into consideration, and deliberate internally and with partners (e.g., YG) to select a preferred option.
- KFN should consider/ revise their Community Land Use Plan to align with selected option.
- If Option 2 or 3 (or a variance on these) are desired, KFN should apply for funding from funding sources identified in this study. EBA would be pleased to offer application support.
- For the selected option, it is recommended that KFN start permitting/approvals process immediately. Geotechnical and permafrost assessments should also be conducted as soon as possible to make the results available for the preliminary and detailed design. EBA has experience with this and would be pleased to support this effort.
- For the selected option, KFN should start preliminary design (EBA can support).

- Water system improvements must be made to address the chlorine contact issue for whichever option is selected; however, an immediate operational recommendation to address this issue would be to ensure that prior to the 2nd, 3rd and 4th deliveries of the day that the water truck sits idle (at the Water Treatment Plant) for 20 minutes prior to departing for the first delivery site. This would achieve the desired 4-log removal of viruses (provided the recommended chlorine concentration is present). The truck end fill time and the truck depart time must be documented in the water treatment plant records and maintained with all other records (such as residual chlorine readings).

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APPENDICES

Appendix A	EBA's General Conditions
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ACRONYMS & ABBREVIATIONS

ADD	average daily demand
As	arsenic
ags	above ground surface
AO	aesthetic objective
bgs	below ground surface
CCME	Canadian Council of Ministers of Environment
CRUM	Cold Climate Utilities Monograph
CT	concentration time
Fe	Iron
GCDWQ	Guidelines for Canadian Drinking Water Quality
KFN	Kluane First Nation
kW	Kilowatt
L/c/d	litres per capita per day
L/s	Litres per second
MAC	maximum allowable concentration
mg	manganese
Mg	milligram
m bg	meters below ground
m asl	meters above sea level
PSI	pounds per square inch
RO	reverse osmosis
SWL	static water level
TDS	total dissolved solids
USgpm	US gallon per minute
WTP	water treatment plant
YES	Yukon Engineering Services
YG	Government of Yukon, Community Services, Infrastructure Development C-13
YG-EHS	YG Environmental Health

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the Yukon Government, Community Services, Infrastructure Development (C-13) and their agents, or the Kluane First Nation. EBA Engineering Consultants Ltd. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the Yukon Government, Community Services, Infrastructure Development (C-13) and their agents, or the Kluane First Nation, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement. EBA's General Conditions are provided in Appendix A of this report.

1.0 INTRODUCTION

EBA Engineering Consultants Ltd., operating as EBA, A Tetra Tech Company (EBA) was retained by the Government of Yukon, Community Services, Infrastructure Development C-13 (YG) on behalf of the Kluane First Nation (KFN) to prepare a guidance document for the development of a cold and warm water well system in Burwash Landing, Yukon. This work was based on EBA proposal PW23103077 submitted to YG on January 10, 2013. Mr. Kyle Rolling, P.Eng., Senior Program Manager for YG, approved this work as part of contract no. C00016603 dated January 25, 2013.

For reference, Figure 1 shows the study area, key landmarks and the three existing water wells considered in this study (KFN-F – existing cold water supply well; KFN-K – new cold water supply well; and KFN-L – new warm water supply well).

1.1 Purpose and Scope of Services

Based on our understanding of overall development plans for wells in Burwash Landing, we included these original objectives in our January 10, 2013 proposal:

1. Update and summarize the existing conditions of the existing water supply well, and two new wells at Burwash Landing in terms of water quantity, water quality and infrastructure.
2. Determine the future drinking water demand for the community of Burwash Landing in consultation with the KFN.
3. Provide options and approximate (Class D - +/- 40%) costs for water treatment (arsenic removal) for the cold water well, and in consideration of existing water treatment infrastructure.
4. Determine the potential heating energy available from the warm water well resource.
5. Determine the potential heating demands (e.g., for pipeline freeze-protection) and anticipated building heating loads (e.g., for greenhouse operation or building conditioning) in the community.
6. Assess the principal infrastructure and operational requirements of a municipal scale open loop geexchange system for Burwash Landing, and the concept of potentially integrating such a system with the existing wood-fired heating system; including Class D cost estimates.
7. Assess options and Class D costs for:
 - a. A separate drinking water supply system using the new cold water well (connected to the existing infrastructure).
 - b. A separate open loop geexchange energy system using the warm water well.
 - c. An integrated drinking water and energy supply system incorporating both the cold water and warm water wells.

Compare expected costs with current KFN funding and existing water system operations (i.e., trucked delivery vs. piped, regulatory requirements (monitoring, sampling, condition of existing infrastructure, and Wellhead Protection Plan implementation status).

- d. Determine the expected permits and approvals required (and timelines) for developing a drinking water and energy supply system for Burwash Landing. This will include municipal, territorial and federal requirements.
- e. Summarize potential funding sources for additional money that may be required for the various options.
- f. Present the findings of this guidance document to the KFN/YG in report form and in a presentation at the KFN Energy Summit in 2013.

After our proposal was accepted, a series of meetings and conference calls were held between EBA, YG and KFN to refine project objectives, assessment philosophy, priorities and specific options for evaluation. A Technical Memo dated February 21, 2013 (Appendix B) summarizes these discussions, including summary information for wells, design criteria and priorities, specific options for consideration, and schedule and deliverables.

Our project work and this report have been structured around this Technical Memo, which repackages and includes all of the key points in the original list of objectives. The project schedule was modified so that preliminary findings on the geothermal heat resource could be presented by EBA at the KFN Energy Summit, and the remainder of the options evaluation to follow.

This work was scoped as a desk-top study with no new intrusive investigation or testing. However, EBA did with the permission of KFN complete a site reconnaissance of the existing water treatment plant (WTP) system while in Burwash Landing to attend the Energy Summit and deployed dataloggers in the water storage tanks to record water levels and temperature. This data assisted with understanding the existing water system operational issues. This project was carried out through EBA's Whitehorse office, except for participation in the KFN Energy Summit, and reconnaissance and datalogger deployment work on March 4-5, 2013 in Burwash Landing.

1.2 Design Criteria and Priorities

The following list presents key design criteria and priorities used here (summarized from Appendix B):

- KFN's first priority is the current water supply and treatment including: lack of redundancy, well KFN-F not meeting operational demands, and water treatment issues.
- KFN will consider upgrades to the existing WTP, and/or a new WTP in the vicinity of KFN-K and L.
- Using warm water from KFN-L for heating purposes is a secondary priority. Possible uses to be considered include: freeze protection for water lines, heating a greenhouse (to be developed near KFN-L), and heating existing (existing WTP, existing residences) and future buildings (e.g., four-plex building, school, swimming pool, new residences).
- Geexchange applications in the area of the KFN administration building, Jacquot Hall, Sedata Centre are not a priority of KFN and are not considered further here.
- Water distribution options should include bulk truck fill operation, and a combined bulk truck fill/supplementary piped distribution (where practicable), including regulatory implications.

- New systems should be as simple as possible to operate, reliable, and sustainable.
- Water demand options should include: low growth (7% every five years), moderate growth (30% every five years); and high growth (large population spike of about 2,000 persons due to possible Wellgreen mine with additional organic population growth of 7% every 5 years) for a design life of 20 years.
- Class D cost estimates (+/- 40%) are acceptable for this study.
- Future developments to be considered in this study (for water supply and geexchange) include a greenhouse (1500 sq. ft. to 3000 sq. ft.), 4-plex residential building, a new school and a pool. EBA to present preliminary findings on warm water well use at the March 4-5, 2013 Energy Summit.

2.0 WATER DEMAND

2.1 Current Water Demand

The current water demand for the community of Burwash Landing includes domestic demands for residences, and commercial demands for KFN Government administration and maintenance buildings. The KFN buildings are served by a separate dedicated water well while the residential demand is served by the KFN-operated public drinking water system with groundwater sourced from one community well (KFN-F) and distribution by trucked delivery. KFN-F was drilled by Midnight Sun Drilling Company Ltd. in 1981 and has served as the main community water supply well since the construction of the existing water treatment plant.

In the recent assessment of the KFN community water system (YES, 2012) completed by Yukon Engineering Services (YES) and EBA, it was reported by YES that the average water demand from the system was about 65 m³/week (9 m³/day). Based on a population in Burwash Landing of 95 persons (Statistic Canada, 2011), this equates to an average daily demand (ADD) of about 100 L/c/d.

KFN has noted that water demands have been increasing in the past five years due to the return of young families to the community, and due to the fact that the community laundromat facility (which was served by a dedicated well) is no longer in use. Families have been installing household washing machines and dishwashers in their homes and the water demand from the community system is increasing as a result.

2.2 Future Water Demand

In accordance with EBA Technical Memo No.1 (Appendix B), water demands for this study were predicted based on low, moderate and high population growth models for the community. The Cold Regions Utilities Monograph (American Society of Civil Engineering et al., 1996) estimates water consumption for truck haul distribution systems and homes with conventional plumbing systems in northern communities, to be approximately 90 L/c/d, which is slightly less than the usage observed currently from the bulk facility.

Analysis of sewage truck pump-outs and trips per week to the Destruction Bay sewage lagoon by EBA during a previous study for KFN indicates a sewage production rate from Burwash Landing of about 125 L/c/d. The discrepancy in water consumption between the supply and the waste side is attributed to

the use of the dedicated well serving the KFN administration building, Jacquot Hall (Health and Social Services building) and the Sedata Centre, which are included in the higher number.

Due to the increasing water demands in the community and the wastewater data presented above, for the purpose of predicting future water demands for this guidance document, the water demand per capita was taken to be 125 L/c/d for each of the three scenarios of growth. This is conservatively higher than values in both the YES report and the CRUM.

The three scenarios for growth and predicted water demand considered in this study are described below:

- **Low Growth:** 7% growth every five years as experienced in Burwash Landing between 2001 to 2006 according to the Community Land Use Plan and based on Statistics Canada (Statistics Canada, 2006).
- **Moderate Growth:** 30% growth every five years for 20 year design life. 30% growth was experienced in Burwash Landing between 2006 and 2011 according to the Community Land Use Plan and based on Statistics Canada (Statistics Canada, 2011).
- **High Growth:** This high growth scenario includes a 2000 person increase by 2018 due to Wellgreen Mine (maintained at this level for 20 years) on top of a base 7% growth of the non-mining community.

Population growth models are presented on five year increments from present to the 2033 design population in Table 1 below.

Table 1: Population Growth Scenarios

Population Growth Scenario	YEAR				
	2013	2018	2023	2028	2033
Low	95	102	109	116	125
Moderate	95	124	161	209	271
High	95	2102	2109	2116	2125

Table 2 below presents the estimated future population for each growth scenario along with average daily demand presented in m³, L/s and US gpm, and based on the above population growth scenarios for a design period of 20 years.

Table 2: Forecasted Water Demand Scenarios

Population Growth Scenario	Forecasted Water Demands				
	Population (2033)	Future ADD (L/c/d)	ADD (m ³)	ADD (L/s)	ADD (USgpm)
Low	125	125	16	0.18	2.8
Moderate	271	125	34	0.39	6.2
High	2125	125	266	3.07	48.6

Other water demands not factored into the above include a proposed greenhouse, a community pool, school and light industrial area. KFN wish to develop a greenhouse to grow local produce, and hope to start with a facility that is about 1500 sq. ft. and extendable to 3000 sq. ft. Water demands for a greenhouse could be supplied from an untreated water source. According to a University of Massachusetts Amherst web site, a rule of thumb is to have available 0.3 to 0.4 gallons/square foot (0.11 to 0.14 L/m²) of growing area per day as a peak use rate for the warmest days (Bartok, 2009). Assuming that greenhouse benches occupy about 80% of the greenhouse footprint, and that the range of size of greenhouses being considered for this study is from 1500 sq. ft. to 3000 sq. ft. (85 to 280 m²), this equates to about 2.3 to 4.5 m³/day of water demand. Thus, this water demand is relatively insignificant since the well supply greatly exceeds this, as do the moderate to high demands which make this within the range of variability and relatively inconsequential. The total demands for the moderate and high growth scenarios including greenhouse demands are 38 and 270 m³/day respectively.

Other potential future water demands include a community pool and school and a possible future light industrial area. These demands for potable water are not considered in the above demand estimates; however, the options to meet the moderate and high growth scenarios of this study would adequately accommodate these additional demands.

As there is a YG operated fire hall with a dedicated water source, the estimates herein have not included fire protection.

3.0 WATER SUPPLY

3.1 Existing Water Wells

Existing water wells in Burwash Landing are shown on Figure 1. For the purposes of this guidance document, the specific wells of interest are: KFN-F, which currently serves the existing water treatment plant and bulk water facility, and two new wells, KFN-K and KFN-L, completed in 2012.

KFN-K is a cold water well that is completed to 73.5 m below ground surface (bgs) and KFN-L, a deep warm water well completed to 387.4 m bgs. KFN-K was originally drilled as a support well during the drilling of the warm water well KFN-L, but was completed for future use as a potential drinking water supply well for the community.

KFN-K and KFN-L are completed in close proximity to each other at the northeast end of the main Village of Burwash Landing. The wells are completed in a clearing which is a “fire-break” and adjacent to a dirt road; there is no other infrastructure at the site or within 60 m of the wellheads.

Relevant details regarding the three existing wells that are the focus of this study are provided in Table 3 below.

Table 3: Well Information Summary for KFN-F, KFN-K and KFN-L

	KFN-F (cold water well near water truck garage)	KFN-K (new cold water well)	KFN-L (new warm water well)
Well Type	Completed in overburden (gravel) with stainless steel screen.	Completed in overburden (sandy gravel) with stainless steel screen.	Completed in overburden (sand) with stainless steel screen.
Well Diameter	152 mm (6 in)	152 mm (6 in)	152 mm (6 in)
Well Depth	60.96 m (200 ft.)	73.5 m (241 ft.)	387.4 m (1,271 ft.)
Well Yield (based on pump test)	3.7 USgpm (with short-term yield up to 12 USgpm) Note: Water system operators report that this may be declining; rehabilitation is likely warranted.	9.5 L/s 150 USgpm	3.5 L/s 55 USgpm. Yield may be up to 100 USgpm but this would require verification through additional pumping tests.
Pump Test Duration	24 hr	24 hr	72 hr
Artesian Pressure at Wellhead	Not artesian (SWL ~12 m (39 ft) bgs)	3 psi (SWL ~2.1 m (6.9 ft) ags)	1 psi (SWL ~0.7 m (2.3 ft) ags)
Water Temperature	~2°C (to be confirmed)	1.9°C	15.9°C
GUDI Status based on Review of Stage 1 GUDI Assessment Criteria	No triggers based on information presently available. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI.	No triggers at this time to suggest GUDI. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI.	No triggers at this time to suggest GUDI. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI.
Water Quality Summary	Meets all GCDWQ MACs. Manganese (0.07 mg/L) slightly exceeds AO (0.05 mg/L).	As (0.012 mg/L) slightly exceeds MAC (0.01 mg/L); hard (150 mg/L CaCO ₃); pH (up to 8.8) exceeds MAC (6.5-8.5).	As (0.075 mg/L) exceeds MAC (0.01 mg/L); exceeds AO for TDS, Fe, colour; very hard (406 mg/L CaCO ₃).

Notes: GUDI – Groundwater Under Direct Influence of Surface Water; GCDWQ – Guidelines for Canadian Drinking Water Quality; USgpm = US gallon per minute; SWL = static water level; bgs = below ground surface; ags = above ground surface; AO = aesthetic objective; MAC = maximum allowable concentration

Pumping tests at KFN-F were conducted as part of a water supply assessment project completed by EBA for KFN in 2005. Based on the results of these pumping tests, the long-term safe yield of KFN-F was calculated to be 0.23 L/s (20 m³/day or 3.7 USgpm). EBA also rated the well for a short-term (8 hour) safe yield of 0.75 L/s (12 USgpm). It has been reported by KFN operators, that the yield of KFN-F appears to be declining, with longer recovery and fill times in recent years. This suggests that there is likely some decline in performance of the well screen (fouling) and that KFN-F is likely in need of rehabilitation (this would cost about \$10,000 to \$20,000 depending on significance of fouling and effort required for rehabilitation).

The safe sustainable yields of KFN-K and KFN-L were rated by EBA based on pumping tests completed in 2012. The long-term safe sustainable yield of KFN-K has been determined as 18 L/s (285 USgpm); however, EBA recommended that KFN-K should not be pumped at a rate higher than about 9.5 L/s (150 USgpm) without further testing (EBA, 2012). The theoretical safe yield of well KFN-L was rated by EBA at 6.3 L/s (100 USgpm) and was limited by screen entrance velocity; however, since the constant rate pumping test was completed at a pumping rate of 3.5 L/s (55 USgpm), EBA recommends pumping at rates

not higher than 3.5 L/s until higher yields are verified through additional pumping tests at higher pumping rates.

Due to the presence of permanently frozen ground (permafrost) at the location of KFN-K and KFN-L, the water in these wells has frozen since drilling and will require thawing prior to future use and freeze protection measures if and when these wells are developed.

3.2 Existing Water System Overview

The existing community water system consists of community well KFN-F that supplies water to the existing WTP where it is chlorinated prior to entering two 8,300 L (2,200 US gal) aboveground polyethylene cone-bottom storage tanks connected in parallel and located in the WTP. Water is drawn from the tanks through a transfer pump and discharged into a 7,200 L (1,900 US gal) capacity water truck via an overhead fill line. The KFN truck fill system is used to generate, treat and deliver (by truck) water to residences within Burwash Landing. Photos of the exterior of the existing WTP and the storage tanks within the WTP are below.



Photo 1: Water Truck Garage (north end). July 2011. Note: A larger truck as desired by KFN would not fit within current geometry.



Photo 2: Water Storage Tanks and Fill Pump (July 2011). Note: The building has inadequate space to add additional storage.

Well KFN-F is completed in a sub-permafrost aquifer and, following recent wellhead upgrades (pitless unit, casing extension and sanitary seal installation); it now meets Canadian Groundwater Association’s Well Construction Guidelines. This water source is considered by EBA to be a groundwater source not under the direct influence of surface water (i.e., not - GUDI) (EBA, 2012).

3.3 Water Quality for Existing Wells

The water quality results for KFN-F, K and L are included in Table 4, attached at the end of this report and summarized below.

KFN- F

The water sample from KFN-F is hard (127 mg/L) and can be characterized as magnesium-sodium-calcium – bicarbonate- sulphate (Na-Mg-Ca-HCO₃-SO₄) type water.

The raw water quality from KFN-F meets all guidelines for Canadian Drinking Water Quality (GCDWQ) with the exception of manganese which is at a concentration slightly above the aesthetic objective. Manganese oxide precipitates have reportedly caused fouling of chlorination equipment and have resulted in some operational issues.

EBA reviewed bacteriological testing results from KFN-F that were on record with YG Environmental Health (YG-EHS). Over the period reviewed (April 6, 2005 to April 14, 2011) there were 74 bacteriological

tests completed from the raw water source and there was only one positive total coliform result (1.4% of all tests). There were no positive *E. coli* results reported from raw water samples over the same period.

KFN-K

The water sample from KFN-K is hard (150 mg/L as CaCO₃) and can be characterized as magnesium-sodium-bicarbonate (Mg-Na-HCO₃) type water.

Based on the analytical results for the water samples collected on July 18 and August 24, 2012, the observed arsenic concentrations (0.0121 mg/L and 0.0118 mg/L, respectively) slightly exceeded the GCDWQ maximum allowable concentration (MAC) of 0.010 mg/L. All other parameters tested met the GCDWQ at the dates of sample collection.

A bacteriological sample taken from the well on August 18, 2012 was submitted to YG-EHS. Sample results showed no presence of total coliforms or *E. coli* on the date sampled.

KFN-L

The water sample from KFN-L is very hard (406 mg/L as CaCO₃) and can be characterized as magnesium-sodium-calcium-bicarbonate (Mg-Na-Ca-HCO₃) type water.

Based on the analytical results for the water samples collected on August 24, 2012, the water from the well exceeded the GCDWQ Maximum Allowable Concentration (MAC) for arsenic and the aesthetic objectives (AO) for temperature, colour, and iron (see Table 4 at end of report). All other parameters tested met the GCDWQ at the dates of sample collection.

A bacteriological sample taken from the well on July 22, 2012 was submitted to the YG-EHS for analysis. Sample results showed no presence of total coliforms or *E. coli* on the date sampled.

3.4 Water Treatment and Operation Regulatory Framework

Water supply and treatment options considered by KFN must consider a source and treatment to meet the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health Canada, 2012), and water system design, construction and operation must comply with the Yukon Public Drinking Water Regulation (Public Health and Safety Act – Drinking Water Regulation Part 1); and the Protocol for Safe Drinking Water in First Nations Communities.

The Yukon Government Drinking Water Regulation (YG, 2007) does not specifically state that primary disinfection is required for a bona fide groundwater source (i.e. non-GUDI); however, it does require secondary disinfection ensuring 0.2 mg/L residual chlorine concentration (residual) throughout any distribution system and a minimum of 0.4 mg/L residual at the point of loading for a trucked distribution system.

In lieu of a prescriptive requirement in Yukon regulations regarding primary disinfection of a bona fide groundwater source, EBA referenced the Ontario Design Guidelines for Drinking Water Systems (as a reference point); and these guidelines suggest that the minimum primary disinfection for a groundwater source is disinfection with a minimum of 2-log (99%) removal and/or activation of viruses before the water is delivered to the first customer. The Protocol for Safe Drinking Water in First Nation Communities

(the Protocol) (INAC, 2006); however, suggests primary disinfection to 4-log removal (99.99%) of viruses. Many water system improvements and operational studies funded by AANDC under the First Nation Water Management Strategy utilize the Protocol for design standards and best management practices. In consideration of the Protocol, it is suggested that water system improvements should meet 4-log removal for primary disinfection as a design criteria.

