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Yukon Government
Community Services - Lands Management Branch
Box 2703 - Whitehorse, Yukon - Y1A 2C6

September 5th, 2019

Attention: Mr.Kevin Fisher, Project Manager, Rural Land Development

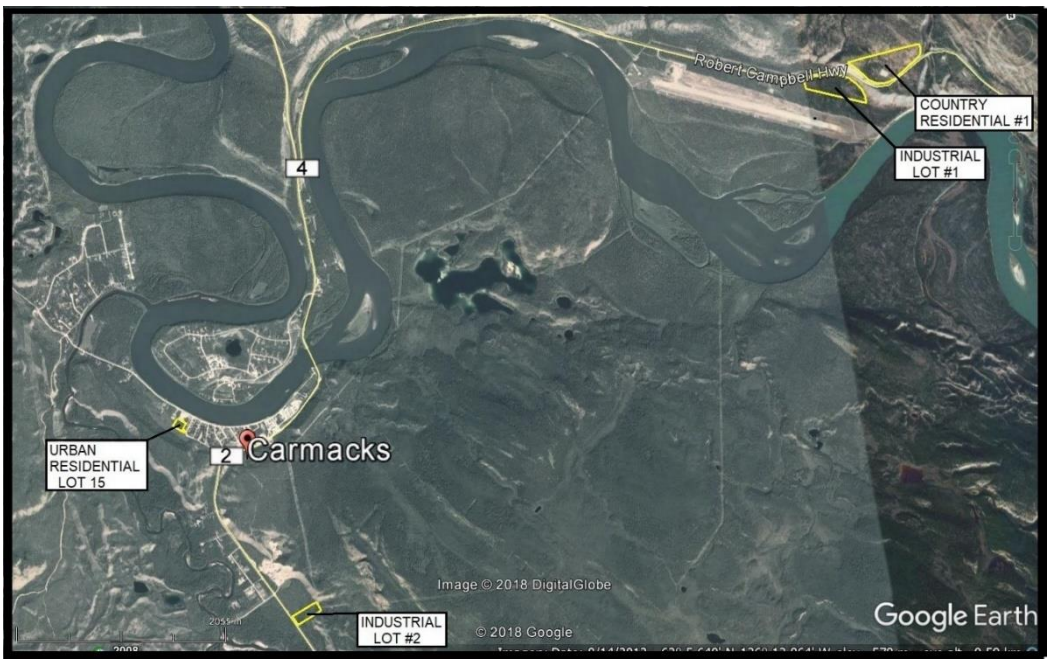
Re: SOA# 2017/2018-2753
Geotechnical Evaluations
Various Lot Developments - Preliminary Findings
Carmacks, Yukon - 2019

Dear Mr.Fisher;

1.0 INTRODUCTION

As per your request, we have prepared the following letter report to present our preliminary findings relative to the above noted project considering that variable subsurface conditions were encountered during our recent field work programs.

As you're aware, the purpose of our geotechnical evaluations was to characterize the subsurface conditions which may be encountered at four (4) sites located in Carmacks, Yukon and formulate geotechnical recommendations to assist in foundation design and lot development where development is deemed feasible. The locations of these sites have been illustrated below for reference purposes.



Our preliminary findings presented herein are based upon data which has been collated to date. Specifically, this data was comprised of our field soil logs, field notes and photos, topographical maps and laboratory analysis which has been completed to date. It should be emphasized that our findings are preliminary in nature as some laboratory results are still pending and as compilation of the soil logs has not yet been completed.

2.0 METHODOLOGY

Our firm conducted both field and laboratory work programs to retain information regarding the respective sites.

The field work program involved conducting site reconnaissance, test pit and auger drilling programs. The site reconnaissance was conducted by the undersigned and was comprised of traversing the sites to note terrain features and layout potential test pit and borehole locations. The test pit program was comprised of excavating a series of test pits at each of the sites utilizing a *Bobcat E63* mini-excavator. The test pits were excavated by our sub-contractor *Yellow Truck Excavating Inc.* and typically attained depths of ~ 3 meters. The drilling program was comprised of advancing a series of 150 mm Ø solid-stem boreholes and 200 mm Ø hollow-stem boreholes utilizing a CME-75 drill mounted on a 5500 series 4 wheel-drive GMC truck. The boreholes were drilled by our sub-contrator *Donjek Drilling*. The drilling program was limited to the Urban Lot #15 and Country Residential sites as access to the other sites was restricted due to the presence of forests. While the depths of borehole advancement varied, they typically attained depths in the order of 6 meters.

The total number of test pits and boreholes which were excavated/drilled is as follows;

Site	***Number of Test Pits***	***Number of Boreholes***
Country Residential	4	6
Urban Lot #15	3	2
Industrial #1	7	0
Industrial #2	3	0

Following completion of the field work programs, our firm and sub-consultant *Golder Associates* conducted a laboratory work program.

The analysis was comprised of;

Description of Analysis	Number of Samples			
	Country Residential	Urban Lot #15	Industrial #1	Industrial #2
moisture content (ASTM D2216-92)	69	29	34	9
grain size distribution (ASTM D422-633)	24	12	13	4
hydrometer (ASTM D422-633)	3	1	2	1
Atterberg limit (ASTM D4318-10)	3	3	2	1
sulphate content (CSA A23.1-3C)	1	1	1	1

While our firm completed the moisture content and grain size distribution analysis, our sub-consultants results (of the hydrometer, Atterberg & sulphate analysis) are pending.

