Appendix E : Mill Creek Relocation Pre-Design Study

CITY OF KELOWNA

MILL CREEK RELOCATION PRE-DESIGN

REPORT

MARCH 2013
ISSUED FOR REVIEW
EBA FILE: V13203027

This "Issued for Review" report is provided solely for the purpose of client review and presents our findings and recommendations to date. Our findings and recommendations are provided only through an "Issued for Use" report, which will be issued subsequent to this review. You should not rely on the interim recommendations made herein. Once our report is issued for use, the "Issued for Review" document should be either returned to EBA or destroyed.

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the City of Kelowna and their agents. EBA Engineering Consultants Ltd. does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the City of Kelowna, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in the signed agreement between EBA and the City of Kelowna.

EBA Engineering Consultants Ltd. operating as EBA, A Tetra Tech Company
Oceanic Plaza, 9th Floor, 1066 West Hastings Street
Vancouver, BC V6E 3X2 CANADA
p. 604.685.0275 f. 604.684.6241

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 MILL CREEK RELOCATION PRE-DESIGN

This report summarizes the findings, conclusions and recommendations of EBA, A Tetra Tech Company (EBA) following our initial field investigation, the meeting with the City of Kelowna (City), Kelowna International Airport (KIA) and the review of available documentation. As presented in EBA's proposal dated October 30, 2012, EBA was tasked with the development of pre-design drawings detailing the relocation of Mill Creek within the property defined by KIA. As detailed in the enclosed report, EBA has completed the initial phase of the project. This includes the development of a set of options detailing possible design scenarios and a subsequent recommendation for the preferred option. The intent of this initial phase is to develop consensus and select an option for design.

The objective of EBA's work during this initial phase of the project was to:

- Complete a field assessment of the project area;
- Review historical documentation provided by the City and by the Airport;
- Assess the drainage system deficiencies;
- Develop options to address the identified deficiencies;
- Identify and recommend a preferred creek alignment option with consideration of future Code “E” taxiway; and
- Prepare and submit a preliminary engineering report (this report).

2.0 PROJECT UNDERSTANDING

KIA is planning to construct a new taxiway along the east side of the existing runway. The new taxiway is part of the Airport’s master plan and is intended to facilitate the addition of larger aircraft currently unable to land at KIA. The Airport is planning to accommodate the construction of a code letter “E” taxiway, allowing aircraft with wing spans up to but not including 65 m to make use of the airport.

In order to accommodate the proposed expansion, the City has identified the need to determine the impacts and limitations of Mill Creek on any proposed expansion plans.

EBA was specifically hired to review all relevant existing documentation and assess if in fact the Creek does limit proposed expansion plans. EBA was also required to develop a series of design options and solutions, were the Creek found to be a limiting factor. Among the considerations for review was the possible realignment of Mill Creek.

Based on the original RFP issued by the City, EBA was tasked with the integration of innovative site drainage improvements needed to maintain and protect existing fish habitat, while recognizing future development requirements and impacts on aviation safety. Transport Canada’s “Aerodrome Standards and Recommended Practices TP312E” 4th Edition (TP312E) was used for aerodrome regulation reference.

3.0 SITE REVIEW

Initial review of the project site was completed in two phases. The first phase entailed a site investigation identifying hydrologic/hydraulic characteristics of the project site and the identification of environmental values and issues specific to Mill Creek. The second phase included the review of existing documentation and identification of key issues endemic to the current creek location. As part of this second phase, EBA was to review historical flooding patterns and capacity limitations.

3.1 Site Investigation

As discussed with the Airport and the City, EBA has completed two site visits. The intent of the first site visit was to develop an understanding of the current hydrologic/hydraulic characteristics of the system and of the hydrologic/hydraulic processes causing the flooding and the deposition of sediment along the Creek channel. Both site visits were completed in November 2012.

3.1.1 Field Hydrologic and Hydraulic Assessment

The reach of Mill Creek section under review covers approximately 3,200 metres and is bounded by Old Vernon Road to the north and the north edge of Shadow Ridge Golf Course to the south (See Figure 1.0).

Over the spring of 2012, large portions of the airport were flooded, including a portion of the glidepath critical area. In order to remove ponding water from the glidepath critical area, temporary channels were excavated. Based on anecdotal evidence provided by airport personnel, flooding of this critical area was caused by a blockage made of wood debris just south of Old Vernon Road. On the other hand, flood levels along the southern portion of the creek were caused by limited capacity within the channel section of Mill Creek itself.

Based on comments provided by the airport personnel, the topography of the land, and the varying capacity of the channel, it is clear that two key issues are responsible for the flooding currently being witnessed at the Airport. The first is the deposition of sediment along the southern section of the creek. This deposition physically reduces the capacity of the channel while simultaneously developing fertile ground on which vegetation is able to grow. This new growth further limits the capacity of the channel (See Figure 2).

Figure 2: Evidence of Gravel Deposition

The second key issue is the topography of the land, which allows water to pond on the surface for extended periods of time (See Figure 3).

Figure 3: Evidence of Flat Topography Promoting Extended Surface Ponding

3.1.2 Field Environmental Assessment

The reach of Mill Creek within the vicinity of the Airport is an engineered, channelized section with no useful riparian vegetation, little complexity, and no overhead or instream cover. Summer flows are very low, and often non-existent during short periods of the summer. These low flows provide little opportunity for juvenile salmonid rearing. Although the stream substrate is suitable for spawning and rearing, it is likely that the above conditions greatly restrict fish use and productivity throughout this area.

The BC Ministry of Environment Fisheries Information Summary System (FISS) lists several fish species in Mill Creek, including brook trout, rainbow trout, and kokanee salmon (a freshwater sockeye). However, the Sensitive Habitat Inventory and Mapping (SHIM) Report for Mill Creek (2006) identified numerous issues in Mill Creek that seriously reduce its habitat quality and capacity for aquatic productivity. These issues include poor water quality, erosion, channelization, and obstructions. Obstructions occur due to beaver activity (32 beaver dams were identified in the SHIM report), natural debris jams, culverts, and one concrete weir/dam (See Figure 4). Overall, the report indicates that only about 11% of Mill Creek within the City of Kelowna remains natural.

Figure 4: Beaver Dam Obstructing Fish Passage (Culvert Outfall)

Based on the present Mill Creek characteristic, it is unlikely that kokanee migrate upstream as far as the airport area. Observations of rainbow trout in pool habitat at Mill Creek Park in 1998 (EBA 1998) indicate that at that time, this species was resident in the Mill Creek headwaters. It is possible that rainbow trout may utilize habitats within the vicinity of the airport under suitable flow conditions; however, this cannot be confirmed due to the lack of empirical information. It is reasonable to assume, though, that improved habitat conditions combined with increased summer base flows may permit improved colonization by rainbow trout in Mill Creek through the airport property. Unless significant improvements to downstream habitats are made, including the removal of obstructions, the upper reaches of Mill Creek will likely remain inaccessible to kokanee.

3.2 Review of Historical Reports

As part of the initial assessment, a detailed review of historical reports was completed. The following is a list of documents EBA has reviewed:

- "Mill Creek Channel Assessment Kelowna Airport" by EBA – completed in 1998;
- "Wildlife Management Plan Update Kelowna Airport" by EBA – completed in 2010;
- "Mill Creek Channel Assessment Update" by EBA - completed in 2006;
- "Mill Creek Relocation Feasibility Study" by InterVISTAS - completed in 2008;
- "Mill Creek Flood Plain Bylaw Phase 1 – Options for Flood Attenuation Upstream of the Kelowna Airport" by Associated Engineering - completed in 2009;
- "Mill Creek Flood Plain Bylaw Analysis" by Associated Engineering – completed in 2010.