3.5 Existing WTP Operational Issues

The current well yield of KFN-F, desired delivery schedule (3 to 4 days per week), and water storage configuration in the existing WTP make it difficult to operate the existing system as intended. According to KFN water system operators, the yield of KFN-F has decreased in recent years and it is taking longer to refill the water storage tanks. YES (YES, 2012) had determined based on some assumptions of water usage that the recommended 4-log (99.99%) removal of viruses was not being achieved as there was inadequate contact time.

In order to understand the operation of the dynamic system and current operational challenges better, EBA consulted with the water system Operator and gathered some additional information while in Burwash Landing attending the Energy Summit in early March 2013. Dataloggers were installed in each of the water storage tanks to collect water level and temperature data over a two week period. Relevant information obtained from the site visit, discussions with the operator and from a review of the datalogger data is summarized below:

- Water delivery primarily occurs on Monday, Tuesday, Wednesday and Friday with delivery ranging from one to four water truck loads per day. Monday is currently the biggest delivery day with four truckloads delivered. The total water demand is about 13 truck-loads per week with the current truck capacity of 7,200 L (1,900 US gal).
- Review of the datalogger data indicates that on delivery days where there were four fill events, the lowest water volume just prior to the fourth fill was about 5,700 L (1,500 US gal) per tank or 11,400 L total; and the tank volume at the end of the fourth fill event was observed to reach a low of about 2,270 L (600 US gal) in each tank for a total volume of about 4500 L (1,200 US gal). This is less than the minimum 75% tank capacity that YES (YES, 2012) had assumed in their contact time calculations.
- The temperature of the water in the storage tanks varies from about 3°C to about 20°C. The groundwater supply is about 2°C. Water temperature in the tanks increases as stored water picks up heat from the building and then drops as water is removed from the tanks and new water is added to the system. The lowest water temperature prior to fourth and final fill event was observed to be 5°C.

The variations in tank storage volume, residual chlorine concentrations and temperature have an effect on the chlorine effectiveness as a primary disinfectant. In review of water quality data that the operators had recorded, the residual chlorine concentrations are variable - ranging from 0.28 mg/L to 1.2 mg/L. YG Drinking Water Regulation requires at least 0.4 mg/L at time of truck fill. According to the Operator (and verified on their records), in the occurrence that the residual is below the required 0.4 mg/L, the staff adds chlorine to the water truck tank to increase the residual chlorine concentration to above the required 0.4 mg/L.

The concentration-time (CT) disinfection concept for primary disinfection uses the combination of a disinfectant residual concentration (in mg/L) and the effective disinfectant contact time (in minutes) to quantify the capability of a chemical disinfection system to provide effective pathogen inactivation. EBA calculated the CT of the water source based on the data available. To achieve 4-log treatment of viruses and bacteria, the required CT at a pH of about 8.3, a minimum temperature of 5°C, a minimum chlorine residual of 0.4 mg/L and to achieve 4-log removal would be 8 mg*min/L. This CT of 8 mg*min/L would require a contact time of 20 minutes to achieve 4-log (99.99%) removal of viruses.

Since the existing KFN tanks are unbaffled and have a low length to width ratio and high exit velocities there can be short circuiting within the tank. As a factor of safety, a baffle factor ratio is applied. Considering a baffle factor of 0.2 (YES, 2012), the minimum contact time in the water tanks under their current configuration increases by a factor of 5x, and should therefore be 100 minutes. Under the current operation, this contact time is more than sufficiently achieved prior to the first fill of a delivery day; however, subsequent truck fills likely have insufficient contact time based on the truck fill rate. As the well is still being replenished with fresh water up to the time of the 2nd, 3rd and 4th truck loading, possible short-circuiting exists and creating the potential for not achieving full treatment.

The long-term solution to this issue is to add additional storage and to increase the “baffle factor” by adding improved mixing at the injection point, adding internal baffling within the tanks or changing the configuration of the tanks (series etc.). However; an immediate operational consideration to address this issue would be to ensure that prior to the 2nd, 3rd and 4th deliveries of the day that the truck sits idle (at the WTP) for 20 minutes prior to departing for the first delivery site. This would achieve the desired 4-log removal of viruses. If this recommended practice is employed, the truck end fill time and the truck depart time must be documented in the water treatment plant records and maintained with all other records (such as residual chlorine readings).

As mentioned previously, it was noted from a review of the operator’s records that there is significant variability in the residual chlorine concentrations measured at the time of truck filling. Detailed analysis of the residual chlorine concentration variability within the system was not within in the scope of this study. The variability is most likely caused because manganese and other metals in the water are creating a chlorine demand and the chlorine residual concentration may be declining based on the time the water is being stored. When this occurs there would be a resultant rise in turbidity. The rise in temperature during storage may also have some impact on this reaction. Data collected on site which demonstrated lower field turbidity than lab results (EBA, 2012) provides further evidence that the reaction of air and chlorine with the raw water anions is a likely occurrence. Oxidizing the metals with a treatment system prior to storage would limit this demand.

3.6 Recommendations for Improvements to Existing WTP

The existing WTP requires upgrades including changes to the treatment process to achieve a viral log treatment of 4-log and manganese (Mn) removal because Mn precipitate is causing operational issues (YES, 2012). Relevant recommendations related to water source, quality and treatment from YES (YES, 2012), Neegan Burnside (2011) and new information obtained in this study are summarized below:

- Develop a back-up water supply for the trucked water delivery system for redundancy in order to improve reliability of water supply.
- KFN-F and any future wells serving this should include data loggers and flow meters.
- Install treatment for manganese removal.
- Provide treatment to reduce or eliminate sulphur smell.
- Increase contact time for disinfection.
- Install redundancy on the chlorination system and correct mechanical deficiencies (in-line mixer, isolation valve, relief, level sensor with alarm).
- Add in-line mixer after chlorine injection to improve contact.
- Obtain a larger delivery truck to make water system operator schedule more efficient (reducing personnel time/effort and cost) and change water system configuration in order to smooth out demand and allow KFN-F water level recovery to “catch up” with the demand.
- Expand the WTP building to facilitate a larger water delivery truck.
- Upgrade controls and instrumentation to be operator-friendly and limit operator intervention needs; also include provisions for remote monitoring.
- Clean and rehabilitate the online free chlorine analyzer following other system improvements.

4.0 SUMMARY OF SUBSURFACE CONDITIONS

4.1 Hydrogeology Overview

Burwash Landing is located on the shore of Kluane Lake approximately 290 km west-northwest of Whitehorse, Yukon in a geological area known as the Shakwak Trench. The direction of groundwater flow in the area around Burwash Landing is anticipated to be northeasterly from the topographic highs of the Kluane Ranges to the topographic lows of Kluane Lake.

Bedrock geology maps indicate that the nearest bedrock exposures are on mountain slopes approximately 4 km southwest of the community. KFN-L is the deepest well that has been drilled in the Burwash area and did not encounter bedrock at a depth of 387 m (1,270 ft.). There is the potential for multiple aquifers with variable water chemistry and temperature to exist within these sediments that are dominated by silt deposits (till and lacustrine sediments). Historically, some shallow dug wells have been completed in the gravelly beach deposits developed alongside Kluane Lake. The most successful wells in the Burwash Landing area are completed at depths ranging between 35 and 75 meters below ground (m bg) with yields ranging from three to more than 150 USgpm.

4.1.1 Cold Water Aquifer

Based on limited available data from wells logs in the Burwash area, the shallow subsurface appears to be highly heterogeneous with dominating low-permeability silt deposits. Water-bearing sand and gravel

lenses and layers within these silt deposits form local aquifers that can be artesian (i.e. with hydraulic heads above the local ground surface elevation).

KFN-F and KFN-K are both completed in a shallow cold water aquifer below permafrost. The aquifers are confined within the permafrost and/or low-permeability silt deposits. Based on the limited data available from well logs and the depth to unfrozen aquifers encountered in the Burwash area, permafrost thickness is likely about 30 to 50 m. The shallow aquifers consist of sand and gravel lenses or layers within the low-permeability silt deposits. Most wells in the Burwash Landing area have a very low yield of less than 0.5 L/s. However, KFN-K is completed in a sand and gravel aquifer at a similar depth as other wells in Burwash but shows a much higher yield exceeding 3 L/s. This aquifer likely has a larger spatial extent than other shallow sub-permafrost aquifers from which other wells in Burwash produce water.

KFN-F is a shallow confined but non-artesian aquifer with a static water level about 12 m bgs. The shallow sub-permafrost aquifer encountered in KFN-K is artesian with a hydraulic head slightly above ground surface (~2 m ags) and a shut-in artesian pressure of about 3 psi at the wellhead.

Based on the heterogeneous nature of the overburden lithology in the Burwash area, depth and yield of aquifers are difficult to predict. Even if a new well is drilled at a location close to an existing well, actual conditions encountered may be significantly different from an existing well nearby.

4.1.2 Deep Warm Water Aquifer

A deep warm water aquifer was encountered at a depth of 384 m bgs in KFN-L. The aquifer is overlain by thick sequences of very dense sandy, gravelly clay and silt, interpreted as over-consolidated till. In the vicinity of KFN-L, the deep aquifer consists of sand with traces to some silt. KFN-L was terminated at a final depth of 387.4 m bgs within the same aquifer; the thickness of the deep warm water aquifer is therefore unknown.

In the area of KFN-L, the deep aquifer is slightly artesian with a shut-in pressure of about 1 psi at the wellhead. Artesian flow from KFN-L was about 0.63 L/s (10 USgpm) at the time of well construction.

4.2 Geotechnical Matters, Permafrost, Ground Temperature Profile

Burwash Landing is located in the discontinuous but widespread permafrost zone of southern Yukon. The mean annual air temperature in the area is about -4°C, with a mean annual ground temperature of about 0°C. This is considered “warm” permafrost, the distribution of which is controlled by surface vegetation (insulating moss and organics), slope aspect (generally no permafrost on south facing slopes), elevation (more permafrost above 1,000 meters above sea level (m asl)), and local topography (most drainage valleys contain permafrost). The thickness of the active layer (soil layer susceptible to seasonal thawing) ranges from less than a metre to several metres. Ground ice contents are variable, but could be locally significant. In areas that have been cleared of vegetation and previously used for construction (building sites, roads and fire breaks) the permafrost may have thawed to a significant depth. As stated above, the base of the permafrost may be about 30 m to 50 m below surface.

Building foundation design must assume that there is permafrost in the subgrade, and designs prepared accordingly. Generally, foundations must be constructed with some form of foundation levelling and/or

clear crawlspace as the permafrost is warming and thawing in response to climate change. This risk of permafrost warming is consistent with permafrost mapping that KFN provided EBA as part of this study which indicates that the area is moderate to high risk of permafrost degradation (moderate thaw-settlement on flat terrain, poor-drainage, slow mass movement on slope due to high pore water pressure and/or moderate geologic hazards).

A site-specific geotechnical investigation will be required for any new structures and along proposed buried utilities.

Buried utilities would generally be insulated in this area of lacustrine silts and/or sands over glacial till (diamicton) soils. EBA has previously completed thermal analyses in the glacial till areas of Whitehorse (similar thermal conductivity and moisture contents) and this data can be extrapolated to Burwash Landing. The following table presents predicted ground temperatures at various depths that can be used for pipe insulation design in Burwash Landing.

Table 5: Minimum predicted ground temperatures at depth

Depth Below Ground (m)	Predicted Ground Temperature (°C)
1.0	-17
2.0	-9
3.0	-3
4.0	-1

4.3 Geothermal Gradient

Temperature variation with depth in the Earth is a function of surface process (i.e., atmospheric and solar) and deep geothermal processes (i.e., magmatic activity, plate tectonics, and hydrothermal activity). Under circumstances where the geothermal gradient is considered *normal*, such as at locations away from tectonic plate boundaries, the subsurface temperature profile over the depth interval of interest for geoexchange can roughly be divided into three thermal regimes:

- **Shallow Thermal Regime:** Here, the Earth temperature is strongly influenced by atmospheric processes. Surface and near-surface temperatures fluctuate seasonally on the order of +/-10°C. These temperature fluctuations dampen with depth and completely diminish at about 5-7 m.
- **Transition Zone:** This zone generally occurs from depth intervals of 5-7 m to about 100 m, and is characterized by thermal influences from above and below. In this zone, the Earth temperature is roughly a constant, equivalent to the average annual air temperature plus about 1.5°C (Signorelli, 2004).
- **Deeper Earth Regime:** In this zone, Earth temperatures are dominated by geothermal processes and begin at a depth of about 100 m. With increasing depth, the Earth temperature rises at an average rate of about 25°C per kilometer, or about 2.5°C per 100 m.

The geothermal gradient at Burwash Landing was estimated from groundwater temperatures measured in wells KFN-K and KFN-L. Over the depth interval of these wells, the Earth temperature is increasing at a rate

of about 4.4°C per 100 m, which is at a rate of approximately 1.8 times greater than the normal geothermal gradient of 2.5°C per 100 m.

5.0 KFN ENERGY SUMMIT OUTCOMES RELATING TO THIS PROJECT

Ryan Martin, P.Eng. of EBA attended and presented at the March 4-5, 2013 Energy Summit event hosted by KFN in Burwash Landing. The following information was learned from other presenters (person providing the information included at end of each item):

- An outcome of the baseline community energy emissions overview is that there is a general dissatisfaction with using diesel fuel as a heating source within the community, and any renewable energy projects that would reduce reliance on diesel would be beneficial (Colin Wright).
- Building heating is the primary energy demand in Burwash Landing (Colin Wright).
- Wind turbine projects are currently being studied, appear feasible, and there is a high probability that KFN would have an independent wind project in the next three years subject to funding. In this scenario, it is likely that Kluane Corp. would be an independent power producer and sell power back to Yukon Electrical Company Limited (J.P. Pinard). In addition, there is a pilot solar photovoltaic project currently in place. KFN has a 4.7 KW system and expect a net export of energy in February through October (J.P. Pinard).
- KFN are in the process of addressing demand side energy management, improving efficiency and building new buildings as “super green” high efficiency homes recognizing that this is the first step to energy conservation/reduction (J.P. Pinard).
- The existing wood fired biomass system serving the KFN Admin building, Sedata building, Jacquot Hall has additional capacity for expansion in the vicinity of the system (J.P. Pinard).
- Private residences have primary heat approved wood stoves, and an ample supply of wood biomass. Wood heating as the primary heating source for homes is considered successful. (Colin Wright). *Note: Based on this, geexchange heating is not considered a suitable heating source for secondary or redundant heat; and therefore district residential heating will not be considered further in this study.*
- Due to the remoteness and harsh climate, and potential lack of trained resources, it will be very important to minimize the complexity of the water systems.

6.0 OPTIONS OVERVIEW

KFN, EBA and YG have discussed and agreed to consider options of integrated water supply and geoexchange with successive options showing increasing infrastructure complexity and use of the warm water resource. We understand that KFN leaders have directed the EBA team toward these options considering a wide range of factors affecting current and future development at Burwash Landing, including their Community Land Use Plan. Details of the three options are described below.

6.1 Option 1 – Lowest Complexity and Relative Cost

Overview: Drill a new well (following the naming convention, this would be called “KFN-M”) near the existing WTP for water supply redundancy to KFN-F; implement water treatment improvements at the existing WTP. Rehabilitate well KFN-F to improve well screen efficiency. A small pump house would be constructed near the KFN-L wellhead to house pump controller and geexchange equipment. For this scenario, geexchange heating would be implemented for a proposed greenhouse nearby water well KFN-L.

Conceptual locations of potential new infrastructure to be considered as part of this study is shown in attached Figure 2. Detail of conceptual upgrades to the existing WTP for Option 1 is illustrated on Figure 3.

Water Supply, Treatment and Distribution:

- Use KFN-M to supplement KFN-F for potable water supply. This option is feasible only for the low population growth model; with a maximum demand of up to 0.25 L/s (4 USgpm) and peak demand up to 0.63 L/s (10 USgpm). This option would not be feasible for the moderate to high growth models.
- Existing WTP will be upgraded to treat water from KFN-F and KFN-M, including Mn removal and primary disinfection improvements to ensure 4-log removal of viruses within the storage system.
- Distribution by truck delivery only.

Geexchange Heat Transfer and Heating Uses:

- For this option, we considered a simple closed-loop geexchange concept only.
- Heat exchange would be accomplished using a closed-loop durable plastic pipe heat exchanger placed in well KFN-L, with the wellhead sealed to prevent artesian overflow.
- Heat transfer fluid in the closed loop would be an environmentally safe antifreeze-water solution.
- An open-ended passive convection promoter pipe is necessary to keep water circulating vertically in the well.
- A pump house would be constructed near KFN-L wellhead, to house heat exchange/recovery equipment and controls.
- Heat from KFN-L would be used for soil heating at a small proposed greenhouse near the KFN-L wellhead and for space heating in the new services building.

Water Disposal:

- With this simplest complexity option, water disposal will not be required.

6.2 Option 2 – Moderate Complexity and Relative Cost

Overview: This moderate complexity and medium cost option integrates the water supply and geexchange options; and includes two sub-options. Two back-up water supply scenarios are considered to meet the medium to high growth average daily demand scenarios. Primary water supply is KFN-K, with back-up water supply from a new water supply well (for convenience, called here “KFN-N”) drilled near

KFN-K (Option 2a) or from the warm water well KFN-L (Option 2b). KFN-F would be maintained as additional back-up, alternative separate use or decommissioned. Piped distribution would also be provided to the eastern end of the Burwash Landing village which would augment trucked delivery to the remainder of the community. This option includes the construction of a new Water Treatment Plant (WTP).

For Option 2a, the benefits are that the secondary water supply would likely have similar water quality to KFN-K and much higher yield than KFN-F.

Option 2b would use existing KFN-L for back-up supply and the water treatment system would need to be designed accordingly to account for treatment of water from both KFN-K and KFN-L (which has higher arsenic and higher TDS concentrations) to meet the GCDWQ. The benefit of this option is that a supplementary well (KFN-N) would not be required.

Geoexchange would include heating for the greenhouse base load heating (assumed 50% peak root zone heating; a separate peaking system would be needed to heat airspace); heating the new WTP, and heating of a proposed 4-plex residence, if sufficient heat is available.

A schematic showing conceptual building locations and conceptual routing of the potential piped distribution is shown on the attached Figure 4.

Water Supply, Treatment and Distribution:

- For Option 2a, the cold water well KFN-K, and a new well (KFN-N) to be drilled in same aquifer near KFN-K would be used for potable water supply. For Option 2b, no new well would be required.
- A new water treatment system in the new WTP would be provided for arsenic removal, and primary and secondary disinfection to comply with Yukon Public Drinking Water Regulation and First Nation Safe Drinking Water Protocol.
- Potable would be distributed through a recirculating distribution system and trucked delivery.
- Other water treatment may be required for artesian flow from KFN-L prior to disposal.

Heat Transfer and Heating Uses:

- A services building to be constructed near KFN-L wellhead, to house heat exchange/recovery equipment and controls.
- Option 2a includes heat exchange through a closed loop; environmentally-safe antifreeze/water heat transfer fluid; an open-ended “convection promoter” tube in the well, and artesian discharge allowed from the wellhead at a rate of about 10 USgpm. Heat from KFN-L is used for soil heating at a proposed greenhouse and space heating the new services building.
- Option 2b would include semi-open loop (a.k.a. standing column well). The heat transfer fluid is the well water itself, circulated through a heat exchanger and discharged back to the top of KFN-L. For this option, it will be necessary to bleed some well water out of the system to moderate well water temperature and prevent freezing. The well water would be isolated from the heat pump equipment to prevent scale, and fouling of heat pumps. Heat from KFN-L would be used for soil heating at the

proposed greenhouse, heating the new services building, and the proposed 4-plex (if sufficient heat is available).

Water Disposal:

- Disposal requirements depend on the heat transfer method from KFN-L. With in-well closed loop heat exchanger (Option 2a), disposal may not be required (depending on artesian flow control, or consumption of artesian overflow water in greenhouse operations). With standing column well concept (Option 2b), minor water disposal will likely be required (depending on heat balancing requirements and artesian flow control).
- For water disposal, options for reinjection into the shallow aquifer or disposal to the surface (e.g., Pothole Lake or Kluane Lake) are assessed. Also, options to use water in the greenhouse operation (e.g., for maintenance, irrigation or hydroponics) are possible. The elevated arsenic concentration may present a technical challenge for disposal options and will require further consideration. There would be some limitations for direct use in the greenhouse, and care and consideration would be required to select species of plants.

A schematic showing conceptual building locations and conceptual routing of the potential piped distribution is shown on the attached Figure 5.

6.3 Option 3 – Highest Complexity and Relative Cost

Overview: Option 3 would utilize wells KFN-K and KFN-N for water supply and use KFN-L to support a geoexchange-based district heating system for commercial buildings depending on magnitude of available heat resource from KFN-L. An open loop geoexchange system would be installed in KFN-L, and a new deep injection well (KFN-P) required for water disposal.

Water Supply, Treatment and Distribution:

- Similar to Option 2b, the cold water well KFN-K and a new well (KFN-N) drilled in same aquifer near KFN-K would be used for potable water supply. KFN-F would be decommissioned, or used for another purpose.
- A new water treatment system in the new WTP would be provided for arsenic removal, and primary and secondary disinfection to comply with YG EHS and First Nation Safe Drinking Water Protocol.
- Potable water would be treated and stored in a new WTP and distributed through a recirculating distribution system and trucked delivery.
- Other water treatment may be required for disposal of KFN-L water in the deep injection well.

