Atmautluak Hydrological Study and Community Drainage Plan

Prepared for:

Atmautluak Traditional Council

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Prepared by:

AECOM

700 G Street, Suite 500

Anchorage, AK 99501

In Association with:

DOWL

Hydraulics Mapping & Modeling

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1.0 EXECUTIVE SUMMARY

1.1 Overview

The Community of Atmautluak is located on the Pitmiktakik River 17 miles northwest of Bethel. Riverine erosion has potential impact on the community due to proximity to the Pitmiktakik River. Erosion due to wave action has also been observed on the banks of the larger lake (not named) on the west side of Atmautluak.

Ponding in the center portion of the community has become a problem in recent years. A road constructed from the airport to the center of the community cut off a natural drainage swale. Water that previously drained to the north began ponding. Community elders report that land that was once higher and dry has subsided and now wet. Pig Lake overflows during high water periods in spring and fall.

1.2 Purpose of Study

The purpose of the Atmautluak Hydrological Study was to determine the recurrence intervals of floods and provide a hydrological basis for the evaluation the existing bank erosion and proposed alternatives to reduce bank erosion along the Pitmiktakik River (Section 7). Two areas on the shore of the larger lake west of the town were also studied (Section 7.3). The purpose of the Community Drainage Plan (which is included in this report as Section 9.0) was to identify alternatives that could drain excess surface waters at Pig Lake to nearby lakes and rivers in order to restore natural drainage, reduce flooding of properties in spring and fall, and reduce heat transfer to underlying tundra from standing water, which could potentially decrease permafrost degradation.

1.3 Conclusions

Erosion is primarily due to hydraulic shear stress on fine grained soils, with soil pore pressures and ice scour also contributing. Bank stability and reduced erosion can be achieved with installation of a sheet pile wall, articulating concrete block matting, or a cellular confinement system (see section 8). Articulating Concrete Block matting is the recommend alternative. A sheet pile wall would be more expensive than the other options and would be subject to corrosion. Articulating Concrete Block matting or a cellular confinement system would provide easier boat access than a sheet pile wall. A cellular confinement system would be susceptible to ice damage and was not recommended.

A new drainage swale can be constructed from Pig Lake to the north to restore natural drainage and keep the water levels in Pig Lake as low as possible (see section 9).

2.0 BACKGROUND

A community map can be downloaded from the State of Alaska at:
https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/CommunityProfileMaps.aspx
A Hazard Impact Assessment (HIA) was completed by WH Pacific in 2010, it can be downloaded at:

https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/ACCIMP/CommunityPlanningGrants/AtmautluakCPG.aspx. The HIA included several potential hazards:

- Wildfire (low probability)
- Earthquake (low probability)
- Flooding
- Erosion
- Ground Failure (due to permafrost thaw)

Potential hazard from wildfire is low due to lack of trees in the area. Atmautluak is not located in an area with high seismic risk. The probability of an earthquake of magnitude of 5.0 or higher occurring in Atmautluak within the next 50 years is 20% (contrast to 100% for Anchorage).

Flooding. Community elders reported in a 2016 meeting with AECOM that the river will slightly overtop the lowest banks and be just under the top of the highest banks during spring snow melt or during fall rains. They noted there has been no significant flooding beyond the banks for over 40 years. The Corps of Engineers reports the 'flood of record' occurred in 1972. (USACE 2007).There was a large flood that covered the whole region 200 years ago according to traditional lore.

Erosion. The U.S. Army Corps of Engineers provided an Erosion Information Paper for the community of Atmautluak in 2007. The paper reported that: *"The entire length of the community has some erosion. Causes of erosion include natural river flow, spring breakup, melting permafrost, boat wakes and ice jams."* The report estimated loss of one foot of bank per year on average.

Ground Failure. Soil conditions underlying Atmautluak have been characterized as organic-rich soils over thaw unstable permafrost soils. (Duane Miller & Associates, 1996 and Shannon & Wilson, 1993). Thaw-unstable subsurface soils are subject to significant settlement if allowed to thaw. Sources of heat and other conditions that can lead to permafrost thaw include: standing water, removal of insulating vegetation layers (tundra), buildings, gravel surfaces, and boardwalks. Settlement of the high ice-content silty soils can occur due to drainage of excess pore water when the soils thaw. Drainage of wet tundra areas would likely increase the depth of frost penetration, and could potentially both decrease the depth of the active thaw layer and decrease permafrost degradation (WHPacific, 2010). The HIA recommended a community wide drainage plan as a way to decrease the amount of standing water in the center of the community. Figure 1 shows the wet low areas that would be addressed by a drainage plan.

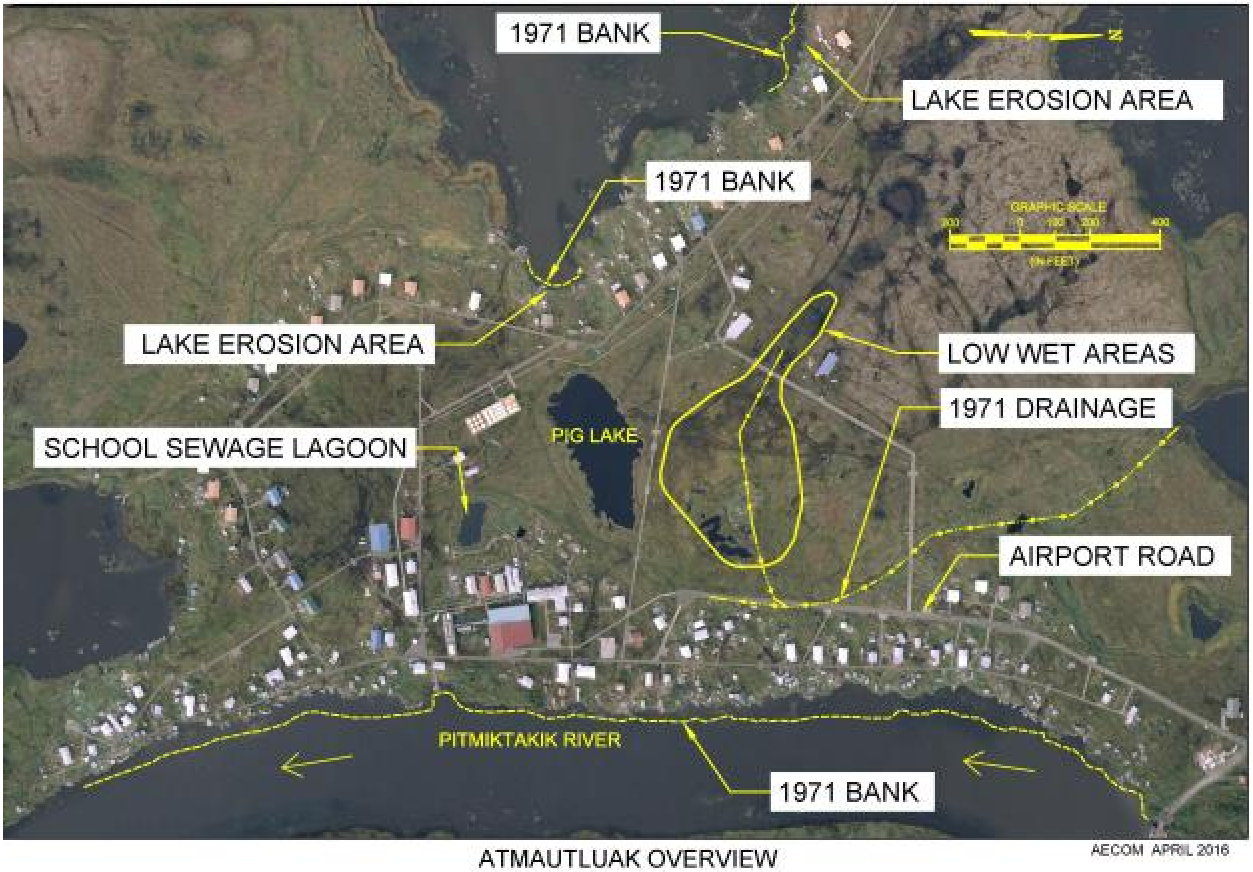

Figure 1: Atmautluak 2007

3.0 STUDY SCOPE

The goals of this study were to provide a hydrological study, determine the most suitable combination of solutions to address bank erosion, and address standing water in the center of the community. The study consisted of the following tasks:

- Field Reconnaissance and Site Survey
- Hydrology and Hydraulic Analysis
- Erosion Analysis
- Bank Stability Alternatives Analysis
- Drainage Study
- Permitting Requirements

AECOM sub-contracted to DOWL for field and river surveying and Hydraulic Mapping and Modeling (HMM) for hydrology and hydraulic analysis.

4.0 FIELD RECONNAISANCE AND SITE SURVEY

The study team traveled to Atmautluak in August 2015 for the site survey and field reconnaissance investigation. The site visit coincided with an introductory meeting with the Atmautluak Traditional Council. The team included an AECOM community outreach specialist, AECOM civil engineer, a hydraulic engineer (Hydraulic Mapping and Modeling), and a surveyor (DOWL).

The site survey included a hydrographic survey of the river (including nine channel cross sections covering 4½ river miles), and topographic survey of upland areas in the center of the community. The field survey was performed by DOWL on August 26th and 27th, 2015. Static Global Satellite (GNSS) observations were taken on the primary control station at the Airport and based on Alaska Department of Transportation & Public Facilities (ADOT&PF) survey control. Upland ground shot points were obtained by Real Time Kinetic (RTK) GPS. The cross-sections were surveyed using a combination of methods (DOWL, 2015). In addition to using an RTK GPS total station for upland and shallow water survey measurements, a SONTEK M9 Acoustic Doppler Profiler was used for the hydrographic survey. The acoustic Doppler profiler supplied both bed elevations along the cross-section lines, and estimates of discharge at each cross-section.

Vertical Datums. The 2015 DOWL survey vertical datum is 8.03 feet higher than the datum developed for the Atmautluak Community Map in 2007. The common point between the two surveys is the ADOT&PF monument HV-1 located at the Atmautluak airport. Vertical conversion: DOWL 2015 elevation of 16.87 feet (see Appendix G) equals Atmautluak Community Map elevation 8.84 feet (the community map can be downloaded from the State of Alaska at: https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/CommunityProfileMaps.aspx)

5.0 GEOTECHNICAL BACKGROUND

Atmautluak is located in a zone of discontinuous permafrost. Permafrost in this region is relatively warm. Measured ground temperatures indicate soil temperatures in the upper 30 feet are within one degree of thawing (Shannon & Wilson 1993). The tundra mat consists of a 2 to 5 foot thick layer of peat. Underlying soils are typically frozen silt materials.

5.1 Previous Geotechnical Explorations

In order to determine the underlying geologic conditions at Atmautluak, a number of previous geotechnical studies were reviewed. These studies included:

- Geotechnical Services for Proposed Lift Station, Honey Bucket Lagoon, Sewage Lagoon and Sewage Pipeline (Shannon & Wilson Inc., 1993); total of 12 borings (test holes) drilled to depths of 12 to 35 feet with a 3-inch diameter core barrel and split spoon sampler; borings were drilled through the active zone and deep into the permafrost soils
- Atmautluak Airport Construction (State of Alaska Department of Public Works Division of Aviation, 1975); 16 borings were drilled in the vicinity of the Atmautluak airport to depths between 10 and 15 feet.

5.2 Permafrost

Permafrost conditions vary widely across the community according to previous geotechnical reports. The active layer thaws to depths of up to four feet deep. Soil was frozen to the bottom of all 12 borings drilled in 1993 (Shannon & Wilson), to depths of 35 feet. The Alaska Department of Environmental Conservation (ADEC) found permafrost to depths down to 235 feet in Atmautluak (ADEC 2010). Borings drilled by ADOT&PF in 1974 near the river encountered unfrozen and saturated soils to depths of 15 feet or greater. This is likely the result of a naturally deep thaw area underlying the river.

5.3 Subsurface Soils

The subsurface soils were generalized into the following layers based on the available information from previous geotechnical reports. The upper four feet is considered to be an active zone consisting of peat and silty peat. The soil descriptions for each generalized layer are summarized below.

- Top organic mat ranging from 1.5 to 5 feet deep: Loose, wet, dark brown, peat (from boring logs, Shannon & Wilson 1993)
- 1.5 to 30 feet depth: Sandy silt, generally frozen (from boring logs, Shannon & Wilson 1993).

6.0 HYDROLOGY AND HYDRAULIC ANALYSIS

Figure 2: Pitmiktakik River (looking upstream).

The Pitmiktakik River is a meandering stream that originates about 60 miles northeast of Atmautluak in a flat tundra and lakes complex area. Atmautluak is located on an actively eroding outside bend of the river. The area around Atmautluak is flat and poorly drained with numerous lakes and small drainages that flow into the Pitmiktakik River (ADCED, 2009).

The hydraulic analysis for the Pikmiktakik River consisted of modeling the flow characteristics using the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) River Analysis System (RAS) water surface profiling computer program HEC-RAS version 4.1. Using the channel cross-sections obtained in August 2015 as part of the hydrographic survey, HMM built the HEC-RAS model of the river to estimate the river discharge volumes and channel conditions during ice jams. A full description of the hydrology and hydraulic analysis is included in Appendix A.

The 2010 WH Pacific Study indicated ice jams have been associated with floods in Atmautluak. The Corps of Engineers attributes the 1972 flood of record in Atmautluak to ice jamming (WHPacific, 2010). In addition, the Corps of Engineers noted in a 2007 report that 'in the last 10 years, three to four ice jams have caused 1 to 2 feet of erosion per event, according to local officials' (USACE, 2007). However, the U.S Army Cold Regions Research and Engineering Laboratory (CRREL) Ice Jam Database, which contains information on past ice jam events including dates, locations, and damage levels, includes no information on ice jams for Atmautluak or the Pitmiktakik River. A second database of ice jams in the State of Alaska contains a database of unofficial river flooding and ice jam observations by pilots and others. Maintained by the Alaska-Pacific River Forecast Center, this National Weather Service web site also contained no information on ice jams for Atmautluak or the Pitmiktakik River. Based on conversations with the Atmautluak Traditional Council in August 2015 and January 2016, flooding due to ice jams has not been an issue in the community. They noted that ice on the Pitmiktakik River does not flow like it does on the Kuskokwim. It appears that flooding on the Pitmiktakik River due to ice jams has not been an issue. Ice jam analysis for the Atmautluak area was completed as part of the Hydrological Study and is included in Appendix A.

7.0 EROSION ANALYSIS

Figure 3: Pitmiktakik River Bank Erosion, Bank Sections Sloughing Into River

A comparison of the 2007 aerial photo with a 1971 photo shows that, on average, the bank has eroded about 47 feet over 36 years, or about 1.3 feet per year. The WH Pacific study showed a similar erosion rate, on average, of 32 feet over a 24 year period (1.3 feet per year).

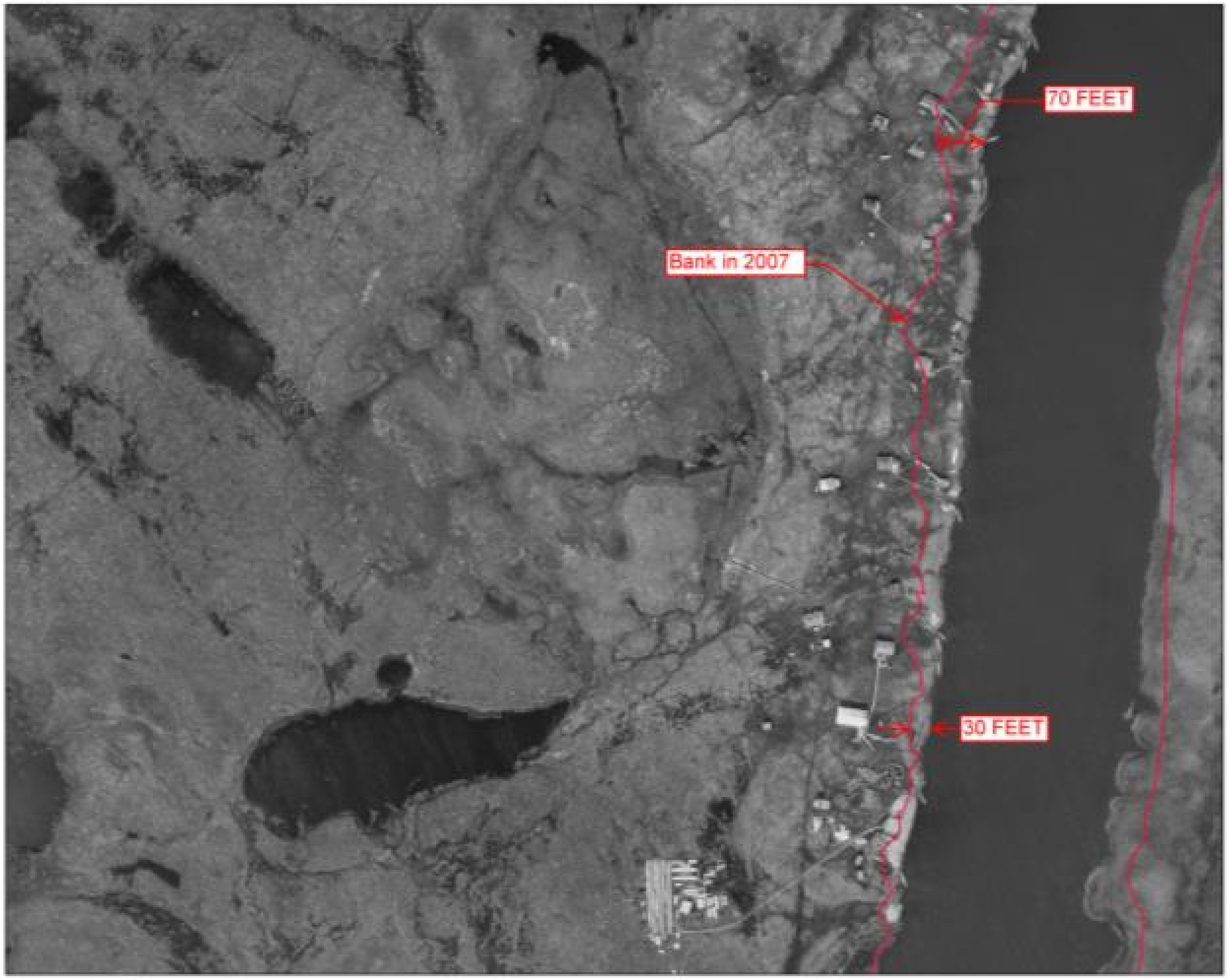

Figure 4: Bank retreat from erosion on Pitmiktakik River, from 1971 (photo) to 2007 (red line).

7.1 Shear Stress

The hydraulic analysis for this study utilized the USDA Bank Stability and Toe Erosion Model (BSTEM) to estimate erosion of the bank and bank toe by hydraulic shear stress. The model estimates strength, shear stress, and erodibility of different layers, and considers the effects of pore-water pressure. The soil layer characterizations were based on descriptions from WH Pacific (2010). Changes in river level associated with twice daily tidal cycles on the Pitmiktakik River result in rapidly changing pore-water pressure in the upper banks. Excess pore-water pressure that develops when the river level falls reduces soil strength and can result in streambank erosion.

The BSTEM analysis estimated that shear stress may be responsible for up to 1 foot or so per year of bank erosion along the Pitmiktakik River. See Appendix A.

7.2 Other Factors Contributing to Erosion

In addition to shear stress, two other contributing factors of bank erosion are likely the freeze/thaw cycle and ice forces during breakup. The freeze/thaw cycle and formation of ice along the riverbanks results in bank sediment being dislodged and moved downslope via gravity. Additionally, ice thrust, ice retreat, and ice movement, which all occur during breakup and ice jam events, abrades and gouges the bank leading to bank erosion.

7.3 Lake Erosion

Erosion has been a problem at two locations on the lake to the west of the community at the Atmautluak Beachfront Subdivision (see Figure 5). Erosion appears to be primarily the result of wave action. Local residents report that wind driven waves are more pronounced at these locations due to their location at the end of a 7000 foot long fetch of the lake (fetch length measured from google earth). The erosion rate is approximately 1 foot per year, based on a comparison between a 1971 aerial photo and a 2007 aerial photo.

Figure 5: Lake Erosion Areas

8.0 BANK STABILITY ALTERNATIVES

Three alternatives were considered as a means to stabilize the bank of the Pitmiktakik River and mitigate the effects of ongoing erosion. The Traditional Council requested shore protection at two areas susceptible to erosion on the lake shore just west of the community, as noted previously. Bank erosion in these locations is encroaching on private homes. River bank stability alternatives would be constructed from the south end of the community north to the airport. Bank stability alternatives considered for river shore protection included sheet pile walls, articulating concrete block matting, and cellular confinement systems (geocells). Bank stability alternatives considered for lake shore protection included articulating concrete block matting, and cellular confinement systems (geocells).

8.1 Sheet Pile Wall Alternative

Installation of a sheet pile wall was considered as a means to stabilize the bank of the Pitmiktakik River from the south end of the community to the airport, approximately 3060 feet in length. Breaks or gaps in the wall would be necessary at identified locations where access to the river is required for launching boats; gravel "launch ramps" would be constructed at these locations to prevent erosion from occurring behind the wall. A steel pile cap would be installed along the top of the wall and fill material or gravel could be placed behind the wall to provide a walkway/landing area for boats and pedestrian traffic. The wall could be constructed in phases over a period of years to spread out the cost and provide initial protection to areas of importance.

To construct the wall, interlocking galvanized steel sheet piles would be driven along the top of the riverbank to within one or two feet of the existing ground elevation. The piles would need to have a minimum of 35 feet of embedment to resist frost jacking, based on previous experience with pile supported structures in the area. Since the wall would have a freestanding (cantilevered) height of roughly 5 feet, the estimated lateral earth pressure forces would be low, and a relatively lightweight sheet pile section could be used. It may be possible to use a composite (fiberglass) sheet pile section if a site specific geotechnical investigation determines that hard permafrost does not exist above the required embedment depth and the native soils are "soft" enough to drive composites through without damaging them. It should be noted that if a galvanized steel section is used, the coating would typically need periodic inspection and repair after 15 years (re-coating above water only) to ensure corrosion protection. Sacrificial metal anodes are typically installed on sheet piling to help reduce corrosion. Anode replacement is typically required every 10 to 20 years. See Figure 6 for proposed wall layout and typical sections.

Where the sheet pile wall is installed in bank sections with a gentle slope from the top of bank down to the submerged toe of bank, it is expected that the riverside bank material will eventually erode back to the sheetpile. This will create a vertical face and deeper water along the sheet pile wall, and will provide boat docking opportunities adjacent to the bank. See Figures 6 and 7.

Soil Parameters. Soil parameters for preliminary design were obtained from the Geotechnical Report for the Proposed Lift Station, Honey Bucket Lagoon, Sewage Lagoon and Sewage Pipeline (Shannon & Wilson Inc., 1993); the material parameters used were considered appropriate for this level of conceptual design. Additional geotechnical investigations along the proposed wall alignment would be required to confirm assumptions of the material parameters and the geologic cross section of the subsurface materials prior to final design.

Cost Estimates. The sheet pile wall would require 3.3 million pounds of steel. The cost to purchase and ship the steel to Atmautluak by barge would be cost a minimum of $3 million. See Table 1 for a preliminary cost summary and Appendix F for a more detailed cost estimate.

Sheet Pile Wall Advantages:

- Resistant to ice damage

Sheet Pile Wall disadvantages:

- High Construction Cost
- Subject to Corrosion
- High Maintenance Cost
- Vertical Face Would Create Potential Safety Hazard for Winter Travel
- Boat Access Made More Difficult

Table 1: Sheet Pile Wall Costs

Cost Estimate	Sheet Pile Wall
Construction Cost	$6.0 Million
Cost per Foot	$1,700
Maintenance Cost (Assume Every 15 Years)	$800,000

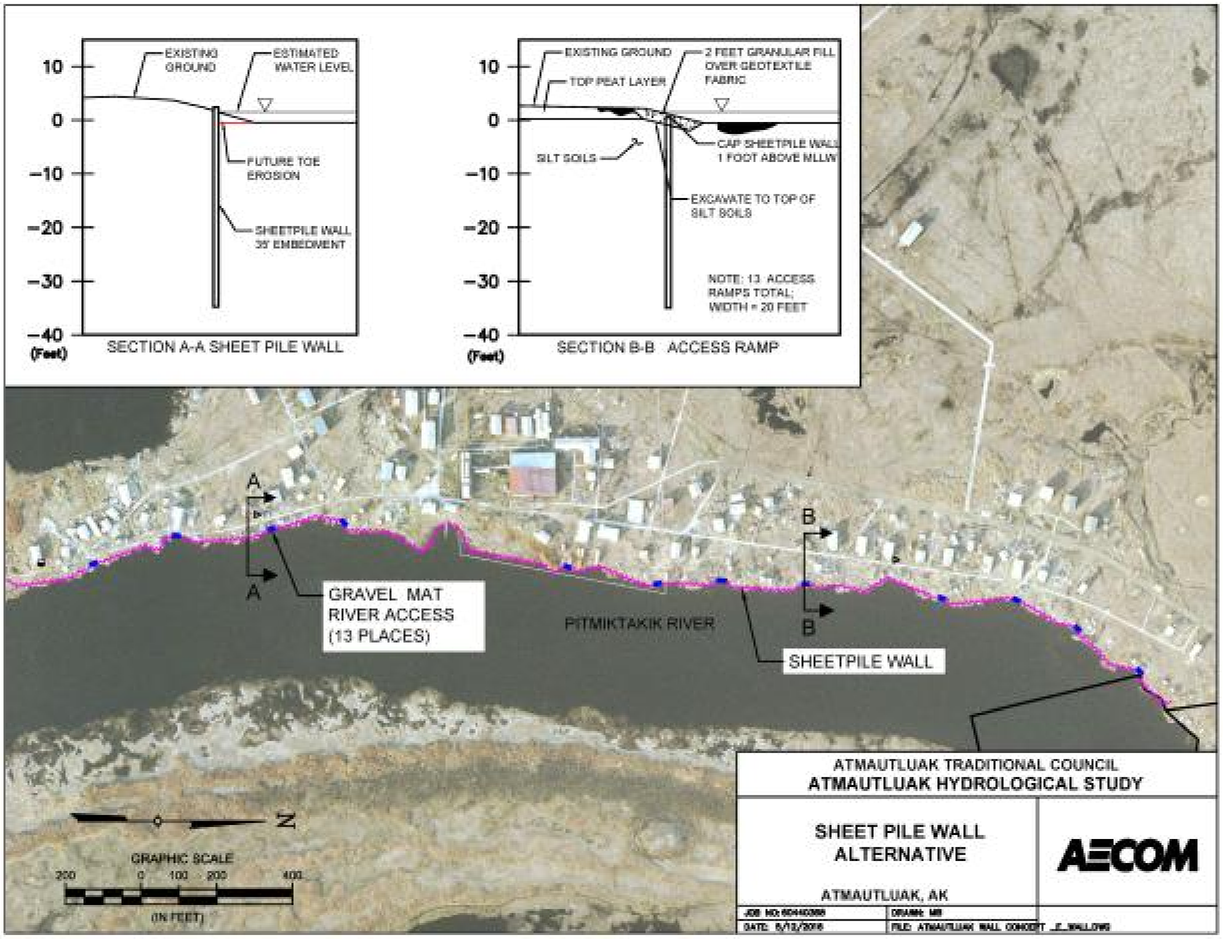

Figure 6: Sheet Pile Wall Alternative.

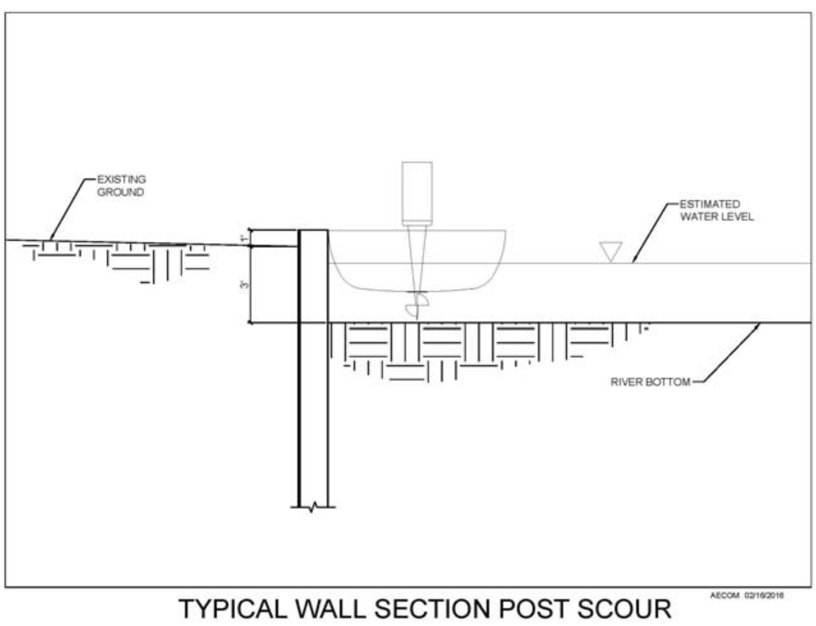

Figure 7: Sheet Pile Wall Section

8.2 Articulating Concrete Block Matting

Articulating Concrete Block (ACB) mats are made of concrete blocks linked together to form a hard-armored erosion-resistant mat, typically 8 feet wide by 24 feet long. ACB matting would be placed along the river bank (3060 linear feet) and at two places along the lake west of the community (470 linear feet). ACB would be an effective revetment for the relatively mild current conditions present in the Pitmiktakik River. Installation of the ACB revetment would require excavation and grading to achieve a uniform surface for placement of the mats, though the term “articulating” implies the ability of the system to conform to some changes in subgrade while remaining interlocked. A site-specific geotechnical investigation would be required to determine the strength of existing soils and their ability to support the weight of the ACB matting. Organic soils would first be removed and high strength geotextile fabric would be placed over the underlying silt soils for reinforcement. A layer of compacted granular fill material (one foot minimum thickness) would be placed over the geotextile fabric. The top of the revetment would be keyed into the bank by excavating a shallow termination trench and backfilling with native material to create a smooth transition from ground to the revetment. The voids in the ACB revetment above the high water line would then be filled with local organic soils and seeded to provide a vegetated bank. See Figure 8 for typical ACB revetment sections and Figure 10 for the plan view. This alternative has assumed that underlying soils are thawed due to proximity to the river, but this should be confirmed by geotechnical exploration prior to final design. If underlying permafrost is present then removal of the top organic layer could lead to thawing. In that case foam board insulation could be installed under the granular layer prior to placement of the ACB matting.

ACB matting installed to stabilize an adjacent riverbank at the nearby Nunapitchuk airport has held up well since it was installed in 2007. The ACB matting was installed along the Nunavakanukaksiak River, which has similar icing conditions to the Pitmiktakik River. AECOM made a site visit in April 2016 and found there was no noticeable settlement of the embankment slopes where ACB had been installed, or evidence of ice damage. Additional details and photographs of the ACB inspection are found in a trip report in Appendix C.

Scour Protection. The river thalweg (deepest portion of the channel) is located over 150 feet from shore and river bed slope is shallow (6%). Channel velocities on the Pitmiktakik River are relatively low, and the thalweg elevations upstream and downstream are fairly consistent, with no large scour holes detected at the surveyed cross-sections. A large thalweg shift is not likely to occur over a long period of time, but more likely to be initiated during a large event (flood or ice jam) when velocities are much higher than normal (See Appendix A). The toe of the revetment would extend 3 feet below the riverbed to prevent undermining due to general scour. If undermined during a large event, the ACB can rotate at the mudline to a 1.5:1 slope to a position 4 feet below river bed. Placement of a layer of imported coarse granular material (angular shot rock material) on top of the ACB would provide additional protection in the unlikely case a deep scour hole develops near the bank.

Cost Estimates. The cost to purchase and deliver the ACB matting to Atmautluak would cost over $2 million. Granular fill material would also need to be barged to Atmautuak. The closest quarry is located at Platinum, Alaska, approximately 140 miles to the southwest on the Bering Sea coast near the mouth of the Kuskokwim River. See Table 2 for a preliminary cost summary and Appendix F for a more detailed cost estimate.

ACB Advantages:

- Resistant to ice damage
- Low maintenance costs

- Can be re-vegetated for natural appearance.

ACB disadvantages:

- Cost is higher than Cellular confinement system (see below).

Table 2: ACB Matting Cost Estimate

Cost Estimate	ACB Matting
Construction Cost	$4.4 Million
Cost Per Foot	$1,260
Maintenance Cost **(Assume Major Repair Every 15 Years)**	$350,000

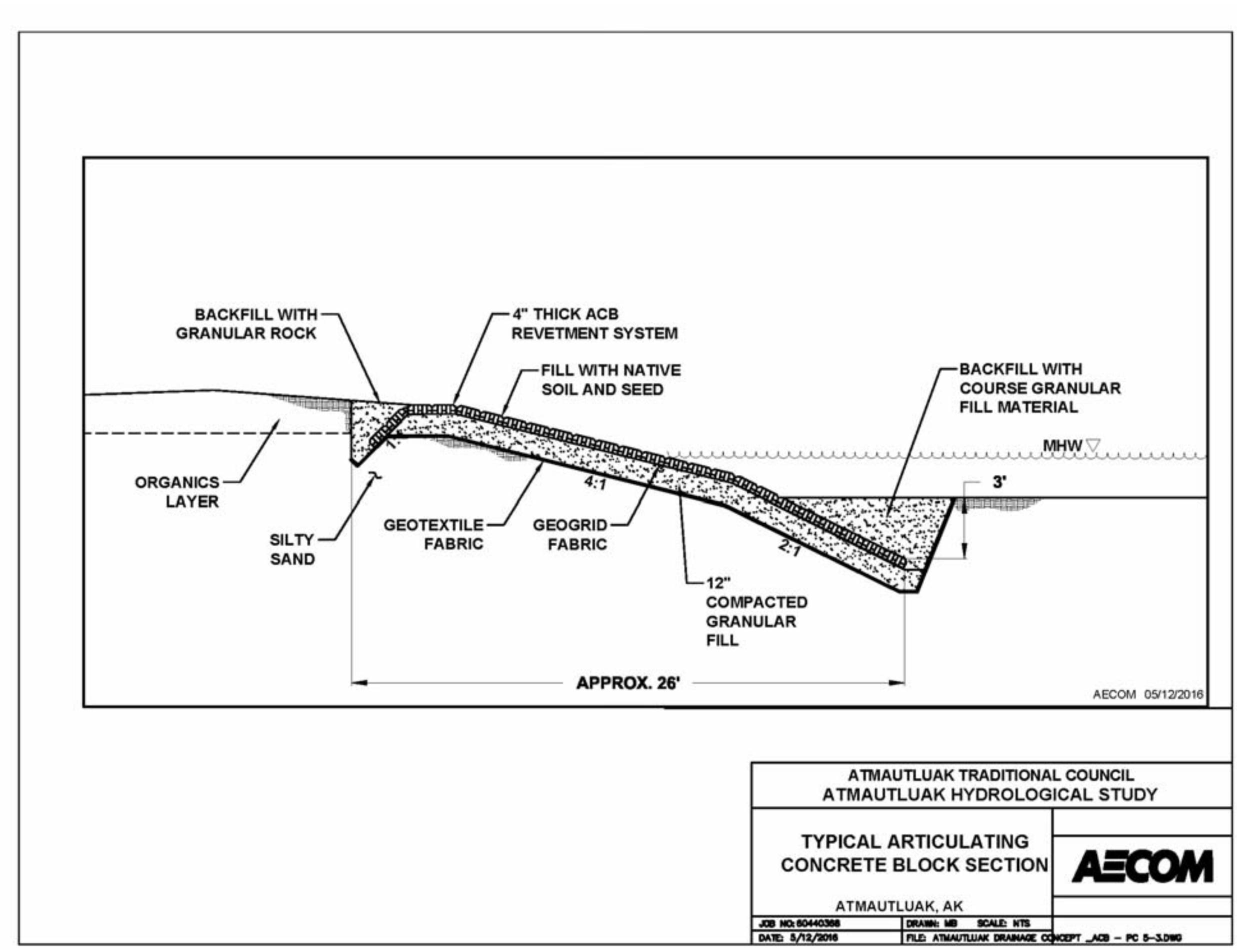

Figure 8: Articulating Concrete Block Section

Figure 9: Examples of ACB Installations. The right photo shows the revegetated ACB installation at Nunapitchuk.