Based on the initial review of the historical documentation, EBA has identified the following key elements:

- Significant sediment deposition takes place along the Mill Creek section running parallel to the runway. In 1998, the Airport removed sediments along the lower portions of the channel to restore the creek capacity;
- On the west side of the runway, Mill Creek's low gradient (0.5%) promotes the accumulation of fine-textured sediment within the channel bed. This has led to a decreased channel depth (avg. 1.5 m) and extensive growth of bullrush vegetation within the channel, both of which reduce hydraulic capacity and the ability to convey storm flows. Recent site visits confirm the presence of dense vegetation;
- There are two notable tributaries to Mill Creek on the Airport property. The first is Wagner Creek, a small stream with an estimated 1 in 100 year flow of 3.0 m^3/s. The second tributary is a small surface ditch with a capacity of approximately 3.0 m^3/s, which enters Mill Creek at the downstream corner of the airport. The ditch transports surface runoff away from the newly expanded long-term parking lot and is connected to the larger stormwater drainage system servicing the Airport parking areas and a large part of the Airport apron.
- The channel cross-section along certain portions of the channel limits the conveyance of the creek;
- Trash racks protect the system from the deposition of wood debris. The options proposed by EBA will have to incorporate a trash rack which could be easily maintained (See Figure 5);
- Seasonal peak flows typically occur in May-June and are attributed to combined snow melt and rainfall events;
- The 1 in 100 year flow at the Airport is estimated to be approximately 6.5 m^3/s;
- The Water Survey Canada (WSC) station ceased operation in July 1996 and was not able to capture the 1997 flood event, which likely exceeded the 1 in 100 year event. The largest recorded flood event on Mill Creek (in 46 a year record) occurred on June 1, 1996. Both the 1996 and 1997 events resulted in flooding at the Airport property (J. Hall, personal communication, 2005).

Figure 5: Existing Trash Racks North End of Mill Creek

3.3 Geotechnical Assessment

In order to gain understanding of general subsurface conditions in this region, the following geotechnical reports used for the Kelowna International Airport expansion have been reviewed:

- Geotechnical Report – Kelowna Airport Runway Extension (2008, EBA);
- Preliminary Geotechnical Engineering Report – Kelowna Airport Baggage Make-up Facility Expansion (February 2010, Levelton Consultants);
- Preliminary Geotechnical Engineering Report – Kelowna Airport Air Terminal Building Expansion (February 2010, Levelton Consultants);
- Preliminary Geotechnical Engineering Report – Kelowna Airport Apron Expansion and Taxiway Echo Extension (March 2010, Levelton Consultants);
- Preliminary Geotechnical Engineering Report – Kelowna Airport Air Terminal North Expansion (April 2011, Levelton Consultants);
- Kelowna Surficial Geologic Map published by Geological Survey of Canada.

Based on the above documents, subsoil in this area generally consists of fine grained glacio-lacustrine deposits of silt, sand and clay. Depending of the percentage of plastic fines, the silt and sand would be loose to compact (considered cohesionless soil). If the percentage of clay fines increased, the material would be soft to stiff (considered cohesive soil). The groundwater table is at a relatively shallow depth of 1.5 m to greater than 3 m below ground surface. Groundwater levels will influence on the geotechnical conditions of the soil layers.

Although not noted in the above documents, organic soil including peat and volcanic ash are known to exist in this area.

Geotechnical Comments

There is no site specific geotechnical information along the proposed Mill Creek realignment project. Assuming that subsurface conditions in the proposed Mill Creek realignment area conform to the regional subsurface condition as mentioned above, EBA provides the following preliminary comments from a geotechnical perspective:

- Side slopes for the new channel should be cut at no steeper than 4H:1V. However, depending on the groundwater level, the soils conditions may be altered and a gentler slope may be required. Steeper cuts may be achievable through clay soil if the consistency of the soil is stiff.
- The side slopes should be adequately protected against erosion. Typical protection designs include riprap underlain by filter fabric. The protection should cover the zone of water surface fluctuations based on design high and low water elevations.
- In the case that organic soil, peat and volcanic ash are encountered during construction, over-excavation under the direct supervision of a geotechnical engineer should be undertaken to remove these materials.

4.0 PROPOSED IMPROVEMENTS

As discussed during the kickoff meeting and subsequent conference call, EBA has developed seven separate options detailing possible solutions the City and the Airport may wish to adopt. All the options presented would allow the Airport to move forward with the construction of the Future Code E Taxiway east of the existing Runway. As detailed below, in developing these options EBA has taken into account the following aspects/issues into consideration.

- Geometric configuration of the existing and proposed pavement surfaces including the existing runway, existing taxiways, proposed taxiways, proposed aprons, proposed parking lots, and proposed hangar/apron development areas;
- Width of the runway and taxiway strips;
- Glidepath critical / sensitive area;
- the ILS Localizer critical area;
- Airport safety;
- Environmental value in the existing and proposed diversions;
- The need to address the sediment deposition by incorporating a sediment control trap;
- Hydraulic capacity of the existing channel;
- Possible plans to address future freshet flooding (Associated Engineering's recommendation to add 300,000 m^3 of storage);
- Options developed by Associated Engineering and InterVistas;
- ALR impacts; and
- Long term maintenance (trash-racks).

EBA initiated the development of these options not only to address current development plans but also to address possible future flooding issues. It should be noted that at this stage of the project, the amount of storage required was neither modelled nor estimated. The storage volume was extracted from the *"Mill Creek Flood Plain Bylaw Phase 1 – Options for Flood Attenuation Upstream of the Kelowna Airport"* report completed by Associated Engineering.

Additionally, EBA has confirmed with Nav Canada that the ILS Glide Path (GP) critical / sensitive limits are slightly different than what has been shown in the Airport base drawings previously. The correct GP sensitive area easterly boundary is approximately six metres further east than previously shown. The discrepancy is currently being reviewed.

The following is a detailed description of the seven options developed for the relocation of Mill Creek.

4.1 Options 1A & 1B – Relocation of Mill Creek East of the Future Code E Taxiway

The first option explored was intended to address the specific problems identified through EBA's discussions with the City and the Airport. The goal was to provide a new diversion channel able to convey the current flows without impacting the properties downstream of the Airport.

Options 1A and 1B propose the relocation of the creek east of the future code E taxiway. The channel would be situated between the future taxiway (named Twy L) and the future apron development area. As detailed in Figures 6 and 7, the channel cross-section would fall outside the graded portion of the taxiway strip. The new channel would match or exceed the current conveyance capacity through the airport property. The channel cross section would be trapezoidal with a bottom width of two metres and side-slopes not steeper than 4 to 1.

As detailed in Figures 6 and 7, the channel would run north to south through a series of culverts and back under the runway through the existing culvert. The channel would then be diverted south and then west along the existing golf course and south of the proposed apron/parking lot expansion.

Option 1A was designed to provide temporary conveyance allowing the Airport to proceed with the relocation of Mill Creek. Option 1B also includes the construction of a detention facility intended to offset the possible flooding associated with future development plans. Developing the eastern portion of the airport (both the Taxiway and Apron Area) would remove the flood storage areas thereby impacting the property owners south of the Airport. At this stage of the analysis, EBA has used the estimated volume of storage proposed by Associated Engineering (AE) of (300,000 m^3). Impacts arising from the development of the taxiway could be offset along the channel length. Impacts arising from the development of the aprons could not be, in all practicality, be offset within the airport property.

In order to address the sediment deposition issues, a new sediment trap would be constructed just north of Old Vernon Road. The estimated dimensions of the sediment trap would be approximately 10 m wide by 25 m long by 4 m deep. The size of the sediment trap was based on the assumption that the accumulation of sediments would take place at an estimated rate of 200 m^3 per year and the City would be willing to remove the sediments every five years. The facility would be similar to the one shown in Figure 8, although alternative design options may be explored.

Figure 8: Example of Sediment Trap (Scott Creek in Surrey, BC)

It should be noted that adoption of this option would force the Airport to build a separate parallel system to drain the infield area bounded by the proposed taxiway and the runway. For the purposes of this phase of the project, we have included the cost of the installation of the culverts under the new connecting taxiways H and J. No additional cost was added for the earthwork needed to formalize a conveyance channels or ditches needed to drain the infield areas.

4.2 Option 2A and 2B

Option 2 provides similar recommendations to those presented for Option 1, except that this case explored the possibility of rerouting the flows around the airport, pushing Mill Creek southward across Scotty Creek and Bullman Road (See Figures 9 and 10). The new creek alignment would then run parallel to Bullman Road, tying into the old alignment of Mill Creek just south of the Golf Course.

The intent of this option was to improve safety by moving the main conveyance system as far as possible from the active airfield. Although this option offered significant benefits, and takes advantage of the open fields south east of the runway, it forces the City to buy significant tracks of land and implies significant excavation costs.