3.0 PRELIMINARY DEVELOPMENT POTENTIAL

In brief, we have compiled a site plan for each of the four (4) sites to illustrate regions where the anticipated subsurface conditions will either be suitable or unsuitable relative to lot development utilizing conventional construction methodologies. Specifically, it's understood lot development would generally be comprised of site grading, road and building construction along with subsurface utility and septic system installations. These suitable/unsuitable regions were differentiated within the individual site plans as follows;

 - Unsuitable Regions

 - Suitable Regions

3.1 Proposed Country Residential Subdivision #1

As much of the east side of the study area (beyond the municipal limits) harbors shallow bedrock, we have limited our discussions to the western portions of the site (within the municipal boundaries) where lot development will be more feasible. Additional site-specific assessments would be required to further evaluate the suitability of the region located east of the municipal boundary.

Soil Conditions

The subsurface soils encountered within regions of the site which were deemed to be suitable were generally comprised of a series of interbedded sandy silts and silty sands which contained varying amounts of gravel. At some locations, these soils overlay sandy gravel deposits or bedrock. While the silts were generally non-plastic, some of these fine-grained deposits may be plastic as will be determined through Atterberg limit analysis. The average moisture contents of the sandy silts to silty sands was noted to be 4.2 % by weight (but varied between 1.7 and 15.9 %), indicating generally damp soil conditions. Based upon SPT N-values which were obtained during drilling, the relative density of these soils was initially noted to be compact but decreased becoming loose beyond a depth of ~3.5 meters.

These deposits were generally overlain with a thin veneer of surficial organics, volcanic ash and oxidized silt deposits which typically measured between 0.6 to 0.9 meters thick.

Bedrock

The site is underlain with bedrock. The terrain in steeper regions are bedrock controlled and so the northern portions of the site will not be suitable for development. The depth of bedrock in these regions is expected to be shallow (generally < 2 meters) as was evidenced in test pit TP 1-19 where bedrock was encountered at a depth of 1.5 meters. Borehole BH 1-19 also encountered refusal due to bedrock at a slightly greater depth of 3.96 meters. The greater depth was attributed to advancing the borehole in what was identified as a local gully.

Regionally, bedrock may also be present in regions where shallow grades prevail as refusal was encountered at a depth of 5.49 meters in borehole BH 4-19 and as bedrock outcrops were intermittently visible along the exposed southern embankment. While the presence of bedrock could not be verified in borehole BH 4-19, the sandy gravel samples retained below a depth of 4.27 meters contained fractured gravels, which with hard grindy drilling, may be an indication of potentially regolithic soils.

Groundwater

While groundwater was not encountered, a monitoring well was installed in borehole BH 3-19 to a depth of~6.5 meters such that future observations could be made.

Permafrost

There was no indication permafrost would be present at the site.

Development Potential

The site and subsurface conditions which were encountered will allow for development in regions which were identified as having a suitable development potential. However, if shallow bedrock is encountered, additional consideration will be required relative to building foundation and road construction.

Geotechnical setbacks (which range between 15 to 30 meters in width) will need to be observed relative to steep slopes which are located within and adjacent to the site as an increased hazard potential may exist in these areas. While building construction should not be allowed, the construction of roads within these setback areas could be considered.

Septic Field Suitability

While the results of laboratory analysis are pending, we anticipate the sandy silt to silty sand soils will generally be suitable to allow for septic field construction. However, caution will need to be exercised during septic field placement as the presence of shallow bedrock may restrict site development. As such, site-specific assessments should be conducted prior to individual lot development to verify the suitability of any potential septic field location relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems* through percolation testing and test pit exploration.

Surface Drainage

The surficial soils which were encountered within the study area are generally free draining and so site drainage can be managed through the use of standard ditches/swales and site grading. However, there were several local drainage courses (illustrated in Figure 1), where additional consideration may be required as these areas will harbor an increased potential for excess run-off considering the topography of the terrain. While we did not observe any signs of erosion in these regions, the allocation of easements should be considered unless other measures are otherwise undertaken.

Additional Consideration

Additional consideration may be required relative to building foundation design and construction given the presence of the loose soil deposits which were encountered below a depth of ~3.5 meters.

As the central portions of the site harbors the remnants of a granular quarry which does not appear to have been remediated to current standards, additional work will be required to predominately grade the slope located on its north-east side. Consideration should be given to routing the subdivision road through this central location as conceptually illustrated in Figure

1. While the quarry operations resulted in creating a depression, there did not appear to be any evidence of standing water within the area as the exposed deposits within the quarry are free draining.

3.2 Proposed Urban Lot #15

The majority of this site would be considered unsuitable (Areas B-1 through B-3) relative to conventional site development practices. This is due to the presence of soft compressible fine-grained soils which cover the site, shallow groundwater and the possible presence of permafrost. However, the site could be improved through progressive excavation/backfill operations such that all the deleterious soils are replaced with imported granular fills. The intent would be to remove the deleterious organic and fine-grained soil deposits (and potential permafrost) such that imported fill can be placed upon the underlying gravel deposit (located ~2 meters below the prevailing grades). The use of a geotextile fabric which underlies the imported granular fills will likely be required.

