BIOENGINEERING DEMONSTRATION AND EDUCATION PROJECT

Site Assessment Technical Report

Prepared for:
Alberta Environment and Parks
Suite 100, 3115 12 St. NE
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Prepared by:
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File: 1873-004.01
September 2016

HEMMERA

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September 14, 2016
File: 1873-004.01

Alberta Environment and Parks
Suite 100, 3115 12 St. NE
Calgary, Alberta T2E 7J2

Attn: David DePape – FISHES Program Manager

Dear David,

Re: Site Assessment Technical Report for the Bioengineering Demonstration and Education Project

Hemmera Envirochem Inc. is pleased to provide you with this copy of the Site Assessment Technical Report.

The enclosed reports are considered Draft, and are provided for discussion purposes. As such, the reports are not signed. Please review the reports and provide Hemmera with any comments and written revisions you feel are appropriate. Once comments and revision requests are received and reviewed, we will finalize the report and circulate signed copies. We have appreciated the opportunity to work with you on this project and trust that this report meets your requirements. Please feel free to contact the undersigned by phone or email regarding any questions or further information that you may require.

Regards,
Hemmera Envirochem Inc.

DRAFT

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1.0 INTRODUCTION

Hemmera's team understands that Alberta Environment and Parks (AEP) primary goal for the Fishes Program's Bioengineering Demonstration and Education is to achieve fish habitat enhancement and riparian restoration at flood affected and impacted sites using bioengineering techniques. Integrating education opportunities and objectives during the design development will facilitate and increase the understanding with a range of identified audiences that bioengineering techniques are an effective and ecologically valuable alternative to conventional bank erosion and riparian restoration practices.

Specifically, Hemmera's team understands from the Project Charter that AEP will consider the Project a success if it meets the following criteria:

i. Effectively stabilizes an area of unstable, steep bank;
ii. Leads to measurable restoration of flood affected habitat or creation of new fish habitat (i.e., bank overhangs, instream refugia, boulder clusters, large woody debris, shade/cover by riparian plantings, etc.);
iii. Is designed and constructed to facilitate increased awareness and understanding, of flood recovery processes, development of new educational programming targeting bioengineering techniques and related design success factors; and
iv. Improves riverbank aesthetics in the area.

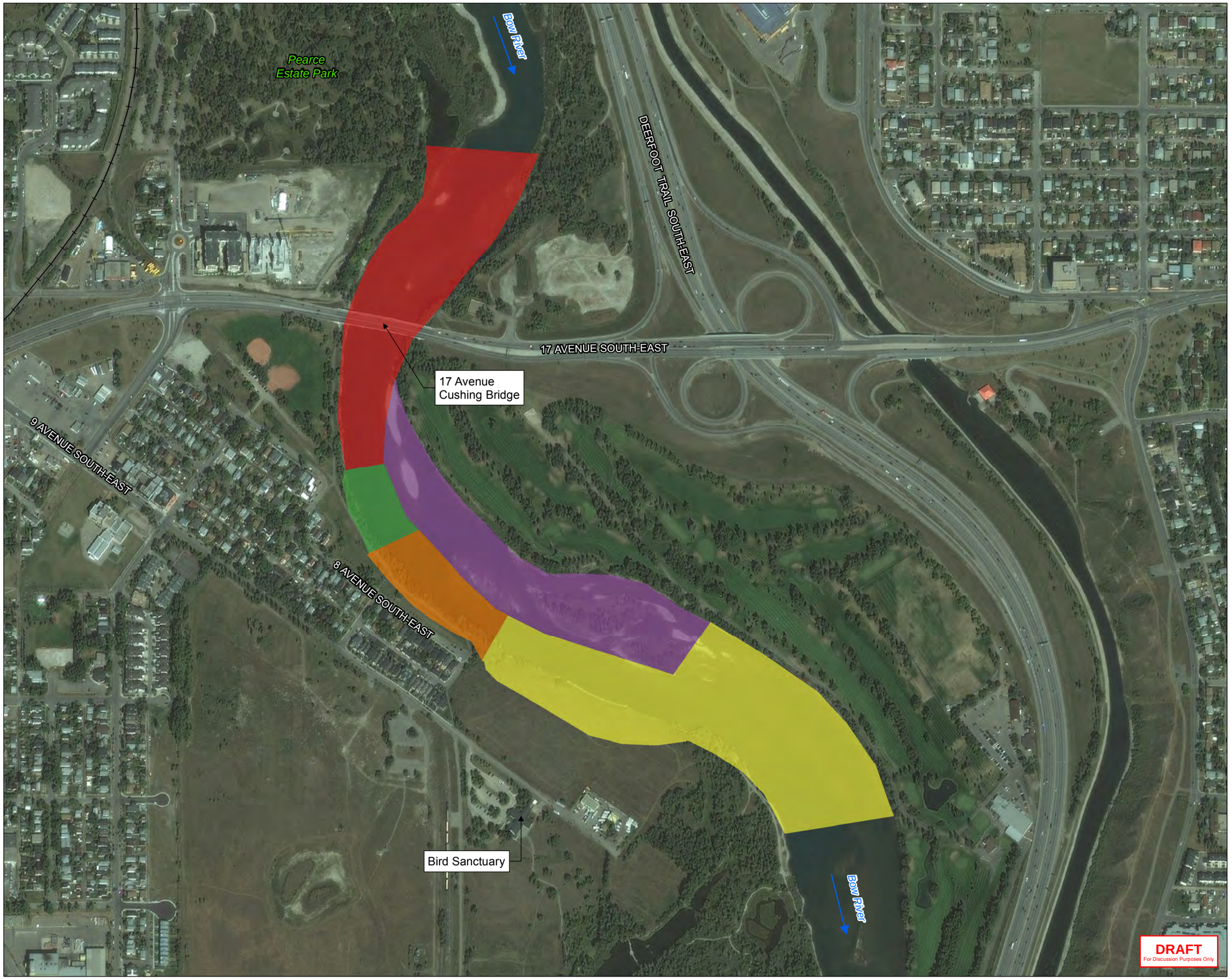
2.0 SITE ASSESSMENT REPORT

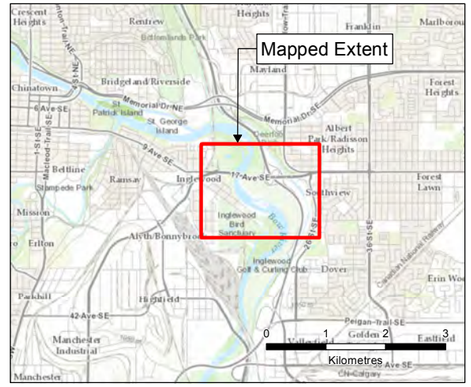
This Site Assessment Report represents one of the early deliverables for the FISHES programs' Bioengineering Demonstration and Education project. It summarizes background knowledge and initial site assessments made by Hemmera's integrated Project team on a site reconnaissance on July 18, 2016 for each of the five project sites (**Figure 1** and **Figure 2**).

Each site assessment identified current conditions, issues, challenges and constraints as well as opportunities for bioengineering options, fish and riparian habitat restoration and/or enhancement, educational messaging and associated educational program infrastructure, as well as landscape design and wayfaring considerations.

Bioengineering Demonstration Project: Site Assessment
Bow River, Calgary, Alberta

Bioengineering Site Assessment Site Map





Legend

- Site 1
- Site 2
- Site 3
- Site 4
- Site 5
- Direction of Flow
- Railway

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Aerial Image: ESRI World Imagery,
- Inset Basemap: ESRI World Topographic Map

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Calgary 3TM

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1873-004.01	Production Date: Sep 12, 2016	Figure 1

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Alberta Environment and Park

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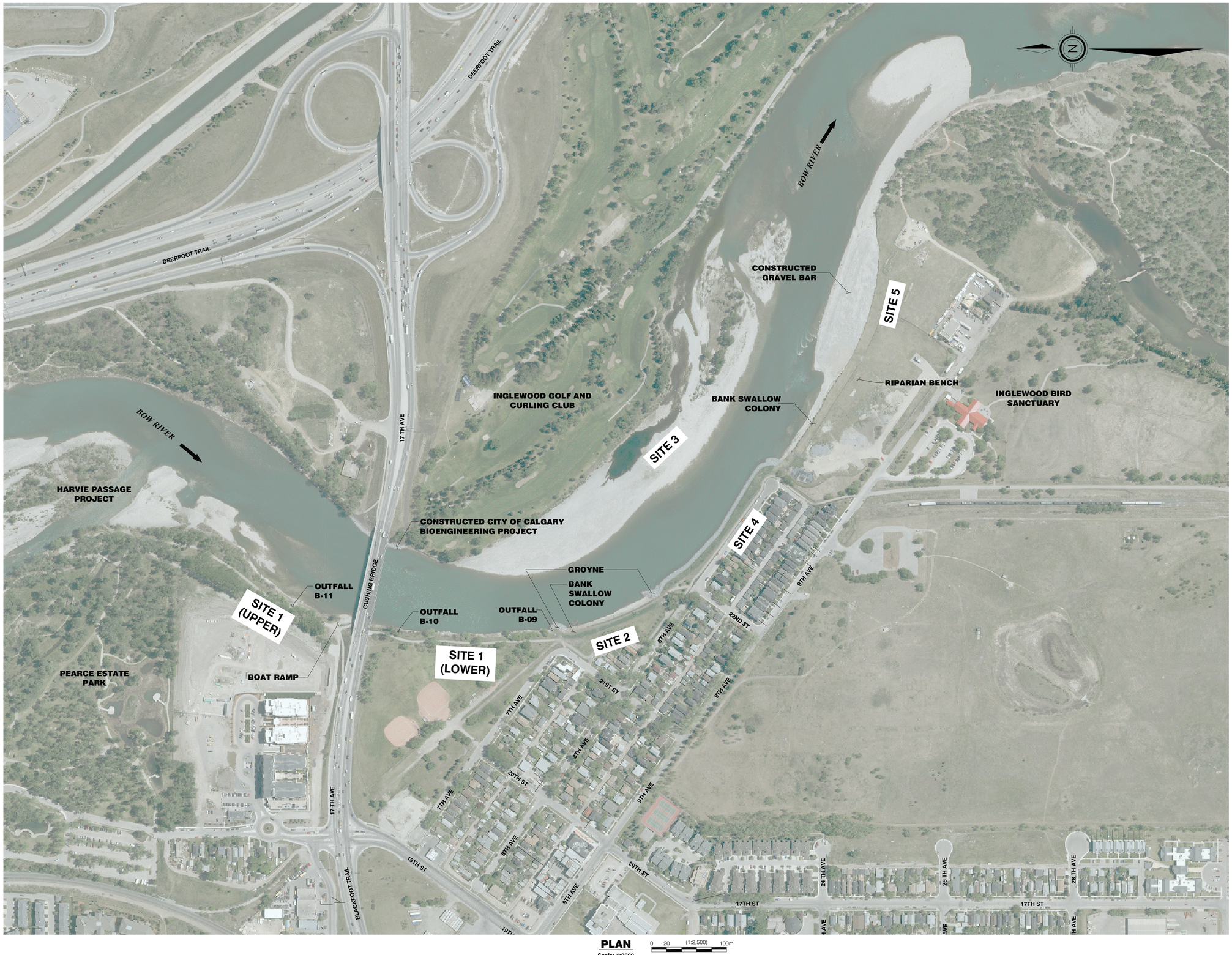

PLAN
Scale: 1:2500

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Seal:

Rev	Date	Des	Dwn	Chk	Description of Revision
A	SEP.13/2017	TWC	TWC	AKS	ORIGINAL PLAN PREPARED

BIOENGINEERING DEMONSTRATION AND EDUCATION PROJECT

FIGURE 2
PROJECT SITE OVERVIEW

Project No.	Drawing No.	Rev.
3552-004		A
Group		

3.0 SITE RECONNAISSANCE

The full integrated Hemmera Project team conducted an on-site reconnaissance on July 18, 2016 to assess the conditions and identify opportunities at each site. An in-field brainstorming session regarding potential concept options in a discipline integrated approach was also completed. Following the site reconnaissance, the Hemmera Project team participated in an internal workshop to develop viable concept options for each site based on background site knowledge and field observations. A minimum of three conceptual bioengineering options for each site were identified.

Prior to the site reconnaissance meeting, Skymatics Ltd. used drone technology to document the existing baseline conditions of the Project area to facilitate the performance evaluation each site regarding riparian vegetation, streambank and slope stability, fish and wildlife habitat. Aerial imagery was collected as well as photos of the river bank and a video of the river bank in the Project area. A georeferenced flight path was documented for use in long-term monitoring of the Project.

Following the site reconnaissance and internal brainstorming workshop, additional baseline and assessment work consisted of:

- a field survey to complete bathymetric mapping (**Figure 3**);
- a preliminary geomorphology assessment to review the historic planform channel changes on the Bow River with specific attention to the channel morphology immediately downstream of the Cushing Bridge; and,
- a desktop geotechnical assessment to provide a general geotechnical site characterization and consideration of geotechnical and materials engineering aspects including riparian slope stability and related riverbank restoration strategies.

The findings of the desktop studies are summarized in a preliminary geomorphology assessment report in **Appendix A** and a preliminary geotechnical assessment report in **Appendix B**.

The results and observations of the on-site reconnaissance were captured and summarized for each Project site on individual Site Assessment Forms (**Section 4.0**). Each form includes the following:

- Concerns/issues and enhancement opportunities related to:
  - Fish and fish habitat;
  - Wildlife and wildlife habitat;
  - Vegetation;
  - Streambank and slope stability;
  - Pathway connectivity; and
  - Impacts on adjacent park spaces and amenities.

- Processes, “filters” or causes for the bank erosion or bank instability issues.
- Biophysical and educational objectives which would drive the development of concept designs and resolve the concerns/issues identified.
- Existing and historical land use.
- Key photos and descriptions.

PLAN
Scale: 1:2500

0 20 (1:2,500) 100m

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Rev	Date	Des	Dwn	Chk	Description of Revision
A	SEP.14/2017	TWC	TWC	AKS	ORIGINAL PLAN PREPARED

BIOENGINEERING DEMONSTRATION AND EDUCATION PROJECT

FIGURE 3
PROJECT SITE TOPOGRAPHY

Project No. 3552-004	Drawing No.	Rev. A
Group		

4.0 SITE ASSESSMENT SUMMARIES

Site Assessments for each of the five Project sites are described in the following sections.

4.1 SITE 1 ASSESSMENT

4.1.1 Key Data:

Watercourse:	Bow River	Upstream Limit:	(Lat)	51.039659	(Long)	-114.011479
		Downstream Limit:	(Lat)	51.035107	(Long)	-114.013988
Address :	Cushing Bridge over Bow River along 17th Avenue SE (right bank)					
Location:	**Site 1** – Located along the right bank of the Bow River extending from approximately 280 m upstream of the Cushing (immediately below the downstream limits of Harvie Passage), to approximately 260 m downstream of the Cushing Bridge, in Inglewood.					

4.1.2 Site Description:

River Morphology:
Extract from KWL technical memorandum titled: '**DRAFT** – Preliminary Geomorphology Assessment', dated August 30, 2016 (**Appendix A**): *Upstream of the Cushing Bridge, the location of both the left and right banks appear to have migrated eastward by ~30 m from 1924 to 1952. From 1952 to 2014, the location of these same banks has not changed significantly. Users of a boat launch located immediately upstream of the Cushing Bridge along the right bank have noted that the thalweg appears to have shifted towards the left bank following the 2013 flood.* *Downstream of the Cushing Bridge, the right bank at Site 1 has remained in the same position for the entire study record (1924 to 2014). Observations during the field visit and discussions with colleagues during the project initiation meeting revealed that this steep, tall bank is a remnant of a former railroad bed that was armoured with large pieces of concrete, which are visible along the bank's toe. The left bank downstream of the Cushing Bridge (upstream of Site 3) has migrated ~15 m to the east from 1924 to 2012. The flood in 2013 caused this same bank to migrate an additional ~15 m eastward.* *The downstream section of Site 1 (below Cushing Bridge) is located on the Bow River where a transition between two meander bends occurs. This is the location where the thalweg crosses over from the left side of the channel towards the right side, along the outside bend of the upstream meander. The thalweg is where the stream velocities are concentrated and where the capacity of a river to erode and transport sediment is greatest. Typically, an outside meander bend erodes as the inside meander bend (on opposite bank) accrete, maintaining a fairly consistent channel width overtime. However, the tall right bank along the lower section of Site 1 is armored and has not migrated westward in the last 90 years as one would expect in a natural system. Yet, the opposite bank (left bank) has migrated or accreted by ~ 20 m (from 1924 to 2014), resulting in a reduction in channel width overtime. This reduction in channel width would exacerbate the concentrations of stream velocities in the thalweg, which at this point is likely situated along the outside bend of the meander at Site 1. Since the bank here is armoured, the excess capacity for the river to erode sediment would likely lead to scouring of the unarmoured river bed.* *In 2014, Golder Associates conducted an assessment of the pre and post flood river bed topographies along the downstream section of Site 1 on the Bow River as part of a bank protection design study. The report is attached to this document (Appendix B). The relevant information from the Golder report (2014), as it pertains to the agenda item #5, is summarized below:* • *A deep scour hole formed along the right bank at the downstream section of Site 1. It is estimated that velocities of 4 to 5 m/s where reached at this location during the 2013 flood.* • *The river bed at the scour hole appears to have scoured approximately by 4 m. This is near the depth of local bedrock.* • *This scour hole is considered high value fish habitat, however it may function as a potential ice anchor where future ice jams may originate.* • *Due to the presence of bedrock, it is unlikely that the scour hole will expand. In fact, the deposited gravel upstream of Cushing Bridge from the 2013 flood will more likely cause the scour hole to eventually fill with gravel.*

Surficial Geology / Bedrock Geology:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

It is recommended that any geotechnical investigation carried out in Site 1 extend to bedrock. The depth of bedrock encountered within the borehole should be compared against the surveyed depth of the scour hole.