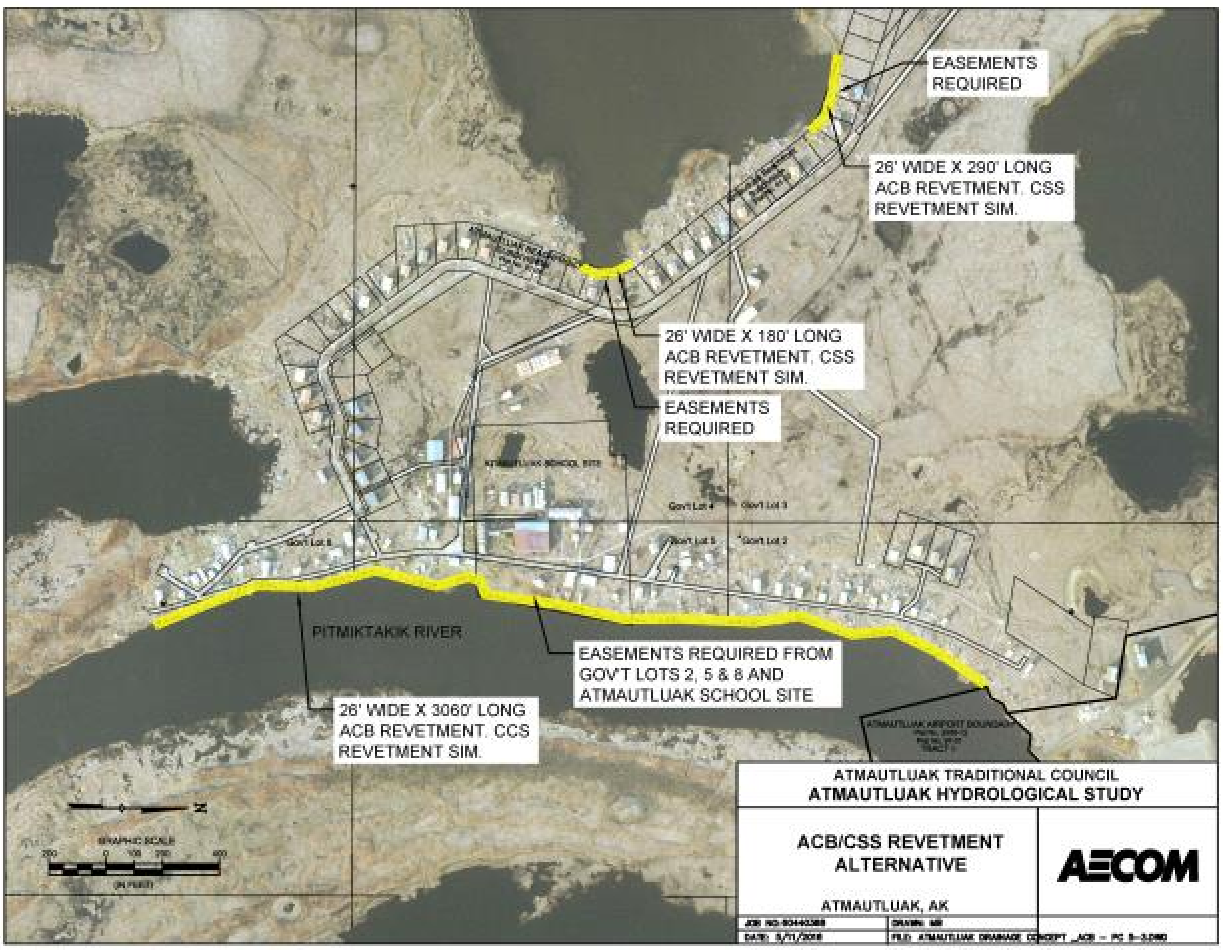

Figure 10: Articulating Concrete Block /Geo-Cell Plan

8.3 Cellular Confinement System (CCS) – Geoweb/Geocell

Cellular confinement systems (CCS) such as Geoweb or Geocell are soil stabilization products made of high density polyethylene (HDPE) strips that are fused together to form honeycomb type cells. We did not find examples of similar CSS systems used in Alaska river locations so the performance of the CSS system in river ice conditions is unknown. The CCS alternative would provide erosion revetment along the river front and at two lake locations similar to the ACB matting alternative. Construction of the CSS system would be similar to ACB matting. CCS systems are typically filled with soil and seeded to create a vegetated mat capable of resisting erosive forces from wind and wave action. A CCS revetment would be constructed in a similar fashion to the ACB revetment mentioned previously. The portion of the CCS above the high water line would be filled with native soils and seeded to create a vegetated bank. Since it would not be possible to establish a vegetated mat below the high water line, the CCS would be filled with concrete slurry in this area to protect the underlying soils from erosion. See Figure 10 for the plan view and Figure 11 for typical CCS sections. See Table 3 for a preliminary cost summary and Appendix F for a more detailed cost estimate.

CCS Advantages:

- Vegetated for natural appearance
- Low construction cost relative to other alternatives

ACB disadvantages:

- Susceptible to ice damage
- Higher maintenance cost and more frequent repairs than other options

Table 3: Cellular Confinement System Cost Estimate

Cost Estimate	Cellular Confinement System
Construction Cost	$2.0 Million
Cost Per Foot	$600
Maintenance Cost (Assume Every 15 Years)	$500,000

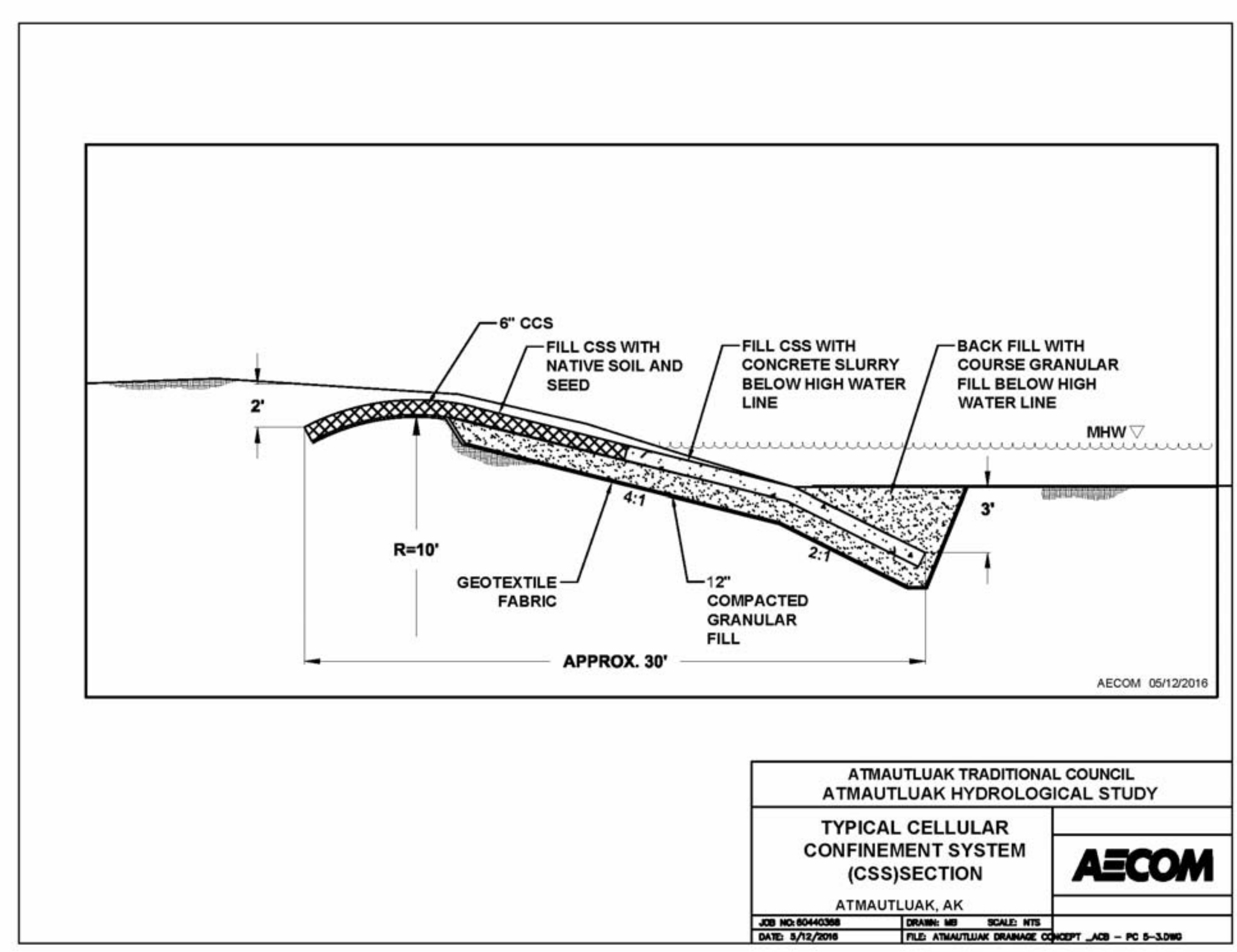

Figure 11: Cellular Confinement System (Geo-Cell) Section

Figure 12: Cellular Confinement System (Geo-Cell) Re-Vegetated

8.4 Construction Below Water

Construction of either the ACB or CCS bank protection methods would require diversion of the river away from the bank toe so that a toe trench can be excavated. A temporary cofferdam could be used to divert the river during construction. There are several rapidly deployed and easily dismantled bladder-type cofferdam systems on the market that could be used for this purpose, which would allow the excavation and installation of the ACB matting or CCS revetment to be completed in segments. See Figures 13 and 14.

Figure 13: Temporary Coffer Dam

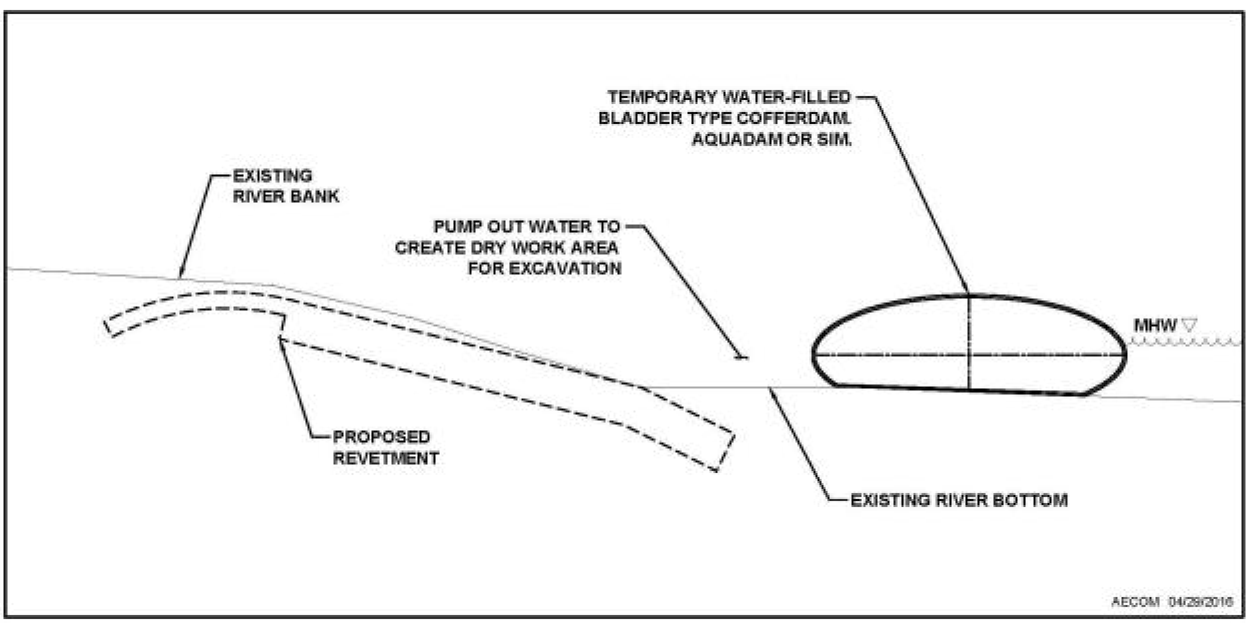

Figure 14: Temporary Coffer Dam Section

8.5 Recommended Bank Stability Alternatives

Articulating Concrete Block (ACB) matting is the recommend alternative for river bank and lake shore erosion protection. Alternatives were presented to the Atmautluak community on April 25th, 2016. The Traditional Council voted in favor of the ACB matting as the option for erosion protection along the river, from the south end of the community north to the airport and at two locations along the lake west of the community. The Council was not in favor of the Sheet Pile Wall alternative; there were concerns that the vertical face of the wall would be a safety hazard with snow machines in the winter. The Council was not in favor of the CCS alternative; there were concerns that when the water is high in the spring the ice could rip out the geo-cells. AECOM concurred that the performance of the CCS would likely be vulnerable to damage from ice and also from foot traffic.

8.6 Phased Construction

Installation of ACB matting should be done in phases in order to allow vegetation to establish. Areas where erosion is identified as a more immediate threat to homes and boardwalks could be done in the first phase. Completed ACB sections should be closed to foot traffic for a minimum of one summer season to allow grass roots to re-establish.

Funding and Bidding Strategy. The final design could divide the ACB revetment design into distinct sections that can be prioritized by the community in order of importance. The construction project can be advertised for bid with a base bid alternative and additional ‘additive alternatives’. With this approach the community can obtain funding for the base bid and add in additive alternatives as project the funding allows. Figure 15 shows suggested layout for a first phase project (2280 linear feet). These are areas where erosion appears to be a more immediate threat to property and boardwalks.

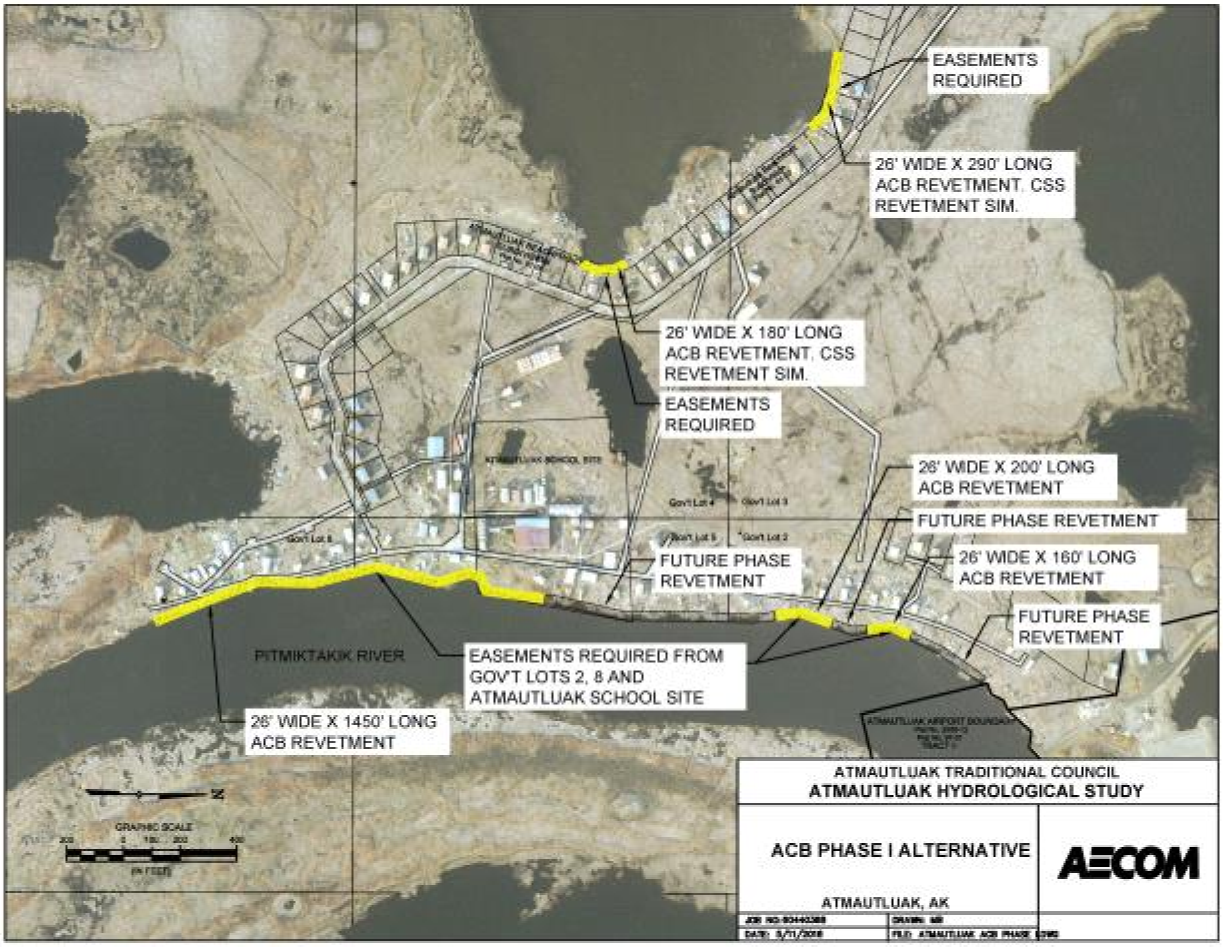

Figure 15: ACB Phased Construction

Table 4: Cost Estimate ACB Phase I Construction

Cost Estimate	ACB Phase I Construction
Construction Cost	$2.2 Million
Cost Per Foot	$1,540
Maintenance Cost (Assume Every 15 Years)	$200,000

8.7 Right of Way and Utilities

Easements would be required where the ACB revetment impacts residential lots, the Atmautluak School property, and Government Lots 2, 5, and 8. There are no known utility conflicts at present time.

9.0 COMMUNITY DRAINAGE PLAN

Insufficient drainage during high water periods is creating problems for the area to the north of Pig Lake. Due to construction of a road across the natural drainage path, the area does not drain well. The water surface elevation of Pig Lake has increased, leading to additional flooding and inundation of previously dry ground. The Traditional Council members said the ground in this area used to be higher and dryer. The resulting standing water may be contributing to permafrost thaw and causing noticeable ground settlement in the area. The pre-road drainage flowed to the lake north of the community, but now appears to be impounded in the circled area shown in Figure 16.

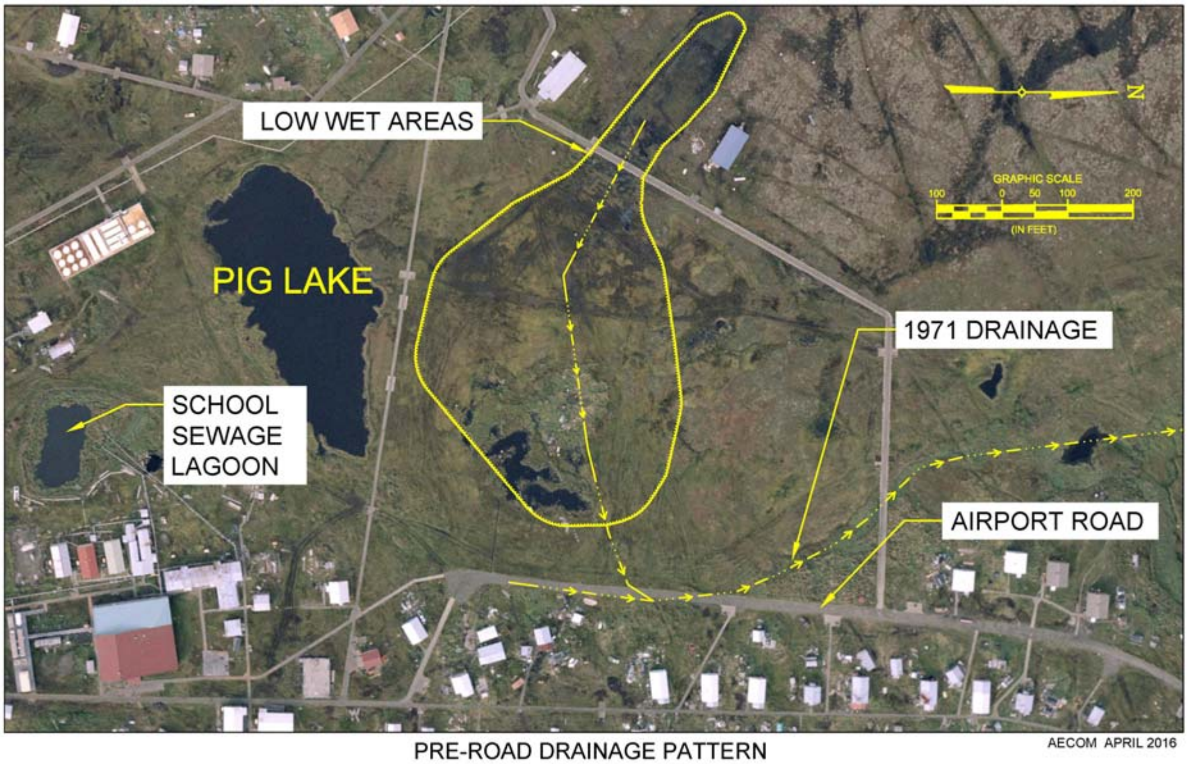

Figure 16: Pre-Road Drainage Pattern

9.1 Drainage Swales

A drainage plan was developed to lower the water level of Pig Lake and help drain the wet area to the north of Pig Lake. Ground elevations in AutoCAD Civil 3D were based on survey points from the August 2015 DOWL ground survey and the 2007 Digital Terrain Model developed for the Community Map (Community Map elevations are 8.03 feet lower than DOWL elevations, see Section 4.0). The drainage plan includes construction of a 1200 foot long drainage swale (D1) to carry water from Pig Lake, North, to low lying marsh land near the airport, then to the large lake north of the townsite (see Figure 1). The low lying marsh area is approximately 4 feet lower than the low wet area shown in Figure 16. An 800 foot long swale (D2) would be constructed starting near the church and draining to the East into swale D1. This will drain the wet low area to the southwest of the church. See Figure 17 for proposed drainage paths. The proposed swales have a "V" shaped cross section with shallow 4:1 Horizontal:Vertical side slopes to mitigate concerns of vegetation "bridging" the swale and effectively closing it off. The swales will have shallow grades of 0.2 percent to 0.3 percent due to flat topography; shallow grades will keep runoff velocity low, reducing the chance of erosion. The swales would ideally be constructed in the spring before the active layer thaws and the underlying soil becomes too soft to support heavy equipment. Drainage profiles and cross sections for swales D1 and D2 can be seen in Appendix D.

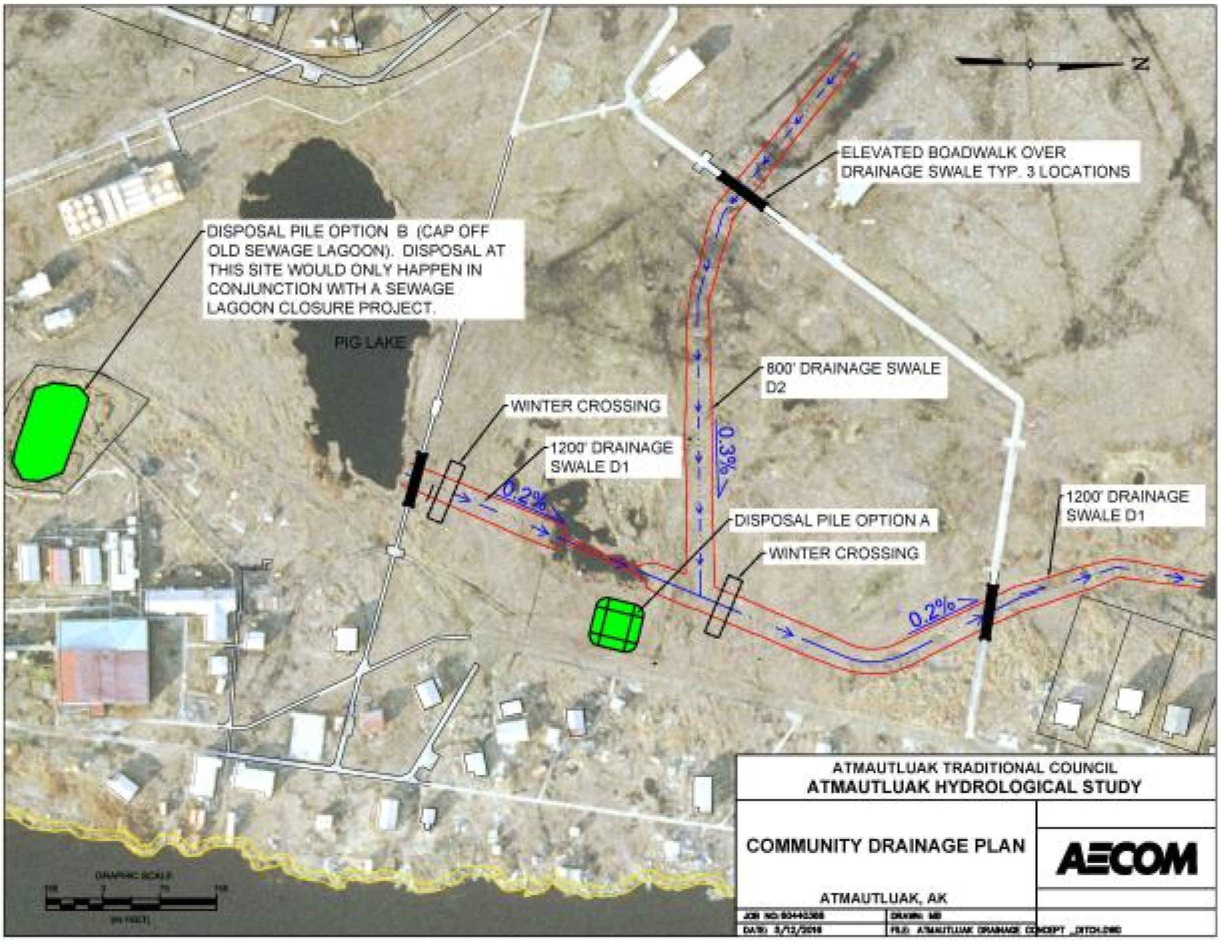

Figure 17: Community Drainage Plan

9.2 Permafrost Considerations

Boring logs show the top organic peat layer ranges from 1.5 to 5 feet deep, with an average depth of 2.5 feet deep (Shannon & Wilson 1993). This peat layer provides an insulating layer to help protect the underlying permafrost from summer heat. Peat has a higher thermal conductivity when frozen than when thawed. (McFadden and Bennet, 1991). This allows more heat to escape in the winter than is gained in the summer. The excavation of the drainage swales should be completed in three steps as shown in Figure 18:

- Careful excavation and stockpile of the peat materials (Section A)
- Complete the excavation of underlying silt layer (Section B)
- Careful placement of peat layer materials back into the swale in order to re-establish a minimum two foot thick insulating layer (Section C).

All disturbed areas would be re-seeded with native seed mix design. The exact effect of the new ditch on the thermal equilibrium of the underlying soil is hard to predict. The ditch bottom grade should be monitored for the first few years for either settlement or frost heaving, until the thermal equilibrium of the soil has been re-established. Settlement could result from consolidation of the peat layer or from thaw of the underlying permafrost. Conversely, with the removal of surface water, the depth of the active thaw layer could decrease, leading to formation of permafrost and localized heaving. Excess material stored in disposal piles could be used to re-grade the ditch (and re-seeded) as needed. Elimination of ponding is important because water has the potential to gain summer heat and lead to thawing of underlying permafrost and further settlement.

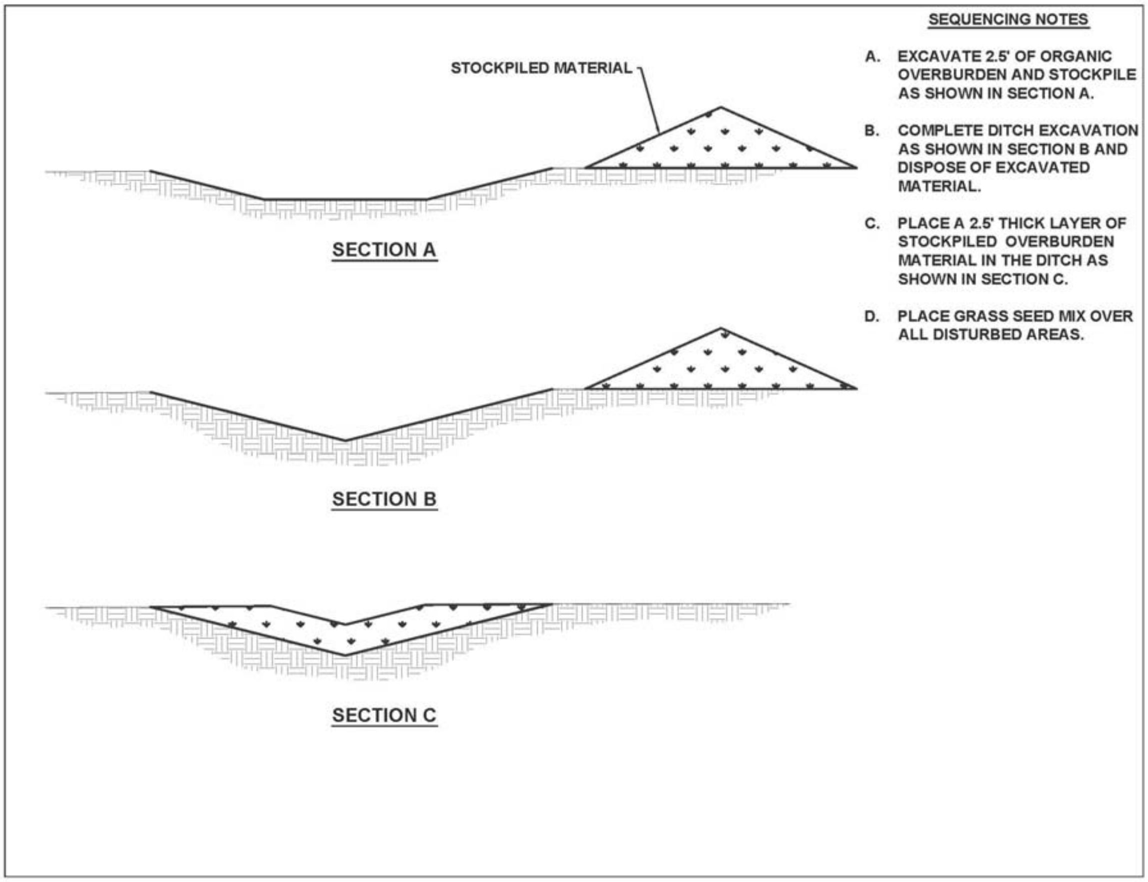

Figure 18: Ditch Excavation Sequence Plan

9.3 School Sewage Lagoon and Water Quality Concerns

The community is concerned with potential contamination from the school sewage lagoon that served the school prior to completion of a new sewage treatment system in 2012. Although the school lagoon is inactive and fenced off, the concern is that seasonal flooding could cause the lagoon to overflow and contaminate the surrounding tundra and water bodies. The fencing, as shown in Figure 19, is in disrepair and unable to keep intruders out. The Traditional Council expressed desire in the August 2015 community meeting to have the lagoon closed. A sewage lagoon closure would need to be completed in accordance with the State of Alaska Department of Environmental Conservations (ADEC) criteria and be coordinated with the Lower Kuskokwim School District. The ADEC sewage lagoon closure criteria document can be downloaded from the ADEC website at: https://dec.alaska.gov/eh/docs/sw/Sewage%20Lagoon%20Closure%20Guidance.pdf

Wastewater from the new sewage treatment plant is disinfected with ultraviolet radiation prior to its discharge into Pig Lake. The discharge into Pig Lake is permitted by an ADEC Discharge Permit. The discharge water is sampled and tested on a regular basis, with regular reports submitted to ADEC. During high water conditions, drainage from Pig Lake via the proposed drainage swale (D1) would not present water quality concerns to the surrounding areas and adjacent water bodies because strict EPA water quality standards are met at the outlet of the new sewage treatment plant discharge pipe (ADEC 2016). However, water quality in the old sewage lagoon is likely hazardous to human health, and overflow from the lagoon should be eliminated.

Figure 19: School District Old Sewage Lagoon

9.4 Silt Stockpiles

Construction of drainage swales would generate approximately 800 cubic yards of excess silt material that could be stockpiled for future use. A second option would be to use the excess material to cap the inactive school sewage lagoon. This option would need to be coordinated with the Lower Kuskokwim School District and could only be implemented after decommissioning of the sewage lagoon was completed and approved by ADEC. If this option is pursued, a survey of the lagoon should be done prior to construction in order to determine the volume of fill material that would be required to cap the lagoon. The final cap over the lagoon must be higher than the surrounding tundra to allow surface water to drain away in all directions. It will be critical to determine if the excess drainage swale material is sufficient for the lagoon closure project prior to construction or if additional material would need to be imported. Some excess material (20 to 30 cubic yards) should be retained to re-grade the ditch, as needed over time, as discussed in Section 9.2.

9.5 Winter Crossing Locations

The Atmautluak Traditional Council commented during the April 25th 2016 Community Meeting that winter travel routes would traverse the proposed swale alignment. Two winter crossings for vehicle traffic were added to the swale design. Shallower swale slopes (8 Horizontal:1Vertical) were incorporated at two locations: one just north of Pig Lake and the second about 500 feet north of Pig Lake near where a public right-of-way corridor is located between the river and the gravel road (see Figure 17). The crossings should be marked with reflective delineators, four for each crossing. Carsonite flexible delineators, with reflectors, are recommended (Figure 21). The delineators can be driven into the tundra during summer and remain throughout the year.