While consideration could be given to limiting excavation/backfill operations to individual building site and road locations, the removal of the deleterious materials from the entire site (Areas A & B1-B3) will allow for greater flexibility with respect to site development and increased housing density as building and road load envelopes are less likely to be compromised.

Soil Conditions

The subsurface soils encountered within the site were comprised of fine-grained silts which contained varying amounts of clay, sand and gravel. Some of these fine-grained deposits are likely plastic (as will be determined through Atterberg limit analysis). While poor in general, the conditions of the soils encountered within regions which have been deemed to be unsuitable will progressively decrease between regions identified as B-1, B-2 and B-3. While similar fine-grained deposits will likely be encountered in Area A, the soils in this region were considered to be more competent relative to those in Areas B-1 through B-3. On average, these fine-grained deposits extended to a depth of approximately 1.96 meters below the prevailing grades. The average moisture contents of the fine-grained deposits was noted to be 22.4 % by weight (but varied between 19.3 and 24.6 %), indicating generally wet soil conditions. Based upon the SPT N-value which was obtained during drilling, the relative density of these soils (above the groundwater table) was noted to be firm. These soils will likely be soft where encountered below the groundwater table. A test pit excavated by *EBA Engineering Consultants Ltd.* in 1995 (File No.0201-11730) encountered ice-rich permafrost within the fine-grained deposits located in the south-eastern portion of the site.

A granular deposit which was predominately comprised of sandy gravel which contained some silt was located below the fine-grained deposits. In some areas, the soils within this deposit were comprised of silty sandy gravels to gravelly sands with a trace of silt. The deposit contained cobble (to potentially boulder) sized materials beyond an average depth of 5.6 meters (although these materials could be encountered at shallower depths). The average moisture content of the granular deposits was noted to be 9.6 % by weight (but varied between 4.2 and 14.5 %), indicating generally wet soil conditions. Based upon the SPT N-value which was obtained during drilling at a relative depth of ~2.7 meters, the relative density of these soils was noted to be compact. It was not possible to progressively conduct SPT sampling beyond this depth due to the influx of fine sands during centerline plug withdrawal. While these granular deposits were underlain with silty sands at a depth of ~ 6.4 meters in borehole BH 1-19, the granular deposit was encountered to the (7.62 m) depth of borehole termination in borehole BH 2-19.

The above noted deposits were overlain by wet organic silt and organic deposits which measured up to 300 mm thick, but which may be thicker in other regions of the site.

Approximately 1.5 to 1.8 meters of fill was encountered on the eastern periphery of the site. These fills were classified as silty sandy gravels (which contained up to 34.3% of fines by weight).

Bedrock

There was no indication of bedrock in any of the test pits or boreholes which were excavated/drilled.

Groundwater

Groundwater was encountered in each of the test pits and boreholes at depths which ranged between 1.2 (TP 1-19) to 1.5 (BH 1-19) meters.

A monitoring well was installed in borehole BH 2-19 to a depth of ~5.8 meters below the prevailing ground surface to allow for future groundwater observations. A measurement of the well revealed groundwater was located ~ 1.5 meters below the prevailing ground surface at the well location. The groundwater was encountered at progressively shallower depths towards the southern limits of the site where a poorly drained (swamp) region is located.

Information retained from the *EBA* report suggests groundwater elevations may be lower during the winter months.

Permafrost

While we did not encounter permafrost in any of our test pits or boreholes, ice-rich permafrost was encountered during the test pit program which was conducted by *EBA Engineering Consultants Ltd.* during their 1995 study. It's possible permafrost may still be present in regions of the site which are heavily shaded and/or else insulated by organic cover.

Development Potential

The site and subsurface conditions which were encountered will not allow for development of the site without conducting excavation/backfill operations to replace the deleterious (and fill) materials which are located above the granular deposits. While the native deleterious organic and fine-grained deposits extended to depths ~ 2 meters below the prevailing grades, there may be regions where thicker deposits are encountered as a result of channel infilling. The resulting excavations would need to be progressively backfilled to design elevations utilizing approved granular backfill. If groundwater is encountered at the base of the excavation(s), the initial lifts of backfill will need to be comprised of an approved drain/blast rock which is placed upon geotextile fabric.

Final design elevations will need to be carefully considered relative to the 1:200-year flood event outlined in the *Carmacks - Official Community Plan (OCP)*. As such, once the deleterious soils are removed from the site, the thickness of backfill will likely need to be greater than 2 meters.

Subsurface Utility Installations

The granular deposits should allow for the installation of subsurface utilities. However, additional consideration will be required as the presence of shallow groundwater will require construction dewatering techniques.

Surface Drainage

The surficial soils which were encountered at the site are poorly drained and standing water was encountered throughout the southern realms of the site.

As development of the site will require the need to import backfill, the finished grades will need to be designed in order to ensure there is adequate surface drainage through the use of ditches/swales and site grading.

Additional Consideration

As a riparian area may be located near the southern realms of the site, an environmental assessment should be conducted by qualified personnel to identify any potential setbacks and potential measures to mitigate the impacts of lot development.