Heat Transfer and Heat Uses:

- Due to the need for maximum heating capacity, only an open loop approach for heat extraction is considered in this option. This will require a heat exchanger at the new WTP near the KFN-L wellhead.

- Heat uses would be the same as per Option 2 plus a district heating system for commercial buildings developed in parallel with the piped potable water distribution system, depending on available heat resource and projected heat demand.

Water Disposal:

- With this option, we anticipate pumping KFN-L at up to the probable maximum well rating (100 USgpm, or 545 m³/d); assuming this yield is proven by subsequent pumping tests. Due to this high flow rate and for appropriate aquifer management, we only considered disposal by re-injection to the deep aquifer in this option.

A schematic showing conceptual building locations and conceptual routing of the potential piped distribution as well as disposal locations for Option 3 is shown on the attached Figure 6.

6.4 Option Considerations

The four options described above intentionally are presented to span the breadth of “minimal” to “maximum” scope of water supply and geoexchange development and based on input provided by KFN and YG. These are intended to span the range of possible water demands as well as the range of simplest/lowest cost/lowest energy output geoexchange options to the more complex/highest energy output options. There are many other intermediate combinations of water and geoexchange development options; however, to consider them all at present is not practical, and not within our current scope. For example, it may be possible to develop a new WTP (considered in Option 2 and 3 only) and develop the base geoexchange option of a closed loop (considered in Option 1 only) as these water and geoexchange options are not required to be exclusively paired.

The options assessed are presented with the intention to provide YG and KFN a range of options, costs and other important considerations such as system complexity and regulatory considerations. The intent is that with the information presented in this guidance document there would be sufficient information to direct further decisions related to water supply and development of the warm water resource for KFN at Burwash Landing.

7.0 REDUNDANCY WATER WELL OPTIONS

For a community water system, a minimum of two potable water supply wells are typically required to provide appropriate redundancy in the case of a well pump failure or if one of the supply wells has to be taken offline for maintenance or rehabilitation. Table 6 summarizes the well configurations for the options assessed as part of this study.

Table 6: Water Well Configuration for Different Options

	Option 1	Option 2a	Option 2a, 3
Water Well 1	KFN-F	KFN-K	KFN-K
Water Well 2	“KFN-M” (new well near KFN-F)	KFN-L	“KFN-N” (new well near KFN-K)

7.1 Option 1 – Potential New Water Well Near KFN-F

If KFN-F will continue to be used for community water supply as considered in Option 1, a new water well (“KFN-M”) should be drilled close to the location of KFN-F to provide suitable redundancy. If a new water treatment plant will be installed at the location of KFN-K and KFN-L as part of Option 3, a second supply well (“KFN-N”) may be drilled near to KFN-K and completed in the same shallow cold water aquifer as KFN-K.

A second well drilled for redundancy close to the location of the existing wells KFN-F or KFN-K will likely cause well interference (i.e., intersecting cones of depression). The location of a second supply well should therefore be selected considering the following:

- The new well should be located far enough from KFN-F or KFN-K to minimize well interference and ensure both wells can meet the future demand.
- If possible, the existing well KFN-F or KFN-K and the new well should be located cross-gradient from each other to minimize the risk of contamination of the wells should a spill occur up-gradient of one of the supply wells.
- The new well has to meet all applicable setback distances from potential sources of contamination as stipulated by the Yukon Public Health and Safety Act.
- The well should be constructed in accordance with applicable regulations and guidelines (i.e., the Yukon Large Public Drinking Water Regulations and the Canadian Groundwater Association’s Guidelines for Water Well Construction).
- Both wells should be located as close as possible to the water treatment plant to minimize costs for piping and freeze protection.

Ideally, the well could be drilled at a distance of about 30-100 m cross gradient of KFN-F. A cross gradient distance of 30-100 m provides protection in the case of an upgradient spill and minimizes the risk of effects on both wells but still allows both wells to be located relatively close to the treatment plant to reduce costs for piping and freeze protection. Since the groundwater flow direction is probably toward Kluane Lake (northeast), a second supply well should ideally be located to the northwest or southeast of KFN-F. As the land to the west of KFN-F is owned by someone other than KFN; and to the east is developed, the available locations for a second well to serve the existing WTP are to the North or South of KFN-F. A theoretical location of KFN-M is shown on Figure 2 to the south and upgradient of KFN-M. The actual well location (if this option is selected), shall be located by EBA to ensure adequate setback distances are maintained.

KFN-M should be completed similar to KFN-F, i.e., at a depth of about 60 m bgs. The exact depth and length of the well screen should be based on actual conditions encountered. The well screen size should be selected based on the results of grain size analysis from the aquifer sediments encountered. The well casing diameter should be 203 mm (8”), i.e., slightly larger than KFN-K, to allow sufficient space for monitoring equipment to be installed. The well should be installed by a qualified drilling contractor in accordance with all applicable regulations and guidelines, including a sanitary surface seal with a minimum radial thickness of 50 mm (2”) to a depth of at least 5 m (15 ft.).

7.2 Option 2b and 3 - Potential New Water Well Near KFN-K

EBA recommends that the well be drilled at a distance of about 30 m cross-gradient of KFN-K. This cross-gradient separation would provide protection in the case of an upgradient spill and minimizes the risk of effects on both wells but still allows both wells to be located relatively close to the treatment plant to reduce costs for piping and freeze protection. Since the groundwater flow direction is probably toward Kluane Lake (northeast), a second supply well should be located to the northwest or southeast of KFN-K. EBA has proposed a conceptual location about 30 m west of KFN-L as indicated on Figure 4. If this option is selected, the actual location shall be located by EBA to ensure adequate setback distances are maintained.

The well should be completed similar to KFN-K, i.e., at a depth of about 74 m bgs. The exact depth and length of the well screen should be based on actual conditions encountered. The well screen size should be selected based on the results of grain size analysis from the aquifer sediments encountered. The well casing diameter should be 203 mm (8"), i.e., slightly larger than KFN-K, to allow sufficient space for monitoring equipment to be installed. The well should be installed by a qualified drilling contractor in accordance with all applicable regulations and guidelines, including a sanitary surface seal with a minimum radial thickness of 50 mm (2") to a depth of at least 5 m (15 ft.).

7.3 Anticipated Water Quality for New Wells

For the water treatment system options presented above, the following assumptions are made regarding groundwater quality at new water supply wells:

- KFN-M (a back-up well to be drilled near KFN-F in Option 1) would have similar water quality to KFN-F. This is a defensible assumption as most sub-permafrost wells in this aquifer have similar water quality. So, we anticipate that the water treatment system proposed with Option 1 would also be suitable to treat back-up well water quality.
- KFN-N (a back-up well to be drilled near KFN-K in Option 2b and 3) would have similar water quality to KFN-K. This is based on KFN-N being completed in the same aquifer as KFN-K; so we anticipate that the water treatment system proposed for KFN-K would also be suitable to treat water from KFN-N.

8.0 WATER TREATMENT AND DISTRIBUTION OPTIONS

The following sections include conceptual level discussion for the water treatment options considered and should not be construed as an engineered design. These concepts are presented for further consideration and to form the basis on which to develop the Class D cost estimates. Further assessment and engineering would be required.

8.1 Option 1 – Water System Improvements

Water system improvements for Option 1 would include improvements to the existing WTP to address deficiencies and the operational issues discussed previously as well as to support the increasing demand for low growth scenario. Note that this option should not be considered for the medium and high population growth scenarios as KFN-F and an additional well in the vicinity of KFN-F would not likely meet the demand of these scenarios. Option 1 improvements would include:

- A new well (KFN-M) would be drilled near KFN-F to provide supply redundancy for water source.
- A new delivery truck with a larger capacity would be obtained to reduce the required delivery days. The proposed new truck tank capacity is 15,500 litres (4,100 US gallons), which is more than double the current bulk truck capacity.
- An expanded system to accommodate a larger water delivery truck and operational changes to “smooth out” demand and allow wells to meet supply requirements.
- A treatment step for manganese (Mn) removal would be added as Mn precipitate is causing operational issues plus increasing the colour and turbidity of delivered water. The same system is anticipated to provide either aeration or oxidation to reduce and/or eliminate the sulfurous smell.
- Replacement of all system controls with an upgraded treatment system, including control and monitoring of the system in the site office as well as in the treatment building. These upgrades are needed due operational issues resulting from current design and aging equipment.
- Expansion of the WTP with a concrete slab foundation, and insulation and cladding to match the façade of the existing building.
- Data loggers for water level and flow placed in KFN-F and KFN-M. Flow data from each well would be monitored and recorded so changes in individual well performance could be observed and managed, as needed.
- Installation of a redundant chlorination system and isolation valve, relief valve, level sensor with alarm and static mixer (to address other deficiencies noted by YES, 2012).
- Cleaning and rehabilitation of the online free chlorine analyzer, once the treatment system for manganese removal had been installed.

Figures 2 and 3 provide schematics indicating the proposed infrastructure for Option 1.

8.1.1 Water Storage Improvements

To provide sufficient storage and to improve chlorine contact time to meet disinfection targets, additional storage capacity would be required. The existing building cannot support installation of more storage volume. Several water storage improvement options were considered including use of an AWWA D 103 bolted tank, concrete below ground reservoir, welded tank and a “sea-can” (intermodal metal container) with polyethylene tanks installed. The most economical option identified consists of a 16.2 m long (53 ft.) heated sea-can container with polyethylene tanks installed. The total storage capacity would be 56,500 litres (14,925 US gal).

The added volume would provide a total of 75,500 L (19,950 US gal) storage capacity including the existing storage in the WTP. With proper control, the system would exceed the required contact to achieve the 4-log virus removal requirement. Tanks in series with cascading flow will provide more effective mixing and thus provide more optimal contact time for pathogen reduction.

8.1.2 Loading Bay Extension

A proposed new truck for water delivery would be 9.5 m (31 feet) long, according to Ray Osborne, Circuit Rider. To fit the proposed new truck into the building we have assumed that an extension of about 2 m is required on the north side of the building.

8.1.3 Water Treatment Improvements

Treatment to remove manganese would be installed to meet aesthetic objectives and reduce the variability of the chlorine residual by reducing the chlorine demand. There were two potential treatment systems considered by the project team: aeration/filtration and manganese greensand treatment. Using manganese greensand has the advantage that it is a proven technology with a long history of treating similarly affected groundwater. In discussion with operation staff, operation of a manganese greensand filtration system is well understood by local operators. Hydrogen sulfide is also removed with this process and can be enhanced with a pre-feed of sodium hypochlorite. The pre-feed of chlorine will reduce hydrogen sulfide and thus limit the “sulphur” odour and will increase run length and service life of manganese greensand.

For this option, the system would include a flow paced chlorination system complete with an in-line mixer. This would provide optimal mixing for the chlorine feed and improve the chlorine contact compared with the existing system configuration. This proposed treatment system would also come installed in a sea-can.

All process elements are to include redundancy to allow for proper operation and maintenance.

8.2 Options 2 and 3 – Water Treatment and Distribution

Water treatment and distribution are similar for Options 2 and 3. The water supply from the new wells KFN-K and KFN-L provide significant capacity and are suitable for both present and future community needs including the high growth scenario. KFN-K provides better water quality than KFN-L, while the KFN-L source provides warm water of poorer quality.

8.2.1 Option 2

This option will include the construction of a new WTP in the vicinity of new wells KFN-K and KFN-L. KFN-K is to be the primary supply well and another well (KFN-N) will be drilled to provide a secondary supply for Option 2a, while Option 2b considers that the deep warm water well KFN-L would be used as back-up. This new system would work more efficiently than the existing WTP system as these supply wells have faster recharge rates than KFN-F and therefore the supply would not lag demand.

The systems would be sized to accommodate both the low or moderate growth rate scenario with an ADD up to 34 m³. For purposes of developing a Class D cost estimate, we assumed the following:

- A new WTP building would be required for use of the larger water delivery truck and to accommodate treatment, storage and larger sized bulk delivery truck. We have assumed that the building would be about 186 m² (2000 sq. ft.).
- The well would pump into a 3,800 L (1,000 US gal) raw water feed tank to prevent excessive cycling of the well pump. The treatment system would be fed by a submersible pump in the raw water tank.

- Water treatment would include ferric based media for arsenic removal and a sodium hypochlorite chlorination system.
- Treated water would be stored in polyethylene tanks located in the new building with a similar storage capacity as discussed in Option 1.
- System to include backwash water system connected to a buried tank that will be drained with the KFN operated vacuum truck for disposal at the Burwash sewage lagoon.
- The water supply and treatment system would be fully redundant.

Other ancillary considerations included:

- Driveway and sidewalk.
- Storm water drainage.
- Exterior lighting.
- Security.
- Heating, Ventilation, and Air-Conditioning (HVAC).
- Process drains.
- Space for geexchange equipment.

8.2.2 Option 2a

For consideration of water supply using KFN-K and KFN-N (assumed to be of similar water quality), the treatment would include an arsenic reduction filter unit followed by sodium hypochlorite injection. The treatment proposed would utilize a ferric-based media for the removal of arsenic and other heavy metals (including iron & manganese) from treated wastewater and drinking water supplies.

8.2.3 Option 2b

For Option 2b (utilizes KFN-L as a backup to KFN-K), the treatment step is more complex to account for the higher arsenic concentrations, higher hardness and Total Dissolved Solids (TDS) in KFN-L water. The conceptual treatment would include the following steps in series:

- Hypochlorite injection for the oxidation of dissolved metals.
- Iron reduction in manganese green sand plus media filter unit.
- Arsenic reduction filter unit.
- TDS reduction unit using reverse osmosis (RO).
- Hypochlorite injection.

A blending valve will be included with the design to allow operators to monitor two water sources during winter. During summer, use of deep well is only for redundancy purpose as heat is not required.

Treatment in winter will include a blending system that would retain a fixed minimum temperature. The treatment is conservatively based on a treatment of the KFN-L water. This would thus allow for full redundancy as supply could be from either source.

8.2.4 Option 3

For this option, the water source is similar to Option 2a. The community would use the water from KFN-K and the treatment would include the arsenic reduction filter unit followed by hypochlorite solution injection system for disinfection at an increased flow rate to meet the demand for the high growth scenario. The system would be similar to Option 2a, but sized for a larger flow to accommodate the highest growth rate demand scenario. Additional storage would also be required to provide adequate primary disinfection to meet the increased demand.

8.2.5 Distribution

For Options 2 and 3, water distribution would include both piped and trucked distribution. The trucked distribution would be similar to the current operation, only with a large truck and tank.

Available funding of piped distribution systems from the Government of Canada (AANDC) related to Water and Wastewater is handled under the Level of Services Standards (Corporate Manual System). The related levels of service standard, determined on a national basis, are the levels of service that AANDC is prepared to financially support to assist First Nations. To be considered or qualified for conventional high-pressure piped water and/or sewage systems, lot frontages shall average no more than 30 metres. In cases where the dwelling units density deviates from this standard, alternative water and sewage systems (e.g. small diameter piped systems, low pressure piped water and sewage systems, trucked water and holding tank systems or centrally managed on-site systems) must be considered and conventional high-pressure piped systems only approved where the LCC is lower than with the use of alternate systems or where environment, health and safety needs cannot be met in any other way. As the current and likely future density would not meet this 30 m frontage requirement, in consideration of piped distribution, we have explored the possibility of low pressure piped water systems (to supplement trucked distribution) similar to those low flow systems that have been installed in the communities of White River First Nation and Little Salmon Carmacks First Nation.

The proposed piped distribution system for these options would consist of a low flow, shallow bury piped distribution loop serving the eastern end of main village to serve existing residences plus future residential development as indicated on Figures 4, 5 and 6. This piped distribution system would be for drinking water only and would not provide water for fire protection. Fire protection in Burwash Landing is provided by YG fire hall with a separate dedicated water source and fire truck.

For this option, we assumed that service pumps will draw from the treated water tank(s) and deliver water to the piped distribution system. A dual pumping system is proposed, having one pump maintaining flows and pressures for circulation during most of the day and a second pump which will activate to maintain system pressures and flows during peak demand periods (i.e., morning and evening periods). The pumps will be equipped with variable frequency drive (VFD) control to modulate and meet the system pressure. Continuous circulation will be provided with the dual pumping system connected to the loop. Service

pumps draw from the treated water tank and deliver water to a shallow buried, insulated High Density Polyethylene (HDPE), looped potable water distribution system. Continuous circulation is provided by a dual pumping system connected to each distribution loop. A chlorine analyzer and chlorine pump would be included to ensure adequate chlorine concentrations within the system at all times.

Since ground frost can penetrate to over 4 m at this site, and permafrost is present, a shallow bury (1 to 1.5 m) HDPE system with insulation, monitoring and tempering for freeze protection was considered the most economical option in consideration of the relatively low density of development and the ground conditions. Similar systems have recently been installed; and operating effectively in Beaver Creek and Pelly Crossing. We assumed that this piped distribution would be installed within the “active layer” above permafrost, and under the existing roads where it is presumed that permafrost has receded to at least a few meters in depth. The temperature of the return loop water would be monitored and heat would be added to the supply water line as necessary using a heat pump (and geexchange).

It is proposed to have the water/geoexchange utility mains installed beneath the road. We understand that road upgrades are planned for 2013/2014; and if a piped distribution and/or a district geoexchange option is advanced, it would be ideal to complete this work concurrently with the road upgrades to minimize disruption and improve the logistics and economics of this project. For the purpose of developing the Class D costs for Options 2a, 2b and 3, EBA has assumed that the trenching and piping installations would be done concurrently with the road improvements.

Service connections would likely consist of two pre-insulated water lines (supply and return) within a carrier pipe, and a recirculating pump at the entrance to each building. For the purpose of this study, water service connections have not been included in the estimated costs.

Installation of a piped distribution system would likely result in increased water usage and hence increased wastewater production. Although this was not included in the scope of this study, EBA understands that the existing sewage lagoon has capacity to handle increased flows; however, this should be considered in more depth once a preferred option is selected.

9.0 HEAT TRANSFER OPTIONS, RESOURCE AND DEMANDS

9.1 Heat Transfer Options, Technologies and Characteristics

Four potential means of extracting heat from KFN-L were examined, and have been arranged by simplicity and cost to correspond with the overall project options analysis (Table 7). For closed-loop heat extraction cases, the following soil thermal properties were assumed:

- Thermal conductivity = $2.0 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$.
- Thermal diffusivity = $0.076 \text{ m}^2\cdot\text{day}^{-1}$.
- Average undisturbed Earth temperature from surface to ~400 m depth = 6.6°C .

Table 7. Summary of Geoexchange Cases for Heat Extraction from KFN-L

Case	Description of Technology	Relative Install Cost	Maintenance/ Complexity	Groundwater Disposal Quantity	Estimated Thermal Output
1	<ul style="list-style-type: none"> ▪ See Figure 2. ▪ Heat exchange accomplished with closed-loop, durable plastic pipe heat exchanger placed in well KFN-L. ▪ Heat carrier fluid is an environmentally-safe antifreeze-water solution. ▪ An open-ended “convection promoter” pipe is necessary to keep water passively circulating vertically in the well. 	Low	<ul style="list-style-type: none"> ▪ Relatively low. ▪ Knowledge of circulating pumps and heat pumps. 	None	<ul style="list-style-type: none"> ▪ ~15 kW (~50,000 Btu/hr). ▪ Could provide base load soil heating for a ~900 sq. ft greenhouse.
2a	<ul style="list-style-type: none"> ▪ See Figure 3. ▪ Heat exchanger system same as Case 1. ▪ <u>Additional feature</u>: Well is allowed to flow artesian. This artesian flow moderates the well water with warm groundwater entering at the well bottom. 	Low to Moderate	<ul style="list-style-type: none"> ▪ Relatively low to moderate. ▪ Knowledge of circulating pumps and heat pumps. ▪ Must deal with water disposal. 	~10 USgpm	<ul style="list-style-type: none"> ▪ ~53 kW (~180,000 Btu/hr). ▪ Could provide base load soil heating for a 3,000 sq. ft greenhouse.
2b	<ul style="list-style-type: none"> ▪ See Figure 4. ▪ “Semi-open” loop (standing column well). ▪ The heat transfer fluid is the well water itself, circulated through surface heat exchanger and disposed of back into the top of well KFN-L. ▪ It is necessary to “bleed” some well water out of the system to moderate well water temperature and prevent freezing. ▪ Well water is isolated from heat pump equipment to prevent possible scale, fouling of the heat pump(s). 	Moderate	<ul style="list-style-type: none"> ▪ Moderate. Need “bleed” controls. ▪ Knowledge of circulating pumps; heat pumps. ▪ Periodic heat exchanger maintenance may be required. ▪ Must deal with water disposal from well. 	~10 USgpm	<ul style="list-style-type: none"> ▪ 73 kW (~250,000 Btu/hr). ▪ Could provide base load soil heating for a 3,000 sq. ft greenhouse, <u>plus</u> ▪ 100% peak load for space heating of new WTP + tempering of recirculated drinking water + ~45% peak load of new 4-Plex.
3	<ul style="list-style-type: none"> ▪ See Figure 5. ▪ Open loop. ▪ The heat transfer fluid is groundwater. ▪ All water must be used or disposed. ▪ Well water is isolated from heat pump equipment to prevent possible scale, fouling of the heat pump(s). 	High. Need an injection well.	<ul style="list-style-type: none"> ▪ Relatively moderate to high. Need “bleed” controls. ▪ Knowledge of circulating pumps; heat pumps; district heating controls and management. ▪ Periodic heat exchanger maintenance may be required. ▪ Must deal with water disposal from well. 	Up to 100 USgpm	<ul style="list-style-type: none"> ▪ 410 kW (1.4 million Btu/hr). ▪ Could provide 100% base load soil heating for 3,000 sq. ft greenhouse, <u>plus</u> ▪ 100% peak load of space heating for greenhouse + water treatment building + new 4-Plex + swimming pool + school + additional ~200 kW.

