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PO Box 159, 13211 Henry Avenue
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PEER REVIEW OF AQUIFER PROTECTION STRATEGY FOR PROPOSED ICASA RESORT LIVING DEVELOPMENT IN SUMMERLAND BC

Dear Sir:

As requested by the District of Summerland, Golder Associates Ltd (Golder) has completed a peer review of the geotechnical and hydrogeological components of the aquifer protection strategy submitted by Lark Enterprises Ltd. (Lark) for the proposed iCasa Resort Living development (development) in Summerland BC. The peer review has been completed in accordance with Golder's proposal to the District of Summerland dated 28 November 2017.

1.0 BACKGROUND

The proposed development is located at 13610 Banks Crescent in Summerland BC, between Highway 97 and the west shore of Okanagan Lake. The 5.8 hectare site is currently comprised of orchard and undeveloped lands with one residence. The proposed development will occupy 2.7 hectares of the site. Golder understands that the development site overlies an aquifer that feeds Shaughnessy Springs. The aquifer has not been mapped by the province and the extent and classification (yield, vulnerability, and demand) have not been determined. Shaughnessy Springs is the water source for the Summerland fish hatchery operated by the Freshwater Fisheries Society of BC (FFSBC). The FFSBC have two surface water licenses on Shaughnessy Springs with a total licenced quantity of 85 L/s (1350 US gpm). The springs are 40 m downslope and 20 m in elevation below the eastern site boundary of the development (Piteau 2017c). A simplified hydrogeological cross-section through the aquifer and overlying confining layer prepared by Piteau is shown as Figure 1 (Piteau 2017c).