3.3 Proposed Industrial Subdivision #1

In general, the site and subsurface conditions which were encountered will allow for unfettered site development in regions deemed to be suitable. However, additional consideration will be required to mitigate the potential hazards related to the presence of local steep slopes and regional drainage courses.

Soil Conditions

The subsurface soils were predominately comprised of sandy silts which were interbedded with sands to silty sands. At some locations (TP 3-19, TP 4-19 & TP 6-19), these soils overlay sandy gravel deposits which contained up to a trace of silt and cobbles in size to 100 mm. The sandy silts which were encountered were predominately non-plastic. The average moisture content of the sandy silt deposits was noted to be 6.4 % by weight (but varied between 3.1 and 12.5 %), indicating generally damp soil conditions. Based upon our observations of the test pit sidewalls, the relative density of these soils was noted to be firm/compact.

These deposits were generally overlain with a veneer of surficial organics, volcanic ash and oxidized silt deposits which typically measured between 0.5 to 0.9 meters thick.

A series of grubbing piles which are remnants from construction of Campbell Highway #4 are located along the north-western periphery of the site as illustrated in Figure 1.

Bedrock

There was no indication of bedrock in any of the test pits which were excavated.

Groundwater

While a trace of oxidation was occasionally noted within the interbedded soil deposits, there was otherwise no indication of groundwater in any of the test pits which were excavated.

Permafrost

There was no indication permafrost would be present at the site.

Development Potential

The site and subsurface conditions which were encountered will allow for development in regions which were identified as having a suitable development potential. While the results of laboratory analysis are pending, we anticipate the sandy silt to silty sand soils will generally be suitable to allow for septic field construction. However, in regions where sandy gravels are present at the depth of the accepting soils, the percolation rates may be too high and so there may be the need to relocate the field or else import suitable bedding sands to reduce the rate of infiltration to acceptable limits.

A geotechnical setback (30 meters in width) will need to be observed relative to the steep slope which is located along the north-eastern periphery of the site. While building construction should not be allowed within the setback limits, the construction of roads within these areas could be considered.

Septic Field Suitability

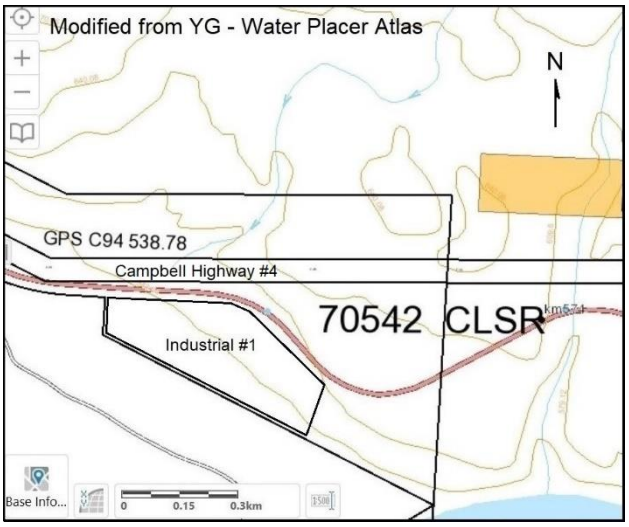
While the results of laboratory analysis are pending, we anticipate the interbedded sandy silt deposits will generally be suitable to allow for septic field construction. Site-specific assessments should be conducted prior to individual lot development to verify the suitability of any potential septic field location relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems* through percolation testing and test pit exploration.

Surface Drainage

The surficial soils which were encountered within the study area are generally free draining and so site drainage can be managed through the use of standard ditches/swales and site grading.

While we did not observe any signs of recent erosion which would be attributed to surface waters (other than regions associated with the highway drainage flume and embankment erosion gullies), silts with interbedded rootlets and organics were observed in test pit TP 7-19 to a depth of 1.6 meters. The interbedded nature of rootlets and organics (which were noted at depths of 1.0, 1.3 and 1.6 meters) suggests this region has been subjected to repeated flood events which may have originated from glaciofluvial complex deposits located upslope of the site (north of the Robert Campbell Highway #4).

While the *YG – Water Placer Atlas* map denoted the location of this drainage course (as noted in the figure – right), there was no sign of free-flowing water during our evaluation.



Currently the existing highway effectively serves as a protective dam relative to the drainage course which is located north of the highway (across from Area B) as there are no highway culverts at this location.

Additional Consideration

Additional consideration may be required up-gradient of the central regions of the site (Area B) and at the base of the slope located along the north-eastern side as these regions may harbor an increased potential for excess run-off originating from regions located upslope of the site.

The discharge flume and erosion gullies located on the highway embankment (as noted in Figure 1) should be rehabilitated to reduce the potential for continued slope erosion.

3.4 Proposed Industrial Subdivision #2

The development potential of this site varies. In general, the eastern realms (Area C) of the site will not be suitable to allow for lot development due to the presence of ice-rich permafrost. The thawed soil conditions encountered in the western realms (Area A) suggests this region may be suitable to allow for development, however, shallow groundwater was encountered in this area and so additional consideration would be required relative to septic field suitability. The conditions with the central regions (Area B) of the site are unknown but likely deteriorate as one progresses east towards higher elevations.