9.2 Heat Resource from KFN-L

The maximum potential heat available from KFN-L is with the fully open-loop case (Case 3 in Table 7), since the heat transfer fluid (groundwater) can be assumed to be available at the bottom-well temperature of $\sim 16^{\circ}\text{C}$. Based on a sustainable well yield of 100 USgpm, and an allowable temperature decrease of 12°C (as heat is extracted from the groundwater flow stream), approximately 315 kW (1.08 million Btu/hr) of gross heat is available from the well. However, since the groundwater will be used in water-source heat pumps, and heat pumps reject more heat to a heating load than they extract from the source, about 420 kW (1.4 million Btu/hr) of net heat is available to buildings equipped with geexchange heat pumps operating at a coefficient of performance (COP) of 4.0.

The case with the least amount of available heat is the fully closed-loop case (Case 1 in the Table 7). Here, the heat transfer rates are dictated by the thermal properties of the soil. Even though the bottom well temperature is $\sim 16^{\circ}\text{C}$, heat extraction occurs over the entire well bore length, and therefore, the underground temperature averaged along the length of KFN-L in this case is lower (estimated here to be 6.6°C). This lower average Earth temperature limits heat extraction rates because it would not be desirable to allow the well water to freeze; freezing of the well water would inhibit vertical convection of the warmer water from below, and could potentially damage the well casing and heat exchange pipe.

9.3 Heat Demand

The heating demands of several buildings were considered for this project per client input, and are summarized in Table 8 below. Assumptions made for the heating load estimates are as follows:

- Outdoor heating design temperature: -42°C .
- For future construction, such as that of the community school and 4-plex, we assumed insulation levels of R-60 for walls and R-100 for roofing, triple-pane windows, and air infiltration rates of 1.0 air-change per hour (ACH).
- The water treatment plant heating load estimates include typical envelope losses plus heating loads due to storage of cold water in the building. The heating load for tempering of re-circulated drinking water is in addition to the space loads of the plant building, and are based on observations and experiences at nearby Beaver Creek. Assumptions for tempering of re-circulated drinking water include a recirculation flow rate of 0.6 L/s and a maximum heat loss through the insulated pipe of 1.1°C .
- Greenhouse: double-walled rigid plastic construction R-2, air infiltration rates of 0.25 ACH. Here, the geexchange heating load was taken as half of the total peak (base-load soil heating) with fossil fuel peaking.
- Prioritized heating loads are as follows (in order): greenhouse, well pump house, water treatment building and storage tank plus tempering of re-circulated drinking water, 4-plex, school, and community pool. A review of Table 7 (above) shows that the only scenario capable of meeting all of these loads is Case 3. Case 2b could meet the prioritized loads up to 45% of the 4-plex (in other words, Case 2b could not meet 55% of the 4-plex peak load, nor any intended heating needs of the school, nor

the community pool). Case 1 could meet the heating demands of a small greenhouse, while Case 2a could meet the intended loads of a 3,000 sq. ft. greenhouse.

- Heating Degree Days: 8,000°C·day⁻¹.

Table 8: Estimated Heating Demands

Building	Heat Load per Floor Area W/m ² (Btu/hr/ft ²)	Floor Area m ² (sq. ft.)	Comments
Future Greenhouse – Base Load	190 (60)	140 up to 280 (1,500 up to 3,000)	This load is an assumed geotexchange base load at 50% peak. Geotexchange would heat root zone, and a separate peaking system would be needed to heat air space.
Future Greenhouse – Full Load	280 (120)	280 (3000)	Geotexchange would heat root zone, and air space. A redundant back-up system would likely still be required.
Future Community Pool	410 (130)	56 (600)	--
Future School	63 (20)	929 (10,000)	Estimated based on 5 classrooms.
Future 4-Plex Residential	38 (12)	353 (3,800)	--
Future Water Treatment Plant	63 (20)	186 (2,000)	Heating load includes tempering of water in indoor storage tanks.
Tempering of re-circulated drinking water			Approximately 10,000 Btu/hr (~3 kW).

10.0 GROUNDWATER QUALITY AND GEOEXCHANGE

Groundwater quality is a critical factor in assessing the suitability of open loop groundwater geotexchange systems. In general, groundwater quality is often overlooked or given scant assessment, but issues related to water quality (e.g., mineral precipitation or scale, biofilm formation, or corrosion of metal components and pipes) constitute a dominant reason that well systems or heat exchangers foul and underperform (or fail) (GeoExchange BC, 2007).

It is important to recognize from a process point of view (i.e., when pumping, treating, exchanging heat, distributing or discharging) that groundwater has dissolved and suspended inorganic components, dissolved gases, and bacteriological organisms which will likely change their concentration or abundance when that water is manipulated. When groundwater experiences a change in pressure or temperature or when groundwater is mixed with another quality of groundwater (or surface water), a wide range of complex and interrelated physical, hydrochemical and bacteriological changes can occur. For this study, issues related to groundwater quality and geochemistry must be considered in Options 2 and 3. Examples of such geochemistry changes would be:

- When KFN-L groundwater flows or is pumped from deep, warm, high-pressure conditions to cool/cold atmospheric pressure at surface leading to drop in groundwater pressure and temperature.
- If deep KFN-L groundwater were mixed with shallow KFN-K groundwater in an injection well, or with surface water during surface disposal to Pothole Lake.

With a suitable range of physical, inorganic, bacteriological and thermal water quality measurements, it is possible to predict in a general way how waters will likely behave under changing pressure and

temperature, and when two water types are mixed. This evaluation, termed hydrochemical modelling, can be approached using computer software as well as physical bench-scale mixing tests. Hydrochemical modelling is a specialized assessment and beyond the scope of this guidance document, but is an essential part of prefeasibility and design engineering studies for a municipal scale groundwater-based geoexchange system.

The types of evaluation typically required to evaluate water quality and support hydrochemical modelling are (GeoExchange BC, 2007):

- A temperature profile from surface to bottom of the geoexchange supply well (KFN-L).
- Additional groundwater chemistry including field measured parameters (pH, dissolved oxygen, electrical conductivity), inorganic parameters (total dissolved solids, total suspended solids, hardness, alkalinity, major anions (chloride, bicarbonate, carbonate, sulphate, sulphide, nitrite, nitrate), major cations (calcium, magnesium, sodium, potassium), dissolved metals (including iron, manganese), Total Organic Carbon (TOC), and stability parameters (Langelier Index (at the maximum operating temperature expected for groundwater) and redox potential). If the groundwater is also to be used for drinking water then potability parameters should be included.
- Groundwater microbiology analysis including: plate count (colonies/mL); iron-oxidizing, sulphate-reducing, and nitrate-reducing bacteria; total and fecal coliform; bacterial count (cells/mL) by adenosine triphosphate (ATP) determination; anaerobic growth (as percent of total bacterial count); and visual microscopic assessment of bacterial activity, inorganic crystal formation, presence of iron oxide, and presence of sheathed and stalked bacteria, and protozoans. This level of microbiological analysis is based on the importance of microbiology in well performance and rehabilitation (Schnieders, 2003).

Hydrochemical mixing/modelling is recommended for Options 2 and 3. The results of hydrochemical mixing tests will indicate what physical, inorganic, bacteriological and thermal characteristics the resulting water will display, and hence the difficulty and complexity in treating, manipulating and disposing of the resulting water. These results will guide water treatment design, both for potability and for process handling (heat exchange and water disposal), as well as costs for treatment systems and consumable treatment chemicals, and the operator skill level required for operation, monitoring and maintenance.

Without hydrochemical modelling results, it is not possible to predict precisely how KFN-L water will behave during heat exchange at surface, or mixing during disposal into shallow aquifer groundwater or surface water. However, we can make some general comments that will help KFN decision-making at this stage of work:

- Mixing KFN-L water (warm with high ionic concentration) at high flow rates with cooler shallow groundwater with lower ionic concentrations (i.e., at an injection well completed into the shallow aquifer) will lead to the greatest degree of hydrochemical and bacteriological reactions, requiring the relatively highest level of water treatment to maintain disposal operation (or to remain within disposal permit guidelines), and the highest level of operator skill and system monitoring/management.

- Handling KFN-L water at the surface (for heat exchange) then re-admitting the spent water back to KFN-L (or to an injection well discharging back into the deep warm aquifer) will likely lead to a lesser degree of hydrochemical and bacteriological reactions (since the only variables would be pressure and temperature changes), possibly requiring a lesser degree of treatment, system complexity and operator skill and management.
- Exchanging heat within KFN-L, with only low flow bleed water from KFN-L, will likely be simpler to manage for treatment complexity and expense than above, due to lower flow rates and the potential to treat and blend KFN-L water with potable water.
- Disposal of spent KFN-L water to surface water (e.g., Pothole Lake) would be the simplest scenario, avoiding problems of fouling in an injection well or at the disposal point within KFN-L, and related operational complexity. Treatment requirements will only be those required to avoid corrosion or fouling of discharge piping and fittings, and to adhere to water discharge permit requirements.

11.0 OPTIONS ANALYSIS

11.1 Principal Constraining Factors

Water disposal (considering arsenic concentrations and other chemistry considerations), regulatory approval requirements and permafrost conditions are the principal non-cost related constraining factors that should be taken into consideration for the options analysis. The options assessed here differ significantly with respect to water disposal needs of the geexchange system, associated potential environmental effects, and regulatory approval requirements. These principal constraining factors are further described in the following sections.

11.1.1 Water Disposal

Using water from KFN-L for heat extraction under Options 2a, 2b or 3 would require water disposal after the heat was extracted. Depending on the configuration for Option 2, some or all of the disposal volume might be integrated into the potable water or greenhouse water systems.

The following disposal options were considered as part of this study:

- Discharge to surface water.
- Injection into shallow cold aquifer.
- Injection into deep warm aquifer.

11.1.1.1 Summary of Disposal Requirements

Table 9 summarizes the disposal requirements for the three different options.

Table 9: Disposal Requirements

Option 1	Sealed closed-loop system; no water disposal required
Option 2a, 2b	Disposal of up to 0.63 L/s (10 USgpm)
Option 3	Disposal of up to 6.3 L/s (100 USgpm)

Option 1 would use a closed-loop geexchange system without any need for water disposal. The disposal requirements for Option 2b would be minimized by the use of KFN-L as a backup/redundancy well for KFN-K (i.e., all or most of the water produced from KFN-L would be incorporated into drinking water, reducing or eliminating the requirement for separate water disposal). However, during times when less drinking water is needed than is produced from KFN-L for geexchange purpose, water disposal of up to 10 USgpm would be required. The water would be treated to meet drinking water quality before disposal.

Option 3 includes the requirement for disposal of up to 100 USgpm. Because the potable water system and the geexchange system would be separate for Option 3, water from KFN-L would not pass through the water treatment system (i.e., the water quality of the discharge water after heat extraction would be similar as the raw water quality from KFN-L). Note, depending on the outcome of future hydrochemical modelling (as part of engineering design), discharge water from KFN-L after heat extraction may need treatment to inhibit fouling in the deep injection well.

Table 4 (attached) shows the raw water quality from KFN-L and a comparison with water quality guidelines for drinking water and the protection of aquatic life.

11.1.1.2 Surface Disposal

Direct disposal to surface water should only be considered for the relatively small discharge rates in Option 2a or 2b. Possible surface water disposal locations include Pothole Lake to the north of the location of KFN-L or Kluane Lake. Disposal to shallow ground (i.e. rock pit or disposal field) was not considered because of the presence of extensive permafrost in the area.

There is currently limited data on Pothole Lake to assess its suitability for disposal of water from KFN-L. Additional information required to further assess this disposal option includes:

- Volume capacity of Pothole Lake.
- Seasonal changes of the lake level and associated changes in acceptance capacity.
- Depth of freezing in the winter.
- Baseline water quality.
- Fish habitat assessment.

The direct disposal into Kluane Lake is less desirable due to potential fish habitat effects. However, depending on the suitability of Pothole Lake, the option of direct disposal into Kluane Lake should also be further assessed if disposal to surface water is considered.

The water quality of the discharge is a key factor in the permitting of the water disposal, especially if the water is to be discharged into a surface water body with potential adverse effects on fish and fish habitat.

Water quality objectives are often based on Canadian Council of Ministers of Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life. However, baseline water quality should be taken into account when developing site specific water quality objectives and effluent quality criteria. There are no baseline water quality data currently available for Pothole Lake.

Table 4 shows that the water sample collected from KFN-L on August 23, 2012 exceeded the CCME guidelines for arsenic, copper, and zinc. Depending on the baseline water quality of the receiving surface water body, site specific water quality objectives, and effluent quality criteria, additional treatment beyond that required for drinking water may be necessary to discharge excess water from the geexchange system into a surface water body.

11.1.1.3 Shallow Well Disposal

Injection of the used water from KFN-L into a shallow aquifer (e.g., the aquifer in which KFN-K is completed) would be the most cost efficient subsurface disposal option. Disposal to a new shallow injection well (referred to here as KFN-O; Figures 4 and 5) should be considered as part of Option 2. A maximum waste water rate of about 0.63 L/s (10 USgpm) would need to be injected.

Water disposal to the shallow aquifer would require the drilling of a new shallow injection well which could be completed within the same aquifer as KFN-K. The waste water would be pumped into the injection well causing a rise in local static groundwater elevation (i.e., groundwater mounding would occur near the injection well).

The injection well should be located cross- or down-gradient from KFN-K to minimize well interference and to protect the water quality of KFN-K. To meet these objectives, the injection well should be placed outside of the capture zone of KFN-K. Well siting and capture zone analysis would be part of engineering feasibility studies.

A disadvantage of subsurface disposal into a different aquifer than the supply aquifer is the risk of depleting (depressurizing or dewatering) the deep warm water aquifer over time. For the wells in Burwash Landing, given the relatively high sustainable yield from KFN-L (6.3 L/s or 100 USgpm) compared with the much lower artesian flow or bleed pumping rate for disposal (0.63 L/s or 10 USgpm), we do not expect a significant loss in KFN-L well yield. However, a long-term decrease in well yield or artesian pressure cannot be entirely excluded based on currently available data.

Finally, for good practice, an alternative disposal option needs to be available for situations when the injection well is off-line (e.g., pump failure or injection well maintenance or rehabilitation). Temporary disposal to surface water (most likely Pothole Lake) should be considered as a practical backup option.

11.1.1.4 Deep Well Disposal

Disposal of the “waste” water from the geexchange system into the deep warm water aquifer is the only disposal method we considered for Option 3. This is to promote long-term sustainable water balance in the deep aquifer (all water taken out is replaced into the aquifer), and to avoid the complex geochemical/biological reactions and fouling we anticipate if large flows from KFN-L were injected into the shallow cold water aquifer.

A deep injection well would be completed in a similar fashion as KFN-L, with slightly more open well screen area to readily accept injected water. Injection well siting, well design and separation from the supply well would be part of engineering feasibility and design studies. Refer to Figure 6, KFN-P.

Finally as with a shallow injection well, for good practice, an alternative disposal option needs to be available for situations when the deep injection well is off-line (e.g., pump failure or injection well maintenance or rehabilitation). Temporary disposal to surface water (most likely Pothole Lake) should be considered as a practical backup option.

11.1.2 Regulatory Permits and Approvals Process

The following sections describe the regulatory approval and environmental and socioeconomic effects assessment requirements of the different options assessed. These requirements differ significantly depending on the water supply and geoexchange option.

11.1.2.1 Permitting Background

Yukon Environment and Socio-economic Assessment Act

In accordance with the *Yukon Environmental and Socio-economic Assessment Act* (YESAA), in December 2010 a Project Proposal was submitted to the Yukon Environmental and Socio-economic Board (YESAB) by EBA on behalf of Yukon Government, Community Services for the purposes of the geothermal/water supply exploratory drilling for KFN-K and KFN-L. The assessment triggers for the YESAB application were (and will be for any new drilling and infrastructure construction activities):

- Project located in Yukon.
- Involves project and accessory activities listed in the Assessable Activities, Exceptions and Executive Committee Project Regulations, including:
 - Part 9, Item 1 (drilling a well for the extraction of groundwater).
 - Part 13, Item 2 (use of a vehicle off a road or train maintained by a First Nation).
 - Part 13, Item 12 (clearing land or moving earth using a self-propelled machine).
- Project requires or may require an authorization / land use permit from the Kluane First Nation.
- Funding for the project is from the federal government.

Following submission of the Project Proposal, an Information Request was issued on January 5, 2011 by YESAB, and a response was submitted by EBA on January 10. The proposal was deemed adequate on January 17 with the Decision Document issued on April 7, 2011 by the sole Decision Body Kluane First Nation in accordance with the requirements of YESAA Section 75.

One would expect a similar process and timeframe (three to six months) from YESAB with any new drilling activity related to any of the options described here, construction of new above ground infrastructure, and depositing a waste from the geoexchange and/or water treatment systems. The process length will depend on the Information Requests and timely responses to them.

Yukon Waters Act – Yukon Water Board

Under the *Yukon Waters Act*, the need for water licenses is triggered by direct water use or water waste. The type of permit required and subsequently the rigour and timeframe of the approvals process is related to the volume of direct water use (per day) and the population served with respect to the deposit of a waste. Groundwater re-injected to another location from where it was extracted can possibly be considered a waste, and in the experience of EBA, if the chemistry is altered through treatment (such as chlorine addition) prior to ground disposal, it would be considered the deposit of a waste. Furthermore, discharges from water treatment operations can be considered the deposit of a waste.

For the low population growth scenario, there is direct use of water with an ADD up to 16 m³/day and waste disposal from the water treatment process would discharge to a rock pit (if permissible) or to the existing sewage eduction tank with ultimate disposal to the Burwash Sewage lagoon (which is already permitted). According to the *Yukon Waters Act*, Schedule 8, this 16 m³/day water demand falls under the water use trigger of less than 100 m³ per day and therefore direct use of water does not trigger a water license requirement. At this time, we do not believe that a water license is required for the low growth scenario.

For the moderate growth scenario, based on the predictions of moderate population growth for the Burwash area, the ADD is 34 m³. According to the *Yukon Waters Act*, Schedule 8, this demand also falls under the water use trigger of less than 100 m³ per day and therefore direct use of water does not trigger a water license requirement. However, depositing waste by means of sewage collection or treatment system serving a population of between 50 and 250 requires a Type B Water Licence; and more than 250 requires a Type A license. EBA has experience with the First Nation of Nacho Nyak Dun (NND), whereby under a Type B Water Licence, the Licensee is allowed to discharge chlorinated water from a geoexchange system into an injection well, and in the event this well is out of commission, the Licensee is allowed to discharge wastewater to surface in a vegetated area for up to five days. NND is further authorized to discharge [treated] wastewater to ground via sewage disposal and discharge backwash wastewater from the water treatment system into a rock pit.

The timeframe for a Type B Water Licence is typically three to five months (following a YESAB Decision Document). This is predicated on the applicant submitting the detailed water licence application to the Water Board Secretariat prior to a YESAA Decision Document for an unofficial review and ability to respond in a timely fashion. This early submission would further facilitate the discussion to determine if this application would be processed as a Type A or B licence application. The water licence cannot be officially registered until the Decision Document is released from YESAB, then the regular course of process occurs.

For the high growth scenario, the expected ADD would be 266 m³, which would exceed 100 m³/day, and a Type A water license would certainly be required. The timeframe for a Type A water license is typically five to eight months depending on information requests and the outcome of the public hearing.

11.1.2.2 Regulatory Permits and Approvals by Option

Option 1

For Option 1, a new well is proposed (referred to in this document as KFN-M) along with improvements to the existing WTP and a closed-loop geoexchange system for the greenhouse. Regulatory and permitting requirements include:

- A screening under the *Yukon Environmental and Socio-economic Act* (YESAA) for the activities related to a new well construction (KFN-M) and building addition (if necessary).
- An approval to modify (Section 20 under the Public Health and Safety Act Drinking Water Regulation O.I.C 2007/139) related to the WTP upgrades as this system falls under the definition as a large public drinking water system.
- The closed-loop option requires no water disposal, and no further permitting commitments.
- A water license would not be required.

Option 2a

For Option 2a, a new well (KFN-N) is proposed to backup KFN-K along with the construction of a new WTP, piped and trucked distribution is planned and geoexchange water disposal is required. This option would require a minimum of the following permits and authorizations:

- Assessment under YESAA for well drilling, construction of WTP, distribution and disposal.
- Permit requirements from YG: development and building permits, plumbing and electrical permits.
- Permit requirements from YG-EHS: Approval to Construct and Permit to Operate a Large Public Drinking Water System (LPDWS).
- Type B (or possibly Type A) water licence for water disposal may be required depending on disposal option and system design.

Surface water disposal would likely require additional baseline data collection and fisheries assessments.

Option 2b

For Option 2b, KFN-K is backed up by KFN-L and therefore there will be no new drilling. All other permits and authorizations summarized above for Option 2a would be required, however, the YESAA screening would include the well drilling and testing related activities. A summary of required permits and authorizations is below:

- Assessment under YESAA for construction of WTP, distribution and disposal.
- Permit requirements from YG: development and building permits, plumbing and electrical permits.
- Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS).
- Type B (or possibly Type A) water licence for water disposal may be required depending on disposal option and system design.