Bank Stability:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Vegetation:

- Snowberry : *Symphoricarpos albus*
- Honeysuckle: *Lonicera spp.*
- Maple: *Acer negundo*
- *Artemisia spp.*
- Tansy : *Tanacetum vulgare*
- Saskatoon berry: *Amelanchier aln.*
- Ash tree: *Fraxinus spp.*
- Sandbar willow: *Salix exigua*
- Yellow willow: *Salix lutea*
- Balsam poplar: *Populus balsamifera*
- Red osier dogwood: *Cornus stolonifera*

Fish Habitat:

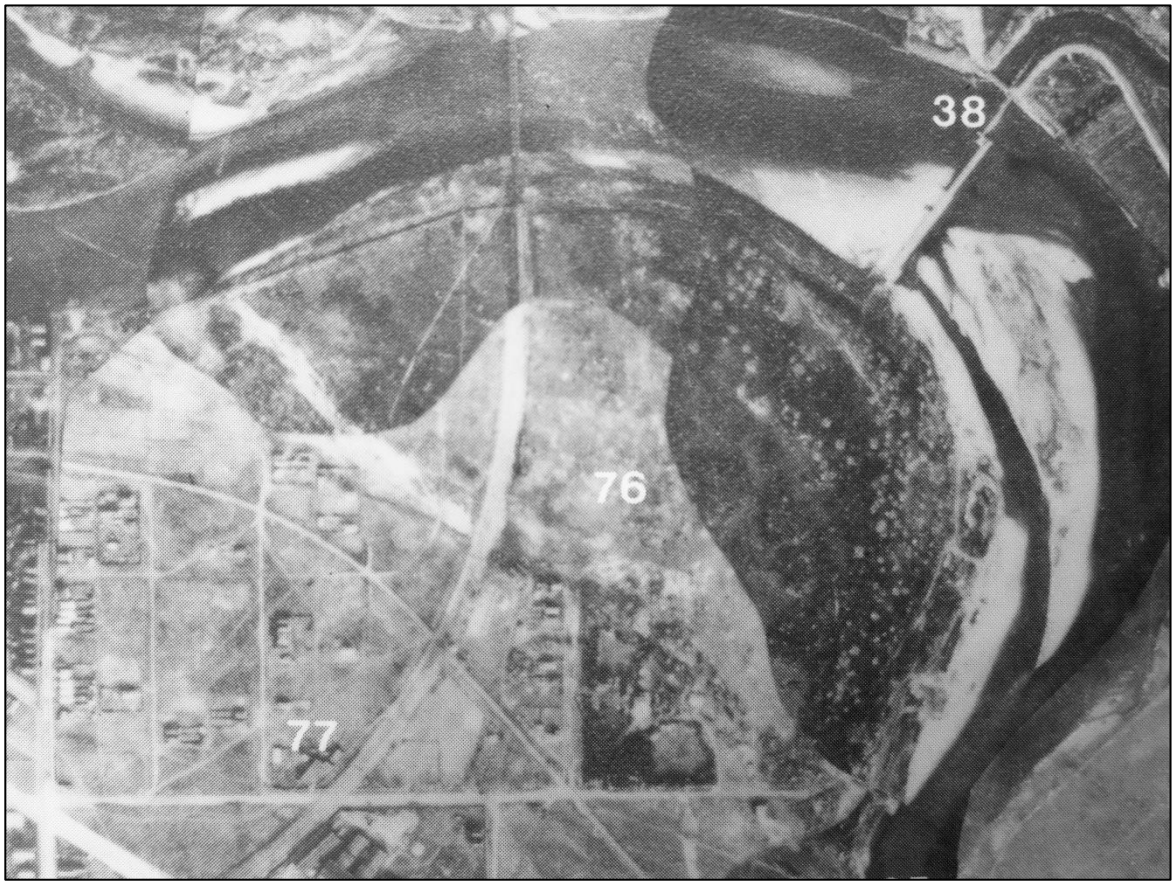
A detailed fish habitat assessment was conducted in 2014 by Klohn Crippen Berger (Klohn), and was provided to the Bioengineering team by the City of Calgary (Klohn 2015). A bathymetry survey of Site 1 was conducted by Kerr Wood Leidal (KWL) in July 2016. The upstream boundary of Site 1 is located approximately 280 metres (m) upstream of the 17 Avenue Cushing Bridge, immediately downstream of Harvie Passage, with the downstream boundary located approximately 200 m downstream of the Cushing Bridge (**Figure 1** and **2**).

Fish habitat within the upstream section of Site 1 (downstream of Harvie Passage and upstream of the Cushing Bridge) consists of alternating deep run (R1) and moderate run (R2) habitat. Shallow pool (P3) habitat is present along the left downstream bank (LDB) with alternating moderate pool (P2) and P3 habitat present along the right downstream bank (RDB). Deep pool habitat (P1) is present in the downstream section of Site 1 (downstream of the Cushing bridge) to the upstream extent of Site 2 and Site 3 (Klohn 2015). Maximum water depth ranges from 0.40 m in P3 habitat to approximately 7 m in R1 and P1 habitat. Substrates throughout Site 1 consist primarily of boulder and cobbles in R1 habitat and cobble and gravel in R2 habitat. Pool habitat (P1, P2, and P3) substrates consist primarily of boulder, cobble, and fines (Klohn 2015). Cover throughout Site 1 is provided primarily by depth and turbulence, with some overhanging cover provided by woody vegetation along the LDB. Boulder substrates present throughout run and pool habitats likely provide instream cover for fish.

Deep run (R1) and pool (P1) habitat is likely utilized as holding, feeding, and overwintering habitat for adult and juvenile fish, with shallower P2, P3, and R2 habitat functioning as holding and rearing habitat for juvenile fish. Deep pool (P1) and R1 habitat within the downstream section of Site 1 likely provides excellent overwintering habitat, with a maximum water depth of approximately 7 m. Back water habitat created by side and mid channel bars likely provides velocity refuge to fish through Site 1. Gravel and cobble substrates located at the downstream end of side and mid channel bars provides suitable spawning habitat for brown trout (*Salmo trutta*) and rainbow trout (*Oncorthynchus mykiss*). Mountain whitefish (*Prosopium williamsoni*) spawning likely occurs over cobble and large gravels located in R1 and R2 habitat.

Historical Information:

Upstream of Cushing Bridge, Site 1 is located adjacent to Pearce Estate Park. William Pearce settled in Calgary in 1887 and subsequently purchased 60 acres of rural property. Most of this area is now known as Pearce Estate Park. Pearce expended considerable effort developing his property, and his estate housed a prominent home constructed of sandstone and modern conveniences called Bow Bend Shack, a pond, an irrigation canal, tree plantings and recreation grounds. Pearce's records document numerous flooding events on his property, as well as efforts by him to plant upwards of 30,000 willows on his property. The photo below shows the site in 1924. Site 1 is comprised primarily of gravel cobble.



Downstream of Cushing Bridge, Site 1 is located at the northern limits of the Grand Trunk Pacific Railway line. At the southern boundary of Site 1, the railway turned westward towards its terminus at Fort Calgary. The raised railbed still remains in this location. At one point, there was a bridge that crossed the Bow River immediately downstream of Cushing Bridge. Remains of the piles are evident across the river and upstream of Site 3.

4.1.3 Photo Record:

Photo 1: Outfall B-10 located within 100 m downstream of Cushing Bridge on right downstream bank.

Photo 2: Looking downstream from outfall B-10.

Photo 3: View looking downstream from middle of Site 1. View of historic broken concrete remediation and steep slope.

Photo 4: Looking towards downstream end of Site 1. Localized bank slump.

Photo 5: View at downstream end of Site 1. Steep slope with historic broken concrete remediation.

Photo 6: Right downstream bank area upstream of Cushing Bridge looking downstream towards the bridge.

Photo 7: View towards right bank deposition area immediately downstream of the Harvie passage site.

Photo 8: View towards right bank deposition area looking upstream immediately downstream of the Harvie passage site.

4.1.4 Field Observations & Notes

General	Issues/Constraints	Opportunities
Hydraulics / Geotechnical:	• Deep scour hole at the toe of the right bank. • Suspected bedrock within scour hole; depth to bedrock to be determined during geotechnical site investigation. • Bank Stability - steep bank (est. 1H:1V) with sharp eroding top of bank • Broken concrete and other unnatural materials scattered over the bank. • Cushing Bridge pier angle potentially directs and concentrates flood flows toward the bank.	• Constructions access from the south with staging areas potential at the south with turnaround to the north (or additional staging area w/temporary access along 17th Ave/Blackfoot Trail). • Potential public meeting space (Amphitheatre), lookout pathway or trail, viewpoint to opposing bank (bioengineering demonstration). • Incorporation of a stepped bank with bioengineered features to offer flood resistance and protection, and a wildlife corridor. • Movement of the City pathway into the ball diamond area (not required for ball diamond) to enhance wildlife habitat and improve wildlife corridor. • Considerations for fish habitat enhancements such as overhangs and fish shelters.
Constructability:	• Scour holes and erosion features below water will be a challenge to in-water design and construction. • Mature trees in path of bank construction efforts. Consider localized preservation. • Recreational Infrastructure - cycle path and recreational infrastructure (baseball diamonds) located along the land side (require temporary path closure or detour). • City of Calgary Outfall No B-10 is located about 100 m downstream of the Cushing Bridge; Outfall No 9 located at the southern limit of Site 1 adjacent a rock groyne.	TBD
Biophysical	**Issues/Constraints**	**Opportunities**
Fish Habitat	• Deep pools and runs offer habitat for fish (potential habitat loss or high net offset requirement). • RAP: May 1 – July 15 and September 16 – April 15 • lack of instream overhead cover • Low habitat complexity	• Create habitat complexity • Create adult holding cover; overhead cover, turbulence • Create adult resting habitat • Addition of boulder clusters, fish shelters • Addition of overhanging vegetation
Wildlife Habitat	• Cushing Bridge area and pathway presents land based wildlife movement constriction/barrier • Nesting birds, including raptors.	• Incorporation of a stepped bank with bioengineered features to offer flood resistance and protection, and a wildlife corridor. • Out of water work may consider construction outside nesting and migration period.

General	Issues/Constraints	Opportunities
Riparian Landscape	• No mature trees or vegetation (recent installation of live stakes).	Potential to enhance riparian health.
Slope Stability	• Upstream of the Cushing Bridge, the right bank stability does not appear to be a concern area. This reach of Site 1 is along the transition point from the inside bend of the Bow River to the outside bend farther downstream past the Cushing Bridge. This reach is aggrading near its upper most point and, as such, the river bank is easily accessible; less than 3 m of elevation change with a shallow bank slope. • Downstream of the Cushing Bridge, the right bank quickly transitions from a low shallow sloped bank to a steep (nearly 1H:1V) bank rising up to as much as 8 m above the normal river elevation. This section of Site 1 will be the subject of a more detailed site geotechnical site investigation to advance and inform the design team regarding the depth to bedrock, the nature of the subsurface materials, and permit the evaluation of the proposed river bank restoration options vis-à-vis bank stability.	TBD
Land Use	S-R Special Purpose - Recreation The S-R designation is primarily for recreation facilities, both indoor and outdoor	

General	Issues/Constraints	Opportunities
Educational	**Issues/Constraints**	**Opportunities**
Gravel beach area immediately below Harvie Passage site	• the gravel deposit in this area may shift and change in size over time • any structures in this area may be subject to periodic inundation and will need to be up higher or will need to withstand inundation without damage	• this area is easily accessible from the pathway. • there is already a lot of use of this area by sunbathers, anglers, and families swimming their dogs and/or children. • this is a potential vantage point to see the wildlife corridor on the Left Downstream bank under and upstream from the Cushing bridge and the storm water outflow B-10. • The succession of the plants and how they affect/encourage the deposition of gravel can be discovered here, especially related to all the willow plants. Willows send out rhizomes in order to spread and quickly stabilise the area and retain water in the gravel. • Balsam poplars are also starting to take root at the waterline offering an interpretive opportunity regarding successional processes and early established species as well as the importance of these trees in creating habitat along the rivers in Calgary. • Installing a circle of large logs (possibly with root wads) for seating could easily create a simple interpretive node that provides a spot to gather people together and will potentially create fish habitat when inundated.
Vegetated slope between Cushing Bridge and Outfall B-10	• the shore in this area is not easily accessible • there is little space on the river side of the pathway to accommodate an interpretive stop without blocking the pathway	• though this is not the best place for interpretive structures, a wildlife camera pointed under the bridge might yield interesting information about wildlife travel through the wildlife corridor and the effects of enhancing the pinch-point under the bridge • Opportunity to focus on outfall B-10 which is adjacent to and accessible to the Regional Pathway and highlight stormwater management messages.

General	Issues/Constraints	Opportunities
Slope South of Cushing Bridge	• this is a very steep slope and not easily accessible from the pathway • once the bioengineering work is completed, it will be difficult to observe what has been done from the pathway	• Potential for a single river-facing sign for recreational users with a simple (large message) e.g. Know what's going on here? BIOENGINEERING that's what!? + QR code" that would link with photos showing all the different sites. People can then click on each to get more information about the bioengineering methods used. • This site is easily visible from the gravel bar in site 3, a pull off for RiverWatch and other river users, providing a good vantage for interpretive programming for RiverWatch and angling guides who have been provided information ahead of time so they can enrich the experience of their clients. • A trail (or staircase) down to shore would provide a good vantage point to highlight the bioengineering and fish habitat enhancement methods up close • A wider trail spot on the trail could be created as a gathering point for small groups for an interpretive talk

From July 17 Site Assessment Inspection

- Remove concrete debris
- Slope stability, assessment of fill material required
- Deep pool, bed rock near vertical slope
- Mostly vegetated north of outfall 09 up to Cushing Bridge, minor erosion at toe
- Balsam poplar located between outfall 09 and Cushing Bridge should be saved by designing a structure on existing bank as described below. This would allow for wildlife corridor to go through existing pedestrian path location.
  - Mature balsam poplars would provide vertical structural diversity within the wildlife corridor and riparian zone.
  - Perching bird habitat
  - Contributing to small organic debris input into the river
- Cardboard and arborist mulch could be used to reduce herbaceous competition around planted riparian species on bench (ps: mulch can attract rodent such a vole and voles can cause damage to planted seedlings, use of milo-organite fertilizer around planted seedlings will deter voles from damaging the plants).
- (see Calgary design guidelines H)

Options (area downstream of bridge)

The combined options below are looking at preserving the existing pedestrian path and as much as possible of the bench width and existing vegetation.

Working on steep slope adjacent to water would also be a good site to demonstrate the versatility and cost efficiency of the use of walking excavator (spyder hoe; pictured below) to implement the work.

Note: Area downstream of section 1 above the existing upstream groyne could be used to demonstrate how brush mattresses with crib toe, simple rock toe or rock / fascine toe would perform in a higher velocity environment. This could be applied in either situation i.e. wither the slope is pulled back or not.

General	Issues/Constraints	Opportunities

Spyder Hoe Excavator

Photo courtesy of Pierre Raymond, Terra Erosion Control Ltd.

From July 18 Post Site Assessment Brainstorming Session

- Deer passage/corridor to allow deer's below Cushing Bridge / City may pay for construction
  - ~ 4 m in width over existing riprap could be filled with gravel to provide a more stable platform for wildlife to travel. Existing riprap at 1:2 yr elevation level
- May move diamond ball park, this would allow to cut back existing slope and provide creation of benches
- Water flow as of today 166 cms on Bow, 20 cms from Elbow
- Deepest pools located downstream of bridge / may have scoured to bedrock
- Area upstream from bridge and boat launch
- Leave *Salix exigua* (sandbar willows) to colonize the sandbar
- Balsam poplar seedlings growing on sandbar
- Potential provide trail to allow increase use of public beaches
  - Put large logs on beach for people to use as benches and resting structures
- Potential fill in of gravel to lower water level and create a wet riparian forest and widen wildlife corridor
  - Could install live siltation to provide riparian cover and catch sediment this would result in accumulating sediment and raising existing ground elevation (with or without placement of gravel).
  - This area is dry ~ 300 days of the year

4.1.5 Bioengineered Options

Description		Cost (Class 5)
OPTION 1	Vegetated crib walls with riprap in lower 2 cribbing secured with steel rods 1-1 Fish shelter above areas with bedrock to be located at lower elevation below LWL alternating every 10 linear m i.e. with fish shelter and with out 1-2 Combined treatment with vegetated soil wrap at 1.5:1.0 to top of slope 1-3 Area located above the upper vegetated soil wrap and onto the bench could have planted potted riparian species of shrubs and trees to enhance riparian wildlife corridor.	TBD
OPTION 2	Vegetated geogrid i.e. bottom layers filled in with rocks and with inserted vegetation on the layers above and combined with option 1-3 Upstream of outfall 09, rock toe or box fascine with one brush layer to protect toe	TBD
OPTION 3	Outfall 09, toe apron, vegetated riprap at 1.5:1.0 3-1 Vegetated soil wraps above riprap to meet with bench elevation 3-2 Or contour fascines with brush layers above riprap to meet with bench elevation.	TBD
Conventional Approach	**Hard engineering** option consisting of a rip rap toe protection, w/ launching apron where bedrock is absence, capable of withstanding scour on part of extreme flood flows. Rip rap slope with max 2H:1V side slope, w/o vegetation, over a granular bedding and transition material to the existing bank material. Synthetic geotextile materials may be used to replace transition materials against the existing bank material. Crest elevation to provide sufficient freeboard. Consideration may be given to bioremediation of the upper portion of the reconstructed 2H:1V bank.	TBD

4.1.6 References:

Klohn Crippen Berger (Klohn) 2015. Calgary Rivers Morphology and Fish Habitat Study, Technical Memo F-1: Existing Fish Habitat. Draft report prepared for the City of Calgary April 2015.