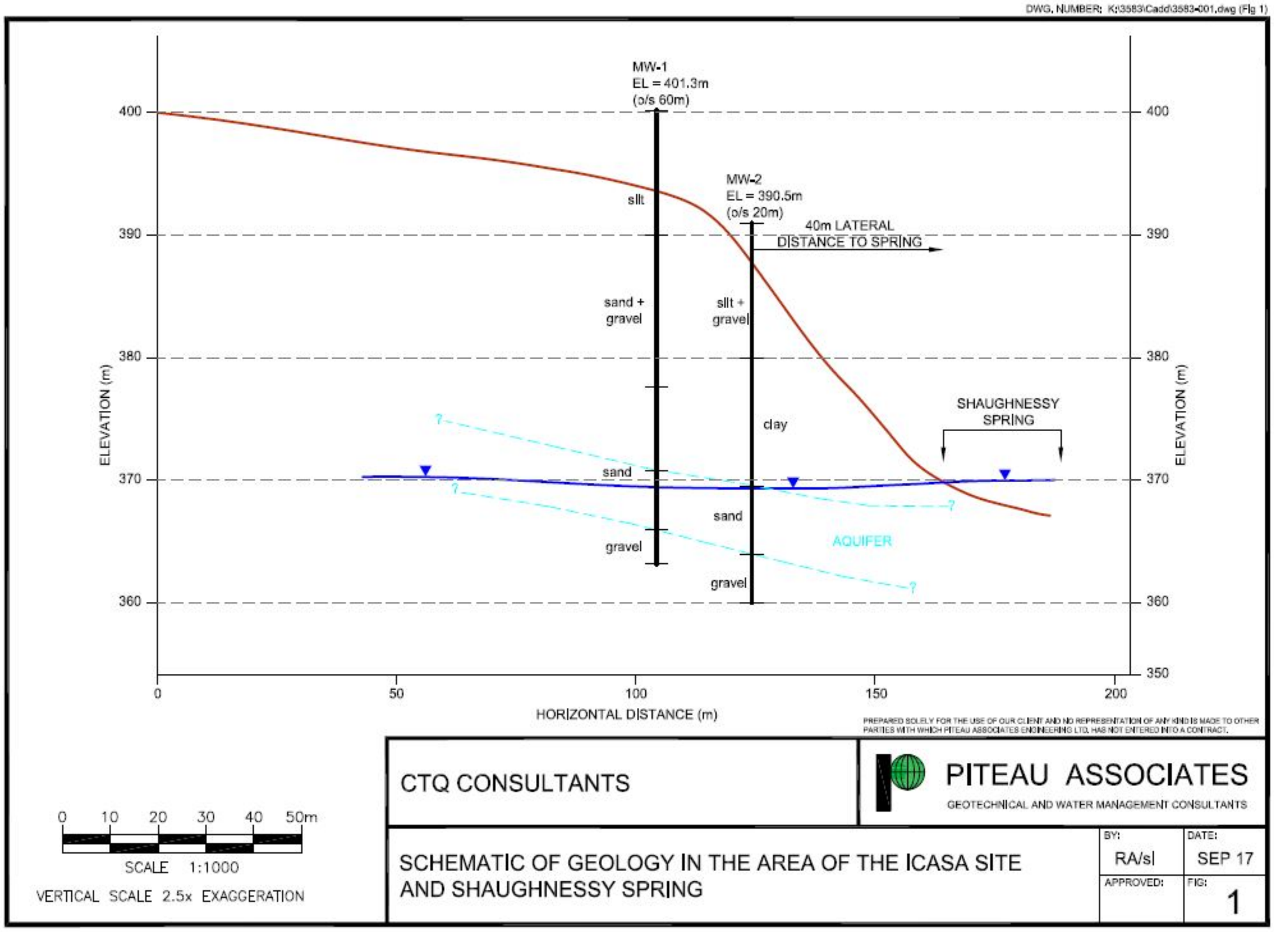

Figure 1: Hydrogeological cross-section though aquifer prepared by Piteau

The proposed construction schedule submitted by Lark indicates that the site earthworks and parkade construction would commence in early 2018 and continue until mid 2019 with above grade building construction beginning in 2019 and continuing until early 2023. In their 2016 report, Piteau Associates Ltd (Piteau) commented that heavy truck movement across the eastern portion of the site could result in vibration induced groundwater turbidity that may not be filtered out by the time the groundwater discharged to Shaughnessy Springs (Piteau 2016). FFSBC became concerned that, in addition to potential surface erosion into the spring, ground disturbance during construction could cause the spring discharge to become turbid and adversely affect the fish hatchery. Further assessment was done by Lark and its consultants concluding that construction of the development presented a very low risk to the aquifer and vibration induced groundwater turbidity was very unlikely to occur (Geopacific 2017, Piteau 2017c, RGC 2017). Lark and its consultants also prepared an aquifer protection strategy for the development (Lark 2017).

2.0 OBJECTIVE AND SCOPE

The objective of the peer review is to examine Lark and its consultants' conclusions on the potential impact or risk of the development to the aquifer and evaluate whether Golder concurs with the conclusions presented. No new information was gathered during Golder's review. The scope of work was to:

- Review the aquifer protection strategy and supporting engineering studies submitted to the District of Summerland by Lark.

- Comment on the compaction characteristics/behaviour of the soil underlying the development.
- Comment on the anticipated depth of penetration / attenuation of construction related soil vibration from construction of the proposed senior housing development.
- Provide an opinion on whether construction of the development is likely to trigger increased turbidity in the aquifer and as a result in Shaughnessy Springs, based on anticipated construction vibrations and soil types.
- Comment on Lark and its consultants' conclusions on the development's impacts on the aquifer.
- Comment on the aquifer protection strategy plan with respect to limiting and monitoring turbidity in the aquifer.
- Summarize the results of the review in a letter report.

3.0 RELEVANT INFORMATION

Golder has read the documents listed below as part of its peer review. The authors of the listed documents were advised of Golder's peer review vial email on 30 November 2017.