Surface water disposal would likely require additional baseline data collection and fisheries assessments.

Option 3

For Option 3 the regulatory regime is the same as in Option 2, with the added complexity of an open-loop geoexchange system. The larger discharge volume of water, which may or may not require some treatment (such as sodium hypochlorite), would be considered the deposit of a waste. A Type A water license would certainly be required. The anticipated permitting requirements for Option 3 are:

- Assessment under YESAA for well drilling, construction of WTP, distribution and disposal.
- Permit requirements from YG: development and building permits, plumbing and electrical permits.
- Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS).
- Type A Water Licence.

11.2 Permafrost

As mentioned previously, there is warm permafrost found throughout the community of Burwash Landing. The existence of the warm, sensitive permafrost and potential permafrost degradation due to climate change or disturbance during construction and operation of the water supply and geoexchange system do present technical challenges and considerations to this project. There have been numerous papers written discussing the problems with maintaining water and sewer line systems in northern communities and the consensus seems to be that additional research is required. However, the cost of additional research may not yield significant financial benefits in this case since the proposed areas for development have been cleared for some time, and even with additional ground temperature data, there are other potential causes that could accelerate permafrost degradation in localized areas (such as future water line leaks).

Installing an insulated, piped distribution system within the active zone under the roadway or in other areas previously cleared (such as the fire break and existing roads) will minimize the risks associated with degradation of the permafrost. Risks could also potentially be further mitigated in areas of ice-rich permafrost (if any identified) by installing insulation of the base and sidewalls of the trench to minimize the potential for accelerated permafrost degradation due to the placement of warm backfill; and, by completing the work in the fall so that the trench sidewalls would not “melt out” and the backfill temperatures would be lowered to more appropriate temperatures.

Engineers and scientists are now generally of the opinion that the degradation of permafrost, especially in the discontinuous permafrost portion of northern regions, is inevitable. The challenge for the design team working on this project will be to specify types and schedules of pipe that can withstand full overburden pressures in areas where lateral support may be lost due to permafrost thaw and settlement. Insulation will not only help mitigate the potential for heat loss into the underlying soils but will also add to the rigidity of the pipe as well.

Risks associated with settling and permafrost degradation can also be minimized by situating heating demands close to the energy source (KFN-L). For example, if the proposed four-plex, school, pool etc., could be developed in the area of the warm water resource this would minimize the length of distribution piping and hence the risk (in addition to the cost) associated with installing buried utilities in a permafrost region.

Some innovative approaches such as placing the utility lines in half shell culvert pipe to increase rigidity have been used in other communities but EBA feels that a cost benefit analysis should be completed for any unconventional solution proposed.

Further geotechnical drilling and permafrost investigations along any proposed distribution alignment are recommended prior to detailed design.

11.3 Choice of Evaluation Factors

The following non-cost-related evaluation factors were included in the options analysis:

- **Technical / System Complexity:**
 - Technical complexity of the water treatment and geoexchange systems.
 - Amount and complexity of new infrastructure required.
- **Regulatory:**
 - Regulatory approval requirements (permits required for construction and operation of the system).
 - Requirements for assessment of the project under YESAA.
 - Requirements for a Water Licence to operate the system.
- **Operator Skill Requirements:**
 - Operator skill requirements based on the assumed Environmental Operators Certification Program EOCP classification of the water system.
 - Operator skill requirements based on the complexity of the geoexchange system.
- **Sustainability:**
 - Sustainability of the water supply and geoexchange system based on water demand and water disposal method.
- **Timeframe:**
 - Timeframe to realize option including design, regulatory approval, tendering, construction, and decommissioning of the system.
 - Note: timeframes stated here are aggressive and assume that funding is readily available and there will be no hold-ups in the regulatory approval process.
- **Environmental:**
 - Environmental considerations including hydrocarbon offset, extent of exploitation of the deep aquifer for geoexchange purpose, and potential adverse environmental effects from water disposal.

Factors and aspects not included in this assessment were:

- System operation and maintenance (O&M) effort/costs or system life-cycle costs;

- Human resources/training issues.
- Ownership/legal liability issues.
- System decommissioning/abandonment effort or costs.

These considerations were beyond the scope of the current study; however, should be considered once YG and KFN select preferred options.

11.4 Evaluation of Options

11.4.1 Comparison of Non-Cost Factors

Table 10 presents details and comparison of the non-cost evaluation factors considered in this study. Key points relating to the evaluation factors are presented, including relative merits and any significant constraints as well as a range of complexity for the particular factor being evaluated.

11.4.2 Comparison of Costs

EBA developed Class D (+/- 40 %) capital cost estimates for the integrated water supply/treatment/distribution and geexchange options discussed in this report. Detailed cost sheets for each option are provided in Appendix C. In general, we developed the Class D costs based on the following:

- Drilling and testing costs are based on recent quotes and actual costs for recent drilling and testing programs in Yukon.
- Water treatment costs are based on proposals we solicited for the water treatment systems proposed from water system design and supply companies - BI Purewater and AdEdge.
- Site development, building construction, distribution costs are based on recent estimates or actual costs on recent northern projects.
- Geexchange costs are based on recent U.S. cost surveys (Kavanaugh et al. (2012) and Battocletti and Glassley (2012)) and includes heat pumps and plus all associated mechanical equipment and installation costs.
- Additional assessment costs are based on EBA's experience with similar projects.

Table 11 provides a summary of the total estimated capital costs for each option, subdivided into costs for water supply, treatment and distribution, geexchange (including water disposal), and additional investigations and consulting services.

Table 11: Class D Cost Estimate Summary for Different Options

	Option 1	Option 2a	Option 2b	Option 3
Water Supply, Treatment and Distribution	\$720,000	\$ 1,640,000	\$1,560,000	\$ 1,670,000
Geexchange (including Water Disposal)	\$ 90,000	\$460,000	\$770,000	\$ 3,160,000
Additional Investigations and Consulting Services*	\$ 60,000	\$ 210,000	\$210,000	\$ 220,000
Total	\$870,000	\$ 2,310,000	\$ 2,540,000	\$ 5,050,000

* described below; required prior to detailed design.

The water and geoexchange cost items include 20% contingency and 20% engineering costs as a percentage of capital costs. The additional investigations include 20% contingency, with no additional fees, as these items include engineering consulting fees. As noted in Table 11, the capital costs rise from Option 1 to Option 3, with increasing levels of complexity. Note that for Options 2a and 2b two options for water disposal were evaluated: 1) shallow injection well and 2) surface water injection to Pothole Lake. To be conservative, only the cost of a shallow injection well (higher cost) was included for these options. Option 2a and 2b costs would be about \$100,000 lower if the injection well is not required.

The proposed new truck was not included in this estimate as we understand that this would be funded through the AANDC FN Water Management Strategy. Should KFN wish to purchase an additional water distribution truck with greater capacity, approximately \$250,000 can be added to all options (assuming a 12,100 L capacity tandem truck).

Additional Investigations and Consulting Services

In order to proceed with detailed design for any of the options, EBA recommends additional investigations and consulting services including:

- Topographic survey.
- Designated office level assessment under YESAA.
- Water License application.
- Permafrost investigation drilling.
- Well thawing and hydrogeological well testing to confirm higher yields possible from KFN-L.

11.4.3 Comparison of Option 2 a and 2b Treatment Costs

As comparison of the two water supply and treatment options presented for Option 2, we estimate that the cost premium for Option 2b to account for the increased arsenic removal and hardness is about a 25% increase in capital cost. Although operating costs are not within the scope of this study, it should be noted that the operating cost would be in the order of 100% higher for Option 2b relative to Option 2a to cover the costs of the increased wastewater and the additional energy consumption of the RO feed due to the higher head required.

Simple Payback for Geoexchange Systems

In terms of geoexchange economics, Table 12 shows metrics for comparing geoexchange options on an economic basis: (i) capital cost per installed heating capacity (\$/kW) and (ii) the simple payback (in years) on energy savings. Simple payback period represents the length of time that it takes for a proposed project to recoup its own initial cost out of the income or savings it generates. The basic premise of the simple payback method is that the more quickly the cost of an investment can be recovered, the more desirable is the investment. The simple payback method, however, does not give insight into the rate of return of a project or profitability of an investment. Rate of return involves life-cycle economics and is beyond the scope of this project.

Table 12: Simple Payback (years) on Energy Savings of the Various Geexchange Cases Examined

	Case 1	Case 2a	Case 2b	Case 3
Installed heating capacity (kW)	15	53	73	410
Estimated capital cost	\$ 90,000	\$ 460,000	\$ 770,000	\$ 3,160,000
Normalized cost per kW of installed heating capacity	\$ 6,000	\$ 8,679	\$ 10,548	\$ 7,707
Avoided annual diesel heating fuel cost*	\$ 5,198	\$ 18,366	\$ 25,297	\$ 142,079
Incurred electricity cost**	\$ 998	\$ 3,526	\$ 4,857	\$ 27,279
Annual energy savings	\$ 4,200	\$ 14,840	\$ 20,440	\$ 114,800
Simple payback period on energy savings (yr)	21.4	31.0	37.7	27.5

The shortest simple payback is for Option 1 (21.4 yrs) and the longest is for Option 2b (37.7 yrs). Note that the payback (27.5 yrs) for Case 3 assumes that the system would be built to full capacity with 410 kW output. This would require additional district heating demands (residential, commercial) around the proposed geexchange loop. If Case 3 were constructed to provide heat to just the greenhouse, WTP, 4-plex, school and pool the payback would be approximately doubled; this is typical of district system economics, where heating loads need to be large enough to offset the capital intensive installation.

12.0 POTENTIAL FUNDING SOURCES

YG currently has money set aside for this project that was provided through the Build Canada Fund. Our understanding is that approximately **\$ 825,000** is remaining for this project, to be spent by March 31, 2014. This YG Build Canada funding alone would be insufficient for all but Option 1. Should Options 2a, 2b or 3 (or similar) be desired, additional funding by KFN, YG or another funding source would be required. As part of our scope, EBA researched potential funding opportunities for this project. Table 13 provides a listing of various organizations, programs and grants that are applicable to First Nation water projects, infrastructure, community improvements, alternative energy and agriculture. Some of these funding opportunities are pertinent to one or more of the project components. This list should not be considered comprehensive and will require follow-up with the KFN Chief and Council and senior staff once the desired option(s) are selected. Partnerships (the ability to demonstrate multiple funding sources) may be a factor in securing additional funding.

Table 13: Summary of Funding Opportunities

Organization	Program / Fund	Contact	Notes
AANDC	First Nation Water and Wastewater Action Plan. http://www.aadnc-aandc.gc.ca/eng/1100100034879/1100100034883	Kevin Rumsey 867-667-3809 Kevin.rumsey@aadnc-aandc.gc.ca	Personal communications reveal that an application for a new backup well and a detailed geoexchange feasibility study would be positively received.
Natural Resources Canada	ecoENERGY Innovation Initiative. http://actionplan.gc.ca/en/initiative/ecoenergy-innovation-initiative	info@actionplan.gc.ca	Funding areas: energy efficiency, clean electricity and renewables, bioenergy, electrification of transportation and unconventional oil and gas. Two streams of funding: one for research and development and one for demonstration projects.
NRC	Communities Equilibrium Initiative. http://canmetenergy.nrcan.gc.ca/buildings-communities/communities/1603		Initiative provides financial, technical and promotional assistance to sustainable community projects.
AANDC	ecoENERGY for Aboriginal and Northern Communities Program 2011 – 2016. http://www.aadnc-aandc.gc.ca/eng/1100100034258/1100100034259		Funding support (up to \$250k) for the planning stages of renewable energy projects (Stream A) and for the design and implementation of renewable energy projects integrated with community buildings (Stream B) up to \$100k.
Yukon College	Cold Climate Innovation. Yukon Research Centre.	Stephen Mooney 867-456-8670 smooney@yukoncollege.yk.ca Clint Sawicki 867-668-8772 csawicki@yukoncollege.yk.ca	Funding areas: research and development particularly cold hardy preparation; demonstrating new technologies; funding levels vary \$50-100k, with partnerships favoured. Access to research and development funding and partnership support. Personal communications with Clint Sawicki, Director of Research Centre, is positive and future discussions are welcome.

Table 13: Summary of Funding Opportunities

Organization	Program / Fund	Contact	Notes
CanNor	Community Infrastructure Improvement Fund. http://www.north.gc.ca/pr/ciif2-eng.asp	Andrew Gaule 867-667-3339 Andrew.Gaule@cannor.gc.ca Ytinfo@cannor.gc.ca	Fund is geared toward improvements to community infrastructure. Projects must have at least 50% funding from other sources. Eligible categories: community centres ; cultural centres; parks, recreational trails such as fitness trails, bike paths and other types of trails; libraries; recreational facilities including local arenas, gymnasias, swimming pools , sports fields, tennis, basketball, volleyball or other sport-specific courts, golf courses, ski hills or other types of recreational facilities; tourism facilities having a local impact; docks ; and other existing community infrastructure assets that have a local community impact, such as local roads, drinking water treatment and distribution systems, connectivity and broadband, local airports, solid waste management and wastewater infrastructure .
CanNor	Aboriginal Business Development Program http://www.north.gc.ca/pr/abdp-eng.asp	Same as above	Intended to support Aboriginal entrepreneurs for a range of activities including business planning, start-up and marketing. <i>This could be applied to the water supply business to Wellgreen Mine and greenhouse business planning.</i>
CanNor	Community Economic Development Program http://www.north.gc.ca/pr/cedp-eng.asp	Same as above	Program supports community economic development planning and capacity development initiatives, development of proposals, leveraging financial resources, and carrying out economic development activities. <i>This could be applied to the water supply business to Wellgreen Mine and greenhouse business planning.</i>
CanNor	Community Economic Opportunities Program http://www.north.gc.ca/pr/ceop-eng.asp	Same as above	Program includes feasibility studies on how communities might take advantage of the spin-off benefits from nearby economic development opportunities (<i>Wellgreen</i>).
Environment Canada	EcoAction Community Funding Program http://www.ec.gc.ca/ecoaction/	ecoaction.pyr@ec.gc.ca	Funding is available for projects that address one of the following: clean air, clean water, climate change and nature.
Canada	Clean Energy Portal http://www.cleanenergy.gc.ca/index.cfm?action=orgs_type.summary&etid=5		Organizations are listed on this portal that fund innovation and development of technologies.

Table 13: Summary of Funding Opportunities

Organization	Program / Fund	Contact	Notes
Canada	Green Infrastructure Fund http://www.infrastructure.gc.ca/prog/gif-fiv-eng.html	info@inf.gc.ca	This fund supports projects that promote cleaner air, reduced greenhouse gas emissions and cleaner water. This includes new or rehabilitation infrastructure projects that fall into the following categories: wastewater, infrastructure, green energy generation and transmission, solid waste and carbon transmission and storage.
Agriculture Canada	Agricultural Flexibility Fund http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1277926779921&lang=eng		Initiatives may be one-time investments for a specific purpose, or multi-year.
Yukon Agriculture / Agriculture Canada	Growing Forward 2 http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1294780620963&lang=eng AgriInnovation: http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1354832113390&lang=eng	Tony Hill, Director tony.hill@gov.yk.ca 867-667-5838	This fund replaces the original Growing Forward program that ends on March 31, 2013. Funding programs for 2 will be in place by April 1, 2013.
Yukon Economic Development	Community Development Fund Business and Industry Development	cdf@gov.yk.ca Tamara Annau tamara.annau@gov.yk.ca	CDF gives Yukon community, industry and professional associations; non-profit and charitable organizations; and municipal and First Nations governments money for projects and events that: <ul style="list-style-type: none"> •Support community well-being. •Create jobs. •Generate spending on Yukon goods and services. •Have measurable social, cultural and economic benefits for Yukon residents and communities. Personal communications with Ms. Annau indicate that future conversations would be beneficial including joint meetings with CDF staff.
Agriculture Canada	Greenhouse and Processing Crops Research Centre http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1180624240102	Ranjana Sharma 519-738-1208 ranjana.sharma@agr.gc.ca	Mission is to develop and transfer new technologies for the production and protection of greenhouse vegetables and ornamentals. The centre leads research in several areas including greenhouse systems and environmentally sustainable agro-ecosystems for full-season crops.

Table 13: Summary of Funding Opportunities

Organization	Program / Fund	Contact	Notes
Walter & Duncan Gordon Foundation	Water / North http://gordonfoundation.ca/	Rana Shamoan rana@gordonfn.org	Foundation supports protection of water and empowering the North. Personal communications with Ms. Shamoan: basic project described (location / intent) and the foundation may be interested in learning more. Expect communications week of March 25, 2013.
W. Garfield Weston Foundation	Science in Canada's North	Susan Cohen info@westonfoundation.org	The foundation supports research to understand and predict the effects of climate change on the physical environment, ecosystems and human population of the North.

13.0 CONCLUSIONS AND RECOMMENDATIONS

13.1 Conclusions

EBA presents the following conclusions from this study:

- Having identified warm and cold water resources in the Community at KFN-K and KFN-L, KFN and YG are in an enviable position to consider an integrated approach to development of these resources.
- Each of the four integrated development options considered in this study are technically feasible based on the current information available; however, there is an increasing amount of cost and risk associated with the more complex options. This risk could be reduced or mitigated through further assessment and proper engineering design and planning.
- EBA has presented four options to span the breadth of “minimal” to “maximum” scope of water supply and geexchange development for KFN. The options presented were specifically selected to span the range of possible water demands as well as the range of simpler to more complex geexchange options. These options are presented with the intention that YG and KFN can consider the range of options and associated costs, and other important considerations such as system complexity and regulatory considerations.
- Although we have presented four options to span the breadth of minimum to maximum scope of development, there are several intermediate options that could also be considered. There should be sufficient information presented in this guidance document to consider and select possible intermediate combinations of options, and to make an educated decision on how to proceed with development of the cold and warm water resources.
- Based on the Class D cost estimated presented, Option 1 could likely be completed with funding currently available; however, this option is somewhat limiting as it relies upon a water supply that has limited yield and therefore this option is only suitable for the low growth population model.
- Additional funding is required to pursue Options 2a, 2b or 3, or to pursue any intermediate combination of options.
- It is possible to reduce the costs for Option 2b and Option 3 significantly by developing the demand (i.e. the infrastructure that would utilize district heating) closer to the warm water source to minimize the development costs by reducing piping and trenching costs. This would also minimize potential risks associated with the permafrost conditions. For example, KFN could give consideration to developing the proposed 4-Plex (if Option 2b selected) and the proposed pool and school (if Option 3 selected) near the warm water resource (KFN-L).
- There are numerous territorial and federal funding sources for technical studies and capital works that might cover any of the options if combined. Since this is a project where some funding already exists (YG-Build Canada), it will likely be easier to obtain other funding as in our experience; partnerships are generally encouraged for these types of projects.

- In consideration of the fact that this project would reduce the risk to the current community water system and because it is a “green” project that would develop around a renewable resource and would reduce reliance on fossil fuels; we believe that it is likely an attractive project for funding agencies.

13.2 Recommendations

EBA presents the following recommendations resulting from this study:

- KFN should take this guidance document into consideration, and deliberate internally and with partners (e.g., YG) to select a preferred option.
- KFN should consider/ revise their Community Land Use Plan to align with selected option.
- If Option 2 or 3 (or a variance on these) are desired, KFN should apply for funding from funding sources identified in this study. EBA would be pleased to offer application support.
- For the selected option, it is recommended that KFN start permitting/approvals process immediately. Geotechnical and permafrost assessments should also be conducted as soon as possible to make the results available for the preliminary and detailed design. EBA has experience with this and would be pleased to support this effort.
- For the selected option, KFN should start preliminary design (EBA can support).

Water system improvements must be made to address the chlorine contact issue for whichever option is selected; however, an immediate operational recommendation to address this issue would be to ensure that prior to the 2nd, 3rd and 4th deliveries of the day that the water truck sits idle (at the Water Treatment Plant) for 20 minutes prior to departing for the first delivery site. This would achieve the desired 4-log removal of viruses (provided the recommended chlorine concentration is present). The truck end fill time and the truck depart time must be documented in the water treatment plant records and maintained with all other records (such as residual chlorine readings).

14.0 ACKNOWLEDGEMENTS

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- Kluane First Nation – Roberta Martell, Executive Director; provided background data and input to the study.
- Yukon Government – Kyle Rolling, P.Eng; as YG’s representative provided funding and direction to the study.
- Marlene Jennings, Senior Project Manager; completed the research and authored the sections related to funding opportunities.
- Stephan Klump, Ph.D.; completed the hydrogeology components of the study.
- Larry Sawchyn, P.Eng.; provided senior technical support for the water treatment aspects of the study.
- Andrew Chiasson, P.Eng. Ph.D.; led the technical components of the geoexchange part of this study.

- Ryan Martin, P.Eng.; was project manager and primary report author.
- Scott Schillereff, Ph.D.; senior technical support and review.