4.2 SITE 2 ASSESSMENT

4.2.1 Key Data:

Watercourse:	Bow River	Upstream Limit:	(Lat)	51.035107	(Long)	-114.013988
		Downstream Limit:	(Lat)	51.034064	(Long)	-114.013297
Address :	7th Avenue and 21st Street SE to 8th Avenue and 23rd Street SE, Calgary, AB					
Location:	**Site 2** – Bow River right bank located approximately 260 m downstream of the Cushing Bridge in Inglewood. The site is bounded by two rock groynes that appear to have been constructed shortly after the June 2013 flood event (**Figure 1**).					

4.2.2 Site Description:

River Morphology:
Extract from KWL technical memorandum titled: '**DRAFT** – Preliminary Geomorphology Assessment', dated August 30, 2016 (**Appendix A**): *The bank along Site 2 appears to have migrated ~ 11m westward from 1924 to 1952. The bank remained relatively unchanged from 1952 to 2012. The flood event in 2013 caused the bank to migrate a further ~ 17 m westward.* Rock groynes constructed immediately following the 2013 flood is anticipated to retard westward movement during future extreme flood events.
Surficial Geology / Bedrock Geology:
Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).
Bank Stability:
Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 **Appendix B**).
Vegetation:
Generally devoid of vegetation along the bank slope. Some historic willow staking evident with low success overbank vegetation generally (non-native) city park vegetation; grass, trees, shrubs.

Fish Habitat:
A detailed fish habitat assessment was conducted in 2014 by Klohn Crippen Berger (Klohn), and was provided to the Bioengineering team by the City of Calgary (Klohn 2015). An additional fish habitat assessment was conducted in May 2016 by Hemmera Envirochem (Hemmera) along with a bathymetry survey of Site 2 completed by Kerr Wood Leidal (KWL) in July 2016. Site 2 is located approximately 260 meters (m) downstream of the 17 avenue Cushing Bridge at the first riprap groyne constructed along the right downstream bank (RDB), extending for approximately 140 m downstream to a second riprap groyne along the RDB to the upstream boundary of Site 4 (**Figure 1** and **2**). Site 2 extends mid-way through the channel width from the RDB to the wetted edge of a cobble side bar along the left downstream bank (LDB) and boundary of Site 3. Fish habitat within Site 2 consists almost entirely of a deep run (R1) habitat, with moderate depth pool (P2) habitat located immediately downstream of riprap groynes constructed out into the Bow River at the upstream and downstream extent of the RDB of Site 2, adjacent to a city of Calgary pathway in Inglewood (Klohn 2015 and Hemmera 2016). Water depth is relatively uniform through this section, ranging from 1 m to 1.5 m. Substrates consist primarily of boulder and large cobbles in R1 habitat and boulder and riprap within P2 habitat downstream of flood mitigation structures (groynes). Cover is provided primarily by depth and turbulence, and by boulder and riprap substrates. Large woody debris has accumulated within the P2 habitat immediately downstream of the riprap groyne present at the upstream boundary of Site 2 along the RDB. Large woody debris provides suitable overhanging and instream cover. Overhanging cover is otherwise severely limited throughout Site 2. Deep run (R1) habitat provides excellent holding, feeding, and overwintering habitat for adult and juvenile fish. P2 habitat present downstream of riprap groynes provides a velocity refuge for fish as well as suitable holding and feeding habitat for juvenile fish. There is limited potential spawning habitat for salmonids through this section of the Bow River due to the larger size of substrates. Potential spawning habitat is limited to cobble substrates along a side cobble bar along the LDB and boundary of Site 3.
Historical Information:
Highly altered by municipal development. Area presents a historic mix of residential, industrial and commercial development. Lands adjacent the river today are predominantly City Parks and residential. Some industrial contamination (i.e., former Grand Trunk Pacific Railway) may be present.

4.2.3 Photo Record:

Photo 1: View looking downstream along Site 2 right bank from rock groyne and outfall at the upstream boundary of Site 2. Large woody debris in foreground.

Photo 2: View looking upstream towards Site 2 from downstream rock groyne at upstream boundary of Site 4.

Photo 3: Bank swallow habitat along vertical section of exposed soil below coir erosion and sediment control. View southwest.

Photo 4: View of historic live staking in eroded bank.

Photo 5: Opposing photo directions of Storm Outfall B-9. View across the river looking East to Site 3.

4.2.4 Field Observations & Notes:

General	Issues/Constraints	Opportunities
Hydraulics / Geotechnical:	• Outside bend sheltered between rock groyne structures. • Bank Stability – steep bank (est. 1H:1V) with sharp eroding top of bank • Vertical edge near top of bank appears to be composed of fill materials assumed as remnants of the former Grand Trunk Pacific Railway embankment. • Top of bank presents wide area if adjacent city lands are included • The main channel thalweg is located at the toe of the right bank with peak channel flow velocities maintained away from the right bank by two rock groynes located at either end of Site 2. • Bedrock not encountered during site inspection; depth to bedrock to be determined during geotechnical site investigation. • Groundwater monitoring wells were observed at the site. • Potential ground contamination from past industrial land use. • Groundwater monitoring wells and piezometers to be protected in place.	• See below.
Constructability:	• Narrow footpath near water's edge may offer a means for access of construction equipment and limit extent of construction footprint into the river. • No mature trees or vegetation. • Recreational Infrastructure – cycle path and foot trail. Partial closure and minor detour required. • Existing rock groyne structures to be considered for incorporation to design. • Recent installation of live stakes was observed. Live stakes did not appear to be thriving. • Adjacent to urban residential area. • Construction access and staging possible from both ends with restrictions due to the presence of the Bank Swallow colony.	• Good access and staging areas for construction. • Positive opportunity for multiple comparative bioengineering bank restoration and protection techniques demonstration. • Incorporation of bank swallow habitat to demonstration. • Proximity of open city land offers potential public meeting space (Amphitheatre), lookout pathway or trail, viewpoint to opposing bank (bioengineering demonstration), and river access for habitat and bioengineering viewing. • Good vantage for overall view of all sites pertaining to the bioengineering demonstration project. Attractive school bus staging area for educational tours. • Potential for aquatic habitat as well as terrestrial habitat development and observation (offset potential). • City wide public accessibility. • Potential to return/enhance riparian health.

General	Issues/Constraints	Opportunities
Biophysical	**Issues/Constraints**	**Opportunities**
Fish Habitat	• lack of instream overhead cover • Low habitat complexity • Bathymetry to confirm the presence of deep pools. • RAP: May 1 – July 15 and September 16 – April 15	• Create habitat complexity • Create adult holding cover; overhead cover, turbulence • Create adult resting habitat • addition • Addition of boulder clusters, fish shelters • Addition of overhanging vegetation
Wildlife Habitat	• Bank Swallow colony present • little riparian vegetation between the river's edge and the City pathway • low cover value, mainly grass • low diversity	• Planting of native vegetation, forbs, herbs, shrubs, trees • Create visual separation of pathway to facilitate wildlife corridor • Create habitat node in grassed area through dense planting of native vegetation
Riparian Landscape	• Highly eroded and unstable bank • Little to no riparian vegetation present along the eroded section of the bank • Top of bank consists of small grasses	• Opportunity to create/restore riparian health through strategic planting of successional stage and regionally appropriate species • Bank swallow colony needs to be protected
Slope Stability	Pending site specific geotechnical investigation.	Pending site specific geotechnical investigation.
Land Use	S-R Special Purpose - Recreation The S-R designation is primarily for recreation facilities, both indoor and outdoor	

General	Issues/Constraints	Opportunities
Educational	**Issues/Constraints**	**Opportunities**
	• Gravel beach and narrow bank swallow nesting colony between 2 rock groynes, park on other side of pathway • Bank swallow colony needs to be protected from construction and ongoing human disturbance	• This site is clearly visible from the gravel bank across the river in site 3, a pull off for RiverWatch and other river users • The south end of the site provides a very good view of the larger bank swallow colony (Site 5) and the shore treatment there and in site 4. Interpretive signage here could address the swallows and how we accommodated them. • The north end of the site has the confluence of a number of pathways and the historic rail bed, as well as 8 Avenue SE. This area is a logical large gathering node for educational programming that will be very visible to pathway users. This confluence area can also provide an assembly site for school classes or other groups. Potential for a roofed structure (such as a large gazebo) pathway users could use for shelter from the sun or rain. • Possibility to link with Bend in Bow infrastructure plans.
From July 17 Site Assessment Inspection		
	• Site conducive to combination of options • Options considered required to preserve the swallow colony at the upstream end of the Site 2 • The upstream and downstream groynes to be considered for incorporation to bioengineering options to be considered.	
Options		
	Note: This assessment was carried out on the day before the official site visit without the information provided by Mike Magnan from O2 of the possibility for the ball park and pedestrian path being relocated and the slope being pulled back. The combined options below are looking at preserving the existing pedestrian path and as much as possible of the bench width and existing vegetation. Working on steep slope adjacent to water would also be a good site to demonstrate the versatility and cost efficiency of the use of walking excavator (spyder hoe; pictured below) to implement the work. Note: Area downstream of section 1 above the existing upstream groyne could be used to demonstrate how brush mattresses with crib toe, simple rock toe or rock / fascine toe would perform in a higher velocity environment. This could be applied in either situation i.e. wither the slope is pulled back or not.	
From July 18 Post Site Assessment Brainstorming Session		
	• Rock groynes to be incorporated • Top groyne to be used as a platform for education / viewing	
Note:	• Due to the presence of the rock groyne most of the energy has been dissipated towards the thawleg away from the bank. • A combination of the structure mentioned below could be incorporated	

4.2.5 Bioengineered Options

Description		Cost (Class 5)
OPTION 1	Fascine box with double poles as a toe protection combined with 1-1 brush mattress and cover with soil 1-2 brush mattress and cover with soil and coir matting 1000 1-3 brush mattress alone with broadcast seeding of native seed mix and planting of native shrubs and tree on slope below vertical bank 1-4 bench, planting of native riparian species, shrubs and trees as potted plants	TBD
OPTION 2	Brush mattress with toe protection using 1-1 small crib and rock 1-2 only rock 1-3 rock and fascine bundles	TBD
OPTION 3	Live staking of toe of slope high density planting Wattles fences on slope.	TBD
Conventional Approach	**Hard engineering** option consisting of a rip rap toe protection, w/ launching apron where bedrock is absence, capable of withstanding scour on part of extreme flood flows. Rip rap slope with max 2H:1V side slope, w/o vegetation, over a granular bedding and transition material to the existing bank material. Synthetic geotextile materials may be used to replace transition materials against the existing bank material. Crest elevation to provide sufficient freeboard. Consideration may be given to bioremediation of the upper portion of the reconstructed 2H:1V bank.	TBD

4.2.6 References:

Klohn Crippen Berger (Klohn) 2015. Calgary Rivers Morphology and Fish Habitat Study, Technical Memo F-1: Existing Fish Habitat. Draft report prepared for the City of Calgary April 2015.

Hemmera Envirochem Inc. (Hemmera) 2016. Request for Proposal: Bioengineering Demonstration and Education Project. Prepared by Hemmera for Alberta Environment and Parks, June 7, 2016.

4.3 SITE 3 ASSESSMENT

4.3.1 Key Data:

Watercourse:	Bow River	Upstream Limit:	(Lat)	51.036313	(Long)	-114.012665
		Downstream Limit:	(Lat)	51.033081	(Long)	-114.005513
Address :	Cushing Bridge over Bow River along 17th Avenue SE adjacent Inglewood Golf and Curling Club (left bank)					
Location:	**Site 3** – located about 100 m downstream of the Cushing Bridge, Site 3 consists of a gravel point bar that extends between 650 and 700 m along the left bank of the Bow River immediately adjacent City lands (Parks) currently leased by the Inglewood Golf and Curling Club.					

4.3.2 Site Description:

River Morphology:

Extract from KWL technical memorandum titled: '**DRAFT** – Preliminary Geomorphology Assessment', dated August 30, 2016 (**Appendix A**):

> *The upstream portion of Site 3 as migrated or accreted westward by ~ 17 m from 1924 to 1952 and has remained relatively unchanged since then. The middle section of Site 3 migrated ~47 m to the southeast between 1924 and 1952. This migration continued, and from 1952 to 2014 the bank advanced a further ~17 m to the southeast. The downstream section of Site 3 has migrated ~ 10 m to the south east from 1924 to 2014.*

Note that Site 3 gravels within the point bar was excavated and placed on Site 5 as part of initial post-flood reclamation measures. This work was completed to increase the hydraulic flow capacity of the Bow River through this area thereby reducing scour potentials at lower river stages, while placement along Site 5 provided bank stability along a high vertical right bank and allowed materials to be accessible for river processes downstream. The intent of the placement at Site 5 was also to maintain the mass balance of bedload materials within the Bow River.

Surficial Geology / Bedrock Geology:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Geotechnical field investigation is not anticipated required at Site 3. Grab bag (shovel) samples may be retrieved of in situ surficial soils for grain size particle analysis. No bedrock was visible at any of the sites during the initial site assessment.

Bank Stability:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Vegetation:

Vegetation observed across the entire project site consist of a combination of some, or none, of the following:

- Snowberry : *Symphoricarpos albus*
- Honeysuckle: *Lonicera spp.*
- Maple :*Acer negundo*
- *Artemisia spp.*
- Tansy : *Tanacetum vulgare*
- Saskatoon : *Amelanchier aln.*
- Ash tree: *Fraxinus spp.*
- Sandbar willow: *Salix exigua*
- Yellow willow: *Salix lutea*
- Balsam poplar: *Populus balsamifera*
- Red osier dogwood: *Cornus stolonifera*

Fish Habitat:
A detailed fish habitat assessment was conducted in 2014 by Klohn Crippen Berger (Klohn), and was provided to the Bioengineering team by the City of Calgary (Klohn 2015). An additional fish habitat assessment was completed in May 2016 for Site 2 and Site 3 as part of the Bioengineering Demonstration proposal (Hemmera 2016). The upstream boundary of Site 3 is located approximately 100 metres (m) downstream of the 17 avenue Cushing Bridge on the left downstream bank (LDB) and extends downstream for approximately 750 m to the downstream end of a large cobble side bar on the LDB (**Figure 1** and **2**). Fish habitat within Site 3 is very limited, as cobble side bar makes up the majority of the area. Subsurface water through the cobble side bar supplies alternating riffle and shallow run (R3) habitat present adjacent to the LDB approximately mid-way through the side bar (Klohn 2015 and Hemmera 2016). Water depth through this section is varied throughout the year with depths ranging from 0.5 m to 0.75 m during high flow periods (i.e. spring freshet) when the cobble side bar is fully submerged, and decreasing to <0.75 m during normal and low flow periods. The downstream end of Site 3 opens into a large R3 habitat into Site 5. Cover is provided primarily by turbulence and by the large cobble and boulder substrates. Overhanging woody vegetation along the LDB may provide some overhanging cover for fish. Site 3 provides limited fish habitat as it does not have consistent flow year round. However, riffle and R3 habitat provides potential refuge and feeding habitat for juvenile fish during high and low flow periods. There is limited spawning habitat for salmonids in this section.
Historical Information:
Site 3 is located adjacent to the current day Inglewood Golf and Curling Club. Originally, these lands were owned by Colonel Walker and formed part of his and his family's estate until they were sold. During that time, this land was incorporated into the Inglewood Bird Sanctuary boundary (and still remains today). Transfer of ownership of lands in Walker's estate occurred in 1952, when it was sold to Jeffries and Sons Limited. During that time, these lands formed part of the company's gravel extraction operations.

4.3.3 Photo Record:

Photo 1: June 2, 2016. Pan view upstream to downstream toward Site 3 from Site 2.

Photo 2: July 18, 2016. View looking across to upper Site 3 from downstream groyne at downstream boundary of Site 1.

Photo 3: July 18, 2016. View looking across to middle of Site 3 from downstream groyne at downstream boundary of Site 1.