- CTQ Consultants Ltd et.al., (CTQ 2017) *Summerland – iCasa Resort Living Erosion and Sediment Control Work Plan*, September 2017.
- Geopacific, (Geopacific 2017) Letter to Lark Group commenting on Rock Glen 2017, 30 June 2017.
- Lark Enterprises Ltd. (Lark 2017a) Letter to Dean Strachan, Director of Development Services, Summerland BC, 27 July 2017.
- Lark Enterprises Ltd. (Lark 2017b), Letter to Summerland Mayor and Council, *Vibration-induced turbidity not a risk to Aquifer, August 14, 2017*
- Lark Enterprises Ltd. (Lark 2017c), *iCasa Resort Living, Aquifer Protection Strategy*, 29 September 2017.
- Piteau Associates Engineering Ltd. (Piteau 2016) Memorandum *Hydrogeological Assessment 13610 Banks Crescent, Summerland, B*C, 12 July 2016.
- Piteau Associates Engineering Ltd. (Piteau 2017a) Memorandum *Hydrogeological (4 January 2017 meeting summary) 13610 Banks Crescent, Summerland, BC*, 19 January 2017.
- Piteau Associates Engineering Ltd. (Piteau 2017b) *Hydrogeological Update Proposed ICASA Resort Living Development 13610 Banks Crescent, Summerland, BC*, 14 August 2017.
- Piteau Associates Engineering Ltd. (Piteau 2017c) *ICASA Site in Summerland – Discussion of Turbidity*, 19 September 2017.
- Rock Glen Consulting Ltd. (RGC 2016a), *Geotechnical Assessment for Proposed Summerland Independent & Assisted Living Development 13610 Banks Crescent, Summerland*, 30 September 2016.
- Rock Glen Consulting Ltd. (RGC 2016b), *Addendum to 30 September 2016 Geotechnical Assessment Report, Proposed Summerland Independent & Assisted Living Development, 13610 Banks Crescent, Summerland, 13 October, 2016*

- Rock Glen Consulting Ltd. (RGC 2017), *Geotechnical Engineering Review of Potential Groundwater Impacts: Proposed ICASA Resort Living Development 13610 Banks Crescent, Summerland*, 3 August 2017.

Golder has also read an undated document by MDM Groundwater Consulting Ltd. (MDM) posted on the District of Summerland's website. MDM was retained by the FFSBC. Golder is not reviewing the MDM document but has referenced it based on a comment on historical causes of turbidity in the spring water.

On 6 December 2017 Golder received email from Piteau (Piteau 2017d) providing additional groundwater sampling results and a field log for a borehole (MW-3) drilled on 6 September 2017. The additional groundwater samples were obtained from MW-1 (TH1) and MW-3 on 30 October 2017 and 15 November 2017.

On 7 December 2017 Golder called the manager of the Summerland Fish Hatchery to inquire about the point-of-diversion (POD) structure and other observations of the springs that hatchery staff could provide. The hatchery manager indicated that:

- Shaughnessy Springs emerge from multiple locations over an area of approximately 1.2 hectares.
- The springs flow overland over a natural stream bed for an estimated 100 m into a covered sump where spring flow is collected and piped 200 m to the hatchery under gravity.
- The area between the springs and sump is partially fenced.
- The hatchery installed a data logger in the sump in August 2017 that collects measurements at 30 minute intervals for parameters that include turbidity, total suspended solids (TSS), electrical conductivity and dissolved oxygen. The data logger stopped recording at the end of October and is in process of being fixed. Prior to installing the data logger, hatchery staff collected one sample per year for laboratory analysis and visually assessed water turbidity.
- Surface erosion into the area between the springs and the sump has caused turbidity. At times, groundwater temporarily emerges at very low rates from new locations in the area of the springs causing erosion at the point of emergence. There is no observed pattern or seasonality associated with these emergences.
- Turbidity is believed to be primarily due to animal disturbance, surface erosion into the stream channel between the springs and the sump and groundwater temporarily emerging at new spring locations.
- Turbidity events do not occur very often and last for roughly one hour to half a day; events are most commonly about one hour in duration.
- Shaughnessy Springs now flow consistently at 2,800 to 3,000 L/min but reportedly flowed at roughly 6,000 L/min (100 L/s) many years ago (for comparison with the licensed withdrawal rate of 85 L/s the Shaughnessy Springs currently flow at 47 to 50 L/s).

On 19 December 2017 the District of Summerland provided Golder with an email excerpt from Lark indicating that an automated water quality monitoring system would be used to monitor and report on groundwater quality in the site monitoring wells during the construction and post construction phases of the development.