15.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Sincerely,
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Table 10: Summary and Evaluation of Options

	Option 1	Option 2 a	Option 2 b	Option 3
Water Supply	KFN-F and KFN-M	KFN-K and KFN-N	KFN-K and KFN-L	KFN-K and KFN-N
Water Treatment	Existing WTP ¹ with expansion and improvements	New WTP – As reduction and chlorination	New WTP – Greensand/As reduction, chlorination, and RO	New WTP - As reduction and chlorination
Water Distribution	Truck only	Truck and piped distribution	Truck and pipe distribution	Truck and piped distribution
Geoexchange	Closed-loop with "convection promoter"	Closed loop with artesian flow or moderate pumping	Semi-open loop standing water column	Open loop
Water Disposal	No water disposal required	Shallow injection well or surface water	Shallow injection well or surface water	Deep injection well
Potable Water Demand Scenario	Low – 2.8 USgpm ADD ²	Moderate – 6.2 USgpm ADD	Moderate – 6.2 USgpm ADD	High – 49 USgpm ADD
Geoexchange Water Demand	None	Moderate – 10 USgpm	Moderate – 10 USgpm	Up to 100 USgpm
Overall Complexity	Low	Moderate	Moderate	High
Technical / System Complexity	<ul style="list-style-type: none"> Lowest overall complexity. Similar to existing system using much of the existing infrastructure. Requires new backup well KFN-M. Water supply and geoexchange systems are completely separated and independent. Simple closed-loop geoexchange system for small greenhouse. Low permafrost risk/ complications. 	<ul style="list-style-type: none"> Moderate overall complexity. Requires new backup well KFN-N. May require shallow injection well. New WTP required. Water supply and geoexchange systems are separated but share some of the infrastructure. Moderately complex geoexchange system for heating of large greenhouse. Requires water disposal. Low permafrost risk/ complications. 	<ul style="list-style-type: none"> Moderate to high overall complexity. No new backup well required. May require shallow injection well. New WTP required. Additional complexity for treatment of KFN-L water to meet GCDWQ³. Water supply and geoexchange systems could be fully integrated. Piped distribution to eastern-end of community. Complex geoexchange system including greenhouse, WTP and 4-plex. Requires water disposal. Moderate permafrost risk/ complications. 	<ul style="list-style-type: none"> High overall complexity. Requires new backup well KFN-N and deep injection well. New WTP required. Water supply and geoexchange systems are separated but share some of the infrastructure (TP, common trenching). Piped distribution system. Complex open-loop geoexchange system including WTP, 4-plex, school, swimming pool, with potential additional capacity. Requires water disposal. Moderate permafrost risk/ complications.
Regulatory	<ul style="list-style-type: none"> "Approval to Modify" from YG-EHS⁴ to upgrade WTP. Assessment under YESAA⁵ for activities related to drilling of KFN-M No Water Licence required. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS⁶). Type A Water Licence for water disposal may be required depending on disposal option and system design. Surface water disposal would likely require additional baseline data collection and fisheries assessments. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS). Type A Water Licence for water disposal may be required depending on disposal option and system design. Surface water disposal would likely require additional baseline data collection and fisheries assessments. 	<ul style="list-style-type: none"> Assessment under YESAA for well drilling, construction of WTP, distribution and disposal. Permit requirements from YG: development and building permits, plumbing and electrical permits. Permit requirements from YG-EHS: Approval to Construct and Permit to Operate (LPDWS). Type A Water Licence for water disposal.
Operator Skill Requirement	<ul style="list-style-type: none"> System would likely be classified by EOCP⁷ as "Small Water System" (serves <500 people). Lowest operator skill requirements (Certified SWS⁸ Operator). Operator would likely not have to be Level 1 certified. Simple geoexchange system with relatively low skill requirements. Knowledge of circulating pumps and heat pumps. 	<ul style="list-style-type: none"> System would likely be classified by EOCP as "Small Water System" (serves <500 people). Low operator skill requirements (Certified SWS Operator). Operator would likely not have to be Level 1 certified. Low to moderate skill requirements for geoexchange system. Knowledge of circulating pumps and heat pumps. Must deal with water disposal. 	<ul style="list-style-type: none"> System would likely be classified by EOCP as "Small Water System" (serves <500 people). Low operator skill requirements (Certified SWS Operator). Operator would likely not have to be Level 1 certified. Moderate skill requirements for geoexchange system. Knowledge of circulating pumps; heat pumps, "bleed" controls. Periodic heat exchanger maintenance may be required. Must deal with water disposal from well. 	<ul style="list-style-type: none"> System would likely <u>not</u> be classified by EOCP as "Small Water System" (serves >500 people). Considerable operator skill requirements (likely at least Level 1 certification). Moderate skill requirements for geoexchange system. Knowledge of circulating pumps; heat pumps, "bleed" controls. Periodic heat exchanger maintenance may be required. Must deal with water disposal from well.

Table 10: Summary and Evaluation of Options

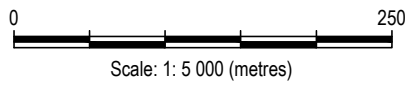
	Option 1	Option 2 a	Option 2 b	Option 3
Sustainability	<ul style="list-style-type: none"> ▪ Sustainable with respect to groundwater quantity because extraction of groundwater for water supply is low and no water is extracted for geexchange (closed-loop system). ▪ Proper design of geexchange system is important to ensure thermal sustainability. 	<ul style="list-style-type: none"> ▪ Water supply is sustainable due to relatively small extraction rate and high-yield well KFN-K. ▪ Moderate sustainability of geexchange system because water is not re-injected into same aquifer; however, relatively small extraction rate from deep aquifer is likely viable. 	<ul style="list-style-type: none"> ▪ Water supply is sustainable due to relatively small extraction rate and high-yield well KFN-K. ▪ Moderate sustainability of geexchange system because water is not re-injected into same aquifer; however, relatively small extraction rate from deep aquifer is likely viable. 	<ul style="list-style-type: none"> ▪ Maximized sustainability of geexchange system with respect to aquifer pressure and water quantity because water is re-injected into same aquifer. ▪ Water disposal at surface or to different aquifer would likely be unsustainable and cause depletion of deep aquifer. ▪ Proper injection well design is important to ensure thermal sustainability.
Timeframe – design / approval / tendering/ construction / commissioning process	<ul style="list-style-type: none"> ▪ Shortest timeframe. ▪ Design, approval, and tendering in spring/summer 2013. ▪ Possibly construction in late summer 2013 and commissioning in the fall of 2013. 	<ul style="list-style-type: none"> ▪ Moderate timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process. 	<ul style="list-style-type: none"> ▪ Moderate timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process. 	<ul style="list-style-type: none"> ▪ Longest timeframe. ▪ Geotechnical investigations in summer 2013. ▪ Design, approval, and tendering by spring 2014. ▪ Construction and commissioning by fall 2014. ▪ Timeline assumes funding is readily available and no hold-ups in the regulatory approval process.
Environmental	<ul style="list-style-type: none"> ▪ Lowest heat energy extraction from KFN-L. ▪ Lowest hydrocarbon offset. ▪ No water disposal required. 	<ul style="list-style-type: none"> ▪ Low to moderate heat extraction from KFN-L. ▪ Low to moderate hydrocarbon offset. ▪ Requires water disposal to shallow aquifer or surface water. ▪ Disposal to surface water may have adverse environmental effects. 	<ul style="list-style-type: none"> ▪ Moderate heat energy extraction from KFN-L. ▪ Moderate hydrocarbon offset. ▪ Requires water disposal to shallow aquifer or surface water. ▪ Disposal to surface water may have adverse environmental effects. 	<ul style="list-style-type: none"> ▪ Very environmentally sound. ▪ Maximum heat energy extraction from KFN-L. ▪ Offsets most hydrocarbon reliance. ▪ Water disposal back to same aquifer.

Notes:

- ¹ WTP – Water treatment plant
- ² ADD – average daily demand
- ³ GCDWQ – Guidelines for Canadian Drinking Water Quality
- ⁴ YG-EHS – Government of Yukon – Environmental Health Services
- ⁵ YESAA – Yukon Environmental and Socioeconomic Assessment Act
- ⁶ LPDWS – Large Public Drinking Water System (definition by Yukon Public Health and Safety Act)
- ⁷ EOCP – Environmental Operators Certification Program
- ⁸ SWS – Small Water System (EOCP definition)

FIGURES

Figure 1	Site Plan Showing Existing Conditions and Relevant Site Features
Figure 2	Site Plan Showing Conceptual Layout for Option 1
Figure 3	Building Details Showing Conceptual Layout for Option 1
Figure 4	Site Plan Showing Conceptual Layout for Option 2a
Figure 5	Site Plan Showing Conceptual Layout for Option 2b
Figure 6	Site Plan Showing Conceptual Layout for Option 3



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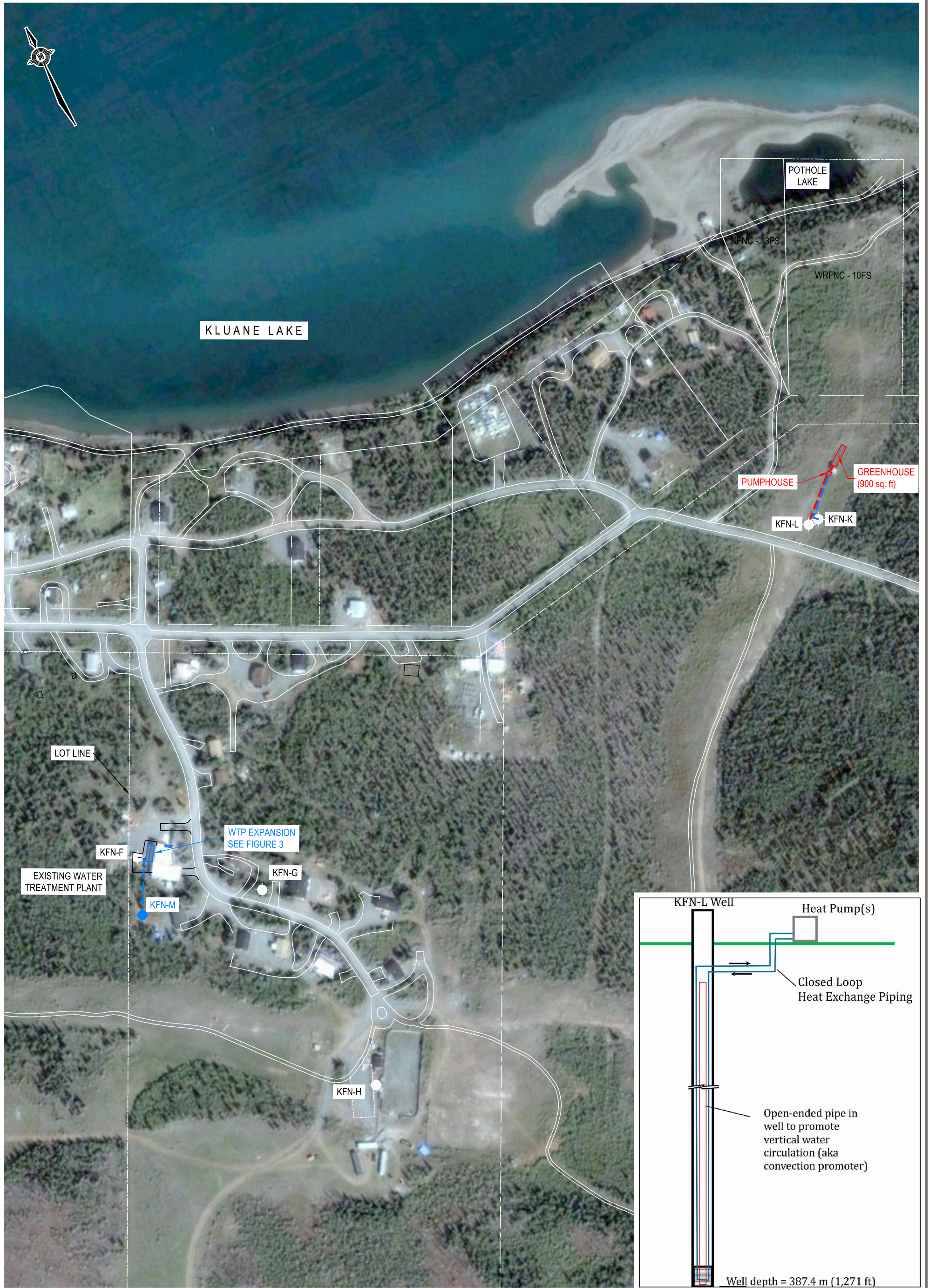
GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM

SITE PLAN SHOWING EXISTING CONDITIONS AND RELEVANT SITE FEATURES

PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0
OFFICE EBA-WHSE	DATE April 18, 2013		

Figure 1

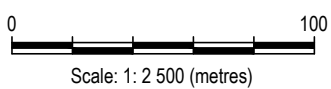
Q:\Whitehorse\Data\0201\Drawings\Burwash\W23103077-01 Guidance Document for Cold & Warm Water Well System\Report\W23103077-01 Fig_1_RD.dwg [FIGURE 1] June 27, 2013 - 9:11:22 am (BY: BUCHAN, CAMERON)



LEGEND:
 - - - CONCEPTUAL WATER DISTRIBUTION SYSTEM
 - - - CONCEPTUAL HEAT DISTRIBUTION SYSTEM
 ■ - INDICATES NEW BUILDING LOCATION

NOTES
 - ALL FEATURES REPRESENTED IN RED OR BLUE ARE POTENTIAL NEW INFRASTRUCTURE, ALL OTHER FEATURES ARE EXISTING

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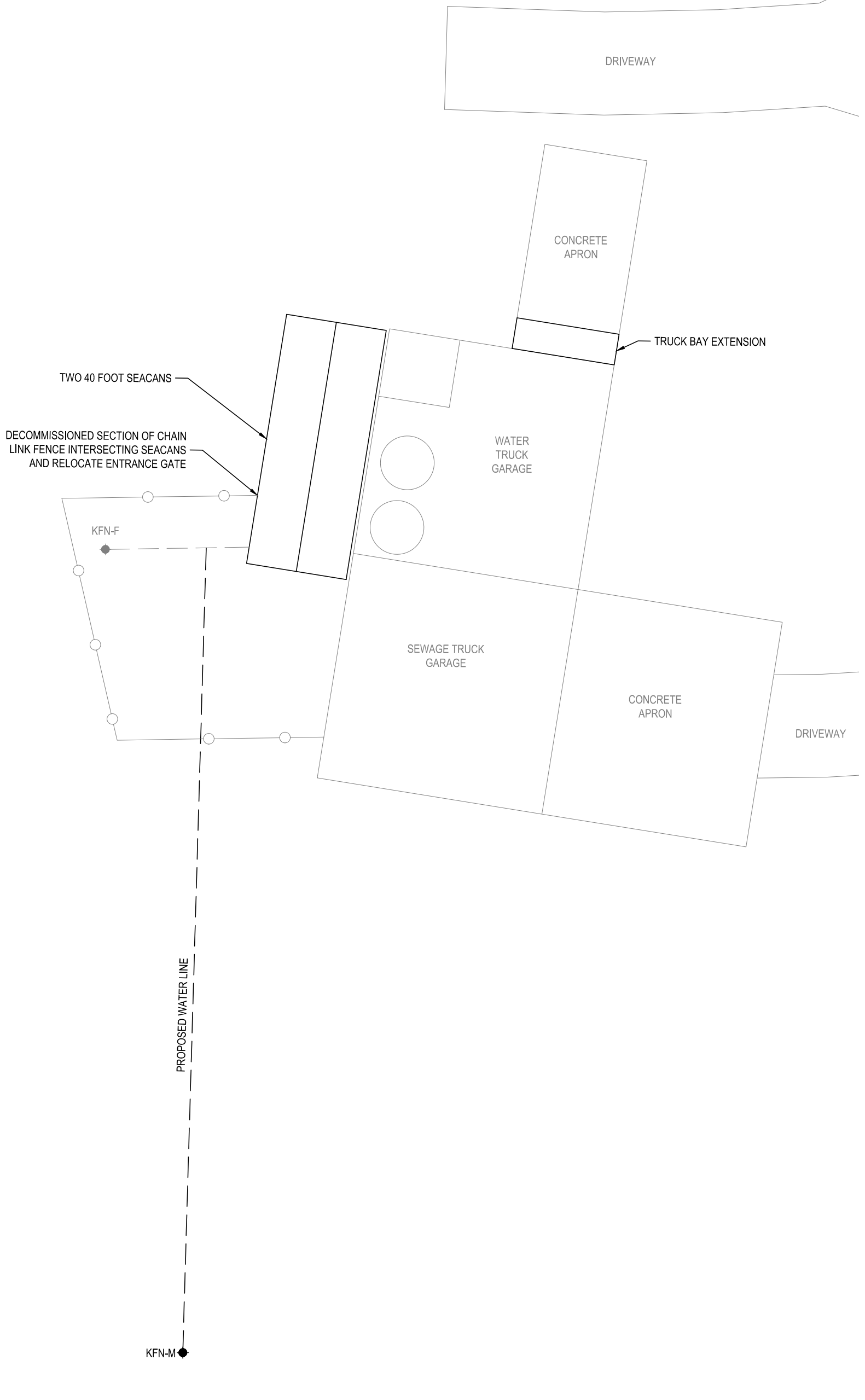
eba
 A TETRA TECH COMPANY

GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM

SITE PLAN SHOWING CONCEPTUAL LAYOUT FOR OPTION 1

PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0
OFFICE EBA-WHSE	DATE April 18, 2013		

Figure 2



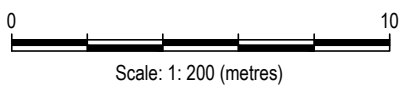
LOT LINE

PROPOSED WATER LINE

KFN-M

NOTES
 - ALL FEATURES REPRESENTED IN BLACK ARE POTENTIAL NEW INFRASTRUCTURE, ALL FEATURES IN GREY ARE EXISTING

STATUS
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Scale: 1: 200 (metres)

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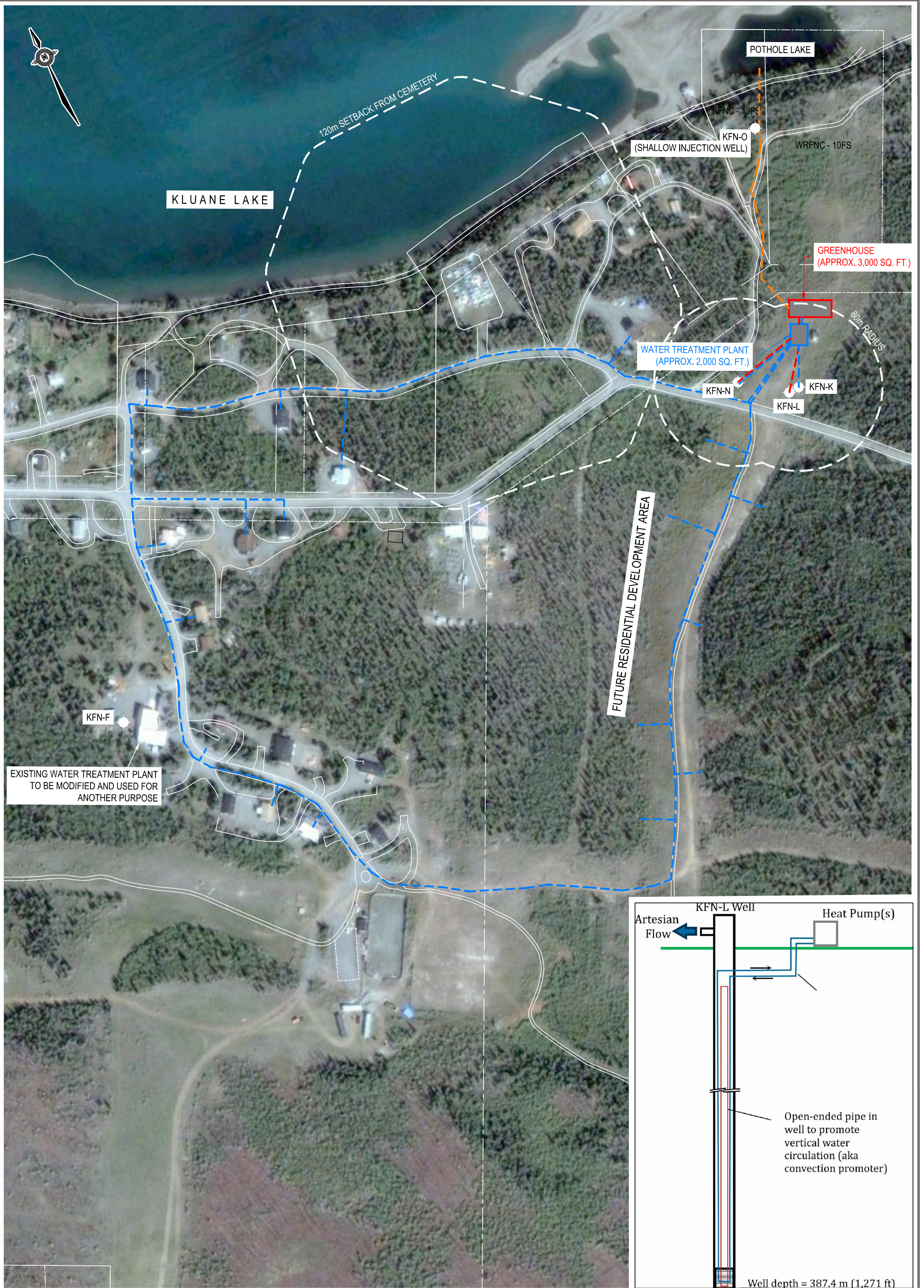


GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM

BUILDING DETAILS SHOWING CONCEPTUAL LAYOUT FOR OPTION 1

PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0
OFFICE EBA-WHSE	DATE April 18, 2013		

Figure 3



LEGEND:

- - - CONCEPTUAL WATER DISTRIBUTION SYSTEM
- - - CONCEPTUAL HEAT DISTRIBUTION SYSTEM
- - - CONCEPTUAL WATER DISCHARGE SYSTEM
- - INDICATES NEW BUILDING LOCATION

0 100
Scale: 1: 2 500 (metres)