Photo 4: July 18, 2016. View looking across to downstream end of Site 3 from Site 4.

Photo 5: June 2, 2016 – Completed City of Calgary Bioengineering project upstream of Site 3 on the left bank immediately downstream of Cushing Bridge.

Photo 6: July 18, 2016. Close-up view of completed City of Calgary bioengineering project from upstream end of project.

Photo 7: July 18, 2016. View of live groyne component above rip rap for the City of Calgary Bioengineering project.

4.3.4 Field Observations & Notes

General	Issues/Constraints	Opportunities
Hydraulics / Geotechnical:	• Inside bend adjacent Inglewood golf and curling club. • Generally stable banks except near the upstream limits nearest the Cushing Bridge and the downstream limits as river flows impinge the left bank as the main thalweg appears to have migrated to the left bank as a result of the 2013 flood. • Aggrading reach with pronounced point bar coarse gravel deposit. • Gravel dredged from Site 3 after the flood was placed in Site 5 so to be 'available to the river'.	• Aquatic vessel landing location; • Potential educational node for river bound recreational enthusiasts. • Gravel bar a candidate for vegetation (e.g., live staking technique) and demonstration. • Braids and low flow backwater channels strong candidates for aquatic species habitat enhancement features. • Strong offset and habitat enhancement potential. • Good vantage point for cross river viewing of Sites 1, 2, 4 and 5.
Constructability:	• Good construction access through the golf and curling club (potential access and maintenance agreement required). • In channel waste debris potential from upstream sources.	
Biophysical	**Issues/Constraints**	**Opportunities**
Fish Habitat	• Vegetation and habitat intrusion due to aggradation of bed load sediments to the gravel bar area; depositional area. • Bathymetry and topographic survey, together with hydraulic model, to validate the potential of habitat enhancements and vegetation potential of the gravel bar • RAP May 1 – July 15 and September 16 – April 15.	Limited opportunity at this site to enhance fish habitat due to shallow depths and accretion pattern.
Wildlife Habitat	Riparian area is extremely narrow and immediately adjacent to the Inglewood Golf and Curling Club; area of high human disturbance and wildlife corridor restriction.	Bar, exposed substrates used as resting area for waterfowl.
Riparian Landscape	Riparian area is extremely narrow and immediately adjacent to the Inglewood Golf and Curling Club; area of high human disturbance and wildlife corridor restriction.	Natural successional species (Balsam poplar and willow) are already establishing and will provide a significant riparian area as vegetation matures.

General	Issues/Constraints	Opportunities
Slope Stability	• Site 3 is located within the depositional environment of the outside bend of the Bow River and was therefore used in the past as a gravel pit (refer to the historical assessment). • The left bank of the river ranges in height from about 5 – 7 m above the normal river level near the Cushing Bridge, but quickly lowers to bank height of between about 1.5 and 2.5 m. • No bank work is envisioned through this site though other bioengineering treatments and channel construction arrangements are being considered. • No additional stability assessments are considered necessary in Site 3 though site investigations may include grab bag/ shovel samples for particle grain size analysis.	
Land Use	S-UN Special Purpose - Urban Nature The S-UN designation is for lands that are to be retained in their natural state or are being rehabilitated to replicate a natural state.	
Educational	**Issues/Constraints**	**Opportunities**
Education	• The adjacent property is owned by the City and leased by the Inglewood Golf and Curling Club. • There are limited options to install any interpretive structures • Access to this site by pedestrian traffic is curtailed in order to maintain pedestrian safety and limiting access to the golf course.	• The large gravel bank is used by RiverWatch and other users as a pull-out • Opportunity to view the south end of site 1 and gives a good view to sites 2 and 4 for interpreter led programing (RiverWatch). If the “island” is vegetated, a large area should be left un-vegetated to allow several rafts to pull up. • Area can be used to demonstrate natural establishment of vegetation
From July 17 Site Assessment Inspection		
Much of Site 3 was observed from the right bank.		
From July 18 Post Site Assessment Brainstorming Session		
• Area considered low priority • Leave as is to be colonized by riparian species naturally. **Note**: Existing soil bioengineering site immediately downstream of the Cushing Bridge was visited. The live groyne design was identified as unique with specific concerns raised over the durability of the installation.		

4.3.5 Bioengineered Options

Description		Cost (Class 5)
OPTION 1	Rock toe and vegetated soil wrap along eroded bank located below the existing soil bioengineering project.	TBD
OPTION 2	Live siltation over existing gravel bar	TBD
OPTION 3	Live gravel bar staking Leave as is to get colonized naturally by native riparian vegetation	TBD
Conventional Approach	**Hard engineering** Riprap along eroded bank	TBD

4.3.6 References:

Klohn Crippen Berger (Klohn) 2015. Calgary Rivers Morphology and Fish Habitat Study, Technical Memo F-1: Existing Fish Habitat. Draft report prepared for the City of Calgary April 2015.

Hemmera Envirochem Inc. (Hemmera) 2016. Request for Proposal: Bioengineering Demonstration and Education Project. Prepared by Hemmera for Alberta Environment and Parks, June 7, 2016.

4.4 SITE 4 ASSESSMENT

4.4.1 Key Data:

Watercourse:	Bow River	Upstream Limit:	(Lat)	51.034064	(Long)	-114.013297
		Downstream Limit:	(Lat)	51.032501	(Long)	-114.010917
Address :	8th Avenue SE between 22nd and 23rd Streets SE, Calgary, Alberta					
Location:	**Site 4** – This site corresponds to that portion adjacent to 8th Avenue SE that was most impacted by the 2013 flood event along the project reach. Approximately 260 m of the downstream left bank (DLB) and about 100 m of the roadway was eroded. Restoration work through Site 4 consists primarily of traditional hard engineering methods using large class rip rap to combat more frequent flood events, and bioremediation above mid bank height. Site 4 is located immediately downstream of Site 2 and terminates adjacent to the 8th Avenue cul-de-sac at 23rd Street at the physical boundary of the Inglewood Bird Sanctuary.					

4.4.2 Site Description:

River Morphology:

Extract from KWL technical memorandum titled: '**DRAFT** – Preliminary Geomorphology Assessment', dated August 30, 2016 (**Appendix A**).

> *The bank along Site 4 appears to have migrated ~ 13 m westward from 1924 to 1952. The bank remained relatively unchanged from 1952 to 2012. The flood event in 2013 caused the bank to migrate a further ~ 27 m westward.*

Surficial Geology / Bedrock Geology:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

No geotechnical field investigation is anticipated required at Site 4 given the available reports of the design and pre-flood restoration works.

Bank Stability:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Vegetation:

Vegetation observed across the entire project site consists of a combination of some, or none, of the following:

- Snowberry : *Symphoricarpos albus*
- Honeysuckle: *Lonicera spp.*
- Maple :*Acer negundo*
- *Artemisia spp.*
- Tansy : *Tanacetum vulgare*
- Saskatoon : *Amelanchier aln.*
- Ash tree: *Fraxinus spp.*
- Sandbar willow: *Salix exigua*
- Yellow willow: *Salix lutea*
- Balsam poplar: *Populus balsamifera*
- Red osier dogwood: *Cornus stolonifera*

Fish Habitat:
A detailed fish habitat assessment was conducted in 2014 by Klohn Crippen Berger (Klohn), and was provided to the Bioengineering team by the City of Calgary (Klohn 2015). A bathymetry survey of Site 4 was conducted by Kerr Wood Leidal (KWL) in July 2016. Site 4 is bounded on the upstream end by the second (downstream) riprap groyne constructed along the RDB and extends to the downstream extent of bank riprapping along the RDB. Site 4 extends to the mid channel to the wetted edge of the cobble side bar along the left downstream bank (LDB) and boundary of Site 3 (**Figure 1** and **2**). Fish habitat within Site 4 consists primarily of deep run (R1) habitat, transitioning into moderate depth run (R2) habitat at the downstream end of the site (Klohn 2015). Substrate consists primarily of cobble and boulder substrate with a maximum depth of approximately 1 m in the thalweg. Cover is provided primarily by depth and turbulence and partially by large riprap present along the RDB and boulder substrate. Site 4 has little to no overhanging cover as a result of bank armoring along the RDB and lack of bank vegetation. Deep run (R1) habitat provides suitable holding, and feeding habitat for adult and juvenile fish. R2 habitat present at the downstream end of the reach provides holding and feeding habitat for juvenile fish. Due to the maximum depth of approximately 1 m, this section of the Bow River provides limited to moderate overwintering habitat. There is limited spawning habitat for salmonids (e.g. brown trout [*Salmo trutta*] and rainbow trout [*Oncorthynchus mykiss*]) due to the lack of suitable gravel substrates through the reach.
Historical Information:
Highly altered by municipal development. Area presents a historic mix of residential, industrial and commercial development. Lands adjacent the river today are predominantly City Parks and residential. This area was includes the former alignment of the Grand Trunk Pacific Railway. Ownership was transferred to The City and it was subsequently developed. Prior to the 2013 flood, this area included a lower bench that was vegetated with a mature balsam poplar forest. This forest, and the lands it was located upon, was completely lost during the flood.

4.4.3 Photo Record:

Photo 1: **L**ooking downstream at Site 4 from Site 2 downstream boundary.

Photo 2: **L**ooking upstream at Site 4 from Site 5 upstream boundary.

Photo 3: Site 4 post-flood bank reconstruction with riparian planting above riprap.

Photo 4: Close-up of Site 4 post-flood bank reconstruction with riparian planting above riprap.

Photo 5: June 2, 2016 – Exposed filter material shows extent and use of synthetic materials in construction at transition from rip rap to riparian planting area.

Photo 6: Looking upstream at Site 4 rip rap and riparian planted area from top of bank.

4.4.4 Field Observations & Notes

General	Issues/Constraints	Opportunities
Hydraulics / Geotechnical:	• Outside bend adjacent to Inglewood residents' single family homes. • Recently stabilized river bank along main thalweg of the Bow River	• Reconfiguring of armor rock below waterline for inclusion of 'fish friendly' / habitat structures below 1:2 year level and revegetation of rock armor in various configurations above the 1:2 year level to the top of the rock placement. • Inclusion of river trail and upper path tie-ins. • Southern extent provides good vantage point to view existing cliff swallow habitat at the northern edge of Site 5. • Test site for vegetating riprap where results could be applied City and Province wide.
Constructability:	• Armor rock on bench presents difficult surface for construction vehicles.	• Good construction access from either end of the site.
Biophysical	**Issues/Constraints**	**Opportunities**
Fish Habitat	• Limited aquatic habitat potential offered by extensive rip rap below waterline. • Potential habitat offered by plantings and reclamation of the river bank above the rock apron. • RAP: May 1 – July 15 and September 16 – April 15	• Create habitat complexity • Create adult holding cover; overhead cover, turbulence through addition of boulder clusters, fish shelters • Root wads could be integrated into the existing riprap to enhance fish habitat • Create adult resting habitat, dep holes created and maintained by structures creating scour • Addition of overhanging vegetation
Wildlife Habitat	• Bank swallow colony. • Some surface garbage visible since construction.	• Incorporation of a stepped bank with bioengineered features to offer flood resistance and protection as well as a wildlife corridor. • Out of water work may consider construction outside nesting and migration period.
Riparian Landscape	• Post-flood riparian planting completed. • Thickness of rip rap appears to be a constraint for planted rip rap options. • 8 Avenue constricts boundary at western edge of riparian area.	• Opportunity to augment riparian planting. • Potential to retroactively plant within rip rap using pocket planting, self-revealing cover and plant[1] and vegetated rip rap techniques.

[1] Remove existing riprap section and synthetic geotextile and install gravel filter and vegetated riprap pockets and brush layer rows to top of slope.

General	Issues/Constraints	Opportunities
Slope Stability	This bank has been restored in 2014 using traditional 'hard engineering' methods. Scour protection is provided using Class II rip rap toe berm up to the 5 year flood level; the toe of the slope includes a Class II rip rap apron. The bank slope above the 5 year flood level is reclaimed using a combination of synthetic erosion control blanket protection and plantings to the 100 year flood level.	Slope stability through Site 4 is viewed as stable. No additional stability assessments are considered necessary though site investigations may include grab bag/ shovel samples for particle grain size analysis.
Land Use	S-SPR Special Purpose - School, Park and Community Reserve The S-SPR designation is for public parks, open space, schools and recreation facilities on land designated reserve land under the Municipal Government Act.	Park and grassy area at top of bank offers opportunity for project objectives
Educational	**Issues/Constraints**	**Opportunities**
	• Coarse rip rap presents a hazard to the public attempting to access the river's edge. • Visually course and unnatural in appearance. • Swift water prevents safe boat landing areas along Site 4. • Off shore debris (concrete blocks) present a stream hazard to the establishment of a landing area for boats along any portion of the armored bank.	• A trail along the top of the riprap by infill pit run and trail gravel would provide the public an opportunity to access the river's edge and get a good view of the different treatments used to vegetate the rip rap • Demonstrate application of bioengineering to existing rip rap areas and compare multiple techniques (e.g., pocket planting, vegetated rip rap and self-revealing cover and plant). • Bank swallow colony presents opportunity to message riparian species, consideration of wildlife values as part of bioengineering bank stabilization.
From July 18 Post Site Assessment Brainstorming Session		
• Root wads could be integrated into the existing riprap to enhance fish habitat • Cardboard and arborist mulch could be used to reduce herbaceous competition around planted riparian species on bench ps: mulch can attract rodent such as voles and cause damage to planted seedlings, use of milo-organite fertilizer around the planted seedlings will deter voles from damaging the plants (See Calgary design guidelines). • The vegetated riprap option using Terra Erosion drawing / design, should look into options to replace the o.s.b. board with another type of fiber board containing ecological friendly glue. Product should be easily available commercially in large quantities for potential future applications.		

4.4.5 Bioengineered Options

Description		Cost (Class 5)
OPTION 1	1-1 Upstream vegetated pocket of live cutting to insert within the existing riprap. 1-2 Insure geotextile liner is perforated when inserting cuttings 1-3 Manual application with long iron bar	TBD
OPTION 2	2-1 Same as option1, but using mechanical application with stinger attachment on excavator or spyder hoe; See Site Assessment Log - Site 1.	TBD
OPTION 3	3-1 Downstream section, upstream from rock groyne. Vegetated riprap, installed by removing existing riprap and geotextile. Placed riprap on thick geotextile (16 mm) on bench above the proposed application. Leave rock toe in place and fold lower portion of geotextile over apron Placed gravel filter Install vegetated pocket using sono tubes Install brush layer on upper location (see draft drawing provided during meeting of July 19) Keep same slope geometry Addition option: Placement of boulder clusters in stream to provide fish habitat.	TBD
Conventional Approach	**Hard engineering** Do nothing: leave a portion of Site 4 As-Is to demonstrate efficacy comparative to bioengineered sections.	TBD

4.4.6 References:

Klohn Crippen Berger (Klohn) 2015. Calgary Rivers Morphology and Fish Habitat Study, Technical Memo F-1: Existing Fish Habitat. Draft report prepared for the City of Calgary April 2015.

4.5 SITE 5 ASSESSMENT

4.5.1 Key Data:

Watercourse:	Bow River	Upstream Limit:	(Lat)	51.032501	(Long)	-114.010917
		Downstream Limit:	(Lat)	51.030149	(Long)	-114.003892
Address :	9th Avenue SE and Sanctuary Road					
Location:	**Site 5** – located immediately downstream of Site 4 and is bounded by the Inglewood Bird Sanctuary. The site extends approximately 580 m and terminates at the 'Bend in the Bow'.					

4.5.2 Site Description:

River Morphology:

Extract from KWL technical memorandum titled: 'DRAFT – Preliminary Geomorphology Assessment', dated August 30, 2016 (**Appendix A**):

The most severe bank retreat observed in the study area occurred along a tall silt bluff located on the right bank (Figure 1). This bluff had been gradually eroding from 1924 to 2012 (~12 m over 88-year period). The 2013 flood caused this bluff to retreat up to 60 m in some areas.

A large amount of gravel/cobble sediment was placed by the City of Calgary in a bar along the base of the bluff post-2013 flood using material excavated from ta gravel bar opposite side of the river near the Cushing Bridge (Site 3). This was intended to provide erosion protection from future flood events. The constructed sediment bar merges into a natural sediment bar to the east at about the halfway point of Site 5. The natural sediment bar was also the result of the 2013 flood.

A small section of Site 5, upstream of the constructed sediment bar, only contains a small strip of sediment along the toe of the silt bluff. During higher flows, this bluff will likely be exposed and may experience continued bank retreat.

Near the downstream end of Site 5 the bank position has remained fairly unchanged from 1975 to 2014. The 1952 bank position at this location was situated ~40 m further northeast.

The large, natural sediment bar that deposited following the 2013 flood is situated along the downstream portion of Site 5. This sediment bar is quite elevated at its most downstream extent (~1.5 m above water level at time of field visit).

Surficial Geology / Bedrock Geology:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Bank Stability:

Refer to Thurber Engineering Ltd. technical memorandum titled: 'DRAFT – Preliminary Geotechnical Assessment', dated August 31, 2016 (**Appendix B**).