Option 2B incorporates the same upstream storage volume of 300,000 m^3 identified by AE to limiting impacts on the properties south of the Airport. Again, the implementation or construction of the storage facility would have to take place before the development of the proposed aprons within the airport.

As in Options 1A and 1B, Options 2A and 2B propose a sediment trap north of Old Vernon Road and a new conveyance system draining the infield area bound by the new Taxiway L and the existing Runway. Unlike Options 1A and 1B, the drainage collection system conveying runoff from the infield area east of the runway would be connected to the new alignment of Mill Creek through a new culvert under the proposed Taxiway L. This would allow the Airport to abandon the culvert under the runway and require the construction of a new conveyance system to drain the infield area west of the runway through a new channel/ditch running parallel to the golf course and south of the proposed apron and parking lots.

4.3 Option 3A and 3B

Options 3A and 3B explored the option of utilizing most of the existing alignment of Mill Creek, except those sections impacted by the proposed new taxiway and future apron. As detailed in Figures 11 and 12, the proposed option would realign the south end of the creek and incorporate a series of culverts under the proposed Taxiways H and J.

As with all previous options, this option includes a sediment trap north of old Vernon Road.

Similarly to the options 1B and 2B, 3B considers the addition of offsite storage to address possible impacts on the properties south of the Airport. As for Options 1 and 2, option 3B would only have to be incorporated if the Airport decided to proceed with the development of the large aprons within the airport.

As detailed in Figure 11, most of the existing creek sits outside the graded portion of the strip or more than 22 m away from the centreline of the proposed taxiway thereby creek bank slopes could meet grading requirements of TP312E.

4.4 Option 4

The last design scenario explored during this initial project phase, Option 4, considers the realignment of the Creek westward, placing the creek within the area bound by the Runway strip and the Proposed Taxiway strip (See Figure 13). This option was explored to take advantage of the infield area and use it for temporary storage. The channel would have a middle low flow channel conveying baseflow throughout the year, and provide a much wider “floodplain” during the freshets. Although the option is very similar to options 3A and 3B, it offers the opportunity to make full use of the infield area and integrates some or all of the storage required to compensate for the active storage likely to be lost to accommodate the construction of the eastern portion of the airport.

As detailed, Option 4 would include the construction of a series of culverts supporting the new taxiways. In addition to these culverts, this option would require the construction of a sediment trap.

4.5 Options Comparison

As requested, EBA has completed a value comparison of the different options. For each option, we have developed a detailed cost estimate, reviewed the environmental benefits, assessed the impacts on the ALR, and considered the relative increase/decrease of risk to air traffic. Table 1 provides a summary comparison. As detailed in the individual cost estimates included in Appendix A, cost estimates do not include the Right-of-Way costs.

With regard to Airport safety, EBA has reviewed each option and has considered the “attractiveness” of these different options to birds; in short, EBA has reviewed how these options could translate in to a higher or lower number of bird strikes at the airport. Although qualitative, we feel the comparison is sufficient to develop an assessment of the different options. In addition to bird strikes, EBA has also reviewed the relative proximity of the proposed channels to the runway, the proposed taxiways and the proposed future aprons.

Table 1: Options Summary

Options Table	Options	Impact on Airport Safety	Environmental Value	ALR Impact (Ha.)	Number of ROWs to be Registered	Estimated Capital Cost
Option 1A	Option 1A - Re-alignment of Mill Creek	6	4	5	1	$4,900,100
Option 1B	Option 1B - Re-alignment of Mill Creek and Upstream Storage	7	6	5	1	$8,205,500
Option 2A	Option 2A - Relocation of Mill Creek to Scotty Creek	2	1	6	7	$6,401,800
Option 2B	Option 2B - Relocation of Mill Creek to Scotty Creek and Upstream Storage	1	2	6	7	$9,707,300
Option 3A	Option 3A - Maintain Mill Creek within Current Alignment	5	3	1	0	$4,208,900
Option 3B	Option 3B - Maintain Mill Creek within Current Alignment with Upstream Storage	4	5	1	0	$7,514,400
Option 4	Option 4 - Relocate Mill Creek to Middle of Field Between Runway and Taxiway	3	7	1	0	$6,552,900

Specific to the environmental value of the proposed options, the following table provides an assessment from an aquatic biology perspective of the options developed for the relocation of Mill Creek.

Table 2: Environmental Impact

Options	Comments
1A	▪ New creek channel to be excavated immediately east of proposed taxiway; top of bank (TOB) 10.5 m from edge of taxiway; two new culverts to be installed at access road and under taxiway upstream of connection to runway culvert; creek bottom to be 2-3 m wide with 4:1 side slopes. ▪ Sediment trap to be constructed upstream of diversion to new channel. ▪ Future relocation of creek downstream of the existing runway culvert crossing due to potential construction of an apron and parking lot at south end of airport. ▪ No changes to flow through golf course; no upstream flood management contemplated. – The eastern limit of the placement of the creek in this option is restricted by potential future airport development to the east of the taxiway. – The potential exists for habitat enhancement by creating low flow channel meanders and pools within the new channel; by creating artificial undercuts and installing limited large woody debris (LWD) complexity; and by placing suitable spawning and rearing substrate material. – The 4:1 side slopes would provide an opportunity for semi-aquatic vegetation planting. Upland vegetation would be mowed up to the TOB (as in all the options). – The benefits of habitat enhancement are limited by low summer flows and the flashy nature of the hydrograph. The addition of two new culverts further reduces available habitat. Downstream access issues (potential/actual migration barriers) may restrict potential increases in fish productivity.

Table 2: Environmental Impact

Options	Comments
1B	▪ Same channel alignment as in 1A, however, with addition of storage immediately upstream of airport property. (It is noted that consideration is being given to storage further upstream (Postill Lake). This would preclude the need for construction of a water retention area upstream of the airport.) – This option provides the same potential habitat enhancement benefits as in 1A, but increases the possibility of improved productivity provided that upstream storage is utilized to increase summer base flows. Planning should also include periodic releases of flushing flows to prevent sediment accumulations in substrates and in enhancement features. – Potentially increased fish productivity due to improved habitat conditions may be restricted due to downstream obstructions.
2A	▪ Same channel alignment as in 1A and 1B for the section upstream of the runway culvert; however, the channel continues south, crosses Scotty Creek and Bullman Road and then follows Bullman Road to the west to join Mill Creek downstream of the golf course. This alignment bypasses the existing runway culvert, but includes five additional culverts. ▪ No upstream storage is contemplated. ▪ Flow through the golf course would be restricted, except for some surface runoff from the parking area and apron. ▪ Future extension of existing storm sewer system southerly to golf course area to allow potential construction of an apron and parking lot at south end of airport. ▪ Scotty Creek flow would not be affected by controlling the distribution of flow. ▪ Agricultural Land Commission approval may be required due to excavation of a new channel south of Bullman Road. – This option provides an opportunity for enhancement along much of the alignment using the methods outlined for Option 1A; however, these potential improvements in habitat productivity may by negated by the increased number of culverts, which can become blocked and require periodic maintenance.
2B	▪ Same channel alignment as in 2A, but with the inclusion of upstream storage to regulate flows and potentially provide increased summer base flows and periodic flushing flows. – Downstream access issues (potential/actual migration barriers) may restrict potential increases in fish productivity.
3A	▪ No changes to Mill Creek location or cross section other than placement of 6 culverts under the taxiway and taxiway accesses to runway. ▪ Sediment trap to be located just upstream of taxiway crossing culvert. ▪ No changes would occur to flow through golf course. ▪ Future relocation of creek downstream of the existing runway culvert crossing due to potential construction of an apron and parking lot at south end of airport.t ▪ This option provides little opportunity for habitat enhancement since no changes to the channel cross section are contemplated. Habitat loss would occur due to the installation of three new culverts.
3B	▪ Same channel alignment as in 3A, but with the inclusion of upstream storage to regulate flows and potentially provide increased summer base flows and periodic flushing flows. ▪ Downstream access issues (potential/actual migration barriers) may restrict potential increases in fish productivity that could result from increased summer base flows.
4	▪ This option would result in Mill Creek flowing in a culvert under the proposed taxiway and then in a constructed channel between the runway and taxiway. Five new culverts would be required for this alignment upstream of the connection to the existing runway culvert. The channel would then follow the existing alignment with a new culvert under future taxiway, west of Taxiway D.