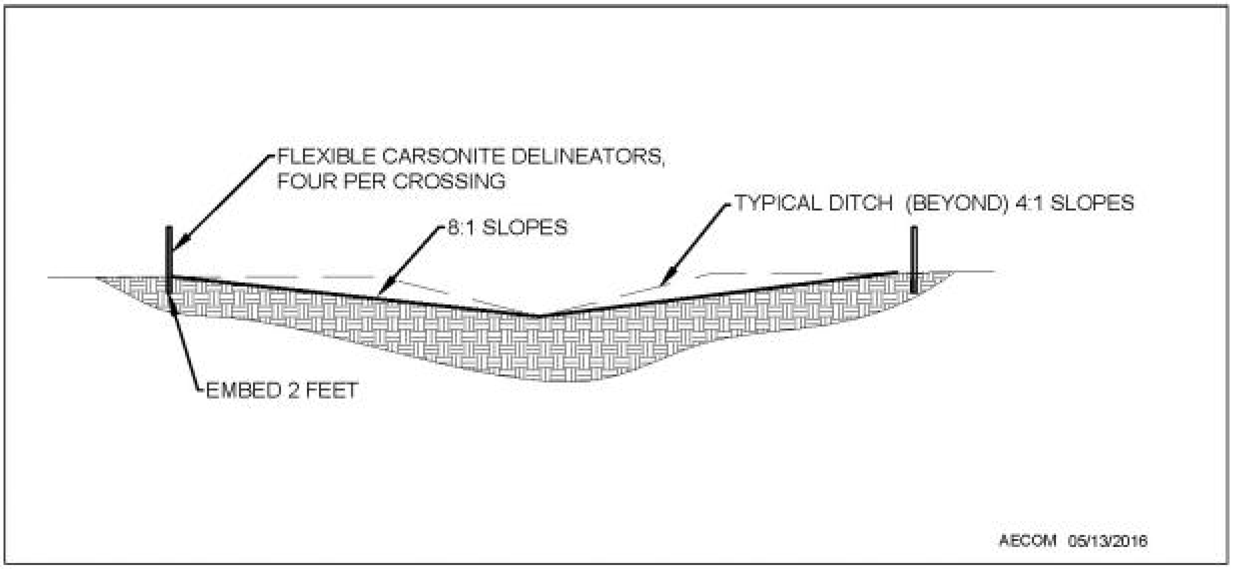

Figure 20: Winter Crossing Profile View

Figure 21: Carsonite Flexible Delineators

9.6 Construction Cost Estimate

Table 5: Drainage Swale Cost Estimate

Drainage Plan Cost Summary				
1200' Ditch D1	**(2) Elevated Boardwalks over D1**	**800' Ditch D2**	**Elevated boardwalk over D2**	**Total Drainage Ditch Cost**
$235,000	$60,000	$160,000	$30,000	$490,000

10.0 PERMITTING

This section provides an overview of permitting requirements for the proposed ACB matting and community drainage projects discussed in previous sections. A more detailed description of permitting requirements is included in Appendix E.

10.1 USACE Department of the Army Permit

U.S. Army Corps of Engineers (USACE) Department of the Army (DOA) Permits would be required for construction of a community drainage project in Atmautluak and a bank erosion project (ACB matting) along the Pitmiktakik River.

The USACE issues permits under the following authorities: 1) Section 404 of the Clean Water Act, which covers the discharge of dredged or fill material into waters of the U.S., including wetlands and 2) Section 10 of the Rivers and Harbors Act of 1899, which covers work in or affecting navigable water of the United States. Based on aerial photo review the area of the community drainage project appears to be comprised of freshwater wetlands. Because there is no wetland mapping available for the project area, the USACE may require delineation by a wetlands professional to confirm the presence of wetlands and determine the wetlands boundary.

There are two primary types of DOA permits, 1) Nationwide Permit and 2) Individual Permit. The proposed project activities do not appear to fall under any of the 2012 Nationwide Permits available in Alaska; the limits of a Nationwide permit are for projects with no more than 500' of disturbance along the bank below the ordinary high water mark and no more than one cubic yard of fill material per foot of revetment; the proposed ACB matting project would not meet these requirements therefore, an Individual Permit would be required. A summary of the 2012 Nationwide Permits can be found at:

http://www.poa.usace.army.mil/Portals/34/docs/regulatory/Summary_Table_2012%20NWPs_14%20Feb%202012.pdf

As the lead Federal permitting agency, the USACE would contact other agencies to determine if the proposed project will have adverse effects on the environment. USACE would:

- Consult with U.S. Fish & Wildlife Service and National Marine Fisheries Service concerning potential Threatened &Endangered species and Critical Habitat
- Consult with National Marine Fisheries Service for an Essential Fish Habitat Assessment

- Coordinate the DOA application with the ADEC to obtain a State Water Quality Certification
- Consult with the State Historic Preservation Office (SHPO) for the presence or absence of historic properties.

Additional permits would include:

- Alaska Department of Fish and Game Fish Habitat Permit (FHP)
- Alaska Pollutant Discharge Elimination System (APDES) Construction General Permit

Any work below the ordinary high water mark of the Pikmiktakik River associated with the bank erosion project would require a FHP. FHPs generally take 30 to 60 days to process. As part of the APDES General Permit, a permittee must prepare a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP documents the selection, design, installation, and implementation of control measures to minimize pollutant discharges as required by law. The construction contractor would be responsible for preparation of the SWPPP and for obtaining coverage under the APDES General Permit, just prior to construction, as part of the construction contract.

Permitting of chosen alternatives would occur after the final designs are in advanced stages and prior to construction. Other permits in addition to the ones listed above could be required once the scope of the project is fully defined. A more detailed description of permit requirements is included in Appendix E.

10.2 National Environmental Policy Act

The National Environmental Policy Act (NEPA) of 1969 requires that prospective impacts of projects be understood and disclosed prior to a Federal agency issuing a permit or providing funding for a project. If USACE can determine that the environmental impacts from the project fall in a category of actions which do not have a significant effect on the environment, then neither an Environmental Assessment (EA) nor an Environmental Impact Statement (EIS) would be required. If the significance of environmental impacts from the proposed action is not clearly established and the activities do not fall under a list of categorically excluded actions from NEPA, the USACE as the lead permitting agency, would need to prepare an EA and may require the applicant to provide appropriate information necessary for the preparation of the EA. The purpose of the EA is to determine if the project will cause significant effects. If the EA concludes that no significant impacts will occur, a Finding of No Significant Impact is prepared and is used to support USACE’s permit decision. In the unlikely event that the EA for the proposed activity identifies significant impacts, an EIS would be required. Preliminary discussions with USACE in 2016 indicate that a small EA would probably be required for a river bank erosion revetment project (ACB matting) or a community drainage project.

10.3 Permitting for a Bank Stabilization Project and Community Drainage Project

As discussed above, a project for bank stabilization (ACB matting) would require a DOA Section 10 permit from USACE. A community drainage project for the purpose of reducing standing water in the community would require a Section 404 DOA permit from USACE. Federal agencies are reluctant to issue a permit that would in some way alter or modify wetlands unless a compelling case is made that the proposed project is the least environmentally damaging practicable alternative.

A purpose and need statement that would accompany a DOA permit application would need to make a case that the proposed project is needed. The need for a bank stabilization project is obvious, to preserve threatened land and property in the community. In the case of the community drainage plan, underlying soils in Atmautluak are within one degree of thawing (Shannon & Wilson 1993). The case could be made in Atmautuluak that removal of standing water is needed because it could potentially slow down or stop permafrost degradation in the center of the community. Degradation of permafrost could result in continuing ground settlement, leading to more surface flooding and even more permafrost degradation. The case also could be made that the road from the airport has blocked the natural drainage and resulted in the impoundment of water. A community drainage project would restore the natural drainage. If the purpose and need statement can demonstrate positive environmental impacts (potentially mitigating permafrost degradation) then compensatory mitigation may not be required.

11.0 REFERENCES

Alaska Department of Commerce, Community, and Economic Development (ADCED). 2009. Alaska Community Information Database Community Information Summaries. Accessed at http://commerce.state.ak.us/dnn/Portals/4/pub/Atmautluak_Final%20Report.pdf.

Alaska Department of Environmental Conservation (ADEC). 2010. Public source water executive summary: Available at: http://www.dec.state.ak.us/EH/dw/DWP/execsummary.aspx?PWSID=271033.001.

DOWL. 2015. Atmautluak Engineering Analysis, Atmautluak, Alaska. Surveying and mapping report. Prepared by DOWL, Anchorage, AK. DOWL HKM Project Number 1127.62038.01.

McFadden and Bennet. 1991. Construction in Cold Regions. Terry T. McFadden and F. Lawrence Bennet. Published by Wiley 1991.

Shannon & Wilson Inc. 1993. Geotechnical Services for Proposed Lift Station, Honey Bucket Lagoon, Sewage Lagoon and Sewage Pipeline. June 1993

State of Alaska Department of Public Works Division of Aviation. 1975. Construction Plans for Atmautluak Airport (1976 As Builts)

US Army Corps of Engineers (USACE). 2007. Erosion information paper - Atmautluak, Alaska. August 27, 2007. Alaska District Corps of Engineers Civil Works Branch.

WHPacific. 2010. Atmautluak hazard impact assessment June 2010. Prepared for the Atmautluak Traditional Council. Prepared by WHPacific with Shannon and Wilson Inc.

Appendix A:
Hydrology and Hydraulic Report

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Hydrologic and Hydraulic Report

for

Atmautluak Hydrologic Study

Prepared for:
Atmautluak Traditional Council
PO Box 6568
Atmautluak, AK 99559

And
AECOM Technical Services, Inc.
700 G Street, Suite 500
Anchorage, AK 99501

Prepared by:
Hydraulic Mapping and Modeling
1091 West Chena Hills Drive
Fairbanks, AK 99709

May 2016

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May 2016

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Project Location and Description

The Village of Atmautluak is located on the Pitmiktakik River 18 miles west of Bethel, 62 miles inland from Kuskokwim Bay and the Bering Sea (Figure 1). The community is located on the outside bend of the river. Atmautluak faces a number of hazard threats, including: 1) river bank erosion, 2) ground settlement due to permafrost, and 3) flooding. A Hazardous Mitigation Plan (HMP) was prepared by the Village of Atmautluak hazard mitigation planning team in 2013. Based on the hazard threats detailed in the HMP, the Atmautluak Traditional Council requires assistance with determining the most suitable combination of solutions to mitigate the three primary hazard threats listed above.

This report includes an analysis of the hydrologic characteristics of Atmautluak and the Pitmiktakik River, hydraulic analyses of bank erosion and ice jam scenarios, and a review of several erosion protection methods.

Hydrology

Atmautluak is located in a maritime climate, approximately 65 miles from Kuskokwim Bay on the Bering Sea coast. The coast is bordered by sea ice in the winter, and the surrounding coastal area is treeless and dotted with numerous small lakes. Although the mean annual temperatures are similar to inland sites at the same latitudes, the seasonal range of temperatures is much lower and the winds are much higher. Annual precipitation at Atmautluak averages 22 inches, with 43 inches of snowfall annually. Summer temperatures range from 41 to 57 °F, and winter temperatures average 6 to 24 °F (ADCED, 2009).

The Pitmiktakik River (also spelled Pikmiktalik) is a meandering stream that originates about 60 miles northeast of Atmautluak in a flat tundra and lakes complex area. Atmautluak is located on an actively eroding bend of the river. The area around Atmautluak is flat and poorly drained with numerous lakes and small drainages that flow into the Pitmiktakik River (ADCED, 2015).

The channel is tidally influenced. On the rising (flood) tide, flow comes up the Kuskokwim River to the Johnson River, before entering the Pitmiktakik River channel adjacent to Atmautluak. Following high tide, the ebb tide flows out the Pitmiktakik River to the Johnson and Kuskokwim Rivers, ultimately to Kuskokwim Bay and the Bering Sea.

Typical of most areas in Alaska, there are no long-term gaging records available for the Pitmiktakik River. As noted in WHPacific (2010), historic river discharge data in the Kuskokwim River delta is very limited and generally unsuited for assessing long-term trends.

Flooding in the Atmautluak area could be caused by several sources, including: runoff from precipitation events, storm surge (high incoming tide) and ice jam floods. Since no gaging information exists for any nearby streams, precipitation-related flood magnitude estimations were developed using USGS regression equations for estimating the magnitude of peak streamflows in Alaska.

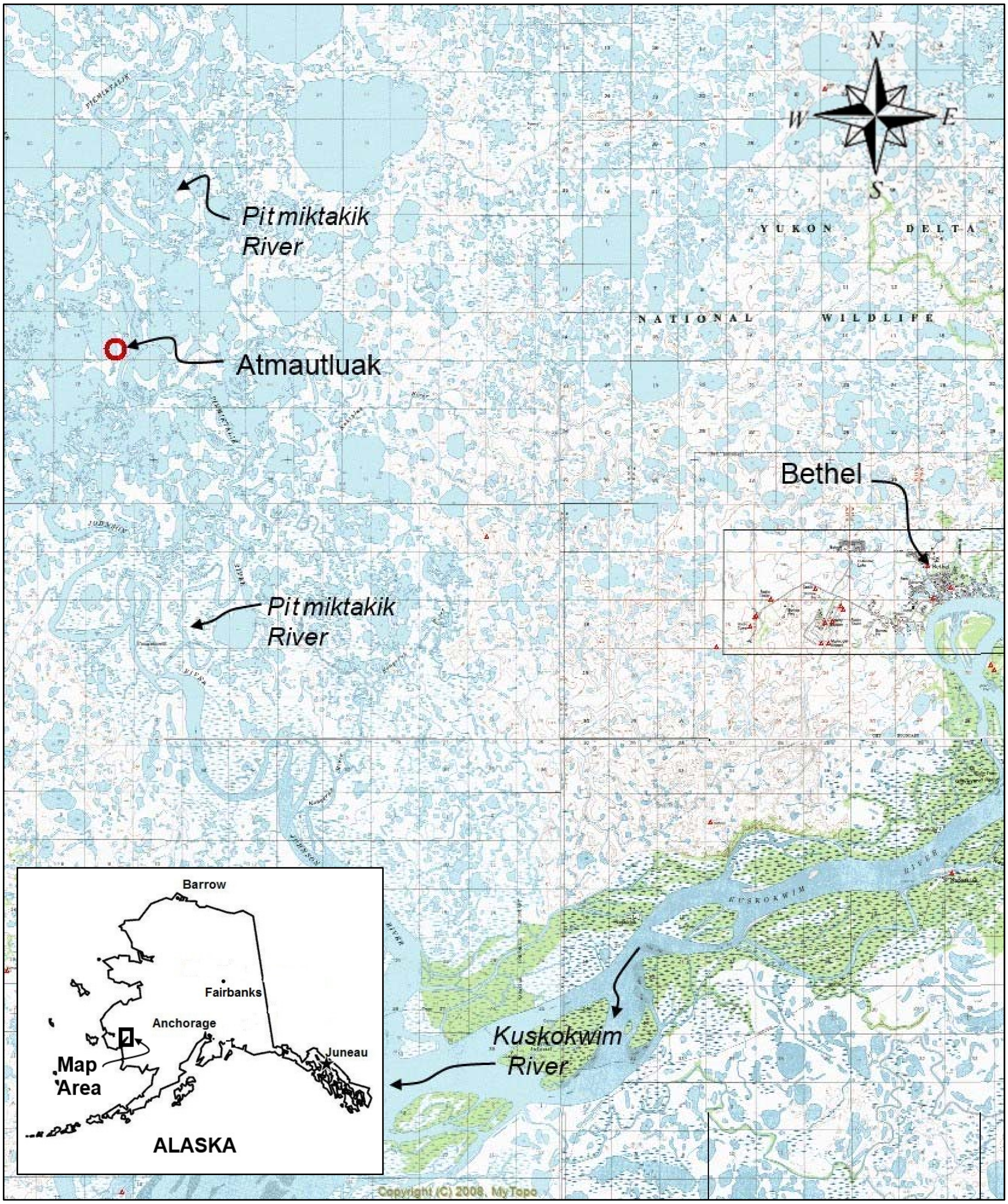


Figure 1. Project location map.

The latest USGS regression method for estimating peak streamflows at ungaged locations is described in the USGS Water Resources Investigations Report 03-4188 (Curran et al., 2003). Basin characteristic information is used in the USGS regression analysis. For Region 6, the characteristics include:

- drainage area upstream from the site,
- percentage of lakes and ponds area,
- percentage of forest areas.

Drainage basin area was obtained from the USGS Watershed Boundary Dataset (USGS, 2015). Other basin characteristics were obtained by planimetric techniques used with USGS 1:63360 quad maps. Due to flat terrain and the ubiquitous presence of lakes, ponds and wetlands, the planimetered basin characteristics in Table 1 should be considered as an approximation.

Table 1. Watershed characteristics.

	Pitmiktakik River Watershed
Drainage Area (mi^2)	671.5
Area of Lakes and Ponds (%)	50
Area of Forests (%)	0

The range of the 'lakes and ponds area' variable used to develop the regression equations for Streamflow Analysis Region 6 is 0 to15 %. The percentage of the 'lakes and ponds' areas for the Pitmiktakik River watershed is significantly larger than the high end of the range. Lakes and ponds act as temporary storage areas during floods, and tend to dampen peak flood magnitudes. Therefore, the peak flood magnitudes for a given recurrence interval in this watershed may be smaller than predicted by the regression equations.

For flooding caused by precipitation events, the estimated magnitudes for the 2-year flood through the 100-year flood for the Pitmiktakik River watershed are shown in Table 2. The adequacy of the regression equations can be evaluated by several measures. Confidence limits provide a measure of the error in a particular prediction. The 5% and 95% confidence limits provide a 90% prediction interval for a particular site. Because this watershed is ungaged, has limited historic hydraulic information, and has boundaries that are difficult to delineate, the lower and upper confidence limits were calculated and included in Table 2. Due to reasons described above and detailed in an analysis later, actual flood magnitudes may be closer to the lower end of the 90% prediction interval. Values should be used with caution.

Table 2. Flood discharges based on precipitation events.

Flood Recurrence Interval	Pitmiktakik River (cfs)	Confidence Limits 5%	Confidence Limits 95%
2-year	6170	2920	13000
5-year	7920	3670	17100
10-year	9040	4010	20400
25-year	10400	4320	25100
50-year	11400	4480	29000
100-year	12400	4590	33200

Bank Erosion at Atmautluak

According to an analysis of erosion by the US Army Corps of Engineers (USACE), erosion is affecting the bank of the Pitmiktakik River along the entire length of the community at Atmautluak (USACE, 2007). A comparison of aerial photographs from 1971 and 2007 shows the bank has eroded on average about 47 feet over 36 years, or about 1.3 feet per year. The 2010 WH Pacific study showed a similar erosion rate over a 32-year period of 1.3 feet per year. During a field visit in August 2015, villagers reported that material sloughing from the bank at Atmautluak was filling in the adjacent near-bank channel, making boat launching conditions difficult or impossible at some water levels. The USACE report attributes the erosion to several causes, including natural river flow, spring breakup, melting permafrost, boat wakes, and ice jams. Various methods of erosion are likely contributing to the high rate of erosion, and are discussed below.

Shear Stress and Pore-Water Pressure

Erosion of the bank and bank toe can occur when a soil block fails because of excessive shear stress. When the hydraulic shear stress in a channel exceeds some threshold above the critical shear stress, or magnitude of shear stress required to move a given particle, then those particles are mobilized and bank/toe erosion is initiated.

Additionally, positive pore-water pressure can lead directly to streambank erosion and instability. In addition to increasing the weight of the bank, pore-water pressure reduces the effective friction (normal stress) between soil particles, thereby weakening the soil and allowing particles to be dislodged. Bank erosion from positive pore water pressure is commonly attributed to areas with shallow water tables and non-cohesive bank materials such as gravels and sand. However, a literature review found papers that focus on the importance of accounting for positive and negative pore-water pressures of unsaturated cohesive materials when considering stream stability, bank erosion, and channel widening. Simon and Collison (2001) note that pore-water pressure within cohesive riverbeds will increase during the rising limb of a flood hydrograph (or tidal inflow). If the water level falls rapidly on the receding limb, bed pore-water pressure will also fall, though the impermeability of the soil delays pressure equalization. As a result, upward-directed seepage occurs to eliminate the pressure differential, and leads to rupture and erosion of the streambed, or to partial liquefaction of the upper part of the bed

Similarities between the Simon and Collison study sites and the Pitmiktakik River bank erosion at Atmautluak include the soil type (silt) and the large rapid variation in the tidal elevations, which occurs approximately every 6 hours. For example, Bethel, Alaska is located on the Kuskokwim River approximately 19 miles upstream of its confluence with the Johnson River. Tidal changes of 2 to 4 feet occur twice a day there. Atmautluak is located approximately 26 miles upstream of the Johnson/Kuskokwim River confluence. Residents report that the typical daily tidal variation is approximately 2 feet.

Ice

River ice can contribute to riverbank erosion in several ways. Freeze-thaw cycling and the formation of ice in riverbanks disrupt bank soil structure, which reduces soil strength. This often results in in-situ bank sediment being dislodged and moved downslope via gravity. Additionally, there are several types of ice movements that can remove and transport in-situ bank soils and accumulated sediments, including: 1) ice retreat from the bank that results in plucking and rafting of material frozen into and lying on the ice, 2) ice thrust into the bank that disrupts the sediments and soils, and 3) ice shear parallel to the bank that abrades and gouges the bank (Gatto, 1993). The USACE (2007) notes that in the last 10 years, three to four ice jams have caused 1 to 2 feet of erosion per event.

Thermal Degradation

Changing thermal conditions may be responsible for melting permafrost and subsequent bank erosion. Reports documenting the effects of coastal shore erosion from warming or melting permafrost, and thermokarsting (thawing process associated with disturbance of the surface thermal regime in areas of ice-rich permafrost) are readily available. Researchers have noted thermally induced erosion of areas with high ground ice content, including hillslopes and river channels (Rowland et al., 2010).

The University of Alaska Geophysical Institute Permafrost Lab (GIPL) has developed a model specifically to assess the effect of a changing climate on permafrost. The GIPL model calculates the active layer thickness and mean annual ground temperature (Romanovsky and Marchenko, 2015). Changes to permafrost temperatures in Alaska for two time periods are found in Figure 2. The area of southwest Alaska in general, and the coastal ecosystems on the Yukon-Kuskokwim Delta in particular, are at high risk for increased soil temperatures and melting permafrost.

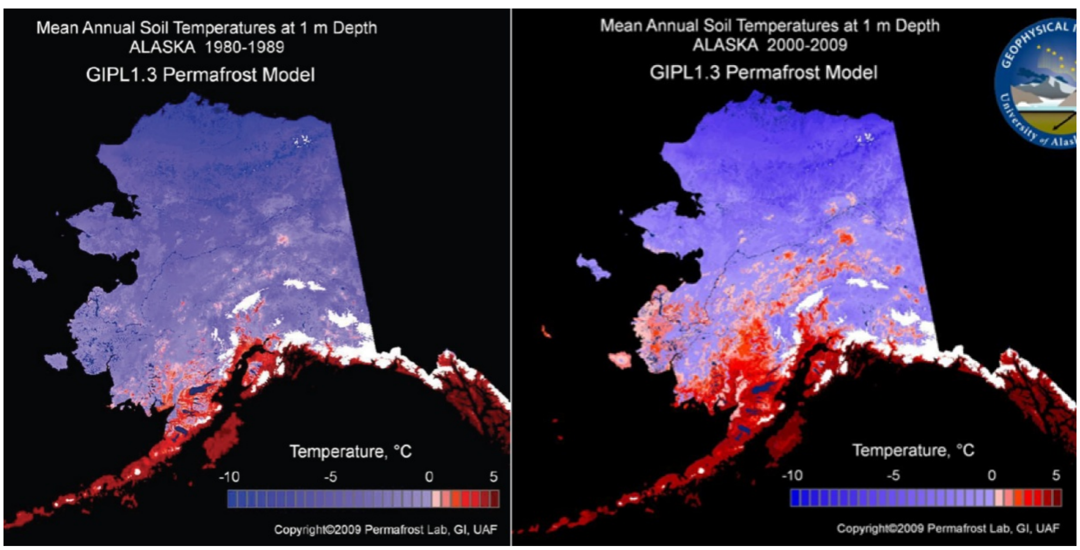


Figure 2. Change in ground temperatures. From UAF (2015).

Boat Wash

Water movements generated by boat motion and prop wash have long been recognized as a contributing factor to bank erosion. The Pitmiktakik River experiences regular small boat usage, though the average daily boat traffic on the river is unknown.

Hydraulic Analysis

An analysis was conducted to determine the hydraulic characteristics of the Pitmiktakik River channel at various flow levels. Parameters to be determined from the analysis include velocity, water surface elevation, shear stress, and others. These hydraulic characteristics will be used to evaluate potential solutions for the bank erosion problem at Atmautluak.

Cross-section geometry is used to create a numerical model of the channel for use in a hydraulic analysis, generally conducted with a computer software program. Cross-sections are located at intervals along a channel to characterize the flow carrying capability of the stream and its adjacent floodplain. Cross-section spacing is determined by balancing the improvements in accuracy (more cross-sections) with the additional costs of collecting such field data.

Cross-sections on the Pitmiktakik River channel were surveyed for this project in August 2015. Cross-sections are spatially located by river stationing; stationing begins at 0 (zero) feet at the downstream end, which is about 4500 feet downstream from the village of Atmautluak. Nine cross-sections, labeled from River Station 0 (units of feet) (downstream) to 25374 (upstream) were used in the model. See Figure 3.

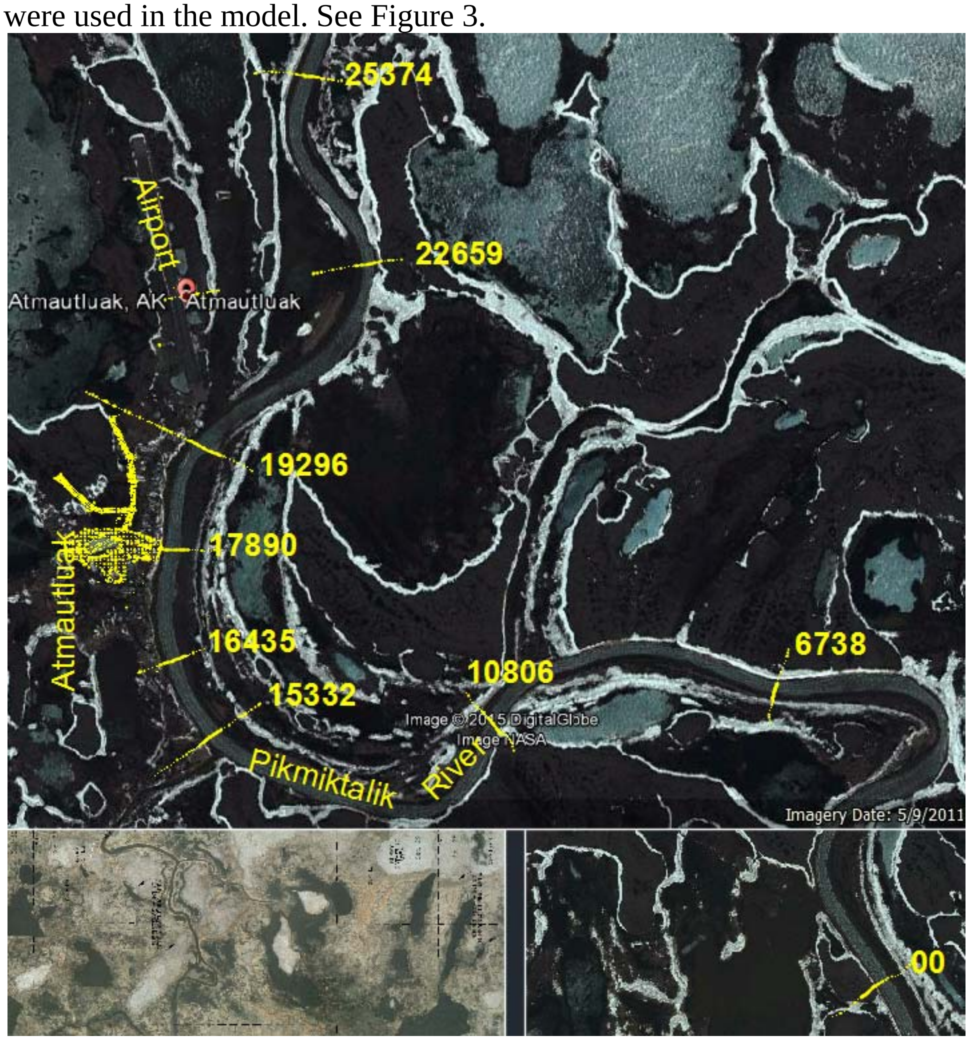


Figure 3. Surveyed cross-sections used for HEC-RAS analysis.

The cross-sections were surveyed using a combination of methods (DOWL, 2015). In addition to using an RTK GPS total station for upland and shallow water survey measurements, a SONTEK M9 Acoustic Doppler Profiler was used for the hydrographic survey. The acoustic Doppler profiler supplied not only bed elevations along the cross-section lines, but estimates of discharge at each cross-section as well. A summary of the ADP measurements is found in Table 3. Note that four of the nine discharge measurements made by the ADP occurred during the rising (flood) tide cycle, when the direction of flow is upstream.

Table 3. Discharge measurements on the Pitmiktakik River.

Cross Section	River Station (ft)	Date Time of Measurement	Discharge (cfs)*	Average Velocity (ft/s)*	Maximum Velocity (ft/s)*	Maximum Depth (ft)
9	0	08/27/15 1742	-1644.4	-0.80	-6.78	13.2
8	6738	08/27/15 1723	-1260.8	-0.71	-6.25	12.2
7	10806	08/27/15 1658	-1303.5	-0.70	-3.82	10.9
6	15332	08/27/15 1627	-341.0	-0.21	-3.76	9.3
5	16435	08/27/15 1445	1555.3	0.93	5.90	9.3
4	17890	08/27/15 1413	1534.2	0.87	4.16	10.6
3	19296	08/27/15 1348	1414.9	0.54	5.79	10.6
2	22659	08/27/15 1340	1424.4	0.88	2.33	14.7
1	25374	08/27/15 1238	1368.7	0.76	4.42	11.5

*negative sign indicates flow is in the upstream direction.

The hydraulic analysis for the Pitmiktakik River consisted of modeling the flow characteristics using the U.S. Army Corps of Engineers Hydrologic Engineering Center water surface profiling computer program HEC-RAS version 4.1. The basic computational procedure for the HEC-RAS program is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion. The momentum equation is utilized in situations where the water surface profile is rapidly varied, such as at bridges (USACE, 1998).

Channel and floodplain roughness coefficients were determined by calibrating the model using the discharge measurement and surveyed water surface elevations made on August 27, 2015 and were based on engineering judgment and values found in Chow (1959), FHWA (1961), and FHWA (1996). Once the model is constructed and calibrated, estimations of channel velocities and stage were calculated for each cross-section for a range of selected flows.

In the HEC-RAS model, boundary conditions are necessary to establish the starting water surface at the ends of the river system. In a subcritical flow regime such as the Pitmiktakik River, boundary conditions are only necessary at the downstream end. For the HEC-RAS model, the normal slope, developed from surveyed water surface elevations, was used for the downstream boundary condition.

The HEC-RAS model was run at several discharges to provide hydraulic characteristics useful for the selection and design of appropriate bank erosion methods. In addition to modeling the measured discharge of 1424 cfs, the HEC-RAS model was also used to estimate the bankfull discharge (approximately 2100 cfs), and channel conditions during an ice jam. See Figure 4 for measured and estimated water surface profiles through the surveyed reach.

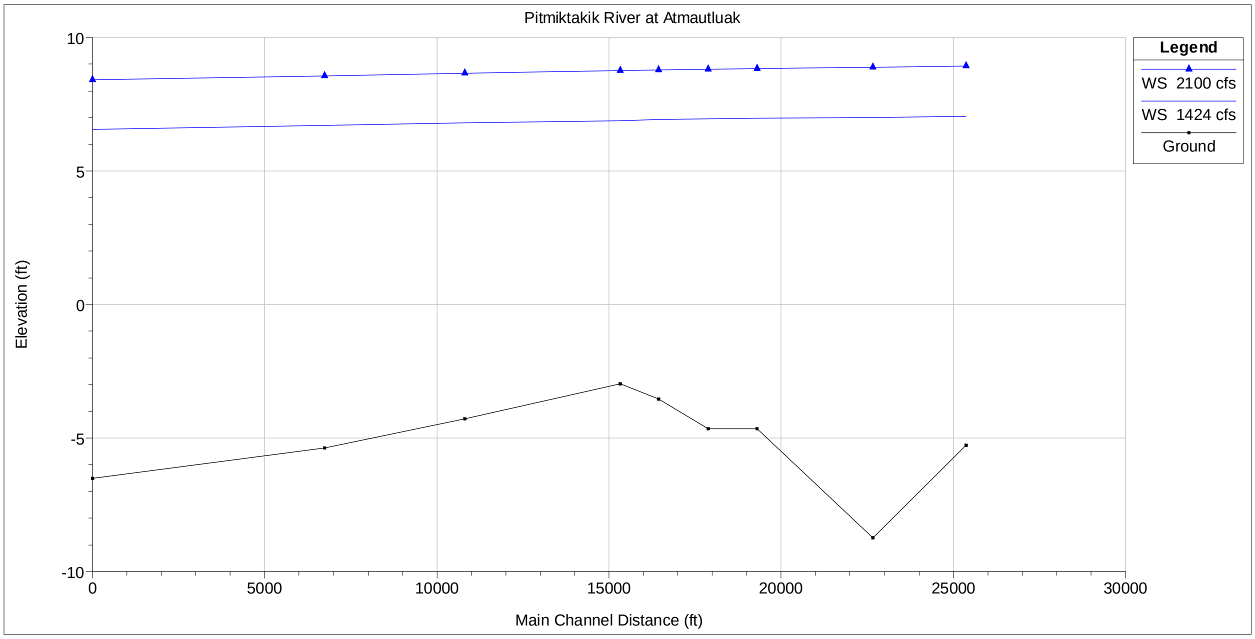


Figure 4. Water surface profiles from HEC-RAS analysis.

The surveyed cross-sections, with water surface elevations from the HEC-RAS results for 1420 cfs, are found in Appendix 1. Appendix 2 includes tabular results from the HEC-RAS analysis at 1420 cfs and 2100 cfs.

Bankfull Discharge

The recurrence interval for bankfull discharge has generally been considered to be 1.5 years (Leopold et al., 1964). In other studies, the average recurrence interval of the bankfull discharge ranged from 1.1 to 1.8 years (Rosgen, 1998). Note that the HEC-RAS analysis found the bankfull discharge of the Pitmiktakik River near Atmautluak to be approximately 2100 cfs, which is considerably smaller than the estimated 2-year discharge of 6170 cfs determined from the regression analysis and found in Table 2. This large discrepancy could indicate that the regression analysis used is inadequate for this watershed.