Soil Conditions

The subsurface soils encountered within the site varied. Test pits TP 1-19 and TP 2-19 each encountered permafrost which was comprised of black organic silts which were overlain with approximately 100 mm of volcanic ash and 250 mm of moss and rootlets. The depth of test pit excavation was limited to 0.7 and 0.5 meters, respectively, due to the frozen nature of the deposits. By contrast, the soil which were encountered in test pit TP 3-19 was comprised of sandy and (potentially clayey) silts which overlay a sandy silty gravel deposit which was encountered at a depth of 2.9 meters below the ground surface. Saturated soil conditions and

sidewall slough which were encountered below a depth of 2.0 meters suggests the presence of shallow groundwater. These soils were overlain with a 0.5-meter thick layer of organics, surficial silts and volcanic ash. The average moisture contents of the fine-grained deposits in test pit TP 3-19 varied between 11.0 and 28.4 %, indicating moist to wet soil conditions. The sandy silty gravels had a moisture content of 12.8 % and fines content of 18.5 %.

A series of grubbing piles which are remnants from construction of Klondike Highway #2 are located along the western periphery of the site (as illustrated in Figure 1).

Bedrock

There was no indication of bedrock in any of the test pits which were excavated.

Groundwater

While not directly observed, groundwater is likely present in the region of test pit TP 3-19 at a depth of ~2.0 meters.

Permafrost

Permafrost was encountered in test pits TP 1-19 and TP 2-19 immediately below a 250 mm thick layer of moss and rootlets. The frozen soils in test pits TP 1-19 and TP 2-19 were classified as being well bonded with no excess ice (Nbn – moisture content = 210%) and as having visible ice crystals in size to 2 mm (Vx - moisture content = 390%), respectively, in accordance with the *National Research Council* classification of frozen soils.

Development Potential

The development potential of the site is limited. While thawed soil conditions were present in its western realms near the Klondike Highway right-of-way, the presence of the steep slope located within the sites eastern realms limits the amount of sunlight available to the remainder of the site, hence the presence of the permafrost which is located in Area C. The extent to which the shade may have promoted permafrost formation in Area B is unknown however portions of this region exhibits hummocky terrain and areas of thick organic moss cover which may be an indication of permafrost.

Septic Field Suitability

While the results of the laboratory analysis are pending, we anticipate the sandy silt and (clayey) silt deposits encountered in test pit TP 3-19 may not be suitable to allow for septic field construction due to their plastic nature. In addition, the presence of shallow groundwater may further restrict septic field construction. As such, site-specific assessments should be conducted prior to individual lot development to verify the suitability of any potential septic

field location relative to *Yukon Health and Social Services – Design Specifications for Sewage Disposal Systems* through percolation testing and test pit exploration.

Insulated holding tanks may be required in regions where the soil types are deemed unsuitable for use as accepting soils. Alternately, the use of raised septic fields may allow for greater flexibility relative to utilizing the soil types which are encountered.

Surface Drainage

Surface drainage within the site is poorly defined as hummocky topography prevails in Area C and portions of Area B. In general, surface waters flow to the west from regions of higher elevation.

Future development of the site will need to control surface drainage through the use of ditches/swales and site grading.

Additional Consideration

Additional geotechnical evaluation would be required utilizing a heavy excavator (or drill) to verify the composition and conditions of soils which are present in Area B and the eastern portions of Area A as the thickness of the insulating organic cover and amount of sunlight varies in these areas and so permafrost may be present.

If development of Areas A and/or B is to proceed, then Area C should be explored in greater detail to assess potential development options and verify whether or not the permafrost presents a potential hazard. Area C's proximity to the steep slope will not likely allow for this region to thaw efficiently following removal of its surficial cover.

4.0 LIMITATIONS

While we have provided discussions regarding the anticipated development potential of the respective sites based upon data which has been collated to date, as our findings are preliminary in nature, the information provided herein should be considered accordingly from a project management perspective.

5.0 CLOSURE

Thank you for providing our firm with the opportunity to conduct the above noted work. We intend to provide you with the geotechnical evaluation reports by mid-October once data collation has been completed.

If you should have any questions regarding the information provided herein, kindly feel free to contact the undersigned at your convenience.

Sincerely,

CHILKOOT GEOLOGICAL ENGINEERS LTD.