Table 2: Environmental Impact

Options	Comments
	▪ Future relocation of creek downstream of the existing runway culvert crossing due to potential construction of an apron and parking lot at south end of airport. ▪ A sediment trap (pond) would be constructed just upstream of the culvert under the proposed taxiway. ▪ Channel would be designed with 7:1 side slopes and a 2-3 m channel bottom to allow for low flow meandering. ▪ No upstream storage is included in this option. ▪ No changes to flow through the golf course. – The shallow side slopes would allow for the planting of useful grass or low shrub riparian vegetation. – Due to the width of the channel, this option provides good opportunities for habitat enhancement, using the methods identified for Option 1A. – Potential increases in productivity due to habitat enhancement would be reduced due to the installation of three new culverts, and may be affected by downstream obstructions. – Increased habitat benefits would result from inclusion of upstream storage and increased summer base flow.

The table above includes ratings based solely on the potential benefits to fish and fish habitat. The preferred option to enhance fish habitat among those identified in the above table is Option 4. Although this option includes additional culverts, it also provides the greatest opportunity for the inclusion of habitat enhancement measures due to the width of the channel and the shallow side slopes. However, none of the options will likely provide suitable conditions for fish production without the provision of increased summer base flows. As indicated earlier, the assessment of benefits to fish populations in Mill Creek due to local habitat improvements at the airport property should be considered in the context of the overall condition of Mill Creek.

None of the options identified will significantly increase overall fish productivity without a comprehensive program to improve water quantity and quality, habitat quality, and fish access issues in this system. Figure 14 provides a comparative summary detailing the potential environmental value for each of the explored options. Within Figure 14 below, option sphere size is proportionate to the environmental value. For example, Option 2B is the most expensive option with the lowest impact on airport safety, offering the second lowest environmental value (second only to Option 2A).

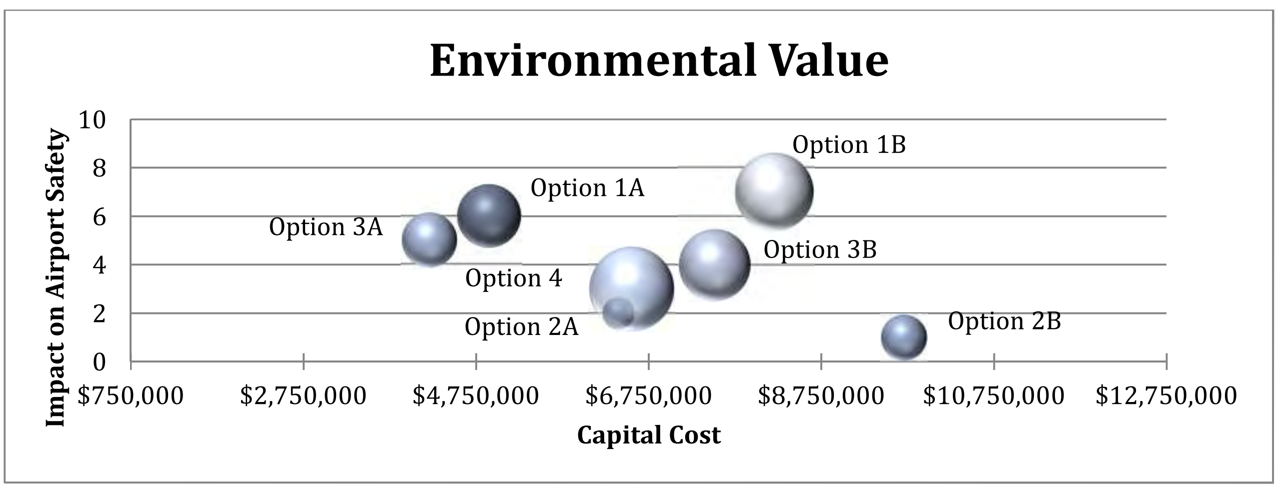


Figure 14: Environmental Value Comparison

Specific to the registration of the Right-of-Ways and loss of ALR land, EBA has identified both the number of right of ways and the number of hectares of ALR Land lost to the project. Figure 15 provides a comparative summary detailing the impacts on the ALR, the impact of the airport safety and the cost of the different options. Within the figure below, option sphere size is proportionate to the impact on the ALR. For example, Option 2B is the most expensive option with the lowest impact on airport safety and with the largest impact on the ALR.

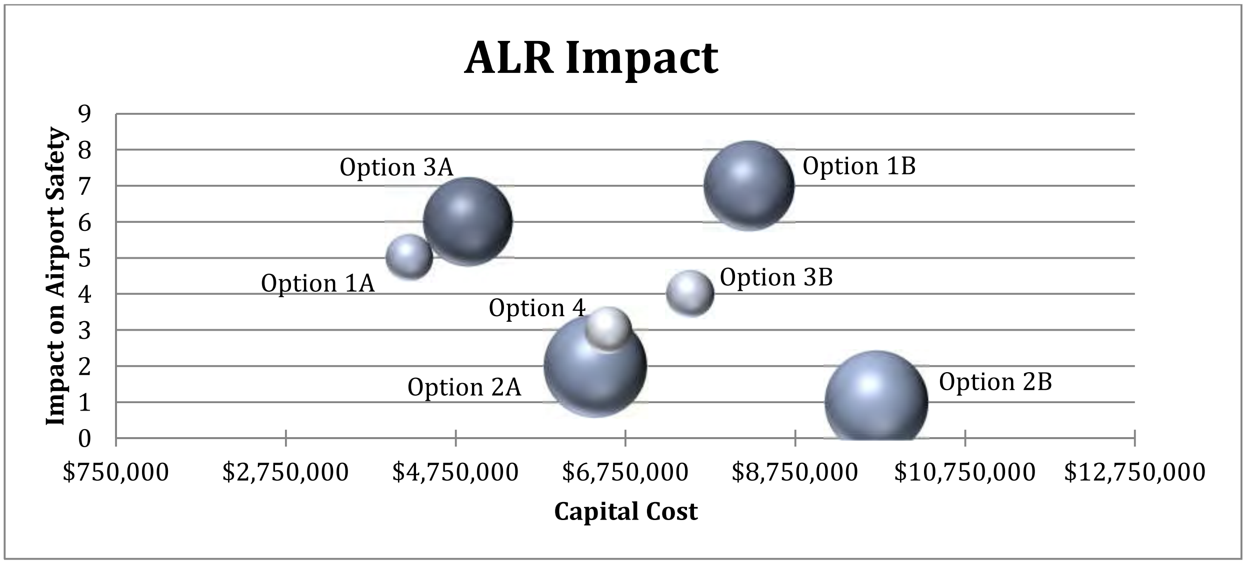


Figure 15: ALR Impacts Comparison

Figure 16 details the location of the ALR land. As shown below, some of the land within the Airport's boundary does fall within the ALR. Any future Taxiway or Apron expansion should be coordinated with the Agricultural Land Commission.

Figure 16: Limits of the ALR

4.6 Preferred Option

Through discussion with the Airport and the City, EBA has identified Option 3B as the preferred option. Although not necessarily the most valuable in terms of fish habitat, maintaining the Creek within its current alignment is a cost effective option. It keeps the creek as far as possible from the existing Runway while allowing the airport to construct the proposed new taxiway. As detailed in Appendix B, EBA completed a cursory design of the proposed taxiway to confirm the viability of this option. The preliminary design was completed to see how the proposed changes in grades could affect the east bank of the creek, and how the proposed grades for the new Taxiway L could be tied-in with the top of bank of the Creek. As detailed in Figure 11, the creek, although outside the graded portion of the future taxiway strip, sits very close to the proposed taxiway. This limits some of the design options the Airport may wish to explore for Taxiway L. Changes to the proposed profile EBA has developed for the future taxiway may greatly affect the current alignment of the creek.

To address the impacts Option 3B may have on the fish habitat, EBA recommends that the creek cross-section along the realigned Creek sections be modified to incorporate complexing features. These features include deeper pools and riffles, overhanging logs, and groins. These compensatory habitat sections could be used to offset the habitat losses resulting from the enclosing (installation of new culverts) of open sections of the Creek.

