Andrea.Kenward

| From: | Kai Woloshyn <kwoloshyn@alexcoresource.com></kwoloshyn@alexcoresource.com> |
|-----------------|----------------------------------------------------------------------------|
| Sent: | Tuesday, January 31, 2017 12:24 PM |
| To: | Andrea.Kenward |
| Subject: | FW: Annual geotech inspection |
| Attachments: | RPT_2016 Bellekeno Annual Geotechnical Inspection_IFU.pdf |
| Follow Up Flag: | Follow up |
| Flag Status: | Flagged |
| Categories: | QML-0009 Keno |

Kai Woloshyn, B.Sc. Senior Environmental Manager Alexco Environmental Group #3 Calcite Business Centre, 151 Industrial Rd., Whitehorse, YT Y1A 2V3 Phone 867-668-6463 ext. 233 | Fax 867-633-4882 | Cell 867-334-3614 www.alexcoresource.com | kwoloshyn@alexcoresource.com

From: Kai Woloshyn
Sent: November-03-16 3:53 PM
To: Julia.Ahlgren@gov.yk.ca; Robert.Holmes@gov.yk.ca
Cc: Brad Thrall
Subject: Annual geotech inspection

Hi Bob and Julia,

As required by clause 13.2 of QML-0009, please find the attached annual geotechnical inspection report.

Kai Woloshyn, B.Sc. Environmental Manager Alexco Resource Corp. #3 Calcite Business Centre, 151 Industrial Rd., Whitehorse, YT Y1A 2V3 Phone 867-668-6463 ext. 233 | Fax 867-633-4882 | Cell 867-334-3614 www.alexcoresource.com | kwoloshyn@alexcoresource.com



October 27, 2016

Alexco Resource Corp. 3 – 151 Industrial Road Whitehorse, YT Y1A 2V3 ISSUED FOR USE FILE: ENG.WARC03152-01 Via Email: kwoloshyn@alexcoresource.com

Attention: Kai Woloshyn – Environmental Manager

Subject: 2016 Annual Geotechnical Inspection – Surface Engineered Earth Structures Bellekeno Mine, Keno City, YT

1.0 INTRODUCTION

Alexco Resource Corp. (Alexco) retained Tetra Tech EBA Inc. (Tetra Tech) to complete the 2016 annual geotechnical inspection of the surface engineered earth structures at the Bellekeno Mine near Keno City, Yukon. Authorization to complete this work was received by way of an Alexco purchase order (PO #17604) dated August 9, 2016. The following structures were identified by Alexco as requiring inspection:

- Potentially acid generating (PAG) waste storage facility
- Bellekeno waste rock pile
- Bellekeno 625 water treatment ponds
- Lightning Creek bridge abutments (Onek Road)
- Lightning Creek bridge abutments (Bellekeno Haul Road)
- Mill water storage pond
- Dry stacked tailings facility (DSTF)

The location of each structure is shown on Figure 1.

2.0 SCOPE OF SERVICES

The following is Tetra Tech's scope of services for the 2016 annual inspection as was presented in the proposal submitted to Alexco on July 7, 2016:

- Complete a visual inspection of the surface engineered earth structures identified by Alexco as requiring
 inspection and collect ground temperature and slope indicator data for the dry stacked tailings facility.
- Prepare an inspection report including the results of the inspection, summary of the stability, integrity, and status
 of all inspected structures, and any recommendations for remedial actions.
- Summarize and interpret the ground temperature and slope indicator data collected for the dry stacked tailings facility.

3.0 INSPECTION SUMMARY AND RECOMMENDATIONS

The 2016 annual inspection was completed by Justin Pigage, P.Eng. on August 18th, 2016. The following sections summarize observations for each structure and provide recommended remedial actions, if necessary. The recommended remedial actions have been separated into critical geotechnical stability concerns and ongoing facility maintenance issues to assist in the prioritization of remedial efforts. Select photographs taken during the inspection are included in the photographs section of this report.

3.1 PAG Waste Facility

The PAG waste storage facility is located south of the Bellekeno portal, as shown on Figure 1. The facility has not been used since mining operations were suspended in winter 2013. As noted in previous inspections, the geonet and geotextile components of the liner system have only been installed in the north half of the facility (Photo 1). If the facility is to be used in the future, the installation of the liner system should be completed as per the original design.

At the time of the inspection, the perimeter berms appeared intact with no visible signs of instability (Photo 2).