Tares Dhara, P.Eng.
Senior Geotechnical Engineer

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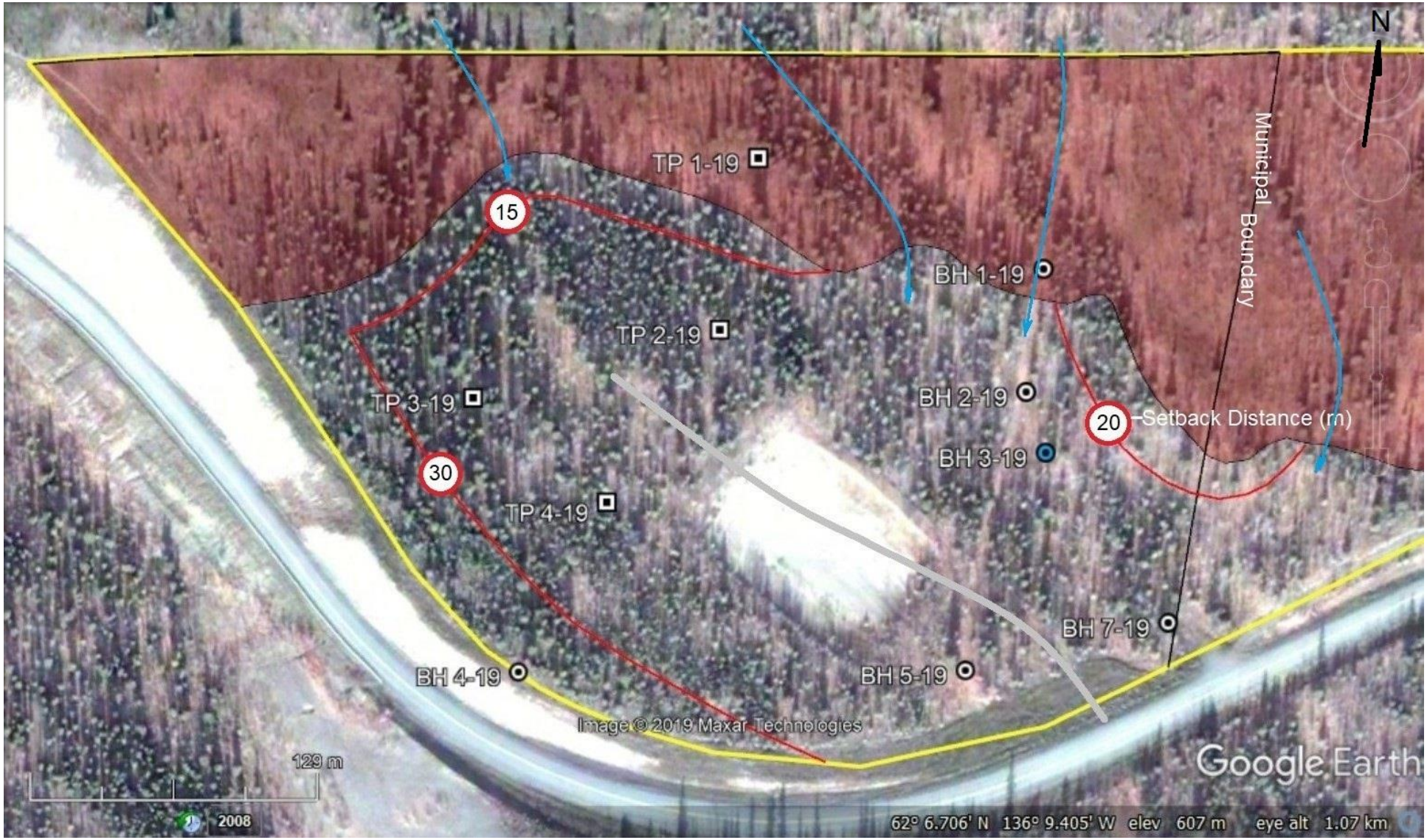
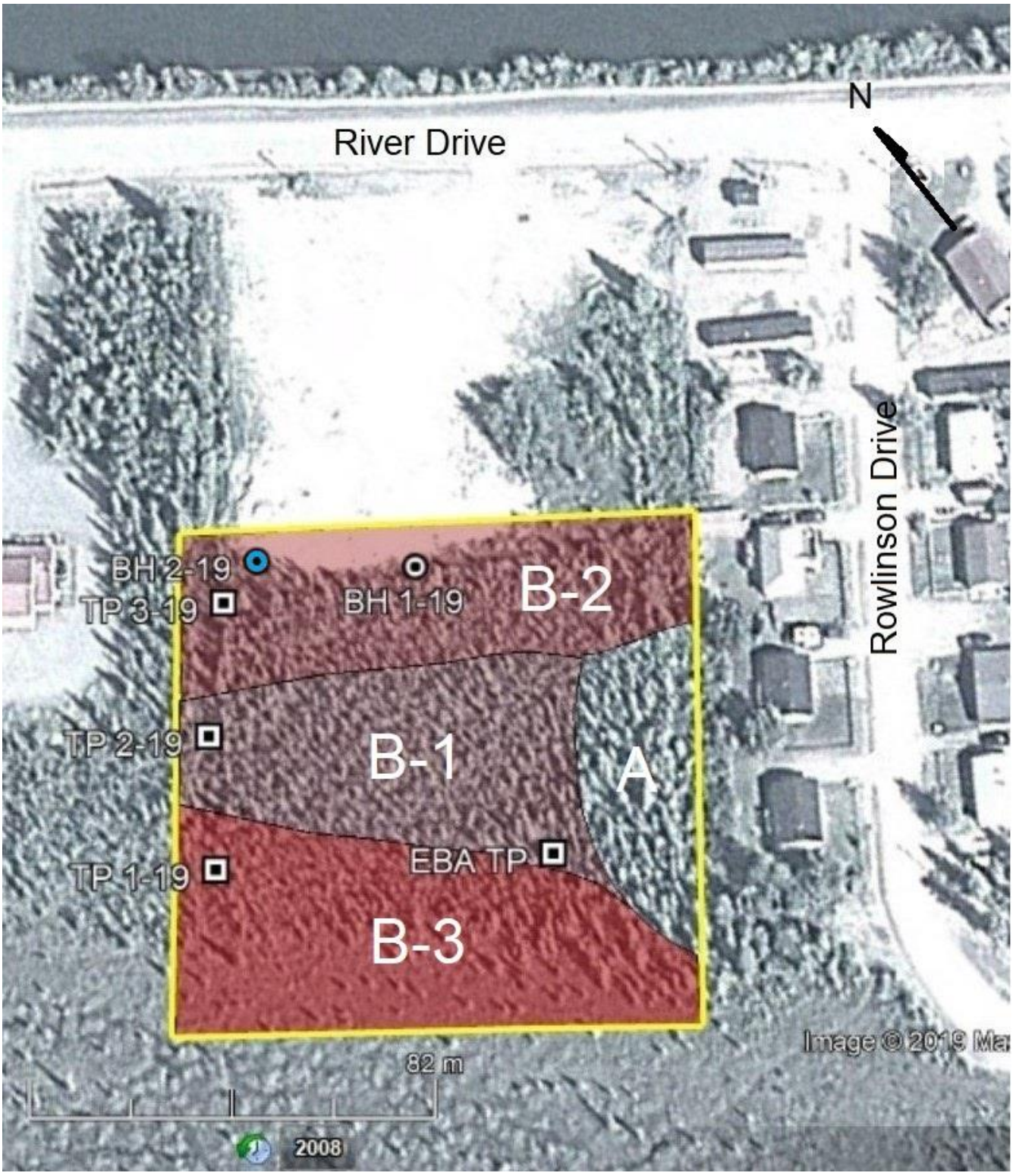
Geotechnical Evaluation
Proposed Country Residential Subdivision (CR#1)
Carmacks, Yukon - 2019
Figure 1 – Development Potential – Preliminary Findings