Following discussions with the City, it is understood that the required 30 m offset between the Creek and any future Taxiways and/or Aprons asphalt edges could be waived specifically for this project. It was decided that shifting Mill Creek westward would bring the creek unnecessarily close to the runway.

As suggested previously, Option 3B would be implemented in two phases. The first would see the construction of the new taxiway and the installation of the proposed culverts. During this phase, the loss of storage imposed by the footprint of the new Taxiway could be offset by changing the geometry of the channel or by developing storage areas within the floodplain east of the proposed Taxiway alignment. Once the Airport decided to move forward and develop the future aprons, the loss of flood storage would have to be reconstituted. One area to be considered is Postill Lake, upstream of the Airport site.

The proposed encroachment of the floodplain will inevitably increase the duration and depth of flooding within the properties south of the Airport. This can be safely assumed without modelling the actual losses of floodplain due to future expansions of the apron systems within the Airport. Mitigation of those flooding impacts can be made in two practical and cost effective ways. The first option would be the creation of an equivalent temporary storage area within the airport. However, such a storage area would likely become an attractant for water fowl. The second option is the construction of a separate storage area outside the Airport's property, preferably far from the glide paths of any arriving or departing aircraft. The possibility of expanding the storage capacity within the upper reaches of Mill Creek could be a practical solution which complements other goals of the City. An increase of water storage within Postill Lake would expand the capacity of the reservoir to provide both the City and the farming community with drinking and irrigation water.

5.0 HYDRAULIC MODEL

After the completion of the site assessments and subsequent review of the available historical documentation, EBA initiated a hydrologic/hydraulic review of the area.

5.1 Model Data

The Mill Creek section reviewed covers approximately 3,200 metres of the creek bounded by Old Vernon Road to the north and the north edge of Shadow Ridge Golf Course to the south. For the purpose of this modelling task, the *Mill Creek Flood Plain Bylaw Analysis* (March 2010) by Associated Engineering and the associated model data for the Mill Creek was reviewed and utilized where necessary.

It is understood that the above model is a one-dimensional HEC-RAS model and comprises a number of surveyed cross sections and field inventory of significant hydraulic structures (see Figure 17). The 200-year return period flood hydrograph was developed for Mill Creek based on over 40 years of flow records.

Some limitations on the hydraulic model were noted prior to utilizing the model data for the purpose of this assessment. These include the following:

- The flood storage areas were modelled as extended cross sections rather than bulk storage areas.
- The 200-year return period event flows were estimated based on the gauge location downstream of the Kelowna Airport and are therefore considered an overestimate for flows at the proposed taxiway development location.
- The Okanagan lake level at the downstream extent of the model is assumed to impact upstream water levels. However, if large storage areas were modelled, the backwater impact from this downstream boundary condition is considered to remain low.
- The Flood Construction Level (FCL) boundaries produced were based on extension of the maximum modelled water levels from the creek on to ground levels (GLs) extracted from contour maps and therefore the floodplain extents are considered conservative.

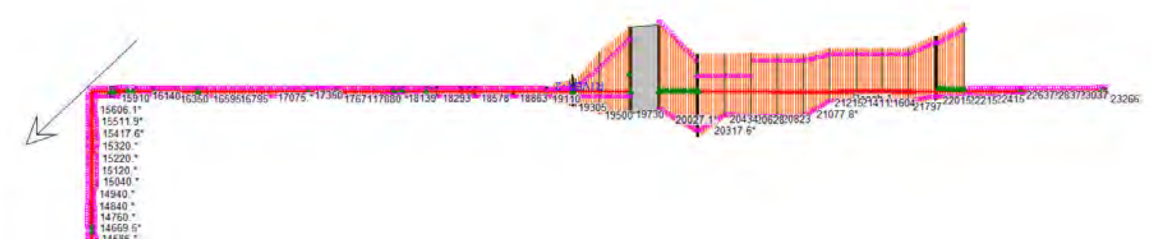


Figure 17: Mill Creek 1-D HEC-RAS model layout

5.2 Hydrology

The hydrology of Mill Creek was assessed in order to develop a better understanding of expected flood flow magnitudes and respective return periods. This assessment also helped confirm the findings of other recent reports pertaining to the hydrology of Mill Creek.

Flows within Mill Creek are partly regulated at Postill Lake and Moore Lake. Both lakes are located in the headwaters at an approximate elevation of 1400 m.

Although there is no recorded flow data for Mill Creek at the airport property, there is historical data available from a WSC hydrometric station located downstream of the airport. The discontinued hydrometric station #08NM053, Kelowna Creek near Kelowna (Lower Reach), is situated approximately nine kilometres downstream of the southern limit of the airport property and has recorded 46 years of flow data from 1950 to 1996. The watershed area of the station is 221 km^2. Kelowna Creek is an alternative name for Mill Creek.

A flood frequency analysis was conducted using maximum instantaneous flows for this station. While the station reported maximum instantaneous and maximum daily flows from 1969 to 1996, between 1950 and 1968 (19 years) only maximum daily flows were recorded. Maximum instantaneous flow records were reconstructed for the missing 19 years by establishing a ratio between the maximum instantaneous flows and the maximum daily flows in the years where both were available (between 1969 to 1996). The maximum daily flow was then increased by this factor to generate an estimate of the maximum instantaneous flows. In this case, a conservative average ratio of 1.09 was used.

Flood frequency statistical software, HYFRAN, was used to fit the flow data to several probability distributions. While several probability distributions were tested, the three-parameter Log Pearson distribution is the most accepted for extreme flow events. Calculated flood flows for three different return periods are presented in Table 3.

The flood estimate based on the above method corresponds well with the findings of the 1998 feasibility study for the area completed by EBA Engineering.

Table 3: Estimated Flood Flows of Varying Return Period

Return Period (Years)	Generalized Extreme Value (Method of Moments) (m³/s)	Log Pearson Type 3 (Method of Moments) (m³/s)	3-Parameter Lognormal (Method of Moments) (m³/s)
200	17.7	17.6	17.8
100	15.2	15.3	15.4
50	12.9	13.1	13.1

The basin upstream of the airport represents about 35% of the total catchment area of the WSC hydrometric gauge. Scaling flows linearly by the ratio of the two watershed sizes results in a 100-year flood flow estimate of 5.4 m^3/s at the upstream end of the airport property. However, in order to acknowledge the differences in basin geometry between a large shallow basin and a smaller steeper basin, the more detailed formula shown below should be used to scale flows.

$$Q_2 = Q_1 * (\frac{A_2}{A_1})^K$$

Where: Q = Flow (m^3/s)

A = Area (km^2)

K = Slope coefficient

Subscripts 1 and 2 denote two watersheds of differing size

For the Province of British Columbia, a value of 0.785 is used as a slope coefficient (K), which was determined in the 1998 British Columbia Streamflow Inventory by comparing peak flows against drainage area for each hydrological zone in the province (Coulson & Obedkoff, 1998). Using this equation, the 100-year event flow for Mill Creek at the upstream end of the airport property is expected to be approximately 6.7 m^3/s. This number agrees with a similar estimate made in the 1998 Channel Assessment produced by EBA Engineering Consultants Ltd.

The flood hydrograph considered for this assessment was based on the 1969 event and used in "Mill Creek Flood Plain Bylaw Analysis, Associated Engineering, March 2010" model assessment and provided the second highest peak flow on record and flood conditions sustained over a long period of time as opposed to short peak conditions. This event was also considered appropriate for a flood event related to a heavy snowpack in the Mill Creek watershed. The hydrograph developed resulted in a similar duration but with the peak flows estimated for this assessment as shown in Table 3. Figure 18 provides the inflows for the Mill Creek at the upstream extent of the development site for different return period events.