4.0 PEER REVIEW COMMENTS

4.1 Aquifer Protection Strategy

FFSBC requested that the two existing site monitoring wells be used to monitor for potential vibration induced turbidity in the aquifer unless there was technical justification that the wells could not be used for that purpose. (Piteau 2017a). The aquifer protection strategy provides for baseline monitoring in Shaughnessy Springs and the two site monitoring wells to establish a natural range of turbidity at the three monitoring stations (CTQ 2017). The turbidity monitoring will continue during construction. The environmental monitor (EM) has been collecting grab samples from the Site monitoring wells to characterise background groundwater quality and plans to install continuously logging turbidity meters in the monitoring wells to monitor groundwater turbidity in the aquifer during and after construction of the development.

Monitoring for turbidity in the site monitoring wells during a turbidity event in Shaughnessy Springs, may be helpful in identifying the source, i.e. turbidity due to turbid groundwater discharging to the spring, versus turbidity caused by surface erosion into the spring. Monitoring for turbidity in groundwater would be a method to support professional opinion that construction activities present a very low risk to the aquifer. In order to provide meaningful data, the wells need to be able to produce samples that represent *insitu* groundwater turbidity/quality as characterized by the groundwater currently discharging at the springs. As an example, drinking water wells are constructed to meet common raw groundwater quality guidelines for turbidity of ≤ 1 nephelometric turbidity units (NTU).

TSS is an analytical method of measuring particulate matter 2 microns or larger in a water sample. Turbidity is an optical measurement of water clarity which is a function of suspended solids; however, there is no set correlation between TSS and turbidity. Piteau (2016) included certificates of analyses for a groundwater sample from MW1 collected on 29 June 2016 and a spring sample collected on 30 June 2016. The (TSS) concentration in the groundwater sample was 144 mg/L and the TSS concentration in the spring sample was <4.0 mg/l where 4.0 mg/L was the method reporting limit. Neither sample was analysed for turbidity.

The water sampling results show that TSS in the monitoring well groundwater sample was substantially higher than the spring water sample and it is inferred that that the groundwater sample was not reflective of groundwater flowing through the aquifer. Golder suspects that the TSS in the groundwater sample was a function of the well construction and that the well screen and sand pack was insufficiently developed to produce a representative groundwater sample using the June 2016 sampling method. Piteau completed additional groundwater sampling of MW-1 and MW-3 using low flow sampling methods to minimize agitation of the groundwater in the monitoring well with laboratory reported turbidity ranging from <0.01 to 0.3 NTU (very low turbidity).

If turbidity in the groundwater monitoring wells is measured during the background and construction phases of the project, in order to provide meaningful data Golder recommends that:

- During the background monitoring period, it is demonstrated that the turbidity of the monitored groundwater is unaffected by well completion and is similar to the spring discharge.
- Groundwater turbidity in the monitoring wells is measured at the same frequency that turbidity is measured in Shaughnessy Spring.
- The hydraulic conductivity of the sand formation the well is screened in is evaluated to demonstrate that it is characteristic of a sand aquifer and that the hydraulic conductivity of the monitoring well sand pack and surrounding formation is sufficient for natural flow through the well screens to occur, i.e. the monitoring well is suitable for low flow sampling and the combined sand pack and formation hydraulic conductivity is 10^{-6} cm/s or higher (Robbins et.al. 2008).

- The groundwater velocity through the aquifer and consequently the travel time from MW-1 and MW-3 to the springs area is estimated so that turbidity events in the spring can be traced back to a sampling timeframe at the monitoring wells.
- The proposed four month background monitoring period includes a season when more extreme rainfall and run off events are most likely to occur; ideally the background monitoring period would include spring melt and freshet.

4.2 Compaction Characteristics of Underlying Soils

The results of the geotechnical investigation conducted at the site are provided in (RGC 2016a), which include a site plan showing the test hole locations and logs for TH-1 to TH-8. Piteau has also provided Golder with a field drill hole log for MW-3, which was constructed on September 6, 2017. It is understood that MW-3 is a replacement for MW-2 and is located in the vicinity of MW-2. MW-2 is the monitoring well installed in TH-2.