Based map modified from Google Earth – Not to Scale – Locations are approximate.

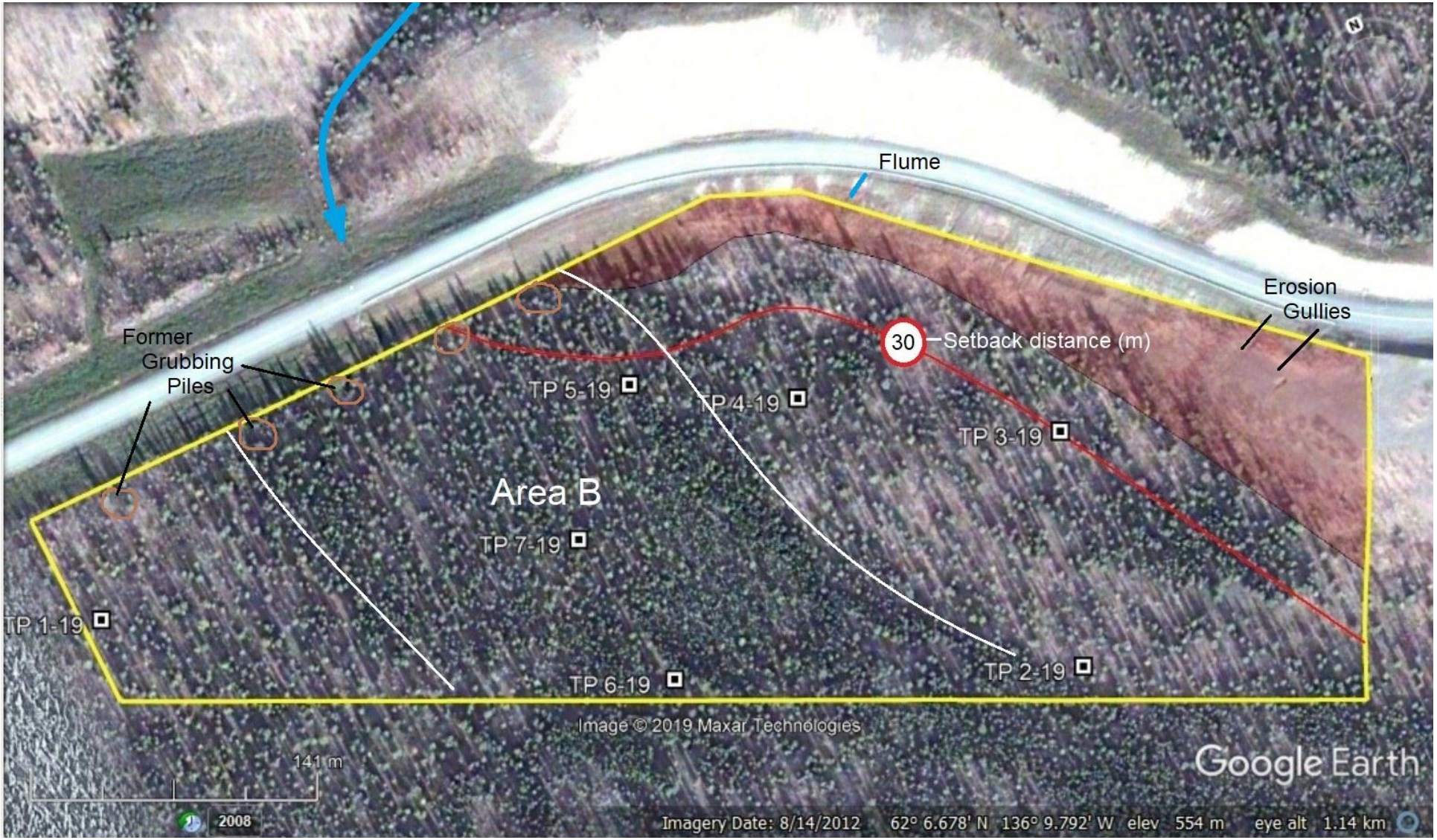
Compiled Aug.30th, 2019 by T.Dhara, P.Eng.