Vegetation:

Site is void of vegetation along the bank slope. Site exhibits low moisture and the gravel bar is particularly susceptible to daytime heating through direct exposure to the sun. Overbank vegetation planting (riparian bench area, **Figure 2**) is in progress with maintenance watering active. Apparent ground contouring has concentrated surface runoff to the river bank to flow overtop the constructed gravel bar and the bank swallow colony.

Vegetation observed across the entire project site consist of a combination of some, or none, of the following:

- Snowberry : *Symphoricarpos albus*
- Honeysuckle: *Lonicera spp.*
- Maple :*Acer negundo*
- *Artemisia spp.*
- Tansy : *Tanacetum vulgare*
- Saskatoon : *Amelanchier aln.*
- Ash tree: *Fraxinus spp.*
- Sandbar willow: *Salix exigua*
- Yellow willow: *Salix lutea*
- Balsam poplar: *Populus balsamifera*
- Red osier dogwood: *Cornus stolonifera*

Fish Habitat:

A detailed fish habitat assessment was conducted in 2014 by Klohn Crippen Berger (Klohn), and was provided to the Bioengineering team by the City of Calgary (Klohn 2015). A bathymetry survey of Site 4 was conducted by Kerr Wood Leidal (KWL) in July 2016. Site 5 is located immediately downstream of Site 4 at the downstream end of bank riprap extending along the right downstream bank (RDB) with a width extending from the RDB to the wetted edge of the cobble side bar along the left downstream bank (LDB) and boundary of Site 3 (**Figure 1** and **2**). The width of the Site 5 encompasses the entire width of the Bow River channel downstream of the Site 3 downstream boundary, approximately 35 meters (m) downstream of the LDB cobble side bar. Site 5 extends for approximately 550 m to the downstream end of a large cobble boulder side bar along the RDB (**Figure 1** and **2**).

Fish habitat within Site 5 consists of alternating riffle and moderate run (R2) habitat with deep pool (P1) habitat present at the downstream end of the reach immediately downstream of a cobble boulder side bar along the RDB. Maximum water depth ranges from 1 m in riffle habitat, 2 m in R1 habitat, to approximately 7 m in the P1 habitat at the downstream end of Site 5. Substrates consist of cobble and gravel in R2 and riffle habitats, with P1 habitat consisting predominately of fines and boulder. Cover is provided primarily from depth, turbulence, and large woody debris present in the downstream P1 habitat. Overhanging cover is limited, provided by sparse woody vegetation along the LDB.

Riffle and R2 habitat likely provides excellent rearing and holding habitat for juvenile fish, and is likely utilized by adults as feeding habitat. P1 habitat at the downstream end of the reach provides excellent overwintering and holding habitat for adult and juvenile fish, also providing a velocity refuge and complex instream cover as a result of the buildup of large woody debris. Spawning habitat is limited through Site 5 as it composed primarily of riffle habitat. However, R2 habitat with suitable gravel and cobble substrates provides suitable spawning habitat for salmonids such as brown trout (*Salmo trutta*), rainbow trout (*Oncorthynchus mykiss*), and mountain whitefish (*Prosopium williamsoni*).

Historical Information:

This site is included within the boundary of the Inglewood Bird Sanctuary, and was formerly part of Walker's Estate. This land was cultivated for agriculture at the same time as the BP Oil Refinery was operating on today's Inglewood Wildlands. Following the flood, archaeological evidence of occupation by First Nation's was identified in the eroded riverbank. The location of this must be documented and the site adequately addressed as part of this project.

4.5.3 Photo Record:

Photo 1: Site 5 looking downstream at active bank swallow colony.

Photo 2: Note runoff through swale on riparian bench flowing toward river.

Photo 3: Close-up of overflow from swale from riparian bench above.

Photo 4: Note sediment accumulation caused by drainage from swale on riparian bench above.

Photo 5: View taken from constructed gravel bar on Site 5 noting large woody debris buried as part of previous post-flood reclamation activities.

Photo 6: View taken from constructed gravel bar on Site 5 towards near vertical bank and bank swallow colony.

Photo 7: View taken from constructed gravel bar. Gravel re-located from Site 3 during post-flood reclamation activities.

Photo 8: **B**alsam poplar seedlings colonizing the constructed gravel bar on Site 5.

Photo 9: Overview of Site 5 looking downstream. Active bank swallow colony near middle of Site.

Photo 10: Post rainfall runoff deposition of eroded sediments via swales constructed in the re-contoured and reclaimed riparian bench.

Photo 11: View looking upstream from placed constructed gravel bar toward Site 4 /5 boundary and active bank swallow colony.

Photo 12: Dried and desiccated vegetation on constructed gravel bar placed from Site 3. Note the lower bench available for active mobilization.

4.5.4 Field Observations & Notes

General	Issues/Constraints	Opportunities
Hydraulics / Geotechnical:	• Outside bend adjacent Inglewood bird sanctuary. • Gravel dredged from Site 3 after the flood was placed in to be 'available to the river'	• Strong candidate site for brush matting, willow staking, and other reclamation techniques and potential use of biochar as soil enrichment to promote the rapid establishment of vegetation. • Riverside 'learning pathways' with observational stops at the river's edge to view the downstream portion of Site 3 across the river. Future habitat restored within Site 5 may provide additional educational point of interest.
Constructability:	Riparian bench area has been planted and potentially restricts access options.	Good construction access and staging areas available for this site, and to adjacent, sites
Biophysical	**Issues/Constraints**	**Opportunities**
Fish Habitat	• Lack of riparian vegetation. • Large woody debris (LWD) installed above average annual water level providing limited to no value as habitat for fish. • RAP: May 1 – July 15 and September 16 – April 15	• Modify existing LWD to below 1:2 flood level (normal high water mark) to create fish habitat value • Create habitat complexity • Create adult holding cover; overhead cover, turbulence • Create adult resting habitat • Addition of boulder clusters, fish shelters • Addition of overhanging vegetation
Wildlife Habitat	• Large bank swallow colony present at the upstream limits of the Site. • Lack of riparian vegetation.	• Incorporation of a stepped bank with bioengineered features to offer flood resistance and protection, and a wildlife corridor. • Out of water work may consider construction outside nesting and migration period.
Riparian Landscape	• Contaminants not anticipated in fill materials placed from Site 3 but possible deleterious material deposits within the downstream point bar. • Thick rip rap layer challenges retroactive planting approaches • Some (post flood) refuse is present due to riverside recreational activity.	

General	Issues/Constraints	Opportunities
Slope Stability	• Site 5 extends nearly 600 m and transitions over approximately 400 m from an eroding outer bank to depositional course gravel point bar morphology in the remaining 200 m. • The first 150 m of Site 5 presents a nearly vertical right bank that has provided suitable habitat for a bank swallow colony. This area will need to be protected and preserved despite the stability issue that has developed naturally and will remain until the bank ravels back naturally. • Beyond the bank swallow colony, the bank has been buttressed by the placement of river gravels excavated from Site 3. No bank work is envisioned through this site though other bioengineering treatments will be considered. • No additional stability assessments are considered necessary though site investigations may include grab bag/ shovel samples for particle grain size analysis.	• Modify surface drainage channel to prevent sediment laden runoff from entering river as well as eroding and destabilizing critical bank habitat • Toe protection
Land Use	• S-R Special Purpose - Recreation The S-R designation is primarily for recreation facilities, both indoor and outdoor. • Riparian bench planted and irrigated part of Inglewood Bird Sanctuary lands.	Low impact visitor use and river viewing.
Educational	**Issues/Constraints**	**Opportunities**
	• Riparian bench property part of the Inglewood Bird Sanctuary (IBS) • Significant education infrastructure limited by IBS land use with e.g. trails or interpretive signage but no large formal structures can be constructed above the bank.	• Location adjacent to cul-de-sac and fence delineating IBS landprovides a good vantage point to message and contrast traditional hard engineering vs bioengineering • This could be an alternative site to address the bank swallows and how we accommodated them • Plans for soft trail along top of bank (Bend in the Bow). • Messaging of importance of riparian health. • Good location for viewing Site 3 and Site 5 constructed gravel bar.
From July 18 Post Site Assessment Brainstorming Session		
• Understanding that swallows potentially use same nesting location The assumption is that no vegetation should interfere within 2 - 3 m of the nest		

4.5.5 Bioengineered Options

Description		Cost (Class 5)
OPTION 1	1-1 Below vertical bank 1-2 Toe protection, either rock toe with brush mattress on angled slope 1-3 Or fascine box with double poles as toe protection with live staking on flat to sloped area	TBD
OPTION 2	2-1 Below vertical bank 2-2 Leave as is	TBD
OPTION 3	3-1 Placed gravel Rough & loose and leave to be colonized by riparian species. This should also facilitate the gravel transport into the Bow river Install large balsam poplar poles in group of 3 – 4 at ~ 35 degree angle into the downstream end of the placed gravel using excavator.	TBD
Conventional Approach	**Hard engineering** Rip rap along edge of bank with launching apron	TBD

4.5.6 References:

Klohn Crippen Berger (Klohn) 2015. Calgary Rivers Morphology and Fish Habitat Study, Technical Memo F-1: Existing Fish Habitat. Draft report prepared for the City of Calgary April 2015.

5.0 CLOSURE

We sincerely appreciate the opportunity to have assisted you with this project and if there are any questions, please do not hesitate to contact the undersigned by phone at 403.264.0671.

Report prepared by:
Hemmera Envirochem Inc.

DRAFT

Trevor Rhodes, M.Sc., P.Biol.
Project Leader
403.264.0671 (306)
trhodes@hemmera.com

Note: This Work was performed in accordance with Contract No. 17OSR820 between Hemmera Envirochem Inc. (“Hemmera”) and Alberta Environment and Parks (“Client”), dated July 4, 2016 (“Contract”). This Report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for sole benefit and use by Alberta Environment and Parks. In performing this Work, Hemmera has relied in good faith on information provided by others, and has assumed that the information provided by those individuals is both complete and accurate. This Work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the Report was produced. The conclusions and recommendations contained in this Report are based upon the applicable guidelines, regulations, and legislation existing at the time the Report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

APPENDIX A

Draft Preliminary Geomorphology Assessment

KERR WOOD LEIDAL
consulting engineers

Vancouver Island
201 - 3045 Douglas Street
Victoria, BC V8T 4N2
T 250 595 4223
F 250 595 4224

Memorandum

DATE: September 13, 2016

DRAFT

TO: KWL Internal

FROM: Chad Davey

RE: **BOW RIVER BIOENGINEERING DEMONSTRATION PROJECT**
Preliminary Geomorphology Assessment
Our File 3552.004-300

1. Introduction

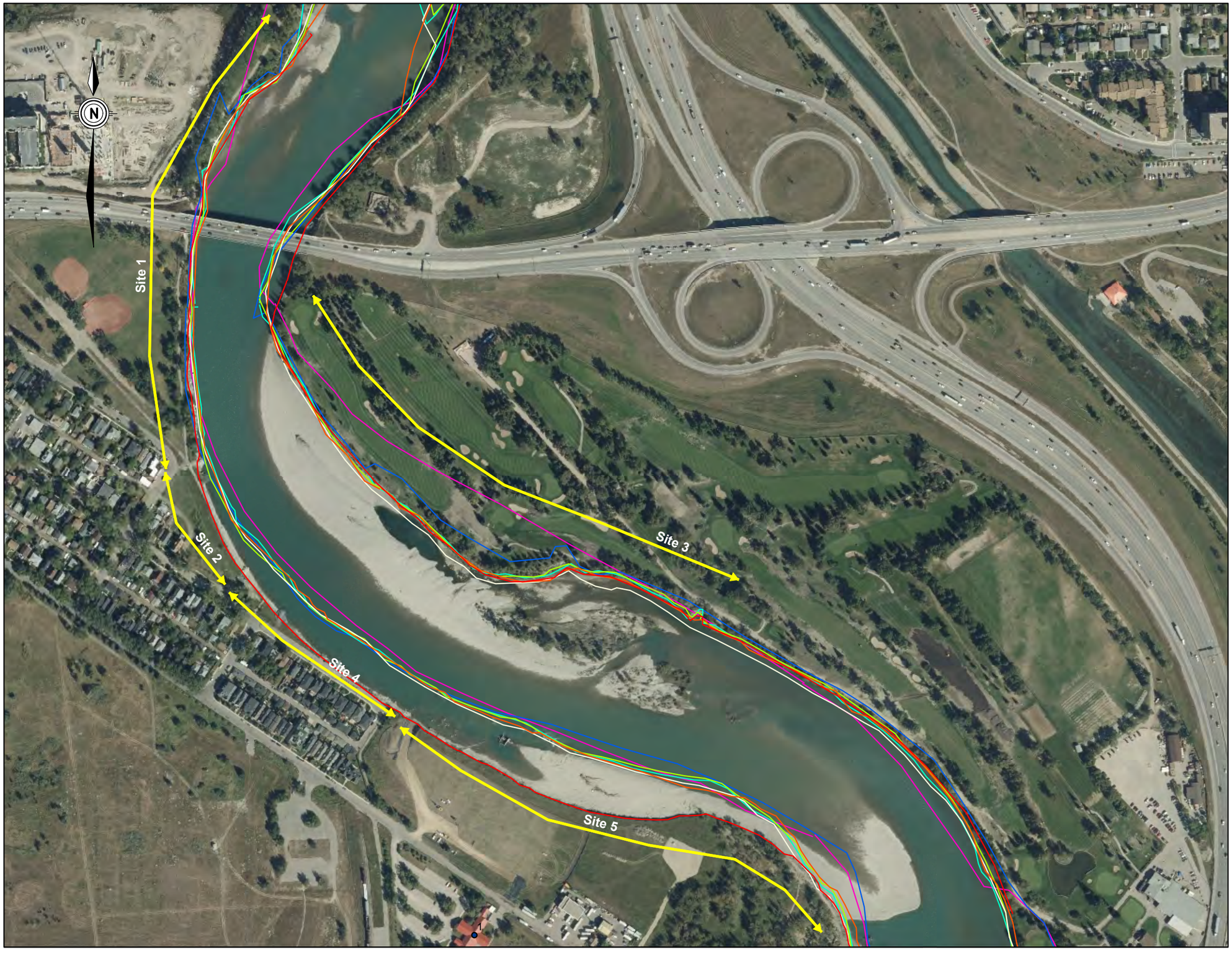
The purpose of this memo is to present the work of KWL's planform channel assessment along sites 1 through 5 that has been completed to date, and to address agenda item #5 for the upcoming meeting with the City of Calgary on September 1st, 2016. The meeting agenda item is as follows:

> ***5. Results of, or plans for, a preliminary morphologic analysis explaining the general processes through that section (i.e. Site 1 below Cushing Bridge) and why such a deep scour hole has formed***

2. Study Site

Five locations where identified as future bioengineering demonstration and education project sites. All five sites are within a contiguous reach of the Bow River, where the upstream edge of the reach is Pearce Estate Park and the downstream edge of the reach is the Inglewood Bird Sanctuary. The location of the five identified sites are presented in Figure 1 and described as follows (all locations are described looking downstream):

- Site 1: Right bank extending from upstream of the 17th Ave./Blackoot Trail (Cushing Bridge) to a point about 250 m downstream. A deep scour hole is present along this reach.
- Site 2: Right bank at Inglewood, immediately downstream of Site 1 and groyne, which is also deeply incised and currently not armoured, ending upstream of the second new rock groyne on the right bank.
- Site 3: Gravel bar along left bank, at Inglewood, immediately downstream of the Cushing Bridge on 17th Ave./Blackfoot Trail.
- Site 4. Right bank at Inglewood Critical Erosion Site (approximately 8th Ave. SE and 22nd St. SE) encompassing that portion of the bank armoured with the placement of riprap in 2014. This site is immediately downstream of Site 2.
- Site 5: Right bank at Inglewood Bird Sanctuary immediately downstream of Site 4 and encompassing that portion of the bank where gravel was removed from Site 3 was relocated.



Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 2012 Banklines
- 2001 Banklines
- 1981 Banklines
- 1975 Banklines
- 1952 Banklines
- 1924-26 Banklines

DRAFT

<bol>Reference: 2013 Orthophoto aerial image.

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consulting engineers

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Project No.	Date
3552-004	September 2016

Historical Bankline Positions (post-flood image)

Figure 1

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Author: CDavey

3. Methods

The following sections outline the methodologies that were used to complete the assessments.

3.1 Channel Planform Analysis

The geomorphic analysis of historic planform channel change on the Bow River along each of the five sites was conducted by reviewing available aerial photography and ortho-rectified photos with coverage of the study area. A list of the photos that were obtained for the analysis is provided in Table 1. The aerial photos obtained for the assessment covered a period of record between 1924 and 2013 (post flood).

To compare channel planform changes over time, aerial photos were geo-rectified in ArcGIS using control points and the 2013 ortho-rectified air photo. Once geo-rectified and transformed, a bank position trace along the active channel was performed for each year of coverage to illustrate the evolution the Bow River channel over time within the study area. In some cases, poor resolution of the aerial photo, significant land use changes over the period of record, and/or varying Bow River water levels caused some difficulty in aligning control points used for the geo-rectification. This reduces the accuracy in quantifying the bank retreat overtime.

Table 1: Airphotos and Orthophotos Obtained for the Geomorphic Analyses.