As noted earlier, the range of the 'lakes and ponds area' variable used to develop the regression equations for Streamflow Analysis Region 6 is zero to 15 percent; however, the percentage of the 'lakes and ponds' areas for the Pitmiktakik River watershed is significantly larger (approximately 50 percent). Lakes and ponds act as temporary storage areas during floods, and can dampen peak flood magnitudes. This would lead to flood magnitude predictions that are much larger than what actually occurs in the watershed. Actual flood magnitudes may be closer to the values in the lower end of the 90% prediction intervals. For example, the 5% confidence value for the 2-year flood is 2920 cfs, and appears to agree more closely with the estimated value of the bankfull discharge. However, note that this does not imply or suggest any relationship between the 'lakes and ponds area' variable used to derive the regression equations, and the range of values given by the 90% confidence intervals. Values should be used with caution.

Ice Cover and Ice Jam

Ice jams often occur at discharges much less than those associated with the annual peak; however, they often produce water levels much higher than the 5-year, 50-year, or even 100-year water levels. Ice jam-related water levels can result in backwater and flooding in certain conditions.

The presence of winter ice changes the geometry of a river channel. By the nature of an ice cover on a river channel, the shear area of the water flow in the river is significantly increased. The wetted perimeter of the channel is essentially doubled; this effect increases the resistance to flow, which increases the depth of water flow. In most southcentral and southwestern areas of Alaska, ice covers are an annual occurrence. Ice jams, however, may or may not occur in any given year due to variations in the spring weather, strength of the ice cover, discharge, and other factors.

The WHPacific report notes that the Corps of Engineers attributes the 1972 flood of record in Atmautluak to ice jamming (WHPacific, 2010). In addition, the Corps of Engineers noted in a 2007 report that ‘in the last 10 years, three to four ice jams have caused 1 to 2 feet of erosion per event, according to local officials’ (USACE, 2007), though ice-jam flooding was not mentioned. However, the CRREL Ice Jam Database, which contains information on past ice jam events including dates, locations and damage levels, includes no information on ice jams for Atmautluak or the Pitmiktakik River. A second database of ice jams in the State of Alaska contains a database of unofficial river flooding and ice jam observations by pilots and others. Maintained by the Alaska-Pacific River Forecast Center, this National Weather Service web site also contained no information on ice jams for Atmautluak or the Pitmiktakik River. Additionally, the Atmautluak Traditional Council noted during two project meetings that flooding due to ice jams has not been an issue for the community.

HEC-RAS can simulate channels with ice covers of known thickness and roughness. It can also simulate wide river ice jams by adjusting the jam thickness and roughness until the ice jam force balance equation and the standard step backwater equation are satisfied. To analyze ice cover conditions and evaluate the effectiveness of erosion control measures on a river that experiences ice jams, the HEC-RAS hydraulic model of the Pitmiktakik River was used.

For the Pitmiktakik River, the HEC-RAS model was used to estimate water surface conditions and velocities on an ice-free channel, and changes to those conditions with an ice cover resulting from an ice jam. Though there is no calibration data for ice conditions on the Pitmiktakik River, conditions were assumed based on knowledge of ice jams elsewhere in Alaska.

To effectively analyze ice jams with the HEC-RAS model, reasonable values of discharge during ice jams are needed. There are no known winter discharge measurements on the Pitmiktakik River, so estimations of appropriate discharge values were based on knowledge of hydrologic regimes in Alaska. Streams in Southcentral Alaska typically have low discharge in winter. Nonglacial streams in the Yukon hydrologic region start to rise rapidly after breakup, and flow peaks in mid to late May, during breakup snowmelt. Breakup ice jams are generally initiated by seasonal increases in discharge that cause the existing ice cover to disintegrate and potentially reform (jam) at another location downstream.

The discharge that occurs during ice jams varies according to location and river. On the Tanana River near Salcha, discharge during ice jams is generally much less than the annual peak flow, which occurs later in the summer. Other reports note that ice jams in the Northeast United States generally require the 2-year discharge, while rivers in North Central Canada experience the annual peak discharge during spring breakup runoff.

With a daily tidal influence, winter discharge of the Pitmiktakik River will be higher than that of a non-tidal river in a similarly sized watershed. For the analysis, several discharge values that may represent late winter/early spring conditions just prior to and during breakup were selected. Modeled discharges include 1424 cfs (measured), and 2100 cfs (bankfull discharge).

Open Water (no ice cover)-The existing conditions model described earlier was used to model the open water example. Modeled discharges include 1400 cfs and 2100 cfs. Results for the open water (winter discharge) model are found in Figures 5 and 7 (channel profile) and Figures 6 and 8 (Cross-section 17890 at Atmautluak).

Ice Jam-To analyze the potential impacts from an ice jam, an ice cover representing an ice jam was placed on the channel by modifying the geometry file. In general, ice jams form at a reach where the downstream transport capacity of ice is exceeded; typical reach conditions include downstream ice jams, channel slope changes, sharp bends, bridge piers, or other restrictions. This is usually due to surface obstructions, a downstream ice jam, bridge piers, width constrictions, or a significant change in bed slope. The jam was assumed to form at the sharp right-hand bend just downstream of cross-section 6738, where the ice thickness was set at 4 feet. This location was selected only to illustrate the possible hydraulic conditions; actual ice jams on the Pitmiktakik River may form at other locations. The ice jam is assumed to extend upriver to station 22659, where ice thickness was set at 2.0 feet. The other parameters, which describe the ice jam material properties, such as the friction angle, porosity, and stress ratio, were all left at their default values.

Results for the ice jam model are found in Figures 5 and 7 (channel profile) and Figures 6 and 8 (Cross-section 17890 at Atmautluak). Note that the ice jam results in an increase to the water surface elevation of 2.5 to 3 feet, depending on cross-section location. The model indicates that an ice jam can create overbank flow even at low discharge levels that would normally stay confined within the channel. See Table 4 for comparisons of water surface elevation and average velocity at each cross-section.

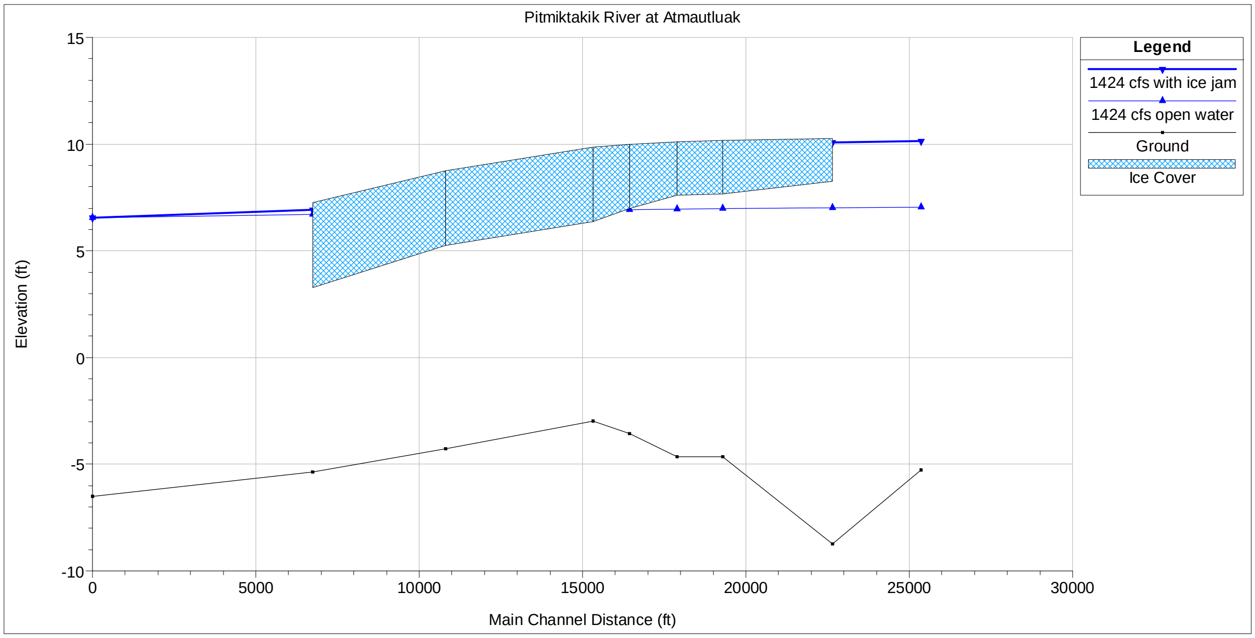


Figure 5. Water surface profile comparisons for Open Water and Ice Jam models at 1424 cfs. Flow downstream is from right to left.

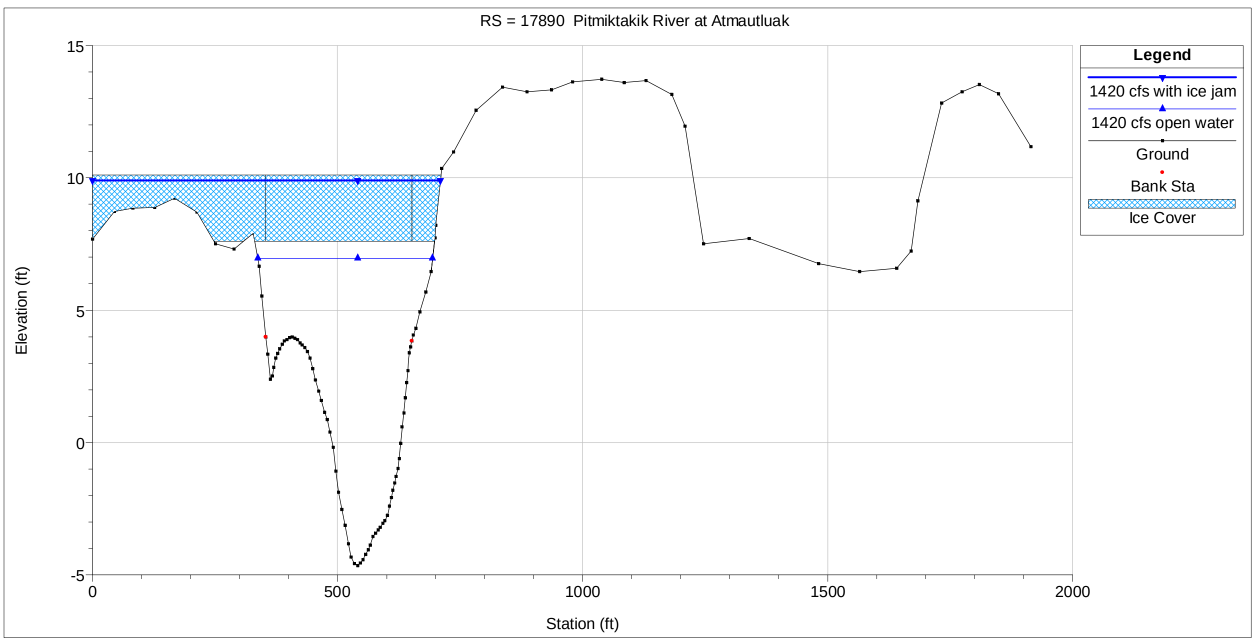


Figure 6. Water surface elevation comparisons at RS 17890 for Open Water and Ice Jam models. Cross-section is looking downstream (south).

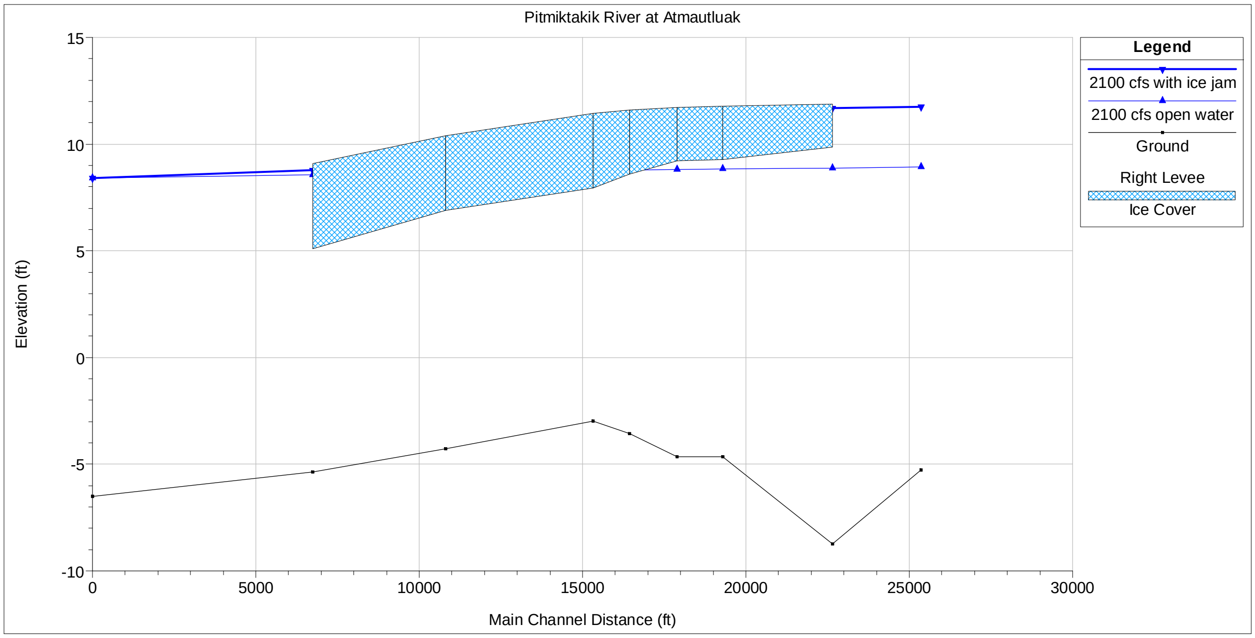


Figure 7. Water surface profile comparisons for Open Water and Ice Jam models at 2100 cfs. Flow is from right to left.

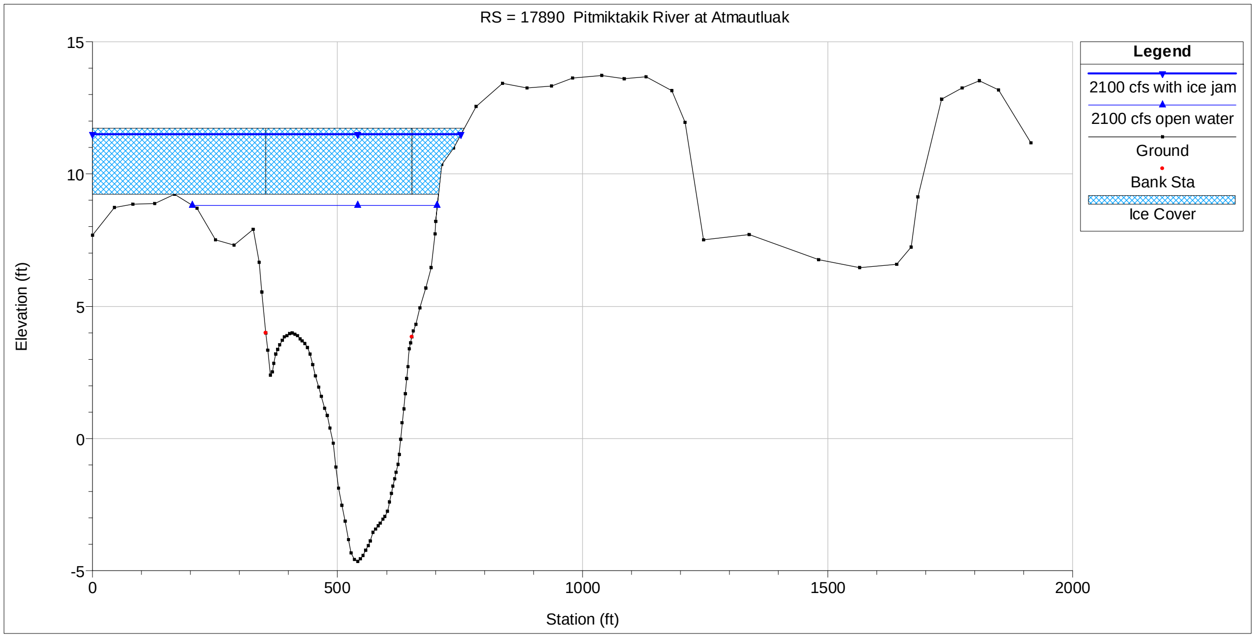


Figure 8. Water surface elevation comparisons at RS 17890 for Open Water and Ice Jam models at 2100 cfs. Cross-section is looking downstream (south).

Table 4. HEC-RAS comparison results of Open Water and Ice Jam models.

River Sta	Plan	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)
0	Ice Jam	1424	-6.51	6.57	0.71	2071.01	368.28
	Open Water	1424	-6.51	6.57	0.71	2071.01	368.28
	Ice Jam	2100	-6.51	8.41	0.83	2871.15	491.52
	Open Water	2100	-6.51	8.41	0.83	2871.15	491.52
6738	Ice Jam	1424	-5.37	6.93	1.38	1105.75	258.28
	Open Water	1424	-5.37	6.71	0.83	1793.83	271.81
	Ice Jam	2100	-5.37	8.77	1.45	1645.17	432.51
	Open Water	2100	-5.37	8.56	0.99	2331.4	326.75
10806	Ice Jam	1424	-4.28	8.46	0.91	1634.35	347.38
	Open Water	1424	-4.28	6.8	0.74	2196.15	381
	Ice Jam	2100	-4.28	10.11	1.05	2235.87	383.25
	Open Water	2100	-4.28	8.65	0.87	2977.9	701.05
15332	Ice Jam	1424	-2.98	9.56	0.93	1645.11	299.83
	Open Water	1424	-2.98	6.89	0.87	1807.62	506.08
	Ice Jam	2100	-2.98	11.15	1.05	2849.12	1244.55
	Open Water	2100	-2.98	8.76	1.02	2784.36	1619.4
16435	Ice Jam	1424	-3.55	9.75	0.76	2141.31	400.97
	Open Water	1424	-3.55	6.92	0.79	2109.9	412
	Ice Jam	2100	-3.55	11.34	0.9	3162.8	813.26
	Open Water	2100	-3.55	8.79	0.92	3145.92	826.37
17890	Ice Jam	1424	-4.66	9.89	0.63	2393.97	427.09
	Open Water	1424	-4.66	6.95	0.69	2147.42	562.66
	Ice Jam	2100	-4.66	11.51	0.74	3254.9	702.32
	Open Water	2100	-4.66	8.82	0.79	2963.74	1016.25
19296	Ice Jam	1424	-4.66	9.96	0.44	3388.7	624.53
	Open Water	1424	-4.66	6.97	0.48	3031.3	765.6
	Ice Jam	2100	-4.66	11.58	0.46	7747	2048.39
	Open Water	2100	-4.66	8.84	0.57	3887.3	1983.03
22659	Ice Jam	1424	-8.73	10.09	0.67	2732.54	895.54
	Open Water	1424	-8.73	7.01	0.8	1922.11	335.38
	Ice Jam	2100	-8.73	11.7	0.78	4180.63	902.34
	Open Water	2100	-8.73	8.88	0.96	2508.99	900.03
25374	Ice Jam	1424	-5.28	10.13	0.54	4834.97	1111.34
	Open Water	1424	-5.28	7.06	0.79	2052.26	343.22
	Ice Jam	2100	-5.28	11.75	0.65	6632.42	1113.93
	Open Water	2100	-5.28	8.94	0.94	2889.15	1108.09

Erosion by Shear Stresses

The USDA Bank Stability and Toe Erosion Model (BSTEM) was utilized to estimate erosion of the bank and bank toe by hydraulic shear stress. The model estimates boundary shear stress from channel geometry and considers critical shear stress and erodibility of two separate zones with potentially different materials: the bank and bank toe (USDA, 2012). The model accounts for the strength of up to five soil layers, and the effects of pore-water pressure, both positive and negative.

Cross-section 17890, surveyed at the high eroding bank at Atmautluak, was used to provide the bank geometry for the analysis. Soil layer characterizations were based on descriptions from WHPacific (2010). The input reach slope was based on water surface elevations surveyed simultaneously at two locations on the Pitmiktakik River channel, upstream and downstream of the village. The analysis was run at the discharge level surveyed August 2015. Analyses were conducted for two flow durations: 4 hours, representing two 2-hour high tide levels in one day, and 1460 hours, representing high tide levels for approximately one year.

Estimated rates of erosion for the bank toe are found in Figure 9 and Table 5.

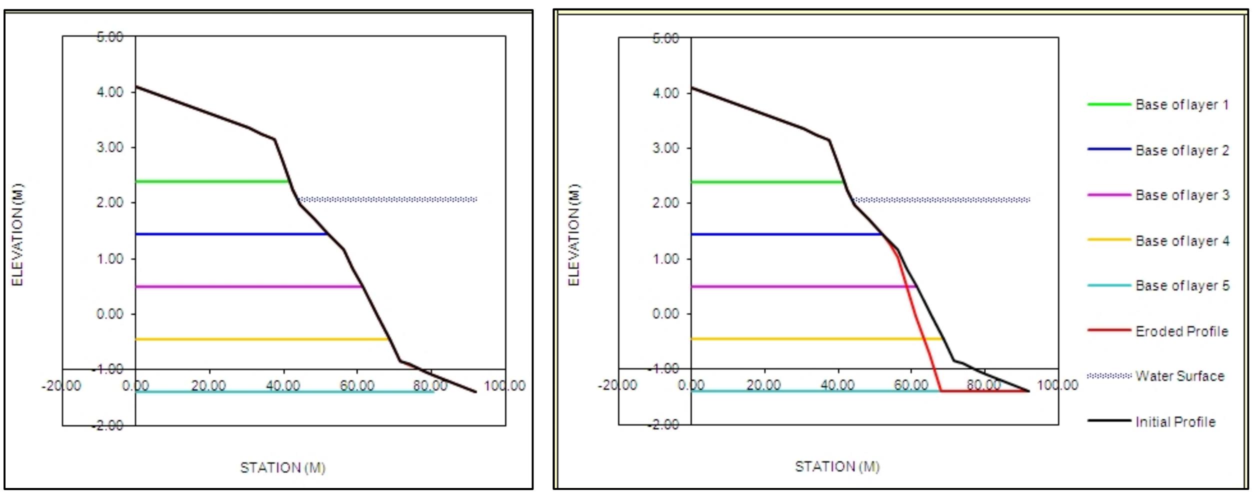


Figure 9. Estimated rates of bank erosion for 4 hours (left) and 1460 hours (right).

Table 5. Estimated shear stress and erosion results at Atmautluak bank for 1 day (two 2-hour high tide levels) and 1 year (1460 hours of high tide levels).

Shear stress and erosion results	4 hours	1460 hours
Average applied boundary shear stress (Pa)	0.350	0.350
Maximum lateral retreat (cm)	1.25	39.36
Eroded area-bank (m^2)	0.029	9.850
Eroded area-bank toe (m^2)	0.014	3.850
Eroded area-bed (m^2)	0.011	1.774
Eroded area-total (m^2)	0.054	15.474

Results show that estimated bank erosion rates attributable to shear stress are approximately one foot per year.

Scour

One of the most common causes of bank revetment failures is from floods scouring bed material from the toe of the revetment structure. With no information or data on long-term bed elevation changes in the Pitmiktakik River, a scour analysis of the channel at Atmautluak focused on general scour.

> *General Scour:* Flow contraction at a revetment project may result in removal of material from the bed across all or most of the channel width. Other general scour conditions include flow around a bend where the scour may be concentrated near the outside of the bend. General scour is different from long-term degradation in that general scour may be cyclic and/or related to the passing of a flood (USDA, 2007).

The numerical computation of scour requires site specific stream data, including the bed material D_{50}, design discharge, and top width and hydraulic radius at the design discharge, which are derived from a hydraulic analysis. Results from the HEC-RAS modeling analysis were used to provide the required hydraulic values for the scour calculations.

Several methods were used to estimate general scour, including Lacey and Blench (USDA, 2007), and Zeller (Zeller, 1981). The Lacey equation was determined to best represent conditions at Atmautluak, including bed material (silt) and upstream conditions. The selected design discharge for scour estimation was 2100 cfs, which represents bankfull flow.

The Lacey equation also includes a bend scour component in the calculations. The upstream radius ‘R’ of the river bend at Atmautluak was estimated at 1600 feet. With a design channel top width ‘T’ of 1016 feet, the degree of curvature ‘R/T’ is 1.6, which is classified as a severe bend.

Based on the Lacey equation, general scour depth for Cross-section 17890, which is located at the center of the community, is estimated at **5.3 feet**. Scour depth is estimated from the lowest part of the streambed.

Hardening a bank can lead to increased bed scouring, incision, and a shift of the thalweg toward the revetment (Stein et al., 2013). With the hardening on an outside bend, this may be even more likely. However, channel velocities on the Pitmiktakik River are relatively low, and the thalweg elevations upstream and downstream are fairly consistent, with no large scour holes detected at the surveyed cross-sections. Note that the thalweg is located over 150 feet from the bank, and the lateral channel slope from the bank to thalweg is shallow (6 %). A large thalweg shift is less likely to occur over a long period of time, but more likely to be initiated during a large event (flood or ice jam) when velocities are much higher than normal.

Note that scour equations are generally considered to provide conservative design values, especially in low risk or non-critical hydrologic conditions (Lagasse et. al., 2013). At the final design phase, a project-specific geotechnical investigation and updated channel survey should be performed. The use of regime scour equations must be balanced with local knowledge of channel conditions, confidence in the data used for each component in the scour equation, and engineering judgment.

Design Alternatives

Previous assessment of the bank erosion problem at Atmautluak indicates that bank erosion has occurred in the recent past, is ongoing, and will likely continue to be a characteristic trait of this river reach for the foreseeable future. The objective of this project is to analyze the hydrologic characteristics of the Pitmiktakik River, and develop methods to reduce or eliminate bank erosion at Atmautluak.

The results from the hydraulic and shear stress analyses described above are summarized here:

- Average velocities in the Pitmiktakik River channel are low, even during high flows.
- Average velocities are also low during ice jam events, though local velocities may temporarily increase at constrictions or during the ice jam breakup.
- The channel slope is shallow. Depths are relatively shallow. As such, average shear stresses are likely low in normal conditions. Upper bank material that fails is settling in lower bank regions, reducing the bank angle.
- The two primary causes of bank erosion along the Pitmiktakik River are likely pore-water pressure in combination with ice forces during breakup and ice jam events.
- Pore-water pressure, which increases and decreases with rapidly changing water levels, contributes to streambank erosion. Twice daily tidal cycles on the Pitmiktakik River result in rapidly changing pore-water pressure in the upper banks.
- The freeze/thaw cycle and formation of ice along the riverbanks results in bank sediment being dislodged and moved downslope via gravity. Additionally, ice thrust, ice retreat and ice movement, which all occur during breakup and ice jam events, abrades and gouges the bank, leading to bank erosion.

These hydraulic characteristics will help determine types and methods of erosion protection that will be most effective at the project site. Most bank erosion protection techniques may be classified as either a resistive method or a redirective method. Resistive methods, such as riprap or sheetpile, are designed to protect against shear stress, and are generally used in a continuous application. Redirective techniques, usually discontinuous, are techniques that redirect the flow and energy of the river or stream away from the area of the eroding bank (McCullah, 2004). Examples of redirective techniques include rock vanes and bendway weirs. Such in-stream structures pose a threat to both large and small boats from boat hull strikes, and therefore were not considered suitable for use in this segment of the Pitmiktakik River.

The alternatives discussed below address those conditions using various approaches and techniques.

Channel shape and estimated velocities are important characteristics when designing bank protection. Results from the HEC-RAS analysis are found in Appendix 2, including velocity distribution across the cross-section. Note that the flow distribution results should be used cautiously, as they are based on a one-dimensional model. A true velocity and flow distribution varies vertically as well as horizontally (USACE, 2010).

Articulated Concrete Block

Articulated concrete block (ACB) systems are a matrix of individual concrete blocks laced together with steel cable to form a hard-armored erosion-resistant revetment. ACBs include several features that may be advantageous for use in a project of this type.

- Retain flexibility under changing grades over time;
- Allow hydrostatic pressure relief through the cellular blocks;
- May be transported to a location, or cast in place at a project site;
- Blocks with open areas allow for vegetation to grow, providing both habitat and erosion protection;
- Can be installed underwater.

An ACB erosion control project designed to protect the embankment of the Nunapitchuk Airport was installed as part of a larger ADOT&PF project in 2007. The embankment sits adjacent to the Nunavakanukakslak River, which flows adjacent to the northeast and southeast corners of the airport. Nunapitchuk is located approximately 6 miles west of Atmautluak; the watershed, like the Pitmiktakik River watershed, is part of the Yukon-Kuskokwim Delta, with a small flat river meandering through a vast flat wetland/tundra complex interspersed by countless ponds and lakes and lakes. See Figure 10.

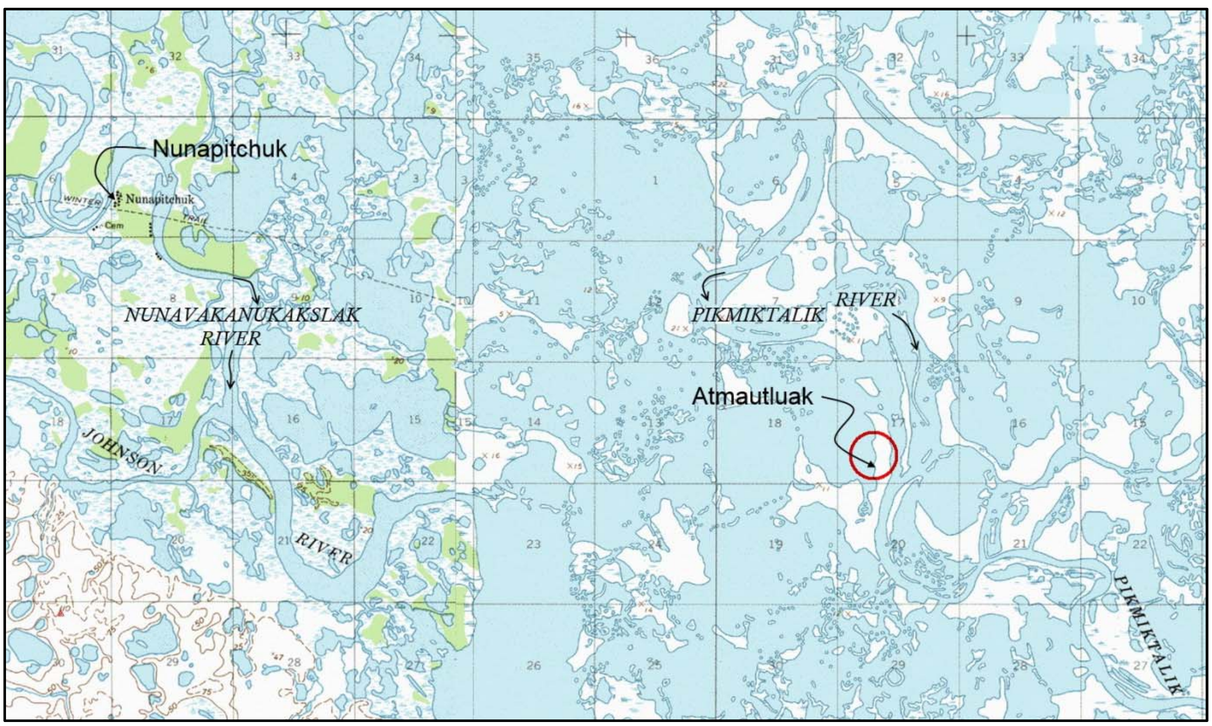


Figure 10. Proximity map of Nunapitchuk and Atmautluak.

The erosion control utilized articulated concrete block (ACB) to protect against embankment scour. The articulated blocks were cabled together in large blankets and overlain on a geotextile filter fabric. The slopes were treated with seeds and rolled matting to provide additional protection. See Figures 11 and 12.


Figure 11. ACB at Nunapitchuk Airport embankment along Nunavakanukakslak River.


Figure 12. ACB installation at Nunapitchuk Airport embankment.

This project was inspected in 2011 in order to assess how well it has performed since installation. Some block slumping at the submerged toe of the blanket is apparent in a few areas, where the ACBs were not keyed in properly. The elevation of the blanket does not appear to be low enough to protect against toe scour if the channel thalweg migrates to the armored bank. Otherwise, most of the installation appears to be in excellent condition and functioning properly.

Another bank erosion project that utilizes ACB was constructed in 2000 along the channel between Lake Hood and Spenard Lake. It protects the bank from waves generated during float-plane high-speed taxis. The ACB appeared to be slightly heavier and larger than the ACBs used at Nunapitchuk. Except for some very slight settlement, the ACB installation appeared to be in excellent condition, and the section above the OHW line had revegetated well, which enhanced the stability and erosion protection of the system. See Figure 13.

Figure 13. ACB installation at Lake Hood/Spenard Lake channel, Anchorage, AK.

Continuous Riprap Bank Protection

Rock riprap is the most widely used type of revetment in the United States (FHWA, 1989). Riprap embankments consist of a layer of rock placed on a bank to prevent erosion, scour, sloughing of a structure or embankment. Advantages of riprap include:

1. The riprap blanket is flexible and is not impaired or weakened by minor movement of the bank caused by settlement or other minor adjustments.
2. Local damage or loss can be repaired by placement of more rock.
3. Construction is not complicated (FHWA, 1989).

Installed riprap protects a bank from the stresses of higher velocity water along it. This type of armoring is not meant to alter the flow of the river, but typically does cause some local scour. In addition, riprap usually provides protection only to the section of bank that is armored.

Riprap can be very expensive. In addition to finding and processing the appropriate size rock, freight/haul costs can significantly affect the cost of these revetments.

Riprap design is well-established, and several guidelines are available. Design requirements include:

- design flood discharge and elevation,
- velocity, bed material gradation,
- scour depth excavation,
- cross-section geometry.

Following the design and selection of rock size, construction of the revetment would most likely occur from the river side of the bank. A road would have to be built at the base of the riprap toe along the length of the project; active river channels would have to be diverted out into the center of the braid plain. Bank preparation would require clearing all trees and debris, and grading the bank surface to the desired slope, generally between 1.5-2:1 (H:V). Where the bank has steepened due to previous erosion, additional bank material would have to be placed first.

A filter is required between the bank material and the riprap layer to prevent migration of the fine soil particles out through the voids, and to allow relief of hydrostatic pressure on the bank side. Filter layers consist of either gravel and small stone or geotextile fabric.

Though shear stresses are low, riprap would likely have to be oversized to resist ice plucking forces on the upper bank.