Geotechnical Evaluation
Proposed Urban Lot #15
Carmacks, Yukon - 2019
Figure 1 – Development Potential – Preliminary Findings



Base map from *Google Earth*- Not to Scale – Locations are approximate
Compiled by T.Dhara, P.Eng. - Aug.30th, 2019

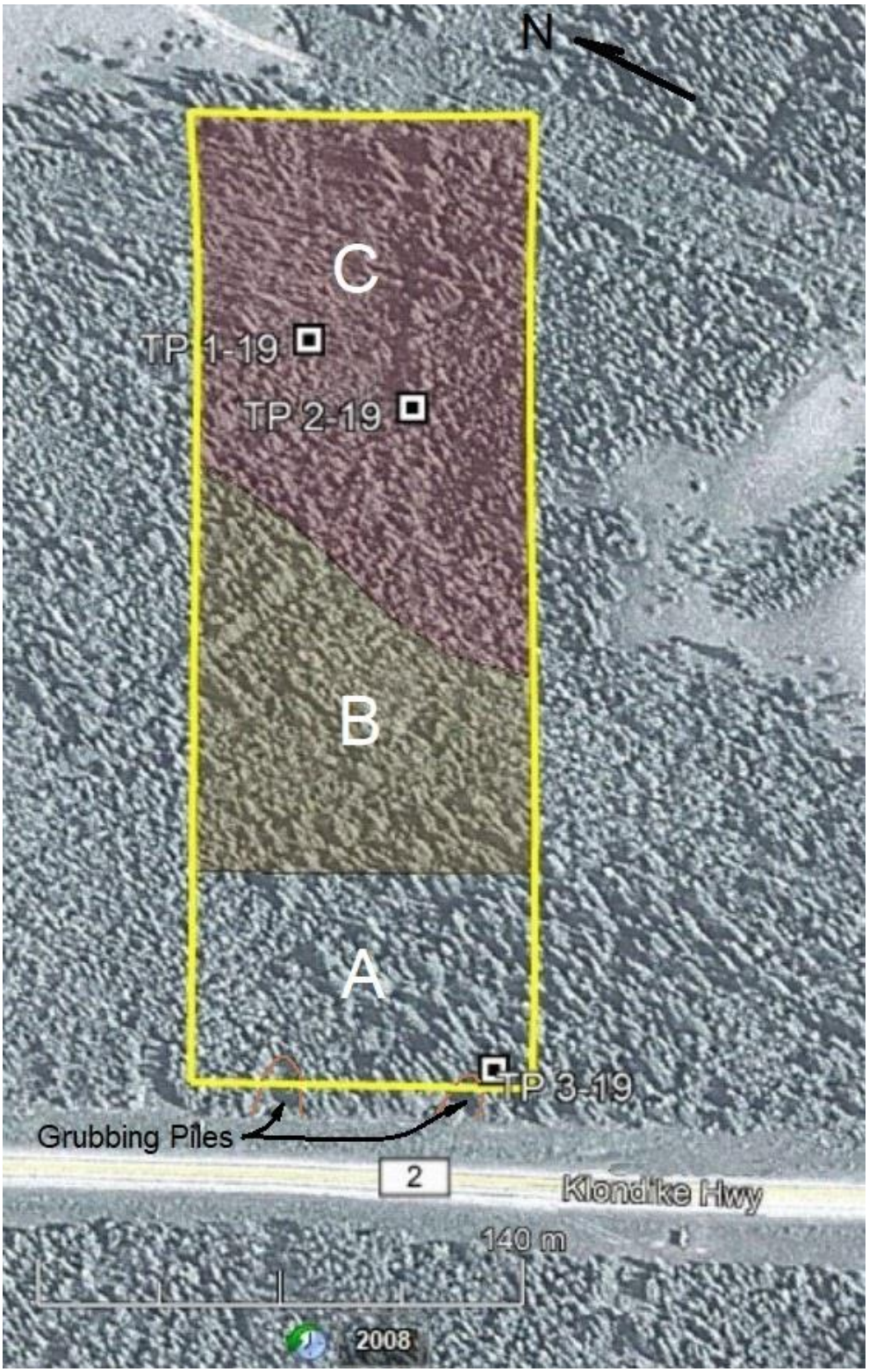
Geotechnical Evaluation
Proposed Industrial Subdivision #1
Carmacks, Yukon - 2019
Figure 1 – Development Potential – Preliminary Findings



Based map modified from Google Earth – Not to Scale – Locations are approximate.

Compiled Aug.30th, 2019 by T.Dhara, P.Eng.

Geotechnical Evaluation
Proposed Industrial Subdivision #2
Carmacks, Yukon - 2019
Figure 1 – Development Potential – Preliminary Findings



Base map from *Google Earth*- Not to Scale – Locations are approximate
Compiled by T.Dhara, P.Eng. - Aug.30th, 2019