3.2 Bellekeno Waste Rock Pile

The Bellekeno waste rock pile forms a portion of the Bellekeno Haul Road and is located north of the Bellekeno portal, as shown on Figure 1. At the time of the inspection the waste rock pile sideslopes appeared intact and stable (Photo 3). No remedial action is required for the Bellekeno waste rock pile at this time.

3.3 Bellekeno 625 Water Treatment Ponds

The Bellekeno 625 water treatment ponds are located north of the Bellekeno portal, as shown on Figure 1. The facility consists of two water treatment ponds that were both operating at the time of the inspection (Photo 4). The primary treatment pond was operating at the discharge invert elevation with a freeboard of 0.5 m below the perimeter berm crest at the time of the inspection. The secondary pond was also operating at the discharge elevation. Freeboard in the secondary pond ranges from about 0.5 m at the south end to about 0.3 m at the north end. Settlement of the north end of the pond has likely caused the diminished freeboard (Photo 5).

Careful examination of the perimeter berms and surrounding ground surface during the inspection did not yield any visual evidence of movement and despite suspected settlement, the liner and perimeter berms appeared intact with no visible signs of distress. Elevation surveys to monitor for settlement of the north end of the pond should be completed monthly during the snow free season. If more settlement occurs, additional geomembrane and fill must be added to restore the design freeboard (0.6 m).

3.4 Lightning Creek Bridge Abutments (Onek Road)

The Lightning Creek bridge on the Onek Road is located east of Keno City, as shown on Figure 1. The bridge is a single span steel structure founded on earth filled timber cribbing abutments. The abutments appeared stable at the time of the inspection. Consistent with previous inspections, some of the rip-rap armouring on the south abutment on the downstream side of the bridge has been displaced exposing the underlying geotextile (Photo 6). The rip-rap should be repaired as part of ongoing site maintenance to prevent erosion.

3.5 Lightning Creek Bridge Abutments (Bellekeno Haul Road)

The Lightning Creek bridge on the Bellekeno Haul Road is located southwest of Keno City, as shown on Figure 1. The bridge is a single span steel structure with a wooden deck founded on earth filled timber cribbing abutments.

The abutments appeared stabled at the time of the inspection and are sufficiently protected from erosion by rip-rap armouring. No remedial action is required for the Lightning Creek bridge on the Bellekeno Haul Road at this time.

3.6 Mill Water Storage Pond

The mill water storage pond is located at the Keno Hill District Mill Site, west of Keno City, as shown on Figure 1. At the time of the inspection the pond was not operating but contained some water, with a freeboard of about 2 m below the perimeter berm crest (Photo 7). The perimeter berms and pond liner appeared intact with no visible signs of instability (Photo 8). No remedial action is required for the mill water storage pond at this time.

3.7 Dry Stacked Tailings Facility

The dry stacked tailings facility (DSTF) is located at the Keno Hill District Mill Site west of Keno City, as shown on Figure 1. No tailings have been placed in the DSTF since mining operations were suspended in winter 2013. The tailings placed to date have been regraded, covered with organic growth medium, and seeded as part of progressive reclamation activities (Photo 9). No visible signs of instability were observed at the time of the inspection and to date, operation and performance of the DSTF has been consistent with the design.

The lower bench of the DSTF has been constructed to the extents of the design footprint and the tailings covered as described above. The toe runoff collection ditch below the facility was designed to collect surface water from the exposed tailings. As part of ongoing progressive reclamation activities, Alexco could consider removing the toe runoff collection ditch to limit the amount of surface water reporting to the mill water storage pond (Photo 10).

3.7.1 Instrumentation

Performance of the DSTF is monitored with compaction testing during tailings placement and regular instrumentation readings. DSTF instrumentation consists of seven ground temperature cables installed to monitor permafrost conditions (six in natural soils adjacent to the DSTF and one through tailings placed within the DSTF footprint), three slope indicators installed to monitor lateral movement of the foundation soils, and one monitoring well installed to the base of the placed tailings in BH39. The locations of installed DSTF instrumentation are shown on Figure 2.

It should be noted that some critical instrumentation located within and adjacent to the DSTF is in need of repair and/or replacement.