NOTES

- ALL FEATURES REPRESENTED IN COLOUR ARE POTENTIAL NEW INFRASTRUCTURE, ALL OTHER FEATURES ARE EXISTING

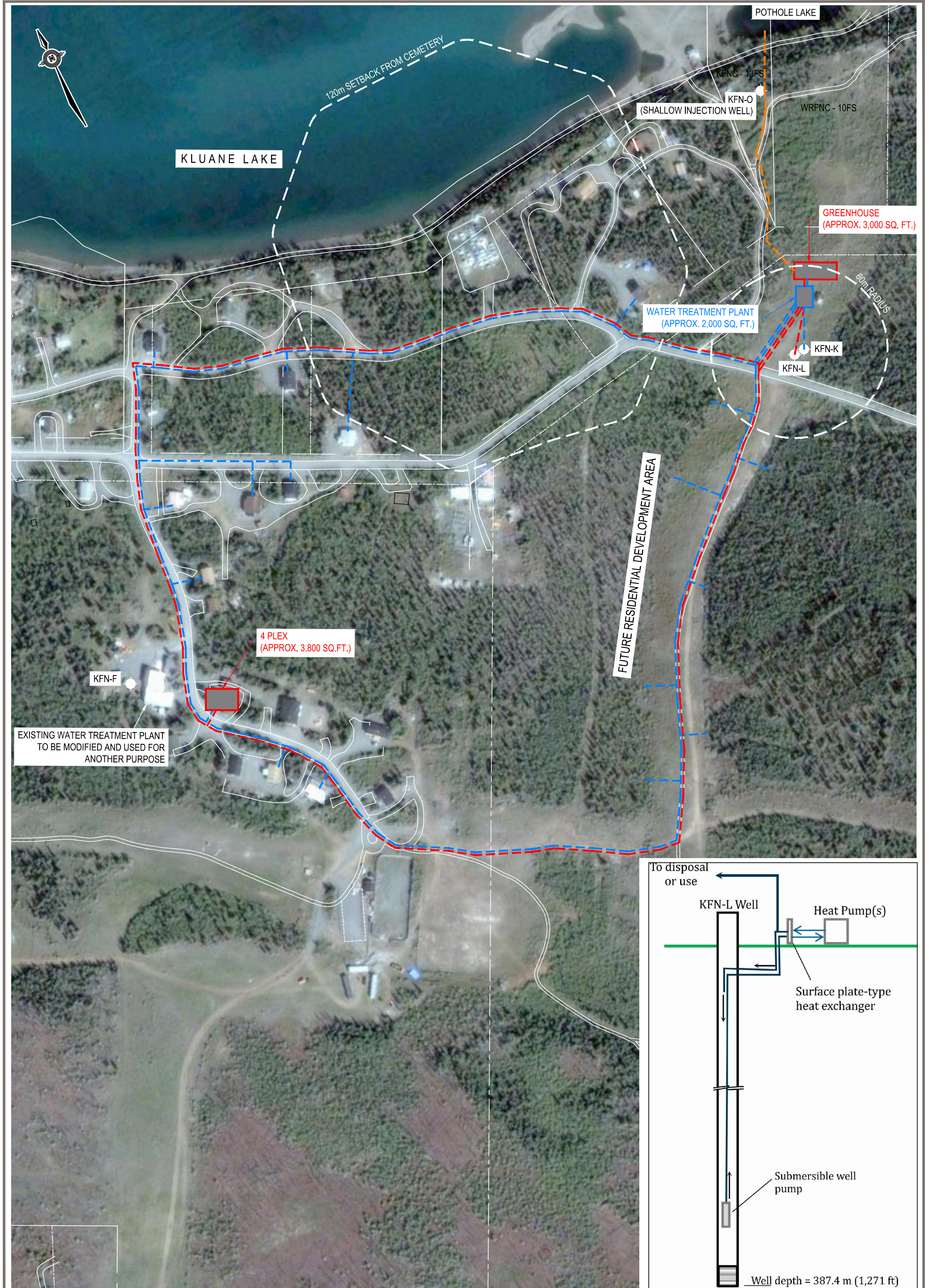
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GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM				
SITE PLAN SHOWING CONCEPTUAL LAYOUT FOR OPTION 2a				
PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0	Figure 4
OFFICE EBA-WHSE	DATE April 18, 2013			



LEGEND:

- CONCEPTUAL WATER DISTRIBUTION SYSTEM
- CONCEPTUAL HEAT DISTRIBUTION SYSTEM
- CONCEPTUAL WATER DISCHARGE SYSTEM
- - INDICATES NEW BUILDING LOCATION

0 100
Scale: 1: 2 500 (metres)

NOTES

- ALL FEATURES REPRESENTED IN COLOUR ARE POTENTIAL NEW INFRASTRUCTURE, ALL OTHER FEATURES ARE EXISTING

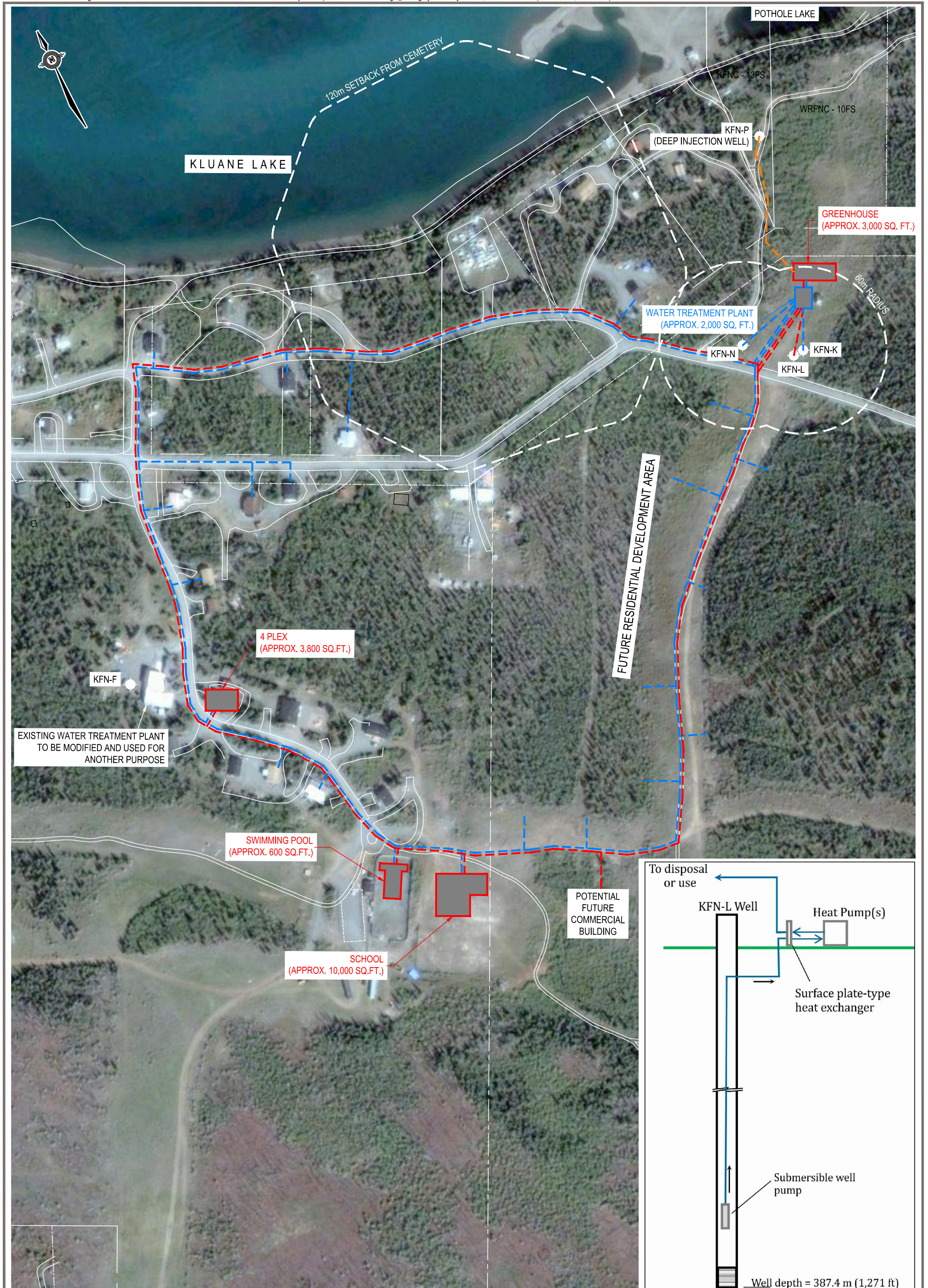
STATUS
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GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM				
SITE PLAN SHOWING CONCEPTUAL LAYOUT FOR OPTION 2b				
PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0	Figure 5
OFFICE EBA-WHSE	DATE April 18, 2013			



LEGEND:

- - - CONCEPTUAL WATER DISTRIBUTION SYSTEM
- - - CONCEPTUAL HEAT DISTRIBUTION SYSTEM
- - - CONCEPTUAL WATER DISCHARGE SYSTEM
- - INDICATES NEW BUILDING LOCATION

0 100
Scale: 1: 2 500 (metres)

NOTES

- ALL FEATURES REPRESENTED IN COLOUR ARE POTENTIAL NEW INFRASTRUCTURE, ALL OTHER FEATURES ARE EXISTING

STATUS
ISSUED FOR USE

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Government
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GUIDANCE DOCUMENT FOR DEVELOPMENT OF COLD AND WARM WATER WELL SYSTEM

SITE PLAN SHOWING CONCEPTUAL LAYOUT FOR OPTION 3

PROJECT NO. W23103077-01	DWN CB	CKD RMM	REV 0
OFFICE EBA-WHSE	DATE April 18, 2013		

Figure 6

APPENDIX A

EBA'S GENERAL CONDITIONS

GENERAL CONDITIONS

GEO-ENVIRONMENTAL REPORT

This report incorporates and is subject to these “General Conditions”.

1.0 USE OF REPORT AND OWNERSHIP

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's Client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

4.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

APPENDIX B

EBA TECHNICAL MEMO NO.1 (FEBRUARY 21, 2013)

TECHNICAL MEMO

ISSUED FOR USE

TO: Kyle Rolling, P.Eng. – Infrastructure Development, Yukon Government
Roberta Martell – Executive Director, Kluane First Nation

DATE: February 21, 2013

C: Math'ieya Alatini - Chief, Kluane First Nation
EBA project team

MEMO NO.: 1

FROM: Ryan Martin, P.Eng. – EBA Project Manager

EBA FILE: W23103077.001

SUBJECT: Summary of Design Considerations and Options to Assess for Guidance Document for Development of Cold and Warm Water Well System
Kluane First Nation, Burwash Landing, Yukon

1.0 INTRODUCTION

EBA, A Tetra Tech Company (EBA) has been retained by Government of Yukon (YG) on behalf of the Kluane First Nation (KFN) to prepare a guidance document for the development of a cold and warm water well system in Burwash Landing, Yukon. As part of this study, the project team will assess several options for improvements of the KFN community water system and geexchange applications to make use of two new water wells that were drilled and completed in August 2012.

This memo summarizes pertinent information for consideration in this study compiled from:

- a meeting between EBA, YG, and KFN on January 23, 2013 to discuss priorities and conceptual design options;
- a meeting between EBA, KFN and the Aboriginal Affairs and Northern Development Canada (AANDC) Circuit Rider (Mr. Ray Osborne) on February 1, 2013 to further discuss priorities, constraints and conceptual design options; and,
- a review of the Kluane First Nation Community Land Use Plan.

This memo includes details of three options developed from the above, for the EBA team to assess in this project. In light of the aggressive project schedule, it was considered essential that EBA, YG and KFN agree on and confirm the study options, so EBA's team can proceed with the technical assessment. An issued for review version of this memo was sent to the Yukon Government Project Manager (Kyle Rolling) and Kluane First Nation Executive Director (Roberta Martell) on February 8th. Review comments were received from Yukon Government on Monday February 11th; and Kluane First Nation on Wednesday February 13th 2013. Comments and clarifications have been added where necessary, and this document constitutes the final options for consideration in this project and is being used by the project team as the basis for proceeding.

2.0 SUMMARY INFORMATION ON WELLS KFN-F, KFN-K AND KFN-L

Table 1 summarizes important information on the existing well used for the Community Water Supply (KFN-F) and the two new wells (KFN-K and KFN-L, drilled in 2012) that will be considered in the guidance document. KFN-L was drilled as an exploratory geoexchange well, and KFN-K as a water supply well for KFN-L drilling. Both KFN-L and KFN-K are now considered as potential water supply wells for options analysis.

Table 1: Well Information Summary for KFN-F, KFN-K and KFN-L

	KFN-F (cold water well near water truck garage)	KFN-K (new cold water well)	KFN-L (new warm water well)
Well Type	Completed in overburden (gravel) with stainless steel screen	Completed in overburden (sandy gravel) with stainless steel screen	Completed in overburden (sand) with stainless steel screen
Well Diameter	152 mm (6 in)	152 mm (6 in)	152 mm (6 in)
Well Depth	60.96 m (200 ft.)	73.5 m (241 ft.)	387.4 m (1,271 ft.)
Well Yield (based on pump test)	3 USgpm (short term up to 10 USgpm)	150 USgpm	100 USgpm
Pump Test Duration	24 hr	24 hr	72 hr
Artesian Pressure at Wellhead	Not artesian (SWL ~12 m (39 ft) bgs)	3 psi (SWL ~2.1 m (6.9 ft) ags)	1 psi (SWL ~0.7 m (2.3 ft) ags)
Water Temperature	~2°C (to be confirmed)	1.9°C	15.9°C
GUDI Status based on Review of Stage 1 GUDI Assessment Criteria	No triggers based on information presently available. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI	No triggers at this time to suggest GUDI. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI	No triggers at this time to suggest GUDI. Well is properly constructed, low vulnerability and adequate set back from surface water. Consider Non-GUDI
Water Quality Summary	Meets all GCDWQ MACs. Manganese (0.07 mg/L) slightly exceeds AO (0.05 mg/L)	As (0.012 mg/L) slightly exceeds MAC (0.01 mg/L); hard (150 mg/L CaCO ₃); pH (up to 8.8) exceeds MAC (6.5-8.5)	As (0.075 mg/L) exceeds MAC (0.01 mg/L); exceeds AO for TDS, Fe, colour; very hard (406 mg/L CaCO ₃)

Notes:

GUDI – Groundwater Under Direct Influence of Surface Water

USgpm = US gallon per minute; SWL = static water level; bgs = below ground surface; ags = above ground surface; AO = aesthetic objective; MAC = maximum allowable concentration

3.0 DESIGN CRITERIA AND PRIORITIES

EBA understands that KFN would like to focus on the following design criteria and priorities:

- KFN's first priority is to address concerns with the current water supply and treatment including: lack of redundancy for water source, issues with the current well (KFN-F) not meeting operational demands, and water treatment issues. The current water treatment plant (WTP) requires upgrades including changes to the treatment process to increase the chlorine contact time to achieve a viral log treatment of 4 log (currently assessed at 0.78) and a treatment step for manganese (Mn) removal because Mn precipitate is causing operational issues. These issues are detailed in a report prepared by Yukon Engineering Services (YES) and sub consultants (including EBA) April 2012; and relevant recommendations related to water source, quality and treatment are provided below:
 - Upgrade the KFN-F wellhead enclosure, or upgrade well to a pitless unit with freeze protection to prevent access by vermin through the building shell. *Note: This was completed in fall 2012.*
 - KFN should update their wellhead protection plan and implement recommendations from this plan. This would include relocating the fuel tank for the water treatment building to the other side of the building to reduce risk to the wellhead from spills or leaks. *Note: This was initiated in fall 2012, project will be completed in 2013.*
 - Develop a back-up water supply for the trucked water delivery system for redundancy in order to ensure uninterrupted water supply. *Note: Well KFN-K (see below) was drilled in 2012 and is being considered as a back-up supply.*
 - KFN-F and any future wells serving this LPDWS should be instrumented with data loggers and flow data from each well should be monitored and recorded so that changes in individual well performance can be observed and mitigated before the overall capacity is compromised.
 - Install a treatment technology for manganese removal.
 - Provide aeration before chlorination to reduce or eliminate the sulphuric smell.
 - Add more contact time for disinfection or change the configuration of the storage tanks (in series).
 - Install redundancy on the chlorination system and correct the deficiencies (isolation valve, relief, level sensor with alarm, static mixer).
 - Once treatment for manganese removal has been installed, clean and rehabilitate the online free chlorine analyzer.
 - Install a recirculation loop for the storage tanks with automatic control of the chlorine residual through an on-line chlorine analyzer.
- KFN will consider upgrades to the existing WTP (as recommended above), **AND/OR** a new WTP in the vicinity of KFN-K and L. In order to complete necessary upgrades to the existing WTP, a building

addition would almost certainly be required to allow for extra tankage, treatment steps, and to provide additional appurtenances recommended in recent assessment (e.g., lab space, eyewash and shower).

Note: Mr. Osborne expressed a concern that with increasing water demand due to increasing population, there will be a need for a larger water delivery truck, which cannot be accommodated in the current WTP building.

- Use of the deep warm water well for geoexchange purpose is a secondary priority according to KFN; however it also does figure prominently in their recently completed Community Land Use Plan (CLUP). Possible uses of the warm water well in an integrated fashion may include freeze protection for water lines, heating for a greenhouse to be developed near the well location, and heating of existing (existing WTP, existing residences) and future buildings (e.g., four-plex, school, swimming pool, residences).
- Possible geoexchange applications for KFN government buildings in the area of the KFN Administration building are not a priority of KFN and will not be further considered in this current assessment.
- KFN would like the water distribution options in this study to include both bulk truck fill operation, and a combined bulk truck fill with supplementary piped distribution (where practicable). Regulatory implications of this will be considered as part of this study.
- A design goal is any new systems shall be as simple as possible to operate, reliable, and sustainable.
- Water demand options to include: expected minimum growth (7% every 5 years), moderate growth (30% growth every 5 years); and high growth scenario assuming large spike in population over the next 20 years due to Wellgreen Mine coming into operation.
- KFN has acknowledged that as they are requesting consideration of more options than originally scoped, and that they had previously requested that cost estimates meet “Class C” level, that in consideration of the expanded options consideration that Class D estimates will be accepted. Furthermore, it was discussed on our Friday Jan 31st call that the Issued for Review report may not be completed prior to the March 4th Energy Summit; however, that there would certainly be enough information to make a presentation on the options being considered at that time. Based on the current schedule, we are now anticipating an Issued for Use report for March 22nd, 2013.

In summary, KFN, EBA and YG have discussed and agreed to consider three options of integrated water supply and geoexchange with successive options showing increasing infrastructure complexity and use of the warm water resource. We understand that KFN leaders have directed the EBA team toward the three options considering a wide range of factors affecting current and future development at Burwash Landing, including their Community Land Use Plan. Details of the three options are described below.

4.0 OPTIONS FOR CONSIDERATION

The client and project team have agreed to three options for consideration in this study, which are summarized below. For each of the three options below that will be considered as part of this study, the pros and cons of the option under the following categories will be considered: regulatory, technical, capital costs (Class D), operational costs (comparative only).

4.1 Option I – Lowest Complexity and Relative Cost

Overview: Use KFN-K for water redundancy to KFN-F; implement water treatment improvements at existing WTP; implement geoexchange for greenhouse heating and tempering water distribution to existing WTP.

A figure showing key infrastructure and very conceptual layout of potential new infrastructure to be considered as part of this study is shown in attached Figure 1.

Water Supply:

- Use cold water well KFN-K to supplement KFN-F for potable water supply via piped connection to existing WTP.
- Existing WTP will be upgraded to treat water from KFN-F and KFN-K, including Mn, Fe and As removal; and disinfection (chlorine contact time (CT) improvements through change in configuration and/or storage volume to ensure 4 Log removal of viruses).
- Depending on heat transfer approach, other water treatment may be required for heat extraction from KFN-L water.

Heat Transfer and Heating Uses:

- A new “pumphouse” building to be constructed near KFN-L wellhead, to house heat exchange/recovery equipment and controls. Various methods to collect heat from KFN-L will be assessed, including an open loop concept (pumping raw water to surface heat exchanger, then disposing away from KFN L), an in-well heat exchanger (e.g., concentric pipe heat exchanger installed into KFN-L), and standing column well concept (pumping raw water to surface heat exchanger, then disposing back to top of KFN L). Only indirect heat transfer will be considered to avoid difficulties of system fouling expected with using raw KFN-L water directly.
- Heat from KFN-L is used for heating at a proposed greenhouse near the KFN-L wellhead;
- Heat from KFN-L used for tempering water to be pumped from KFN-K to the existing WTP for treatment.

Water Disposal:

- Disposal requirements depend on heat transfer method from KFN-L. With open loop concept, substantial water disposal will be required. With in-well heat exchanger, disposal may not be required (depending on artesian flow control). With standing column well concept, minor water disposal will likely be required (depending on heat balancing requirements and artesian flow control).

- For substantial water disposal, options for reinjection into the shallow aquifer or disposal to the surface (e.g., Pothole Lake or Kluane Lake) will be assessed. To maintain lower relative cost, a deep injection well would not be considered in this option.
- For minor water disposal, options to use water in the greenhouse operation (maintenance, irrigation, hydroponics) as well as disposal at surface will be assessed.

4.2 Option 2 – Moderate Complexity and Relative Cost

Concept Overview: Primary water supply is KFN-K, with a new cold water well near KFN-K (located cross gradient) for redundancy, and KFN-F used as backup or decommissioned. For this option the benefits are that the secondary supply would likely have similar water quality (to KFN-K) and much higher yield than KFN-F. This option would include a New WTP at KFN-K/L wellhead. Piped Distribution to the core of Burwash Landing Village (that will supplement trucked delivery). A very conceptual routing of the potential piped distribution is shown on the attached Figure 1. Geexchange for heating greenhouse and tempering of water for distribution system.