Based on the soil descriptions and standard penetration test (SPT) blow count data provided on the test hole logs, the subsoils at the subject site are generally compact (or firm to stiff) to the full depth of drilling which, for the monitoring wells, ranges from about 30 m to 38 m below the existing (pre-construction) site grade. While the soils up to 9 m depth were found to contain layers or lenses of sand and gravel, the soil deposits encountered above the Shaughnessy Aquifer but greater than 9 m below existing grade appear to be silty but otherwise variable across the site. These soils are variously described as compact silty sand and gravel, firm silty clay, sandy silt, and compact mixtures of sand, silt and clay.

In consideration of the moderate relative density of the soils above the Shaughnessy Aquifer, and perhaps in consideration of the variability of these soils, RGC concluded that the soils above the aquifer could represent ablation till deposits. Golder concurs that the soils above the aquifer are similar to, and could be, ablation till deposits which are an unsorted and unstratified accumulation of heterogeneous glacial sediment deposited by melting of in-place stagnant glacial ice. Ablation tills do not have the higher density of lodgement tills deposited and compressed under moving continental glacial ice which, in British Columbia, may have been greater than 1 km in thickness.

The groundwater table beneath the site is understood to have been close to the groundwater elevation at Shaughnessy Springs (about 370 masl - Figure 1) when measured in the monitoring wells. The groundwater level reported on the MW-3 field log was about 20 m below surface. The field log reports heaving (saturated and under upward hydraulic pressure) silt and sand from 20 to 27 m below grade underlain by a stable sand and gravel unit that was assessed (by Golder) to be the aquifer.

Compact silty soils above the water table generally require considerable effort to compact to a higher level of compaction than is already present. Large ride-on vibratory roller compactors are generally capable of increasing the *insitu* density of a 300 mm thick layer of soil from a compact to dense condition with several passes of the roller when the soil has an optimum moisture content for compaction, but would likely have no discernable effect on the *insitu* density of soils just a metre or two below the ground surface being compacted.

In summary, the results of investigation by others indicate that the subsoils at the site are generally compact. Compact soils that are greater than a metre or two below ground surface are not susceptible to further densification from conventional ride-on vibratory roller compactors operating at ground surface (or other moderate level vibrations typical of normal construction). Accordingly, the density of the soils within the Shaughnessy Springs Aquifer, located roughly 20 m below the proposed depth of excavation, is unlikely to be materially affected by normal construction vibrations including soil compaction at surface. Further, turbidity within the Aquifer is unlikely to result from compaction of the Aquifer soils resulting from construction vibrations at the proposed design grade roughly 20 m above the Aquifer.

4.3 Attenuation of Construction Related Soil Vibration

Common sources of construction vibrations include vibratory or impact compactors, traffic, blasting, uneven access routes that cause heavily loaded vehicle to bounce, pile driving, dropped loads, and the like. The effects of construction vibrations on structures have been studied in detail and many jurisdictions have detailed guidelines and threshold limits for vibrations intended to limit risk of damage to structures. Research into the vibration threshold limits for other objects is generally less advanced.

A practical review of the state of knowledge and practice with respect to construction vibrations is provided in the New Zealand Transportation Agency Research Report 485 (New Zealand 2012). The principal wave types generated from vibratory sources are compression, shear and Rayleigh waves. The compression and shear waves are body waves that radiate outward through the ground from the point of impact resulting in a spherical wave front. With a 3-dimensional wave front, the compression and shear waves attenuate more quickly than Rayleigh waves. Rayleigh waves are surface waves that radiate from the point of impact resulting in a 2-dimensional wave front. When the exciting force is applied vertically to the ground, Rayleigh waves account for 67 percent of the total energy, while shear waves and compression waves account for 26 percent and 7 percent, respectively.

Accordingly, the waves of primary interest in construction vibrations are normally the Rayleigh waves which have the greater energy and travel farther with less attenuation than other vibrations. However, the amplitude of the Rayleigh surface wave reduces exponentially with depth and about 99 percent of the Rayleigh wave energy is contained within a 1 wavelength depth from ground surface, and almost 90 percent is contained within half a wavelength of ground surface. The limited depth of influence of the Rayleigh wave is reflective of the properties of the surface wave, and should not be confused with attenuation. Attenuation is the reduction in wave amplitude with distance travelled along the direction of wave travel, which for Rayleigh waves is radially along the ground surface from the point of impact.