Date	Source/Roll/Photo Number	Scale
2013	Orthophoto	1:~20,000
2012	AS5512 #4	1:10,000
2001	AS5166B #11	1:30,000
1981	AS2397 #164	1:25,000
1975	AS2891 #235 - 237	1:12,000
1952	AS168 #35 and 36	1:~40,000
~1924-1926	CA110 #90	1:~10,000

The planform channel analysis only focuses on observed changes to the active channel over time using the available imagery (Table 1). With the exception of the large flood that occurred in 2013, causal factors that may explain some of the observed channel changes (i.e., previous floods, change of land use, etc.) were not scoped as part of the project objectives and thus not considered in this internal memo.

3.2 Agenda Item #5

In early 2014, Golder produced a technical memorandum that compared the channel morphology immediately downstream of the Cushion Bridge before and after the 2013 flood using a 2D hydraulic model. Addressing meeting agenda item #5 will mostly involve a summary of results of Golders technical memorandum (2014) and field observations collected by KWL during the project initiation meeting on July 18th 2016.

4. Results

4.1 Channel Planform Analysis

A summary of the channel planform analysis is presented in Figure 1. The Bow River bank position for individual years presented in Figures A1 through A7 (Appendix A). The bank position for each year assessed is represented by the coloured lines in Figure 1. The yellow lines show the approximate boundaries of Sites 1 through 5. All references to left and right bank in these sections below are assuming the observer is looking downstream.

Site 1

Upstream of the Cushing Bridge, the location of both the left and right banks appear to have migrated eastward by ~30 m from 1924 to 1952. From 1952 to 2014, the location of these same banks has not changed significantly. Users of a boat launch located immediately upstream of the Cushing Bridge along the right bank have noted that the thalweg appears to have shifted towards the left bank following the 2013 flood.

Downstream of the Cushing Bridge, the right bank at Site 1 has remained in the same position for the entire study record (1924 to 2014). Observations during the field visit and discussions with colleagues during the project initiation meeting revealed that this steep, tall bank is a remnant of a former railroad bed that was armoured with large pieces of concrete, which are visible along the bank's toe. The left bank downstream of the Cushing Bridge (upstream of Site 3) has migrated ~15 m to the east from 1924 to 2012. The flood in 2013 caused this same bank to migrate an additional ~15 m eastward.

Site 2

The bank along Site 2 appears to have migrated ~ 11m westward from 1924 to 1952. The bank remained relatively unchanged from 1952 to 2012. The flood event in 2013 caused the bank to migrate a further ~ 17 m westward.

Site 3

The upstream portion of Site 3 as migrated or accreted westward by ~ 17 m from 1924 to 1952 and has remained relatively unchanged since then. The middle section of Site 3 migrated ~47 m to the southeast between 1924 and 1952. This migration continued, and from 1952 to 2014 the bank advanced a further ~17 m to the southeast. The downstream section of Site 3 has migrated ~ 10 m to the south east from 1924 to 2014. The perimeter of the gravel bar situated along Site 3 has not been mapped to analyse the change overtime. This analysis is expected to be completed in the next couple of weeks.

Site 4

The bank along Site 4 appears to have migrated ~ 13 m westward from 1924 to 1952. The bank remained relatively unchanged from 1952 to 2012. The flood event in 2013 caused the bank to migrate a further ~ 42 m westward.

Site 5

The most severe bank retreat observed in the study area occurred along a tall silt bluff located on the right bank (Figure 1). This bluff had been gradually eroding from 1924 to 2012 (~12 m over 88-year period). The 2013 flood caused this bluff to retreat up to 60 m in some areas.

A large amount of gravel/cobble sediment was placed by the City of Calgary in a bar along the base of the bluff post-2013 flood using material excavated from the gravel bar opposite side of the river near the Cushing Bridge (Site 3). This was intended to provide erosion protection from future flood events. The constructed sediment bar merges into a natural sediment bar to the east at about the halfway point of Site 5. The natural sediment bar was also the result of the 2013 flood.

A small section of Site 5, upstream of the constructed sediment bar, only contains a small strip of sediment along the toe of the silt bluff. During higher flows, this bluff will likely be exposed and may experience continued bank retreat.

Near the downstream end of Site 5 the bank position has remained fairly unchanged from 1975 to 2014. The 1952 bank position at this location was situated ~40 m further northeast.

The large, natural sediment bar that deposited following the 2013 flood is situated along the downstream portion of Site 5 (Figure 1). This sediment bar is quite elevated at its most downstream extent (~1.5 m above water level at time of field visit).

4.2 Agenda Item #5

The agenda item #5 is as follows:

> ***5. Results of, or plans for, a preliminary morphologic analysis explaining the general processes through that section (i.e. Site 1 below Cushing Bridge) and why such a deep scour hole has formed***

The downstream section of Site 1 (below Cushing Bridge) is located on the Bow River where a transition between two meander bends occur. This is the location where the thalweg is expected cross over from the left side of the channel towards the right side, along the outside bend of the upstream meander. The thalweg is where the stream velocities are concentrated and where the capacity of a river to erode and transport sediment is greatest. Typically, an outside meander bend erodes as the inside meander bend (on opposite bank) accrete, maintaining a fairly consistent channel width overtime. However, the tall bank along the lower section of Site 1 is armored and has not migrated westward in the last 90 years as one would expect in a natural system. Yet, the opposite bank has migrated or accreted by ~ 20 m (from 1924 to 2014), resulting in a reduction in channel width overtime. This reduction in channel width would exacerbate the concentrations of stream velocities in the thalweg, which at this point is likely situated along the outside bend of the meander at Site 1. Since the bank here is armoured, the excess capacity for the river to erode sediment would likely lead to scouring of the unarmoured river bed.

In 2014, Golder Associates[1] conducted an assessment of the pre and post flood river bed topographies along the downstream section of Site 1 on the Bow River as part of a bank protection design study. The relevant information from the Golder report (2014), as it pertains to the agenda item #5, is summarized below:

[1] Golder Associates, 2014. Bank Protection Between Cushing Bridge and Outfall B09, Inglewood. Technical Memorandum for City of Calgary.

- A deep scour hole formed along the right bank at the downstream section of Site 1. It is estimated that velocities of 4 to 5 m/s where reached at this location during the 2013 flood.
- The river bed at the scour hole appears to have scoured approximately by 4 m. This is near the depth of local bedrock.
- This scour hole is considered high value fish habitat, however it may function as a potential ice anchor where future ice jams may originate.
- Due to the presence of bedrock, it is unlikely that the scour hole will expand. It is possible that the deposited gravel upstream of Cushing Bridge from the 2013 flood will more likely cause the scour hole to eventually fill with gravel.

5. Next Steps

The following work is proposed:

- Complete a perimeter map of the gravel bar along Site 3 for each year we have photos record. This analysis would allow us to determine how the gravel bar as evolved over time and how the flood affected this feature.
- Review existing documents for information regarding thalweg locations pre and post flood and summarize findings.
- Review existing documents for information on pre and post flood terrain assessment and summarize findings.
-

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Chad Davey, M.Sc., R.P.Bio.
Project Geomorphologist

Reviewed by:

Andrew K. Szojka, P.Eng.
Senior Project Manager, Water Resources

CD/aks

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the intended recipient. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

Copyright Notice

Revision History

Revision #	Date	Status	Revision Description	Author
1	September 12, 2016	DRAFT		CD/AS

KERR WOOD LEIDAL
consulting engineers

DRAFT

Appendix A

Bank Line Locations

Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 2012 Banklines

DRAFT

<bol>Reference: 2012 aerial image.

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Project No.	Date
3552-004	September 2016

Bankline Position 2012 (pre-flood image 2012)

Figure A1

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Author: CDavey

Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 2001 Banklines

DRAFT

<bol>Reference: 2001 aerial image.

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Project No.	Date
3552-004	September 2016

Bankline Position 2001

Figure A2

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Author: CDavey

Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 1981 Banklines

DRAFT

<bol>Reference: 1981 aerial image.

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Project No.	Date
3552-004	September 2016

Bankline Position 1981

Figure A3

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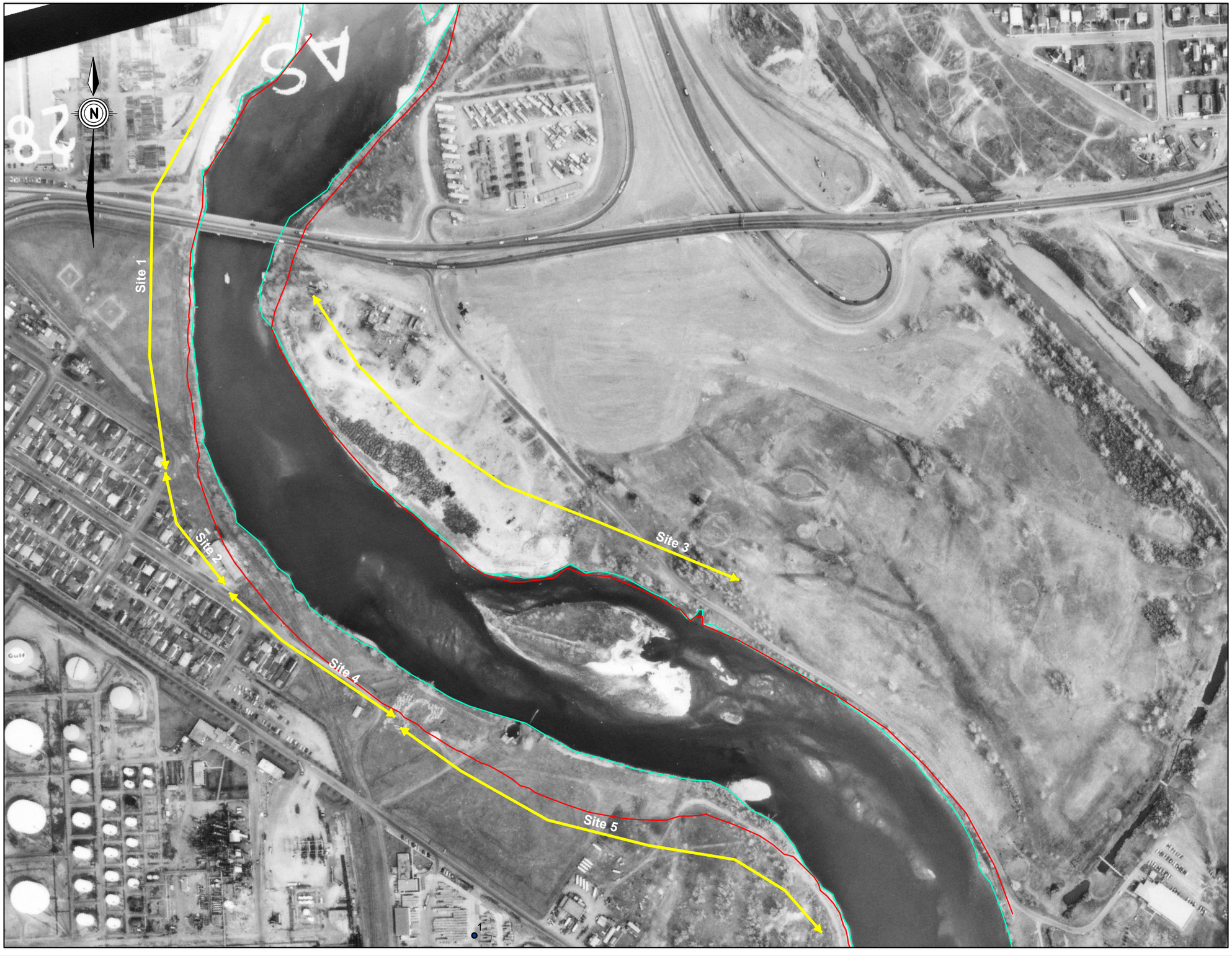
Author: CDavey



Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 1975 Banklines

DRAFT

<bol>Reference: 1975 aerial image.

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consulting engineers

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Project No.	Date
3552-004	September 2016

Bankline Position 1975

Figure A4

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Author: CDavey

Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 1952 Banklines

DRAFT

<bol>Reference: 1952 aerial image.

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consulting engineers

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Project No.	Date
3552-004	September 2016

Bankline Position 1952

Figure A5

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Author: CDavey

Bioengineering Demonstration Project

Legend

- Sites
- 2013 Banklines
- 1924-26 Banklines

DRAFT

<bol>Reference: 1924 to1926 aerial image.

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consulting engineers

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Project No.	Date
3552-004	September 2016

Bankline Position 1924-26

Figure A6

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Author: CDavey

APPENDIX B

Draft Preliminary Geotechnical Assessment

THURBER ENGINEERING LTD.

DRAFT MEMORANDUM

To: Trevor Rhodes
Hemmera Envirochem Inc.

Date: August 31, 2016

From: Victor Bravo, P.Eng. (Project Engineer)
Charles Kwok, M.Sc., P.Eng. (Senior Engineer)
Trempess Moore, M.Eng., P.Eng. (Reviewer)

File: 13155

FISHERIES HABITAT ENHANCEMENT AND SUSTAINABILITY PROGRAM ALONG THE BOW RIVER
PRELIMINARY GEOTECHNICAL ASSESSMENT

1. INTRODUCTION

This memorandum provides a preliminary geotechnical assessment for five sites extending along an approximately 1.5 km reach of the Bow River in southeast Calgary, Alberta. This assignment has been conducted at the request of Hemmera Envirochem Inc. (Hemmera) as part of the Fisheries Habitat Enhancement and Sustainability (FISHES) Program for Alberta Environment and Parks (AEP).

The FISHES Program generally involves the design of slope stabilization, erosion reduction, and vegetation establishment using a bioengineering approach, which incorporates living and non-living plant materials in combination with natural and synthetic materials. The geotechnical component of the FISHES Program is expected to involve a general geotechnical site characterization and consideration of geotechnical and materials engineering aspects including riparian slope stability and related riverbank restoration strategies.

The five sites, denoted as Sites 1 through 5, are located along the Bow River extending from approximately 280 m north of the Cushing Bridge (just south of the Harvie Passage) to a gravel bar located approximately 1.2 km south of the Cushing Bridge.

The extent and locations of the five sites are summarized as followed:

- Site 1: Approximate length 530 m, located on the west bank of the Bow River. The north extent is approximately 280 m north of the Cushing Bridge and the south extent is approximately 250 m south of the Cushing Bridge.
- Site 2: Approximate length 130 m, located on the west bank of the Bow River. From the south extent of Site 1, Site 2 extends to approximately 380 m south of the Cushing Bridge.
- Site 3: Approximate length 660 m, located on the east bank of the Bow River and includes a gravel bar. The north extent is approximately 100 m south of the Cushing Bridge and the south extent is approximately 760 m south of the Cushing Bridge.
- Site 4: Approximate length 230 m, located on the west bank of the Bow River. From the south extent of Site 2, Site 4 extends to approximately 610 m south of the Cushing Bridge.

- Site 5: Approximate length 620 m, located on the west bank of the Bow River and includes a gravel bar. From the south extent of Site 4, Site 5 extends approximately 1.2 km south of the Cushing Bridge.

A site plan presenting the locations of the respective sites is presented in Figure 1 in Appendix A.

It is understood that the sites have been affected by the flood event of June 2013. Erosion has occurred along the Bow River banks within the site areas. While some of the sites have undergone some form of post-2013 flood remediation involving riparian site improvements, some of the sites, namely Sites 1 and 2, likely require further riparian remediation.

It should be noted that no site specific test holes were drilled to confirm the subsurface conditions as part of this preliminary assessment.

It is a condition of this memo that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SCOPE OF WORK AND METHODOLOGY

The scope of work and methodology for this preliminary assessment included the following:

- An initial site visit was conducted with various members of the project team on July 18, 2016. The initial site visit was followed with a more thorough site reconnaissance conducted by Thurber on July 26, 2016. Exposed soils along the eroded river bank were observed, namely in portions of Sites 1 and 5. Photographs were taken during the site reconnaissance, and select photographs are included in Appendix B.
- A review of surficial geological mapping of the area, specifically *"Surficial Geology of the Calgary Urban Area", S.R. Moran 1986, Alberta Research Council, Bulletin No. 53"*.
- A review of available test hole information in the vicinity of the project site. The closest available Thurber test hole information was approximately 120 m from the Bow River banks within the study area. In addition, Hemmera has provided two environmental assessment reports which include relevant subsurface information. The provided reports are as followed:
    - "Phase II & Phase III Environmental Site Assessment Program, 2040-7th Avenue SE & 616-20th Street SE, Calgary, Alberta" prepared by Envirotech Engineering (Envirotech), dated March 28, 2007; and
    - "Phase II Environmental Site Assessment, Inglewood Golf and Curling Club – 19 Gosling Way SE, Calgary, Alberta" prepared by Jacques Whitford Stantec AXYS Ltd. (Jacques), dated May 6, 2009.
- Preparation of a preliminary geotechnical assessment memorandum, including a summary of anticipated soil conditions along the river bank, as well as general geotechnical and bank restoration considerations.

3. GENERAL SITE OBSERVATIONS

The select photographs and captions included in Appendix B present some general observations from the site reconnaissance conducted on July 26, 2016. The approximate locations of the photographs are shown on Figure 2 in Appendix A.

No visible signs of overall global slope instability, e.g. tension cracks and slump scars were observed at the top of the river bank during the site reconnaissance visit.