Bioengineering

Bioengineering techniques generally involve using a combination of materials to armor and protect stream banks, including vegetation (willow), root wads, toe rock, coconut fiber bio-logs (coir logs), and coir blankets. The subarctic and arctic climates in Alaska present special design challenges for bioengineered erosion control methods. The revegetation of barren and disturbed areas in colder climates, often a critical element of bioengineered bank protection, is very slow compared with similar situations in warmer climates. Contributing to slow re-establishment of natural conditions are such factors as: short cool growing seasons, permafrost, aufeis deposits, lack of annual plant species, and the resulting dependency on asexual vegetation reproduction. As a result, structures are often designed improperly and may fail prematurely, or not function properly from the start.

Another challenge to the successful implementation of bioengineered bank protection methods is the need to understand the many complex processes associated with river behavior. Many of the structures that have been installed throughout the U.S. and Alaska in the past twenty years have essentially changed the dimension, pattern, and the profile of the host river. Designers may not focus on understanding the morphological variables that determine the river's natural stability, and may attempt to apply standardized techniques to a wide variety of conditions. Other common problems include a design that has been developed only for a particular reach, ignoring upstream and downstream considerations.

In 2003, an analysis of bioengineered erosion control structures was conducted at 11 sites around the State of Alaska (Karle, 2003). Part of that analysis documented any observed damage to these structures from winter ice. Such damage was documented at several sites. In several short sections of the Anchor River-Silverking site (willow brushlayering with coir logs and spruce tree revetment), ice damage was noted on the soil lifts. Ice damage was also noted on longer sections of the Chena River-Doyon site (willow brushlayering with soil lifts and toe rock).

Damage from flowing ice left a distinctive mark; the fabric had been ripped out and pulled downstream, where it was found in a compacted bundle. A failed outer wrap was noted in numerous locations at the Chena River-Doyon site. The failed outer wrap, combined with a deteriorated inner wrap, led to the spillage of bank material used in the soil lifts, and subsequent failure of those lifts. Damage at the Chena River site may also be related to floating ice which attaches to the bank during the winter. Ice covers tend to follow the water level. As the winter progresses and discharge drops, the bank ice falls into the channel, and exerts a shear force on the bank material. Nearby residents reported that annual bank erosion results from bank ice action each spring. Additional problems may occur at sites with fixed structures which extend into the channel, such as root wads. River ice may attach to such structures; a buoyant force is then exerted on the structure if the water level rises.

Table 6. Summary table of three design methods for bank erosion protection.

Method	Riprap	ACB	Bioengineered	Other
Advantage	Well-established design and installation guidelines. Flexible installation is self-healing in the event of toe erosion.	Blocks can be transported or cast onsite. Can be vegetated to add stability and habitat features. Hard protection against ice forces.	Use local materials. Suitable for channels with low average velocities and low shear stress. Easier approval from permitting agencies. Can be repaired relatively easily.	
Technical Challenge	Rocks must be heavy enough to resist ice plucking. Large heavy rock may sink through silt/melting permafrost channel banks. Rock must be imported.	Upper and lower borders must be securely anchored in silt bank to prevent block overturning. Concrete cast-in-place would require strict quality control measures to ensure conformance with required concrete specifications.	Slow establishment of vegetation creates failure risk for several years after installation. Can be damaged by ice forces.	
Cost Range	High	High	Low-Medium	

Summary

The Pitmiktakik River is a tidally-influenced meandering stream that originates about 60 miles northeast of Atmautluak in a flat tundra and lakes complex area. Atmautluak is located on an actively eroding bend of the river. The area around Atmautluak is flat and poorly drained with numerous lakes and small drainages that flow into the Pitmiktakik River (ADCED, 2015).

USGS regression equations were used to develop a flood frequency analysis for the Pitmiktakik River at Atmautluak. However, due to watershed characteristics that are outside of the range of those used to develop the regression equations, the actual flood magnitudes may be closer to the lower end of the calculated 90% prediction interval.

The bank of the Pitmiktakik River is eroding along the entire length of the community at Atmautluak. The average erosion rate is estimated at 1.3 feet per year. Possible reasons for the ongoing bank erosion include: shear stress, pore-water pressure, thermal degradation, river ice, and boat wash.

An analysis was conducted to determine the hydraulic characteristics of the Pitmiktakik River channel at various flow levels. Cross-sections on the Pitmiktakik River channel were surveyed in August 2015 and used to create a numerical model of the channel. The model was used to predict water velocities and channel widths at bankfull discharge, and to simulate conditions with an ice cover and ice jam. Results indicate that average velocities in the Pitmiktakik River channel are low, even during high flows. Average velocities are also low during ice jam events, though local velocities may temporarily increase at constrictions or during the ice jam breakup.

The USDA Bank Stability and Toe Erosion Model (BSTEM) was utilized to estimate erosion of the bank and bank toe by hydraulic shear stress. Results show that estimated bank erosion rates attributable to shear stress are low, about 1.3 feet per year, even though banks consist of fine-grained, easily erodible soils.

The hydraulic analysis indicates that the two primary causes of bank erosion along the Pitmiktakik River are likely pore-water pressure in combination with ice forces during breakup and ice jam events. Pore-water pressure, which increases and decreases with rapidly changing water levels, contributes to streambank erosion. Twice daily tidal cycles on the Pitmiktakik River result in rapidly changing pore-water pressure in the upper banks. The freeze/thaw cycle and formation of ice along the riverbanks results in bank sediment being dislodged and moved downslope via gravity. Additionally, ice thrust, ice retreat and ice movement, which all occur during breakup and ice jam events, abrades and gouges the bank, leading to bank erosion.

Based on the results of the hydraulic analysis, alternatives for bank erosion protection were analyzed. Articulated concrete block systems, riprap, and bio-engineered revetments all present advantages and disadvantages for the Atmautluak location.

References

Alaska Department of Commerce, Community, and Economic Development (ADCED). 2009. Alaska Community Information Database Community Information Summaries. Accessed at http://commerce.state.ak.us/dnn/Portals/4/pub/Atmautluak_Final%20Report.pdf.

Curran, J. H., D. F. Meyer, and G.D. Tasker. 2003. Estimating the magnitude and frequency of peak streamflows for ungaged sites on streams in Alaska and conterminous basins in Canada. U.S. Geological Survey, Water-resources investigations report 03-4188. Anchorage, AK.

DOWL. 2015. Atmautluak engineering analysis, Atmautluak, Alaska. Surveying and mapping report. Prepared by DOWL, Anchorage, AK. DOWL HKM Project Number 1127.62038.01.

Gatto, L.W. 1993. Riverbank conditions and erosion in winter. Proceedings of the workshop on environmental aspects of river ice. T.D. Prowse, editor, National Hydrology Research Institute, Saskatoon, Saskatchewan, NHRI Symposium Series No. 12, p. 43-56.

Karle, K.F. N. Moore, and W.W. Emmett. 2003. Evaluation of bioengineered stream bank stabilization in Alaska. FHWA-AK-RD-0303. Prepared for Alaska Department of Transportation.

Lagasse, P.F., M. Ghosn, P.A. Johnson, L.W. Zevenbergen, and P.E. Clopper. Reference guide for applying risk and reliability-based approaches for bridge scour prediction. NCHRP Report 761, Transportation Research Board, Washington, D.C.

Leopold, L.B., M. G. Wolman, and J.P. Miller. 1964. Fluvial processes in geomorphology. Dover Publications, Inc. New York, NY.

Rowland, J. C., C. E. Jones, G. Altmann, R. Bryan, B. T. Crosby, G. L. Geernaert, L.D. Hinzman, D. L. Kane, D. M. Lawrence, A. Mancino, P. Marsh, J. P. Mcnamara, V.E. Romanovsky, H. Toniolo, B. J. Travis, E. Trochim, and C. J. Wilson. 2010. Arctic landscapes in transition: responses to thawing permafrost. Eos, Transactions, AGU, 91, 229-236.

Simon, A, and A. Collinson. 2001. Pore-water pressure effects on the detachment of cohesive streambeds: seepage forces and matric suction. Earth Surf. Process. Landforms. 26, 1421-1442. John Wiley & Sons, Ltd.

Stein, E.D., M.R. Cover, A.E. Fetscher, C.O'Reilly, R. Guardado, and C.W. Solek. 2013. Reach-scale geomorphic and biological effects of localized streambank armoring. JAWR, Vol. 49, Issue 4 pp. 780-792.

US Army Corps of Engineers (USACE). 2007. Erosion information paper - Atmautluak, Alaska. August 27, 2007. Alaska District Corps of Engineers Civil Works Branch.

US Army Corps of Engineers (USACE). 2010. HEC-RAS River analysis system. Hydraulic reference manual, version 4.1, January 2010. CPD-69.

US Department of Agriculture (USDA). 2007. Technical Supplement 14B, Scour calculations. National Engineering Handbook. Natural Resources Conservation Service.
US Geological Survey (USGS). 2015. Watershed boundary dataset. Accessed at http://nhd.usgs.gov/wbd.html.

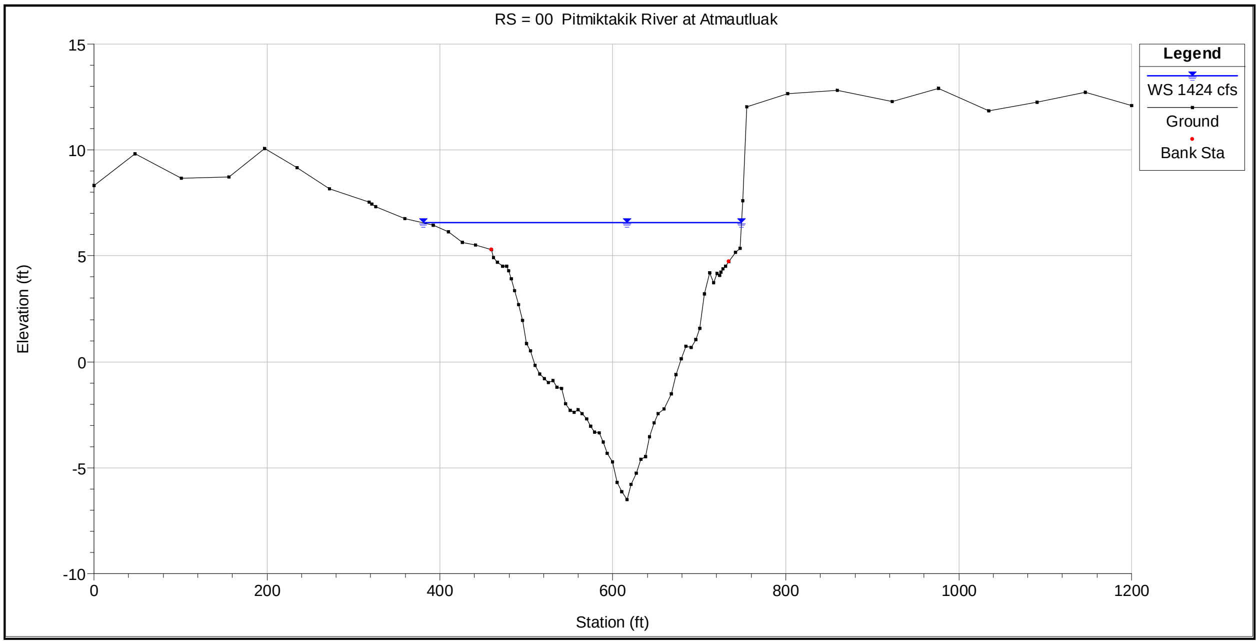
Western Regional Climate Center (WRCC). 2012. Bethel WSO Airport, Alaska (500754), 1981-2010 monthly climate summary. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak0754.

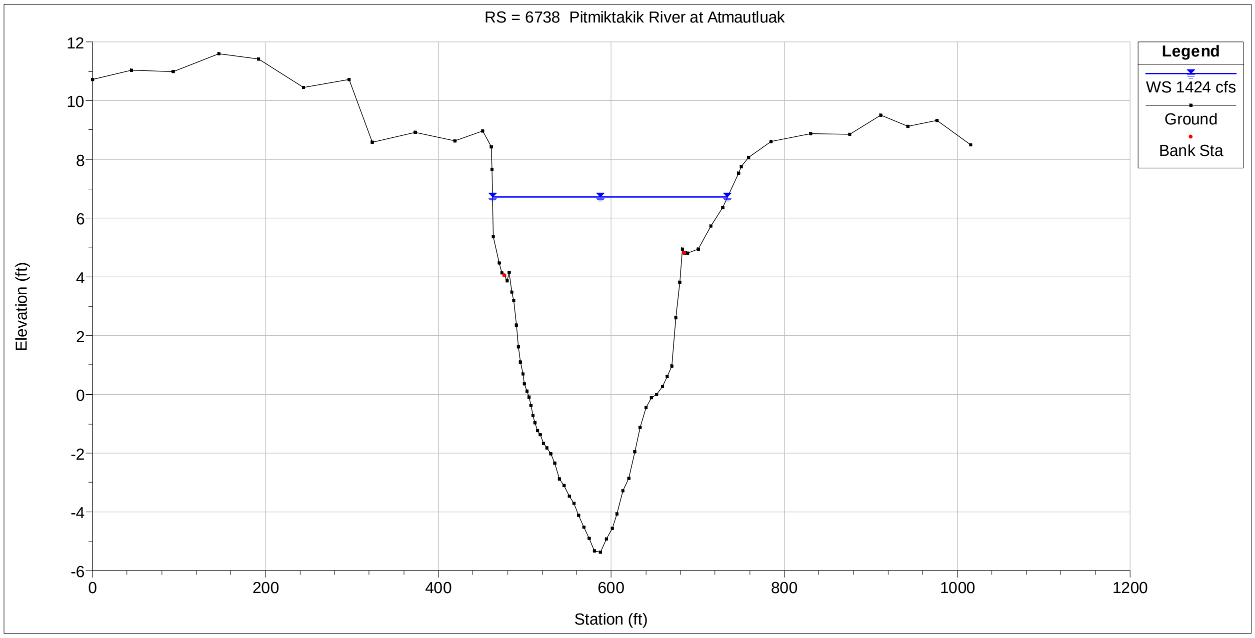
WHPacific. 2010. Atmautluak hazard impact assessment June 2010. Prepared for the Atmautluak Traditional Council. Prepared by WHPacific with Shannon and Wilson Inc.

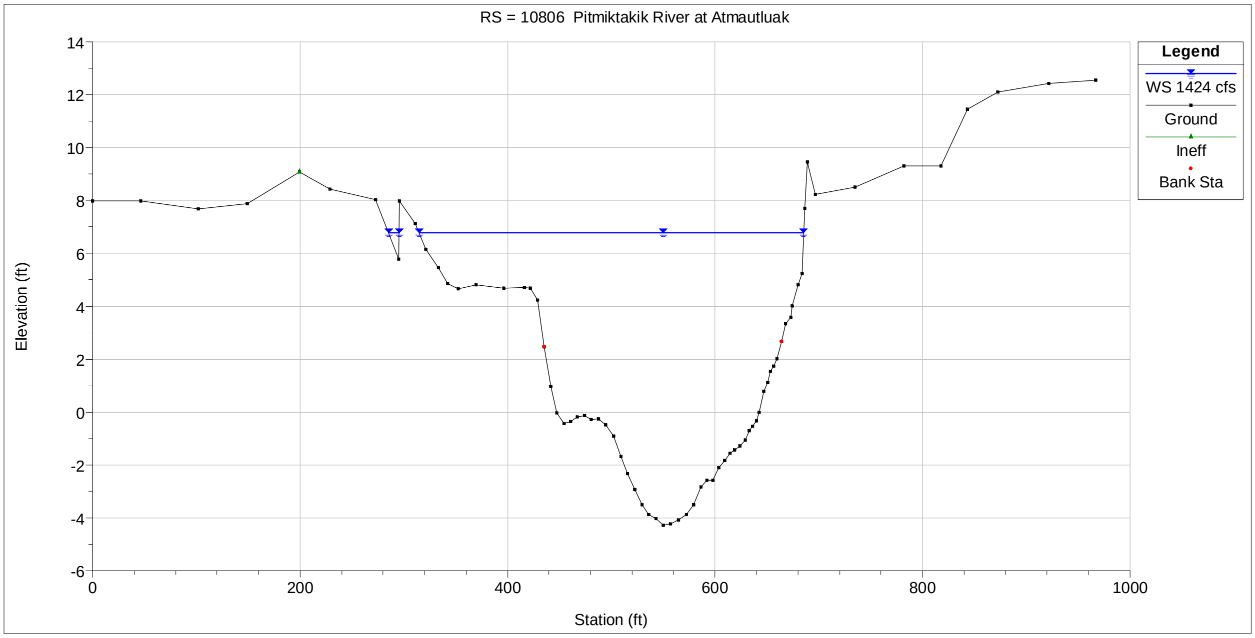
Zeller, M.E. 1981. Scour depth formula for estimation of toe protection against general scour. Pima County Department of Transportation and Flood Control District, Tucson, AZ.

Appendix 1-Surveyed Cross-sections and Results from HEC-RAS

All cross-section views are downstream.



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Legend
WS 1424 cfs
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Bank Sta
Elevation (ft)
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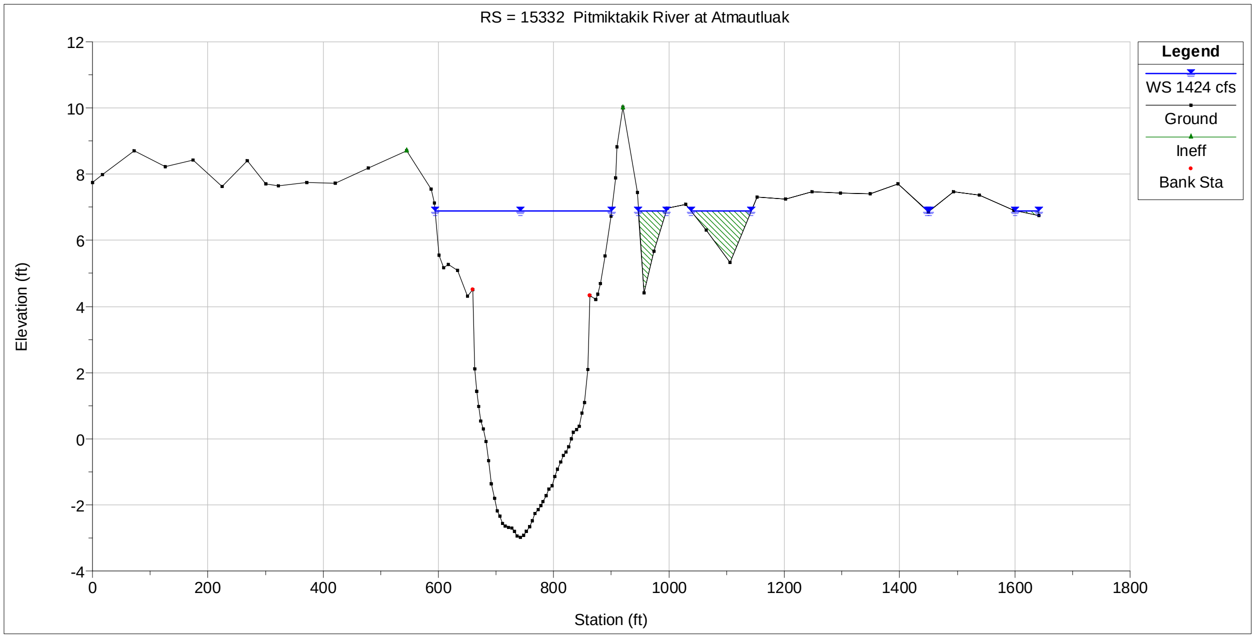
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Elevation (ft)
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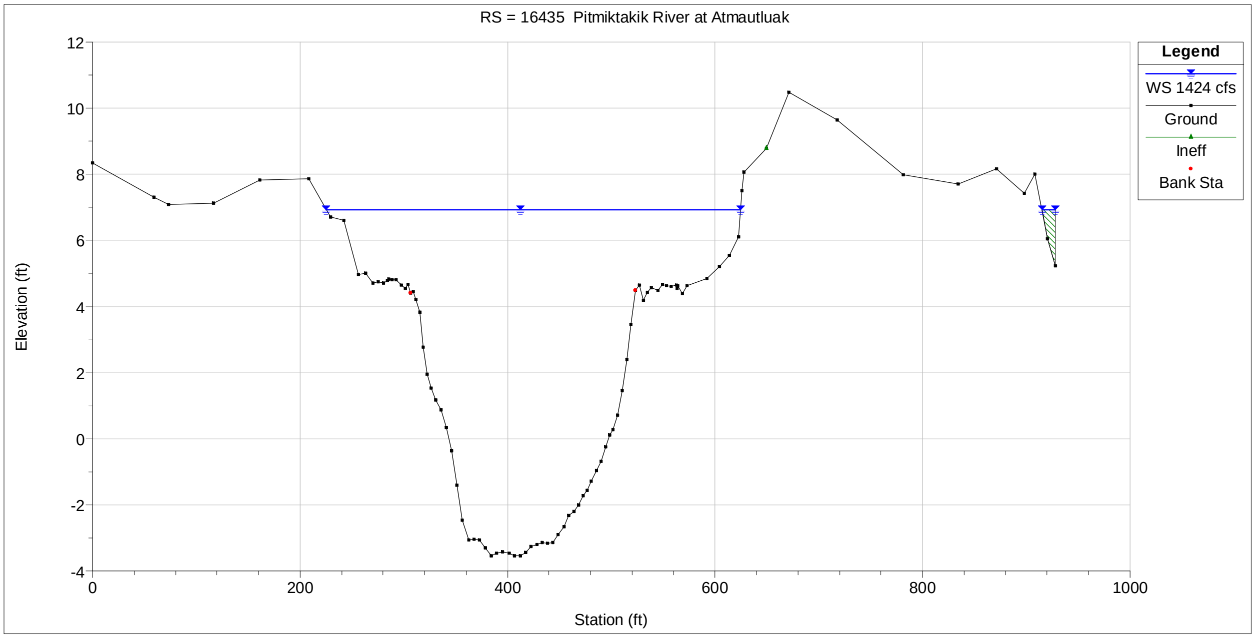
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Legend
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Elevation (ft)
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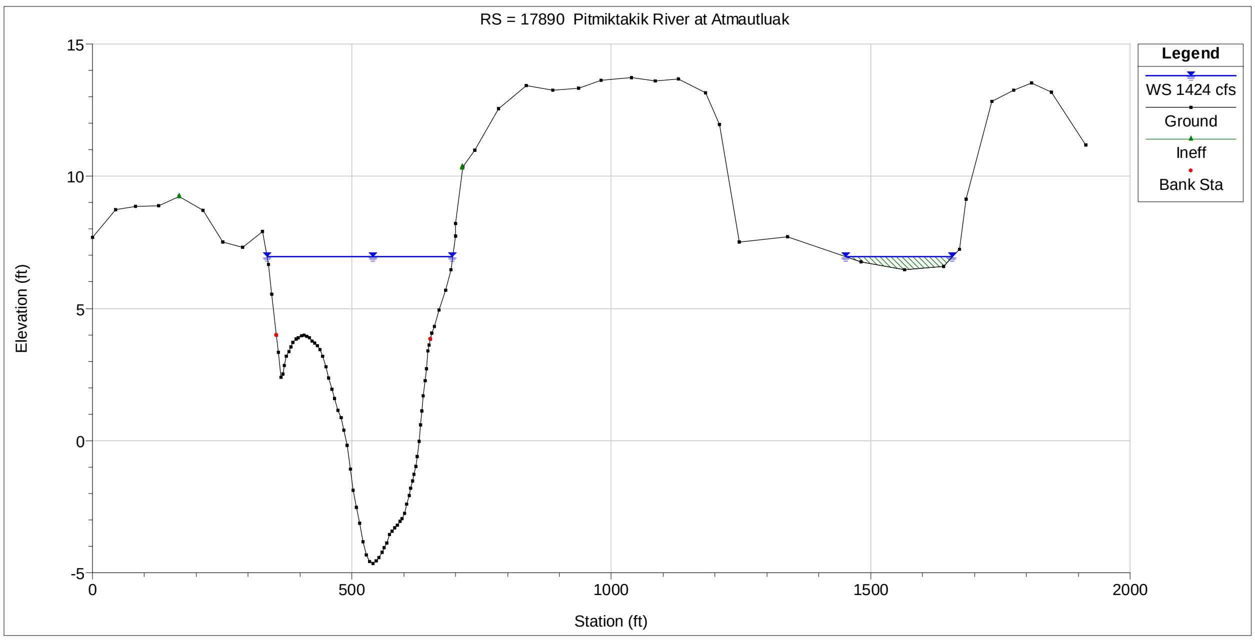
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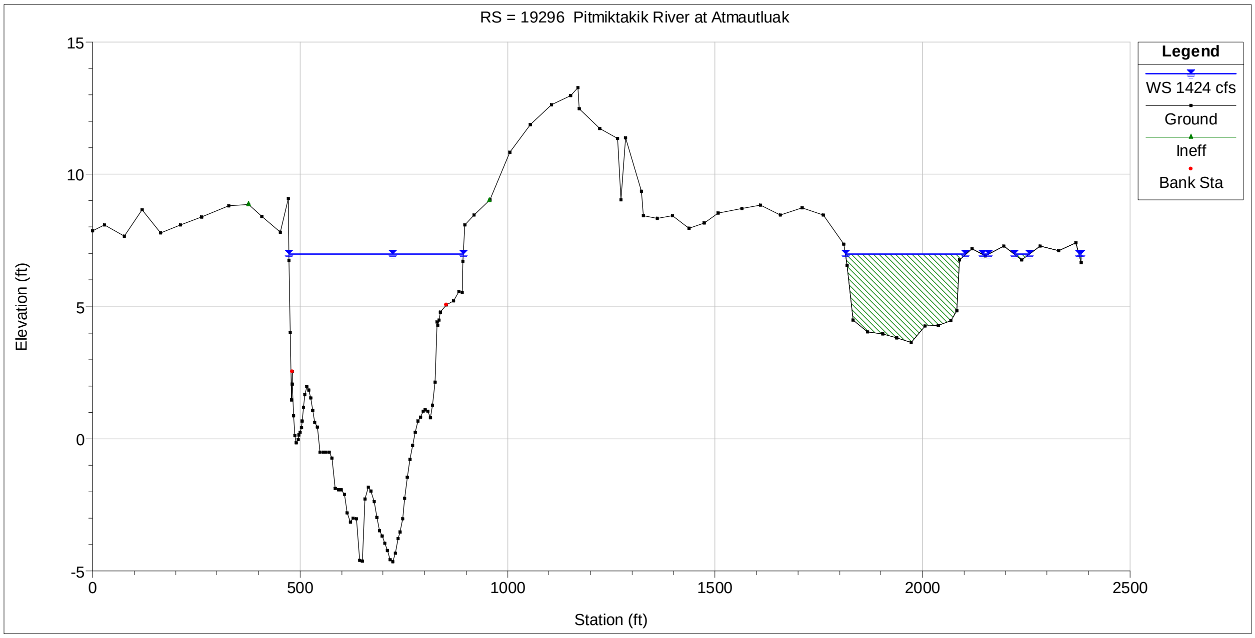
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Legend
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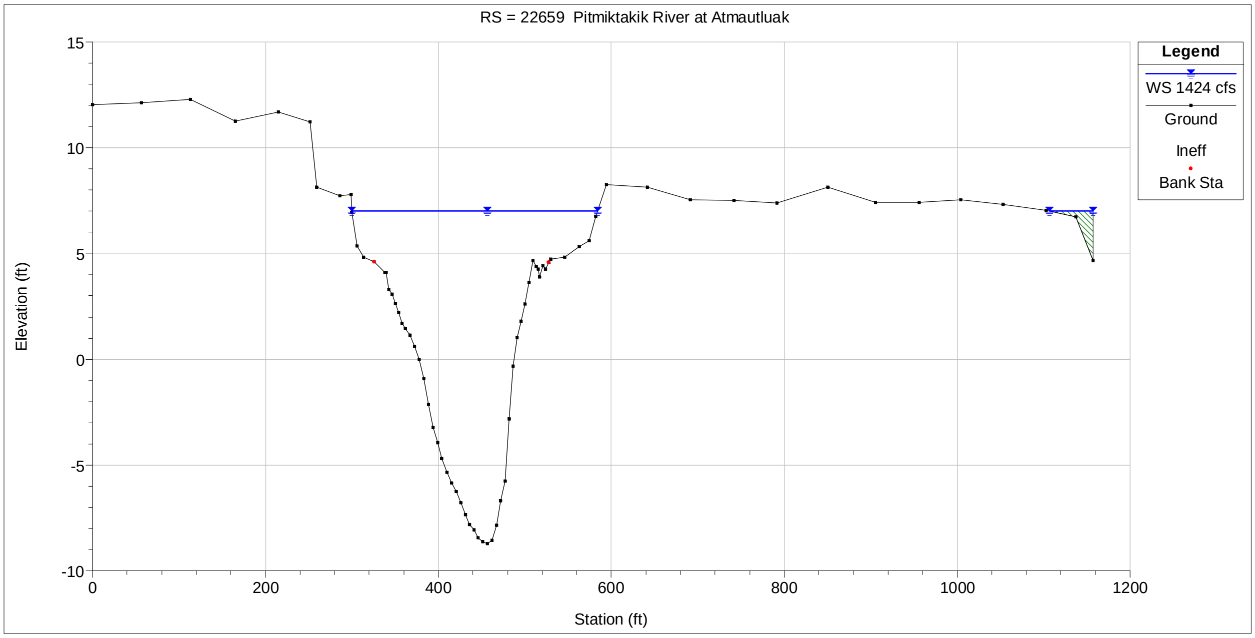
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Ground
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Bank Sta
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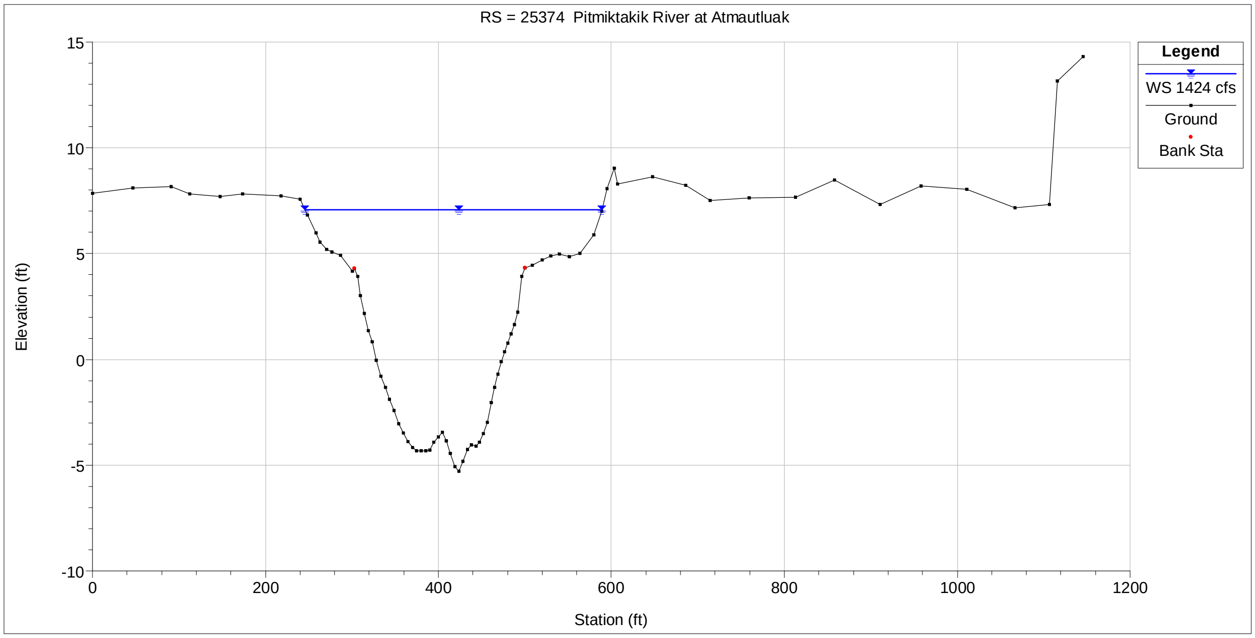
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Legend
WS 1424 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
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Appendix 2- Results from HEC-RAS Open Water Analysis

River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
0	1424	-6.51	6.57	-2.19	6.57	0.00002	0.71	2071.01	368.28	0.05
	2100	-6.51	8.41	-1.65	8.42	0.00002	0.83	2871.15	491.52	0.05
6738	1424	-5.37	6.71		6.72	0.000023	0.83	1793.83	271.81	0.05
	2100	-5.37	8.56		8.58	0.000025	0.99	2331.4	326.75	0.06
10806	1424	-4.28	6.8	-1.39	6.8	0.000018	0.74	2196.15	381	0.04
	2100	-4.28	8.65	-0.83	8.67	0.000019	0.87	2977.9	701.05	0.05
15332	1424	-2.98	6.89	-0.55	6.9	0.000027	0.87	1807.62	506.08	0.05
	2100	-2.98	8.76	-0.03	8.77	0.000028	1.02	2784.36	1619.4	0.06
16435	1424	-3.55	6.92	-1.39	6.93	0.000021	0.79	2109.9	412	0.05
	2100	-3.55	8.79	-0.89	8.8	0.000022	0.92	3145.92	826.37	0.05
17890	1424	-4.66	6.95	-1.8	6.96	0.00002	0.69	2147.42	562.66	0.05
	2100	-4.66	8.82	-1.25	8.83	0.000019	0.79	2963.74	1016.25	0.05
19296	1424	-4.66	6.97	-1.85	6.98	0.000008	0.48	3031.3	765.6	0.03
	2100	-4.66	8.84	-1.46	8.85	0.000009	0.57	3887.3	1983.03	0.03
22659	1424	-8.73	7.01	-4.98	7.02	0.00002	0.8	1922.11	335.38	0.05
	2100	-8.73	8.88	-4.25	8.89	0.000022	0.96	2508.99	900.03	0.05
25374	1424	-5.28	7.06	-2.26	7.07	0.000019	0.79	2052.26	343.22	0.05
	2100	-5.28	8.94	-1.73	8.95	0.000021	0.94	2889.15	1108.09	0.05

Appendix B:
Community Meeting Notes

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700 G Street, Suite 500
Anchorage, AK 99501
907-562-3366

Atmautluak Community Meeting Notes, April 25th

AECOM: Peter Crews, Civil Engineer

Traditional Council: President: Melvin Egoak, Nicholai Evan, Nicholai Pavilla Sr

Meeting: Melvin Egoak introduced Peter Crews. Peter Crews explained the study and Melvin translated from English. Peter reviewed the erosion options: Sheet Pile Walls; Articulating Concrete Block matting; Confined Cellular Systems (Geo Cells). Peter also explained the proposed Community Drainage Plan. Melvin Translated from English.