3.7.1.1 Background Ground Temperature Readings

Updated ground temperature readings were collected from five of the six ground temperature cables installed in natural soils adjacent to the DSTF during the inspection. Readings were not collected from BH17 as the protective steel casing remains damaged, with the instrument connector wedged out of reach. The protective casing should be repaired or removed to allow for continued instrumentation reading. As indicated on the updated ground temperature profiles included in Appendix B, the slight near surface warming trend observed in previous years has continued. The warming trend appears to be more significant in areas of recent disturbance, such as BH32, indicating it may be the result of disturbance to the insulating vegetative cover during instrumentation installation. Continued regular instrumentation readings are recommended to monitor ground temperature conditions.

3.7.1.2 DSTF Ground Temperature Readings

The ground temperature cable installed in BH40, through the placed tailings and into the foundation soils below the DSTF has been damaged and requires replacement. This is a critical installation needed to confirm design assumptions and provide ongoing temperature monitoring.

3.7.1.3 Slope Indicator Readings

An updated lateral movement profile developed from readings collected from the slope indicator installed in BH36 in natural soils adjacent to the DSTF is included in Appendix C. No significant lateral movement of the foundation soils has been observed in the slope indicator results to date, although it should be noted that readings from BH28 and BH30 have not been possible in recent years as described below.

Readings were not possible in BH30 despite efforts to steam out the blockage at 3.5 m below the ground surface. Inspection of the blockage with a downhole camera indicated that the casing is likely blocked with a large rock or accumulation of surficial soil that inundated the installation. Salvage of the installation is not considered likely, a replacement borehole should be advanced near BH30 the next time a geotechnical drill program is conducted near the DSTF.

Readings were not possible in BH28 as the casing was blocked at 3.7 m below the ground surface. Inspection with a downhole camera confirmed the installation is blocked with ice and requires steaming. Partial ice blockage was likely the cause of the probe derailment experienced during prior reading attempts. At the time of the inspection there was not enough hose available for the steam unit to reach BH28 to remove the ice blockage.

BH28 should be steamed and purged of water. The casing should then be filled using liquid with a depressed freezing point to allow for future readings. Tetra Tech has had success with Envirobind (dust suppressant) and glycol based liquids in permafrost conditions on other sites. We would be pleased to assist with the rehabilitation of the installation, if requested.

3.7.2 Monitoring Well Readings

A water level sounder was used to check for accumulated water at the base of the placed tailings in the DSTF within BH39. At the time of the inspection, moisture was detected but no measureable column of water was observed. The moist condition observed is likely indicative of surface water that infiltrated the placed tailings draining along the top of the liner, as the original facility design intended.

4.0 CONCLUSIONS

The surface engineered earth structures inspected pose no significant risk to the environment or human health and safety in their current condition. The remedial actions recommended in the previous sections are summarized in the following Table 1 for reference.

| Structure | Stability Recommendations | Maintenance Recommendations | |
|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|--|
| PAG Waste Storage Facility | None | Complete liner installation as per the original design if facility is to be used in the future | |
| Bellekeno Waste Rock Pile | None | None | |
| Bellekeno 625 Water Treatment Ponds | Conduct monthly elevation surveys during snow free season of perimeter berm crest of secondary pond to monitor for settlement | Add geomembrane and fill if freeboard decreases to less than 0.3 m | |
| Lightning Creek Bridge Abutments (Onek Road) | None | Repair displaced rip-rap on south abutment (downstream side) | |

Table 1: Summary of Remedial Recommendations

| Structure | Stability Recommendations | Maintenance Recommendations | | |
|-----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|--|--|
| Lightning Creek Bridge Abutments (Bellekeno Haul Road) | None | None | | |
| Mill Water Storage Pond | None | None | | |
| | Advance replacement borehole for BH40 within DSTF and install ground temperature cable | | | |
| Dry Stacked Tailings Facility | Advance replacement borehole for BH30 and install slope indicator Rehabilitate BH28 by steaming, purging, and filling slope indicator casing with liquid suitable for use in permafrost conditions | Continue regular instrumentation readings to monitor DSTF foundation conditions | | |

Table 1: Summary of Remedial Recommendations

5.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of Alexco Resource Corp. and their agents. Tetra Tech EBA Inc. (Tetra Tech) 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 Alexco Resource Corp., 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. Tetra Tech's General Conditions are provided in Appendix A of this report.

6.0 CLOSURE

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

Respectfully submitted, Tetra Tech EBA Inc.