The wavelength can be calculated from propagation velocity and frequency as follows:

Wavelength = (wave velocity / frequency).

Vibratory roller compactors are generally tuned to have an exciting frequency of 20 Hz or greater, which helps to reduce the risk of building vibration in resonance with the exciting frequency and related vibration damage to buildings, which typically have a natural frequency less than 15 Hz.

Assuming a Rayleigh wave velocity in the range of 200 to 400 m/s and an exciting frequency of 20 Hz applied at ground surface, the wavelength would be in the range of 10 to 20 m, which means that 99 percent of the Rayleigh wave energy would be contained with the upper 10 to 20 m of ground surface, and about 90 percent of the Rayleigh wave energy would be contained within 5 to 10 m of ground surface.

The conclusion that can be drawn from this is that the dominant vibrations generated by construction activities are Rayleigh waves which have greater amplitude and more limited attenuation than compression or shear waves but, as surface waves, have a limited depth of penetration into the earth. Preliminary calculations suggest that, where the depth of burial of the Aquifer is greater than 10 m below ground surface, a depth below which the Rayleigh waves effectively do not penetrate, the compression and shear body waves will become the dominant vibrations.

In areas where the depth of cover over the Aquifer is less than 10 m; that is, at the Shaughnessy Springs and adjoining areas, the Rayleigh waves will be the dominant vibrations and will primarily affect shallow ground to depths of the order of 5 to 10 m below ground surface. However, the intensity of the vibrations will be attenuated by the distance from the source.

Measured ground vibration levels for Ingersoll-Rand SD150 and Dynapac CA301 large ride on vibratory roller-compactors at various distances is provided in Figure 2.9 of New Zealand Research Report 485 (New Zealand 2012). The plots show that, under the ground conditions tested with a separation distance of 40 m, the recorded Peak Particle Velocities (PPV) generally ranged from a high of about 3 mm/s to 0.2 mm/s. The frequency of the vibrations was not given. Based on the German DIN4150-3:1999 vibration guidelines, the vibration threshold for structural damage to residential structures ranges from 5 mm/s to 15 mm/s for short term vibrations up to 50 Hz, and from 3 to 8 mm/s in short term vibrations for sensitive/historic structures in a similar frequency range.

As pointed out by (Tamura, 1996), surface waves attenuate with the square root of distance, whereas body waves attenuate with the square of distance. From this, we can estimate that the intensity of shear body waves in the Aquifer at a depth of 20 m below ground surface will be roughly 2/3 of the intensity of Rayleigh surface wave vibrations at surface at a distance of 40 m laterally from the vibration source. Accordingly, for a vibration intensity of 3 mm/s to 0.2 mm/s PPV for Rayleigh waves 40 m from the springs, the corresponding vibration intensity at 20 m depth in the Aquifer would be about 2 mm/s to 0.1 mm/s PPV.

We are not aware of any vibration threshold criteria for damage to aquifers and springs, so the German threshold criteria for sensitive/historic structures cannot be considered directly applicable. Nonetheless, it suggests that, for some sensitive objects, the threshold for damage can be as low as a PPV of 3 mm/s in the frequency range up to 50 Hz.

As previously noted, by attenuation, the vibration intensity drops with increased distance from the point of impact or vibration source. Accordingly, simply increasing separation distance between the vibration source and springs will reduce the vibration intensity experienced at the springs. For instance, to reduce a Rayleigh wave intensity of 3 mm/s PPV to 2 mm/s would require an increase in separation distance from approximately 40 m to 70 m.