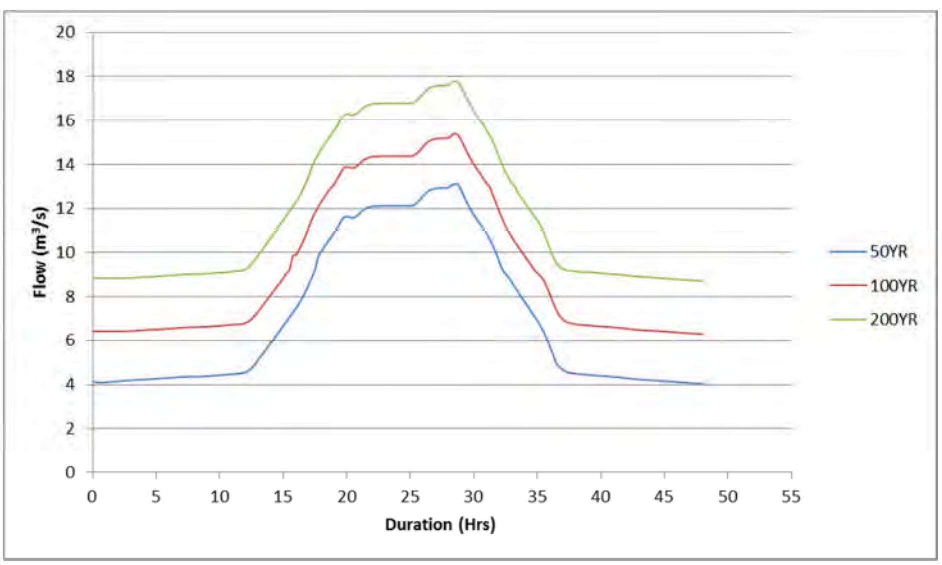


Figure 18: Flood Hydrograph (Model Inflows)

5.3 Model Build and Run

The current HEC-RAS model produced as part of the Mill Creek Flood Plain Bylaw Analysis, March 2010 was run with the revised hydrology for the suite of return period events including the 50, 100 and 200 years.

In order to assess the current hydraulic capacity and flooding conditions for the proposed Taxiway design, a separate hydraulic model was constructed incorporating actual surveyed cross sections of Mill Creek. The model extends for a total reach length of 2,480 m between the twin pipe arch culverts located upstream, and the single culvert located approximately 450 m downstream of the Airport's runway.

The modelling software ISIS version 3.60 was utilized for this purpose. ISIS is a one-dimensional open channel and culverted flow simulation engine capable of handling complex structures and operating rules. This tool was considered appropriate for this assessment, as it provides additional capability for future flood mapping and can seamlessly upgrade to 2-D flood assessment as the project dictates.

5.4 Baseline Condition

The baseline condition represents the existing conditions and therefore provides information on the hydraulic capacity and flooding issues near the existing airport runway and proposed taxiway locations. The baseline 1-D hydraulic model uses surveyed cross sections of Mill Creek. The hydraulic structures include the 1.76 m diameter triple culvert modelled as a single large circular culvert of similar capacity and the 3 m x 2.4 m box culvert that passes under the runway. The surveyed cross sections utilized in the model include mainly in-channel geometry and therefore the floodplain was extended to approximately 200 m with a set bank top level. An unsteady state run was performed with flow boundary conditions for the upstream end of the model, and a normal depth boundary condition for the downstream end of the model. The model was run for a suite of return period events including the 50, 100 and 200-year events. Figure 19 below shows the model extent for the baseline condition.

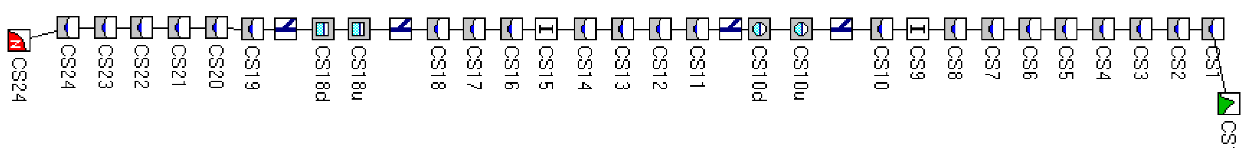


Figure 19: Baseline Model Layout – Kelowna Airport Reach

The model results show some overbank flooding at two specific locations. The first is near Mill Creek model node reach CS5-CS8 located approximately 500 m upstream of the 1.76 m diameter triple circular culverts. The second location is approximately 250 m upstream of the 3.0 m x 2.4 m box culvert located under the runway CS18u. Further investigation on the model geometry and peak water levels at individual cross sections showed the flooding occurred due to insufficient channel capacity at these locations and associated low bank top levels in Mill Creek and not as a result of culvert capacity limitations. Based on the model results, it was concluded that these locations in Mill Creek provide a standard of protection below the 50-year return period flood with a flood depth of approximately 450 mm during a 200-year event. Individual model cross section flood levels are presented in Appendix C to this report.

Table 4: Baseline Modelled Maximum Water Levels (m)

Location	Label	50-Year	100-Year	200-Year
Mill Creek upstream extent of Runway	CS1	425.01	425.10	425.19
Circular Culvert (adjacent Runway)	CS10u	416.44	416.51	416.56
Box Culvert under Runway	CS18u	412.98	413.11	413.25
Mill Creek Downstream extent of Runway	CS23	411.69	411.80	411.88

5.5 Option 3A Results

The post scheme model includes a revised alignment of Mill Creek near the proposed taxiway location and includes new culverts and an extension of the existing box culvert under the main runway. A new cross sectional geometry was introduced for a specific reach of Mill Creek to provide additional in-channel storage. Detailed plans showing the proposed taxiway route, Mill Creek realignment, reaches with new cross section geometry and new culverts are included in Appendix C of this report.

The details of the proposed new culverts in Mill Creek are shown in Table 5 below. Figure 20 below shows the post construction model extent and includes surveyed and proposed cross sections and culverts.

Table 5: Proposed New Culverts

Culvert Dimension	Location (approximate)
66.50 m long single 2.4 m x 2.4 m box culvert	1690 m upstream of Runway Culvert
44.00 m long single 2.4 m x 2.4 m box culvert	1200 m upstream of Runway Culvert
44.00 m long single 2.4 m x 2.4 m box culvert	480 m upstream of Runway Culvert
84.00 m extension to existing single 3.0 m x 2.4 m box culvert	Existing Runway Box Culvert
44.00 m long single 2.4 m x 2.4 m box culvert	90 m downstream of Runway Culvert

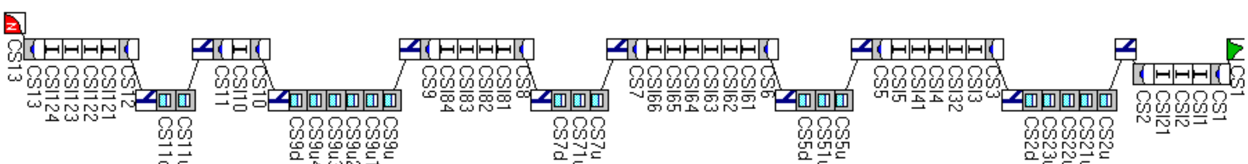


Figure 20: Post Construction Model Layout – Kelowna Airport Reach

The model was run for a suite of return period events including the 50, 100 and 200-year events. The results were analysed near, upstream and downstream of the proposed taxiway and Mill Creek realignment works (see Table 6). It was found that some overland flooding will occur between the cross section nodes CS6 and CS7 near the proposed new 44.0 m long box culvert that is located approximately 500 m upstream of the main runway box culvert. Further investigation of the model geometry and peak water levels shows this is due to insufficient capacity of the existing channel at these locations and associated low bank top levels in Mill Creek. There is no overbank flooding observed upstream or downstream of this reach and the new cross sectional geometry provides sufficient capacity with an available freeboard of 300 to–500 mm above the 200-year return period event. There is an insignificant increase of approximately 0.2 m^3/s in flows is observed at the downstream extent due to the proposed changes. The hydraulic model does not extend further downstream of the airport location as this would be outside the scope of this assessment, therefore further modelling is recommended to accurately assess downstream impacts.