Prepared by: Justin Pigage, P.Eng. Geotechnical Engineer, Arctic Region Direct Line: 867.668.9213 Justin.Pigage@tetratech.com



Reviewed by: J. Richard Trimble, P.Eng., FEC Principal Consultant, Arctic Region Direct Line: 867.668.9216 <u>Richard.Trimble@tetratech.com</u>

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| l | Engineers of Yukon | |

FIGURES

Figure 1 Site Plan Showing Structure Locations

Figure 2 DSTF Site Plan Showing Instrumentation Locations



| PROJECT NO. | DWN | CKD | REV | |
|------------------|------------------|-----|-----|----------|
| ENG.WARC03152-01 | CB | JTP | 0 | |
| | | | | Figure 1 |
| OFFICE | DATE | | - | |
| EBA-WHSE | October 24, 2016 | | | |



| PROJECT NO. | DWN | CKD | REV | |
|------------------|------------------|-----|-----|--------|
| ENG.WARC03152-01 | СВ | JTP | 0 | |
| OFFICE | DATE | | | Figure |
| EBA-WHSE | October 24, 2016 | | | |
| | | , | | |

PHOTOGRAPHS



Photo 1: PAG Waste Storage Facility Unfinished liner installation Facing north - August 18, 2016



Photo 2: PAG Waste Storage Facility Stable perimeter berm Facing north - August 18, 2016





Photo 3: Bellekeno Waste Rock Pile Stable pile sideslope Facing north - August 18, 2016



Photo 4: Bellekeno 625 Water Treatment Ponds Operating water treatment ponds Facing north - August 18, 2016





Photo 5: Bellekeno 625 Water Treatment Ponds Diminished freeboard at north end of facility Facing north - August 18, 2016



Photo 6: Lightning Creek Bridge (Onek Road) Exposed geotextile on south abutment Facing south - August 18, 2016





Photo 7: Mill Water Storage Pond Water level in pond Facing west - August 18, 2016



Photo 8: Mill Water Storage Pond Intact liner and stable perimeter berm Facing south - August 18, 2016





Photo 9: Dry Stacked Tailings Facility Covered and seeded tailings Facing north - August 18, 2016



Photo 10: Dry Stacked Tailings Facility Toe runoff collection ditch below facility Facing east - August 18, 2016



APPENDIX A TETRA TECH'S GENERAL CONDITIONS



GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these "General Conditions".

1.1 USE OF REPORT AND OWNERSHIP

This geotechnical 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 that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of TETRA TECH's Client. TETRA TECH does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than TETRA TECH's Client unless otherwise authorized in writing by TETRA TECH. 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 TETRA TECH. Additional copies of the report, if required, may be obtained upon request.

1.2 ALTERNATE REPORT FORMAT

Where TETRA TECH submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed TETRA TECH'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 TETRA TECH shall be deemed to be the original for the Project.

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

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

1.3 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.4 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.5 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.6 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of testholes and/or soil/rock exposures. Stratigraphy is known only at the locations of the testhole or exposure. Actual geology and stratigraphy between testholes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

1.7 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.8 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.9 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

1.10 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.11 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

1.12 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

1.13 SAMPLES

TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

1.14 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

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

APPENDIX B DSTF GROUND TEMPERATURE PROFILES











Figure T5



APPENDIX C DSTF LATERAL MOVEMENT PROFILES



RST Instruments Ltd.

Borehole : BH36

Northing : 7086872

Easting: 483931

Collar :

Project : Keno Location : DSTF

CUMULATIVE DISPLACEMENT

Inclinalysis v. 2.47.5

Spiral Correction : N/A Collar Elevation : 0.0 meters Borehole Total Depth : 14.5 meters A+ Groove Azimuth : Base Reading : 2011 Dec 14 16:52 Applied Azimuth : 0.0 degrees

Axis - A 1.5 0.8 0.0 Gravel -0.8 Sand and Gravel (Till) -1.5 -2.3--3.0 -3.8--4.5 -5.3 -6.0 Depth (meters) -6.8 -7.5 -8.3 -9.0 -9.8 -10.5 -11.3 Rock -12.0 -12.8 -13.5 -14.3 Borehole 36(19) 17-Aug-16
 Borehole 36(18) 10-Aug-15 Borehole 36(17) 13-Aug-14 -15.0 Borehole 36(14) 09-Sep-13 ---- Borehole 36(8) 12-Sep-12 -15.8 0.00 0.50 -0.50 Cumulative Displacement (meters)