Specific Comments from the Community:

- Council was not in favor of the sheetpile wall. There were concerns that the vertical face of the wall would be a safety hazard with snow machines in the winter.
- Council was not in favor the CSS option. When the water is high in the spring the ice could rip out the mesh. The CSS might be OK for erosion protection on the two lake sections identified (on the west side of the community.
- Council was in favor of the Articulating Concrete Block matting as the option for erosion protection along the river, from the south end of the community north to the airport.
- Council was OK with the swale option. Council suggested using the spoils to build up the road. There was discussion of the community requesting the Lower Kuskokwim School District to close the old sewage lagoon. Spoils could be stockpiled or be used to cap the old sewage lagoon (note- this would need to be done in conjunction with a sewage lagoon closure project).
- The council decided the fence around Pig Lake should not be installed, a fence would block winter travel routes.
- Two winter crossings should be added to the swale design so that vehicle traffic in the winter can cross the swales. AECOM suggested shallower swale slopes at two locations. One would be located just north of Pig Lake and the second about 500 feet north of Pig Lake near where there is a public right of way corridor between the river and the gravel road.

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Trip Notes Atmautluak Jan-6-2016

AECOM (Peter Crews) met with Atmautluak Traditional Council to discuss scope of study.

Council Members Present: Melvin Egoak (Vice President), Nicholai Evan, Nicholai Pavilla Sr, Daniel Waska (Administrator)

Council: We want to provide drainage for pig lake. The lake used to drain to the lake to the north and the level of the lake was lower. Now during spring and fall the lake can overflow. The whole area is wet. It used to not be as wet. Water comes down the swale to the west (near the church) and goes into the lake. When the road from the airport was built the drainage was cut off. The ditch can terminate just north of the boardwalk (northernmost east-west boardwalk). Suggest a spur to the west near the south end of the road.

AECOM: We can provide a ditch to the north. The ditch would be a v ditch, covered with top soil and seeded. The soil would be scraped to the side before the ditch is excavated, the ditch would be re-covered with soil and seeded, to try to restore the tundra mat. There is a possibility the permafrost could thaw or create unlevel drainage slope, it might have to be re-graded at some point if it begins to pond. The slope will be very flat so the bottom will always be a little wet.

Council: We don't want a pipe, they clog. Consider a half pipe. The vegetation grows out and clogs the ditch.

AECOM: The ditch could have flat slopes. A half pipe could absorb heat in the summer and cause the underlying permafrost to thaw, unless insulation boards are placed under.

Council: The flat slope ditch is OK.

Council: Bank erosion is a problem along river and also at the lake (west side of town). Need seawall or something to stop erosion and save the good land.

AECOM: We propose articulating concrete blocks. These were installed in Nunapitchuk.

Council: They have sunk out of sight. They are too heavy and have sunk into the soil.

AECOM: There are similar plastic matting that could work, we are concerned with the ice damaging the mats.

Council: The ice does not move fast. Speed depends on the tide. It does not move like it does on the Kuskokwim.

AECOM: We can consider a wall but walls are expensive.

Council: Sloping protection instead of wall preferred but it needs to work and last 40-50 years. If wall is built it needs gaps for boats to park, ramps in the gaps.

Council: We would like to have a public meeting. Would like AECOM to come out (maybe February) to show alternatives.

AECOM: We can show a wall alternative and sloping protection alternative with costs.

AECOM: Any flooding in the last 45 years where the water went over the bank?

Council: During spring snow melt or in fall when it rains a lot the river will slightly overtop the low elevation banks and be just under the top of the higher elevation banks. There has been no flooding beyond the banks. 200 years ago there was a large flood that covered the whole region.

AECOM: How high are the tides?

Council: 2 feet

AECOM: how thick does the ice get?

Council: 3 feet maybe up to 4 feet.

August 26, 2015
Atmauthluak Traditional Council
P.O. Box 6568
Atmauthluak, Alaska 99559
(907) 553-5613

2:35 p.m.

AECOM
Brian Giese
Donne Fleagle, Rural Community Engagement Specialist

TRADITIONAL COUNCIL STAFF
Moses Pavilla Jr., Compliance Officer (Cell) 553-2146

TRADITIONAL COUNCIL
Vice President: Melvin Egoak
Treasurer: Nelson Nicholai
Council Member: Nicholai Evan
Council Member: Nicholai Pavilla Sr.

ATMAUTHLUAK LIMITED LAND DEPARTMENT P.O. Box 6548 Atmauthluak, Alaska 99559
Sydney Nicholas
Laure Nicholai
Kim Daniel

Brian Giese: Introduction of the Project and scope of work.

Melvin Egoak, Vice President: Our main concern is erosion near the Clinic. There was land that has been covered by water that used to be there before the subdivision was built. When a SW or W wind blows it causes waves that erode the edges of the pond. There is a building about 3500' from the pond and it is very important. We might lose it. There is an inner lake that fills with water when it rains or when the water rises in the fall time or during spring snowmelt. In 1969 the whole village moved. In 1970 we settled along the river. In the 1980's new houses were built around this main concern.
The inner lake used to have a little channel that drained into the far right lake (on the map) but when the road was build it covered and blocked the channel. The high ground began to erode so we had to move the parsonage because the water could not drain. Before we had the gravel road, that ground was high ground. Inner lake is filling with more water and when its too full it spreads all over. We tried to drain it but its not working. I want the drainage addressed, a channel or something, to save the land. The

2 lakes are now 1. When the airport was built there was a man made lake constructed. When the tide comes in (showed us on the map) it causes this.
We are afraid of our lagoon now. Starting to drain, wets the tundra and lifts it up and floats the tundra while water flows underneath and on top of the clay level which sits on permafrost. So we have 2 concerns. The inner lake needs drainage and the lagoon is sickness. Our 3rd concern is the River Erosion at the end of the village to almost to the aport. Suggest a seawall in front of our village to save our good land.
BRIAN: When the hydrologist arrives he will be doing an ice jam study and cross sectional study of the river. Of course with snow melt the river rises but there aren't ice jams. The water in the river has varying heights with the tide from the Kuskokwim River. Our 4th concern is sickness in the state man made lake that the school used for their waste. There is contamination and it needs to be purified and dumped into the inner lake. Wish we could permanently get rid of it before it hurts our children. Our hope is to get help.

Appendix C:
Trip Report, Inspection of Nunapitchuk Articulating Concrete Block

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700 G Street, Suite 500
Anchorage, AK 99501
907-562-3366

Trip Report Nunapitchuk Runway April 26th

Present: Peter Crews, Civil Engineer

Background: Articulating Concrete Block (ACB) matting is proposed at Atmautluak as an alternative to address the eroding river bank in the community, as part of the Atmautluak Hydrological Study/Community Drainage Plan. Residents of Atmautluak expressed concern that ACB blocks installed in this area might be too heavy and sink into the tundra. The purpose of the trip was to document condition of ACB matting installed at the nearby Nunapichuk airport in 2007, and verify that no significant settlement has taken place over the course of 9 years. Nunapichuk is located 6 miles west of Atmautluak. 2011 photos were provided by Ken Karle of Hydraulic Mapping and Modeling from a site visit in 2011.

Findings: There was no noticeable settlement of the embankment slopes where ACB was installed. The side slopes appeared uniform from the top of the embankments to the toe at all areas inspected.

Southeast Corner Runway Looking West 2016

Southeast Corner Runway Looking West 2011

AECOM
700 G Street, Suite 500
Anchorage, AK 99501
907-562-3366

Southeast Corner Runway Looking South 2016

Southeast Corner Runway Looking South 2011

Southeast Corner Runway Looking East 2016

Southeast Corner Runway Looking East 2011

AECOM
700 G Street, Suite 500
Anchorage, AK 99501
907-562-3366

Northeast Corner Runway Looking South 2016

Northeast Corner Runway Looking South 2011

2016 Photo: Note Thick Vegetated Mat on Top of Blocks, Typical

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Appendix D:
Drainage Swale Profiles and Cross Sections

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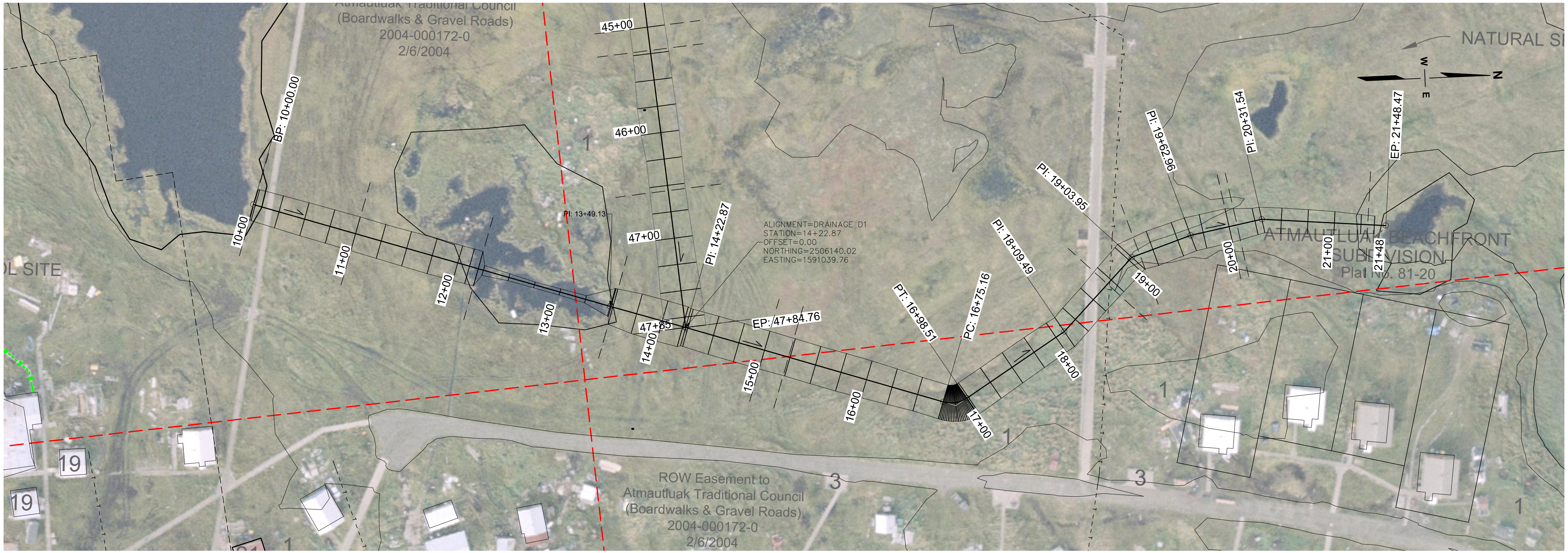


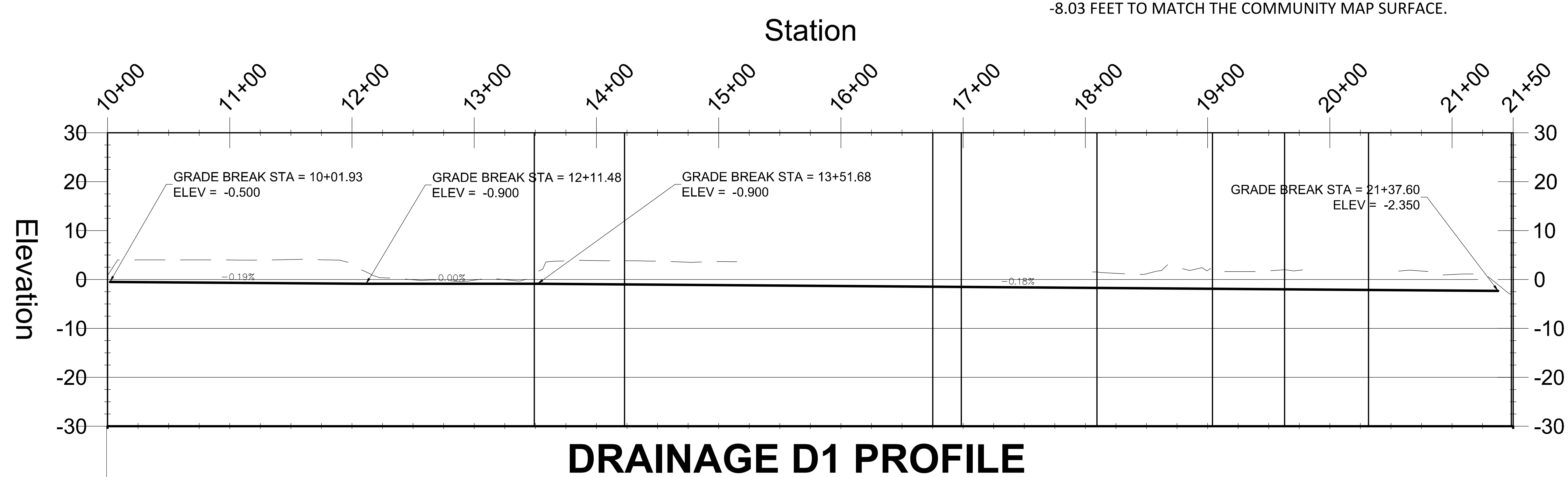
GRAPHIC SCALE

50' 0 25' 50' 100'

(IN FEET)

DRAINAGE D1 PLAN

NOTE: A DIGITAL TERRAIN MODEL SURFACE FOR THIS DRAWING WAS BUILT BASED ON DOWL 2015 SURVEY POINTS AND SURFACE DATA PROVIDED TO BY AEROMETRIC IN 2007 FOR THE ATMAUTLUAK COMMUNITY MAP. THE DOWL SURVEY POINTS WERE ADJUSTED BY -8.03 FEET TO MATCH THE COMMUNITY MAP SURFACE.



DRAINAGE D1 PROFILE

NO.	BY	DATE	DESCRIPTION

REVISIONS

AECOM
700 G STREET, SUITE 500
ANCHORAGE, AK 99501
TEL: (907) 279-0543
FAX: (907) 276-7679

ATMAUTLUAK

ATMAUTLUAK HYDROLOGICAL STUDY

ATMAUTLUAK, AK

DRAINAGE PATH D1 PLAN AND PROFILE

PROJECT No. 60440368
DATE: 05/18/2016
DESIGNED: PC
DRAWN BY: MB
CHECKED BY:
SHEET: D1 PNP
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REV. 3/2010

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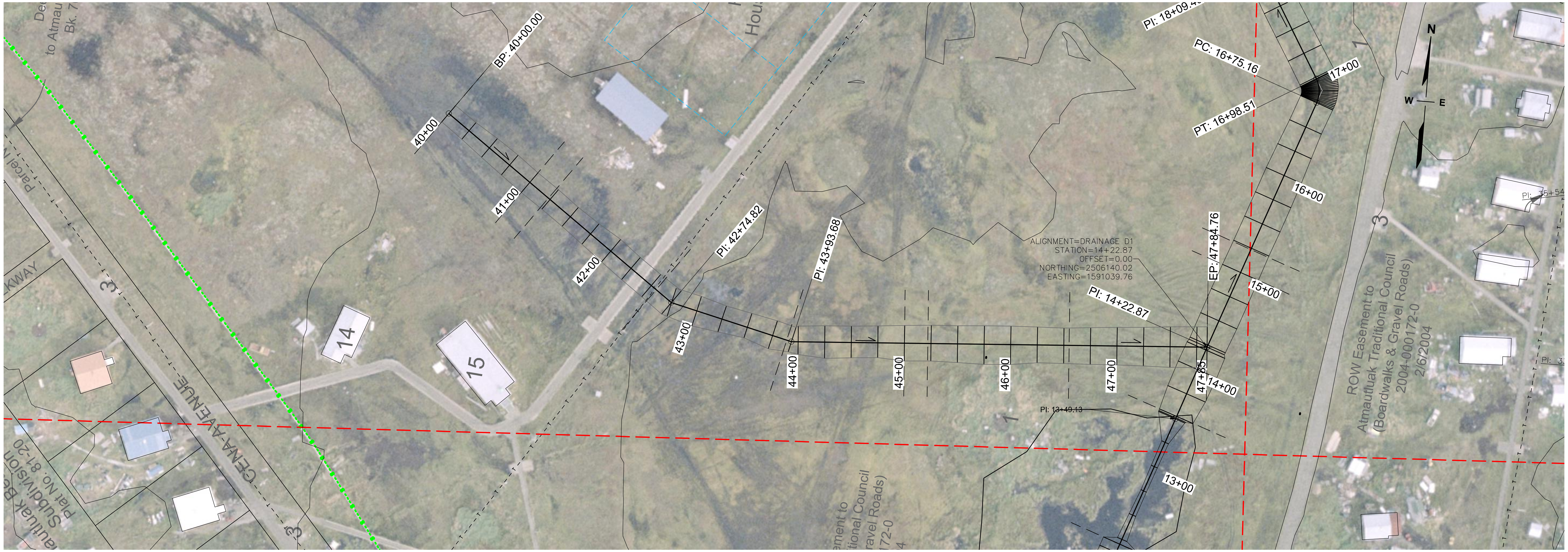

GRAPHIC SCALE
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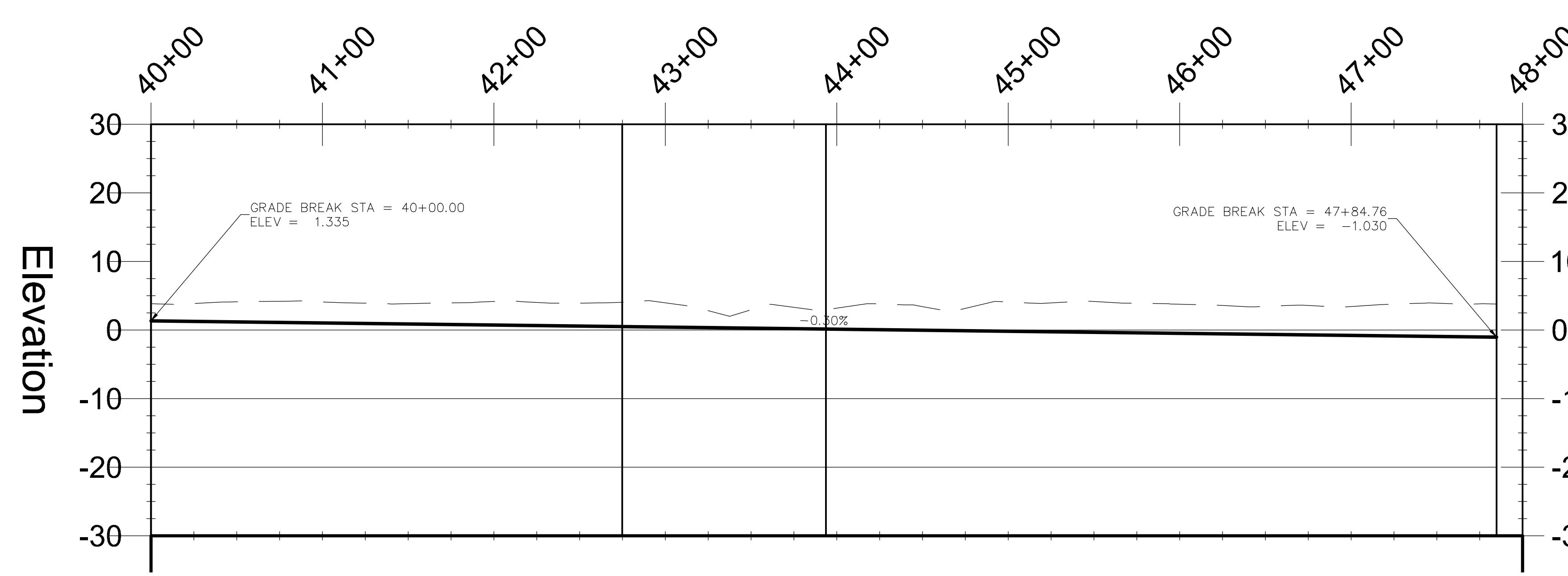
(IN FEET)

DRAINAGE D2 PLAN

NOTE: A DIGITAL TERRAIN MODEL SURFACE FOR THIS DRAWING WAS BUILT BASED ON DOWL 2015 SURVEY POINTS AND SURFACE DATA PROVIDED TO BY AEROMETRIC IN 2007 FOR THE ATMAUTLUAK COMMUNITY MAP. THE DOWL SURVEY POINTS WERE ADJUSTED BY -8.03 FEET TO MATCH THE COMMUNITY MAP SURFACE.



DRAINAGE D2 PROFILE

AECOM
700 G STREET, SUITE 500
ANCHORAGE, AK 99501
TEL: (907) 279-0543
FAX: (907) 276-7679

NO.	BY	DATE	DESCRIPTION
REVISIONS			

ATMAUTLUAK

ATMAUTLUAK HYDROLOGICAL STUDY

ATMAUTLUAK, AK

DRAINAGE PATH D2 PLAN AND PROFILE

PROJECT No:	60440368
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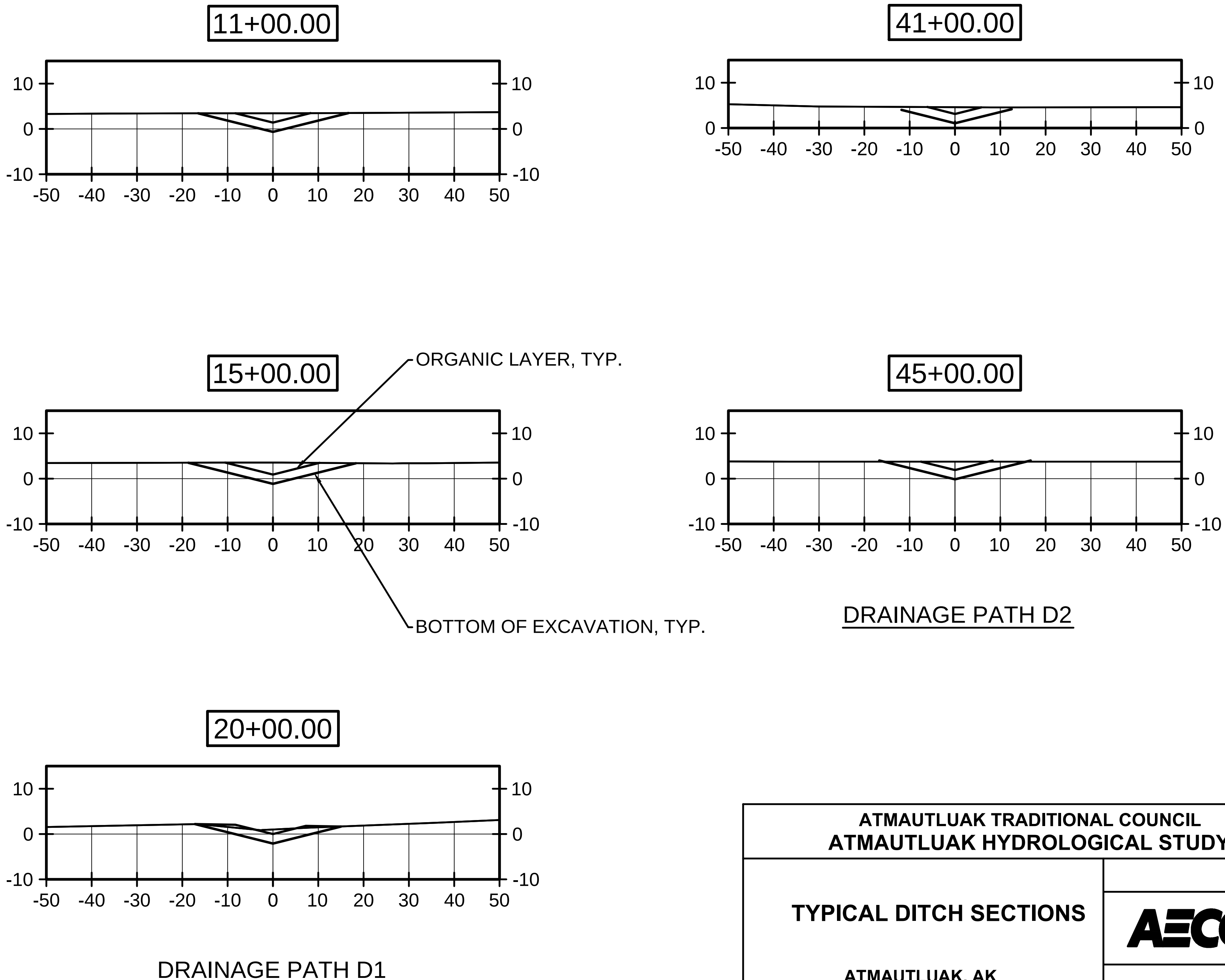

ATMAUTLUAK TRADITIONAL COUNCIL

ATMAUTLUAK HYDROLOGICAL STUDY

TYPICAL DITCH SECTIONS

ATMAUTLUAK, AK

AECOM

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DATE: 5/18/2016	FILE: ATMAUTLUAK DRAINAGE CONCEPT _DITCH5.17.DWG

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Appendix E:
Permitting Requirements

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AECOM

Atmautluak Hydrology Study

Permitting Research

April 2016

Project Scope

The purpose of the Atmautluak Hydrology Study is to determine the recurrence intervals of floods and provide a hydrological basis for the evaluation of alternatives to reduce bank erosion along the Pitmiktalik River. The purpose of the Community Drainage Plan is to identify alternatives that could drain excess surface waters to nearby lakes and rivers in order to restore natural drainage, reduce flooding of properties in spring and fall, and reduce heat transfer to underlying tundra from standing water, which could potentially decrease permafrost degradation. The scope includes a task to determine whether or not this activity would be allowed under current wetland provisions of local, state and federal law and what would actions would be required to mitigate environmental and regulatory considerations.

Natural Resources

AECOM researched publically available information on agency websites to summarize the natural resources in the vicinity of the project area. This information can be used to guide project design and evaluate potential impacts associate with project construction. A summary of AECOM's research is provided below.

AECOM consulted the U.S. Fish and Wildlife Service's (USFWS) IPaC online system[1] for a preliminary assessment of natural resources potentially impacted by the proposed project. This web application is designed to assist private citizens and public employees who need information to assist in determining how their activities may impact sensitive natural resources managed by the USFWS. Based on the IPaC Trust Resources Report generated for the project location, there are no Threatened and Endangered (T&E) species or Critical Habitat concerns. However, there are multiple species of migratory birds that could potentially be affected by activities in this area. An official species list can be obtained from the USFWS during project permitting.

AECOM reviewed USFWS National Wetlands Inventory (NWI) mapping[2] to verify the presence of wetlands in the project area. Unfortunately, there is no NWI mapping for area. It does appear however, based on aerial photography review, that wetlands are present in the project

[1] USFWS IPaC: http://ecos.fws.gov/ipac/

[2] USFWS NWI Mapping: http://www.fws.gov/wetlands/Data/Mapper.html

area. An onsite delineation of wetlands may help expedite project permitting (see further discussion under the permitting section).

The Alaska Department of Fish and Game (AD&G) Fish Resource Monitor[3] was viewed to identify anadromous water bodies in the vicinity of the project. According to these maps, there are two anadromous water bodies in the vicinity of the project area: Nunavakanukakslak Lake (AWC Code: 335-10-16600-2197-0040) and Pikmiktalik River (AWC Code: 335-10-16600-2197-3115).

The Office of History and Archaeology maintains a data repository called the Alaska Heritage Resources Survey (AHRS) with information on reported cultural resources in Alaska[4]. AECOM was granted permission to use the AHRS Mapper to identify the presence or absence of reported cultural resource sites in the vicinity of projects for baseline research. According to the AHRS Mapper, there are no reported sites within the Atmautluak project vicinity. However, the absence of reported cultural sites may simply mean that no surveys have been conducted in the project location (see further discussion under the permitting section).

The National Marine Fisheries Service provides an Essential Fish Habitat (EFH) Mapper[5] as an online tool for the public to identify habitats specified as necessary to fish for spawning, breeding, feeding or growth to maturity. According to the EFH mapper, there are no Habitat Areas of Particular Concern but the Pitmiktalik River was identified as EFH for all five salmon species for Pitmiktalik River.

Permitting

The following permits / agency consultation would likely be required for construction of a drainage project in Atmautluak and a bank erosion project along the Pitmiktalik River. Permitting of chosen alternatives would occur after the final designs are in advanced stages and prior to construction. Other permits in addition to the ones listed below could be required once the scope of the project is fully defined.

- U.S. Army Corps of Engineers Department of the Army Permit and National Environmental Policy Act
- Consultation for T&E species and Critical Habitat
- National Marine Fisheries Service EFH Assessment
- State Water Quality Certification
- Alaska Pollutant Discharge Elimination System Construction General Permit
- Alaska Department of Fish and Game Fish Habitat Permit

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[3] ADFG Fish Resource Monitor: http://extra.sf.adfg.state.ak.us/FishResourceMonitor/?mode=culv

[4] AHRS Mapper: https://dnr.alaska.gov/parks/oha/ahrs/ahrs.htm

[5] http://www.habitat.noaa.gov/protection/efh/efhmapper/index.html

U.S Army Corps of Engineers Department of the Army Permit and National Environmental Policy Act

The U.S Army Corps of Engineers (USACE) issues permits under the following authorities: 1) Section 404 of the Clean Water Act (CWA), which covers the discharge of dredged or fill material into waters of the U.S., including wetlands and 2) Section 10 of the Rivers and Harbors Act of 1899, which covers work in or affecting navigable water of the United States. These permits are often referred to as Department of the Army (DOA) permits. Based on aerial photo review, the project area appears to be comprised of freshwater wetlands in the vicinity of the drainage project, which would fall under Section 404 of the CWA. If the USACE determines that the Pitmiktalik River is a navigable water body, work associated bank erosion project would fall under Section 10 of the Rivers and Harbors Act. Navigable waters is defined as "those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.". Because there is no wetland mapping available for the project area, the USACE may require delineation by a wetlands professional to confirm the presence of wetlands and determine the wetlands boundary.

There are two types of DOA permits, 1) Nationwide Permit and 2) Individual Permit. The proposed project activities do not appear to fall under any of the 2012 Nationwide Permits available in Alaska; therefore, an Individual Permit would be required. A summary of the 2012 Nationwide Permits can be found at:
http://www.poa.usace.army.mil/Portals/34/docs/regulatory/Summary_Table_2012%20NWPs_14%20Feb%202012.pdf

There are three primary steps to the Individual Permit process:

1) Pre-application (Optional). Meeting between the applicant, USACE, and resource agencies (Federal. State, or local) prior to submittal of a written application. The basic purpose of the Pre-application meeting is to facilitate discussions about a proposed activity before the applicant makes irreversible commitments of resources (funds, detailed design, etc.) The pre-application process is intended to provide the applicant with an assessment of the viability of some of the more obvious alternatives available to accomplish the project purpose, to discuss measures for reducing the impacts of the project, and to inform the applicant of factors the USACE must consider in it decision-making process. 2) Formal Review. After USACE receives a written application they will determine if the application is complete. Additional information may be requested if the application is determined incomplete. Once the application is determined complete the USACE will begin their formal review. During the formal review USACE determines if they have authority over project activities and issues a Public Notice to initiate public review. As discussed above, the USACE may require the applicant to conduct a wetland delineation by a wetlands professional in order to make their Jurisdictional Determination. They may also request that the consultant prepare a preliminary jurisdictional determination.

3) Evaluation and Decision. During this time the USACE will evaluate the environmental impacts of the proposed project and all public comments received during the public comment period. USACE will explain its decision in a decision document. This document may include a

Categorical Exclusion, an Environmental Assessment (EA), Environmental Impact Statement (EIS), a statement of findings or record of decision, a section 404(b)(1) guidelines evaluation (if necessary), and a public interest review evaluation. The USACE's decision to issue or deny the permit is usually made within 120 days of receipt of application.

DOA application materials include:

- Written Application – Form ENG 4345. Includes information on the project location, description, purpose and need of the project, type of discharge, and surface area and volume of fill material.
- Mitigation Statement – statement to demonstrate how impacts to US waters and wetlands will be avoided, minimized, and compensated. The mitigation statement needs to be submitted with the written application. Information on applicant mitigation statements can be found at: http://www.poa.usace.army.mil/Portals/34/docs/regulatory/applicantproposedmitigationstatements.pdf.
- Project/Property Location Map – overhead view of property that shows where proposed project will be built. Include landmarks, useful features, property boundaries, proposed project boundaries, MTSR, and latitude / longitude.
- Project Plan View – Drawing to show the plan view of the proposed project, including details and dimensions of the proposed project (e.g., length, width, fill dimension and volumes).
- Project Cross-Section View – Drawing showing the cross section of proposed project. Include all dimensions and quantities associated with the proposed project.

National Environmental Policy Act:

The National Environmental Policy Act (NEPA) of 1969 requires that prospective impacts of projects be understood and disclosed prior to a Federal agency issuing a permit or providing funding for a project. If the significance of environmental impacts from the proposed action is not clearly established and the activities do not fall under a list of categorically excluded actions from NEPA, the USACE as the lead permitting agency, will need to prepare an EA and may require the applicant to provide appropriate information necessary for the preparation of the EA. The purpose of the EA is to determine if the project will cause significant effects. If the EA concludes that no significant impacts will occur, a Finding of No Significant Impact is prepared and is used to support USACE's permit decision. In the unlikely event that the EA for the proposed activity identifies significant impacts, an EIS would be required.

Preliminary discussions with USACE in 2016 indicated that a small EA would probably be required for a river bank erosion revetment project (sheet pile walls, or articulating concrete block matting, etc.) or a community drainage project.

DOA Permit strategy:

An informal pre-application meeting with the USACE Regulatory Division and appropriate resource agencies would be beneficial to discuss the proposed project prior to submitting an application. During the pre-application meeting the applicant can seek regulatory input regarding potential environmental impacts, ways to reduce or minimize impacts, and determine if any studies, data, or analyses are needed to support the permitting effort (e.g., wetlands delineation and data to support an EA, as necessary).

The project area falls within the North Section which is coordinated through the Alaska District Office located on JBER in Anchorage. Contact information is provided below:

Alaska District Office
P.O. Box 6898
JBER, Alaska 99506-0898
(907) 753-2712

The Purpose and Need (P&N) for the project needs to be well crafted. Incorporating a safety component provides a strong case for permitting. An alternative analysis summary can also helpful to demonstrate how the proposed design was selected and ideally that it is has the least environmental impact. It will also be important to demonstrate that construction of the drainage project will not cause a complete loss of wetlands (i.e., not draining the wetlands) and that the proposed drainage project will be restoring the area to its natural drainage; if this is the case.

The mitigation statement is another key component of the permit application. Some initial thoughts on mitigation are provided below for future discussion.

Avoidance – the area appears to be all wetland so avoidance may not be possible. A discussion of negative effects that could result with no action (i.e., increasing thaw bulb due to ponding water and continued bank erosion) may be helpful to stress the need for the project.

Minimization – If possible, the applicant should demonstrate that the project footprint has been minimized to the maximum extent. A discussion of other alternatives considered may also be helpful if there are alternatives with greater impacts that were eliminated or if there are alternatives with less impacts that are not feasible (i.e., drainage culverts that have failed).