Water Supply:

- Cold water well KFN-K, and a new well drilled in same aquifer near KFN-K is used for potable water supply. KFN-F will be decommissioned; or used for another purpose (maintained as back-up).
- New Water treatment system in new WTP would be constructed to include arsenic removal, and primary and secondary disinfection to comply with all YG EHS requirements.
- Potable water handled in heated water reservoir and recirculating distribution system.
- Depending on heat transfer approach, other water treatment may be required for heat extraction from KFN-L water.

Heat Transfer and Heating Uses:

- A new pumphouse building to be constructed near KFN-L wellhead, to house heat exchange/recovery equipment and controls. Various ways to collect heat from KFN-L will be assessed, including an open loop concept (pumping raw water to surface heat exchanger, then disposing away from KFN-L), an in-well heat exchanger (e.g., concentric pipe heat exchanger installed into KFN-L), and standing column well concept (pumping raw water to surface heat exchanger, then disposing back to top of KFN-L). Only indirect heat transfer will be considered to avoid difficulties of system fouling expected with using raw KFN-L water directly.
- Heat from KFN-L is used for heating at a proposed greenhouse near the KFN-L wellhead.
- Heat from KFN-L used for tempering water in new WTP, water reservoir and recirculating piped water distribution system.

Water Disposal:

- Disposal requirements depend on heat transfer method from KFN-L. With open loop concept, substantial water disposal will be required. With in-well heat exchanger, disposal may not be required (depending on artesian flow control). With standing column well concept, minor water disposal will likely be required (depending on heat balancing requirements and artesian flow control).
- For substantial water disposal, options for reinjection into the deep aquifer, reinjection into the shallow aquifer or disposal to the surface (e.g., Pothole Lake or Kluane Lake) will be assessed.
- For minor water disposal, options to use water in the greenhouse operation (maintenance, irrigation, hydroponics) as well as disposal at surface will be assessed.

4.3 Option 3 – Highest Complexity and Relative Cost

Concept Overview: Option 2 plus a geexchange-based district heating system for up to four commercial buildings and 20 residences (depending on magnitude of available heat resource from KFN-L). Note that this option will likely be constrained by the resource.

Water Supply:

- As in Option 2

Heat Transfer and Heat Uses:

- Due to need for maximum heating capacity, only an open loop approach for heat extraction is considered in this option. This will require a heat exchanger at the new WTP near KFN-L wellhead.
- Heat uses as per Option 2, plus below.
- District heating for commercial and residential buildings around the piped distribution system, depending on available heat resource and projected heat demand.

Water Disposal:

- With this option, we anticipate pumping KFN-L at maximum well rating (100 USgpm, or 545 m³/d) Due to this high flow rate and for appropriate aquifer management, only disposal by re-injection to the deep aquifer is considered in this option.

5.0 SCHEDULE AND DELIVERABLES

We will present preliminary information and findings about this study and the three options being considered at the March 4, 2013 Energy Summit to be held by KFN.

The Issued for Review report for this project will be presented with Level D (+/- 40%) capital cost estimates on March 22nd, 2013.

Following our receiving written comments from YG and KFN, we will prepare and submit the Issued for Use report for this project. This is anticipated to be completed for March 31st, 2013.

6.0 CLOSURE

We understand that factors and considerations affecting development for Burwash Landing are constantly evolving. We trust that this work will form a sound basis for KFN to select and scope funding for future development, and to schedule the development in a practical manner that balances the need to move ahead with a sense of urgency, with the need for proper planning and engineering design steps leading up to construction.

We appreciate the opportunity to work with the YG and KFN on this interesting and important project. If you have any questions, please contact Ryan Martin at EBA Whitehorse.

Attachments:

General Terms and Conditions

Site Plan Showing Relevant Site Features and Conceptual Infrastructure Locations

APPENDIX C

DETERMINATION OF COSTS FOR OPTIONS IN THIS STUDY

Table C1: Option 1 - Water Supply, Treatment and Distribution Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Water Supply Works (includes mob/demob)</u>			
1.1	New back-up well (KFN-M)	Lump Sum	1	\$ 39,550.00
1.2	Connection of new backup well (KFN-M)	Lump Sum	1	\$ 60,000.00
1.3	KFN-F Well Rehab	Lump Sum	1	\$ 20,000.00
<u>2.0</u>	<u>Civil Works</u>			
2.1	Mob/demob	Lump Sum	1	\$ 20,000.00
2.2	Sub-excavation and base preparation for pumphouse, truck bay extension and two 40 foot Seacans (includes removal of frost susceptible material and backfill with clean non-frost susceptible material)	m3	780	\$ 30.00
2.3	Monolithic concrete slab on grade for Seacans and pumphouse (130 mm thick)	Lump Sum	1	\$ 25,000.00
2.4	Building addition for truck bay extension	m2	9	\$ 1,000.00
2.5	Lighting modification	Lump Sum	1	\$ 250.00
2.6	Sidewalk construction	Lump Sum	1	\$ 500.00
2.7	Drainage modification	Lump Sum	1	\$ 1,000.00
2.8	Chain-link fence modifications	Lump Sum	1	\$ 2,000.00
2.9	Distribution (Trenching, Backfilling, Piping)	m	0	\$ 640.00
<u>3.0</u>	<u>Mechanical and Electrical Water Treatment Works</u>			
3.1	Mob/demob	Lump Sum	1	\$ 20,000.00
3.2	Water Treatment System	Lump Sum	1	\$150,000
3.3	Water Storage Tanks	Lump Sum	1	\$95,000
3.4	Chlorination upgrade and inline mixer	Lump Sum	1	\$1,000
3.5	Seacan cladding	Lump Sum	1	\$1,500
3.6	Interconnecting piping	Lump Sum	1	\$750
3.7	Transfer pump with redundant unit	Lump Sum	1	\$7,500
3.8	Instrumentation and control	Lump Sum	1	\$2,500
3.9	CSA upgrade to I&C	Lump Sum	1	\$10,000
3.10	Mechanical Systems	Lump Sum	1	\$500
3.11	Computer /SCADA / Printer	Lump Sum	1	\$5,000
3.12	Electrical interconnection	Lump Sum	1	\$4,500
3.13	Shower Eyewash	Lump Sum	1	\$2,000
3.14	Rock Pit connection (for eye wash, emergency shower, and water spillage from truck filling)	Lump Sum	1	\$2,000
3.15	Septic Tank and piping, heat trace	Lump Sum	0	\$5,000
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest ten thousand)			

Table C2: Option 2a - Water Supply, Treatment and Distribution Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Water Supply Works (includes mob/demob)</u>			
1.1	New back-up well (KFN-N)	Lump Sum	1	\$ 52,550.00
1.2	Connection of new backup well (KFN-N) and wellhead protection	Lump Sum	1	\$ 50,000.00
1.3	Connection of KFN-K and wellhead protection	Lump Sum	1	\$ 50,000.00
1.4	Dataloggers on Supply Wells (installed)	Lump Sum	2	\$ 1,500.00
<u>2.0</u>	<u>Civil Works</u>			
2.1	Mob/demob	Lump Sum	1	\$ 30,000.00
2.2	Clearing, Grubbing, Stripping, Access Road Construction	Lump Sum	1	\$ 35,000.00
2.3	Sub-excavation and base preparation for water treatment building	m3	1244	\$ 30.00
2.4	Monolithic concrete slab on grade for water treatment building (130 mm thick) + Insulation	Lump Sum	1	\$ 60,000.00
2.5	Concrete Driveway and Sidewalks	Lump Sum	1	\$ 20,000.00
2.6	Drainage	Lump Sum	1	\$ 2,000.00
2.7	Distribution (Trenching, Backfilling, Piping)	m	1600	\$ 150.00
<u>3.0</u>	<u>Mechanical and Electrical Water Treatment Works</u>			
3.1	Mob/demob	Lump Sum	1	\$ 30,000.00
3.2	Provision of Power to Site	Lump Sum	1	\$ 18,000.00
3.3	Water Treatment System	Lump Sum	1	\$ 120,000.00
3.4	Water Storage Tanks	Lump Sum	1	\$ 65,000.00
3.5	Treatment and storage buildings	m2	185	\$ 1,500.00
3.6	Inline mixer	Lump Sum	1	\$ 750.00
3.7	Interconnecting piping	Lump Sum	1	\$ 750.00
3.8	Transfer pump with redundant unit	Lump Sum	1	\$ 7,500.00
3.9	Instrumentation and control	Lump Sum	1	\$ 2,500.00
3.10	CSA upgrade to I&C	Lump Sum	1	\$ 10,000.00
3.11	Mechanical Systems	Lump Sum	1	\$ 500.00
3.12	Computer /SCADA / Printer	Lump Sum	1	\$ 5,000.00
3.13	Electrical interconnection	Lump Sum	1	\$ 7,500.00
3.14	Shower Eyewash	Lump Sum	1	\$ 2,000.00
3.15	Rock Pit (for eye wash, emergency shower, and water spillage from truck filling)	Lump Sum	1	\$ 3,500.00
3.16	Septic Tank and piping, heat trace	Lump Sum	1	\$ 5,000.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest ten thousand)			

Table C3: Option 2b - Water Supply, Treatment and Distribution Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Water Supply Works (includes mob/demob)</u>			
1.1	Connection of backup well (KFN-L)	Lump Sum	0	\$ 50,000.00
1.2	Connecton of KFN-K	Lump Sum	1	\$ 50,000.00
1.4	Dataloggers on Supply Wells (installed)	Lump Sum	2	\$ 1,500.00
<u>2.0</u>	<u>Civil Works</u>			
2.1	Mob/demob	Lump Sum	1	\$ 30,000.00
2.2	Clearing, Grubbing, Stripping, Access Road Construction	Lump Sum	1	\$ 35,000.00
2.3	Sub-excavation and base preparation for water treatment building	m3	1244	\$ 30.00
2.4	Monolithic concrete slab on grade for water treatment building (130 mm thick)	Lump Sum	1	\$ 60,000.00
2.5	Concrete Driveway and Sidewalks	Lump Sum	1	\$ 20,000.00
2.6	Drainage	lot	1	\$ 2,000.00
2.7	Distribution (Trenching, Backfilling, Piping)	m	1600	\$ 150.00
<u>3.0</u>	<u>Mechanical and Electrical Water Treatment Works</u>			
3.1	Mob/demob	Lump Sum	1	\$ 30,000.00
3.2	Provision of Power to Site	Lump Sum	1	\$ 18,000.00
3.2	Water Treatment System	Lump Sum	1	\$ 160,000.00
3.3	Water Storage Tanks	Lump Sum	1	\$ 65,000.00
3.4	Treatment and storage buildings	m2	185	\$ 1,500.00
3.5	Inline mixer	Lump Sum	1	\$ 750.00
3.6	Interconnecting piping	Lump Sum	1	\$ 1,000.00
3.7	Transfer pump with redundant unit	Lump Sum	1	\$ 7,500.00
3.8	Instrumentation and control	Lump Sum	1	\$ 3,000.00
3.9	CSA upgrade to I&C	Lump Sum	1	\$ 10,000.00
3.10	Mechanical Systems	Lump Sum	1	\$ 500.00
3.11	Computer /SCADA / Printer	Lump Sum	1	\$ 5,000.00
3.12	Electrical interconnection	Lump Sum	1	\$ 7,500.00
3.13	Shower Eyewash	Lump Sum	1	\$ 2,000.00
3.14	Rock Pit (for eye wash, emergency shower, and water spillage from truck filling)	Lump Sum	1	\$ 3,500.00
3.15	Septic Tank and piping, heat trace	Lump Sum	1	\$ 5,000.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C4: Option 3 - Water Supply, Treatment and Distribution Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Water Supply Works (includes mob/demob)</u>			
1.1	New back-up well (KFN-N)	Lump Sum	1	\$ 52,550.00
1.2	Connection of new backup well (KFN-N)	Lump Sum	1	\$ 50,000.00
1.3	Connection to KFN-K	Lump Sum	1	\$ 50,000.00
1.4	Dataloggers on Supply Wells (installed)	Lump Sum	2	\$ 1,500.00
<u>2.0</u>	<u>Civil Works</u>			
2.1	Mob/demob	Lump Sum	1	\$ 30,000.00
2.2	Clearing, Grubbing, Stripping, Access Road Construction	Lump Sum	1	\$ 35,000.00
2.3	Sub-excavation and base preparation for water treatment building	m3	1244	\$ 30.00
2.4	Monolithic concrete slab on grade for water treatment building (130 mm thick)	Lump Sum	1	\$ 60,000.00
2.5	Concrete Driveway and Sidewalks	Lump Sum	1	\$ 20,000.00
2.6	Drainage	Lump Sum	1	\$ 2,000.00
2.7	Distribution (Trenching, Backfilling, Piping)	m	1600	\$ 150.00
<u>3.0</u>	<u>Mechanical and Electrical Water Treatment Works</u>			
3.1	Mob/demob	Lump Sum	1	\$ 30,000.00
3.2	Provision of Power to Site	Lump Sum	1	\$ 18,000.00
3.2	Water Treatment System	Lump Sum	1	\$ 140,000.00
3.3	CSA upgrade to I&C	Lump Sum	1	\$ 10,000.00
3.4	Water Storage Tanks	Lump Sum	1	\$ 65,000.00
3.5	Inline mixer	Lump Sum	1	\$ 750.00
3.6	Treatment and storage buildings	m2	185	\$ 1,500.00
3.7	Interconnecting piping	Lump Sum	1	\$ 1,000.00
3.8	Transfer pump with redundant unit	Lump Sum	1	\$ 7,500.00
3.9	Instrumentation and control	Lump Sum	1	\$ 2,500.00
3.10	Mechanical Systems	Lump Sum	1	\$ 500.00
3.11	Computer /SCADA / Printer	Lump Sum	1	\$ 5,000.00
3.12	Electrical interconnection	Lump Sum	1	\$ 7,500.00
3.13	Shower Eyewash	Lump Sum	1	\$ 2,000.00
3.14	Rock Pit (for eye wash, emergency shower, and water spillage from truck filling)	Lump Sum	1	\$ 3,500.00
3.15	Septic Tank and piping, heat trace	Lump Sum	1	\$ 5,000.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C5: Option 1 - Geoexchange Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<i>Earth Coupling Works</i>			
1.1	Downhole heat exchange piping	m	400	\$ 16.80
1.2	Antifreeze fluid	m ³	0.6	\$ 630.00
<u>2.0</u>	<i>Distribution System and Piping Works</i>			
2.1	Pre-insulated main (supply + return)	m	45	\$ 130.00
2.2	Trenching and backfilling	m	0	\$ 60.00
<u>3.0</u>	<i>Heat Pumps and Mechanical Works</i>	kW	15	\$ 3,080.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C6: Option 2a - Geexchange Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Earth Coupling Works</u>			
1.1	Downhole heat exchange piping	m	400	\$ 16.80
1.2	Antifreeze fluid	m3	0.6	\$ 630.00
<u>2.0</u>	<u>Distribution System and Piping Works</u>			
2.1	Pre-insulated main (supply + return)	m	40	\$ 130.00
2.2	Trenching and backfilling	m	0	\$ 60.00
2.3	Shallow injection well (KFN-O)	Lump Sum	1	\$ 99,900.00
2.4	Shallow injection well connection (KFN-O)	Lump Sum	1	\$ 50,000.00
<u>3.0</u>	<u>Heat Pumps and Mechanical Works</u>			
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C7: Option 2b - Geexchange Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Earth Coupling Works</u>			
1.3	Submersible well pump	kW	0.4	\$ 2,800.00
1.4	Well pump house	lump	0	\$ 21,000.00
1.5	Surface plate-type heat exchanger(s)	kW	73	\$ 21.00
<u>2.0</u>	<u>Distribution System and Piping Works</u>			
2.1	Pre-insulated main (supply + return)	m	1640	\$ 100.00
2.2	Pre-insulated branches (supply + return)	m	30	\$ 182.00
2.3	Trenching and backfilling	m	0	\$ 60.00
2.4	Shallow injection well (KFN-O)	Lump Sum	1	\$ 99,900.00
2.5	Shallow injection well connection (KFN-O)	Lump Sum	1	\$ 50,000.00
<u>3.0</u>	<u>Heat Pumps and Mechanical Works</u>	kW	73	\$ 3,080.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C8: Option 3 - Geoexchange Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	<u>Earth Coupling Works</u>			
1.3	Submersible well pump	kW	2.4	\$ 2,800.00
1.4	Well pump house	lump	1	\$ 21,000.00
1.5	Surface plate-type heat exchanger(s)	kW	73	\$ 21.00
<u>2.0</u>	<u>Distribution System and Piping Works</u>			
2.1	Pre-insulated main (supply + return)	m	1640	\$ 100.00
2.2	Pre-insulated branches (supply + return)	m	120	\$ 182.00
2.3	Trenching and backfilling	m	120	\$ 60.00
2.4	Deep injection well (KFN-P)	lump	1	\$ 714,400.00
2.5	Deep injection well connection (KFN-P)	Lump Sum	1	\$ 50,000.00
<u>3.0</u>	<u>Heat Pumps and Mechanical Works</u>	kW	410	\$ 3,080.00
	Sub-Total			
	Engineering (20 %), (rounded up to nearest thousand)			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C9: Option 1 Additional Investigations and Consulting Services Class D Capital Cost Estimat

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	Topographic survey	Lump Sum	1	\$ 2,000.00
<u>2.0</u>	Designated office level assessment under YESAA	Lump Sum	1	\$ 10,000.00
<u>3.0</u>	<i>Permafrost investigation drilling</i>			
3.1	Drilling company	Lump Sum	1	\$ 12,000.00
3.2	EBA oversight	Lump Sum	1	\$ 8,000.00
3.3	EBA reporting	Lump Sum	1	\$ 5,000.00
<u>4.0</u>	<i>Hydrogeological well testing</i>			
4.1	Drilling company	Lump Sum	1	\$ 2,500.00
4.2	EBA oversight	Lump Sum	1	\$ 5,000.00
4.3	EBA reporting	Lump Sum	0	\$ 5,000.00
4.4	Analytical	Lump Sum	0	\$ 1,500.00
	Sub-Total			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C10: Option 2a Additional Investigations and Consulting Services Class D Capital Cost Estir

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	Topographic survey	Lump Sum	1	\$ 8,000.00
<u>2.0</u>	Designated office level assessment under YESAA	Lump Sum	1	\$ 10,000.00
<u>3.0</u>	Type B water license application	Lump Sum	1	\$ 50,000.00
<u>4.0</u>	<i>Permafrost investigation drilling</i>			
4.1	Drilling company	Lump Sum	1	\$ 35,000.00
4.2	EBA oversight	Lump Sum	1	\$ 24,000.00
4.3	EBA reporting	Lump Sum	1	\$ 8,000.00
<u>5.0</u>	<i>Hydrogeological well testing</i>			
5.1	Drilling company	Lump Sum	1	\$ 15,000.00
5.2	EBA oversight	Lump Sum	1	\$ 7,000.00
5.3	EBA reporting	Lump Sum	1	\$ 8,000.00
5.4	Analytical	Lump Sum	1	\$ 3,000.00
	Sub-Total			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C11: Option 2b Additional Investigations and Consulting Services Class D Capital Cost Estin

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	Topographic survey	Lump Sum	1	\$ 8,000.00
<u>2.0</u>	Designated office level assessment under YESAA	Lump Sum	1	\$ 10,000.00
<u>3.0</u>	Type B water license application	Lump Sum	1	\$ 50,000.00
<u>4.0</u>	<i>Permafrost investigation drilling</i>			
4.1	Drilling company	Lump Sum	1	\$ 35,000.00
4.2	EBA oversight	Lump Sum	1	\$ 24,000.00
4.3	EBA reporting	Lump Sum	1	\$ 8,000.00
<u>5.0</u>	<i>Hydrogeological well testing</i>			
5.1	Drilling company	Lump Sum	1	\$ 15,000.00
5.2	EBA oversight	Lump Sum	1	\$ 7,000.00
5.3	EBA reporting	Lump Sum	1	\$ 8,000.00
5.4	Analytical	Lump Sum	1	\$ 3,000.00
	Sub-Total			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			

Table C12: Option 3 Additional Investigations and Consulting Services Class D Capital Cost Estimate

Item Number	Item	Unit	Quantity	Unit Cost
<u>1.0</u>	Topographic survey	Lump Sum	1	\$ 8,000.00
<u>2.0</u>	Designated office level assessment under YESAA	Lump Sum	1	\$ 10,000.00
<u>3.0</u>	Type B water license application	Lump Sum	1	\$ 50,000.00
<u>4.0</u>	<i>Geotechnical/Permafrost investigation drilling</i>			
4.1	Drilling company	Lump Sum	1	\$ 35,000.00
4.2	EBA oversight	Lump Sum	1	\$ 24,000.00
4.3	EBA reporting	Lump Sum	1	\$ 8,000.00
<u>5.0</u>	<i>Hydrogeological well testing</i>			
5.1	Well Thaw and Pumping Tests	Lump Sum	1	\$ 20,000.00
5.2	EBA oversight	Lump Sum	1	\$ 10,000.00
5.3	EBA reporting	Lump Sum	1	\$ 8,000.00
5.4	Analytical	Lump Sum	1	\$ 3,000.00
	Sub-Total			
	Contingency (20 %), (rounded up to nearest thousand)			
	Total (rounded up to nearest thousand)			