4. PRELIMINARY GEOTECHNICAL ASSESSMENT AND CONSIDERATIONS

4.1 Anticipated Subsurface Conditions

4.1.1 Surficial Geological Mapping

The local surficial geological map referenced in Section 2 above indicates the presence of fluvial-overbank sediment consisting primarily of silty soil overlying fluvial-channel sediment consisting of gravelly soil. Figure 2 in Appendix A presents the surficial geology overlain on a site plan. This is generally consistent with our visual observations of the study area.

4.1.2 Field Reconnaissance

During the site reconnaissance visits, exposed soils along the eroded river bank were observed. Located in the south portion of Site 1, just north of Site 2, soil stratigraphy from the top of the river bank to the water level was exposed at a location just north of an existing stormwater outfall. The exposed soil stratigraphy at this location was observed to consist of approximately 1 m of silt/clay fill soil including some concrete debris near the top of the river bank, underlain by a silt layer, which was measured to be approximately 1.5 to 2 m thick at this exposed portion of the river bank, and all underlain by sandy gravel soil extending to below the river water level. Exposed bedrock along the river bank was not observed at any of the sites. As such, the depth to bedrock along the river bank within the study area is unknown.

4.1.3 Existing Thurber Test Hole Information

Previously, Thurber has conducted drilling programs in the vicinity of the current study area for Suncor Energy (Suncor). The existing Suncor test hole locations are presented on Figure 1 in Appendix A. In summary, the available subsurface information indicates an upper layer of native silt and/or clay with an approximate thickness ranging between 1 m and 4 m, underlain by sandy gravel and/or gravelly sand soil up to the termination depth of the test holes, which was approximately 8 m at the deepest. In general, the existing Thurber test hole data in the vicinity of the study area is consistent with the published surficial geological mapping and the site observations reported herein.

4.1.4 Provided Test Hole Information

As mentioned in Section 2 of this memorandum, Hemmera has provided relevant subsurface information including test hole logs taken from environmental assessment reports from Envirotech and Jacques. The test hole locations from the Envirotech test holes drilled in 2004 and the Jacques test holes drilled in 2009 are presented on Figure 1 in Appendix A. The provided test hole logs are included in Appendix C for reference.

The Envirotech test holes generally indicate an upper layer of sandy silt and/or sand with an approximate thickness ranging between 1 m and 3 m, underlain by sandy gravel with cobbles up to the termination depth of the test holes. Bedrock was not encountered in the test holes which were advanced to depths ranging between 6.1 m and 8.5 m. Hydrocarbon odor was encountered in MW04-003A, MW04-004, and MW04-010 at respective depths of 6 m, 6m, and 5.9 m.

The Jacques test holes indicate an upper layer of silty sand with an approximate thickness ranging between 0.5 m and 3 m, underlain by sandy gravel or a sand and gravel mix up to the termination depth of the test holes. Bedrock was not encountered in the test holes which were advanced to a depth of 6.1 m.

In general, the provided test hole data is consistent with above-mentioned existing Thurber test hole information and the published surficial geological mapping and the site observations reported herein.

4.1.5 Groundwater

It is expected that the groundwater across the study area is hydraulically connected to the Bow River water level due to the proximity to the Bow River and the likelihood that the subsurface gravel deposits are continuous across the study area. Furthermore, groundwater levels will fluctuate seasonally and in response to climatic conditions and/or variation of the Bow River water levels.

4.2 Geotechnical Considerations

While it is understood that some forms of river bank restoration will be proposed for the various sites, preliminary restoration designs have not been provided at this stage. It is assumed that traditional riverbank restoration techniques, including placing riprap and backfilling in behind and above the riprap with fill material may be considered. Slope flattening may also be considered to increase the overall stability at certain sections of the bank. Pole plantings may also be placed within the fill to re-vegetate and stabilize the reconstructed river banks. This method is referred to as Longitudinal Peak Stone Toe Protection (LPSTP), which is further described in a document entitled "*Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration*", prepared by AMEC Environment & Infrastructure for the City of Calgary, dated February, 2012. No evidence of any potentially soft soils was observed along the river water level. As such, river bank reconstruction is expected to be founded on coarse river gravels.

In general, the proposed restoration techniques, should be evaluated on an individual basis. It is understood that Thurber will conduct a site-specific geotechnical evaluation (inclusive of a subsurface exploration program) to further evaluate the geotechnical aspects of the project once river bank restoration designs are proposed. It is anticipated that site-specific slope stability analyses will be required to evaluate the proposed river bank restoration options.

THURBER

PUBLISHED REFERENCES

Moran, S. R. (1986). Surficial geology of the Calgary urban area. Alberta Research Council, Bulletin 53.

TECHNICAL REPORT REFERENCES

Envirotech Engineering (March, 2007). Phase II & Phase III Environmental Site Assessment Program, 2040-7th Avenue SE & 616-20th Street SE, Calgary, Alberta.

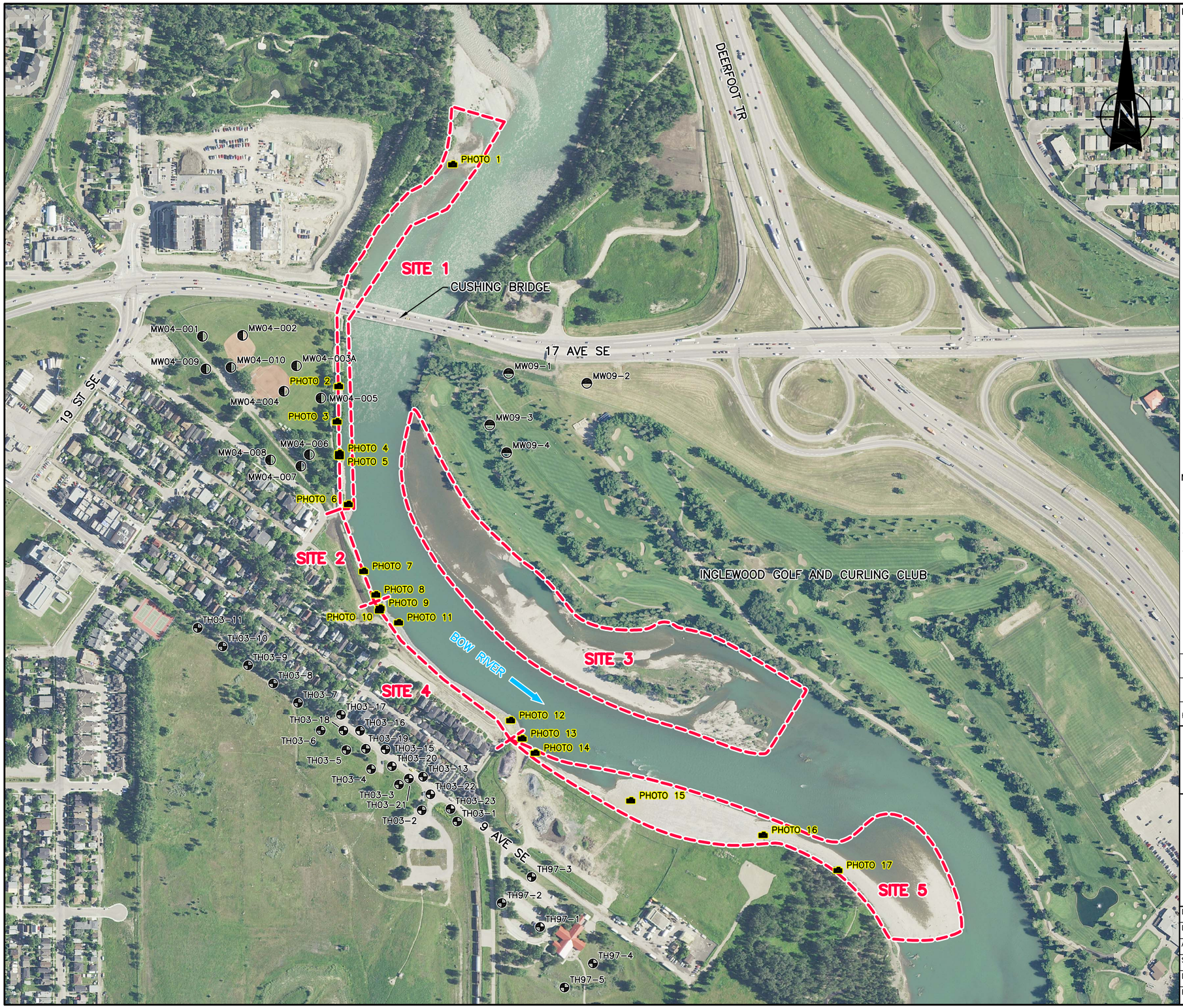
Jacques Whitford Stantec AXYS Ltd. (May, 2009). Phase II Environmental Site Assessment, Inglewood Golf and Curling Club – 19 Gosling Way SE, Calgary, Alberta.

AMEC Environment & Infrastructure (February, 2012). Design Guidelines for Erosion and Flood Control Projects for Streambank and Riparian Stability Restoration.

THURBER

APPENDIX A

Figures



LEGEND:

SITE BOUNDARY (APPROXIMATE)

PHOTO LOCATION (APPROXIMATE)

EXISTING THURBER TEST HOLE LOCATION — THYY–##

DRILLING YEAR = YY HOLE NUMBER = ##

TEST HOLE LOCATION (STANTEC) 2009

TEST HOLE LOCATION (ENVIROTECH ENGINEERING) 2004

DRAFT

NOTES:

1 DRAWING MUST BE USED IN CONJUNCTION WITH THE ATTACHED PROPOSAL REFERENCE 13155 DATED AUGUST 2016 AND IS SUBJECT TO THE STATEMENT OF LIMITATIONS AND CONDITIONS INCLUDED IN THE REPORT.

2 AIR PHOTO BASE FROM TARIN RESOURCE SERVICES LTD. 0.3 m/PIXEL (2014).

3 SITE BOUNDARIES ESTIMATED FROM CLIENT SUPPLIED HARD COPIES.

0 50 100 150 200 250 m

REV	DESCRIPTION	DRAWN BY	APPROVED BY	DATE (MM/DD/YY)
1	ADDED TEST HOLES FROM OTHERS	ICB	VB	08/29/16

HEMMERA

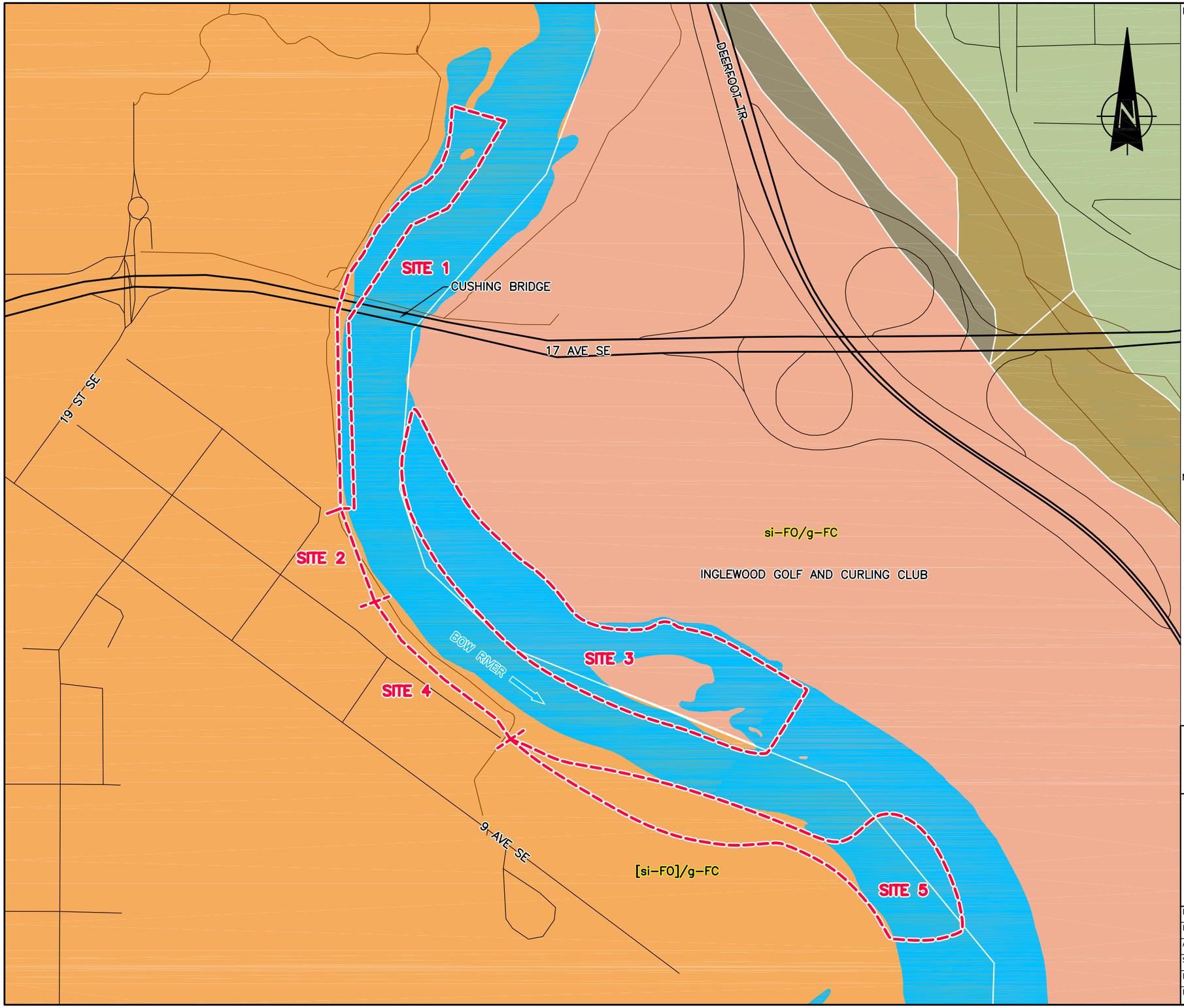
FISHERIES HABITAT ENHANCEMENT AND SUSTAINABILITY PROGRAM

SITE PLAN

FIGURE 1

DRAWN BY	ICB
DESIGNED BY	VB
APPROVED BY	CKK
SCALE	1:5000
DATE	JULY 21, 2016
FILE No.	13155–A0C

THURBER ENGINEERING LTD.



LEGEND:

SITE BOUNDARY (APPROXIMATE)

SURFICIAL GEOLOGY:

FLUVIAL–OVERBANK SEDIMENT (SILT) OVERLYING FLUVIAL–CHANNEL SEDIMENT (GRAVEL) — si–FO/g–FC

FLUVIAL–OVERBANK SEDIMENT (SILT–VENEER) OVERLYING FLUVIAL–CHANNEL SEDIMENT (GRAVEL) — [si–FO]/g–FC

DRAFT

NOTES:

1 DRAWING MUST BE USED IN CONJUNCTION WITH THE ATTACHED PROPOSAL REFERENCE 13155 DATED AUGUST 2016 AND IS SUBJECT TO THE STATEMENT OF LIMITATIONS AND CONDITIONS INCLUDED IN THE REPORT.

2 DRAWING COMPILED FROM CANVEC DATA PRODUCED BY NATURAL RESOURCES CANADA, EARTH SCIENCES SECTOR, DATED JUNE 30, 2014.

3 SURFICIAL GEOLOGY BASE MAP MORAN, S.R., ALBERTA GEOLOGICAL SURVEY, DIG 2008–0874, 2008.

4 SITE BOUNDARIES ESTIMATED FROM CLIENT SUPPLIED HARD COPIES.

0 50 100 150 200 250 m

HEMMERA

FISHERIES HABITAT ENHANCEMENT AND SUSTAINABILITY PROGRAM

SURFICIAL GEOLOGY

FIGURE 2

DRAWN BY	ICB
DESIGNED BY	VB
APPROVED BY	CKK
SCALE	1:5000
DATE	JULY 21, 2016
FILE No.	13155–A0C

THURBER ENGINEERING LTD.

THURBER

APPENDIX B

Selected Photographs

Photo 1. Looking southwest. Gravel bar comprising coarse fluvial channel deposits located in northern portion of Site 1.

Photo 2. Looking south. River bank erosion in near top of bank of Site 1. Concrete debris is visible at the river water level.

Photo 3. Looking south. River bank erosion near top of bank of Site 1 and exposed soil stratigraphy.

Photo 4. Looking north. River bank erosion of Site 1 and exposed soil stratigraphy. Concrete debris is noted near the river water level.