Compensation – Compensatory mitigation means, for the purposes of the USACE regulatory program, the restoration, establishment, enhancement, or protection/maintenance of wetlands and/or other aquatic resources for the purpose of compensating for unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization have been achieved. If possible, demonstration that the project would enhance aquatic habitat (i.e., by restoring natural drainage and mitigating continued bank erosion) could be used as a starting proposal for compensatory mitigation. However, typically unavoidable impacts are required to be mitigated at a 2:1 (or greater) ratio of mitigation to direct impacts.

Consultation for T&E Species and Critical Habitat

The Endangered Species Act requires Federal agencies to consult with the USFWS and the National Marine Fisheries Service (NMFS), as appropriate, if any activity that requires Federal authorization may affect T&E species and critical habitat. The USACE, as the Federal permitting agency, will make a determination on the effect the proposed project may have on any listed (or proposed) T&E species and their critical habitat and determine the appropriate consultation with the USFWS and NMFS. Based on AECOM's preliminary research, there are no T&E species or Critical Habitat in the vicinity of the project; therefore, formal consultation is not expected. However, USACE will coordinate with all applicable resource agencies during the public comment period of the DOA permit and any comments that the USFWS and NMFS may have concerning T&E species and Critical Habitat will be considered in their final assessment.

Essential Fish Habitat Assessment

The Magnuson-Stevens Fishery Conservation and Management Act requires the identification of EFH, which is defined as waters necessary for fish for spawning, breeding, feeding, or growth to maturity. This law requires Federal agencies to consult with the NMFS on proposed actions that are permitted, funded, or undertaken by the agency that may adversely affect EFH. USACE, as the Federal permitting agency, will assess potential project impacts to EFH and consult with the NMFS during the DOA permitting process. If the USACE determines that project activities may adversely affect EFH, an EFH Assessment would be required. The EFH Assessment provides information to the NMFS on the potential affects to EFH and ways to minimize any adverse effect. Any comments or EFH conservation recommendations that the NMFS may have will be considered in the USACE's final permit decision and special conditions may be added to the DOA permit to minimize project impacts to EFH. Based on AECOM's preliminary research, the Pikmiktalik River may provide EFH to Federally-managed salmon fisheries (based on the EFH mapper). However, the ADFG Fish Resource Monitor only identifies the presence of Sheefish and Whitefish for Pikmiktalik River. AECOM recommends contacting the NMFS once the design for Pitmiktalik River bank stabilization is complete to discuss the project and the verify the EFH mapping for this stretch of the river.

State Water Quality Certification

Any applicant for a federal license or permit to conduct an activity that might result in a discharge into navigable waters, in accordance with Section 401 of the Clean Water Act of 1977, also must apply for and obtain a certification from the ADEC stating that the discharge will comply with the Clean Water Act, the Alaska Water Quality Standards, and other applicable State laws. By agreement between the USACE and ADEC, application for the DOA permit also serves as application for the State Water Quality Certification. The USACE will coordinate with ADEC to obtain the certification prior to issuing the DOA permit. As necessary, special conditions may be added to the DOA permit and/or water quality certification to ensure water quality standards are met.

Alaska Pollutant Discharge Elimination System Construction General Permit

If the project footprint (e.g., ground disturbance) is greater than one acre, coverage under the ADEC's Alaska Pollutant Discharge Elimination System Construction General Permit (CGP) will be required. To obtain coverage under the CGP the operator will need to file a Notice of Intent and prepare a Stormwater Pollution Prevention Plan prior to commencing construction. The goal of the CGP is to minimize erosion and reduce or eliminate the discharge of pollutants, such as sediments carried in storm water runoff from construction sites through implementation of appropriate control measures. Instructions for filing an NOI and preparing a SWPPP can be found at: http://dec.alaska.gov/water/wnpspc/stormwater/sw_construction.htm.

ADFG Fish Habitat Permit

ADFG has the statutory responsibility for protecting freshwater anadromous fish habitat and providing free passage for anadromous and resident fish in fresh water bodies. Any activity or project that is conducted below the ordinary high water mark of an anadromous stream requires a Fish Habitat Permit (FHP). FHPs are required for the following activities:

- construct a hydraulic project, or
- use, divert, obstruct, pollute, or change the natural flow or bed of a specified river, lake, or stream, or
- use wheeled, tracked, or excavating equipment or log-dragging equipment in the bed of a specified river, lake, or stream.

The two anadromous water bodies present in the project vicinity are the Nunavakanukakslak Lake and Pikmiktalik River. Depending on the final design of the drainage project a FHP may be required. The boundary of Nunavakanukakslak Lake was unclear from the ADFG mapper so AECOM recommends contacting the ADFG once the drainage design is complete to discuss the project and determine if a FHP will be required. Any work below the ordinary high water mark of Pikmiktalik River associated with the bank erosion project will require a FHP. FHPs generally take 30-60 days to process. Instructions for completing a Fish Habitat Permit application can be found at: http://www.adfg.alaska.gov/index.cfm?adfg=uselicense.main.

Cultural Resources

Section 106 of the National Historic Preservation Act requires the USACE to take into account the effects that activities authorized by DOA permits are likely to have on historic properties. USACE as the lead permitting agency will consult the latest published version of the AHRS for the presence or absence of historic properties and will coordinate with the State Historic Preservation Office (SHPO) during the DOA permitting process. Any comments that SHPO may have concerning presently known archaeological or historic data that may be lost or destroyed by work under the DOA permit will be considered in their final assessment. Based on AECOM's research, there are no reported cultural resource sites around Atmautluak. However, the absence of reported cultural sites may simply mean that no surveys have been conducted in the project location. Although unlikely, that the SHPO may require an evaluation of the project area by a cultural resource professional to identify potential historic properties that could be affected by the proposed project. The need for a reconnaissance survey would depend on the project area's prehistory and history and the likelihood for cultural/historic resources to be present in the project area.

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Appendix F:
Cost Estimates

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Sheet Pile Wall Alternative Cost Estimate

Item Description	Unit	Unit Cost	Quantity	Cost $	Comments
Sheet Pile Wall - Furnish and Install	sf	30	141,200	4,284,290	Scaled down cost from $65 per sf for 25 lb/sf wall
Gravel Ramps	CY	160	200	32,000	Unit cost based on $132/cy materials delivered from Platinum, plus $28/cy to install
Contingency				1,079,073	25%
Mobilization/Demobilization				500,000	
Sub-Total Estimated Construction Costs				*$5,895,363*	
Engineering, Permiting, Geotech				*100,000*	
Sub-Total Estimated Engineering Costs				*$100,000*	
Total Estimated Cost				**$5,995,363**	
$/Linear Foot				**$1,698.40**	

Notes : 1. Quantities above based on autocad measurements
2. Includes wall along river front (3060 ft), and two locations on lake on west side of community (3530 feet total)
3. 35 foot embedment of piles
4. Shipping cost =$.3 per pound, purchase price for steel = $.8 per pound FOB Seattle

Maintenance

Epoxy Coating	sf	45	10500	$472,500	Unit cost from Ketchikan Shipyard CP project 2102, area assumes 3 feet high x length of wall
Anodes	ea	500	350	$175,000	Unit cost from Ketchikan Shipyard CP project 2103, 350 anodes (every 10 feet)
Mob				$50,000	
Contingency 15%				$97,125	
Total				**$794,625**	

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ACB Matting Alternative Cost Estimate

Item Description	Unit	Unit Cost	Quantity	Cost $	Comments
Excavation	CY	20	8,000	160,000	Unit cost based on ADOT&PF bid tabs
Temporary Cofferdam	LS	100,000	1	100,000	Lump sum estimate
Geotextile Fabric - Furnish and Install	YD^2	2	11,000	22,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Granular Fill (Borrow)	CY	160	4,000	640,000	Unit cost based on $132/cy materials delivered from Platinum, plus $28/cy to install
Geogrid - Furnish and Install	YD^2	6	11,000	70,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
ACB- Furnish and Install	YD^2	185	11,000	2,040,000	Unit cost includes $170/sq yd for procuement and shipping and $15/sq yd for placement
Top Soil Above Waterline	CY	20	2,700	54,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Seeding	lb	70	200	14,000	Unit cost based on ADOT&PF bid tabs, assumes 2lbs per 1000 sf
Granular Fill Below Waterline	CY	160	1,400	224,000	See above
Contingency				831,000	25%
Mobilization/Demobilization				100,000	
		Sub-Total Estimated Construction Costs		*$4,255,000*	
Engineering, Permiting, Geotech				*200,000*	
		Sub-Total Estimated Engineering Costs		*$200,000*	
		Total Estimated Cost		**$4,455,000**	
		$/Linear Foot		**$1,262.04**	

Notes : 1. Quantities above based on autocad measurements
2. Includes ACB along river fron (3060 ft), and two locations on lake on west side of community (3530 feet total)

Maintnance Cost

Repair 10% of ACB				$332,400	Assume 10% of ACB Area
Mobilization/Demobilization				$50,000	
Total				**$382,400**	**Round to $350,000**

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Cellular Confinement System (CCS) Alternative Cost Estimate

Item Description	Unit	Unit Cost	Quantity	Cost $	Comments
Excavation	CY	20	8,000	160,000	Unit cost based on ADOT&PF bid tabs
Temporary Cofferdam	LS	100,000	1	100,000	Lump sum estimate
Geotextile Fabric - Furnish and Install	YD^2	2	11,000	22,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Granular Fill (Borrow)	CY	160	2,700	432,000	Unit cost based on $132/cy materials delivered from Platinum, plus $28/cy to install
CSS- Furnish and Install	YD^2	30	11,000	330,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Top Soil Above Waterline	CY	20	2,700	54,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Seeding	lb	70	200	14,000	Assumes 2lbs per 1000 sf
Concrete Slurry	LS			350,000	Purchase & ship cement = $180k; $80k import aggregate; 150 crew hours to mix & pour $75k
Contingency				365,500	25%
Mobilization/Demobilization				100,000	
Sub-Total Estimated Construction Costs				*$1,927,500*	
Engineering, Permiting, Geotech				*100,000*	
Sub-Total Estimated Engineering Costs				*$100,000*	
Total Estimated Cost				**$2,027,500**	
$/foot				$574.36	

Notes : 1. Quantities above based on autocad measurements
2. Includes CCS along river fron (3060 ft), and two locations on lake on west side of community (3530 feet total)

Maintnance Cost

Repair 10% of CSS		$438,600	Assume 30% of ACB Area
Mobilization/Demobilization		$50,000	
Total		**$488,600**	Round to $500,000

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ACB Matting Alternative Phase I Cost Estimate

Base Bid Riverfront-South End of Community = 1450 LF

Item Description	Unit	Unit Cost	Quantity	Cost $	Comments
Excavation	CY	20	4,000	80,000	Unit cost based on ADOT&PF bid tabs
Temporary Cofferdam	LS	100,000	1	100,000	Lump sum estimate
Geotextile Fabric - Furnish and Install	YD^2	2	5,000	10,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Granular Fill (Borrow)	CY	160	1,700	272,000	Unit cost based on $132/cy materials delivered from Platinum, plus $28/cy to install
Geogrid - Furnish and Install	YD^2	6	5,000	30,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
ACB- Furnish and Install	YD^2	185	5,000	930,000	Unit cost includes $170/sq yd for procuement and shipping and $15/sq yd for placement
Top Soil Above Waterline	CY	20	1,100	22,000	Unit cost based on ADOT&PF bid tabs (Kipnuk)
Seeding	lb	70	100	7,000	Unit cost based on ADOT&PF bid tabs, assumes 2lbs per 1000 sf
Granular Fill Below Waterline	CY	160	600	96,000	See above
Contingency				386,750	25%
Mobilization/Demobilization				100,000	
Sub-Total Estimated Construction Costs				*$2,033,750*	
Engineering, Permiting, Geotech				*200,000*	
Sub-Total Estimated Engineering Costs				*$200,000*	
Total Estimated Cost				**$2,233,750**	
$/Linear Foot				$1,540.52	

ACB Matting Additive Alternates

Additive Alternates, Cost Per Foot				$1,334	Equals above costs, minus mobilization/engineering/permitting/ divided by 1450 ft (includes 25% contingency
				Cost	
Additive Alternate #1 Lake (West) Length =	290	ft		**$390,000**	Equals cost per foot x length
Additive Alternate #2 Lake (East) length =	180	ft		**$240,000**	Equals cost per foot x length
Additive Alternate #3 River (middle) length =	200	ft		**$270,000**	Equals cost per foot x length
Additive Alternate # 4 River (north) length =	160	ft		**$210,000**	Equals cost per foot x length

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Drainage Swale Alternative Cost Estimate

Item Description	Unit	Jnit Cos	Quantity	Cost $	Comments
Excavation	CY	20	4,500	90,000	Unit cost based on ADOT&PF bid tabs
Backfill (Top Soiling)	CY	20	3600	72,000	80% of excavated material
Seeding	lb	70	240	16,800	2 lbs per 1000 sf
Elevated Boardwalk	EA	30000	3	90,000	Unit cost based on ADOT&PF bid tabs, Kipnuk Boardwalk
Contingency				67,200	25%
Mobilization/Demobilization				100,000	
Sub-Total Estimated Construction Costs				*$436,000*	
Engineering, Permiting, Geotech				*50,000*	
Total Estimated Cost				***$486,000***	

Note: Quantites measured from autocad drawing

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Appendix G:
DOWL Survey Control, Discharge Reports, and River Cross Sections

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DOWL AUGUST 2015
CONTROL POINT LISTING
ATMAUTLUAK ENGINEERING ANALYSIS
ATMAUTLUAK, ALASKA

Control Monuments used this Survey

ID	Northing	Easting	Elevation	Description	Survey Point #
ARS-1	2504877.77	1590959.44	14.383	ALCAP	1
HV-1	2508293.83	1591395.96	16.87	SS Rod	551
TBM-601	2505659	1590314	16.11	NE Bolt	601

Horizontal Control

Coordinates are NAD83(2011) (EPOCH 2010.0000) Alaska State Plane Zone 7, expressed in U.S. Survey Feet. Coordinates were determined by the National Geodetic Survey Online Positioning User Service (NGS OPUS). HV-1 is located approximately 800' north of airport equipment building near NW corner of apron; ARS-1 is located approximately140 feet south of Post Office. TBM-601 is located approximately 120 feet west of Pig Lake.

Vertical Control

Elevations are NAVD88 Orthometric Heights expressed in U.S. Survey Feet as determined by the National Geodetic Survey Online Positioning User Service (NGS OPUS) at station "ARS-1" using Geoid-12A modeling.TBM 601 is the north-east bolt on the north-east leg of the antennae tower on the west side of Atmautluak.

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CROSS SECTION POINT LISTING
ATMAUTLUAK ENGINEERING ANALYSIS
ATMAUTLUAK, ALASKA

Cross Section 1

Survey Point #	Northing	Easting	Elevation	Description
6141	2511746.54	1593498.09	5.55	GS/
6142	2511751.37	1593490.36	5.20	GS/
6143	2511756.46	1593485.25	5.06	GS/
6144	2511759.68	1593475.33	4.92	GS/
6145	2511762.83	1593461.98	4.16	GS/
6146	2511744.54	1593502.43	5.99	GS/
6147	2511745.96	1593512.37	6.83	EW
6148	2511747.61	1593521.41	7.58	GS/
6149	2511746.57	1593542.90	7.73	VEG
6150	2511738.16	1593586.64	7.82	GS/
6151	2511735.52	1593613.10	7.71	GS/
6152	2511729.75	1593647.59	7.82	GS/
6153	2511722.31	1593668.04	8.15	GS/
6154	2511714.76	1593712.84	8.09	GS/
6155	2511716.62	1593759.19	7.85	GS/
6156	2511799.59	1593176.35	7.00	EW
6157	2511794.24	1593184.64	5.88	GS/
6158	2511791.38	1593200.77	5.02	GS/
6159	2511786.68	1593212.58	4.87	GS/
6160	2511785.62	1593223.28	4.98	GS/
6161	2511788.93	1593233.84	4.89	GS/
6162	2511790.38	1593244.69	4.70	GS/
6163	2511791.67	1593256.11	4.46	GS/
6164	2511803.33	1593170.89	8.06	GS/
6165	2511806.66	1593162.28	9.03	GS/
6166	2511806.82	1593158.30	8.30	VEG
6167	2511816.28	1593119.39	8.64	GS/
6168	2511824.99	1593081.75	8.24	GS/
6169	2511821.78	1593052.69	7.50	GS/
6170	2511822.57	1593007.32	7.63	GS/
6171	2511825.54	1592953.90	7.65	GS/
6172	2511823.10	1592907.79	8.47	GS/
6173	2511836.20	1592855.81	7.32	GS/
6174	2511840.93	1592808.95	8.19	GS/
6175	2511838.29	1592755.09	8.05	GS/
6176	2511826.48	1592697.65	7.16	GS/
6177	2511820.01	1592657.17	7.33	GS/
6178	2511816.63	1592647.49	13.15	GS/
6179	2511812.75	1592617.77	14.31	GS/
8881	2511791.77	1593264.54	4.33	SOUN
8882	2511790.21	1593268.15	3.91	SOUN
8883	2511789.69	1593272.70	2.23	SOUN
8884	2511787.43	1593276.28	1.64	SOUN

8885	2511784.74	1593279.90	1.20	SOUN
8886	2511781.67	1593283.29	0.76	SOUN
8887	2511779.48	1593286.93	0.36	SOUN
8888	2511777.90	1593290.53	-0.12	SOUN
8889	2511776.81	1593294.03	-0.71	SOUN
8890	2511776.13	1593297.70	-1.32	SOUN
8891	2511775.30	1593301.69	-2.05	SOUN
8892	2511773.98	1593306.32	-2.98	SOUN
8893	2511772.79	1593310.56	-3.51	SOUN
8894	2511772.21	1593315.05	-3.92	SOUN
8895	2511771.95	1593319.38	-4.10	SOUN
8896	2511772.26	1593324.26	-4.05	SOUN
8897	2511771.85	1593329.36	-4.26	SOUN
8898	2511771.20	1593334.18	-4.81	SOUN
8899	2511771.17	1593338.79	-5.28	SOUN
8900	2511771.44	1593343.81	-5.07	SOUN
8901	2511771.85	1593348.83	-4.43	SOUN
8902	2511772.37	1593353.75	-3.84	SOUN
8903	2511773.22	1593358.59	-3.46	SOUN
8904	2511773.88	1593363.46	-3.65	SOUN
8905	2511774.19	1593368.43	-3.90	SOUN
8906	2511774.18	1593373.51	-4.30	SOUN
8907	2511774.30	1593378.43	-4.33	SOUN
8908	2511774.25	1593383.56	-4.32	SOUN
8909	2511773.91	1593388.57	-4.32	SOUN
8910	2511773.56	1593393.76	-4.17	SOUN
8911	2511773.15	1593398.76	-3.89	SOUN
8912	2511772.48	1593403.93	-3.47	SOUN
8913	2511771.95	1593409.08	-3.03	SOUN
8914	2511771.09	1593414.35	-2.42	SOUN
8915	2511769.72	1593419.53	-1.87	SOUN
8916	2511768.59	1593424.74	-1.33	SOUN
8917	2511767.42	1593429.89	-0.80	SOUN
8918	2511766.54	1593434.63	-0.04	SOUN
8919	2511765.72	1593439.63	0.83	SOUN
8920	2511764.87	1593443.98	1.35	SOUN
8921	2511764.01	1593448.53	2.18	SOUN
8922	2511763.25	1593452.77	3.02	SOUN
8923	2511763.59	1593456.34	3.91	SOUN
8924	2511764.33	1593460.19	4.29	SOUN

Cross Section 2

Survey Point #	Northing	Easting	Elevation	Description
6180	2509363.41	1594239.72	6.95	EW
6181	2509364.03	1594240.67	7.80	VEG

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6182	2509362.90	1594233.45	5.37	GS/
6183	2509361.41	1594226.25	4.82	GS/
6184	2509359.85	1594214.05	4.60	GS/
6185	2509356.61	1594202.29	4.12	GS/
6186	2509369.86	1594252.99	7.73	GS/
6187	2509378.74	1594279.50	8.13	GS/
6188	2509376.90	1594286.90	11.23	GS/
6189	2509385.15	1594323.19	11.68	GS/
6190	2509386.79	1594372.64	11.26	GS/
6191	2509389.75	1594424.50	12.30	GS/
6192	2509399.44	1594481.40	12.14	GS/
6193	2509394.04	1594537.96	12.03	GS/
6194	2509318.41	1593960.63	6.76	EW
6195	2509319.96	1593968.09	5.59	GS/
6196	2509322.85	1593979.52	5.31	GS/
6197	2509325.12	1593996.40	4.83	GS/
6198	2509327.62	1594011.75	4.72	GS/
6199	2509331.62	1594026.41	4.25	GS/
6200	2509317.38	1593948.56	8.27	GS/
6201	2509310.31	1593901.82	8.13	GS/
6202	2509304.78	1593852.53	7.54	GS/
6203	2509290.72	1593803.15	7.51	GS/
6204	2509285.08	1593753.71	7.37	GS/
6205	2509271.98	1593696.57	8.13	GS/
6206	2509267.53	1593641.09	7.42	GS/
6207	2509251.77	1593592.74	7.41	GS/
6208	2509238.67	1593545.58	7.54	GS/
6209	2509231.34	1593497.52	7.33	GS/
6210	2509225.80	1593447.84	7.04	GS/
6211	2509218.07	1593414.21	6.72	GS/
6212	2509213.72	1593394.92	4.68	GS/
8737	2509327.30	1594014.70	4.59	SOUN
8738	2509327.36	1594018.12	4.25	SOUN
8739	2509327.52	1594021.70	4.43	SOUN
8740	2509327.87	1594025.27	3.88	SOUN
8741	2509328.62	1594028.81	4.39	SOUN
8742	2509328.80	1594032.93	4.66	SOUN
8743	2509328.92	1594037.29	3.63	SOUN
8744	2509329.05	1594041.88	2.62	SOUN
8745	2509329.49	1594046.58	1.80	SOUN
8746	2509329.99	1594051.24	1.02	SOUN
8747	2509330.76	1594055.75	-0.31	SOUN
8748	2509331.81	1594060.39	-2.82	SOUN
8749	2509332.22	1594064.98	-5.75	SOUN
8750	2509332.74	1594069.71	-6.70	SOUN
8751	2509333.11	1594075.02	-7.84	SOUN

8752	2509333.24	1594080.16	-8.57	SOUN
8753	2509333.57	1594085.71	-8.73	SOUN
8754	2509333.76	1594091.11	-8.62	SOUN
8755	2509334.13	1594095.93	-8.44	SOUN
8756	2509334.97	1594100.71	-8.06	SOUN
8757	2509335.84	1594105.63	-7.80	SOUN
8758	2509336.42	1594110.74	-7.36	SOUN
8759	2509336.79	1594115.83	-6.78	SOUN
8760	2509337.19	1594121.26	-6.27	SOUN
8761	2509337.56	1594126.57	-5.85	SOUN
8762	2509338.65	1594132.15	-5.36	SOUN
8763	2509339.20	1594137.64	-4.68	SOUN
8764	2509339.74	1594142.70	-3.96	SOUN
8765	2509341.02	1594147.97	-3.23	SOUN
8766	2509342.40	1594153.16	-2.15	SOUN
8767	2509343.70	1594158.30	-0.92	SOUN
8768	2509345.06	1594163.43	0.00	SOUN
8769	2509346.38	1594168.70	0.60	SOUN
8770	2509347.74	1594173.67	1.13	SOUN
8771	2509349.48	1594178.71	1.44	SOUN
8772	2509351.49	1594182.70	1.70	SOUN
8773	2509353.60	1594186.20	2.20	SOUN
8774	2509355.87	1594189.79	2.63	SOUN
8775	2509357.94	1594193.26	3.08	SOUN
8776	2509360.00	1594196.73	3.30	SOUN
8777	2509362.06	1594200.20	4.11	SOUN

Cross Section 3

Survey Point #	Northing	Easting	Elevation	Description
6021	2507045.27	1591784.40	8.09	EW
6022	2507045.70	1591789.78	6.70	VEG
6023	2507045.69	1591792.15	5.54	GS/
6024	2507043.23	1591799.94	5.57	GS/
6025	2507034.03	1591808.36	5.21	GS/
6026	2507027.80	1591824.52	5.06	GS/
6027	2507020.48	1591837.48	4.80	GS/
6028	2507017.22	1591843.74	4.28	GS/
6029	2507056.47	1591765.56	8.46	GS/
6030	2507071.81	1591730.52	9.04	GS/
6031	2507092.01	1591686.51	10.82	GS/
6032	2507114.94	1591642.58	11.89	GS/
6033	2507136.36	1591597.21	12.63	GS/
6034	2507156.92	1591555.76	12.97	GS/
6035	2507163.76	1591539.48	13.27	GS/
6036	2507165.53	1591535.67	12.48	GS/

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6037	2507184.58	1591490.86	11.72	GS/
6038	2507201.23	1591451.43	11.35	GS/
6039	2507205.44	1591443.28	9.04	GS/
6040	2507209.03	1591433.73	11.38	GS/
6041	2507226.32	1591398.43	9.35	GS/
6042	2507228.78	1591395.89	8.44	GS/
6043	2507242.92	1591365.54	8.34	GS/
6044	2507259.69	1591332.71	8.43	GS/
6045	2507275.98	1591296.40	7.95	GS/
6046	2507291.52	1591261.83	8.15	GS/
6047	2507303.28	1591231.17	8.54	GS/
6048	2507328.90	1591179.77	8.72	GS/
6049	2507346.01	1591139.35	8.84	GS/
6050	2507364.06	1591093.98	8.46	GS/
6051	2507386.26	1591046.87	8.73	GS/
6052	2507409.27	1591000.29	8.47	GS/
6053	2507428.78	1590956.12	7.37	GS/
6054	2507433.84	1590948.42	6.56	EW
6055	2507439.41	1590935.33	4.49	GS/
6056	2507455.37	1590905.38	4.05	GS/
6057	2507470.69	1590871.28	3.97	GS/
6058	2507484.26	1590841.19	3.82	GS/
6059	2507497.69	1590808.71	3.64	GS/
6060	2507510.97	1590777.06	4.27	GS/
6061	2507527.29	1590750.33	4.30	GS/
6062	2507542.80	1590724.62	4.47	GS/
6063	2507549.70	1590712.19	4.83	GS/
6064	2507551.11	1590705.32	6.77	EW
6065	2507564.44	1590677.35	7.19	GS/
6066	2507577.25	1590648.33	6.91	GS/
6067	2507596.13	1590607.92	7.28	GS/
6068	2507617.66	1590570.36	6.76	GS/
6069	2507638.87	1590530.69	7.28	GS/
6070	2507653.63	1590488.59	7.11	GS/
6071	2507673.98	1590452.52	7.40	GS/
6072	2507681.97	1590443.00	6.65	EW
6213	2506862.94	1592169.19	9.07	VEG
6214	2506864.27	1592167.59	6.73	EW
6215	2506865.82	1592164.07	4.01	GS/
6216	2506867.41	1592160.87	2.55	GS/
6217	2506868.29	1592160.42	2.07	GS/
6218	2506853.44	1592185.65	7.81	GS/
6219	2506844.66	1592230.45	8.41	GS/
6220	2506832.90	1592259.66	8.85	GS/
6221	2506813.76	1592304.76	8.82	GS/
6222	2506785.17	1592363.69	8.39	GS/

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6223	2506762.62	1592408.40	8.09	GS/
6224	2506745.15	1592453.43	7.79	GS/
6225	2506723.36	1592493.86	8.66	GS/
6226	2506701.46	1592530.62	7.67	GS/
6227	2506673.83	1592569.49	8.08	GS/
6228	2506660.22	1592594.47	7.87	GS/
8634	2507018.79	1591840.46	4.48	SOUN
8635	2507016.72	1591844.65	4.41	SOUN
8636	2507014.18	1591849.20	2.13	SOUN
8637	2507011.46	1591853.76	1.27	SOUN
8638	2507008.98	1591858.76	0.80	SOUN
8639	2507006.81	1591864.24	1.03	SOUN
8640	2507003.59	1591869.64	1.10	SOUN
8641	2507000.65	1591874.93	1.03	SOUN
8642	2506997.63	1591880.40	0.81	SOUN
8643	2506994.65	1591885.54	0.67	SOUN
8644	2506992.00	1591891.02	0.25	SOUN
8645	2506989.77	1591896.73	-0.25	SOUN
8646	2506987.94	1591902.75	-0.77	SOUN
8647	2506984.52	1591908.29	-1.46	SOUN
8648	2506980.91	1591913.77	-2.26	SOUN
8649	2506977.13	1591918.36	-3.03	SOUN
8650	2506974.76	1591923.13	-3.52	SOUN
8651	2506972.44	1591928.13	-3.77	SOUN
8652	2506969.64	1591933.43	-4.32	SOUN
8653	2506966.43	1591939.21	-4.66	SOUN
8654	2506962.96	1591945.03	-4.57	SOUN
8655	2506959.92	1591950.11	-4.22	SOUN
8656	2506956.65	1591955.78	-3.94	SOUN
8657	2506953.36	1591961.29	-3.68	SOUN
8658	2506949.94	1591966.80	-3.48	SOUN
8659	2506947.29	1591972.46	-2.97	SOUN
8660	2506944.02	1591978.67	-2.37	SOUN
8661	2506940.53	1591984.75	-1.98	SOUN
8662	2506936.88	1591990.89	-1.84	SOUN
8663	2506933.35	1591997.02	-2.28	SOUN
8664	2506929.96	1592003.21	-4.62	SOUN
8665	2506926.60	1592009.23	-4.60	SOUN
8666	2506922.50	1592015.43	-3.02	SOUN
8667	2506918.39	1592021.62	-3.01	SOUN
8668	2506916.35	1592028.64	-3.16	SOUN
8669	2506914.21	1592035.51	-2.81	SOUN
8670	2506912.34	1592042.41	-2.11	SOUN
8671	2506910.12	1592049.37	-1.93	SOUN
8672	2506907.32	1592056.28	-1.92	SOUN
8673	2506904.37	1592062.96	-1.87	SOUN

8674	2506901.42	1592069.65	-0.74	SOUN
8675	2506898.48	1592076.33	-0.50	SOUN
8676	2506895.53	1592083.02	-0.50	SOUN
8677	2506892.59	1592089.70	-0.50	SOUN
8678	2506889.65	1592096.39	-0.50	SOUN
8679	2506886.70	1592103.07	0.44	SOUN
8680	2506885.38	1592108.31	0.62	SOUN
8681	2506883.53	1592114.03	1.06	SOUN
8682	2506882.47	1592118.33	1.55	SOUN
8683	2506881.78	1592123.29	1.84	SOUN
8684	2506880.35	1592127.25	1.96	SOUN
8685	2506878.67	1592131.19	1.66	SOUN
8686	2506877.62	1592134.65	1.19	SOUN
8687	2506876.82	1592137.59	0.68	SOUN
8688	2506875.91	1592140.35	0.43	SOUN
8689	2506874.77	1592142.81	0.24	SOUN
8690	2506873.74	1592145.25	0.14	SOUN
8691	2506873.01	1592147.70	-0.02	SOUN
8693	2506872.34	1592151.62	-0.15	SOUN
8695	2506872.27	1592154.71	0.11	SOUN
8697	2506870.99	1592157.72	0.86	SOUN
8699	2506868.20	1592161.78	1.46	SOUN

Cross Section 4

Survey Point #	Northing	Easting	Elevation	Description
5787	2505644.55	1590862.26	7.52	GS/
5790	2505626.11	1590768.96	7.72	GS/
5831	2505640.86	1590194.30	11.18	TOP03
5973	2505638.43	1590627.85	6.75	GS/
5979	2505637.11	1590438.12	7.24	GS/
5980	2505649.83	1590468.13	6.59	GS/
5991	2505630.64	1590543.29	6.45	GS/
6073	2505637.53	1590260.30	13.17	GS/
6074	2505635.85	1590299.21	13.53	GS/
6075	2505635.15	1590333.93	13.24	GS/
6076	2505637.77	1590376.03	12.82	GS/
6077	2505640.03	1590425.04	9.12	GS/
6078	2505633.73	1590900.41	11.96	GS/
6079	2505631.91	1591418.53	6.45	GS/
6080	2505632.02	1591428.55	5.68	GS/
6081	2505631.65	1591440.63	4.94	GS/
6082	2505631.36	1591449.69	4.32	GS/
6083	2505634.80	1591409.82	7.74	EW
6084	2505634.77	1591409.30	8.21	VEG
6085	2505631.13	1591395.81	10.35	GS/

6086	2505631.07	1591372.82	10.99	GS/
6087	2505632.52	1591326.01	12.56	GS/
6088	2505634.22	1591272.73	13.43	GS/
6089	2505631.36	1591222.32	13.24	GS/
6090	2505635.83	1591172.50	13.32	GS/
6091	2505633.16	1591128.62	13.62	GS/
6092	2505633.15	1591069.72	13.72	GS/
6093	2505633.59	1591023.81	13.60	GS/
6094	2505635.32	1590979.59	13.67	GS/
6095	2505634.73	1590926.78	13.15	GS/
6229	2505628.73	1591769.33	6.66	EW
6230	2505630.30	1591764.05	5.53	GS/
6231	2505631.28	1591754.90	3.99	GS/
6232	2505630.55	1591750.82	3.34	GS/
6233	2505624.74	1591780.98	7.91	GS/
6234	2505629.87	1591820.31	7.32	GS/
6235	2505629.14	1591858.26	7.52	VEG
6236	2505624.71	1591896.31	8.71	GS/
6237	2505620.03	1591942.08	9.24	GS/
6238	2505609.22	1591982.76	8.89	GS/
6239	2505614.61	1592027.21	8.86	GS/
6240	2505618.89	1592064.86	8.74	GS/
6241	2505626.30	1592109.01	7.69	GS/
8483	2505630.23	1591454.68	4.07	SOUN
8484	2505630.59	1591457.19	3.85	SOUN
8485	2505630.58	1591460.20	3.62	SOUN
8486	2505631.42	1591462.97	3.39	SOUN
8487	2505632.53	1591465.76	2.71	SOUN
8488	2505633.88	1591468.41	2.26	SOUN
8489	2505635.13	1591471.29	1.68	SOUN
8490	2505636.03	1591474.13	1.12	SOUN
8491	2505636.47	1591476.96	0.60	SOUN
8492	2505636.53	1591479.78	-0.03	SOUN
8493	2505636.27	1591482.72	-0.60	SOUN
8494	2505635.70	1591485.92	-0.98	SOUN
8495	2505635.32	1591489.27	-1.28	SOUN
8496	2505634.74	1591492.37	-1.54	SOUN
8497	2505634.49	1591495.71	-1.80	SOUN
8498	2505634.27	1591499.11	-2.09	SOUN
8499	2505634.66	1591503.44	-2.41	SOUN
8500	2505634.08	1591507.73	-2.76	SOUN
8501	2505633.44	1591512.06	-2.95	SOUN
8502	2505633.06	1591516.80	-3.04	SOUN
8503	2505632.92	1591521.59	-3.20	SOUN
8504	2505632.72	1591526.43	-3.31	SOUN
8505	2505633.16	1591531.73	-3.42	SOUN