Table 6: Post Construction Modelled Maximum Water Levels (m)

Location	Label	50-Year	100-Year	200-Year
Upstream extent of Runway	CS1	424.78	424.85	424.92
66.50 m Single 2.4 x 2.4 mm box culvert- under new Taxiway	CS2u	422.82	422.94	423.06
44 m Single 2.4 x 2.4 mm box culvert - under new Taxiway	CS5u	418.78	418.89	419.00
44 m Single 2.4 x 2.4 mm box culvert - under new Taxiway	CS7u	414.97	415.04	415.12
3.0 m x 2.4 m Box Culvert under Runway (extended)	CS9u	413.08	413.23	413.38
44 m Single 2.4 x 2.4 mm box culvert - under new Taxiway	CS11u	411.95	412.07	412.19
Downstream extent of Runway	CS13	410.35	410.44	410.53

5.6 Model Outputs

The model outputs include detailed layouts of the model extent, key cross sections peak water level profile, long section profile and peak water levels table for pre- and post- construction conditions. These are presented in Appendix C within this report.

Based on the above assessment, the following modelling conclusions and recommendations are presented.

5.7 Modelling Conclusions

The limitations that were identified from the available model data obtained (Associated Engineering, March 2010) for this assessment includes the following:

- The flood storage areas were modelled as extended cross sections rather than bulk storage areas therefore showing conservative flood extents and levels.
- The 200-year return period event flows were estimated based on the gauge location downstream of Kelowna Airport and therefore considered an overestimate for flows at the proposed taxiway development location.
- The Okanagan lake level at the downstream extent of the model is assumed to impact upstream water levels. However, if large storage areas were modelled, the backwater impact from this downstream boundary condition is considered to remain low.
- The Flood Construction Level (FCL) boundaries produced were based on extension of the maximum modelled water levels from the creek on to ground levels (GLs) extracted from contour maps and therefore the floodplain extent is considered conservative.

Based on the baseline modelling assessment undertaken, the following can be concluded:

- A revised hydrological assessment provided updated flood flows for the development site.
- The baseline model results show the taxiway location is subject to flooding and the current level of protection is below the 50-year return period flood.
- The flooding occurs due to insufficient channel capacity and associated low bank top levels in Mill Creek and not as a result of current culvert capacity.

Based on the modelling results covering Option 3A, the following can be concluded:

- The model results for Option 3A indicates that the proposed realignment and new cross sectional geometry for Mill Creek reach provides sufficient capacity with an available freeboard of 300 to 500 mm above the 200-year return period event.
- There is some localised flooding which could occur at the location between the new culvert sections CS5u and CS7u due to insufficient capacity of the existing channel. Although this may not be an issue at this time, future development of the area east of the runway will limit the area available for flooding and therefore impact the properties downstream of the Airport. This could be avoided by providing additional storage to be developed within the upper reaches of the Mill Creek catchment (Option 3B).
- The hydraulic model developed for this assessment is limited to the Airport property. Downstream impacts were not fully assessed.

5.8 Modelling Recommendations

Further detailed assessment is recommended to assess the possible consequences of increased flooding in the downstream areas due to the development and design appropriate flood mitigation measures. A detailed assessment of the downstream hydrology and hydraulic modelling is recommended. It is suggested that a new 1-D hydraulic model of the downstream reach of Mill Creek and associated tributaries incorporating extended surveyed cross sections is utilized.

A 2-D overland flood model for critical and heavily urbanized areas should be considered to understand the flood hazard and risks accurately. This could also become a potentially useful tool for future land use planning and zoning decisions and to identify relevant mitigation.

6.0 PROJECT CONCLUSIONS & RECOMMENDATIONS

A number of recommendations are provided for the City in the context of moving forward and restoring the functionality of the drainage system along Mill Creek. All the proposed improvements address the estimated flood events without impacting the downstream properties. These options would have to be phased in conjunction with the development plans of the Airport. Depending on the City's ability to secure the required ROWs, the options explored within this report may be limited to Option 1, or the preferred Option 3. At this stage of the project EBA recommends that the available options be reviewed and that a more detailed assessment be developed as the project progresses. The loss of flood storage within the airport would inevitably translate into more damaging flood events along the properties south of the Airport.

Any flood storage losses must be preceded by the development of an equivalent flood storage facility or a mitigation program to protect the properties south of the Airport. As detailed in the report for each of the options we have developed we have included a second option/phase labeled 'B' to include the offsite storage proposed by AE.

Based on the cost estimates developed for Options 1, 2, 3, and 4, EBA believes that Option 3A will provide the lowest costs of construction. That said, option 3A will only help the airport proceed with the development of the new taxiway system and not necessarily with the hanger aprons planned for the eastern portion of the airport. Option 3B includes all the recommendations of Option 3A, but contains the additional offsite storage needed to offset the losses of floodplain storage likely to arise with the development of the hangers, the aprons, and the associated taxiways.

As part of our recommendations, it is suggested that a more detailed survey of the airport property as well as Mill Creek sections downstream of the airport be completed. Although the model developed by AE may have been appropriately detailed for budgetary planning purposes, it does not meet the needs of a detailed design project.

With regards to the management of sediment, we are recommending that a sediment trap be incorporated into the design options. The study area is identified as a sediment deposition zone due to its lower gradient compared to the upstream reaches. A sediment trap in this area would allow for the deposited material in this reach to be collected in a single confined area. The trap would be engineered so that it could be cleaned out on a regular basis efficiently and cost effectively with excavators and hauled off-site with trucks (Figure 8).

The use of a sediment trap can be effective in managing sedimentation in the system, however it needs to be managed effectively in order to maintain a certain level of stability in the channel and promote overall channel equilibrium. Too much sediment accumulation in the study reach will decrease the storage capacity of the channel and hence the ability of the creek to convey the desired flows, hence, our recommendation for a sediment trap. However, the trap needs to be property designed and maintained because a certain amount of bedload material and suspended sediment in the creek is required to maintain a stable channel. For example, if all of the transported sediment is trapped and removed from the system, the creek will respond by degrading the channel downstream of the trap to maintain equilibrium and a balance between flow and sediment. In other words, removing too much material would result in accelerated bank erosion and bed scour. Armouring the channel downstream of the trap would not solve this problem of degradation as it would simply shift the process further downstream to the next unarmoured reach. The design of the sediment trap would also have to take into account the function of the upstream Postill Lake with respect to its effectiveness as a sediment trap as well.

7.0 CLOSURE

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

Sincerely,
EBA Engineering Consultants Ltd.

Prepared by:

ISSUED FOR REVIEW

David Moschini, P.Eng.
Senior Project Manager, Water & Marine Group
Direct Line: 604.685.0017 x225
David.Moschini@tetratech.com

Reviewed by:

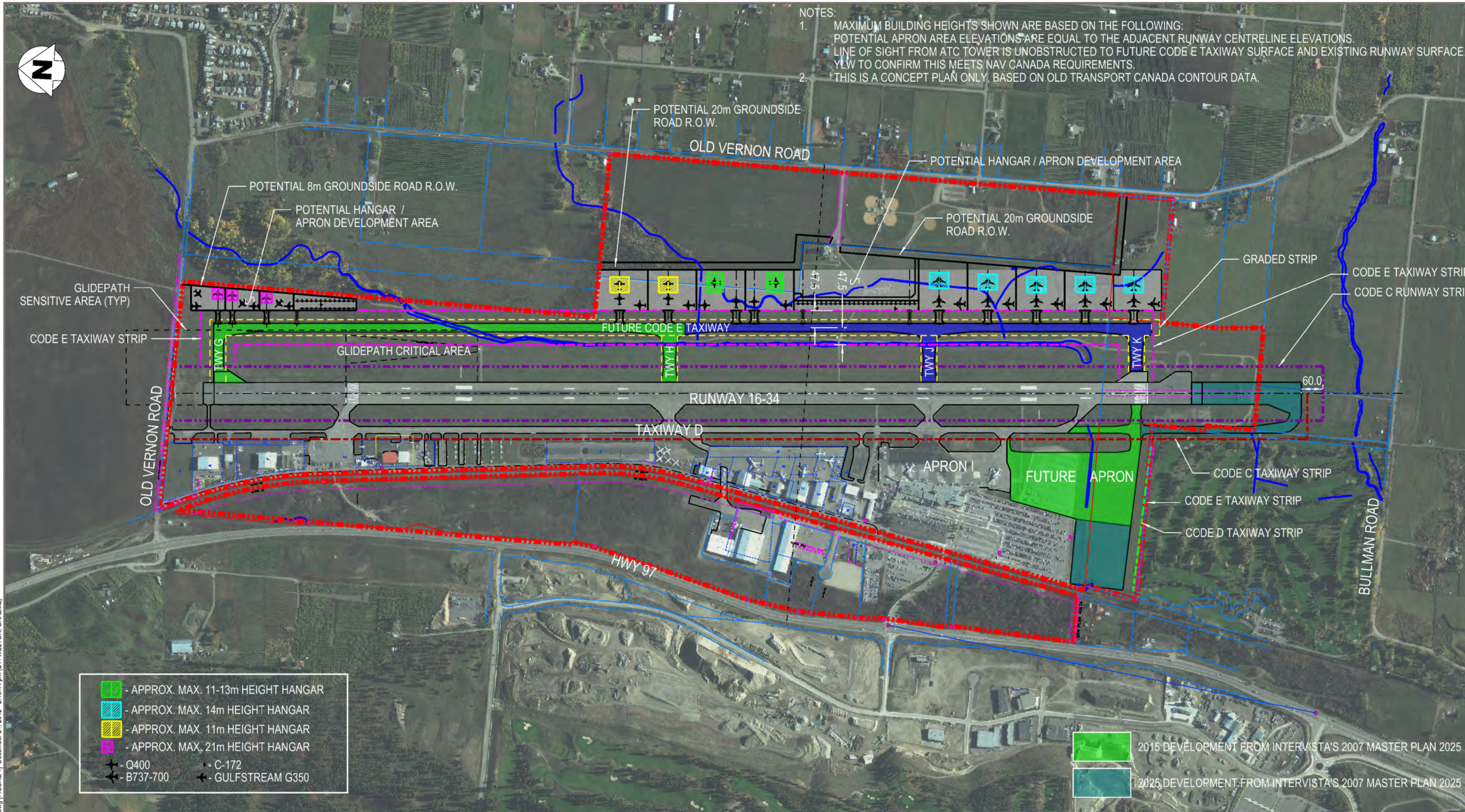
ISSUED FOR REVIEW

Adrian Chantler, Ph.D., P.Eng.
Senior Reviewer, Water & Marine Group
Phone: 604.685.0275
achantler@eba.ca

DM/AGC/rbt

FIGURES

Figure 1	Project Site
Figure 2	Evidence of Gravel Deposition
Figure 3	Evidence of Flat Topography Promoting Extended Surface Ponding
Figure 4	Beaver Dam Obstructing Fish Passage (Culvert Outfall)
Figure 5	Existing Trash Racks North End of Mill Creek
Figure 6	Option 1A
Figure 7	Option 1B
Figure 8	Example of Sediment Trap (Scott Creek in Surrey, BC)
Figure 9	Option 2A
Figure 10	Option 2B
Figure 11	Option 3A
Figure 12	Option 3B
Figure 13	Option 4
Figure 14	Environmental Value Comparison
Figure 15	ALR Impacts Comparison
Figure 16	Limits of the ALR
Figure 17	Mill Creek 1-D HEC-RAS model layout
Figure 18	Flood Hydrograph (Model Inflows)
Figure 19	Baseline Model Layout – Kelowna Airport Reach
Figure 20	Post Construction Model Layout – Kelowna Airport Reach



0 100 200 300 400 500

Scale: 1: 10000 (metres)

CLIENT

City of Kelowna

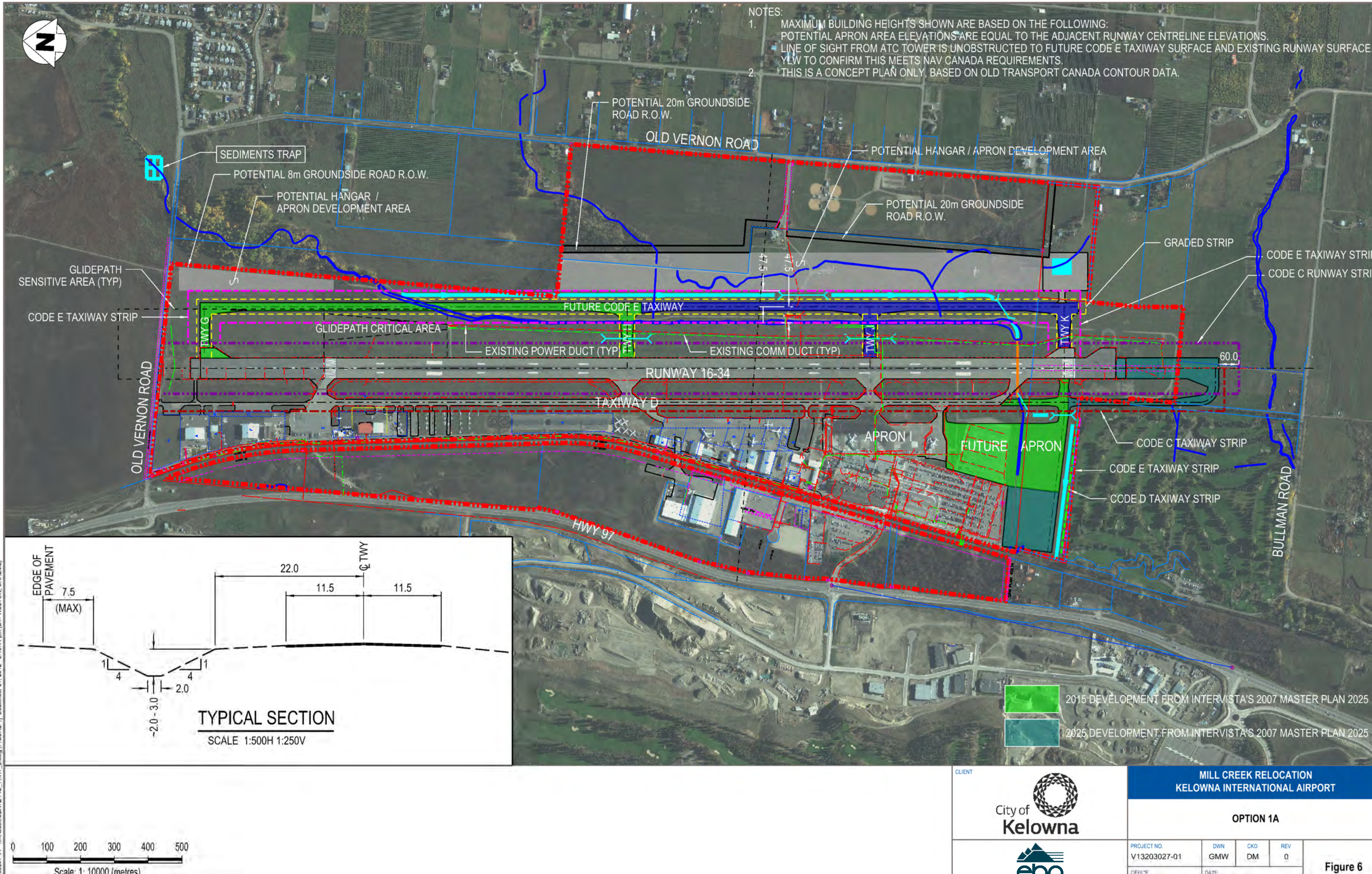
eba A TETRA TECH COMPANY

MILL CREEK RELOCATION
KELOWNA INTERNATIONAL AIRPORT

PROJECT SITE

PROJECT NO.	DWN	CKD	REV	
V13203027-01	GMW	DM	0	**Figure 1.0**
OFFICE	DATE			
VANC	March 06, 2013			

Figure 1 Project Site.dgn 3/7/2013 8:49:26 AM G.Welton C.Tech



K:\V13203027-01 - mill creek\EBATB FIG_11x17_L.dwg [FIGURE 1] December 21, 2012 - 2:16:44 pm (BY: WELTON, GRAEME)

CLIENT
City of Kelowna

eba
A TETRA TECH COMPANY

MILL CREEK RELOCATION
KELOWNA INTERNATIONAL AIRPORT

OPTION 1A

PROJECT NO.	DWN	CKD	REV	
V13203027-01	GMW	DM	0	**Figure 6**
OFFICE	DATE			
VANC	March 18, 2013			

OPTION 1A 11x17.dgn 3/18/2013 3:31:52 PM G.Welton C.Tech