To summarize, the anticipated Rayleigh wave surface vibration intensity at Shaughnessy Springs with a 40 m separation from the vibration source is of the order of 3 mm/s PPV, and the anticipated shear body wave vibration intensity within the top of the aquifer 20 m below a vibration source is of the order of 2 mm/s PPV, assuming a Ingersoll-Rand SD150 ride on roller-compactor or equivalent maximum vibration source. These results compare favourably with the German vibration threshold criteria for damage to sensitive/historic structures of 3 mm/s to 8 mm/s PPV. The German criteria set for sensitive/historic criteria would be amongst the lowest available vibration threshold standards for structures. In our professional opinion, the anticipated vibration levels are low and, in consequence, the risk of a turbidity event from the vibrations within the Shaughnessy Springs Aquifer is considered to be low, and the frequency of turbidity events at Shaughnessy Springs is considered likely to be only slightly elevated over that normally experienced at the Springs.

While the risk to the Aquifer and Springs appears to be low, it is acknowledged that there are uncertainties in the assessments involving limited information and professional judgement. It is therefore important that these assessments be supported and confirmed by monitoring.

In our professional opinion frequent, preferably real-time, monitoring of spring water for turbidity, combined with regular vibration monitoring to confirm actual shallow vibration levels encountered at Shaughnessy Springs during construction should be implemented. Real-time turbidity monitoring at the spring will provide the basis for rapidly identifying turbidity event occurrences and durations, and will support a determination of probable cause for any such events. Anomalous conditions that are identified as likely to be associated with construction can then be addressed in expeditious and effective fashion. Regular vibration monitoring should be used to assess the validity of vibration estimates which are the basis for assessments of risk.

The reference paper (Kim 2000) used to by RGC and Piteau to support their assessments of vibration attenuation is a narrow scope collection of monitoring results from specific sources that adds to but does not define the larger body of knowledge. Neither the soil conditions nor the vibration sources used in that paper have any particular relevance to the subject site. However, there are other studies that could be considered that provide a broad review of the state of knowledge and practice for construction vibration assessment and mitigation.

5.0 POTENTIAL IMPACT ON WATER TURBIDITY AT SHAUGHNESSY SPRINGS

5.1 Ground Stability at Shaughnessy Springs

It is understood that the Shaughnessy Springs emerge from many existing locations over an area of sloping ground and that, from time to time, new areas of flow temporarily emerge resulting in sloughing of the ground, causing turbidity events. The continuous water discharges combined with occasional sloughing suggests that the spring area is marginally stable at least with respect to shallow failures.

It is therefore reasonable to suspect that ground vibrations from construction may have the potential to trigger new sloughing, or an increased frequency of sloughing, in the marginally stable wet to saturated ground within or adjacent to the area of the Springs, causing turbidity. There may also be some threshold limit for vibrations below which no change in the frequency or scale of sloughing is detectable. At this time, however, the value of this threshold limit is unknown.

5.2 Aquifer Impacts

FFSBC report that Shaughnessy Springs emerge at multiple locations over an area of approximately 1.2 hectares. Piteau indicate that the proposed development will come within 40 m of the springs area (Piteau 2017c). The depth to the Shaughnessy Springs Aquifer is not known over much of the site, but at the locations of monitoring wells MW-1, MW-2 and MW-3 the depth of cover over the Aquifer is approximately 20 to 30 m or greater. Reports provided generally indicated an assumed minimum soil cover over the aquifer at the maximum depth of excavation to be about 20 m.

At such depths, the Rayleigh waves should have no significant impact, and the shear and compression waves should be attenuated. For purposes of discussion, it is assumed that the intensity of these vibrations at a depth of 20 m is small, perhaps similar in amplitude to the Rayleigh waves at 40 m distance.

For low to moderate vibrations generated in normal construction and excluding larger vibration sources such as pile driving and blasting, it is our expectation that the construction vibrations are unlikely to alter the basic structure of the aquifer and overlying soils. Consequently, it is our professional opinion that normal construction vibrations are unlikely to cause any permanent detrimental impact on the aquifer or its water quality. Additionally, under these conditions it is considered that the potential for a major change in turbidity within the aquifer is also low.

Some conditions associated with significant changes to deep aquifers include large earthquakes, blasting, pile driving, heavy vehicles bouncing on uneven haul roads (such as loaded haul trucks and scrapers) and installed piles subjected to alternating tension and compression loading, such as wind turbine foundations. Normal construction vibrations attenuated through thick soil cover are on a very much smaller scale compared to those other major intrusions.