8506	2505632.59	1591536.96	-3.56	SOUN
8507	2505631.78	1591541.95	-3.88	SOUN
8508	2505630.79	1591546.37	-4.06	SOUN
8509	2505630.81	1591551.16	-4.22	SOUN
8510	2505631.04	1591556.61	-4.43	SOUN
8511	2505630.74	1591562.44	-4.56	SOUN
8512	2505630.18	1591568.51	-4.66	SOUN
8513	2505629.78	1591574.80	-4.57	SOUN
8514	2505629.35	1591580.97	-4.32	SOUN
8515	2505628.31	1591587.40	-3.83	SOUN
8516	2505627.70	1591593.84	-3.13	SOUN
8517	2505627.35	1591600.01	-2.53	SOUN
8518	2505627.83	1591606.37	-1.89	SOUN
8519	2505628.12	1591612.14	-1.09	SOUN
8520	2505628.61	1591618.23	-0.19	SOUN
8521	2505629.31	1591624.32	0.40	SOUN
8522	2505629.70	1591630.23	0.87	SOUN
8523	2505630.32	1591635.91	1.15	SOUN
8524	2505630.11	1591642.04	1.58	SOUN
8525	2505629.41	1591647.88	1.94	SOUN
8526	2505628.83	1591653.62	2.37	SOUN
8527	2505628.62	1591659.30	2.80	SOUN
8528	2505628.16	1591665.02	3.18	SOUN
8529	2505627.94	1591670.24	3.44	SOUN
8530	2505628.68	1591675.44	3.58	SOUN
8531	2505629.20	1591680.63	3.69	SOUN
8532	2505629.47	1591685.92	3.76	SOUN
8533	2505629.68	1591690.96	3.88	SOUN
8534	2505629.89	1591696.06	3.94	SOUN
8535	2505630.09	1591701.25	3.99	SOUN
8536	2505630.32	1591706.44	3.97	SOUN
8537	2505630.26	1591711.97	3.88	SOUN
8538	2505629.98	1591717.03	3.85	SOUN
8539	2505629.88	1591722.25	3.71	SOUN
8540	2505630.02	1591726.61	3.53	SOUN
8541	2505630.47	1591730.81	3.37	SOUN
8542	2505630.65	1591734.93	3.19	SOUN
8543	2505630.57	1591738.76	2.85	SOUN
8544	2505630.25	1591742.34	2.51	SOUN
8545	2505630.06	1591746.29	2.40	SOUN

Cross Section 5

Survey Point #	Northing	Easting	Elevation	Description
6096	2504132.53	1591392.03	8.06	EW
6097	2504132.82	1591393.73	7.50	VEG

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6098	2504133.52	1591397.28	6.11	GS/
6099	2504136.70	1591405.65	5.55	GS/
6100	2504139.71	1591414.83	5.20	GS/
6101	2504143.59	1591425.83	4.84	GS/
6102	2504148.74	1591444.54	4.62	GS/
6103	2504149.83	1591448.75	4.39	GS/
6104	2504123.74	1591372.13	8.79	GS/
6105	2504114.79	1591352.17	10.49	GS/
6106	2504104.90	1591306.12	9.64	GS/
6107	2504083.14	1591246.64	7.99	GS/
6108	2504060.98	1591198.30	7.71	GS/
6109	2504049.22	1591163.57	8.17	GS/
6110	2504042.17	1591137.16	7.43	GS/
6111	2504040.85	1591126.76	8.01	EW
6112	2504035.83	1591115.73	6.04	GS/
6113	2504033.44	1591108.88	5.22	GS/
6242	2504259.35	1591756.21	6.61	EW
6243	2504255.79	1591742.89	4.96	GS/
6244	2504253.63	1591736.22	5.00	GS/
6245	2504264.37	1591768.28	6.70	GS/
6246	2504270.71	1591788.21	7.86	GS/
6247	2504287.13	1591832.42	7.82	GS/
6248	2504308.61	1591871.75	7.13	GS/
6249	2504323.08	1591912.72	7.09	GS/
6250	2504326.14	1591926.43	7.30	VEG
6251	2504347.08	1591982.01	8.35	GS/
8968	2504153.50	1591452.19	4.62	SOUN
8971	2504149.27	1591454.72	4.55	SOUN
8972	2504148.07	1591455.61	4.64	SOUN
8973	2504155.42	1591458.31	4.60	SOUN
8974	2504157.34	1591462.34	4.63	SOUN
8975	2504158.17	1591466.10	4.66	SOUN
8976	2504161.54	1591469.60	4.49	SOUN
8979	2504162.35	1591475.93	4.56	SOUN
8983	2504163.22	1591479.98	4.42	SOUN
8986	2504164.22	1591483.37	4.18	SOUN
8989	2504165.50	1591487.34	4.65	SOUN
8991	2504166.83	1591491.04	4.49	SOUN
8994	2504167.71	1591494.93	3.45	SOUN
8996	2504169.37	1591498.92	2.40	SOUN
9000	2504170.83	1591502.91	1.46	SOUN
9005	2504172.88	1591506.78	0.71	SOUN
9008	2504174.07	1591511.38	0.28	SOUN
9009	2504176.02	1591513.56	0.12	SOUN
9010	2504174.72	1591518.44	-0.25	SOUN
9011	2504174.21	1591523.09	-0.68	SOUN

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9012	2504174.54	1591527.94	-0.96	SOUN
9013	2504175.36	1591533.10	-1.28	SOUN
9014	2504175.76	1591537.19	-1.57	SOUN
9015	2504176.70	1591540.60	-1.73	SOUN
9016	2504177.98	1591545.33	-2.00	SOUN
9017	2504178.75	1591549.45	-2.20	SOUN
9018	2504180.37	1591554.15	-2.33	SOUN
9019	2504182.11	1591558.89	-2.66	SOUN
9020	2504184.87	1591563.58	-2.91	SOUN
9021	2504187.60	1591568.12	-3.14	SOUN
9022	2504190.51	1591572.56	-3.17	SOUN
9023	2504193.25	1591576.70	-3.14	SOUN
9024	2504196.12	1591581.36	-3.20	SOUN
9025	2504198.21	1591586.28	-3.27	SOUN
9026	2504200.49	1591591.06	-3.44	SOUN
9027	2504202.71	1591595.81	-3.55	SOUN
9028	2504204.87	1591600.84	-3.54	SOUN
9029	2504206.89	1591606.07	-3.47	SOUN
9030	2504207.74	1591611.98	-3.43	SOUN
9031	2504208.44	1591617.93	-3.47	SOUN
9032	2504208.59	1591623.83	-3.54	SOUN
9033	2504210.17	1591629.10	-3.30	SOUN
9034	2504212.11	1591634.14	-3.07	SOUN
9035	2504214.04	1591639.12	-3.05	SOUN
9036	2504215.62	1591644.30	-3.07	SOUN
9037	2504217.29	1591649.99	-2.47	SOUN
9038	2504218.85	1591655.31	-1.41	SOUN
9039	2504220.17	1591660.26	-0.36	SOUN
9040	2504222.23	1591664.93	0.33	SOUN
9041	2504224.03	1591669.64	0.87	SOUN
9042	2504225.74	1591674.25	1.17	SOUN
9043	2504228.05	1591677.92	1.53	SOUN
9044	2504230.66	1591681.46	1.95	SOUN
9045	2504232.62	1591684.73	2.78	SOUN
9046	2504234.31	1591687.52	3.83	SOUN
9047	2504235.99	1591690.74	4.21	SOUN
9048	2504238.49	1591692.86	4.44	SOUN
9049	2504238.32	1591695.50	4.40	SOUN
9050	2504238.15	1591698.14	4.67	SOUN
9051	2504237.98	1591700.79	4.55	SOUN
9052	2504239.51	1591704.63	4.64	SOUN
9053	2504241.85	1591708.99	4.80	SOUN
9054	2504242.80	1591712.68	4.80	SOUN
9055	2504243.76	1591715.51	4.83	SOUN
9056	2504244.41	1591717.12	4.79	SOUN
9057	2504246.35	1591720.33	4.70	SOUN

9058	2504248.54	1591724.69	4.74	SOUN
9059	2504250.29	1591730.00	4.71	SOUN

Cross Section 6

Survey Point #	Northing	Easting	Elevation	Description
6114	2503118.89	1591946.35	7.88	EW
6115	2503123.81	1591951.97	6.72	GS/
6116	2503129.15	1591960.92	5.53	GS/
6117	2503133.42	1591967.52	4.69	VEG
6118	2503135.94	1591972.17	4.37	GS/
6119	2503138.13	1591975.14	4.21	GS/
6120	2503118.25	1591943.08	8.83	GS/
6121	2503112.94	1591934.71	10.03	GS/
6122	2503093.50	1591918.07	7.45	GS/
6123	2503085.29	1591909.28	4.41	GS/
6124	2503075.37	1591895.55	5.67	GS/
6125	2503061.82	1591876.59	6.96	GS/
6126	2503047.00	1591847.31	7.08	GS/
6127	2503028.11	1591817.96	6.30	GS/
6128	2503004.51	1591783.20	5.33	GS/
6129	2502977.34	1591745.52	7.30	GS/
6130	2502950.07	1591704.09	7.25	GS/
6131	2502925.68	1591665.98	7.46	GS/
6132	2502899.11	1591623.29	7.43	GS/
6133	2502868.58	1591582.29	7.41	GS/
6134	2502840.94	1591542.23	7.70	GS/
6135	2502810.29	1591499.71	6.86	GS/
6136	2502783.50	1591465.12	7.47	GS/
6137	2502760.19	1591426.25	7.37	GS/
6138	2502725.70	1591378.49	6.90	GS/
6139	2502698.22	1591344.06	6.75	GS/
6253	2503302.09	1592202.10	7.12	EW
6254	2503294.79	1592197.10	5.54	GS/
6255	2503289.39	1592191.39	5.16	GS/
6256	2503285.52	1592184.25	5.27	GS/
6257	2503276.68	1592170.24	5.08	GS/
6258	2503267.33	1592156.08	4.31	GS/
6259	2503302.37	1592208.34	7.55	GS/
6260	2503324.51	1592244.48	8.70	GS/
6261	2503359.55	1592301.52	8.19	GS/
6262	2503394.81	1592345.95	7.73	GS/
6263	2503425.87	1592385.39	7.74	VEG
6264	2503454.14	1592425.57	7.64	GS/
6265	2503465.05	1592445.03	7.70	GS/
6266	2503478.64	1592473.51	8.41	GS/

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6267	2503502.36	1592510.56	7.63	GS/
6268	2503526.10	1592555.05	8.43	GS/
6269	2503557.04	1592593.20	8.22	GS/
6270	2503591.03	1592635.09	8.71	GS/
6271	2503621.50	1592682.04	7.99	GS/
6272	2503626.03	1592698.49	7.74	GS/
8392	2503144.37	1591982.24	4.32	SOUN
8393	2503146.71	1591985.95	2.09	SOUN
8394	2503150.60	1591989.13	1.09	SOUN
8395	2503155.01	1591991.97	0.78	SOUN
8396	2503157.92	1591995.73	0.38	SOUN
8397	2503160.95	1591999.65	0.27	SOUN
8398	2503164.31	1592003.47	0.19	SOUN
8399	2503167.28	1592006.73	-0.01	SOUN
8400	2503169.89	1592010.34	-0.24	SOUN
8401	2503173.15	1592013.74	-0.40	SOUN
8402	2503175.47	1592017.70	-0.51	SOUN
8403	2503177.94	1592021.66	-0.70	SOUN
8404	2503180.83	1592025.44	-0.93	SOUN
8405	2503183.68	1592029.64	-1.15	SOUN
8406	2503186.51	1592033.76	-1.42	SOUN
8407	2503189.45	1592037.64	-1.53	SOUN
8408	2503193.10	1592041.54	-1.72	SOUN
8409	2503196.31	1592045.37	-1.90	SOUN
8410	2503198.96	1592048.91	-2.03	SOUN
8411	2503201.99	1592052.17	-2.15	SOUN
8412	2503204.90	1592056.78	-2.26	SOUN
8413	2503206.43	1592061.02	-2.48	SOUN
8414	2503208.94	1592065.32	-2.66	SOUN
8415	2503211.80	1592069.64	-2.81	SOUN
8416	2503215.12	1592073.84	-2.92	SOUN
8417	2503217.74	1592078.51	-2.98	SOUN
8418	2503220.30	1592083.34	-2.94	SOUN
8419	2503222.39	1592088.12	-2.81	SOUN
8420	2503225.20	1592092.23	-2.71	SOUN
8421	2503228.62	1592096.30	-2.68	SOUN
8422	2503231.36	1592100.62	-2.65	SOUN
8423	2503234.44	1592104.35	-2.57	SOUN
8424	2503237.21	1592108.10	-2.35	SOUN
8425	2503240.09	1592111.99	-2.19	SOUN
8426	2503242.94	1592116.13	-1.80	SOUN
8427	2503244.53	1592121.03	-1.36	SOUN
8428	2503247.06	1592125.24	-0.66	SOUN
8429	2503249.50	1592129.06	-0.09	SOUN
8430	2503252.77	1592132.07	0.29	SOUN
8431	2503255.57	1592135.52	0.54	SOUN

8432	2503257.90	1592138.46	0.98	SOUN
8433	2503259.86	1592141.61	1.44	SOUN
8434	2503260.97	1592144.88	2.12	SOUN
8435	2503262.31	1592147.56	4.51	SOUN

Cross Section 7

Survey Point #	Northing	Easting	Elevation	Description
6273	2503246.49	1595827.67	9.46	VEG
6274	2503247.15	1595824.80	7.70	EW
6275	2503248.69	1595822.68	5.23	GS/
6276	2503251.25	1595819.52	4.81	GS/
6277	2503254.31	1595814.39	4.02	GS/
6278	2503254.81	1595812.75	3.59	GS/
6279	2503243.36	1595835.80	8.23	GS/
6280	2503229.11	1595877.76	8.50	GS/
6281	2503199.41	1595915.36	9.30	GS/
6282	2503173.16	1595939.48	9.31	GS/
6283	2503155.58	1595958.50	11.46	GS/
6284	2503122.63	1595965.15	12.10	GS/
6285	2503073.64	1595983.54	12.43	GS/
6286	2503027.02	1595999.12	12.54	GS/
6287	2503532.65	1595581.37	7.13	EW
6288	2503526.68	1595590.16	6.15	GS/
6289	2503519.76	1595600.88	5.45	GS/
6290	2503513.10	1595606.22	4.85	GS/
6291	2503505.92	1595613.41	4.65	GS/
6292	2503492.83	1595625.21	4.82	GS/
6293	2503471.71	1595641.20	4.69	GS/
6294	2503457.02	1595654.89	4.72	GS/
6295	2503543.74	1595570.46	7.98	GS/
6296	2503560.39	1595554.82	8.02	VEG
6297	2503590.67	1595522.00	8.42	GS/
6298	2503612.77	1595501.90	9.08	GS/
6299	2503645.86	1595461.75	7.88	GS/
6300	2503685.63	1595436.11	7.68	GS/
6301	2503733.60	1595407.91	7.99	GS/
6302	2503773.90	1595384.74	7.98	GS/
8259	2503542.82	1595568.71	5.79	SOUN
8298	2503451.30	1595657.13	4.69	SOUN
8299	2503446.34	1595661.27	4.23	SOUN
8300	2503441.80	1595665.98	2.46	SOUN
8301	2503437.29	1595670.73	0.96	SOUN
8302	2503432.74	1595674.48	-0.02	SOUN
8303	2503427.61	1595678.95	-0.43	SOUN
8304	2503423.06	1595683.66	-0.36	SOUN

8305	2503418.51	1595688.38	-0.19	SOUN
8306	2503414.20	1595693.88	-0.12	SOUN
8307	2503409.06	1595697.75	-0.27	SOUN
8308	2503403.04	1595701.52	-0.25	SOUN
8309	2503397.04	1595705.32	-0.47	SOUN
8310	2503391.30	1595709.61	-0.91	SOUN
8311	2503386.02	1595714.60	-1.68	SOUN
8312	2503382.23	1595720.02	-2.32	SOUN
8313	2503377.07	1595724.59	-2.94	SOUN
8314	2503371.88	1595729.08	-3.50	SOUN
8315	2503366.22	1595732.99	-3.88	SOUN
8316	2503360.62	1595736.80	-4.03	SOUN
8317	2503354.79	1595741.01	-4.28	SOUN
8318	2503349.14	1595745.13	-4.23	SOUN
8319	2503343.13	1595749.89	-4.08	SOUN
8320	2503338.47	1595755.84	-3.87	SOUN
8321	2503332.92	1595760.75	-3.51	SOUN
8322	2503327.78	1595764.79	-2.84	SOUN
8323	2503322.33	1595767.54	-2.58	SOUN
8324	2503317.11	1595770.73	-2.57	SOUN
8325	2503312.03	1595773.26	-2.10	SOUN
8326	2503307.03	1595775.75	-1.84	SOUN
8327	2503302.46	1595778.38	-1.55	SOUN
8328	2503298.43	1595780.75	-1.42	SOUN
8329	2503294.35	1595784.09	-1.29	SOUN
8330	2503290.09	1595787.00	-1.05	SOUN
8331	2503287.06	1595789.06	-0.70	SOUN
8332	2503284.37	1595791.30	-0.54	SOUN
8333	2503281.81	1595793.49	-0.32	SOUN
8334	2503279.58	1595795.21	-0.01	SOUN
8336	2503276.03	1595797.92	0.78	SOUN
8338	2503272.97	1595800.00	1.11	SOUN
8340	2503270.59	1595801.34	1.53	SOUN
8342	2503267.78	1595803.04	1.73	SOUN
8344	2503264.99	1595804.88	2.02	SOUN
8346	2503261.53	1595807.17	2.67	SOUN
8348	2503258.68	1595809.43	3.34	SOUN

Cross Section 8

Survey Point #	Northing	Easting	Elevation	Description
6332	2503900.75	1599421.48	8.42	VEG
6333	2503900.00	1599421.09	7.66	EW
6334	2503898.44	1599420.71	5.36	GS/
6335	2503891.55	1599419.31	4.47	GS/
6336	2503888.86	1599419.25	4.13	GS/

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6337	2503910.07	1599424.98	8.97	GS/
6338	2503942.47	1599428.59	8.63	GS/
6339	2503986.62	1599441.71	8.92	GS/
6340	2504032.72	1599461.32	8.59	GS/
6341	2504057.10	1599472.42	10.72	GS/
6342	2504106.04	1599491.39	10.46	GS/
6343	2504153.42	1599514.74	11.41	GS/
6344	2504196.00	1599531.74	11.60	GS/
6345	2504248.30	1599543.30	11.00	GS/
6346	2504294.77	1599556.29	11.03	GS/
6347	2504337.26	1599570.36	10.71	GS/
6348	2503622.81	1599351.16	7.53	EW
6349	2503640.03	1599357.34	6.36	GS/
6350	2503652.84	1599362.10	5.72	GS/
6351	2503667.66	1599365.13	4.94	GS/
6352	2503679.66	1599367.69	4.82	GS/
6353	2503619.38	1599351.71	7.76	GS/
6354	2503610.92	1599350.09	8.06	VEG
6355	2503587.66	1599339.43	8.61	GS/
6356	2503543.19	1599326.57	8.88	GS/
6357	2503499.73	1599315.47	8.85	GS/
6358	2503462.52	1599313.39	9.50	GS/
6359	2503428.44	1599319.87	9.13	GS/
6360	2503389.41	1599335.28	9.33	GS/
6361	2503354.02	1599317.01	8.49	GS/
8190	2503682.80	1599366.41	4.84	SOUN
8191	2503684.28	1599364.71	4.81	SOUN
8192	2503686.97	1599363.07	4.95	SOUN
8193	2503690.74	1599362.29	3.81	SOUN
8194	2503695.70	1599361.97	2.60	SOUN
8195	2503700.69	1599362.16	0.97	SOUN
8196	2503706.24	1599362.68	0.60	SOUN
8197	2503711.88	1599362.77	0.28	SOUN
8198	2503718.01	1599364.90	-0.01	SOUN
8199	2503724.65	1599365.13	-0.11	SOUN
8200	2503730.59	1599367.09	-0.45	SOUN
8201	2503736.87	1599368.56	-1.12	SOUN
8202	2503743.22	1599370.50	-1.96	SOUN
8203	2503749.50	1599372.52	-2.85	SOUN
8204	2503755.94	1599374.25	-3.27	SOUN
8205	2503762.43	1599375.88	-4.06	SOUN
8206	2503768.62	1599376.49	-4.56	SOUN
8207	2503775.41	1599377.40	-4.92	SOUN
8208	2503781.69	1599379.03	-5.37	SOUN
8209	2503788.30	1599380.75	-5.33	SOUN
8210	2503794.35	1599382.64	-4.89	SOUN

8211	2503799.88	1599384.76	-4.52	SOUN
8212	2503805.60	1599386.68	-4.11	SOUN
8213	2503811.14	1599388.41	-3.70	SOUN
8214	2503816.33	1599390.19	-3.47	SOUN
8215	2503821.66	1599392.05	-3.09	SOUN
8216	2503826.85	1599394.10	-2.88	SOUN
8217	2503831.98	1599395.60	-2.33	SOUN
8218	2503836.30	1599397.24	-2.02	SOUN
8219	2503840.59	1599397.96	-1.82	SOUN
8220	2503844.61	1599399.94	-1.66	SOUN
8221	2503847.92	1599401.03	-1.37	SOUN
8222	2503850.79	1599402.36	-1.24	SOUN
8223	2503853.37	1599403.60	-0.96	SOUN
8224	2503855.55	1599404.57	-0.71	SOUN
8225	2503857.60	1599405.56	-0.39	SOUN
8226	2503859.54	1599406.85	-0.10	SOUN
8227	2503861.87	1599408.74	0.12	SOUN
8228	2503863.77	1599410.50	0.37	SOUN
8229	2503865.42	1599412.23	0.69	SOUN
8230	2503867.92	1599413.23	1.11	SOUN
8231	2503870.40	1599414.01	1.61	SOUN
8232	2503872.91	1599414.31	2.35	SOUN
8233	2503875.80	1599414.99	3.18	SOUN
8234	2503878.00	1599415.71	3.49	SOUN
8235	2503880.39	1599416.30	4.16	SOUN
8236	2503883.14	1599416.83	3.87	SOUN
8237	2503885.83	1599417.59	4.05	SOUN

Cross Section 9

Survey Point #	Northing	Easting	Elevation	Description
6303	2499821.82	1600509.77	12.02	VEG
6304	2499795.57	1600470.62	12.65	GS/
6305	2499754.09	1600429.13	12.83	GS/
6306	2499712.01	1600381.05	12.30	GS/
6307	2499674.66	1600342.14	12.90	GS/
6308	2499643.32	1600293.29	11.84	GS/
6309	2499613.95	1600245.80	12.25	GS/
6310	2499593.31	1600192.07	12.72	GS/
6311	2499573.30	1600141.21	12.09	GS/
6312	2499824.39	1600513.44	7.60	EW
6313	2499826.32	1600516.57	5.36	GS/
6314	2499828.20	1600521.55	5.16	GS/
6315	2499831.99	1600527.84	4.73	GS/
6316	2500036.08	1600803.37	6.46	GS/
6317	2500050.87	1600832.81	6.76	GS/

CROSS SECTION POINT LISTING
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6318	2500068.97	1600861.57	7.32	GS/
6319	2500072.99	1600868.06	7.55	VEG
6320	2500071.20	1600865.05	7.46	EW
6321	2500088.31	1600912.47	8.18	GS/
6322	2500098.92	1600951.36	9.15	GS/
6323	2500112.70	1600988.44	10.08	GS/
6324	2500133.76	1601024.98	8.74	GS/
6325	2500174.69	1601061.81	8.67	GS/
6326	2500212.52	1601099.69	9.83	GS/
6327	2500241.13	1601137.77	8.31	GS/
6328	2500025.27	1600789.56	6.14	GS/
6329	2500017.85	1600774.65	5.63	GS/
6330	2500011.77	1600760.61	5.52	GS/
6331	2500005.43	1600742.72	5.28	GS/
8005	2499836.21	1600530.01	4.50	SOUN
8006	2499838.69	1600532.20	4.40	SOUN
8007	2499839.82	1600533.88	4.22	SOUN
8008	2499840.97	1600535.35	4.07	SOUN
8009	2499842.84	1600537.52	4.18	SOUN
8010	2499843.98	1600541.09	3.74	SOUN
8011	2499845.39	1600545.82	4.20	SOUN
8012	2499848.43	1600551.28	3.21	SOUN
8013	2499851.34	1600555.52	1.59	SOUN
8014	2499854.27	1600559.60	1.05	SOUN
8015	2499855.96	1600564.34	0.67	SOUN
8016	2499858.65	1600569.76	0.74	SOUN
8017	2499861.96	1600574.60	0.14	SOUN
8018	2499866.13	1600579.26	-0.61	SOUN
8019	2499870.09	1600583.00	-1.51	SOUN
8022	2499874.16	1600590.05	-2.22	SOUN
8023	2499877.06	1600595.97	-2.46	SOUN
8024	2499881.59	1600598.73	-2.88	SOUN
8025	2499886.76	1600601.57	-3.53	SOUN
8026	2499891.46	1600604.54	-4.47	SOUN
8027	2499896.11	1600607.53	-4.59	SOUN
8028	2499900.99	1600610.85	-5.25	SOUN
8029	2499906.09	1600614.68	-5.80	SOUN
8030	2499909.37	1600618.63	-6.51	SOUN
8031	2499913.70	1600622.47	-6.14	SOUN
8032	2499916.79	1600626.80	-5.70	SOUN
8033	2499920.66	1600631.00	-4.71	SOUN
8034	2499924.55	1600635.50	-4.32	SOUN
8035	2499928.27	1600638.96	-3.80	SOUN
8036	2499932.65	1600641.93	-3.35	SOUN
8037	2499936.41	1600645.36	-3.32	SOUN
8038	2499940.36	1600648.38	-3.05	SOUN

8039	2499943.92	1600651.72	-2.70	SOUN
8040	2499946.99	1600655.59	-2.44	SOUN
8041	2499950.13	1600659.71	-2.27	SOUN
8042	2499952.52	1600663.72	-2.39	SOUN
8043	2499954.86	1600667.67	-2.29	SOUN
8044	2499957.23	1600671.98	-1.97	SOUN
8045	2499959.81	1600676.36	-1.26	SOUN
8046	2499961.45	1600680.96	-1.20	SOUN
8047	2499964.11	1600685.13	-0.88	SOUN
8048	2499966.18	1600689.65	-0.98	SOUN
8049	2499969.40	1600693.52	-0.78	SOUN
8050	2499972.46	1600697.92	-0.57	SOUN
8051	2499976.29	1600701.82	-0.17	SOUN
8052	2499977.72	1600706.94	0.53	SOUN
8053	2499979.32	1600711.53	0.86	SOUN
8054	2499982.58	1600715.11	1.94	SOUN
8055	2499984.03	1600719.28	2.69	SOUN
8056	2499986.78	1600723.42	3.36	SOUN
8057	2499988.84	1600726.06	3.93	SOUN
8058	2499991.02	1600728.77	4.31	SOUN
8061	2499992.46	1600730.82	4.52	SOUN
8062	2499994.51	1600734.59	4.52	SOUN
8063	2499997.83	1600739.80	4.71	SOUN
8064	2500000.08	1600743.46	4.93	SOUN

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Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 1
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	360.761
Area (ft2)	1,801.634
Mean Speed (ft/s)	0.760
Total Q (cfs)	1,368.653
Maximum Measured Depth	11.483
Maximum Measured Speed	4.419

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	R	12:37:59 PM	0:08:33	53.8	431.24	327.76	360.761	1,801.634	0.841	0.760	1.61	0.00	84.10	1,061.83	221.12	1,368.653	--	77.6
			Mean	53.8	431.24	327.76	360.761	1,801.634	0.841	0.760	1.61	0.00	84.10	1,061.83	221.12	1,368.653	0.000	77.6
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:08:33

Tr1=20150827103721.riv;

Comments

Tr1=20150827103721.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 2
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	259.555
Area (ft2)	1,626.654
Mean Speed (ft/s)	0.876
Total Q (cfs)	1,424.446
Maximum Measured Depth	14.728
Maximum Measured Speed	2.326

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	R	1:40:41 PM	0:03:51	52.5	267.01	233.55	259.555	1,626.654	1.156	0.876	0.30	0.81	77.63	1,124.38	221.33	1,424.446	--	78.9
			Mean	52.5	267.01	233.55	259.555	1,626.654	1.156	0.876	0.30	0.81	77.63	1,124.38	221.33	1,424.446	0.000	78.9
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:03:51

Tr1=20150827114003.riv;

Comments

Tr1=20150827114003.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 3
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	423.904
Area (ft2)	2,610.958
Mean Speed (ft/s)	0.542
Total Q (cfs)	1,414.884
Maximum Measured Depth	10.564
Maximum Measured Speed	5.785

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	R	1:58:21 PM	0:03:35	53.0	451.14	400.90	423.904	2,610.958	2.098	0.542	-0.13	1.53	94.06	1,076.28	243.14	1,414.884	--	76.1
			Mean	53.0	451.14	400.90	423.904	2,610.958	2.098	0.542	-0.13	1.53	94.06	1,076.28	243.14	1,414.884	0.000	76.1
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:03:35

Tr1=20150827115743.riv;

Comments

Tr1=20150827115743.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 4
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	334.859
Area (ft2)	1,761.055
Mean Speed (ft/s)	0.871
Total Q (cfs)	1,534.158
Maximum Measured Depth	10.564
Maximum Measured Speed	4.159

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
3	R	2:13:54 PM	0:03:24	52.8	354.40	314.86	334.859	1,761.055	1.737	0.871	-0.07	-0.41	104.87	1,189.75	240.01	1,534.158	--	77.5
			Mean	52.8	354.40	314.86	334.859	1,761.055	1.737	0.871	-0.07	-0.41	104.87	1,189.75	240.01	1,534.158	0.000	77.5
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:03:24

Tr3=20150827121317.riv;

Comments

Tr3=20150827121317.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 5
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	390.317
Area (ft2)	1,677.949
Mean Speed (ft/s)	0.927
Total Q (cfs)	1,555.345
Maximum Measured Depth	9.354
Maximum Measured Speed	5.897

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	R	2:45:44 PM	0:03:46	52.2	461.21	376.32	390.317	1,677.949	2.041	0.927	-0.59	0.22	110.59	1,203.75	241.37	1,555.345	--	77.3
			Mean	52.2	461.21	376.32	390.317	1,677.949	2.041	0.927	-0.59	0.22	110.59	1,203.75	241.37	1,555.345	0.000	77.3
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:03:46

Tr1=20150827124505.riv;

Comments

Tr1=20150827124505.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 6
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	284.474
Area (ft2)	1,641.055
Mean Speed (ft/s)	-0.208
Total Q (cfs)	-341.020
Maximum Measured Depth	9.301
Maximum Measured Speed	3.756

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	R	4:27:02 PM	0:05:24	51.9	378.65	278.97	284.474	1,641.055	1.169	-0.208	0.00	0.14	-19.54	-268.69	-52.92	-341.020	--	78.7
			Mean	51.9	378.65	278.97	284.474	1,641.055	1.169	-0.208	0.00	0.14	-19.54	-268.69	-52.92	-341.020	0.000	78.7
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:05:24

Tr1=20150827142623.riv;

Comments

Tr1=20150827142623.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

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Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 7
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Vertical Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	369.984
Area (ft2)	1,855.877
Mean Speed (ft/s)	-0.702
Total Q (cfs)	-1,303.452
Maximum Measured Depth	10.876
Maximum Measured Speed	3.819

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
2	L	4:58:55 PM	0:11:53	52.9	388.92	359.48	369.984	1,855.877	0.545	-0.702	-0.08	-0.99	-85.45	-1,027.02	-189.92	-1,303.452	--	78.8
			Mean	52.9	388.92	359.48	369.984	1,855.877	0.545	-0.702	-0.08	-0.99	-85.45	-1,027.02	-189.92	-1,303.452	0.000	78.8
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:11:53

Tr2=20150827145817.riv;

Comments

Tr2=20150827145817.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 8
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Sloped Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	264.064
Area (ft2)	1,772.716
Mean Speed (ft/s)	-0.711
Total Q (cfs)	-1,260.813
Maximum Measured Depth	12.172
Maximum Measured Speed	6.252

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
5	R	5:23:53 PM	0:04:56	53.8	318.67	241.06	264.064	1,772.716	1.077	-0.711	0.08	0.00	-73.90	-1,002.44	-184.55	-1,260.813	--	79.5
			Mean	53.8	318.67	241.06	264.064	1,772.716	1.077	-0.711	0.08	0.00	-73.90	-1,002.44	-184.55	-1,260.813	0.000	79.5
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:04:56

Tr5=20150827152314.riv;

Comments

Tr5=20150827152314.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8

Discharge Measurement Summary

Date Measured: Thursday, August 27, 2015

Site Information

Site Name	Atmautluak, Alaska
Station Number	Cross Section 9
Location	

Measurement Information

Party	
Boat/Motor	
Meas. Number	

System Information

System Type	RS-M9
Serial Number	3107
Firmware Version	2.00
Software Version	3.8

System Setup

Transducer Depth (ft)	0.00
Salinity (ppt)	0.0
Magnetic Declination (deg)	0.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	Bottom-Track	Left Method	Sloped Bank
Depth Reference	Vertical Beam	Right Method	Vertical Bank
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	362.495
Area (ft2)	2,056.523
Mean Speed (ft/s)	-0.800
Total Q (cfs)	-1,644.357
Maximum Measured Depth	13.205
Maximum Measured Speed	6.778

Measurement Results

Tr		Time			Distance				Mean Vel		Discharge							%
#		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
5	R	5:42:52 PM	0:04:19	53.5	385.86	339.49	362.495	2,056.523	1.490	-0.800	-0.23	-0.51	-105.20	-1,267.83	-270.58	-1,644.357	--	77.1
			Mean	53.5	385.86	339.49	362.495	2,056.523	1.490	-0.800	-0.23	-0.51	-105.20	-1,267.83	-270.58	-1,644.357	0.000	77.1
			Std Dev	0.0	0.00	0.00	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.0
			COV	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Exposure Time: 0:04:19

Tr5=20150827154214.riv;

Comments

Tr5=20150827154214.riv - ;

Compass Calibration

Passed Calibration
Calibration duration = 110 seconds
M10.00 = Magnetic influence is acceptable
Q9 = Magnetic field is uniform
H9 = Complete horizontal rotation
V9 = High pitch/roll
Recommendation(s):
Avoid any changes to the instrument setup or its orientation to the magnetic influences detected during the compass calibration.
Measurements should be made in locations with similar magnetic influences as the location of the compass calibration.

System Test

System Test: PASS

Parameters and settings marked with a * are not constant for all files.

Report generated using SonTek RiverSurveyor Live v3.8