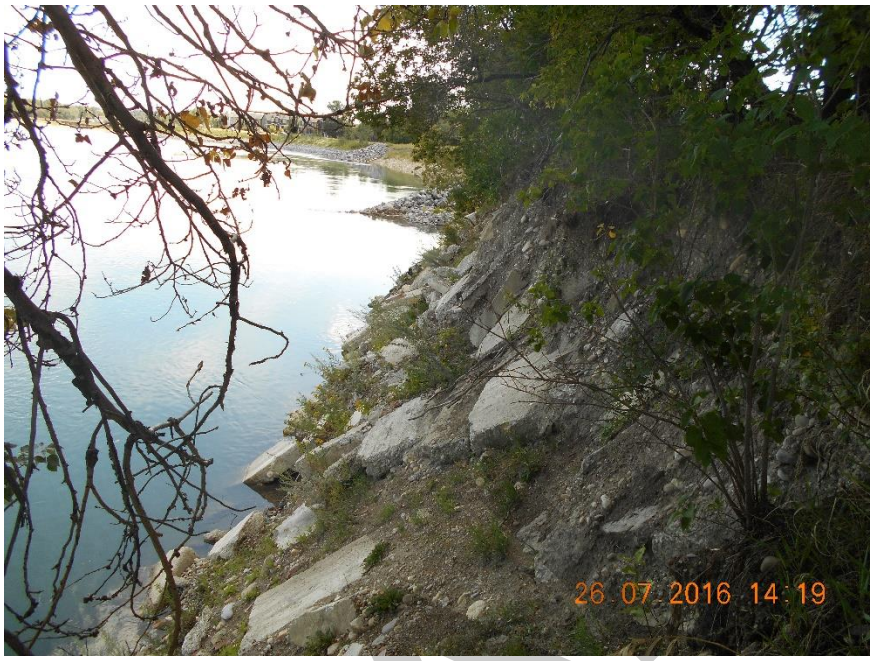


Photo 5. Looking south. Eroded river bank of Site 1 and concrete debris.

Photo 6. Looking northwest. Eroded river bank and exposed soil stratigraphy in southern portion of Site 1, just north of an existing outfall. Concrete debris is also noted along the river bank.

Photo 7. Looking south. River bank of Site 2. Coarse fluvial channel deposits were noted.

Photo 8. Looking west. River bank of Site 2. Apparent live planter steaks were noted.

Photo 9. Looking northwest. River bank of Site 2.

Photo 10. Looking east. Gravel bar comprising coarse fluvial channel deposits in central portion of Site 3.

Photo 11. Looking southeast. Riprap along the river bank of Site 4.

Photo 12. Looking northwest. Riprap along the river bank of Site 4.

Photo 13. Looking southeast. Northern portion of the river bank of Site 5 and an exposed eroded river bank.

Photo 14. Looking south. Erosion near top of bank of Site 5 and exposed soil stratigraphy.

Photo 15. Looking east. Gravel bar comprising coarse fluvial channel deposits and river bank of Site 5.

Photo 16. Looking southwest. Gravel bar and river bank of Site 5.

Photo 17. Looking east. Gravel bar in southern portion of Site 5.

THURBER

APPENDIX C

Provided Test Hole Logs

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

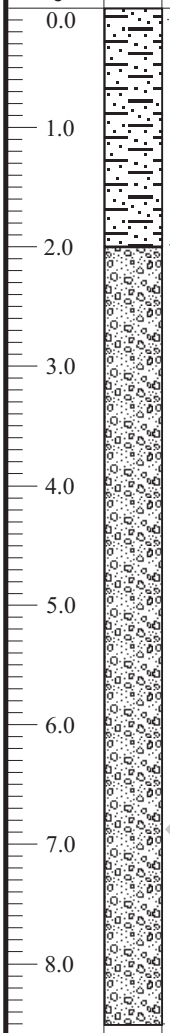
BOREHOLE: MW04-001

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004



DEPTH BELOW GROUND SURFACE METRES	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (IPpm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0	SANDY SILT TRACE GRAVEL; tan, dry, very loose.						Flush-mount Well Protector	
1.0		1	H	P	40		Bentonite Chips	
2.0	SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	2	H	P	40		Fill	
3.0		3	H	P	50			
4.0		4	H	P	40		Bentonite Chips	
5.0		5	H	P	50		Silica Sand	
							▼ (05/01/05)	94.98
6.0		6	H	P	30			
7.0		7	H	P	25		PVC Sch. 40 Screen 20 Slot	
8.0		8	H	P	25			
	END OF HOLE 8.50 m							
9.0								
10.0								
11.0								

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-002

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (IPpm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0		SANDY SILT; tan, dry, very loose.						Flush-mount Well Protector	
1.0			1	H	P	75		Bentonite Chips	
2.0		SANDY SILT GRAVEL; brown, dry, very loose.	2	H	P	25		Fill	
3.0		SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	3	H	P	30		Bentonite Chips	
4.0			4	H	P	30		Silica Sand	
5.0			5	H	P	30		▼ (05/01/05)	95.16
6.0			6	H	P	30		PVC Sch. 40 Screen 20 Slot	
7.0			7	H	P	25			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-003A

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Dec 20, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (IPpm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0								Flush-mount Well Protector	
		SANDY SILT; tan, dry, very loose.	1	H	P	20			
1.0									
2.0		SANDY SILT GRAVEL; brown, dry, very loose.	2	H	P	10		Bentonite Chips	
3.0		SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	3	H	P	50			
4.0			4	H	P	50		Silica Sand	
5.0			5	H	P	50		▼ (05/01/05)	94.58
6.0		- Hydrocarbon odors at 6.0 m (Diesel).	6	H	P	100		PVC Sch. 40 Screen 20 Slot	
		SANDY GRAVEL; brown, wet, loose.							
7.0		SANDY SILT GRAVEL AND COBBLES; brown, wet, loose.	7	H	P	70			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: The City of Calgary
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-004

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (*Ppm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0		SANDY SILT; tan, dry, very loose.						Flush-mount Well Protector	
1.0			1	H	P	50			
2.0		SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	2	H	P	40		Bentonite Chips	
3.0			3	H	P	40			
4.0			4	H	P	90		Silica Sand	
5.0			5	H	P	80		▼ (05/01/05)	94.62
6.0		SANDY GRAVEL; brown, wet, loose. - Hydrocarbon odors at 6.0 m (Diesel).	6	H	PG	100		PVC Sch. 40 Screen 20 Slot	
7.0		SANDY SILT GRAVEL AND COBBLES; brown, wet, loose.	7	H	P	45			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-005

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (IPpm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0		SANDY SILT; tan, dry, very loose.						Flush-mount Well Protector	
1.0			1	H	P	25		Bentonite Chips	
		- Asphalt debris at 1.75 m						Fill	
2.0		SANDY SILT GRAVEL; brown, dry, very loose.	2	H		No Sample			
3.0		SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	3	H	P	35		Bentonite Chips	
4.0			4	H	P	50		Silica Sand	
5.0			5	H	P	25		▼ (05/01/05)	94.50
6.0			6	H	P	20		PVC Sch. 40 Screen 20 Slot	
7.0			7	H	P	15			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: The City of Calgary
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-006

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (*Ppm)	MONITOR WELL DATA: WELL	MONITOR WELL DATA: DESCRIPTION	ELEVATION METRES
0.0		SANDY SILT; tan, dry, very loose.						Flush-mount Well Protector	
1.0		SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	1	H	P	25		Bentonite Chips	
2.0		SANDY GRAVEL TRACE COBBLE; tan, dry, very loose.	2	H	P	25		Fill	
3.0			3	H	P	45		Bentonite Chips	
4.0			4	H	P	20		Silica Sand	
5.0			5	H	P	25		▼ (05/01/05)	94.48
6.0			6	H	P	10		PVC Sch. 40 Screen 20 Slot	
7.0			7	H	P	10			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: The City of Calgary
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-007

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 23, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (*Ppm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0		SAND; tan, dry, very loose.						Flush-mount Well Protector	
1.0		SANDY GRAVEL; brown, dry, very loose.	1	H	P	50		Bentonite Chips	
2.0		SILTY SAND SOME GRAVEL & COBBLE; tan, dry, loose.	2	H	P	50		Fill	
3.0			3	H	P	30		Bentonite Chips	
4.0			4	H	P	35		Silica Sand	
5.0			5	H	P	25		▼ (05/01/05)	94.51
6.0			6	H	P	30		PVC Sch. 40 Screen 20 Slot	
7.0			7	H	P	20			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-008

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 23, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (*Ppm)	MONITOR WELL DATA: WELL	MONITOR WELL DATA: DESCRIPTION	ELEVATION METRES
0.0								Flush-mount Well Protector	
		SANDY SILT; tan, moist, loose.							
1.0			1	H	P	25		Bentonite Chips	
		SAND WITH GRAVEL & COBBLES; brown, dry, very loose.							
2.0			2	H	P	30			
								Silica Sand	
3.0			3	H	P	20			
								▼ (05/01/05)	94.57
4.0			4	H	P	20			
								PVC Sch. 40 Screen 20 Slot	
5.0			5	H	P	25			
6.0			6	H	P	20			
		END OF HOLE 6.10 m							
7.0									
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: The City of Calgary
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

BOREHOLE: MW04-009

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 23, 2004

DEPTH BELOW GROUND SURFACE METRES	SOIL SYMBOL	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (IPpm)	MONITOR WELL DATA: WELL	MONITOR WELL DATA: DESCRIPTION	ELEVATION METRES
0.0		SILTY SAND; tan, dry, loose.						Flush-mount Well Protector	
1.0			1	H	P	25		Bentonite Chips	
2.0			2	H	P	No Sample		Fill	
3.0		SILTY SAND AND GRAVEL; tan, dry, loose.	3	H	P	35		Bentonite Chips	
4.0			4	H	P	50		Silica Sand	
5.0			5	H	P	25		▼ (05/01/05)	95.05
6.0			6	H	P	20		PVC Sch. 40 Screen 20 Slot	
7.0			7	H	P	10			
		END OF HOLE 7.62 m							
8.0									
9.0									
10.0									
11.0									

SAMPLE METHOD: A - Auger, H - Hammer, V - Shovel, S - Split Tube

CONTAINER: G - Glass Jar, P - Plastic Bag, T - Tube, B - Core Box

Envirotech Engineering
Environmental Management, Assessment & Remediation Services

PROJECT: **The City of Calgary**
Phase II Site Assessment
616 - 20 Street S.E.
Calgary, Alberta

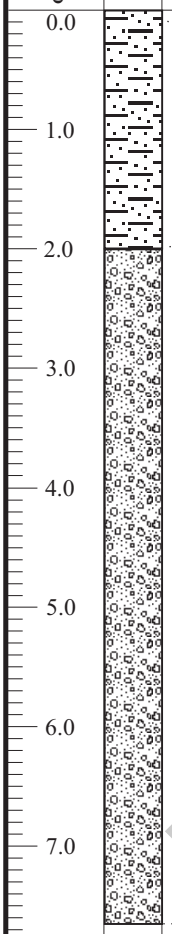
BOREHOLE: MW04-010

PROJECT No.: 04-088

FIELD SUPERVISION PERSONNEL: Wayne Storey

DRILLING CONTRACTOR: Beck Drilling, Calgary, Alberta

DATE DRILLED: Nov 22, 2004



DEPTH BELOW GROUND SURFACE METRES	LITHOLOGY	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE CONTAINER	HC VAPOUR CONCENTR. (*Ppm)	MONITOR WELL DATA WELL	MONITOR WELL DATA DESCRIPTION	ELEVATION METRES
0.0	SANDY SILT; tan, dry, very loose.						Flush-mount Well Protector	
1.0		1	H	P	75			
2.0	SANDY SILT GRAVEL AND COBBLES; brown, dry, very loose.	2	H	P	85		Bentonite Chips	
3.0		3	H	P	50			
4.0		4	H	P	50		Silica Sand	
5.0		5	H	P	60		▼ (05/01/05)	94.71
6.0	- Hydrocarbon odors at 5.9 m.	6	H	PG	125		PVC Sch. 40 Screen 20 Slot	
7.0		7	H	P	75			
	END OF HOLE 7.62 m							
8.0								
9.0								
10.0								
11.0								

SAMPLE METHOD: A - Auger; H - Hammer; V - Shovel; S - Split Tube

CONTAINER: G - Glass Jar; P - Plastic Bag; T - Tube; B - Core Box

MONITORING WELL RECORD

MW09-1

CLIENT **City of Calgary** PROJECT No. **1032231.04**

LOCATION **Inglewood Golf and Curling Club - 19 Gosling Way SE, Calgary, Alberta** WELL No. **MW09-1**

DATES (mm/dd/yy): BORING **1/13/09** WATER LEVEL **3.78 m (1/20/09)** DATUM **ASCM 298539**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	SAMPLES FIELD Ec (mS/cm)	FIELD pH	VAPOUR LEVEL GASTECH (ppm)	VAPOUR LEVEL PID (ppm)	WATER LEVEL	FREE HYDROCARBON	WELL CONSTRUCTION DETAILS
0	1050.70	Top of Pipe = 1050.62 m												
	1050.20	Hydrovac												Bentonite
1		firm, medium to dark brown, SILTY SAND, trace gravel, moist		BS	1					<10	0.0			
2				BS	2					<10	0.1			Sand
		- trace cobbles at 2.3 m		BS	3					<10	0.1			
3	1047.70	compact, medium brown, SAND and GRAVEL, trace cobbles, dry to moist		BS	4					<10	0.0	▼		
4				BS	5					10 *	0.1			50 mm Well Screen
		- becomes moist to wet below 4.6 m		BS	6					<10	0.0			
5		- becomes wet below 5.3 m		BS	7					<10 *	0.0			
6	1044.60	End of Borehole at 6.1 m * Soil Samples Submitted for Laboratory Analysis												Slough
7														
8														
9														
10														

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MONITORING WELL RECORD

MW09-2

CLIENT **City of Calgary**

PROJECT No. **1032231.04**

LOCATION **Inglewood Golf and Curling Club - 19 Gosling Way SE, Calgary, Alberta**

WELL No. **MW09-2**

DATES (mm/dd/yy): BORING **1/13/09** WATER LEVEL **3.92 m (1/20/09)**

DATUM **ASCM 298539**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	SAMPLES FIELD Ec (mS/cm)	FIELD pH	VAPOUR LEVEL GASTECH (ppm)	VAPOUR LEVEL PID (ppm)	WATER LEVEL	FREE HYDROCARBON	WELL CONSTRUCTION DETAILS
0	1050.63	Top of Pipe = 1050.17 m												
	1050.13	Hydrovac												Bentonite
1	1049.13	GRAVEL, with cobbles		BS	1					<10	0.0			
2		compact, medium brown, SAND and GRAVEL, trace cobbles, dry to damp		BS	2					<10	0.1			Sand
3				BS	3					<10	0.1			
				BS	4					<10 *	0.1			
4		- becomes moist below 3.8 m		BS	5					<10	0.0	▼		50 mm Well Screen
5				BS	6					10	0.1			
				BS	7					10 *	0.1			
6	1044.53	End of Borehole at 6.1 m * Soil Samples Submitted for Laboratory Analysis												Slough
7														
8														
9														
10														

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MONITORING WELL RECORD

MW09-3

CLIENT **City of Calgary** PROJECT No. **1032231.04**

LOCATION **Inglewood Golf and Curling Club - 19 Gosling Way SE, Calgary, Alberta** WELL No. **MW09-3**

DATES (mm/dd/yy): BORING **1/13/09** WATER LEVEL **3.47 m (1/20/09)** DATUM **ASCM 298539**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	SAMPLES FIELD Ec (mS/cm)	FIELD pH	VAPOUR LEVEL GASTECH (ppm)	VAPOUR LEVEL PID (ppm)	WATER LEVEL	FREE HYDROCARBON	WELL CONSTRUCTION DETAILS
0	1050.54	Top of Pipe = 1050.54 m												
	1050.04	Hydrovac												Bentonite
1	1049.04	compact, medium to dark brown, SILTY SAND, trace gravel and organics, moist		BS	1					10	0.0			
2		compact, medium brown, SAND and GRAVEL, trace cobbles, dry to damp		BS	2					10	0.0			Sand
3		- becomes moist below 3.0 m		BS	3					<10	0.1			
4		- becomes wet below 3.8 m		BS	4					30 *	5.0	▼		50 mm Well Screen
5				BS	5					10	0.8			
6	1044.44			BS	6					<10	0.4			Slough
				BS	7					25 *	0.0			
7		End of Borehole at 6.1 m * Soil Samples Submitted for Laboratory Analysis Note: Water elevation and water level are read from top of pipe												
8														
9														
10														

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MONITORING WELL RECORD

MW09-4

CLIENT **City of Calgary** PROJECT No. **1032231.04**

LOCATION **Inglewood Golf and Curling Club - 19 Gosling Way SE, Calgary, Alberta** WELL No. **MW09-4**

DATES (mm/dd/yy): BORING **1/13/09** WATER LEVEL **3.95 m (1/20/09)** DATUM **ASCM 298539**

DEPTH(m)	ELEVATION(m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	SAMPLES FIELD Ec (mS/cm)	FIELD pH	VAPOUR LEVEL GASTECH (ppm)	VAPOUR LEVEL PID (ppm)	WATER LEVEL	FREE HYDROCARBON	WELL CONSTRUCTION DETAILS
0	1051.01	Top of Pipe = 1050.94 m												
	1050.51	Hydrovac												Bentonite
1		compact, medium brown, SAND and GRAVEL		BS	1					<10	0.1			
2				BS	2					25 *	0.2			Sand
		- trace cobbles below 2.3 m		BS	3					<10	0.1			
3		- becomes moist below 3.0 m		BS	4					20	0.1			
4		- becomes moist to wet below 3.8 m		BS	5					20	0.2	▼		50 mm Well Screen
5		- trace sandstone inclusions below 4.6 m		BS	6					10	0.1			
6	1044.91			BS	7					10 *	0.1			Slough
		End of Borehole at 6.1 m * Soil Samples Submitted for Laboratory Analysis												
7														
8														
9														
10														

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