Golder's review indicates construction works will likely result in low levels of vibration in the aquifer and at Shaughnessy Springs, and that attenuation is unlikely to entirely eliminate the construction related ground vibrations at these locations. While Golder acknowledges that lower vibration levels are associated with a lower risk, it is our professional opinion that the characterization of risk as negligible is not supported when a vibration threshold limit has yet to be established.

Golder considers that the risk of turbidity generation within the Aquifer from normal construction-related vibrations is likely low in areas where there is deep cover over the Aquifer, while the risk to turbidity generation at Shaughnessy Springs where groundwater daylights may be low-to-moderate considering; turbidity events have previously occurred in that area, the near-surface groundwater levels with springs that reduce ground stability, and the depth of cover over the Aquifer that is reduced to nil.

6.0 PEER REVIEW SUMMARY

Golder supports the conclusion of Lark’s consultants that the earthworks and heavy vehicle movement will result in relatively low vibration levels in the aquifer and at Shaughnessy Springs and therefore presents a low risk to the aquifer. Golder also agrees that earthwork and heavy vehicle movement are unlikely to cause a change in turbidity within the aquifer. It is Golders’s assessment that the consultant’s conclusions appear to be primarily derived from attenuation curves and professional opinion, but could be strengthened if supported by calculation. Being attentive to the difference between depth of influence and attenuation is an important consideration.

Monitoring turbidity in the aquifer via the monitoring wells as proposed in the Aquifer Protection Strategy would provide some science to support professional opinion; however, in order to provide meaningful data Golder recommends that the monitoring be completed at the same frequency (hourly is proposed in the strategy) as turbidity is measured in Shaughnessy Springs; furthermore, it must be demonstrated prior to beginning construction, that the electronic monitoring system proposed for the construction and post-construction phases of the development can provide reliable data..

Shaughnessy Springs are reported to emerge from many existing locations over an area of sloping ground. It is further reported that from time to time, new areas of flow temporarily emerge resulting in erosion or sloughing of the ground, causing turbidity events. The continuous groundwater discharges combined with occasional sloughing suggests that the spring area is marginally stable at least with respect to shallow failures. Ground vibrations from construction have the potential to trigger new sloughing, or an increased frequency of sloughing in the marginally stable wet to saturated ground within or adjacent to the area of the springs. There may also be some threshold limit for vibrations below which no change in the frequency or scale of sloughing is detectable. At this time the value of this threshold is unknown. Due to this uncertainty, it is considered that the proposed earthworks and heavy vehicle movement present a sloughing and associated turbidity risk to Shaughnessy Springs.

It is also recommended that:

- Vibration monitoring be conducted to provide field confirmation of the amplitude and frequency of vibrations reaching Shaughnessy Springs, with frequency of monitoring increased in the event of elevated vibration levels or turbidity events. This monitoring should be conducted at times of maximum vibration and the results of the vibration monitoring must be reviewed by a qualified professional after each day of construction.
- Vibrations be mitigated by such means as ensuring all access roads are kept smooth to minimize bouncing of heavy vehicles and using smaller compaction equipment as needed.

7.0 LIMITATIONS

This report was prepared for the exclusive use of the District of Summerland. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder Associates Ltd. (Golder) accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The report is based data provided to Golder as described in this report. Golder has relied in good faith on information provided by third parties. We accept no responsibility for any deficiency, misstatements, or inaccuracies contained in this report as a result of omissions, misinterpretations, or fraudulent or negligent acts of others.

Golder makes no warranty, expressed or implied, and assumes no liability with respect to the use of the information contained in this report at the subject Site, or any other site, for other than its intended purpose. If new information is discovered during future work, including excavations, borings or other studies, Golder should be requested to re-evaluate the conclusions of this report and provide amendments as required prior to any reliance upon the information presented herein.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

8.0 CLOSURE

We trust that this report provides you with the information you require at this time. Should you require anything further, please feel free to contact us at your convenience.

Yours very truly,

GOLDER ASSOCIATES LTD.

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